Department for
Business, Energy
& Industrial Strategy

REALISING THE POTENTIAL OF DEMAND-SIDE RESPONSE TO 2025

A focus on Small Energy Users

Rapid Evidence Assessment report

November 2017

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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*)

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Contents

1. Introduction

This report sets out the detailed methodology and findings of the Rapid Evidence Assessment (REA) component of the project, supporting the synthesis of findings and conclusions set out in the separate Summary Report[1].

The report is structured according to the research areas and questions for the project, as set out in Table 1. Chapter 2 sets out the detailed methodology. Chapter 3 discusses findings on policy, Chapter 4 discusses business models and strategies, Chapter 5 DSR products and services, and Chapter 6 discusses small energy user engagement with DSR. References are provided in the reference document (insert link).

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?

The REA sought evidence on these areas and questions from reports of trials, programmes and surveys, focus groups or interviews, as well as reviews and meta-analyses of such studies.

The REA revealed considerably more evidence focused on products, services and consumer engagement and participation than on policy or business strategies. Much of the evidence base is derived from surveys, trials and existing utility programmes featuring static time-of-use or peak load control. Innovative forms of DSR are mainly explored through trial and surveys, with limited experience of large scale deployment. There may thus be some bias in the evidence base toward stated preference rather than actual behaviours and towards those sections of the population more willing to engage in a trial.

[1] Insert link

The review revealed limited discussion of policy and business models. This reflects a focus on consumers and their engagement in trials/programmes or stated preferences revealed through surveys. In many cases supportive policies may be required or presupposed but are not discussed in detail. Table 2 indicates that around 80% of the evidence revealed in the REA focused upon products, services and energy user engagement. This is reflected in the balance of the synthesis discussion provided in this section. A full list of studies reviewed in the REA is provided in the Appendix.

Table 2: Coverage by research area

Research area	Proportion of documents that address this research area
Policy and regulation	26%
Business models	32%
Products and services	84%
Consumer engagement	81%

Table 3 contains an overview of the REA evidence base, and shows the number of studies identified by the REA according to the type of small energy user and the type of DSR product or service included in the study. It is important to note that many studies included more than one type of product or service, and that some more uncommon DSR products and services (information only, peer to peer trading and battery-enabled DSR) are not included in Table 3.

Table 3 indicates that the evidence base is dominated by trials and surveys, with a much smaller number of full programmes. Stand-alone surveys, focus groups and interviews capture data from members of the general population on attitudes, beliefs and stated preferences (i.e. the participants may have no first-hand experience of the DSR products/functions that they are commenting on). This may or may not translate into actual behaviour or revealed preferences, which can be explored in a trial. However, many trials recruit end users on an opt-in basis (voluntary recruitment) and so involve a self-selected group of participants. Surveys, focus groups and interviews can offer some insight into the attitudes of those who might fall outside of this self-selected group, which may be particularly relevant to considering factors that might influence responses to DSR across the general population.

The studies concerned with consumer attitudes and motivations draw on a range of theoretical perspectives, each of which focuses on how different factors influence user engagement with DSR. These include behavioural economics, social psychology and social practice theory. The REA findings combine insights from these different perspectives but are focused principally on empirical review and synthesis and do not derive findings within any particular disciplinary perspective.

Table 3: Overview of the DSR evidence base

Location	Evidence type	Total no. of studies	Residential: no. studies (mean no. participants)	SME: no. studies (mean no. participants)	No. studies by DSR products and services						
					sTOU	CPP	CPR	dTOU/RTP	IHD	DLC	Automation
UK	Trial	10	8 (442)	2 (4)	4	0	0	1	3	3	3
	Programme	0	0	0	0	0	0	0	0	0	0
	Survey	2	2 (1017)	0	2	0	1	1	0	1	2
Europe	Trial	9	9 (923)	0	4	1	0	5	1	1	2
	Programme	1	1 (no data)	0	1	0	0	0	0	0	0
	Survey	4	4 (666)	0	1	0	0	2	0	2	3
North America	Trial	21	19 (7414)	2 (1000)	11	10	3	3	8	0	7
	Programme	2	2 (no data)	0	0	0	0	0	0	2	0
	Survey	6	6 (1599)	0	2	1	0	0	0	1	1
Australia & NZ	Trial	3	3 (142)	0	2	2	0	0	0	1	1
	Programme	1	1 (no data)	0	0	0	0	0	0	1	0
	Survey	1	1 (53)	0	1	0	0	0	1	1	0
Totals		60	56	4	28	14	4	12	13	13	19
Reviews, meta-analysis and policy-analyses		18 studies									

2. REA methodology

The REA was conducted in accordance with guidelines from the Government Social Research Service. The aim was to establish the current state of the secondary evidence base in respect of the research questions described in Table 1. Evidence reviews typically require a trade-off between rigour and rapidity, and as Figure 1 shows, the REA approach is a form of constrained systematic review which aims to maintain as much as possible of the rigour of full systematic review within the time and resources available.

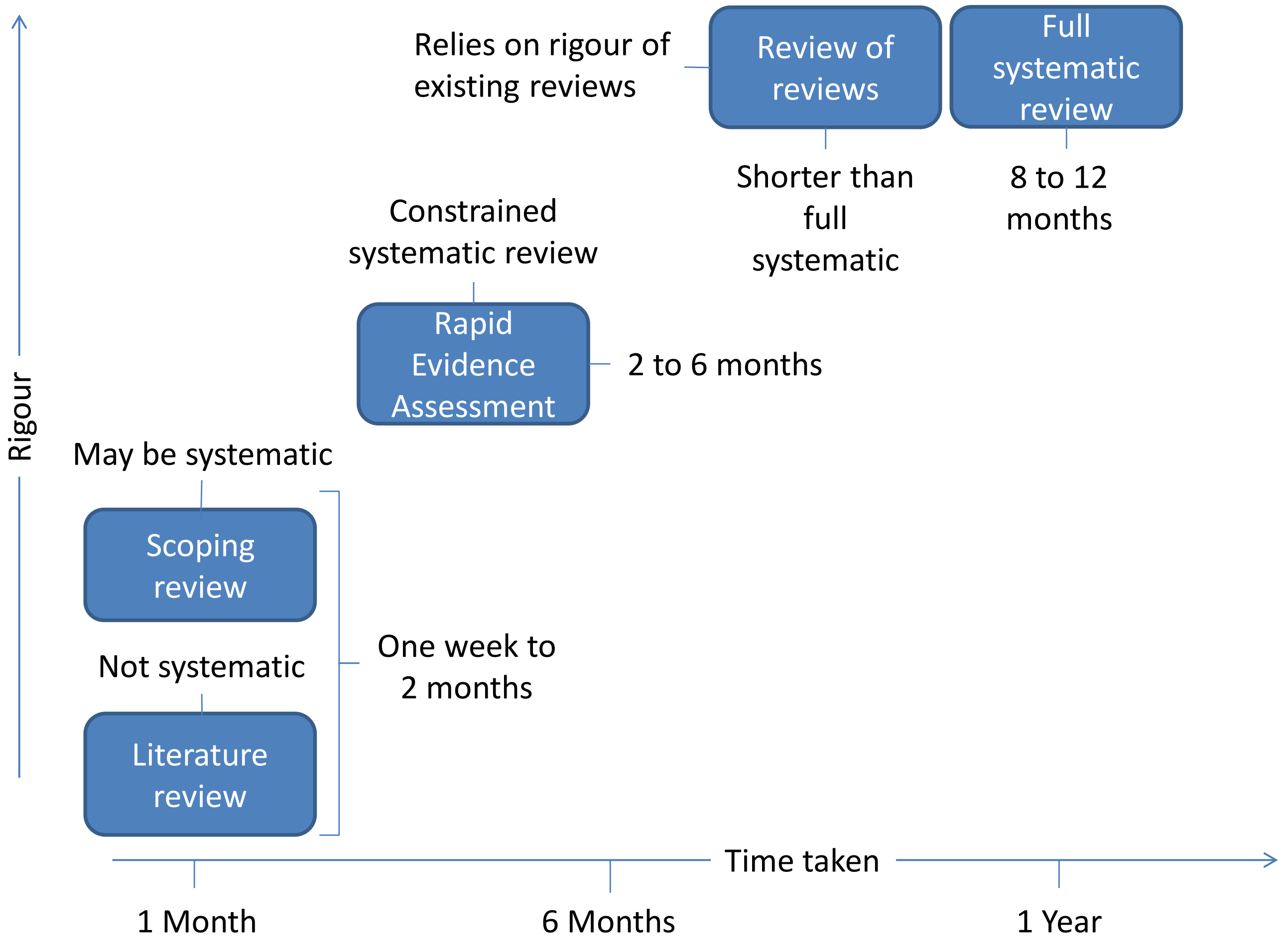

Figure 1: Mapping the different types of literature and evidence review methodologies

The key stages of the REA process adopted for this project are described in Table 4, with the outcome summarised in the form a flow chart in Figure 2.

Table 4: Key stages of the REA

Stage	Description
1	**Identify search sources and inclusion/exclusion criteria** The sources to be searched were agreed with BEIS, together with the evidence inclusion/exclusion criteria (see Appendix 1), the evidence quality assessment protocol, and the format of the evidence capture spreadsheet. Following discussion with BEIS, it was agreed that the project would adopt a combination of UKERC Relevance Rating approach and the BEIS Quality Assessment (QA) scale) to allow the team to focus on the most relevant evidence and ensure that evidence was of sufficient quality to warrant inclusion.
2	**Identify search terms and conduct searches** Combinations of search terms were trialled (see Appendix 1) to establish the most appropriate and the finalised search terms were applied to ScienceDirect and grey literature sources i.e. Electric Power Research Institute (EPRI), SmartGrid Consumer Behaviour Studies (CBS), European Commission Joint Research Centre (EC JRC) and the International Energy Agency's Demand-side Management (IEA DSM) program. In addition, two sets of policy-specific terms were applied to Google, and given the very large number of results returned the top 100 items from each of these two searches were taken forward to the first screening stage described below.
3	**Screening 1** Documents were excluded based on their title/abstracts. Bibliographic details for all the documents that passed this stage were recorded in the evidence spreadsheet.
4	**Screening 2** Documents were excluded based on their Relevance Rating, established by examination of the full document text. Only the most relevant were included in the next stage.
5	**Quality Assessment** The included documents were scored based on the BEIS Quality Assessment scale.
6	**Evidence gathering and synthesis** Documents that passed the Quality Assessment were examined in detail and their findings recorded in the evidence spreadsheet. The project team drew upon the completed evidence spreadsheet to draft the REA findings and synthesis sections of the final report.

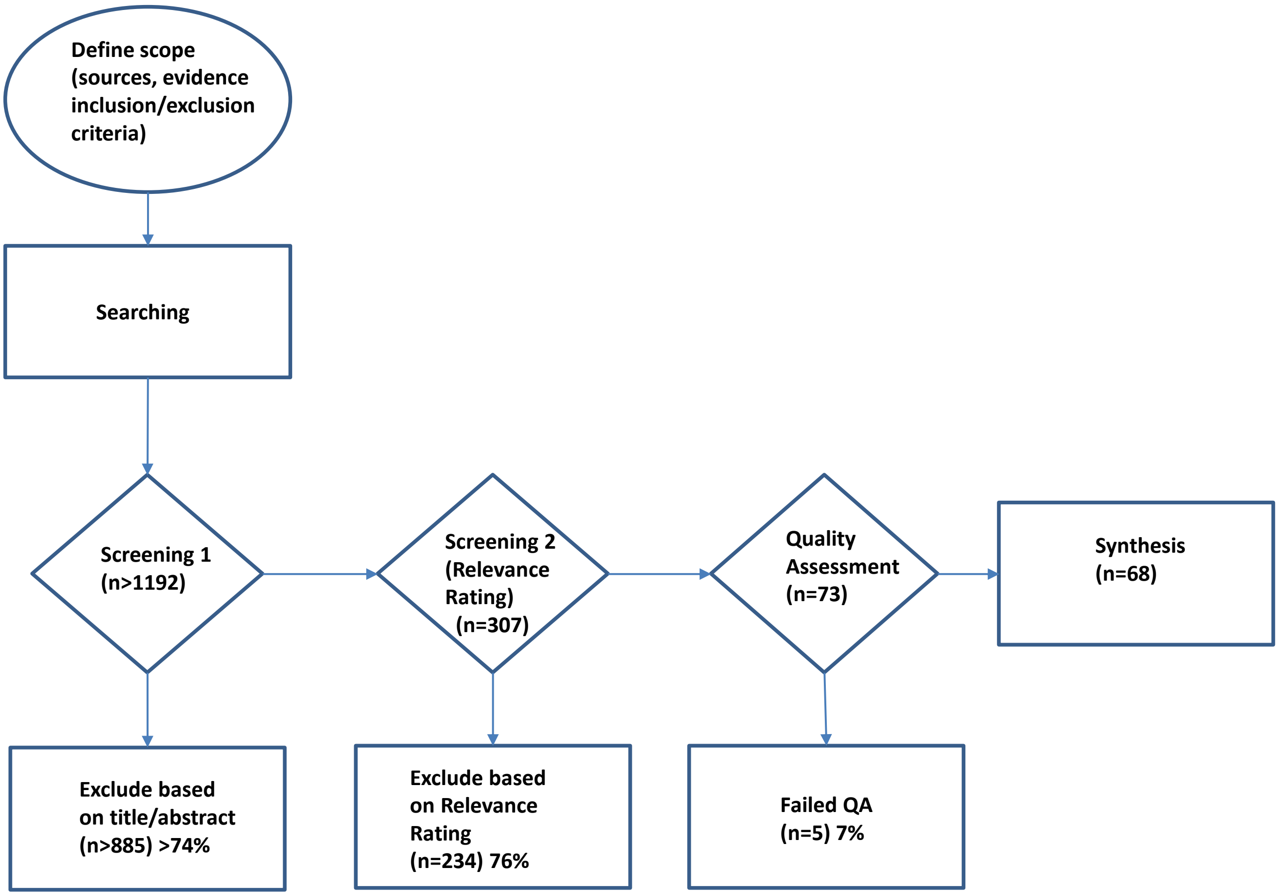

Figure 2: REA process flowchart[2]

The reporting and research quality of the documents that passed the first two screening stages were assessed using the Quality Assessment scale recommended by BEIS (Table 5). 68 documents which scored 6 or above were used for the synthesis.

The project team carried out parallel tests of both the evidence quality assessment protocol and data extraction process to confirm that these stages were being carried out consistently. For the evidence quality assessment test this involved two members of the project team independently evaluating the Relevance Rating and Quality Assessment scale of five documents and then comparing the ratings which they had assigned to each document. Any differences were then discussed to establish the reason and any issues arising from this discussion that required clarification were addressed with BEIS.

For the data extraction test, two members of the team independently populated separate copies of the evidence spreadsheet for five documents, capturing key data such as study

[2] 1192 represents the number of references revealed through searches of Science Direct and those grey literature sources for which the number of hits was available. A very much larger number of hits (over 400,000) were indicated in the Google searches. Google hits do not provide meaningful numbers in terms of evidence revealed and so are not reported here. Further details are provided in Appendix 1 and the supporting evidence spreadsheets.

or trial name, dates, number of participants, and sampling limitations, together with contextual factors and data relating to the research questions. Extracted findings were then compared to identify any significant differences in identification and/or interpretation. In practice, only very minor differences were revealed.

Table 5: BEIS Evidence Quality Assessment scale

Reporting Quality	Maximum score	Score
Are the rationale (1 point) and research questions (1 point) clear and justified?	2	
Does the document acknowledge resource contributions (1 point) and possible conflicts of interest (1 point)?	2	
Has the document been peer reviewed or independently verified by one (1 point) or more (2 points total) reputable experts?	2	
Are the methods used suitable for the aims of the study (1 point)?	1	
Do the conclusions match the data presented? (1 point)	1	
Does the author / publishing organisation have a track record in the area? (1 point)	1	
TOTAL (documents must score ≥ 6/9)	**9**	

3. Evidence on policy interventions

Key findings

Limited evidence about the role of policy 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.

Historically policy has played a key role in mandating DSR through static pricing or rebates, with direct load control. There is consensus across several reports that policy and regulation are essential to overcome barriers to DSR, and that without them, DSR amongst smaller users will remain low. Establishing effective regulatory frameworks and appropriate incentives that support and enable DSR are key to wider implementation of DSR.

Several documents discuss the role of policy in relation to smart metering mandates, 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.

3.1 Main features of the evidence base

Policy has played a key role in the development of DSR over several decades, in the US the Public Utility Regulatory Policies Act (PURPA) introduced a requirement to consider load management in 1978, with specific attention to time-of-use tariffs/smart meters initiated in 2005 (FERC 2016).The timeline in Europe is similar, with time-of-use tariffs introduced in the 1970s or 1980s (for example Economy 7 was introduced in the UK in 1978 (Electricity Council 1987)). More recent policy developments include the EU Third Energy Package of 2009 and Energy efficiency Directive of 2012 both of which contained important provisions related to promote the use of “so called smart meters” and allow for the introduction of time based prices (COWI 2016).

Despite this long history, relatively little discussion of policy and regulation was found in the REA. Many of the documents reviewed are concerned with the evaluation of programmes or trials, for which facilitating policy is either explicitly mentioned or is likely to have been required. However in many cases they provide little commentary on the underpinning policy environment. This does not in any way indicate that policy is not important. It is simply that many of the documents revealed in the REA take supportive policy as a given in order to investigate other aspects of DSR.

Regulatory obligations to implement demand-side management or consider it as part of integrated resource planning have led to considerable demand-side management activity in the US electricity industry (Crossley 2008b). However, the REA did not set out to document policy developments over decades and so does not capture, for example, the historical development of policy to permit demand-side programmes such as critical peak pricing/rebates/load control discussed elsewhere in the report.

The wider literature (documents not revealed through the REA) also provides some discussion of policy, which provides some context for the findings of the REA. For example Paterakis et al (2017) discuss the potential for policies to act as a barrier to DSR, noting that technical definitions and standards related to power system operation can explicitly exclude or effectively limit the participation of demand-side resources. In a review across the full range of demand-side policies, Warren (2015) finds that regulatory frameworks and appropriate incentives are the most important policy success factors related to demand-side management as a whole, and also for incentive payment-based DSR and price-based DSR specifically (the other key success factors for price-based DSR were found to be information infrastructure, clear aims and targeting, and consumer commitment). The findings from the REA on the evidence base are also broadly consistent with a more general concern that limited attention has been given to policy evaluation aspects of demand-side management, including DSR (Warren 2015). Many documents, both within the REA and in the wider literature only briefly mention policy before going on to discuss programmes, trials and DSR products and services in detail (see for example Paterakis et al 2017 and Strbac 2008).

The remainder of this section first summarises the key overarching findings relating to policy and regulation before discussing specific examples of specific policy or regulatory interventions revealed in the REA.

3.2 High level findings on the role of policy

Almost all of those REA documents that discuss the policy and regulatory aspects of DSR conclude that supportive policy and regulation are key factors that both enable and drive DSR. For example, the COWI (2016) study, which assessed the potential benefits of different policy options and the effects of different policies on different actors, concludes that the best compromise of costs and benefits may lie with policy where 'Demand [side] response is promoted by legislation that gives all EU consumers a right to demand access to smart meters and dynamic pricing contracts, and standardised EU market rules are established for demand response service providers'. FERC (2016) also stress the importance of overcoming regulatory barriers to increasing DSR, noting the considerable number of federal and state-level policy responses to these barriers. Policy is expanding in the US as various state energy regulators have imposed requirements for the development of demand-side response, partially in response to federal requirements and incentives (FERC 2016) (Crossley 2008a). In the USA, smart meters had been installed for 40% of customers by 2014. Federal reporting also indicates strong growth in demand-side response programmes involving time-based incentives in the period to 2014 (FERC 2016).

Smith & Hledik (2011) finds a strong correlation between supportive policy and the penetration of DSR in the USA. The authors went on to conclude that DSR penetration levels were highest in the presence of market restructuring, retail competition, an independent system operator or regional transmission operator, or where a combination of these were in place.

The focus of EU policy on DSR increased with the 2012 Energy Efficiency Directive (EED) which requires the promotion of DSR and the removal of barriers preventing the uptake of DSR (Liu et al. 2015). However, a recent report for the European Commission notes significant barriers to DSR in many Member States, notwithstanding the progress that is being made in respect of smart metering (COWI 2016). Analysis by the Smart Energy Demand Coalition (2014) found that DSR markets in some European countries, such as Belgium, Great Britain, Switzerland, Finland, France and Ireland are relatively well developed, but this assessment did not focus on small energy user participation (Liu et al. 2015). The COWI (2016) analysis associates positive progress in some EU countries such as Belgium, Ireland, France, UK and Finland with the need for new capacity and system flexibility requirements in those states. It observes that Norway, Sweden and Finland ('heavy electricity per capita users') 'lead the way' in terms of take-up of 'more robust' real-time pricing, and elsewhere in Europe, take up of real-time pricing is limited. This study also observes that whilst most EU member states already offer some form of time-based tariffs, nearly all of these are simple dual peak day/off -peak night supplier tariffs which have been in place for several decades and do not require smart metering technologies. The analysis concludes that DSR will 'remain marginal' without 'considerable push by policymakers' (COWI 2016).

Liu et al. (2015) emphasise the importance of regulatory incentives and also the role of enabling technologies such as smart metering and appliances, whilst recognising the GB-specific regulatory changes designed to either incentivise or remove barriers to DSR. These include demand-side participation in the capacity market, price control frameworks for distribution network operators and the electricity balancing and settlement code arrangements. Martínez Ceseña et al. (2015) identify a need to revise and update market regulations (both in the UK and other countries) to ensure that costs and benefits are borne by the economically appropriate party. They go on to suggest that such regulation must recognise the technical and economic implications of DSR (including the impacts on electricity prices) and the cost-reflectiveness of charges for the distribution network. They also observe that whilst DSR could reduce or defer network reinforcement costs, there is currently no GB regulatory framework through which the value of this can be realised.

Work commissioned by the UK Government focussed on the non-domestic sector (not specifically SMEs) suggests that financial incentives alone would not be effective and that any incentives would require an enabling framework and mechanisms, including policy, to be effective (Element Energy 2012). This study highlights concerns amongst companies that DSR may reduce service or comfort levels, noting that there is very little tolerance for this in the commercial sector. It also notes that that concerns over relatively low and uncertain financial rewards are a significant barrier to DSR. The authors advocates a range of enabling factors, grouping these into: confidence building and education (to address negative perceptions of DSR, concerns of impacts on services and comfort, low awareness and priority attached to DSR), economic incentives (to address the lack of an economic case for implementing DSR measures), and reducing complexity of DSR contracts.

Work for the European Commission (COWI 2016) identifies the primary barriers to DSR under two main categories, firstly the ‘Consumer's ability to react (meters, tariff structure and knowledge)’, and secondly, ‘market design and regulation (access rules and incentives) and advocates legislation to address these barriers’. The work endorses the Smart Energy Demand Coalition (SEDC) conclusions that regulatory interventions to facilitate and encourage DSR should be focused on enabling customer participation, creating viable products requirements, developing measurement and verification requirements, and ensuring fair payment and penalties.

The findings from both COWI (2016) and Element Energy (2012), above, overlap with many of the issues discussed in sections 4.4 and 4.5 below, illustrating the general point that many studies start from a discussion of policy and move into a more detailed discussion of DSR products and services.

3.3 Specific findings on policy and regulation revealed in the REA

The REA revealed a number of documents assessing the roles of specific policies and regulations in facilitating demand-side response.

Policies to support smart metering roll out

Smart metering is seen as an important general enabler for developing DSR (Hull 2010; Bird 2015; Moreno 2013; Vallés et al. 2016). Smart metering is particularly important as an enabler for products and services that involve time-varying pricing. Direct load control can also be enabled by smart metering, although smart metering is not required for some types of direct load control as it can also be delivered through direct communication with the appliance being controlled – for example through teleswitching using a radio signal. Similarly, the incentive to participate in direct load control may come from shifting demand towards low price periods, and time varying pricing would be enabled by smart meters, but may also come from payments or preferential tariffs offered as a reward for participation in direct load control (Hull 2010).

The role of market rules and network regulation

Several reports revealed by the REA discuss the relationship between market rules (for example gate closure and minimum unit size to participate in capacity markets) and the ability of the demand-side to participate in wholesale or capacity markets and to provide system services. The general findings are that the detailed design of market rules affects the ability of demand-side actors to participate, hence changes to regulation have the ability to facilitate DSR.

Mismatches between the technical features of small user DSR and more established flexibility services can increase risk and costs for aggregators. These include:

- the difficulty of aggregating enough small user load to meet defined minimum bid sizes;
- long lead times between DSR resource being offered and called, which increases uncertainty about resource availability and;
- the risk of actual responses deviating from those offered (Katz 2014; Koliou et al. 2014).

Intra-day markets could reduce this uncertainty as well as offering higher value, but the short activation times will generally mean additional investment in automation equipment is needed. Similarly, regulating power markets involve requirements that may be poorly matched to DSR technical characteristics such as duration of response or speed of return to load (Katz 2014). Because forward markets are poorly suited to DSR participation, DSR organisers cannot use them to hedge investments in automation technology or other equipment, and other products or tariffs may be required for this purpose (Katz 2014).

Other barriers can relate to a lack of price visibility to the demand-side, and delayed feedback on system imbalances to suppliers or other balancing responsible parties. Price variability could only be communicated to the demand-side by suppliers or similar commercial actors (Katz 2014; Hull 2010). Balancing responsible parties may not be notified of imbalances until well after they have occurred, meaning that they could not use DSR to proactively address these imbalances. Conversely, changes in electricity use by small energy users with half-hourly metering may not be recorded quickly enough to reduce imbalances (Katz 2014)

Finally, in many European countries there is no framework to address supplier imbalances created by DSR actions undertaken by aggregators. This issue could be avoided if suppliers themselves act as DSR providers. Otherwise, the transmission system operator could manage imbalances as they occur with the supplier being compensated by the aggregator, preferably according to a standard price; this arrangement is being proposed in France (Vallés et al. 2016).

Appliance standards

The REA revealed some information about the potential for appliance regulation to enable DSR. From 2007, Australian electrical product policy has provided 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. All major air conditioning brands now include “demand response ready” air conditioners in their range. This supported the development of the novel business model in which appliance retailers and installers act as intermediaries in recruiting users to participate in demand response - after purchasing a smart air conditioner, consumers can start to participate in a utility direct load control programme by entering into an agreement with the utility and installing a demand response enabling device (Swinson et al. 2015). For example, in South East Queensland the air conditioning direct load control programme grew 62% in 2013/14 and 95% in 2014/15. Since the programme launch around 50,000 demand-response air conditioners have been installed as a result of the programme, and an estimated 23% of new air conditioners sold in South East Queensland now contribute to the programme (Swinson et al. 2015).

Distribution network operator price control framework supporting demand-side management, including DSR

In the Australian state of New South Wales, the regulator adjusted the price control framework for distribution network operators to support investment in demand-side management in 2004. The state government also imposed a condition on the licenses of distribution network operators to consider demand-side options when planning upgrades. The new framework allowed distribution network operators to recover approved costs associated with implementing all types of demand-side management, including demand-side response, as well as approved recovery of lost revenue resulting from the implementation of demand-side management not implemented through varying prices. This contributed to the development of direct load control programmes involving small energy users, as well as energy efficiency and other forms of demand-side management (Crossley 2008a).

Investments in DSR are discouraged by remunerating capital expenditure based on actual costs while operating expenditure must be met through allowed yearly revenue set under price control periods. Great Britain and Germany avoid this issue by targeting total operating expenditure. Profit sharing is an alternative approach that could further reduce risk for distribution network operators. Under this approach revenue is agreed ex-ante, but if actual expenditure differs, it is adjusted ex-post based on pre-defined rules. Spain plans to introduce this type of framework, where distribution network companies would be able to keep, or have to pay, 50% of the difference between actual investments and estimated investments. DSR investments could also be discouraged if price control periods are not long enough for efficiency benefits of DSR to become apparent, but at eight years price control periods in Great Britain are relatively long (Vallés et al. 2016).

4. Evidence on DSR business models and strategy

Key findings

The REA revealed limited information on business models or business strategies. 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 ISO. These have had significant impact on DSR but have not required or been led by significant changes to business model.

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 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. 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 does receive some discussion in the studies reviewed, is the 'bring your own device' model. This can be enabled by regulation and could reduce the cost of entry for companies that are considering DSR.

4.1 Main features of the evidence base

Limited evidence focusing on business models was revealed through the REA. Because the REA investigates the evidence base on small energy the business models of aggregators or energy service companies whose customers are larger commercial energy users are not included. No evidence was revealed which discussed the applicability of business models for DSR involving larger energy users (though the size and value of small loads may be a barrier to DSR, discussed below). The relative lack of data reflects the predominance of evidence from trials and surveys which serve primarily to gather data on consumer behaviour and perceptions and/or technology performance rather than requirements or potential for novel business strategies. Trial conditions are not necessarily representative of business as usual costs or benefits: for example, some UK trials of time-of-use pricing involved larger price spreads than might be realistic as part of business as usual deployment (Hull et al. 2013; Carmichael et al. 2014).

It is also important to note that much of the experience with DSR takes the form of established programmes of static time-of-use pricing or peak load management (with or without direct load control), usually implemented by incumbents. In some respects any shift to manage demand rather than organise supply to meet demand could be argued to represent a change to the ‘business model’ for suppliers or network operators. However there is no *prima facie* reason why implementation of regulated DSR programmes such as critical peak rebate or static time-of-use tariffs should require a significant change to the fundamentals of industry business models.

The REA also revealed some discussion of more novel business models and these are also reviewed. The principal finding however is that there does not appear to be very much discussion of business models in the evidence on DSR revealed by the REA.

The limited evidence on business models is also unsurprising given the status of small energy user DSR. Trials and surveys represent an exploratory stage in the development of DSR. Their outcomes will need to be evaluated by prospective providers of DSR before business strategies can be evaluated by companies or reviewed by academics or others. For the most part, enabling technologies such as smart meters and appliances are yet to be rolled out. Established static time-of-use or peak saving programmes do not require any change to business strategy (though it is possible that existing technologies could be repurposed, as discussed below). For these reasons the case studies provide an important complementary source of evidence on the attitudes of industry participants and the potential to realise DSR through novel business strategies.

This section first summarises general findings on business models for small energy user DSR identified from evidence based upon reviews of existing projects or interviews with industry experts. It then discusses those examples of novel business models identified in the REA in small energy user DSR programmes. The UK projects summarised were funded by the Low Carbon Networks Fund and consequently include focus on distribution networks.

4.2 General points on small energy user business models

Crossley (2008) reviews international demand-side management projects, including small user DSR, and identifies a number of success factors relating to business engagement with DSR, which in very broad terms could be considered to offer insights on business strategy. These include clearly defining the project objectives; selecting target markets, including intermediaries and allied actors such as appliance and equipment suppliers, that directly relate to achieving these objectives; and selecting demand-side measures that suit the project objectives and target market. Barriers to user participation should be identified and addressed. Outreach and marketing, effective customer support and ease of participation can be critical success factors for projects involving small energy users.

However, the evidence suggests that high marketing costs may make business models involving small energy users less cost effective.

European industry experts interviewed by Helms et al. (2016) also identified high costs as a barrier to small energy user DSR. These interviewees appeared to focus on direct load control. High costs were associated with making incentive payments that are large enough for participants to consider worthwhile, and the need to install two way communication and control equipment. The interviewees suggested that it is currently unclear how far users might be prepared to share these costs; the US-based “bring your own device” business model (Narayanamurthy & Robinson 2015) could have some relevance to this issue and is described later in this section. In addition, interview findings suggested there is currently limited electrical load with demand high enough to make direct load control worthwhile, and that this is currently limited to heat pumps and electric storage heating.

In general, costs and cost effectiveness of small user DSR in the European context are still uncertain (Vallés et al. 2016; Koliou et al. 2014). It is difficult to assess the value available from small user DSR because little is known about electricity use at different times, particularly by small and medium sized enterprises (SMEs); developing business models around specific electrical loads rather than specific user types could help to address this issue (Hull 2010).

Shared benefits

The benefits of DSR are shared across multiple electricity system actors. As a result, electricity industry unbundling could present a barrier to demand-side response, because the use of DSR by any single actor will not capture the value of any co-benefits to other electricity system actors (Hull 2010). The involvement of an aggregator could help to address this barrier by accessing the value of DSR for multiple electricity system actors, but this could limit the types of DSR products and services offered, since only an actor responsible for electricity supply is able to offer time varying pricing. Incentive-payment based products and services could be offered by a wider range of actors, including aggregators (Hull 2010).

Cost effectiveness of DSR for distribution network management

The value of DSR may be too low for cost-effective implementation by distribution network operators. The UK CLNR suggested that direct load control of domestic appliances in a highly constrained distribution network may have annual values to network operators of £0.20 per year for fridges and freezers, £2 - £4 for wet goods, and up to £15 per year for water heaters and air source heat pumps. Although the uppermost savings are high enough to be potentially interesting to distribution network operators, implementation would depend on sufficiently low costs (Bird 2015). The UK SoLa Bristol trial indicates the cost and time associated with user engagement activity may be considerable and should be accounted for when considering cost effectiveness (Western Power Distribution 2016). The UK Northern Isles New Energy (NINES) trial, however, does suggest that direct load control technology trialled could be rolled out to help integrate renewable generation and otherwise manage electricity networks in the specific context of the Shetland Isles (Coote & MacLeman 2012).

4.3 Novel business models deployed in small energy user DSR programmes

The review revealed a small number of examples of innovations in technology and regulation which could be considered to give rise to a change in business model or strategy.

Bring Your Own Device (BYOD)

BYOD refers to DSR enabled by technologies, such as programmable communicating or 'smart' thermostats[3], which users have purchased themselves. It differs from traditional direct load control business models where the organisers arrange for a specific type of enabling technology to be installed at user premises. BYOD could offer advantages to users in the form of greater technology choice, and there is some evidence that users are already independently purchasing these types of devices. It could also reduce the implementation costs of DSR by reducing technology costs for the DSR organiser, and reducing recruitment costs, since users are recruited by the technology vendor who then provides DSR capability to DSR organisers such as utility companies or aggregators (Narayanamurthy & Robinson 2015). Such connected devices can provide continuous feedback on targeted appliances' electricity demand, which could improve verification of DSR and enable participants to be paid for the actual demand reductions they provide (Narayanamurthy & Robinson 2015).

ComEd, a large regulated investor owned utility in Illinois, ran a BYOD pilot in 2014 where they gave a 100 USD rebate to users to purchase and install a Nest thermostat and sign up for ComEd's existing AC cycling programme to reduce peak electricity demand through Nest's "Rush Hour Rewards" feature. Around 3,000 customers enrolled, and performance during events was slightly better than the traditional programme. Following this, ComEd expanded their BYOD products and services to include another type of smart thermostat, and considered how to expand to allow any smart thermostat to participate, including more prescriptively defining the methods for impact analysis. In a BYOD business model it is important that the DSR organiser receives the information they need to effectively run the programme. In this example, data sharing agreements are made between the user and Nest; these might enable Nest to share specified raw data with the DSR organiser, or Nest might carry out the required analysis and share this with the DSR organiser. ComEd suggest that Nest's high level of interaction with the user is also a valuable feature of the service they provide to partner utilities (ibid.).

[3] Strictly speaking smart communicating 'thermostats' or PCTs are not thermostats but heating controllers. However the terms 'smart thermostat' and 'PCT' have entered into widespread usage and are therefore retained in this review.

Business models and regulatory change

Standards for smart appliances including air conditioners have been implemented in New South Wales from 2004 (described in the previous chapter, referring to appliance standards). In some respects these standards have enabled a new business model for customer recruitment to the traditional programme of direct load control of air conditioning to reduce peak demand. Appliance manufacturers, retailers and installers become allied actors through the production and sale of “demand response ready” air conditioners. Consumers who purchase such air conditioners have the option to enrol in a direct load control programme. This involves entering an agreement with the local utility and installing a “demand response enabling device” (DRED), in return for which they receive a cash incentive (although the nature of the incentive is not described). The novelty in the business model arises from the fact that the regulation effectively creates the conditions for ‘bring your own device’ and creates a new relationship between suppliers and electricity providers. The specific details of air conditioning operation are also relevant to consumer response and retention rates, these are discussed in the next chapter.

Adapting existing DSR products and services to address new objectives

Two cases reviewed adapted existing DSR products and services to address new objectives. In the NINES trial, existing electric storage heating was replaced with smart storage heaters able to provide autonomous frequency response as well as direct load control, which could support the integration of renewable energy as well as other network management objectives if rolled out more widely (Coote & MacLeman 2012). In the Australian state of New South Wales, distribution network operators have managed peak demand by direct load control of electric water heating since the 1950s, and this technology has been adapted to increase the use of embedded photovoltaic generation and reduce its impact on the distribution network (Swinson et al. 2015). However it is not clear whether or not this represents any fundamental change of business model or strategy.

5. Evidence on the range of DSR products and services

Key findings

The REA revealed a substantial evidence base on a range of DSR products and services and how consumers respond to different offerings. There is a long history of demand-side response in many countries. However until recently almost all offerings were static/dual price time-of-use or peak load management programmes. Roll out of smart meters and trials of dynamic time-of-use have both increased since the mid-2000s. 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 the 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 adopt 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 electric 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 DSR options.

5.1 Main features of the evidence base

This chapter first summarises evidence on how different forms of pricing, in-home displays and automation can influence user engagement. It then describes more novel DSR products and services offered to small energy users in programmes and trials identified in the REA, and describes the effect of these products and services on user engagement.

DSR products and services are discussed using the definitions of intervention described in Chapter 2 of the Summary Report: *participation* (or enrolment) – the decision to enrol in a

DSR programme; *response* – the level of response that is provided by participant; and *persistence* – the decision to remain enrolled in the programme and continue to respond.

DSR products and services commonly vary in terms of the nature of the incentive (price/rebate/information), and whether enabling technologies in the form of in-home displays, automation or direct load control are involved.

One of the most important factors affecting enrolment in and response to DSR products and services is whether consumers ‘opt-in’ or ‘opt-out’. In the case of opt-in recruitment to a particular tariff, programme or scheme consumers can be invited or encouraged to join but otherwise default to non-membership. The obverse is the case with opt-out – consumers are placed onto a new tariff or programme by default unless they select not to take part. Unsurprisingly, this has a substantial impact on enrolment and response rates across a range of DSR products and services, and is discussed in detail in the next Chapter.

5.2 The status of DSR products and services

The REA revealed some data on overall consumer participation in DSR internationally. In the US around 16 million customers are enrolled in some form of either incentive based or time based pricing (FERC 2016). This represents around 11% of metered customers. EU data at this level of detail was not revealed through the REA, however COWI (2016) note that time-of-use tariffs of some form (mainly static time-of-use pricing) are available to around 90% of EU customers. COWI (2016) also report that smart metering roll out is complete in Italy and scheduled to be completed in the UK, France and Ireland by 2020. The picture within the EU is complicated by different interpretations of guidance related to assessing the cost/benefits of smart meters and different smart meter variants (COWI 2016). However the REA indicates that there has been significant growth in DSR programmes over recent years, with the most substantial growth being in time-of-use pricing.

5.3 Price ratios and response rates

The price ratio represents the differential between peak and off-peak prices. Larger or smaller price ratios are usually associated with different DSR products and services. For example time-of-use pricing typically uses much lower price ratios than critical peak pricing, but also involves prices that change every day. In contrast, critical peak pricing is applied during occasional ‘events’ that are accompanied by notification and may carry a sense of urgency.

The evidence suggests that the relationship between price ratio and behaviour is not straightforward. Some studies that included different price levels did not identify any clear effect (Thorsnes et al. 2012; Herter & Wayland 2010). A review of the US DoE Consumer Behaviour Studies (CBS) found that average response without automation technology was higher for higher price ratios, but there was considerable variation in responses and some overlap between responses to different levels of price ratios. A review of a large number of international DSR studies found that the average level of response increases as price ratio increases, but at a diminishing rate (Faruqui & Sergici 2013). The use of enabling technology such as automation or direct load control can also explain variation in response. Faruqui & Sergici (2013) found that both enabling technologies and price ratio have a strong relationship with demand reduction for TOU pricing, while for critical peak pricing the impact of enabling technology is greater than price. However, another review of North American DSR studies separately analysed time-of-use and critical peak pricing and found no clear trend for an effect of price ratio on peak load reduction (Newsham & Bowker 2010).

5.4 Dynamic pricing

Less 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 (including the UK LCL trial which achieved significant manual responses to dynamic time-of-use pricing (Carmichael et al. 2014)). In two trials, participants found it too difficult to respond to real time pricing manually (Belmans et al. 2014; Friis & Haunstrup Christensen 2016). In two other trials, participants did respond to real time pricing, but followed patterns of high and low pricing at different times of the day rather than regularly checking prices (Allcott 2011; EcoGrid EU 2016).

Limited and/or pattern-based response may or may not represent engagement with more dynamic DSR. It is possible that the observed responses could have been achieved with a simple and predictable form of time-varying pricing. Indeed in one trial of real-time pricing, users were actively encouraged to respond to average pricing patterns (Allcott 2011). Another trial of dynamic pricing noted a simple pattern of demand shifting that would typically achieve a good performance (Belmans et al. 2014), and a third trial suggested that additional complexity in pricing may do little to change responses since demand was typically shifted to night time hours (enabled by automation) irrespective of the exact time of peak pricing (Kobus et al. 2015).

No studies were identified that directly compared enrolment, response or persistence for highly dynamic forms of pricing such as dynamic time-of-use or real time pricing with other more predictable forms of time varying pricing.

5.5 Prices vs rebates

Financial incentives can also vary according to whether they take the form of time varying *pricing*, or *rebates* - where users are financially rewarded for reductions in peak period demand. The US CBS review found that without the use of automation, average demand reductions under critical peak pricing were more than twice what was achieved with critical peak rebate (US DOE 2016). It also appears that pricing delivers more reliable response, since variability in response between different events was lower. Applying the New York Independent System Operator performance definition of DSR resources in providing capacity services during declared system reliability emergencies, critical peak pricing would have claimed capacity derated by 10% to account for variable performance, while critical peak rebates would have claimed capacity derated by 30%. This is likely to be due to participant loss aversion. However, average retention (persistence) rates for critical peak rebate are somewhat higher than for critical peak pricing. This is likely to be due to a lower risk of receiving higher bills due to underperformance. Rates of enrolment to critical peak rebate and critical peak pricing are similar (US DOE 2016).

5.6 In-home displays

Information can be provided to consumers through in-home displays or ambient displays, through web portals, smart phone apps, or by notifying participants of price changes via email or SMS messages. Web portals were widely offered to all participants in the studies reviewed, but some studies compared engagement with and without in-home displays. Evidence is mixed on the impact of in-home displays consumers. There is evidence to suggest that additional information in the form of in-home or ambient displays can act as an enabler of response (Carmichael et al. 2014; Allcott 2011). However, provision of displays had no significant impact on response in the BC Hydro TOU/critical peak pricing pilot study (Chi-Keung et al. 2013). Similarly, the US CBS identified no impact of in-home displays on peak demand reduction and found that many participants who received a free in-home display never actually turned it on and connected it to the utility's system (US DOE 2016). In the EDRP, additional information was associated with a decreased response in one trial (AECOM 2011). Overall, the US CBS found that free in-home display offers made little difference to enrolment or retention rates (US DOE 2016).

5.7 Automation and direct load control

Several studies found that the use of automation technology or direct load control enabled user responses or increased average response (Friis & Haunstrup Christensen 2016; Bradley et al. 2016; Dütschke & Paetz 2013; Moreno 2013; EcoGrid EU 2016; US DOE 2016; Newsham & Bowker 2010; Chi-Keung et al. 2013; Belmans et al. 2014). As well as substantially increasing peak demand reductions, particularly at higher price ratios, use of programmable communicating thermostats also results in responses to critical peak rebate that are similar to peak pricing (US DOE 2016), and decrease response variability (US DOE 2016; EcoGrid EU 2016; Belmans et al. 2014). Specific ways in which automation can increase response include accessing flexibility from load types, that offer substantial flexibility but are not changed as part of manual response (for example electric water heating), and enabling demand shifting further into the night (Belmans et al. 2014). The REA did not reveal any evidence on the impact of automation and direct load control on persistence other than that use of programmable communicating thermostats was found to have little or no impact on customer retention rates (US DOE 2016).

There is also evidence that the use of automation for 'wet' goods such as dishwashers and washing machines may be relatively low. In the PowerMatching City and Your Energy Moment trials, users implemented the 'smart' configuration of washing machines for only 12% and 14% of uses respectively (Wiekens et al. 2014; Kobus et al. 2015). The Linear trial achieved a somewhat higher level of 29% ‘smart’ configurations of washing machines, which may be linked to users receiving a ‘capacity payment’ according to the flexibility of each ‘smart’ configuration (that is, the distance into the future of the latest acceptable cycle end time) (Vanthournout et al. 2015). The CLNR trial also identified low user engagement with the use of smart washing machines (Bird 2015).

5.8 Summary of previous findings on response by category of intervention

In a previous study (Parrish et al 2015) the authors provide a summary of response rates for different categories of DSR products and services. This is reproduced below in Figure 3.

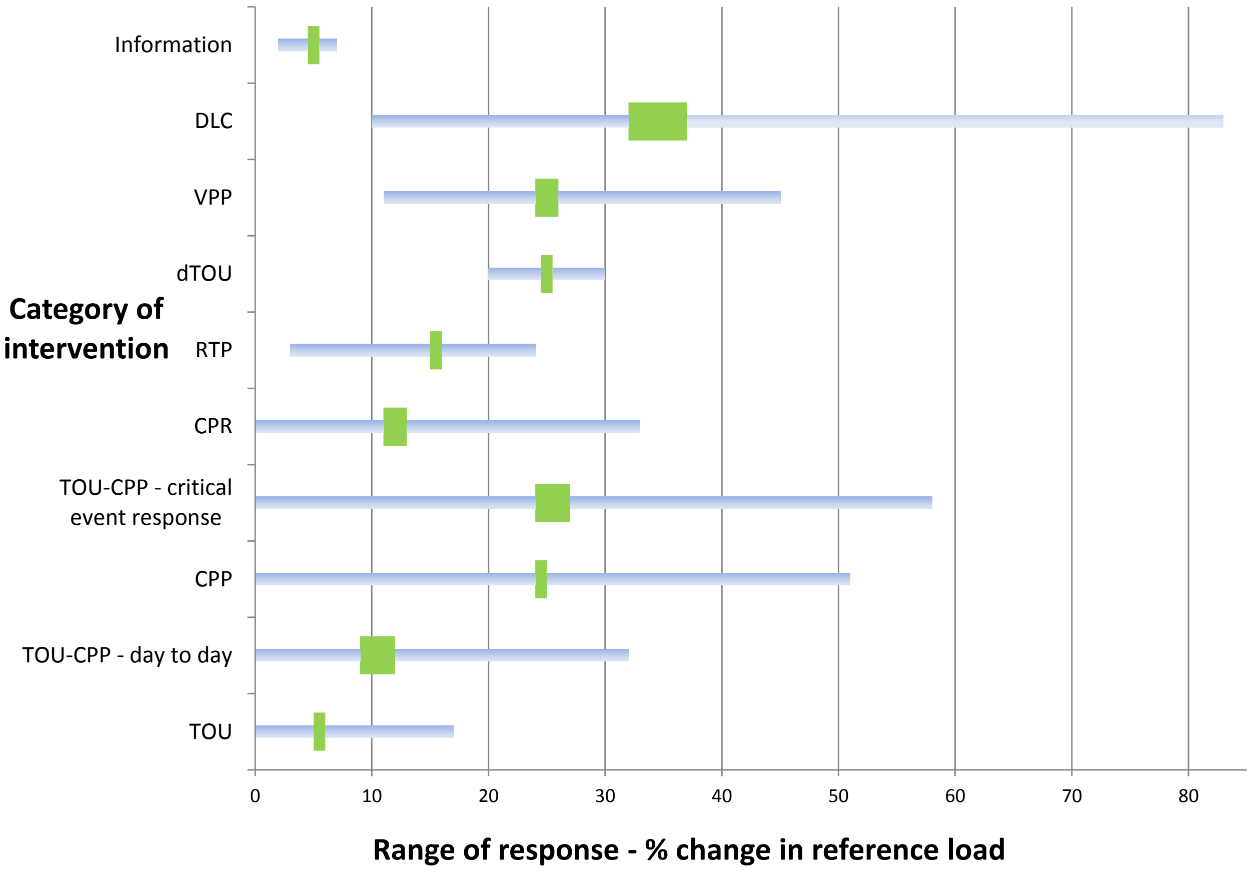

Figure 3: Summary of findings by category of DSR (Parrish et al 2015)[4]

In most cases response refers to the percentage reduction in the reference load, but the dynamic time-of-use (dTOU) study achieved a 30% increase in demand at low price periods, simulating increased use of wind generation, as well as 20% reduction in demand during high price periods. The blue bars represent the full range for each intervention type

4 These categories are explained in Table (pg.12)

and the central green blocks cover the range between the mean and median values for each intervention type.

5.9 Novel DSR products and services

The REA revealed a small number of trials involving innovative DSR products and services. There is not enough evidence to draw definitive conclusions from most of these experiments but they are included here because they provide an interesting set of examples of emerging thinking in the novel DSR product and service literature.

Information only

DSR products and services typically reward customers for participation through either financial incentive payments or the opportunity to save by shifting electricity demand from high price to low price periods. Information on high or low price periods provided by in-home displays, or through mobile phone apps or other remote communication options can enable this response. However, it is also possible to use information only, without financial incentives or time varying pricing, to encourage users to change their electricity demand at specific times. Information only demand-side response was tested in the EnergyAustralia DPP trial (Strengers 2010) and resulted in peak demand reduction of 13% of baseline demand in summer and 11% in winter. This finding is rather inconsistent with the limited/mixed response to displays and information (accompanying price/rebate incentives) noted in the discussion on in-home displays. The REA is not able to provide a definitive answer on the prospective role of information only DSR.

Short duration direct load control or automatic frequency response

Direct load control of small energy user air conditioning lasting for short durations of around 15 minutes has the potential to provide standing and spinning reserves to the electricity system while going unnoticed by participants (Eto et al. 2012). The NINES trial in the Shetland Isles tested autonomous frequency response by smart electric storage heaters to provide frequency response, with control durations often lasting only a few seconds, in addition to other forms of demand response. Users were generally more satisfied with the new smart storage heaters than those they replaced because the availability of heat and hot water throughout the day improved (Coote & MacLeman 2012).

Local supply following

Local supply following describes demand shifting that aims to increase the use of renewable electricity generated locally (Lebosse 2016; Carmichael et al. 2014; EcoGrid EU 2016). Different DSR products and services can be adapted to local supply following: The Your Energy moment trial in the Netherlands tested real time pricing and smart appliances to increase the use of local PV generation (Kobus et al. 2015). The EcoGrid EU trial tested real time pricing and direct load control of heating to increase the use of local wind generation on the Danish island of Bornholm (EcoGrid EU 2016). The Grid4EU Nice Grid project tested direct load control of electric water heating and time varying financial incentives to balance local PV generation (Lebosse 2016). In Australia, distribution network operators have historically used direct load control of residential electric water heaters to manage their impact on the distribution network; this has been adapted to act as a “solar sponge”, reducing the impact of roof top solar generation (Swinson et al., 2015).

Peer-to-peer trading

In peer-to-peer trading, users increase the use of embedded generation by directly trading surplus generation with other users locally. The PowerMatching City trial in the Netherlands used smart appliances as well as manual response to time varying pricing to trade generation of rooftop PV and micro-combined heat and power amongst 40 households living nearby to one another. Trading met one of two objectives: to maximise the use of local generation, or to minimise costs for the user (Wiekens et al. 2014).

The NOBEL trial tested peer-to-peer trading on a larger scale, involving 5,000 residential users. Members of a local electricity cooperative in Alginet, Spain who were prosumers (i.e. owned some form of electricity generation) were given access via web and android apps to the trial’s BAF (brokerage agent front end) application for 6 months. The BAF application allowed users to view their predicted future electricity use and generation, and buy or sell electricity over specific timeframes, either manually or using an automated process configured by users. The BAF application was published open source for industrial and academic use. The trial, which also included elements relating to demand reduction, achieved its aims of decreasing CO_2 emissions, increasing the use of local renewable generation, and generating financial benefits for the participants (Moreno 2013).

Smart appliances

A number of trials have focused specifically on smart ‘wet goods’ (washing machines, dishwashers, and tumble driers) (Kobus et al. 2015; Wiekens et al. 2014; Belmans et al. 2014; Chassin & Kiesling 2008). In most cases, the user programmed the latest acceptable cycle end time and the smart appliance automatically started its cycle at the optimum time in this window according to its control algorithm, typically at times of high renewable generation, although users could also start the appliance immediately. In the Your Energy Moment and PowerMatching City trials, users were incentivised to use smart control through time varying pricing, while in the Linear trial they also received a ‘capacity payment’, a fee that varied according to the duration of the ‘flexibility window’ they programmed (Kobus et al. 2015; Wiekens et al. 2014; Belmans et al. 2014). In the Olympic Peninsula GridWise testbed project, smart tumble dryers responding to electricity prices enabled demand-side bidding (Chassin & Kiesling 2008).

Smart charging for electric vehicles

Two trials tested the use of technology to automate EV charging during the night time. The test (an EV trial in Denmark) included installation of a timer on participants’ home chargers (Friis & Haunstrup Christensen 2016), while a trial conducted by the Renewable and Sustainable Energy Institute at the University of Colorado, Boulder used smart plugs that were programmed to limit vehicle charging to between 10pm – 6am, but users could override or change these control settings via a web portal (Farhar et al. 2016).

The UK I^2EV trial tested more sophisticated smart charging technology, which dynamically curtailed charging for periods of 15 – 60 minutes during times of high network load. The duration of charging curtailments was determined accounting for the impact on EV batteries and heat pumps (an additional possible application of the technology). Timing of curtailments was determined by monitoring low voltage distribution networks using technology installed at local network substations, and control signals were transmitted to technology installed at customer premises using power line carrier communications, although reliability issues led to the recommendation that alternative communication methods should be investigated. Drivers were asked to use the vehicles as normal and were not informed of curtailments taking place. Over 7,000 curtailments of EV charging took place in residential areas but only impacted user behaviour in one case. The technology was not viable for drivers plugging in at work in commercial areas, because the flat day time load profile and large background demand from commercial premises limited opportunities for EV charging that was curtailed during high network load. As network loads in commercial districts were consistently high EV charge rates were inadequate (EA Technology & Southern Electric Power Distribution 2016). It is important to note that the study did not explore overnight charging in commercial areas, for example of delivery vans or other commercial vehicles.

Battery-enabled DSR

Battery storage could facilitate DSR by, for example, increasing electricity use during times of high renewable generation or reducing electricity use during peak demand periods. It could also enable other forms of demand-side participation which are outside the scope of DSR as defined in this report, such as increasing PV self-consumption or exporting electricity to the grid to provide ancillary services (Parrish et al. 2016). The SoLa Bristol trial included in-home battery storage that was shared between users and the distribution network operator. Batteries stored surplus PV generation to the capacity of the battery and provided electricity to households during evening peak periods, thereby reducing the use of peak electricity. The distribution network operator could also directly control battery charge and discharge to help manage network constraints (Western Power Distribution 2016).

Demand-side bidding

Demand-side bidding describes demand-side participation in electricity markets by offering specified demand reductions for specified income levels at a certain time. The Olympic Peninsula GridWise testbed demonstration project used smart appliances and smart thermostats to automate demand-side bidding by both small and large energy users. This enabled the real-time pricing implemented during the trial to be set through a double auction between electricity users and wholesale and retail level distributed generation (Chassin & Kiesling 2008).

6. Evidence on consumer engagement and participation

Key findings

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 considered consumer attitudes and perceptions. Most of the evidence is focused on domestic consumers rather than SMEs.

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. However, beyond this the evidence presents a complicated and mixed picture, for example in terms of which actors are 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.

6.1 Main features of the evidence base

The REA revealed a substantial body of evidence on consumer motivations, and on barriers and enablers to consumer engagement, response and persistence. Much of the evidence is focused on domestic consumers with much less evidence revealed through the REA about SMEs. The evidence base derives from surveys and focus groups involving both trial participants and individuals not currently involved in DSR.

This chapter is divided into two parts, the first discusses domestic consumers and the second the more limited evidence available on SMEs. Both consider motivations and a range of barriers and enablers. The one on residential customers also includes discussion of different customer segments.

6.2 Residential user engagement

This part outlines a range of motivations, barriers and enablers for residential user engagement with DSR identified as themes in the evidence on user engagement. It describes how these might influence user enrolment, response, and persistence in demand-side response.

6.3 Residential consumer motivations

The majority of evidence identified on residential user motivations to participate in DSR relates to enrolment, rather than response or persistence. This and the following sub-sections focus on opt-in recruitment: why small energy users might chose to enrol in DSR. Evidence on factors that might influence enrolment came from two general sources: surveys and focus groups conducted separately from a trial or programme, and surveys and interviews carried out with trial or programme participants or users who chose not to participate.

The most common types of motivations identified were financial and environmental benefits. In studies that assessed the relative importance of different motivations, financial benefits were most often found to have the highest importance (Dütschke & Paetz 2013; Allcott 2011; Torstensson & Wallin 2014; AECOM 2011; Carmichael et al. 2014; US DOE 2016); in two trials the primary stated motivations for participation were environmental and society-wide economic benefits (Bradley et al. 2016; EcoGrid EU 2016). Other studies found both motivations were important, or did not discuss their relative importance (Lebosse 2016; Hall et al. 2016; Shipman et al. 2013; Western Power Distribution 2016).

Some evidence suggested the way environmental and financial benefits are presented to participants could influence their role as motivating factors. The potential environmental benefits of demand shifting, such as using lower carbon electricity, may not be obvious to users: for example, some focus group participants questioned the environmental benefits of participating in DSR after realising that it would not necessarily reduce total electricity use (Hall et al. 2016). This finding suggests that less familiar environmental benefits may need to be clearly presented for this motivation to have an effect.

Participants in a series of focus groups said they were more interested in benefiting from reductions to bills than receiving rewards or incentives. These groups were much less interested in financial benefits offered to the community rather than to individuals (Buchanan et al. 2016).

Other motivations for enrolment included: offers of free or reduced cost technology (Bradley et al. 2016; Bird 2015); social benefits, including increasing electricity system reliability (Bird 2015; Lebosse 2016); increasing control over energy use and bills, including through access to additional information as part of DSR products and services (Hall et al. 2016; Western Power Distribution 2016; AECOM 2011); thinking participation in DSR might be fun or interesting (Strengers 2010; Dütschke & Paetz 2013); and social factors such as pride discussing participation with neighbours or being encouraged by children to be more environmentally friendly (Western Power Distribution 2016). If DSR has a local focus this can act as an additional motivation (Lebosse 2016; Carmichael et al. 2014; EcoGrid EU 2016).

Considering motivations for response, there is some evidence that after enrolling users continue to weigh up the potential financial savings against effort, time, convenience and comfort when deciding whether to change their electricity use (Bradley et al. 2016; Friis & Haunstrup Christensen 2016; EcoGrid EU 2016; Bartusch et al. 2011). Participants might enjoy the challenge of responding to dynamic pricing and treat it like a game or project (Carmichael et al. 2014).

6.4 Barriers and enablers for residential consumers

Barriers to and enablers of small energy user enrolment in DSR relate to users' perceptions, including the reputation of DSR and its organisers and what users expect of the experience of participating in DSR. Barriers to response relate to users' actual experiences, and also technical issues. However, there is some overlap in themes between perceptions and actual experiences.

Opt-in and opt-out recruitment

Enrolment in demand-side response is typically voluntary, but can be implemented on an opt-out basis where users are placed onto the new tariff with the option to leave. Unsurprisingly, recruitment by opt-out results in much higher enrolment than recruitment by opt-in, possibly due to default or status quo bias. For example, on average the US CBS study finds that opt-in recruitment results in 15% enrolment, and opt-out recruitment in 93% enrolment (US DOE 2016). In the ComEd CAP, opt-out recruitment resulted in an enrolment rate of around 98% (EPRI 2011).

The authors previously undertook a review of enrolment rates for opt-in and opt-out, summarised in Figure 4.

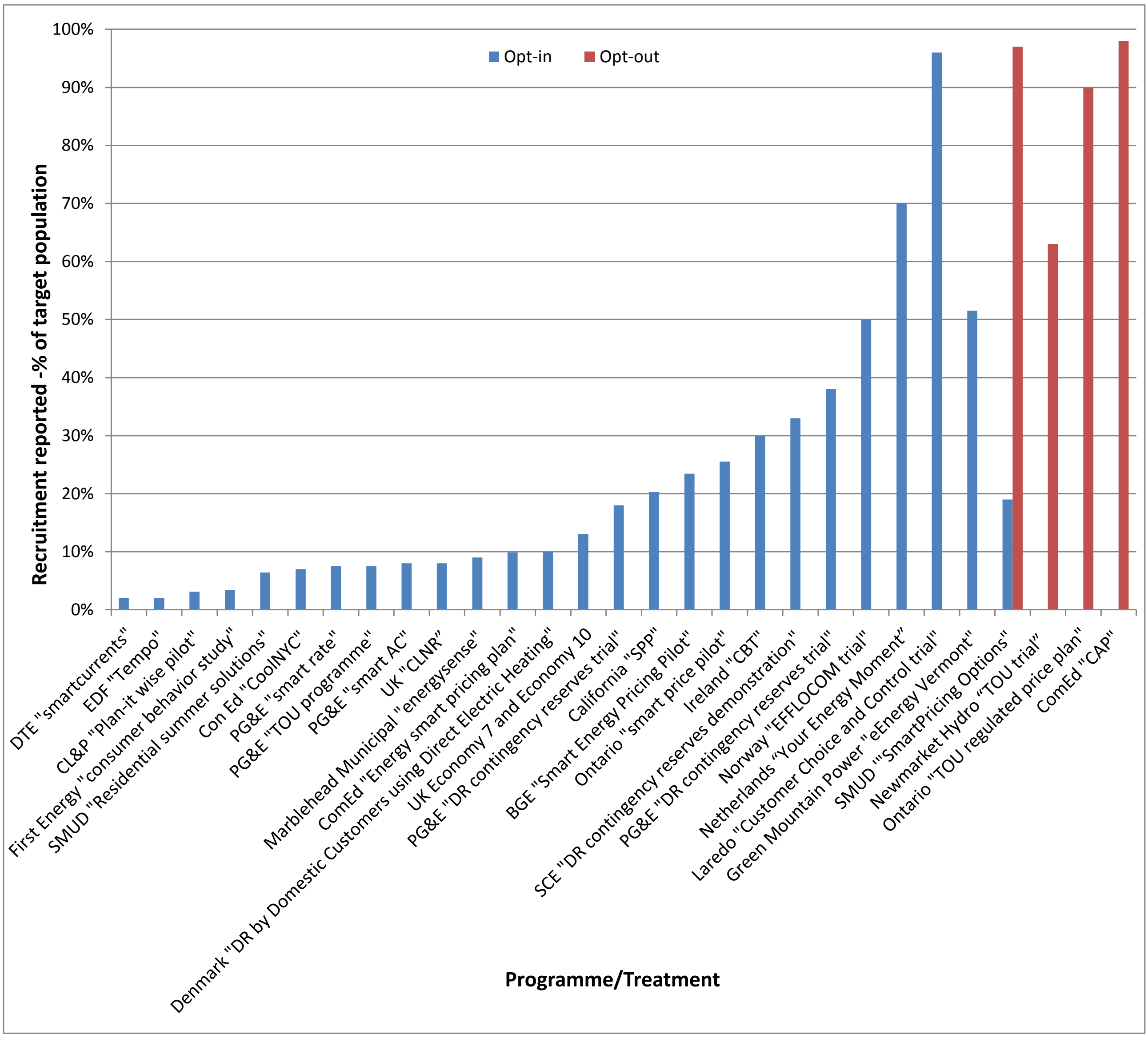

Figure 4: Reported recruitment using opt-in and opt-out (Parrish et al 2015)

While opt-out recruitment can achieve very high rates of enrolment, many users who remain enrolled do not change their electricity use to respond to time varying pricing. 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 (EPRI 2011). These ‘event responders’ appear to represent a similar proportion of users and level of demand reduction as might be expected through opt-in recruitment, so the findings of the ComEd CAP suggests the aggregate response achieved through opt-out recruitment might be similar to that achieved through opt-in recruitment, despite the much higher number of users enrolled (EPRI 2011). Few studies discuss the implications of this or whether it applies in all cases. It is possible for example that if opt-out were associated with a high degree of direct load control or automation then it could deliver a larger aggregate response than opt-in. It is also possible that opt-out could be a more straightforward or cost effective way of achieving the same level of response as an opt-in programme (Parrish et al 2015). This is predicated on an assumption that opt-out enrolment is easier/cheaper which may or may not be the case in practice. Opt-out recruitment may also dissatisfy or disadvantage some consumers (Parrish et al 2015).

The SMUD trial in the US CBS found peak demand reductions for customers enrolled in time-of-use pricing through opt-in recruitment were about twice as large as those for customers enrolled through opt-out recruitment (US DOE 2016). Similarly, peak demand reductions for customers enrolled in critical peak pricing were about 50% higher for opt-in compared to opt-out recruitment (US DOE 2016). Analysis of customers recruited through opt-out recruitment identified a large group of ‘complacent’ users who would likely not have enrolled through opt-in recruitment, but did not opt-out. The idea that there is a similar sized group of ‘event responders’ whether recruitment is opt-in or opt-out is also supported by the Lakeland Electric Utility Consumer Behaviour Study. In this instance, opt-out recruitment was applied to unenrolled users after opt-in recruitment efforts had ended. Hence, the segment of users who would choose to opt-in were not represented in a group of opt-out participants – for whom opt-out recruitment resulted in zero response rates (US DOE 2016).

In Italy, consumers who had chosen to be on a regulated price tariff were moved onto time-of-use pricing, with the option to leave the regulated tariff (Hull 2014). This form of opt-out recruitment appears to have mixed results. For example, in one analysis of users in the Trento province, the pricing was associated with demand reduction during the morning peak, but the evening peak was split in two (Torriti 2013). Another analysis of 28,000 users showed around 60% of users shifted demand away from peak times, but for unknown reasons the remainder shifted demand towards peak, so the overall peak demand reduction was minimal (Hull 2014).

Considering persistence, the SMUD CBS found that many ‘complacent’ participants were seemingly indifferent to being placed on time varying pricing and were reasonably satisfied with the rate. However, those whose electricity demand patterns made them likely to lose the most financially by being placed on the rate were interested in leaving it when given a direct opportunity to do so (US DOE 2016).

Familiarity and knowledge

Consumer familiarity with DSR in general and/or with specific DSR products could act as either a barrier or an enabler to enrolment. Hall et al. (2016) found higher stated acceptance of time-of-use pricing amongst users in a city where it was already available, which they suggest may be the result of greater familiarity with the concept. Conversely, in another area users were concerned about installing smart meters as an enabler for DSR because they were aware of public concerns around lack of choice over smart meter installation, lack of information about the roll out, difficulty in using meters, and having to pay for smart meters without receiving benefits. The UK EDRP trial found users were unfamiliar with the concept of load shifting, which contributed to mistrust of supplier motivations for offering time-of-use tariffs (AECOM 2011).

Users' lack of understanding of new and existing technologies may act as a barrier to response. Users might be unaware of built in appliance timers (Carmichael et al. 2014) or be unfamiliar with mobile technologies and find it difficult to use in-home displays (Western Power Distribution 2016). Even after participating in DSR, users may not understand how much energy different appliances use and incorrectly assess the impact of different forms of demand shifting (Wiekens et al. 2014). Users might also misunderstand the structure of different DSR offerings and the timing and nature of the responses they are being asked to make (Lebosse 2016; Shipman et al. 2013), or form their own incorrect theories about the use of unfamiliar technologies (Western Power Distribution 2016).

Trust

Issues around trust could form a barrier to enrolment in the form of privacy and autonomy concerns around direct load control, or perceptions of energy company motivations for pursuing DSR (Lopes et al. 2016; Bartusch et al. 2011; AECOM 2011; Wiekens et al. 2014). This could be overcome through providing feedback on the direct load control actions that have been taken (Lopes et al. 2016), or providing information on DSR from independent sources (Hall et al. 2016). Trust may also be improved by transparently communicating how energy users are rewarded for providing electricity system services and how other parties (energy companies etc.) benefit from DSR (Buchanan et al. 2016; Lebosse 2016). Involving trusted actors can support recruitment (Western Power Distribution 2016; Bird 2015), and this has included initial recruitment efforts by neighbours (EA Technology & Southern Electric Power Distribution 2016).

Trust can also be an issue once users have enrolled in DSR, associated with installation delays (Western Power Distribution 2016), technical issues (Wiekens et al. 2014), and lack of transparency around the schedule of dynamic pricing or automation (Carmichael et al. 2014; Wiekens et al. 2014). Engagement might be promoted by honesty and accountability about delays and technical issues (Western Power Distribution 2016; EcoGrid EU 2016), but it can be hard to rebuild trust once this has been eroded (Wiekens et al. 2014). The US CBS found that successful engagement strategies included following up on customer questions and problems, anticipating and preventing common issues before they escalate, and setting realistic expectations about participation, performance of technology, and potential bill savings (US DOE 2016). Responses that involve community action, such as peer-to-peer trading, may also be reduced if users do not trust other community members to behave sustainably (Wiekens et al. 2014).

Technology requirements and technical issues

The absence of enabling technologies required for DSR can act as a barrier to recruitment or response. This has included lack of home internet access, which could limit the use of smart appliances (Bird 2015; Western Power Distribution 2016), not having appliances with built-in timers (Carmichael et al. 2014) and not having compatible electric heating

(Lebosse 2016). Conversely, being able to switch to alternative fuels or appliances for cooking or heating, and having installed additional building insulation, can enable greater response (Lebosse 2016; Carmichael et al. 2014).

The requirement to install new technologies can act as a barrier to recruitment. Examples include the need to install a smart meter (AECOM 2011), the cost of smart appliances (Belmans et al. 2014), the space required for thermal storage to enable flexible heating (Bird 2015) and the disruption associated with installations, for example needing time off work or creating nuisance for rental tenants (Bird 2015)(Hall et al. 2016). The UK CLNR identified the technologies involved in DSR and the process of installation as a critical part of the customer experience (Bird 2015).

In some cases technical issues limited response or resulted in consumers reducing their participation over time, even after users had accepted and installed new technologies. Examples include problems with data communication for direct load control and notifications to encourage manual demand shifting (Bird 2015; Lebosse 2016; Belmans et al. 2014; EA Technology & Southern Electric Power Distribution 2016) (EA Technology & Southern Electric Power Distribution 2016). In the Linear trial, however, technical issues caused only a temporary pause in response (Belmans et al. 2014).

Risk

Perceptions of risk can be associated with different characteristics of time varying pricing or financial incentives, and act as barriers or enablers to enrolment. Real time pricing may be perceived as risky or complex, which deters some consumers from enrolling (Allcott 2011). In the UK LCL trial of dynamic time-of-use pricing participants said they would be more likely to sign up for a similar offer if price changes were more predictable (Carmichael et al. 2014). The much higher price ratios associated with critical peak pricing appear to have led some users to prefer time-of-use pricing (Buryk et al. 2015). Similarly, some users prefer smaller high:low price ratios or a cap on price (Dütschke & Paetz 2013). and similarly, some users prefer smaller high:low price ratios or a cap on price (Dütschke & Paetz 2013). Other studies report a stated preference for financial rebates rather than time varying pricing due to the absence of risk associated with the former (Bradley et al. 2016). Similarly, Lebosse (2016) reported that the use of rewards rather than financial penalties facilitated recruitment. However, the CBS found little difference in actual enrolment rates for critical peak pricing and critical peak rebates (US DOE 2016).

Automation might help to overcome recruitment barriers associated with unpredictable pricing, since it was associated with higher acceptance of dynamic time-of-use pricing in a survey of UK consumers (Fell et al. 2015). On the other hand, users might be concerned about risks associated with automation or direct load control, mainly related to loss of control, discussed in detail below (Lopes et al. 2016; Hall et al. 2016).It is possible that these could be addressed by approaches such as specific agreements on allowed control including limited duration, adequate notification of control, and the option to override (Lopes et al. 2016; Hall et al. 2016).

Although financial risk might act as a barrier to enrolment, it could also act to support response. In the US CBS, responses to critical peak pricing are larger and more consistent than responses to critical peak rebates, probably because of the financial loss that could be associated with critical peak pricing if users do not reduce demand during peak periods (US DOE 2016). However, retention rates for critical peak rebate were somewhat higher than for critical peak pricing, which is also likely to be due to the lower risk of receiving higher bills due to underperformance (US DOE 2016). Hence there is potential for trade-offs between recruitment, response and persistence, in this area as in others.

Perceived control

Perceptions of control as a barrier or enabler mostly relate to direct load control and automation. The evidence on this topic is quite mixed; there is evidence to suggest that perceptions change with participation in trials but that this is highly context specific.

Providing choice about how and when appliance automation takes place, and the option to override direct load control, could increase user perceptions of control and act as an enabler for recruitment to this form of DSR (Buchanan et al. 2016; Lopes et al. 2016). Perceptions of control may change as a result of participant experiences. Market research conducted pre-trial as part of the US CBS trial suggested users were reluctant to allow utility control of programmable communicating thermostats, and strongly preferred to programme these themselves. However, experiences in the trials suggested that after devices were installed and customers gained familiarity with them, most relaxed their concerns and allowed direct load control by their utility (US DOE 2016).

Participants in the PowerMatching City trial stated a preference for automation rather than direct load control because it allowed them to retain control (Wiekens et al. 2014). Over the course of the Linear trial, participant enthusiasm for smart appliances fell, in part due to a perceived loss of control associated with a lack of feedback on the start and end times of automated smart appliances (Belmans et al. 2014). In the EcoGrid EU trial participants given more control options felt more positive about direct load control of their heating, although they did not override control any more frequently than other groups (EcoGrid EU 2016).

The appliance standards set for air conditioners in New South Wales (see Chapter 3) do not allow users to override the external control of their air conditioning. Participants can leave the programme at any time, but attrition has been low (Swinson et al. 2015). Survey findings report that 87% of surveyed participants state that they are satisfied with the programme. Survey findings also suggest that direct load control has limited impact on participant comfort. It seems likely that this relates to the control strategy followed: participants can select for control to switch off the air conditioner for the entire control period, or to limit its operation to a maximum of 50% or 75% of each half hour within the control period. This control strategy will reduce air conditioner operation by less than 50% or 25% unless it would otherwise be running at maximum capacity. Graphs of demand reduction suggest that the event periods in this example are also fairly short, at around two hours (Swinson et al. 2015)

Complexity and effort

The level of complexity and effort associated with DSR can affect consumer engagement. The evidence base appears to be very mixed; with some studies reporting complexity to be a barrier to DSR enrolment and others suggesting that consumers do not perceive DSR to be excessively complicated or to require too much effort. Several studies point to the importance of the benefits expected by consumers from participation relative to the effort involved (Allcott 2011; Lopes et al. 2016). Expectations of inconvenience and impact on daily routines that would make changing demand patterns difficult or undesirable are also cited as factors affecting consumer engagement (Buryk et al. 2015; Lopes et al. 2016; Bradley et al. 2016). Finally, some studies report an expectation from some consumers that changing demand would be easy (Buryk et al. 2015; Fell et al. 2015; Lopes et al. 2016).

Some users found responding to time varying pricing to be too complex and to require too much effort. Two trials of real time pricing reported very limited manual demand shifting as a result (Belmans et al. 2014; Friis & Haunstrup Christensen 2016). DSR applying to only some days, rather than daily, can also make response more difficult for some users (Lebosse 2016). Even routine responses to static time-of-use pricing may be perceived as too much effort by some users (Farhar et al. 2016). However, the evidence base on this issue is mixed, 79% of respondents in the UK LCL post-trial survey said they did not find the dynamic time-of-use tariff too complex, 60% agreed it was easy to take advantage of low rates, and 50% agreed it was easy to avoid high rates (Carmichael et al. 2014).

There is some evidence to suggest that automation or direct load control can reduce the complexity and/or effort involved in responding to time varying pricing (Farhar et al. 2016; Wiekens et al. 2014; Belmans et al. 2014; Friis & Haunstrup Christensen 2016). However in some cases use of automation or accessing additional information can be perceived as excessively complex or difficult (Carmichael et al. 2014; Belmans et al. 2014; Farhar et al. 2016; AECOM 2011). Perceived ease of use was linked to automation and direct load control by Fell et al. (2015), and in the NiceGrid trial automated response was often chosen by users away from home during the day to increase response, although other users preferred manual response (Lebosse 2016).

There is some evidence to suggest that consumers can find it difficult to accurately assess their demand patterns. For example, opt-in participants in the Midwest Power Systems time-of-use pricing experiment perceived themselves to have more ability to shift usage to off-peak times than non-volunteers and thought they had lower electricity use during peak times than non-volunteers. However measured load data indicated that their perceptions were incorrect (Mostafa Baladi et al. 1998). In the NiceGrid trial, some recruited households were unsure how they might respond as they expected any reduction in their peak demand to significantly reduce comfort and wellbeing, but in practice they found direct load control to require little effort and impose few constraints on everyday life (Lebosse 2016). Some evidence also suggests that users may prefer feedback in units of price rather than kWh or representations of sustainability as this can be more tangible and easier to understand (Wiekens et al. 2014; Farhar et al. 2016).

Concerns about complexity and effort could be relevant to the idea of autonomous frequency response by domestic fridges and freezers. On the one hand, refrigeration appliances run in the background rather than being run as part of user routines, so changes to their demand patterns that respect thermal constraints seem highly unlikely to inconvenience users. On the other hand, unlike heating or cooling, it seems unlikely that users would be able to make an assessment of how any changes to demand are affecting refrigeration appliances' performance, and there is currently limited evidence that consumers will accept shifting of refrigeration loads (Parrish et al. 2016).

Interaction with user routines and activities

In general, the UK LCL trial found that the appliances participants identified as most flexible were those for which they had the least fixed routines. In line with theoretical expectations, wet goods were the appliances most often involved in manual demand shifting across a number of studies (Wiekens et al. 2014; Carmichael et al. 2014; Lebosse 2016). Some studies report users who also changed their use of energy services often considered inflexible, including cooking, lighting and showering. However, it is possible that these users represented highly engaged and perhaps non-typical participants (Carmichael et al. 2014; Lebosse 2016). Barriers to shifting wet goods included noise (Lebosse 2016; Carmichael et al. 2014; Friis & Haunstrup Christensen 2016), concerns about wet laundry getting crumpled or musty (Carmichael et al. 2014), and safety concerns around leaving appliances running unattended during the night or while no-one is home (Belmans et al. 2014; Carmichael et al. 2014).

The EcoGrid EU trial found manual demand shifting did not produce a statistically significant response, which was suggested to be mostly because users prefer to use wet goods when it is convenient (EcoGrid EU 2016). Comfort and convenience were also identified as important limitations to demand shifting in the UK LCL trial (Carmichael et al. 2014). This can include unwillingness to lose quality time (valuable leisure or family time) in the home (Bartusch et al. 2011; Friis & Haunstrup Christensen 2016), and fixed roles for certain household members to use appliances can also limit flexibility (Carmichael et al. 2014). Comfort and convenience can also affect the performance of direct load control of heating or cooling, for example use of the override switch for direct load control of water heating reduced response in the Linear trial (Belmans et al. 2014).

Demand shifting could be enabled if it can involve behaviours that fit well with existing routines. Dishwashers may provide greater flexibility than other wet goods because users more frequently programme them in the evening (Belmans et al. 2014). Users may be more prepared to run dishwashers than washing machines overnight because it is less disruptive to existing family routines to unload clean dishes in the kitchen in the morning than hang laundry (Friis & Haunstrup Christensen 2016). Similarly it is suggested that night-time charging of electric vehicles can become part of the routine of locking up for the night (Friis & Haunstrup Christensen 2016). In other cases, direct load control was implemented in a way that simply had little impact on participants, for example NiceGrid involved relatively short duration curtailments of heating that took account of differing insulation levels (Lebosse 2016).

Some users appear to have greater ability and adaptability to change their routines in response to DSR. This can involve understanding the operation of technologies such as built in appliance timers (Bradley et al. 2016). It may also require techniques to help keep houses cool without using air conditioning over certain periods of the day (Strengers 2010). Some studies also discuss access to alternative technologies and fuels for heating and cooking, such as gas, wood, and alternative cooking appliances (Lebosse 2016; Carmichael et al. 2014). Finally, several studies identified time outside the home as a barrier to shifting demand, and spending more time in the home, or flexible working hours, as an enabler of response (EcoGrid EU 2016; Dütschke & Paetz 2013; Bradley et al. 2016; Thorsnes et al. 2012; Torriti 2013; Carmichael et al. 2014; Lebosse 2016; Strengers & Maller 2014; Friis & Haunstrup Christensen 2016).

The REA also revealed evidence of consumers who exhibited particularly active responses to DSR trials. For example, householders who left the house to avoid electricity use at certain times (Carmichael et al. 2014; Strengers 2010), changed which household member used appliances (Carmichael et al. 2014), or created a fun family occasion out of using less electricity (Strengers 2010; Western Power Distribution 2016). Some studies report consumers who treated responding to dynamic pricing as a game or a motivator to complete household chores (Carmichael et al. 2014). Some DSR participants simply experienced different levels of disruption to their daily lives and routines (Bradley et al. 2016). It is not clear which groups of users might be willing or able to offer these sorts of behavioural adaptability, or whether such behaviours would persist over time.

Timing of response – time of day, week or season

A number of studies reported different levels of response associated with different seasons, times of day or days of the week. This seems to be associated with the size of baseline loads and opportunities for users to be flexible.

The UK CLNR trial found peak demand reduction was statistically significant during winter months only, although there was no significant demand reduction during the half hour of highest peak demand (Bird 2015). UK LCL trial in general identified lower demand reductions at times of lower baseline demand, and reported greater demand response during winter and spring than summer and autumn (Carmichael et al. 2014). A trial of time-of-use pricing in New Zealand also identified significant response levels during winter months only (Thorsnes et al. 2012). In Australia and California, where peak electricity demand occurs during summer, the highest average peak demand reductions took place during summer (Faruqui & George 2005; Strengers 2010) and were also associated with more extreme temperatures (Faruqui & George 2005).

User routines may also vary seasonally. The Linear trial identified around twice as many flexible configurations of tumble dryers during winter, and also more flexible use of washing machines in winter than in summer (Belmans et al. 2014). Increases in demand occurred around an hour later in summer than winter, which may be due to different seasonal routines (Bartusch & Alvehag 2014). Users in Denmark indicated they would be reluctant to go outside to plug in an electric vehicle during winter (Friis & Haunstrup Christensen 2016).

Some studies considered response at different times of day and days of the week. The UK EDRP identified greater flexibility during weekends (AECOM, 2011), and the LCL trial found flexibility was greater during waking hours and demand increases were greatest during Fridays and Sundays (Carmichael et al. 2014). Bartusch & Alvehag (2014) note demand reductions were lower early in the morning, shortly before lunch time and late in the afternoon, and suggest these may be times when many people might be expected to be doing chores and preparing meals. Participants in the NiceGrid trial reported finding it easier to reduce demand during winter evenings than shift it towards high PV generation during summer afternoons as people were at home more often and dishwashers and washing machines were more often used during this period (Lebosse 2016).

6.5 Characterising different end user segments

Different groups of DSR participants offer quite different levels of enrolment and response. For example, in the UK LCL trial average responses by the highest responding households were around three times the mean response (Carmichael et al. 2014). Respondents to a survey of the general population in Belgium were characterised as advocates, supporters, sceptics and refusers of smart appliances (36%, 27%, 25%, and 12% of respondents, respectively) (Belmans et al. 2014). Understanding which characteristics explain these differences could allow DSR potential to be more accurately predicted, or reduce marketing costs by target marketing to users who are likely to offer the greatest performance. It could also help to protect users by better informing them of whether they are likely to benefit from DSR products and services. However the evidence reveals a considerable degree of complexity and some overlap, with different studies exploring different categorisations of consumers.

Households with larger electrical loads demonstrated larger responses (Midwest Power Systems time-of-use pricing experiment; Faruqui & George 2005) and this effect was also seen with larger houses, which may be linked to higher appliance ownership (Thorsnes et al. 2012; Faruqui & George 2005). In the California SPP trial users with high baseline demand in the hottest climate zones contributed the largest absolute peak demand reduction, but users with low baseline demand in milder climate zones made larger percentage reductions and hence larger savings on their electricity bills (Herter & Wayland 2010).

Response can also decrease if a higher proportion of household electricity use already occurs off peak (Bradley et al. 2016), but this can mean that households save money on a time-of-use tariff even without shifting electricity use. These types of savings were not linked with the decision to participate in the SMUD CBS, but some users with higher on peak baseline demand were actually more satisfied with time-of-use pricing than those who needed to make less effort to save money from the tariff, perhaps because participants valued actively being able to manage their bills (US DOE 2016).

Some studies also considered how user engagement varies with socio-demographic characteristics. Response was higher by households with higher income in the California SPP trial (Faruqui & George 2005), and by homeowners in the UK CLNR trial (Bird 2015). Evidence related to household size and composition is somewhat mixed. Smaller households gave larger average responses in the California SPP and UK EDRP (AECOM 2011), but the opposite effect was identified by Thorsnes et al. (2012) and in the UK LCL trial (Carmichael et al. 2014).

The composition as well as the number of household members may be important. The UK CLNR found that larger households owned more appliances, but households without dependents were more likely to respond to time-of-use pricing, which suggests the composition as well as the number of household members is important (Bird 2015). Similarly, (Friis & Haunstrup Christensen 2016) reported that families with small children tended to find shifting wet goods more stressful, although some reported finding it easy because they were already used to a high degree of planning. Overall this suggests that the presence of children or other dependents could make demand shifting more difficult.

Overall, the UK LCL trial found only weak correlations between household characteristics and demand response (Carmichael et al. 2014). The CLNR trial suggested socio-demographic groups may not be most appropriate way to identify more flexible customer segments, who could instead be identified by "socio-technical" groups (e.g. households with more appliances) or "flexibility capital" (e.g. shift workers) (Bird 2015).

6.6 Evidence on SME engagement with DSR

Evidence from the USA indicates that the commercial sector can play a substantial role in demand response programmes – data from FERC indicates that commercial DSR (as opposed to industrial or domestic) accounted for 20% of peak reductions in the US overall in 2014 and occupied a higher share in some regions (FERC 2016). However, very little evidence was identified on small and medium sized enterprise (SME) engagement with DSR. This section summarises the motivations, barriers and enablers that were identified.

6.7 SME Motivations, barriers and enablers

The UK CLNR approached over 20,000 SMEs. It found that several hundred SMEs were interested in participating in DSR, and were motivated by reducing their electricity bills (Bird 2015). The SoLa Bristol trial, involving battery enabled DSR, also recruited primary schools and found that designing or emphasising opportunities for pupils to learn about energy could act as an important motivator. However, the relative importance of different motivations can depend on the main point of contact for recruitment, with some staff being more interested in the possibility of financial savings (Western Power Distribution 2016).

It is important to note that only two of the 20,000 SMEs approached in the UK CLNR trial signed up to take part in DSR trials (Bird 2015). Concerns about the risk to normal business operations, particularly when timing is dictated by client or customer needs, represents an important barrier to SME recruitment to DSR trials. SMEs also have concerns about the impact of participation on regulatory requirements, including animal welfare in the farming sector and health and safety and environmental health in hotels, pubs and restaurants (Bird 2015).

An additional barrier to recruiting SMEs may be their diversity, which makes it difficult to propose a single DSR offering. Recruitment efforts in the UK CLRN involved time consuming technical surveys of individual SME premises, and the diversity of electrical loads made it difficult to estimate cost savings that might be achieved by DSR participation (Bird 2015).

In the UK CLNR, the two SME loads which did participate (a chiller unit in a beer cellar and an immersion heater in an office) both included a degree of thermal inertia which is likely to have enabled response (Bird 2015). The California SPP involved larger numbers of SMEs, almost all of which had air conditioning, and identified significant average peak demand reductions which increased with SME demand level (Faruqui & George 2005).

The SoLa Bristol trial suggested that end users in offices may not feel involved in DSR projects or behave as expected because users change frequently and decision makers involved in recruitment to a DSR programme tend not to represent the majority of energy end users within a company (Western Power Distribution 2016).

7. Conclusions from the REA

7.1 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.

7.2 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.

7.3 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 found that in-home displays have limited or marginal direct impact on response. 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.

7.4 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.

Appendix tables

Table A1 References in the REA (passed QA and included in synthesis)

Name	QA score	Evidence type	User type	Location	Dates	No. participants
Arcturus (Faruqui & Sergici 2013)	7	Review/ meta-analysis	Resi-dential	Studies spanning 7 countries and 4 continents	Data not available	34 studies
BC Hydro time-of-use/critical peak pricing pilot study (Chi-Keung et al. 2013)	9	Trial and measured load impact	Resi-dential	Canada	Nov 2007 - Feb 2008	1717; 44 volunteered for direct load control
BGE Wi-Fi Thermostat Pilot Impact Evaluation (Robinson 2016)	7	Trial	Resi-dential	US	June – Septem-ber 2015	2,5000 thermostats (1,500 thermostat upgrades, 1,000 to new direct load control participants)
Bradley et al. (2016)	9	Trial with measured load impacts, survey of participants and non-participants, and interviews	Resi-dential	UK (GB)	5 months (dates not available)	10

Name	QA score	Evidence type	User type	Location	Dates	No. participants
Bring Your Own Device Programme Approaches (Narayanamurthy & Robinson 2015)	7	Overview of BYOD business models from EPRI and presentation of current approach from US utility ComEd	Residential	US	Data not available	Data not available
Buchanan et al. (2016)	9	Focus group	Residential	UK (GB)	Data not available	32
Buryk et al. (2015)	9	Survey (not nationally representative)	Residential	US and EU	2012	160
California SPP (Herter & Wayland 2010)(Faruqui & George 2005)(Herter et al. 2007)	9	Trial	Residential, SMEs	US (California)	2003 – 2004	~2500
Martínez Ceseña et al. (2015)	8	Used for policy-focus	Residential SME	UK (GB)	Data not available	Data not available
ComEd CAP(EPRI 2011)	7	Trial plus survey	Residential	US (Illinois)	2010 – 2011	8,000
Chen & Sintov (2016)	9	Survey	Residential	US	2013	856

Name	QA score	Evidence type	User type	Location	Dates	No. participants
COWI (2016)	6	Used for policy-focus	Resi-dential Com-mercial	EU	Data not available	Data not available
Customer lead network revolution (CLNR) (Bird 2015)	6	Trial plus survey and interviews	Resi-dential SME	UK (GB)	2012 – 2013	727 residential 2 SME
Dütschke & Paetz (2013)	9	Survey (not nationally representa-tive) and trial with users in 'living lab' demonstra-tion home.	Resi-dential	Germany	'Living lab': 5 weeks with 2 residents, 8 weeks with 2 residents.	Survey: 160 'living lab': 4
EcoGrid EU (EcoGrid EU 2016)	6	Trial plus surveys and focus groups	Resi-dential	Denmark (island of Bornholm)	2012 – 2014 (first live test of pricing May 2013)	2,000
Element Energy (2012)	6	Used for policy-focus	Non-domes-tic	UK (GB)	Data not available	Data not available
Energy Demand Research Project (EDRP) (AECOM 2011).	6	Trial plus survey	Resi-dential	UK (GB)	2007 – 2010	1546 (time-of-use pricing – larger number of participants in trial overall)
EnergyAus-tralia DPP (Dynamic Peak Pricing) trial (Strengers 2010)	9	Trial plus interviews	Resi-dential	Australia	2006 – 2008	23 trial participants opted into qualitative study reported in this paper

Name	QA score	Evidence type	User type	Location	Dates	No. participants
EPRI Program on Technology Innovation: Measuring Customer Preferences for Alternative Electricity Service Plans – An Application of a Discrete Choice Experiment (Neenan 2015)	7	Choice experiment. Plus review of choice experiments by a number of US utilities.	Resi-dential	US	Between 2000 and 2014	630 Number of respondents in reviewed choice experiments ranged from 800 to 5,300
Farhar et al. (2016)	9	Trial plus interviews and survey	Resi-dential	US (Colorado)	Succes-sive trials of 9 weeks per household	142 households,
Fell et al. (2015)	9	Survey (nationally representa-tive)	Resi-dential	UK (GB)	2014	2002
FERC (2016)	6	Used for policy-focus	Market-wide	US	Data not available	Data not available

Name	QA score	Evidence type	User type	Location	Dates	No. participants
Grid4EU NiceGrid (Lebosse 2016)	7	Trial plus survey, interviews and focus groups	Resi-dential	France	2013 – 2015	Summer, not specified. Winter, “voluntary saving”: up to 180; “controlled heating”, 15. Survey – administered to all participating households. Focus group: 23 households.
GridWise Olympic Peninsula Demonstra-tion (Chassin & Kiesling 2008)	7	Trial	Resi-dential, SMEs	US	April 2006 – March 2007	116 households
Hall et al. (2016)	7	Focus groups	Resi-dential	Australia	2014	53
Helms et al. (2016)	7	Interviews with industry experts	Small users in general	Europe	Data not available	2 interviewees involved in small user DSR
IEA-DSM Interaction between Customers and Smart Grid Related Initiatives (Hull et al. 2013)	7	Includes case studies of surveys, trials and pro-grammes	Resi-dential	Various	Various	Various

Name	QA score	Evidence type	User type	Location	Dates	No. participants
IEA-DSM Assessment and Develop-ment of Network-driven Demand-side Manage-ment Measures (Crossley 2008a)	7	Review of trials and pro-grammes	Resi-dential and SME	Various	Various	Various
IEA-DSM Incorpora-tion of DSM Measures into Network Planning (Crossley 2008b)	7	Review of trials and pro-grammes	Resi-dential and SME	Various	Various	Various
IEA-DSM Micro Demand Response and Energy Saving Products: Require-ments and options for effective delivery (Hull 2010)	7	Review of trials and pro-grammes	Resi-dential and SME	Various	Various	Various

Name	QA score	Evidence type	User type	Location	Dates	No. participants
IEA-DSM Worldwide Survey of Network-driven Demand-side Management Projects (Crossley 2008c)	7	Review of trials and programmes	Residential and SME	Various	Various	Various
I^2EV (My Electric Avenue) (EA Technology & Southern Electric Power Distribution 2016)	6	Trial	Residential	UK (GB)	January 2014 – October 2015	101
Italy regulated time-of-use pricing (Torriti 2013)	7	Programme	Residential	Italy	Analysis July 2010 – September 2011	1446 included in analysis
Katz (2014)	9	Analysis of market and regulatory barriers	Residential and SME	Denmark	Data not available	Data not available
Kitakyushu dynamic pricing experiment (Zhang et al. 2016)	9	Trial	Residential	Japan	2012 – 2013	200
Koliou et al. (2014)	9	Analysis of market and regulatory barriers	Residential and SME	Germany	Data not available	Data not available

Name	QA score	Evidence type	User type	Location	Dates	No. participants
Linear (Vanthournout et al. 2015) (Belmans et al. 2014)	9	Trial plus survey and interviews Stand-alone survey	Resi-dential	Belgium	2011 – 2014; field tests Septem-ber 2013 – July 2014	Trial: 240 Survey: 500
Liu et al. (2015)	7	Used for policy-focus	Market-wide	Shanghai (but evidence from OECD)		
Lopes et al. (2016)	9	Survey (not nationally representa-tive)	Resi-dential	Portugal	2013	1084
Low Carbon London (Carmichael et al. 2014)	6	Trial plus surveys and interviews.	Resi-dential	UK (GB)	12 months	1119
Midwest Power Systems time-of-use pricing experiment (Mostafa Baladi et al. 1998)	9	Trial plus survey	Resi-dential	US (Iowa)	2 year study 'recent' to publication in 1998	775
Newsham & Bowker (2010)	9	Review	Resi-dential	US (various states)	Reviews studies 'recent' to publication in 2010	22 studies
NOBEL (Moreno 2013)	6	Trial plus survey Stand-alone survey	Resi-dential	Spain	Overall project – February 2010 – December 2012. Trial – 6 months	5,000

Name	QA score	Evidence type	User type	Location	Dates	No. participants
Northern Isles New Energy Solutions (NINES) (Coote & MacLeman 2012)	6	Trial focussed on technology demonstration, plus participant surveys	Residential	UK (Shetland)	2010 – 2012	6
PowerCo Smart House Pilot (Rotmann 2014)	7	Trial	Residential	New Zealand	2014	3
PowerMatching City (Wiekens et al. 2014)	6	Trial plus survey and focus groups	Residential	Netherlands	June 2013 – June 2014	40
Sala-Heby Energi Elnait AB (Bartusch et al. 2011)(Bartusch & Alvehag 2014)	9	Trial plus survey and interviews	Residential	Sweden	Single family homes: April 2006 – March 2012 Rental and condominium apartments: October 2009 – March 2012	Single family homes: 38 Condominium apartments: 29 Rental apartments: 28
Shipman et al. (2013)	9	Trial plus interviews	Residential	UK (GB)	Case studies between 2 – 4 weeks duration	3
Smith & Hledik (2011)	6	Used for policy-focus	Market-wide	US	Data not available	Data not available

Name	QA score	Evidence type	User type	Location	Dates	No. participants
SoLa Bristol (Western Power Distribution 2016).	6	Trial	Residential SME	UK (GB)	2012 – 2015 (publicity started 2012, installation started 2014)	26 homes 2 offices 3 schools
Straub & Switzer (2013)	7	Programme	Residential	US (Maryland)	2012	46
Swinson et al. (2015)	7	Programme plus survey	Residential	Australia (Queensland)	At least from 2013 to 2015.	Over 5,000 enrolled. Survey: 344 Measured load data: 60. 36 of these responded to additional survey.
Test an EV (TEV) (Friis & Haunstrup Christensen 2016)	9	Trial plus interviews.	Residential	Denmark	around 7 months in 2012	Interviews:8 Load profile analysis: 159
Thorsnes et al. (2012)	9	Trial plus measured load impacts and survey	Residential	New Zealand	August 2008 – July 2009	400
Torstensson & Wallin (2014)	9	Survey	Residential	Sweden	2013	534
Understanding Electric Utility Customers Summary Report (EPRI 2012)	7	Review	Residential, SME	US and Europe	From the last decade	Large field trials

Name	QA score	Evidence type	User type	Location	Dates	No. participants
US DoE Consumer Behaviour Studies (CBS) (US DOE 2016)	7	Trials plus surveys and focus groups in some cases	Resi-dential	US (various states)	Data not available	CEIC: aimed for ~5,000, but fell short. DTE: aimed for over 6,000, but fell short. GMP:over 3,500. LE: over 2,000. MMLD: ~500. MP: over 4,500. NVE: over 16,000 OG&E: about 5,000 residential and over 1,000 SME. SMUD: about 57,000. VEC: more than 3,500.
Vallés et al. (2016)	8	Reviews regulatory/ market barriers	Resi-dential and SME	Spain, Italy, Germany, France, Great Britain and Sweden	Data not available	Data not available
Your Energy Moment, Zwolle (Kobus et al. 2015)(Klaassen et al. 2016)	9	Trial with measured load impacts and surveys	Resi-dential	Nether-lands	2012 – 2014 Analysed data from May 2014 – May 2015, for all partici-pants	From 2012: 77. From 2014: 111. Total: 188

Table A2 References that passed relevance screening but failed QA rating (not included in REA synthesis)

Author	Date	Title and publisher	QA rating
Drizard et al.	2016	Demo 6 - final assessment of the demonstrator, Grid4EU	5
Neenan et al.	2014	Peak Time Rebate vs. Critical Peak Pricing: A Distinction without a Difference?, EPRI	4
Neenan et al.	2014	What We Have Learned and How to Apply it to Your Utility, Program 182: Understanding Electric Utility Customers - Electric Service Plan/Behavioural Program Evidence Review Webcast, EPRI	4
Neenan et al.	2016	Multi-Year Study of the Impacts of OG&E's SmartHours Residential Electric Service, EPRI	4
Stifter et al.	2016	Pilot Studies and Best Practices Demand Flexibility in Households and Buildings, IEA-DSM	4

Table A3: REA search strings used in Science Direct and Google

Search trial no.	Number of results and search terms (note that 'TAK' confines the search to the Title, Abstract and Keywords)
1	Search results: 2,635 results found for pub-date > 1989 and (pilot OR trial OR programme OR program OR survey OR "focus group") AND ("demand response" OR "demand side response" OR "direct load control" OR "time varying pricing") AND (residential OR domestic OR "SME" OR commercial OR business) AND electricity

Search trial no.	Number of results and search terms (note that 'TAK' confines the search to the Title, Abstract and Keywords)
2	299 results found for pub-date > 1989 and TAK(pilot OR trial OR programme OR program OR survey OR "focus group") AND TAK("demand response" OR "demand side response" OR "direct load control" OR "time varying pricing") AND (residential OR domestic OR "SME" OR commercial OR business) AND electricity
3	960 results found for pub-date > 1989 and (pilot OR trial OR programme OR program OR survey OR "focus group") AND TAK("demand response" OR "demand side response" OR "direct load control" OR "time varying pric*" OR "dynamic pric*" OR "real time pric*" OR "time-of-use") AND (residential OR domestic OR "SME" OR commercial OR business) AND electricity **These terms were used for the full search of ScienceDirect**
4	603 results found for pub-date > 1989 and (pilot OR trial OR programme OR program OR survey OR "focus group") AND TAK("demand response" OR "demand side response" OR "direct load control" OR "time varying pric*" OR "dynamic pric*" OR "real time pric*" OR "time-of-use") AND (residential OR domestic OR "SME" OR commercial OR business) AND TAK(electricity)
5	683 results found for pub-date > 1989 and TAK(pilot OR trial OR programme OR program OR survey OR "focus group" OR project OR study OR experiment OR test) AND TAK("demand response" OR "demand side response" OR "direct load control" OR "time varying pric*" OR "dynamic pric*" OR "real time pric*" OR "time-of-use") AND (residential OR domestic OR "SME" OR commercial OR business) AND electricity

Search trial no.	Number of results and search terms (note that 'TAK' confines the search to the Title, Abstract and Keywords)
6	1,117 results found for pub-date > 1989 and TAK(pilot OR trial OR programme OR program OR survey OR "focus group" OR project OR study OR experiment OR test) AND TAK("demand response" OR "demand side response" OR "direct load control" OR "time varying pric*" OR "dynamic pric*" OR "real time pric*" OR "time-of-use" OR "smart grid*") AND (residential OR domestic OR "SME" OR commercial OR business) AND electricity
7	392 results found for pub-date > 1989 and TAK(pilot OR trial OR programme OR program OR survey OR "focus group" OR project OR study OR experiment OR test) AND TAK("demand response" OR "demand side response" OR "direct load control" OR "time varying pric*" OR "dynamic pric*" OR "real time pric*" OR "time-of-use" OR "smart grid*") AND (residential OR domestic OR "SME" OR commercial OR business) AND electricity AND NOT simulation
8	763 results found for pub-date > 1989 and TAK(pilot OR trial OR programme OR program OR survey OR "focus group" OR project OR study OR experiment OR test) AND TAK("demand response" OR "demand side response" OR "direct load control" OR "time varying pric*" OR "dynamic pric*" OR "real time pric*" OR "time-of-use" OR "smart grid*") AND (residential OR domestic OR "SME" OR commercial OR business) AND electricity AND NOT TAK(simulation OR algorithm)
9	408 results found for pub-date > 1989 and TAK(pilot OR trial OR programme OR program OR survey OR "focus group" OR project OR study OR experiment OR test) AND TAK("demand response" OR "demand side response" OR "direct load control" OR "time varying pric*" OR "dynamic pric*" OR "real time pric*" OR "time-of-use" OR "smart grid*") AND (residential OR domestic OR "SME" OR commercial OR business) AND electricity AND NOT TAK(simulation OR algorithm OR modelling)

Search trial no.	Number of results and search terms (note that 'TAK' confines the search to the Title, Abstract and Keywords)
10	435 results found for pub-date > 1989 and TAK(pilot OR trial OR programme OR program OR survey OR "focus group" OR project OR study OR experiment* OR test OR evidence) AND TAK("demand response" OR "demand side response" OR "direct load control" OR "time varying pric*" OR "dynamic pric*" OR "real time pric*" OR "time-of-use" OR "smart grid*" OR "price respons*" OR "responsive load" OR "active demand") AND (residential OR domestic OR "SME" OR commercial OR business) AND electricity AND NOT TAK(simulation OR algorithm OR modelling)
11	809 results found for pub-date > 1989 and TAK(pilot OR trial OR programme OR program OR survey OR "focus group" OR project OR study OR experiment* OR test OR evidence) AND TAK("demand response" OR "demand side response" OR "direct load control" OR "time varying pric*" OR "dynamic pric*" OR "real time pric*" OR "time-of-use" OR "smart grid*" OR "price respons*" OR "responsive load" OR "active demand") AND (residential OR domestic OR "SME" OR commercial OR business) AND electricity AND NOT TAK(simulation OR algorithm)

Search trial no.	Number of results and search terms (note that 'TAK' confines the search to the Title, Abstract and Keywords)
	Policy-specific search terms used in Google: "demand response" OR "demand side response" OR "direct load control") AND (residential OR domestic OR "SME" OR "commercial consumers" OR "small businesses" OR "business users") AND electricity) AND (policy OR education OR incentive OR label OR marketing OR promotion OR R&D OR RD&D OR regulation OR standards OR support) AND (evaluation OR assessment OR effectiveness OR success OR failure OR analysis OR impact 'About 407,000' results were returned from this search. The first 100 hits were examined. Google excluded the word 'success' and subsequent words because of a limit on the number of words that can be searched. The search terms were therefore then revised to: "demand response" OR "demand side response" OR "direct load control") AND (residential OR domestic OR "SME" OR "commercial consumers" OR "small businesses" OR "business users") AND electricity) AND (policy OR education OR incentive OR label OR marketing OR promotion OR R&D OR RD&D OR regulation OR standards OR support) 'About 478,000' results were returned from this revised search. The first 100 hits were examined.

Table A4: REA inclusion and exclusion criteria

Inclusion criteria: • Geographical: Europe, North America, Australia and New Zealand, also Japan • Sector: residential or small and medium commercial (250 employees or fewer, or described as small commercial or SMEs) • Evidence type: including some form of empirical evidence rather than theory alone • Access: publications in English, available for free (or where the project team have journal database access) • Any type of time varying pricing aiming to change electricity use at specific times, with or without additional information or automation (static time-of-use, dynamic time-of-use, critical peak pricing, variable peak pricing, day ahead real time pricing, real time real time pricing) • Direct load control or automation (e.g. via smart appliances) aiming to change electricity use at specific times • Rebates aiming to change electricity use at specific times (critical peak rebate) • Information (alone) aiming to change electricity use at specific times • Include all of the above acting over specific local areas • Include all of the above using battery storage, PV etc. to facilitate DSR – note this as an enabling factor and analyse separately, but don’t search separately, nor for local demand shifting
Exclusion criteria: • Spontaneous self-consumption of PV generation • V2G or home battery discharge to grid, or other forms of dispatchable generation (micro CHP)

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