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Transition towards a Decentralised Energy System: Analysing Prospects for Innovation Facilitation and Regime Destabilisation in Finland

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Abstract

The Finnish energy system is rather centralized and its governing regime is characterised as exclusive. Recently, pressure to move towards decentralised, small-scale energy production has increased. This article utilises a combination of ideas from technological innovation systems and regime destabilisation and analyses the prospects for the transition towards a decentralised energy system in Finland's socio-economic context. We argue that the transition towards a decentralised energy system requires both innovation facilitation and proactive destabilisation of the existing regime, and therefore these issues must also be included in energy transition analyses.

Keywords: technological innovation systems; decentralisation; energy regime; energy transitions

1. Introduction

In 2014, a group of professors published a pamphlet on Finnish energy policy (Halme et al. 2014). They declared that Finland should start emulating Germany's Energiewende – Germany's transition towards decentralised and small-scale renewable energy production. As opposed to centralised energy production, renewable decentralised energy (ReDE) is produced in proximity to end users, typically utilising local resources, which improves energy supply security. With renewable resources, ReDE also reduces CO_2 emissions. (Motiva 2010) Halme et al. (2014) have argued that an energy transition in Finland would also result in innovation, economic growth, and new jobs.

Energy transition means long-term change in an energy system, which is the technological system used for energy generation at the country level. Energy systems are governed by an energy regime consisting of actors and institutions, that define how energy is produced and delivered. Energy regimes differ from country to country in their openness to diverse forms of energy generation. Regimes in countries, like Germany and Denmark, that are considered leaders in ReDE deployment, have been more inclusive of new actors and novel energy production methods.

At the same time, the development of the Finnish energy system has remained rather centralised. For example, while there are a large number of actors in the electricity generation sector, the three largest companies hold about 50% of the total installed capacity (Energy Authority 2018). In general, the role of renewables is significant and approximately 35% of the total energy consumption in Finland is based on renewables. The industry, as the largest energy user (OSF 2016), is covering its heat requirements with wood fuels and most of the electricity generated domestically is based on renewables, followed by nuclear (45% and 34% in 2015, respectively) (OSF 2015).

Although Finland's current energy regime is highly exclusive (Ruostetsaari 2010b), there is indication that a transition towards an energy system based on ReDE has begun. However, leading countries in ReDE began similar processes in the 1970s or earlier, and thus, Finland has lagged behind. This provides an interesting opportunity to study how a transition begins to unfold in a centralised energy system which is supported by an exclusive regime. Our analysis is guided by the following research question: what kinds of activities are needed in the transition towards an energy system based on ReDE in Finland? In order to explore the potential for this transition, we also ask: what are the current strengths and weaknesses of ReDE innovations in the Finnish energy system? In terms of technological applications, our scope is rather broad. We have included heat pumps, bio, wind, solar and hydro in our ReDE technologies. However, our interest is in the positioning of ReDE innovations in relation to the existing energy regime, not in the detailed positioning of individual ReDE technologies.

We build our analysis by utilising the analytical framework proposed by Kivimaa and Kern (2016), which combines ideas from technological innovation systems (TIS) and regime destabilisation. TIS focuses on the structure and functional performance of innovation facilitation within a particular socio-economic environment, while the destabilisation perspective emphasises actions that diminish support for the existing regime.

In the following section, we introduce our analytical framework and data. In section 3, we describe the current position of ReDE in Finland and introduce our findings concerning innovation facilitation and regime destabilisation. In section 4, we assess how functional patterns of ReDE in Finland differ from countries that are considered ReDE forerunners. Finally, we present concluding remarks.

2. Material and Methods

2.1. Analytical framework

We aim to understand the dynamics between changes in the Finnish energy system and the regime governing it. Energy regimes form technological trajectories, and the innovations generated within regimes are incremental developments of existing technologies. Radical innovations will not materialise in an energy system if they are not aligned with the values and worldviews of the regime actors (Kemp, Rip, and Schot 2001). TIS can be used as an analytical framework to conceptualise the obstacles and drivers of energy innovation. In this article, we utilise the TIS framework to examine prospects for innovation facilitation as part of energy transition. We use the term ReDE innovation system to describe the combination of technologies under observation (see section 2.2) and the institutions, actors and actor networks embedded in it.

Policy is in a central position for accelerating system changes when path dependencies block novel innovations (Bergek et al. 2008). However, because regime actors can mobilise more resources than novel actors, they have more power to influence policy in their favour (Avelino and Rotmans 2009). Therefore, energy systems with strong regimes tend to be characterised by path dependency and institutional inertia (Unruh 2000). When the same actors remain in the regime for long periods of time, the regime can be considered exclusive (Scott 1991).

Finland is an example of an exclusive regime (Ruostetsaari 2010b) and therefore, it is important to include destabilisation functions (Kivimaa and Kern 2016) into our analysis. Destabilisation describes the weakening of the regime and the removal of obstacles for ReDE innovation. Together with traditional TIS functions they analyse both innovation facilitation and regime destabilisation aspects. The following section introduces these functions.

2.1.1. TIS functions

TIS functions operate in the interplay between actors and institutions (van Alphen et al. 2009). Bergek et al. (2008) and Hekkert et al. (2007) identified six key functions of TIS: knowledge development and diffusion, entrepreneurial activity, market formation, resource mobilisation, guidance of search and creation of legitimacy. Table 1 summarises these functions and their indicators, which have been modified to fit the context of this study.

Table 1. TIS functions, indicators (adapted from Bergek et al. 2008; Hekkert et al. 2007) and data sources.

TIS Function	**Indicators**	**Data sources**
Knowledge development and diffusion	Publications & dedicated journals	Science Direct: www.sciencedirect.com; searched: decentralized energy, distributed energy, wind, solar, hydro, bio, heat pumps, smart grids, energy storage, heat entrepreneurs and Finland (Science Direct 2017)
		Ministry of Employment and the Economy report (TEM) (2014)
		Wind Power Association magazine (2017b)
	R&D Projects & funding schemes	Academy of Finland (AKA) funding database: www.akafi; searched: decentralized energy, distributed energy, smart grid, net metering, energy storage (AKA 2017)
		AKA programme data (AKA 2014)
		Tekes funding database: www.extranet.tekes.fi; searched: decentralized energy, distributed energy, smart grid, net metering, energy storage (Tekes 2017b)
		Tekes programme data (Tekes 2008, 2014, 2017a)

Resource mobilisation	Financial: government support for research, testing and demonstration	International Energy Agency (IEA) Data Services: http://wds.iea.org/WDS/Common/Login/login.aspx; searched: decentralized energy, distributed energy, smart grid, net metering, and energy storage (IEA 2017)
		Tekes funding database (Tekes 2017b)
		Tekes programme data (Tekes 2008, 2014, 2017a)
		AKA funding decisions database (AKA 2017)
		AKA programme data (AKA 2014)
		Work Efficiency Society (TTS) report (2014)
		Finnish Clean Energy Association publication (FCEA) (2017)
		Scientific publications (Vilhola and Heljo 2012; Heiskanen et al. 2017)
	Human: education and expertise	FCEA publication (2016c)
Entrepreneurial activity	New entrants	Publications of ReDE producer associations (Lämpöyrittäjät 2017; SULPU 2017a, 2017b)
	Companies diversifying	Energy company publications (Helen 2016; Oulun Energia 2016)
	Patents	Patent and Registration Offices (PRH) database: https://patent.prh.fi/patinfo/default2.asp?Lng=; searched: decentralized energy, distributed energy, smart grids, energy storage, solar, hydro, heat pumps, heat and electricity grid (PRH 2017)
Market formation	Market size and drivers (installations, plants and entrepreneurs)	FCEA publication (2017)
		Publications of ReDE producer associations (Lämpöyrittäjät, 2017; Small Hydro Association 2017)

		Scientific publication on renewable energy investments in Finland (Heiskanen et al. 2017)
	Regulation and financial support mechanisms	Customs guide (Customs Finland 2015)
		Tax Information table (Tax Authority 2017)
		TEM reports (2013, 2018)
Guidance of search	Expectations/growth potential (goals and framing in strategies)	TEM reports (2014, 2016a)
		Publications of ReDE-related associations (Auvinen 2015; Energy Renovation 2015 (ER2015) 2017a)
Creation of legitimacy	Rise and growth of interest groups	ReDE association publications (FCEA 2016a; ER2015 2017a, 2017b)
		Finnish Heat Pump Association publication (SULPU) (2017a)
		Scientific publication on solar energy in Finland (Haukkala 2015)
		Wind Power Association publication (2017a)
	Alignment with legislation	FCEA publication (2016a)
		Green Cultural Association report (Salo 2015)
	Public procurement	Government Resolution (Finnish Government 2013)
		TEM report (2014)
		Public procurement guideline (Motiva 2017)

2.1.2. Destabilisation functions

Destabilisation functions create avenues for innovation, new ideas and new ways of doing things within the energy system (Kivimaa and Kern 2016). Kivimaa and Kern (2016) identified four destabilisation functions: new control policies, significant changes in the rules of the regime, reducing support for regime technologies and the replacement of key actors. Table 2 summarises these functions and the indicators we have employed in our study.

Table 2. Destabilisation functions, indicators (adapted from Kivimaa and Kern 2016) and data sources.

Destabilisation function	**Indicators**	**Data sources**
Control policies	Restrictive policies (taxes, import restrictions) and regulations (technology ban)	TEM reports (2016a, 2016b)
Significant changes in regime rules	Legal reforms that change the structure of the existing system	TEM reports (2016a, 2016b)
Reduced support for regime technologies	Removal of subsidies and tax deductions	Law on compensation for indirect costs of emissions trading (138/2017) (FINLEX 2017)
		Ministry of Finance report (VM) (2016)
		VATT Institute for Economic Research report (2016)
		EU Commission news (EU Commission 2017)
	Cuts in R&D funding	IEA Data Services (http://wds.iea.org/WDS/Common/Login/login.aspx; searched: nuclear, fossil fuels)
Replacement of key actors	Inclusion of new actors	Scientific publications (Ruostetsaari 2010b; Gronow and Ylä-Anttila 2016)

		FCEA publication (2016b)
		TEM report (2014)
	Formation of new organisations or networks	Publications of ReDE-related associations (FCEA 2016b; ER2015 2017b)
		Scientific publication (Haukkala 2018)

2.2. Data

TIS analysis has been applied to various energy-related innovations, such as CO_2 capture and storage in Norway (Van Alphen et al. 2009), microgeneration in the UK and Germany (Praetorius et al. 2010) and micro-CHP in the UK (Hudson, Winskel, and Allen 2011). These studies analysed the structural elements and evaluating functional performance of a TIS using interviews, either as a main source or to supplement, when academic and industry literature were not sufficient. Functional performance was assessed using indicators. In van Alphen (2009), this was further enhanced by a historical comparison and expert ratings, while Praetorius et al. (2010), compared country-specific results. Hudson, Winskel and Allen (2011) evaluated functional success by making a brief comparison with a country with a greater uptake of the investigated technology (the Netherlands).

As a source of data, we conducted a document analysis of government reports and strategies, commissioned working group or consultant reports, interest group websites, professional journals and scientific literature. Documentary data were combined with statistical data extracted from the databases of the IEA, the Finnish Patent and Registration Office (PRH), ministries, associations and other interest groups as well as research funding agencies (see tables 1 and 2 for more detailed information). We build on earlier studies on the innovation systems of ReDE technologies in Finland. Due to the availability and comprehensiveness of the data, we decided that there was no need for additional sources. We limited our time span to the last 10 years, starting from 2007, which allowed us to capture the slowly unfolding transition and related events. The gathered data were used to provide insights into the performance of the functions as well as the structure of the ReDE innovation system.

For evaluating the success of the functional pattern of a system Bergek et al. (2008) has suggested a comparison with other countries. We performed a brief comparison with two of the countries that Halme et al. (2014) listed as forerunners for renewables and decentralised energy: Germany and Denmark. Because of this comparison, areas for support or other actions could be identified for policy recommendations (Bergek et al. 2008). We focused on the positive developments in these countries, since they are further along in their energy transition. However, it is worth noting that the development in these countries has not been straightforward, nor has it been without problems (see, e.g. Renn and Marshall 2015; Eikeland and Inderberg 2016).

Decentralised energy generally covers electricity and heat as well as fuels, but in this study, we looked at decentralised, renewable technologies; small-scale bio (CHP), wind, solar, hydro and heat pumps for either electricity generation or heating and cooling. We included both off-grid installations and those connected to the grid and limited our observations to units (including CHP) with a maximum capacity of 2 MW, which is the definition of decentralised electricity given in Finnish law for electricity markets (FINLEX 2013). Decentralised heat (other than CHP) is mostly off-grid heat pumps or solar heating units servicing a single building or building complex.

3. Results

3.1. The structure of the Finnish ReDE innovation system

We begin our analysis by exploring the structural characteristics of the Finnish ReDE innovation system, i.e. its institutions, the actors involved and the networks formed by these actors, in relation to the surrounding energy system.

In terms of *institutions*, one of the central goals of Finnish energy policy has been to maintain low electricity prices to ensure the competitiveness of energy-intensive industries (Halme et al. 2014; Ruggiero, Varho, and Rikkonen 2015). This has resulted in formal institutions that facilitate large-scale units and do not sufficiently support ReDE implementation (Ruggiero et al. 2015). The role of ReDE is, and is expected to remain, minor, although it was investigated as an option by a Ministry of Employment and the Economy (TEM) working group (TEM 2014).

The core *actors* in the Finnish energy system (i.e. regime actors) include EU, the national parliament and two of the largest political parties (the Centre Party and the National Coalition), who set objectives and regulation. The most relevant ministries (i.e. TEM, the Ministry of Finance (VM), and the Ministry of the Environment) also belong to this core group. TEM has the overall responsibility for energy policy and most of the background reports, which are used for decision making. It also controls energy research policy and funding. The core group also includes the largest energy operators, Fortum and Pohjolan Voima (PVO), and fuel solutions supplier Neste. The Finnish state is the majority shareholder in Fortum and Neste, while Finnish export industry companies hold the majority of PVO shares. Thus, these companies have close connections to ministries, politicians and industry. Other core actors include the Confederation of Finnish Industries, Finnish Energy Industries (Energiateollisuus) and the Technical Research

Centre Finland (VTT), who is a major supplier of data for ministry reports (Ruostetsaari 2010b).

The most significant actors involved with ReDE include companies that participate in importing, manufacturing, selling, installation and maintenance of technological applications as well as electricity generation and brokering. ReDE producers have formed their own technology-specific support organisations including the Small Hydro Association, the Finnish Heat Pump Association (SULPU) and the associations for heat entrepreneurs (Lämpöyrittäjät) and solar technology (Aurinkoteknillinen yhdistys). Most of these associations are members of the Finnish Clean Energy Association (FCEA), whose aim is to promote efficient and smart renewable energy, particularly small-scale decentralised solutions (FCEA 2016a). R&D funding organisations, such as Tekes and the Academy of Finland (AKA), play an important role in supporting technological development, while ENGOs and members of academia, such as the professor group (Halme et al. 2014), have spoken of the need to increase ReDE in Finland. A citizen's movement called Energy Renovation 2015 (ER2015) was initiated to gather support for the aims listed by the professors and to promote more ambitious targets for renewables in energy policy (ER2015 2017a).

The FCEA can be regarded as a *network*, as it has members from a wide range of actors, including companies, associations, members of academia and ordinary citizens (FCEA 2016d). It is also part of the ER2015 (FCEA 2016b), which is a similar network aimed at advancing renewables. These form the basis of the ReDE network. The relations between the actors in this network are informal; however, the actors are closely connected, since many individuals and organisations are members in other organisations (FCEA 2016d). Although this network has been expanding in recent years, it does not have significant influence on the energy system.

The core actors of the Finnish energy system form a network which has large amounts of resources and is closely linked to the government and the major governing parties. Therefore, it has been able to influence climate policy (Gronow and Ylä-Anttila 2016). The actor network was formed over decades of co-operation between actors and is partly based on personal, unofficial contacts. As a result, some of the discussion and decision-making take place 'behind the scenes', outside actual hearings (Ruostetsaari 2010a). This makes it difficult for other actors to influence policy, and according to Gronow and Ylä-Anttila (2016), it may have led to path dependency. A study by Haukkala (2015) showed that Finnish energy policy is 'set in its ways' and that there is a resistance to change, including the increased use of renewables.

3.2. Functional assessment of innovation facilitation and regime destabilisation in Finland

This section presents our results on the functional performance of the Finnish ReDE innovation system as well as the level of destabilisation activities in the energy system. This will provide information on the strengths and weaknesses of the ReDE innovation system and whether the innovation system has the space to grow and potentially become part of the existing energy system.

3.2.1. TIS function performance

Knowledge development and diffusion describe the current knowledge base and its diffusion in the system (Bergek et al. 2008). Activity surrounding this function has been increasing for Finnish ReDE technologies. The number of organisations promoting renewable technologies and decentralised energy has increased, and many of them publish professional papers, including the Wind Power Association (2017b). There are many different projects aimed at ReDE within various ReDE related programmes. Tekes has funded the Distributed Energy Systems Programme (2003–2007), with 123 projects (Tekes 2008), the Clean SHOK Programme on Smart Grids and Energy Markets (2010–2015) (Tekes 2014) and the Smart Energy Programme (2017–2021) (Tekes 2017a). Furthermore, AKA has been funding the New Energy Programme (2015–2018), which has 29 projects (AKA, 2014). They have also funded individual projects in other programmes (AKA 2017; Tekes 2017b). New research results are being published at an increasing rate for all technologies, and the body of knowledge is growing rapidly (30–50% of relevant articles were published after 2014 [Science Direct 2017]). Knowledge diffusion for ReDE has improved significantly since 2010, and organisations, ministries and companies actively share information (TEM 2014).

Resource mobilisation entails the availability of human and financial resources in the form of investments or government support for research programmes, testing and demonstration (Hekkert et al. 2007). This function appears rather strong, but is driven by households, although public R&D funding and private investments are also increasing. The availability of skilled staff and a lack of training programmes represent constraints, but companies have been training their own staff (FCEA 2016c). Government funding for renewables in Finland has remained static (IEA 2017).The largest R&D funding organisations, Tekes and AKA, have provided approximately €107 million (Tekes 2008, 2014, 2017a) and €9 million (AKA 2014) in funding through targeted programmes. In addition, individual projects or projects within other programmes have received a further €38 million (Tekes 2017b; AKA 2017). The financial downturn has diminished industry investments in ReDE, leaving households the largest private investors (Vihola and Heljo 2012). For example, small-scale heating companies invested €50 million between 2009 and 2013 (TTS 2014), while private citizens spent €350 million in heat pumps in 2016 (FCEA 2017). Popular investments for households have been solar PV and heat pumps, and households made 67% of the investments in solar between 2009 and 2013 (Heiskanen et al. 2017).

Entrepreneurial activity – which is comprised of actions that entrepreneurs take to generate new business opportunities from the new knowledge, networks and markets – is necessary for a well-functioning innovation system (Hekkert et al. 2007). There is increased activity in ReDE by both regime companies and new entrants. Existing companies have entered the market by, for example, establishing solar plants (Helen 2016) or by acting as a broker between small energy producers and consumers (Oulun Energia 2016). The first (bio) heat entrepreneurs began operations in 1992, and by 2013 there were approximately 310 of them (Lämpöyrittäjät 2017). SULPU currently has 151 member companies (SULPU 2017a), and this number is expected to grow rapidly (SULPU 2017b). In addition, a significant share (48%) of patents related to renewables were filed after 2007 (PRH 2017).

Market formation concerns the development of the market for novel technologies. Markets go through three phases, evolving from a nursing market into a bridging market and, finally, a mass market, usually after decades of development (Bergek et al. 2008). Market formation for ReDE in Finland is mainly at the bridging stage, while the market for heat pumps might be in the process of becoming a mass market, as heat pumps are popular for heating and cooling in Finland (FCEA 2017). The markets for small-scale bioenergy plants and PV systems (mostly off-grid) have experienced growth and have future potential (Lämpöyrittäjät 2017, Heiskanen et al. 2017), while the small hydropower market remains small with low growth expectations (Small Hydro Association 2017). Investment support and tax reliefs support market development (TEM 2013; 2018; Tax Authority 2017; Customs Finland 2015).

Guidance of search is the process of selecting between applications or technologies, to determine which ones are distributed through knowledge diffusion (Hekkert et al. 2007). There have been some positive indications following a ministry report estimating ReDE potential (TEM 2014), but the strength of this function remains low. Ministry reports mostly frame ReDE technologies as exportable cleantech products with a marginal domestic role (TEM 2014). While the National Energy and Climate Strategy (TEM 2016a) outlines that ReDE has the potential to reduce energy imports and generate marketable products for export, it also expects domestic electricity production to remain marginal. ReDE actors have criticised the National Energy Strategy regarding its unambitious aims for renewables (over 50% by 2030) and have stated that Finland should aim towards using 100% renewables by 2050 (Auvinen 2015; ER2015 2017a).

Creation of legitimacy means that a new technology or application becomes part of the established system and is in line with its institutions, gaining acceptance from the actors involved (Bergek et al. 2008). ReDE legitimacy is increasing despite its low importance in official strategy documents. More groups dedicated to supporting the energy transition or ReDE have been formed, including the FCEA in 2013 (FCEA 2016a), the ER2015 in 2015 (ER2015 2017a) with its parliamentary section (ER2015 2017b). Older technology-specific organisations have also increased their membership (Wind Power Association 2017a; SULPU 2017a). The government (Finnish Government 2013) has outlined that cleantech solutions should be supported by public procurement. Advice and tools for sustainable procurement have been available for public organisations free of charge since 2008 (Motiva 2017), but more support and consulting services are needed (TEM 2014). In terms of alignment with energy legislation and policy measures, there is still room for improvement, most notably in terms of the installation permit practices, that vary depending on municipality (FCEA 2016a), and exclusion from feed-in tariffs due to minimum size limits (Salo 2015).

3.2.2. Destabilisation activities

Control policies are measures that put pressure on the regime. These can be taxes, import restrictions or restrictive regulations, such as banning the use of certain technologies (Kivimaa and Kern 2016). There are some signs that control policies could be introduced, and the national energy strategy contains a plan to phase out coal by 2030 (TEM 2016a). Nevertheless, the energy strategy incorporates the promotion of peat, and the scenarios expect increase in nuclear until 2030 (TEM 2016b), indicating that control policies targeting these energy sources are unlikely in the near future. The planned changes are not sufficient to be considered *significant changes in regime rules*. These changes would encompass structural reforms in legislation or drastic new laws that change the structure of the existing energy system (Kivimaa and Kern 2016).

Reducing support for regime technologies through cuts in subsidies, R&D funding and the removal of tax subsidies can create an even playing field for new technologies entering the market (Kivimaa and Kern 2016). However, support policies for regime technologies in Finland seem to be increasing, not decreasing. For instance, government R&D funding for regime technologies is increasing (IEA 2017) and a new law to compensate companies for the costs of the EU emissions trading programme has been introduced (FINLEX 2017). The latter has been evaluated to cost €149 million between 2016–2020 (EU Commission 2017). The Finnish state also supports certain energy use options through tax subsidies (e.g. peat) and energy-intensive industries through tax returns (VM 2016). A report by the VATT Institute for Economic Research (VATT 2016) demonstrated that tax reliefs have increased remarkably since 2012 and instead of improving company competitiveness, they are creating market distortions, by removing incentives for energy efficiency and low-carbon technologies and creating a competitive advantage for large companies against small newcomers (VATT 2016).

Replacement of key actors means decreasing the legitimacy of the regime by altering governance organisations or networks, for example, by replacing incumbents in policy configurations or by forming new organisations and networks in working towards changing the system (Kivimaa and Kern 2016). Despite the same actors having remained at the core of Finland's energy system for decades (Ruostetsaari 2010b), there are subtle signals of change. New ReDE-related associations, such as the FCEA, as well as some technology-specific associations have appeared before parliamentary committees and have been invited to give statements for various matters relating to ReDE (FCEA 2016b; TEM 2014). This indicates that they might be gaining influence in the energy system. Nevertheless, while ReDE actors gave statements to the ministry working group on the advancement of small-scale energy production, permanent expert members were incumbents (TEM 2014). In addition, Gronow and Ylä-Anttila (2016) have noted that while ENGOs have political access in Finland, they lack the requisite informal recognition that would enable them to influence policy. This might signify that the influence of their statements could be limited (and serve to legitimise policy outcomes).

Conversely, Haukkala (2018) found the ER2015 significant in briefly uniting both regime members and challengers to work towards a shared goal and the movements parliamentary group has members who are representatives of the parliament and the national government (ER2015 2017b), and have opportunities to influence policymaking from within.

4. Discussion

Based on the analysis, we can say that most of the functions point towards the empowerment of the Finnish ReDE innovation system. Knowledge development and diffusion are strengthening the transition, due to an increase in the number of relevant organisations and the number of projects aimed at ReDE. Resource mobilisation from public funding and private households has been strong, encouraging increased entrepreneurial activity. This has resulted in expanding market development, particularly with heat pumps and solar PV. However, some functions have remained relatively weak, including the creation of legitimacy and guidance of search. Despite the emergence of new support groups and the inclusion of ReDE in the public procurement guidelines, legislation and policy measures do not support legitimacy. In guidance of search ReDE is mostly framed as an exportable cleantech product with a marginal domestic role.

Furthermore, there are no signs of significant changes in regime rules, and support for regime technologies appears to be increasing. In summary, although most of the TIS functions are strengthening, weak destabilisation and lack of legitimacy, as well as low support for guidance of search, do not support the transition towards a ReDE-based energy system.

When we compare Finnish support and destabilisation policies with those in Germany and Denmark, it is easy to point to significant country differences. ReDE is expected to play a significant role in the German energy system (Schmid, Knopf, and Pechan 2016). Although the German energy system has been rather stationary, with a high level of coal, ReDE innovation has been strengthening (Renn and Marshall 2015). One of the key drivers for a ReDE-based energy system in Germany has been the legitimacy provided by government statements and targets, as substantiated by Praetorius et al. (2010) in the case of micro-generation. Central goals include a roadmap to a renewable energy system (Renn and Marshall 2015), which aims to reach 60% renewables by 2050 (Quitzow et al. 2016) and to reduce coal from 80 to 20% by 2022

(Ethik-Kommission 2011; in Renn and Marshall 2015). Market development and entrepreneurial activity have been enhanced by a feed-in scheme that includes small prosumers (Schmid, Knopf, and Pechan 2016). Guidance of search was led by a high level of R&D funding for renewables in 2014 (IEA 2017). Renewables in Germany have very powerful support groups with links to industries and political parties (Praetorius et al. 2010), implying that they are becoming actors in the energy system. Interestingly, support for regime technologies has not diminished in all areas, and R&D funding for nuclear energy has remained high and relatively stable since 2011 (IEA 2017).

In the 1970s, Denmark had a highly centralised energy system (with less than 20 large plants) and was quite dependent on oil and coal. However, the country experienced a shift to a decentralised system of more than 4,000 small-scale producers (Sovacool 2013). The initial aim was to promote self-sufficiency, but it was decided early on that Denmark would invest in renewables, rather than nuclear, and the focus has been on CHP and wind power, which are now the largest renewable sources (Eikeland and Inderberg 2016). In 2006, Denmark's National Energy Plan outlined its goals to reach 30% renewables by 2030 and 100% by 2050 (Lund and Mathiesen 2009), which sets strong guidance of search for the Danish energy system. Market development has been supported with significant research funding (ten times higher than in Finland) (IEA 2017), a feed-in tariff and generous investment support for producers, including individuals and municipalities (Sovacool 2013). Control policies have also been utilised to ensure the success of renewables and small-scale power production; this has been accomplished through a tax on CO_2 emissions and a ban on building new coal power plants, both of which have been in place since the 1990s (Sovacool 2013).

The main driver in both Germany and Denmark seems to be a strong guidance of search directed by government goals. In addition, both ReDE deployment and regime destabilisation are supported by policy, particularly in Denmark. These drivers are significantly weaker in Finland. The energy systems in Germany and Denmark have less exclusive regimes and, therefore, are more open to introducing new actors and technologies. In the case of Denmark, this was indicated by the decision to increase renewables instead of nuclear, despite having a highly centralised energy system. Denmark's dramatic system change has been encouraged by the employment of a strong support policy for ReDE and the introduction of destabilisation measures. German policy has focused on supporting the ReDE innovation system, but a phase-out plan was also introduced. We find that support from guidance of search and destabilisation measures are important in supporting and speeding up transitions and are particularly important in energy systems with strong regimes.

5. Conclusions

In this paper, we explored the strengths and weaknesses of ReDE innovations in the Finnish energy system in order to determine what kinds of activities are needed to transition the current energy system towards a system based on ReDE. We found that there are a significant number of R&D activities and that the number of new units has increased significantly. However, guidance of search, which has been driving ReDE innovations in Germany and Denmark, places ReDE in a marginal role in Finland. In addition, legislation and policy measures do not support ReDE legitimacy, destabilisation activities are weak, and support for regime technologies appears to be increasing.

To advance the transition towards an energy system based on ReDE, these weaknesses should be addressed, mainly by unifying current legislation and permit practices so that they do not hinder installations of new units. Destabilisation measures play an important role in the transition and have been stronger in Germany and Denmark. In Finland, support for the regime should be decreased dramatically, by reducing financial compensation measures, introducing significant changes in regime rules and/or integrating ReDE actors into decision-making processes. For this to happen, significant political pressure from the public would be needed to make climate issues a focal point in future elections and in selecting a government that would strengthen the guidance of search for ReDE, ensuring a role for ReDE in the new system. Our analysis shows that both innovation building and proactive destabilisation measures are necessary to advance transitions. In countries with exclusive energy regimes, destabilisation is particularly important, otherwise the TIS analysis can give an overly optimistic view of transition potential. We find that it is necessary to include an analysis of the regime and whether there are indications of changes that would weaken the regime and facilitate a transition.

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