An assessment of the economic value of demand-side participation in the Balancing Mechanism and an evaluation of options to improve access

Prepared for

Ofgem

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GLOSSARY OF KEY TERMS AND ABBREVIATIONS

Battery-led DSR	Using batteries (either stand-alone or in combination with intermittent production resource such as solar PV) to reduce electricity consumption from the grid during peak times
BEIS	Department for Business, Energy and Industrial Strategy
Bid	A Bid is a proposal to reduce generation or increase demand
BM	Balancing Mechanism, which National Grid (as System Operator) uses to balance electricity supply and demand close to real time
BM STOR	STOR provided by an offer from a BMU
BMU	Balancing Mechanism Unit; BMUs are used as units of trade within the BM. Each BMU accounts for a collection of plant and/or apparatus, and is considered the smallest grouping that can be independently controlled. As a result, most BMUs contain either a generating unit or a collection of consumption meters. Any energy produced or consumed by the contents of a BMU is accredited to that BMU.
BSUoS	Balancing Services Use of System; the BSUoS charge recovers the cost of day to day operation of the transmission system. Generators and suppliers are liable for these charges, which are calculated daily as a flat tariff across all users.
CMA	Competition and Markets Authority
CMU	Capacity Market Unit
CONE	Cost of New Entry
Contracted Generation	Ex ante purchases of energy (prior to gate closure and commencement of BM)
CRA	Charles River Associates
DNO	Distribution Network Operator
DSBR	Demand-side Balancing Reserves
DSR	Demand-side Response comprising explicit DSR including Turn-Down DSR, Turn-Up DSR, Stand-by DSR and Battery-led DSR
Explicit DSR	Selling demand response in organised electricity markets
FCDM	Frequency Control by Demand Management
FES	Future Energy Scenarios; as prepared by National Grid
FFR	Fast Frequency Response

FOM	Fixed Operation and Maintenance
GB	Great Britain
HH	Half-hourly
HHI	Herfindahl-Hirschman Index
Historical BM Pricing	CRA approach to determining wholesale energy prices based on historical pricing in the BM
HVAC	Heating, ventilation and air-conditioning
I&C	Industrial and Commercial
IDA	Independent demand-side aggregators; IDAs are third-parties which are independent of the supplier of the customer providing the DSR and as such are not responsible for the customer's metered supply. This means that IDAs are not currently able to register Balancing Mechanism Units and thereby participate in the BM
Imbalance Price	Energy Imbalance prices as estimated from Bid-Offer acceptances (and other parameters) in the BM are used to settle the difference between contracted generation or consumption and the amount that was actually generated or consumed in each half hour trading period
Implicit DSR	Demand response to a price signal
Load reduction	Reducing demand during peak times
Load shifting	Shifting demand away from the peak
LoLE	Loss of Load Expectation
LoLP	Loss of Load Probability
LoLP pricing	CRA approach to determining wholesale energy prices based on an estimated LoLP and a regulated VoLL
Non-BM STOR	STOR provided by an increase in generation or reduction in demand which is embedded in a Supplier BMU
Offer	Offer is a proposal to increase generation or reduce demand
Ofgem	Office of Gas and Electricity Markets; the energy regulator for Great Britain
PJM	PJM refers to the regional power market covering all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia

P*	Market clearing price following supply shock (in CRA's economic analysis)
p^r	Component of customer's retail energy price that determines marginal consumption by the customer
Project TERRE	Project TERRE is implementing the Trans-European Replacement Reserves Exchange
RSP	Reserve Scarcity Price; calculated as the product the VoLL and the LoLP for each Settlement Period
RPM	Reliability Pricing Model; as applied in PJM Capacity Market
SBR	Supplemental Balancing Reserves
Standby DSR	Reduction of electricity taken from the grid by using on-site generators to temporarily meet electricity requirements
SRMC	Short-run marginal costs
STOR	Short-term Operating Reserve
Supplier	Licensed retailer of electricity
TSO	Transmission System Operator
Turn-down DSR	Reducing demand during peak times or shifting demand away from the peak by temporarily reducing the electricity consumed in electricity-intensive processes
Turn-up DSR	Increasing demand during periods of excess supply
Unproven DSR	Unproven DSR is defined in the Capacity Market Regulations as a DSR Capacity Market Unit ("CMU") for which a DSR test has not been carried out.
VBMU	Virtual BMU; a proposed new form of BMU not associated with physical metered volumes
VI	Vertically-integrated
VoLL	Value of Loss of Load

EXECUTIVE SUMMARY

This report provides an assessment of the economic impact of barriers to the aggregation of demand-side response ("**DSR**") in the Balancing Mechanism ("**BM**") and an evaluation of options to provide direct access to the BM for independent demand-side aggregators ("**IDAs")**.[1]

This report has benefitted from comments and advice from Professor Tooraj Jamasb (Co-Director, Durham Energy Institute) as well as advice on BM–related issues from Yellow Wood Energy Consulting. But the report and its recommendations are the sole responsibility of CRA.

Context

There is currently considerable focus on the potential for DSR to improve the efficiency of GB's electricity markets. Ofgem's new Flexibility Programme includes a workstream on DSR and the role of aggregators in promoting the development of DSR.[2] The importance of DSR aggregators was further emphasised in the joint call for evidence from the Department for Business, Energy & Industrial Strategy and Ofgem in November 2016.[3] At the same time, the European Commission has recently published proposals for "pulling all flexible distributed resources concerning generation, demand and storage into the market".[4] Finally, more detailed work has already been carried out on how to facilitate balancing market participation as part of Project TERRE.[5]

Background: the overall market for DSR

DSR is growing but its penetration is still relatively low. In the new capacity market, DSR participation through successive auctions since 2014 has now reached just under 3% of awarded contracts. This contrasts with a more mature market such as PJM in the USA where DSR in the capacity market for delivery 2019/20 has reached just over 6% of cleared capacity. DSR also makes up 4% of the total expenditure in GB by National Grid on Response and Reserve Balancing services.

Aggregators are responsible for the substantial majority of DSR. Aggregators enable the participation of individual DSR resources that would not meet the minimum capacity requirement of DSR products on their own. Aggregators can support reliability through the diversification of DSR resources within a single portfolio.

1 IDAs, in this report, are third-parties which are independent of the supplier of the customer providing the DSR and as such are not responsible for the customer's metered supply. This means that IDAs are not currently able to register Balancing Mechanism Units and thereby participate in the BM.

2 *Making the electricity system more flexible and delivering the benefits for consumers* Ofgem 30 September 2015

3 Paragraph 23 *A SMART, FLEXIBLE ENERGY SYSTEM - A call for evidence* Department for Business, Energy and Industrial Strategy and Ofgem November 2016

4 Page 9 *Commission Staff working document Impact assessment* Brussels 30.11.2016 SWD(2016) 410 Final Part 1/5

5 See *Interim Assessment Report P344 'Project Terre implementation into GB market arrangements.* Elexon 6 October 2016. Project TERRE is implementing the Trans-European Replacement Reserves Exchange.

IDAs have played a key role in driving the growth of DSR. The recent Ofgem survey found that 74% of survey respondents currently providing DSR do so through an IDA.[6]

However IDAs, despite quadrupling in number over the last decade remain concerned with a number of barriers to aggregation. Barriers that have been identified include regulations in the capacity market (especially those limiting contract duration for DSR); the organisation of the energy markets (which, as described below, exclude IDA's DSR from direct participation); and a general lack of customer understanding of DSR opportunities, combined with reticence to risk compromising their core business activities with load interruptions. At the same time, market conditions have not been favourable with relatively low (until recently) energy market prices.

The barriers to growth for DSR in the Balancing Mechanism

The current arrangements for DSR do not enable it to participate directly in the BM. In practice, it may only be provided by the supplier of the DSR-provider[7] which can access the benefit of any margin between the imbalance price and the foregone retail revenue on the DSR volumes.

We consider two theories of harm by which growth in DSR in the BM may be less than is economically efficient, and which follow from the dependency of IDAs on suppliers.

- Theory of Harm 1: Suppliers may be inadequately incentivised to develop DSR due to (i) suppliers in some cases being vertically integrated with generation with which DSR competes and (ii) customers lack of interest in and understanding of DSR, combined with insufficient competition between suppliers.
- Theory of Harm 2: Suppliers may prevent the growth of IDAs in order (i) as with the first theory of harm, to limit competition from DSR with their own upstream generation, (ii) to promote their own DSR products with their customers and/or (iii) to avoid sharing their customer relationship with the IDA in order not to risk losing their customer's business.

This report, given its scale, does not conclude on the extent to which these theories of harm apply in practice. However, it is noted that:

- The incentives potentially supporting these theories of harm are mitigated by competitive conditions in upstream generation markets and the I&C retail supply market**.** Costs incurred by the supplier to suppress DSR (such as discounting prices to induce customers not to offer DSR) may, in practice, be difficult to recover from higher upstream market prices due to competing generators or other DSR providers. And, similarly, by imposing adverse supply contract conditions or prices on customers that provide DSR in order to discourage DSR, suppliers risk losing those customers to competitors.

6 Ofgem. Industrial & Commercial demand-side response in GB: barriers and potential. October 2016. (https://www.ofgem.gov.uk/system/files/docs/2016/10/industrial_and_commercial_demand-side_response_in_gb_barriers_and_potential.pdf)

7 The term 'DSR-provider' is used in this report to refer to the Customer or the IDA or both that provide and source the DSR.

- In any event, the extent of vertical integration has recently reduced with the strategic and ownership re-positioning of the supply businesses of E.ON, RWE and Centrica.
- The likely financial returns from DSR have been depressed with low energy market prices, but these have recently increased and are set to become more volatile with the prospective growth in renewables. This should improve incentives to develop efficient DSR.
- There is some evidence of increasing competition between suppliers to have an attractive DSR-offering for their customers.

But, even with increasing competition between suppliers to develop DSR, IDAs may still have an important role to play in further intensifying competition for the development of DSR. It is noticeable that in the last few years, IDAs have been the leading developer of DSR in the capacity market. Consequently, addressing the market foreclosure concerns of IDAs through facilitating direct access to the BM for IDAs may increase net economic welfare by further promoting competition in the provision of DSR.

Estimated economic benefit from the provision of DSR in the Balancing Mechanism

We estimate the potential economic benefit from increasing the provision of DSR in the BM in terms of the changes in the costs of energy, generation capacity and network infrastructure that would follow from an increase in DSR provided by Industrial and Commercial ("**I&C**") consumers in the wholesale energy market.

Our work focusses on I&C customers given that is who IDAs are currently contracting with. Moreover, IDAs are likely to have a competitive disadvantage to incumbent suppliers in trying to serve larger portfolios of residential/micro-business customers. This follows from incumbent suppliers already having mass market customer management and billing systems established to serve these customers.

There is potential for significant increases in the provision of DSR by I&C customers. There are currently around 2.1 GW of DSR participating in the Balancing Services market, and around 1.4 GW of DSR participating in the GB Capacity Market. These numbers are not additive. Our analysis indicates technical potential for up to 14.7 GW of DSR across Turn-up DSR, Turn-Down DSR and behind-the-meter stand-by generation and batteries.

We estimate the economic utilisation of these DSR resources by dispatching DSR in competition with conventional generation otherwise required to supply residual system load (i.e. system load after deducting output from intermittent and inflexible sources of generation). During peak periods, we include an addition to short-run marginal costs to reflect the effect of 'scarcity pricing'. We use two approaches to determining scarcity prices: an uplift based on Elexon's loss-of-load probability ("**LoLP**") curve[8] and an uplift from historic prices in 2016 observed in the BM.

Our approach to DSR dispatch takes into account the activation costs of Turn-Down DSR and is constrained by an assessment of the possible rebound effect of DSR on system load.

8 https://www.elexon.co.uk/wp-content/uploads/2015/10/Loss_of_Load_Probability_Calculation_Statement_v1.0.pdf

We develop estimates of the economic benefits of DSR under assumptions on demand and generation mix taken from National Grid's Future Energy Scenarios ("**FES**"). These benefits are presented as the difference between scenarios with estimated existing DSR capacity and the full economic potential of DSR capacity. The estimated benefits are principally in the form of avoided generation capacity costs and avoided network reinforcement costs.

We do *not* attribute directly a share of such benefits to the removal of specific barriers (whether these are barriers directly affecting BM participation or with a wider impact) to DSR aggregation. It has not been possible within the scope of this report to isolate the incremental impact of BM access on avoided capacity costs, which is closely related to the related financial support to DSR provided by the Capacity Market. However, we note that improvements in the efficiency of the energy market (such as follow from the recent revision to imbalance pricing[9]) may lead to increased margins in the energy market, thereby depressing capacity market prices. This would serve to increase the importance of access to the BM as a source of revenue for DSR.

We estimate an indicative range of £110 - £400 million of economic benefits in 2020, rising to £160 - £440 million in 2030 following from a removal of barriers that limit efficient competition from DSR in the BM. This range may be explained by a number of factors but principally reflects the mix of generation and capacity margins under different scenarios. After allowing for further uncertainty in relation to the capital cost of new peaking capacity,[10] this range widens to £100 - £530 million in 2020, rising to £140 - £580 million by 2030. This is shown in Figure 1. Our results are generally consistent with the findings presented by other recent studies by Imperial College and NERA, and by the Carbon Trust and Imperial College.[11] The size of potential economic benefits indicates the importance of providing DSR access to revenue sources, including the BM, to support its efficient provision.

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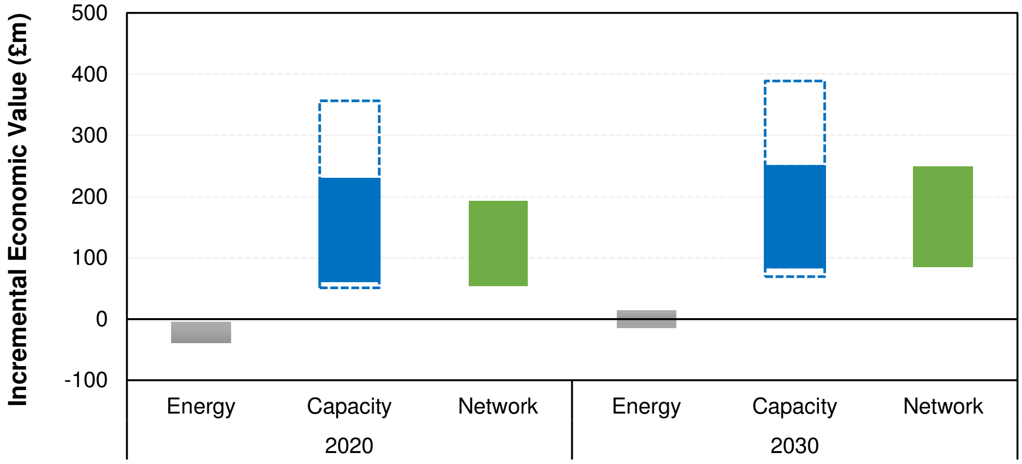
9 See Imbalance Pricing Guidance – A Guide to Electricity Imbalance Pricing in Great Britain, version 11.0. (https://www.elexon.co.uk/wp-content/uploads/2016/10/Imbalance_Pricing_guidance_v11.0.pdf)

10 BEIS' range of annualised capacity and fixed O&M costs for a new OCGT range from £47/kW-year to £90/kW-year, assuming a discount rate of 7.6% over a 25-year period. For purposes of this analysis, we have assumed no capital costs and no ongoing fixed cost for DSR. While we recognise that some costs may be incurred, our understanding from our stakeholder interviews is that such costs are negligible.

11 In the report "Understanding the Balancing Challenge", August 2012, Imperial College and NERA estimate annual system savings in 2020 of £500 Million for Pathway A, a scenario with high renewable development; high energy efficiency and high demand electrification. Similarly, the Carbon Trust and Imperial College Report "An analysis of electricity system flexibility for Great Britain", November 2016 presents cumulative savings to 2050 ranging from £15 billion to £40 billion. This is roughly equivalent to annual savings between £300 Million and £800 Million (at a 3.5% social discount rate over 35 years). While our numbers are within that range, we note that there are important differences. First, the Carbon Trust and Imperial College report account for the value of interconnectors in their estimates; we do not. Second, they model a significant uptick in DSR utilisation post 2030, which our analysis does not capture.

Figure 1: Range of incremental economic value resulting from increased DSR participation in the BM (Existing DSR vs Full Economic Potential)



Note: The dashed blue line under economic value from capacity savings shows the sensitivity of our estimates of capacity cost savings to BEIS's range of capacity costs from £47/kW-year to £90/kW-year.
Source: CRA Analysis

We have not estimated an impact on consumer prices. Given that DSR (excluding Turn-up), is principally activated during peak hours in which there is scarcity pricing, the impact on market prices may be quite small.[12]

Options for treatment of IDAs in the Balancing Mechanism

Reform of the treatment of IDAs in the BM, while addressing barriers to aggregation, should also be consistent with necessary conditions for promoting economic efficiency. In this regard, providers of DSR should receive the marginal value of units of consumption withdrawn from the market (unless they have already purchased the underlying energy).

We show that the economically efficient remuneration for DSR (considered here as demand reduction) is the market clearing price less the 'retail' price for generation. In this context, the 'retail' price for generation should be understood as the price level that determines the consumer's marginal consumption and as such excludes components of the supplier's retail charges that do not vary as a function of demand in a given time-period. The same approach also applies to Turn-up DSR.

We identify two approaches to DSR settlement that provide direct access to the BM for IDAs and can be consistent with the efficient remuneration of DSR in the BM:

- A Central Settlement system approach in which the supplier of the customer/IDA providing the DSR (together the DSR-provider) is exposed to the imbalance price for DSR volumes and the DSR-provider is remunerated at the offer price less 'retail' price. This results in a funding deficit for the BM which may be recovered from the

12 Consumers would benefit in terms of price reductions where the increased participation of DSR had the effect of shifting the supply and demand curves for capacity in the capacity market, resulting in lower clearing prices for capacity agreements.

supplier of the DSR-provider, all parties or the parties responsible for the system imbalance.

- A Supplier-Customer Settlement system approach in which the supplier of the DSR-provider is remunerated for DSR volumes by the DSR-provider at its avoided 'retail' price and the DSR-provider is remunerated at its full offer price.

Other important parameters to be determined in providing access to the BM for IDAs include whether explicit consent from the supplier of the DSR provider for its provision of DSR may or may not be required and the treatment of non-delivery by the IDA.

Assessment of issues and options for IDA's direct access to the BM

We summarise below our assessment of the issues and options for providing IDAs with direct access to the BM.

Market competitiveness

- This report has not concluded on the extent to which there may or may not be limits to the effectiveness of competition in the overall power market or, more narrowly, in the market for the provision of DSR.
- There are some incentives on vertically-integrated suppliers to limit DSR (in particular, where their generation resources are able to raise prices during periods of capacity scarcity). Other suppliers may also wish to frustrate IDAs where they are perceived to be in competition with the supplier's own DSR products or potentially, over time, improving their positioning to compete for the supply contract.
- However, these incentives are mitigated by competitive conditions in upstream generation markets and the I&C retail supply market**.** Competition in upstream generation means that any supplier incurring costs to suppress DSR (such as by discounting prices to their customers) may not in practice recover these costs from anticipated generation market prices given competing generators or other DSR providers. Competition in I&C retail supply means that suppliers imposing excess costs on customers that provide DSR risk losing those customers to competitors.
- Moreover, recently reduced levels of vertical integration have in any case mitigated incentives on some suppliers to limit the development of DSR
- These considerations indicate that market conditions may be sufficiently competitive to deliver the efficient development of DSR and that the Theories of Harm set out in this report are of limited concern.
- But, while the risk of market foreclosure to IDAs cannot be fully excluded, enhancing revenue opportunities for IDAs by providing direct access to the BM may assist in the development of efficient of DSR provided an economically efficient system can be established at reasonable cost.

DSR Settlement systems

- This report has reviewed two efficient approaches to DSR settlement: i) a Central Settlement system approach in which the supplier of the DSR-provider is exposed to the imbalance price for DSR volumes and the DSR-provider is remunerated at the offer price less 'retail' price; and ii) a Supplier-Customer Settlement system approach in which the supplier of the DSR-provider is 'cashed-out' of DSR volumes by the DSR-provider at its avoided 'retail' and the DSR-provider is remunerated at its full offer price. Both these settlement systems can be consistent with the efficient remuneration of DSR in the BM.

- A Supplier-Customer Settlement system has some advantages over a Central Settlement system. In particular, Supplier-Customer settlement:
    - Avoids the need to report 'retail' prices centrally (with associated risks of over/under-reporting) and to calculate centrally avoided retail payments on activated DSR volumes;
    - Avoids exposing the supplier of the DSR-provider to imbalance price risk or DSR non-delivery risk as a result of DSR volumes (though the Central Settlement System may be modified to avoid this problem);
    - Provides for some mitigation of the risk of baseline gaming through the correction of the supplier's position in the BM (which means that not just the customer but also the supplier may be affected by the baseline); and
    - Assuming a competitive supply market, will support an efficient negotiated outcome between supplier and customer.
- However the Supplier-Customer system by its nature requires closer involvement of the incumbent supplier. In particular, the supplier is informed of its customer's delivered DSR volumes (in order to adjust its billing), while this customer-specific information need not necessarily be made available to the supplier under variants of the Central Settlement system. Consequently, some IDAs may consider that the Central Settlement system assists in preserving the confidentiality of commercially significant data.

Theory of Harm 2: Foreclosure risk

- Consideration of Theory of Harm 1 does not impact the potential choice of appropriate DSR payment system.
- Theory of Harm 2 - the risk of incumbent suppliers foreclosing the provision of efficient DSR by IDAs - is of key concern to IDAs.
- The Central Settlement System may then be preferred by IDAs where it limits access by suppliers to data on customer-specific DSR volumes that may be considered commercially significant.
- However, there are other efficiency considerations indicating that Supplier-Customer Settlement may be preferred; in particular, it may be easier to implement. While the Central Settlement System may be adapted to ease implementation such as by using a standardised proxy retail price, this would introduce some inefficiency since such proxies are likely to poorly reflect actual retail prices.
- Moreover, allowing suppliers access to some relevant information with which to adjust their retail contracts in the context of DSR provision (as discussed further below) may be efficient. We recognise that this may equally be considered by some IDAs as an opportunity for suppliers to react anti-competitively. But to the extent that there are concerns about the competitiveness of I&C suppliers, arguably these should be dealt with by regulatory interventions in the retail supply market (and not be adopting less efficient approaches to DSR).

- Given the overall competitiveness of upstream generation and the I&C supply market together with the reduction in levels of vertical integration which mitigate the incentives identified in Theory of Harm 2, we conclude that any remaining foreclosure risks are not sufficient to prefer the Central Settlement system over the Suppler-Customer Settlement system.

Advance notification

- Advance notification to relevant suppliers of DSR providers' intentions to offer DSR volumes (in general as opposed to offer by offer) appears important in enabling suppliers to make potentially efficient adjustments to their generation procurement and supply contracts. It may also be necessary to ensure the appropriate 'retail price' is used in DSR payments.
- Where advance notification is considered important, then the advantages of Central Settlement in relation to preserving the confidentiality of commercially significant data is reduced.
- In any event, we expect that suppliers concerned about the provision of DSR by their customers will deduce such provision from their customers' metered data.

Ex post notification

- It is necessary for the supplier to be notified ex post of accepted and delivered DSR offers under the Supplier-Customer Settlement system approach so that the supplier can adjust its invoices appropriately to charge the customer for its DSR volumes.

Supplier consent

- Not requiring consent from the supplier of the DSR-provider is consistent with the existing approach of suppliers to DSR and avoids introducing any new potential barrier for IDAs.
- However, in the absence of withholding consent, suppliers may wish to be able to exercise break-clauses or otherwise adjust retail contract terms. This may require some further regulatory over-sight (at least in the initial period following the implementation of reforms to access to the BM).
- By implication then, Ofgem should not require supplier consent or intervene to stipulate that suppliers may not withhold consent.

The efficient level of DSR remuneration

- Determination of the 'retail' price to be used in DSR settlement may most straightforwardly be taken from the prevailing retail supply contract as the avoided contract costs for the customer with foregone demand.
- Given the concerns about market competitiveness, this level of remuneration may not be agreed in bi-lateral negotiation. But, direct regulatory intervention would be unattractive in a market segment that is otherwise unregulated. This leaves the option of Ofgem providing guidance to market participants, with the possibility of ex post intervention to address abusive or discriminatory behaviour by suppliers.

The potential for 'gaming' DSR baselines.

- Potential for 'gaming' DSR baselines may arise from an administrative approach to setting baselines.
- However this risk may be mitigated by suppliers having advance notification of customers' intention to provide DSR so that the terms of suppliers' retail contracts may be appropriately adjusted, such as by introducing charges for more volatile or apparently higher customer loads.

Non-delivery risk

- The risk of non-delivery in the BM of an accepted DSR offer should be borne directly by the DSR-provider. Allocating this risk to the incumbent supplier is only likely to see it passed back to the DSR-provider, potentially at a high cost given the associated credit risk for the supplier.

Residential/micro-business customers

- In the event that IDAs do wish to compete for residential/micro-business customers, then the Supplier-Customer Settlement system is still applicable. Bi-lateral negotiation of the relevant 'retail price' is not currently feasible on a mass market basis. If it appears that there is up-take of residential/micro-business customers (possibly supported by smart meters and smart appliances), and notwithstanding the protections already in licences and regulations, Ofgem could encourage suppliers to develop a clear and transparent framework when setting prices (after allowing for network charges and levies) to allow for the difference between 'metered volumes' and imputed-DSR volumes.
- A simplification of the Central Settlement system with proxy 'retail prices' (approved by Ofgem) would risk setting a focal point for suppliers' pricing.

Key recommendations

The key recommendations resulting from this report are:

- Direct access should be provided to the BM for IDAs.
- The efficient remuneration for the DSR-provider of DSR offered in the BM is the market clearing price less its 'retail' price.
- The Supplier-Customer settlement system approach should be adopted on the grounds that by avoiding the need for reporting 'retail' prices centrally or adopting a proxy 'retail price', it is easier and more efficient to implement. The concerns raised by Theory of Harm 2 do not appear sufficiently well supported to justify the potential inefficiencies and higher costs of the Central Settlement System model.
- The 'retail' price should be the payments in the retail supply contract that are avoided by the delivery of DSR volumes.
- Advance notification of suppliers of customers' intent to provide DSR should be provided to allow for efficient procurement by suppliers, as well as potential supply contract adjustments (which can play a role in mitigating incentives for gaming DSR baselines).
- Ofgem should consider setting out guidance to suppliers and potential DSR providers on payment terms relating to DSR provision rather than regulating such

payment terms in the absence of any evidence of related consumer harm. This would include recognising that suppliers may add delivered DSR volumes to customers' metered demand in determining their retail supply bills.

- Suppliers should not be required to consent to the provision of DSR by their customers (but should not be prevented from breaking or amending their supply contracts subject to any such amendments having objective justification).
- Further work may be required on how best to establish robust baselines for use in the BM. This may require third party measurement and verification.
- Ofgem should monitor baseline compliance in order to assess the efficacy of the approach used to determine baselines and to identify potential gaming, which may require subsequent regulatory intervention.
- Non-delivery risk should be allocated to the DSR-provider rather than the related supplier.

1. INTRODUCTION

This report provides an assessment of the economic impact of barriers to the aggregation of demand-side response ("**DSR**") in the Balancing Mechanism ("**BM**") and an evaluation of options to provide direct access to the BM for independent demand-side aggregators ("**IDAs**"). IDAs, in this report, are third-parties which are independent of the supplier of the customer providing the DSR and as such are not responsible for the customer's metered supply. This means that IDAs are not currently able to register Balancing Mechanism Units ("**BMU**") and thereby participate in the BM.

This report has benefitted from comments and advice from Professor Tooraj Jamasb (Co-Director, Durham Energy Institute) as well as advice on BM–related issues from Yellow Wood Energy Consulting. But the report and its recommendations are the sole responsibility of CRA.

1.1. Context for this report

In September 2015 Ofgem set out a work programme to determine how regulation could best support an efficient, flexible energy system. The need to support increased flexibility follows from structural changes to the energy sector in which generation is increasingly distributed and intermittent, consumers are better able to monitor and manage their consumption and new technologies and business models are emerging.[13] Ofgem's new Flexibility Programme of work includes a focus on DSR and the role of aggregators in promoting the development of DSR. In particular, Ofgem has noted: "DSR is an important part of our vision for a flexible energy system."[14]

The importance of DSR aggregators was further emphasised in the joint call for evidence from the Department for Business, Energy & Industrial Strategy and Ofgem in November 2016. This stated that: "Aggregators have a role to play in delivering smart technology and processes. They enable consumers to offer flexibility by providing an intermediary role". But it also acknowledged a number of reported barriers to growth for DSR including challenges in selling services to the System Operator and accessing the BM.[15]

At the same time, the European Commission has developed a package of legislative measures to support a new regulatory framework, which includes the adaptation of power market design to better ensure secure and sustainable energy supplies at competitive prices.[16] As part of this, proposals were published in November 2016 for "pulling all flexible distributed resources concerning generation, demand and storage into the market".[17] The

13 *Making the electricity system more flexible and delivering the benefits for consumers* Ofgem 30 September 2015

14 https://www.ofgem.gov.uk/electricity/retail-market/market-review-and-reform/smarter-markets-programme/electricity-system-flexibility

15 Paragraph 23 *A SMART, FLEXIBLE ENERGY SYSTEM - A call for evidence* Department for Business, Energy and Industrial Strategy and Ofgem November 2016

16 http://europa.eu/rapid/press-release_IP-16-4009_en.htm

17 Page 9 Commission Staff working document Impact assessment Brussels 30.11.2016 SWD (2016) 410 Final Part 1/5. See https://ec.europa.eu/energy/sites/ener/files/documents/mdi_impact_assessment_main_report_for_publication.pdf

European Commission is especially concerned that "national regulatory authorities encourage final customers, including those offering demand response through aggregators, to participate alongside generators in a non-discriminatory manner in all organised markets."[18]

Finally, some detailed work has already been carried out on how to facilitate participation by customers and aggregators wanting to offer demand flexibility to manage imbalances in the BM. This forms part of proposals being developed to align the Balancing and Settlement Code with the requirements of the European Balancing Project TERRE (the Trans-European Replacement Reserves Exchange). Project TERRE aims to harmonise the dispatch of replacement reserve across several Transmission System Operator ("**TSO**") areas.[19]

1.2. Ofgem's main objectives for this report

Ofgem has commissioned this report from Charles River Associates ("**CRA**") to take forward its Flexibility Programme of work and to meet two main objectives.

First, Ofgem wants an assessment of the extent of any consumer detriment arising from arrangements for aggregation both at present and as projected into the future. This requires consideration of the incentives on retailers to constrain or enhance aggregation opportunities, including through their interaction with third party aggregators, together with empirical analysis of the scale of potential benefits from maximising the efficient provision of DSR in the BM.

Second, Ofgem requires the identification and assessment of targeted reforms to address and alleviate any consumer detriment. This includes consideration of reforms to facilitate access to the BM for third party aggregators and other regulatory interventions to promote efficient competition for the provision of DSR in the BM.

1.3. Overview of approach

CRA's approach to meeting Ofgem's objectives and preparing this report is in three main stages. In the first stage of work, we review market data and trends in order to be able set down an overview of the market for DSR services. This stage is informed by interviews with aggregators, suppliers, Elexon and National Grid. It provides the basis for identifying a number of possible barriers to aggregation in the BM which are summarised in two theories of harm.[20] The report does not conclude on the extent to which the market in practice conforms to these theories; instead, they provide a focus for developing and then assessing the potential impact of reform options.

Next, we have developed a wholesale market model in order to estimate the indicative scale of economic benefit that may be provided by full development of efficient DSR in the

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18 Article 17 Paragraph 1 *Proposal for a Directive of the European Parliament and of the Council on common rules for the internal market in electricity* Brussels 30.11.2016 COMN(2016) 864 Final 2016/0380 (COD)

19 See *Interim Assessment Report P344 'Project Terre implementation into GB market arrangements.* Elexon 6 October 2016

20 A theory of harm is intended to constitute an internally consistent set of competition concerns with an adverse effect on consumers that may then be subjected to rigorous assessment.

BM. This analysis is based on a supply-curve representing the technical potential for DSR – including turn-down and turn-up DSR as well as behind-the-meter generation and batteries – to be utilised in the BM. The resulting estimation of economic benefit should not be attributed wholly to the removal of barriers to aggregation, or indeed to access to the BM given the close relationship between DSR contracted in the Capacity Market, DSR providing Balancing Services and DSR in wholesale energy markets. However, this analysis provides an estimate of the economic benefit that may be realised absent barriers to aggregation in the BM and any other inefficient restrictions.

Then, third, we present two main approaches to providing direct access for DSR in the BM. These aim to satisfy necessary conditions for economic efficiency, while also addressing possible concerns about market competitiveness as set out in the theories of harm. We provide an assessment of these two main reform options; this is supported by economic analysis of the pay-offs to the principal parties affected by DSR. The report concludes with a number of recommendations.

1.4. Structure of report

This report is in five further sections and has additional supporting appendices.

- Section 2 provides an overview of the market for DSR describing the scale of provision of DSR services and the development of IDAs.
- Section 3 considers the current treatment of DSR in the BM and sets down two theories of harm to be taken into account in considering reforms to the BM to remove barriers to aggregation.
- Section 4 sets out projections for the supply for DSR and provides an estimate of the economic benefit that may be realised absent barriers to the efficient participation of DSR in the BM.
- Section 5 sets down the necessary conditions to be satisfied in providing direct access to the BM for IDAs and outlines two reform options for the settlement of DSR-related payments. Further implementation issues are also identified.
- Section 6 concludes by providing an assessment of the reform options and presenting a number of recommendations.

Appendix A comprises the detailed economic analysis of the efficient use of DSR in the BM. Appendix B provide additional detail on our modelling of the economic value of DSR in wholesale energy markets. Appendix C provides additional detail on the impact of DSR rebound on our modelling results. Appendix D has further analysis of the provision of DSR to support balancing services.

2. THE MARKET FOR DEMAND SIDE RESPONSE

This section provides an overview of the market for DSR. It begins by reporting on growing demand for DSR in the Capacity Market and for Balancing Services. It then describes the structure of supply in the sector in terms of end-customer participation and the different types of DSR aggregators that are active. It concludes by summarising the main barriers to growth that are faced by aggregators, as identified by market participants.

2.1. Definition of DSR

The definition of DSR that is used by analysts and market participants varies. The term DSR usually refers to an active reduction/increment in the electricity that a consumer takes from the grid. This can be in response to a price signal (this is referred to as "**implicit DSR"**) or by selling demand response in organised electricity markets (this is referred to as "**explicit DSR**"). The definition of DSR typically excludes permanent reductions in demand, like those that may result from energy efficiency or other energy management programmes undertaken by the consumer.

In this report, given our focus on the use of DSR in the BM, we use the term DSR to refer only to explicit DSR. Under this definition, DSR can be achieved in four main ways:

1. By reducing demand during peak times ("**load reduction**") or shifting demand away from the peak ("**load shifting**"). This can be achieved by temporarily reducing the electricity consumed in electricity-intensive processes for short periods. We refer to this as "**Turn-down DSR**".
2. By increasing demand during periods of excess supply. We refer to this as "**Turn-up DSR**".[21]
3. By using on-site generators[22] to temporarily meet electricity requirements, reducing the electricity taken from the grid. On-site generators are common for emergency use across industrial and commercial sites. We refer to this as "**Standby DSR**".
4. By using batteries (either stand-alone or in combination with intermittent production resource such as solar PV) to reduce electricity consumption from the grid during peak times. We refer to this as "**Battery-led DSR**".

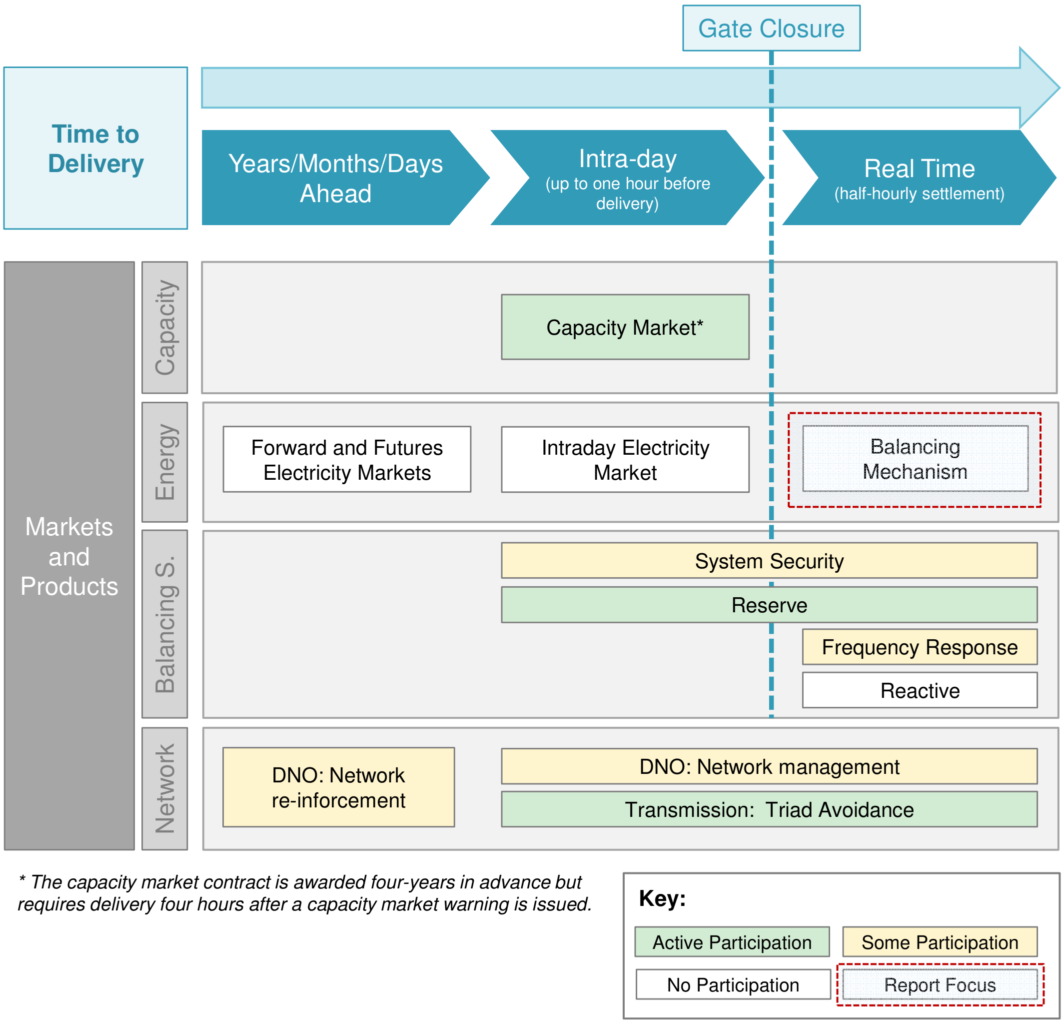
2.2. Opportunities for DSR in the GB Electricity Market

The markets and products in developed electricity markets typically span four major categories, each covering distinct (albeit often overlapping) market needs: these are capacity, energy, balancing services and network support. This is illustrated in Figure 2, which identifies the scope for DSR participation across potential markets for DSR.

21 We use the term Load Response to refer to both Turn-down and Turn-up DSR.

22 We do not include generators independently connected to the distribution network as DSR.

Figure 2: Opportunities for DSR in the GB Electricity Market



Source: CRA Analysis

While DSR does not currently compete *directly* in the GB energy markets or the BM by making bids or offers,[23] it does compete with traditional transmission-connected generation, embedded generation and other forms of DSR in the Balancing Services and Capacity Market. The focus of this report is on the access of DSR to the BM but, for context, the rest of this section provides an overview of the current market for DSR across capacity, balancing services and network support.

2.2.1. Capacity Market

The GB Capacity Market is a market-wide mechanism open to both supply-side and demand-side resources.[24] Successful participants receive a fixed revenue stream (in

23 As explained in Section 3.1, while DSR does not currently have independent access to the BM, it can participate in the Balancing Mechanism through its electricity supplier.

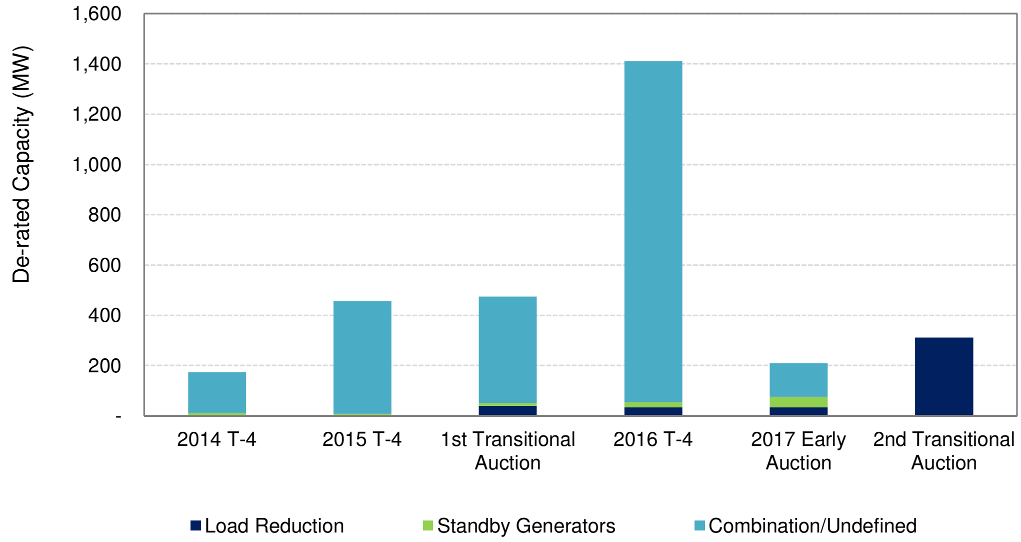
24 See EMR Delivery Body website for Capacity Market overview (https://www.emrdeliverybody.com/CM/overview.aspx)

£/kW-year) in exchange for the obligation to generate/activate during times of system stress.

DSR Participation in the Capacity Market

The participation of DSR in the Capacity Market has been growing over time. The first T-4 auction in 2014 (for delivery in 2018) awarded contracts to less than 200 MW of DSR. But in the recent 2016 T-4 auction (for delivery in 2020) contracts awarded to DSR capacity increased to over 1.4 GW. The 2017 Early Auction saw only 209 MW of DSR contracts awarded. This might have been due in part to an expectation of higher clearing prices for the second Transitional Auction[25] which took place on 22 March 2017 for delivery in the same period as the Early Auction (October 2017 – September 2018).[26]

Figure 3: Evolution of DSR in the Capacity Market (in order of auction dates)



Source: CRA Analysis of Capacity Market results published by the EMR Delivery Body

Incentives for DSR Participation in the Capacity Market

The design of the Capacity Market provides some clear incentives for the development of DSR. First, the implementation of the Capacity Market has included two Transitional Auctions specifically targeting DSR. Second, the market design allows the participation of Unproven DSR.[27] This allows DSR aggregators to bid capacity into the auction on the

25 The Transitional Auctions were created to offer targeted support to DSR and increase levels of participation ahead of the delivery period of the first T-4 auction.

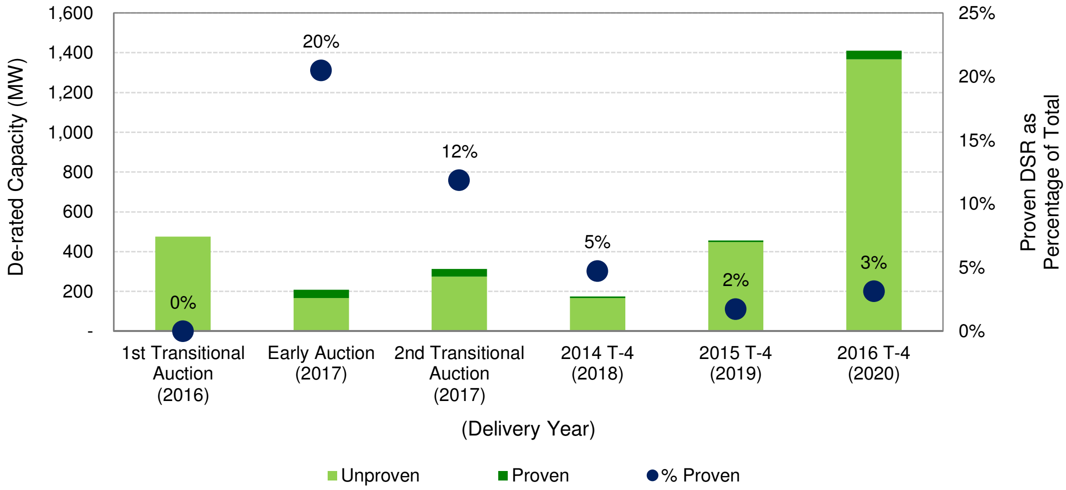
26 The second Transitional Auction concluded on 22 March at a clearing price of £45/kW-year with 312 MW of awarded capacity agreements. (See https://www.emrdeliverybody.com/Capacity%20Markets%20Document%20Library/ Transitional%20Auction%2017-18%20Provisional%20Results%20Report.pdf)

27 Unproven DSR is defined in the Capacity Market Regulations as a DSR Capacity Market Unit (“**CMU**”) for which a DSR test has not been carried out.

basis of a business plan outlining, among other things, how the DSR Capacity has or will be secured by the DSR provider.[28]

It is worth noting that Unproven DSR makes up the majority of the awarded contracts to DSR over the auctions held to date. Proven DSR, as shown in Figure 4, comprised around 20% of the contracts awarded in the 2017 Early Auction, but only 3% of the contracts awarded in the 2016 T-4 auction. The first Transitional Auction which took place early in 2016 for delivery during the winter of 2016 – 2017, did not clear any proven DSR.

Figure 4: Capacity Market Proven vs. Unproven DSR Participation (in order of delivery year)



Source: CRA Analysis of Capacity Market results published by the EMR Delivery Body

While DSR participation in the Capacity Market has been growing, the share of DSR as a percentage of awarded capacity contracts is still less than 3%. This contrasts with a more mature market such as PJM[29] in the USA where DSR capacity reached 15 GW for delivery in the summer of 2015[30] (9% based on a forecasted peak demand of 163 GW).[31] Since then, the amount of DSR capacity clearing in the PJM auctions has declined, reaching 10.3 GW in the latest auction for delivery in 2019/2020[32] (or 6.5% based on a peak load forecast

28 National Grid. *Capacity Market Prequalification Guidance.* August 2016 (https://www.emrdeliverybody.com/Capacity%20Markets%20Document%20Library/Capacity%20Market%20Prequal%20Guide%202016%20v2.pdf)

29 PJM refers to the regional power market covering all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia.

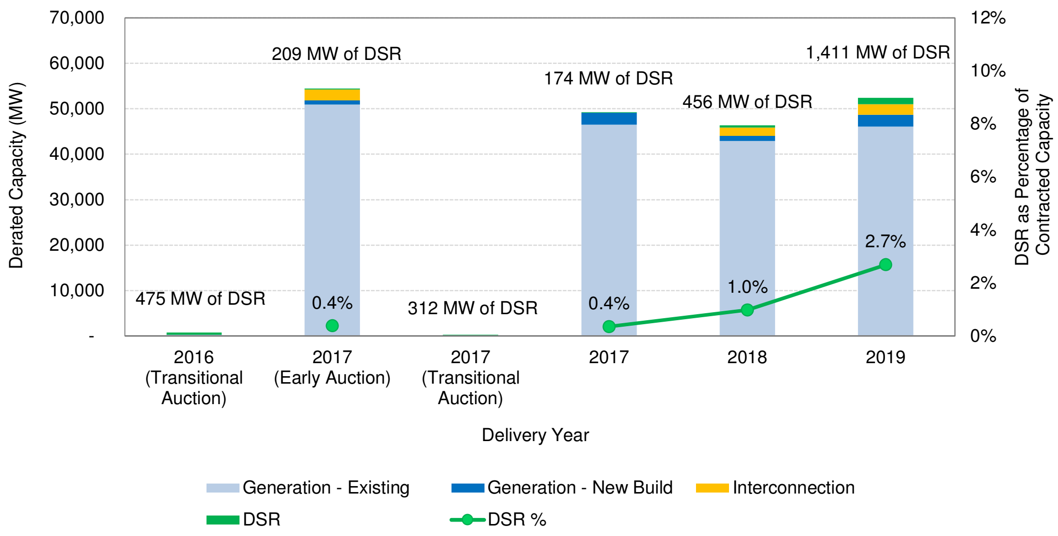
30 PJM 2019/2020 RPM Base Residual Auction Results (http://www.pjm.com/~/media/markets-ops/rpm/rpm-auction-info/2019-2020-base-residual-auction-report.ashx)

31 PJM Updated 2015/2016 RPM Base Residual Auction Planning Period Parameters (https://www.pjm.com/~/media/markets-ops/rpm/rpm-auction-info/2015-2016-planning-period-parameters-report.ashx)

32 PJM 2019/2020 RPM Base Residual Auction Results (http://www.pjm.com/~/media/markets-ops/rpm/rpm-auction-info/2019-2020-base-residual-auction-report.ashx)

of 157 GW).[33,34] However, while PJM is a useful indicator it should not be taken as a direct benchmark for GB. This is because the underlying load and generation mix is different. In particular, PJM has more air-conditioning load which is more suitable for DSR than many other types of demand.

Figure 5: DSR as a Percentage of Total Capacity Market Contracted Capacity (in order of delivery year)



Source: CRA Analysis of Capacity Market results published by the EMR Delivery Body

2.2.2. Market for Balancing Services

Ensuring reliability and a continuous balance of supply and demand requires the power system to cope with large and rapid swings in demand, supply, or both. National Grid uses the term "Balancing Services" to refer to the range of products it uses "to balance demand and supply and to ensure the security and quality of electricity supply across the GB Transmission System."[35] National Grid currently procures over 20 different balancing services products across the categories of System Security, Reserve, Frequency Response, and Reactive Power.

- **System Security.** In 2014 National Grid held auctions for Supplemental Balancing Reserves ("**SBR**") and Demand-side Balancing Reserves ("**DSBR**").[36] These services were designed to ensure enough capacity in the system during the winters

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33 PJM 2019/2020 RPM Base Residual Auction Planning Period Parameters (http://www.pjm.com/~/media/markets-ops/rpm/rpm-auction-info/2019-2020-rpm-bra-planning-parameters-report.ashx)

34 These figures should be interpreted with some caution. Much of the DSR that is contracted in the PJM base auctions is subsequently sold back to the market in the incremental auctions. PJM's independent market monitor reports that DSR providers have replaced up to 58% of the commitments from base auctions in incremental auctions. (See Table 9, Monitoring Analytics. Analysis of Replacement Capacity for RPM Commitments: June 1, 2007 to June 1, 2016. December, 2016)

35 http://www2.nationalgrid.com/uk/services/balancing-services/

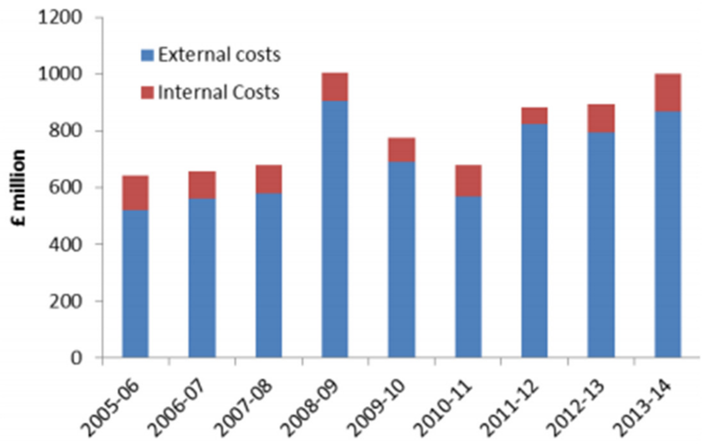
36 National Grid classifies SBR and DSBR as system security services despite referred to as 'reserve'.

of 2014/2015, 2015/2016, 2016/2017 and 2017/2018, ahead of the first delivery year of the capacity market. While the SBR tender was only open to supply-side resources, the DSBR tender targeted commercial and industrial electricity consumers able to reduce demand between 4 pm and 8 pm on winter weekdays. 37

- **Reserve**. National Grid procures a number of reserve products that enable it to respond over a short timeframe to unforeseen demand increase and/or generation unavailability.
- **Frequency Response** products comprise generation and demand that is held in automatic readiness to manage all credible circumstances that might result in frequency variations outside ±1% of a target of 50.00Hz.
- **Reactive power** products are required to manage voltage levels on a local level to meet the varying needs of the system.

Total expenditure on Balancing Services is currently about £1 billion a year[38] and is projected to increase further in the future.[39]

Figure 6: Balancing Services Costs



Source: National Audit Office. Electricity Balancing Services Briefing. 2014 Data from Ofgem, National Grid and NAO analysis

DSR participation across the different Balancing Services varies significantly across products. In some cases, DSR participation is limited by the requirements of the product definition itself, in other cases, the economics of different resource options results in low

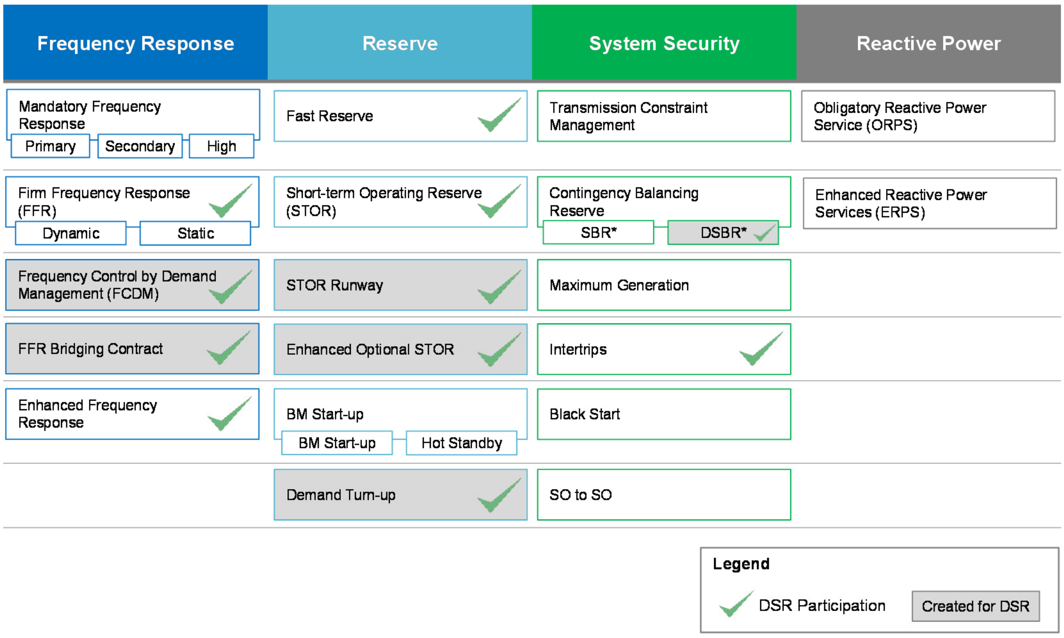
37 The SBR and DSBR have been replaced by contracts awarded in the Early Auction of the Capacity Market in February 2017 for delivery 2017/2018. See SBR Documentation on National Grid's Website (http://www2.nationalgrid.com/UK/Services/Balancing-services/System-security/Contingency-balancing-reserve/SBR-Tender-Documentation/). These services are discussed further at Section 2.2.2

38 National Grid spent £1.043 billion on balancing services in the year from April 2015 through March 2016 (http://utilityweek.co.uk/news/balancing-costs-could-double-to-2bn-within-five-years-report/1257062#.WMK9C2-LSUk)

39 In June of 2016, National Grid's head of Electricity Network Development estimated that the costs of Balancing Services could double in the next five years (see http://www.telegraph.co.uk/business/2016/06/26/balancing-demand-could-cost-national-grid-2bn/)

DSR participation. However, National Grid has tailored some products specifically to enable DSR participation in products providing Frequency Response, Reserve and System Security. Figure 7 presents a categorisation of Balancing Services products, along with a visual guide on the ability of DSR to provide each of the services.

Figure 7: Balancing Services Products and DSR Participation



** Note that SBR and DSBR have been replaced with Capacity Market agreements.*

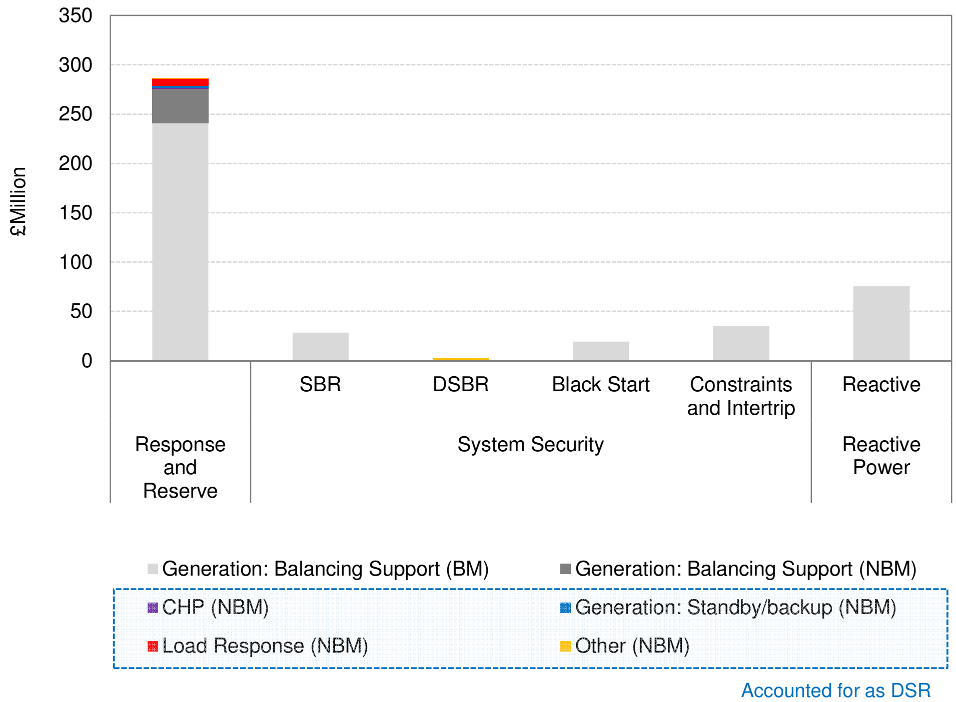
Source: CRA Analysis of National Grid's Balancing Services webpage

DSR Participation in the market for Balancing Services

DSR participation in the Balancing Services market is concentrated in the Frequency Response and Reserve categories. The total spend on the Response and Reserve categories for the 2015-2016 financial year was £287 Million.[40]

40 National Grid. *Non-BM Balancing Services Volumes and Expenditure*. 1 April 2015 to 31 March 2016 (http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=8589937379)

Figure 8: Total 2015-2016 Spend on Balancing Services*

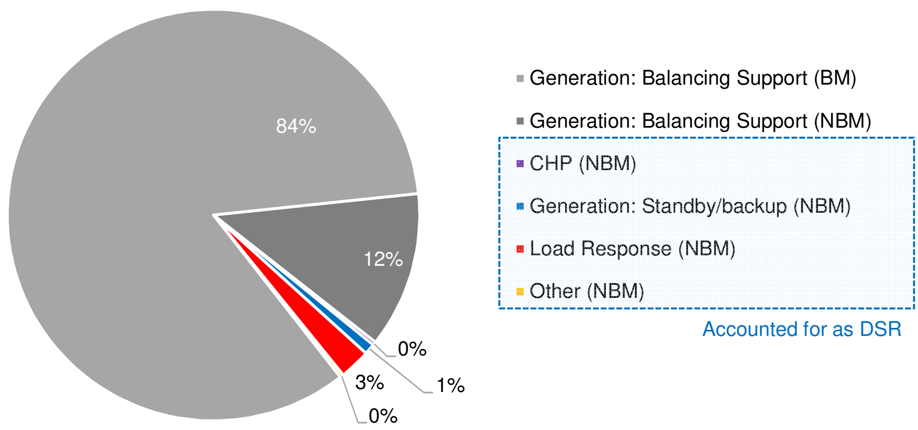


** Excludes Constraint payments*

Source: CRA Analysis of National Grid's Non-BM Balancing Services Tracking Report

As shown in Figure 9, DSR made up 4% of the total expenditure on Response and Reserve Balancing services from April 2015 through March 2016.

Figure 9: 2015-2016 Response and Reserve Percentage of Total Spend by Provider Type



Source: CRA Analysis of National Grid's Non-BM Balancing Services Tracking Report

Incentives for DSR Participation in the Balancing Services Market

Some of the current complexity in the Balancing Services market has been a direct result of the development of products specifically tailored to DSR. The products created with DSR in mind are shown in Figure 7 and include: Frequency Control by Demand

Management ("**FCDM**"), FFR Bridging Contract, STOR Runway, Enhanced Optional STOR, Demand Turn-up, and the now withdrawn DSBR.

While there are no detailed statistics available to assess the growth of DSR in the Balancing Services market following the introduction of these products, it is likely that they have been an important catalyst for the growth of DSR in the GB market.

Further, National Grid's Power Responsive initiative has since 2015 specifically encouraged the participation of demand side flexibility in GB electricity markets by promoting transparency and facilitating consumer information. Power Responsive is a stakeholder-led programme facilitated by National Grid which brings together industry and energy users in order to:

- Raise awareness of DSR and engage effectively with businesses; and
- Ensure that demand and supply have equal opportunities when it comes to balancing the system.[41]

2.2.3. Benefits of DSR to Network Infrastructure Investment

Investment in network re-enforcement and network management costs can be deferred or reduced by DSR. The market for DSR to sell services to Distribution Network Operators ("**DNOs**") is in its early stages, but the understanding from pilot projects is being used to better capture the benefits of DSR and introduce new routes to market. Two sample pilot projects are described below.

The Customer-Led Network Revolution project trialled direct control which required industrial and commercial customers to adapt their energy usage upon request by the DNO, Northern Power Grid. The trial included 14 sites, 13 of which were signed up through aggregators. The trial resulted in 33 DSR instructions with 31 resulting in successful DSR response (94% reliability).[42]

The Low Carbon London project was developed with the aim of understanding and characterising the performance of DSR services within the distribution network. Trials included 11 hotels, water pumping stations, offices, a hospital, a data centre and a department store. All of the demand-led DSR sites attempted to fulfil their DSR contracts by heating, ventilation and air-conditioning ("**HVAC")** load reduction, except for four water pumping stations, which turned down water pumps. DSR was able to deliver 95% of requested response.[43]

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41 Power Responsive website (http://powerresponsive.com/)

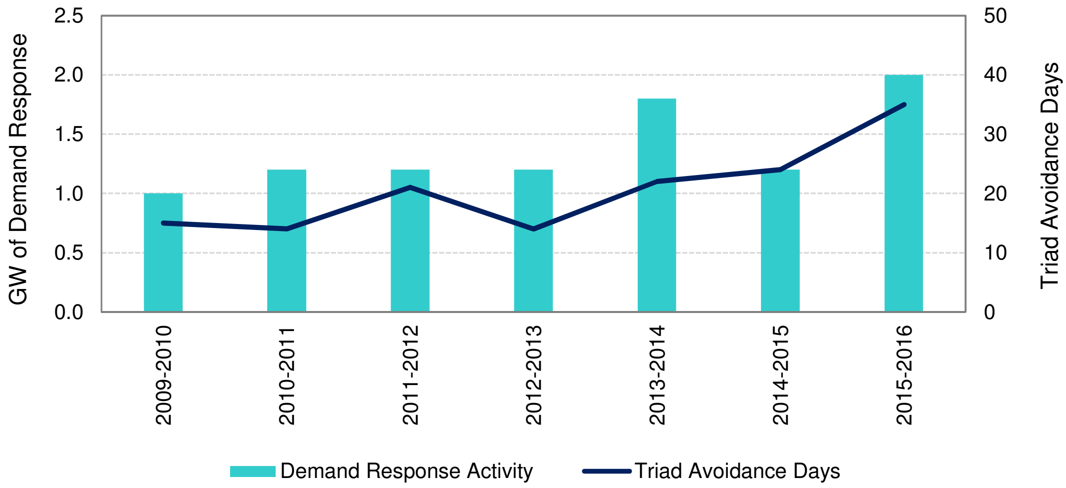
42 Customer-Led Network Revolution. *CLNR Industrial & Commercial DSR Trials*. December 2014 http://www.networkrevolution.co.uk/wp-content/uploads/2014/12/CLNR-I-and-C-Demand-Side-Response-Trials-2014-v0.92.pdf

43 Imperial College London. *Distributed Generation and Demand Side Response – Services for Smart Distribution Networks*. September 2014. (http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Low-Carbon-London-(LCL)/Project-Documents/LCL%20Learning%20Report%20-%20A7%20-%20Distributed%20Generation%20and%20Demand%20Side%20Response%20services%20for%20smart%20Distribution%20Networks.pdf)

DSR Participation in Triad Avoidance

The recent increase in the Transmission Network Use of System Charges Demand Residual has incentivised DSR to mitigate the incidence of these charges by reducing demand during particular peak hours (known as Triad peaks). As shown in Figure 10, over the past five years, Power Responsive estimates that there has been a significant increase in the amount of load reduction in response to Triads. Notably, on its website Flexitricity states that "Triad management is one of the most lucrative demand-response revenue sources".[44] The value of Triad avoidance has recently amounted to up to £45/kW-year. Recent proposals from Ofgem may reduce this progressively for exporting generation (in-front-of-the-meter) to the level of avoided cost at the Grid Supply Point, estimated at less than £2/kW. While this may not immediately affect behind-the-meter generation, it is possible that a wider review of network charging arrangements may result in a similar reduction for behind-the-meter generation.[45]

Figure 10: Triad Avoidance Activity



Source: Power Responsive Annual Report 2016

2.2.4. Summary of Current DSR Participation in GB Markets

As described in the previous sections, DSR is active in the Capacity Market, Balancing Services and Triad avoidance. However, as shown in Table 1, DSR's share of the Capacity Market and Balancing Services market value is still below 5%. We note that based on the available data, DSR's share of savings from Triad avoidance is almost 30%.

44 https://www.flexitricity.com/en-gb/solutions/triad/

45 https://www.ofgem.gov.uk/system/files/docs/2017/03/minded_to_decision_and_draft_impact_assessment_of_industrys_proposals_cmp264_and_cmp265_to_change_electricity_transmission_charging_arrangements_for_embedded_generators_0.pdf

Table 1: Summary of DSR participation in GB Markets

Market	Total Market		DSR Participation		DSR Share of Market Value
	Volume (GW)	Value (£ Million)	Volume (GW)	Value (£ Million)	
2016 T-4 Capacity Market Auction	52	1,180	1.4	32	3%
Response and Reserve Balancing Services	NA	287	2.1	11	4%
Triad Avoidance	7	315	2.0	90	29%

Source: CRA Analysis of CM Auction results; National Grid Non-BM Balancing Services Volume Tracking Report; National Grid CMP264: Embedded Generation Triad Avoidance Standstill and CMP265: Gross charging of TNUoS for HH demand where Embedded Generation is in the Capacity Market. Table 5.

2.3. Structure of DSR Supply

2.3.1. Customer-base

The provision of DSR currently and in the next decade is expected to remain primarily sourced from industrial and commercial ("**I&C**") consumers. This is the current focus of National Grid's Power Responsive initiative and of the Association for Decentralised Energy.[46]

The extension of smart metering to include the residential sector and introduction of smart appliances may increase the ability to exploit flexibility in residential load. But we consider that this is likely to be mostly in the form of implicit DSR,[47] and also likely to largely remain a market better suited for suppliers as a mass-market offering.[48] This is because it will be necessary for residential DSR to comprise a portfolio of a very large number of aggregated residential customers in order to reach an efficient scale. Given their price inelasticity, individual customers are only likely to be willing to bear limited interruptions to their load (although we note that technology developments could possibly overcome this barrier over time). Moreover, a large number of customers will be required to establish a credible 'baseline' given the volatility of individual customer loads. In this regard, we expect that in the short term established suppliers that have an existing mass-market operation with supporting customer management and billing systems (the cost of which are already recovered through their supply contracts), will have a significant competitive advantage over IDAs. Given the focus of this report on direct access to the BM for IDAs, we have limited our analysis of the economic potential of DSR to I&C consumers.

According to *the energyst* survey "*Demand Side Response 2016 Report*",[49] of those companies that participate in DSR, 42.5% are in the industrial sector, 17% in the

46 The Association for Decentralised Energy is developing a Code of Conduct for its members that is limited to non-domestic customers.

47 This is consistent with the assumptions in the COWI report for the EU, DG Energy *Impact Assessment Study on Downstream Flexibility, Price Flexibility, Demand Response & Smart Metering.* See page 132.

48 See also http://theenergyst.com/wp-content/uploads/2016/09/Baringa.pdf

49 The survey covered respondent's across the following sectors: Industrial, Finance, Manufacturing, Commercial, Food and Drink, Retail and Public Sector.

commercial sector, and 17% in the public sector.[50] The remaining 23.5% is split across food and drink, manufacturing, finance and retail. In general, there are two types of flexible loads: (i) energy intensive processes which can vary their load, and (ii) cross-sectional technologies that are suitable for offering flexible loads.[51] Cross sectional technologies can include motors, pumps, compressors, refrigeration and HVAC.[52]

However, Ofgem's survey "*Industrial & Commercial demand-side response in GB: barriers and potential*",[53] found that 71% of companies in the industrial, commercial and public sectors do not participate in DSR. Ofgem's survey also found that this is likely due to a number of barriers, including concerns over the impact of DSR provision on business performance and difficulty in understanding the products and channels available for participation.

2.3.2. Aggregators

In a market with overlapping opportunities and a wide range of product requirements, aggregators provide an important route to market for customers' DSR. They provide market information and distil market opportunities to what is relevant for each potential DSR provider. Moreover, through aggregation they can enhance the value of DSR by selling services across different markets for which some customers would be too small to access in their own right. They can also increase the reliability of DSR by pooling together resources across different industries and geographies. Table 2 summarises the key performance requirements, procurement processes and contract duration for the major revenue opportunities for DSR.

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50 Page 4, *the energys*t survey (http://theenergyst.com/dsr/)

51 Gruber, Biederman and von Roon. *The Merit Order of Demand Response in Industry*. Page 1. (https://www.ffegmbh.de/download/veroeffentlichungen/454_dr_industry_enerday/ffe_demand-response-industry_paper.pdf)

52 See page 13, Ofgem Industrial & Commercial demand-side response in GB: barriers and potential. October 2016.

53 https://www.ofgem.gov.uk/system/files/docs/2016/10/industrial_and_commercial_demand-side_response_in_gb_barriers_and_potential.pdf

Table 2: DSR Participation in GB Electricity Market

Market	Procuring Entity	Product Category	Product	Minimum Size (MW)*	Notice Period	Duration	Regularity**	Procurement Process	Contract Duration	Value*
Capacity Market	Electricity Settlements Company	Capacity Market Obligation	Transitional Auction	0.5	4 hours	Indefinite (in theory)	No history	Auction	1 year for DSR	£
			T-4 Auction	2	4 hours	Indefinite (in theory)	No history	Auction	1 year for DSR	£
Balancing Services	National Grid	Frequency Response Services	Static Firm Frequency Response (FFR)	10	30 sec	Max 30 min, typically 5 min	10 - 30	Monthly tender	One month	££
			Dynamic FFR	10	2 sec	Max 30 min, typically 3-4 min	Daily	Monthly tender	One month	£££
			FFR Bridging	< 10	30 sec	30 min	10 - 30	Bilateral	1 - 2 years	££
			Frequency Control by Demand Management (FCDM)	3	2 sec	30 min	~ 10	Bilateral	1 - 2 years	££
			Enhanced Frequency Response	1 - 50	1 sec Dynamic	Max 15 min, typically 3-4 min		Trial tender	4 years	£££
		Reserve Services	STOR	3	20 min	2-4 hrs, typically <20 min	Able to deliver 3x per week	Tender	2 months - 2 years	£
			STOR Runway	< 3	20 min	2-4 hrs, typically <20 min	Able to deliver 3x per week	Bilateral	2 years	£
			Fast Reserve	50	2 min, reaching 50 MW in 4 min	15 min		Monthly tender	One month	£
			Demand Turn Up	1	10 min, sometimes requested day-ahead	Min 30 min		Trial tender	7 months	£

** The "Value" column provides a high-level indication of the relative value of different products per unit (MWh or MW, depending on product) compared to each other. It does not indicate the relative value of each service to individual DSR providers, as they may be focused on a different mix of services.*

Source: Power Responsive 2016 Annual Report and CRA Analysis based on National Grid's website

Number and type of aggregators

There are currently 19 aggregators registered as Commercial Aggregation Service Providers on the National Grid website, including three of the large six vertically-integrated suppliers.[54] In addition, according to Ofgem, there are another six aggregators currently operating in the market, including another one of the large big six suppliers.

There are three main types of aggregator: stand-alone, in partnership with suppliers and supplier-led (with own supply license). IDAs – that are not part of or owned by a large supplier – are represented in each of these three types of aggregator. Different aggregators within these broad categories focus to a greater or lesser extent on different DSR and DSR-related products. This is described next.

Figure 11: DSR Aggregators Business Models

	Stand-alone	Stand-alone and in partnership with suppliers	With Supply License
Focus on Turn-down and Turn-up DSR	EnerNOC Endeco Technologies Origami Energy	Open Energi	*Tempus Energy Supply**
Focus on Standby DSR	Peak Gen	UK Power Reserve	
Broad DSR focus	Pearlstone Energy Upside Energy Moixa	Flexitricity REstore KiWi Power Open Utility	Limejump
DSR combined with other energy services	Ameresco Actility Reactive Technologies Energy Pool/ Schneider Cynergin Projects		npower Centrica Engie EDF Energy SSE SmartestEnergy

** Turn-down DSR excludes Standby DSR*

*** Tempus Energy Supply exited the supply market in October of 2016.*[55]

Source: CRA Analysis based on company websites

Type of DSR

While some aggregators support both Turn-down/Turn-up DSR and Standby DSR, others focus on one or the other. Open Energi, for example, is focused on shifting electricity consumption for very short periods in response to second-by-second fluctuations in the system. Their approach relies on a technology platform linked to electricity-consuming

54 http://www2.nationalgrid.com/UK/Services/Balancing-services/Demand-Side-Response/

55 http://utilityweek.co.uk/news/tempus-energy-exits-energy-supply-market/1286152#.WL7k8W-LSUk

equipment.[56] Other aggregators like UK Power Reserve focus on providing a route to market for existing standby generators.[57] Lastly, aggregators like Flexitricity and KiWi Power have developed portfolios that include both Turn-down/Turn-up DSR and Standby DSR.

Scope of services provided

In addition to providing DSR aggregation services, some aggregators provide other energy management services. These services can include energy efficiency consulting, renewable energy and distributed generation project delivery, and invoice management.

Go-to-market strategy

Another source of differentiation between aggregators is the way they choose to go to market. Our interviews with stakeholders suggest that while some aggregators partner in different ways with energy suppliers, other aggregators are, for the most part, going to market as stand-alone aggregators. Aggregator-supplier partnerships can take a number of different forms; these range from aggregators providing a white-label service to suppliers, to equity investments by suppliers in aggregators.

Having a supplier licence is not currently a requirement to provide DSR services in the GB electricity market. However, some aggregators do have a supply license. In the majority of cases, the supply license has preceded the aggregation service. This is the case for all of the Vertically-integrated ("**VI**") suppliers with aggregator businesses, as well as some independent suppliers that have started to develop a DSR service offering (e.g. Engie and SmartestEnergy). Limejump is currently the only independent aggregator with a supply license.[58]

The Role of Aggregators in the Capacity Market

The participation of aggregators in the Capacity Market has two important benefits. First, aggregators enable the participation of individual DSR resources that would not meet the minimum capacity requirement on their own. The minimum capacity required to participate in the Capacity Market is 2 MW, although we note that the minimum capacity threshold was lowered to 500 kW for the 2017/2018 Transitional Auction.[59] Second, aggregators can support reliability through the diversification of DSR resources within a single portfolio. A well-diversified portfolio that aggregates numerous customer sites with differing types of load and on-site generation diversifies the risk of standby generation outages and unresponsive demand.

Aggregators (both supplier-led and IDAs) represent the majority of DSR participation in the Capacity Market. Only 3% of DSR in the Capacity Market involves direct participation by a DSR-provider (shown as "Other" in Figure 12). Further, in the first auction, virtually all DSR

56 http://www.openenergi.com/our-technology-dynamic-demand/

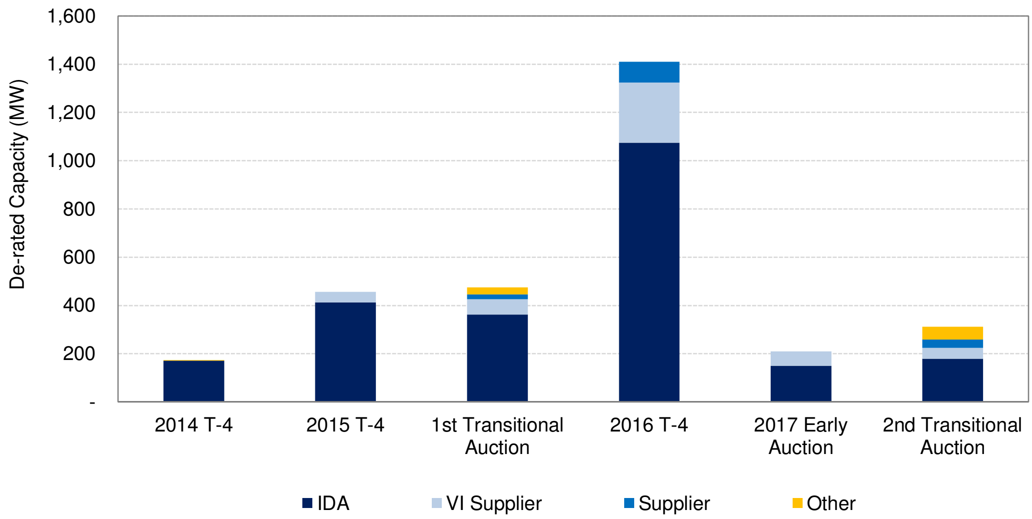
57 http://www.ukpowerreserve.com/operations-and-services/stor-aggregationdemand-side-management/

58 Tempus Energy, a company with an explicit business model to supply energy to small businesses and trade the flexibility in their energy usage closed its supply business at the end of 2016.

59 National Grid. *Market Auction Guidelines.* 15 November 2019. Page 6. (https://www.emrdeliverybody.com/Lists/Latest%20News/Attachments/71/Capacity%20Market%20Auction%20Guidelines%2015th%20November%202016.pdf)

participated through an IDA. The share of large VI Suppliers and other smaller suppliers has increased over time, as Figure 12 shows. But IDAs still represent the majority of DSR participation in the Capacity Market. In the 2016 T-4 auction, IDAs represented 76% of the contracts awarded to DSR capacity.

Figure 12: Capacity Market DSR Participation by Market Participant Type (in order of auction dates)



Source: CRA Analysis of Capacity Market results published by the EMR Delivery Body

The Role of Aggregators in the market for Balancing Services

As with the Capacity Market, aggregators enable the participation of small, individual loads in the Balancing Services market. This not only increases the level of participation by DSR, but also provides reliability benefits through diversity. The economies of scope possible through aggregation also supports penetration of DSR in the Balancing Services market. PA Consulting estimates that 82% of DSR participating in the STOR product is provided through Aggregators (both IDAs and Supplier-led aggregators).[60]

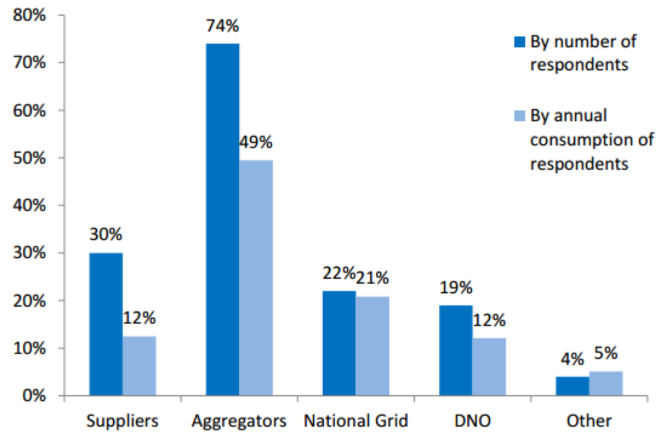
2.3.3. The Role of IDAs in the provision of DSR

The recent Ofgem survey found that while a third of consumers use at least two routes to market for their DSR, 74% of survey respondents currently providing DSR do so through an IDA (referred to as "Aggregators" in their survey). [61] This is shown in Figure 13.

60 PA Consulting. Aggregators - Barriers and External Impacts, May 2016. Table 4.

61 Ofgem. Industrial & Commercial demand-side response in GB: barriers and potential. October 2016. (https://www.ofgem.gov.uk/system/files/docs/2016/10/industrial_and_commercial_demand-side_response_in_gb_barriers_and_potential.pdf)

Figure 13: Current Routes to Market for DSR Participation

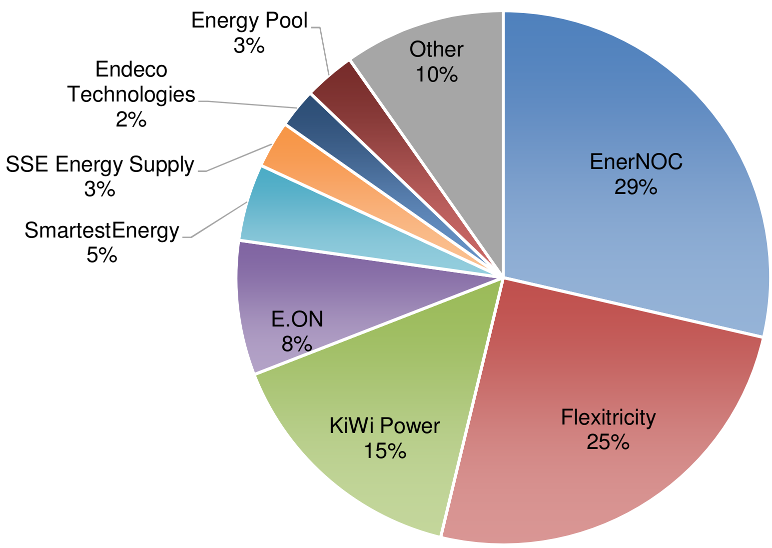


Source: Ofgem survey "Industrial & Commercial demand-side response in GB: barriers and potential", page 16

IDAs play a significant role in the participation of DSR in both the Capacity Market and the Balancing Services market. Between 70% and 98% of the DSR capacity participating in the Capacity Market currently does so through an IDA (see Figure 12).

Figure 14 summarises the share by applicant of contracted capacity in the Capacity Market across all auctions to date. As shown, the three largest IDAs (by capacity market share), EnerNOC, Flexitricity and KiWi Power, account for 69% of all contracted capacity across all auctions to date. The fourth largest participant is the Supplier-Aggregator E.ON, one of the UK's six large suppliers.[62] The other participants' shares are all less than 5% of the market.

Figure 14: DSR Participation in the Capacity Market by Applicant



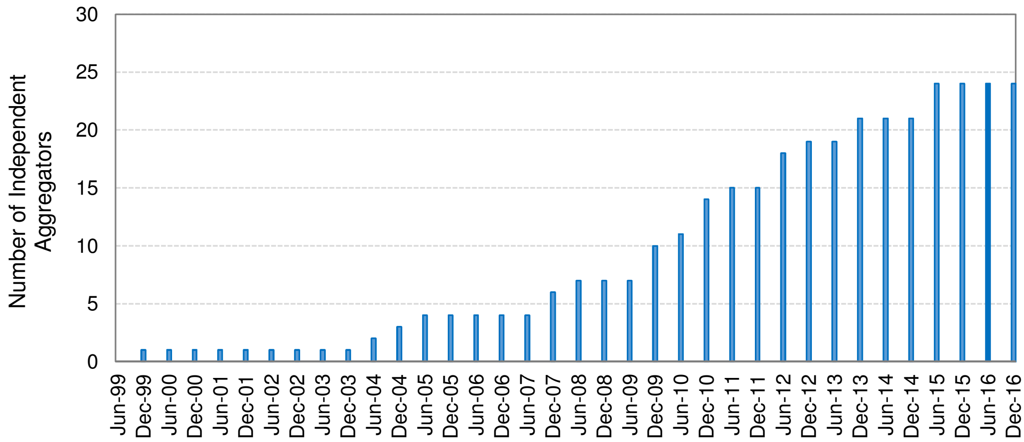
Source: CRA Analysis of CRA Analysis of Capacity Market results published by the EMR Delivery Body

62 E.ON has recently re-structured, placing its conventional, dispatchable generation into a separate company, Uniper.

Rate of Market Entry

Our analysis suggests that the rate of entry for IDAs accelerated from the middle of 2007 through the middle of 2015. Open Energi was the only one of the current aggregators in operation by the end of 1999, Flexitricity and REstore entered the market in 2004 and by the end of 2007 there were six independent aggregators in the market. Since then, the number of IDAs grew rapidly, reaching 24 by the middle of 2015. This is shown in Figure 15.

Figure 15: Rate of Market Entry for Independent Aggregators



Source: CRA Analysis (based on date of incorporation)

2.4. Barriers to growth for DSR and IDAs

Market participants have identified a number of barriers to growth for DSR in both the Capacity Market and Balancing Services. These are discussed in the responses to the Call for Evidence[63] and are summarised below under the headings: structural, regulatory and market organisation.

2.4.1. Structural barriers

There are a number of structural features of the market for DSR that act as barriers.

Economies of scale and scope. Our interviews with IDAs have indicated that despite the market entry highlighted above levels of profitability are mixed. Aggregator businesses incur significant initial customer acquisition costs (as mentioned below, customers may be reticent about accepting the compatibility of DSR with their business operations) and have lacked access to sufficient revenue opportunities. This requires aggregators to build and retain substantial DSR portfolios which given the issues noted here has proved difficult.

63 *A SMART, FLEXIBLE ENERGY SYSTEM - A call for evidence.* Department for Business, Energy and Industrial Strategy and Ofgem November 2016. The responses were not yet published at the time of completing this report.

Low prices. The lack of sufficient revenue opportunities for DSR has in part been a function of low energy market prices[64] and competition from other resources, as evidenced by over-subscribed auctions.[65] In Ofgem's recent survey "nearly half of respondents not providing DSR said that there was no financial incentive that could persuade them to participate".[66]

2.4.2. Regulatory barriers

There are a number of barriers that are a function of specific regulations or requirements.

Duration of contracts in the Capacity Market. A principal concern of aggregators targeting the Capacity Market is the inability of DSR to access long-term contracts. DSR resources can only secure 1-year contracts in the capacity market, though new generating resources can secure contracts of up to 15 years. For IDAs in particular, this may affect their access to finance and its cost.

Regulatory costs. Aggregators in the Capacity Market have argued that regulations impose high costs on DSR in terms of bid bonds and the testing regime applied to DSR. The bid bond for participating in the Capacity Market has been increased from £5/kW to £10/kW for new build generation and interconnection capacity after the latest consultation by BEIS. The bid bond for unproven DSR has been kept at £5/kW but may be subject to further review.[67] Moreover, the testing regime for the GB Capacity Market requires three successful instances of load reduction delivery.[68]

Performance requirements. Potentially time-unlimited dispatch required during a Capacity Market stress event means that, in theory, even high-cost DSR may be required to generate/reduce load for extended periods of time, regardless of its position in the dispatch merit order.

The benefits from Triad Peak avoidance have assisted in the development of DSR, in particular Stand-by DSR, and as such have not been a barrier to the development of DSR.

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64 Low energy prices reduce the attractiveness to a consumer of foregoing consumption since the incremental margin to be earned in the wholesale market by effectively 'selling back' energy through DSR is limited. However, it is also worth noting that higher energy prices may in turn lead to increased implicit-DSR, thereby moderating demand for explicit DSR. See pages 37-40 *EMR Panel of Technical Experts' Final Report on National Grid's Electricity Capacity Report* Department of Energy and Climate Change June 2016

65 Figure 1, National Grid *STOR Market Information Report TR28*. March 2016. (www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=8589934881)

66 Page 8, Ofgem. Industrial & Commercial demand-side response in GB: barriers and potential. October 2016. (https://www.ofgem.gov.uk/system/files/docs/2016/10/industrial_and_commercial_demand-side_response_in_gb_barriers_and_potential.pdf). See also page 15 *Demand side responses Turning inertia into inertia* The Energyst 2016 Report

67 DECC. Government Response to the March 2016 consultation on further reforms to the Capacity Market. Pages 10-11. (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/521301/Govt_response_to_March_2016_consultation_FINAL.pdf)

68 Rule 13.2, Capacity Market Rules (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/340046/capacity_market_rules.pdf)

But, as noted above, these regulated network charges are likely to be re-structured to remove an overall pricing distortion though initially this may be limited to in-front-of-the-meter generation.

2.4.3. Barriers from market organisation and conduct

The way in which the energy and balancing services markets are organised and operated give rise to some barriers for aggregators.

Transparency and market liquidity. While some of National Grid's Balancing Services products are procured through open market tenders, other contracts are negotiated bilaterally (see Table 2). During our stakeholder interviews, the lack of transparency in the procurement process for some products was mentioned as a barrier to the further development of DSR. The perceived lack of transparency – together with the multiplicity of balancing products, discussed next – also leads market participants to be concerned with the potential instability of balancing product demand and revenue uncertainty. These issues have been cited as reasons for dissatisfaction with the provision of DSR in *the energyst* survey

Accessibility of information and customer understanding. The complexity of products and applicable rules and restrictions can lead to a lack of customer understanding around the ways in which their DSR capability can be monetised.[69] Understanding the operational requirements and potential overlap between National Grid's over 20 Balancing Services products has been referenced by many stakeholders as a significant barrier to entry. Participating in one product may limit a provider's ability to participate in another, but understanding the dependencies and conflicts of different products is difficult and time-consuming. Aggregators consistently highlight the time and effort required to educate customers on the compatibility of DSR with their business operations and to tailor services that can receive wide company support. However, as part of their Power Responsive programme, National Grid is working on the simplification of flexibility products, making markets clearer and easier to participate in.[70]

Treatment of BM and Non-BM STOR. STOR can be provided through accepting an offer from a BM Unit ("**BM STOR**") or through instructing an increase in generation or reduction in demand which is embedded in a Supplier BM Unit ("**Non BM STOR**"). Whereas the activation of BM STOR results in the STOR provider being rewarded through the balancing mechanism, Non BM STOR results both in an activation payment to the STOR provider and an imbalance payment which accrues to the Supplier. Suppliers may share this imbalance payment with the STOR provider, enabling non BM STOR providers to bid down activation rates, suppressing the development of BM STOR.[71] This distortion has acted as a barrier for some DSR providers.

69 Page 25 Ofgem survey "Industrial & Commercial demand-side response in GB: barriers and potential",

70 Page 5, Power Responsive. Annual Report 2016. (http://powerresponsive.com/wp-content/uploads/2017/01/Power-Responsive-Annual-Report-2016-FINAL.pdf)

71 This issue (which acts as a market distortion more than barrier to aggregators) is being addressed through a proposed modification to the Balancing and Settlement Code, P354. See https://www.elexon.co.uk/mod-proposal/p354/

Lack of access to energy prices. Unlike traditional generation, DSR is not currently able to receive directly an energy price in the ex-ante markets (day-ahead or intra-day) or in the BM, whether reducing load during a system stress event or at other times. Therefore, unlike traditional supply-side resources which may be able to offset some or all of their running costs with an energy revenue, DSR resources (other than for Balancing Services) have to absorb all of their activation costs. Accordingly, DSR providers have to take account of their likely full activation costs, along with an assessment on the probably of a stress event, into their capacity market bids. This, in turn, reduces the competitiveness of DSR in the capacity market. We discuss access to the BM in more detail in the next section.

2.5. Summary

In summary, this section has shown that DSR is growing but its penetration is still relatively low. IDAs have played a key role in driving the growth of DSR, despite reticence among many end-customers. However, IDAs remain concerned with a number of barriers to aggregation.

Growth in DSR provision

The opportunities for the participation of DSR across electricity markets in GB has grown over the last five years. On the demand side, the growth of DSR participation in the Capacity Market suggests it has been a catalyst for DSR growth.[72] Similarly, National Grid's increased focus on DSR participation across Balancing Services has supported the growth of DSR in GB's electricity markets.

DSR penetration still low

Despite the growth in DSR provision, its penetration still remains relatively low. It is as yet less than 3% of awarded contracts in the Capacity Market and in terms of Balancing Services, DSR constitutes 4% of total expenditure on Response and Reserve products.

Customer interest limited but may be growing

Customer awareness of DSR opportunities may be growing as a result, among other things, of improved information dissemination by National Grid as part so if its Power Responsive initiative and the increased rate of entry by IDAs. However, in a recent survey, some 28% of respondents responded that they have not considered DSR because they do not understand enough about the market.[73]

Aggregators, especially IDAs, have played a key role in developing DSR

Aggregators (both supplier-led and IDAs) in the Capacity Market comprise the majority of DSR contracts awarded across all auctions. Moreover, among aggregators, it is IDAs that clearly mediate most DSR in the Capacity Market, with 76% of DSR capacity being contracted through IDAs in the last T-4 auction. Similarly around 80% of DSR in STOR is provided through aggregators.

72 This is also supported by some of our stakeholder interviews that pointed to the Capacity Market as a reason for entering the market.

73 *The energyst*. Demand Side Response 2016 Report. Page 15

This is consistent with experience in other markets. 82% of all PJM demand response is estimated to be provided by DSR aggregators.[74]

IDAs are concerned with a number of barriers to growth

The number of IDAs has more than quadrupled over the last decade. But some, including large IDAs, are reportedly unprofitable. This may be due in part to competitive pressures which have kept prices for DSR products in both the Capacity Market and for Balancing Services at ‘low’ levels. It is also likely to follow from some of the barriers to growth identified above concerning regulation, market organisation and structural features of the market for DSR. The remainder of this report focusses on one of these barriers – access to the Balancing Mechanism.

74 Pages 41-42 *Impact assessment study on downstream flexibility, price flexibility, demand response and smart metering Final Report* July 2016 prepared by COWI for the European Commission. See also page 19 *Assessment of demand response and advanced metering* Federal Energy Regulatory Commission November 2011

3. THE CURRENT TREATMENT OF DSR IN THE BALANCING MECHANISM

This section considers the current treatment of DSR in the BM. It begins by outlining how DSR may be offered by suppliers (as registrants of a BM Unit). This provides the necessary background to a discussion on the incentives on suppliers to develop DSR in their own right or to support IDAs (that are not able to be registrants of BM Units).

3.1. Current treatment of DSR in the Balancing Mechanism

Currently there is no provision in the design of the BM for explicit DSR. In other words, there is no mechanism for making bids and offers for a customer's potential demand since there is no baselining of a customer's demand against which such bids/offers may be assessed in order to monitor delivery. As a result, DSR is limited to provision by incumbent suppliers that may activate DSR in their customers in order, for example, to create a long-position in the BM in relation to their contracted generation and so benefit from anticipated high imbalance prices.[75] IDAs are limited to indirect access to the BM through suppliers that are willing to reach an agreement with an IDA to use its customer's DSR capability in this way. The IDA's customer that is providing the DSR must be supplied by the same supplier offering the DSR into the BM.

3.1.1. Example of current treatment of DSR in the BM

Illustrative payment flows

Figure 16 illustrates the principal transactions currently related to the activation of a DSR offer in the BM. In this example, the IDA is shown as having developed a DSR capability with the customer but is reliant on the customer's supplier to provide the DSR in the BM. The IDA is dependent on an agreement with the supplier to receive a share of the value achieved by the activated DSR. In practice, there is little or no DSR provided to suppliers for offering into the BM.

In the example:

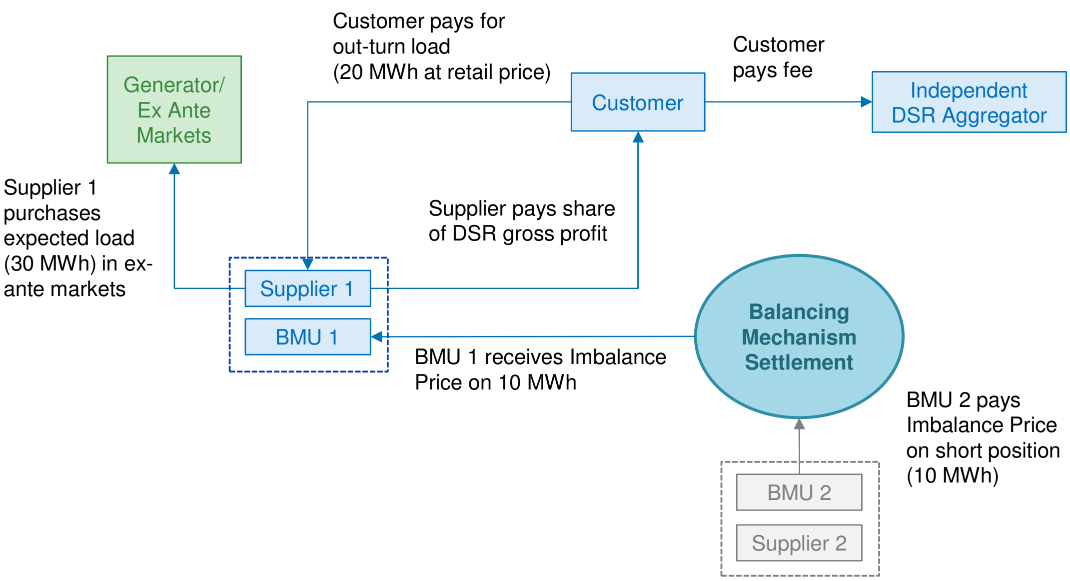
- The Customer's expected demand is 30MWh
- Supplier 1 (which in the BM is the Balancing Responsible Party 1) has procured generation contracts of 30MWh and notified 30MWh of ex ante purchases of energy (these are referred to in the rest of this report as "**Contracted Generation**" though the counterparty is not necessarily a physical generator) to Elexon (responsible for BM settlement);
- The IDA requests the supplier to offer 10MWh of DSR which is then accepted to meet incremental demand of 10MWh from Supplier 2;
- The metered demand of Customer in out-turn is 20MWh;

75 The supplier's position in the BM is contracted Generation less metered demand, so any reduction in demand would make the supplier's position more long in generation than without the DSR. Similarly, if the retailer's starting position is short generation, the DSR reduces this short position.

- Suppliers 1's (i.e. BRP 1's) imbalance of 10MWh (30MWh of notified Contracted Generation less metered demand of 20MWh) is sold in the BM at the Imbalance Price;
- Suppliers 1 receives the retail supply price on 20MWh (from the Customer) and the Imbalance Price on 10MWh (from imbalance settlement);
- Suppliers 1 pays out for 30MWh of Contracted Generation and shares the proceeds from the accepted DSR volume (i.e. the difference between the imbalance price and the retail price on 10MWh) with the Customer and the IDA.[76]
- Supplier 2 (i.e. BRP 2) which in out-turn is short 10MWh purchases the 10MWh at the imbalance price.

The figure shows how the net position of Supplier 1 and the BM are 'balanced' in terms of the receipts and payments relating to energy.

Figure 16: Current treatment of DSR in the BM



Source: CRA Analysis

Illustrative payments

An illustration of the net financial position of the supplier is set out in the table below. This shows how an incumbent supplier may gain from DSR (as presented in row 8 of the table compared to row 7) after allowing for sharing some of the profits of DSR with the DSR provider. This profit sharing, together with the reduced purchases of energy serves to reduce the customer's expenditure relative to the pre-DSR position (as presented in row 9 of the table compared to row 1).

76 In practice, the payments to the Customer could flow though the IDA.

Table 3: Illustrative example of current payment flows

		Volume MWh	Price £/MWh	Revenue/(Cost)* £
		[A]	[B]	[C]=[A]x[B]
Expected retail sales	[1]	30	52	1560
Ex ante generation procurement	[2]	30	50	-1500
DSR gross profits: value less retail price	[3]	10	8	80
DSR imbalance revenues	[4]	10	60	600
Out-turn retail sales	[5]	20	52	1040
Supplier allocation of DSR gross profits	[6]=(2/3)x[3]x-1			-53
Supplier net financial position pre-DSR	[7]=[1]+[2]			60
Supplier net financial position post-DSR	[8]=[2]+[4]+[5]+[6]			87
Customer/IDA net financial position	[9]=-[5]-[6]			-987

Notes
* Positive figures represent revenues. Negative figures represent costs.
[6] Supplier allocates 2/3 share of net value of DSR
[8] Supplier's improved financial position is share of DSR value less retail price
[9] Customer/IDA improved financial position is share of DSR Value

Source: CRA Analysis

This analysis of illustrative payments indicates how the incumbent supplier may have an incentive, under certain market conditions, to activate DSR in order to improve its position in the BM. This may also create additional revenues to be shared with DSR providers and so potentially leads to all parties having an incentive to facilitate DSR. Importantly, the scale of the DSR is small relative to total sales which means that in a negotiation over how best to share the DSR profits, the supplier is likely to be more concerned about retaining the supply contract with the customer than gaining an 'unreasonable' share of the DSR profits. However, the risk of failing to retain the customer is dependent on the customer's preparedness to switch to an alternative supplier and confidence in being able to achieve equally attractive supply contract terms with that alternative supplier. This is discussed next.

3.2. Theories of Harm

We consider two main theories of harm concerning the development of DSR for I&C customers that relate to barriers to aggregation and as such may impact the competitiveness of the market for balancing bids/offers in the BM. A theory of harm does *not* imply any prejudgement of an adverse effect on competition; it simply provides a focus for consideration of some of the issues that have been raised by market participants. The theories of harm discussed below are not mutually exclusive but, rather, are closely related.

3.2.1. Theory of Harm 1: Suppliers face weak incentives to develop DSR

Concerns have been raised by some market participants that suppliers have not been competing to develop DSR – whether by themselves or working with IDAs - for structural reasons.

Section 2.4.1 has described the barriers to developing DSR that are perceived by customers. This has arguably limited the extent of any competitive pressure on suppliers to develop DSR for their I&C customers. At the same time, vertically integrated suppliers may have also been incentivised not to develop DSR – and not to support IDAs' development of DSR for their customers- because it may reduce profits by constraining demand for their generation.[77] This assumes that such generation - which might expect to be used instead of potential DSR - is able to recover more than its marginal costs.[78] The excess generation capacity which has characterised the power market in recent years[79] may have also had the effect of making the integrated suppliers especially concerned over DSR initiatives that might further exacerbate such excess generation.

Finally, some suppliers may be discouraged from developing DSR by imbalance price risks. Suppliers have generally been incentivised to marginally over-contract for generation capacity relative to demand because of the risk of exposure to imbalance prices. In this regard, DSR may not have been perceived as a reliable substitute for generation resources because of the need for customers to place restrictions on the activation of DSR. In this regard, Sustainability First have reported:

> *In addition, suppliers with whom we spoke stressed that delivery of a reliable electricity supply was paramount. From a supplier perspective today, this is more readily assured through generation than by DSR. On sound business grounds, suppliers as of today do not view the two alternatives as substitutes.* [80]

3.2.2. Theory of Harm 2: Suppliers use their incumbency position with supply customers to foreclose IDAs from developing DSR

Some IDAs have suggested that under the current arrangements, suppliers use their incumbency position to limit IDA access to customers' potential DSR capability. The contention is that some suppliers - by prolonging negotiations on the terms under which DSR might be activated and by seeking to extract a high share for themselves of any associated revenues from activating DSR - prevent IDAs from developing DSR capabilities with customers. Suppliers are allegedly motivated to foreclose the market for DSR to IDAs for three main reasons.

First, as noted above, DSR may reduce profits for the vertically integrated supplier by constraining demand from related generation assets. Second, some suppliers may prefer their customers to take up their own DSR products rather than use an IDA. And, third, IDAs may in the long-run also pose a competitive threat to the incumbent supplier's retail supply contract by developing a commercial relationship with a supplier's customer. However, this would require the IDA to partner with another supplier or take on a supply licence and

77 See page 23 *Paper 4 What demand-side services can provide value to the electricity sector* Judith Ward, Maria Pooley and Gill Owen Sustainability First. July 2012. "DSR could dampen prices in STOR otherwise available to BM units and/or smooth prices in the wholesale market – and so perhaps reduce available generator revenues". See also page 69.

78 This is discussed further below at Section 6.3.1 and in Appendix A, Section 5.2.

79 The capacity margin increased year on year from 2007 through 2012 due to both decreasing demand and growing capacity. (See National Statistics and DECC. *UK in Brief 2012*. Page 19. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65898/5942-uk-energy-in-brief-2012.pdf)

80 Page 25, *Paper 4 What demand-side services can provide value to the electricity sector* Judith Ward, Maria Pooley and Gill Owen Sustainability First. July 2012.

associated obligations (and gain sufficient supply customers to establish a viable supply business).

Suppliers may have been assisted in foreclosing the market to IDAs (to the extent that this has occurred) because of their customers' switching costs. Customers, it is argued, have been unwilling to break their supply contracts in order to replace a 'recalcitrant' supplier with one more willing to accept DSR for a number of reasons, including the procurement costs associated with re-competing a supply contract; the advantageous terms in the existing supply contract relative to the limited returns that may be available to them from DSR; and the general difficulty of gaining internal management agreement, on not just interrupting load with the implementation of DSR, but also on a further requirement, namely replacing the incumbent supplier.

IDAs are not readily in a position to mitigate the costs for the customer of replacing the incumbent supplier by gaining a supply licence and themselves offering replacement supply terms. This is because of the barriers to developing a supply business for I&C customers that are most likely to be able to offer DSR. In particular, the retail margins for the largest power customers are relatively small,[81] which means that retail supply businesses require substantial sales in volume terms in order to recover their costs. It is not feasible to enter the market with a view to serving only a few large customers and to date the customer-base for DSR has been relatively small.[82]

3.3. Consideration of Theories of Harm

The extent to which suppliers may have weak incentives to develop DSR – other than it being uneconomic to do so - arises in principle from vertical integration reinforced by possible lack of competitive pressure from other generators, suppliers, and DSR customers. The gains from reducing one's own customers' DSR activities could only outweigh the costs (in terms of compensation to the customers or loss of business if that induces them to leave for other suppliers) if such DSR suppression increases the supplier's upstream generation revenues in the BM by a sufficiently large amount. However, such increase in revenues may be hard to realise if (as seems likely) there is strong competition in the BM, from other generators and/or from the DSR customers of other suppliers. In other words, the putative benefits to the generation business from suppressing DSR may be competed away almost entirely by other generators and other providers of DSR.

Moreover, the market for the supply of I&C customers is also relatively competitive. This means that suppliers seeking to suppress DSR at the cost of their customers (by, say, increasing their supply prices to DSR providers or requiring their customers to take their own less efficient offer of DSR) risk losing those customers to their competitors.

At the same time, there is some evidence to suggest that the issues raised in Theory of Harm 1 concerning vertical integration and lack of customer interest have been mitigated in recent years due to a number of market developments. This is discussed next.

81 The Competition & Markets Authority in its recent energy market investigation reported on combined EBIT margins for the six largest retailer suppliers: I&C 1.9%, domestic 3.5% and SME 8.0%. See paragraph 5 *Appendix 9.13: Retail profit margins Energy Market investigation* Competition & Markets Authority 24 June 2016

82 Independent retail suppliers compete predominantly for domestic and SME customers and not I&C customers. See *Case studies on barriers to entry and expansion in the retail supply of energy in Great Britain* Competition & Markets Authority 18 February 2015

However, we recognise that IDAs are concerned about the risk of foreclosure from incumbent suppliers. This risk may be greatest where suppliers are fully incentivised to develop DSR and wish to foreclose such opportunities to IDAs in order to exploit them to their own benefit. As noted above, this may only be damaging to consumers where competition between suppliers is insufficient to ensure that suppliers' concerns over customer retention are strong enough to result in efficient DSR being developed and its rewards shared appropriately. IDAs may in any event be at a competitive disadvantage to large suppliers for the further reasons set out below.

3.3.1. Competitiveness of I&C supply market

The market for I&C customers may be considered relatively competitive by reference to a number of indicators including rates of market entry, market shares and customer engagement. For these reasons, among others, it was not the focus of the recent Competition and Markets Authority ("CMA") energy market investigation which instead focussed on the residential and micro-business supply market.[83]

Market entry, shares and concentration

At March 2016 there were over 40 active suppliers in the non-domestic market for supply of electricity. These included the six large suppliers, a number of other firms with upstream generation businesses as well and various smaller suppliers. Ofgem has noted that market entry has recently risen rapidly, with four new suppliers entering the non-domestic electricity supply market (either by itself or in conjunction with the non-domestic gas market).[84]

Table 4: Total number of non-domestic suppliers (I&C and SMEs)

	June 2015	March 2016
Gas & Electricity	24	26
Electricity	18	18
Total	42	44

Source: CRA analysis based on Ofgem Retail Energy Market Reports for 2015[85] and 2016[86]

The market shares of the largest I&C suppliers (as represented by sales to half-hourly meters) includes relatively recent entrants such as Haven Power (7%) and SmartestEnergy (7%). Market concentration is also relatively low. The Herfindahl-Hirschman Index ("**HHI**")

83 See https://assets.publishing.service.gov.uk/media/5773de34e5274a0da3000113/final-report-energy-market-investigation.pdf

84 Paragraphs 2.6-2.8 *Retail energy markets in 2016* Ofgem August 2016

85 https://www.ofgem.gov.uk/sites/default/files/docs/2015/09/retail_energy_markets_in_2015_report_0.pdf

86 https://www.ofgem.gov.uk/system/files/docs/2016/08/retail_energy_markets_in_2016.pdf

measuring market concentration was 1,287[87] in 2016, which is below the 1,500 threshold at which the US Department of Justice regards markets to be moderately concentrated.[88]

Table 5: Market shares of non-domestic electricity suppliers

	June 2015*	March 2016**
EDF	21%	19%
npower	19%	18%
E.ON	13%	11%
SSE	10%	11%
Haven Power	7%	7%
Engie	6%	6%
Smartest Energy	6%	7%
Other	17%	21%
HHI	**1,341**	**1,287**

** Half-hourly ("**HH**") metered customers, by volume*
*** Half-hourly metered customers and profile classes 5-8 (Non HH), by volume*
Source: CRA analysis based on Ofgem Retail Energy Market Reports for 2015 and 2016

Customer engagement

I&C customers appear to be relatively engaged with the market, as indicated by their switching rates. The proportion of half-hourly metered customers that have not switched since 2002 is below 26%, and over 30% of half-hourly meter points have switched over four times. Moreover, the rate of switching over the last two years has been increasing.[89]

In addition, Ofgem has noted that increasingly businesses are on fixed term contracts and that there has been a shift away from simply extending or rolling over a contract at the end of its term towards negotiating a new contract.[90] Similarly, in our interviews with suppliers, we were informed that I&C supply contracts were mostly 1-2 years in duration and that increasing customer engagement on their part was required to retain business. This is especially important in limiting the risk of foreclosure since, while the incumbent supplier may have exclusive responsibility for the customer's meter point during the period of the supply contract, this is of relatively limited duration. This is discussed further below at Section 3.3.3.

87 Because the "Other" category of suppliers in 2016 include 37 suppliers (44 suppliers in Table 4 minus 7 suppliers listed in Table 5), the HHI presented in the table is an average of the HHI calculated assuming that the "Other" category is a single supplier (HHI of 1502) and assuming that the "Other" Category is equally split among 37 suppliers (HHI of 1073).

88 https://www.justice.gov/atr/herfindahl-hirschman-index. In the CMA's *Merger Assessment Guidelines* at paragraph 5.3.5 (September 2010 CC2 Revised OFT 1254) 'any market with a post-merger HHI exceeding 1,000 may be regarded as concentrated and any market with a post-merger HHI exceeding 2,000 as highly concentrated'.

89 Paragraph 3.29 *Retail energy markets in 2016* Ofgem August 2016

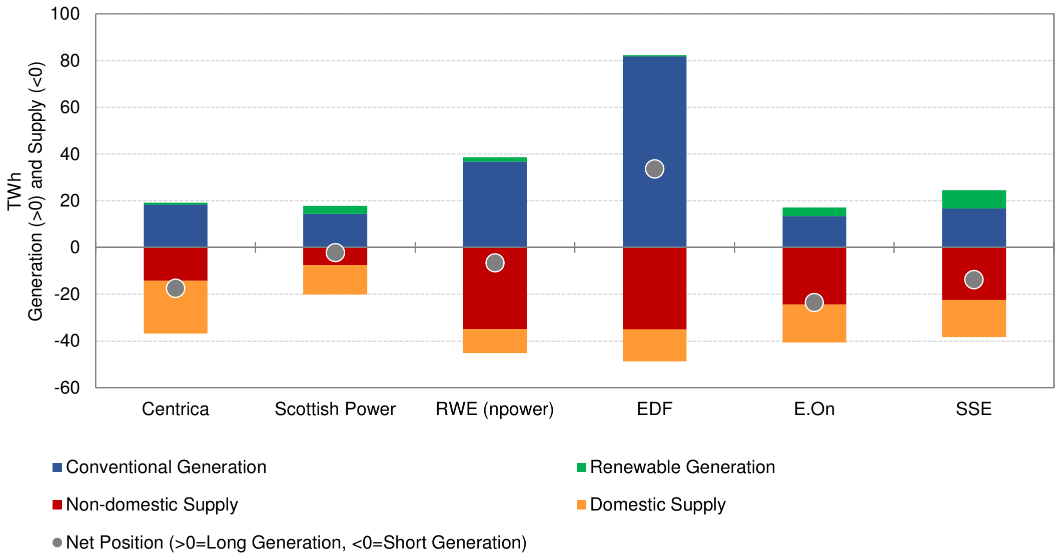
90 Paragraph 3.30 *ibid*

3.3.2. Reduction in the potential impact of vertical integration on suppliers' approach to DSR

The UK's six largest energy suppliers have until recently all been vertically integrated with substantial upstream generation portfolios.[91] Ofgem noted in its market assessment prior to the CMA energy market investigation that "since 2000, generation capacity ownership by the largest six suppliers has increased from around 36 per cent to around 70 per cent in 2013".[92] Indeed, the CMA presented the vertical integration of suppliers as one of its theories of harm in its energy market investigation.[93]

However, more recently there have been significant changes in the market positioning of some suppliers as well as in the overall generation market. As shown in the figure below, most of the large six suppliers are overall short generation (in other words with customer demand exceeding output from vertically-related generation).

Figure 17: Degree of vertical integration by the large six suppliers



Source: CRA analysis based on Energy Companies Consolidated Segmental Statements[94]

In the GB power market, RWE is now separated from the supply business of npower[95] and, similarly, E.ON in 2016 placed all its gas and coal-fired assets into a separate

91 Figure 41 *Case studies on barriers to entry and expansion in the retail supply of energy in Great Britain* Competition & Markets Authority 18 February 2015

92 Paragraph 5.58 *State of the market assessment* OFT, Ofgem and CMA 27 March 2014

93 "Vertically integrated electricity companies harm the competitive position of non-integrated firms to the detriment of customers" paragraph 23 *Energy market investigation issues statement* CMA 24 July 2014

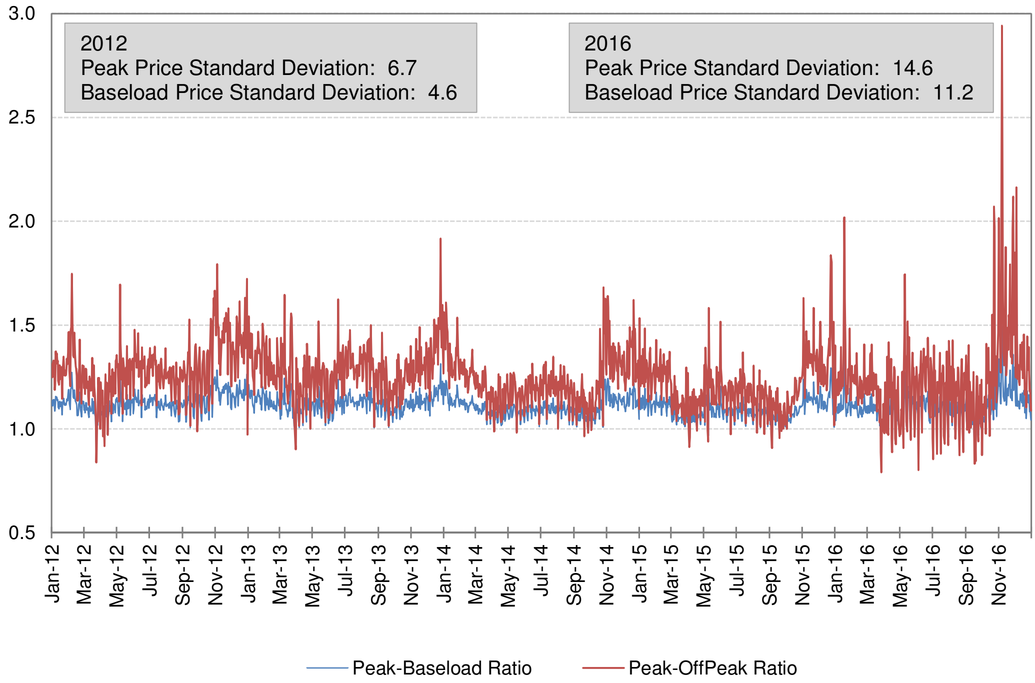
94 https://www.ofgem.gov.uk/system/files/docs/2016/07/energy_companies_consolidated_segmental_statements_css_july2016.pdf

95 Financial Times 11 August 2016 (https://www.ft.com/content/f0cc1ed0-5f84-11e6-ae3f-77baadeb1c93). Full ownership separation has not yet occurred.

company, Uniper.[96] Moreover, Centrica, following a strategic review has "concluded that Centrica is a customer facing business and we are an energy and services company." This means that Centrica is scaling back its upstream assets.[97]

On the other hand, in the generation market the over-hang of excess generation capacity that has persisted over the last few years has more recently been eroded and market prices have increased. Reforms to the determination of imbalance prices in the BM following Ofgem's Significant Balancing Code Review have also resulted in peakier power prices.[98] This was highlighted in National Grid's 2016 *Demand Side Flexibility Annual Report.*[99] The figure below shows increasing price volatility between 2012 and 2016.

Figure 18: Day-ahead price variability



Source: CRA analysis of APX prices

Consequently, the extent of any suppliers' incentives not to support the development of DSR capabilities because of their upstream generation positioning has been reduced by recent changes in these positons. The prospect of improved returns for generation (and DSR) following the recovery of upstream market prices and growing volatility may further reinforce incentives for vertically-integrated suppliers to favour their own generation (or DSR) over the DSR of IDAs. However, in this regard, it should be noted that the CMA in its energy market investigation concluded:

96 Financial Times 18 May 2016 (https://www.ft.com/content/316ce884-1cdc-11e6-a7bc-ee846770ec15)

97 See https://www.centrica.com/sites/default/files/transcript-iain-conn-strategic-review-group_overview.pdf

98 See https://www.ofgem.gov.uk/electricity/wholesale-market/market-efficiency-review-and-reform/electricity-balancing-significant-code-review

99 Page 14 Power Responsive: *Demand Side Flexibility Annual Report.* National Grid

> *[O]ur view is that vertical integration does not have a detrimental impact on competition for independent suppliers and generators, and that there are likely to be some modest efficiencies resulting from vertical integration, that may be passed through to customers. As a result, our conclusion is that vertical integration does not give rise to an AEC.*[100]

Similarly, the CMA concluded:

> *Our analysis of the ability and incentive of generators to exercise unilateral market power indicates that there is currently no risk of an AEC.*[101]

In conclusion, the competitiveness of the upstream generation and supply markets means that the gains to incumbent suppliers from suppressing DSR are likely to be limited. In particular, any supplier that seeks to foreclose IDAs by:

- Discouraging its customers from adopting the IDA's DSR by supply price increases or requiring the customer to adopt its own less efficient DSR offer, risks losing the customer to competing suppliers; or
- Encouraging its customers not to adopt the IDA's DSR by providing supply price discounts risks not recovering the value of these discounts from its upstream generation due to competing generators or DSR providers.

3.3.3. Customer interest in DSR and switching costs

There is some evidence of an increase in customers' interest in DSR. This – combined with relatively low switching costs for customers - may be expected to have the effect of reducing any supplier's reluctance to support the development of DSR capabilities out of concern that not to do so might risk failing to retain the customer's supply contract. In this regard the incumbent supplier is incentivised to offer at least as efficient DSR support as an IDA.

The evidence for increased customer interest in DSR includes:

- The increase in the sale of DSR associated with new revenue opportunities such as the Capacity Market (see Section 2.2.1);
- The reported scope for DSR identified by customers themselves as represented in the results of Ofgem's recent survey of DSR provision by large Industrial and Commercial consumers;[102] and
- The explanation provided to us by one of the large six suppliers for its increased commitment of resources to developing DSR services for its customers. This supplier noted that some of its customers after having been approached by IDAs had then asked what equivalent DSR-support was available from their incumbent supplier.

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100 Paragraph 7.137 *Energy market investigation Final Report* CMA 24 June 2016

101 Paragraph 4.103 *ibid*

102 Page 8 *Industrial & Commercial DSR in GB: barriers and potential* Ofgem October 2016 "Around 60% of DSR non-providers identified potential for demand reduction DSR, while just under half identified potential to increase demand, without affecting their business".

This evidence of some increased interest from customers should *not* be taken to imply that the barriers to aggregation – including potentially onerous product requirements - perceived by customers are all exaggerated. Indeed, as noted above, "nearly half of respondents not providing DSR said that there was no financial incentive that could persuade them to participate".[103]

IDAs have suggested to us that switching costs are cited by customers as a reason for not taking up DSR where their related supplier is unresponsive or unwilling to accommodate DSR. However, switching costs are not identified in the surveys of customers (that we have reviewed[104]) as a barrier to taking up DSR. Switching costs for a customer are principally limited to the internal costs of undertaking a competitive procurement process and for many customers these procurements are run annually or bi-annually indicating that related costs are not especially high. However, IDAs note that customers are as much concerned with the indirect costs of management time and 'disruption' as direct procurement costs.

3.3.4. DSR offerings of major suppliers

Consistent with the observations above on the changing structure of some of the largest supply businesses and increased customer interest, there is some evidence of commitment to developing DSR services by major I&C suppliers. In particular, the share of VI Suppliers of DSR participation in the Capacity Market has increased over time, as Figure 12 shows. In addition, the websites of most of the largest VI Suppliers indicate interest in the provision of DSR for Balancing Services. However, we note that evidence of DSR services being promoted on supplier websites is not the same as evidence of committed marketing and development expenditure. At least one IDA has reported to us its experience of the absence of large supplier competition for DSR services.

3.3.5. Competition between suppliers and IDAs to provide DSR

We recognise that suppliers, though they may be better incentivised to support DSR following recent market developments, may still have an interest in limiting the growth of IDAs. This follows from the opportunity to profit from the sale of DSR services which the incumbent supplier may prefer was taken by itself as opposed to being conceded to an IDA. The supplier may also be motivated, as noted under Theory of Harm 2, by the long-term competitive threat to its own supply contract posed by successful IDAs which develop a commercial relationship with a supplier's customer, and then seek to enter into the supply business. It is certainly the case that the absolute scale of prospective profits on sales of DSR into the BM are less than profits on electricity supply.[105]

This prompts the question: would providing direct BM access for IDAs have much impact given other competitive advantages that suppliers may have over IDAs? We identify a number of comparative advantages for suppliers. We note, however, that the evidence

103 See Section 2.4.1.

104 These surveys include the, *energyst* survey *Demand Side Response 2016 Report,* Ofgem's survey *Industrial & Commercial demand-side response in GB: barriers and potential,* Ofgem's *Retail energy markets in 2016* and papers prepared by Sustainability First.

105 See Section B.1 in APPENDIX B:, which highlights the relatively small quantity of energy likely to result from DSR activation in the BM.

suggests that to date, IDAs have developed the skills and capabilities to deliver DSR to a greater extent than suppliers (see Section 2.3.3.).

Supplier advantages

(i) Access to customers and other supply business synergies

Suppliers, in contrast to IDAs, have a pre-existing portfolio of customers with which they have a commercial relationship. This may provide some marketing advantage to suppliers. As such, it explains some of the partnering arrangements in the current market between IDAs and suppliers.

Further, in providing DSR services retail supply businesses may be able to exploit economies of scope by sharing costs with their existing trading activities. For example, the trading activities of supply businesses may enable them to better price their DSR offers in the BM. However, IDAs may also be able to exploit synergies in providing aggregated DSR across multiple revenue opportunities (such as the Capacity Market and Balancing Services).

(ii) Transaction costs

An IDA under the current arrangements is likely to face higher transaction costs than an incumbent supplier because of the need for the supplier's active involvement before DSR may be provided from its supply customer into the BM. In other words, an IDA seeking to provide DSR into the BM must not only reach an agreement with a customer but also with its supplier on how DSR should be offered and its remuneration shared. Moreover, IDAs are dependent on the aggregation of multiple customer loads in order to achieve economies of scale in implementation costs and to have the ability to offer DSR that meets the minimum scale and quality requirements into balancing services. This means that an IDA, as it attempts to build its portfolio of DSR across multiple customers for whom energy is supplied by more than one supplier, would need agreements to be reached with more than one supplier. This increases the costs for IDAs relative to incumbent suppliers focussed on aggregating the DSR of their own customers. Such suppliers would determine DSR and supply contract terms jointly with their customers. Consequently, reforms that eliminate the requirement for independent aggregators to reach an agreement with incumbent suppliers as to how they mediate the provision of DSR would improve their competitiveness by reducing their transaction costs.[106]

(iii) Access to competitor information

The supplier providing DSR in the BM on behalf of an IDA would have access to commercially sensitive information concerning the IDAs business and its offerings to customers. This would potentially provide the incumbent supplier with some insight into optimal ways in which to reduce a customer's load and so develop its own DSR offerings in competition to the IDA where it regarded this as sufficiently profitable. The commercial sensitivity of information provided to an incumbent supplier is likely to be reduced with any reform to reduce IDA dependency on incumbent suppliers. However, at the same time, the IDAs may be provided with access to the customer's supply contract (in order to refine its DSR offering) which could then assist the IDA in developing a competing supply contract.

106 There does not appear to be any case for socialising directly such costs through regulatory intervention since this would distort efficient competition with generation resources.

IDA skills and capabilities

The addition of a DSR capability to a retail supply business is *not* a straightforward extension of the role of existing retail account managers and other core supply business functions. This is because converting a customer to providing DSR requires the aggregator to have a close understanding of how the customer's technical processes drive its energy consumption (though some large industrial groups may have their own DSR manager). This is necessary in order to determine how any interruption to energy consumption can be designed to minimise disruption to the customer's core business activity. Such understanding is a function of experience and technical skills that are not usually required in a retail supply business. This is highlighted in the case study presented below. However, gaining the client-site knowledge of an existing IDA together with the required communications technology is not in practice likely to be a substantial barrier to suppliers interested in developing DSR.

Case Study: Rainbow Growers

Rainbow Growers has one of the largest single unit greenhouses in the UK. It is powered by two large CHP generators, totalling 5.34MW. On average, just under half of this capacity is standing idle at any time, and this spare capacity is made available to Flexitricity to provide as STOR to National Grid. However this can only be delivered within the constraints of normal business operations. Flexitricity created elective arrangements, allowing Rainbow to opt in and opt out in accordance with its needs.

Source: https://d1dev8zqxu1caz.cloudfront.net/media/cms_page_media/100/Rainbow%20Growers%20Case%20Study_oP6LDD1.pdf

3.4. Potential consumer harm from current limitation on IDA access to the BM

The incentives on incumbent suppliers not to develop DSR as a result of their vertical relationships with generation and the lack of interest on the part of customers have arguably been mitigated to some extent by recent market developments. Indeed, there is some evidence of increasing competition between suppliers to have an attractive DSR-offering for their customers increasing (see Section 3.3.4). Moreover the extent of competition between suppliers (see Section 3.3.1) is itself also likely to encourage suppliers to develop efficient DSR to the benefit of their customers in order to ensure customer retention.

This report does not conclude on the extent to which the theories of harm identified above apply in practice. But, even with increasing competition between suppliers to develop DSR, IDAs may still have an important role to play in further intensifying competition for the development of DSR. It is noticeable that in the last few years, IDAs have been the leading developer of DSR in the capacity market (see Section 2.3.3). Consequently, addressing the market foreclosure concerns of IDAs raised in Theory of Harm 2 through facilitating independent access to the BM for IDAs with an efficient framework for pricing arrangements may reasonably be assumed to further promote competition in the provision of DSR.

The scale of economic benefits achievable from further growth of DSR in the BM (and the related Capacity Market) is set out in the next section. We do not suggest that this could only be realised by providing IDAs direct access to the BM. However, given the important role played by IDAs to date in developing DSR, it is reasonable to assume that they will also contribute, at least to some extent, to the further growth in DSR provided that some of the barriers to aggregation are addressed.

4. RANGE OF ECONOMIC IMPACT OF INCREASING DSR PARTICIPATION IN THE BALANCING MECHANISM

In this section, we provide a range of estimates of the economic benefit from increasing the efficient provision of DSR in the BM through the removal of all relevant barriers. This is presented in terms of the reduction in the costs of energy, generation capacity and network infrastructure that would follow from an increase in DSR provided by I&C consumers.

There is potential for significant increases in the provision of DSR. As shown in the previous section, there are currently around 2.1 GW of DSR participating in Balancing Services market, and around 1.4 GW of DSR participating in the GB Capacity Market. These numbers are not additive (since some DSR may participate across multiple markets) but in any event amount to less than 5% of peak demand.[107] This contrasts with the provision of DSR capacity in some US ISOs and RTOs which exceeds 10% of peak demand,[108] most of which is in the Commercial and Industrial sectors.[109]

Our estimates of economic value from increased DSR provision provide an indication of what may be gained by promoting DSR in the BM. We are not able to attribute a specific share of the overall projected increase in DSR to the elimination of barriers to aggregation for IDAs in the BM. This is because DSR not able to participate in the BM through IDAs might – subject to sufficient incentives[110] - otherwise participate through their incumbent suppliers. In addition, we recognise that some of the capacity cost savings from more DSR being available in the BM may be achievable through the capacity market even without direct access to an energy market.

Further, our modelling approach does not differentiate between the BM (in which 2% of energy is currently traded), and the forward, day-ahead and intra-day markets ahead of gate closure; instead, we model a single, real-time market.[111]

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107 Calculated as 2.6 GW over National Grid's Base Case peak demand for 2020/2021 of 60.2 (See Table 5, National Grid EMR Electricity Capacity Report. May 2016. https://www.emrdeliverybody.com/Lists/Latest%20News/Attachments/47/Electricity%20Capacity%20Report%20 2016_Final_080716.pdf)

108 Although PJM allows for the participation of DSR in the capacity, energy and balancing services markets, in 2016, 99% of DSR revenue in PJM came from the capacity market. Balancing services (synchronised reserves) accounted for another 0.5% and energy market revenues (Energy Economic program) accounted for the remaining 0.5%.
(Monitoring Analytics. *PJM State of the Market -2016*. Section 6. http://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2016/2016-som-pjm-sec6.pdf)

109 See Figure 2, ECI. *Assessment of Demand Response Market Potential and Benefits in Shanghai*. July 2015 (http://www.eci.ox.ac.uk/research/energy/downloads/Assessment%20of%20Demand%20Response%20Market %20Potential%20and%20Benefits%20in%20Shanghai.pdf)

110 See Sections 5 and 6 for further discussion of the incentives on suppliers to develop DSR.

111 By employing this approach, we are effectively assuming that average prices converge across ex-ante and real time energy markets. In other words, we assume that there is arbitrage between ex-ante and real-time markets, and, accordingly, activation of DSR in the BM will over time affect pricing in ex-ante markets.

In particular our estimates of economic value are based on:

- DSR displacing the need for OCGT capacity during peak periods. In other words, in the absence of DSR, more OCGT capacity would be required to provide capacity adequacy;
- The exploitation of excess generation in off-peak periods (with Turn-Up DSR);

This section begins by setting out our estimates of the technical potential of I&C DSR, as well as our view of the demand for DSR on the basis of available electricity demand and intermittent generation forecasts. We then determine the potential economic utilisation of DSR by dispatching it to meet residual demand (that is, system demand less generation by intermittent producers and nuclear). From this, we derive estimates of cost savings due to DSR.

4.1. Supply projections – technical DSR potential

Our estimates of the technical DSR potential in the GB I&C sector are based on a review of existing data and analytical approaches. We consider separately, DSR Turn-Down, Turn-up, Stand-by and batteries.

4.1.1. Estimate of Turn-down DSR potential

Our estimate of the technical potential of Turn-down DSR is largely based on the approach established by Steurer et al. in their paper *Enabling Demand Side Integration*.[112] Our assumptions are sourced from a combination of academic papers[113] and BEIS statistics on the consumption of energy in the UK. Our methodology is based on the following three steps:

1. **Calculate electricity demand by load type that can provide DSR**

   We start with an analysis of electricity consumption by major industrial process and load type across the commercial and industrial sectors in GB, identifying loads that may be suitable for DSR. We apply industry-specific capacity utilisation factors to BEIS' statistics of yearly energy consumption by industrial process and load type[114] to arrive at an average hourly load in MW.

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112 Martin Steurer, Michael Miller, Ulrich Fahl and KaiHufendiek. *Enabling demand side integration – assessment of appropriate information and communication technology infrastructures, their costs and possible impacts on the electricity system.* Smarter Europe, E-world energy & water 2015. (http://www.ier.uni-stuttgart.de/publikationen/veroeffentlichungen/downloads/20150121_SmartER_Europe_Steurer_Miller_et_al.pdf)

113 Anna Gruber, Franziska Biederman and Serafin, von Roon. *The Merit Order of Demand Response in Industry.* ENERDAY - 9 TH Conference on energy economics and technology, Dresden/Germany (https://www.ffegmbh.de/download/veroeffentlichungen/454_dr_industry_enerday/ffe_demand-response-industry_paper.pdf); and Moritz Paulus and Frieder Borggrefe. *Economic Potential of Demand Side Management in an Industrialised Country – the Case of Germany* (http://www.aaee.at/2009-IAEE/uploads/fullpaper_iaee09/P_488_Paulus_Moritz_31-Aug-2009,%2019:08.pdf)

114 Table 4.05 of BEIS Energy Consumption in the UK 2016

2. **Estimate DSR potential by sector and usage**

   Using industry-specific factors estimated by Gruver et al., we use the average MW load estimated in Step 1 to arrive at a DSR potential in MW by sector and major industrial process/load type. We define eight different categories of DSR Turn-Up covering commercial and industrial air conditioning, industrial cooling, and electricity-intensive processes in the Chemicals, Aluminium, Copper & Zinc, Cement, Iron & Steel and Pulp & Paper sectors.

3. **Establish load shift duration and activation costs by type of DSR category**

   We then establish the activation cost and maximum load shift duration for each category of DSR. Our analysis suggests that there are close to 2.5 GW of potential DSR in commercial and industrial air conditioning and industrial cooling alone, which are estimated to have activation costs of less than £15/MWh. DSR related to industrial processes in electricity-intensive industries add another 2.5 GW of capacity with activation costs ranging from around £80/MWh to over £400/MWh.[115]

   Our analysis also suggests a wide range of load shift durations. While the lowest cost DSR available in commercial and industrial air conditioning and cooling may only be able to shift load for an hour or so, the majority of industrial processes compatible with DSR may allow for load to be shifted for up to four hours. For the purposes of this analysis, we have assumed that load rebounds with the same profile as the original load reduction. We note that in practice the rebound profile of electricity-intensive processes may be spread over a larger number of periods. Further, as described in Appendix B, we have constrained Turn-down DSR activations to 25 instances per year for Commercial & Industrial A/C and Industrial Cooling;[116] and to 10 instances per year for all categories of Turn-down DSR covering industrial processes.[117]

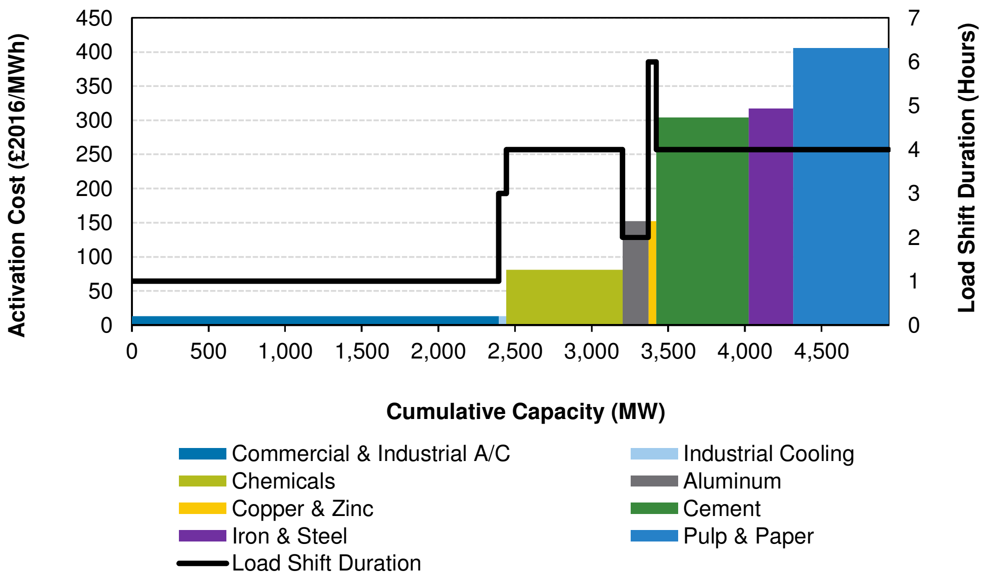
Our supply curve of technical Turn-down DSR potential is presented in Figure 19.

115 We have assumed that the activation costs reported in the literature include the "hassle costs" of DSR activation.

116 This is consistent with the number of Triad Avoidance days in the last five years, and below the 35 Triad Avoidance days in 2015-2016.

117 This is consistent with feedback from our stakeholder interviews.

Figure 19: CRA's estimate of I&C Turn-down DSR technical potential



Source: CRA analysis

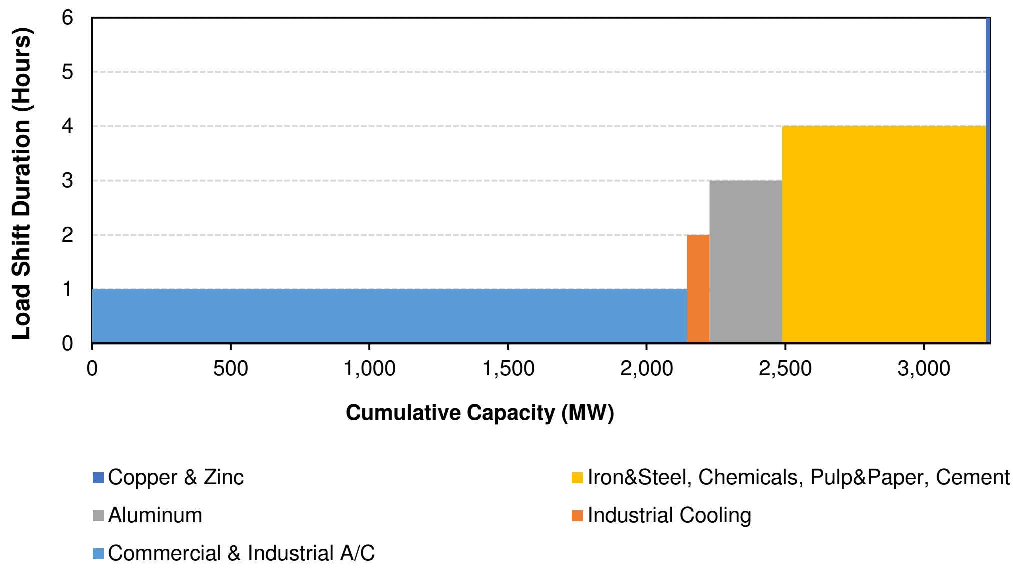
4.1.2. Estimate of Turn-up DSR potential

We have used a similar methodology to estimate the technical potential of Turn-up DSR. Using the turn-up DSR potential factors in Steurer et al. and industry-specific load factors, we use BEIS' statistics on the electricity consumption by major process across the commercial and industrial sectors to estimate a MW potential across five DSR categories.

Similar to our assumptions on Turn-down DSR, we assume that the activation of Turn-up DSR is followed by a reduction in consumption from the baseline after a period of time dictated by the assumed load shift duration. Our supply curve of technical Turn-up DSR potential is presented in Figure 20.

We note that while the activation of Turn-up and Turn-down DSR would take place at different ends of the residual load curve, the technical potential of Turn-up and Turn-down DSR in GW may not be additive if the same loads can respond with both load increases and load reductions. Note that in this report, Turn-up DSR potential excludes batteries, which are evaluated separately.

Figure 20: CRA's estimate of I&C Turn-up DSR technical potential



Source: CRA analysis

4.1.3. Estimate of Standby DSR potential

There are wide-ranging estimates of the capacity of standby generators in the I&C sector.[118] Our analysis is based on 2.1 GW of Standby DSR as estimated by the 2015 Digest of UK Energy Statistics for own generating plant, increasing by 1 GW to 3.1 GW in 2020. By 2030, we assume the addition of another 1 GW, reaching a total capacity of 4.1 GW.

The dispatch of Standby DSR is determined by its short-run marginal costs ("**SRMC**"). Unlike Turn-down DSR, there are no assumed technical limits to the duration of a demand response using standby generators. Similarly, assuming most standby generators would otherwise be idle, load rebound is not an issue with Standby DSR. Our SRMC assumptions for standby generators are derived from BEIS' efficiency and non-fuel variable cost assumptions for reciprocating engines,[119] CO_2 emission factors are taken from the 2016 Government Greenhouse Gas Conversion Factors[120] and the commodity cost assumptions are taken from FES 16.

4.1.4. Estimate of Battery-led DSR potential

In FES 16, National Grid estimates that installed battery capacity by 2020 ranges between 300 MW and 1.4 GW. By 2030 installed battery capacity ranges from 700 MW to 7 GW.

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118 Estimates for installed back-up plant in the UK go as high as 20 GW (see estimates quoted in Sustainability First's report What Demand-Side Services Can Provide Value to the Electricity Sector). However, it is unclear how much of that capacity would be suitable for DSR due to its operational characteristics and outage rates. As shown in Table 5, however, more conservative estimates start at around 3 GW.

119 BEIS, *Electricity Generation Cost Report,* November 2016. We note that in practice, generation used for I&C site back-up may be smaller than the average used by BEIS for their assessment. This may in turn result in lower efficiencies and higher operating costs than assumed for this analysis.

120 BEIS, *2016 Government GHG Conversion Factors for Company Reporting*

The distribution of this battery capacity between transmission-connected, distribution-connected and micro capacity is presented in Table 6.

Table 6: National Grid FES 16 Battery Installed Capacity Scenarios

	2020			
	Gone Green	Slow Progression	No Progression	Consumer Power
Total Capacity	1,362	320	320	917
Distribution-Connected	350	220	220	810
Sub 1 MW	12	0	0	7

	2030			
	Gone Green	Slow Progression	No Progression	Consumer Power
Total Capacity	3,951	835	708	7,126
Distribution-Connected	1,400	600	500	6,600
Sub 1 MW	551	35	8	326

Source: National Grid FES 16

We treat batteries as peak shaving resources, charging when residual load is low and discharging when residual load is high. For simplicity, we have assumed that all battery capacity cycles once a day, generating during the four hours with the highest residual load during the day. We have further assumed an efficiency factor of 93%.[121,122] We use these assumptions to estimate the impact of the total installed capacity of batteries on the half-hourly residual load profile in 2020 and 2030 across the different FES 16 scenarios.

While FES 16 does not provide an estimate of the amount of battery capacity that would be located behind-the-meter (and therefore falling under our definition of DSR), we have assumed that all micro capacity (less than 1 MW) and a third of distribution-connected capacity is battery-led DSR.

4.1.5. Summary of technical DSR potential estimate

The table below summarises our estimates of technical potential for Turn-down, Turn-up, Standby and battery DSR across all four FES 16 scenarios. As noted above, while Turn-down and Turn-up DSR are expected to participate at opposite extremes of the system's residual load curve, the GW estimates for each of those categories may not be additive if the same loads can provide both turn-down and turn-up capacity.

121 We recognise that these simplifying assumptions will not capture all types of batteries, with their associated operation constraints and cycling capacity. However, for the purposes of this analysis we believe our assumptions approximate the impact of new battery technology on residual demand during the most critical times of the year.

122 These assumptions are based on a Lithium battery. See *Lazard's Levelised Cost of Storage – Version 2.0.* Lazard December 2016 (https://www.lazard.com/media/438042/lazard-levelized-cost-of-storage-v20.pdf)

Table 7: CRA Estimates of Technical DSR Potential across Scenarios

	2020		2030	
	No Progression	Consumer Power	No Progression	Consumer Power
Turn-down DSR	5.1	5.1	5.1	5.1
Turn-up DSR	3.2	3.2	3.2	3.2
Standby DSR	3.1	3.1	4.1	4.1
Battery-led DSR	0.1	0.2	0.2	2.3

Source: CRA Analysis and National Grid FES 16

As shown in Table 8, our estimate of technical DSR potential is generally within the bounds of other estimates for DSR potential in GB.

Table 8: Summary of Estimates of Technical DSR Potential in GB (GW)

DSR Category	COWI[123]	Fron-tier[124]	Ele-ment[125]	Ofgem Survey[126]	National Grid FES 16
Standby DSR		5 - 20	3 - 20		NA
Turn-down DSR	5.5	NA	1.2 - 4.4		1 - 3.5
Combined (Turn-down and Standby)				3	
Turn-up DSR				1.9	

Note: Figures for 2020, if available. Otherwise, figures represent estimates of technical potential at the time of the report.
Source: CRA Analysis

4.2. Demand projections

To estimate the future demand for DSR, we first establish the demand for dispatchable resources in 2020 and 2030. We do this by estimating the half-hourly residual load under different FES 16 scenarios. The residual load is the difference between the system load, including exports, and non-dispatchable generation, including onshore wind, offshore wind, solar PV and nuclear. Further, the half-hourly residual load is adjusted by the impact of all batteries[127] across each FES 16 scenario.

We have estimated half-hourly residual load curves for 2020 and 2030 under different scenarios covering half-hourly system load profiles, peak load and annual electricity demand, installed wind and solar capacity and interconnector capacity. The residual load

123 https://ec.europa.eu/energy/sites/ener/files/documents/demand_response_ia_study_final_report_12-08-2016.pdf

124 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/467024/rpt-frontier-DECC_DSR_phase_2_report-rev3-PDF-021015.pdf

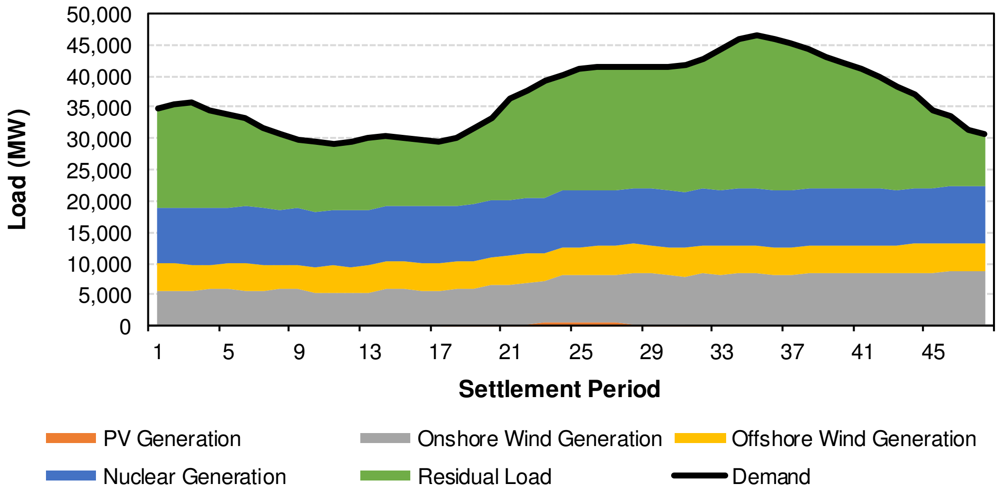
125 http://www.element-energy.co.uk/wordpress/wp-content/uploads/2012/07/Demand-Side-Response-in-the-non-domestic-sector.pdf

126 https://www.ofgem.gov.uk/system/files/docs/2016/10/industrial_and_commercial_demand-side_response_in_gb_barriers_and_potential.pdf

127 In this step, we account for the impact of all transmission-connected batteries, as well as those distribution-connected batteries that we do not consider as DSR.

for an illustrative day in 2020 in the FES 16 Slow Progression scenario is shown as the green area in Figure 21.

Figure 21: GB residual load curve – 2020 Slow Progression Scenario



Source: CRA Analysis

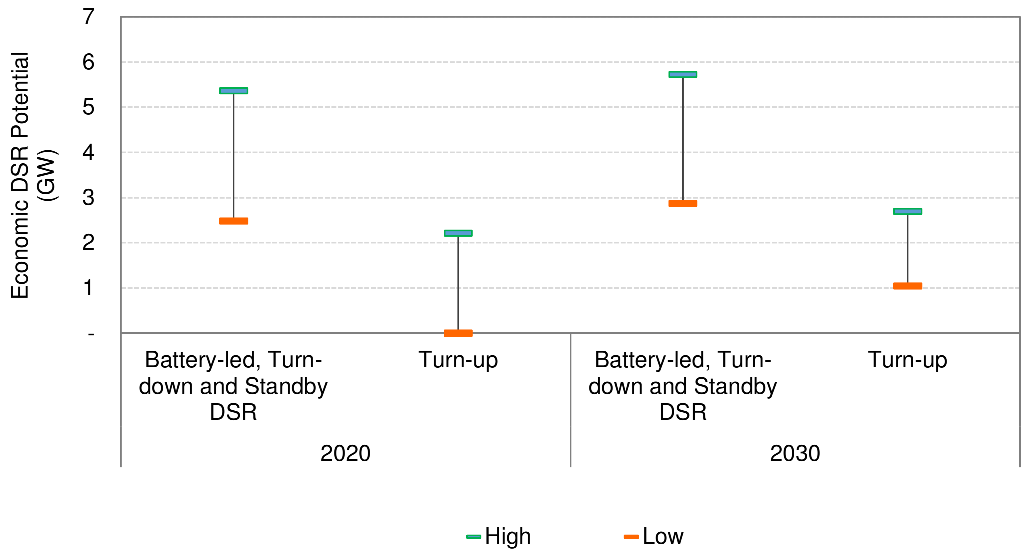
These residual load projections establish the demand for dispatchable generation that DSR may also aim to satisfy.

4.3. Economic DSR potential

We assess the economic potential of DSR by evaluating how much DSR capacity would be competitive against dispatchable generation in meeting projected residual load. This analysis is based on a half-hourly assessment of the expected demand and supply in the GB energy market in 2020 and 2030. As described at the beginning of this section, we do not differentiate between the BM and the forward, day-ahead and intra-day markets ahead of gate closure; instead, we model a single, real-time market. The details of our analysis are presented in Appendix B.

Our analysis indicates that Turn-down, Standby and Battery-led DSR can contribute to reducing peak demand by 2.5 to 5.4 GW by 2020, and by 2.9 to 5.7 GW by 2030. Our analysis also indicates that Turn-up DSR can reach an equivalent of 0.0 to 2.2 GW by 2020 and 1.0 to 2.7 GW by 2030. The peak demand reduction achieved by DSR is less than the full technical potential indicated in Table 7 because the rebound effect of some DSR reduces its net impact on system peak (see APPENDIX B: for a more detailed explanation). These results are summarised in Figure 22.

Figure 22: Range of Economic DSR Potential across Scenarios (GW)



Source: CRA Analysis

4.4. Economic benefit of DSR in the GB Balancing Mechanism

For the purposes of this analysis, we estimate the economic benefit of DSR in terms of the changes in the costs of energy, generation capacity and network infrastructure that follow from increased DSR development. While Figure 22 presents a range of our estimate of the total economic DSR potential in GB by 2020 and 2030, it is important to recognise that part of this potential has already been developed. As described in Section 2.2.4, there are currently around 2.1 GW of DSR participating in the Balancing Services and 1.4 GW of DSR participating in the Capacity Market.[128] Therefore, as a starting point, the incremental value of prospective growth in DSR in the GB market should be assessed as the difference between the full economic potential of DSR and the existing amount of DSR.

However, not all of the incremental DSR capacity may be attributed to the elimination of barriers to aggregation for IDAs in the BM. This is because DSR not able to participate in the BM through IDAs might – subject to sufficient incentives[129] - otherwise participate through their incumbent suppliers. In addition, we recognise that some or all of the capacity cost and network cost savings resulting from more DSR development may be achievable through the Capacity Market or direct contracting with DNOs, even without allowing DSR direct access to a wholesale energy market.

However, we note that improvements in the efficiency of the energy market (such as follow from the recent revision to imbalance pricing[130]) may lead to increased margins in the

128 These numbers are not additive as a large portion of the capacity in the Capacity Market may also be able to provide Balancing Services.

129 See Sections 5 and 6 for further discussion of the incentives on suppliers to develop DSR.

130 See Imbalance Pricing Guidance – A Guide to Electricity Imbalance Pricing in Great Britain, version 11.0. (https://www.elexon.co.uk/wp-content/uploads/2016/10/Imbalance_Pricing_guidance_v11.0.pdf)

energy market, thereby depressing capacity market prices. This would serve to increase the importance of access to the BM as a source of revenue for DSR to cover its activation costs. Direct BM access is also beneficial because it allows DSR providers a choice of when to participate in the energy market, in contrast to DSR providers with capacity obligations, which have to dispatch whenever there is a stress event (regardless of the implications it may have on the business operation of the DSR provider).[131] However, we note that capacity market clearing prices that are sufficiently high to cover both activation costs and risks for DSR providers associated with the uncertainty of system stress events may encourage the same amount of DSR development as allowing DSR direct access to the BM. Within the scope of work to prepare this report, it has not been possible to isolate the impact of direct access to the BM for IDAs from other factors driving the potential development of DSR.

Accordingly, our estimates of the incremental economic value resulting from increased DSR contribution to system capacity requirements are only an indication of what can be gained by promoting explicit DSR across a range of scenarios and assumptions. The likely impact of providing direct access to the BM on these overall estimates of economic value has *not* been separately quantified. But the scale of these benefits allows us to conclude that even a relatively small impact on the achievement of these benefits from direct BM access is likely to be significant in terms of economic value.

Our range of indicative estimates is presented in Figure 23. These show a range of £110 - £400 million of economic benefits of realising all economic DSR potential in 2020, rising to £160 - £440 million in 2030. This range may be explained by a number of factors but principally reflects the mix of generation and capacity margins under different scenarios. After allowing for further uncertainty in relation to the capital cost of new peaking capacity,[132] this range widens to £100 - £530 million in 2020, rising to £140 - £580 million by 2030. Note that these estimates represent annual benefits to the system, but the extent to which these savings would be then passed on to consumers is uncertain. These estimates are consistent with results derived in other recent studies,[133] and indicate the importance of providing DSR access to revenue sources, including the BM, to support its efficient provision.

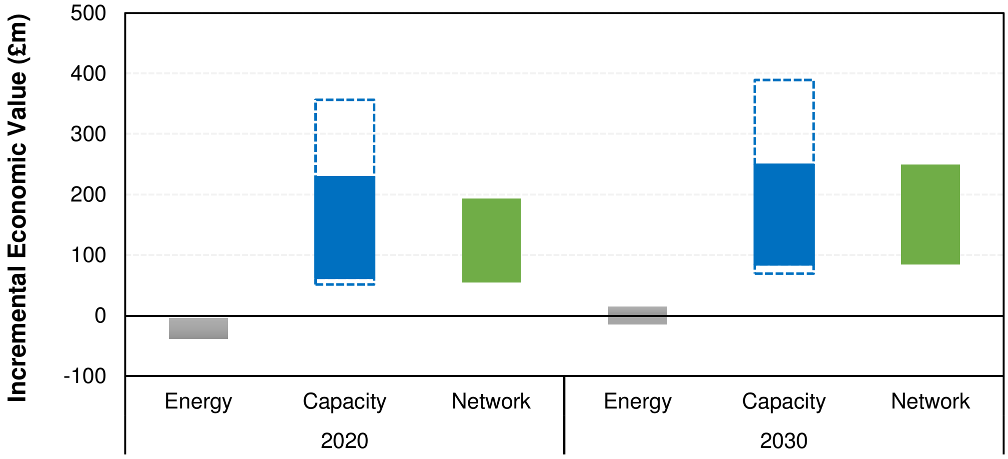
Our approach is described in more detail in Appendix B.

131 We note that if a DSR provider has a capacity obligation, access to the BM does not necessarily provide any flexibility on when the resource needs to be dispatched in response to a capacity market warning.

132 BEIS' range of annualised capacity costs and fixed O&M costs for a new OCGT range from £47/kW-year to £90/kW-year, assuming a discount rate of 7.6% over a 25-year period.

133 Our results are generally consistent with the findings presented for Pathway A in 2020 by Imperial College and NERA in the report "Understanding the Balancing Challenge", August 2012. In this scenario, Imperial College and NERA estimate annual system savings in 2020 of £500 Million. Similarly, the Carbon Trust and Imperial College Report "An analysis of electricity system flexibility for Great Britain", November 2016 presents cumulative savings to 2050 ranging from £15 billion to £40 billion. This is roughly equivalent to annual savings between £300 Million and £800 Million (at a 3.5% social discount rate over 35 years). While our numbers are within that range, we note that there are important differences. First, the Carbon Trust and Imperial College report account for the value of interconnectors in their estimates; we do not. Second, they model a significant uptick in DSR utilisation post 2030, which our analysis does not capture.

Figure 23: Range of incremental economic value resulting from increased DSR participation in the BM (Existing DSR vs Full Economic Potential)



Note: The dashed blue line under economic value from capacity savings shows the sensitivity of our estimates of capacity cost savings to BEIS's range of capacity costs from £47/kW-year to £90/kW-year.
Source: CRA Analysis

5. OPTIONS FOR TREATMENT OF INDEPENDENT DEMAND-SIDE AGGREGATORS IN THE BALANCING MECHANISM

This section outlines two options for the treatment of IDAs in the BM. These are referred to as a Central Settlement System and a Supplier-Customer Settlement; they differ in the way in which payment flows are determined.

This section begins by setting out the critical conditions that any reform option should satisfy and, in particular, identifying the efficient level of remuneration for DSR. This then enables the structure of the two reform options to be identified and discussed.

5.1. Conditions for efficient reform

Reform of the treatment of IDAs in the BM is intended to address barriers to aggregation for IDAs while also promoting overall economic efficiency. There are three main conditions for economic efficiency. These are as follows:

i. Providers of DSR should receive the marginal value[134] of units of consumption withdrawn from the market.[135]

ii. Generators providing incremental output in response to a supply/demand imbalance should receive the marginal value of units of production.

iii. The payment scheme supporting DSR in the BM should have no perverse effect on retail prices, ex-ante market contracting or investment incentives.

The second of these conditions is straightforward, so we turn to discuss next the first and third of these conditions.

5.1.1. Efficient remuneration for DSR

The figure below provides the framework for demonstrating that the economically efficient remuneration for DSR (considered for purposes of this example as the marginal value of units of consumption withdrawn from the market through demand reduction) is the market clearing price less the ‘retail’ price for generation.[136] In this regard, the ‘retail’ price for generation should be understood as the price level that determines the consumer’s marginal consumption and as such excludes components of the supplier’s retail charges that do not vary as a function of demand in a given time-period.

Figure 24 shows a consumer demand curve, D and an initial supply curve, S^a. Consumers purchase quantity, Q^a, at a retail price p^r. This retail price may be above the price for

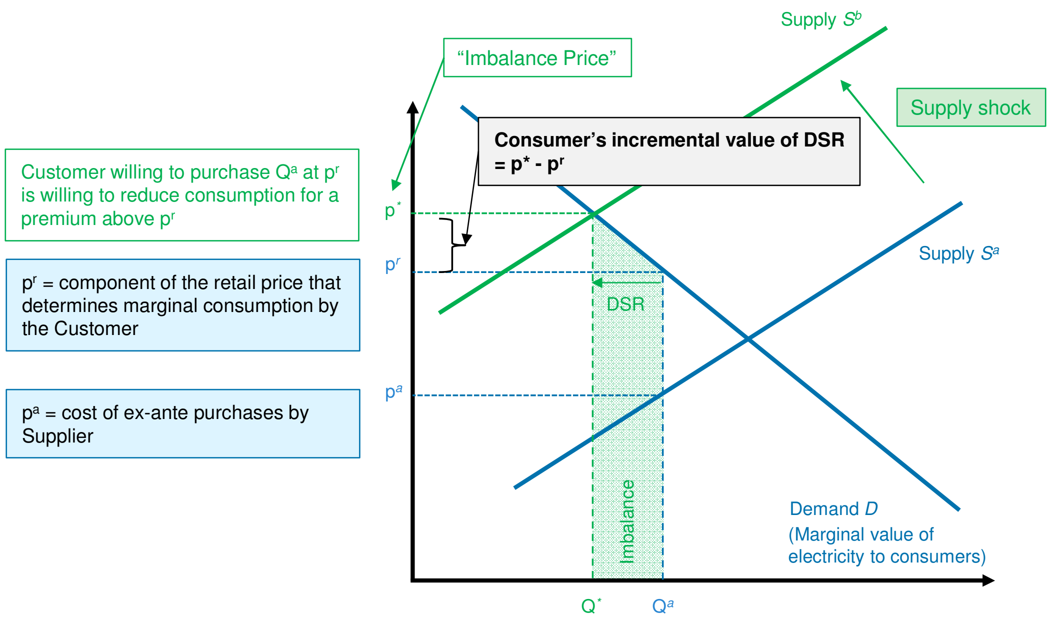
134 The modelling analysis set out in Section 4 and APPENDIX B: assumes that the margin between the market price and the DSR activation costs recovers the marginal value of DSR units of foregone consumption.

135 Or, in the case of demand turn-up, required from the market.

136 The demand curve is assumed to reflect consumer’s willingness to pay – or, more precisely, the consumer’s minimum DSR prices at which it is willing to forego an additional unit of energy consumption at short notice (in general, this could be somewhat different from the consumer’s willingness to pay for those units in “normal” times). As such the margin provided by the gap between the market clearing price (or DSR offer price) and the ‘retail price’ is assumed to be sufficient to recover transaction costs and foregone consumer surplus (as shown in Figure 25).

generation determined in ex ante markets, p^a, due to the addition of any volume-related levies or other mark-ups by the customers' suppliers. In this example, there is then a supply shock such as a generator tripping or lower than expected wind speeds in which the supply curve shifts to S^b following a generator failure.[137] This leads to an imbalance that may in part be met by incremental generation. In addition, at the new clearing price, p*, there is scope for the efficient provision of DSR to bring the system back into balance. DSR of Q^a – Q* is provided by offering the DSR provider a premium over their purchase cost p^r. This premium is equal to p*- p^r which is sufficient to induce the DSR provider to reduce demand by Q^a – Q*.

Figure 24: The efficient remuneration of DSR



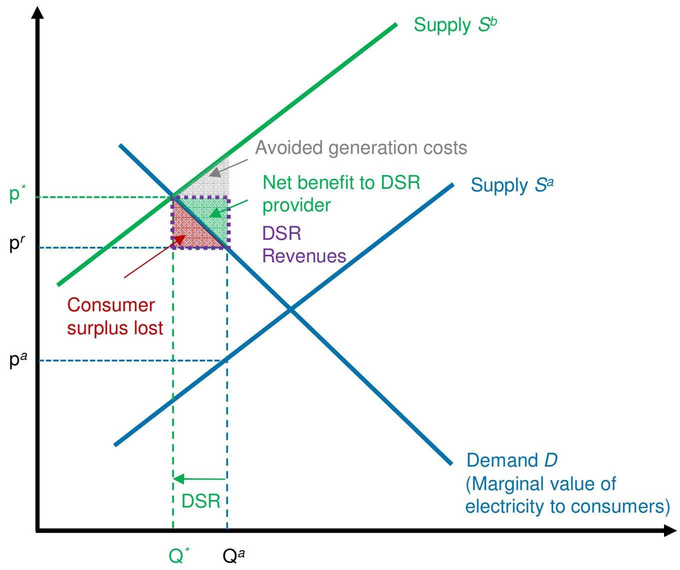
Source: CRA Analysis

It is *not* necessary to remunerate the DSR provider at the full market clearing price because the DSR provider, by reducing consumption, avoids paying its supplier for its amount of demand reduction. [138] This is further illustrated in Figure 25. This shows the loss of consumer surplus to the DSR provider from foregoing consumption at the price p^r; this is the red triangle in the figure. However, this is more than offset where the DSR provider is efficiently remunerated at p*- p^r, resulting in a net benefit indicated by the green triangle. In addition, there is a further welfare benefit from avoiding the higher generation costs, indicated by the grey triangle, that would otherwise have been incurred in balancing the system.

137 The same results holds for a demand shock.

138 This assumes that the customer does not have a take-or-pay contract.

Figure 25: The net benefit to the DSR provider



Source: CRA Analysis

DSR Turn-up

DSR Turn-up may be economic during off-peak periods when there is excess supply of inflexible conventional generation and near-zero marginal cost renewables. This can cause wholesale market prices to become negative and so DSR Turn-up can enhance overall economic value by avoiding the increased marginal costs of inflexible generators and enabling DSR providers to obtain the benefit of the very low marginal costs of renewables. 139

As such, DSR Turn-up works like DSR Turn-down but in reverse. In other words, to incentivise consumers to increase their consumption beyond Q^a, they need to be paid $p^r - p^*$ on their increased demand (where p* has now fallen below p^r).

5.1.2. Example of inefficient DSR remuneration: DSR provider remunerated at full market price

The finding set out above on the efficient level of remuneration for DSR may be further demonstrated by considering a simple example.[140] This is set out in Table 9 which shows that with remuneration of DSR at the full market price, a consumer can make gains just by moving a genset to behind-the-meter while, of course, there are no underlying economic benefits from re-locating a genset in this way.

In the example, the genset production capacity is 6MWh and its costs are £50/MWh. The market price is £50/MWh and the consumer's load is 10MWh. Thus with the genset in-front-of-the-meter, the genset earns zero net revenue (i.e. it earns revenues of £300 and

139 Some inflexible generators may require payment to reduce their output, thereby offsetting the benefit of low marginal cost renewables.

140 See Hogan, William. *Demand Response Pricing in Organized Wholesale Markets.* 2010 (https://www.hks.harvard.edu/fs/whogan/Hogan_IRC_DR_051310.pdf)

incurs costs of £300) and the cost to the consumer of satisfying its demand is £500. The net position is -£500.

However, with moving the genset behind-the-meter and allowing DSR to be remunerated at the market price, the genset continues to earn £300 (and incur costs of £300) by enabling DSR of 6MWh. The customer's net load then costs £200 and its net position is -£200. This is an improvement of £300 over its position with the genset in-front-of-the-meter. However, if instead, the activated DSR is remunerated at p^*-p^r (which for convenience in this example is zero), then the net position with the genset behind-the-meter reverts to -£500.

Table 9: Example of inefficient DSR remuneration (Hogan Example)

Assumptions	
Real-time price (p*):	£50/MWh
Genset production cost:	£50/MWh
Customer load:	10 MWh

Genset in front of the meter	
Genset outputs 6 MWh and earns revenue	£300
Genset output costs	-£300
Customer load of 10 MWh at p*	-£500
Net position	**-£500**

Genset behind the meter	
Genset outputs 6 MWh and earns revenue	£300
Genset output costs	-£300
Customer *net load* of 4 MWh at p*	-£200
Net position	**-£200**

Customer enjoys benefit of genset output to meet behind-the-meter load *and also* sells it on as DSR.

Note: Customer net load of 4MWh is 10MWh demand less 6MWh of DSR

Source: Hogan, William. *Demand Response Pricing in Organized Wholesale Markets*. 2010[141]

5.1.3. Non-distortionary payment scheme

The third of the necessary economic conditions for an efficient payment scheme is the most challenging. This is because it needs to take into account the competition issues set out in earlier sections, especially, the market power (if any) of retail suppliers. It also needs to satisfy detailed implementation issues such as the scope for 'gaming' the baselines against which the delivery of DSR may be monitored. Further, the efficiency of related markets for energy, capacity or ancillary services should not be distorted. The preferred reform option should not have wider un-intended, adverse consequences.

5.2. Central Settlement System

5.2.1. Overview of Central Settlement System

We set out here a Central Settlement System approach to DSR remuneration that provides direct access to the BM for IDAs. The principal DSR related payments are managed centrally through the BM. This is shown in Figure 26.

Under this approach, the DSR-provider (shown in the figure as the IDA) is paid the DSR offer price from which is subtracted the relevant 'retail' price in accordance with the efficient remuneration of DSR set out in Section 5.1.1. The supplier of the DSR-provider (which is made longer as a result of the DSR activation) is compensated at the resulting imbalance price for the otherwise unbilled energy effectively released by the aggregator through DSR.

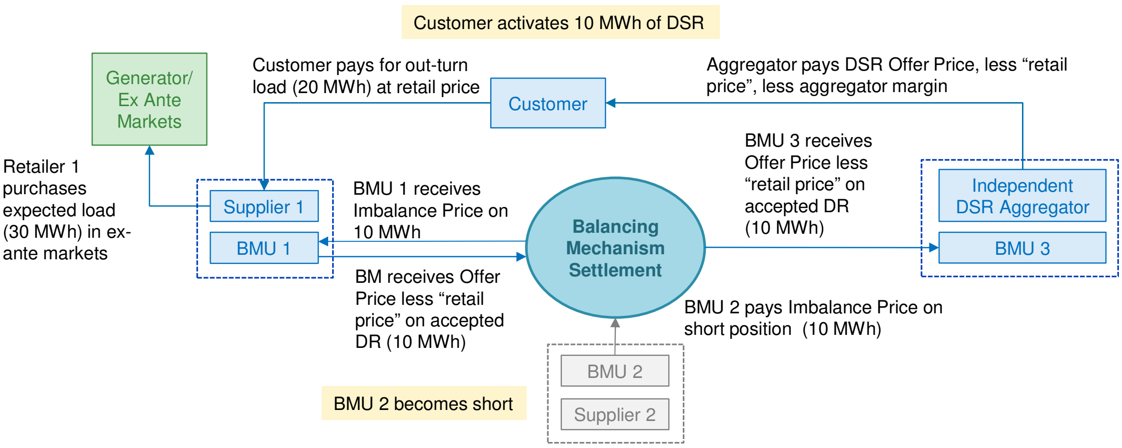
141 Ibid.

The party which caused the imbalance - in the figure, this is Supplier 2 - is charged the imbalance price on its short position.

Together these three payments, may leave the BM with an under-recovery of funds for the payment to the DSR provider (assuming the DSR offer price is close to the imbalance price). There are then three options for the recovery of the DSR payment (namely the offer price less 'retail' price on the delivered DSR volume). This DSR payment may be recovered from:

- All BM parties – this approach socialises the cost of DSR delivery, treating the DSR payment as a 'non-market' cost such as the congestion element of balancing services;
- The supplier of the DSR-related party – this supplier has likely benefitted from an imbalance price on its long position that is in excess of the retail price it would otherwise have received given the likely conditions under which DSR is activated. This approach leaves the Supplier 1 broadly receiving on a net basis, its retail price on the foregone DSR volumes; or
- The BM party (or parties) with the imbalance that has contributed to the need to activate DSR to balance the system.

Figure 26: Central Settlement System



Note: In this illustration of the Central Settlement System approach, Supplier 1 bears the DSR payment of Offer Price less 'retail price' though it could also have been allocated to Supplier 2 or socialised across all BM parties.
Source: CRA Analysis

DSR Turn-up in Central Settlement system

Under DSR Turn-up, the DSR remuneration to the IDA is adjusted to become a payment of the 'Retail' price less bid price. Given that the Customer then pays-out the retail price on the demand turn-up to the Supplier 1, the Customer's net position is to have paid the bid price for its DSR Turn-Up (assuming the DSR remuneration to the IDA is passed on to the consumer). In this way, the Customer effectively pays *less* for energy purchased through DSR Turn-up than through 'normal' purchases.

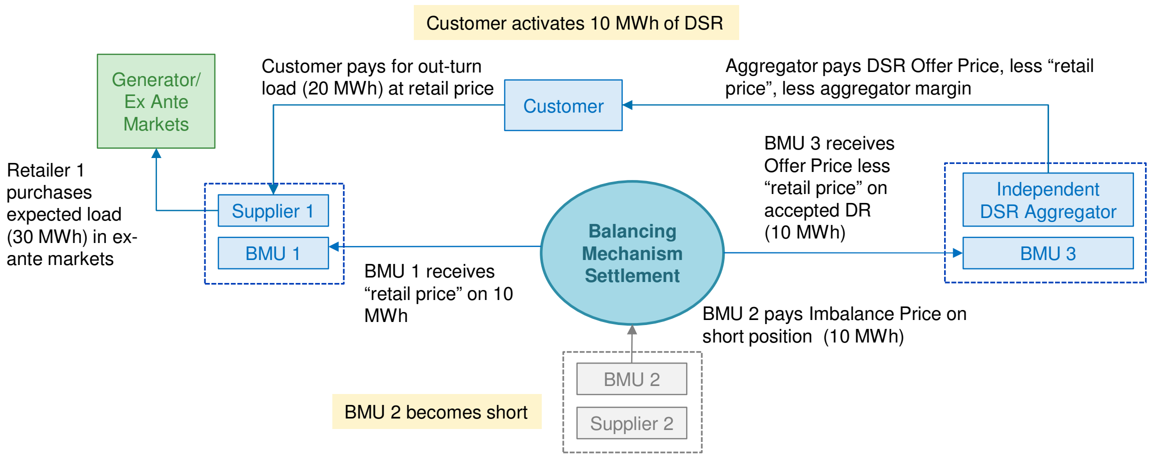
Supplier 1 might be made short by the DSR Turn-up and thus potentially benefits from the difference (positive in this case) between the retail price and the (possibly even negative) imbalance prices. However, this may be offset by the DSR payment – also reversed – of

'Retail' price less bid price. This would leave the Supplier 1 broadly, on a net basis, paying out the 'retail' price to the BM to fund its additional sales to its customer.

Variant on Supplier 1 DSR Payment in Central Settlement System

A simplification of the Central Settlement System approach set out above would involve Supplier 1 receiving the 'retail price' on the DSR delivered volumes while its position in the BM is "neutralised" by adding its customers' DSR volumes to it (similar to the Supplier-Customer settlement approach discussed in section 5.3). In other words, instead of allowing a potential difference between imbalance price and offer price, it is effectively assumed that these are the same and so they cancel each other out, leaving Supplier 1 receiving the 'retail price'. This may be regarded as being funded through deduction from the IDA's offer price.

Figure 27: Variant on Central Settlement System



Source: CRA Analysis

5.2.2. Illustrative payments under Central Settlement System

Illustrative payments are set out below showing how the Central Settlement System affects different parties. These follow the example in Figure 26.

- The Customer's expected demand is 30MWh
- Supplier 1 has procured generation contracts of 30MWh and notified 30MWh of Contracted Generation to the BM;
- The IDA offers 10MWh of DSR which is then accepted to meet incremental demand of 10MWh from Supplier 2;
- The metered demand of Customer in out-turn is 20MWh;
- Supplier 1's imbalance of 10MWh (30MWh of notified Contracted Generation less metered demand of 20MWh) is *not* corrected in the BM by the delivered DSR volume of 10MWh;[142]

142 Note that in the variant of the Central Settlement System, the Supplier 1's imbalance position is neutralised by the DSR volume and Supplier 1 is 'cashed out' in the BM at the 'retail price' (and not the imbalance price).

- Supplier 1 receives the retail supply price on 20MWh, and the centrally determined imbalance price on its imbalance position. On the basis that the Supplier was balanced prior to the DSR delivery, this is the imbalance price on 10MWh;[143]
- Supplier 1 pays out for 30MWh of Contracted Generation;
- Supplier 1 also pays out to the BM the Offer price less 'retail price' on the DSR volumes;
- The IDA receives the accepted offer price on the DSR of 10MWh; the IDA pays out the 'retail' price to the BM and passes on a DSR margin to the Customer
- Supplier 2 purchases the 10MWh at the imbalance price.

Table 10: Illustrative example of Central Settlement System payment flows

		Volume MWh	Price £/MWh	Revenue/(Cost)* £
		[A]	[B]	[C]=[A]x[B]
Expected retail sales	[1]	30	52	1560
Ex ante generation procurement	[2]	30	50	-1500
DSR revenues	[3]	10	60	600
DSR payment to BM	[4]	10	52	-520
DSR gross profits: value less supplier compensation cost	[5]	10	8	80
Out-turn retail sales	[6]	20	52	1040
Supplier 1 payment from BM	[7]	10	60	600
Supplier 1 payment to BM	[8]=-[5]	10	-8	-80
Supplier net financial position pre-DSR	[9]=[1]+[2]			60
Supplier net financial position post-DSR	[10]=[2]+[6]+[7]+[8]			60
Customer/IDA net financial position	[11]=[5]-[6]			-960

Notes
* Positive figures represent revenues. Negative figures represent costs.
[3] DSR offer price of £60/MWh
[7] Imbalance price assumed equal to DSR offer price
[10] Supplier's compensated position is indifferent to dSR

Source: CRA Analysis

This analysis of illustrative payments shows how the incumbent supplier, which is not sourcing the DSR, may be left indifferent to the provision of DSR by its customer (the result for row 9 is the same as for row 10). The Customer/IDA (as shown in row 11 relative to row 1) have reduced their total expenditures by providing the DSR (and, not visible as a financial flow, has lost a smaller amount of surplus by not consuming the DSR volumes it provided).

143 In this way, the impact on the Supplier is to gain by the difference between the imbalance price and the retail price. In the event the Supplier was out-of-balance relative to its customer, prior to the DSR delivery, then the Supplier's exposure to the imbalance price is reduced with equivalent effect.

5.3. Supplier-Customer Settlement System

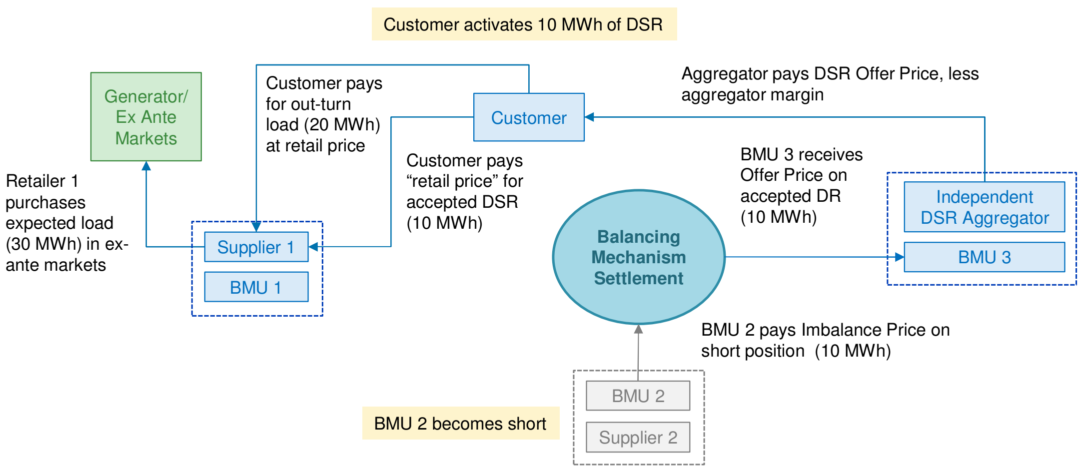
5.3.1. Overview of Supplier-Customer Settlement System

In the Supplier-Customer Settlement System approach to DSR remuneration, the principal DSR related payments are managed both through the BM and bi-laterally between Supplier and Customer. This is shown in Figure 28.

Under the Supplier-Customer approach, the DSR-provider is paid its full offer price (without any deduction) in the BM. However, the imbalance position of the Supplier of the DSR-provider is 'corrected' in the BM by the amount of the delivered DSR volume. This means that the Supplier has no opportunity to 'cash-in' any imbalance that has been created as a result of the activation of DSR volumes. As a consequence, it is necessary for the DSR-provider effectively to purchase the Supplier's unsold DSR-delivered volumes to be on-sold by the IDA into the BM. This can be most efficiently done at the Customer's 'retail' price; this is the price that the Customer would otherwise have paid for the energy. This provides the efficient level of remuneration for the Customer as DSR provider; its net remuneration is now, as set out in Section 5.1.1, the DSR Offer price (received from the BM via the IDA) less the 'retail' price. It also leaves the related Supplier neither worse off nor better off from the provision of DSR.

The 'short' Supplier, as under Central Settlement, pays the imbalance price on its short position. There is no deficiency of payments to the BM and so no further charges are required to be levied by the BM.

Figure 28: Supplier-Customer Settlement System



Source: CRA Analysis

DSR Turn-up in Supplier-Customer Settlement system

In the decentralised, Supplier-Customer Settlement system, the supplier of the DSR-provider should have its imbalance position corrected so that the Supplier is not made short (or less long) as a result of the increase in customer demand. Similarly, the supplier should not charge the customer for its increased volumes.[144] The customer would as a result pay its bid price on its increased demand without any further payment to other parties.

144 This should be provided for in the supplier-customer contract.

5.3.2. Illustrative payments under Supplier-Customer Settlement System

Illustrative payments are set out below showing how the Supplier-Customer Settlement System affects different parties. These follow the example in Figure 28.

In the example:

- The Customer's expected demand is 30MWh
- Supplier 1 has procured generation contracts of 30MWh and notified 30MWh of Contracted Generation to the BM;
- The IDA offers 10MWh of DSR which is then accepted to meet incremental demand of 10MWh from Supplier 2;
- The metered demand of Customer in out-turn is 20MWh;
- Supplier 1's imbalance of 10MWh (30MWh of notified Contracted Generation less metered demand of 20MWh) is corrected in the BM by the delivered DSR volume of 10MWh;
- Supplier 1 receives the retail supply price on both the 20MWh of metered demand and the 10MWh of the accepted and delivered DSR;
- Supplier 1 pays out for 30MWh of Contracted Generation;
- The IDA receives the accepted offer price on the DSR of 10MWh and pays out to the Customer to cover the Customer's DSR costs;
- Supplier 2 purchases the 10MWh at the imbalance price.

The illustrative payments show the impact of bi-lateral settlement of the Supplier of the DSR-provider.

Table 11: Illustrative example of Supplier-Customer Settlement System payment flows

		Volume MWh	Price £/MWh	Revenue/(Cost)* £
		[A]	[B]	[C]=[A]x[B]
Expected retail sales	[1]	30	52	1560
Ex ante generation procurement	[2]	30	50	-1500
DSR revenues	[3]	10	60	600
DSR payment to Supplier 1	[4]	10	-52	-520
DSR gross profits: value less supplier compensation costs	[5]=[3]+[4]	10	8	80
Out-turn retail sales	[6]	20	52	1040
Supplier 1 payment from DSR	[7]=-[4]	10	52	520
Supplier net financial position pre-DSR	[8]=[1]+[2]			60
Supplier net financial position post-DSR	[9]=[2]+[6]+[7]			60
Customer/IDA net financial position	[10]=[5]-[6]			-960

Notes
* Positive figures represent revenues. Negative figures represent costs.
[4] Supplier compensation at foregone retail revenues
[9] Supplier's compensated position is indifferent to dSR

Source: CRA Analysis

This analysis of illustrative payments, as with the Central Settlement System approach, shows how the incumbent supplier, which is not sourcing the DSR, may be left indifferent to the provision of DSR by its customer (the result for row 9 is the same as for row 8).

5.4. Additional BM access issues

There are a number of additional issues that need to be determined under both Central and Supplier-Customer Settlement approaches. These are identified next.

5.4.1. Form of access to the BM for IDAs

Direct access to the BM for IDAs is necessary in all reform options in order to facilitate direct competition between IDAs and supplier-led aggregators across all DSR product markets.

Under the Balancing and Settlement Code, the BM Unit is the mechanism by which energy is injected into or off-taken from the system and by which participation in the BM is effected. Hence, if IDAs are to participate in the BM Mechanism then they require BM Units as a means to do so. To the extent that such BM Units are not associated with physical metered volumes but account only for changes in physical metered volumes, we may refer to them as 'virtual' BM Units ("**VBMUs**").[145] VBMUs may aggregate multiple customers' loads across multiple suppliers and present aggregated DSR offers.[146] This is required in order to facilitate aggregation to a reasonable scale which may not be possible by limiting aggregation to loads of a single supplier; it also has the benefit of avoiding the need for loads to switch VBMUs when customers switch supplier. Under this approach VBMUs are credited as responsible for the delivery of any accepted DSR and may (or may not) then be exposed to non-delivery charges and imbalance for any over/under-performance.[147]

5.4.2. Advance notification to supplier of customer DSR contracting

It is assumed that in all reform options, the supplier will be notified of its customer's commitment to an IDA. [148] This may not be strictly necessary in the Central Settlement System approach to complete the necessary transactions (provided that the supplier is not required to notify or agree the appropriate 'retail price' to be used in DSR transactions). However, it means that the supplier is able to change, if efficient, its ex ante position in Contracted Generation in the light of potential DSR activation and may also (subject to the provisions of its retail contract terms and conditions) be able to change its retail terms.[149] This assumption is made because, in any event, the supplier is likely to discover, at least

145 This is the approach taken at present in the BSC Modification Proposal P344 for implementation of settlement arrangements for acceptances to balancing service providers under Project TERRE. See *Settlement of replacement reserve in GB: a summary of the P344 workgroup's proposed solution* Elexon 3 February 2017

146 This may be subject to the requirement that each VBMU is limited to loads related to the same Grid Supply Point.

147 See Section 6.4.2 under which non-delivery risk is placed with the related retailer.

148 This advance notification of commitment to an IDA, as discussed in this section, does not comprise repeated notifications prior to presenting offers/bids in the BM. It is simply notification of a future intent to participate in the BM when the occasion arises.

149 For example, a supplier may consider such changes necessary to manage an increased volatility in its customer's load.

for its larger customers, whether a particular customer is providing DSR. This should be apparent from the customer's metered data as compared to its baseline (or anticipated load profiles otherwise provided to the supplier on the basis of which the supply contract was determined).

The benefit of advance notification is that it eliminates any 'speculation' on the part of the supplier as to the customer's intention with respect to DSR that might otherwise lead to generation contracting being less informed and, as such, less efficient than is necessary.[150] It is also necessary under Supplier-Customer Settlement where the supplier should receive a payment from its customer in relation to delivered DSR and under Central Settlement where the supplier may be required to make payment to enable BM settlement.

Advance notification to the supplier could lead the supplier to present an offer for competing DSR to its customer. Such increased competition would be efficient provided that it was not supported by inefficient cross-subsidies or otherwise 'chilled' competition in the provision of DSR.

5.4.3. Ex post notification to supplier of customer accepted/delivered DSR offers

It is necessary for the supplier to be notified ex post of accepted and delivered DSR offers under the Supplier-Customer Settlement system approach so that the supplier can adjust its invoices appropriately to charge the supplier for its DSR volumes. The supplier could rely on notification from its customer but may prefer independent notification from the BM administrator. Under the Central Settlement system approach, the supplier does not need this notification to prepare invoices but rather to check that its BM payments and receipts have been correctly calculated.

5.4.4. The issue of supplier consent

Explicit consent from the supplier of the DSR provider for its provision of DSR may or may not be required. This is an important issue for IDAs.

IDAs are concerned that requiring consent from the supplier may discourage some customers for whom committing to DSR is already a difficult decision given that DSR is seen by many as not core to their business and potentially disruptive.

In the event that consent is withheld (for example, because the supplier does not regard any 'compensation' under the proposed settlement system as sufficient[151]), then the customer would either not be able to undertake DSR until the end of its existing retail supply contract or it would have to re-compete its supply contract in order to switch to a supplier that was willing to provide consent. This approach has the benefit of not 'trapping' a supplier with a customer to the end of its supply contract in a situation where the supplier regards the 'compensation' as inadequate. But it has the potential cost for the customer and IDA of having to defer its DSR to the end of its existing supplier contract. This may be problematic where the supply contract has a relatively long duration; and some supply contracts currently do extend beyond one year. IDAs are also concerned that the need to

150 For example, it may reduce the risk that suppliers spread any consequential costs of DSR over their non-DSR customers.

151 For example, the supplier may be concerned about the strategic implications of independent DSR being adopted by its customer or by the costs of rebound where this is not adequately allowed for in the retail supply contract.

obtain consent rather than leading to out-right refusal might result in prolonged negotiation with the supplier over acceptable terms with the same substantive effect as out-right refusal.

In the alternative, where consent is *not* required and incumbent suppliers are not permitted to break their contract when the customer wants to provide DSR, then it may be necessary to provide for some form of supplier 'right' to pre-determined compensation to the supplier. For example, under the Supplier-Customer Settlement approach, it would be necessary to accept that the Supplier has the 'right' to bill for the delivered DSR volumes, which by definition are not part of the Customer's metered volumes, at the 'retail' price that it would otherwise have charged.[152] More generally, the supplier may be 'trapped' to the end of its supply contract with a customer whose load has become more volatile than expected because of DSR activities, and thus is more costly to serve.

Alternatively, if it is stipulated by Ofgem that consent is not required from suppliers for a customer to provide DSR, then suppliers may be expected to include (where they do not already do so so) a break clause in their supply contracts, enabling them to break or revise their existing supply terms for a customer wanting to commit to DSR. IDAs have expressed concerns that such supply contract revisions may discourage independent DSR provision.[153] This would imply that if regulatory intervention were deemed necessary to enable DSR to proceed without supplier consent it might need to be more extensive than just determining the rate of compensation for the supplier. However, the competitiveness of the I&C retail supply markets (see Section 3.3) limits the ability of suppliers to distort supply contract prices.

5.4.5. Treatment of non-delivery by the IDA

In the event that the IDA over/under-delivers on an accepted DSR bid/offer, then the IDA may be treated consistently with the approach taken to over/under delivery of generation in the BM. This would require the IDA to pay to the BM a non-delivery charge of the higher of the imbalance price and the accepted offer price on the non-delivered volumes[154] (so that it does not benefit from its accepted offer) and to pay the imbalance price on the imbalance which it has caused.

Alternatively, as currently proposed under P344, the supplier's position in the BM could be corrected only by the accepted DSR volume rather than delivered volume. This would then leave the supplier exposed under the Supplier-Customer Settlement approach to the imbalance price on any under/over delivery. The supplier's imbalance exposure might also be affected in this way under Central Settlement, if the supplier's net imbalance were to be adjusted for any over/under delivery. However, this may not be an efficient allocation of risk as discussed in section 6.4.2.

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152 For example, (subject to further assessment) supply licences may need to be amended so that the term *Charges* applies not just to the supply of electricity which excludes electricity not supplied. See page 13 https://epr.ofgem.gov.uk//Content/Documents/Electricity%20Supply%20Standard%20Licence%20Conditions%20Consolidated%20-%20Current%20Version.pdf

153 Suppliers interviewed by CRA have noted that their current supply contracts do not enable them to withhold consent to DSR but IDAs are nevertheless concerned that suppliers may seek to discourage customers by changing supply contract terms. This is discussed further in Section 0.

154 See Balancing and Settlement Code T4.8.11.

5.5. Summary: Selected reform options for assessment

This section has set out two main approaches to settlement of DSR in the BM; the Central Settlement and Supplier-Customer Settlement reform options. Both these approaches are structured to provide efficient remuneration of DSR. However they differ, in particular, in terms of:

- the potential exposure of the supplier of the DSR provider to imbalance prices following DSR activation (though this could be avoided under the variant presented in Section 5.2.1);
- whether a payment is required from the DSR-provider/customer to its supplier (as is required in the Supplier-Customer model only); and
- the data flows required to support the payment arrangements

Separately from the overall structure of DSR settlement, further parameters for assessment include:

- The issue of notification and whether consent is required from the supplier of the DSR provider;
- The scope for 'gaming' the baselining of DSR; and
- The treatment of non-delivery.

In all of the options, IDAs gain direct access to the BM as VBMUs. Further more detailed implementation issues, such as metering requirements and the determination of baselines of consumer demand against which the delivery of DSR may be monitored are not covered in this report.

6. ASSESSMENT OF OPTIONS

The main options for IDA access to the BM outlined in Section 5 are assessed here in relation to:

- The efficient level of DSR remuneration;
- The choice between Central Settlement and Supplier-Customer Settlement systems;
- The impact of potential concerns with market competitiveness relating to the provision of DSR services; and
- Consideration of some further implementation issues.

The section concludes with a summary of findings and recommendations.

6.1. The efficient level of DSR remuneration

This report has shown that the efficient level of remuneration for DSR should offset from the DSR-provider's offer price (for DSR Turn-Down), the 'retail' price for energy that it would otherwise have paid.[155] This can in principle be achieved through either the Central Settlement system or the Supplier-Customer Settlement system. Some of the issues relating to whether one is in practice likely to be more efficient than the other are discussed below. First, we consider some ways of determining the 'retail' price.

6.1.1. The supplier's generation procurement and sourcing costs

The DSR-providers avoided 'retail' price may be proxied by the supplier's generation procurement and sourcing costs. These comprise the costs incurred in the ex ante markets (whether intra-day, day-ahead or years ahead of real-time delivery) in purchasing generation contracts together with the internal costs of the supplier's wholesale trading activities.

It is certainly possible that these costs may constitute the 'retail' price avoided by the DSR-provider. However, a cost-based approach to determining this component of DSR-related payments is in practice likely to be problematic. First, it is not likely to be possible to determine the costs incurred in contracting generation in relation to an *individual* customer's expected load given that such costs will have been incurred over an extended period of time on a portfolio basis in anticipation of multiple customers' loads. This problem may only be avoided by the acceptance of a high-degree of approximation. For example, in France the regulator simply fixes the 'allowed' generation cost to be paid by 'Demand Side Management Operators' to the suppliers of electricity to the related consumers.[156]

Second, the ex-ante generation costs may under-state the 'retail' price on the basis of which the customer has made its marginal consumption decisions. This is because the generation costs may have been marked-up to include some of the supplier's other internal costs together with any volume-related levies. Understating the 'retail' price would in principle lead to over-provision of DSR.

155 See Section 5.1.1 and Appendix A Section 3.

156 See *The Block Exchange Notification of Demand Response mechanism* https://clients.rte-france.com/lang/an/clients_producteurs/services_clients/dispositif_nebef.jsp

On the other hand, it might be contended that payment of the 'retail' price would result in a windfall for the supplier since the supplier might avoid incurring certain costs (such as volume-related levies) as a result of the activation of DSR volumes. This is regarded as a windfall because the incumbent supplier, where an IDA has set-up the DSR capability, has not itself incurred any associated expense. However, while this may be the case, it is arguably more important to provide for the efficient remuneration of DSR and at the same time to provide some (limited) further inducement for suppliers to support the development of DSR.[157]

6.1.2. The day-ahead or intra-day energy price

Under this option, the supplier's DSR-related exposure is cashed-out at an approximation of its wholesale market value. The day-ahead/intra-day price for the relevant time period of DSR activation could be used. This option in practice may be similar to the option of compensation at foregone retail revenues for customers that are on 'spot price' linked retail contracts.

The main advantage of this option is that it uses a transparent and independently verifiable price for settling DSR-related payments. As such it avoids the potential for disagreement between supplier and DSR-provider over what should or should not be included in the 'retail' price. It may also in some cases better reflect generation costs than the regulated approach adopted in France, as mentioned above.

However, IDAs have noted that using the day-ahead/intra-day price for DSR settlement would probably depress the available margin for DSR-providers since DSR in the BM is most likely to be activated during periods of capacity scarcity that may already be reflected in high day-ahead/intra-day prices prior to gate closure and the operation of the BM. Moreover, at present DSR cannot be directly traded in the ex ante markets and so DSR-providers cannot otherwise access the potential margins for DSR during periods of capacity scarcity in those markets. In this way, using the day-ahead/intra-day prices might inefficiently suppress the development of DSR.

We note that consumers that have retail supply contracts that pass through the day-ahead price (and their 'retail' price is in effect the day-ahead price) would already be appropriately incentivised to undertake *implicit* DSR where such prices exceeded their marginal valuation for electricity. Furthermore, suppliers have indicated to us that in practice there are multiple types of retail contracts with many different approaches to retail price determination. This implies that, as with a standard generation cost approach discussed above, using a standard assumed 'retail price' is likely to result in inefficiencies because for many customers it will be an inaccurate proxy.

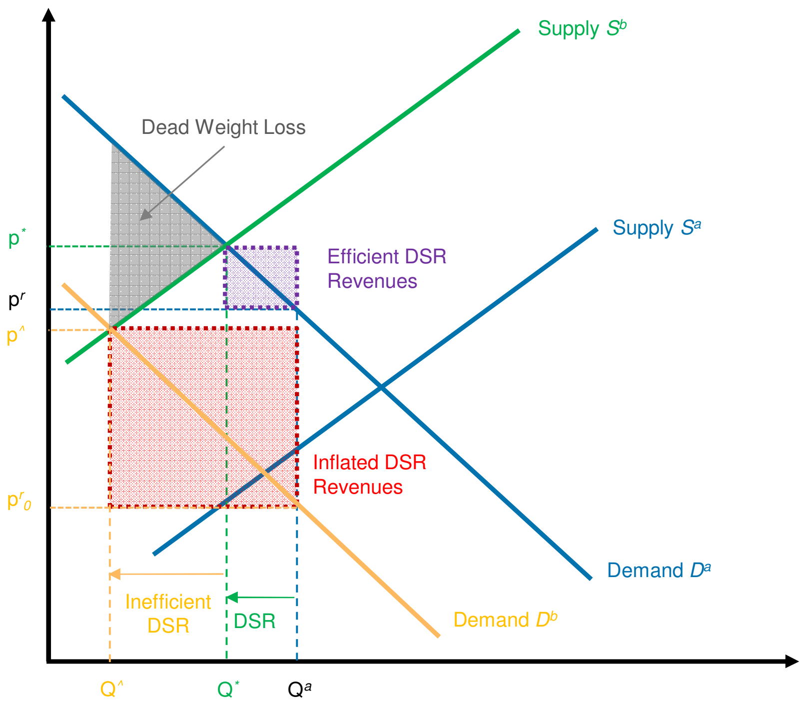
6.1.3. Zero compensation for suppliers

Some have taken the view that since suppliers for the most part do not have 'take-or-pay' contracts with consumers, then they should not be 'compensated' by any 'retail' price payment. This is the approach taken under the Central Settlement system approach. But, in order to remunerate DSR efficiently under Central Settlement (as shown at 5.2), it is necessary to offset the DSR offer price with the 'retail' price. Thus a 'retail' price is still required.

157 See Section 6.3.

If, there was a more limited offset to the DSR offer price than p^r , and the DSR provider's remuneration was increased, then the DSR provider would have an incentive to offer excessive (socially inefficient) levels of DSR. This can be graphically illustrated in the figure below where the use of notional retail price smaller than the actual one (p^r_0) is equivalent to a downward shift of the demand curve (by an amount equal to the underestimation of the retail price). The grey triangle indicates the scale of the deadweight loss. The extreme case of 'zero' compensation to the supplier (which is *not* shown in the figure below) while remunerating the customer at the full offer price would shift the demand curve further down and lead to even more over-provision of DSR.

Figure 29: Over-compensation to the DSR provider



Note: DRS revenues shown are net of the "retail price"
Source: CRA Analysis

6.1.4. Contracted retail price

Most straightforwardly, the 'retail price' to be used in DSR-related payments could be taken from the existing retail supply contract for a DSR provider. The 'retail price' could be calculated from the difference in retail bills with and without DSR delivered volumes (which should also have the effect of excluding components that do not vary with marginal changes in consumption such as network and balancing charges).

Moreover, to ensure that the BM is financially in balance the DSR-payment needs to be recovered from one or all of the BM parties. In the event this payment is recovered from the supplier of the DSR-provider, then the supplier's net revenue will be close to the 'retail' price. The advantages and disadvantages of Central and Supplier-Customer Settlement, including options for the recovery of the DSR payment, are discussed below.

6.2. Central vs Supplier-Customer Settlement

This section considers the choice between Central and Supplier-Customer Settlement separately from related competition issues. The potential impact of any market power on the efficient provision of DSR is covered in the following section.

6.2.1. Recovery of DSR payment in Central Settlement system

There are three options for the recovery of the DSR payment (i.e. offer price less 'retail' price) in the Central Settlement system.[158] It should be noted that this issue is mitigated by the variant on the Central Settlement system outlined in Figure 27

All BM parties

One option is to socialise the recovery of the DSR payment by spreading it across all BM parties in the same way that the Balancing Services use-of-system ("**BSUoS**") charge allocates across all parties in proportion to metered offtake or delivery of energy costs incurred, such costs as congestion management.[159] Such an approach to recovering the costs of DSR-payment seems inherently 'unfair'. It would involve charging generators that in out-turn deliver their contracted generation. It would also involve charging generators for DSR as a result of which some have missed out on the opportunity to earn incremental revenues to balance the system. In addition, allocating the DSR payment in proportion to size or imbalance volumes might distort existing incentives to achieve a balance position and to make bids/offers into the BM - and thereby undermine efficiency. In this regard, generators/suppliers should be responsive to their own estimated risks of being out of balance as opposed to the risks of others being out of balance.

The out-of-balance BM party (or parties)

The BM parties with the imbalances that contributed to the need to activate DSR in order to balance the system are obvious candidates to bear the DSR payment. It is likely that these 'short' parties would still be better off after being exposed to the imbalance price *and* incurring the DSR payment than otherwise facing the higher imbalance price that would follow from higher priced generation being used instead of the DSR.[160] But it is possible for this not to be the case where there is limited margin between the new market clearing price and the price that would have prevailed but-for the DSR activation. Finally, such 'short' parties are already incentivised to minimise imbalances through exposure to the imbalance price and further adding to these incentives is not by itself necessary for the promotion of economic efficiency.

The supplier of the DSR-provider

Requiring the DSR payment to be made by the supplier of the DSR-provider has the potential advantage of funding the payment out of the windfall that the supplier would otherwise receive by cashing-out its DSR-related imbalance at the imbalance price. This imbalance price may generally be expected to be above the 'retail' price (with DSR Turn-Down) that the supplier would otherwise have received given the likely capacity scarcity during periods of DSR activation and associated DSR offer prices. At the same time, the

158 See Section 5.2.1 and Appendix A Section 3.3

159 The net exposure to BSUoS is offset to some extent by the Residual Cashflow Reallocation Cashflow payment

160 See Appendix A Section 3.3

supplier would for the most part be left no worse off than if it had continued to sell electricity to the customer in the absence of any DSR (which has the benefit of leaving its pricing and investment incentives unchanged).

However, there are circumstances in which the DSR offer price may exceed the imbalance price thereby leaving the supplier worse off. This may occur where DSR has been activated, for example, to manage a transmission constraint and under the current BM approach to calculating the imbalance price by averaging offer prices across the marginal 50MWh.[161] In such circumstances, the supplier would then be exposed to the difference between the offer price and the imbalance price which would seem 'unfair' on the supplier that had not itself incurred any imbalance (separate from the DSR induced imbalance for which it was not responsible).[162] However, simply leaving the supplier with the benefit (in most circumstances) of receiving the imbalance price on the DSR activated volumes may introduce some 'tension' between the supplier and its customer since the customer is likely to perceive the supplier as being better off as a result of its DSR provision.

Conclusion on DSR payment

There is no clearly compelling solution to the issue of which party should bear the DSR payment under the Central Settlement system approach. Allocating payment to the supplier of the DSR provider avoids the 'unfairness' of requiring all parties to contribute and the potential imposition of excess costs on the short BM party. But it then may leave the incumbent supplier exposed to the margin between the imbalance price and the offer price. This by itself is one reason for preferring the Supplier-Customer Settlement system approach (unless such exposure is managed by socialising such costs in BSUoS or by the variant Central Settlement System presented in Section 5.2.1).

6.2.2. Data flows and Theory of Harm 2

The Central and Supplier-Customer Settlement system approaches differ with respect to the associated flows of data and reporting requirements. These are summarised at a high level in Figure 30 (where 'supplier' refers to the incumbent supplier of the DSR provider separate from the IDA).

161 https://www.elexon.co.uk/reference/credit-pricing/imbalance-pricing/

162 It would be possible to avoid this problem by making an exception when offer prices exceed imbalance prices and allocating such payments to BSUoS. Similarly, the variant option presented in Section 5.2.1 would avoid this problem.

Figure 30: High-level summary of data flows across settlement models

	Central Settlement System: Incumbent supplier makes DSR payment	Central Settlement System Variant: Incumbent supplier receives retail price	Supplier-Customer Settlement System
Individual customer DSR accepted/delivered volumes	Required by BM to check delivery and by IDA for settlement		
	Only required by supplier to check DSR payment		Required by Supplier to determine DSR payment
IDA-aggregated accepted/delivered volumes	Required by BM to check delivery and by IDA for settlement		
	Only required by supplier to check DSR payment		
Individual customer metered volumes	Available to Supplier for billing and IDA for checking delivery of DSR		
	Required by BM to check delivery of DSR		
Individual customer DSR bid/offer prices	Agreed between Customer and IDA		
	Not required by BM and Supplier		
IDA-aggregated DSR bids/offers	Available to all parties		
Individual customer DSR retail price	Agreed between Customer and Supplier		
	Required by BM and IDA to determine/check DSR payment		Not required by BM or IDA
IDA-aggregated retail price	Available to Supplier and IDA to check DSR Payment		
	Required by BM to determine DSR Payment		

Source: CRA Analysis

Reporting retail prices for Central Settlement

The Central Settlement system approach requires central notification to the BM settlement administrator of ‘retail’ prices to be included in settlement of DSR payments. On the assumption that some external and standardised ‘retail price’ is not applied, for the reasons set out above, then the scale and complexity of data to be handled centrally may be problematic. The required ‘retail’ price is likely to differ across many thousands of retail supply contracts and to be constantly changing as supply contracts are renegotiated. Moreover, the determination of the ‘retail’ price to be applied may not be as straightforward as multiplying a price by delivered DSR volumes; there may be some bespoke calculation required to determine the ‘retail’ price.

We note that the customers providing the DSR have an incentive to under-report the required ‘retail’ price. This is because the reported ‘retail’ price is deducted from the offer price and so minimising this reported price would increase DSR margins. However, the suppliers of the DSR-providers conversely have an incentive to ensure that the ‘retail’ price is as high as possible, where the supplier is required to fund the DSR payment. As a result these competing incentives may be taken to counteract each other; there is no joint incentive for an integrated supplier-DSR provider to over/under-report ‘retail’ prices.[163] This limits the main disadvantage of reporting retail prices under Central Settlement to the administrative burden.

163 See Appendix A Section 4.1.1

Data flows and confidentiality

The Central Settlement system approach requires central handling of data on 'retail' prices, DSR offer prices and DSR acceptances and delivered volumes. Some of this data might also need to be provided to the supplier of the DSR-provider where it is funding the DSR payment to the DSR provider. In particular, the supplier is likely to require information on its customers' accepted/delivered DSR volumes and the associated offer and retail prices so that it could check the DSR funding payment However, this may not be considered necessary where suppliers are willing to accept that independent and confidential audit services are sufficient. This may be considered an advantage in relation to the concerns raised by Theory of Harm 2.

It is clear though that, under Supplier-Customer Settlement, the Supplier would need to be informed of DSR activation so that it could add this volume to out-turn metered demand and charge the appropriate 'retail' price. While DSR offer prices would in any event be visible to the Suppler (as generators bids/offers are currently made publicly available), it would only be under the Central Settlement approach that the supplier might be able to link specific offer prices to its own customers' provision of DSR.[164] This may provide the supplier aiming to displace an IDA's DSR products with its own products with, ceteris paribus, some competitive advantage.

Consequently, the Supplier-Customer Settlement approach may be preferred over Central Settlement because it avoids the need for the development of potentially complex central settlement systems. There is no equivalent need for Supplier-Customer Settlement because suppliers and customers already have systems and procedures in place for the settlement of the retail supply contract. However, under Supplier-Customer Settlement the incumbent supplier is required to have access to information on customer-specific activation of DSR volumes which some IDAs may regard as providing a commercial advantage to a potential competitor.

6.3. Possible supplier market power and the provision of DSR services

This report has not concluded on the extent to which there may or may not be limits to the effectiveness of competition in the overall electricity market or, more narrowly, in the market for the provision of DSR. The discussion of two main theories of harm in Section 3.2 has served to highlight a number of possible concerns which are then taken into account in the assessment of possible reform options.

6.3.1. Theory of Harm 1 and 2: the potential impact of vertical integration

Vertically-integrated suppliers may benefit from DSR where they have a short position in the BM and but-for the DSR activation would face a higher imbalance price (and/or other charges).

Conversely, vertically-integrated suppliers may be harmed by DSR where but–for the DSR activation they would receive a higher imbalance price on a long position or sell incremental

164 The specific metering points supporting a VBMU may not be made generally available to all market participants.

generation at a higher imbalance price. This harm is increased where such a vertically-integrated supplier itself does not share in any margin from the DSR provision.[165]

Thus, each vertically-integrated supply may be impacted differently depending on such factors as the scale of their upstream generation portfolio relative to their downstream customer demand, the reliability of their generation that may make it more/less prone to shortfalls and market factors in the BM that may allow incremental generation offers to be made at a margin above marginal cost during periods of capacity scarcity.

Specifically, portfolios with relatively unreliable generation may benefit from DSR mitigating exposure to otherwise high imbalance prices. But conversely, portfolios with flexible, peaking generation may be out-competed by DSR and lose out on marginal income. It is likely that at least some of the vertically-integrated suppliers are harmed more by DSR than they benefit from its impact on reducing imbalance prices.

However, the competitiveness of upstream generation markets (see Section 3.3.2) means that it is likely to be difficult for a vertically-integrated supplier to be confident of recovering any costs incurred to suppress DSR (such as pricing discounts to customer not taking up DSR offers) and foreclose IDAs. And, similarly, given the competitiveness of the I&C supply markets, customers may switch relatively easily to other suppliers in the event their incumbent is reluctant to facilitate DSR or otherwise attempts to impose some penalty on them for accepting an IDA's DSR offer. These competitive conditions provide customers with some leverage in negotiating over DSR terms with suppliers keen to retain their supply contract (which, in absolute terms, will be more profitable than the relatively few megawatt hours that most DSR providers are able to activate).

6.3.2. Theory of Harm 1: limited incentives on suppliers to develop DSR

To the extent that the incentives on suppliers to develop DSR may be limited by lack of customer interest and the associated absence of competitive pressure from other suppliers, then making provision for IDAs to offer DSR services directly into the BM would be beneficial (provided that the required systems for DSR settlement can be implemented efficiently and at reasonable cost). IDAs, as we have determined through a number of interviews and, as reflected in the responses to the recent Call for Evidence, are generally optimistic about the commercial prospects for the development of DSR. The commitment of such IDAs to the market for DSR may lead to its faster development[166] and, as a result, the achievement of consumer benefits more quickly, if not also to a greater extent. But at the same time, it is worth noting that with improved prospects for DSR though higher energy market prices and increased revenue opportunities (in the form of the Capacity Market and potential access to the BM), suppliers may be more encouraged to commit to developing DSR than in the past.

We recognise that the business models of most IDAs are not dependent on any single source of DSR revenue. This was highlighted in Section 2.3.2. However, access to the BM by providing a further revenue opportunity will play a role in facilitating growth among IDAs (and remove some barriers to wholesale market participation).Theory of Harm 2:

165 Analysis presented in Appendix A Section 5.2 shows that vertically integrated suppliers do not have an incentive to suppress DSR under (perfectly) competitive market conditions where generation offer prices are equal to marginal cost and the supplier cannot affect the BM equilibrium price.

166 See Section 2.5

Suppliers use their incumbency position with supply customers to foreclose IDAs from developing DSR

The ability of suppliers to frustrate the development of DSR by IDAs is not substantially affected by the choice of payment system. Instead, any such ability largely follows from possible limitations in competition between suppliers which mean that suppliers do not have to ensure their customers are offered the 'best' DSR products or the 'best' supply contract terms in order to retain their business. However the issue of supplier consent and determination of the 'retail' price which are common to both settlement systems assessed here are important to the ease with which IDAs can implement DSR. These are discussed next; the data issues relating to Theory of Harm 2 were covered above (See Section 6.2.2)

No explicit consent requirement

Explicit consent from a supplier is not currently required for a customer to provide DSR services. Moreover, the provision of DSR in the BM is not so substantially different from other DSR services that there is a clear reason to treat it differently in this regard. However DSR may change the risk exposures of the supplier, depending on the DSR payment system adopted and the terms of the retail supply contract.[167] This would suggest that suppliers – where they are not able to withhold consent – should have the ability to break their supply contract or introduce amendments to it. In practice, this is similar to existing supply contracts under which the customer is obliged only to inform its supplier of a decision to provide DSR services.

Determination of the 'retail' price

There are three main options.

(i) Bi-lateral negotiation

Under an unconstrained bi-lateral negotiation approach,[168] there is the possibility that the negotiation may fail to converge on a mutually acceptable 'retail' price. This would then lead to (a) the customer being unable to provide DSR (and effectively the supplier withholding consent), or (b) the supplier or customer being able to break the supply contract enabling the customer to re-compete the supply contract, or (c) the imposition of a regulated 'fall-back' determination.

Solution (c) seems likely to result where neither party is able to break the contract since it will be a better solution for at least one of the parties than any other possible negotiated 'retail' price. But Solution (b) appears preferable to both (a) and (c), as discussed next.

(ii) Regulatory determination

The regulator could, as in France, step-in to impose a regulatory determination of the 'retail' price.[169] But this is likely to result in a 'retail' price that is not close to actual 'retail'

167 For example, a change in risk exposure may follow from exposure to demand re-bound where a customer's demand is increased in subsequent time periods to make-up for its DSR.

168 Eurelectic consider a "Contractual model" in which the IDA and the supplier agree on compensation. But given the need for customer participation in this agreement, it is not in effect a different option from the proposed P344 approach of requiring bi-lateral negotiation between supplier and customer. See page 13 *Designing fair and equitable market rules for demand response aggregation* Eurelectic March 2015

169 See Section 6.1.1

prices for many customers and as such is clearly a second-best approach. Moreover, it would constitute a direct regulatory intervention to 'fix' prices where it has not yet been established that bi-lateral negotiation and market forces will fail.

(iii) Regulatory guidance and ex post enforcement

In light of the above – namely, on the one hand, the potential risk of failure of bi-lateral negotiation but, on the other hand, the unattractiveness of regulatory intervention – a third option is to provide regulatory guidance to market participants. Such guidance could explicitly set out that, under the Supplier-Customer Settlement system, the supplier should expect to be able to add the delivered DSR volumes to the customer's metered demand in determining its retail supply bill. This could be facilitated by requiring the BM administrator to notify the relevant suppliers of any delivered DSR volumes.

Retail supply contract amendments

It is important to note that the use of a regulated or guide 'retail' price does not prevent suppliers from otherwise adjusting their supply terms so that they are indirectly further compensated. [170] However, the extent to which suppliers are able to remunerate their DSR-related costs from their retail supply prices is limited by the extent of competition in retail supply. Thus a supplier faced with a 'low' compensation price that attempts to increase its retail supply prices either to increase its compensation or to discourage DSR may be faced with competing suppliers potentially willing to accept the 'low' compensation together with undistorted supply prices.

Finally, we note that where the regulator has continuing concerns about the adoption of its regulatory guidance and suppliers' reactions, then it can seek to facilitate the exercise of its ex post powers to intervene. For example, in Singapore (which has a relatively uncompetitive retail supply market[171]) the regulator has added a clause to suppliers' licenses requiring that:

> *[A Licensee shall] not discourage, restrict or prohibit consumers from participating in demand response-related or energy efficiency-related initiatives.[172]*

6.4. Further implementation issues

6.4.1. Baseline gaming

A key design component for explicitly including DSR in the BM (or other energy markets) is the method adopted for determining whether the offered demand reduction (or demand

170 Similarly the *Impact assessment study on downstream flexibility, price flexibility, demand response and smart metering Final Report* July 2016 prepared by COWI for the European Commission notes at page 169 that the absence of compensation to relevant Balance Responsible Parties 'introduces a possibility demand aggregators being free-riders and therefore creating inefficiencies'. For example, inefficiencies may arise from retailers seeking to compensate themselves through increasing their retail energy prices and thereby risk distorting demand. https://ec.europa.eu/energy/sites/ener/files/documents/demand_response_ia_study_final_report_12-08-2016.pdf

171 Page 14 *Ranking the Competitiveness of Retail Electricity and Gas Markets: A proposed methodology to ACER* IPA Advisory Limited 4 September 2015

172 Clause 2.2.2(k) : https://www.ema.gov.sg/Licensees_Electricity_Codes_of_Practice.aspx

increase) has in practice been delivered. In many jurisdictions an administrative process sets the baseline, using, for example, historic load data to assess what would have been the DSR-provider's consumption during similar operating conditions to the load curtailment period.[173]

These methods for determining a baseline may be subject to 'gaming'.[174] DSR-providers may seek to benefit by inflating their baseline above the quantity of energy of consumption that they actually expect to consume. In this way the DSR-provider may be able to sell DSR without also incurring the disruption of reducing their consumption by as much as would be required with a 'genuine' baseline.[175]

Incentives for gaming baselines can also be reduced by introducing penalties for baseline manipulation, though establishing such manipulation may itself not always be clear-cut. However, we also note that retail supply contracts may constrain some of the incentives on DSR-providers to inflate their baselines. This is because suppliers usually increase their charges to customers in relation to the out-turn volatility of their load. Such volatility would be increased for suppliers affected by baseline gaming under the Supplier Customer settlement approach. This is because the 'inflated' baseline would lead to an inflated DSR correction of the supplier's position in the BM. In other words, the supplier's position would be out-turn metered load plus the 'delivered' DSR volume which would be in excess of expected (without any distortion) consumption and as such risk causing the supplier to be short in the BM. This is shown in the table below. In this example, the customer uses an inflated baseline (110 in Table 12) to offer a DSR volume and then not reduce their metered load (100 in Table 12) below their uninflated baseline. The supplier corrected demand (110 in Table 12), then leads to a supplier imbalance (10 in Table 12) rather than restoring the supplier to balance.

The potential role of suppliers' retail contracts in constraining baseline gaming incentives may be taken as a further reason for ensuring that suppliers are notified about intended DSR provision by their customers and have the opportunity to re-determine their supply contract terms.

173 See, for example, *Demand response and verification* Association of Edison Illuminating Companies March 2009 and *PJM empirical analysis of demand response baseline methods* Prepared for the PJM Markets Implementation Committee by KEMA 20 April 2011

174 Page 26 *International review of demand response mechanism prepared for Australian Energy Market Commission by Brattle October 2015*

175 The scope of this report does not include an assessment of the potential for 'gaming' baselines. The determination of baselines is closely related to metering requirements. For example, some market participants have suggested that BM-standard metering of sub-loads on a consumer's premises may be required to establish robust baselines.

Table 12: Incentives for gaming baselines

	Uninflated baseline	Inflated baseline
Baseline	-100	-110
DSR volume	-10	-10
Metered load	-90	-100
Supplier contracted generation	100	100
Supplier BM corrected demand	-100	-110
Supplier imbalance	0	-10

Source: CRA Analysis

In the event that the supplier anticipates gaming and bases its forward contracting on the inflated baseline, then in most periods (in which DSR is not activated) it risks contracting for an excess of generation. This excess would also imply excess retail supply contract charges for the DSR-provider.

The electricity market in Singapore provides an example of an alternative to the administrative approach to determining baselines. In Singapore there are self-declared baselines relative to a strike price with penalties for deficient consumption.[176] In other words, the DSR-provider declares the quantity that it will consume (within tolerance thresholds) for a declared 'retail' price. A DSR-provider is penalised if consumption falls below the declared baseline when the market price is less than or equal to the declared strike/'retail' price (and the DSR offer is not accepted). In these circumstances, the customer is expected to consume at least its baseline because prices have not risen higher than anticipated. This approach is likely to be dependent on customers having predictable loads and accordingly being prepared to take such risk on their baseline declarations.

6.4.2. Non-delivery risk

It may be argued that the IDAs are at present less well-resourced than incumbent suppliers and as such not well placed to bear non-performance risks that would, with equivalent treatment to generators, be priced at the imbalance price. However, the Customer/IDA are better placed than the supplier to assess the likely occurrence of such risks given that they have direct control over the DSR capability and to manage these risks across their portfolio of aggregated DSR. Moreover, if the DSR-related supplier were allocated the residual imbalance risk of non-performance, then it can in any event be expected to pass its assessment of the cost of this risk on to the Customer in its retail supply contract.[177]

So the risk of non-performance is better placed directly on the Customer/IDA. This is because the alternative, namely placing it directly on the related supplier would at best lead to it being transferred to the Customer/IDA through the retail supply contract. And, at worst it might lead to tariff adjustments in the retail supply contract for the Customer/IDA over/under-stating the risk of non-performance. Such tariff adjustments might arise not

176 Pages 26-27 *International review of demand response mechanism prepared for Australian Energy Market Commission by Brattle October 2015*

177 Page 13 *Examples of Supplier Imbalance Adjustment* in *Settlement of replacement reserve in GB: A summary of the P344 Workgroup's proposed solution* version 0.3 Elexon 3 February 2017

least because of the increased credit risk for the supplier in the event that the supplier had to have recourse to the customer for recovery of imbalance costs from non-delivery of DSR.

6.5. Treatment of residential/micro-business consumers

This report, for the reasons set out at Section 2.3.1, has focussed on I&C DSR providers. This sets out that in practice, the large number of individual consumers required in a residential /micro-business DSR portfolio are likely to make it uneconomic (unless technology costs change substantially) for an independent aggregator to develop a customer management and payment system *without* also trying to take on retail supply for those customers (i.e. an IDA would likely be very uncompetitive relative to the incumbent supplier). However, we briefly consider here the applicability of the Supplier-Customer and Central Settlement Systems to residential/micro-business customers.

6.5.1. Efficient remuneration for residential/micro-business consumers' DSR

The efficient remuneration for residential/micro-business DSR, remains the same as for I&C DSR i.e. $p^* - p^r$

6.5.2. Difficulty of using individual residential/micro-business 'retail prices' in Central Settlement System

Given the need for residential/micro-business DSR offers to be pooled across many more consumers than I&C DSR, there would be a very large number of underlying 'retail prices' related to an individual DSR offer in the BM. Different consumers in the same DSR portfolio will in practice be on many different – and frequently changing – tariff terms across many different suppliers. This makes it impractical (at least with current technology and IT) to use actual retail prices in the Central Settlement System. This is an amplification of the difficulty noted in relation to I&C customers (for which bespoke tariff calculations might also be impractical).

Using an approximation of residential/micro-business customers 'retail price' may not be as distortionary as with I&C customers given the price inelasticity of residential consumers. However, imposing a 'regulated' p^r is unattractive because: (i) it may act as a focal point for suppliers' pricing and/or (ii) suppliers/aggregators are likely to complain that it is being set too low/high. Suppliers will complain if the price is less than p^r, that they are being forced to make a sale of electricity at a price below which they are willing to sell.

6.5.3. 'Retail prices' in the Supplier-Customer Settlement System

The aggregator will need to inform the incumbent supplier of the DSR customers of the demand reduction achieved by its individual customers. Similarly, the aggregator will need to inform the BM of which suppliers serve the customers who have provided DSR so that the 'correction' of BM positions is allocated correctly across suppliers. This information is required from the aggregator because baselines are likely to be established at a portfolio level and so DSR delivery may not be inferred direct from individual customers' metered demand.

The provision of information to the supplier would enable it to adjust the metered demand for its customer with the DSR amount, in order to bill the customer for its DSR at its relevant (i.e. customer-specific) retail price. We recognise though that this presents the potential problem of customers' metered demand not directly reconciling to their bills.

We also recognise that bi-lateral negotiation of the relevant 'retail price' is not feasible. Ofgem may be able to rely on competition between suppliers to result in the relevant retail price being used. However, this may not be likely for 'sticky' customers even with regulatory requirements put in place for suppliers to make it clear to customers what they are being charged for DSR volumes. In the absence of an efficient solution being likely through competition, then Ofgem could seek to achieve industry-wide agreement on using the relevant (customer-specific) retail price. In other words, a standard framework could be established under which it is acknowledged that it would be discriminatory for suppliers to set different prices (after allowing for network charges and levies) between 'metered volumes' and imputed-DSR volumes.

6.5.4. Consumer benefits

At this stage, it seems unlikely that independent aggregators would find it profitable to provide DSR on a mass-market basis to residential residential/micro-business retail customers. Therefore, we believe that consumer benefits from DSR are likely to be maximised (at least in the short-term) by incumbent suppliers providing DSR services. This is straightforward under the Supplier-Customer Settlement approach. The incumbent supplier simply provides the relevant customers with a DSR payment in return for activated DSR which need not require any direct reference to meter readings.

6.6. Summary of assessment and recommendations

6.6.1. Summary of assessment

Market competitiveness

- This report has not concluded on the extent to which there may or may not be limits to the effectiveness of competition in the overall power market or, more narrowly, in the market for the provision of DSR.
- There are some incentives on vertically-integrated suppliers to limit DSR (in particular, where their generation resources are able to raise prices during periods of capacity scarcity). Other suppliers may also wish to frustrate IDAs where they are perceived to be in competition with the supplier's own DSR products or potentially, over time, improving their positioning to compete for the supply contract.
- However, these incentives are mitigated by competitive conditions in upstream generation markets and the I&C retail supply market**.** Competition in upstream generation means that any supplier incurring costs to suppress DSR may not in practice recover these costs from anticipated generation market prices given competing generators or other DSR providers. Competition in I&C retail supply means that suppliers imposing costs on customers in order to discourage DSR risk losing those customers to competitors.
- Moreover recently reduced levels of vertical integration have in any case mitigated incentives on some suppliers to limit the development of DSR.
- These considerations indicate that market conditions may be sufficiently competitive to deliver the efficient development of DSR and that the Theories of Harm set out in this report are of limited concern.

- But, while the risk of market foreclosure to IDAs cannot be fully excluded, enhancing revenue opportunities for IDAs by providing direct access to the BM may assist in the development of efficient of DSR provided an economically efficient system can be established at reasonable cost.

DSR Settlement systems

- This report has reviewed two efficient approaches to DSR settlement:
    - A Central Settlement system approach in which the supplier of the DSR-provider is exposed to the imbalance price for DSR volumes and the DSR-provider is remunerated at the offer price less 'retail' price. The BM's deficit in funding the DSR may then be recovered from the supplier of the DSR-provider, all parties or the parties responsible for the system imbalance. A variant of this approach which simplifies BM payments to the supplier has also been considered.
    - A Supplier-Customer Settlement system approach in which the supplier of the DSR-provider is 'cashed-out' of DSR volumes by the DSR-provider at its avoided 'retail' and the DSR-provider is remunerated at its full offer price.
- Both these settlement systems can be consistent with the efficient remuneration of DSR in the BM.
- A Supplier-Customer Settlement system has some advantages over a Central Settlement system. In particular, Supplier-Customer settlement:
    - Avoids the need to report 'retail' prices centrally (with associated risks of over/under-reporting) and to calculate centrally avoided retail payments on activated DSR volumes;
    - Avoids exposing the supplier of the DSR-provider to imbalance price risk or DSR non-delivery risk as a result of DSR volumes (though the Central Settlement System may be modified to avoid this problem);
    - Provides for some mitigation of the risk of baseline gaming through the correction of the supplier's position in the BM (which means that not just the customer but also the supplier may be affected by the baseline); and
    - Assuming a competitive supply market, will support an efficient negotiated outcome between supplier and customer.
- However the Supplier-Customer system by its nature requires closer involvement of the incumbent supplier. In particular, the supplier is informed of its customer's delivered DSR volumes (in order to adjust its billing), while this customer-specific information need not necessarily be made available to the supplier under variants of the Central Settlement system. Consequently, some IDAs may consider that the Central Settlement system assists in preserving the confidentiality of commercially significant data.

Theory of Harm 2: Foreclosure risk

- Theory of Harm 2 - the risk of incumbent suppliers foreclosing the provision of efficient DSR by IDAs - is of key concern to IDAs.

- The Central Settlement System may then be preferred by IDAs where it limits access by suppliers to data on customer-specific DSR volumes that may be considered commercially significant.
- However, there are other efficiency considerations indicating that Supplier-Customer Settlement may be preferred; in particular, it may be easier to implement. While the Central Settlement System may be adapted to ease implementation such as by using a standardised proxy retail price this would introduce some inefficiency since such proxies are likely to poorly reflect actual retail prices.
- Moreover, allowing suppliers access to some relevant information with which to adjust their retail contracts in the context of DSR provision (as discussed further below) may be efficient. We recognise that this may equally be considered by some IDAs as an opportunity for suppliers to react anti-competitively. But to the extent that there are concerns about the competitiveness of I&C suppliers, arguably these should be dealt with by regulatory interventions in the retail supply market (and not be adopting less efficient approaches to DSR).
- Given the overall competitiveness of upstream generation, the I&C supply market and the reduction in levels of vertical integration which mitigate the incentives identified in Theory of Harm 2, we conclude that any remaining foreclosure risks are not sufficient to prefer the Central Settlement system over the Suppler-Customer Settlement system.

Advance notification

- Advance notification to relevant suppliers of DSR providers' intentions appears important in enabling suppliers to make potentially efficient adjustments to their generation procurement and supply contracts.
- Where advance notification is considered important, then the advantages of Central Settlement in relation to preserving the confidentiality of commercially significant data is reduced.
- In any event, we expect that suppliers concerned about the provision of DSR by their customers will deduce such provision from their customers' metered data.

Ex post notification

- It is necessary for the supplier to be notified ex post of accepted and delivered DSR offers under the Supplier-Customer Settlement system approach so that the supplier can adjust its invoices appropriately to charge the supplier for its DSR volumes.

Supplier consent

- Not requiring consent from the supplier of the DSR-provider is consistent with the existing approach of suppliers to DSR and avoids introducing any new potential barrier for IDAs
- However, in the absence of withholding consent, suppliers may wish to be able to exercise break-clauses or otherwise adjust retail contract terms. This may require some further regulatory over-sight (at least in the initial period following the implementation of reforms to access to the BM).

- By implication then, Ofgem should not require supplier consent or intervene to stipulate that suppliers may not withhold consent.

The efficient level of DSR remuneration

- Determination of the 'retail' price to be used in DSR settlement may most straightforwardly be taken from the prevailing retail supply contract as the avoided contract costs for the customer with foregone demand.
- Given the concerns about market competitiveness, this level of remuneration may not be agreed in bi-lateral negotiation. But, direct regulatory intervention would be unattractive in a market segment that is otherwise unregulated. This leaves the option of Ofgem providing guidance to market participants, with the possibility of ex post intervention to address abusive or discriminatory behaviour by suppliers.

The potential for 'gaming' DSR baselines.

- Potential for 'gaming' DSR baselines may arise from an administrative approach to setting baselines.
- However this risk may be mitigated by suppliers having advance notification of customers' intention to provide DSR so that the terms of suppliers' retail contracts may be appropriately adjusted, such as by introducing charges for more volatile or apparently higher customer loads

Non-delivery risk

- The risk of DSR non-delivery should be borne directly by the DSR-provider. Allocating this risk to the incumbent supplier is only likely to see it passed back to the DSR-provider, potentially at a high cost given the associated credit risk for the supplier.

Residential/micro-business customers

- In the event that IDAs do wish to compete for residential/micro-business customers, then the Supplier-Customer Settlement system is still applicable. Bi-lateral negotiation of the relevant 'retail price' is not currently feasible on a mass market basis. If it appears that there is up-take of residential/micro-business customers (possibly supported by smart meters and smart appliances), and notwithstanding the protections already in licences and regulations, Ofgem could encourage suppliers to develop a clear and transparent framework when setting prices (after allowing for network charges and levies) to allow for the difference between 'metered volumes' and imputed-DSR volumes.
- A simplification of the Central Settlement system with proxy 'retail prices' (approved by Ofgem) would risk setting a focal point for suppliers' pricing.

6.6.2. Key recommendations

The key recommendations resulting from this report are:

- Direct access should be provided to the BM for IDAs
- The efficient remuneration for the DSR-provider of DSR offered in the BM is the market clearing price less its 'retail' price

- The Supplier-Customer settlement system approach should be adopted on the grounds that by avoiding the need for reporting ‘retail’ prices centrally or adopting a proxy ‘retail price’, it is easier and more efficient to implement. The concerns raised by Theory of Harm 2 do not appear sufficiently well supported to justify the potential inefficiencies and higher costs of the Central Settlement System model.
- The ‘retail’ price should be the payments in the retail supply contract that are avoided by the delivery of DSR volumes
- Advance notification of suppliers of customers’ intent to provide DSR should be provided to allow for efficient procurement by suppliers as well as potential supply contract adjustments (which can play a role in mitigating incentives for gaming DSR baselines).
- Ofgem should consider setting out guidance to suppliers and potential DSR providers on payment terms relating to DSR provision rather than regulating such payment terms in the absence of any evidence of related consumer harm. This would include recognising that suppliers may add delivered DSR volumes to customers’ metered demand in determining their retail supply bills.
- Suppliers should not be required to consent to the provision of DSR by their customers (but should not be prevented from breaking or amending their supply contracts subject to any such amendments having objective justification).
- Further work may be required on how best to establish robust baselines for use in the BM. This may require third party measurement and verification and/or obligations for DSR-enabled consumers to credibly commit to baseline consumption levels when DSR is not activated.
- Ofgem should monitor baseline compliance in order to assess the efficacy of baseline determining and potential gaming which may require subsequent regulatory intervention.
- Non-delivery risk should be allocated to the DSR-provider rather than the related supplier.

APPENDIX A: EFFICIENT USE OF DSR IN THE BALANCING MECHANISM

A.1 Introduction

This appendix sets out the competition analysis of DSR in the Balancing Mechanism (BM). It begins by setting out a necessarily simplified framework in order to make the analysis tractable and the appropriate level of remuneration required to incentivise the provision of DSR by a consumer. It then goes on to define the core financial flows affecting each party – the generators, the consumer providing the DSR, the supplier of the consumer providing the DSR ,and in the case of a supply or demand shock leading to an imbalance, the 'short' supplier.

Next we set out the main properties that an efficient payment scheme for DSR should be shown to satisfy before then considering four possible payment schemes. The analysis is then extended to consider in more detail a centralised payment scheme with supplier mediated and IDA mediated DSR. The impact of allowing for potential monopoly power is also assessed. We then contrast the centralised payment scheme with a decentralised scheme.

This appendix looks only at demand side reductions. It should however be clear that the analysis can readily be transposed to the case of demand expansion. Similarly, while most of the analysis is couched in terms of a supply shock, it also holds if the need for adjustment in the BM comes from a demand shock, as discussed briefly at the end of this appendix.

A.2 A simplified Market Set-up

Electricity markets are complex as several markets clearing at different times interact and the type of contracts into which various parties enter are not necessarily standardised. In order to examine the specific issue of DSR we need a simplified representation of market operations. Our first simplification is to reduce the number of markets involved and take a short-cut to capture how these markets behave. We only consider two markets, the 'ahead/ex ante' market where suppliers contract with generators for the supply of a specified amount of power and the balancing market where imbalances due to events occurring after the ex ante market is closed must be resolved. We do not therefore consider further markets meant to deal with imbalances that arise with an even shorter time horizon. We also 'cut through' the step by step working of these markets by treating the contracts between suppliers and generators as 'contract for differences' (CfDs).[178] In practice, this means that transactions between suppliers and generators take place at the initially contracted price and for the initially contracted volume, regardless of the equilibrium price that prevails in the balancing market.

We start with a simple demand and supply framework shown in Figure 1. The black curve is the supply function in the 'ahead/ex-ante' market and the D curve is consumer's willingness-to-pay (demand) function. We define P^r as the retail price charged by suppliers to consumers and P^a as the equilibrium wholesale price in the ahead-market. In this context, $\boldsymbol{P^r}$ **is the component of the full retail price that determines the marginal willingness to pay for electricity** (and as such excludes largely fixed components such

178 These CfDs do not include renewables contracts.

as network charges). **Q^a is the equilibrium wholesale quantity in the ahead-market** and, absent any DSR, the quantity that the TSO would have to ensure is satisfied.

In this simple set up, generators get $P^a Q^a$ and bear their own generation costs, the supplier gets $P^r Q^a$ and pays $P^a Q^a$ and consumers get a consumer surplus equal to $CS(P^r)$. The TSO charges $P^a Q^a$ to suppliers and pays out the same amount to generators, balancing its accounts.

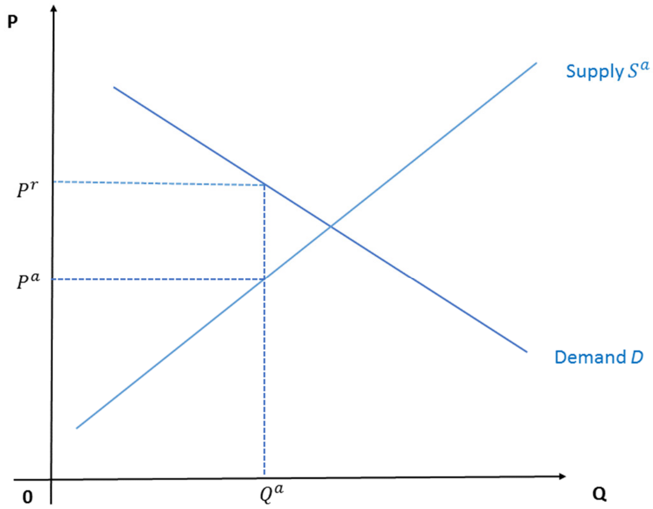


Figure 1: Balancing Market

A.3 Introducing DSR in the Balancing Mechanism

In order for DSR to have a role, we need negative supply shocks or positive demand shocks. Moreover, because of the initial margin between P^r and P^a, we need these shocks to be large enough. This can be seen in the following figure for the case of a supply shock.

If the supply curve only shifts from S^a to S_o^B, then, without DSR, the market clears at the same quantity Q^a but at a higher price, P_o^*. At this price, the willingness to pay of the consumers is still higher than the price and hence than the cost of providing Q^a by expanding the output of generators who are not affected by the supply shock. The price is therefore not sufficiently high to induce consumers to offer DSR. However, if the supply curve shifts as far away as S_1^B, then the price without SDR, P_1^* is higher than the consumers' willingness to pay at an output of Q^a. It is therefore efficient to have consumers reduce their demand rather than rely exclusively on greater production by unaffected power plants. From now on we will assume that the **supply shock ΔS (**e.g., due to failure of a generator which was expected to supply that volume**)** is large enough to create an opening for DSR services. The case of demand shocks is essentially the same as supply shocks though clearly different parties are affected.

The supply or demand-shocks needed to create a role for DSR are larger when the gap between retail prices and wholesale prices on the ahead market are also larger. This gap reflects both the retail margin that suppliers need to ensure that their operations are profitable and a variety of taxes (e.g., environmental) which are included in the retail price.

It seems therefore appropriate to assume that, on average at least, the wedge between retail and wholesale prices in the ahead market is not negligible. However, as we understand that retail prices do not necessarily fully pass variations in the ex ante prices to the consumers, there can still be situations where the gap is very small or even negative. In fact, it might well be in just such situations that DSRs are needed. For completeness then, we also show in Figure 2b a situation where the retail price is smaller than the wholesale price in the ahead market.

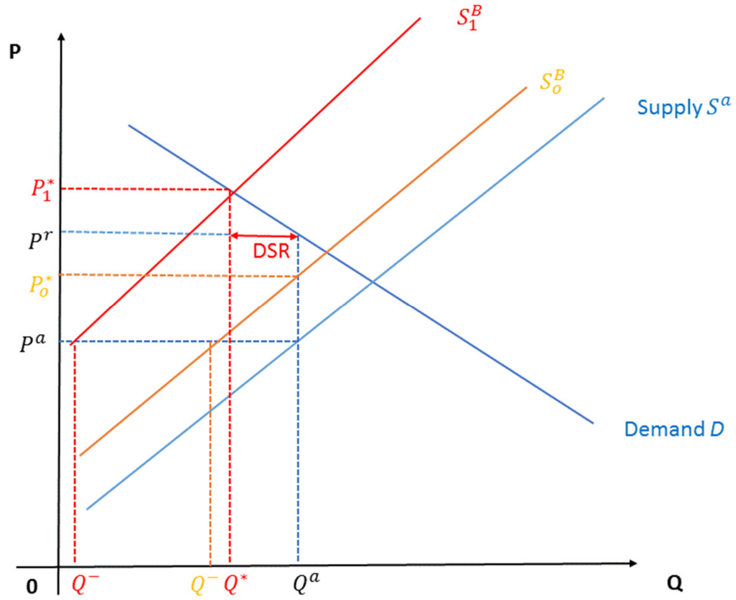


Figure 2a: DSR needs a large enough shock.

From an economic perspective, the situation depicted in Figure 2.b. is a little odd since, in order to achieve the social optimal, it would be desirable to use DSR even though there is no shock intervening between the clearing of the ahead market and the clearing of the BM: it would be desirable to reduce total output from the contracted Q^a to the efficient level Q^*. However, we will assume that previous 'orders' by suppliers are binding and generators are dispatched accordingly. This means that there is only room for DSR to fill in the quantity corresponding to the supply shock, shown in red as 'DSR' in Figure 2.b. This leads us to an equilibrium where the price is equal to P^* and the quantity is equal to $Q^a - \Delta S$. We therefore stop short of moving back to the first best allocation (P^*, Q^*). We see that not only the whole supply shock should be compensated through DSR, but now, *any* supply shock – however small – creates room for DSR.

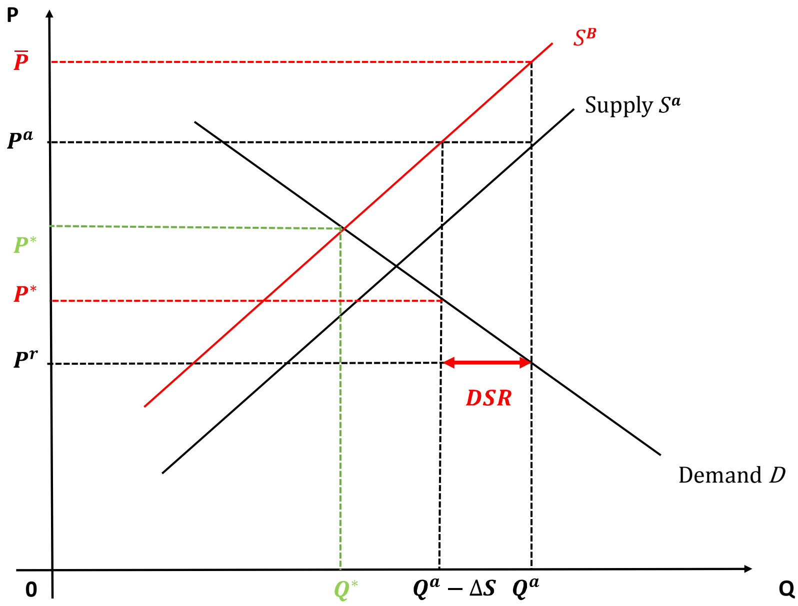


Figure 2b

A.3. Financial Flows without vertical integration

We can now go through the financial flows involved when DSR is used. We focus on the situation represented in Figure 2.a. In order to do so, we assume that consumers receive the compensation required in order to supply the efficient amount of DSR, i.e. we assume that each unit of DSR is paid at $P^* - P^r$. To keep matters simple we assume that there are three suppliers, three generators and three groups of customers. Each group is indexed from A to C. Supplier B is the supplier experiencing the supply shock ΔS. Again, to keep matters as simple as possible, we assume that the supply of DSR comes exclusively from consumer group A. We also assume that the supply shock corresponds to the shutting down of Generator B. In other words, Generator B had sold this quantity, ΔS, to some Supplier B in the 'ex-ante' market at price P^a, but its plant has failed (assume Generator B had no other production or sales).

The efficient outcome is for producing and consuming quantity Q^* through a combination of supply response/increase SR^* (by Generator C) and demand response/reduction DSR^* (Consumer group A). This corresponds to an equilibrium price P^* in the real-time market. To achieve the efficient outcome, Generator C must be paid the full value of its contribution (P^*SR^*), while Consumer A (or its IDA) must be paid $(P^* - P^r)DSR^*$ since reducing demand also means saving on the payments to its Supplier A (see below). For the moment, we assume that P^r is common knowledge. Suppose that $P^* > P^r$ (the 'red curve' case) since otherwise there is no need for DSR.

Consumer *A* has a contract with Supplier A (at price P^r) where it would normally consume quantity $Q_I^a > DSR^*$. Supplier A has bought that quantity in the ahead market (at price P^a) from Generator A, and neither the supplier nor the generator have any other transaction pending. There is perfect competition between zero cost IDAs, so IDAs have zero profits and we can think of Consumer A as playing directly in the real-time market. All contracts in the ex ante market are merely financial CFDs and the price established in the real-time market is the one that will be applied to the actual production and consumption of electricity (effectively consider the TSO charging P^* to all suppliers and paying the same price to all generators for the quantities that are actually consumed/produced). We now consider the payoffs of all players involved (nothing changes for any consumer, supplier or generator not mentioned below).

Supplier A:

- was expecting profits $\pi_I^a = (P^r - P^a)Q_I^a$
- after the shock it gets $P^r(Q_I^a - DSR^*)$ from Consumer X, pays $P^*(Q_I^a - DSR^*)$ to the TSO and gets $(P^* - P^a)Q_I^a$ from the CFD with Generator A, so $\pi_I = \pi_I^a + (P^* - P^r)DSR^*$
- Note that, under our assumptions, $\pi_I > \pi_I^a$ so *Supplier A is not harmed by the demand response: it benefits from it.*

Generator A:

- *nothing changes* for A: it gets more from the TSO ($P^*Q_I^a$ instead of the expected $P^aQ_I^a$), but pays that gain on the CFD with Supplier A.
- the same is true for all other generators not explicitly mentioned here.

Consumer A:

- It pays $P^r(Q_I^a - DSR^*)$ to Supplier A and gets $(P^* - P^r)DSR^*$ from the TSO (directly or via an IDA) for a surplus gain equal to the small triangle with area $(P^* - P^r)(Q^a - Q^*)/2$ or $(P^* - P^r)DSR^*/2$. So *Consumer A benefits from the DSR scheme*.

Generator B:

- Generator B does not get any revenues and has to pay $(P^* - P^a)\Delta S$ on the CFD with Supplier B
- Generator B would have paid even more (i.e., $(\bar{P} - P^a)\Delta S$, where $\bar{P} > P^*$ is the real-time equilibrium price in the absence of demand so it also *benefits from the presence of demand response*.

Supplier B:

- *nothing changes for Supplier B*: it pays more to the TSO ($P^*\Delta S$ instead of the expected $P^a\Delta S$), but get that loss back from the CFD with Generator B

Generator C:

- *Generator C is the only one that loses from the presence of a demand response mechanism*: it could have sold a higher quantity ($\Delta S > SR^*$) at a higher price ($\bar{P} > P^*$), therefore getting a higher producer surplus.

TSO:

- The TSO is **NOT** budget-balanced: it pays P^*Q^* to generators and gets the same from suppliers, but is short of the payment for demand reduction $(P^* - P^r)DSR^*$
- To summarise, the TSO:
  - Gets $P^*(Q_I^a - DSR^*)$ from Supplier A to deliver $(Q_I^a - DSR^*)$

- Pays $P^*Q_I^a$ to Generator A to receive Q_I^a
- Pays $(P^* - P^r)DSR^*$ to Consumer A for reducing its demand by DSR^*
- Gets $P^*\Delta S$ from Supplier B to deliver ΔS
- Pays P^*SR^* to Generator C to receive SR^*
- Budget balance: $P^*(Q_I^a - DSR^*) - P^*Q_I^a - (P^* - P^r)DSR^* + P^*\Delta S - P^*SR^* = P^*(Q_I^a - DSR^* - Q - DSR^* + \Delta S - SR^*) = -(P^* - P^r)DSR^* < 0$
- Quantity balance: $-(Q_I^a - DSR^*) + Q_I^a - \Delta S + SR^* = 0$

So the TSO is out-of-pocket for the payment to Consumer A (or to its IDA) of $(P^* - P^r)DSR^*$.

To allow for the presence of vertical integration between suppliers we can also compute the pay-offs of each of the three generator-supplier 'chains'.

- Chain A clearly gains from the introduction of DSR since Supplier A and Consumer A benefit and Generator A is indifferent (in fact, this would hold even if the TSO's entire out-of-pocket payment to Consumer A were to be clawed back from Supplier A, who would then be as well off as without DSR while Consumer A would still enjoy its welfare gain).
- Chain B is also better off since Generator B gains while Supplier B and Consumer B are indifferent (whether this gain is larger than the DSR payment depends on whether $(\bar{P} - P^*)(SR^* + DSR^*) > (P^* - P^r)DSR^*$ or, equivalently, $(\bar{P} - P^*)SR^* > [(\bar{P} - P^*) - (P^* - P^r)]DSR^*$).
- Chain C on the other hand loses when the DSRs are introduced as Consumer C and Supplier C are indifferent while Generator C loses out as it is (partially) outcompeted by Consumer A's DSR.

In sum, in this stylised model, **DSR activation would benefit all participants except for the generators it outcompetes**. Since **DSR activation increases total welfare** (by an amount equal to Consumer A's welfare gain plus the incremental cost that Generator C would have incurred if it had supplied the DSR volumes), it would be theoretically possible to compensate even those generators – though this may be both impractical and unjustified (in general there is no reason to compensate firms for their loss of profit following the entry of competitors in their market). Moreover, **all generators *may* be better off *on average*** from the possibility of DSR since the generator that is outcompeted in one instance may be the one who suffers from a supply shock in another; we discuss this possibility in the next subsection.

A.3. A Symmetric Model

In the previous subsection, we assumed that the supply shock affected a single generator and that the demand-side response only came from the customers of one supplier. We now turn to a more symmetric set up where only one generator at a time experiences a supply shock but each generator has the same ex ante probability of being affected by this shock. Similarly, now all consumers can engage in supply-response. **We define f as the probability that the system experiences a supply-side shock and assume that any**

shock would be confined to just one generator; given our symmetry assumption, this means that each generator has a probability $f/3$ of experiencing a shock. We also assume that each of the three suppliers serves one third of consumers and that each of these three consumer groups has the same demand function.

Consumers: whenever a shock hits, consumers are better off since they get extra surplus on the consumption units that they forego.

Suppliers: each supplier gets a windfall from the DSR units provided by their consumers.

Generators: when the shock affects another generator, generators lose out because DSR competes with their own additional supply to fill the gap, but the affected generator is better off with DSR. We can compute the net effect on generators as:

$$\frac{f}{3}[\bar{P} - P^*]\Delta S - \frac{2f}{3}\frac{SS(DSR)}{2} = \frac{f}{3}[\Delta S(\bar{P} - P^*) - SS(DSR)]$$

Where *SS(DSR)* is the total additional supplier surplus from providing an additional number of units equal to the DSR. The first term in brackets is equal to the green rectangle in Figure 3.a., while the second term is equal to the red triangle in Figure 3.b. Clearly then, the first effect dominates and *generators are also better off with the DSR system* – at least if they are not charged for the DSR payment and DSR is activated predominantly in response to supply shocks.

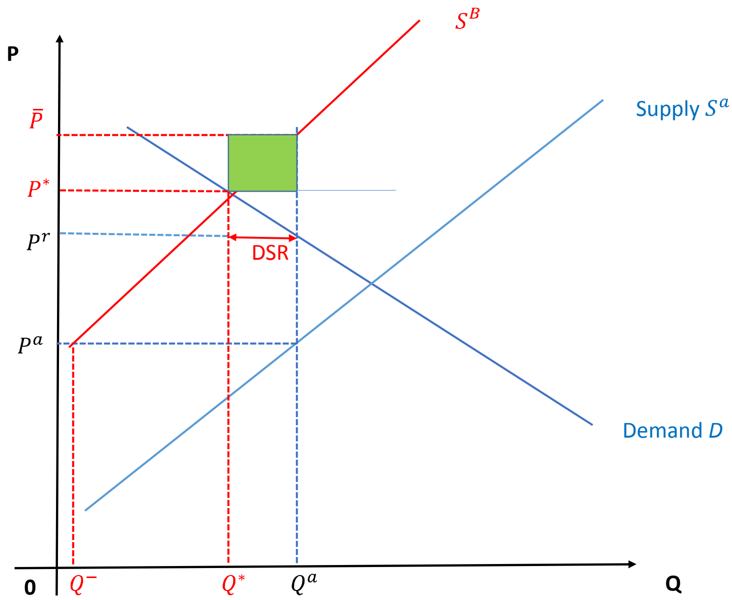


Figure 3.a.

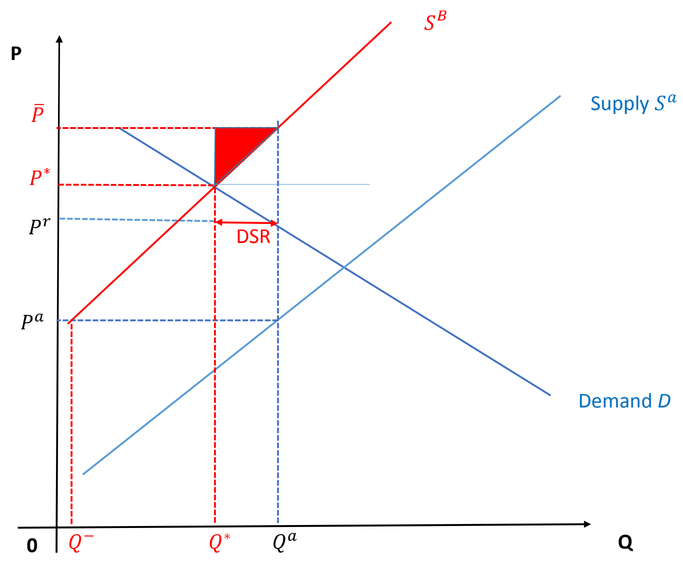


Figure 3.b.

Of course since suppliers and generators are better off, vertical couplings of suppliers and generators also benefit from the DSR system.[179] However, as the TSO's accounts face an imbalance equal to the efficient DSR payments, we must now turn to the issue of who should be funding this payment.

The conclusion would be different if DSR were to be activated often because of demand shocks, since in such cases there may be no generator that comes up "short" in the BM and that would benefit from lower equilibrium prices (the first term in brackets in the previous expression) and generators only experience the loss of business to DSR (the second term in brackets in the previous expression).

A.3. Efficient Payment Schemes

To be efficient, the scheme designed to finance the DSR payments – and hence to ensure that the TSO is again in balance – should satisfy the following three properties:

Property One: The party deciding whether or not to supply the DSR (consumers in our framework so far) must receive a payment equal to $(P^* - P^r)$ per unit of consumption withdrawn from the market in order to ensure that the efficient amount of DSR is offered (as long as offering DSR implies saving the retail price on the corresponding volumes).

Property Two: The active generators must receive P^* for their output to ensure that the efficient amount of power is supplied.

Property Three: The payment scheme should not have any perverse effect on retail prices, ex ante market quantities or incentives to invest in new technologies.

[179] Note that the fact that suppliers are better off with a DSR system than without one does not mean that they necessarily have the incentive to allow the *socially optimal* level of DSR to be supplied. Whether suppliers might have an incentive to under-provide DSR is discussed later in the appendix. Also, in reality generators are not fully symmetric and may differ in the probability of experiencing a shock and/or in the probability of being the supplier displaced by DSR when a shock to another generator occurs.

For realism, we might also add:

Property Four: no party should be made worse off by the introduction of the DSR system.

Notice that this last property is ‘generous’ to generators. After all, since DSR represents a ‘new technology’ that competes with generation, it would be natural to expect that its introduction would lead to lower pay-offs for generators as a whole. However, we are fully aware that any proposal is more likely to be successful if there are no clear losers.

This third property is of course the most challenging one to satisfy. Taking it into account also requires further developments of our analytical framework, which we undertake in Section 5 below. For now, then, let us focus on the first two criteria. They can be satisfied by a number of financing schemes.

Scheme 1: Impose a fee of $[P^* - P^r]$ *on each supplier for each unit of DSR offered by one of its customers.*

Such a ‘tax’ makes the TSO exactly balanced and leaves the suppliers indifferent between a world with DSR and a world without it. This last aspect is important: since the supplier’s net pay-offs are not affected by the introduction of DSR, its pricing and investment incentives should also remain unchanged.

Scheme 2: Make the short-side generator pay.

There is some logic to this approach as the generator experiencing the shock is ‘responsible’ for the presence of DSR in the market: agents causing systemic problems should in principle be charged for the damage done. However, this view is simplistic. There already are systems in place to ensure that generators have incentives to supply their committed amount to the market. Adding an additional shortage-related payment to the actual system might therefore distort the existing system of incentives. However, as the short-side generator does benefit from the introduction of DSRs, taxing away this windfall would appear to be innocuous. If anything, not taxing it away would then decrease the generators’ incentives to ‘hit their targets’ compared to a regime without DSR. From Figures 3a. and 3.b. we see that the required payment to consumers (equal to twice the orange rectangle area) is smaller than the benefits to the short generator (the green rectangle). However, this is not a general result, as the relative size of these areas could be reversed if the supply function was very flat. So, while this method of financing is also potentially attractive, it might not be sufficient.

Scheme 3: Make (All) Generators Pay

Charging generators meeting their planned load in order to finance the DSR payment makes little sense, for two main reasons. The first one is that these generators already suffer from the presence of DSR. While this ‘loss’ might not be problematic as it simply comes from increased competition from a more efficient technology[180], taxing these generators with a further payment would violate Property 4 above. The second reason is that dividing the total payment between generators cannot be done by tying the payment to the output of generators: doing so would affect the generators’ incentives to offer the efficient amount of output to the BM (property 2). How to divide the total payment across generator in a manner that seems ‘fair’ without tying the payment to the ‘size’ of the generator is not entirely obvious.

180 We mean ‘more efficient’ over the range of output for which DSR is supplied.

Scheme 4: Consumer buy out

This is essentially a variant of Scheme 1. The consumer pays the retail price to the supplier for the whole ex ante commitment. The consumer then assumes ownership of the amount of power that it does not use and can therefore sell an amount equal to the DSR at a price P^* in the BM. This provides the consumer with an additional payment $P^* - P^r$ for each unit not consumed, which is exactly what is needed to satisfy Property 1. In this scheme, suppliers' pay-offs are also unaffected by DSR, ensuring that there are no additional perverse effects on that side. Implementing this scheme is not necessarily straightforward as it involves knowing what the consumer's 'normal' consumption would have been. Such difficulties and the potential for manipulation that they may introduce are discussed in Section 6.

A.4 Centralised Approach: Main Issues

We have just seen that a centralised approach, where the TSO offers a payment equal to the difference between the BSM clearing price and the retail price for each unit of DSR provided would ensure that the optimal amount of DSR is offered. While the scheme leaves the TSO 'out of pocket' for the full amount of the TSO payment, several attractive financing options exist. In particular levying an equivalent tax on the supplier whose consumers offer DSR would leave this supplier no worse off than in the absence of DSR.

However such a scheme can only be implemented rigorously if two conditions are satisfied: the TSO must observe the relevant retail price and it must also be able to verify the amount of DSR actually offered.

A.4. Observing the Relevant Prices

In all of the schemes considered so far, the TSO had to make the efficient DSR payment equal to $P^* - P^r$. This raises the question of how the TSO can reliably learn about the level of retail price(s).

Do consumers and/or suppliers have incentives to reveal the true retail price(s)?

Banking on the goodwill of the parties would seem risky. To see this, assume that the supplier and/or consumer report a lower price $P_o^r < P^r$. This leads the consumer to supply more DSR than it otherwise would have, since it gets a larger payment. This involves a net gain for the consumer as the size of the additional payment must exceed the additional consumer surplus cost due to lower consumption. What about the supplier?

The supplier gets $P^r(Q_I^a - DSR)$ from Consumer A, pays $P^*(Q_I^a - DSR)$ to the TSO and gets $(P^* - P^a)Q_I^a$ from the CFD with Generator A, so $\pi_I = \pi_I^a + (P^* - P^r)DR(P_o^R)$, where Q_I^a is the supplier's ex-ante volume and we have noted in the last expression that the amount of demand reduction from Consumer A depends on (more precisely, it is decreasing in) the reported retail price. However, if we follow our suggested financing rule – where the payment made to the consumers is billed to the supplier, then the net pay-off to the supplier is:

$$\pi_I = \pi_I^a + (P^* - P^r)DSR(P_o^r) - (P^* - P_o^r)DSR(P_o^r) = \pi_I^a - DSR(P_o^r)(P^r - P_o^r)$$

This pay-off is higher if the supplier actually reports the correct price instead of a smaller value since the negative term then disappears. So the supplier has no incentive to underreport the retail price. This leaves us with two questions. First, would the supplier have an incentive to *over*-report the retail price? Second, if we assume that consumers and suppliers can find ways of making side-payments between them, are consumers and suppliers *jointly* better off by underreporting the retail price?

Here and in the following (unless otherwise noted) we assume that the parties take the equilibrium price P^* as fixed, i.e., that they do not have market power in the BM.

Let us look at the first issue and suppose that the supplier decided to report $P_1^r > P^r$. Then its pay-off would be equal to:

$$\pi^S(P_1^r) = \pi_I^a + (P^* - P^r)DSR(P_1^r) - (P^* - P_1^r)DSR(P_1^r) = \pi_I^a + DSR(P_1^r)(P_1^r - P^r)$$

Let us start with the supplier being truthful and then ask how his pay-off changes if he starts increasing the reported price. We have:

$$\frac{d\pi^S}{dP_1^r} = DSR(P_1^r) + (P_1^r - P^r)\frac{\partial DSR}{\partial P_1^r}$$

Evaluated at $P_1^r = P^r$, this derivative is positive so *the supplier has an incentive to over-report the retail price.*

The fact that the consumer has an incentive to under-report the retail price and the supplier has an incentive to over-report it is not necessarily bad news. Maybe their best *joint* decision would still be to report the true retail price. To check this, we need to look at the joint pay-offs of the supplier and the consumer. We take P_o^r to be the reported retail price without any presumption as to whether it is higher or lower than the true retail price. Define $q \equiv D(P^r) - DSR(P_o^r)$, which represents the actual level of consumption of the consumer after deducting DSR and let $u(q)$ be the consumer's "utility" from consuming q, gross of payments. The consumer's total pay-off is thus equal to:

$$\pi^C = u(q) - P^r q + (P^* - P_0^r)(D(P^r) - q)$$

The consumer will chose the (final) quantity that maximizes its pay-off and the corresponding FOC is:

$$0 = u'(q) - P^r - P^* + P_0^r$$

Hence, using the fact the demand function is the inverse of the marginal utility function:

$$q = (u')^{-1}(P^r + P^* - P_0^r) = D(P^r + P^* - P_0^r)$$

So:

$$DR(P_0^r) = D(P^r) - D(P^r + P^* - P_0^r)$$

The consumer's pay-off is thus:

$$\begin{aligned}\pi^C(P_0^r) &= u\big(D(P^r + P^* - P_0^r)\big) - P^r D(P^r + P^* - P_0^r) \\ &\quad + (P^* - P_0^r)\big(D(P^r) - D(P^r + P^* - P_0^r)\big) \\ &= u\big(D(P^r + P^* - P_0^r)\big) - (P^r + P^* - P_0^r)D(P^r + P^* - P_0^r) \\ &\quad + (P^* - P_0^r)D(P^r)\end{aligned}$$

The supplier's profits are, as established before:

$$\pi^S(P_0^r) = \pi_I^a - (P^r - P_0^r)DR(P_0^r) = \pi_I^a - (P^r - P_0^r)(D(P^r) - D(P^r + P^* - P_0^r))$$

So the joint profits are:

$$\begin{aligned}\pi^C + \pi^S = \ & u\big(D(P^r + P^* - P_0^r)\big) - (P^r + P^* - P_0^r)D(P^r + P^* - P_0^r) \\ &+ (P^* - P_0^r)D(P^r) + \pi_I^a - (P^r - P_0^r)(D(P^r) \\ &- D(P^r + P^* - P_0^r))\end{aligned}$$

Simplifying and getting rid of the terms that do not depend on the reported price we get:

$$\pi^C + \pi^S = u\big(D(P^r + P^* - P_0^r)\big) - P^* D(P^r + P^* - P_0^r)$$

Maximizing this with respect to the reported price we get the following FOC:

$$0 = -u'\big(D(P^r + P^* - P_0^r)\big)D'(P^r + P^* - P_0^r) + P^* D'(P^r + P^* - P_0^r)$$

Divide by D' to get:

$$u'\big(D(P^r + P^* - P_0^r)\big) = P^*$$

Hence:

$$\left(u'\right)^{-1}\left(u'\big(D(P^r + P^* - P_0^r)\big)\right) = \left(u'\right)^{-1}(P^*)$$

$$D(P^r + P^* - P_0^r) = (u')^{-1}(P^*) = D(P^*)$$

$$D^{-1}(D(P^r + P^* - P_0^r)) = D^{-1}(D(P^*))$$

$$P^r + P^* - P_0^r = P^*$$

and, finally:

$$P_0^r = P^r$$

So we can conclude that **the supplier and the consumer do not have any joint incentive to mis-report the retail price**. In principle, then, one could simply rely on the information provided by the consumer/supplier pair in order to compute the relevant DSR payment $P^* - P^r$. **However, in practice, this would require the communication of a large number of prices**. Moreover, even though our analysis indicates that there would be no incentive to distort the reported prices, the suspicion that some form of "gaming" still takes place might be difficult to fully dispel in practice, making decentralised systems relatively more attractive.

Confidentiality

Even if one *could* devise a scheme that would induce the revelation of actual retail prices, it is not entirely clear that this would be desirable, for reasons of confidentiality. Once retail prices are communicated to some central organisation, suppliers may learn about the terms offered by their rivals to different types of clients. This might lead to less competitive behaviour.

Using the day ahead market as a proxy?

In our discussions with large customers, we were given to understand that, while these customers declare a base load to their suppliers and pay the agreed retail price for baseload consumption, 'peak demand' may be settled at the clearing price in the day ahead market.

Under such circumstances, the actual consumption level of the customer is determined by the day ahead market price P^a, not the retail price P^r. In our previous analysis, P^r mattered precisely because it determined the level of consumption of the consumer absent DSR. If the ahead-market price P^a now plays this role, then the socially efficient level of payment becomes $P^* - P^a$ instead of $P^* - P^a$. Since P^a is known to the TSO, the issue of learning the true level of retail prices becomes irrelevant.

Unfortunately, this 'solution' only works when the consumer's demand is high (compared to his 'normal' load), which might just be the type of situation where we would expect the consumer to be reluctant to offer DSR to the BM. When the customer consumes less than its normal load, the price that applies to his marginal consumption units is still the retail price.

This does not necessarily imply that the price set in the day ahead market cannot be a useful point of reference. Indeed, if competition between supplier was intense enough to ensure that supply margins are small, than P^a might be a good *proxy* for the retail price. Since, on average, P^a should be somewhat smaller than P^r, this proxy approach would over-compensate consumers and lead to an excess supply of DSR compared to the social optimum. However, one could agree to 'tag on' an additional amount corresponding to an average retail margin to P^a, to get closer to P^r, and hence minimise this distortion. Actually this type of adjustment would be necessary anyway to take into account the various levies that, in practice, drive a wedge between P^a and P^r.

Still, **overall, relying on the TSO to make efficient payments to DSR supplier does raise some difficulties**. It is therefore useful to ask whether the suppliers of DSR might be appropriately compensated without the direct intervention of the TSO.

A.4. Verifying the Amount of DSR Actually Offered

Since the socially efficient payment from the TSO is equal to the difference between the BM price and the retail price times the volume of DSR offered, there is a clear incentive for the parties receiving the payment to overstate the difference between what they ended up consuming and what their 'normal' consumption would have been. This issue is somewhat obscured in our modelling where, for simplicity, we assume that there is a single consumer per supplier and that suppliers aim at getting into the BM balanced. In this case, the DSR can readily be computed as the difference between actual consumption and the quantities that the supplier chose to book in the ahead market. However, with more than one consumer per supplier – or if we were to also allow suppliers to manipulate their ex ante market commitments, one can no longer compute the amount of DSR in such a simple manner.

The feedback that we have obtained from our interviews – and which was strongly supported in the workshop of February 23rd with stakeholders organised by CRA – is that, while the true volume of DSR might not be determined exactly, today's metering technology made it possible to estimate a consumer's normal load level with enough precision that systematic misrepresentation of DSR volumes should not be possible. Accordingly, **for the purposes of this appendix, we assume that DSR can be measured**. However we are aware that baselining DSR has been a significant issue in other jurisdictions.

Still, for completeness, we also analyse (in section A.6.2) a system based on some form of 'take or pay' contracts and try to assess how large the deviation between declared and actual DSR volumes would be. We find that, given that shocks large enough to activate DSR are likely to be relatively rare, the difference between declared and actual volumes of DSR would tend to be small. This provides some additional comfort.

A.5 Fully Decentralised Schemes

By fully decentralised schemes, we mean schemes where the TSO has no direct involvement in the sense that it does not make any direct DSR payment and does not therefore need to finance them by taxing one of the parties in the system. This is therefore very different from the 'partially -decentralised' set ups that we have already reviewed where the TSO made payments to the supplier (or the aggregator) who agreed terms with the consumers.

Fully decentralised schemes have the advantage that they rely on information that is easily available to the parties making the relevant decisions. On the other hand, precisely because the parties operate without direct intervention by the TSO, it is crucial to check that the parties are likely to behave in a manner that is socially desirable. Such analysis can be tricky.

A.5. Negotiations between Supplier and Consumer

Assume that, in the absence of shock, the supplier pays a price P^a to contract a quantity Q^a in the ahead market which corresponds to the consumer's demand at the retail price, i.e. $Q^a = D(P^r)$. Now there is a supply shock. What kind of agreement might supplier and consumer reach? We analyse this issue by using the so called 'Nash Bargaining Solution' (NBS, which is one of the main tools that economist rely on to analyse bargaining between two parties).

In the absence of agreement, the consumer gets a pay-off equal to $CS(P^r) = u\big(D(P^r)\big) - P^r D(P^r)$ and the supplier gets $(P^r - P^a)Q^a$. These are the 'disagreement' pay-offs of the two parties.

We need to specify the form of the agreement. In the first sub-section below, we give the parties a lot of contractual flexibility as they can agree both on a level of DSR and on a lump sum transfer. In the next sub-section, we then restrict the payments to the consumers to be a share of the DSR proceeds.

Agreement on Volume and Fixed Fee

We now assume that the parties can reach a more efficient form of agreement, where they bargain both about the size of the DSR and the total compensation *F* due to the consumer. We have the following NBS:

$$Max_{F,DSR}[U(Q^a - DSR) + F - P^r(Q^a - DSR) - CS(P^r)][P^r(Q^a - DSR) - F - P^aQ^a + P^*DSR - (P^r - P^a)Q^a]$$

$$\leftrightarrow Max_{F,DSR}[U(Q^a - DSR) + F - P^r(Q^a - DSR) - CS(P^r)][P^*DSR - P^rDSR - F]$$

Rather than deal with the rather complex FOCs corresponding to the NBS maximization problem, we can rely on the fact that, with a fixed payment *F* as part of the contract, the parties choose DSR to maximise their joint surplus (F will then be chosen to split the gains). This joint surplus is equal to:

$$\begin{aligned} &U(Q^a - DSR) - P^r(Q^a - DSR) - CS(P^r) + (P^* - P^r)DSR \\ &\qquad = U(Q^a - DSR) - P^rQ^a - CS(P^r) + P^*\,DSR \end{aligned}$$

Maximising this expression with respect to DSR, we get:

$$-U'(Q^a - DSR) + P^* = 0$$

Following the same steps as in section 0, this ensures that the chosen level of DSR is socially efficient.

Share the DSR Revenues

We define the share of receipts that goes to the consumer as '*a*'. Again, In the absence of agreement, the consumer gets a pay-off equal to $CS(P^r) = u(Q^a) - P^rQ^a$ and the supplier gets $(P^r - P^a)Q^a$. These are the 'disagreement' pay-offs of the two parties. If the parties agree then the pay-off of the consumer is equal to:

$$u(Q^a - DSR) - (Q^q - DSR)P^r + aP^*DSR$$

And the pay-off of the supplier is given by:

$$P^{*}DSR(1-a)+P^{r}(Q^{a}-DSR)-P^{a}Q^{a}$$

Therefore we have the Nash Bargaining objective:

$$Max_{a,DSR}[u(Q^{a}-DSR)-(Q^{a}-DSR)P^{r}+aP^{*}DSR-CS(P^{r})][P^{*}DSR(1-a) + P^{r}(Q^{a}-DSR)-P^{a}Q^{a}-(P^{r}-P^{a})Q^{a}]$$

$$\leftrightarrow Max_{a,DSR}[u(Q^{a}-DSR)-(Q^{a}-DSR)P^{r}+aP^{*}DSR-CS(P^{r})][P^{*}DSR(1-a)-P^{r}DSR]$$

If the parties can negotiate on both a and DSR, then the problem is exactly identical to the case of a fixed fee payment to the consumer discussed in the previous section. To see this, note that the NBS maximization problem becomes equal to the one in the previous section when we use the (invertible) change of variable $F\equiv aP^{*}DSR \leftrightarrow a=F/(P^{*}DSR)$.

In sum, if the parties can bargain efficiently over the level of DSR and the terms of compensation for the consumer (either as fixed fees or as a fraction of DSR revenues), then they will choose the socially optimal level of DSR.

A.5. Vertically-Integrated Supplier

In order to focus on the effect of vertical integration, we assume that fixed fees are again available so that, in the absence of integration, the socially optimal level of DSR would be chosen. The joint surplus of the parties is now given by:

$$(Non\ Integrated\ Surplus)-\frac{f}{n}P^{*}\Delta S+\frac{2f}{n}\left(\frac{P^{a}Q^{a}}{n}+P^{*}\frac{\Delta S-DSR}{n-1}-(C(\frac{Q^{a}}{n}+\frac{\Delta S-DSR}{n-1}\right) - C(\frac{Q^{a}}{n})))$$

where n (equal to 3 in our symmetric example) is the total number of (otherwise identical) generators and C(.) is the cost function of the generator. Accordingly, the surplus of the generator is equal to minus the payment it has to make for coming short if it is the unit at fault. If the generator is not at fault for the shortage, then its pay-off is equal to its payment for its share of the pre-committed load plus additional payments received for expanding its output (if DSR is insufficient to absorb the whole shock) minus the additional cost incurred.

Hence, assuming an interior solution, the surplus is maximised where:

$$\frac{\partial(Non\ Integrated\ Surplus)}{\partial DSR}-\frac{2f}{n}[\frac{P^{*}-C'\left(\frac{Q^{a}}{n}+\frac{\Delta S-DSR}{n-1}\right)}{n-1}]$$

Notice that, if the generator increases its output at all in response to the shock (i.e., if it produces more than Q^{a}/n) then the numerator of the term in square brackets must be equal to zero as the output will be determined where the BM price is equal to the marginal cost. It follows that:

A vertically integrated supplier without market power in the BM negotiating with his consumers about the level of DSR and the (lump sum) payment to the consumers would choose the socially optimal level of DSR.

It should be clear that this conclusion is tied to our assumption that suppliers and generators do not have significant market power in the BM. If generators had such power, the additional term in the condition above would not be equal to zero. Introducing such market power would not help clarify matters as it would be hard to distinguish which part of the optimal policy that we would obtain is aimed at making the DSR mechanism work well and which part comes from trying to address the undesirable consequences of market power through the design of the DSR system. Since our task is strictly limited to the first issue, we find the assumption of competitive behaviour to be a convenient simplification. However, we note that **vertically integrated generators with market power in the BM may have an incentive to suppress their customers' DSR (at least when they are not the source of the imbalance!) below the efficient level, but they would also need to have sufficient market power in the downstream market to act on that incentive without merely losing customers to more accommodating suppliers**.

A.5. Partially Decentralised system: Supplier-Customer settlement between Aggregator and Consumer

The institutional arrangement that we consider is described in the following figure.

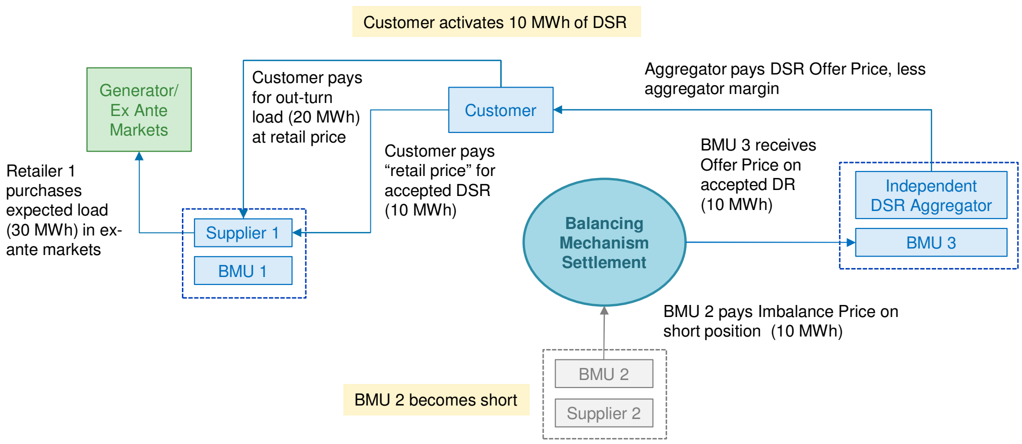


Figure 4

The main features of this system are:

- The consumer pays his supplier the retail price for his consumption and for the DSR. The DSR is defined as the difference between the customer's baseline demand and the actual consumption.
- The long position of the supplier is neutralised by the TSO and, effectively, 'transferred' to the customer/aggregator who get the settlement price on the DSR.

This arrangement has features of the 'take or pay' contracts that we discuss in the next section. There is one important difference however: in this set-up the consumer is not obliged to take ownership of the consumption amount equal to the DSR. Another difference is that, because we now *assume* that the actual amount of 'normal' consumption corresponds to the ahead market quantities and can be measured without ambiguity, we do not consider the type of incentives to over or under declare 'normal' loads/consumption which will keep us occupied in the section on take or pay contracts.

As for the supplier-mediated arrangements, we consider that the agreement between the aggregator and the consumer is reached through efficient bilateral negotiations and we find that **the socially efficient level of DSR will be chosen**.

Agreement on Volume and Fixed Fee

As we have done throughout most of our analysis, we take P^r and P^* as given

$$Max_{F,DSR}[u(Q^a - DSR) - P^r D(P^r) + F - CS(P^r)][P^* DSR - F]$$

As in our previous analysis, it is enough for the parties to find the DSR level that maximizes the joint surplus and then use the fee to share the spoils. The total surplus is equal to:

$$P^* DSR + u(Q^a - DSR) - P^r Q^a - CS(P^r)$$

Maximising this surplus with respect to DSR, we get:

$$P^* - U'(Q^a - DSR) = 0$$

This is the usual condition for efficient provision of DSR.

Share of the DSR Payment

We define the share of receipts that goes to the consumer as '*a*'. We have

$$Max_{a,DSR}[U(Q^a - DSR) - P^r D(P^r) + aP^* DSR - CS(P^r)][P^* DSR(1 - a)]$$

The same (invertible) change of variable $F \equiv aP^* DSR \leftrightarrow a = F/(P^* DSR)$ used in the previous section shows that this maximization problem is equivalent to the one with fixed fee above and thus **also leads to the choice of the socially efficient level of DSR**.

A.6 Other Potential Issues

In this section, we explore two additional dimensions of the DSR mechanism. We begin by sketching out how our analysis, which has been conducted in the context of a supply shock, could be adapted to the case of a demand shock. We then return to the question of how the actual volume of DSR provided might be measured. As discussed earlier, industry participants appear to feel that "normal" loads can be estimated fairly accurately so that the difference between these loads and actual consumption should closely approximate the true volume of DSR which is the difference between what consumption would have been at retail prices and actual consumption. Still, for completeness we attempt to assess how significant manipulation of reported DSR might be if it could not be measured sufficiently accurately.

A.6. Positive Demand Shock

The analysis is very much the same if there is a positive demand shock, i.e., an unexpected increase in demand (say, because of unexpected weather) as if there is a negative supply shock.

In this case (see Figure 5.1) the demand curve shifts to the right (red curve). If the shift is small enough, i.e., if the new demand curve intersects the supply curve to the left of where it intersects the horizontal $p = p^r$ line, then there is no scope for demand reduction (Orange demand curve). The TSO can efficiently call on the marginal suppliers to satisfy the unexpected demand. If the shifts is large enough (red demand curve), then we are back to a situation which is similar to that of a negative supply shock. We provide the payoff details for completeness.

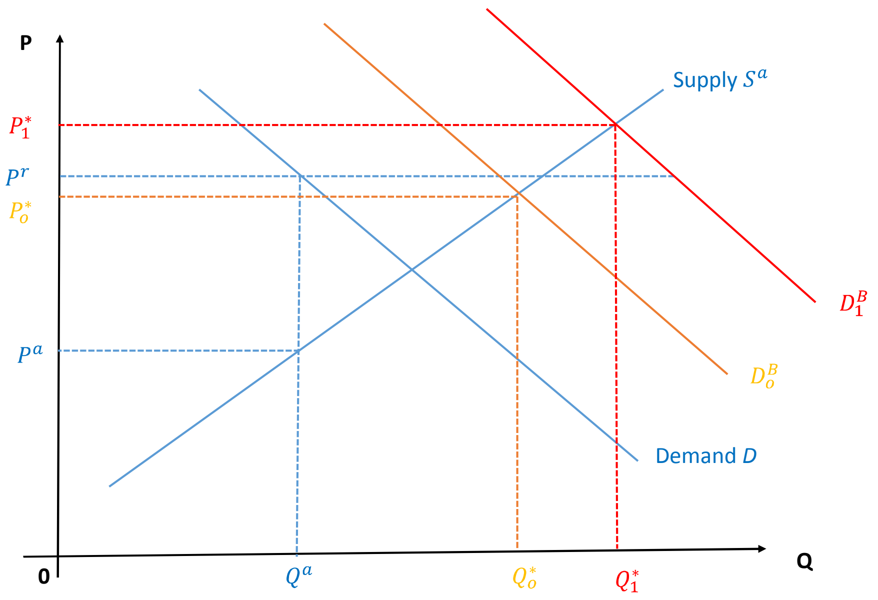


Figure 5.1

All notation refers to Figure 5.2. **Let $\Delta > 0$ be the demand shock.** As before, let's continue to assume that the shock is due to a single event, this time an increase in demand by Consumer A, supplied by Supplier A who had contracted with Generator A whose production decisions are not affected by the shock (i.e., Supplier A was an inframarginal supplier). There is now a marginal Consumer B with demand $q_Z \geq DR$ at price p^r, supplied by Supplier B who sold nothing else and had procured that quantity in the ahead market from infra-marginal Generator B. Finally there is a Generator C with capacity SR that is represented in the supply curve just between its intersections with the old and new demand curves.

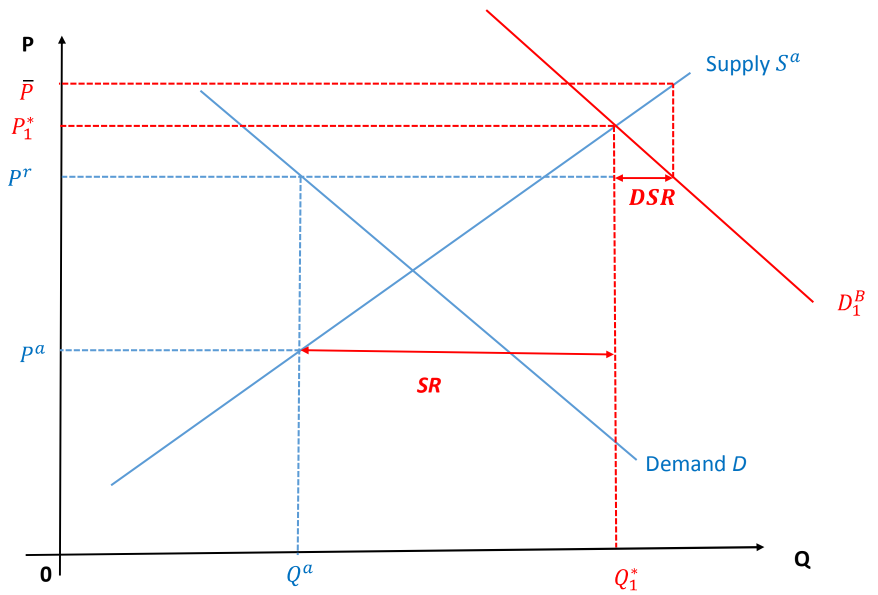


Figure 5.2

Now let's consider the payoffs of all players involved.

Supplier A:

- 'yesterday' it was expecting profits $\pi_K^a = (P^r - P)Q$
- 'now' it gets $P^r(Q_A - DR)$ from Consumer A, pays $P^*(Q_A - DR)$ to the TSO and gets $(P^* - P^a)q_A$ from the CFD with Generator A, so $\pi_A = \pi_A^a + (P^* - P^r)DR^*$
- Note that, under our assumptions, $\pi_A > \pi_A^a$
- *So Supplier A is not harmed by the demand response: it benefits from it.*

Generator A:

- *nothing changes for Generator A*: it gets more from the TSO ($P^* \; Q_A$ instead of the expected $P^a Q_A$), but pays that gain on the CFD with I
- *the same is true for all other generators not explicitly mentioned here*

Consumer A:

- It pays $p^r(q_A - DR)$ to supplier A and gets $(P^* - P^r)DR$ from the TSO (directly or via an IDA) and *so Consumer A gains* surplus equal to the small triangle with area $(P^* - P^r)(Q^a - Q^*)/2$ or $(P^* - P^r)DR/2$

Supplier B, Consumer B, and Generator B:

- Supplier B now get $p^r(Q_B + \Delta)$ from Customer B (assuming that B does not pay any penalty for its extra demand; that is an issue between supplier and consumer that needs not concern us here), $(p^* - p^a)q_B$ from the CFD with Generator B, and pays $P^*(Q_B + \Delta)$ to the TSO for the electricity (plus any penalty discussed later), for a total of $P^r(Q_B + \Delta) + (P^* - P^a)Q_B - P^*(Q_B + \Delta) = (P^r - P^a)Q_B - (P^* - P^r)\Delta$
- This is a loss of $-(P^* - P^r)\Delta$ compared to supplier B's expectation, but it would have lost even more (i.e., $\left(\overline{\overline{P}} - P^r\right)\Delta$, where $\overline{\overline{P}} > P^*$ is the real-time equilibrium price in the absence of demand response), so *Supplier B also benefits from the presence of demand response*. Note this windfall could be used to cover the TSO's deficit (below) to leave Supplier B indifferent
- Consumer B pays $P^r(Q_W + \Delta)$ to supplier B (and possibly supplier B will pass on some penalties, but this is not relevant for the analysis). *Consumer B is therefore better off*
- Generator B now gets P^*Q_B from the TSO, but pays $(P^* - P^a)q_B$ on its CFD with supplier B, so it still gets $p^a q_B$. So *Generator B is indifferent to the DSR*

- Generator C:
  - C gets P^*SR from the TSO for being called on to supply. The net gain is the producer surplus corresponding to that output.

- TSO:
  - The TSO is **NOT** budget-balanced: it pays P^*Q^* to generators and gets the same from suppliers, but is short of the payment for demand reduction $(P^* - P^r)DR$
  - To summarise, the TSO:
    - Gets $P^*(Q_A - DR)$ from A to deliver $(q_A - DR)$
    - Pays p^*q_Z from G to receive q_Z
    - Pays $(p^* - p^r)DR$ to Z for Z reducing demand by DR
    - Gets $p^*(q_W + \Delta)$ from J to deliver $(q_W + \Delta)$
    - Pays p^*q_W to F to receive q_W
    - Pays p^*SR to H to receive SR
    - Budget balance: $p^*(q_Z - DR) - p^*q_Z - (p^* - p^r)DR + p^*(q_W + \Delta) - p^*q_W - p^*SR = p^*(q_Z - DR - q_Z - DR + q_W + \Delta - \mathrm{q_W} - SR) + p^rDR = -(p^* - p^r)DR^* < 0$
    - Quantity balance: $-(q_Z - DR) + q_Z - (q_W + \Delta) + q_W + SR = 0$

So the TSO is out-of-pocket for the payment to Consumer B (or to its IDA) of $(p^* - p^r)DR$.

As before, this could be charged as a penalty to Supplier C or taken from Supplier B's windfall gains.

In sum, the welfare implications of DSR are analogous to those for the case of supply shocks: assuming that the payments to the DSR-providing consumers are recovered from the suppliers of those consumers, there is a welfare gain for the consumers providing DSR and for the suppliers/consumers who caused the imbalance, while all other parties are left indifferent with the obvious exception of the generators who are outcompeted by DSR.

A.7 Summary

We have looked at both centralised and decentralised schemes. In a centralised scheme the TSO would make a payment per unit of DSR equal to the difference between the BM price and the retail price. This would ensure that the optimal amount of DSR is supplied but would leave the TSO needing to find a source to finance this payment. A natural approach would be to tax the suppliers of consumers offering DSR since they get a windfall which is equal to the payment due to their consumers. Having the suppliers finance the TSO payment would therefore leave them exactly as well off as without DSR, so that the introduction of DSR would not affect the supplier's incentives when it comes to setting retail prices and making investment decisions. If there is a preference for a centralised system, then it might also be possible to rely on wholesale prices rather than retail prices in order to calculate the TSO payments. While this would not lead to the precise social optimum, this system would still perform well as long as the wholesale price is close enough to the retail price experienced by consumers in states of the world where DSR is needed.

The centralised approach's main drawback is the need for the TSO to know all relevant retail prices. Although supplier/consumer pairs do not have an incentive to mis-report these prices, the number of prices that need to be communicated would be very large.

By contrast, decentralised schemes do not require the TSO to know retail prices as DSR is remunerated at the BM price. We have shown that, as long as contracts between suppliers and consumers are sufficiently flexible, the efficient level of DSR would once again be chosen. This is true both in a regime where the supplier enables the DSR supply of his consumers and in a regime where consumers are serviced by an aggregator. Interestingly, the conclusion holds even if the supplier is vertically integrated into generation.

These results were derived in a simple framework where all agents behave competitively in the BM market. The possible existence of some market power is an additional reason for allowing both suppliers and aggregators to directly offer DSR services to consumers.

APPENDIX B: DSR ECONOMIC POTENTIAL AND RANGE OF ECONOMIC BENEFITS

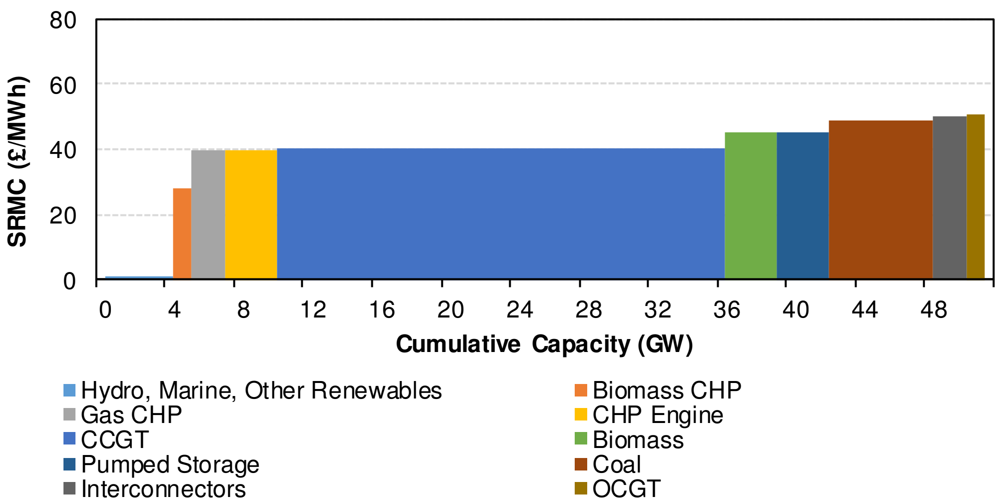
B.1 Economic potential of DSR in the GB market

Our analysis of the economic potential of DSR in the GB market comprises four steps.

1. Establish the merit order of generation (excluding DSR)

We start by assessing the economic dispatch of the assumed generation capacity in 2020 and 2030, excluding DSR. Our assumed generation capacity and SRMC are based on FES 16. This is illustrated in Figure B.1.

Figure B.1: Generation merit order 2020 (FES 16 Slow Progression Scenario)



Note: commodity cost assumptions based on FES 16 mid-case scenario

Source: CRA analysis based on FES 2016

2. Estimate half-hourly energy market prices

We estimate half-hourly prices based on two separate components: the SRMC of the marginal unit to dispatch during each half hourly period (assuming no DSR participation), and an "uplift" calculated on the basis of an estimated Loss of Load Probability ("**LoLP**") and a regulated Value of Loss of Load.[181] Under this approach ("**LoLP" pricing**"), energy market gross margins for a new peaking plant are in the

181 See Section 9, Appendix 1, Elexon. Imbalance Pricing Guidance – A Guide to Electricity Imbalance Pricing in Great Britain, version 11.0. (https://www.elexon.co.uk/wp-content/uploads/2016/10/Imbalance_Pricing_guidance_v11.0.pdf)

order of £18/kW-year.[182] This approach is adopted because of the limited historic data on the relationship between observed capacity margins and out-turn prices (including a LoLP uplift).

However, as a variant, we have also calculated the uplift component based on an analysis of BM cash-out prices and capacity margins from January 1, 2016 through January 31, 2017.[183] We use this analysis to estimate the price uplift as a function of half-hourly capacity margins in each scenario ("**Historical BM Pricing**").

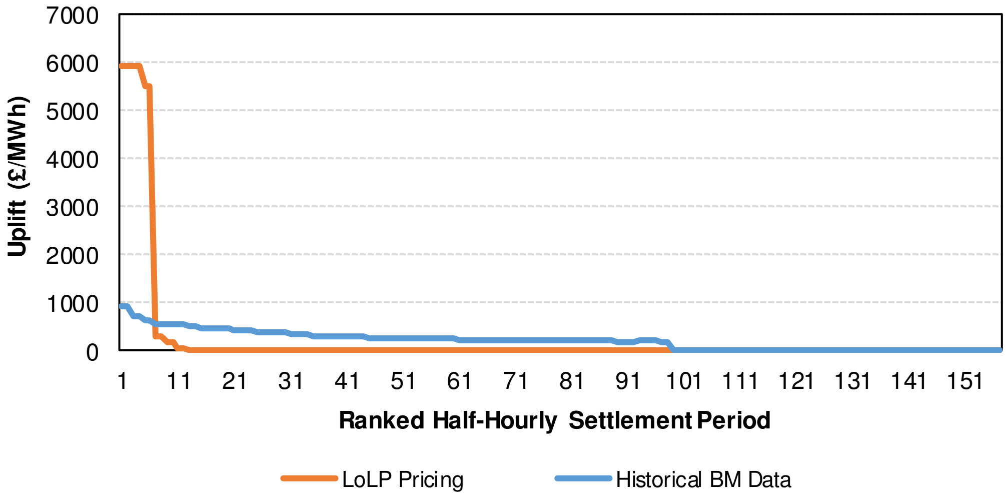
Both uplift assumptions are illustrated in Figure B.2. The difference between the two curves reflect differences in two key assumptions: i) how high prices rise under scarcity conditions, and ii) at what capacity margin power prices start including a scarcity uplift.[184]

182 This is equal to a planning reliability standard of 3 hours Loss of Load Expectation ("**LoLE**") and a maximum allowed Value of Loss Load ("**VoLL**") of £6,000/MWh. In other words, a one MW peaking plant participating in the energy market could expect to receive £18,000 per year towards the recovery of its investment costs if the supply/demand balance in the market resulted in the planning standard of three hours LoLE. This is equivalent to £18/kW-year and is consistent with the assumptions of energy margins made by DECC in defining the Net Cost of New Entry ("**CONE**") at the inception of the Capacity Market. See https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/223653/emr_consultation_annex_c.pdf.

183 This analysis suggests that, had a peaking plant been able to capture revenues from all periods of scarcity pricing in 2016, it would have received £32/kW-yr in contribution towards the recovery of its investment costs. In other words, a one MW peaking plant participating in the Balancing Mechanism during all hours in 2016 would have received £32,000 (or £32/kW-year). Our analysis is based on cash-out prices. A more accurate analysis would require review of individual bid-offer acceptances and adjustments to remove NIV tagging.

184 In the case of the LoLP Pricing curve, we have assumed that prices reach the allowed VOLL of £6,000/MWh when the LoLE is 1. The rest of the curve is shaped to provide peaking plant with £18,000 towards the recovery of its investment costs based on the LoLE for the remaining hours. In the case of the Historical BM pricing curve, the shape of the curve reflects historical bidding behaviour in the BM, which indicates that prices may not rise as high as £6,000/MWh in any one hour, but the uplift may be spread over many more hours.

Figure B.2: 2020 energy market prices under different capacity scarcity pricing assumptions



Source: CRA analysis based on FES 2016 Slow Progression Scenario for 2020

3. Estimate the amount of dispatchable DSR by half-hourly period

The amount of dispatchable DSR in each half-hourly settlement period varies by type of DSR. While Standby DSR can be technically dispatched at any time and for as long as needed (assuming positive margins from doing so), Turn-down and Turn-up DSR can only be dispatched for limited periods and needs to be calculated based on the maximum shift duration and associated rebound.[185]

The sum of Standby DSR and the load shifting potential constrained by our estimate of Turn-down and Turn-up DSR capacity together with utilisation of battery-led DSR results in the "usable" DSR capacity by half-hourly settlement period.

4. Estimate the economic utilisation of DSR

Once we have established the half-hourly price curve and the "usable" DSR capacity by half-hourly period, we can assess when DSR would be economically activated if it had access to the energy market. This analysis simply assumes that Turn-down and Standby DSR would be dispatched when the half-hourly price exceeds the activation cost of DSR, staying within set constraints for technical DSR capacity, load shift duration and maximum number of activations by category of DSR. The assumption on load shift duration is important because individual categories of DSR are not activated when the rebound effect would result in system peak demand simply being shifted from one time period to another.[186] Further, we have constrained Turn-down DSR

185 We have assumed that all Turn-down DSR rebounds. We understand, however, that there may not be such rebound for some types of DSR (e.g. lighting) and that other loads may rebound over such a long period of time that their impact on baseline consumption profiles would be barely noticeable.

186 However, the cumulative effect of load rebound across different categories of DSR may still result in a shifting of peak demand (see APPENDIX B:).

activations to 25 instances for Commercial & Industrial A/C and Industrial Cooling;[187] and to 10 instances for all categories of Turn-down DSR covering industrial processes.[188]

For Turn-up DSR, we assume that demand is turned up when the half-hourly price is zero (or may in practice be bid down below zero), staying within a similar set of constraints as Turn-down DSR. These include load shift duration and maximum number of activations.

In general, the impact of deploying DSR is a "flatter" residual load profile, with lower generation requirements at the peak and less renewable curtailment. To the extent that the activation of DSR results in a rebound effect (either an increase in demand from the baseline in the case of Turn-down DSR or a reduction from the baseline in the case of Turn-up DSR), these rebounds occur when the demand/supply balance in the system is better able to accommodate the change from the baseline.

Our analysis indicates that:

- The total economic potential of DSR ranges from 2.5-5.7 GW in terms of peak demand reduction, 0.0-2.7 GW in terms of maximum Turn-up activation and 0.0-0.4 TWh in terms of displaced generation. This is based on a counterfactual in which there is no DSR provision in the GB energy markets. These results do not take into account any additional incentives to activate DSR such as are currently provided through embedded benefits.
- The peak demand reduction achieved by DSR is less than the full technical potential indicated in Table 8. This is because the rebound effect of some DSR reduces its net impact on system peak (see APPENDIX B: for a more detailed explanation).
- There is generally more DSR capacity contributing to peak load reduction under the Historical BM Pricing approach since this results in a higher price curve in non-peak hours, enabling more DSR activation to mitigate the rebound effect from DSR activated at the peak. Similarly, the Historical BM Pricing scenario leads to more displaced generation by DSR due to the higher number of settlement periods with prices exceeding DSR activation costs.
- Our estimates of peak demand reduction in 2030 under Consumer Power in the LoLP pricing and Historical BM pricing scenario are similar (around 2.9 GW in both cases). This is because the higher expected capacity margin associated with the scenario suppresses the price curve, making further DSR activation non-viable. However, renewable intermittency not captured in this analysis may result in higher DSR utilisation in practice due to more volatile prices.

187 This is consistent with the number of Triad Avoidance days in the last five years, and below the 35 Triad Avoidance days in 2015-2016.

188 This is consistent with feedback from our stakeholder interviews, which indicate industrial's consumer's limited willingness to modify their load consumption patterns.

- There is more DSR capacity able to contribute to reducing peak load in the Slow Progression scenario than in the Consumer Power scenario in 2030 due to lower capacity margins under Slow Progression.[189]

The results of our analysis of the economic potential of DSR are summarised in Table B.1.

189 In practice, although the expected capacity margin might be higher in the Consumer Power scenario, renewable intermittency not captured in this analysis may result in higher DSR utilisation.

Table B.1: CRA Estimates of Economic DSR Potential across Scenarios (GW)

Pricing Scenario	Metric	2020				2030			
		Gone Green	No Progress.	Slow Progress.	Consumer Power	Gone Green	No Progress.	Slow Progress.	Consumer Power
LoLP Pricing	Peak Demand Reduction from Battery-led, Turn-down and Standby DSR (GW)	2.5	3.0	3.2	3.1	3.0	3.9	3.6	2.9
	Maximum Turn-up Activation (GW)	0.7	0.0	1.5	1.5	2.7	1.0	2.0	2.3
	Displaced Generation (MWh)	191,875	29,174	36,582	109,355	431,068	249,179	369,405	437,254
Historical BM Pricing	Peak Demand Reduction from Battery-led, Turn-down and Standby DSR (GW)	4.8	5.0	5.4	5.2	3.0	5.3	5.7	2.9
	Maximum Turn-up Activation (GW)	2.2	0.0	1.5	1.5	2.7	1.0	2.0	2.3
	Displaced Generation (MWh)	333,447	117,498	145,270	168,902	419,631	245,998	409,811	388,999

Source: CRA Analysis

B.2 Economic benefit of DSR in the GB Balancing Mechanism

The overall economic benefit of DSR in GB's BM is quantified as the difference in the costs of energy, generation capacity and network infrastructure across differing levels of assumed DSR.

Capacity Costs Savings

By reducing the need for new back-up capacity that would only be built to provide the system with a form of "insurance" during times of high residual load, DSR can reduce the need for new peaking capacity, resulting in capacity cost savings. In other words, the dispatch of DSR during peak periods reduces the need for OCGT capacity, which would otherwise be required to meet peak demand. In estimating capacity costs savings we assume that DSR reduces the need for new OCGTs, for which we have calculated an annualised capital and fixed O&M cost of £58/kW-year.[190] Based on BEIS's estimates, however, this can range between £47/kW-year and £90/kW-year.[191]

Energy Cost Savings

We quantify the impact of DSR on energy costs as the difference between meeting the residual load curve with and without DSR. In our calculations we assume that when DSR is activated it displaces what would otherwise have been generating in the settlement period to meet demand. In estimating energy cost savings we take into account fuel costs, VOM costs, CO_2 emissions costs and the cost of DSR activation.

Turn-up DSR and battery-led DSR can also reduce energy costs by shifting load to periods with over-supply. By shifting load to periods of excess low-cost generation, these DSR resources can reduce the overall cost of meeting system demand.

Network cost savings

The reduction of peak load can also lead to network-related savings. Re-enforcement costs at the transmission and distribution level are largely driven by peak demand expectations, so lower system peaks reduce the need for re-enforcement CAPEX. Similarly, both distribution and transmission losses are higher during peak load times, so increasing the system load factor can marginally reduce the cost of network losses.

Our estimates of network re-enforcement cost savings are based on the expected change in peak load resulting from the activation of DSR (under different scenarios) and the £/kW

190 This is based on capital costs and Fixed Operation and Maintenance ("**FOM**") assumptions for BEIS Electricity Generation Cost Report (November 2016), using a 7.8% real discount rate over 25 years. We note that our analysis is focused on the capacity cost savings resulting from a reduction in the need for new peak capacity. While DSR may result in slightly lower utilisation for mid-merit generation (like CCGTs), we have not quantified the impact of reduced mid-merit load factors on the optimal capacity mix in each scenario. In any event, our analysis suggest that this impact would be very small (less than the equivalent of 100 MW of CCGT capacity running at a 50%).

191 For purposes of this analysis we have assumed no capital cost and no FOM costs for DSR. While in practice we recognise that some investment costs may be necessary, we understand from our stakeholder interviews that these are typically negligible.

estimate of re-enforcement costs in the latest RIIO submissions.[192] Our estimates of network loss savings are based on the expected change in demand load factor (ratio of average demand to peak demand) in each scenario, historic network and distribution losses[193], and assumed peak-load losses from *Electric Power Distribution* by A S Pabla.

Our estimates of network cost savings do not consider the additional system costs for maintaining levels of inertia and reactive power that might be imposed when displacing rotating generation with DSR. Estimate of economic value of DSR

To estimate the economic value of different levels of growth in DSR we consider three scenarios:

1. **No DSR**: In this scenario we assume zero DSR capacity. This scenario sets an extreme point for comparison purposes.
2. **Existing DSR Capacity:** In this scenario we assume that total DSR capacity available for dispatch in the wholesale energy market is 0.9 GW,[194] or around half of the DSR capacity currently participating in STOR.[195] We also assume that DSR is already contributing some 1.4 GW to reducing peak capacity requirements, consistent with DSR's participation in the latest T-4 Capacity Market auction.
3. **Full Economic Potential of DSR:** In this scenario we assume that all barriers to aggregation are removed[196] and the full economic development of DSR is achieved. In this scenario total DSR capacity available for dispatch ranges from 2.9 GW to 5.3 GW.

These cases are then evaluated against the range of economic DSR capacity across the different FES scenarios and a range of capital costs for a new OCGT between £47/kW-year and £90/kW-year.

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192 We use the final RIIO-ED1 submissions for each distribution network operators and the ENSG report entitled Our *Electricity Transmission Network: A vision for 2020* for transmission networks. Based on these documents, our analysis assumes £35/kW cost of distribution network re-enforcement and £13/kW cost of transmission network re-enforcement. We assume that the peak in our estimated residual system demand is coincident with system peak demand.

193 Table 1, National Grid Electricity Plc S*pecial Condition 2K.4 – Transmission Losses Report Reporting Period 1 April 2014 to 31 March 2015 (http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=43615)*; Sohn Associates. *Electricity Distribution Systems Losses – Non-technical Overview*. 2009 (https://www.ofgem.gov.uk/sites/default/files/docs/2009/05/sohn-overview-of-losses-final-internet-version.pdf)

194 We note, however, that in practice DSR participation in the wholesale market could be much larger or smaller, depending on the relative value DSR providers attach to different markets and the ability to stack different revenue streams. To estimate the GWh equivalent of this capacity, we converted the 0.9 GW to a utilisation estimate by applying the average load factor of DSR resources for the relevant FES scenario from our modelling. The load factor of DSR across our scenarios ranges from 0.25% to 0.69%. This approach assumes that the current mix of DSR capacity is roughly consistent with the mix of capacity in our modelling scenarios.

195 In assuming that some of the DSR capacity currently participating in STOR would chose to participate instead in the energy market, we have not made any offsetting adjustment to our estimate of overall economic value from increments in DSR. In other words, we have not accounted for any value that would simply move from the Balancing Services market into the wholesale energy market.

196 As discussed in Section 2.4, barriers can be structural, regulatory or related to market organisation and conduct.

The results of our estimate of DSR economic value are shown in Table B.2.[197]

The “No DSR vs. Full Economic Potential” case is presented as an extreme benchmark to show the full economic value of DSR participation in wholesale energy markets from a baseline of zero. In practice, the economic value of introducing IDAs in the BM will be lower for three key reasons:

i) The starting point for DSR capacity is not zero - DSR capacity is already active in the Capacity Market and Balancing Services market, and, at least in theory, is also active in the wholesale energy through suppliers;

ii) IDAs may not be fully responsible for the development of DSR, with suppliers already starting to play an increasing role in its development; and

iii) Incremental DSR capacity may choose to participate in other electricity markets or to contract directly with network operators.

Although it would be impossible to assign any credible parameters to i) through iii) above, the “Existing DSR vs. Full Economic Potential” case closes the gap between two extreme cases by making assumptions on the degree of incremental DSR participation in both the energy and capacity markets. As noted in Section 4.4, however, the economic value of introducing IDAs in the BM may fall to zero depending on interactions between the different GB electricity markets and the role IDAs play in the further development of DSR.

Nonetheless, our analysis shows that:

- Overall, increased development of DSR can benefit consumers by reducing the need for new peaking capacity and network re-enforcement costs. DSR can also result in a small reduction in system losses.
- Energy cost savings may be negative where DSR activation costs are in excess of the SRMC of displaced generation. This may occur at peak times when there is a significant uplift for scarcity pricing included in market prices, making it economic to dispatch DSR. DSR at such times is assumed to displace the construction of lower marginal cost conventional generating plant, such as OCGTs, because there are no additional capital costs to be recovered by DSR. Conventional plant are dependent on the Capacity Market for the recovery of such costs, but would be displaced in this market by DSR recovering its activation costs in the BM.
- Capacity costs savings are higher in the Historical BM Pricing scenarios because, as noted above, there is greater DSR capacity contributing to peak demand reduction.

197 Our results are generally consistent with the findings presented for Pathway A in 2020 by Imperial College and NERA in the report “Understanding the Balancing Challenge”, August 2012. In this scenario, Imperial College and NERA estimate annual system savings in 2020 of £500 Million. Similarly, the Carbon Trust and Imperial College Report “An analysis of electricity system flexibility for Great Britain”, November 2016 presents cumulative savings to 2050 ranging from £15 billion to £40 billion. This is roughly equivalent to annual savings between £300 Million and £800 Million (at a 3.5% social discount rate over 35 years). While our numbers are within that range, we note that there are important differences. First, the Carbon Trust and Imperial College report account for the value of interconnectors in their estimates; we do not. Second, they model a significant uptick in DSR utilisation post 2030, which our analysis does not capture.

- Capacity cost savings are higher in the No Progression than in the Consumer Power scenario because of lower projected system capacity margins, which result in higher DSR utilisation.[198]
- Capacity cost savings are lower in the Gone Green scenario than in the Consumer Power scenario in 2020 because of lower projected peak demand, which result in lower peak residual demand and thus lower contribution of DSR capacity to peak demand reduction.

198 We note that in practice, the higher share of intermittent generation in the Consumer Power scenario may result in greater price volatility, which could result in higher DSR activation.

Table B.2: Estimate of economic value of DSR (£ Million)

Pricing Scenario	Case	Metric (£Million)	2020				2030			
			Gone Green	No Progress.	Slow Progress.	Consumer Power	Gone Green	No Progress.	Slow Progress.	Consumer Power
LoLP Pricing	No DSR vs Full Economic Potential	Energy Cost Savings*	-9	-7	-7	-8	7	-14	-12	-4
		Capacity Cost Savings	143	170	185	177	171	224	207	166
		Network Cost Savings	125	146	157	155	147	194	177	149
		Total Cost Savings	259	309	335	324	326	403	372	311
	Existing DSR vs Full Economic Potential	Energy Cost Savings	-8	-5	-5	-7	6	-13	-11	-3
		Capacity Cost Savings	62	90	104	97	91	143	127	85
		Network Cost Savings	54	77	88	84	78	124	108	77
		Total Cost Savings	109	162	187	174	175	254	223	158
Historical BM Pricing	No DSR vs Full Economic Potential	Energy Cost Savings	-39	-16	-22	-22	16	-12	-17	6
		Capacity Cost Savings	279	288	309	299	171	303	330	166
		Network Cost Savings	237	245	262	255	147	259	278	149
		Total Cost Savings	478	517	548	532	334	551	591	321
	Existing DSR vs Full Economic Potential	Energy Cost Savings	-34	-13	-19	-19	14	-10	-15	5
		Capacity Cost Savings	199	207	228	218	91	223	249	85
		Network Cost Savings	169	176	193	186	78	190	210	77
		Total Cost Savings	334	370	403	386	183	402	444	167

** Energy cost savings are shown as negative when the sum of fuel, emissions and VOM costs are lower than the activation costs of DSR. This can happen when DSR is dispatched as a function of prices which include an uplift, even when the SRMC of the underlying marginal plant is lower than the activation cost of DSR. Energy cost savings are positive in scenarios where a significant portion of the displaced generation is a result of Battery-led DSR, as is the case in the Gone Green scenario. Capacity cost savings are based on the Medium cost scenario in BEIS Electricity Generation Cost Report. Using the Low cost scenario would reduce capacity cost savings by 18% and using the High cost scenario would increase capacity cost savings by 56%.*

Source: CRA Analysis

B.3 Estimate of pricing impact

The results of the analysis show in Table B.2 assume that DSR activation does not result in lower prices.[199] In other words, we assume that DSR simply replaces the marginal resource at the same offer price.

However, in the absence of LoLP scarcity pricing,[200] DSR activation in the wholesale energy market may lead to a reduction in energy prices, where the DSR is marginal and as such is price-setting. This in turn would lead to a reduction in the gross energy margin (energy market prices less fuel and other variable costs) for conventional generating plant. As a consequence, such generating plant would require higher capacity market prices in order to recover their full investment cost.

This means that where conventional generating plants continue to be the marginal providers of capacity, then in principle reductions in energy market prices for consumers will be offset by increases in capacity market prices. In practice, we recognise that the prices in the wholesale energy market and the capacity market may not directly offset each other in this way.

We have not estimated an impact on consumer prices. Given that DSR (excluding Turn-up), is principally activated during peak hours in which there is scarcity pricing, then the impact on market prices may be quite small. However we recognise that competition from DSR may in practice lead to some reduction in the bid mark-ups by conventional generators during periods of capacity scarcity (that lead to 'scarcity prices', as reflected in our Historical BM pricing scenario). For example, it is possible that increased DSR could have competed the 2016 scarcity price premium in the BM of £32/kW-year[201] down towards the £18/kW-year level that is consistent with the Value of Loss of Load included in the LoLP pricing administered by Elexon. However, we would expect this energy price decrease to be offset, at least in part, by an increase in Capacity Market prices.

199 In other words, we assume that DSR would offer their capacity into the market at a price just under what would have been the offer from the marginal resources in the absence of DSR. Given that the activation cost of DSR may be higher than the SRMC of the marginal resource, would require a lower price uplift.

200 During periods of low capacity margins under the LoLP pricing framework, a Reserve Scarcity Price ("**RSP**") is calculated as the product the VoLL and the LoLP for each Settlement Period. The price in the Balancing Market is then adjusted to reflect the greater of the Utilisation Price for any STOR action called upon or the RSP. Therefore, under this framework, periods of system scarcity would be priced at the RSP, regardless of whether the marginal unit was DSR or traditional generation.

201 See Section B.1.

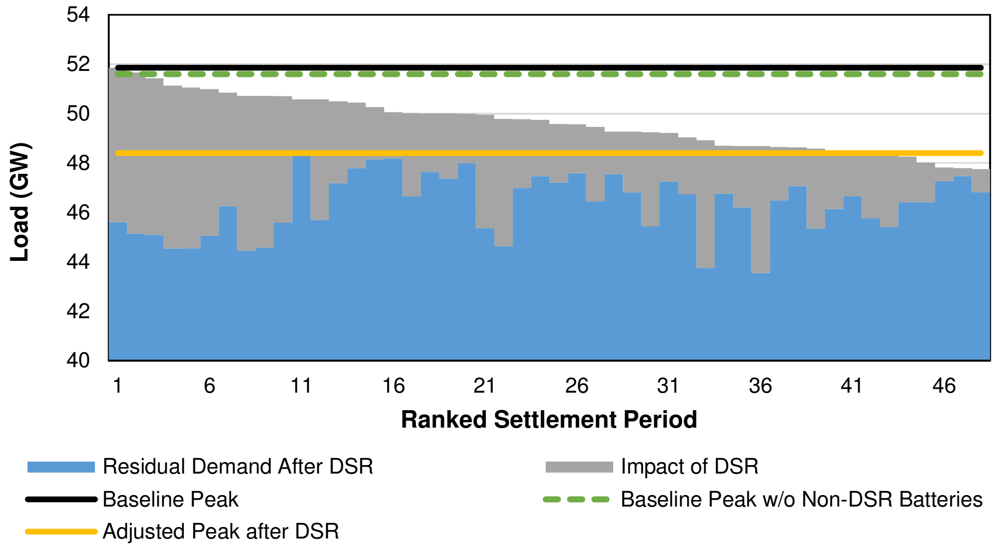
APPENDIX C: THE IMPACT OF REBOUND ON THE ECONOMIC BENEFIT OF DSR

This appendix provides additional detail on our estimates of peak demand reduction and displaced generation. We use the Slow Progression scenarios to illustrate the analysis.

C.1 Slow Progression – LoLP Pricing – 2020

Under the Slow Progression scenario with LoLP pricing in 2020, DSR activations could reduce peak capacity requirements by 3.2 GW. This is shown in Figure C.1 as the difference between the dashed green line (the peak residual load in the baseline after adjusting for the impact of non-DSR batteries) and the yellow line (the peak residual load after the effect of DSR activations). The area shaded grey represents total generation displaced in MWh due to DSR activations.

Figure C.1: Residual Load Duration Curve for the Top 48 Settlement Periods



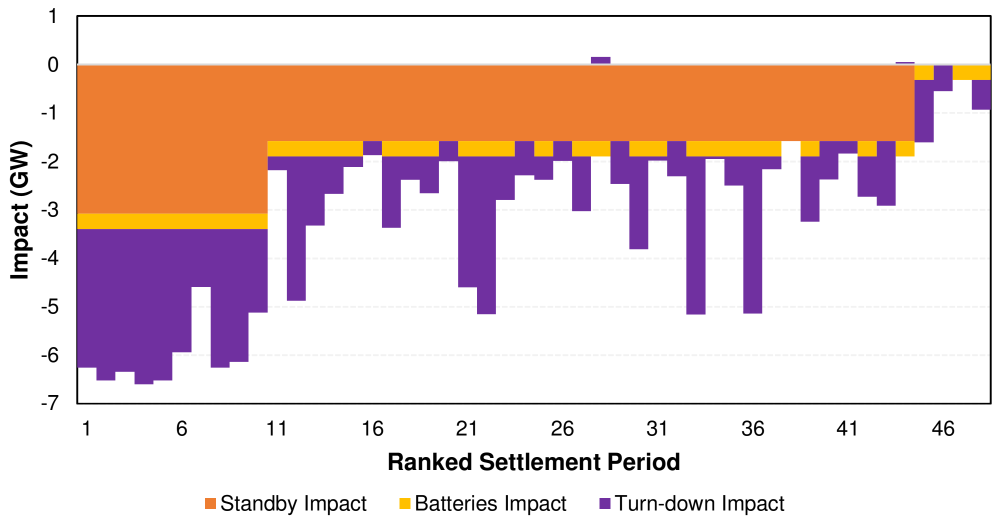
Source: CRA Analysis

The grey area in Figure C.1 shows that, at maximum, about 6.6 GW of DSR capacity is simultaneously activated. However, this only translates to a 3.2 GW reduction in peak capacity requirements for two reasons:

- First, turn-down DSR with a short load shift duration starts experiencing load rebound, which significantly diminishes their contribution to peak residual load reduction. This is illustrated in the purple area in Figure C.2, where the cumulative impact of turn-down DSR on residual load reduces from 2.9 GW in settlement period 1 to below 0.2 GW in settlement period 11.
- Second, the improving capacity margin reduces the half-hourly prices sufficiently below the activation cost of a group of standby DSR from settlement period 13 onwards. As a result standby DSR contribution reduces from 3.1 GW in settlement period 1 to below 1.6 GW in settlement period.

The combination of the two effects constrains DSR contribution to the reduction in peak capacity requirements below the maximum amount of simultaneous DSR activation.

Figure C.2: DSR Activations during the Top 48 Settlement Periods

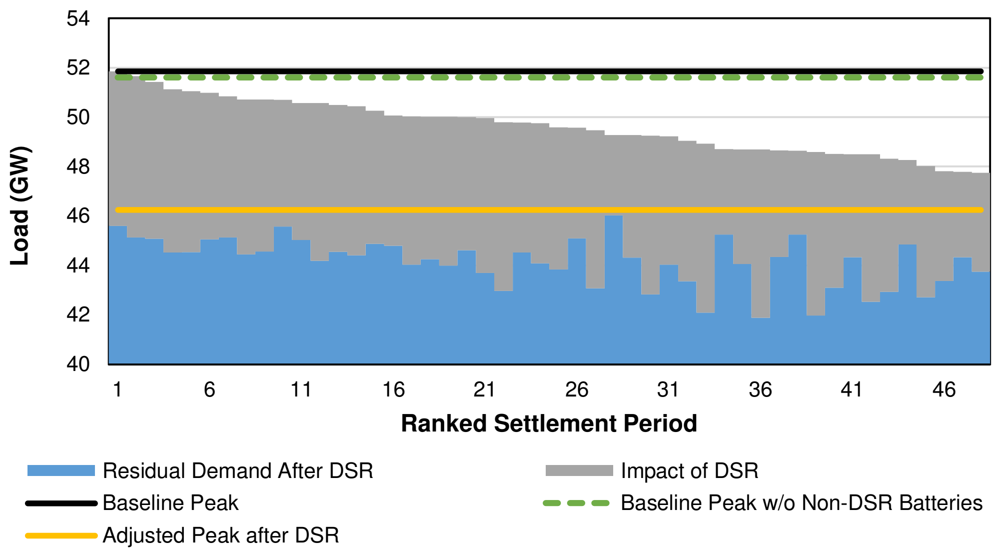


Source: CRA Analysis

C.2 Slow Progression – Historical BM Pricing – 2020

Under the Slow Progression scenario with Historical BM pricing in 2020, DSR activations could reduce peak capacity requirements by 5.4 GW as shown in Figure C.3 DSR utilisation is higher with historical BM pricing than LoLP pricing due to a higher number of hours within which DSR could operate profitably.

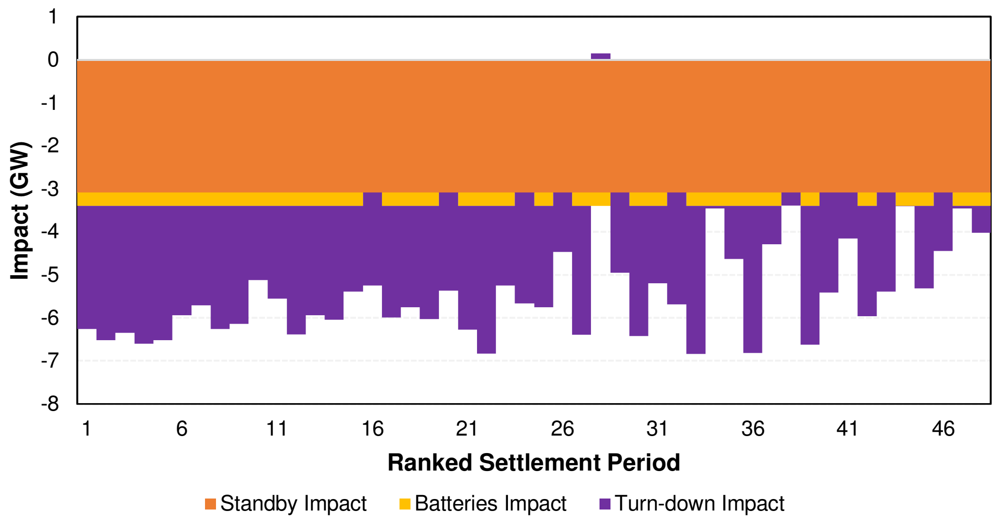
Figure C.3: Residual Load Duration Curve for the Top 48 Settlement Periods



Source: CRA Analysis

At maximum, 6.8 GW of DSR capacity is simultaneously activated. However, this only translates to a 5.4 GW reduction in peak capacity requirements due to similar reasons with LoLP pricing. Figure C.4 shows the pattern of DSR activations during the top 48 settlement periods for this scenario.

Figure C.4: DSR Activations during the Top 48 Settlement Periods



Source: CRA Analysis

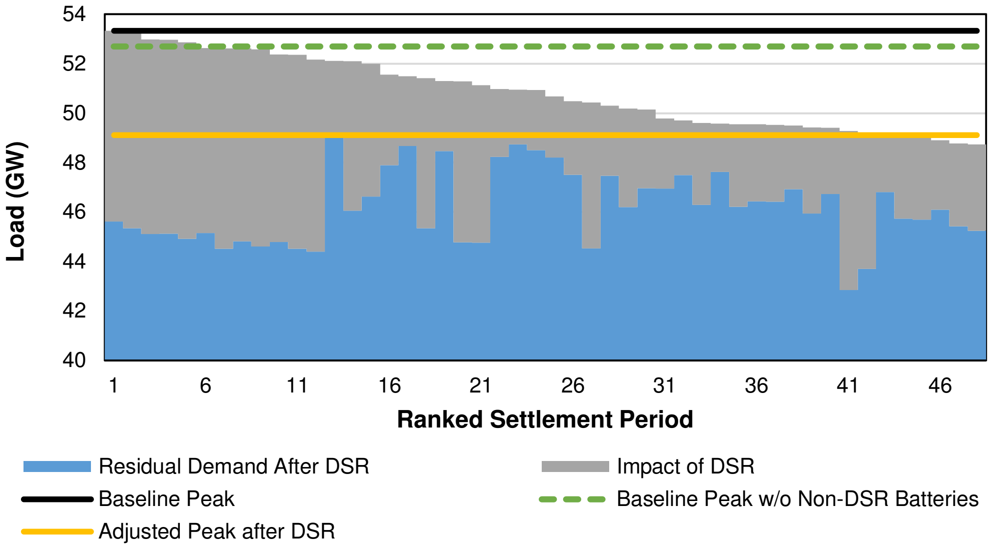
C.3 Slow Progression – LoLP Pricing – 2030

Under the Slow Progression scenario with LoLP pricing in 2030, DSR activations could reduce peak capacity requirements by 3.6 GW as shown in Figure C.5. As shown in Table B.1, this is higher than the reduction in peak capacity requirements in the Consumer Power scenario for a number of reasons.

First, batteries cannot fully contribute to the reduction of peak capacity requirements when they cannot fully recharge before the next incidence of high residual demand. The amount of battery capacity assumed in the Consumer Power scenario is multiple times higher than the Slow Progression scenario. As a result, the behaviour of batteries during the times of peak demand has greater effect on the reduction in peak capacity requirements in the Consumer Power scenario than in the Slow Progression scenario.

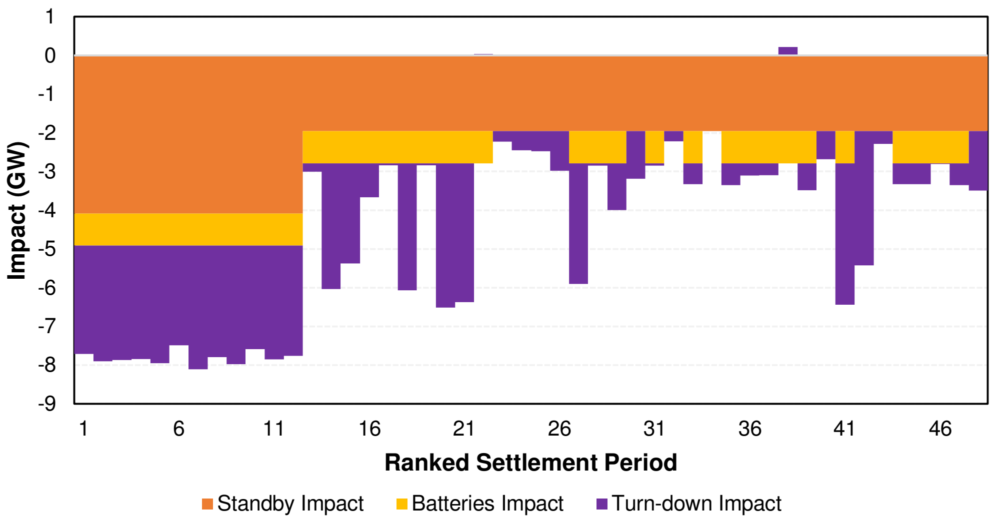
Second, our model suggests that the Consumer Power scenario has a higher level of capacity margin across the whole year than the No Progression scenario in 2030. As a result, the half-hourly prices against which turn-down and standby DSR are dispatched are lower in the Consumer Power scenario than in the No Progression scenario. Accordingly, turn-down and standby DSR is activated less frequently leading to a lower contribution of DSR to the reduction in peak capacity requirements.

Figure C.5: Residual Load Duration Curve for the Top 48 Settlement Periods



Source: CRA Analysis

Figure C.6: DSR Activations during the Top 48 Settlement Periods

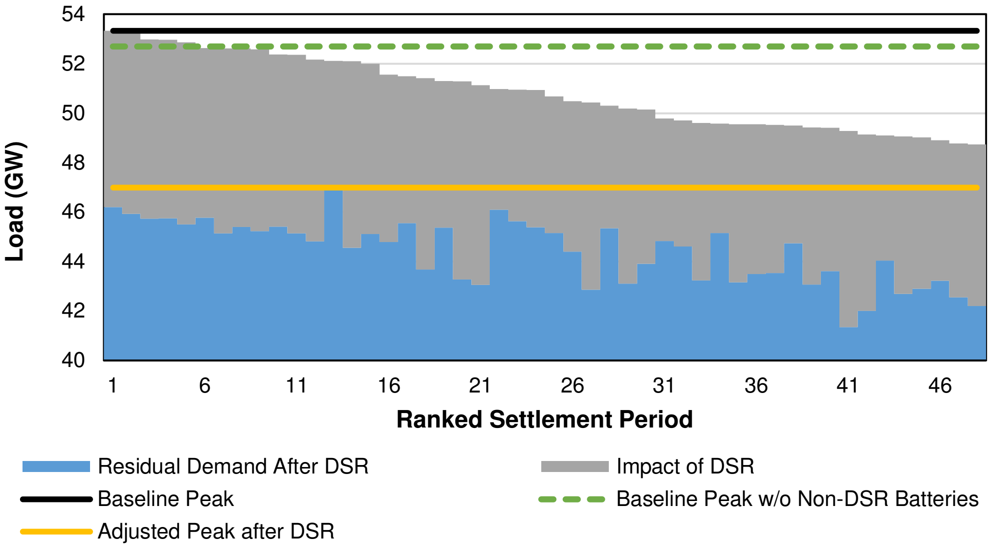


Source: CRA Analysis

C.4 Slow Progression – Historical BM Pricing – 2030

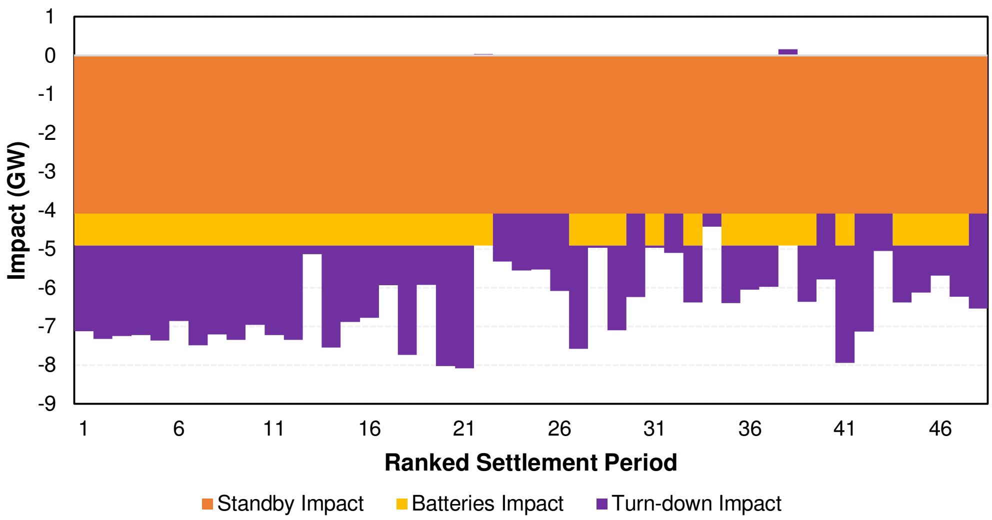
Under the Slow Progression scenario with Historical BM pricing in 2030, DSR activations could reduce peak capacity requirements by 5.7 GW as shown in Figure C.7. This is significantly higher than the reduction in peak capacity requirements in the Consumer Power scenario due to the reasons discussed under the LoLP pricing scenario.

Figure C.7: Residual Load Duration Curve for the Top 48 Settlement Periods



Source: CRA Analysis

Figure C.8: DSR Activations during the Top 48 Settlement Periods



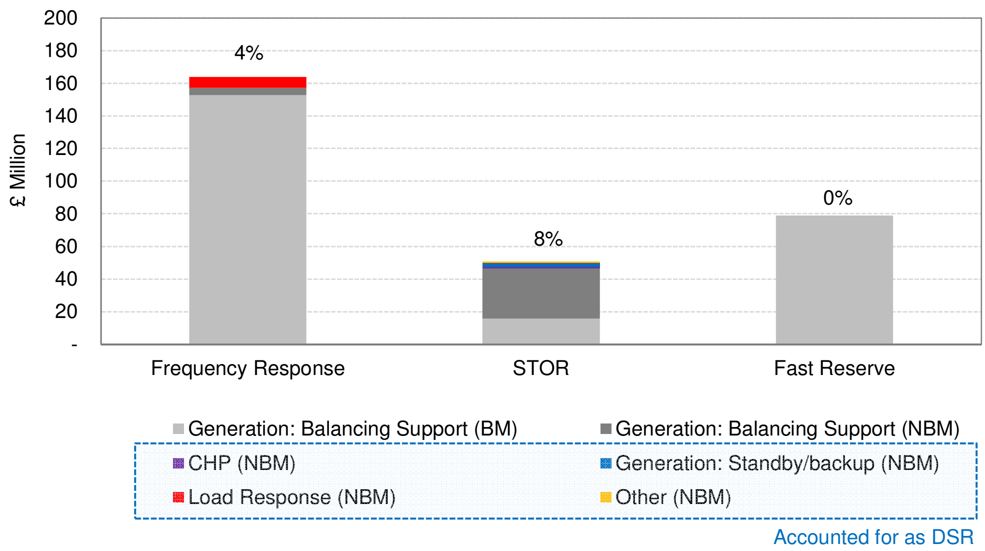
Source: CRA Analysis

APPENDIX D: FURTHER ANALYSIS OF PROVISION OF DSR TO SUPPORT BALANCING SERVICES

D.1 Share of DSR across Response and Reserve products

The share of DSR across National Grid's Response and Reserve products varies significantly. As shown in Figure D.1, in 2015-2016 DSR accounted for 4% of total spend on Frequency Response and 8% of total spend on STOR, but had no participation in Fast Reserve products.

Figure D.1: Share of DSR across Response and Reserve Products



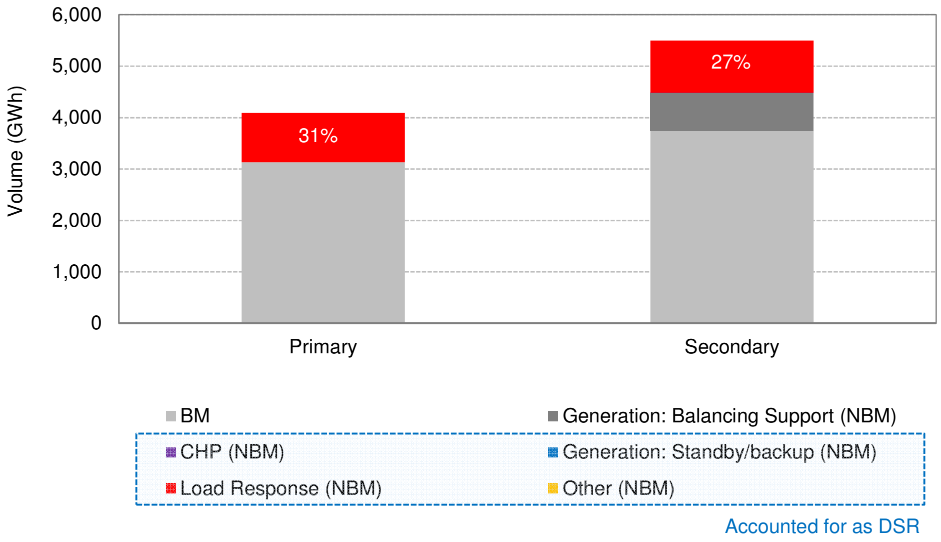
Source: CRA Analysis of National Grid's Non-BM Balancing Services Tracking Report

The participation of DSR across the Response and Reserve categories varies further by specific product. The sections below summarise the share of DSR participation within each category.

Frequency Response

The total cost of Frequency Response services for 2015-2016 was £164 Million of which DSR accounted for 4%. This is primarily driven by the share of Turn-down DSR in Primary and Secondary Frequency Response services. As shown in Figure D.2, for the 2015-2016 fiscal year, Load Response made up 31% of the contracted Primary Response volume and 27% of the contracted Secondary Response volume. However, DSR made up less than 2% of the High Frequency Response volumes procured for 2015-2016 (not shown in the graph).

Figure D.2: Share of DSR in Primary and Secondary Frequency Response Volumes

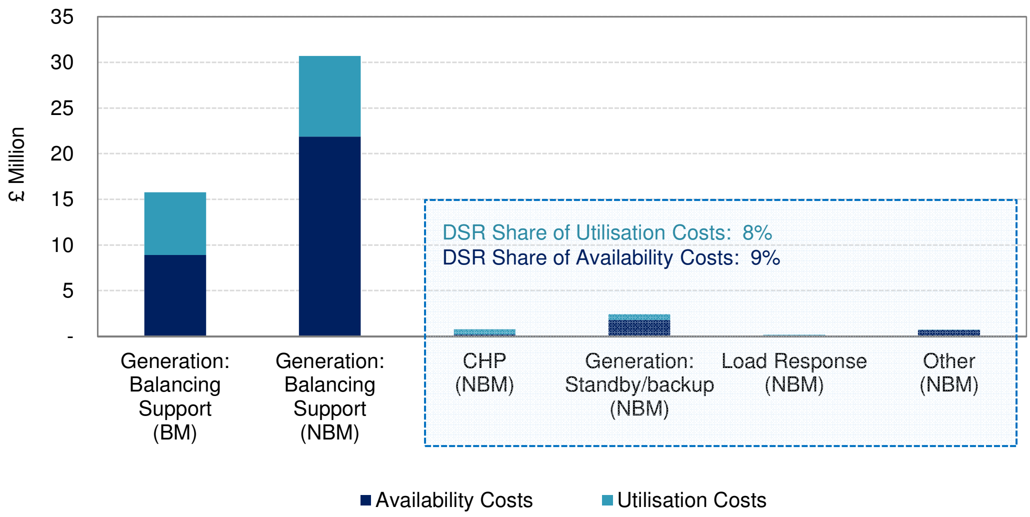


Source: CRA Analysis of National Grid's Non-BM Balancing Services Tracking Report

STOR

The total cost of STOR services for 2015-2016 was £51 Million. As shown in Figure D.1, DSR accounted for 8% of the total expenditure. Total STOR costs include expenditure on both availability and utilisation payments. For 2015-2016, STOR availability payments amounted to £34 Million (of which DSR made up 9%), while utilisation payments amounted to £17 Million (of which DSR made up 8%). This is shown in Figure D.3.

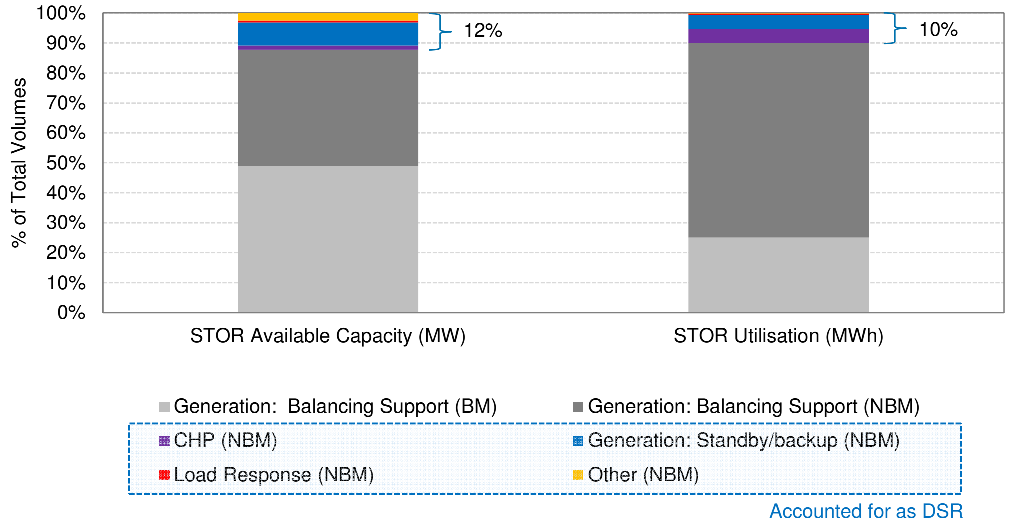
Figure D.3: Share of DSR in total STOR Costs



Source: CRA Analysis of National Grid's Non-BM Balancing Services Tracking Report

DSR represented a higher share of the market by volume, with 12% of the available capacity and 10% of the utilisation volumes. This is illustrated in Figure D.4.

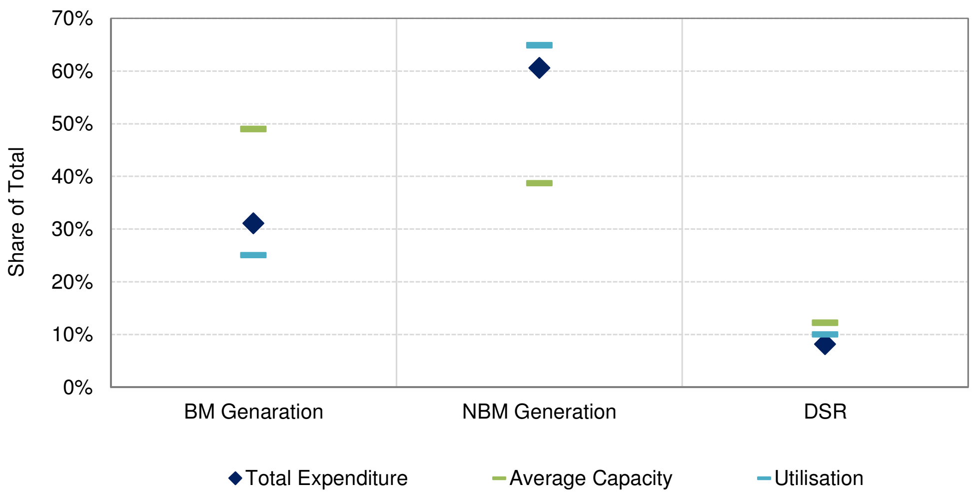
Figure D.4: Share of DSR in STOR Availability and Utilisation Volumes



Source: CRA Analysis of National Grid's Non-BM Balancing Services Tracking Report

There is also a discrepancy between the relative shares of availability and utilisation of BM and Non-BM generation. As shown in Figure D.5, Non-BM generation represents 40% of average capacity but around 65% of utilisation.

Figure D.5: 2015-2016 Total STOR Expenditure and Volume Shares



Source: CRA Analysis of National Grid's Non-BM Balancing Services Tracking Report

The relative differences in volume and expenditure shares between BM and Non-BM STOR providers reflects the distortion created by the treatment of BM and Non-BM volumes on the position of suppliers in the Balancing Mechanism. While the position of suppliers is neutralised for the STOR actions of BM generation, the STOR actions of Non-BM generation are not currently neutralised in the Balancing Mechanism. This leaves suppliers of Non-BM STOR benefitting from a long position in the BM during periods of high prices. These additional revenues are then passed back to Non-BM generation through bilateral agreements allowing Non-BM generation to bid in lower utilisation prices and resulting in a higher share of the utilisation.