Department for Business, Energy & Industrial Strategy

REALISING THE POTENTIAL OF DEMAND-SIDE RESPONSE TO 2025

A focus on Small Energy Users

Summary report

November 2017

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REALISING THE POTENTIAL OF DEMAND-SIDE RESPONSE TO 2025

Summary report

Acknowledgements

This report was prepared by a team comprised of E4tech staff working closely with specialists from several academic organisations:

Adam Chase (*E4tech*), Dr. Rob Gross (*Imperial College*),
Dr. Phil Heptonstall (*Imperial College*), Dr. Malte Jansen (*E4tech*),
Michael Kenefick (*E4tech*), Bryony Parrish (*University of Sussex*), Paul Robson (*E4tech*)

In addition to review by BEIS' quality assurance panel, the work was independently reviewed by a separate Expert Group:

Prof. David Hart (*E4tech*)

Prof. Nick Pidgeon (*Cardiff University*)

Prof. Steve Sorrell (*University of Sussex*)

Any enquiries regarding this publication should be sent to us at: smartenergy@beis.gov.uk.

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1 Introduction

1.1 Research context

Demand-side response (DSR) is understood as the short term response of electricity consumers to price changes or incentive payments (Strbac, 2008). DSR offers the potential for a paradigm shift in the operation of electricity markets, away from a unidirectional mode where increasing or decreasing demand creates price signals on the supply side which incentivise changes in generation. Other than customers with Economy 7 meters and electric space or water heating, the vast majority of consumers are not exposed to any price signals related to scarcity by time-of-use or by season. DSR on the GB power system has primarily been restricted to large industrial consumers that are able to participate in wholesale markets or enter into ancillary service contracts with the System Operator.

However, the smart meter roll out combined with new information and communications technology (ICT) and remote load control technologies make new forms of demand-side participation possible. As a result, a larger number of consumers, including households and small commercial entities, could be enabled to receive electricity tariffs that approximate the real time price of electricity. This could increase the efficiency of the system, realising cost savings for consumers. It may also reduce the need for new power plant construction, thus increasing asset utilisation and reducing overall costs, whilst retaining high levels of system security.

Moreover, if the UK is to meet its carbon budgets under the *Climate Change Act*, the power system will need to evolve. Variable renewables, such as wind and solar, already provide growing shares of electricity, and this is expected to increase further in future years alongside new nuclear power. The potential decarbonisation of heat and transport through electrification will provide further challenges to the power system. Recent research has highlighted the high potential value of up to £8 billion per year of flexibility in a system with high levels of variable renewables and inflexible nuclear generation (Carbon Trust & Imperial College 2016, Heptonstall et al 2017). In addition, many decarbonisation scenarios suggest that the role of electric heating and electric vehicles is likely to increase, creating new challenges for system operation by both increasing total peak demand and changing demand profiles.

In this context DSR is potentially attractive, and many power system scenarios envisage a significant increase in DSR, but its potential is largely unproven in GB. This is particularly true amongst small electricity users, which are currently settled on standard load profiles[1].

This report provides lessons regarding the potential for DSR for small users in GB, drawing upon technical, commercial and behavioural evidence from UK and international trials, surveys and programmes using a Rapid Evidence Assessment (REA) and in-depth country case studies. The international evidence base includes a wide range of demand-side programmes, including many programmes to reduce peak demand in North America, and trials of more innovative forms of DSR, such as renewable supply-following (i.e. increasing consumption when renewable output is high and reducing consumption when renewable output is low) across specific geographic locations in Europe. The case study section includes a review of small-scale DSR development from five international regions in the US and Europe.

It is acknowledged that the GB energy system is changing, with the transition to a smarter energy system and the potential decarbonisation of heat and transport through electrification, for example. The report therefore does not provide a prescriptive set of conditions to realise the potential of small-scale DSR in GB, rather it is intended to provide additional evidence to inform policy decisions, innovation support and wider industry decisions relating to DSR.

1.2 Research objectives

The study aims to inform policy development targeted at a smarter energy system, alongside the joint BEIS/Ofgem Call for Evidence on a Smart, Flexible Energy System issued in November 2016, by improving policymakers' understanding of the conditions under which small-scale DSR is likely to develop. The overarching objective of the proposed study is to provide a robust evidence base for the design of strategic DSR policies for small energy users up to 2025, considering four related research areas described in table 1 below:

[1] The term 'small electricity user' here refers to these domestic and smaller non-domestic consumers, within which domestic users are numerically dominant over non-domestic users. Analysis by BEIS indicates that the large majority of non-domestic users covered by this definition are small-to-medium-sized enterprises (SMEs) (<250 employees) or micro-businesses. The smart meter rollout mandate applies to the small energy users that are currently settled with standard load profiles (profile classes 1-4) (see e.g. (ELEXON, 2013)).

Table 1: Research scope and questions

Research area	Research questions
Policy intervention	What is the role of policy in promoting DSR from smaller users, what has worked and why?
Business strategies	What novel business models are being used to access DSR from smaller users, have they worked and why?
DSR products & services	What DSR products and services have been used internationally to secure demand response from smaller consumers?
Consumer engagement & participation	What are the key factors affecting consumer engagement in terms of: recruitment, level of response and persistence?

2 Understanding DSR

2.1 The importance of DSR and options for its delivery

Electricity systems require supply and demand to be balanced within tight limits in real-time, which has traditionally been achieved by ensuring sufficient generation is available to meet the forecasted demand at any time, plus a margin to allow for forecast errors and equipment failures. Changes in demand of flexible users can therefore reduce the necessary generation capacity. DSR involves achieving changes in electricity demand at different times based on grid conditions – for example, shifting demand from peak to off-peak demand periods. DSR differs from demand reduction, as it aims to change the timing of demand rather than reduce it overall.

The idea that consumers could increase the flexibility of their energy demand is based on the premise that consumers desire the energy services rather than the energy itself. This gives rise to two categories of theoretically flexible loads. The first is those loads with *thermal inertia* (space and water heating, air conditioning and refrigeration). It takes time for temperature to rise or fall and this may allow electricity supply to be interrupted for short periods without interfering with energy service provision. This can be enhanced by increasing thermal insulation or including additional thermal storage, such as hot water tanks, chilled water or ice storage. The second category comprises loads which may not be time-critical and includes washing machines, dishwashers and tumble dryers ('wet' goods or appliances) and are those where the energy service (e.g. cleaning) may not be required immediately. Other energy services, such as lighting, cooking and entertainment, are generally not considered to be flexible (see also (Powells, et al., 2014)).

The enabling technologies which can be used to facilitate DSR for these potentially flexible loads include in-home displays (IHD) either linked to or integrated with smart meters, direct load control, programmable communicating thermostats (PCT), smart appliances, smart plugs and conventional timers[2].

DSR has recently seen significantly more attention both in GB and internationally. These enabling technologies mean that an increased number of consumers, including households and small commercial premises, could potentially be offered commercial terms which reflect in some way the real time price of electricity.

[2] This report applies the following definitions: an IHD is an accessible display that works with a smart meter to provide information on the energy use, including prices. Direct load control is defined as a remote controlled switch to control a load or appliance. A PCT is a device that allows the energy consumption of electric heating or cooling to be changed. Smart plugs are switchable sockets, typically controlled by and connected to a home automation system. Timers are used to control the energy consumption of an appliance or an electrical load based on the time, e.g. day/month/year.

2.2 Different categories of DSR

DSR products and services offered to small energy users in the form of different types of time-varying pricing or direct control of appliances are well defined, in for example (Strbac, 2008) and (Paterakis, et al., 2017). The mechanisms through which DSR may be achieved in practice can be characterised according to how and when responses are triggered. *Price-based* DSR uses time varying pricing with the aim of shifting demand towards lower price periods, while *incentive payment-based* DSR uses incentives such as direct payments or bill credits. DSR may also be achieved through *external control* or *automation* of appliances (possibly linked to a lower tariff or incentive scheme). In all cases there may also be additional *information provision*, for example through displays linked to meters, on appliances, or through mobile phone apps or other web-based systems.

With respect to timing, static DSR aims to change demand at pre-set times of the day, while dynamic DSR aims to change demand based on prevailing electricity system conditions as they vary at different times throughout the day or year. Whilst DSR has traditionally focussed on reducing demand at certain times in response to system needs, the increasing use of renewable generation means the potential for low pricing to increase demand (at times of high renewable output) is now also being explored. In addition to these traditional economic stimuli, information about environmental conditions or grid stability can be used to trigger DSR, and DSR can include self-consumption of micro-generation such as PV. The range of specific mechanisms within the DSR category is shown in

Table 2 below, together with short descriptions.

In addition to these categories is the provision of 'information only' approaches, designed to encourage DSR without the use of financial incentives. This may include the use of in-home displays, but would more typically use media and other information campaigns to inform users of the need for a DSR. The term 'information only' is used to differentiate from those cases where the provision of information is a supporting part of a primarily financial incentive programme.

Table 2: Categories of DSR product and service

Price based schemes	Description
Static time-of-use (sTOU)	Prices vary by time-of-use between fixed price levels and over fixed periods. May also vary by season
Critical Peak Pricing (CPP)	Prices increase by a known amount during specified system operating or market conditions. This applies during a narrowly defined period and is usually applied only during a limited number of days in the year
Time-of-use critical peak pricing (TOU-CPP)	Critical peak pricing overlaid onto time-of-use pricing
Variable Peak Pricing (VPP)	Similar to time-of-use, but the peak period price varies daily based on system and/or market conditions rather than being fixed
Dynamic time-of-use (dTOU)	Prices vary between fixed price levels, but the timing of different prices is not fixed
Real-time-pricing (RTP), including DA-RTP (day ahead real time pricing) and RT-RTP (real time real time pricing)	Price can differ on a daily basis and change each hour of the day (or more frequently) based on system or market conditions. DA-RTP provides the 24 hour price schedule a day in advance; RT-RTP notifies the price in real time. If the response is automated, RTP can create short term responses for system balancing
Incentive based schemes	**Description**
Critical Peak Rebates (CPR)	Similar to critical peak pricing, but customers are provided with a billing credit for reducing usage during critical hours below a baseline level of consumption
Direct Load Control (DLC)	Utility (or aggregator) is able to directly change electricity consumption of certain appliances; customer receives a payment for this. Customer may be able to override control. Direct load control can create short term responses for system balancing

2.3 Current status of DSR in GB

Small-scale DSR in GB is currently characterised by limited commercial activity and as yet only a minority of consumers have smart meters to accurately measure the actual time of energy consumption. Time-of-use tariffs have been in use in GB for a long time, however, connected to Economy 7 meters and storage heaters on a day-night time tariff. Sustainability First estimated a total installed demand of 18 GW from the current GB storage heater stock (Frontier Economics and Sustainability First, 2012). At the same time, past and current trials and demonstration projects promise possible technical solutions and business models for small-scale DSR.

These trials and projects are complemented by the rollout of 53 million smart gas and electricity meters to all homes and small business sites in GB, aimed to be complete by the end of 2020. New business models will be available through these smart meters as they enable the settlement of electricity consumption on actual half-hourly measurement values, rather than standard load profiles. This is expected to lay the foundation for increased commercial activity. There are also a number of DSR companies established in GB, currently focusing on commercial and industrial customers, as well as a vibrant start-up sector assessing opportunities for targeting smaller users.

2.4 Consumer engagement with DSR – enrolment, response and staying enrolled

The extent to which different categories of DSR product or service elicit responses from users is affected by a wide range of factors, which are reviewed in detail in the chapters that follow. In all cases it is important to recognise that consumer engagement is multidimensional. Different types of end user will have different motivations to engage (or not). The same consumer may vary in the extent to which he or she engages over time, and their willingness to engage with a programme, respond to an incentive or to stay on a particular DSR tariff or service is subject to a range of complex influences.

It is important to define some preliminary measures of engagement with DSR and how it may change over time. The authors have therefore considered consumer engagement in terms of three categories which broadly follow definitions provided by the U.S. Electric Power Research Institute in (EPRI 2012): *participation*; *response*; and *persistence* – summarised in

Figure 1 below. We return to these categories as we review the evidence revealed in the Rapid Evidence Assessment.

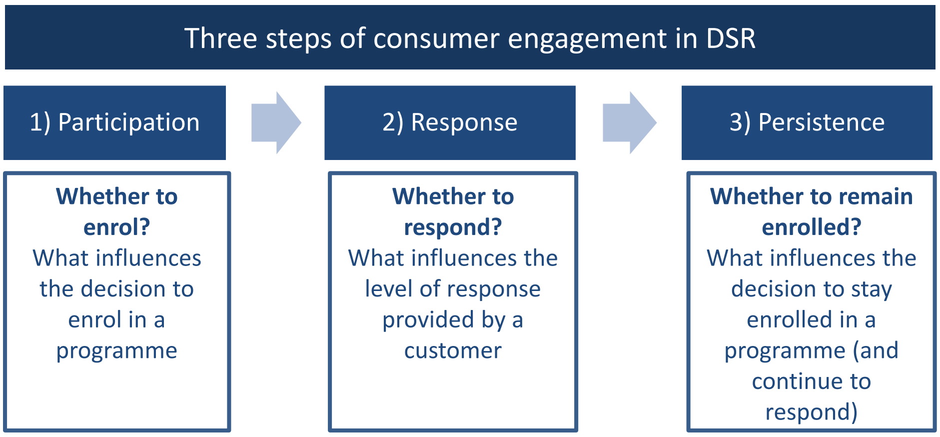


Figure 1: Stages of consumer engagement in DSR (adapted from EPRI 2012)

3 Research methods

3.1 Complementary evidence types

A combination of rapid evidence assessment (REA) and case studies was chosen due to their complementary nature. REA enables a comprehensive synthesis of the large existing base of evidence from programmes, trials, surveys and reviews and also identifies evidence gaps. The case studies fill these gaps and provide the opportunity to understand how the concepts explored in the REA have operated in real world examples. Five non-GB regions were chosen as case studies that have similar enough contexts to GB that insights are applicable. The findings from the case studies have been combined with the REA findings to draw out conclusions for small-scale DSR in GB.

Evidence reviews, such as REAs, are an established research method based around clearly defined search terms related to the research question. An REA provides a comprehensive review of the existing evidence base but may not provide full coverage of the small energy user landscape for DSR as:

- Small-scale DSR remains an emerging area and evidence may not be published
- Some international evidence may be hard to access due to not being publicly available or being in a language beyond the resources of the project team
- Emerging evidence may be conflicting or have limited applicability to the GB context

The case study research provides a complementary evidence base on small-scale DSR to the REA. Case studies enable a holistic understanding of how small-scale DSR has developed in chosen countries or regions, providing additions to the evidence base that otherwise might not have been assessed in the REA. Alongside shedding additional light on the four main research questions, the main objectives of the case studies are to:

- Describe the policies, regulations and markets relevant to enabling small-scale DSR in the case study regions.
- Describe the associated DSR products, services and business strategies
- Explain the relative success of these products, services and strategies together with the broader factors that explain the development of small-scale DSR in each region.

The first two are fundamentally descriptive and are covered within each case. The third question, however, requires a specific methodology as described in Appendix 1. The key study design and outputs have been quality assured by an external expert panel.

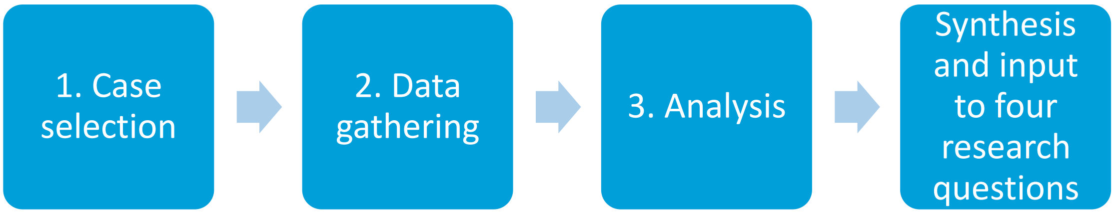


Figure 2: Case study methodology

A detailed description of the REA and case study methodologies is provided in the supporting reports.

3.2 Analysis and synthesis of the two approaches

The synthesis of the REA and case studies was based on an inductive logic pyramid which used the evidence base gathered in both approaches. The REA findings are those in which the project team has the highest confidence, based on a qualitative weighting of the evidence presented in the reviewed documents. For the case studies, the project team analysed commonalities between the interviews in each case study to derive region-specific themes. The team then assessed commonalities across the regions. These commonalities then led to a number of higher level findings which were merged with the findings from the REA to address each research question. These merged findings then allowed the project team to derive conclusions. From these the team could then logically derive implications for GB. This process is shown in Figure 3

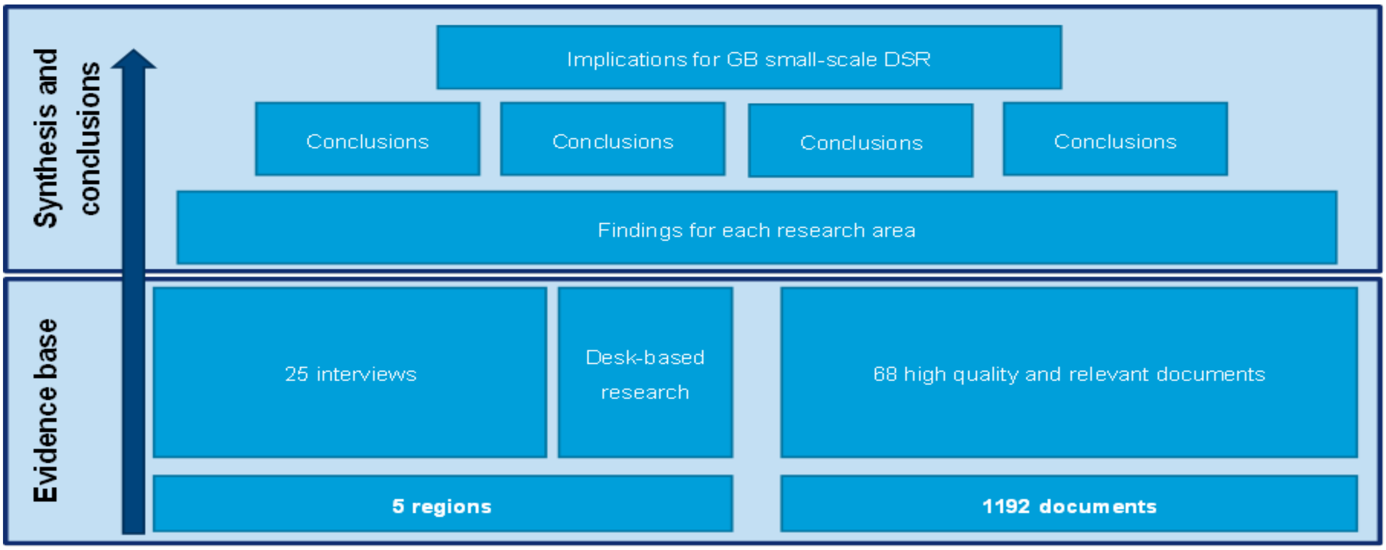


Figure 3: Analysis process for synthesising REA and case studies

The report follows a similar structure by first presenting summaries of the findings from the two different approaches (Chapters 4-5), followed by an overall synthesis, conclusions and potential implications for GB small-scale DSR (Chapter 6). References are provided in the References document.

4 The Rapid Evidence Assessment

The full REA analysis and findings are set out in the separate Rapid Evidence Assessment report. This chapter contains the REA synthesis and conclusions.

4.1 Synthesis of findings from the REA

4.1.1 Introduction

The REA revealed a rich evidence base on the international experience with DSR. Much of the evidence is focused on domestic consumer engagement and how this is affected by the detailed design of different forms of DSR offering. It is difficult to draw unequivocal conclusions about any of the individual dimensions of DSR offerings, since consumer responses depend critically on detailed aspects of design, implementation and context. Contextual factors include the nature of loads, climate and what DSR seeks to achieve (peak load or frequency control, fixed periods or dynamic, etc.). However they also include issues associated with trust, household routines, motivations and risk aversion that may vary markedly between consumer segments and countries.

Historically, most DSR has taken the form of simple and static time-of-day or critical peak pricing/rebates, often combined with direct load control. Looking to the future and to the possibility of increased DSR activity, the evidence suggests that this is likely to be facilitated through automation, as well as financial incentives. It requires consumer offerings to be straightforward and intelligible. Moreover it will be important to build and maintain consumer trust if end users are to engage, respond and remain enrolled in DSR tariffs, products and services.

This section discusses the evidence available on consumer enrolment, response and persistence. It considers different DSR products and services and reviews evidence on different dimensions of consumer engagement (summarised in Table 3 on pg. 14). It then considers motivations, barriers and enablers (summarised in Table 4 on pg. 16). The main conclusions for each of the research questions defined for the report are provided in section 4.2.

4.1.2 Policy interventions and business models

Policy is essential to the development of DSR programmes; it has driven trials and would be required to deliver many of the DSR offerings that are discussed in surveys or focus groups. It can also create opportunities for new business models and/or overcome obstacles to DSR that have the potential to make it unattractive as a business proposition. For example, policy could help to facilitate aggregation of benefits across multiple participants in the energy system. The evidence includes discussion of new business strategies enabled through smart appliance standards. Hence, there are important interactions between policy and business strategy since policy developments such as standards and mandatory smart meters can enable new business models.

Both policy and business strategy potentially have the capacity to affect the DSR products and services offered to consumers and how these are perceived by energy end users. Examples include how policy treats opt-in/opt-out recruitment, or how business strategies impact upon prices, consumer understanding, perceived complexity and trust. Policy will also affect contextual factors which are likely to be significant to the potential for DSR in future – for example wider policies affecting the energy system transition. These issues are returned to in Section 6. However, much of the detail revealed in the REA is concerned with products, services and consumer motivations and the remainder of this section focuses on these aspects.

4.1.3 DSR products and services and their role in engaging users

Table 8 (pg. 44) provides a summary of the main findings on key DSR product design features in terms of what the evidence suggests with respect to enrolment, response and persistence. The evidence base tends to focus most on response and enrolment with more evidence gaps apparent with regards to persistence. In many cases there is a complex overall picture and the evidence is conflicting. Whilst it is difficult to draw unequivocal conclusions due to the wide diversity of factors that affect how consumers respond to different products and services, a number of points stand out.

There is considerable evidence on the relationship between different forms of financial incentive and consumer enrolment and response. Evidence on the impact of the price ratio (difference between high/low prices) is mixed. A minimum peak:off peak price ratio would be required for users to have a sufficient financial incentive to change demand. However, beyond a certain point higher prices are unlikely to result in any further demand reduction, probably because users have already changed behaviour as much as they feel able to reduce demand at that time. There is some evidence to suggest that very high peak price levels could deter some users from enrolling in DSR because of the associated financial risk. Average responses to critical peak pricing are generally higher than average responses to time-of-use pricing, but features other than the different price levels involved may contribute to this effect – for example the fact that critical peak occurrences are less frequent (occasional rather than daily) or that the size of individual loads under direct load control are larger.

Responses to critical peak rebates are on average lower and more variable than responses to critical peak pricing. Less evidence was identified on residential user engagement with more dynamic and unpredictable forms of pricing. Some studies suggest that it may be difficult for users to change electricity demand in response to more dynamic pricing, particularly without automation or direct load control. There is also evidence that consumers prefer to follow regular patterns of high and low pricing at different times of day rather than regularly checking prices, even if they are on a dynamic pricing tariff.

There is mixed evidence on the impact of in-home displays on response and enrolment and some evidence to suggest that they may be ignored or not even connected. However, some form of additional information is a prerequisite to notify users of price changes for any form of pricing which is not set in advance.

Automation and direct load control often act as enablers to response. They can increase the size of response, access load types that might not be feasible for manual response, and increase response reliability. Automation can also enable responses to more dynamic pricing which participants may find too difficult to perform manually, and enable responses outside of waking hours or at times when no-one is at home. Automation or direct load control would be likely to be essential for DSR to provide response and reserve services to the electricity system (see Rapid Evidence Assessment report for more detail).

Unsurprisingly the evidence suggests that programmes which require consumers to opt-out of mass DSR enrollment by default recruit much larger number of participants than schemes which invite consumers to opt-in. There is evidence that in aggregate response rates are similar and little attention has been paid to retention rates.

Table 3: Key differences in potential DSR offerings – price ratio, price/rebate, information/display, automation/direct load control and recruitment (opt-in or opt-out).

Product design features	Enrolment	Response	Persistence
Larger vs smaller price ratio	No evidence identified	Mixed results. Often co-varies with other DSR characteristics, complicating evaluation	No evidence identified
Rebates vs pricing	Similar for both pricing and rebates, though some evidence that enrolment in rebate schemes is lower risk	Smaller and more variable for rebates	Slightly higher for rebates
In-home display	No impact on measured enrolment rates in US CBS[3]	Mixed results	No evidence identified
Automation/direct load control	No evidence on measured recruitment rates, but automation suggested as a motivator for some users	Presence of automation and direct load control tends to increase response	No evidence identified
Opt out vs opt in recruitment	Much higher for opt-out	Lower average response for opt-out. Similar aggregate response, although evidence is mixed	Limited and mixed evidence. Some evidence that consumers made worse off through opt-out seek to leave DSR schemes

[3] US DoE Consumer Behaviour Studies

4.1.4 Consumer motivations and end user segmentation

The REA also revealed evidence on wider factors that affect consumer engagement with DSR. This is summarised in Table 4. This indicates that the principal motivation for engagement with DSR is to reduce bills and that familiarity with DSR technologies increases both enrolment and response. There is considerable discussion in the evidence base of who consumers trust, their understanding of DSR technologies, perceived risk and loss of control and how complex engaging with DSR is perceived to be. In some instances there is little specific evidence on enrolment, response or persistence as the evidence base discusses DSR in more general terms.

The evidence in this area is particularly complex and it is difficult to draw unequivocal conclusions that apply across all categories of consumer. It is also notable that opinions differ as to how to segment consumers – different studies focus variously on household size, nature of electric loads, and socio-demographic factors. The evidence demonstrates that users are heterogeneous in their approaches to DSR. In some cases, ownership of specific load types such as electric heating may be required for certain DSR products and services. Spending more time in the home can increase demand flexibility, and overall, the presence of children or other dependents seems likely to reduce flexibility.

The evidence suggests that there is a strong interrelationship between consumer routines, which technology types are included in or affected by DSR, perceptions of complexity, and factors such as trust, perceived risk and loss of control. Taken together these have a significant effect on how consumers view DSR. Some factors affecting DSR will be partially exogenous (for example which actors are trusted) but the specifics of DSR product design also play a role (for example trust can be undermined by poor technical performance). This suggests that in broad terms the success or otherwise of DSR products will be context specific but also affected strongly by the detail of the product offered to consumers. There is clearly a need for additional learning about ‘what works’ as novel forms of DSR are explored in trials or begin to emerge in the marketplace.

Table 4: Motivations, barriers and enablers for residential user engagement with DSR

	Enrolment	Response	Persistence
Motivation	Mainly financial benefits, with a secondary focus on environmental and social benefits	No evidence identified	No evidence identified
Familiarity with and knowledge of DSR	Reputation/awareness of DSR and supporting technologies may be a barrier or enabler	Lack of technical skills and understanding of DSR may decrease response	No evidence identified
Trust	Barriers may be associated with organiser motivations, privacy and autonomy	Trust may be undermined by poor technical performance, delays or unexpected outcomes. Could be reduced by proactive management and open communication about any problems, and provision of clear information about the range of outcomes consumers may expect of a DSR programme	
Technology requirements and technical issues	Absence of certain technologies or requirement to install new technologies can act as barriers to enrolment.	Technical problems, especially with communication, can limit response	Technical problems may reduce engagement and erode trust
Risk	Stated preferences suggest financial risk is a barrier, but little difference in recruitment rates for critical peak rebates and critical peak pricing in US CBS	Financial risk may increase response (evidence on higher price levels, price rather than rebate)	Financial risk may decrease persistence (Retention somewhat higher for critical peak rebates than critical peak pricing in US CBS)

	Enrolment	Response	Persistence
Perceived control	Concerns may be associated with direct load control, and be reduced by override and other control options	Concerns may increase or decrease following actual experiences of direct load control or smart automation, influenced by familiarity, level of feedback and control options provided to users	
Complexity and effort	Perceptions of and experienced ease or difficulty of response can change with DSR product/service - in particular automation may reduce perceived effort and enable response (though some automation can itself can be difficult to use), while more complex pricing may increase perceived effort and hinder manual response. Perceptions and experiences also seem to vary amongst users		
Interaction with user routines and activities	No evidence identified	Automated responses to heating/cooling may have minimal impact on routines. Manual response involving wet appliances appears to be limited. Demand shifting could be enabled if it fits well with existing routines, or does not affect routines. Some users make larger changes to routines and activities	

4.2 Overall conclusions from the REA

4.2.1 Policy interventions

Research question 1: what is the role of policy in promoting DSR from smaller users, what has worked and why?

Historically the principal role for policy in promoting DSR from small users has been in enabling or mandating time-of-use tariffs and direct load control. For the most part these are static and there is a mix of static time-of-use and critical peak price/rebate in the international evidence base. More recently policy has been important in stimulating interest in more dynamic offerings, in part through the roll out of smart meters, in part through a range of trials of various DSR products and services. Supportive policy has been essential to the development of DSR programmes, has driven various trials and would be required for many of the DSR offerings that are discussed in surveys or focus groups.

Limited analysis focussed specifically on the role of policy and regulation was found in the REA. Many reports make reference to policy but do not discuss it in detail, focusing instead on outcomes from programmes or trials. These are often enabled by policy but beyond pointing to the need for supporting policy there is often little analysis of policy provided in the evidence base.

There is consensus across several documents that policy and regulation is essential to overcome barriers to DSR, and that without it, DSR amongst smaller users will remain low. Establishing regulatory frameworks and incentives that support and enable DSR are key to wider implementation of DSR.

A number of reports discuss the role of policy in enabling smart metering, noting that smart meters can in turn enable DSR offerings involving time-of-use pricing and direct load control.

Several reports discuss the potential for policy to help address problems associated with integrating the demand-side into wholesale and capacity markets, for example in terms of minimum unit sizes or gate closure periods. Revised market and technical arrangements initiated by regulators or system operators, and affecting network owners/operators can also allow market participants to access the value of DSR.

Smart appliance standards can enable new business models and customer offerings.

4.2.2 Business models and strategies

Research question 2: what novel business models are being used to access DSR from smaller users, have they worked and why?

The REA revealed limited information on business models or business strategy. No evidence was revealed which sought to draw findings for small energy users from energy service companies targeting large energy users.

Much of the historical evidence on DSR derives from static time-of-use or peak load programmes, with or without direct load control, usually implemented by incumbents in response to a requirement from the regulator or Independent System Operator (ISO). These have had substantial impact on DSR but have not required or been led by significant changes to business models.

A number of high level points are made in some studies that have some bearing on business strategies. These include marketing and engagement strategies. Several studies note that the high costs of securing participation, when combined with relatively modest availability of flexible load per household, may act as a barrier to businesses considering offering DSR. The evidence also includes discussion of the difficulties associated with securing benefits shared across different energy sector participants in unbundled markets.

The principal business model innovation revealed in the REA, which receives some discussion in the studies reviewed, pertains to so called ‘bring your own device’ (BYOD). This can be enabled by regulation and could reduce the cost of entry for companies considering DSR.

4.2.3 DSR products and services

Research question 3: what DSR products and services have been used internationally to secure demand response from smaller consumers?

The REA revealed a substantial evidence base on a range of DSR products and services and how consumers respond to different offerings. The evidence derives from programmes using static pricing/rebates and direct load control and trials of more dynamic/real time pricing. Surveys and focus groups are also reported in the evidence.

There is strong evidence that consumers respond to static time-of-use and/or critical peak pricing. The evidence suggests that price ratios are important but predictability and availability of automation are also strong determinants of the level of price response. There is some evidence that pricing delivers greater response than rebates. Evidence on dynamic time-of-use pricing is limited and somewhat mixed. However there is some evidence that consumers favour fixed patterns of response even when presented with dynamic prices.

Several studies find that in-home displays have limited or marginal direct impact on response and retention. By contrast there is strong evidence that automation or direct load control increases response, particularly for loads such as heating and air conditioning.

The REA also revealed a variety of innovative DSR offerings. The evidence on these is too limited to draw definitive conclusions but the trials in question are included to provide information on emerging options in DSR.

4.2.4 Consumer engagement and participation

Research question 4: what are the key factors affecting consumer engagement in terms of: recruitment, level of response and persistence?

The REA revealed a substantial evidence base on consumer motivations for enrolling in DSR programmes/trials, together with a good body of evidence from surveys and focus groups which consider attitudes and perceptions. Most of the evidence is concerned with domestic consumers.

The primary motivation for enrolment is financial, but environmental and other drivers are also significant.

There is strong evidence that opt-out recruitment secures much higher levels of enrolment, but also that the aggregate response rates of opt-in and opt-out populations are relatively similar. Hence, opt-out may be a simpler or cheaper recruitment method but also risks enrolling a substantial population of non-responding consumers who may pay higher prices as a result of low response levels.

Trust, risk and complexity feature strongly in the evidence base on motivations for enrolment, response and persistence. Clearly the presence of trusted actors, absence of perceived risk of higher bills and minimal complexity all enable engagement. Beyond this however the evidence presents a complicated and mixed picture, for example in terms of who is trusted and how to minimise risk or complexity.

The evidence base contains considerable attention to routines, with both daily and seasonal factors affecting response.

There is a considerable amount of discussion of various end user types/segments and clear evidence that some households respond much more than others. However the evidence is too complex and varied to reveal any simple overarching conclusions about which consumers are most responsive to DSR offerings and why.

5 Lessons from selected regions: Case studies

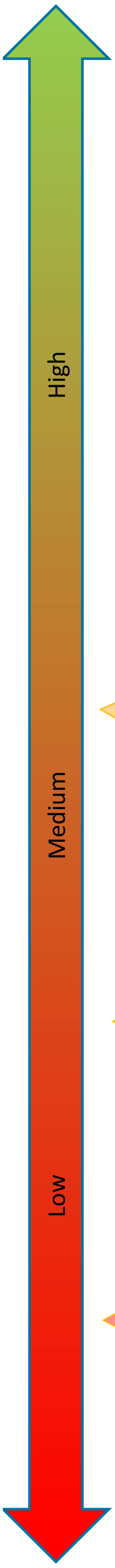
5.1 Introduction

The case study research provides a complementary evidence base to the REA. Case studies enable a holistic understanding of how small-scale DSR has developed in the selected regions, providing valuable additions to the evidence base. Alongside addressing the four main research questions, the objectives of the case studies are to:

- Describe the policies, regulations and markets relevant to enabling small-scale DSR in the case study regions
- Describe the associated DSR products, services and business strategies
- Explain the relative success of these products, services and strategies together with the broader factors that explain the development of small-scale DSR development in each region.

The case studies show that development of small-scale DSR has taken a variety of different paths based on factors such as market conditions, the availability of cost saving or revenue opportunities presented to DSR providers and the need for flexibility in the power system. While the markets DSR providers participate in differ between regions, the interviews revealed that business models and the offering of products and services generally face similar challenges such as high cost of customer acquisition (in particular for independent aggregators) and hardware installation. One way commercial actors deal with the high costs is through establishing partnerships that allow for knowledge and resource sharing. DSR providers also target high electric loads (via electric heating or cooling appliances) to minimise customer acquisition and technology costs. Policies and regulation often take the form of standards and mandates that incorporate DSR in to the relevant markets. The key markets discovered for small-scale DSR currently consist of energy and capacity markets while participation in reserve markets is proving harder for commercial actors.

The case studies are presented in order of the maturity ranking in Figure 4, based on smart meter roll out and availability of small-scale DSR products and services, starting with Texas.



1. Texas

DSR efforts in Texas (as governed by the system operator ERCOT) are driven by a high need for flexibility and have led to ERCOT's status as a relatively advanced market for small-scale DSR. Retailers offer a large number of products and services enabled by efficient settlement processes and relatively few high pricing events. However, interviews also revealed that a general low price environment and challenging techno-economics create barriers for further uptake particularly in the reserve markets. Policy and mandates have played an important role in supporting the DSR in the ERCOT markets.

2. Illinois

The Illinois section of the PJM network operator region is an advanced small-scale DSR market with a number of products and services offered. Due to the lack of appropriate price signals on the energy market, these products are encouraged via capacity payments. Interestingly, PJM has pursued small-scale DSR despite not requiring further flexibility or capacity. Policy and mandates have also played an important role in supporting the inclusion of DSR in the PJM markets.

3. Finland

Finnish DSR efforts are driven by high need for flexibility and capacity. However, the main commercial business models in novel DSR products are real-time pricing combined with home automation. Retailers and home automation providers are proactive and currently designing new business models in the reserve and balancing markets. The Finnish system operator is also actively supporting the testing of new small-scale DSR products. Other than the mandating of smart meters and accurate settlement, government policy and mandates appear to have played less of a role in the deployment of small-scale DSR products compared to Texas and Illinois.

4. Germany

A well interconnected power system, lack of accommodating price signals and smart meter infrastructure means that Germany lags behind ERCOT, PJM and Finland in small-scale DSR deployment. Some interesting commercial activity can be observed in the solar and storage market. There have not been any major regulatory efforts to include DSR in the power system (as those seen in ERCOT and PJM), likely due to the lack of a pressing flexibility need.

5. Norway

An abundance of hydro power and a lack of smart metering means Norway lags behind the other case study regions. However, the mandatory smart meter roll out and high electric loads may open up the small-scale DSR market. Current small-scale DSR efforts are driven by high grid investment needs and growing power demand (most visibly in the consumer segment from electric vehicles) as flexible hydropower dominates the reserve and energy markets. The regulator played a role in instigating DSR efforts in the early 2000s but has not implemented any significant mandates other than the smart meter roll out since.

Figure 4: Overview of case study regions based on small-scale DSR maturity

Due to the level of detail and length of the individual case studies these are published in a separate report[4].

5.2 Analysis

This section analyses the findings from the five case studies. The findings are discussed and summed up in relation to the conceptual framework used in the case study work (see country case study report): 1) policy, markets and regulation; 2) business models; and 3) consumer engagement.

The findings were identified via analysis of the interview and documentary evidence, as indicated in Figure 5. The themes have been identified to explain what factors have been relevant for small-scale DSR development in each case study.

Figure 5: Approach to case study analysis and synthesis

5.2.1 Discussion of main findings

5.2.1.1 Policy, markets and regulation

Amount of existing flexibility and capacity on the system drives countries' initial efforts in DSR

Power systems with a shortage of generation capacity and lack of flexibility tend to have higher prices and/or higher price spreads between different hours of the day. In the case studies these factors appeared to foster the use of domestic DSR as a source of flexibility,

[4] Insert title and link

as these systems offer sufficient revenue opportunities for relatively expensive use of this small-scale resource. This is evident when looking at the ratio of peak demand to available generation and interconnection capacity (GW). For Germany this is 80/120, for Finland it is 15/17 and for ERCOT[5] it is 71 /74. Even in the constrained systems of Finland and ERCOT, the economics for small-scale DSR are tough with several actors trying to find a niche in the market to be profitable. These niche markets vary across the case studies but generally include capacity and energy balancing markets. In Norway, small-scale DSR is not yet considered competitive in a market dominated by flexible hydro power.

In all of the case studies, DSR typically starts with the lowest hanging fruits at the commercial and industrial level, typically large, multi-megawatt chemical or heavy industry plants. Increasing automation and efficiency in consumer acquisition allows DSR aggregators to decrease unit sizes and potentially move into the small-scale DSR market. This may firstly focus on large electrical loads, which serve heating or cooling purposes and then, when the learning curve goes on, potentially connect white goods and other small-scale appliances. The case studies therefore suggest that even in highly flexible power systems, such as those of Germany and Norway, industrial DSR can participate. Small-scale DSR, however, may require additional flexibility needs from constrained power systems.

DSR providers must have access to tangible revenue or cost saving opportunities

The case studies assessed the market opportunities available to retail suppliers and other DSR providers. Looking across the case studies it is clear that there are a variety of markets small-scale DSR can participate in. However, those markets need to provide tangible revenue or cost saving opportunity incentivising a reduction in load[6]. The interviews revealed that price signals are key in shaping these opportunities in at least three ways.

First, volatile price signals encourage trading and arbitrage on the energy markets in particular with controllable loads. In ERCOT, this is viewed as an efficient way to encourage response as balancing prices are only high when the system is short of generation, and hence demand reduction is encouraged through this price signal. In the event that the system is long, or potentially prices turn negative, demand resources would not be encouraged to reduce load as it could incur a payment to ERCOT. This business model relies on price spikes in the energy market, a controllable load resource and consumers being settled on real consumption, otherwise individual demand reduction efforts are averaged out across a customer portfolio and users do not have an incentive to

[5] Electric Reliability Council of Texas, the independent system operator for 90% of electric load in Texas and the focus of the case study
[6] It is also possible that in vertically systems integrated power companies can realise financial savings through DSR, for example by obviating the need to build peaking plants. In this instance price signals may be rather less transparent since the utility is reducing costs rather than responding to an explicit price signal.

reduce demand. While ERCOT does not experience frequent and sustained high pricing events, products and services in the deregulated areas of ERCOT are designed to take advantage of these spikes. Ideally, price spikes should be frequent and of a sufficient scale to create viable commercial opportunities from trading with load resources.

Illinois (PJM) has not experienced sufficient price volatility to enable this value opportunity. DSR in the Illinois utility ComEd therefore mainly participates via the capacity market. In Finland, Germany and Norway intra-day trading does provide an opportunity to balance portfolios but so far these have not proved sufficiently volatile (with frequent and sustained price spikes) to encourage load reductions. It should be mentioned that for retailers or DSR providers to act on these price signals, they must have visibility to the price before the relevant settlement interval. ERCOT does not provide advanced notification of prices but do publish non-binding prices which retailers can combine with wind forecasts and signals from the day-ahead market to forecast real-time balancing prices. PJM does provide advanced notification of prices while Finland, Germany and Norway provide price visibility via the intra-day market as far as 20 minutes prior to gate closure.

Second, the final price that consumers pay should be sufficiently high to encourage DSR enrolment and response. Interviewees from all case studies commented that the retail price of electricity is today too low to create a DSR product with mass appeal. In ERCOT, the price of electricity has been kept down over the last decade by cheap natural gas (and partially by increasing low marginal cost renewables) while in Finland and Norway cheap hydropower in NordPool puts downward pressure on the merit order.

Third, Germany has also shown that the price signal to consumers can be watered down. Even if they had access to real-time-pricing, with only 20% of the electricity bill being time-variable and the rest consisting of fixed levies, fees and taxes, the price signal at the moment is reduced and not strong enough to foster small-scale DSR. In all case studies the energy tariff only constitutes a part of the energy bill the customer sees – the others being made up by grid fees, taxes and renewable levies and it was reported that this constitutes a barrier to increasing the relevance of price signals.

Small-scale DSR can also participate in frequency reserve markets. The price received here is normally known in advance and consists of both an availability payment and an energy payment. The frequency markets have as of yet not seen participation from small-scale DSR in the studied regions, which is due to both technical and economic issues explained below. According to our interviews, Finland is the country closest to commercialising a business model around frequency response from electric heaters and other thermal loads although these are still in the making.

Additionally, the ability of the consumer to receive real-time prices and be rewarded for reacting to them is clearly important. The smart meter rollout in Finland has enabled new business models that are supported by the constrained Finnish system. Germany on the other hand has not progressed in its roll out of smart meters. The situation is similar in Norway as in Germany (with respect to both smart meters and price signals) and consumers therefore currently do not have an incentive to reduce demand. Even if price signals were adequate on the market, consumers would not have an incentive to respond.

Another value opportunity identified in the case studies is that of deferred grid investments. This was particularly brought up in the Norway and Illinois (PJM) interviews. The degree to which this is considered a tangible revenue opportunity was questioned by the interviewees, however. The DNO in Norway did not primarily pursue variable grid tariffs for a clear return on investment, but rather to create a more equitable sharing of grid costs amongst its customer base. An interview in Illinois (PJM) revealed that DNOs are more likely to take on DSR with the aim of saving costs on grid upgrades as they have a longer capital outlook than e.g. retailers. Deferred grid investments are also likely to be more common as a value driver for small-scale DSR in locations with high congestion costs.

5.2.1.2 Business Strategies

Availability of high electricity loads per customer enables small-scale DSR

High electric loads that can be connected cheaply keep the costs of a business model down. Regions with larger electric household loads are therefore more likely to build a successful DSR business case. Electric energy use per household as a share of the total energy consumption is shown in Table 5.

Table 5: Electricity use per household and types of loads

Region	Electricity use / household as % of their total energy consumption	Type of load
Texas (ERCOT)	61.2%	Air conditioning, space, water and pool heating
PJM (ComEd)	27.6%[7]	Air conditioning, space and water heating
Finland	36.2%	Space and water heating (including floor heating), sauna
Germany	21.6%	Space and water heating
Norway	83.2%	Space and water heating (including floor heating), electric vehicles

For reference, GB share is currently 20%, which partly reflects the low penetration of electric heating but also the low energy efficiency standards of buildings, typically heated with gas.

There are a few caveats to this observation. Norway has a high share of electric heating; however, it is not a mature market for small-scale DSR products and services. This can be explained by the existence of abundant flexible hydro power in the system, together with the lack of smart metering and real consumption settlement. Once the smart meter roll out is complete and the country moves to real consumption settlement, commercial actors will indeed have a large market volume due to the high prevalence of electric heating and loads with high thermal inertia (floor, space and water heating). Whether the correct price signals will materialise in the market is another uncertainty as the existing flexibility in the power system might dampen price volatility.

For the ComEd region of Illinois, electricity accounts for 26% of the energy usage for the average household. The lower electricity use is due to the higher use of natural gas to provide heating during the winter. However, despite this relatively low electricity demand in comparison with other US states, the DSR market is considerably more active. The vast

[7] For the state of Illinois

majority of this activity is focused in the PJM capacity market and it is important to note that the DSR products offered to small scale consumers are primarily run during the summer season. The summer season provides the times of highest strain on the power network and the DSR products are concentrated on reducing the loads from household air conditioning units during these months. These air conditioning loads combined with the high capacity market prices means small-scale DSR is feasible for the ComEd region.

Successful small-scale DSR therefore may require multiple conditions to be fulfilled, such as sizeable electric loads, high flexibility needs and smart metering infrastructure.

Partnerships along the supply chain enable cost reduction and new business models

The partnerships identified throughout the case studies are generally between a technology service provider (e.g. a home automation platform provider), a retail supplier and potentially with the involvement of a smart appliance manufacturer.

To create a viable business model, independent aggregators may require cooperation with retailers who have established relationships with a wide customer base. This brings down customer acquisitions costs and having a trusted brand name helps in the initial contact with the customer. Retailers may also be able to provide reassurance to the consumers that a fall-back option is open and that costs will not increase compared to status-quo.[8]

Appliance manufacturers were mentioned as important partners throughout the five cases. Generally, this takes the form of the manufacturer creating DSR-ready appliances which significantly reduces installation costs (of e.g. smart thermostats). The case studies do not yield any evidence on the strength of the ties and how this varies in between the regions. However, this partnership example is best seen in the BYOD business model in PJM and ERCOT. Finland, Germany and Norway are lagging behind. This can partially be explained by the general lack of smart metering infrastructure and products and services available to consumers, and by appliance manufacturers not being willing to take the risk of setting up new manufacturing processes prior to the DSR market. Figure 6 shows the relationship between the three main stakeholders.

[8] However, one of the main benefits to retailers of offering a real-time price to consumers is the hedging of price spikes, and in both ERCOT and PJM, price caps for the consumer are not common.

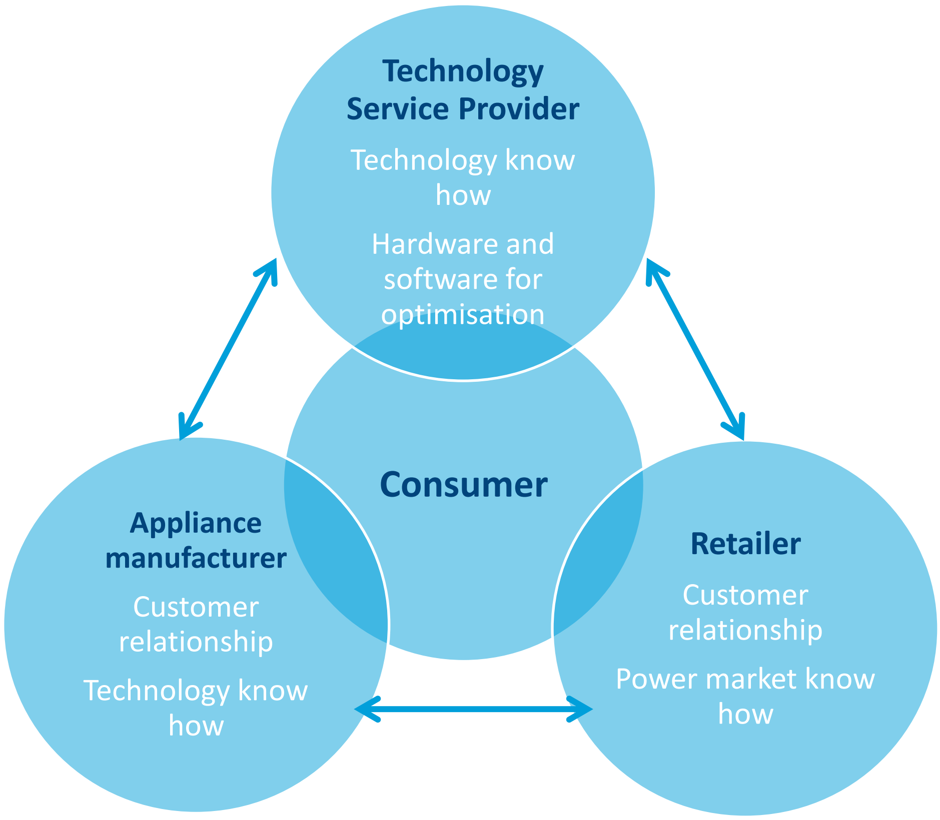


Figure 6: Partnership triangle for enabling new business models in small-scale DSR

The techno-economics of novel small-scale DSR remain challenging and influence the accessible markets

Operation of small-scale DSR involves the use of large amounts of IT infrastructure to control and aggregate a distributed load resource. The costs of consumer engagement, installation and technology costs are relatively high on a per kW basis, compared to conventional generators where a single connection connects hundreds of kW. It is therefore crucial for any small-scale DSR business model to minimise the per-unit costs. One approach to bring down the per-unit costs is to increase the unit size, going for larger loads and partnering with businesses which already have a relationship with the relevant customer bases.

On the income side, small-scale DSR requires large price spreads and high revenue markets to cover the costs. The cost-of-connection to potential revenue ratio is high in the frequency control and reserve markets, as connection costs for DSR in these markets are very similar to the spot markets, with much higher yields. Less competition in frequency and reserve markets leads to higher prices. However, they are technically more challenging for most of the market participants including small-scale DSR. In ERCOT stakeholders do not consider small-scale DSR suitable for any frequency markets due to the technical challenges of aggregating distributed loads and the speed at which these loads must communicate and react to frequency deviations. On the other hand, certain actors in Finland, including technology service providers and retailers, are cooperating to aggregate loads and bid in to frequency reserves although this is a new revenue opportunity for them and not yet commercially implemented. In PJM, the major barrier for small-scale DSR participation in frequency markets is the small market volume, and in Norway it is the prevalence of cheap flexible hydropower. Business models based on storage devices may be more suited for frequency markets; Germany and ERCOT currently have battery storage capacity providing frequency support.

5.2.1.3 Consumer engagement and participation

The case study research does not allow general conclusions on whether one type of consumer engagement strategy is particularly useful over another as different strategies were reported in each case. This section therefore reports on the general observations made under this area and lists the main engagement strategies pursued by the interviewees in each region.

Consumer engagement strategies are diverse. This stems from the variety in the customer base, so successful strategies alternate between them and between regions. The main consumer engagement strategies identified in the case studies are:

- Economic benefits: appealing to cost saving potential
- Environmental benefits: appealing to ‘green’ credentials and CO_2 savings
- Customisation of product offerings: providing tailored products and services based on behavioural data of consumer segments.
- Simplification: ensuring products are simple to understand which makes it easier for customers to both trust and use the product.

A pathway to small-scale DSR mentioned was the use of smart home technology that is brought into the consumer’s house for comfort and security purposes. DSR would be a welcome by-product and could be realized at low cost. Smart home applications are not a DSR enabler per se, but can become a major player. In the case studies, home automation serves as a ‘door opener’ for small-scale DSR. Consumers are not primarily interested in demand response, but are interested in home automation for comfort and security. As one home automation provider put it: *“what we give is a perfect home. We can give you very accurately the type of comfort you want. And that is why the customer is getting involved – they don’t even know about DSR…!”* Driven by this interest, the consumers are willing to cover the costs of the technology and installation.

Having smart-enabled homes allows small-scale DSR to use existing infrastructure and thereby avoid some of the technology costs. With partnerships, the smart home technology can be developed with DSR applications in mind, ensuring that it is ‘DSR-ready’. Without partnerships, the interviews suggest that home automation providers would not be interested in DSR applications. .

Table 6 summarises these findings.

Table 6: Overview of the main themes and their presence or absence in each case study.

	Norway	Germany	Finland	Illinois	Texas (ERCOT)
High flexibility and capacity needs?	No – 98% of country's power production is flexible hydro power	No – 120 GW capacity (including interconnection) compared to 80 GW peak demand	Yes – 15 GW of peak demand compared to 11 GW of capacity.	No – highly interconnected with surrounding states. Large capacity market	Yes – electrically an island with limited interconnection
DSR has access to appropriate markets and tangible revenue or cost saving opportuni-ties?	No – no small-scale DSR partaking actively in markets. Price signals currently flattened by average consumption settlement profiles and abundance of flexible hydro	No - no small-scale DSR partaking actively in markets. Price signals currently flattened by average consumption settlement profiles and lack volatility	Neutral - small-scale DSR participating via RTP and time-of-use. Real consumption settlement rewards reductions and commercial actors are positioning themselves to offer a wider suite of products	Yes – however, power prices lack volatility. Capacity market encouraging participation in lieu of energy market signals	Yes – settlement arrangements in real-time balancing market combined with sufficient price volatility encourage load reductions
High electricity loads per customer site?	Yes – highest of all cases with 85% of energy household consumption from electricity	No – lowest of all cases with 21% of energy household consumption from electricity	Neutral – 36% of energy household consumption from electricity	No – 27% of energy household consumption from electricity	Yes – 61% of energy household consumption from electricity

	Norway	Germany	Finland	Illinois	Texas (ERCOT)
Utilises partnerships to enable value creation?	Neutral – only to a lesser extent as there are limited products and services	Yes	Yes – retailers and technology service providers (TSPs)	Yes – retailers, TSPs and appliance manufacturers	Yes – retailers, TSPs and appliance manufacturers
Challenging techno-economics?	Yes – hardware and installation costs currently high	Yes – hardware and installation costs currently high	Yes – hardware and installation costs currently high	Yes – hardware and installation costs currently high	Yes – hardware and installation costs currently high
Home automation considered an in for DSR services	Yes	Neutral	Yes	Yes	Yes

5.2.2 Other observations

Policy and regulation play an important role in developing DSR, but the majority of products, services and business models are developed in response to market and power system needs.

The experiences reviewed in the case studies indicate that regulators generally set the direction and trend of DSR efforts, for example by mandating a level playing field for DSR in the ancillary markets, legislating grid operators to consider demand-side management in their system planning, or mandating the roll out of smart meters and real consumption settlement. These regulations are normally a response to a perceived need for energy security, resulting from lack of flexibility or narrowing capacity margins. It merits emphasis that in regions like ERCOT and PJM these mandates have played crucial roles in including DSR as a flexibility option in the power system and likewise in Finland and Norway smart meters were implemented in response to government mandates.

Once these regulations are in place, DSR development is mostly driven by market actors, the system operator and other involved stakeholders. Ultimately there has to be a market need and market demand for the service provided by DSR. Regulators can set the direction but whether consumers ultimately sign up for a time-varying tariff will depend on factors such as the value opportunity, the business model and the marketing and customer engagement practices of the operators.

There is no single solution for involving small-scale users in DSR

All five cases are at different stages in the development of small-scale DSR and all have followed different paths. PJM encourages DSR via the capacity markets while ERCOT does so via the energy market. Finland is currently pursuing options via real-time pricing and is carefully considering options in the reserve markets. The interviews suggest that the key factor is to provide an attractive market opportunity for the DSR provider which generally includes favourable price signals and revenue certainty.

5.3 Conclusions from the case studies

The case studies set out to understand what factors have led to the relative development of small-scale DSR in the five regions studied. The project team applied a conceptual framework that stressed the presence or absence of factors (the identified themes) in each of the three areas of the conceptual framework: 1) policy, markets and regulation, 2) business models and 3) consumer engagement. The main findings are listed below in respect to the four research questions:

Research question 1: what is the role of policy in promoting DSR from smaller users, what has worked and why?

1. The case studies show that policy and regulatory interventions generally take the form of mandating a certain direction of travel to incorporate DSR in to the power system. This type of regulation has especially been observed in PJM and ERCOT where either the state legislature or the relevant Public Utilities Commission have mandated either price responsive tariffs (as in Illinois PJM) or that the market operator creates rules to the benefit of load reductions.
2. High flexibility and capacity needs in the power system, whose development, e.g. through policy on renewables, create an opportunity for more novel and (currently) higher cost flexibility options to contribute.
3. Tangible revenue or cost saving opportunities must be present for the retailer also after mandates or standards have been implemented. Appropriate price signals flowing from a market (either energy, ancillary, capacity or balancing) through to retailer and the consumer are necessary. Prices need to be volatile to encourage DSR participation in the energy markets.

Research question 2: what novel business models are being used to access DSR from smaller users, have they worked and why?

4. Bring Your Own Device (BYOD) is one novel business model particularly observed in the US where the customer buys a DSR-ready device (e.g. smart thermostat) from an appliance manufacturer, which helps reduce costs.
5. Capacity markets and energy markets are currently the two major value opportunities for retailers and DSR providers in the case study regions as these provide revenue and cost saving opportunities (link to point 3 above). No small-scale participation in the reserve markets was observed.
6. Commercial actors target high electricity loads (often via heating or cooling needs) per customer site as this lowers costs per connection and creates the necessary market volumes of shiftable loads.
7. Business models tend to focus on establishing partnerships across the supply chain as to allow for sharing of specialised knowhow and cost reductions.
8. The techno-economics of small-scale DSR in particular in regard to cost of hardware and customer acquisition and the technical requirements of reserve markets are still considered a challenge for wide spread adoption of small-scale DSR.

Research question 3: what DSR products and services have been used internationally to secure demand response from smaller consumers?

9. The most popular tariff (apart from legacy time-of-use tariffs) identified in the case studies is the critical peak rebate with an uptake in ERCOT and PJM of 7% and 4% respectively. Real-time pricing is one of the least popular tariffs of the products identified in the cases – less than 1% of households in Finland, ERCOT and PJM are enrolled in a real-time pricing tariff.[9]

Research question 4: what are the key factors affecting consumer engagement in terms of: recruitment, level of response and persistence?

The case studies do not produce definitive conclusions about the merits of one consumer engagement strategy over another and the key factors influencing level of response and persistence. However the main engagement strategies mentioned by the interviewees are:

- Economic benefits: appealing to cost saving potential
- Environmental benefits: appealing to 'green' credentials and CO_2 savings
- Customisation of product offerings: providing tailored products and services based on behavioural data of consumer segments.
- Simplification: ensuring customers are on board with and fully understand the product they are buying

Another consumer engagement strategy mentioned was the use of smart home technology brought into the consumer's house for comfort and security purposes with DSR services tagged on at a later stage.

[9] However, it merits mentioning that the Peak Rebate numbers, in particular from ERCOT, are based on voluntary information provided by retailers and estimations from ERCOT and should be considered indicative.

6 Synthesis and GB conclusions

This section presents and discusses the combined findings from the REA and the case studies. Together they show that there is no single path to engaging small-scale users in providing DSR services. Potential paths feature a need in the power system, business models that capitalise on this market need, and a willing consumer base that participates in the offered products and services. Furthermore, the way products and services are designed and the way customers are engaged plays an important role in determining the uptake of these products and services. The combined findings are summarised in the following sections which follow the four research areas. Please refer to Figure 3 (pg. 11) for the synthesis methodology.

6.1 Policy interventions

Research question 1: what is the role of policy in promoting DSR from smaller users, what has worked and why?

6.1.1 Policy has been crucial to support small-scale DSR development and is generally driven by a high need for flexibility

The REA found limited evidence assessing the success of various policy and regulatory interventions in supporting small-scale DSR. However, the existing evidence suggests that DSR has required strong policy and regulatory support in the absence of which development would have remained low. This has been identified in a range of studies from across the EU and US. The case studies support this notion and show that policy and regulatory interventions generally take the form of mandating a certain direction of travel to incorporate DSR in to the power system. Other regulatory interventions include mandating smart metering and transitions to accurate settlement processes.

Experiences from the case studies include where the regulator has been driven to promote demand-side resources by events that reveal the vulnerability of the power system and its ability to satisfactorily maintain the integrity of the grid. (In Norway, the event was a capacity squeeze due to low rainfall in the early 2000s, leading to low output from the country’s hydropower dams. In ERCOT, the deregulation of the retail sector led to a loss of 3,000 MW of flexible demand-side resource).

Overall, the main policy interventions identified across the REA and case studies include:

- **Policies to support smart metering roll out –** which are widely seen as an enabler for developing DSR.

- **Standards for smart appliances -** an open standard for the development of smart appliances, including a minimum set of demand response functionalities for key appliances and the requirement for a standard interface.
- **DSR product definition -** programmes to enable end-users to receive payments for reducing demand at times of high market prices, or capacity shortages (Crossley 2008a), sometimes referred to as economic and emergency DSR.
- **DNO price control framework** – a new price control framework in Australia was created to support investment in demand-side management in 2004. These have also been in place for Oncor (the main TSO in ERCOT).
- **Mandating retail suppliers to offer time-varying tariffs -** such as real-time pricing and critical peak pricing, this has particularly been pursued in the US including PJM and California.
- **Mandating DNOs to account for demand-side management** in network planning
- **Mandating** system operators to allow DSR resources to participate in all relevant markets on equal footing with generation

6.1.2 Tangible revenue or cost saving opportunities should be present in the market

The review of evidence on policy interventions included evidence collected on market conditions.

The REA found that revised market and technical arrangements initiated by regulators or system operators, and affecting network owners/operators can allow market participants to access the value of DSR. The case study experience suggest that the success of DSR once such market arrangements have been put in place is also influenced by factors including the existence of appropriate price signals and whether there is a tangible revenue or cost saving opportunity present for the DSR provider and end consumer.

Small-scale DSR participates almost exclusively in the real-time energy market in the deregulated areas of ERCOT which is enabled by relatively volatile prices (compared to the other regions examined in this study). This means retailers and aggregators can instigate a load reduction in their portfolio to capitalise on high price events. In PJM, the capacity market provides the appropriate price signals to support small-scale DSR participation. Overall the evidence suggests that markets and regulatory frameworks must present a tangible revenue or cost saving opportunity for actors to invest in DSR products and services even after intervention from the regulator.

6.2 Business strategies

Research question 2: what novel business models are being used to access DSR from smaller users, have they worked and why?

The REA revealed relatively limited evidence on business models and much more of the evidence related to products, services and consumer motivation. This may reflect the fact that in many instances consumer-level DSR is at the trial stage, whilst longer standing programmes may have been introduced in regions where unbundling is limited and DSR was rolled out by incumbent utilities. The majority of findings in this section are therefore from the case studies. Nevertheless, there is general agreement across the evidence base on how commercial actors attempt to bring their products to market and the various enablers and barriers they face in doing so. This report's conclusions on business models include:

- Business models (as for any commercial activity) should have clearly defined project objectives, then select target markets and promote demand-side measures that suit the project objectives and target market.
- Establishing partnerships, such as those including appliance manufacturers and other companies with specialised knowhow, is a well-used strategy for scaling and reaching a wide customer base. A common partnership model observed is that between a technology service provider, a retailer and an appliance manufacturer. Bring Your Own Device (BYOD) is an example of a common business model in the US, including Texas and Illinois, utilising these types of partnerships.
- Both the REA and case studies note that the relative high costs of securing participation, when combined with relatively modest availability of flexible load per household, may act as a barrier to businesses considering DSR. This may be a more pronounced barrier for smaller independent actors who do not have access to an established customer base.
- The evidence base also suggests that high electric loads are important enablers of small-scale DSR business models. Two of the more advanced DSR regions (Finland and Texas) have a high percentage of final household energy consumption met by electricity via electric space and water heating or electric cooling via air conditioners.

6.3 DSR products & services

Research question 3: what DSR products and services have been used internationally to secure demand response from smaller consumers?

6.3.1 DSR products and services are becoming increasingly popular with consumers

The evidence base identified a large number of product types, tariffs and services offered to consumers. The REA revealed that at least 11% of US metered customers (16 million customers) are on some type of incentive base or time-based pricing. Equivalent data was not available for the EU but overall the evidence indicates that DSR programmes are growing and becoming increasingly popular with consumers. The most widely used product identified in the case studies is the critical peak rebate with an uptake in Texas (ERCOT) and Illinois (PJM) of 7% and 4% of customers respectively although these numbers should be taken as indicative only and are not robust enough to make assumptions about uptake outside of the case study regions. Neither did the interviews reveal any information on the specific designs of these products and the overall evidence base suggests a wide range of design features are being used from opt-in and opt-out to automation and manual response.

Real-time pricing is one of the least prevalent tariffs of the products identified in the cases – less than 1% of households both in Finland, ERCOT and PJM are enrolled in a real-time pricing tariff. In ERCOT the low uptake was pinned on the fact that when the first real-time tariffs were introduced, customers were highly penalised by a series of high price spikes. In Norway, however, the consumer is exposed to real-time prices but is billed on a monthly average and not exposed to hourly fluctuations. This is generally considered to be cheaper than the standard fixed tariff and is one of the more prevalent options in Norway.

6.3.2 Whether a tariff is opt-in or opt-out affects consumer engagement, as does automation

The REA considered both specific evidence on effectiveness of products identified in the rapid evidence assessment and the role of the user motivations, barriers and enablers. Limited evidence was identified on residential user engagement with more dynamic and unpredictable forms of pricing, such as dynamic time-of-use pricing and real time pricing. Some of this evidence suggests that it may be difficult for users to change electricity demand in response to more dynamic pricing, particularly without automation, although there are exceptions where users did manually respond. However, there is strong evidence that consumers respond to more static time-of-use and/or critical peak pricing.

The REA found a substantial difference between opt-out and opt-in tariffs on enrolment, but also, and offsetting this, in the extent to which enrolled consumers then respond. (The case studies did not find any type of evidence on opt-out versus opt-in tariffs). Enrolment in DSR is typically voluntary, but time varying pricing can be implemented on an opt-out basis where users are placed onto the tariff with the option to leave. This could reduce recruitment costs compared with opt-in recruitment. Unsurprisingly, recruitment by opt-out results in much higher recruitment than by opt-in, which is likely due to default or status quo bias. However, many users who choose to not opt-out do not change their electricity use. The ComEd CAP identified no significant demand reductions overall in a participant group of around 8,000 households, but identified a subset of around 10% of participants who did respond, which is similar to the response one can expect from an opt-in tariff.

Automation or direct load control was identified to enable high response but also that it is more suited to background loads like heating. Enrolment, however, is not improved by offering automated products, nor did the evidence suggest an impact on retention rates. It should be noted that automation is essential if small-scale DSR is to be used for balancing the grid via frequency reserve markets due to the fast response times required. Experience from the case studies also suggests that controllable loads may be more valuable for an aggregator or retailer (compared to a dynamic tariff) as they can be used to balance scheduled portfolios in the power markets.

The REA found less conclusive evidence on the impact of price ratios and in-home displays on user engagement. Overall, in-home displays have the potential to act as an enabler of response. However, evidence from trials suggests that in-home displays have no impact on peak-demand reduction.

Overall the evidence on price ratio and its effect on consumer engagement is inconclusive. A review of the US DoE Consumer Behaviour Studies (CBS), for example, found that average response without automation technology was higher for higher price ratios, but there was considerable variation in responses. A review of a large number of international DSR studies found that average levels of response increases as price ratio increases, but at a diminishing rate. This evidence is also made unclear by the fact that results appear to vary by other DSR characteristics (e.g. presence or absence of automation) which further complicates evaluation.

Table 7, on the next page, summarises the effectiveness of product or service design features on enrolment, response and persistence.

Table 7: Summary of evidence on effectiveness against key differences in potential DSR offerings – price ratio, price/rebate, information/display, automation/direct load control and recruitment (opt-in or opt-out).

Product design features	Enrolment	Response	Persistence
Larger vs smaller price ratio	No evidence identified	Mixed results. Often co-varies with other DSR characteristics, complicating evaluation	No evidence identified
Rebates vs pricing	Similar for both pricing and rebates, though some evidence that enrolment in rebate schemes is lower risk	Smaller and more variable for rebates	Slightly higher for rebates
In-home display	No impact on measured enrolment rates in US CBS	Mixed results	No evidence identified
Automation/direct load control	No evidence on measured recruitment rates, but automation suggested as a motivator for some users	Presence of automation and direct load control tends to increase response	No evidence identified
Opt out vs opt in recruitment	Much higher for opt-out	Lower average response for op-out. Similar aggregate response, although evidence is mixed	Limited and mixed evidence. Some evidence that consumers made worse off through opt-out seek to leave DSR schemes

6.4 Consumer engagement & participation

Research question 4: what are the key factors affecting consumer engagement in terms of: recruitment, level of response and persistence?

The REA revealed a rich evidence base on wider factors that affect consumer engagement with DSR. There is evidence on motivations for enrolment, trust and reputational issues, technology, risk, control/over-ride, complexity and household routines. Three key areas to which the evidence gives a considerable amount of attention are discussed below while the evidence base as a whole is summarised in Table 8 on the next page.

6.4.1 Financial and environmental benefits are main motivations for enrolment in DSR programmes

The most common types of motivations identified in the REA were financial and environmental benefits. These motivations were often mentioned by interviewees in the case studies and listed as primary selling points from a customer engagement point of view. Interviewees also noted that environmental selling points are not sufficient in and of themselves and that some type of cost saving is expected before a customer signs up to a product or service.

6.4.2 Trust, risk and complexity are key factors affecting consumer engagement

Issues around trust could form a barrier to enrolment in the form of concerns about privacy and autonomy, or energy company motivations for pursuing DSR. Evidence reviewed in the REA also found that trust can be an issue after users have enrolled in DSR, which is generally associated with technical issues and lack of transparency around automation or dynamic pricing. This could be overcome through providing feedback on the direct load control actions that have been taken, providing information on DSR from independent sources, and transparently communicating how users and energy companies are rewarded for providing electricity system services and how other parties benefit from DSR. The case studies found that trusted intermediaries, such as a local authority or trusted retail supplier, could be used to increase engagement.

The evidence also suggests that both perceived and actual ease / difficulty of response can change due to the design of DSR products and services - in particular automation may reduce perceived effort and enable response (though some automation itself can be difficult to use), while more complex pricing may increase perceived effort and risk and hinder manual response. Some users may therefore prefer low price spreads or a price cap to more dynamic pricing schemes. Simplification of product offerings could potentially increase trust which in PJM was reported to increase customer enrolment in real-time pricing. However, the evidence reviewed in the REA is not clear on how to most effectively minimise risk or complexity. It merits mentioning that while perceived financial risk can deter enrolment in more complex pricing schemes, it may also support response once a customer has enrolled. The US CBS trial found that responses to critical peak pricing were larger and more consistent than responses to critical peak rebate. This may be due to the absence of financial loss associated with critical peak rebate (as the user only forfeits a cost saving or additional revenue).

6.4.3 Household routines impact consumer response

The evidence base pays considerable attention to routines, with both daily and seasonal factors affecting response. For example, one trial found that participants viewed appliances for which they had the least fixed routines as the most flexible. Demand shifting could therefore be enabled if it can involve behaviours that fit well with existing routines. Although the case studies did not touch on this explicitly, the customisation of product offerings based on behavioural data of consumer segments was mentioned as one of the key strategies utilised in Texas to engage consumers. The perceived impact DSR may have on comfort levels in the home was identified as a barrier to automatic response if the customer decides to utilise the override switch. Also, several studies identified time outside the home as an important variable impacting response, and spending more time in the home, or flexible working hours, was found to be an enabler of response. The review did not identify any evidence on the degree to which household routines affect enrolment.

Table 8: Motivations, barriers and enablers for residential user engagement with DSR

	Enrolment	Response	Persistence
Motivation	Mainly financial benefits, with a secondary focus on environmental and social benefits	No evidence identified	No evidence identified
Familiarity with and knowledge of DSR	Reputation/awareness of DSR and supporting technologies may be a barrier or enabler	Lack of technical skills and understanding of DSR may decrease response	No evidence identified
Trust	Barriers may be associated with organiser motivations, privacy and autonomy	Trust may be undermined by poor technical performance, delays or unexpected outcomes. Could be reduced by proactive management and open communication about any problems, and provision of clear information about the range of outcomes consumers may expect of a DSR programme	

	Enrolment	Response	Persistence
Technology requirements and technical issues	Absence of certain technologies or requirement to install new technologies can act as barriers to enrolment	Technical problems, especially with communication, can limit response	Technical problems may reduce engagement and erode trust
Risk	Stated preferences suggest financial risk is a barrier, but little difference in recruitment rates for critical peak rebates and critical peak pricing in US CBS	Financial risk may increase response (evidence on higher price levels, price rather than rebate)	Financial risk may decrease persistence (Retention somewhat higher for critical peak rebates than critical peak pricing in US CBS)
Perceived control	Concerns may be associated with direct load control, and be reduced by override and other control options	Concerns may increase or decrease following actual experiences of direct load control or smart automation, influenced by familiarity, level of feedback and control options provided to users	
Complexity and effort	Perceptions of and experienced ease or difficulty of response can change with DSR product/service - in particular automation may reduce perceived effort and enable response (though some automation can itself can be difficult to use), while more complex pricing may increase perceived effort and hinder manual response. Perceptions and experiences also seem to vary amongst users		
Interaction with user routines and activities	No evidence identified	Automated responses to heating/cooling may have minimal impact on routines. Manual response involving wet appliances appears to be limited. Demand shifting could be enabled if it fits well with existing routines, or does not affect routines. Some users make larger changes to routines and activities	

6.5 Enablers and barriers: Evaluation of findings in the GB context

The evidence suggests that consumers respond to time-of-use prices, will accept a degree of automation or direct load control, and that small-scale DSR is clearly feasible. However, beyond that the overall picture is rather complicated and highly context specific. This means it is important to think carefully about GB context.

In general, key enablers include the provision of incentives of some form for consumers, whether price signals or rebates, differentiated by time-of-use. There is some experience in GB already (time-of-use tariffs such as ‘Economy 7’), though GB smart meter roll-out will be a step change that could enable much higher rates of participation. However, the research presented here indicates that consumer response to price varies considerably, as does response to information. The wider enabling environment includes who consumers trust, whether DSR is intelligible and whether financial incentives are material for engagement – both for consumers and for DSR service providers. For DSR service providers (e.g. retailers) the evidence suggests that a tangible business opportunity should be presented to encourage the development of products and services.

For DSR business models to create sufficient value for consumers and commercial actors the evidence suggests that there needs to be sufficiently high electric loads at each customer site. This helps reduce connection costs and increases the economic value of each site. The evidence also suggests that the load must be shiftable – in many of the cases reviewed this is through electric heating, water heating or cooling. Yet in GB the majority of heat demand is met using natural gas and electrical loads are modest. *Prima facie* this suggests that most GB households currently are unlikely to offer high DSR value to commercial actors (although this is subject to change, particularly with the electrification of heat and transport, as set out below).

The evidence base also suggests that high price volatility is important to unlock the full value of DSR. How GB electricity prices develop will likely depend on a number of energy policy decisions on issues of resource adequacy (e.g. the capacity and reserve market) and available flexibility in the power system (e.g. level of nuclear versus fluctuating renewables and interconnection options).

Trust in the energy sector and whichever entity is providing the DSR product or service to the consumer has been identified as a key component of customer engagement. Issues around trust could form a barrier to enrolment and appears to focus on two areas: 1. privacy and autonomy concerns around direct load control, and 2. uncertainty around energy company motivations for pursuing DSR. The evidence suggests a number of solutions, as described previously. The case studies found that trusted intermediaries could be used to increase engagement, although who is trusted is likely to vary between countries.

The question of which companies are trusted by different sections of GB also bears upon another finding in this study, namely that partnerships are important to enabling new business models in the small-scale DSR space. Partnerships allow resource sharing, tapping into specialised knowhow and ultimately reducing costs. Key to these partnerships is the electricity retail suppliers that were found to provide both access to a large customer base and a recognised and trusted brand name. Whether aggregators and other technology service providers can count on retailers as a way in to GB consumers' homes, as for example has happened in Finland, Texas and Illinois, is likely to depend on the level of the public's trust in these companies.

6.6 Potential implications for future deployment in GB

6.6.1 DSR is one of several flexibility options to be evaluated

Where DSR has been successfully applied, it has been able to address a system need for flexibility cost effectively, whilst also providing value for commercial actors and consumers. Flexibility is a growing requirement in GB system, but DSR is just one of several options that can provide it, and this study has not compared DSR with other approaches. Market and policy developments that affect the commissioning and use of interconnection, flexible generation and storage will affect the overall context in which small-scale DSR may be financially feasible.

6.6.2 Electric loads could be affected by transitions across the energy system

The evidence presented in this study suggests that if small-scale DSR is to be attractive to prospective providers there need to be a sufficient volume of shiftable loads per customer site. Current electricity consumption in GB households and the type of loads constituting this consumption (fridges, washing machines, kettles and other light weight appliances) may not provide sufficient volume of shiftable load for wide scale application. One important question is therefore whether higher electric loads will increase in future. Developments in domestic heating and vehicle electrification may impact this, as discussed below.

Storage heaters: Sustainability First estimated 18 GW (125 GWh) of installed demand of electric storage heaters in GB (Frontier Economics and Sustainability First, 2012) – or about 2 million households (*Ibid.).* The majority of which use Economy 7 meters and time-of-use pricing to receive a cheaper tariff overnight. It is estimated that 500,000 of these are switched dynamically while the remainders are switched at static times (Ibid.). In England, the English Housing Survey (EHS) reports that 5%, or 1.2 million households, use storage heating (Department for Communities and Local Government, 2016a). The EHS further reports that 8% of English households have an immersion hot water tank (Department for Communities and Local Government, 2016b). In contrast to electric vehicles or other forms of electric heating, storage heaters and hot water tanks therefore represent an established source of shiftable load in GB. However, households with storage heaters may need to replace them with newer ones capable of providing a wider range of DSR services.

Decarbonisation of heat: developments related to the decarbonisation of domestic heating may influence the viability of small-scale DSR. A largely hydrogen or biogas-based approach is unlikely to develop the needed electricity volumes for residential DSR. District heating would also keep electricity loads to modest levels. Electrifying heating via heat pumps, electric hot water tanks and cookers would increase the electric load per customer site, and potentially provide greater business opportunities for DSR.

Deployment of electric vehicles: the roll-out of electric vehicles provides another possibility for increasing electric loads. Although uptake is currently modest, many vehicle makers and observers expect a strong rise in electric vehicle sales in coming years. National Grid's Gone Green scenario in its Future Energy Scenarios estimates that electric vehicles' annual electricity demand could increase to 5 TWh/year by 2025 and have a peak demand of 1.7 GW. This load will be strongly coincident with the evening electricity peak without utility-managed 'smart charging' which is a logical expectation of the system operator.

Domestic battery storage: although domestic battery storage is still not an economic proposition for customers, costs are expected to fall significantly over the next decade, contributing to a wider adoption. The economic case will likely strengthen further in combination with solar PV and a wider suite of time-varying prices related to the smart meter roll out. Eunomia (2016) estimates 800 MW of behind-the-meter domestic storage by 2020.

6.6.3 Potential business models

The evidence in this research suggests a number of potentially operational business models by 2025. The below presents a possible business model scenario for 1) storage heaters and 2) electric vehicles. It should be stressed that these have not been subject to a detailed appraisal, and they should be treated as examples of potential business models rather than the only ones available. The figures below show the high-level process of each model and the enablers as identified in the evidence base.

6.6.3.1 Retrofitted storage heaters load following renewable energy or responding to high price signals

This model could be adopted based on a retrofit of the existing stock of storage heaters. In contrast to today's predominantly static charge settings, updated communication features and the smart meter roll-out may enable a more dynamic use of these loads to enable retailers to achieve additional cost savings via optimised wholesale purchasing. These savings can then be passed on to the consumer. This is currently the case in Finland with the use of real-time pricing in combination with home automation systems. This model is outlined in Figure 7.

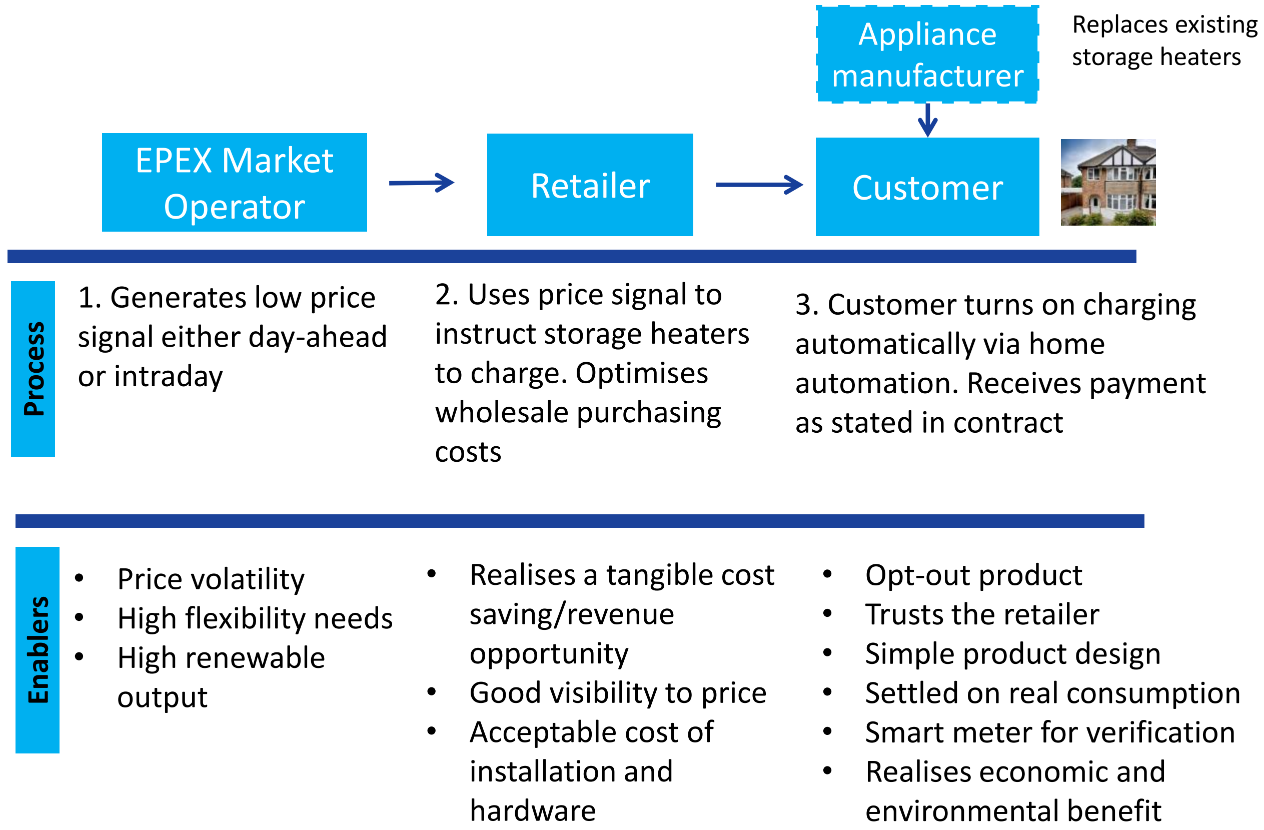


Figure 7: Potential storage heater business model

An alternative would be for retailers to use the storage heaters for trading on the day-ahead or intra-day markets and exploiting price swings (as currently the case in Texas) combined with renewable load following. However, this business model presupposes that charge times for storage heaters coincide with price spikes which may not be the case. There is also uncertainty around the degree to which storage heaters would drive peak demand in GB as air conditioners drive peak demand in Texas during summer months.

6.6.3.2 Vehicle-to-grid providing frequency response services to National Grid

Electric vehicles are suitable to provide a range of services to National Grid. Costs of charging infrastructure and challenges associated with aggregation are still barriers to deployment, although these may be overcome over the next decade. One potential business model by 2025 would be an aggregated vehicle pool providing frequency response to National Grid. In this example, the car manufacturer provides the DSR ready charger with an opt-out option to the customer. This way the aggregator can immediately aggregate the load in the EV to provide frequency support to the grid, while minimising customer acquisition costs. This model is outlined in Figure 8.

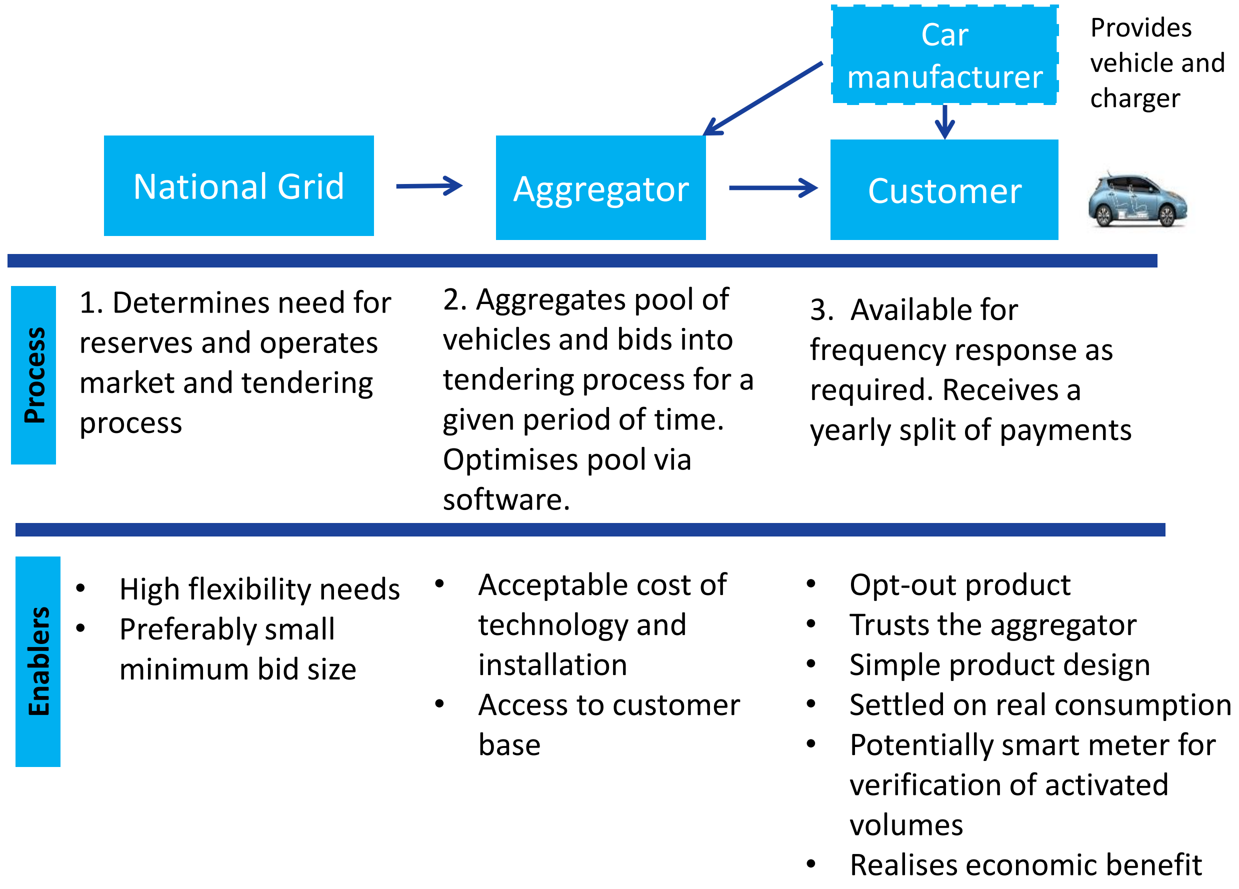


Figure 8: Potential vehicle-to-grid business model

6.6.4 Summary

Shifting demand offers the potential for benefits such as reduced need for generation and network capacity that may only be used for limited periods during a year. It may reduce the need for some new power plant construction, increase asset utilisation and reduce overall costs, whilst retaining high levels of system security, and realising cost savings for consumers. The smart meter roll out combined with new ICT and remote load control technologies make new forms of demand-side participation possible, and DSR has recently seen significantly more attention both in GB and internationally. These enabling technologies mean that an increased number of consumers, including households and small commercial premises, could potentially be offered commercial terms which reflect in some way the real time price of electricity.

Through a combined approach of an REA and five international case studies, this report reviewed and contributed to the evidence base in several areas critical to the deployment of small-scale DSR including policy interventions, business strategies, products and services and consumer engagement.

The evidence highlights that most DSR has historically taken the form of simple and static time-of-use or critical peak pricing tariffs, often combined with direct load control. Facilitating more engaged and more active DSR in the future is likely to come through automation, as well as pricing. This may be delivered through new business models, but supportive policy and market conditions are required to enable the potential value of DSR to be realised by market participants. Successful deployment of DSR depends on consumer offerings being straightforward and comprehensible. Moreover, it will be important to build and maintain consumer trust if end users are to engage, respond and remain enrolled in DSR tariffs, products and services.

Department for Business, Energy & Industrial Strategy
1 Victoria Street, London SW1H 0ET
www.gov.uk/beis