Department for Business, Energy & Industrial Strategy

REALISING THE POTENTIAL OF DEMAND-SIDE RESPONSE TO 2025

A focus on Small Energy Users

Lessons from selected regions:

Country case studies report

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Acknowledgements

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Contents

1. Introduction

This report contains the methodology and detailed findings from the five individual case studies; these are further analysed and brought together in the separate summary report.

Following the outline of the methodology used, in chapter 2, separate chapters deal with each of the five case studies. The structure for each case study chapter is as follows:

- Overview: brief introduction to relevant features of the region's energy system
    - Development of demand-side response (DSR): a short history of DSR in the region
    - Markets for DSR resources: an explanation of markets open to DSR and which markets DSR and small-scale participate in
    - Products and services: an overview of the products and services available
    - Business models: an overview of a DSR business model in the region
- Interview themes: a presentation of the main themes identified in the interviews in each case
- Summary: a summary of the case study

Two chapters (on Texas and Illinois) have annexes containing further detailed information. References are provided in the References document.

The main actors and concepts referred to in the case studies are presented in Box 1.1

Box 1.1: Case study terminology

A variety of markets, products, actors and definitions exist in the international small-scale DSR landscape. These include at the very least:

- **The markets DSR can compete in:**
  - *Energy market:* where DSR participants get paid for bidding in an offer to reduce or shut down load or via energy trading and arbitrage
  - *Reserve markets*: also referred to as 'ancillary markets' where participants get paid for providing grid services. In this report we generally refer to these markets to mean frequency response
  - *Balancing market*: where participants get paid or must pay for being out of balance from their submitted supply and demand schedules. In the Nordic countries this is categorised as a part of the reserve market
  - *Capacity markets*: where participants get paid for the capacity to generate or shut down load
- **Appliance manufacturer:** a manufacturer of, for example, electric heating and cooling appliances, thermostats, electric vehicle chargers
- **Technology Service Provider (TSP):** a company providing the technology necessary for a customer to participate in DSR products and services. This could be, for example, an independent aggregator installing communication controls on a customer premise or a company offering home automation equipment or software solutions
- **Balance Responsible Party (BRP):** the entity responsible for being in balance in relation to a submitted load schedule for a given settlement interval. In this report a BRP generally refers to a retail supplier
- **Home automation:** the automatic adjustment of heating, cooling or lighting in response to a resident's needs. These can be linked to personal behaviour parameters, weather forecasts and real-time prices on the energy market. The primary purpose of home automation is generally not DSR services but increased comfort at home

2. Case study methodology

Case selection

An important factor is the applicability of the lessons learned from each case study to the context of Great Britain (GB). The cases therefore need to be different enough to draw meaningful lessons from the outcomes observed, and similar enough to draw comparisons between each case study and to GB. To achieve this, we established criteria to guide the selection process. The use of criteria for selecting case studies is a well-established methodology (Shakir, 2002).

Initial list of case studies (nineteen regions)

The project team first built up a long list of potentially interesting regions based on a literature review. This task identified regions that have made progress on small-scale DSR. As this is still an undeveloped market we included regions that have: a) late stage pilot projects and testing of novel tariffs; b) markets and regulatory frameworks open to DSR; or c) fully developed commercial models involving small-scale users. This process resulted in a list of nineteen potentially interesting regions.

Screening criteria (seven regions)

The project team then applied screening criteria to the nineteen regions to test their relevance to GB. These included indicators of DSR maturity, including the extent of smart meter roll-out, a preliminary search of products, services and tariffs, and whether the regions had been covered in previous studies. This resulted in a list of seven regions considered to be both interesting and relevant.

Contextual factors (5 regions)

Finally, the authors applied a number of contextual factors to help ensure transferability of the lessons learnt to the GB context. Each of the seven regions was scored on the contextual factors (i.e. their similarity to GB) on a scale of 1-4. We also considered the availability of data and whether the region had a liberalised or deregulated retail market. Liberalised retail markets were preferred to ensure consistency with GB context. The contextual factors were chosen based on a desk-based literature review and an *a priori* assessment of what factors influence the context for small-scale DSR markets. The project team also sought input from the expert panel. Data for the contextual factors was gathered through further desk-based research of academic and grey literature. The contextual factors assessed included:

- Summer/winter temperature difference
- Home ownership
- Residential electricity demand per capita
- Ratio of peak to low residential demand
- Percentage of total demand met by non-hydro renewable (yearly)

- Degree of competition in electricity retail market (Herfindahl-Hirschman Index)
- Switching rates amongst residential customers
- Average residential electricity bill compared to average income
- Utility customer satisfaction surveys
- Regulated or deregulated retail markets

This resulted in a final list of five regions, defined in some cases by their regional electricity system operator, namely **Finland, Germany, Norway, Texas** and **Illinois**. This process is shown in Figure 1.

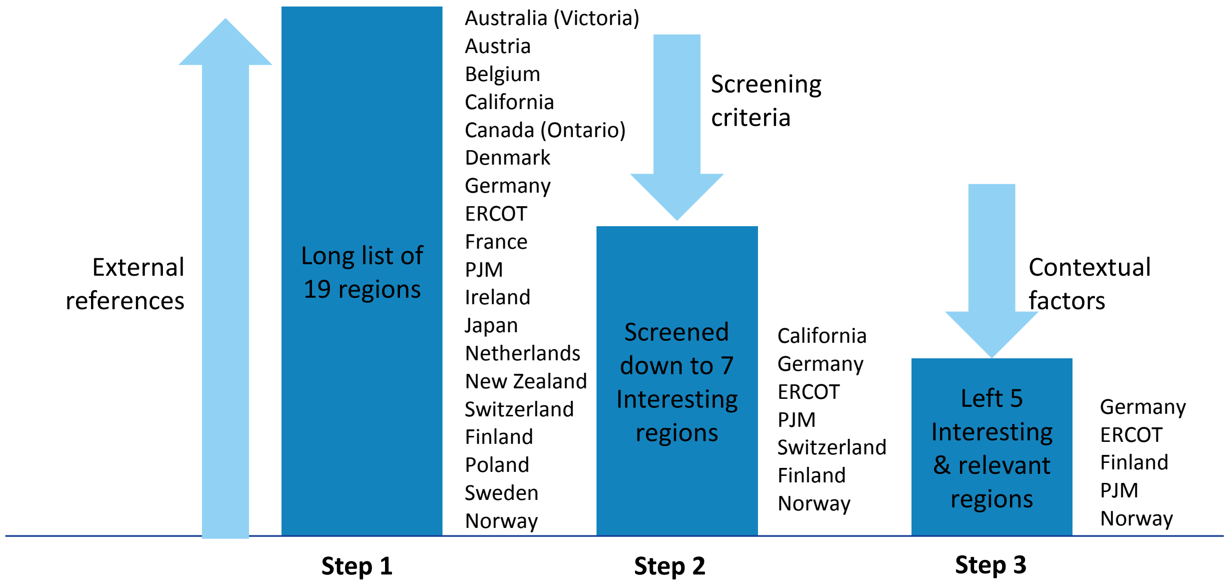

Figure 1: Step-wise process for case selection

These five regions represent a wide range of small-scale DSR markets from nascent to relatively mature which enables a comparative analysis. Due to the large size and diversity found within PJM, we further narrowed down the case study to Illinois and the area of Illinois covered by the PJM market operator, where DSR features strongly.

Data gathering: interviews and literature

The primary evidence gathering took place via 25 phone interviews with stakeholders in the relevant regions. The interviewees received a list of topics and questions beforehand. Context and verification of interview data were ensured through reviews of academic and grey literature including government reports, websites, trade associations and company reports. Language was not a major barrier as project team members were fluent in all languages spoken in the case study regions, except Finnish, and there was considerable information available in English.

The number of interviews and types of organisations interviewed per region are listed in Table 1. The project team aimed at five interviews per case as this was deemed sufficient within the time available to cover the breadth of organisations involved in providing DSR solutions to small-scale users. Interviewees were chosen based on their involvement in the organisations identified as relevant; this was determined either through the team's own network or via preliminary desk-based research in each region. Interviewees were contacted either via the team's network, or via cold emails and calls. The participation rate was 49% across the case studies. Interviews were recorded and logged in a project sheet.

Documentary analysis also played an important role in the data gathering both to provide context and additional evidence and for verifying the interview data. Official original source documents were preferred over other sources and interviewees were followed up with, as necessary, by email to discuss information gathered in the documentary analysis. The majority of sources were obtained via desk-based research while a few documents were obtained from interviewees.

Table 1: Number of interviews and types of organisations per region

Region	Number of interviews	Types of organisations
Texas	5	ERCOT, software and hardware solution providers, retailers
Illinois	5	ComEd, retailers, PJM, consultancies
Finland	5	Home automation providers, FinGrid, retailers, appliance manufacturer
Germany	6	Think tanks, grid operator, consumer organisation, appliance manufacturer, retailer
Norway	5	Think tanks, distribution network operator (DNO), a software and hardware solution provider, electric vehicle smart charger developer

We applied a theory-led approach by establishing a 'conceptual framework', as suggested by Baxter and Jack (2008). Conceptual frameworks are helpful to: a) identify what will and will not be included in the case study; b) describe what relationships may be present in the case study; and c) provide conceptual 'bins' to facilitate the data gathering and analysis. A conceptual framework does not lead directly to hypotheses but rather helps make logical sense of the information gathered during the interview process.

The conceptual framework also included guiding propositions of types of conditions expected to be found within a developed small-scale DSR market, to explore within the case study interviews. These propositions were based on our team's knowledge of the factors affecting small-scale DSR development as well as insights gained from the Rapid Evidence Assessment (REA). The propositions facilitated the interviews and the types of issues raised with the interviewees. However, as one of the benefits of case studies is flexibility in the data gathering process we did not limit ourselves only to the propositions and explored other factors which were deemed relevant to the overarching research objective as they emerged from the interview process. Figure 2 shows the conceptual framework and examples of the propositions.

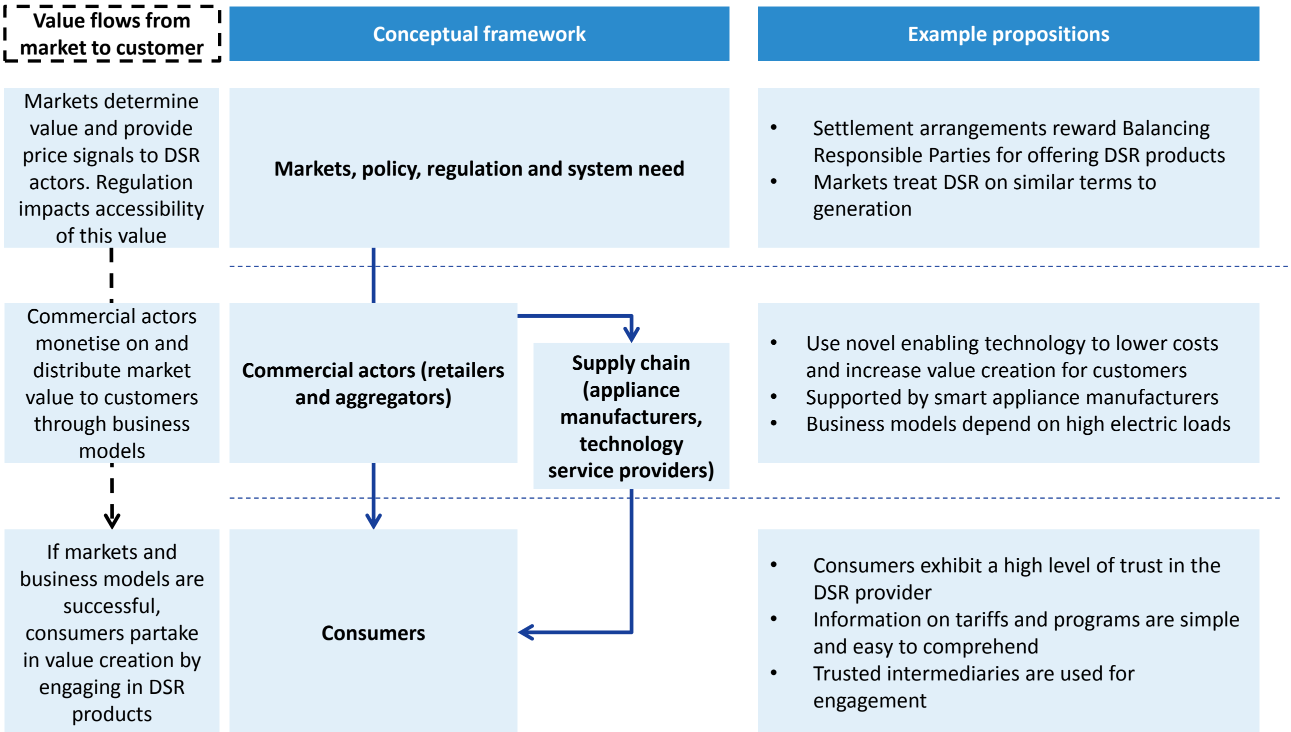

Figure 2: Conceptual framework used for case studies

Conceptual framework

The conceptual framework is based on a concept of **value creation** in which:

1. Markets, policy, regulation and system need to determine the overall demand and accessible value of demand response services. The market opportunities for DSR are largely the same as for any flexibility service in the power system, such as trading in the energy-only markets, bids in the capacity markets or provision of frequency services.

2. Once the market values DSR, it is assumed that commercial actors can capitalise on this value by creating business models offering DSR products and services to consumers. Supply chain actors, such as appliance manufacturers may contribute to distributing the value to consumers.

3. Ultimately, consumers will need to buy or participate in the relevant products and services to partake in the value opportunity in the market.

The case studies explore small-scale DSR through this conceptual framework, expecting to find enabling factors and barriers in each of the three areas.

3. Texas

Key message

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

Overview

Texas has a well-developed small-scale DSR market with a large number of products and services offered to residential and small commercial customers. The Electric Reliability Council of Texas (ERCOT) is the Independent System Operator for 90% of the electric load in Texas and its responsibility includes the scheduling, settlement and balancing of power on the wholesale market (ERCOT, 2017). ERCOT has 74 GW of generation capacity with a peak demand of 71 GW. ERCOT began the roll-out of smart meters in 2009 and by 2014 nearly all 7 million retail customers had a smart meter installed. These are settled on actual consumption data on a 15-minute interval which is communicated back to the participants in the wholesale market.

ERCOT operates a day-ahead energy and ancillary service market, where participants can fine-tune their portfolios and place offers for ancillary services, and a real-time market for balancing portfolios. Small-scale DSR can in theory participate in all these markets. The main residential electric loads in the ERCOT region comprise air conditioning, water and pool heating, but peak demand is driven by summer air conditioning load.

Development of DSR in ERCOT

ERCOT has overseen a deregulated wholesale and retail electricity market with separation of generation, transmission and retail since 2002. Prior to this, there were high levels of participation from industrial DSR responding to interruptible or real-time tariffs (Zarnikau, 2009). One cited reason for this has been that the regulator in Texas, the Public Utilities Commission of Texas (PUCT), mandated in the 1980s that vertically integrated utilities factor in demand-side management schemes in its resource planning. Under the regulated electricity regime, the vertically integrated utilities could recover the costs of the demand-side programmes via the retail rates approved by the PUCT (SPEER, 2014).

After deregulation, all the DSR resource in ERCOT was lost; interruptible and real-time tariffs had to be temporarily suspended in the restructuring process and the benefits of providing DSR programs to customers were socialised across the system (SPEER, 2014). The DSR resource at the time has been estimated to 3 GW (Zarnikau, 2009). As a result, concerns of resource adequacy emerged in the transition phase. The PUCT subsequently established that ERCOT should “develop new measures and refine existing measures to enable load resources a greater opportunity to participate in the ERCOT market” (Zarnikau, 2009).

Texas began rolling out smart meters in 2005, following a mandate from the Texas Legislature, and ERCOT began settling wholesale and retail suppliers on accurate 15-minute data in 2010. Over this time, two main ways have since developed for DSR resources to bid in to the markets: 1) via formal bids in the energy and ancillary markets; and 2) via informal voluntary responses to anticipated price volatility. The latter was specifically designed to encourage price-responsive demand sources (ERCOT, 2002). In 2011, the Texas legislature passed a bill requiring the PUCT to create rules “ensuring that ERCOT allows load participation in all energy markets for residential, commercial and industrial classes, either directly or through aggregators of retail customers…” (ERCOT, 2015). While this set the direction of allowing DSR participation in the markets, the exact design features of ERCOT markets is generally left to ERCOT and involved stakeholders (Zarnikau, 2009).

Markets for DSR resources

Following deregulation in 2002, ERCOT now offers demand-side resources which allow for a number of new ways in which to participate in the ancillary and energy markets[1]; however, small-scale DSR is only present in two of them. The type of response offered can largely be broken down into two separate categories: formal and voluntary. Overall, the main distinction between the formal and voluntary schemes is that the formal arrangements require a formal agreement between the customer (via the retail supplier) and ERCOT, while a voluntary response is a voluntary load reduction by the customer based on a price signal from the market. The consumer is not introduced to the distinction between formal and voluntary. The products and services offered to consumers can therefore be tied to either a formal agreement between the retailer and ERCOT or simply a voluntary response. For a more detailed discussion of the reserve markets available to DSR see the chapter annex.

Formal

Formal responses constitute the majority of ways in which small-scale DSR can participate in the ERCOT markets. These consist of formal bids for providing ancillary services on the

[1] It should be mentioned that ERCOT does not operate a formal capacity market.

day-ahead market as well as bids for load reductions in the real-time market. There is also a type of capacity market available to loads known as Weather Sensitive Emergency Response Service (WS ERS). Of these options, small-scale DSR only participates in the WS ERS, which in 2016 consisted of 22 MW of aggregated load. The WS ERS was designed to take into account the availability factors of residential demand specifically in regards to air conditioning load.

Voluntary

Voluntary responses refer to load reductions in response to a price signal from the energy market. Indicative numbers suggest that this is the main means by which small-scale DSR participates in the deregulated ERCOT markets (ERCOT, 2015).[2] Retail suppliers offer a host of products and services to households that allow them to use the small-scale load in the real-time energy market on a voluntary basis. There are no minimum bid requirements or contract lengths.

Table 2 presents the types of products and services available to consumers in the deregulated areas of Texas. These products enable both formal and voluntary responses. It merits mentioning that the number for customer uptake of Peak Rebates is subject to a degree of uncertainty as they are based on voluntary information provided by retailers, combined with ERCOT estimates. Overall, more than 12% of residential customers in ERCOT are now on some form of DSR programme (Wattles, 2015).

[2] Another mechanism for voluntary load reduction is the 4CP. 4CP (Four Coincident Peaks) are the four 15-minute settlement intervals corresponding with highest load in each of the four summer months (June – September). Load during 4CP determines a customer's grid tariff and as such encourages demand reduction during these periods. However, 4CP is only available to large industrial customers in the deregulated areas of ERCOT and has therefore not been discussed further here. In the regulated areas 4CP is available to residential customers and reportedly constitutes a significant share of DSR response.

Table 2: Overview of time-varying tariffs and services in ERCOT (Raish, 2015)

Product/service	Commercially available?	Uptake (% of customers)	Primary application
Time-of-use	Yes	328,642 (4.91%)	Load shifting
Peak Rebate	Yes	499,085 (7.45%)	Load shifting, peak shaving
Real-Time Pricing (RTP)	Yes	5,261 (0.08%)	Peak shaving
Block & Index Pricing	Yes	9,574 (0.14%)	Load shifting
Other Load Control	Yes	14,927 (0.22%)	Load shifting, energy conservation, peak shaving

Business models

The number of residential products and services available in ERCOT are supported by a few core business models that largely draw on the same mechanism in the real-time energy market. This section deals with Peak Rebate. However, Peak Rebate is only a representative example of a voluntary response – a similar form of value generation may take place with any customer who has given up control of its load to its retailer.

Using Peak Rebate to create revenues via the real-time energy market

Peak Rebate offers customers a financial incentive to reduce loads during periods identified by the retail supplier. These periods are communicated to the customer ahead of the identified period and the customer can either respond manually or the retail supplier can adjust load via a smart thermostat, if installed on the customer's premises. It may also be that the customer is not made aware of the price changes and that the retailer shifts the load automatically. The payment received by the customer is then a contractual matter between the retailer and customer. The contract often states how many times per year the retailer can control the customer's load. Generally, the customer is entitled to a payment corresponding to the reduction in load. For monitoring and verification purposes, the retailer needs to have established a methodology for determining the amount of response provided by the customer based on a baseline consumption. The smart thermostat can be provided either by the retailer as part of a packaged customer offering or via a smart appliance manufacturer via a 'Bring You Own Device' (BYOD) model (see, for example, Section 1.1 of the summary report).

The retailer captures value through additional revenue opportunities on the real-time market. In ERCOT, the retail supplier (as the Balance Responsible Party) has to submit its supply and demand schedule to ERCOT on a day-ahead basis via a Qualified Scheduling Entity (QSE) (i.e. how much demand it obliges to meet in a given settlement interval and how much supply it has scheduled to meet that demand). In most instances, the generation to meet demand has been sourced ahead of time, for example, on the bilateral forward markets for a set price (USD/MWh). In the event that the retailer forecasts a high price event, the retailer reduces its load compared to its scheduled position. In ERCOT, as long as the amount of generation it has purchased remains unchanged, the retailer can 'sell back' the excess power at the market price as part of the settlement process. The retailer would know whether it would be economic to reduce load via price signals on the day-ahead market and via indicative non-binding prices posted by ERCOT. The retailer may also have its own price prediction tools also factoring in, for example, wind forecasts.

The retailer thus captures the difference between the hedged power purchase price and the real-time balancing price.[3] The customer, on the other hand, will only consume a few kWhs less than usual, normally at a fixed price. The exact share of the value accruing to the retailer that gets passed on to the consumer is always a contractual matter between the two. If a customer has not offered up a controllable load but is on a time-varying tariff, such as real-time price, this can work as a perfect hedge for the retailer in that any exposure to price spikes is passed through to the customer.

[3] For example, a retailer has purchased supply at $50/MWh via bilateral contracts for a given settlement interval. Due to low wind forecasts and extreme summer temperatures leading to peaking air conditioning demand, the retailer forecasts a price spike of $1,000/MWh on the real-time energy market. If the retailer reduces 1 MWh of load for that same settlement interval, and its forecast is correct, it will essentially capture $1,000 MW/h - $50 MW/h = $950/MWh as part of the settlement payment which is calculated using real-time market prices.

Interview themes

The following sections highlight themes from the interviews conducted with stakeholders in the ERCOT DSR landscape, including commercial stakeholders (technology service providers and retail suppliers) and the market operator (ERCOT). The sections highlight the factors that, according to our interviewees, can explain the relatively high levels of small-user DSR engagement observed in ERCOT to date, while also touching on barriers to full scale deployment. The themes are presented according to the conceptual framework.

Policy, markets and regulation

Theme 1: Texas operates as an 'electric island'

One interviewee noted that ERCOT operates as an electric island with limited exports and imports. While there is therefore not a general lack of capacity in the system (ERCOT has more capacity than required to meet its peak demand), an important flexibility option is lacking in that there is limited interconnection with surrounding states. Frequency issues on the grid are therefore a big concern and listed as a key driver for ERCOT's keenness to pursue DSR solutions. Limited electricity trading with surrounding states lies behind ERCOT not being under the jurisdiction of the Federal Energy Regulatory Commission (FERC), giving it independent authority to pursue alternative flexibility options. ERCOT also has a high penetration of intermittent wind generation (15% in 2016) which increases the need for flexibility (ERCOT, 2016).

Theme 2: Settlement arrangements reward suppliers for offering DSR products

A supporting feature for DSR that emerged repeatedly was the balancing settlement process. After the end of a settlement interval, ERCOT tallies the positions of all Balance Responsible Parties (BRP) to understand whether they are short of their original positions (too little generation compared to demand) or long (too much generation compared to demand). If a BRP comes up long, it can effectively sell back power to ERCOT at the real-time balancing price for that interval as long as generation remains unchanged. While prices are not published in advance, ERCOT publishes non-binding advanced prices. A BRP can therefore instruct the loads in its portfolio to reduce consumption, come up long, and receive the market clearing price in the real-time balancing market. If a BRP has hedged its purchase either on the day-ahead or bilateral markets, this can represent a significant revenue opportunity. The BRP therefore solely relies on the forecasted prices on the energy markets to instruct its customers to decrease load.[4] As one interviewee said: *"in ERCOT we do not have a separate stream of energy payments associated with*

[4] From a system balancing perspective, this still encourages participants to balance their portfolios relative to the system position. A high price signal represents a congested area or lack of electricity supply compared to demand. If the BRP receives a low or even negative price signal, due to an excess of supply on the system, the BRP would not instruct its resources to reduce load.

demand response… any time there is a reduction in usage that immediately accrues to the retailer… [either through] the retailer avoiding significant charge for any unhedged consumption or selling any hedge into the real time market so you know, they are doing alright." Another interviewee commented that the way that that market mechanism was set up is really the *"foundation of the smart grid".*

Another feature that allows for this business model is the settlement of customers on real consumption data, not average load profiles across a customer group. This means the BRP, and by extension the household, is rewarded for the actual reductions achieved in a given settlement interval. The short settlement interval of 15 minutes was also reported to provide more operational certainty to less flexible DSR resources, such as peak air conditioning loads, which may not be able to turn off for longer periods of time in summer when most peak price intervals occur.

Theme 3: Cheap electricity holds back the full potential of DSR and price signals could be improved

Despite the beneficial settlement arrangements, low electricity prices were in general mentioned as a barrier to further uptake of small-scale DSR. Availability of cheap natural gas over the last decade has driven down wholesale electricity prices and put pressure on other market players. Low electricity prices and slim profit margins have discouraged new technologies and market entrants, such as DSR. One technology service provider said: "*what we have struggled with is the actual installation of the device. If it requires an electrician the cost can jump an additional $200. So how much money can a customer actually save with the price of electricity so cheap? If we were sitting on $100 MWh it would be a lot easier to justify many of the programmes."* Several interviewees also mentioned that while price spikes on the energy markets are sufficient to justify products and services their relatively low occurrence is holding back the full potential of DSR. For example: *"most of our pricing events are very short in duration and may not even last a full 15 minute interval and it is very rare to have a sustained pricing event because a) we have a lot of demand-side response by now but b) we also have a lot of fast reacting generators."*

In ERCOT all loads are also settled based on the zonal average price, rather than the nodal specific price, which further blunts locational price spikes: *"It's not a disastrous barrier but it mutes the locational variation which by definition can be more extreme than the average. Prices are still going to be high around system peak."*

Business models

Theme 4: Hardware and installation costs are still too high to allow participation in all ERCOT markets and technical requirements in reserve markets are demanding

The majority of small-scale DSR participates either as voluntary load reduction in the energy market or in the WS ERS. There are no residential loads providing frequency or any other ancillary service. One interviewee (a retail supplier and BRP) pinned this on the technical requirements of the frequency markets which require very fast response times and communication between loads. The resource is meant to respond in less than a second to a change in frequency. In a disaggregated pool of loads this leaves insufficient time for all of the loads to respond in time. An alternative would be to equip all the loads in the pool with under frequency relay devices.[5] However, *"those UFRs are generally rather expensive pieces of equipment".* Hence, participation of aggregated residential loads in ERCOT reserve markets involves both technical and economic challenges.

ERCOT has a high penetration of renewables (especially wind power) as well as highly fluctuating loads (such as arc furnaces and steel mills) on the system, meaning that frequency can change quickly. According to one interviewee, all of ERCOT's ancillary service markets are built around maintaining frequency and they have never seen a way for residential loads to provide that. It was further stated that ERCOT will probably *"never be able to qualify anyone for the [reserve] market"* due to its technical requirements. When speaking of air conditioners formally bidding in to the real-time energy market, requiring a response to a 5 minute dispatch signal, one interviewee stated that:

"We have never had anybody qualified to provide that service – [real-time market pricing] runs every 5 minutes – the way we set it up is that you need to be able to move incrementally every 5 minutes. That's not something, we learned, AC is good at doing. They are just not good at doing it. Their control systems aren't there yet or the physics of the compressors don't allow them to restore that load that fast. I don't think we'll be able to qualify anyone for the reserve markets because that is not 5 minutes that is every couple of seconds and you'll have to move in both directions."

Costs were also mentioned by two other interviewees who argued that the cost of residential DSR services jump significantly once installation is factored in – even for established and mass-produced devices such as smart thermostats which also complicates the business case in the energy market.

Theme 5: Partnerships are key to enabling business models

Establishing strategic partnerships was mentioned as a key driver for improving the economics of small-scale DSR. BYOD is a customer engagement and cost reduction strategy adopted by multiple utilities, appliance manufacturers and technology providers across the US, including in Texas. This model allows customers to purchase appliances with preinstalled capability to respond to signals from retail suppliers. One technology service provider mentioned that it had signed several agreements with appliance manufacturers such as Honeywell, Nest and Ecobee under which it pays those companies to speak with their customers, reducing its customer acquisition costs. A retail supplier interviewee noted, however, that it is difficult for appliance manufacturers to embed, for

[5] These devices allow the air conditioning unit to monitor grid frequency.

example, frequency relay devices to allow participation in the ancillary services market, as it is not clear whether the devices can be configured correctly and provide the information in the time required by ERCOT, again speaking of the technical difficulties of qualifying small-scale DSR for ancillary services.

In general, interviewees agreed that making the economics of small-scale DSR stack up is very hard for any one aggregator or technology provider as the hardware installation and customer acquisition costs are too high. Partnerships are therefore viewed as key to reducing cost and capturing market value.

Theme 6: High electricity loads (via electric heating and cooling) are important enablers

The majority of small-scale electricity usage in ERCOT comes from air conditioning loads, pool, space and water heating. More than 40% of heating is met by electricity and over 80% of Texas residents use central air conditioning for cooling (EIA, 2009). The average annual electricity bill in Texas is amongst the highest in the country (Ibid.) and average electricity consumption is 26% higher than the national average (Ibid.). Overall this leads to fewer units needing to be aggregated and lower customer acquisition costs.

Consumer engagement

Theme 7: Tailored value propositions can increase uptake

A recurring subject brought up by the interviewees was the need to customise products and services to each customer. A software solution provider stated that it is important to have the customer segment of interest in mind when developing products and services. Very few customers understand energy so it is important to relate to them in other ways. There is therefore a big trend towards customising products almost down to the household level and catering to customer’s identities (for example, technology enthusiasts, four-person family, student housing etc.). This trend is largely driven by an increase in customer data. For example, retail suppliers can monitor energy usage in a house with data covering how large the house is, what year it was built, insulation levels and so on.

That data is then tied in with 15 minute usage data to identify product opportunities or specific areas where the customer might need help in using energy more efficiently. The importance of offering flexible products was also brought up in this context, where software and hardware now provide opportunities for customers to choose how and when they want to respond to price changes. This flexibility is offered in most smart thermostats provided by appliance manufacturers which again relates to the BYOD campaign.

Theme 8: High switching rates discourage retailers from providing hardware-based offerings

Two technology service providers stated that retail suppliers are discouraged from providing smart appliances upfront due to high switching rates amongst customers. It was reported that the return on investment for retail suppliers is generally not seen before three years of a customer staying on a DSR program. Customers in the ERCOT region typically enrol into one year contracts with their electricity supplier and often switch supplier at the end of that contract.

Summary

Texas (ERCOT) has a well-developed small-scale DSR market with a large number of products and services offered to residential and small commercial customers. Policy and regulation, in particular in the forms of mandates from the Texas Legislature and the Public Utilities Commission of Texas, have played an important role in ensuring the participation of DSR resources in the ERCOT region. The majority of small-scale DSR currently participates in the markets through voluntary load responses to high price events. These voluntary responses take place through products and services, largely enabled through smart thermostats connected to air conditioning loads driving peak demand in the summer. The products and services commonly used are variations of Peak Rebate in combination with direct load control or manual reduction by the customer. However, a general low price environment and infrequency of high price events stand in the way of a more widespread adoption of small-scale DSR products. To engage customers, retailers are attempting to customise their product offering as much as possible, which is enabled by access to more detailed customer data. Table 3 summarises Texas (ERCOT) in relation to the conceptual framework.

Table 3: Summary of Texas (ERCOT) findings

Conceptual framework area	Themes
Policy, markets and regulation	• Due to its operating as an 'electric island', Texas has limited flexibility options combined with high levels of fluctuating wind output • DSR has been pursued as an alternative flexibility option and has mainly been encouraged through a market design that rewards load reductions in the settlement arrangements. There are sufficient price spikes in the energy markets to encourage the products and services currently seen • However, a generally low price environment and zonal settlement for consumers mean that price signals are not ideal and worsen the small-scale DSR business case • Smart meters and real consumption settlement (based on 15 minute settlement intervals) are important enablers allowing consumers to be rewarded for load reductions
Business models	• Hardware and installation costs are still barriers to widespread adoption of small-scale DSR • Air conditioners have been deemed unfit for providing ancillary services in ERCOT. The high electric loads from air conditioners however enable business models that tap in to other value opportunities • Partnerships are considered key to reducing costs
Consumer engagement strategies	• Retailers attempt to create as customised and flexible products as possible to engage consumers. These customised offerings are enabled by increased access to consumer data on lifestyle choices and preferences • High switching rates amongst consumers currently constitute a barrier to retailers' product offerings (but only where retailers offer the hardware for free)

Annex to Chapter 3

Detailed description of markets open to DSR

The following is a description of the various markets open to DSR resources in Texas (ERCOT).

Reserve markets

Responsive Reserve Services (RRS): RRS is a frequency response service operated by ERCOT and is the most common service for large DSR to provide. The service requires providers to operate with an under frequency relay and an ability to respond at full output within 10 minutes to a manual dispatch instruction from ERCOT. The minimum size requirement for participation is 100 kW; however, aggregation is currently not allowed implying that there is no participation from households. Total requirement for this service tends to vary between 2300 – 3000 MW per procurement round and procurement from demand-side resources is capped at 50% of the total. No small-scale load is currently participating in this market.

Emergency Response Service (ERS): ERS is an in-effect capacity market in that ERCOT provides a longer term availability payment to participants to maintain adequate capacity during emergency and other conditions of system stress. The ERS is procured three times a year each round covering a four month period. The minimum required load is 100 kW and aggregated loads are allowed. Participants can make themselves available either 10 or 30 minutes after receiving a signal from ERCOT. Residential loads do not participate in this market but rather in a version of this market called Weather Sensitive Emergency Response Service (WS ERS).

Weather Sensitive ERS: ERS includes a sub-market specifically designed for residential loads known as Weather Sensitive ERS (WS ERS). Loads bidding into this market are aggregated air conditioning loads using smart thermostats to receive signals from an aggregator. This market is relatively small – ERCOT data shows a total of 22 MW procured from 4 aggregated loads over the summer period in 2016 compared to 550 MW over the same period for the standard ERS service (Anon., 2016). Minimum required size in this market is 500 kW. The WS ERS was designed to take into account the availability factors of residential demand specifically in regards to air conditioning load.

Non-Spinning Reserve (NSR): This requires participants to provide their committed load within 30 minutes of an electronic dispatch instruction. Minimum bid size is 100 kW and aggregation is allowed. No small-scale DSR appears to be participating in this market.

Regulation Up/Regulation Down: This market is designed for participants capable of regulating power consumption up *or* down according to grid frequency requirements.

Minimum size requirement is 100 kW but aggregation is currently not allowed and no residential load is participating. This market is predominantly served by generators and some storage assets although it is technically open to demand-side resources.

Energy market

Real-time market (via Controllable Load Resources): Demand-side resources may participate in the real-time energy market by submitting formal bids for load reduction. Minimum size is 100 kW and aggregation is allowed. At the moment there are no residential DSR resources participating in this market. This has been reported to be due to the relatively high penalties of not complying with a dispatch order.

Grid incentives

These two opportunities are not markets per se but offer DSR a cost saving opportunity via reducing load during times of peak demand or other system stress.

Transmission and Distribution Service Provider (TDSP) Load Management: Under this program, customers agree to accept payment from their TDSP in exchange for reducing peak demand over a specific period upon request by the TDSP. The program is mainly targeted at large commercial and industrial loads.

4CP: 4CP (Four Coincident Peaks) are the four 15-minute settlement intervals corresponding with highest load in each of the four summer months (June – September). Load during 4CP determines a customer's grid tariff and as such encourages demand reduction during these periods. However, 4CP is only available to large industrial customers in the deregulated areas of ERCOT. In the regulated areas 4CP is available to residential customers and reportedly constitutes a significant share of DSR response.

4. Illinois

Key message

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

Overview

PJM Interconnection (part of the original Pennsylvania New Jersey Maryland utility) was formed in 1997 as the Regional Transmission Operator (RTO) for all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and the District of Columbia. PJM operates the transmission network across the entire region, controlling power flows and ensuring grid stability but it is important to note that PJM does not own the transmission infrastructure. PJM also operates the wholesale power market and ancillary service markets. The wholesale market is liberalised across the entire region while retail market liberalisation varies from state to state. The PJM area differs from the power market in GB as PJM operates the wholesale energy market, the ancillary markets and capacity market.

Although PJM can claim to be the largest DSR market in the world (9.8 GW of capacity, 8.9 GW of which is committed to the Capacity Market accounting for approximately 6% of peak demand) this message must be tempered. All PJM markets (energy, ancillary and capacity) are open to DSR participation but it has been the capacity market that has primarily encouraged the uptake of DSR. The clear and high payments from the capacity market have been effective signals to end users. However, these high payments have arguably been to the detriment of other DSR programmes. Other market conditions, such as low price volatility, also act as a barrier to DSR's participation in energy markets. At the retail level, real time pricing has been available to consumers since 2006 although uptake to date has been small. Other consumer-facing DSR products, critical peak rebate and direct load control have received greater participation.

Development of DSR in Illinois

In 2006, the Illinois legislator amended the Public Utilities Act. This amendment mandated that utilities offer all their electricity customers price responsive tariff options. This amendment was then implemented by the regulator, the Illinois Commerce Commission. It is important to note that in Illinois "utilities" refers to ComEd and Ameren Illinois, the DNOs and default electricity suppliers, and not to all retail electricity suppliers. This legislation was implemented due to pressures to increase the flexibility of electricity demand which would have the positive benefits of reducing overall costs and reducing environmental impacts.

When discussing DSR in the United States, it is important to refer to the Federal Energy Regulatory Commission (FERC) Order 745. This order ensures that demand response resources are entitled to be compensated at the same rates as generation resources. Other significant FERC Orders which influenced the development of DSR in PJM were FERC 719 and 755. Please refer to the chapter annex for more detail about these orders.

The Energy Infrastructure Modernization Act was enacted by the state of Illinois in 2011. The goal of this Act was to improve the overall infrastructure of the power network and one aspect of this was for ComEd to replace 4 million meters with smart meters by 2021 (ComEd, 2013). At the end of 2016 smart meters had been installed in 35% of areas (ComEd, 2017). This case study focuses on Illinois and ComEd in particular, though this is referred to as PJM (in the same way that 'ERCOT' is used for Texas).

Markets for DSR Resources

All PJM markets are open to DSR. The participation of DSR must be made through a Curtailment Service Provider (CSP) who is free to aggregate loads and then submit these to the markets. PJM is load agnostic, in that it is not mindful of where the load reductions originate, and only deals with the single administration point of the CSP; PJM does not have any interaction with the individual loads. CSPs must undergo a mandatory annual load test to prove that the load can be provided when called upon. The PJM DSR markets can be categorised into three groups; energy, capacity[6] and ancillary.

Energy market

The PJM energy market operates by a system known as 'Two Settlement'. The PJM market consists of a day-ahead and a real-time market in which PJM members can participate and settlement is determined between these two markets. Due to the large size of PJM, prices are set at regional level to account for local resources and network conditions. These regional prices are known as the Local Marginal Price (LMP). Participants either pay or receive the LMP to balance their position against their previously submitted schedule in the same way as in ERCOT. For the latest results for 2016, an average of 133 GW of supply offers were submitted to the day-ahead market. Figures are unavailable for how much DSR was submitted to the energy markets, though 2.5 GW of DSR was registered to participate.

[6] In PJM, the Energy and Capacity markets are referred to as the Economic and Emergency markets respectively. The terms have been altered here in order to harmonise the language across case studies.

Capacity market

The capacity market in PJM is known as the Reliability Pricing Model; however, for this study we shall refer to it as the capacity market. An auction is held annually to secure capacity three years in advance. The auction is open to generation, DSR and energy efficiency resources. In the latest auction results, PJM secured 167 GW of capacity for the 2019/2020 period of which 10.3 GW was DSR. Participants receive availability payments for this service. The capacity market is the greatest source of revenue for DSR resources and accounts of 99% of the value that DSR receives (Monitoring Analytics, 2016).

Reserve market

The PJM ancillary markets consist of a Primary Reserve and a Day-Ahead Scheduling Reserve which require participants to respond within 10 and 30 minutes respectively. Frequency control is provided through the Regulation Reserve. DSR is eligible to participate in these markets however to date, DSR participation, and in particular small user DSR participation, in the ancillary markets has been minimal.

For an overview of technical requirements in these markets please see the chapter annex. Table 4 provides an overview of products and services that link to the above markets.

Table 4: Overview of products and services in PJM (Monitoring Analytics, 2016)

Product/ Service	Commercially available?	Uptake	Year of introduction	Markets
Time-of-use	Yes – offered by a small number of suppliers	No public data available	N/A	Energy
Direct load control	Yes – only ComEd	80,000 (2.2%)	1980s	Energy, Capacity
Critical peak rebate	Yes – only ComEd	164,000 (4.6%)	2014	Capacity
Real time pricing	Yes – only ComEd	15,000 (0.4%)	2006	Capacity
Home automation with Demand Response	Yes – can be integrated with retail supply products	N/A	2016	Energy, Capacity

Business models

ComEd offer several DSR products including the Hourly Pricing (real-time pricing), AC Cycling (direct load control) and Peak Time Savings (critical peak rebate) while several other suppliers offer standard time-of-use tariffs. Home automation is commercially available in the ComEd region and through a "Bring Your Own Device" program, similar to that in ERCOT; consumers with selected home automation products are eligible to integrate their home automation with DSR products. Retail electricity suppliers, Direct Energy and mc2, offer standard time-of-use tariffs as part of their rate offerings but these have not been investigated as part of this study. In this section, we provide a description of the Real-Time Pricing program offered by ComEd, the Hourly Pricing program. For descriptions of the other DSR products offered by ComEd and the related business models, please refer to the chapter annnex.

ComEd's Hourly Pricing Program – a non-profit real time pricing programme

The only real time pricing program in operation in the ComEd region is that which ComEd offers itself. ComEd, as the incumbent pre-liberalisation supplier, is primarily the operator of the local distribution network and profits are regulated relative to its capital investment. ComEd still operates as a supplier but is restricted from making profit from its supply business. For this reason, ComEd's real time pricing program, called 'Hourly Pricing', is operated by an external non-profit organisation, Elevate Energy.

Hourly Pricing is operated on a relatively simple model. Participants in the program must have a smart meter installed in their homes and are charged real-time prices, based upon the wholesale price. The operating costs of the program are recovered through a one-time enrolment fee in the program and an administration fee applied to the participant's monthly bill.

The participants are informed of the day-ahead prices as an indication of the real-time prices. Participants can access a price alert service, which notifies the participant when prices exceed 14 cUSD/kWh, incentivising load shifting or peak shaving. This price alert service can also be integrated with ComEd's Load Guard program. If the participant is also enrolled in ComEd's AC Cycling Program, the participant can enrol in the Load Guard program which will automatically reduce the participant's AC load in response to the high price alert.

Interview Themes

Policy, markets and regulation

Theme 1: PJM has adopted a flexible approach to market design and market rules

In the mid-2000s, regulators and grid operators recognised that DSR could be a valuable resource to manage most severe times of peak demand. Reducing demand at peak times was considered cheaper than constructing and operating new "peaker" power plants. It was also believed that an increase in demand elasticity would improve the grid's reliability, and FERC implemented several orders to promote the integration of DSR.

PJM decided to integrate DSR into their existing market services through rule changes. PJM strives to be technology neutral, wanting to create a "level playing field" for all resources. Achieving this goal requires PJM to constantly revise its market rules. Whilst one interviewee hailed this rule evolution as innovative, another said that these constant rules changes did not provide certainty to market players to plan their businesses.

Theme 2: High capacity margins and cheap natural gas reduce the price volatility needed to enable DSR and reduce the need to pursue flexibility options

DSR resources can access all PJM markets and could certainly participate in the real time energy market. However, the wholesale power price conditions were often cited as a barrier to DSR participating in real-time markets. PJM has a 28% supply capacity margin and a plentiful supply of cheap, reliable natural gas due to local shale gas reserves. This has led to sustained low prices and low levels of volatility in the wholesale market as generation assets are ready and available to respond to any high price signals. Several interviewees commented that if PJM experienced the same level of price volatility that it did over 10 years ago then they would expect to see a greater participation of DSR in the energy markets.

Theme 3: Market design facilitates DSR deployment in the capacity market

The capacity market is the primary driver for DSR in the PJM and ComEd regions with 99% of the value of DSR in PJM being generated through this market (Monitoring Analytics, 2016). Interviewees also confirmed that residential DSR predominantly generates its revenues through the capacity market. The research identified five reasons for this:

1. Initially, the market rules for the participation of DSR in the capacity market, relative to those for generation sources were considered lenient and allowed for easy access
2. The forward pricing signals from the capacity market to DSR resources are stable and clear
3. In the last several years, the capacity market has been used to dispatch resources only a limited number of times
4. The concept of using DSR to manage capacity concerns and grid reliability has been implemented by utilities in PJM for at least 40 years and the argument is that large industrial loads were comfortable with participating in the capacity market
5. The opening of the DSR market to independent aggregators was considered a contributing factor as these third parties were capable of finding the DSR resources and building an appealing value proposition

The lack of dispatch calls under the capacity market has allowed for DSR resources to participate in the capacity market and receive availability payments with limited risk of an interruption to the participant's operations. It was generally believed that an increase in the number of dispatch calls under the capacity market would lead to a decrease of DSR participation in the capacity market. The lack of dispatch has prompted the question whether the DSR resource is 'real' and whether it is available to respond when called upon. The grid operator, when this concern was raised, stated that the resources undergo an annual mandatory test but that they are in *"unchartered territory"* handling these levels of DSR resources and have always faced the risk of generation resources not responding when called upon.

Theme 4: Techno-economics of ancillary markets are onerous and discourage DSR participation

DSR has had minimal participation in the PJM ancillary markets and in particular interviewees only knew of a handful of pilots where residential DSR participated in these markets, none of which were in the ComEd region or had progressed into wider commercialisation. PJM believes that DSR is, in theory, a *"great fit to provide ancillary services"* as it does not have the same physical limitations as conventional generation assets. However, there was an almost unanimous feeling amongst interviewees that the requirements to participate in these markets are *"too onerous for residential DSR resources"*. Whilst technically possible, the cost of implementing the control, metering and communications infrastructure to provide ancillary services, such as frequency regulation, are still too costly. One interviewee said that they foresee a major change to ancillary markets design to accommodate new technologies and is closely watching developments in GB. It should also be mentioned that one interviewee pinned the problem on the relatively small volumes in the ancillary markets and did not see any major technical barriers.

Business models

Theme 5: Smart meter roll-out has not reached a sufficient stage to accommodate DSR products and services linked to real-time pricing

The interviews indicated that suppliers do not provide these products as the market does not have economically viable size yet. The size of the residential DSR market is heavily dependent on the installation of smart meters and suppliers regard the level of roll-out to be insufficient to invest in the systems to run such DSR programs. One interviewee claimed that for suppliers to offer DSR products in the near future, *"either technology costs would need to fall drastically or there must be an increase in the value of the service"*. However, with the increasing roll-out of smart meters, the technology costs will decrease, and all interviewees predicted greater DSR products offerings in the future.

Similarly, independent aggregators have limited interest in entering the residential DSR market. Aggregators have traditionally targeted large commercial and industrial loads and consider the cost of acquisition at the residential level too high. These aggregators will continue to focus on the ‘low hanging fruit’ of commercial and industrial loads.

Theme 6: Access to cheap capital and a longer term outlook allows investment in DSR business models that have a longer return horizon

ComEd does not face the same issues as competitive suppliers and, as the distribution network operator, it can capture additional value. ComEd is responsible for the installation of the smart meters in northern Illinois and so has a better understanding of the infrastructure. As the distribution network operator, ComEd has a longer-term investment outlook than the retail electricity supplier and access to cheaper sources of capital. For these reasons, ComEd is comfortable investing in the systems required to operate their DSR products.

ComEd anticipates growth in their Hourly Pricing and Peak Time Savings programs. The Hourly Pricing program has to date been a success for its participants and ComEd will continue to promote it through new consumer engagement strategies. ComEd is more bullish about the Peak Time Savings program as opposed to the AC Cycling program, as the former has a lower cost structure (the primary requirement is the smart meter). ComEd feels that there will be a greater number of critical peak rebate programs from other suppliers with the further roll-out of smart meters.

Theme 7: Partnerships allow value creation and knowledge sharing but also take a toll on profitability due to revenue sharing

ComEd sees smart thermostats as a growth area for their business. The installation of their switches was relatively expensive and ComEd views the use of BYOD schemes as a means to reduce customer acquisition costs. However, BYOD is still an expensive option from a systems and operation point of view. The technology service provider (TSP) charges ComEd for access to the participant and this can be costly. ComEd has not reached a level of maturity where they can control the thermostat without going through the TSP’s cloud and until that point the TSP will continue to ‘take their toll’.

ComEd ran its first smart thermostat program in 2013 and although ComEd has been using direct load control since the mid-1980s, their biggest challenge integrating the smart thermostat was understanding how to offer the program with customer-owned equipment. Since the integration of Nest into their DSR programs, ComEd sees the same level of response from the smart thermostat as direct load control.

Consumer engagement

Theme 8: Simplification of product offerings improves customer involvement

One of the key messages learned from interviews about consumer engagement was the importance of simplifying the DSR program. DSR is a new concept to the general public and simplifying the message has proved to be effective at educating consumers and increasing the uptake of DSR programs. ComEd has adopted this simplification strategy in a number of ways to make the DSR concept easier to understand.

One interviewee said that their research indicated that the ComEd's original name for the RTP program, Residential Real Time Pricing, had deterred participants and that the new name, Hourly Pricing, is more effective at engaging consumers. The simpler title better communicated to consumers the concept of the program. Consumers are aware of dynamic pricing and one interviewee referred to Uber's "surge pricing" as an example, but cautioned that dynamic pricing often has negative connotations for consumers.

ComEd has found that customers have traditionally not been engaged in electricity consumption and hence do not want to be burdened by their participation in a DSR program. Following the effort of simplifying their message with regard to DSR, ComEd tried to reduce the number of decisions for consumers for several of their programs. Initially under the Hourly Pricing price alert and Load Guard program ComEd would alert participants when prices were at two different pricing levels, (10 cUSD/kWh and 14 cUSD/kWh). As a result of market research, this has been streamlined to a single price level (14 cUSD/kWh).

Alongside simplification, participants want certainty about what is expected of them: i.e. what they need to do, when and how often. To this end, ComEd supplies DSR participants with a 'Summer Preparedness Guide' which provides advice on how participants can manage their electricity consumption in convenient ways. This principle can also be seen in programs where a single action-orientated response is required and this action must be prioritised. For example, for the Peak Time Savings program, ComEd asks the participant to reduce their air conditioning use as opposed to turning off the lights as this will be more effective. This, again, reduces the number of decision points for the consumer.

In relation to its marketing, ComEd has seen success in its direct mail marketing. ComEd focused marketing for Hourly Pricing towards current participants in the Peak Time Savings program. ComEd felt this was effective at increasing the uptake in RTP as these consumers were comfortable with the concept of managing their electricity consumption in response to signals.

Theme 9: Reinforcement of benefits can lead to continued engagement

The ComEd Hourly Pricing program has been, from a participant point of view, a successful program. Participants save on average 150 USD per year relative to the standard fixed tariff offered by ComEd. ComEd goes to some length to communicate these savings, reinforcing the benefit of the program to the consumer. Consumers receive a bill comparison with their monthly bill, indicating the cost difference for that month between the RTP tariff and the fixed tariff. These saving benefits are further reinforced through milestone letters to the participant, notifying the participant when they have reached a saving milestone, such as 500 USD and 1,000 USD. One interviewee indicated that participants were satisfied with the Hourly Pricing program and that these reinforcement strategies communicate the benefits of continued participation in the program.

Summary

As in the ERCOT region, various policies and mandates (in particular FERC orders) have been instrumental in establishing small-scale DSR as a flexibility resource in PJM. Although PJM can claim to be the largest DSR market in the world, this message must be tempered. All PJM markets (energy, capacity and ancillary) are open to DSR participation but it has been the capacity market that has primarily encouraged the uptake of DSR in Illinois. ComEd offers several DSR products to customers whose business models capture value in the capacity market. However, rule changes to the capacity market may impede the feasibility of these business models. The Hourly Pricing program from ComEd has succeeded in reducing costs for its participants but uptake remains low. Due to a limited addressable market (due to lack of smart metering infrastructure) among other factors, independent suppliers do not offer consumers real-time pricing tariffs. However, through improved marketing strategies and increased deployment of smart meters, stakeholders foresee that real-time pricing offerings and uptake will both increase. ComEd believes that simplification of its product offering to customers has led to an increase in enrolment. Table 5 summarises the findings for the Illinois (PJM (ComEd)) case study.

Table 5: Summary of Illinois (PJM) findings

Conceptual framework area	Themes
Policy, markets and regulation	• Federal encouragement of DSR leads to favourable rules for DSR in the capacity market relative to conventional generation. However, future rule changes may lead to decreasing levels of DSR participation in the capacity market • The clear and high payments from the capacity market have been effective signals to end users • Market conditions such as low price volatility, due to plentiful and cheap natural gas, act as a barrier to DSR's participation in energy markets

Business models	• The threat of potential capacity market rule changes are recognised as threats to the business model
	• ComEd anticipates that its Peak Time Savings program will be a key DSR product for the future because of its low operating costs. Similarly, ComEd is encouraged by the further use of BYOD schemes, though the cost of consumer access through the smart thermostat provider can be a barrier
	• Although ComEd was directed to offer a real-time pricing product over 10 years ago, independent suppliers have yet to offer a similar product, possibly due to:
	  • the competition from a non-profit supplier (ComEd)
	  • low uptake numbers to date
	  • limited addressable market (low smart meter deployment)

Consumer engagement strategies	• Consumers who are familiar with the concept of altering their energy use in response to a signal, e.g. Peak Time Savings participants, were found to being more amenable to signing up to its Hourly Pricing program • ComEd has simplified Hourly Pricing to improve its consumer engagement. The initial evidence is that this simplification has proved effective and combined with the continuing smart meter roll-out the outlook for real-time pricing uptake is positive

Annex to Chapter 4

This annex presents additional information to the Illinois (PJM) case study including information on the ComEd retail market which sits under the Illinois (PJM) market.

Overview of the PJM and ComEd Market in Illinois

The PJM area is broken down into Locational Deliverability Areas (LDA) where a Local Distribution Company (LDC) is responsible for management of electricity over the distribution network to the end consumer. These companies are commonly referred to as the 'utilities' and, depending on the state, also act as a retail electricity supplier. The LDC regions often spread over multiple states and an individual state may have multiple LDCs; for example, the state of Pennsylvania has 13 LDCs. PJM, as it operates interstate, comes under the regulations set out by the Federal Energy Regulatory Commission. The retail markets and the LDCs must adhere to the state's energy regulator, typically the Public Utilities Commission.

PJM has a total generating capacity of 184 GW from 1,376 generation sources and has over 900 companies as members (generators, retailers, large consumers, aggregators) and serves approximately 61 million customers. PJM has a forecast peak electricity demand of 153 GW which means the available reserve margin is roughly 28%. PJM has the largest DSR participation in the world with 9.8 GW of capacity, 8.9 GW of which is committed to the capacity market and accounts for approximately 6% of peak demand. These DSR markets include the participation of local generation units to offset grid imports.

PJM is divided into separate zones for pricing to account for demand variations, different supply resources and network congestion. The price for each of these zones is known as the Locational Marginal Price (LMP).

Northern Illinois is covered by PJM and is operated by the LDC Commonwealth Edison (ComEd). The ComEd retail market was liberalised in 1997 and covers approximately 3.5 million residential customers. ComEd joined the PJM market in 2004 and has the largest demand response resource for a liberalised retail market in PJM with 1,366 MW (PJM, 2017). ComEd is a DNO and as the incumbent supplier from before the liberalisation of the Illinois retail market, ComEd is regulated by the state public utility commission (PUC) and must run its supply operations as a non-profit. ComEd is the largest supplier in the region with 58% of the small-scale customers. As well as supply, ComEd offers various demand response products to consumers. ComEd does not acquire any frequency reserves or operate any markets but does use its DSR products to participate in the PJM capacity market and to aid its own network management and reliability.

FERC Orders

Order 719, issued in 2008, required Regional Transmission Operators (RTO) and Independent System Operators (ISO) to explain how demand response could participate in the ancillary markets on a comparable basis to generation (FERC, 2008). Order 755, issued in 2011, sought to further promote the participation of new technologies in ancillary services by asking RTOs and ISOs to review frequency regulation compensation methods to better acknowledge the services provided by new technologies with faster ramping rates, such as DSR (FERC, 2011). Federal and state policy were instrumental in the development of the DSR market in PJM. Figure 3 provides a timeline of these policy and regulatory developments.

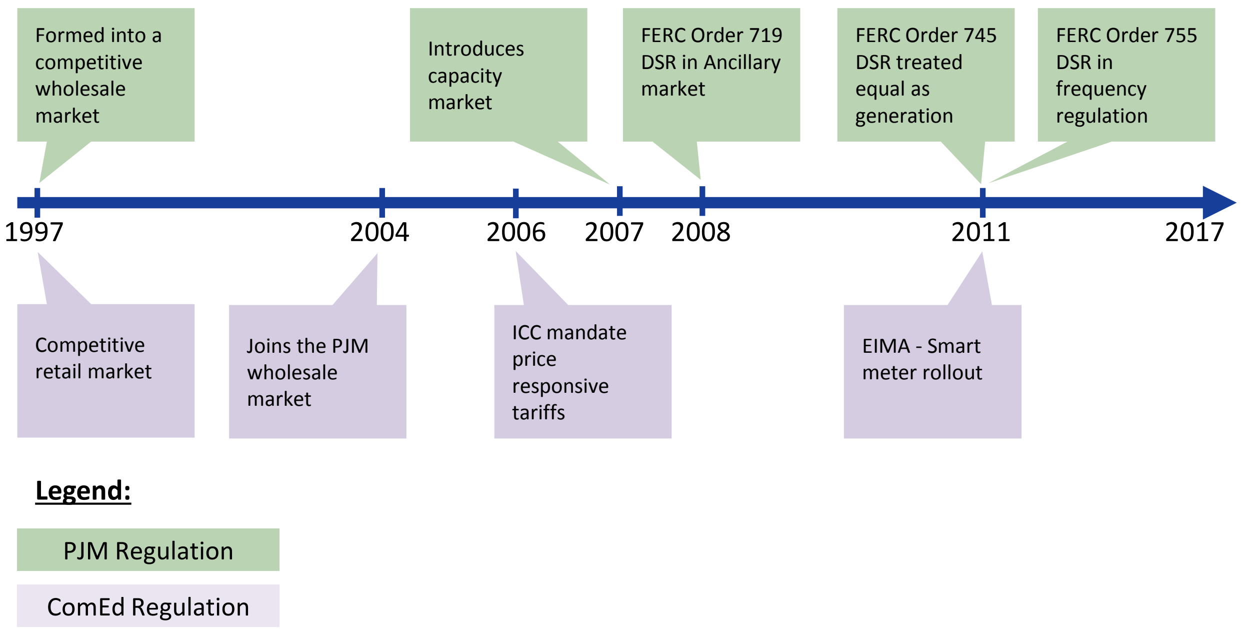

Figure 3: Timeline for DSR development in PJM

Markets for DSR Resources

Energy

The market participants submit demand bids and supply offer schedules to PJM for the following day, PJM analyses these offerings and generates an hourly pricing schedule that meets cost optimisation and congestion criteria. The PJM energy market operates by a system known as '**Two Settlement**'. The PJM market consists of a day-ahead and a real-time market in which PJM members can participate and settlement is determined between these two markets.

The real-time market prices are calculated from the actual market conditions at 5 minute intervals. The real-time price is calculated from supply and demand bids from market participants and is based on actual hourly derivations from the day-ahead schedule. Due to the large size of PJM, prices are set at regional level to account for local resources and network conditions. These are the Local Marginal Price (LMP). Participants either pay or receive the LMP to balance their position against their previously submitted schedule. For the latest results for 2016, an average of 133 GW of supply offers were submitted to the day-ahead market. Figures are unavailable for how much DSR was submitted to the energy markets, though 2.5 GW of DSR was registered to participate.

PJM introduced a program called **Price Responsive Demand** (PRD) to encourage elasticity in energy market demand. The concept behind PRD is that consumers will guarantee a reduction in their load at times of high wholesale prices, therefore PJM is not required to procure the expected capacity to provide for that customer's load. However, the PRD program has yet to receive any offers. Market actors feel the terms and requirements of the program are too severe and the capacity market provides equivalent rewards for more agreeable terms (Monitoring Analytics, 2014).

Capacity

DSR can participate in the capacity market in two forms, either "Summer Period DR", also known as Base Capacity, which requires the participant to be available from May through to October and "Annual DR", also known as Capacity Performance which requires participants to be available all year round. The cleared participants of the capacity market are required to submit schedules and bids into the day-ahead market and are obliged to deliver capacity when notified by PJM.

For the ComEd region, 1,757 MW of demand response (DR) out of a total of was cleared in the 2019/2020 capacity market auction. According to the PJM activity report, 18% of capacity registered as demand response resources are residential in origin (PJM, 2017). Due to the isolated nature of the ComEd region in relation to the wider PJM area, and its reduced interconnection, a premium is applied to the ComEd capacity market price.

Ancillary Services

Primary Reserve in the PJM market consists of **Synchronised Reserve and Non-Synchronised Reserve**, which requires participants to be available to respond within 10 minutes of notification. The required capacity for this market is equal to 150% of the largest contingency on the system which for 2016 equals 2,180 MW (Monitoring Analytics, 2016). DSR is eligible to participate in these markets; however, to date, DSR participation and in particular small user DSR participation in the ancillary markets has been minimal.

The **Day-Ahead Scheduling Reserve Market** is an offer-based market for 30 minute secondary reserve and requires participants to respond within 30 minutes of notification. The market does not have performance obligations. DSR is eligible to participate in this market and several resources have submitted offers. However, DSR like in the other ancillary markets, has had minimal participation in this market.

The PJM **Regulation Reserve** market is a real-time market. Participants, either generation or DSR, must follow the regulation signal within five minutes in order to maintain the target system frequency of 60Hz. Resources must be able to maintain their full output for 40 minutes and the accuracy of response is monitored every ten seconds. Payments are reduced if a resource does not fulfil its requirements (Argonne, 2016). Residential DSR does not participate in the frequency regulation market.

Table 6 summarises the markets available in PJM.

Table 6: Overview over the wholesale and reserve markets in PJM

Market place	Type of contract	Bid size	Activation time	Remuneration scheme
Day-Ahead	Daily	0.1 MW	24 hours	Day-ahead price
Real-Time	Hourly	0 MW	60 minutes	LMP energy payment
Reliability Pricing Model	Yearly	0.1 MW	30 minutes	Availability payment + energy payment
Day-Ahead Scheduling Reserve (DASR)*	Daily	0 MW	30 minutes	Real-time energy payment
Synchronized Reserve	Daily	0 MW	10 minutes	Real-time energy payment
Non-Synchronized Reserve	Daily	0 MW	10 minutes	Real-time energy payment
Frequency Regulation	Daily	0.1 MW	Immediate	Real-time energy payment

* DSR participation is limited to 25% of DASR requirement

Products, services and business models

Real time pricing

The Illinois Commerce Commission mandated in 2006 that utilities (including ComEd but not all retail electricity suppliers) must offer real-time pricing tariffs to residential consumers. ComEd adopted the mandate and its RTP program operates today as ComEd's Hourly Pricing Rate. In accordance with the mandate, the program must be operated by a separate, non-profit organisation. In this case, the administrator is Elevate Energy who is responsible for marketing, communication with participants and billing. Participants need a smart meter to participate and are charged the real-time LMP. As of December 2015, 12,563 residential and small electricity consumers (<100 kW) had chosen real-time pricing (Illinois Commerce Commission, 2016).

Additionally, Hourly Pricing participants who have central air conditioning units, internet access and participate in ComEd Central A/C Cycling can also participate in the Hourly Pricing program's ‘Load Guard Automated Price Response Service’. This service allows the participants to define a desired target price at which the participant’s air conditioner will cycle on and off every 15 minutes for a two-hour period.

Critical Peak Rebate

The ComEd ‘Peak Time Savings’ program credits participants for reducing their electricity consumption during ‘Peak Times Savings Hours’. Participants are notified of these time periods three to five times a year, either by phone, text or email, and are credited based on their reduction relative to their typical consumption. It is not a requirement for ComEd to be the participant’s electricity supplier to enrol in this program. Enrolment into the program is free and no penalties are applied for non-participation.

ComEd offers a demand response program, the ‘Voluntary Load Reduction Program’, to business consumers. It is not a requirement for ComEd to be the participant’s electricity supplier to enrol in this program. To be eligible, participants must have a smart meter and be able to reduce their consumption by at least 10 kW. Participants are notified an hour before the event which may last between two and eight hours. Rewards are calculated based on reduction against ‘typical’ consumption and there are no penalties for limited or non-participation.

ComEd operates two critical peak rebates programs: one for residential customers, Peak Time Savings, and another for commercial customers, Voluntary Load Reduction.

Any residential customer with a smart meter, regardless of who supplies their electricity, be it ComEd or not, is eligible to enrol into ComEd’s Peak Time Savings program. This is a voluntary program and does not incur any costs to the participants. The program operates by notifying the participants of days with Peak Time Savings Hours and then manually reducing their household electricity usage in response to the notification. The participant receives the notification, either by phone, email or text depending on the participant’s preference, as early as 9 a.m. or at least 30 minutes prior to the start of each Peak Time Savings Hours. The participant receives credit to their bills relative to their load reduction during the Peak Time Savings Hours; the participant will earn 1 USD for each kWh of electricity saved during the event period. These electricity reductions are measured against the participant’s typical electricity usage. ComEd captures the value from these load reductions through the PJM capacity market. ComEd estimates the resource to bid into the capacity market using historical data on the level of resource participation. The percentage of load resource reduced relative to the load enrolled is a value in the high single digits, on a MW basis.

The Voluntary Load Reduction (VLR) program operates in a similar way. However, the VLR program requires that participants must reduce electricity consumption by at least 10 kW during the event periods. Participants can earn at least 0.25 USD/kWh for reduction in electricity usage although incentives may be larger depending on wholesale market prices during the event time period. Like the Peak Times Savings program, VLR is used to participate in the capacity market but VLR is also used by ComEd for reasons of network reliability. ComEd can manage loads which, under this program, can be larger commercial and industrial loads to reduce demand at a specific local level to alleviate network and substation congestion. However, the value created by DSR for network management can only be captured by ComEd and even then, it is difficult for ComEd to accurately quantify that benefit.

Direct Load Control

The ComEd Central AC Cycling program is the only direct load control program available in the ComEd region. Participants can partake in the program either through the installation of control switch by ComEd or through the Nest home automation product, if they have it. There are several types of participation that vary by the level of commitment for load reduction and the associated reward. Consumers do not have to be customers of ComEd to participate in this program.

Under the ComEd AC Cycling program, participants provide remote control access of their central air conditioning unit to ComEd. ComEd then cycles the unit's operation, reducing the load during times of capacity limitations in the PJM area, and generates further value from the load reductions through bidding those reductions into the PJM capacity market. As with the Peak Time Savings Program, ComEd does not need to be the consumer's electricity supplier to participate in this program. Participants receive 10 USD per month of participation between June and September. These payments are derived from the payments received by ComEd for participation in the PJM capacity market. Participants cannot enrol in both the Peak Time Savings and AC Cycling programs as these both bid into the PJM capacity market. Similar to the Voluntary Load Reduction program, ComEd also creates value through the AC Cycling program through local network management.

Participants in the AC Cycling have a choice of two control mechanisms. The first option, and the initial control option for the program, involves ComEd installing a direct control switch to the participant's central air conditioning unit. Under this control mechanism, the participant has a choice in what level of participation or service interruption they are willing to accept: 50% option or 100% option. This also reflects the level of remuneration the participant will receive. Under the 50% option, participants can receive up to 20 USD per summer season to reduce their AC use by 50% during event periods; while under the

100% option, this can be as high as 40 USD per summer season and means complete shutdown of the AC unit. Cycling is only done when called upon by the capacity market and there is no override option available to the participant and so no penalties can be incurred.

The second option, available since the summer of 2016, allows participants to use a smart thermostat system (home automation). ComEd partners with a technology service provider, who provide ComEd with access to the participant’s air conditioning system. This allows ComEd to interrupt the AC unit’s operation. Only the 100% option is open to the smart thermostat participants, who receive up to 40 USD per summer season. The smart thermostat participants have the option to override the event interruption but then forfeit any credit for the month in which the event occurred. Nest is currently the only approved partner for this program, however, ComEd is open to integrating other smart thermostat systems.

5. Finland

Key message

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

Overview

Finland has significant seasonal variations in heat and electricity demand. The country is a part of the Nordic electricity market, NordPool, and has functioned as a deregulated electricity market since 1998 with free consumer choice of retail supplier. Household electricity consumption per capita in Finland was 3900 kWh/year in 2014 (Eurostat, 2014) and national peak electricity consumption is ~15 GW in winter conditions at which point Finland relies upon imports to meet demand. Demand-side management, mostly commercial and industrial, plays a significant role in ensuring system adequacy at time of peak consumption. While small-scale DSR is still a small market in Finland, the country has growing activity both on the market and business model sides with commercial actors actively testing new products and services.

Development of DSR in Finland

Finland has a long history of DSR on a residential level and introduced time-varying prices to domestic customers in the 1970s. Several of these tariffs were attached to direct load control of electric heating appliances but this practice vanished after deregulation as unbundling created a new business environment and lowered electricity prices to the detriment of DSR provision (Kärkkäinen, 2007). DSR in Finland is therefore dominated by commercial and industrial loads. However, in 2007 the Ministry of Employment and the Economy convened a working group to assess the opportunities and barriers to engaging small scale users in DSR for balancing the electricity system. The group concluded that hourly metering and hourly balance settlements were prerequisites for involving smaller users and that hourly smart meters should be rolled out by 2014 (Annala, 2015). More than 97% of metering points are now using smart metering infrastructure and are settled on hourly data, which has led to the commercialisation of a few products, services and business models to accommodate involvement from smaller users.

Markets for DSR resources

There are three main types of market available to Finnish DSR resources. These are the energy market NordPool, the reserve markets operated by FinGrid, the grid operator, and the capacity market operated by the Finnish regulator (Energiavirasto).

Energy market

The NordPool Spot ELSPOT and ELBAS markets are spot markets serving the Nordic countries Norway, Sweden, Denmark and Finland, as well as the Baltic countries Estonia, Latvia and Lithuania. The spot markets provide a price signal for the entire wholesale market and facilitates the day-ahead planning of the power system operation by matching demand and supply. Any imbalance in a BRP's portfolio can be balanced by other market members, ensuring cost-optimal allocation of assets in the power system. Time-varying tariffs, in one form or another, currently tap in to value from the NordPool market.

Reserve markets

FinGrid offers several markets that are open to DSR known as reserve markets. The main task of these markets is to ensure the matching of supply and demand in real-time and that the grid frequency does not deviate from the standard 50 Hz. These markets are procured either hourly or yearly. Participants, including demand-side resources, receive either an availability payment (EUR/MW) and/or an energy payment (EUR/MW/h) depending on whether the resource is called upon or not. There is some industrial DSR participating in these markets but no small-scale commercial DSR currently participating. For technical conditions of the different wholesale and reserve markets, see Table 7 below.

Table 7: Overview over the wholesale and reserve markets in Finland

Market place	Contractor	Type of contract	Minimum bid size	Activation time	Remunera-tion scheme	Possible revenue*
FCR-N Frequency controlled normal operation reserve	FinGrid	Yearly and hourly	0,1 MW	3 min	Capacity payment + price of electricity	125,800 EUR/MW/yr

Market place		Contractor	Type of contract	Minimum bid size	Activation time	Remuneration scheme	Possible revenue*
FCR-D	Frequency controlled disturbance reserve	FinGrid	Yearly and hourly	1 MW	5 s / 50%, 30 s / 100%, when f < 49,9 Hz OR 30 s, when f < 49,7 Hz and 5s when f < 49 ,5 Hz	Capacity payment	29,400 EUR/MW/yr
	Frequency controlled disturbance reserve (on-off-model)	FinGrid	Long-term	10 MW	Instantly, when f under 49,5 Hz	Capacity payment + activation fee	-
aFRR		FinGrid	Hourly	5 MW	First reaction 30 s, 100% in 2 min	Hourly market + energy price	-
mFRR Regulating power market		FinGrid	Hourly	10 MW	15 min	Market price	22,500 EUR/MW/yr

Market place	**Contractor**	**Type of contract**	**Minimum bid size**	**Activation time**	**Remunera-tion scheme**	**Possible revenue***
mFRR Fast disturbance reserve	FinGrid	Long-term	10 MW	15 min	Capacity payment + energy price	4,960 EUR/MW/yr
Strategic reserves	Ener-giavirasto (Regulator)	Long-term	10 MW	15 min	Capacity payment	-
Elspot	NordPool	Hourly	0,1 MW	12 h	Market price	-
Elbas	Nordpool	Hourly	0,1 MW	1 h	Market price	-

Capacity market

The Finnish regulator (Energiavirasto) has created a capacity market for generators and DSR. This is intended to secure electricity supply during shortages of generation. Contracted units may not participate in the energy markets when providing strategic reserves whilst being compensated with an availability payment. The regulator decides on the amount of strategic reserve needed, which was 600 MW from 2007 to 2013, 365 MW from 2013 to 2015 and 299 MW between 2015 and 2017. For the 2015-2017 period, two power plants and one DSR unit was contracted. The DSR unit is a 10 MW heat pump owned by Fortum Power and Heat Oy (Energiavirasto, 2017).

Products and services

From the markets discussed above, products and services in Finland predominantly tap into value from NordPool while participation from smaller users in the reserve markets has been minimal due to the lack of aggregation and advanced communication controls between loads. Aggregated residential loads have been reported to bid in to the reserve markets as pilot projects, but should not be considered a mature commercial product in Finland. Products and services cover dynamic pricing, such as time-of-use and real-time pricing, as well as home automation services tied to the real-time price. Time-of-use pricing has been available in Finland since the introduction of electric heating in the 1970s while RTP has been available at least since 2010 after the introduction of smart meters the year before. The real-time price in Finland is based on hourly prices in the NordPool market and communicated to households on a day-ahead basis. The uptake of RTP has been low so far with estimates of less than 1% of households. The products and services available in Finland are summarised in Table 8.

Table 8: DSR products and services in Finland

Product/ Service	Commercially available?	Uptake	Year of introduction
Time-of-use	Yes – offered by most retail suppliers	Estimated to be 17% of all households and 85% of residential customers with electric heating (Annala, 2015)	1970s
Real-time pricing (RTP)	Yes – offered by most retail suppliers	No public data available but estimates are low at <1% of households	2010
Home automation	Yes – offered by a few technology providers in partnership with suppliers. Based on RTP	At least 2000 units delivered as of 2014, corresponding to <0.1% of all households and 0.4% of electrically heated households	2014

There are a few technology providers that, in partnership with utilities, offer home automation devices. These optimise energy consumption based on price forecasts (linked to the day-ahead RTP), personal behaviour parameters and weather forecasts. At least 0.4% of electrically heated households had installed these devices as of 2014. The main technology providers for these services include There Corporation, OptiWatti and ASEMA. An example of these home automation devices can be found here: http://ecosummit.net/uploads/eco15-150519-1200-there.pdf, which is There Corporation's home automation device sold via Fortum. Direct load control was applied extensively in Finland (via direct power line communication) between the period of 1970-1998 alongside time-of-use when the Finnish power market was regulated. Deregulation, however, led to the economic case for direct load control deteriorating and the legacy direct load control systems being removed and replaced more recently with smart metering infrastructure. A few retail suppliers are currently piloting direct load control based on the new smart meters, with the possibility of bidding into the reserve markets, but, as of yet, there is no commercial offering of direct load control to residential or small commercial customers.

Business models

The business model described below involves the interaction between commercial actors and how value from DSR is created and shared amongst them. In general, the more sophisticated the DSR business model, the more interactions it needs. The explanation below describes business models for RTP with home automation as this is the most novel commercial offering in the Finnish market. This model taps in to value in the NordPool day-ahead market and allows the retailer to optimise wholesale purchasing cost. DSR providers are testing products in the NordPool intra-day market, connected to arbitraging direct load control resources but these are not yet commercial.

Real-time pricing connected to NordPool spot price with home automation

This business model involves the use of smart technology and home automation to access DSR loads. The business model therefore follows a similar pattern to simple real-time pricing, but includes a significant role for the home automation device.

The retailer provides the real-time price to the final customer and also provides the technology to control the customer's energy appliances. The technology is provided by a technology service provider (TSP), which has a contractual relation to the retailer. The customer chooses the tariff and agrees to the installation of the technology to their electric heating system. There is no contractual interaction between the TSP and the customer. The home automation device receives the price signal from the retailer and optimizes the use of the associated energy appliances.

The retailer procures electricity for its customer based on the day-ahead spot market. For customers without RTP, the retailer procures the standard load profile for each customer category. For its customers with RTP and home automation, the retailer calculates a new load profile based on weather conditions and the characteristics of the connected heating system. The required amount of electricity can be calculated with high confidence levels.

The procurement costs at the exchange vary from hour to hour. Price signals for automated RTP customers are generated for each hour of the day by the retailer, based upon prices at the exchange. In rare cases, the retailer may have an economic reason to incentivise a behaviour that is not correlated to the spot market; for example, due to cross market optimisation in different markets (reserves, gas, etc.). The conversion of spot market prices into RTPs is dependent on the retailer's decision and may differ between different retailers.

Before the day of operation, the home automation device receives the RTP and plans the use of electricity to both ensure that the level of comfort is maintained at all times and that the cost-optimal solution is used. The customer typically would not notice the changes in the electricity consumption patterns compared to the classic flat tariff without RTP. The customer can override the automation process by, for example, instructing a 'boost' to the heating.

The smart meter measures the energy consumption of the customer on an hourly basis. The results are communicated to the retailer, which multiplies the hourly consumption by the corresponding hourly price. The customer is billed by the retailer for its electricity use based on the smart meter readings. Assuming that the optimisation technology has worked as intended, the customers are billed less under the RTP scheme than under the normal tariff scheme.

The changes in procurement costs by the retailer are partially used to reduce the tariff costs of the customer. A part of the reduced costs may be realised as additional profit by the retailer. The customer currently pays for the home automation equipment upfront.

Interview themes

The previous section reviewed the products and business models available in Finland. These include home automation with and without real-time pricing while commercial actors are testing direct load control in the reserve markets. The following sections highlight themes from the interviews conducted with stakeholders in the Finnish DSR landscape including commercial stakeholders (aggregators, technology service providers or retail suppliers), the grid operator (FinGrid) and appliance manufacturers. The sections highlight the factors that, according to our interviewees, have led to the level of small-user DSR engagement observed in Finland to date. Barriers to further deployment are also discussed as these constituted a large part of the conversations. The themes are presented in the order of the conceptual framework.

Policy, markets and regulation

Theme 1: Increasing lack of conventional generation capacity and the need for flexibility drives DSR efforts

Several interviewees stated that the Finnish power system is experiencing an increasing lack of capacity and flexibility, which sets it apart from the Nordic countries Sweden and Norway which have large amounts of hydropower in their generation fleet. At its highest, the Finnish annual peak demand can be 15.1 GW with installed capacity of 11.6 GW, effectively depending on up to 3.5 GW of energy imports during this period. It was also mentioned that most of electricity production is determined by the heat demand of district heating combined heat and power (CHP) plants, which follow weather patterns rather than electricity demand and therefore reduce flexibility in the power system further. According to this interviewee, flexibility to balance the system is further reduced by the introduction of wind power and conventional plants going offline. However, it should be noted that another interviewee stated that the interconnection with the rest of the Nordic market reduced the need for alternative flexibility options and that overall the demand for DSR is too low to create a thriving DSR market. This is expected to change as the level of intermittent renewable penetration increases and conventional generation is pushed out of the merit order.

Theme 2: An active grid operator open to experimenting with new markets has encouraged DSR

The loss of flexible generating capacity has encouraged the grid operator (FinGrid) to pursue alternative flexibility options in the reserve and spot markets. FinGrid was identified as a major facilitator for DSR by the majority of interview partners. Over time, markets have been opened and refined, encouraging DSR participation. One interviewee stated that *"FinGrid is the driving factor behind DSR integration"* and the influence of the government, policy and regulations was deemed less important.

Theme 3: Settlement arrangements are accurate, rewarding suppliers and consumers for load reductions

A large number of retailers offer real-time pricing to their customers. This tariff is almost exclusively enabled by the hourly settlement of residential consumers on real consumption enabled by the high penetration of smart meters (the information systems in Finland no longer support the use of estimated load profiles). Settling domestic customers on actual consumption allows suppliers to use appliances, such as electric hot water tanks, to optimise their balancing portfolios and wholesale purchasing costs. For example, lower consumption during peak hours translates into lower purchasing costs for the retailer (from the wholesale market) which can be passed onto the consumer to encourage further demand reductions. DSR measures therefore constitute a cost-saving opportunity for Finnish retailers, which is not present in markets with estimated load profiles for customers such as GB.

Theme 4: Reserve and balancing markets are generally fair and actors are positioning themselves for entry

The interviewees revealed that currently there is no small-scale DSR in the reserve and balancing markets, although DSR providers are proactively testing new products for entry. As one retailer said, *"frequency markets are interesting and the balancing power market is interesting – so we have different market places and different business cases that connect the customer to the market".* One option discussed was that of shutting down customer load, via direct load control, in response to high prices on the balancing power market and then sharing some of that revenue with the customer[7]. Despite a general enthusiasm regarding opportunities offered in the market, interviewees also said that conditions could be improved to encourage more DSR. One commercial DSR aggregator said that markets are not as attractive as they could be in Finland, as aggregation is not allowed in certain reserve markets and that the minimum bid size, for example in the balancing power market, is still too large to encourage participation from small-scale DSR.

Business models

Theme 6: Electric heating creates a large market volume for DSR products and services

Residential DSR products and services in Finland focus on shifting electric heating loads in particular for space and hot water heating and it was mentioned several times that larger shares of electric heating allow for more accessible DSR loads. Approximately 30% of Finnish houses use electricity to meet their heating needs (Finnish Energy, 2017), which includes the demand from heat pumps and saunas. This makes Finland the country with the highest per capita electricity consumption in the European Union (Eurostat, 2014). It is estimated that up to 30% of the residential peak electricity consumption is shiftable with home automation and up to 20% without home automation (Stromback, et al., 2010).

Theme 7: Partnerships along the supply chain allow synergies for unlocking value

Several DSR providers focus on targeting appliance manufacturers. One interviewee stated that appliance manufacturers, in general, favour the move towards smart appliances in Finland, as they see additional revenue streams and do not want to be left behind when the market moves towards smart appliances. Appliances such as white goods are already capable of providing additional services e.g. reordering food if the fridge is empty. These capabilities are extending to provide load management, either through an app or an interface with the smart meter. One of the main appliance manufacturers mentioned was Jaspi, while Bosch is another active player in Finland. One retailer said, "*of*

[7] This is similar to the market mechanisms explained in regards to voluntary reduction of load in response to a high price event in Texas (ERCOT). See here for current FinGrid trial for aggregation in the balancing markets: http://www.fingrid.fi/en/electricity-market/balancing-power/aggregator%20pilot%20project/Pages/default.aspx

course, we are trying to find different partners for us to develop these models". Interviewees stated that offering DSR products via the retail supplier, who has a pre-existing customer base, significantly improves the profitability of the product as less time and resource is spent on customer acquisition.

Theme 8: Improving hardware and reducing customer acquisition costs is key to enabling small-scale DSR

Several interviewees stated that technology and customer acquisition costs are too high for wide-scale adoption of small-scale DSR business models. This was confirmed by an industrial DSR provider who sees hardware costs as a major barrier which is on the same level as customer acquisition costs. Costs of the hardware typically comprise the cost of the hardware controller, its installation by a technician and running costs, such as for wireless data communication. Costs of customer acquisition are marketing and direct consumer engagement. Today, no independent aggregator in Finland has created a viable business model targeting small-scale users independently of a retailer.

Lower costs of communication technology, combined with higher revenues from flexibility services as intermittent generation increases, are expected to be major enablers for the domestic DSR business case. Two commercial actors stated that improving technology and communication costs are making these types of business models increasingly viable, but costs are still a challenge. Once costs come down to acceptable levels, advanced domestic DSR offerings are expected to be more valuable to DSR providers than different tariff types. For one market player, this could lead to a business model where the main service to the consumer is home automation with the DSR capabilities in the reserve markets as an add-on business model. One interviewee said, "*technology is getting cheaper and I think that is driving us to find services and solutions that are not based on DSR – so the main service could be the home automation and optimisation, and DSR could be an add-on to that."*

Consumer engagement

Theme 9: Consumer engagement strategies are diverse but in general focus on economic and environmental value propositions

An industrial DSR aggregator with ambitions to provide products to the domestic DSR market is testing different consumer engagement strategies. These include:

- the economic value proposition (lower costs for the consumer)
- additional benefits (such as cinema tickets)
- the green argument (helping the environment), although this was not seen as a sufficient selling point in and of itself
- the appeal of home automation to technophiles and first movers

Home automation services were considered as a door opener by a few retailers. Another DSR provider suggested that local authorities should be engaged to reach out to consumers. An interviewee in a large retail company also said it was important that the consumer understands the business model, as affecting the customers' use of electricity could inhibit the roll-out of DSR.

Summary

Compared with ERCOT and PJM (and apart from the mandatory implementation of smart meters and accurate settlement processes), government policy and mandates appear to have played less of a role in encouraging DSR uptake. The use of DSR in Finnish households goes back to the 1970s with the use of time-of-use pricing to control domestic heating appliances. After deregulation, this product became increasingly uneconomic for retailers and was slowly phased out and then replaced by smart meter infrastructure starting in 2009. Uptake of real-time pricing has been low, however, while there are still a large number of users on time-of-use in particular connected to electric heating. Given that small-scale DSR is a nascent sector, the Finnish market is relatively advanced with retailers, aggregators and appliance manufacturers assessing market opportunities.

Table 9: Summary of Finland findings

Conceptual framework area	Themes
Policy, markets and regulation	• High flexibility needs and tight capacity margins encourage the regulator and FinGrid to assess all flexibility options including small-scale DSR • FinGrid is considered an instigator of small-scale DSR • Settlement arrangements reward suppliers for load reductions which has led to the offering of time varying prices such as real-time pricing • Markets are considered fair and commercial actors are actively considering new products and services
Business models	• Commercial actors target high electric loads predominantly via electric heating (space and/or hot water tanks) • Retailers are teaming up with appliance manufacturers and home automation providers to create new market offerings • Costs of providing DSR services are still considered high. However, falling technology costs are encouraging commercial actors to consider business models in the reserve markets
Consumer engagement strategies	• The main consumer engagement strategies pursued include appealing to economic and environmental benefits • Home automation technology is considered a major way in to consumers' homes that later on can offer opportunities for DSR services

6. Germany

Key message

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

Overview

Germany is highly interconnected with its surrounding countries and embedded in the largest jointly-operated electricity grid in the world. The total interconnector capacity with its neighbouring countries was 21.3 GW in 2012 (RAP, 2015), with expected future connections to the Nordic power system. The total non-fluctuating non-renewable generation capacity was 105 GW in 2016 (Fraunhofer ISE, 2017) while the peak demand was 83 GW in 2013 (RAP, 2015), with another 90.5 GW of intermittent renewables.

Household electricity consumption per capita was 1,900 kWh/year in 2014 (Eurostat, 2014) and total household electricity demand was 129.6 TWh in 2014. 21.6% of the household total energy demand was supplied by electricity (European Commission, 2014). Recently, Germany has experienced challenges from the growth in renewables capacity, increasing the need for new transmission lines and flexibility in the power system. In 2016, Germany decided to digitalize its energy infrastructure and mandated the roll-out of smart meters for all electrical measuring points exceeding 6 MWh/year. These will allow quarter-hourly metering of electricity consumption. With an average four-person-household consumption of 4.2 MWh (BDEW, 2016), smart meters will be installed at most households on a voluntary basis only.

Development of DSR in Germany

Classic time-of-use tariffs have been in use since storage heaters were introduced in the late 1950s/ early 1960s. Before the liberalisation, there was no regulation or policy incentive to promote this type of tariff, but it was driven by the integrated utilities' interest in increasing power plant utilization and improving operation across monopoly areas. The roll-out of night storage heaters was subsidized through lower tariffs by the integrated utilities, but, apart from a short period following the 1973 oil crisis, night storage heaters did not become competitive, leading to a steady decline particularly as gas became widely available.

Time-of-use tariffs face high costs of metering compared to the low saving potentials they offer. Despite this, 1.6 million households in Germany are still using night storage heaters with time-of-use tariffs, and 98% of these households have never switched their electricity supplier despite the high costs. More recently, storage heaters have regained some attention due to expansion of fluctuating renewables, offering a possibility to store excess electricity. However, it is unlikely that the legacy technology is suited to the flexibility requirements of a renewable power system. Heat pumps, on the other hand, are on the rise, with more than 30% of new-build homes equipped with heat pumps (Bundesverband Wärmepumpe, 2016). This however has not (yet) led to innovative tariffs for the utilisation of their flexibility, which is mostly due to the lack of smart meters. It is very likely that those households will be captured by the 6,000 kWh threshold of the mandatory smart meter roll-out and therefore will receive a smart meter no later than 2020.

Markets for DSR resources

There are two organized types of markets in Germany that in principle are open to DSR resources: the independently-run energy market (EPEX SPOT/NordPool Spot) and the TSO-run reserve market (regelleistung.net).

Energy markets

EPEX SPOT and its predecessor EEX have served the single Germany/Austria price zone since 2000. Participants can trade 30 minutes prior to operation. The day-ahead auction product offers the highest liquidity in the market and provides a price indicator for the rest of the market, including bilateral trading. This market segment is also used for the European market coupling, allowing electricity to be traded freely in nineteen countries and therefore acting as another flexibility option. Traded volumes in this market segment are also essential for the announcement of the schedules by the BRP. The other three market segments are used for balancing forecast deviations that occur prior to operation. This is typically for forecast deviation by generators (for example, wind forecast error) and allows DSR to provide flexibility at short notice, taking advantage of potentially high price fluctuations. In 2016 NordPool Spot opened the options of trading intra-day products with a gate closure time (GCT) of 20 minutes, beating EPEX Spot’s GCT of 30 minutes. Minor amounts of small-scale DSR from battery storage participate in this market (see below for explanation of business model).

Reserve markets

Regelleistung.net is the TSO-organised market platform for procuring the necessary amounts of reserve for frequency control and interruptible load service (commercial and industrial DSR). Three types of frequency reserves are procured: the fast automatic decentralised FCR (also called primary reserve), the automatic TSO-dispatched aFRR (secondary reserve) and the manually TSO-activated mFRR (tertiary reserve). All market participants, including DSR applications, have to fulfil prequalification requirements to be granted access. This includes tests of the quality of communication infrastructure and the dispatch of the resource. The intent to enable more small-energy users to take part in the market and increase market efficiency has led to a revision of market rules by the regulator. The proposed changes envisage daily auctioning and shorter product lengths. Minor amounts of small-scale DSR from battery storage participates in this market (see below for explanation of business model).

The technical conditions of the different energy and reserve markets available to DSR are presented in Table 10 below.

Table 10: Overview of the wholesale and reserve markets in Germany

Market place	Contractor	Type of contract	Bid size	Activation time	Remuneration scheme
FCR (Primary reserve)	TSOs	Weekly, all day round	1 MW	5s first reaction, 30s full activation	Capacity payment (pay-as-bid)
aFRR (Secondary reserve)	TSOs	Weekly, one contract for high tariff (Monday to Saturday 08:00-20:00) and low tariff the rest of the week, positive and negative separate	5 MW	30 s first reaction, 5 mins full activation	Capacity payment (pay-as-bid) + energy price (pay-as-bid)
mFRR (Tertiary reserve)	TSOs	Working-daily, six contracts daily for blocks of 4 hours positive and negative separate	5 MW	7.5 mins first reaction, 15 mins full activation	Capacity payment (pay-as-bid) + energy price (pay-as-bid)
SOL (Immediately interruptible loads)	TSOs	Weekly[8]	Minimum 50 MW, Maximum 200 MW	Immediate	Capacity payment (pay-as-bid) + energy price (pay-as-bid)

[8] Since March 2017.

Market place	Contractor	Type of contract	Bid size	Activation time	Remuneration scheme
SNL (Fast interruptible loads)	TSOs	Weekly	Minimum 50 MW, Maximum 200 MW	Maximum 15 mins	Capacity payment (pay-as-bid) + energy price (pay-as-bid)
Day-Ahead Auction	EPEX SPOT	Hourly, at 15:00 day-head	0.1 MW	Day-Ahead	Market price
Intraday Auction	EPEX SPOT	Quarter-hourly, at 15:00 day-head	0.1 MW	Day-Ahead	Market price
Intraday Hourly Continuous Trading	EPEX SPOT	Hourly, until 30 mins before fulfilment	0.1 MW	30 mins	Market price
Intraday Quarter-Hourly Continuous Trading	EPEX SPOT	Quarter-hourly, until 30 mins before fulfilment	0.1 MW	30 mins	Market price
Intraday Continuous Trading	Nordpool	Hourly (PH), Quarter-hourly (QH), Half-hour (HH) products	0,1 MW	0 mins within TSO area, 20 mins across TSO areas	Market price

Products and services

The DSR market is dominated by static time-of-use tariffs, with few innovative tariffs available for households. Despite the absence of new tariffs and products, some market activity can be observed. Table 11 provides an overview of the available products.

The most innovative approach so far has been a monthly changing tariff by VIVI Power (VIVI Power, 2017). Small and medium-sized enterprises (SMEs) are able to negotiate other tariffs with their supplier and potentially get access to an RTP tariff. However, the requirement for more expensive metering reduces the viability of such business models

(Schnurre, 2014). The lack of uptake correlates with low prices and low price spreads in the energy spot markets.

The pilot project, Flexibler Wärmestrom (flexible heat flow), led by retailer EnBW, is optimising the electricity use of 150 households equipped with a heat pump. This reduces grid fee payments following § 14a of the German Energy Act (EnWG) - which addresses controllable loads, explicitly mentioning electric vehicles.

Several actors engage with household customers to provide reserves in the frequency reserve markets. Using residential solar PV and a storage battery, Caterva is offering free-of-charge use of electricity equivalent to the annual solar energy production. Sonnen, with its product SonnenFlat (Sonnen, 2017), is following the same business model in Switzerland and will soon launch in Germany. In both business models, the user pays for capacity rather than consumption. Both models rely on direct control of the distributed fleet of batteries.

Lichtblick is an innovative green electricity supplier that has developed a number of new business models, one of which, the Zuhausekraftwerk (home power plant), was launched in 2010. It addressed the increasing demand for flexibility through installation of thousands of natural gas powered microCHPs for domestic heating, operating like a large-scale power station offering its flexibility to the energy and frequency reserve markets. The entire fleet of mini power plants was connected to a central controller, allowing Lichtblick to manage the 'swarm'. The microCHPs are owned and operated by Lichtblick, the consumer only has a heat supply tariff, which also removes the need for investment in a new heating system. 5 MW of capacity were accumulated, but problems with the technology and the limited viability of the business model led Lichtblick to focus on larger CHP units.

Table 11: Overview of time-varying tariffs and services in Germany

Product/service	Commercially available?	Uptake	Year of introduction
Time-of-use	Yes – offered by most retail suppliers	4% 1.6 million households (Tartler, 2016)	1950s/1960s
Real-time pricing (RTP)	No – for domestic customers Yes – for SMEs with RLM meter	No public data available for B2B	Before 2010

Product/service	Commercially available?	Uptake	Year of introduction
Home automation	Yes – offered by many technology providers. Usually not used for RTPs	26% of German consumers own a smart home product or device (GfK, 2016)	For example, 2016 for Bosch

Business models

Night storage heaters access reduced wholesale purchasing costs for the retailer and cost savings for the household

Now in decline, time-of-use tariffs require the use of dual-tariff meters that switch between the two tariff periods, or two individual meters with a switchbox to activate the relevant meter for the current tariff. Time-of-use tariffs were incentivised until market liberalization in 2000 with customers only paying 3-4 cEUR/kWh for consumption during low (night) tariff times. Today electricity rates for the low tariff period are 11-17 cEUR/kWh. The increasing focus on energy efficiency has led to the decision to phase out night storage heaters by 2019, replacing them with more efficient types of heating, including heat pumps.

In the business model of the time-of-use tariff, the retailer provides the consumer with two tariffs, each at a certain price point. The retailer estimates the energy consumption in both price zones and procures the estimated amounts at the exchange/OTC-markets. At the end of the billing period, the meters are read and the measured amounts are billed to the customer.

Solar storage with “free” electricity for 20 years and frequency reserve provision

Siemens’ spin-out Caterva is a manufacturer, supplier and operator of battery-based solar PV storage. The main business model is the operation of aggregate distributed storages to achieve energy independence for its users and to provide frequency response services to the grid. The business has been operating since July 2015 in the reserve market and in the EPEX SPOT intraday market with a fully automated 24/7 energy trading system. Each battery has a rating of 20 kW with a storage capacity of 21 kWh (photovoltaikforum.com, 2017). Up to 16 kW of each battery can be used for frequency provision and 65 batteries together are bid as 1.3 MW of frequency capacity. The battery can be paired with any solar PV system with up to 10 kWp installed capacity. Solar PV systems over the 10 kWp threshold are obligated to pay grid fees, EEG levy and additional surcharges on the self-produced and self-consumed electricity.

The average capacity price per week for 1 MW of frequency capacity was between 2,000 EUR and 5,000 EUR, for the time between August 2015 and September 2016. It is estimated that an income between 2,000 EUR/kW/year and 2,500 EUR/kW/year from the operation within several different markets is possible, as opposed to earning 200 EUR/year through self-consumption. If the storage was operated in the intraday market only, about two thirds of the frequency market income could be generated. Alongside the operation of the storage fleet, revenue is generated from the sales of the storage, which is priced at 27,500 EUR, including installation. The investment costs for the battery are eligible for the battery support programme of the KfW[9].

The consumer acquires the storage from Caterva, with no additional costs during operation. It enables the consumer to achieve energy autonomy of up to 100%, as it is allowing the time-independent consumption of the production of its solar PV system. Practically this means that the consumer has ‘fee-free’ electricity for 20 years. Additionally, each year the consumer receives 1000 EUR from the revenues of the participation in the virtual large-scale battery.

Interview themes

Interview findings from the German DSR landscape are presented here. In total six interviews were conducted with representatives from aggregators, smart home technology providers, retail suppliers, grid operators, renewable energy think tanks and consumer organisations. The interviews discussed potentials and barriers of small-scale DSR users and also address the lack of commercial activity in the markets.

Policy, markets and regulation

Theme 1: Sufficient generation side flexibility and interconnection discourage the rollout of DSR

At the heart of the continental power system with more than 100 GW (Fraunhofer ISE, 2017) of non-fluctuating generation capacity and more than 20 GW of interconnector capacity (RAP, 2015) at a peak demand of slightly over 80 GW (RAP, 2015) Germany is not short of flexibility options. Wholesale energy prices in total and price spreads have been falling for several consecutive years. The market does not produce sufficient shortage signals to encourage new capacity or flexibility. One interviewee stated that the desirable volatility of market prices that is required to promote DSR is not *“desirable from a societal perspective nor is it politically sustainable”*.

Theme 2: Market products allows trading of flexibility but regulation need to be improved to achieve small-scale DSR in the market

The interviews have shown that value opportunities are in theory available to DSR but regulatory barriers are currently preventing access for small-scale assets.

[9] Government owned bank: Kreditanstalt für Wiederaufbau.

On the markets side, several interviewees confirmed that the market conditions offer sufficient trading options for DSR activities. A commercially active flexibility provider and retailer stated that *“the day-ahead spot and intraday markets are liquid and product conditions are suitable for DSR with a product length of 15 minutes and trading opportunities until 30 minutes prior consumption”*. Market conditions on the reserve markets are suitable as well and are likely to be improved further in the future, but the *“life and death of innovative actors like Sonnen does not depend on further improvement”*.

On the regulatory side, a consumer organisation representative stated that the regulatory environment is not designed for DSR, variable prices and aggregators. This was supported by a renewables think tank, which emphasised that regulatory conditions are unfavourable to the demand-side. A level-playing field would have to be created to allow DSR to contribute flexibility to the power system. Another interviewee encouraged legislation to be designed with low barriers and streamlined processes. If this, ultimately, *“doesn’t foster DSR, then there is no need to take extra measures”*. Whether wholesale and ancillary service markets are suitable for the use of short term flexibility depends directly on the product specification in the market. Large minimum bid sizes, product lengths and long lead times[10], are the *“biggest barriers for flexibility”* and actors still face significant business development and forecasting risks.

Market change processes take time, as a compromise between the different stakeholders is sought. The speed of change was criticised by at least one interviewee: *“having a flexible regulatory setup would be desirable, but there seems to be a long way to go until we achieve that.”* The development in the market should be accompanied with a *“learning market design”*.

Theme 3: Price signals do not encourage residential DSR

The interviews found two ways in which today’s price signals in the German market do not support small-scale DSR. First, flexibility needs of the power system can be measured in wide price spreads in the wholesale market and high prices in the reserve market. The absence of both indicates that the power system does not require additional flexibility. Interviewees stated that fixed costs in the power markets are high and price volatility in the German market is *“not high enough to pay off the initial investment in smart meters and flexible appliances”* which, again, can be traced back to presence of existing flexibility options in the German system. According to one think tank, current price volatility does not support small-scale DSR, *“even with the remaining regulatory and market barriers removed”*. Currently SMEs and domestic consumers (less than 1 MW) are currently not ready to be used as DSR sources. According to the interviewee, over 1 MW the aggregation costs are sufficiently low to create a viable business model with today’s

[10] Product length is the amount of time over which a resource must operate. Lead time is the time between the end of trading and real-time operation.

market conditions. The lack of price signals, therefore, amplify technical and business model challenges in using small scale DSR. The current uptake of solar PV storage in Germany, for example, is not driven by attractive price signals from the wholesale market but by the desire to increase self-consumption. One interviewee stated that it is *"actively considering offering RTP tariffs to its customers"*. However, plans have been postponed as price spreads in the wholesale markets are currently insufficient to incentive retailers to offer RTP. According to some, this situation will change as the last nuclear power plant will be removed from the merit-order by December 2022. At the same time, additional fluctuating renewable generation will increase the flexibility demand of the power system. As price volatility increases, small-scale DSR might become a viable option if all regulatory barriers are removed.

Second, the case for small-scale DSR is further watered-down by surcharges on the final electricity price that are much higher than the costs of electricity itself. Approximately 80% of the 30 cEUR/kWh of the price of electricity are fixed costs, such as levies, taxes and grid fees. Energy prices that the consumer sees in Germany were reported to fluctuate by between 2cEUR/kWh and 8 cEUR/kWh, which is not enough to support a viable business model or encourage response from the consumer.

Another issue that was brought up was the use of standard load profiles which do not allow the use of demand-side flexibility. Further rollout of smart meters is therefore needed to build business models that attract a sufficient number of customers.

Business models

Theme 4: Germany's domestic electricity loads are currently not well-suited to DSR

One grid operator raised concerns about the nature of domestic DSR. It is possible that Germany simply has the *"wrong"* energy appliances in the household sector. Another interviewee added that *"household electricity demand in Germany is not necessarily flexible"*; it comprises mostly cooking and IT applications and *"no one changes their habits, just because the electricity is a bit cheaper"*. Modern white goods are potentially too efficient to provide a significant DSR potential, but *"even with the energy efficiency standard from ten years ago we would not have an economic potential for household DSR from these appliances"*.

Electrical loads have to be substantial and shiftable for DSR to work. Electric vehicles and batteries are energy-intensive and could be a good enabler for future RTP business models and grid support. A study commissioned by one interviewee has investigated the conditions under which smart meters would pay off. The results showed that the smart meter is only useful for households with annual consumption of 6 MWh or more, which is also the threshold for the mandatory smart meter rollout. Fridges, for example, can only be shifted for 1-2 hours, so their *"economic potential is very limited as it doesn't even generate enough flexibility to compensate the smart meter costs of around 100 Euros"*.

The unit size of 3-5 kW of battery capacity is seen as the economically viable minimum in one of the reserve markets. Sonnen will be prequalified for the frequency containment reserve (FCR) market in Germany mid-2017. The costs of the integrated controller have decreased enough to enable the business model. CATERVA is already providing 1 MW of FCR in this market. It has to be noted that storage is not necessarily used for economic reasons but its use is driven by the desire to *“increase energy autonomy by technophiles”* and is financially supported by the KfW.

Theme 5: Techno-economics are challenging in Germany until the market demands small-scale DSR solutions

Technologically, off-the-shelf hardware can be used. This can be seen by the success of various retail electricity supply aggregators where the *“technical integration was realized in very short time”*. However, technology costs are too high for small-scale DSR in light of the possible income from the market. The market conditions require lower cost technology than is available right now, despite recent drops in IT infrastructure costs for reserve markets. For the small-scale DSR case, the smart meter will be the technical basis for new business models, but communication and technology costs of smart meters are heavily influenced by security standards. Innovation is expected to bring down costs in the future, but it is questioned whether it will be enough to allow for a viable business model.

Consumer engagement

Theme 6: Home automation can enable DSR as an add-on service but is not the main focus for consumers

A smart home and appliance manufacturer stated that none of its products are targeted towards smart appliances for DSR purposes, as *“consumers do not value DSR yet”*. The lack of interest is partly due to the lack of RTP tariffs on the one hand, and the low perceived value by consumers on the other hand. However, manufacturers are exploring higher integration as, for example, through active participation in alliances working on a common smart home communication standard. Based on surveys by, for example, German Gesellschaft für Konsumforschung (GfK), generally a large potential is seen for the smart home market, but not in the smart appliance for DSR market. According to consumer surveys, the use of smart home systems is for improvements in comfort first, followed by the wish to have better security at home and then the use of DSR last. Consumer engagement for DSR products is realized through the same marketing channels.

Theme 7: Trusted intermediaries are used to engage consumers

Consumer organisations expect energy retailers to play an important role as they provide the interface with the customers. In public perception, the current retailers are not necessarily the ones that will be the most innovative with new DSR products. Newer retailers with higher shares of renewable energy would be more likely to have the necessary *“flexibility in thinking”*, but even these do not offer such new tariffs at the moment.

One smart home technology provider relies upon its brand name to increase trust. Consumers know and respect the brand in several areas, so maintaining this reputation is paramount. The interaction with third parties (such as electricity retailers) is kept to a minimum, as “*they tend to mess up the system”*. Home automation providers are preoccupied with the technical challenges of their own products and focus on delivering these to the consumers. There are concerns that the power market introduces complexity to their products that contradicts the main value proposition of comfort and security. DSR options are therefore not included at this early stage of home automation systems.

Summary

Despite its profile as a leader in renewable electricity, Germany lags behind other regions in engaging small-scale users in DSR, due to abundant flexibility and capacity in the power system. Currently there are no DSR tariffs and products offered to consumers, apart from the legacy time-of-use tariffs. However, several actors are testing alternative business models around storage and electric vehicles.

Table 12: Summary of Germany findings

Conceptual framework area	Themes
Policy, markets and regulation	• Abundance of flexibility and capacity on the generation side and through interconnections means limited regulatory efforts have been made to incorporate DSR • Market price signals do not foster DSR • Markets are available for trading of flexibility but regulations hinder DSR participation
Business models	• Lack of innovative products and tariffs (e.g. real time pricing or direct load control) • Active market for flexibility management aggregators (generation, storage, consumption) • Household electricity demand mostly consists of non-shiftable loads with small unit sizes, which prevents business models • 80% of the final electricity price is mostly price fixed levies, fees and taxes, not wholesale market prices
Consumer engagement strategies	• Retailer central for consumer engagement in DSR • Smart home automation may offer an avenue in to consumer’s homes based on the value proposition of increasing comfort. DSR capabilities can potentially be added later

7. Norway

Key message

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

Overview

This case study highlights the factors that have influenced the current state of small-scale DSR in Norway. Norway has seasonally fluctuating energy demand and is part of the NordPool power exchange. Statnett is the grid operator and bears the responsibility of balancing supply and demand as well as operation of the interconnectors to Sweden, Denmark and the Netherlands. Statnett manages a peak demand of around 24 GW (Statnett, 2015). 98% of Norway's power production comes from hydropower which also provides a considerable amount of flexibility to the power system. 75% of Norwegian households use electricity as their main source for heating either via electric boilers, floor heating or heat pumps (SSB, 2014). There are also around 70,000 electric cars in Norway which is the highest number per capita in the world (Kolbenstvedt, 2013). Average household electricity consumption Norway is 16,000 kWh/year (SSB, 2014) which is also one of the highest in the world. Norway has started its smart meter deployment and intends to have smart meters deployed in every home, via local DNOs, by the start of 2019. There are currently 400,000 smart meters installed in Norway (17% of households).

Norwegian electricity bills are currently based upon standard load profiles and therefore provide little incentive to shift consumption. This prevents Norway from being an advanced small-scale DSR country, despite the high potential from high residential electricity consumption. This can also be explained by the abundance of flexible hydro power in the system which makes it difficult for small-scale DSR to compete.

Development of DSR in Norway

Statnett has pursued DSR since at least 2003, when the Ministry of Petroleum and Energy issued a White Paper discussing the need for improved grid balancing and ensuring adequate capacity margins. While the Norwegian power system is characterised by an abundance of flexible hydro power, it also depends on sufficient precipitation to fill the reservoirs. Norway experienced exceptionally dry autumns in the early 2000s, which led to concerns that hydro reservoirs would be insufficient to meet demand. Although early snow melt in certain areas of the country avoided the deployment of critical measures (for example, involuntary shut down of load), the situation highlighted the vulnerability of the Norwegian power system (Walther, 2005). The White Paper highlighted that Statnett should contribute actively to the promotion and development of demand-side flexibility. It should be mentioned that this period also saw unprecedented spikes in the variable prices paid by households (von Der Fehr & Hansen, 2010).

More recent DSR efforts, such as the smart meter mandate, are being pursued due to the need for grid upgrades to accommodate population growth in major cities, increases in fluctuating renewable generation and growing demand from industry. The large-scale deployment of electric vehicles (EVs) has also been mentioned as a driver for current efforts and the regulator considers smart meters to be essential for modernising the Norwegian power system. A recent regulation is mandating all new parking places (from 2018) to provide electric charging for EVs although there are no mandates in regards to the DSR capabilities of these charging stations.

In its five year development plan, Statnett plans for historically high investments in grid infrastructure with a total of 120-140 billion NOK (11.5-13.4 billion GBP)[11] invested by 2023 (Statnett, 2015). DSR may therefore represent an interesting flexibility option for Statnett and other local DNOs faced with grid upgrades.

Markets for DSR resources

There are two types of markets available to Norwegian DSR resources: the energy markets operated by NordPool and the reserve markets operated by Statnett. Residential DSR is still under development in Norway, although DSR can theoretically bid into all the markets that are open to generation. Industrial DSR participates in the reserve markets, while no residential DSR is present in either in the energy or the reserve markets.

Energy markets

The NordPool Spot ELSPOT and ELBAS markets are spot markets serving the Nordic countries Norway, Sweden, Denmark and Finland as well as the Baltic countries Estonia, Latvia and Lithuania. The spot markets provide a price signal for the entire wholesale market and facilitates the day-ahead planning of the power system operation by matching demand and supply. Any imbalance in a BRP’s portfolio can be balanced by other market members, ensuring cost-optimal allocation of assets in the power system. Time-varying tariffs, in one form or another, currently tap in to value from the NordPool market. Norway is divided into five different price zones. There is no residential DSR bidding into the day-

[11] 1 NOK = 0.096 GBP, February 2017 (www.xe.com)

ahead or intra-day markets in Norway, nor is there any meaningful level of industrial DSR using these markets.

Reserve markets

Statnett offers several markets that are in theory open to DSR. The main task of these markets is to ensure supply and demand is matched in real-time and that the grid frequency does not deviate from 50 Hz. Participants in these markets, including demand-side resources, are paid for availability (NOK/MW) and also for energy (NOK/MW/h) if they are called. Large industrial loads participate in this market, but small-scale DSR does not. An overview of the reserve markets in Norway is provided in Table 13 below.

Table 13: Overview of the reserve markets in Norway

Market place		Tot. capacity/ energy contracted	Load access and participation	Aggregated load accepted
Frequency controlled normal operation reserve (FCR-N)		210 MW	Yes (since 9.03.2015)	Yes
Frequency controlled disturbance reserve (FCR-D)		353 MW	Yes (since 9.03.2015)	Yes
Automatic frequency restoration reserve (FRR-A)		300 MW	Yes	Yes
Fast disturb-ance reserve (FRR-M)	RKOM week	0-926 MW	Yes	
	RKOM season	749 MW	Yes	
	Bilateral agreement	136-186 MW	Yes	
Balancing Market (RK)		~2000 MW	Yes - ~1000 MW	Yes
Strategic reserves		300 MW	No	No
Energy Options (strategic reserves in consumption)		392 MW	Yes	No

Source: Smart Energy Demand Coalition (2015)

Products and services

Spot price (a type of real-time pricing)

One product aimed at small-scale users is the spot price tariff offered by all retail suppliers. This is linked to the RTP on NordPool's day-ahead market and is generally considered to offer a better deal for consumers than a fixed price tariff, hence the majority of Norwegian consumers have chosen it. However, this tariff is not the same as the RTP in Finland and ERCOT. Due to the low deployment of smart meters, consumers are not exposed to hourly price fluctuations. Instead, for billing purposes the retail supplier applies the monthly average of the spot price. Expected price fluctuations over weeks or a month are communicated to users via apps, emails or other communication channels. The resulting behavioural changes are relatively long-term and are not well suited for the reserve markets.

Variable price

A second available tariff is a variable-price product. Retailers decide a price per kWh, which may change once a week. The retailer is obliged to inform customers about any price changes, and a price change has to be communicated well in advance before it comes into force. Hafslund, for example, one of the largest retailers in the country, provides the tariff and notifies customers of a price change two weeks in advance via email or text message. If the price change is deemed to be substantial the retailer must contact the customer directly via a phone call (von Der Fehr & Hansen, 2010).

Variable grid tariff

Another tariff which has been available commercially since August 2015 is a variable grid tariff operated by a distribution network operator (Fredrikstad Nett) in partnership with an electricity retailer (Smart Energi Hvaler) set up specifically to develop innovative tariffs. The tariff consists of three parts: a non-variable administrative portion, a capacity portion related to the three peak hours of consumption in a month multiplied by a standard grid tariff, and an energy portion. The bill is calculated every month. As the distribution operator is regulated, they do not make additional revenue from this tariff. In the long run, the company benefits from deferred investments in the distribution grid and considers it a fairer way of distributing grid costs amongst its customers. All of the retailers' customers on smart meters are subject to this tariff.

Table 14: Overview of time-varying tariffs and services in Norway

Product/service	Commercially available?	Uptake	Markets
RTP (connected to spot price)	Yes – offered by most retail suppliers	Significant uptake	Elspot
Variable-price	Yes – offered by most retail suppliers	Significant uptake – this is the standard tariff	Wholesale markets
Variable grid tariff	Yes – offered by at least one DNO	Limited to single DNO's area (10,000 customers)	No market per se – potential long term value in deferred grid investment and fairer cost distribution

Business models

Other than those utilising the variable tariffs discussed above, no commercial business models were observed in the small-scale market.

Interview themes

The five interviews were conducted with representatives from aggregators, retail suppliers and renewable energy think tanks. The interviews discussed potentials and barriers of small-scale DSR users. Other than the variable tariffs, no commercial activity can be observed in the small-scale market.

Policy, markets and regulation

Theme 1: The need for grid investments drives DSR – flexibility and capacity margins are less of a concern due to existing hydro power

All interviewees pointed out that Norway has large amounts of flexible hydropower to balance supply and demand. Several interviewees stated that this *"dampens the need for additional flexibility options and reduces price volatility in the energy-only markets"*. Interviewees listed the main drivers for Norwegian DSR to be investment needs in the grid and increasing electricity demand. Statnett's grid investments will be historically high over the next decade and they are considering economically viable options to mitigate some of these costs.

One start-up technology service provider (TSP) which is developing smart charging systems for EVs to manage increasing demand agreed with this sentiment. Amongst other consumer focused value propositions, their business model aims at creating value for the distribution network operators via peak shaving and shifting of EV load although there is currently uncertainty around exactly how that value can be accurately measured and captured. One DNO interviewed (offering the variable grid tariff) also aims at long-term cost savings from deferred grid investments. It should be mentioned, however, that in this case the value accruing to the DNO was not considered the main business proposition but instead the more equitable distribution of network costs that may follow from a variable grid tariff.

Theme 2: Reserve markets are designed for large generators and hinder DSR participation

The main reserve markets for DSR in Norway still present barriers to a higher uptake of DSR. Barriers mentioned are that the markets are designed for few and large units, so it very much depends on market processes and manual activation (i.e. via phone calls). This was reported to benefit large resources (that can activate 10 MW in one call) but poses a challenge for distributed aggregated resources that would require automated processes to reduce costs. The minimum bid size of 10 MW in the reserve market was also named as a market entry barrier, giving preference to large resources. DSR is also labelled as a 'low-quality' resource which only entitles them to 10% of the capacity payments that are being paid to generators that are deemed 'high-quality' resources in the same market. The required product length of one hour is also listed as a barrier as DSR resources in general are not capable of economically curtailing load for such a time span.

Business models

Theme 3: Techno-economics are challenging for small-scale DSR in reserve markets

One interviewee (a software solution provider and aggregator) stated that they do not expect small-scale DSR to become commercially viable in Norway for several years. It will be difficult to use households in the reserve markets because an aggregator will have to document activated volume and should be able to disaggregate these for accurate payments. Furthermore, the economics of small-scale DSR (mainly residential in this context) are not considered to be viable on their own in Norway, as there is insufficient savings potential for individual consumers. This sentiment was reiterated by the TSP developing smart charging. It was further stated that residential DSR will most likely be used for balancing individual portfolios rather than contributing to reserve markets and grid balancing.

Consumer engagement

Theme 4: Customers are not interested in DSR for the purpose of DSR

Several interviewees stated that customers do not care for the DSR offering itself but rather, and unsurprisingly, the benefits accruing directly to the customer. Customer engagement strategies therefore need to focus on those benefits rather than the more technical aspects (for example, frequency regulation) that can sit behind the products. One interviewee suggested that home automation systems offer a way into consumers' homes, while DSR products could be added as a secondary value proposition. The main strategy for engaging consumers in the existing tariffs is focussed on economic value propositions. Overall, the RTP and variable price tend to be lower than the fixed tariffs and it is generally accepted that it is an economically sensible tariff to sign up for.

Summary

The Norwegian grid operator (Statnett) has pursued DSR as a flexibility resource since the early 2000s, when tightening capacity margins led to the realisation that demand resources could provide an economical option for ensuring capacity adequacy. This push was instigated by a government White Paper and the regulator. Current DSR efforts, such as the smart meter roll-out, are driven by an increasing electricity demand and a corresponding need for grid upgrades. However, the dominance of flexible hydro power undermines the economics of DSR as it reduces price volatility and reduces the regulatory drive to support DSR as a flexibility option. Only industrial scale DSR participates in the Norwegian reserve markets and commercial actors remain sceptical about the potential of small-scale DSR in these markets. Once the smart meter roll-out is complete, however, the high electric loads offer a foundation for load shifting and time varying tariffs, although it remains to be seen how the challenges of low prices in the reserve and energy markets will be overcome. Table 15 summarises the Norwegian experience with small-scale DSR.

Table 15: Summary of Norway findings

Conceptual framework area	Themes
Policy, markets and regulation	• Norway's DSR efforts are driven by increasing electricity demand (in particular from electric vehicles on the residential level) and an ageing grid network • However, Norway does not have a flexibility need due to abundant cheap hydropower which both limits price volatility and dominates reserve markets
Business models	• The technical, regulatory and economic challenges of small-scale DSR in the reserve markets, combined with cheap flexible hydropower, mean that commercial actors are sceptical about the ability of small-scale DSR to participate

Consumer engagement strategies	• DSR is not considered a viable value proposition for consumers. Home automation might provide a way in to consumers' homes and DSR services could be tagged on later • Economic value propositions have been used to engage consumers in the available spot price tariffs

8. Conclusions from the case studies

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

Policy interventions

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

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

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?

4. Bring Your Own Device (BYOD) is one novel business model particularly observed in the US where the customer buys a DSR-ready device (for example, smart thermostat) from an appliance manufacturer, which helps reduce costs.
5. Capacity markets and energy markets are currently the two major value opportunities for retailers and DSR providers in the case study regions, as these provide

revenue and cost saving opportunities (link to point 3 above). No small-scale participation in the reserve markets was observed.

6. Commercial actors target high electricity loads (often via heating or cooling needs) per customer site as this lowers costs per connection and creates the necessary market volumes of shiftable loads.
7. Business models tend to focus on establishing partnerships across the supply chain as to allow for sharing of specialised know-how and cost reductions.
8. The techno-economics of small-scale DSR, in particular in regard to cost of hardware and customer acquisition and the technical requirements of reserve markets, are still considered a challenge for wide-spread adoption of small-scale DSR.

DSR products and services

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

9. The most popular tariff (apart from legacy time-of-use tariffs) identified in the case studies is the critical peak rebate with an uptake in ERCOT and PJM of 7% and 4% respectively. Real-time pricing is one of the least popular tariffs of the products identified in the cases – less than 1% of households in Finland, ERCOT and PJM are enrolled in a real-time pricing tariff.[12]

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

- Economic benefits: appealing to cost saving potential
- Environmental benefits: appealing to 'green' credentials and CO_2 savings
- Customisation of product offerings: providing tailored products and services based on behavioural data of consumer segments

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

- Simplification: ensuring customers are on board with and fully understand the product they are buying

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

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