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# Piloting Demand Response in Retailing: Lessons Learned in Real-Life Context

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**Abstract:** This article presents a case study on a demand response (DR) pilot project dealing with the application of DR in a grocery store with the utilization of refrigeration equipment as energy storage and photovoltaics (PV) as an energy source. DR has recently gained increased interest due to the growing penetration of intermittent renewable energy requiring flexibility in power consumption. The smart power grid enables the introduction of novel solutions to increase flexibility and the entrance of new actors into the markets. Developing new solutions for the mainstream markets requires experimentation in real-life settings serving the development of technological capabilities, necessary policies and regulation, and user and market needs, as well as adaptation of and to infrastructure and maintenance systems. Our case study on a DR pilot in a grocery store in Northern Finland focuses on how the project contributes to knowledge on the potential for DR and scaling up. It was found that energy efficiency, DR, and self-generated PV power can be aligned and even enhance the potential for DR. While mature technologies exist, applications and installations have not yet been standardized to enable rapid scaling up, and current DR market rules and practices fail to accommodate for small electricity consumers.

**Keywords:** demand response; smart power grid; experimentation; pilot project; grocery supermarket; refrigeration equipment; energy storage; photovoltaics

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## 1. Introduction

The development of an intelligent electricity system is progressing well in most European countries. A so-called smart power grid has been made possible by the integration of metering technologies that make not only electricity consumption but also the feed-in of electricity into the distribution grid possible for small consumers and producers, as well as technological advances in the production and storage technologies of electricity. These offer an important contribution to the transition of the energy sector towards sustainability and therefore ultimately to climate change mitigation as the energy sector is a major source of carbon dioxide emissions. The emerging smart power grid enables the introduction of novel solutions and new participation models as well as the entrance of new actors into the electricity markets.

Although demand response (DR) as such is an old concept, novel DR solutions made possible by the smart grid technologies hold the promise to support the transformation of the energy market. DR is based on the willingness of the actors in the energy market to shift the timing and the amount of their energy consumption to a point of time when, on the system level, energy demand is not on a peak period [1]. The Federal Energy Regulatory Commission (FERC) defines DR as "changes in electricity usage by end-use consumers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized" [2] (pp. 343–344). This reduces the overall cost of the system, keeping energy prices lower, but more importantly, from the sustainability point of view, it makes it possible to avoid the production of electricity with the most polluting technologies, such as coal or oil. Novel kinds of demand response solutions can also be a source of regulating power that support the system in adjusting to the intermittency of electricity production with wind and solar power. Altogether, DR increases the reliability of the energy system and improves the functioning of the electricity market [3].

DR refers to a wide range of actions which can be taken at the customer side of the electricity market in response to particular conditions within the electricity system (such as peak period network congestion or high prices) [4]. Experimentation with novel solutions in real-life settings is an important step in the development of the market. Moreover, the service sector has been identified as an interesting new source for DR in addition to the traditional industry sector. Our study is focused on studying a recent DR pilot, the Virtual Service Environment (VSE) pilot conducted in Finland. At the core of the pilot is the integration of different renewable energy production technologies (photovoltaics (PV), ground heat) with the cooling equipment in a grocery supermarket chain and studying the DR potential as well as its consequences to the functioning of the operations of the supermarket (such as ensuring the maintaining of the cold chain of groceries).

Finland is a country that has opened the electricity grid to all users and producers of electricity. It is among one of the first countries in Europe to do so and, alongside other Nordic countries, has been estimated to have a relatively high demand response potential [5]. Aggregated loads are able to participate in all eight market places controlled by the transmission system operator Fingrid. Traditionally the electricity grid has been balanced by electricity producers and large industrial end-users, but recently Fingrid has been looking for possibilities to diversify power-balance options. In addition, the pilot is conducted by one of Finland's leading grocery store chains (S-Group), which is the largest non-industrial energy consumer in the country and holds a percent share of the overall electricity use of the country. Therefore, the results of such a pilot and its upscaling have nationwide impacts and are also of international interest.

The research questions for our case study are: how does the pilot project contribute to knowledge on the potential for DR for the future development of the Nordic energy market? In which different ways can pilot projects scale up? We focus on the lessons learned in the VSE and the following upscaling of the pilot. The contribution of our study is to provide new insights for the future development of DR, infrastructure development in the energy sector and the scaling up of the lessons from experimentation for the transition of the energy sector towards sustainability. In Figure 1, we present a schematic overview of the paper and the analysis.

In the next section, we discuss the previous literature on DR and how pilot projects in real-life contexts contribute to a transition in socio-technical structures in such a key sector as the energy sector. The methodology section first introduces the relevant literature as the context of DR and then our study case of VSE as well as the utilized data sources for the in-depth case study. The fourth section explains the results of the pilot and discusses factors resulting in scaling up of the pilot. In the concluding section, we discuss the implications of the experimentation to the regulation and the further development of the energy market.

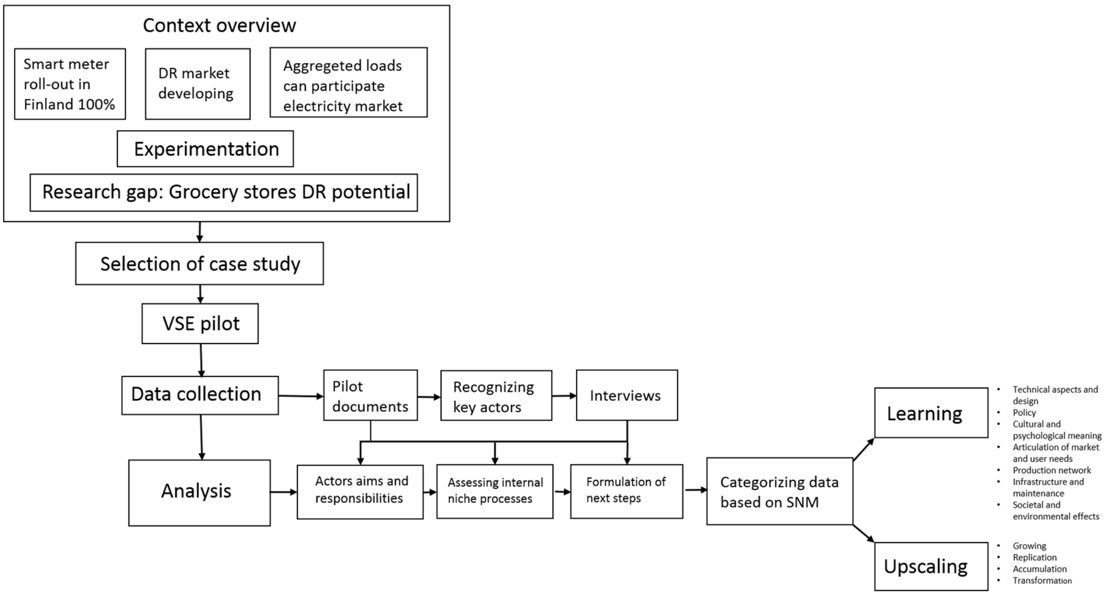


**Figure 1.** Schematic overview of the case study on demand response pilot in retailing. DR: demand response; VSE: Virtual Service Environment.

## 2. Materials and Methods

This section aims at presenting the context of our case study positioning it to the previous literature as well as introduces the VSE pilot in more detail. We explain the relevance of piloting to the development of DR and the energy market in a real-life setting. We also present our study data and its sources.

### 2.1. Contextualising the Problem: Previous Literature on Demand Response and the Importance of Learning

Demand response is not a new topic, but it has recently gained increased interest. Researchers agree that the growing penetration of intermittent renewable power production will require increased flexibility in consumption, i.e., demand response—alongside other options such as power storage and dispatchable reserves [6,7]. Policies to promote DR include variable tariffs, various market incentives for users to provide DR services, as well as research and development and public education and information [2,4,5,8]. On the other hand, the feasibility of DR has been enhanced in recent years by the cost reductions in ICT solutions such as automation and communications in the power transmission and real estate sectors [9].

Previous research has focused on estimating national and international DR potentials [5,7,10,11] or simulating or monitoring DR potentials in individual power-consuming units [12–14]. There is also literature on how markets have responded to new, more variable tariff structures [1,2,15]. In criticism toward this economics-based view of DR, other researchers highlight the importance of learning and behavioral aspects in DR, rather than a linear relationship between price and power consumption at a given time [16]. So far it has been considered that the controller is in charge of all intelligence in the system [17].

Estimating opportunities and barriers for DR in various sectors is an important topic, since different types of energy users have different possibilities and incentives for flexibility in their power use. Research and policy have focused more on the DR potential of industry [9,18], whereas increasing research is currently emerging on DR in households based on novel smart grid technologies made possible by the relatively recent smart meter rollout [12,15]. However, the tertiary or service sector has been identified as interesting for DR [10,11]. Examples of interesting applications include cold storage in warehouses and retailing [7,10]. Yet the diffusion of DR solutions among companies encounters several barriers; of these, the greatest include concerns that DR might interfere with core processes and product quality, and that that savings or revenues might not cover capital and operating costs [18].

Alcázar-Ortega et al. [19] have also found in their research on barriers to DR in some European countries that regulatory barriers are the most difficult and important to overcome.

The previous paragraphs show that DR has been investigated mainly from an engineering and neoclassical economics approach, although the importance of learning and bounded rationality has been pointed out [16,18]. Such aspects are addressed in the evolutionary economics-based research tradition of sociotechnical systems research, which highlights the importance of learning [20] in the acquisition of technological capabilities, in the development of cost-effective solutions, and in their acceptance and normalization in society [21]. Economic agents are unlikely to take up novel solutions unless they are recognized as reliable and economically sensible, which often requires real-life exemplars and peer communications [22].

From a sociotechnical perspective, pilot projects in real-life conditions are crucial for the learning required for market deployment of innovative technologies like DR solutions and practices [21,23]. In contrast to simulations and lab tests, real life operations in the field exhibit a greater variety of unexpected occurrences and variable user practices and requirements. Thus, the experimental deployment of solutions in real-life conditions is an important first step in improving the technical reliability, robustness and cost-effectiveness of solutions and in developing the requisite skills [21,24]. Moreover, experimentation in the field, such as the VSE pilot, serves as a way to explore user and market requirements for solutions, explore the compatibility of new solutions with existing infrastructure and regulation, gain experience of social and environmental impacts, as well as develop cultural meaning for novel solutions [21]. For example, in the context of DR deployment, pilot projects are also important in alleviating users' concerns about operational risks [18]. Finally, yet equally importantly, pilot projects serve the important task of creating the first users and producers of a new technology [25], thus sowing the seeds for the political and market advocacy that is necessary for a technology to gain legitimacy and political and market support [26].

While pilot projects are necessary to reach market readiness of solutions through learning throughout the value chain and beyond—in society at large—they are not sufficient. Several technologies remain at the pilot or niche stages for decades, or forever [21]. Hence, an important next step is the scaling up of these technologies—i.e., their selection and eventual retention as mainstream solutions. Naber et al. [27] have identified four categories of processes through which local experimentation with new smart grid technologies might scale up. *Growing* refers to increase in size and number of participants. In the case of a demand response pilot project, this would entail that the tested solution is taken up by a larger number of users (in the case of a wholesale-retail chain, by a larger number of units within that chain). *Replication* deals with repeat performances of the pilot project, whereas *accumulation* involves processes in which pilot projects are linked to other related initiatives (in the case of demand response solutions, e.g., local deployment of renewables). *Transformation* relates to processes where the pilot shapes wider institutional change (in the case of demand response solutions, for example, the market rules and incentives for various demand response services that power users can provide, such as load shedding or frequency regulation reserves).

### 2.2. Case Study Research Frame

The study is based on the case study design [28,29], which is an appropriate research method here as we focus on an experimentation in a real-life context. We present a process-oriented single case study that relies on multiple sources of evidence and qualitative, empirical research. This case represents an interesting case of the interaction of new actors in the electricity market that is enabled by novel application of energy technology in a smart power grid. As this is a novel kind of pilot in the Finnish context, a case study frame enables an in-depth analysis of the case offering new and important insight and implications for a future development of DR services to the electricity market as well as infrastructure development.

Our research was guided by theoretical propositions on the significance of experimentation on the societal sustainability transitions and how experimentation can define paths along which to proceed in the development of the DR as described above. This novel information can support the transition of the energy sector towards more efficiency through improved peak shaving and less energy consumption as well as lessons learned from the intelligent combination of increased photovoltaic and using cooling devices as storage, while creating a new source for demand response.

Our study contributes to fill the research gap concerning the tertiary sector (more specifically, the wholesale-retail trade with large amounts of cooling/freezing appliances) and the role of learning and scaling up from demand response pilots. We explore how a large wholesale-retail chain learns about demand response through piloting, and what barriers and opportunities it experiences for scaling up demand response solutions from its pilots in different ways.

Our case study was selected due to its strategic importance in relation to the general problem: hence, it represents a critical case [30] because it is deployed in a country, Finland, where electricity markets were liberalized early, smart metering technologies are widespread, and the potential for DR is considered to be high [5,7]. Furthermore, it represents the frontier of DR development, the tertiary sector and the utilization of cold storage for demand response [7,10,11]. Our case organization, S-Group, is the largest wholesale-retail chain in Finland, thus presenting an opportunity to investigate the process (and problems) of scaling up from pilot projects. Furthermore, our case study is unique because it highlights issues of integrating DR, energy efficiency and local power production using solar PV, with the ultimate aim of testing novel kind of earning logic in the Nordic electricity markets.

### *2.3. Data*

The research data is mainly comprised of interview data as well as written background material and reports of the pilots. The interview data was collected in two sets: the first set of interviews was executed during the VSE pilot in May–June 2017. The second set of interview data was collected during April–June 2018 when the upscaling phase of the VSE started. The interviews, in total eight, were semi-structured and lasted 30–60 min. They were transcribed, coded and carefully analyzed. The Table 1 lists the interviews in both sets of the data collection and the Appendix A lists the interview questions in both sets of interviews. The views of the transmission system operator, Fingrid, which operates the DR market, have been collected from an interview, official reports and position papers.

News sites, reports and blogs were used, on the one hand, as a source of details that were otherwise not available or did not come up during the interviews. On the other hand, these sources were used as a verification to the facts told by the interviewees. They were also used to observe where the pilot is heading after the first interviews were conducted and to advise the second set of interviews. These are listed in more detail in Appendix B.

**Table 1.** The sets of interview data sources.

| Type of Actor | First Set of Interviews 2017, Representatives from: | Second set of Interviews in 2018 |
|---|---|---|
| Business actors | S-Group's energy company S-Voima, Managing Director<br>Arina S-market, Construction Manager<br>Rejlers Oy, Business Director | S-Voima Oy, Managing Director<br>Fingrid Oyj (transmission system operator), Development manager |
| Research actors | Technical Research Centre of Finland (VTT), Senior researcher,<br>Lappeenranta University of Technology (LUT), Professor | Technical Research Centre of Finland (VTT), Senior researcher |

### *2.4. Case Description*

The pilot with the virtual service environment was organized jointly by a leading department store and grocery shop chain manager in Finland, the S-Group, the transmission grid operator Fingrid Oyj, and business actors that delivered the equipment and IoT-technology solutions to the stores, Rejlers Oy, Emtele Oy, Fidelix Oy, Green Energy Finland Oy, Jetitek Oy and Jalecon Oy, as well as the research actors, the University of Oulu and the Technical Research Centre of Finland (VTT). The S-Group is a major energy consumer in Finland with its 1600 business premises. Its electricity consumption comprises circa one percent of the electricity consumption in Finland and it is the biggest non-industrial energy consumer in the country. S-group also invests in renewable energy and is co-owner of Tuuliwatti Oy, the largest wind power producer in Finland. It has circa 600 grocery supermarkets in Finland similar to that in which the VSE pilot was executed.

Practically, the piloting with the VSE took place in one grocery supermarket, the S-market Arina, which has therefore taken the leading role in the VSE pilot, with another standard grocery supermarket as a point of reference. The piloting was funded by the participating businesses and a publicly funded research and innovation organization, Business Finland (during the time of the pilot still called Finnish Funding Agency for Technology and Innovation). The volume of the funding for the pilot was one million euros. In the currently starting upscaling stage of the VSE pilot, the lessons from the first piloting will be scaled up and modified with the S-Group still leading the experimentation in further grocery retail outlets. It is installing solar panels on the rooftops of 40 further business premises. The cost of the upscaling phase is estimated as 8 million euros, of which the state subsidies are 20 percent. The target of the S-Group is to produce 80 percent of its energy by renewable energy by 2025 [31].

The piloting with DR has been executed in several different projects, during which the lessons of the first piloting have been scaled up and modified in the consecutive pilots. The S-Group pre-piloted DR first in one large department store already in 2011. In the first pilot, electricity consumption was controlled against the spot price. The S-group executed a second pre-pilot in 2015 expanding the pilot of 2011 to seven large department stores and two grocery supermarkets with incentive based DR. In these two pre-pilots, the focus was on studying the potential of electricity market integration of demand response.

The upscaling of these two smaller pilots followed 2015. The piloting with the VSE started in one grocery store, the S-market Arina, in the city of Oulu in the northern part of Finland in 2017. The experimentation with DR is followed up with the upscaling phase in 2018.

The initial objective of the experimentation with the VSE was to find out how much potential for demand response there is in the energy systems of grocery supermarkets based on a comparison of an energy efficient market and a standard market. Following from the results of such a comparison, another objective of the experimentation was to find out what kinds of demand response services the owners of such grocery shops could offer to the electricity markets. Researchers from VTT modelled the pilot markets' DR capacity to estimate the DR capacity of the entire building stock of the S-Group.

Practically, the experimentation tested how a part of the infrastructure in the grocery supermarkets could be changed so that the systems within the building itself could adjust their energy consumption in order to deliver potential for demand response [32]. This aggregated regulating power could be sold to electricity markets. For the S-Group, the experimentation was thus realized mainly to find ways to reduce energy costs in the grocery supermarkets and to find new earning possibilities with smart energy management. For the participating research institutions the expectation in the pilots was to model and analyze what kinds of power regulating products could be aggregated from regulating power that is created in different sources.

In the VSE-pilot, several solutions were executed that target the reduction of the energy consumption and the electricity costs of the store. The optimization of the energy use and efficiency has been considered throughout the whole building. Figure 2 presents a simplified figure of the energy flows piloted in the project. It is modified from VTT's open data source, which monitors in real time the energy production and consumption of the Arina S-market. Because the figure monitors the real-time energy flow, the numbers of watts presented in the Figure 2 constantly change and thus need to be treated here also as examples. The Figure 2 presents the situation on 12 June 2017.

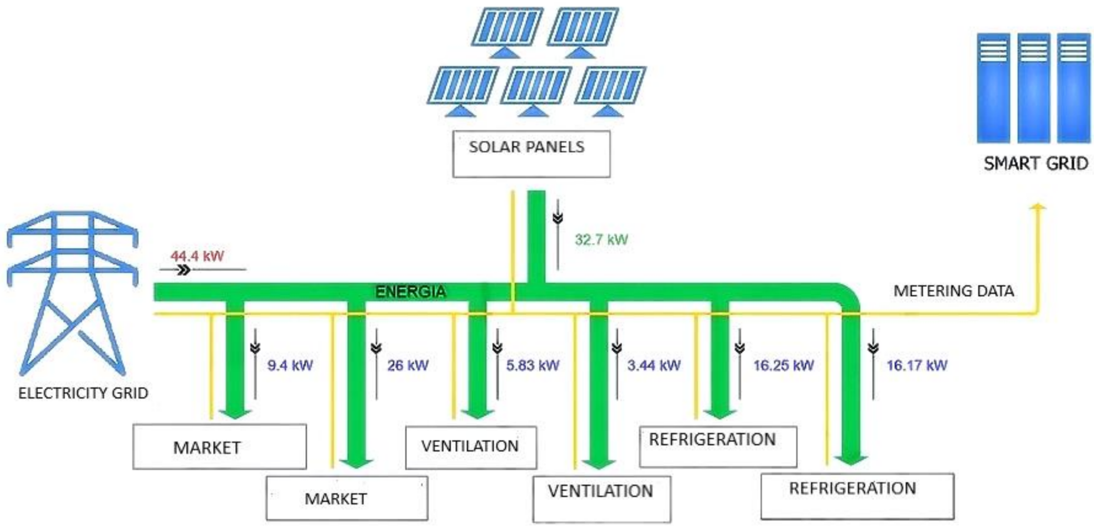


**Figure 2.** Demonstrative figure of Arina grocery store's energy system with solar panels, different electricity appliances and a smart grid server. (Simplified and translated from [33]).

The next bullet points shortly describe some technical details of the VSE pilot:

- The energy in the Arina supermarket is produced with ground source heat pumps and photovoltaics. The impact of PV on energy consumption and the PV production capacity in the grocery store is tested.
- Stores installed advanced metering technology. The energy consumption is monitored on the level of a day, an hour and a minute. Typically, electricity consumption is monitored only on hour-level in the other S-Group stores.
- The own power production, consumption and local storage of energy is dynamically designed and guided by Internet of Things (IoT) technology. Over the internet, individual buildings could then be combined as a virtual power plant.
- The operation of the refrigeration equipment have been optimized to adjust to the energy need. The regulating power is tested by "storing" power in the cold storage equipment and their electricity consumption can be regulated by even turning them off for half an hour, which does not influence the functioning of the store or jeopardize the cold chain of the groceries.
- The waste heat produced by the cold storage equipment is utilized in the heating of the store or transferred and stored to the ground with the help of the ground source heat pump, thus improving the operating efficiency of the heat pump.
- The lighting based on LED and the air cooling can be adjusted when necessary.
- Energy efficiency has been considered comprehensively in the energy efficient pilot-store. In regular grocery stores electricity consumption is circa 600 kWh/m$^2$, whereas the energy efficient store consumes only 240 kWh/m$^2$. Efficiency improvements resulted in yearly savings of 180,000 euros.

The next section discusses the results of the analysis of the case study.

## 3. Results

This section presents the results of our case study. We first discuss the different aspects of lessons learned in the pilot, drawing on the framework set out by Schot and Geels [21]. The second subsection focuses on scaling up of these lessons, drawing on the framework by Naber et al. [27].

## 3.1. Learning

### 3.1.1. Technical Aspects and Design

The interviews highlighted the observation that technology is not the limiting factor in demand response. For example, metering technology has been tested in earlier pilots, which has shown that there is no need for radically new technology. However, the installation (i.e., the deployment of existing technology) has proved challenging. Due to the novelty of the metering technology not previously tested in the grocery stores of the S-Group and the integrated energy system, it has required more reconciliation of ideas from participants to make it work. After the initial installation, researchers discovered that the local electricity company was unable to provide the data needed for the analysis of the energy consumption and DR. Therefore, the system for metering and measuring had to be re-instrumented afterwards to achieve sufficiently accurate data for the analysis. It would seem that although the metering technology has matured, the applications and installations have not yet been standardized.

In the VSE pilot, the system of refrigeration equipment was optimized to improve the DR capacity. Despite the high energy efficiency of the appliances, it appeared that it is possible to achieve similar DR capacity as in less energy efficient systems of refrigeration. The optimized equipment could be adjusted more than the regular systems, which compensated for the lower energy consumption. The results would imply that by optimizing electric appliances, the DR capacity of the building could be improved further.

Another positive result is that the studied equipment reacted to the commands quickly. This indicates that small appliances could be used as quick DR, whereas in large industrial processes the reaction time is slower. Therefore, they could be a valuable addition to the electricity markets as the need for flexibility increases.

In the VSE pilot, DR was integrated into an advanced energy system. The high energy efficiency in the VSE pilot store was achieved largely by a heat recovery system and energy efficiency, while solar panels helped to cut the peak load during the summer. At best, photovoltaics covered the total electricity demand of the refrigeration system in the store. Typically, refrigerators consume over half of the electricity in grocery stores. Therefore, the optimization of the energy system was considered successful. The energy consumption was cut by 60 percent compared to an average grocery store. The pilot offered the equipment providers an opportunity to further improve their appliances. According to the interviews, innovations were developed during the construction process.

The opportunities for DR in retail buildings became more evident during the pilot. Refrigeration systems had not been tested in the company before the VSE pilot. Based on the energy consumption data gathered from pilot locations, the researchers could analyze the DR capacity in a grocery supermarket. The result was that the refrigeration equipment can be disconnected from the power source for half an hour without any consequences for operating conditions of the store. Nevertheless, while the pilot helped to increase the understanding about DR in a commercial building, the operating procedures and policies of an individual store determine the actual DR capacity.

### 3.1.2. Policy

The interviews highlighted the fact that the current reserve and balancing markets have been developed for power plants and large industrial energy consumers, and they seem unsuitable for smaller aggregated loads. The challenge is manifold. In the pilot, researchers recorded energy consumption patterns in two locations. Pilot projects in grocery stores have shown that electricity consumption could vary significantly over time. One discovered challenge are the requirements set for measuring demand response. The current metering system records energy consumption on a building level, where adjustments in one or two appliances are hard to verify. If the electricity user participates in DR by adjusting the energy consumption of one device, it is difficult to see the small change (less than 100 kW) in the aggregate consumption data due to the characteristic variation and measurement accuracy. Commercial buildings can have several electric appliances where the energy consumption is measured. However, all of them are not necessarily participating in DR. On a building level, it is hard to tell how much each device has been adjusted.

As a solution, the VTT suggests that the imbalance settlement period applied would be shortened from an hour to fifteen minutes to improve the verification of DR. In fact, the EU has agreed that the imbalance settlement period to be adjusted to fifteen minutes across the EU by 2025 [34].

A second challenge is that, while there is capacity for DR in grocery stores, aggregating it might not be profitable in the current market environment. The minimum power to enter the reserve market is 0.1 MW and balancing market 5 MW, therefore the aggregator needs tens, even hundreds of appliances in order to be able to aggregate enough capacity for the market. While the VSE pilot supermarket did not consider that the investment costs were too high, researchers were worried that the aggregation of such small loads might not be profitable business for small new independent operators.

While the participants all seemed to agree that the market rules need to change to promote DR, they also felt that the reforms would increase the uncertainty in the market. End-users and demand side management service providers were reluctant to make large investments since the market rules can be very different in five years from now. The market administrator also needs to take into account the integration of EU electricity market. To promote DR, market operators have the option to either change the current rules to accommodate small aggregated loads or to create a new market place for DR. Based on the lessons of the VSE pilot, the participants suggest that a new digital market place should be opened for small aggregated loads to make the market entry and participation easier for end-users and thus to increase the flexibility in the grid [35].

#### 3.1.3. Cultural and Psychological Meaning

Forming cultural and psychological meaning for new technologies or services constitute important processes for the social embedding of new technology [21,23]. All participants attached similar meanings and values to DR. It would seem that participant and markets share a common vision of a green, market based and economic electricity service. During the interviews, many participants compared the voluntary DR programs with the building of new peak power plants. In comparison, DR was seen as less investment intensive and would bring savings across the field in the form of lower electricity prices. In addition, it could open up new business opportunities for many new actors.

While the environmental benefits were not in the scope of the pilot, many participants saw DR also as an environmental solution to mitigate climate change. For businesses, sustainability is increasing their value, and promoting DR was seen as responsible business. As the S-Group invests heavily on renewable intermitted energy, it wants to be responsible and participate in taking actions to support the balancing of the grid.

The current way of balancing the grid was believed to become outdated as the renewable and intermittent electricity production increases. Participants wanted to shift to new solutions that would be based on smarter technology.

#### 3.1.4. Articulation of Market and User Needs

The S-group has gained experience on DR from several pilots. According to the S-Group, the stores are free to pilot automated DR. Engaging grocery store managers within the S-Group (i.e., users), has not been challenging. One challenge, however, has been the deployment of metering technology and understanding the rules for aggregated DR set by the market places. From a user perspective, the specifications in the market are very technical and understanding them requires in-depth knowledge even from such a large and experienced electricity buyer as the S-Group. From a user point of view, the participation should be made easier for small aggregated loads.

During the pilot projects, users have discovered that measuring DR is more complicated than expected. The realized DR capacity in grocery stores has been lower than originally calculated. The variability of electricity consumption, within the observation time, complicates the interpretation of the actual demand response adjustment. Due to the variation in the data, the national grid operator, Fingrid, as the operator of the DR market, and the users interpret the results differently. S-Group estimates that it could have tens of megawatts capacity in its building stock. From a user perspective, the determination of capacity should be unambiguous, and the capacity should respond with the realized adjustments in energy consumption. The DR capacity is directly linked to how attractive the DR investment is for the user. If determining the DR capacity is unclear, the risks of the investment increase.

According to the interviews, the amount of investment is not seen as much of an issue as is the uncertainty about the profitability of the investment. It was suggested that new actors feel reluctant to make large investments to participate in DR since the user cannot be certain whether the market entry is possible and whether the investment will be profitable.

The VSE pilot delivered understanding on how much DR capacity the grocery retail actors might provide and what are the challenges for the participation of the actors in retailing. The results here are from only two grocery stores, but it would seem that aggregating many appliances in several buildings would make the verifying of actual demand reduction of one appliance complicated. Despite the challenges, the supermarket Arina thought that promoting DR was worth investing in and experimenting with, and that the current challenges can be overcome. In the end, the profitability of DR investment depends on many factors such as the number and condition of electrical appliances, market situation, how DR adjustments are calculated and the age of the building. Therefore, the VSE pilot cannot definitely give an answer on how much DR capacity could be aggregated profitably in one location or the S-Group in total.

### 3.1.5. Production Network

Important players in DR are the aggregators. They are new actors in electricity markets in Finland that can profoundly change the functioning of the market. However, results from the VSE pilot indicate that the current operating environment may not be profitable to new independent aggregators. Aggregating sufficient amounts of small loads to enter the market might increase investments payback time too far. Larger aggregators might do better.

The pilot project shed light on the complexity of the DR value chain. From the service provider perspective, there are several customers in DR. An aggregator needs to serve the need of the electricity users as well as the market administrators, while preferably making a profit itself. According to one participant, the pilot project was good learning platform for developing DR service.

The market administrator has announced that market places are under development due to transition of electricity production. While interviewees wanted the market rules to change to accommodate smaller end-users, they also thought that market developments increase the uncertainty of DR investments.

### 3.1.6. Infrastructure and Maintenance

The objective of the pilot project was to better understand the demand response capacity in grocery supermarkets and consequently in commercial buildings more generally. Before the pilot project, the understanding of DR possibilities in grocery supermarkets was limited, and refrigeration devices had never been tested in Finland. The comparison of two different locations showed that integrating DR with advanced energy system and optimization of DR capacity is greater in highly energy efficient systems, even though total power consumption is lower than in conventional systems.

The pilot project also indicated that DR brings new opportunities for building energy management. While energy efficiency has been a key issue for new building design and facility management, DR can be an alternative way to reduce greenhouse gas emissions from buildings by allowing the greater integration of intermittent, renewable power in the energy system, for example by reducing peak loads. In the VSE pilot, it was shown that solar panels helped to manage peak loads in the grocery stores. DR also brings new challenges for energy management in commercial facilities: while energy efficiency is the conventional goal in facilities energy management, sometimes it might be more useful to increase energy consumption for a time. DR is thus a new service that buildings can provide to the energy system, requiring new technological capabilities in infrastructure development and maintenance.

#### 3.1.7. Societal and Environmental Effects

In the interviews, two positive effects emerged. DR was seen to have positive effect both economically and environmentally. On the other hand, the pilot project indicated that concerns about potential negative effects in the form of compromising product quality and safety were unfounded.

All participants interviewed brought up the economic aspect of demand response. Participants seemed to appreciate that demand response is promoted on market terms. DR was seen as a more economical solution than building new peak power plants. Another benefit is the creation of new business models that will engage operators in a new way. All the participants felt that DR could deliver significant social benefits.

Also, environmental benefits were seen for DR, though they were not in the scope of VSE pilot. DR was seen to promote integration of renewable energy technology. Actors deemed demand side management more environmentally friendly way to increase flexibility, when compared to building new power plants.

As expected, the pilot project served to alleviate concerns about the risks to core operations and product quality and safety, which are key barriers to participation in demand response [18]. Eliminating such concerns is a crucial step toward the wider diffusion and scaling up of DR solutions, and is unlikely to occur without the experiences gained from pilot projects in real-life conditions.

### *3.2. Scaling up*

The VSE pilot project came to an end in April 2018. The interviews were conducted soon after that. In this section we describe how the participants planned to scale up the lessons from pilot in terms of growing, replication, accumulation and transformation.

#### 3.2.1. Growing

During the pilot project, there were plans to add new locations to scale up the use of the piloted technology. Those plans were not realized and the pilot ended in April 2018, with no further plans to continue. While a direct scaling up by growing the pilot did not happen, the VSE pilot created ideas for new pilot projects and research projects and many participants expressed a will to continue developing demand response. These ideas are presented in the next sections. However, some participants expressed that at some point demand response should move from piloting into a real business. There is thus a desire to scale up by growing, but the conditions for this are not yet in place. The first steps toward scaling up by growing were however taken in the form of installing solar panels in 40 new business premises and other estates of S-Group that enable DR service piloting and design at a larger scale in the future.

#### 3.2.2. Replication

The S-Market Arina has been developing grocery supermarket energy systems for several years. For Arina the focus of the VSE pilot was in improving energy efficiency and decreasing electricity expenses. They actively incorporate new energy technology and learn from each project. The VSE pilot grocery supermarket has the most advanced system so far, with an energy consumption that is only 40% of that of a standard store. The lessons drawn from the VSE pilot will be put to use in other new locations within this local division of the S-Group.

The VSE pilot was the first time the S-Group has piloted DR with refrigerators. The S-Group continues to test demand response and improve capacity of grocery store appliances. It has started a pilot with refrigerator system supplier to improve the adjustability of appliances. The goal is, together with appliance supplier, to improve the demand response capacity of refrigerator systems without compromising energy efficiency and product quality.

During the VSE pilot project, VTT got ideas for new pilots that use the lessons from VSE and develop them further. For VTT the focus will be on developing market rules to accommodate aggregated loads from small units. VTT hopes to continue pilots with Fingrid and S-group.

One possible strategy is to have a new market place for smaller end-user to overcome the barriers related to current market places.

### 3.2.3. Accumulation

In the VSE pilot project, solar panels and demand response technology complemented each other well. The S-Group's strategy is to increase the use of renewable energy and they actively invest in solar and wind energy. Its newest solar energy acquisition will make S-Group the largest solar electricity producer in Finland. While solar panels will be installed in about 30 grocery stores, they will also look into the opportunity to include DR solutions. Those decisions will be made after visiting in the store building and estimating the profitability of the DR investment.

### 3.2.4. Transformation

Transformation means that the pilot project changes the regime's selection environment to accommodate the new technology. Soon after the VSE pilot project, there was no sign that the pilot project would have led to an immediate transformation in the regime. Rather the pilot project pointed out the barriers for demand response.

However, participants have actively promoted DR in their communication channels and the Arina S-Market has received attention in the local media. In addition, the partners have reported on the results in expert hearings and seminars. Therefore, the results have also spread to interest groups such as Smart Grid Working Group led by the Ministry of Economic Affairs and Employment of Finland [36]. Through active communication, the lessons from the DR pilot project are gradually raising the problems of DR participation by small units to the policy agenda.

## 4. Discussion

Most of the previous research on DR has focused on estimating potentials at a national, pan-national, and sector level, using data on hourly load consumption [5,7,10,11]. This is an important first step, but as Olsthoorn et al. [18] point out, there are several barriers to actual DR participation in each sector, which remain unresolved. In the service sector, these include concerns about profitability, core operations disruption, and product quality [18]. Real-life pilot projects are an important first step in addressing and—if successful—alleviating such concerns [16]. Moreover, literature on sustainability transitions [20] show that real-life pilot projects also serve other purposes: development of technological capabilities and skills, necessary policies and regulation, articulation of cultural meaning and user and market needs, as well as adaptation of and to infrastructure and maintenance systems. These are interconnected and simultaneous processes that feed into each other and highlight the complexity of organizing real-life pilot projects and the diverseness of the knowledge they can produce. Several stakeholders have benefitted and in the future can further benefit from the knowledge created in the pilot. Table 2 lists the stakeholders that we have identified benefitting from the pilot study based on the knowledge type as described in Section 3.1. Clearly, all participants and other stakeholders benefit from all kinds of learning, but the table lists the most obvious actors that can benefit and have benefitted from the experiences of the VSE-pilot.

Our case study contributes to and combines these literatures on DR potentials and the role of pilot projects in sustainability transitions by focusing on the integration of energy systems, building systems and particularly commercial buildings. By examining a unique case of piloting by a service-sector company that has invested for several years in learning about demand response, while also being a major producer of intermittent renewable energy and a major investor in energy efficiency, we are able to go beyond average potentials and abstract concepts of learning from pilots. Piloting in real-life conditions indicated that energy efficiency, DR and self-generated PV power can be aligned and can even enhance each other, once these aspects are taken into account in facilities and equipment design. The DR potential can thus be greater than estimated on the basis of current mainstream technology. On the other hand, our case study showed that although the metering technology has matured, the applications and installations have not yet been standardized, which show that the technological capabilities and skills and necessary policies and regulations develop in different paces. One solution for adding knowledge on installing smart metering systems would be to make them mandatory in new buildings which shows that adaptation is much dependent on infrastructure systems and their regulation. Moreover, our case study highlights the importance of cultural meaning in promoting DR: it is important that there are profitable opportunities, but market players also need to be aware of the environmental and economic opportunities of DR.

**Table 2.** Stakeholders benefitting from learnings of the Virtual Service Environment (VSE)-pilot.

| Type of Learning | Stakeholders |
| --- | --- |
| Technical aspects and design | S-market Arina, S-Group, Fingrid, participating business actors, researchers |
| Policy | S-Group, Fingrid, Ministry of the Economy and Employment |
| Cultural and psychological meaning | S-market Arina, S-Group, participating business actors |
| Articulation of market and user needs | S-market Arina, S-Group, Ministry of the Economy and Employment, Fingrid, participating business actors, aggregators of small loads, researchers |
| Production network | S-Group, Fingrid |
| Infrastructure and maintenance | S-market Arina, S-Group, participating business actors, researchers |
| Societal and environmental effects | S-market Arina, S-Group, Ministry of the Economy and Employment, researchers |

While the pilot project provided an opportunity for learning throughout the value chain involved (including users, technology producers and energy market operators), the case study also served to reveal problems in scaling up DR solutions: It showed that current market rules and practices for measuring DR are not suitable for small electricity consumers bringing forth the discrepancy between the user and market needs and policies and regulations. This has significant implications for rolling out DR in society: If the S-Group's markets do not have enough capacity to be aggregated profitably, how would DR aggregation work for households? It also shows that there are barriers to entering the DR market that need to be addressed before the full potential of DR can be captured.

Scaling up from individual pilot projects is never self-evident [21]. We used Naber's et al. [27] framework to explore various pathways for scaling up in our case study. Our results extend this framework by suggesting that a failure to scale up via growing might indicate that the conditions for this type of scaling up are still lacking. Instead, the S-Group's VSE pilot scaled up via replication (the creation of new pilots) and accumulation (integration with other technical systems). Our case study also highlights the importance of transformation, i.e., institutional change, as a key process in scaling up DR systems. It showed that market rules do not accommodate for small DR participants, and metering and measurement systems might also make participation of the service sector difficult. While participants deemed market reform and the creation of perhaps a separate market for small aggregate loads necessary, they were also concerned about the uncertain investment environment created by pending market reforms. Our case study thus showed that pilot projects can also be critical in highlighting gaps in market regulations that are not self-evident to regulators, especially in the case where new players are entering a market.

Our case study has certain limitations. It is obvious that the results cannot be generalized to retailing in Finland or other countries as such. Since DR is not yet widespread in the retail sector, our case study pilot project can be seen as a forerunner, with unique characteristics in its integration of energy efficiency, DR and local production of intermittent, renewable power. This kind of case can reveal the potential, but also the barriers to DR participation in retailing: if difficulties are encountered by forerunners, they are likely to be even more severe elsewhere. There is thus much scope for future research, for example on whether investing in DR is profitable for smaller electricity users in the current market. Our case study shows that such research should address several variables: capacity for DR, market roles and rules, the age of the buildings, as well as the state of technical equipment and the quality of installation and operation. Our framework could also be enhanced by examining several pilots over an extended period of time.

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## Appendix A. Interview Questions of VSE Pilot Project

### I. First set of interviews in 2017

1. How did you become involved with the VSE pilot? Where did the idea for the VSE pilot come from and how many pilot locations were chosen?
2. Has the project proceeded as planned or has there been surprises? If yes, what kind of surprises?
3. What was challenging?
    - 3.1 In technical aspect?
    - 3.2 In coordination and planning?
4. What was easy in the VSE project?
5. Did you have to change your plans during the project?
6. Was there expertise needed from outside of participant organizations?
7. Did the pilot project bring new practices to your organization?
8. What do you expect from the VSE pilot? Do the participants have different expectations? Have the expectations changed during the project?
9. How do the participants communicate during the project?
10. Do you exchange experiences/lessons with other pilot projects?
11. How have you documented the pilot?
12. Have you reported about the pilot? Where and to whom?
13. Have you assessed the pilot project somehow?
14. Are there factors that limit scaling up the project to other locations?

### II. Second set of interviews in 2018

1. What did you learn from the VSE pilot?
    - 1.1 What were the results of the VSE pilot project?
    - 1.2 Would you do something differently?
    - 1.3 How would you describe the cooperation between the participants?
    - 1.4 Did the network change during the pilot? How?
    - 1.5 How was information shared?
    - 1.6 Did the expectations change during the VSE pilot?
    - 1.7 Did the pilot meet your expectations?
    - 1.8 What did you learn?
        - 1.8.1 about technology?
        - 1.8.2 about end-user requirements?
        - 1.8.3 Something else?
    - 1.9 How would you evaluate the project?
2. Will you scale up the pilot?
    - 2.1 Are going to continue the VSE pilot?

2.2 How?
2.3 Why?
2.4 Are you going to replicate the pilot similar as in VSE?
2.5 With whom are you going to continue experimenting with DR?
2.6 What factors limit upscaling?
2.7 In what other ways will you benefit from the lessons and experience of the VSE pilot?
2.8 Are you going to invest in DR in the future?
2.9 What should be done to promote DR? (For example change in legislation, etc.?)

3. How demand response promotes the transition to a sustainable energy system?
3.1 What benefit does DR have in a supermarket? Can it be applied to other commercial buildings?
3.2 How much DR capacity does one supermarket has?
3.3 Have you made $CO_2$ calculations during the VSE? Have you seen any energy savings?
3.4 Why are solar power investments executed together with the DR investments?
3.5. Does DR complement renewable energy technologies? How?

## Appendix B. Data Sources from News Sites, Reports and Blogs

| Name of Publication (Translated by the Authors) | Name of Publication (in Original Language) | Date/Author | Source |
|---|---|---|---|
| New method helps to balance electricity production and consumption | Uusi menetelmä auttaa tasapainottamaan sähkön tuotantoa ja kulutusta | 8 February 2016/VTT | https://www.vtt.fi/medialle/uutiset/uusi-menetelm%C3%A4-auttaa-tasapainottamaan-s%C3%A4hk%C3%B6n-tuotantoa-ja-kulutusta |
| The energy cheapest market is found in Finland—takes a half of its energy from the sun | Maailman energiapihein market löytyy Suomesta—ottaa puolet energiastaan auringosta | 13 June 2017/VTT | https://www.vtt.fi/medialle/uutiset/maailman-energiapihein-market-l%C3%B6ytyy-suomesta-ottaa-puolet-energiastaan-auringosta |
| The energy cheapest market utilizes solar energy—carbon footprint is reduced and savings are created | Energiapihi market käyttää hyväkseen aurinkoa—hiilijalanjälki pienenee ja säästöjä syntyy | 13 June 2017/Risto Degerman, Yle | https://yle.fi/uutiset/3-9665949 |
| The world's energy cheapest store in functioning in Oulu—even the cold chain can manage on its own for a while | Oulussa toimii maailman energiapihein kauppa—jopa kylmäketju pärjää hetkittäin omillaan. | 26 April 2017/Arja Mikkola, Kaleva | http://www.kaleva.fi/uutiset/talous/oulussa-toimii-maailman-energiapihein-kauppa-jopa-kylmaketju-parjaa-hetkittain-omillaan/758238/ |
| Case: Electricity consumption is flexible | Case: Sähkönkulutus joustaa | S-Group annual report 2015, (p. 92) | https://www.s-kanava.fi/web/s-ryhma/raportit |
| VTT: Demand response requires functioning markets | VTT: Kysynnänjousto edellyttää toimivia markkinoita | 29 May 2018/Sähköala.fi | http://www.sahkoala.fi/ammattilaiset/artikkelit/energiatehokkuus/fi_FI/VTT_kysynnanjousto_edellyttaa_toimivia_markkinoita/ |
| Regulatory power for the future electricity market—The building to tell its own consumption | Säätövoimaa tulevaisuuden sähkömarkkinalle—Rakennus kertomaan omasta kulutuksestaan | 18 April 2018/VTT | https://www.vtt.fi/medialle/uutiset/s%C3%A4%C3%A4t%C3%B6voimaa-tulevaisuuden-s%C3%A4hk%C3%B6markkinalle |
| Pausing electric heating for a while, reducing air conditioning—the automarkets to balance the intermittency of wind power | Sähkölämmitys toviksi pois, ilmanvaihto pienemmälle—Automarketit halutaan tasaamaan tuulivoiman vaihtelua | 18 April 2018 at 17:35 o'clock/Yle | https://yle.fi/uutiset/3-10165328 |
| On a joint road towards the future electricity system | Yhteisellä tiellä kohti tulevaisuuden sähköjärjestelmää | authored 5 December 2016/Fingrid, | https://www.fingrid.fi/globalassets/dokumentit/fi/julkaisut/sahkomarkkinoiden_tulevaisuus.pdf |
| S-Group to become the largest photovoltaic producer in Finland | S-ryhmästä Suomen suurin aurinkosähkön tuottaja | 18 April 2018/S-Group | https://www.s-kanava.fi/uutinen/s-ryhmasta-suomen-suurin-aurinkosahkon-tuottaja/4451599_384136 |
| VTT White Paper, Balancing the future energy market | Säätövoimaa tulevaisuuden sähkömarkkinalle | 18 April 2018/VTTKlaus Känsälä ja Kalle Hammar | https://www.vtt.fi/inf/pdf/whitepapers/VTTWhitePaper2018-Saatovoimaa_tulevaisuuden_sahkomarkkinalle.pdf |

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