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Early adopters boosting the diffusion of sustainable small-scale energy solutions

Abstract

Local level actors have an important role in developing small-scale energy innovations as well as disseminating the gained knowledge to key audiences. Diffusion of these energy solutions from innovators and early adopters to wider user groups has often been slow. This study explores the innovators' and early adopters' experiences of their projects, motivations for their behavior, and obstacles that inhibit the diffusion of energy innovations. Four different types of innovators and early adopters of new energy solutions are identified: Enthusiasts, Utilizers, Green Developers and Green Consumers. These groups are characterized by different sets of motivating factors, including environmental concern, interest in technology, economic profit, self-sufficiency, willingness to utilize excess material, promotion of innovations and image reasons. They also have encountered different kinds of barriers to their actions, such as lack of relevant information, poor product quality and lack of economic and institutional support. The different motivating and forestalling factors should be identified and taken into account when developing incentives as well as interaction and communication strategies to enhance the diffusion of innovative, sustainable small-scale energy solutions.

Keywords

Renewable energy; Energy efficiency; Early adopters; Innovators; Social context of energy; Path dependence

1. Introduction

Climate change and the depletion of non-renewable energy sources are major challenges encountered by societies of our time. A transition towards renewable energy sources and more efficient energy consumption is essential [1], [2]. For example, the European Union has set three targets for mitigating climate change until the year 2020. These are reducing greenhouse gas emissions by 20% from the 1990 level, increasing the share of renewable energy to 20% and improving energy efficiency by 20% [3]. The Renewable Energy Directive [4] defines the binding national targets for the shares of consumed energy from renewable sources in the EU-27 member states by 2020. The share of renewable energy is to be 27% in the EU by the year 2030, but this target is not defined as binding national targets. Even more ambitious targets have been called for and potential solutions to meet the targets have been presented. Jacobson and Delucchi [5] have suggested that all of the world's energy need could be produced by wind, water and solar power by the year 2050. They argue that the barriers to realize the plan are primarily social and political instead of technological or economic. To achieve the ambitious targets and to build a society less dependent on the depleting sources of energy, transitions of energy production and consumption are required [6], [7].

Renewable energy sources are typically more diffuse than non-renewable energy sources and possibilities to increase their small-scale local production are ample [2], [8]. As for energy efficiency, it can be improved everywhere where energy is being used. Due to the losses and transfers in centralized energy production, local production and efficient use of energy are promising future strategies for the energy system.

Various technologies to produce and save energy at small-scale exist and, for example, biogas and PV (photovoltaics) production have increased rapidly in some countries, but the adoption of these solutions has been slow in many European countries, such as Finland [9]. Large-scale transitions to sustainability entail not only technologies, but also cultural meanings, policies, user practices, information sharing and markets [10]. This is also the case in the smaller scale processes of diffusion of innovations. Diffusion of innovation refers to a process, where information and ideas of a certain innovation spread through interaction channels inside a social system [11]. Diffusion of innovations and adoption of new technologies is not just a matter of technological development and rational choices; it is also a social process. Even evidently advantageous innovations will not automatically diffuse among potential adopters. Competing innovations, social norms and routines or simply lack of efficient communication, for example, might hinder or prevent the diffusion processes [11].

The diffusion of new energy technologies takes place in stages ranging from innovation to adoption and stabilization and in this article we will focus on the first adopters of innovations, whom we call forerunners. Syvänen and Mikkonen have noted a great interest among homeowners towards energy efficiency and new local services of small-scale production of renewable energy in Finland [12]. To convert the interest into action, it is vital to review and explore the reasons that hinder or advance forerunners in the adoption of renewable energy and energy efficiency solutions. This knowledge could help in developing effective interaction and communication strategies as well as in supporting the diffusion of the energy innovations.

Our objective is to study how the forerunners enhance diffusion of innovations and create paths for innovative small-scale sustainable energy solutions. We review the experiences of forerunners of such solutions in Finland and report the results from interviews and an internet survey. Based on 54 interviews and 36 questionnaire responses, a qualitative analysis of the characteristics, experiences and perceptions of the forerunners is performed. The informants were selected from the 'Forerunners'-project, consisting of over 250 Finnish innovators and early adopters of new energy solutions. These actors have implemented concrete and innovative measures to switch to renewable energy sources or to improve energy efficiency. The project focused on identifying the key factors contributing to the actions or restraining them. Based on the material, a typology of the respondents is created. We argue that different types of forerunners have different kinds of needs for support and communication.

We start by briefly reviewing some key concepts of diffusion of innovations (Section 2). We will then describe our case (Section 3) and the material and methods used (Section 4). Results are presented in Section 5. We discuss the results and present some concluding remarks in Section 6.

2. Diffusion of innovations

One key factor hindering adoption of new innovations is path dependence [13], [14]. Technological "lock-in" is also a commonly used term. Both terms refer to a situation where earlier choices and processes have created structures that hinder the adoption of new innovations. Not only physical infrastructures such as grids but also knowledge, education, social norms, and legislation are structures causing lock-in. Many actors within the structures have vested interests in the existing system. Energy production systems are highly path dependent: they usually require large set-up or fixed costs, enjoy high learning effects from past experiences, have remarkable coordination benefits with other actors on the field, and profit from customers' existing expectations of the product [15], [16], [17]. These factors hinder new energy alternatives and entrepreneurs from entering the field and challenging the existing structures.

In the coming decades energy prices will probably increase due to the depletion of conventional energy resources and the tightening greenhouse gas emission regulations. This will likely counter the old path dependencies and increase demand for renewable energy production and energy efficiency solutions. In this kind of forced change the role of state and energy and environmental policy is emphasized over pure innovation-driven change [15]. A strong and focused innovation policy directed to renewable energy innovations could be a part of the process, and has been called for in the case of Finland, as well [18], [19].

In energy systems, the physical product that a consumer receives – electricity or heat (or cooling) – is quite similar regardless of the production manner [15]. Therefore the price, other resource demands (e.g. related workload or energy storage needs), perceived environmental effects and risks, and social values dominate the decisions related to energy consumption. External costs and benefits of different energy sources are difficult to assess and they are typically not included in prices. This has often given advantage to the conventional centralized energy sources that have better price competitiveness compared to alternative energy solutions. Heat pumps are a good example, as the technology has been available for decades, but not until recent years have they started to become common in Finland [20]. The change has been induced by the increasing prices of oil and electricity and renewable energy subsidies that have been available [21]. Simultaneously, social structures and supply chains have developed and user experiences have proven that heat pumps are rather easy to use.

Even when the adoption of an alternative energy system or device is cost-effective, the lack of supporting social structures, supply chains, services and conventions can make adoption difficult for individuals [22]. (A "device" here refers also to entire systems such as an array of PVs, wiring, batteries, etc.). For many people, it takes too much personal level effort to tackle all the challenges related to the adoption of new technology: they rather wait until the adequate experiences are collected, practices are established and the risks for unexpected difficulties appear to be lower.

Despite the challenges, some individuals are so determined that they are willing to act as forerunners and invest in the development of new innovations. They create new social conventions and demand for solutions and supporting services that are needed in order to a device to be widely adopted (Fig. 1). The very first experimenters of an innovation are called innovators, and the next group adopting innovations that are still without well-established references, are called early adopters [11]. Through multiple trials and tests of the innovation, these users mobilize actors, conventions and systems to create the required knowledge of the innovation [23]. In addition, it is noted that the first users, or "Lead users" as von Hippel calls them, are active in innovating as well [24]. Users construct new conventions of using devices and create completely new products and services. Particularly in the process of transition to decentralized energy system, the users have a crucial role in innovating and developing products and practices [16], [25], [26]

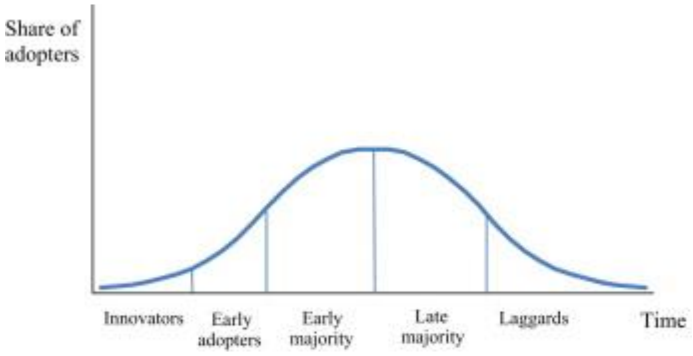

Fig. 1. Different types of adopters on an adoption curve. Innovators and early adopters are the first users of an innovation. Modified from Rogers 1995 [11].

Rogers [11] has listed factors that affect the adoption rate of an innovation. These include 1) relative advantage of a new innovation compared to earlier solutions, 2) compatibility with existing values and experiences, 3) complexity (or simplicity) of an innovation, 4) trialability, and 5) observability (the results of an innovation are visible and will stimulate peer-discussions). Besides of creating new knowledge and conventions concerning new energy solutions, the innovators and early adopters provide opportunities for peer-observation of the solutions. Observability is not only a question of one-way dissemination of knowledge and experiences but also a question of communication and interaction helping to widen the assessment of the potential implications of the innovation and to discover the previously unidentified effects [27]. Ornetzeder and Rohracher [28] have analyzed three successful cases of collective user-action in the context of sustainable energy technologies. In the cases they reviewed, the users have participated in self-building communities to exchange knowledge, expertise and experiences on related energy solutions. The users managed to enhance social embedding of unconventional sustainable technology, stimulate diffusion and adaptation of innovations significantly, and create new technological innovations. Within user-innovation processes and individual behavioral change, the importance of belonging to a supporting community has been acknowledged [22], [29]. Small-scale renewable energy producers have identified a need and importance of mutual networking in Finland, as well [30]. Within the community, the members can receive assistance from others and satisfaction with the gained knowledge can, in turn, positively affect the diffusion of innovations outside of the community.

3. The Finnish case: the Forerunners-project

For centuries the Finnish heating energy consumption in households was based on wood, but it has largely been replaced by district heating, electricity and oil since the 1950s [20], [31]. Finland also has a tradition of centralized wood energy use in forest industry, but local, small-scale renewable energy production is argued to be weakly supported and production rates are currently modest compared to other European Union countries [9], [32]. The available incentives for renewable energy are targeted for large-scale industrial production, unlike in many other European countries, where for example feed-in tariffs are available also for small-scale production [33]. Also, the renewable energy investment subsidy is available solely for companies and communities, not for private persons or housing cooperatives. In spite of this critique, wood contributed 23% of the energy used in households in Finland in 2012 [34]. Other renewable energy sources were less used: heat pumps produced 6% of total household energy consumption. The amounts of solar and wind energy produced at household level are not separated from large-scale industrial production in statistics, but as the share of wind power of total energy consumption was 0.12% (1733 TJ) and the share of solar energy was 0.004% (61 TJ) in 2011, the production rates at household level seem to be very low as well [20]. The use of biofuels in transport has mainly been based on the addition of 5 or 10% of bioethanol into standard gasolines. The share of biogas used in road transport was 0.004% (6 TJ) of total fuel use in 2011 [20]. Energy efficiency in transport has been encouraged by taxing reforms that favor cars with lower CO_2/km emissions [35].

The Forerunners-project was run by Finnish Environment Institute (SYKE) and Finnish Innovation Fund (SITRA) in 2011–2012. The main objective was to develop novel ways to boost the diffusion of energy efficient innovations as well as to promote the utilization of local renewable energy. The project was not limited to any particular technology or energy source; the innovations were to be related to energy and to reduce greenhouse gas emissions significantly compared to an earlier solution.

The first task of the project was finding the potential forerunners. We were not only after “emerging Davids” that challenge the existing “Goliaths” [36], but also ordinary citizens who are among the first adopters of new energy innovations. This was accomplished by contracting three regional partners to collaboration: two universities and an energy agency that markets and implements renewable energy and energy efficiency expert services. As the partners were experts in energy issues in different regions, the forerunners were found throughout the country.

The forerunners were searched through multiple channels: researchers’ contacts, partners’ contacts, earlier projects, magazines, and the internet. Inquiries were also sent to social media focusing on renewable energy use and to renewable energy associations and other NGOs. The found forerunners represented various sectors of the society, including individual households, small-scale family farms, private entrepreneurs, small and medium sized enterprises (SMEs), academies, communities, and housing cooperatives.

A collection of implemented energy projects was gathered and their characteristics, such as the investment and operating costs, the emissions reductions, as well as the related advantages and challenges were presented in an Internet-database (https://wwwp5.ymparisto.fi/hinku/Aloitus.aspx, in Finnish). In the database the characteristics of each project are displayed to anyone interested. However, the participants have a possibility to modify or delete the information from the database. The database is described in detail elsewhere [37], [38].

To promote mutual collaboration between forerunners, a weekend workshop involving 13 forerunners and an electronic interaction platform were organized. At the workshop, the forerunners networked and exchanged experiences, as well as created and developed ideas on how to solve the challenges related to adoption of sustainable energy solutions. The developed ideas were further delivered to various experts and decision-makers in another workshop. A service designer worked with forerunners to identify obstacles for diffusion of energy innovations, to design measures how to overcome the barriers and to create a common platform for communication between forerunners and those seeking information on energy solutions. As a result, a Facebook-page and an e-mailing list were offered to the forerunners for communication. The ideas to be further developed were: energy saving competition broadcasted on TV, cooperative for individual energy innovators and tightening energy saving targets of the government funded energy advising organization Motiva.

4. Material and methods

The research material of the study constitutes of the following materials. First, the structured research interviews [39] were conucted in the fall 2011. The interviewees were chosen among the found forerunners. Also co-nomination, or “snowball sampling” [40], [41] was applied as the interviewees were asked to name other individuals matching the scope. The selection criteria of the interviewees were following: 1) the interviewees should represent a mix of all sectors involved in the project. SMEs that were retailers of energy devices were excluded, however, as the information they provide might be biased due to commercial interests. 2) The renewable energy or energy efficiency solutions of the interviewees should represent many different technologies and applications. 3) The solutions should reduce greenhouse gas emissions either directly or indirectly. From the total of over 250 identified forerunners, 88 structured interviews were conducted either on telephone or face-to-face. The interviews lasted from a half to one hour and were audio-taped.

The following themes were addressed:

- characteristics of the implemented renewable energy or energy efficiency project,
- timeframe of the project,
- products and services purchased, involved actors,
- investment and operating costs, work contribution,
- amount of produced/saved energy,
- positive experiences,
- negative experiences,
- motivations for implementing the project,
- abundance and sources of information,
- interest in joining a forerunner community,
- background information.

This study employs data from 54 interviews, in which the interviewee was identified as an “innovator” or an “early adopter”. The criteria for separating these groups were the technologies they were using. The “innovators” had created some new solution or innovation, while “early adopters” were using technologies that were already available, but that had limited user experiences. The 34 interviewees that were assessed to be using solely already well-established energy technologies, such as ground or air heat pumps, were considered to represent “early majority” (see Fig. 1) and were excluded from this research.

The included interviewees represented a variety of small-scale energy projects and different societal roles and regions (Table 1) The project types varied from using a single source of renewable energy to hybrid projects, in which several different means to achieve a certain target were combined, such as solar collectors and pellets to heat a house. Similarly, there were single energy saving changes as well as hybrids where several different energy saving measures were taken in the same location. Finally, some projects combined renewable energy and energy efficiency measures.

Table 1. Project types and characteristics of the interviewees. RE=renewable energy project, Hybrid RE=project combining different renewable energy sources, EE=energy efficiency project, Hybrid EE=project combining different energy efficiency procedures, RE+EE combination=project combining renewable energy and energy efficiency procedures.

		Renewable energy (RE)	Hybrid RE	Energy efficiency (EE)	Hybrid EE	RE+EE combination	Total
	Total	20	12	4	6	12	54
Gender	Male	19	11	4	4	10	48
	Female	1	1	0	2	2	6
Region	Metropolitan area	1	0	0	2	2	5
	Other town area	10	9	4	4	4	31
	Countryside	9	3	0	0	6	18
Sector	Homeowner/private person	9	8	2	4	8	31
	Business	6	0	1	1	0	8
	Farm	4	1	0	0	2	7
	Association	0	2	0	0	1	3
	Summer cottage	1	1	0	0	1	3
	State's organization	0	0	1	1	0	2

The interviews were interpreted by using the qualitative content analysis method [39], [42]. The interview tapes were listened to and the written interviewers’ notes were read through. Key phrases were identified and classified under thematic categories, such as motivations, and positive and negative experiences. The classified phrases, or coding units, were then reduced, listed and clustered into subcategories. For example, the category motivation contained a subcategory interest in technology, which included all the comments that referred to a personal interest in technology, as well as another subcategory environmental concerns, which included the comments that indicated interest in environmental issues, such as the willingness to find an ecological solution or to mitigate climate change (see Section 5.2).

Second, a short qualitative online expert survey was directed to all identified forerunners in the beginning of 2012. The invitation and link to the survey were sent by e-mail. At the time the survey was conducted, there were 173 forerunners identified. 36 responses to the survey were received. Due to the rather low response rate (21%), we regard the expert survey as a secondary material of the study. The survey consisted of the following seven open-ended questions:

- How should renewable energy production and use be promoted in Finland? (Wood energy, wind energy, ground heat, solar power etc.)
- How should the energy efficiency of buildings be promoted in Finland?
- How should the alternative fuels, technologies and practices related to mobility be promoted?
- What are the most significant obstacles to further renewable energy and energy efficiency?
- What motivates you in your energy projects?
- What challenges have you encountered in your energy projects?
- Other messages to decision-makers and authorities?

The expert survey material was processed using qualitative content analysis, as well. The survey material was read through and relevant expressions were marked and extracted. The extracted expressions were then reduced, listed and clustered into different categories. By observing the found categories, condensed answers to each survey question were constructed.

The results from the interviews and survey responses were combined in a table. It contained all categories and subcategories and through observing which of them typically appeared together, four different ideal forerunner types were inductively identified. The types were named Enthusiasts, Utilizers, Green Developers and Green Consumers. The motivation for the energy project was the category that most effectively differentiated between groups. The ideal types characterize key features of the groups and do not necessarily apply to every interviewee very particular.

5. Results

5.1. The forerunners' experiences

The interviewees had implemented a wide variety of renewable energy or energy efficiency projects. The projects included 1) renewable energy: PVs, micro-wind turbines, heat pumps, production and consumption of biogas, biodiesel and wood energy (pellets, chips, firewood) 2) energy efficiency: heat recovery systems, energy renovations, energy efficient equipment and low energy construction 3) changes of the energy source in vehicles: wood gas cars and electric cars.

The majority of the interviewees had implemented different kinds of combinations of the above, or hybrid solutions which integrate different measures within one of the categories above. Popularity of the hybrid solutions indicates that within current options for sustainable small-scale energy production and use, taking into account the limitations caused by the existing infrastructure and building stock, one RE technology is not necessarily suitable for replacing the old. For example, a combination of solar collectors, pellet furnace, heat recovery and wood stove can be used for heating. The forerunners search for best results by applying a combination of different novel and well established solutions.

Environmental concerns were the most common motivation for initiating and conducting the forerunners' actions. Environmental issues were mentioned by nearly half of the interviewees. Other often mentioned motivations were a wish to save money through energy savings and a general level interest in technology. Some of the interviewees needed to solve a specific practical problem, for example processing of manure or utilization of excess wood. Other frequently mentioned motivations were a presumption of rising energy prices, image reasons, willingness to promote sustainable energy innovations and product development, aspiration for self-sufficiency and willingness to use local energy sources.

A great majority (80%) of the interviewees reported positive experiences and expressed satisfaction related to their energy projects. Interviewees generally claimed to be very satisfied with their projects, although it must be taken into account that as they had spent considerable amount of time and funding on the projects, the satisfaction may be related to the end-result, and not the process as a whole. Also, the sampling method may have influenced the results, as the most satisfied might be most willing to tell about their experiences. Persons implementing their projects by themselves were more satisfied than the acquirers of ready-made products. Nearly half of the interviewees reported plans for future energy efficiency or renewable energy projects. They either planned upgrades to their existing systems or they had visions of new applications or products.

Despite the general satisfaction, two thirds of interviewees also reported some negative experiences, of which the most common were problems in product quality, related workload, and that implementing the project requires close familiarization with the subject and a high level of devotion. Unexpected needs for technical adjustments in the beginning, incompetent retailers, and weaker performance compared to the earlier system were also often mentioned.

A majority of the interviewees had been able to find relevant information concerning their projects. The Internet was the most commonly mentioned source of information, followed by other users of similar devices, and friends, neighbors and other acquaintances. Also retailers, literature, energy advisors, associations and courses provided information. Some interviewees noted that the information provided by experts is often inadequate and finding the relevant information is difficult even if it is abundant.

A majority of interviewees showed interest in sharing their gained knowledge and acquiring peer-information from other users. Only about one fifth of interviewees had doubts about attending the activities of the planned forerunner-community. For the ones hesitating, the main reason not to attend was a shortage of time. In conclusion, the interest in information exchange and communal activities was broad among forerunners.

5.2. Forerunner types

Based on the qualitative content analysis of the interviews and the survey responses, four distinct forerunner ideal types were identified. The key characteristics of the types are presented in Table 2.

Table 2. Forerunner ideal types.

Forerunner type	Enthusiast	Utilizer	Green developer	Green consumer
Motivations	Interest in technology, self-sufficiency, assumption of oil depletion, cost savings	Using excess material, energy and material efficiency	Environmental concerns, cost savings, functionality, interest in technology	Environmental concerns, support for product development, reputation
Implemented projects	Different kinds of energy experiments, hybrid solutions	Produces or uses renewable energy from excess material	Searches for total benefit in energy use, optimizes energy systems	Purchases renewable energy or energy efficiency device as ready-made
Role in the diffusion of innovations	Innovators	Innovators and early adopters	Mostly early adopters	Early adopters
Positive experiences	Proud of the implemented projects	Satisfied with the projects	Satisfied with their own solutions and decisions	Satisfied for realizing the project
Negative experiences	Projects are time consuming	Technical setbacks	Retailers' lack of expertise, lack of unbiased information	Setbacks related to costs and functionality, insufficient information
Key information sources	Acquaintances, own experiments	Literature, acquaintances, own experiments	Energy associations, retailers	Retailers
An example of the type	A person constructed a self-sufficient off-grid house. Electricity and heat is produced by photovoltaic panels, micro-wind turbines and wood. The longest wall of the house is directed to south in order to absorb light and warmth from the sun. The photovoltaic panels and solar collectors are optimized for energy production in the wintertime, as the energy demand is highest in winter. The person considers his project a hobby. He had problems with imported micro-wind turbines' functionality and availability of different components in Finland. He has several plans to improve his systems in the future.	A person converted an old car to be fueled by wood gas. He is interested in the wood gas technology and wants to use excess wood material from his forest as a fuel. Wood gas car works well in everyday life and is continuously in use. The person is motivated by the fact that he controls the whole production chain of the fuel from the beginning, and the fuel is renewable and domestic. As he owns forest, he considers that the fuel is completely free for him. Conversion of the car, and its refueling and maintenance are burdensome, but he considers it a hobby.	A person renovated an old wooden house to be more energy efficient. He added insulation and heat recovery system to the house. He reached significant savings in the use of heating oil, but renovations were expensive and burdensome. He considered different options for the best solution, but none of the available systems seemed optimal. Competent planners and workers were difficult to find and plenty of the work had to be done by himself. Main motivations for him are to reduce the carbon footprint of the house, an interest in housing technologies, and willingness to produce a good solution for housing energy consumption.	A family bought 2 kW photovoltaic panels to produce electricity and heat in their house. The system was delivered as a turnkey, but the family considers the service insufficient. There were technical difficulties with installations and in spite of expectations, selling excess electricity to the grid was not possible. However, the family is satisfied with the system as it lowered their external electricity consumption significantly. Main motivations for the project were willingness to utilize renewable energy and to promote innovations and product development.
Quotation	"Decision-makers and funders want to follow the old paths that are perceived as safe. Therefore there is a lack of funding and willingness for innovative experiments".	"In the case of energy efficiency, there is missing some kind of "last click" that would prove that the society takes this target seriously".	"If the employment, export and education related to renewable energy technologies are desired to be promoted, the production limit for the feed-in-tariff should be lowered remarkably".	"There is a great lack of knowledge and suspicions in the minds of ordinary homeowners --. There is a clear need for development and information projects that would eliminate the barriers in people's minds".

5.2.1. Enthusiasts

Enthusiasts are interested in the energy technology and have implemented different kinds of hybrid energy systems. They often utilize heat pumps, PVs, wood, and energy saving measures. Main motivation to their actions is a willingness to save energy and to be as self-sufficient as possible. Drivers behind their motives are environmental concern, the assumption of oil depletion and price increase. Enthusiasts use much of their free time to tune up the systems and they often consider energy systems as a key part of their lifestyle. In many cases their interest has arisen at work. They admit that their energy solutions require much time and familiarization, but they do not consider it a problem. Enthusiasts are generally satisfied with their energy solutions and they feel pleased when they succeed in making their systems work.

Enthusiasts typically find information from the Internet and from acquaintances who have implemented similar systems. They also learn from their own experience. Enthusiasts improve their systems continuously and have many plans for future actions. The majority of Enthusiasts are innovators in Rogers's categorization [11].

As the Enthusiasts are interested in new applications of energy systems and are themselves innovators, they consider more research and pilot projects, and spreading information on the findings, to be efficient means to promote the new technologies. The biggest challenges that they have experienced during their energy projects are financing and prejudices. They state that established energy industry defends its economic interests and is able to impact the innovation and subsidy policies to favor centralized energy production. The Enthusiasts want to challenge these established actors and show that they can provide the same product locally, more economically and with smaller environmental impact.

5.2.2. Utilizers

Utilizers are people who have some extra material that they want to use to produce energy. They have developed or bought machinery to convert waste material into energy, for example into biogas, wood gas or biodiesel. Their motivation is often to solve a practical problem, for example, a need to process manure to better enable fertilization of the fields, and energy production may have appeared as an addition. They are interested in energy and material efficiency and wish to save money. Some have also environmental concerns as a motivation. Utilizers have usually faced some technical setbacks, which they have managed to repair and are generally satisfied with their systems.

Utilizers have plans of developing and upgrading their systems and some of them may commercialize their inventions. Utilizers are innovators and early adopters.

The Utilizers identify several obstacles that prevent renewable energy use and energy efficiency. These include negative attitudes towards alternative energy systems, domination of large energy companies, and too inexpensive fossil fuels compared to alternative systems. According to them, innovations are hindered because of the lack of subsidies. They state that energy policy changes frequently and is unpredictable due to the absence of common political goals. They call for a change in attitudes and clear policy targets that would lead to stable subsidy policies.

5.2.3. Green Developers

Green Developers search for an optimal solution for energy effectiveness, environment and usability. They consider the pros and cons of different solutions and try to develop an energy system that could be widely adopted. Often their projects involve energy efficient construction or renovations and a mixture of renewable energy technologies, for example solar, wind and wood energy. Main motivations for them are environmental concerns, interest in technology and public recognition as a forerunner.

Green Developers are satisfied with their own realized systems, but dissatisfied with retailers' expertise on different renewable energy technologies. They seek information from the Internet, associations and retailers, but feel that information is not abundant enough or it is biased. Green Developers continuously plan upgrades for their systems. Majority of Green Developers are early adopters.

Green Developers argue that efficient means to encourage renewable and energy efficiency technologies would be economic incentives, such as feed-in-tariffs, investment subsidies, tax exemptions, and higher taxation for conventional energy sources. They believe that these incentives would encourage domestic markets for small-scale energy systems. They also call for raising awareness among homeowners and professionals about both the environmental effects of housing and alternative technologies and solutions to alleviate the environmental effects.

5.2.4. Green Consumers

Green Consumers are interested in purchasing novel ready-to-use renewable energy devices. These devices include housing energy solutions, for example PVs or heat pumps, and electric vehicles. Green Consumers are motivated by willingness to solve environmental problems and to promote sustainable energy innovations and product development. They are also motivated by image reasons: they want to be profiled as environmentally conscious renewable energy users. Money saving is seldom a key motivation, since their projects do not necessarily pay back the money invested, and this is usually anticipated already at the stage of purchase.

Green Consumers have often faced surprises concerning the functionality or costs of the device. The device has not necessarily worked as expected and it has had to be adjusted, which has presented unexpected trouble and costs. Green Consumers find information from the Internet and retailers, but feel that this information is inadequate. Despite these difficulties, Green Consumers have planned to purchase additional renewable energy devices.

For Green Consumers the most severe obstacle seems to be a lack of relevant information available and incompetent retailers. The Green Consumers have the will to promote renewable energy and energy efficiency technologies, but they feel that the supply of needed devices as well as technical expertise have been limited. They believe that training of professionals and retailers would increase the use of renewable energy. Regulations in energy use would also be helpful.

6. Discussion

Energy is rather "invisible" to most people in their everyday life, and they often take the large companies of energy production and transfer as granted [43]. Even renegotiating the electricity contract can be considered as too difficult or time-consuming [44], and adopting a new energy system requires much more effort. Energy issues need to be perceived as interesting or pressing enough that innovators and early adopters choose to spend the required time and effort to start planning a change. The forerunners' role is important for the diffusion, as they are able to overcome the barriers and initiate the processes that gradually change the field.

Nearly all interviewees were motivated by either environmental concern, saving money, or utilizing some excess material. However, environmental motives push only certain segments towards more sustainable energy solutions, in this case mostly Green Developers and Green Consumers. As the pro-environmental attitudes do not necessarily produce environmental actions, the incentives for change should go beyond merely raising awareness on environmental issues [44], [45], [46]. If a person does not have the excess material available as Utilizers do or is not motivated by environmental issues, economic attractiveness seems to be the motivation that can create a larger demand for new energy solutions. Similar results have been found concerning Finnish small-scale district heating entrepreneurs using renewables: the main reason seems to be extra income, even though some consider it a hobby and some an environmental action [30]. Concern for the environment, a green image and reducing fuel bills seem to be the intertwined main motivations also found in other studies about renewable energy and energy efficiency [47], [48], [49].

As the interviewees in our case tended to have a quite long term future orientation, the criteria for economic attractiveness included presumptions about rising energy prices and the gradual depletion of conventional energy sources. The economic attractiveness can therefore be based also on lower operating costs in the long term, and not necessarily on the acquisition costs. Thus, the interest rate for future payback times can be lowered from mainstream thinking. Various economic incentives or regulations can also enhance the attractiveness of sustainable energy solutions. These were demanded by many of the interviewees, but the current regulations were claimed to be changing too often and to be difficult to anticipate. Thus, our results focusing on individual actors support earlier studies focusing on larger scale actors stating that in order to enhance diffusion of innovations, the policy measures should be foreseeable and consistent. To allow pilot projects, flexibility of regulations and incentives is also greatly favored, but it can sometimes be in contradiction with the desired stability of policy measures. [50], [51], [52].

Public images are quite relevant in energy transitions. The interviewees often described how small-scale production is belittled in Finland. This phenomenon was observed in an earlier study, regarding wind power in general and small-scale wind turbines in particular [51]. It is a typical example of path dependency: current Finnish energy (especially electricity) systems have mainly been built on large power plants and extensive grids. The education of many current energy sector professionals has focused on the large scale solutions and they may find small-scale applications either insignificant or even a source of problems to the reliability of the energy system [53]. This lock-in is connected to other obstacles identified by the interviewees. The first is the lacking competence of retailers and installers. It is a direct reflection of the small market and limited experience regarding small-scale solutions. Some interviewees also complained about institutional difficulties, such as not being able to sell their excess electricity to the grid. This can follow either from legislation, grid technology, or lack of support from larger electricity and grid operators. The domination and power of incumbent energy supply companies have been recognized by both our interviewees and earlier studies [52], [54].

Two studies carried out in Sweden and the UK noted that quality problems, performance problems and incompetent retailers are among the key barriers for adoption and diffusion of new small-scale energy technologies [47], [48]. These issues are likely to be at least partially solved if the technologies become more widely used. The key question is whether the early adopters receive adequate support to overcome problems caused by major workload and weak performance of devices compared to earlier systems. It seems that the Enthusiasts are not too bothered by technical setbacks, but finding adequate external support is a crucial question for the other groups. For Green Developers and Green Consumers the lack of relevant information may be the strongest barrier for adoption. For them, the retailers are a more important source of information than for Enthusiasts and Utilizers, who usually find information usually from the Internet or acquaintances. This implies that to successfully promote diffusion, relevant and unbiased information directed to different and wider audiences should be easily available.

The Utilizers and Enthusiasts find the relevant information from various sources and no common source was identified. They are also confronted by prejudice and legal and organizational barriers, such as tight preconditions of feed-in-tariffs and opposition from established energy companies. Therefore, it seems that a key issue for diffusion of innovations is communication activities aiming to overcome the misinformation and prejudices. The use of novel information platforms utilizing social media could be helpful in this task, for examples, see [26], [37]. Also different kinds of networking activities, such as user communities, cooperatives or associations might work towards the target [55].

The diffusion channels established by the Forerunners-project, namely the Facebook-page and the e-mailing list, were however not as effective as expected. After the project coordinators ceased feeding news to the groups, other communication inside the group finished as well, which reflects the long-term communities' need for active facilitation. This contradicts the interviewees' claim of interest to voluntarily share and acquire peer-information. One explanation might be the diversity of individuals involved in the groups. Rogers also noted that the uniformity of the participants affects the effectiveness of communication [11]. There is a wide selection of energy solutions available and the forerunners had diverse backgrounds, characteristics and interests as well as knowledge of very different applications. On the other hand, hybrid solutions, which were very common among interviewees, employ different solutions simultaneously.

The lacking feature accounting for low activity in the established community could be trust. The initiative for networking came from project organization and the community members did not know each other before the project activities. The workshop was apparently not enough for creating personal bonds and social capital needed for active communication [55]. This facelessness presumably reduced the willingness to provide information and prevented members from acquiring assistance from each other. In the earlier successful examples presented [28], the user communities were based on existing social relations, which helped the members to organize around a new topic. It is notable, though that in the successful examples, a coordinating structure was identified as an important factor for cultivating the activities. Bottom-up networking, a few active participants, more face-to-face gatherings, or longer-term external coordination and commitment for building the community would perhaps have helped to provoke the established virtual communities to self-sustained information sharing. The time period of less than a year was clearly too short for a top-down initiative to succeed. This result supports earlier findings regarding problems related to short-term communication projects and projectification of organizational actions [37].

As the technical setbacks and image reasons were frequently mentioned in our research materials, it can be concluded that the sustainable energy solutions are likely to diffuse widely if they become easier to use, if they are considered economically attractive and/or they become generally accepted as a realistic choice for heating or producing electricity. For example, the use of wood pellets or wood chips as a fuel for house heating has been at low level in Finland, not only because of the need for maintenance, but also because of prejudice and lack of general acceptance and supporting structures, one interviewee argued. Another survey study has reported that the most important criteria for choosing a certain heating system were ease of use, cheap operation costs, and reliable availability of fuel [56]. Similar development patterns have characterized earlier changes in heating systems in Finland. Wood energy was partly replaced by oil when oil prices were low during 1960s and wood was increasingly processed into export products [31], [57]. Oil heating was considered the easiest system and furthermore, oil was connected with images of modernity, wealth and efficiency, in contrast with traditional wood ovens often connected with images of backwardness [58]. In many cases, oil was replaced by electricity later, when oil prices rose and electricity was considered an easier means to produce heat.

To replace a current electric heating system with a more energy efficient or environmentally friendly system, the new system has to be considered easier to use, cheaper (either during installation or in the long term) or more fashionable and appealing than the older solution. It is therefore encouraging that Finnish consumers consider that the use of sun, wind, waste, biomass and wood energy should be increased the most in the Finnish energy production palette [56]. In addition, wood energy is considered environmentally friendly, cheap, and trendy. Non-wood bioenergy production has also received increasing attention in Finnish discussion recently [59] and small-scale bioenergy production has found new paths [60].

The technologies that are taken to use by an innovator or an early adopter are constantly changing. Retailers are beginning to offer more versatile solutions and multiple technologies in Finland. In addition, some solutions that were designed by the participating forerunners have since been offered also by commercial actors. The issues of this study could be explored further. For example, many interviewees named the Internet as a key information channel, but it is not clear, what information and from which sites they were using. In addition, it might be possible to study quantitatively the shares of different types of forerunners, although their small population would make this challenging. This study used a qualitative approach, and the resulting ideal types have some overlap. A larger sample might reveal more types, which did not emerge with the material used here. It would also be very interesting to see if similar ideal types would be found in other countries.

7. Conclusions

A clear finding regarding the diffusion of energy innovations was that it is important to focus on the forerunners, their personal motivations and information sources as well as on the surrounding society. The transition towards a wide-spread use of renewable energy sources and energy efficient practices requires multilevel incentives not only allowing the development work by the forerunners but also enhancing the diffusion of successful initiatives. Based on the experiences of forerunners, individuals need to have both a motivation for the action and appropriate renewable or energy efficiency technologies available. However, institutional changes are also required to ease the adopters' way. These mean, for example, networks of communication, proper maintenance and other services by retailers, unbiased information provision, education, encouraging policies, legislation and administration and an approving atmosphere.

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