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Published in:

Journal of Cleaner Production

DOI:

[10.1016/j.jclepro.2018.05.276](https://doi.org/10.1016/j.jclepro.2018.05.276)

Published: 10/09/2018

Document Version

Peer reviewed version

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Please cite the original version:

Annala, S., Lukkarinen, J., Primmer, E., Honkapuro, S., Ollikka, K., Sunila, K., & Ahonen, T. (2018). Regulation as an enabler of demand response in electricity markets and power systems. *Journal of Cleaner Production*, 195, 1139-1148. <https://doi.org/10.1016/j.jclepro.2018.05.276>

Regulation as an enabler of demand response in electricity markets and power systems

Annala, Salla; Lukkarinen, Jani; Primmer, Eeva; Honkapuro, Samuli; Ollikka, Kimmo; Sunila, Kanerva; Ahonen, Tero

Abstract: The reduction of environmental impacts of electricity use and the transition to renewable power generation crucially depend on demand response (DR). This article takes the political commitment to DR as a starting point and empirically examines Finnish stakeholders' views on barriers to the utilization of DR and the ways in which these barriers could be overcome. The analysis is based on surveys of Finnish electricity retailers and distribution system operators (DSOs), a survey of a wider range of energy specialists, and a follow-up workshop of the latter survey. According to the participants, the main barriers are related to customer engagement and DR automation. Thus, the proposed solutions focused largely on end-user incentives and obligations as well as technical issues. Especially the latter topic would benefit from regulative measures such as standardization of appliance interfaces, whereas changes in electricity tariff structures may take place either through normative changes by the retailers and DSOs or through regulation.

Keywords: Demand response, environmental impacts of electricity, regulatory environment, tariff structure

1 Introduction

Power generation accounts for about 40% of CO₂ emissions in the OECD countries because of reliance on fossil fuels (60% of generation in 2014) (OECD/IEA, 2016). The European Union (EU), for example, has set goals to reduce its greenhouse gas emissions by 40% compared with 1990 and to cover at least 27% of its energy consumption with renewable energy by 2030, which would require increasing the proportion in the electricity sector to at least 45% (EC, 2014).

Demand response (DR) is an important tool in meeting these targets. DR means reduction of electricity consumption when there is lack of generation (e.g. as a result of intermittency of renewable generation) or network capacity. It can also mean shifting of loads to times when power is available or when networks are less congested. DR can mitigate the challenges caused

by intermittent generation by reducing the need for backup power (Kies et al., 2016) and by helping to avoid spillage on windy days (Dietrich et al., 2012). Further, in areas where peak demand is covered with high-emission generation, shifting consumption away from the peak hours and leveling the consumption profile can help reduce emissions (Holland and Mansur, 2008).

A range of potential benefits of DR, in addition to the environmental and system-wide ones, would be experienced by the stakeholders in the electricity markets and networks. For example, transmission and distribution system operators (TSOs, DSOs) that are responsible for maintaining and developing the electricity networks could utilize DR for congestion management (ENTSO-E et al., 2016). Fig. 1 summarizes the roles of different stakeholders in the power system and the benefits that TSOs, DSOs, retailers, aggregators, and end-users could get from DR.

Fig. 1. Stakeholder roles in the power system and DR benefits¹.

At present, DR resources constitute a largely untapped potential in Europe (EC, 2013). The challenges for their utilization include identification of investment and business models that can compete with the traditional capital-intensive models in the electricity sector (Abiri-Jahromi et al., 2015), lacking incentives for end-users to modify their consumption (Fingrid, 2016), and lack of suitable methods and technologies to verify and facilitate the response². In many European countries, most households are still equipped with traditional meters that do not measure the time of consumption (ACER and CEER, 2016). Table 1 summarizes previous literature on other stakeholder-specific barriers.

Table 1. Possible barriers to DR

Stakeholder	Barrier
DSO, TSO	Economic regulation favoring investments in network infrastructure (Vallés et al., 2016)
	Regulated network tariffs hampering use of DR incentives (Weck et al., 2016)
Retailer	In certain markets, retail price regulation hampering use of DR incentives (CEER, 2014)
End-user	Lack of interest
	Limited and uncertain benefits

¹ See (He et al., 2013; Safdarian et al. 2016) for DSO, TSO benefits, (He et al. 2013; Safdarian et al. 2016) for retailer benefits, (SEDC, 2015; McKenna and Thomson, 2014; Chen and Sintov, 2016) for end-user benefits, (Heleno et al., 2016) for aggregator benefits.

² E.g. Amini et al. (2013) have developed new methods to automate DR.

	Difficulties in changing consumption patterns
	Privacy concerns
	(Weck et al., 2016)
Aggregator	Market rules preventing participation of aggregated loads in wholesale, balancing and capacity markets
	Lack of standardized processes between balance responsible parties and aggregator
	(SEDC, 2015)

Moreover, the DR needs of different actors may occur at different times, and they may also conflict with each other. As transmission and distribution grids are interconnected, the decisions and operation of TSOs affect DSOs, and vice versa, and while one entity's main goal may be cost minimization, another might pursue reliability maximization (Mohammadi et al., 2018). Furthermore, controlling loads based on wholesale market prices (retailers' objective) may increase peak load in distribution networks (Belonogova et al., 2013) whereas controlling loads to avoid local network congestions, which would be beneficial for DSO, could shift consumption to hours with a higher market price. Controls conducted by market actors without balance responsibility (e.g. independent aggregators) could create imbalances between retailers' purchases and sales if the issue is not addressed in the market rules (Eurelectric, 2015). Finally, DR may cause discomfort for the end-users (Bahrami et al., 2017).

This article presents an analysis of the opportunities and barriers to utilize DR in the Finnish electricity market and power system. Finland stands out as one of the forerunner countries in having laid the basis for DR by accepting aggregated loads as power reserves (SEDC, 2017) and completing a smart meter rollout in 2013 (Zhou et al., 2017). These recent institutional changes place Finland in an interesting position, as the conditions for improving DR have been shown to depend on market rules and investments in enabling technologies (Eid et al., 2016). In addition to these regulatory conditions, DR will depend on the standards and practices that the electricity market actors follow (Apajalahti et al., 2015) and the cultural practices of energy consumers (Heiskanen and Matchoss, 2016).

Following Scott (2005), regulatory, normative, and cultural institutions can be taken to frame the ways in which new practices can be developed. The framework has been used to conceptualize sector and system level innovations (Geels, 2004), and to evaluate the introduction of a new policy (Primmer et al., 2013). We use the framework and analyze

solutions needed to promote efficient use of DR and to discuss which of the solutions can be facilitated with appropriate regulation.

The contributions of the paper are:

- Analysis and review of the regulatory and political status of DR in Finland and the impact of the proposed changes in the EU legislation on opportunities to utilize DR resources.
- Identification of the remaining barriers for DR utilization in Finland and solutions to these barriers based on surveys and a workshop with Finnish electricity retailers, DSOs, and other energy specialists.
- Categorization of the proposed solutions and an analysis of the stakeholders that should be active in implementing the solutions.

The article is organized as follows. Section two reviews DR policies and legislation in the EU and in Finland. Section three outlines the data and methods. Section four presents and discusses the results. Section five concludes the article.

2 DR policies and legislation in the EU and Finland

2.1 EU

EU has no specific targets for DR, although its central role in facilitating the integration of renewables and reaching the greenhouse gas reduction targets is widely acknowledged. For example, the European Commission (EC, 2013) has stated in 2013 that “flexible demand reduces the needs for costly conventional generation capacities necessary for dealing with demand peaks and the integration of variable renewable energy. It thus makes the supply chain more efficient, triggering lower energy costs and eventually better prices for consumers.”

Currently, DR is considered in particular in the Directive 2009/72/EC³ concerning common rules for the internal market in electricity and in the Directive 2012/27/EU on energy efficiency. The preamble of 2009/72/EC states that “national regulatory authorities should ensure that transmission and distribution tariffs are non-discriminatory and cost-reflective, and should take account of the long-term, marginal, avoided network costs from distributed generation and

³ Directive 2009/72/EC uses a fairly similar term ‘demand-side management’ instead of demand response.

demand-side management measures.” The Directive requires the DSOs to consider energy efficiency and demand-side management measures or distributed generation as alternatives to capacity upgrades or replacements. Further, the Directive states that the Member States shall ensure the implementation of smart metering systems. The implementation may be subject to a national cost-benefit analysis and if the outcome of such analysis is positive, at least 80% of consumers should be equipped with smart metering systems by 2020.

The Directive 2012/27/EU addresses DR through tariff structures, stating that “network or retail tariffs may support dynamic pricing for demand response measures by final customers, such as: a) time-of-use tariffs; b) critical peak pricing; c) real time pricing; and d) peak time rebates.” Further requirements are set for network tariffs: transmission and distribution tariffs shall not include incentives that might hamper participation of DR in balancing markets and ancillary services procurement. Additionally, Member States must ensure that TSOs and DSOs treat DR providers (including aggregators) in a non-discriminatory fashion in the procurement of balancing and ancillary services and that national energy regulatory authorities encourage the participation of demand side resources in the wholesale and retail markets.

In November 2016, the European Commission published its ‘Clean Energy for All Europeans’ package, which includes proposals to deliver a new market design for the EU electricity sector (EC, 2016a). This new market design emphasizes the importance of flexibility in the electricity markets, and especially the proposed recast Electricity Directive and Regulation consider DR with the aim to remove existing barriers (EC, 2016b). As the package seeks consumer empowerment (EC, 2016a), the proposed measures focus on enabling and encouraging the active participation of final customers in the markets through DR and aggregation. The definition of ‘demand response’ is introduced in the recast Electricity Directive referring to final customers’ changes in their electricity load in response to market signals or acceptance of their bids to sell demand reduction or increase.⁴

The Clean Energy package seeks to phase out the regulated and below-cost retail prices (EC, 2016b). According to the recast Electricity Directive, electricity suppliers should be able to

⁴ “‘Demand response’ means the change of electricity load by final customers from their normal or current consumption patterns in response to market signals, including time-variable electricity prices or incentive payments, or in response to acceptance of the final customer's bid, alone or through aggregation, to sell demand reduction or increase at a price in organized markets” (EC, 2016c).

define their tariffs freely. In addition, final customers should have a possibility to choose dynamic contracts that reflect spot market prices. The proposed measures of DR are mainly based on the idea of an ‘active customer’, the definition of which is also introduced.⁵ According to the European Commission, “the price signals should allow for adequate remuneration of flexible resources”, such as DR (EC, 2016c). Further, network tariffs should not create disincentives for DR (EC, 2016c).

According to the recast Electricity Directive, the final customers should be allowed and encouraged to participate in all organized markets through DR. This covers also DR through independent aggregators. In addition, the national legal frameworks, including rules on roles and responsibilities as well as data exchange, should encourage aggregators to participate in the retail markets without a need for a consent from other market participants. Further, customers should be allowed to conclude a contract with an aggregator without consent from their suppliers. The aggregators could be required to pay compensations to balance responsible parties only exceptionally in cases where the aggregator has caused imbalances and financial cost to them.

The recast Electricity Regulation aims to ensure a non-discriminatory access to market participants into balancing, day-ahead and intraday markets. A requirement to set minimum bid size to 1 MW or less in day-ahead and intraday markets aims to allow effective participation of DR. It can also be noted that the minimum and maximum wholesale market prices should not be limited, with some derogations.

The recast Electricity Directive considers the use of flexibility in the distribution network operation. According to the proposal, “Member States shall provide the necessary regulatory framework to allow and incentivise distribution system operators to procure services in order to improve efficiencies in the operation and development of the distribution system, including local congestion management.” DSOs should define standardized market products for these services and procure them in a transparent, non-discriminatory and market-based manner. Interestingly, in this context, DR is stated to be one of the sources of these services.

⁵ “‘Active customer’ means a customer or a group of jointly acting customers who consume, store or sell electricity generated on their premises, including through aggregators, or participate in demand response or energy efficiency schemes provided that these activities do not constitute their primary commercial or professional activity” (EC, 2016c).

Highlighting that DSOs could replace network reinforcements by procuring services, the use of DR, energy efficiency, energy storage facilities, and other resources should be demonstrated in the distribution network development plans.

The Clean Energy package also addresses the interface of smart grids and buildings. The proposal for a revised Energy Performance of Buildings Directive would enable the Commission to define a ‘smartness indicator’ that would provide information to prospective tenants or buyers (EC, 2016d). This indicator should cover “flexibility features, enhanced functionalities and capabilities resulting from more interconnected and built-in intelligent devices being integrated into the conventional technical building systems”, and its features would enhance the abilities to take part in DR.

The proposal for a revised Renewable Energy Directive (EC, 2016e) states that Member States shall require DSOs to assess “the potential of district heating or cooling systems to provide balancing and other system services, including demand response and storing of excess electricity produced from renewable sources and if the use of the identified potential would be more resource- and cost-efficient than alternative solutions.”

All the proposed directives and regulations will go through the ordinary legislative procedure. The European Parliament and the Council shall jointly adopt the Commission’s proposal after the possible amendments (EU, 2012).

In addition to the legislative measures, the European Commission is active in the development of a European standard for smart appliances (EC, 2016f). This standard will allow information exchange between home devices and energy management systems and will potentially facilitate DR in smart grids.

To conclude, the importance of DR is widely understood in the EU legislative proposals. Further, many of the barriers to DR use, and the roles of, for example, customers, DSOs, and TSOs to overcome these barriers, are acknowledged in the proposals. However, to put these proposals in operation, they should be implemented in legislations of the Member States.

2.2 Finland

The Finnish Ministry of Economic Affairs and Employment (2015) has stated that DR should be developed based on market needs without detailed regulation and that the promotion of DR should focus on removing market entry barriers for new entrants. As an illustration of this approach, the Electricity Market Act (588/2013) approaches DR only concerning pricing of network services and implementing the requirements set in Directive 2012/27/EU (Government Bill 182/2014).

An extensive roll-out of smart meters was mandated in the Governmental Decree on Settlement and Metering of Electricity Deliveries (66/2009). It required the DSOs to equip the consumption points within their network with meters that measure hourly consumption and that can be read remotely. The rollout had to be completed already by the end of 2013 as compared with the EU time frame of 2020. Further, the balance settlement is based on the measured hourly consumption.

Electricity retail prices have not been regulated since the electricity market opening, which started in 1995. Time of use (TOU) tariffs with separate prices for day and nighttime have been offered to residential customers since 1970s (Helynen et al., 2007) and are currently commonly offered by both DSOs and retailers. Ariu et al. (2012) estimated that 85% of residential customers with electric heating (17% of all households) are buying electricity under such tariffs. Typically, the response is facilitated by control of electric boilers. Further, many retailers offer tariffs based on the hourly price in the Nordic power exchange Nord Pool Spot. However, only 7% of Finnish retail customers did choose such a tariff in 2016 (Energy Authority, 2017).

Large or aggregated loads can participate in the reserve markets operated by the Finnish TSO Fingrid (Fingrid, 2017). The minimum bid sizes vary between 0.1–10 MW depending on the market. However, only electricity retailers or balance responsible parties can offer aggregated loads. Further, loads can be offered to the strategic reserves acquired by the Energy Authority.

New legislation may further improve the opportunities to utilize DR. For example, a draft for Decree on Energy Efficiency of New Buildings (Ympäristöministeriö, 2017) states that

opportunities to reduce the needed peak power and to improve the controllability of electric power must be considered in planning.

There are still gaps in the current Finnish legislation to fully exploit the opportunities of DR. This paper provides insights into close these gaps by analyzing experts' views on barriers and specific means to promote DR solutions in Finland.

3 Data and methods

To understand the opportunities and constraints of the DR policy perceived by different actors, we conducted an empirical analysis that combined quantitative and qualitative datasets. The datasets were derived from web-based surveys and detailed workshop notes, as summarized in Table 2.

Table 2. Use of different datasets

Survey	Time	Respondents	Purpose in this article
DSO survey	March 2014	30 respondents representing different Finnish DSOs (about third of Finnish DSOs)	DSOs' and retailers views on barriers for DR and ways to engage customers
Retailer survey	September 2014	18 respondents representing 17 Finnish electricity retailers (about 20% of Finnish retailers)	
Smart Energy Transition Delphi survey	Round 1: March – April 2016	47 respondents <ul style="list-style-type: none"> - Academics 29% - Organizations 6% - Public sector 15% - Large companies 19% - Medium size companies (personnel <200) 19% - Small companies (personnel <10) 12% 	Wider perspective on barriers for DR
	Round 2: May 2016	39 respondents <ul style="list-style-type: none"> - Academics 23% - Organizations 18% - Public sector 26% - Large companies 10% 	Suggestions for solving the barriers

			- Medium-size companies (personnel <200) 10%
			- Small companies (personnel <10) 13%
Smart Energy Transition workshop	June 2016	about 30 participants (similar types of stakeholders as in the two Delphi rounds)	

The first two datasets addressed DSOs' and retailers' views on DR through web-based surveys sent to all Finnish retailers and DSOs as a part of the 'Demand Response – Practical Solutions and Impacts for DSOs in Finland' project (Järventausta et al., 2015). From these surveys, we analyzed the main barriers to the use of DR as identified by Finnish retailers and DSOs, and the means to incentivize end-users to take part in DR. Quantitative data were analyzed to reveal the most important barriers to DR and preferred options to engage end-users in DR. Qualitative data were analyzed to ensure that all relevant barriers were identified, and to identify ways to tackle the barriers⁶.

The second survey dataset was a Delphi survey⁷ analyzed with an aim to identify a broad set of barriers to DR and ways to overcome these barriers. The companies that participated in the Delphi survey represented a wide range of stakeholders active in the energy sector, including suppliers of energy management systems, wind and solar power plants, and energy storages, whereas traditional electric utilities a minority of the respondent group. Two web-based surveys were conducted in 2016. The first round explored the impact that different drivers could have on the Finnish energy system in 2030 and the potential of new energy technologies. The second round gathered further views on DR and other technology themes (e.g. wind and solar power).

The final dataset consisted of detailed reports from a workshop, organized as a follow-up of the Delphi survey. The workshop identified prerequisites for fast wide-scale deployment of DR and other energy technologies. Each technology was discussed in a separate table with a help of researchers designated as a facilitator and a rapporteur. The participants were allowed to

⁶ Honkapuro et al. (2015a, 2015b) rely on the same survey and report results on e.g. controlling loads by smart meters and the role division in the development of DR services.

⁷ For a description of the Delphi method, see e.g. Rowe and Wright (1999). The planning of the Delphi survey used in this article is described in Jalas, M., Rask, M., Marttila, T., Ahonen, T., Futures in the making: Facilitating smart energy disruption through a strategic Delphi process.

choose their table, and they could change the table during the day. They listed required changes on sticky notes, and a detailed memorandum was written based on the rapporteur's notes on the discussions.

The qualitative analysis commenced by reading all the written responses to the Delphi survey addressing DR in any way. Then, we coded the data marking statements that defined a barrier or a solution to better utilization of DR. For these organized data, we sought matching coded solutions from the workshop notes on the discussion on the required changes to enable fast implementation of DR resources.

The proposed solutions were then analyzed qualitatively, organizing them into the categories of regulative, normative, and cultural institutions as defined by Scott (2005), and identifying the stakeholders that should be active in implementing the change. The classification and coding were initially done individually by each coauthor and then cross-checked by other authors to avoid coder-biases.

The research design is summarized in Fig. 2.

Fig. 2. Research design and results

The research has certain limitations. It focuses on views of professionals, and no end-users (i.e., source of DR) have been surveyed. Furthermore, the feasibility of the proposed solutions has not been analyzed in detail. The survey and workshop participants may have proposed solutions that best serve their interests. Furthermore, some of the barriers and solutions may be country-specific.

4 Analysis of survey results

4.1 Retailer and DSO surveys

4.1.1 Barriers to utilization

A major barrier to the utilization of DR identified by both the retailers and the DSOs was the small economic benefits (Fig. 3). Additionally, many retailers and DSOs considered the lack

of standardized interfaces between different data systems a barrier, whereas retailers highlighted also a lack of motivation among customers.

Fig. 3. Proportion of retailers (n=17) and DSOs (n=30) that ticked the alternative among the three most important barriers

The respondents referred also to high costs of the required technologies and systems and to the lack of common rules in the sector and questions regarding responsibilities. One DSO also doubted retailers' willingness to utilize DR.

Both groups acknowledged that the control needs of different actors would not necessarily occur at the same time and may be conflicting. Especially DSOs were concerned about how the costs of the control systems would be divided between the different actors and worried that they would have to bear the costs while retailers would be the ones getting most of the benefits. The respondents called for a proper market model to match benefits and costs or, alternatively, regulation of network business to incentivize including the control into the network service. One respondent stated that from the DSOs' point of view there were too few incentives to promote DR, and regulation, if anything, slows the development.

Retailers feared that controls by other actors would increase their imbalances and stated that retailers should be in charge of DR services or that the financial risks/damages caused by controls to the retailers should be compensated for. One respondent was concerned that customers and aggregators could optimize their DR after the spot prices are published, whereas retailers would need to estimate the flexibility in advance during bidding process. This way, DR causes volume and price risks only to retailers. The legal responsibility for possible damages caused by errors in control was also brought up (e.g. if heating does not switch back on). One respondent pointed out that the increasing numbers of stops and starts can wear down devices, which generates a need for clear rules for the controls.

4.1.2 Ways to engage customers

Retailers were asked to choose the most optimal models to engage customers in DR. Hourly electricity pricing (e.g. based on the spot price of electricity) was the most popular option, but several other forms of rewards were supported (Fig. 4).

Fig. 4. Retailer survey, most optimal operation/pricing models to engage customers (n=16)

One DSO respondent stated that power-based distribution tariffs would definitely increase interest. Another one reminded that a significant part of the DR potential is already in use as a result of the day/night tariffs common in Finland, and this limits the benefits that can be gained through new systems. One DSO respondent stated that it would be good to have uniform guidelines for distribution board installations on end-user premises that would define the relays and wiring that would execute DR.

4.2 Delphi survey and workshop

4.2.1 Barriers

The identified barriers related to end-users included lack of incentives as well as concerns about consumer activity. The proportion of potentially active consumers was expected to be low, based on the current electricity supplier switching rates⁸. Consumer attitudes and their willingness to allow automatic DR actions by electricity utilities were also considered a potential barrier.

Technical barriers related mainly to automation of especially small-scale end-users' response. The participants emphasized barriers related to system interfaces and transfer of data and the importance of data security. Automation was considered difficult especially in old buildings. The participants also reminded that not all consumption data could be open. Especially companies may need to hold back data because of competition. Furthermore, investments were considered to occur slowly on the consumer scale, and consumers' courage to invest was questioned.

The professional and political discussion regarding the level of peak demand in Finland was criticized as some participants considered that the necessity of peaks was not questioned enough in the public discourse. Furthermore, the difficulty of developing business models and services related to DR was addressed. For example, one participant held that the financial sense was still lost in the "subsidy jungle" of the electricity market. Also new actors' entrance to the market was considered problematic, and it was pointed out that (independent) aggregators lacked opportunity to sell flexibility because they were not parties in the electricity market.

⁸ 10–12% in 2013–2016 (Energy Authority, 2017)

4.2.2 Changes needed

The participants identified several changes that would trigger or facilitate the efficient use of DR. These suggestions are classified into regulative, normative, and cultural mechanisms in Table 3. In addition to Scott's (2005) framework of different mechanisms, in Table 3, we have identified the actors that the proposals may concern, and we have also categorized the solutions according to their topic.

Regulative mechanisms

The proposed regulative mechanisms included electricity market rules related to market access (e.g. lowering minimum bid size in reserve markets, allowing aggregators) and incentives for end-users. Removal of price caps in electricity markets was suggested along with changes to retail pricing, for example prohibiting fixed tariffs or making hourly pricing mandatory. Moreover, the participants suggested that the energy regulatory authority should create incentives for the DSOs to introduce power-based distribution tariffs. The proposed ideas included also the introduction of incentives in the electricity tax and investment subsidies for households.

Mandatory participation in a "flexibility service" was suggested for end-users with electric heating. An obligatory requirement was brought up by also another participant:

"Why would consumers even need to be asked whether they allow the control of their consumption as with technological solutions it is possible to do it so that the consumer will not even notice it."

Promoting DR in public buildings through regulation was suggested, as the public sector could encourage the transition by starting the investments. Furthermore, participants wished for regulation on ownership of energy consumption data.

Many of the technical issues hindering the automation of DR could be mitigated through standards and other regulative mechanisms. The participants emphasized especially the need for standardized appliance interfaces.

At the building level, the participants suggested incorporation of DR into building codes. On the other hand, the energy efficiency certificate scheme was suggested to be removed in its

current form as the participants found that it does not guide to resource efficiency. Participants stated that there should be an electrical plan for buildings and documentation of installations allowing DR. Guidelines for these plans and installations were also expected to prevent demand peaks caused by large simultaneous loads. Also related to preventing peaks, participants proposed regulation to control the minimum sizes of heat pumps.

Normative mechanisms

The proposed normative mechanisms related largely to the need to develop new types of business models that would depart from the idea of the sale of electricity as a product and rather approach the provision as a service. Suggestions included wrapping DR, solar panels, electric vehicles, and heating of living spaces and water into service packages for end-users. The importance of the ease of use of these services and packages was emphasized in several comments. For example:

“Right systems in right places. Consumer friendliness, user interfaces, not everyone is an engineer!”

The changes suggested to end-user tariffs included, for example, moving to retail pricing based on the wholesale market price or selling electricity as a “power band” with a defined maximum power. However, the power band solution was also doubted. One participant said that it would wipe out even the little interest that consumers show in their energy consumption today. Furthermore, some participants considered that the day/night tariffs (TOU) could be waived as they themselves create demand peaks in cold winter nights. Gamification of DR was also discussed as an option to increase consumer interest.

One proposal was that consumers could be notified when changes in electricity use would be needed for example by text messages highlighting the available savings in electricity costs. However, a large proportion of the comments focused on facilitating automation of end-users’ response. In general, informing building owners and consumers about the possibilities and encouraging them to adopt new technologies and appliances with DR interfaces were called for. Public sector organizations could act as examples and open their consumption data.

Further technical solutions suggested included wireless technology to facilitate automation of DR in old buildings and developing a smart electric vehicle charging system so that peak loads would not increase with the increasing number of electric vehicles.

Cultural mechanisms

The participants considered that both the consumers and the electricity professionals have to adjust their mindsets. In particular, participants urged consumers to have courage to invest. In addition, the regulative, professional, and cultural mechanisms coincided in the idea of selling electricity as a service, as they did also in the views related to the obligatory/default participation in automated DR.

Classification of solutions

Table 3. Institutional and thematic classification of the proposed solutions

Solution	Institutional framework			Relevant stakeholders
	Regulative	Normative	Cultural	
MARKET ACCESS				
Reducing the minimum bid size in backup power and reserve markets	✓			TSO
Allowing aggregators in reserve markets	✓			TSO
Cross-border trade of DR	✓			TSO, market operator (Nord Pool Spot)
BUSINESS MODELS AND SERVICES				
Selling electricity as a service, not a product, easy total service packages to end-users		✓	✓	Retailer, new actors
New business models and services, e.g. virtual energy services to utilize DR and solar PV		✓		Retailer, DSO, new actors
Gamification of DR		✓		New actors
END-USER INCENTIVES/OBLIGATIONS				
Removal of price caps in electricity markets	✓			Market operator
Consumer pricing based on wholesale market price		✓		Retailer
Abandonment of TOU (day/night) tariffs		✓		Legislator, DSO, retailer
Prohibiting fixed electricity pricing / mandatory hourly pricing for end-users	✓			Legislator

Selling electricity distribution as “power band” with defined maximum power		✓		DSO
Energy regulatory authority to create incentives for DSOs to introduce power-based distribution tariffs	✓	✓		Legislator, Regulator
DR incentives in the electricity tax	✓			Legislator
Classifying the levels of supply security and pricing based on the chosen level	✓	✓		TSO
Investment subsidies for households	✓			Legislator
Mandatory participation for households (with electric heating)	✓	✓	✓	Legislator
Regulation on DR, energy saving and power-based pricing in public buildings	✓			Legislator, public users (municipalities etc.)
INFORMATION/EXAMPLES				
Informing end-users about times when changes in consumption are needed and about the impacts on electricity costs		✓		Retailer, DSO
Informing building owners about the opportunities and encouragement to the use of new technology		✓		Public bodies
Encouraging households to use appliances with DR interface	✓	✓		Retailer, DSO
Regulation on ownership of energy consumption data	✓			Legislator
Public sector could lead the way and open their consumption data		✓	✓	Public users (municipalities etc.)
Public sector could encourage transition to DR by starting the investments		✓	✓	Public users (municipalities etc.)
ATTITUDES				
Change in consumer attitudes, courage to invest			✓	Public bodies
Change in the attitudes of electricity professionals			✓	Educational institutes, professional communities
TECHNICAL ISSUES				
Automation of end-users’ response		✓		Appliance manufacturers

Forcing regulation to make gadgets and systems communicate,	✓		Legislator, appliance manufacturers, builders
Standardized interfaces for appliances			
Wireless technology to facilitate automation in old buildings		✓	Appliance manufacturers, builders
Electricity plan of building and documentation of installation prepared for DR infrastructure	✓	✓	Legislator, builders, designers (of electrification)
Guidelines for electricity planning and installation in buildings to prevent demand peaks caused by large simultaneous loads	✓	✓	Legislator, builders, designers (of electrification)
Incorporation of energy and material efficiency and DR into building codes	✓	✓	Legislator, builders, designers (of electrification)
Removal of energy efficiency certificate scheme	✓		Legislator
Regulation to forbid undersizing of pumps	✓		Legislator
Smart electric vehicle charging systems		✓	Charging system providers

4.2.3 Discussion

Consistent with previous research (Lampropoulos et al., 2013; Shen et al., 2014), our analysis highlights the importance of automated DR. The barriers to automation include cultural framings about consumers allowing remote control of their appliances. Also more professional and regulation-based steps would need to be taken to advance automation, including standards in data system and appliance interfaces for external load control and automation. The respondents in our surveys and workshops see facilitating automated and externally controlled responses as a prerequisite for efficient utilization of DR.

The rights and responsibilities of different stakeholders remain open and under debate. These include the independent aggregators' market access, conflicting control needs (discussed also in (Eid et al. 2016)), and the responsibilities to invest in enabling technologies. Coordination challenges have been noticed to hamper also other sustainability projects (see Shi et al. (2016) for difficulties in coordinating interests of stakeholders in sustainable neighborhood development).

Nevertheless, our analysis shows that actions are needed from several stakeholders. Prohibiting or mandating the use of specific pricing structures would require changes in legislation. On the other hand, retailers and DSOs could introduce new tariff structures also without legislated obligations. Further, legislators may promote automation by requiring the use of certain standards at appliance interfaces or setting requirements in the building codes; nevertheless, changes in the practices of builders and appliance manufacturers are also needed.

The Finnish stakeholders suggest nudging the transition to more flexible tariffs through clearly novel regulative measures, such as making hourly pricing mandatory or banning fixed prices. These ideas, however, can be considered inconsistent with the EU goal of consumer empowerment (EC, 2016a) and also with the Finnish goal of market-based introduction of DR (Ministry of Economic Affairs and Employment, 2015). Further, introduction of power-based distribution tariffs to provide incentive to limit peak power was also proposed. Such tariffs have been discussed also in Honkapuro et al. (2017).

Slightly challenging the existing political commitment, the stakeholders suggest economic and fiscal incentives (tax reductions, investment subsidies). Introduction of such mechanisms has to be considered carefully to avoid the risks of distorting competition, over-heated markets, and efficiency of the mechanisms (Majuri, 2016); furthermore, for example the proposed changes in the EU electricity legislation do not mandate incentives. In any case, our findings draw attention to a need for reconsidering market rules. According to our informants, some barriers can be mitigated only through changes in the formal rules of the markets. This applies especially to the role of independent aggregators and to price caps in the wholesale or reserve markets.

To back up technical standards, the Finnish stakeholders identify a need for readjusting professional norms. The participants in our empirical analyses consider regulation crucial for triggering changes in practices. A clear regulatory framework could thus condition the emergence of the normative mechanisms necessary for transition. The participants consider the development of new business models and service packages for the end-users to need a regulative basis, and to condition the taking up of DR resources. Further, the cultural barriers mainly identified among end-users and electricity professionals importantly create resistance to the changes. The proposition of the public sector starting the DR investments could facilitate the change in attitudes by initiating new practices.

The result of the coding could be different in countries where electricity tariffs are regulated. As the Finnish retailers and DSOs are able to set their tariffs freely (DSO regulation focuses on the total revenue and on the maximum level of price increases per year), the propositions related to tariff structures were coded as normative unless the participant had clearly stated that the transition should be implemented through regulation.

5 Conclusions

Taking the political commitment to DR as a starting point (EC, 2013, 2016a) and building on the various identified barriers, we have empirically investigated the barriers perceived and encountered by different stakeholders. Our analysis of DR taps into the ways in which regulative, normative, and cultural institutions can facilitate the transition to the full use of DR resources.

According to our results, the main barriers to DR utilization in Finland are related to customer engagement and automation of their response. Thereby, also a majority of the proposed solutions were thematically classified as end-user incentives/obligations or as technical issues. The other themes identified were market access, business models and services, information/examples, and attitudes. Apart from business models and services that would require normative/professional mechanisms, and attitudes that require cultural changes, regulative mechanisms were widely suggested to enable the use of DR. For the market access of DR, they are crucial but they can also hinder/remove barriers related to customer engagement and automation.

The EU and Finnish DR policies have focused on removing barriers to DR instead of setting specific targets or obligations, and the Clean Energy package continues on the same path. For example, the proposed phase-out of price regulation will facilitate the introduction of tariffs with DR incentives at the European level. The package may also open new markets for DR as DSOs should be incentivized to define standardized products for services to improve the efficiency of operating and developing their networks.

The feasibility of the proposed solutions was not analyzed in the research. Thus, future work should focus on identifying the most critical changes that need to take place and also on a careful analysis of the impacts of the proposed changes on all stakeholders.

Acknowledgment

Smart Energy Transition project (293405) thanks the Strategic Research Council in collaboration with the Academy of Finland for their continuing support for the project. The authors would like to thank the reviewers for their helpful comments.

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Fig. 1. Stakeholder roles in the power system and DR benefits.

Fig. 2.

Fig. 3. Proportion of retailers (n=17) and DSOs (n=30) that ticked the alternative among three most important barriers

Fig. 4. Retailer survey, most optimal operation/pricing models to engage customers (n=16)