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Impact of home market on business development and internationalization of demand response firms

Salla Annala [a, *], Salvatore Ruggiero [b, c], Hanna-Liisa Kangas [d], Samuli Honkapuro [a], Tiina Ohrling [c]

[a] LUT University, School of Energy Systems, P.O. Box 20, FI-53851, Lappeenranta, Finland
[b] University of Helsinki, Centre for Consumer Society Research, P.O. Box 16, FI-00014, Helsinki, Finland
[c] Aalto University, School of Business, P.O. Box 21210, FI-00076, Aalto, Finland
[d] Finnish Environment Institute (SYKE), Latokartanonkaari 11, FI-00790, Helsinki, Finland

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ABSTRACT

The transition toward more renewable-based energy systems increases the need for new flexible resources, such as demand response (DR). Previous literature has found various barriers for DR utilization, but much of this research has focused on the initiation of DR operations or barriers in national markets and not on factors that hinder market upscaling and firm internationalization. We address this gap by analyzing interviews with 22 DR companies active in Finland, one of the early mover countries for automated DR. While most of previous research has focused on electricity DR, our interviewees also include district heating DR companies. By using the Technological Innovation System (TIS) framework, we study how the advanced regulatory and market framework and the technology rollout in Finland have affected the DR service development and the internationalization of Finnish companies. Based on our results, the DR market formation in Finland has largely relied on the Finnish transmission system operator's early decision to allow independent aggregation and the early large-scale rollout of smart meters. The advanced home market has enabled firms to develop new solutions and prove their concept. Yet, the highly structured nature of energy markets complicates the access to both advanced and less advanced foreign markets.

1. Introduction

Countries around the world are striving to decarbonize their energy systems while ensuring security of supply and access to affordable energy [1]. National and EU-level energy policies also seek to improve the competitiveness of domestic industries in international markets while simultaneously fulfilling domestic energy needs [1,2].

Whereas the amount of intermittent renewable generation increases, fossil fuel plants traditionally used for system balancing are being phased out. Thus, the need for other flexible resources, such as demand response (DR), is increasing. The role of DR as an enabler of the decarbonization of the energy sector [3–7] and consumer empowerment [8–12] has been discussed widely, but explicit DR goals have not been set and even the formal definition of DR was introduced in the EU legislation only recently[1]; the Recast Electricity Directive of 2019 [13] defines DR as:

> "the change of electricity load by final customers from their normal or current consumption patterns in response to market signals, including in response to time-variable electricity prices or incentive payments, or in response to the acceptance of the final customer's bid to sell demand reduction or increase at a price in an organised market … whether alone or through aggregation".

Distribution system operators (DSOs) could tap DR in congestion management [14], transmission system operators (TSOs) in maintaining the system in balance [15], balance responsible parties (BRPs, i.e., market participants commercially responsible to the TSO

* Corresponding author.
E-mail address: salla.annala@lut.fi (S. Annala).

[1] Less formal definitions had been introduced earlier, e.g., in reports by the European Commission [74] and the U.S. Department of Energy [75].

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for the imbalances they cause in the electricity market) and retailers in portfolio optimization [16] and imbalance management, and energy end-users to minimize their costs by responding to time variable prices (implicit DR) or to gain revenue from selling their flexibility to other actors directly or through an aggregator (explicit DR) [17,18]. Most DR research has focused on electric loads although DR could provide benefits also for the district heating (DH) sector. For example [19], showed how smoothing the variations in system heat demand would reduce the costs of heat generation by decreasing the need to start peaking units (for a recent review on the use of DR in DH networks, see Ref. [20]).

From an energy end-user's viewpoint, DR barriers include market rules preventing participation of (aggregated) loads in balancing and capacity markets [21,22], difficulties in changing consumption patterns [23], the lack of shiftable loads [24], privacy concerns, and uncertain benefits [25]. In some countries, electricity supply and network tariffs are regulated, limiting retailers' and DSOs' opportunities to provide their customers with DR incentives [26]. Furthermore, the monopoly regulation of DSOs and TSOs may favor infrastructure investments over the use of services such as DR [27].[2] While DR barriers have been widely discussed in previous literature, studies have focused, for instance, on the initial stages of the development of the DR sector (e.g. Ref. [28]) or on barriers in national markets (e.g. Refs. [25,29,30]), less attention has been devoted to the factors that hinder market upscaling and opportunities for internationalization, which we understand as the process leading firms to increase their footprint or market share outside the country of domicile. Furthermore, a recent review [31] concluded that most aggregators have, until now, focused on large energy users. Thus, analyses of real-life experiences from DR services to small end-users are sparse.

We address this gap by offering insights from companies that are actively developing and operating DR services for various types of customers including households. We consider services that help energy end-users sell their DR capability (e.g., aggregation) and control their loads based on accepted bids, and services that help end-users automate their loads based on DR incentives in energy tariffs. We refer to these services as automated DR to distinguish them from DR programs relying on behavioral change. In addition to electricity DR, we also consider companies focusing on DH DR. The empirical material used in this study consists of semi-structured interviews with 22 companies active in the Finnish DR sector. The interviewees include both employees of Finnish companies and foreign companies operating in Finland.

We focus on Finland as it has been listed among the six European countries with the most conducive framework for DR development [17], and because it hosts one of the most active markets for DR in Europe [32]. This allows us to gather insights into the role of the home market in the business development and internationalization of demand response firms. While the Finnish market cannot be considered mature yet, Finland stands out in the breadth of end-user segments engaged in DR as it is one of the few countries in Europe where even aggregated residential loads are used as DR resources [33,34] and dynamic electricity price contracts are available for consumers [18,35]. Several factors support DR development in Finland. Firstly, Finland was among the first countries in Europe to complete a large-scale smart meter rollout for electricity users [18]. Secondly, electricity retail tariffs are not regulated, nor is the structure of distribution tariffs (both retailers and DSOs are able to include DR incentives in their tariffs). Thirdly, DR resources are eligible in all the markets operated by the TSO Fingrid [36]. Furthermore, smart energy solutions are considered to hold a large potential in terms of export activities. For instance, in a Delphi survey conducted in 2016 to gather expert opinions on the potential of new energy technologies and their impact on the Finnish energy system, out of 14 energy technologies in the survey, the export potential of automated DR systems was considered the highest [37].

In summary, this paper studies how the relatively advanced regulatory and market framework and the early smart meter rollout affect the DR product and service development and the internationalization of companies active in Finland. The research questions we address are formulated as follows:

- Which home market characteristics have promoted or hindered the business development of automated DR?
- What role has the advanced home market had in the internationalization of DR companies?

To conduct our analysis, we choose as a theoretical lens the Technological Innovation System (TIS) framework as it helps us in gathering insights into the conditions leading to market formation and the related firm internationalization opportunities [38]. We present our theoretical framework in section 2. Section 3 describes the research data and methods. The results of the study are presented and discussed in section 4. Section 5 concludes the paper.

2. Technological Innovation Systems and internationalization

The Technological Innovation System framework has been widely used to study the transition toward clean technologies [39–41] and, more in general, the factors hindering the development and implementation of new technologies [42]. Although the framework is typically applied to manufactured products, a recent paper [43] proposed that it is “generic enough to be useful in analyzing any sociotechnical innovation phenomena” and demonstrated its usefulness in analyzing software-based technologies. The TIS framework captures structural components of the innovation system (actors, networks, institutions) and processes important for well-performing innovation systems, labeled as functions [44,45] (Table 1). Analysis of the functions helps identify weaknesses that should be addressed by actors interested in improving the functioning of an innovation system [46]. In addition, the analysis of these functions helps us in understanding how a well-defined home market may help firms access international markets.

While a large number of studies deploying the TIS framework apply the set of functions based on the seminal works of Hekkert et al. [44] and Bergek et al. [45] (Table 1), some researchers have applied a more condensed list. For example [47], combines *knowledge development*, *knowledge diffusion*, and *entrepreneurial experimentation* into the function of *knowledge development* and considers that the function *legitimation* includes also *the guidance of search*.

Although TIS is generally considered a global system [45], several studies (e.g. Refs. [40,41]) have applied the TIS framework to study the development and diffusion of technologies within specific countries.[3] While the national focus has been criticized, it may be justified by the national character of many institutions and national governments' interest in accelerating specific technological trajectories [46]. Furthermore, actors' access to resources at different geographical levels may differ substantially [49].

[2] Some barriers are likely alleviated in Europe once the Recast Electricity Directive 2019/944 has been transposed to national legislation. The Directive requires that Member States allow DR aggregators to participate in all electricity markets, and allow and provide incentives to DSOs to procure flexibility services.

[3] Applying a wider geographical boundary, a recent paper [55] used the TIS framework to analyze decarbonization options in the EU steel industry.

Table 1
TIS functions [44,45].

TIS functions	Description
Entrepreneurial activities/experimentation	Reducing uncertainty related to a (evolving) TIS through experimentation, probing into new technologies and applications.
Knowledge development and diffusion	Breadth and depth of the current knowledge base of the TIS, its evolution, and how knowledge is diffused and combined in the system.
Influence on the direction of search/ Guidance of search	Incentives or pressures for organizations to enter the TIS and the strength of such factors. Mechanisms having an influence on the direction of search within the TIS.
Market formation	For an emerging TIS, marketplaces may not exist, potential customers may not have articulated their demand, and price/ performance of the new technology may be poor. First, the market needs to evolve and then grow, potentially toward a mass market.
Resource mobilization	Ability to mobilize human and capital resources.
Legitimation	Gaining social acceptance and compliance with relevant institutions.

Actors, networks, and institutions located or primarily active within a country belong to a national subsystem of the TIS (national TIS), while all other actors, networks, and institutions identified in the technological field are attributed to the international TIS [50]. Couplings between the national and international TIS may compensate deficits of the national TIS [50].

Research has found the home market or a well-functioning national TIS to be especially relevant for young and small firms, and for complex technologies [38,51,52]. However, the presence of firms and markets in related industries may counterbalance the weaknesses of the home market [51]. Young companies may access international markets by partnering with local established firms or by securing their first contract with them and thus proving their technologies [38].

Recent research on the transnational aspects of TIS has mainly focused on how the countries with a weak or small home market can access international markets [38,39,51]. Apart from the notion that early mover advantages are not necessarily sustained [53], the position and potential problems faced by the firms from early mover countries have received less attention. We address this gap by analyzing the DR TIS in Finland and its interaction with the international DR TIS.

3. Data and methods

Previous TIS studies have used various types of research methods including comparative and historical case studies, systematic literature reviews [54,55], interviews, and patent analysis [56]. Our data are based on semi-structured qualitative interviews (conducted during autumn 2018) with companies active in the Finnish DR sector. Potential interviewees were identified by performing an internet search with the search words 'kysyntäjousto' (demand response), 'jousto' (flexibility), and 'energianhallinta' (energy management). The resulting list of companies was further analyzed based on the information on their websites and by telephone calls to the companies. In total, 32 companies active in the Finnish DR sector were identified. Some believed their DR development was in too early a phase to be discussed or could not allocate time for the interview. The final dataset thus consists of interviews with 22 companies, of which 18 are Finnish and four are foreign companies with activities in Finland.

The interviews were structured around the following topics: a) company information; b) demand for DR services; c) energy market environment; d) sociotechnical systems (e.g., questions related to policies, infrastructure, and collaboration); and e) conflicts and barriers related to DR. A detailed interview guide can be found in the appendix. The interview guide was designed by the authors after a literature review on the drivers and barriers to DR and preliminary interviews with two expert organizations: the Finnish TSO Fingrid and an energy sector branch organization Finnish Energy association.

All the interviews were recorded and transcribed verbatim. The transcripts were coded using a two-phase coding scheme. First, we identified 1) information about the company's DR services and their history; 2) characteristics of the company's business model (including, e.g., value proposition, key resources, and networks); 3) critical factors for the DR business (barriers, drivers, competition, and cooperation); 4) views on policies, legislation, regulation, market rules, and public funding; 5) expectations and attitudes related to DR; 6) opportunities for exports and activities in foreign markets; 7) company strategy; 8) conflicts; 9) market formation; and 10) DR infrastructure. Based on the initial coding, we noticed that many codes were related to the characteristics of the market environment in Finland and in foreign countries. Therefore, in the second phase, we categorized our codes based on the TIS framework to understand the impact of home market on DR business development and internationalization opportunities.

Because we identified overlaps in TIS functions in the previous literature [42,54–60], we applied a condensed function list. In this shorter list of TIS functions, knowledge development also covers knowledge diffusion and entrepreneurial experimentation, and legitimation includes guidance of search. The indicators of these condensed functions that we looked at throughout our data are listed in Table 2.

4. Results

This section discusses first the structure of the Finnish DR TIS (utilizing both the interview data and additional references related to legislation, market rules, and the role of DR) and then analyzes its functioning including linkages to the international DR markets based on interview data. Sections 4.2–4.5 present the key issues raised in the interviews, whereas section 4.6 provides a summary also including some smaller details raised by individual interviewees.

4.1. Structure of the Finnish DR TIS

As illustrated in another article by the present authors relying on the same dataset we use in this paper [28], the companies developing and operating DR services in Finland can be categorized as technology start-ups, companies from adjacent industries, and incumbent energy companies. Table 3 summarizes the DR activities of the interviewed companies (for more detailed information, see Ref. [28]).

In the (translated) quotes from the interviewees, we distinguish between technology/software companies (TSC, start-ups, and companies from adjacent industries) and energy companies (EC). Only a small subset of energy companies is actively involved in DR. Most typically, these are retail arms of energy companies. While there are about 70 electricity retailers in Finland [64], there are only six energy companies in our study.

Table 2
Functions analyzed in this paper and their indicators (indicators summarized from Refs. [46,57–63]).

Functions	Indicators
Knowledge development	R&D projects and funding, laboratory trials, feasibility studies, pilots, projects with a commercial aim, knowledge exchange, research networks, conferences, workshops, collaboration, organizations or companies entering/leaving the market, portfolio expansions, creation of start-ups
Market formation	Policies that stimulate market formation and expansion, market regulations, financial market incentives, favorable tax regimes and environmental standards (or lack of them), mandatory targets, niche markets, market size and potential, doubts and uncertainties
Resource mobilization	Subsidies, public funding, investments, human resources, physical resources, availability of complementary assets
Legitimation	Expectations, opinions, promises, policy or industrial targets, support (or lack of it) by government or industry or organizations, standards, explicit regulations or expressed deficit of regulations, lobbying, public debates, depiction in media, arguments against or for, recognition of societal benefits, articulation of demand by customers and users, positive or negative research outcomes, awards

Table 3
DR activities of the interviewed companies [28].

	DR activities, number of companies		
	Electricity	DH	Both
Technology start-ups	4	1	1
Companies from adjacent industries	7	3	0
Incumbent energy companies	3	2	1

The technology start-ups include companies founded after 2010 that have focused on DR services from the very early phase of their business development. Many of them are small (less than five employees). The companies from adjacent industries include ICT, building automation, and electronics companies who have added DR to their service portfolio. These include both SMEs and large internationally active companies. Some of them have a long history of cooperation with energy companies in activities not related to DR. Both start-ups and companies from adjacent industries cooperate with energy companies in DR service provision [65].

DR services targeted directly to residential end-users focus mainly on controlling electric heating in detached houses. Electricity DR services for commercial and industrial customers cover a broader array of loads. District heating DR services aim to decrease DH demand peaks. Services related to implicit electricity DR are possible because Finnish retail tariffs have not been regulated since the electricity market opened in 1995–1998 [66], over 99% of the electricity users are equipped with smart meters [64] as the Decree of the Council of State 66/2009 required DSOs to equip end-users with smart meters by the end of 2013. Smart meter data are used in the balance settlement, and retailers offer electricity tariffs based on hourly prices in the power exchange Nord Pool Spot even to residential customers [64].

In the case of explicit electricity DR, the Finnish TSO Fingrid is the main buyer of flexibility. DR resources are allowed to compete alongside flexible generation in all markets operated by Fingrid, see Table 4.

Independent aggregators (i.e., operators that are not electricity suppliers or BRPs for the end-users whose flexibility they offer) may provide frequency-controlled reserves (FFR, FCR-D, FCR-N), and arrangements related to their participation in balancing energy markets (mFRR) have been piloted. DR has gained a significant position especially in the FCR-D market. In 2017 – the first year when independent aggregators were eligible – loads accounted for 50% of the FCR-D capacity contracted from the annual market, doubling their proportion from 2016 [70,71]. In 2018, the proportion was even higher, at 70% [72].

In the DH DR, the situation differs largely from the electricity sector. In Finland, DH network and generation plants connected to it are usually owned by the same stakeholder, and the DH market has not been opened to competition.

4.2. Knowledge development

Development of DR services in Finland began in earnest in the 2010s when 15 of the interviewed 18 Finnish companies started development and piloting of DR services. In some cases, this was due to portfolio expansions, but many of the companies were founded only in this decade. Some of the companies were mapping the foreign markets from a very early phase and had considered the international scalability of their services from the very beginning, whereas others preferred to develop and test their services and business models first in Finland.

Nevertheless, the well-functioning home market was seen as an asset for firms aiming to access foreign markets.

> *"If you think this from the export potential point of view, Finland has a developed electricity market, and if we get it to work here, it should be valuable for many companies exportwise."* [TSC1]

Table 4
Reserve markets in Finland.

	Fast frequency reserve, FFR	Frequency containment reserve for disturbances, FCR-D	Frequency containment reserve for normal operation, FCR-N	Automatic frequency restoration reserve, aFRR	Manual frequency restoration reserve, mFRR
Purpose [67]	Handling of low-inertia situations	Containing the frequency between 49.5 and 50.5 Hz during disturbances	Containing the frequency between 49.9 and 50.1 Hz during normal operation	Returning the frequency to its normal range and releasing activated FCR back into use	
Minimum bid size [68]	1 MW	1 MW	0.1 MW	5 MW	10 MW Electrical orders: 5 MW (1 MW when electrical activation is possible)
Bid symmetricity [68]	Only up-regulation	Only up-regulation (down-regulation product will be introduced in 2022)	Symmetrical product	Separate up- and down-regulation bids	
Independent aggregation [69]	Yes	Yes	Yes	No, only BRPs may aggregate (independent aggregation piloted in mFRR in 2020–2021)	

Many viewed Finland as a sort of "laboratory" where they can prove their concept.

> "*We have a clear strategy to test this in Finland as we are here, we know the market and Fingrid has worked progressively and opened these markets. It's easy to spar these things with them.*" [TSC2]

Interestingly, also some of the international firms were developing and testing their services first in Finland, which, according to them, had a more favorable regulatory framework than many other European countries.

Many companies have participated in joint R&D projects involving energy companies, DR hardware and service providers, universities, and other research centers. However, one company mentioned that it has been difficult to engage manufacturers of electrical appliances, such as heat pumps, in DR discussions.

There has been some cooperation between energy incumbents and other DR companies but not so much between the newcomers apart from informal discussions and people participating in the same events. Better access to results of DR research also for industrial stakeholders was hoped for.

4.3. Resource mobilization

The interviewees did not identify any major barriers related to the Finnish infrastructure, and the high level of digitalization was considered a key enabler of DR development. However, automated DR services depend on reliable internet connections. According to one interviewee, the amount of internet outages especially in holiday homes had surprised them. Therefore, aggregators need to secure backup capacity to make sure that they can provide the flexibility they sell to Fingrid. This is problematic especially for the newcomer firms only building their portfolio. Furthermore, related to DH DR, heating systems in old buildings do not necessarily have any remote connections, which makes initial investments high. In addition, there are no support mechanisms for end-users investing in DR-enabling technologies.

The historically strong Finnish ICT sector[4] has been an important source of human resources for the Finnish DR companies. Four of the interviewed companies were actually founded by former employees of the Finnish telecommunications and ICT company Nokia, which was in the 2000s best known for mobile phones but was also actively developing building automation services before forgoing both specializations.[5]

> *"Nokia has been a strong actor here and although its significance has decreased, the know-how has remained in this area and new companies have emerged in the IoT and digitalization fields, and that has brought new offerings to the energy sector."* [EC1]

Over half of the interviewed companies had received public support. Most of it came from national funding agencies, but some had received also EU funding. In addition, some companies had been partly bought by larger companies providing new resources for business development and internationalization. One interviewee mentioned that successful projects have facilitated access to venture capital.

Many of the companies are small, and while they had managed to operate in Finland (e.g. by partnering between energy companies and technology/software companies, the former benefiting from solutions developed by the latter, and the latter benefiting from the ready customer channels of the former), many considered their resources too small for foreign markets.

> "*You need to have quite a lot of capital, you need to accept that a few hundred thousands or even a million will be gone before anything starts to happen. … There is so much market and so much to do here that perhaps going abroad is not the first thing to do.*" [TSC3]

Furthermore, no evidence of cooperation between Finnish companies aiming at foreign markets was found.

4.4. Market formation

The interviewees referred to two main factors that have enabled electricity DR service development in Finland: 1) eligibility of DR and aggregators in ancillary service markets and 2) the completed smart meter rollout enabling time variable electricity pricing and thus products and services that facilitate scheduling of consumption based on them. This was also shown by the service offerings: 15 of the 16 companies active in the electricity DR were offering or developing services related to aggregation and 13 related to spot price optimization.

4.4.1. Ancillary service market

Independent aggregation was considered straightforward especially in the FCR market. Furthermore, for some reserve products, the minimum bid sizes were lower than in some European markets. Fingrid's automated trading interface had also paved the way for participation of smaller players.

However, while many praised the progressiveness of Fingrid, some considered its market rules stiff (e.g., minimum bid sizes too high for some products, verification of flexibility too burdensome, required activation duration too long for DR). In addition, Fingrid's dual role as the main customer and the market rule maker was criticized by both energy and technology/software companies:

> *"To be mean it's not a market … the buyer maintains the marketplace and determines rules and conditions for buying. It doesn't sound like a functioning market when there's just one buyer."* [EC2]

> "*The challenge in the Fingrid market is that they have the monopoly and also the right to change the market rules every year. The most difficult thing for energy companies and also for us is how you can make multiyear investments when you don't know what the market will be like the next year.*" [TSC4]

As a result of rule changes and recent access of new players to the market, there was a lot of uncertainty related to the price level, which makes estimations of the business case difficult.

Most interviewees saw Europe as their primary target market, although some had activities on several continents. The basic principles of the electricity market design have been harmonized, and Europe in general was considered a more favorable environment than other regions of the world (e.g. liberalization and unbundling in the electricity sector). However, also the level of competition e.g., in Central European markets was considered to be higher than in Finland.

Yet, most European TSOs were not considered progressive, and reserve markets were in many cases out of reach of independent aggregators. In other advanced markets, differing market rules and resource requirements were seen as a challenge, and therefore,

[4] For example in 2019, the ICT sector accounted for 37% of the Finnish service exports [76].

[5] For more discussion regarding the role of Nokia in the Finnish DR development, see Ref. [28].

some interviewees mentioned that they had opted for a smaller role in foreign markets. Instead of participating directly in the TSO reserve markets as they did in Finland, they had focused on providing technology and software solutions for other parties active in these markets.

> "*We see Europe and the EU as our home market … but I must say the markets do differ. We have outlined that we will not carry out aggregation business abroad. Instead, we will seek partners who are willing to put our technology into use.*" [TSC5]

4.4.2. Services for electricity users

Service provision directly to end-users in foreign markets was challenged especially by the slower uptake of smart meters and the lack of dynamic contracts, but also by the need to adapt the services developed initially for electric heating loads, which are not common in many countries.

> "*It's going to take a long time before remote metering and spot price electricity contracts are genuinely available in Europe. So the market is not open. We would be ready, though*." [TSC6]

4.4.3. District heating

In Finland, DH companies act as local monopolies, and there is no explicit DH DR market. Thus, DH DR companies' options are to provide a) services that enable the end-users to reduce their heating costs or b) services for the monopolistic DH companies to reduce their own costs. In some foreign markets, DH generation and networks have been unbundled, providing a better starting point for DR service development.

Overall, the market for DH DR was seen to be in a very early phase. Yet, there were both energy companies and other stakeholders developing DH DR services. However, differences in DH pricing structures both between Finnish towns and their monopolistic DH operators and between countries make the development of services difficult.

4.5. Legitimation

4.5.1. Main drivers for DR

The need for DR was expected to grow as a result of the increasing amount of intermittent generation, phaseout of fossil-fuel-based generation, new nuclear power, and digitalization. The policy target (from the Finnish energy and climate strategy published in 2016 [73]) to stop the use of coal in energy generation in Finland by 2030 was expected to drive the need especially for DH DR, as in electricity generation the role of fossil fuels is already smaller. In addition, changes in loads, e.g., the spread of electric vehicles (EVs) and heat pumps, were expected to increase the need for DR.

Opinions of whether the value of DR is understood and acknowledged sufficiently differed; some questioning mainly the understanding and motivation of energy users and others also the lack of vision in the industry and society in general. In addition, some considered that public authorities could take a larger role in promoting DR.

> *"I think that the Government and politicians could take a more active role. I don't know if any subsidies are required, but provision of information and opinion-molding could promote this and speed up things."* [TSC7]

4.5.2. End-user awareness and interest in DR

In general, the awareness of DR and its impacts among energy users was considered low by our interviewees.

> *"The load owners understand nothing about electricity markets. They haven't had to. … So when you go talk to them about demand response, they have never heard of it, they know nothing."* [TSC8]

While DR can provide environmental benefits, they are not well understood and appeal only to a small proportion of end-users. Instead, changes in the structure of energy prices (dynamic tariffs, peak load components) and other monetary benefits were believed to increase the customer demand for DR services. However, some services targeted to residential electricity users would first require choosing a spot-price-based contract, which many consider difficult to understand and risky according to our interviewees.

In addition, DR companies apply different revenue-sharing arrangements with especially the larger end-users taking part in explicit DR. While DR was thought to provide considerable benefits to large end-users, some found the monetary benefits for small individual users, such as households, unclear and too small. On the other hand, interviewees mentioned that large industrial users are active in DR on their own without the need for service providers as intermediaries.

Industrial end-users are concerned about how DR would affect their processes and their main business and have questions related to potential costs and effort related to DR. Furthermore, DR service providers compete for customers' interest and time not only with each other but also with electricity suppliers, energy efficiency service providers, and solar PV providers. Energy end-users are also increasingly concerned about data security issues.

The DR companies not acting as energy suppliers also felt it challenging to gain customers' trust. Several interviewees expected that DR services will not be sold separately but as part of a larger service package, and energy companies believed that they had better capabilities in providing such packages.

To tackle the problems related to customer demand, many interviewees welcomed competition.

> *"If we were the only actor, the market wouldn't open. If no one else was doing this, people wouldn't believe how this could work."* [TSC3]

4.5.3. Energy companies as users and developers of DR services

DR can be a tool for energy companies to both reduce their own costs and gain additional revenue from new services. Many of the DR companies not originating from the energy sector offer their DR services to or in cooperation with energy companies. Thus, we found considerable discussion regarding energy companies' attitudes and opinions toward DR. A few large energy companies are actively developing DR, but a majority have been quite passive. Many energy companies are small and do not have resources for other than their core activities. In addition, several interviewees referred to the municipal ownership as a factor reducing energy companies' willingness to take risks or do anything that might impact their profits.

The interviewed energy companies mentioned the need to keep up with the changing environment and the increasing number of actors in the energy value chain. Although DH companies have a local monopoly position, some interviewees considered that they have to develop their services to maintain DH's position as a competitive energy form.

4.5.4. Conflicts and indifferences

Some interviewees were of the opinion that DR incentives in tariffs and control based on them do not lead to optimum results from the energy system's viewpoint and are unfeasible when the amount of intermittent generation increases. On the other hand, companies focusing on spot-price-based consumption optimization were not content with the recent proposals to include peak demand-based components in electricity distribution tariffs.

Some companies stated that involving small customers is too expensive and wished for standardized appliance interfaces or that the next generation of smart meters would have control capabilities to remove the need for individual installations on the customer premises. The ones focusing on control services for small end-users argued that smart meters do not provide enough information about the conditions and temperature in the apartment and are thus not suitable for DR.

Some of the non-energy company interviewees criticized the lobbying power of energy incumbents when it comes to the balance responsibility and independent aggregation. One interviewee mentioned that if some compensations need to be paid to retailers whose customers' DR is activated, it will make DR unprofitable. With regard to this issue, energy companies' opinions differed from the others although also they acted as independent aggregators in markets for frequency-controlled reserves. While the energy sector companies have joint lobbying activities, the other DR companies are not organized. Their DR vision does not match that of the energy companies, but there is no shared vision between the newcomers either.

4.5.5. Regulatory framework and standards

Apart from questions related to independent aggregation (and some detailed reserve market rules), interviewees were quite content with the Finnish regulatory framework. One interviewee considered that too detailed legislation and regulation would kill innovation and competition, while another said additional support would distort the market. Interviewees wished for more coordination between national TSOs to harmonize market rules in Europe. However, if ancillary service rules were to be harmonized, one interviewee expected that Finland's (or even Nordic countries') lobbying power would probably not be strong enough to make the Nordic market rules a European standard.

While different market arrangements and regulatory frameworks were believed to be the main barriers, a lack of technical standards was noted even within Finland and Europe. The situation may be even more difficult if considering, e.g., Asian or American markets where different standards and information exchange protocols are applied.

4.5.6. DR companies' interest in internationalization

Unlike the technology and software companies, most of whom were interested in internationalization, many energy companies considered DR mainly an addition to their current energy service portfolio. Thus, if they were not active in foreign energy markets with conventional energy services, they expressed no interest in foreign DR markets. For some firms it was not yet a timely issue, as their business model was still in a development phase. Another group of interviewees, instead, mentioned that export opportunities had guided the development of services from the beginning, and led to focusing on electricity DR instead of DH, which is not used in all countries. Some saw a significant business potential also in foreign DH DR markets, and one of them mentioned that it had considered the scalability of its service already in the development phase. Furthermore, according to another interviewee, some foreign DH markets may be easier than the Finnish market as generation and network operation have already been separated. Related to electricity DR, the market opportunities were considered to be greater in international markets because of the faster uptake of renewables and more congested distribution networks.

4.6. Summary

In Table 5, we present a summary of the findings according to the functions of the Finnish DR TIS (FI) and international aspects (INT).

5. Conclusions

This paper studied how the advanced regulatory and market framework and technology rollout in Finland have affected the DR service development and internationalization of Finnish DR companies. The analysis was based on the TIS framework. Based on our results, the electricity DR market formation in Finland has largely relied on the Finnish TSO's early decision to allow independent aggregation and the early large-scale rollout of smart meters and dynamic electricity pricing enabled by them. However, the TSO's dual role as the rule maker and the main buyer of DR has caused uncertainty among DR companies.

The market for DH DR was seen to be in a very early phase. There, the main challenges were related to the monopoly position of DH companies and differences in their pricing structures.

When it comes to the relationship between home market and internationalization of Finnish firms, the study shows a mixed picture. In some cases, it appears that there is a relationship between the two, but in others, it seems that this relationship is less evident or that firms did not even consider the possibility to internationalize in the first place. For example, energy companies not active in foreign energy markets did not express interest in foreign DR markets either. Furthermore, for companies focusing on DH DR, the range of potential export countries is narrower than for those focusing on electricity DR.

Non-energy companies were more focused on foreign markets, but in many cases, their small size and the lack of resources hindered internationalization. However, also the small companies have adopted very different strategies regarding the timing of their international activities. Because of the energy companies' lack of interest in foreign markets and the lack of cooperation between other types of DR companies, we found no evidence of established companies facilitating young/small companies' internationalization. However, the strong ICT sector in Finland has contributed to the emergence of the Finnish DR TIS trough portfolio expansions and by providing capability and expertise.

Our study has shown that products and services developed for an advanced home market do not necessarily lead to benefits in international markets that are not equally advanced. This is especially relevant in highly structured markets, such as the energy and reserve markets, where market rules may hamper the participation of certain resources or players even if that was not necessarily their primary intention. In addition, as the detailed market rules in this sector vary between countries, access also to other advanced markets can be challenging or require changes or adaptation of products and services.

Nevertheless, both Finnish and foreign companies have used the advanced Finnish DR market as a test bed and a proof of concept for their technologies and services. Some have, however, decided to limit their role in the foreign markets as software/technology providers instead of the wider role, for example as market aggregators, that they have played in Finland.

At the policy level, the importance of DR has been acknowledged and projects have received public funding. However, no detailed DR goals have been set, and it is unclear whether the sole

Table 5
Summary of the results ('+' = positive indicators, '-' = negative indicators, FI = Finnish aspect, INT = International aspects).

	Knowledge development	Market formation	Resource mobilization	Legitimation
FI	+ Analyses of potential benefits + Development of DR solutions (mostly after 2010) + Pilots + Public funding for R&D + Cooperation + Start-ups + Knowledge exchange in events - Unclear roles of players, earning logic, benefit-sharing models, and future marketplaces - Missing engagement of appliance manufacturers - No access to results of previous projects	+ Smart electricity meters and spot price contracts + TSO open to innovations + Balance responsibility handled well for frequency-controlled reserves + Independent aggregation easy in FCR market + Low minimum bid size requirements for some reserve products + Automated trading interface - Big clients manage without help - No critical mass (DH) outside cities - DH monopoly - Differences in DH pricing structures - No incentives in current electricity tax - Disagreement over smart meters' role - Buyer maintains market-place/ defines rules, unpredictability of rules - Volatile market prices - Only BRPs can aggregate in some markets - Minimum bid sizes too high for some reserve products - Activation times too long - Verification of activated DR burdensome	+ High level of digitalization + Skilled (IoT, digitalization) labor + Use of partners (e.g., product sales, installations) + Public funding and loans for development + Funding from new owners + Private venture capital after successful projects - Small energy companies - Finding controllable loads burdensome - Unreliable internet connections - Balance between data security/ costs - Lack of remote connection in old buildings - No support mechanism for end-users	+ Changes in generation and demand + Cleaner, cheaper, and faster than generation + Increased self-sufficiency + Competition increases awareness + Lobbying + Savings through tariff-based optimization + Better use of own generation + Increased reliability + Increasing electricity price volatility + Reduction of dependence on energy companies + Willingness to adopt technologies + Interest expressed by B2B customers + Shorter imbalance settlement periods + Reduction of energy company's costs + Maintaining DH prices at a competitive level + Keeping up with new types of service providers - Stable system, small need - Value not understood in the society - Insufficient promotion by authorities/legislator - Conflicting needs and incentives - Suboptimization - Dissent over independent aggregation - Lack of interface standards - Community aspects in DH DR - Lack of awareness and interest in DR - Lack of interest in sustainability aspects - Benefits to individual end-users unclear - DR incentives difficult to understand, risky - Low variation in hourly spot prices - Low electricity prices - Unfeasibility of dynamic pricing - DR alone expensive, uninteresting - Lack of trust in artificial intelligence - Impact on industrial processes, extra work, data security - Established customer relationships - Public actors prefer larger companies - Improved forecasts decrease BRPs' interest - Difficult to estimate benefits - Energy companies conservative, risk averse - Robust distribution networks
INT	+ Mapping of foreign markets + Scalability for other countries + Finnish pilots attracting international interest + International pilots and projects - Unfinished business model, no foreign activities	+ Europe the main target area + EU electricity market harmonization + EU decision to ban TSOs from building backup power + Unbundling of the DH sector - Varying market rules - More competition - Varying flexible resources - Price of products too high - Lack of smart meters - Varying energy pricing methods - Most projects unprofitable - Foreign TSOs not as progressive - Minimum bid sizes too high - Aggregation not possible - Tight balance responsibility - Smaller role in foreign markets	+ EU funding (e.g. Horizon 2020 projects) + Internationalization in cooperation with a new partial owner - Lack of resources - Mostly no funding for internationalization - No cooperation between Finnish companies	+ Larger needs (faster uptake of renewables, more congested networks) + Large global potential in electricity DR - Different information exchange protocols - No unbundling, less potential customers - DR a complement to energy sales - Service concept should be ready first

goal of the Finnish DR policy is to achieve low-cost DR capacity or also to create an environment that enables the development of exportable products and services. If the former is the main goal, more public efforts should be directed toward increasing awareness of DR. To reach the latter goal, more support could be targeted toward export and internationalization activities of firms.

While previous research has used the TIS framework mostly for manufactured products, this paper has demonstrated its usefulness in studying complex technology and service combinations. Furthermore, it has shown problems that firms from early mover countries may face when exporting complex technologies and services to foreign markets.

A limitation of this paper is that we had no data on the export volumes of the interviewed companies or of the DR sector in general. Furthermore, we interviewed only companies operating in Finland. Thus, further research with quantitative data and comparisons between companies emerging from different countries would strengthen our conclusions. In addition, energy end-users' viewpoints were not directly analyzed in this study as we relied on firms' characterizations of energy end-users.

Credit author statement

Salla Annala: Conceptualization, Formal analysis, Writing – original draft. Salvatore Ruggiero: Conceptualization, Writing – review & editing. Hanna-Liisa Kangas: Conceptualization, Formal analysis. Samuli Honkapuro: Writing – review & editing. Tiina Ohrling: Investigation

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix. Interview guide

Company

1. What is your role in the company?
2. Explain in brief the company's development over time, and how your company got interested in DR. Is there a separate DR unit in your company?
3. Personnel
   a. How much personnel does your company have working for DR?
   b. What is the typical education/background of your DR employees?
4. DR company type
   a. Energy service entity (including DR)
   b. Independent aggregators (only DR)
   c. Other
5. How do you plan to receive revenue from DR?
6. Why do you operate in Finland? Do you operate in other countries?
7. Technology and business model
   a. What technology and/or service do you deliver to your customers (e.g. monitoring technology, digital platforms, customer service)?
   b. Does your company provide the technology and platforms?
   c. Do you think your main innovation is in the DR technology or in your business model, or both?
   d. Is your DR solution easy to scale up (e.g. new areas, markets, customer segments, sectors)?
   e. Are you thinking about developing new DR technologies or services?

Demand

1. What customer segments do you serve (energy producers, distributers; end-users of energy: what sector)?
2. Are consumers aware of and interested in DR?
3. Are consumers suspicious? Are there trust issues with customers?
4. How does your customer benefit from DR?

Energy market environment

1. Which market type do you serve:
   a. Electricity market (Nordpool (Elspot and/or Elbas), Reserve and balancing markets, Peak load power)
2. Collaboration, competition
   a. Who are you main competitors in the DR business?
   b. Do you collaborate with other DR-providing companies; if yes, how?
3. Changing market environment:
   a. How does your DR service change the energy system?
   b. Do other actors have to adapt their business to comply with your DR service?
4. Interaction with incumbents
   a. Do you cooperate with energy companies? Why and how early on?
   b. How do the traditional energy market actors feel about DR, and are they similar to each other in their views? How do they adapt to your BM? If not, why?
   c. How has your company taken the energy companies into consideration when planning and developing your DR business model? Did this force your company to make compromises?
   d. Are you collaborating with the energy producers/distributers? If yes, how?
   e. What do you think about other DR companies' cooperation with the energy companies?

Socio-technical system

1. Readiness for DR in Finland:
   a. Is it possible to have profitable DR business in Finland currently?
   b. Does the Finnish society value DR?
   c. Is the infrastructure in Finland ready for DR?
   d. What do you think about the future of DR services in Finland?
2. Policy:
   a. Is there any financial or other support provided by the government that supports your DR activities?
   b. What kind of policy changes, if any, would you find useful for your company?
   c. How do you try to influence future policies; do you collaborate with other DR providers or other actors?
   d. Why is DR not more widely in use in Finland?
3. What are your most important collaborators/networks we have not discusses yet?

4. Which societal changes are driving your DR business forward most strongly?
5. Which societal changes pose challenges for your business model?

Conflicts, barriers

1. What are the difficulties in starting the DR business?
2. Have there been DR conflicts between the actors, and how have you adopted your BM in response to them, e.g.:
   a. Different actors have conflicting needs for DR
   b. No clear rules and responsibilities
   c. Financial losses for incumbent actors
3. If other DR companies are successful, does it enhance or harm your business?
4. Do your views on the future of DR align or conflict with other DR providers and other actors?

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