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The rejection of innovations? Rethinking technology diffusion and the non-use of smart energy services in Finland

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ABSTRACT

Energy markets are in a state of considerable transformation. As a result of new smart energy technologies, novel services can now be offered to customers. The adoption of innovations is often conceptualized in terms of technology diffusion, the success or failure of the new technology depending on how it is able to move across a market. It is taken as given that novel technologies diffuse from innovators to the mass market – a transfer in which non-use is thought to disappear over time. The article challenges the received approach to non-use, building on a typology by Satchell and Dourish, who suggest that non-use is more than lagging adoption: it can also manifest as active resistance, disenchantment, disenfranchisement, disinterest and displacement. The article draws on a survey carried out in Finland in 2013. We proceed from examining the non-adoption of smart energy services to analysing the attitudes linked to the many types of non-use. Thereafter, we will consider forms of non-use that are closely linked to assets and housing. We find that in the case of smart energy services the most important dimensions of non-use are disinterest and disenchantment, alongside lagging adoption. Moreover, disenfranchisement also has a role in explaining non-use.

1. Introduction

The European energy system is facing several simultaneous challenges: the need to reduce carbon dioxide emissions, increase the share of renewables and reduce total energy demand. One of the responses of information and communication technologies (ICTs) to these challenges and opportunities is the development of the smart grid [1–3]. Another response is a change in the role of energy companies, reflected, for example, in energy service obligations and the Energy Efficiency Directive [4]. The need to reduce energy demand and challenge for energy companies to reformulate new products and services are often seen as intertwined [5]. Also the emergence of active energy consumers is presented as an evolutionary process in which the improved information provided by, for example, informative energy bills and smart meters supports the change [6].

Current research on the diffusion of innovations and consumer interest in novel technologies is generally more concerned with the use of these technologies [7,8] than with their non-use. Based on Rogers' canonical diffusion of innovations framework [9], efforts to promote smart energy services are thought to require enhanced consumer segmentation [3], as the evolutionary process begins with *early adopters* [9,10], who are a critical first market for the development and diffusion of new services. There is an emerging body of literature on the motivations and experiences of pioneering consumers, which offers valuable insights into the development of smart energy services [11–17]. However, focusing solely on the adoption of innovations and early use can lead to a partial understanding of how innovation diffuses through markets [18]. Studying non-use can provide insight into future market evolutions and the proportion of consumers who could become active players in the energy market if their initial motivation for non-use were better understood.

During the present upheaval in the energy markets, consumers are expected to play an active role in adopting novel smart energy services, with sophisticated equipment and services reducing energy demand, shifting consumption away from peak periods and producing and potentially storing electricity at or near home [19]. Nevertheless, recent research has challenged optimistic expectations that consumers will embrace smart energy technologies [20], suggesting there is a pressing need to better understand non-adopters and non-users. Indeed, understanding why certain people choose not to use smart energy services can provide important information for service providers and policy makers.

Alongside the smart energy hype, there is growing unease about consumer reactions to the smart grid rollout and the changing energy market [3], highlighting concerns about privacy [21], as well as issues of control, security and cost [22]. Innovation diffusion in the energy

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market has been the focus of a wide range of studies, including analyses of high-profile controversies [23,24], desk-based, expert-based and stakeholder studies of consumer concerns [21,22] and qualitative research addressing the potential effects of smart meters [25,26]. Nonetheless, relatively little is known about consumers who are reluctant to adopt smart energy services: are they merely sceptical, uninterested or uneducated? Conversely, are they actively opposed to some aspects of smart services, such as technology, energy companies or external intrusion into their households?

In this article, we study the non-adoption of smart energy services by focusing on the group of *non-users*, a consumer segment reluctant to adopt new technology. In Rogers' innovation diffusion theory [9], late adopters are termed laggards, whereas non-users are excluded from the theory altogether. Our starting point is that non-use is not merely delayed uptake or the passive absence of use; instead, it is a choice with many dimensions and motivations. In the analysis, we apply a conceptual framework of the reasons and motivations of non-use [27–30] to empirical data on the adoption of smart energy services.

The objective of this paper is to examine the non-use of smart energy services and its relationship to consumer attitudes, social background and housing conditions. The article builds on [Energy Efficiency in Finland] survey data collected in 2013 on the attitudes of Finnish consumers to energy and technology and ultimately their interest in smart energy services. Finland makes an interesting country case, as it is one of the leading countries in renewable energy and energy efficiency with aggressive climate and energy policies [31]. The smart meter roll-out in Finland has been the most advanced in Europe, with 100% of households with smart meters installed by 2015, which has enabled the offering of smart energy services in the market early as compared to most European countries. Therefore, four years after the data collection, the data still offers an interesting viewpoint to the manifestation of non-use in early stages of the smart energy service market. Besides, Finland represents a country where cold climate and high heating needs lead to high energy consumption and dependency. This implies an interest towards novel services enabling energy efficiency as well as home electricity generation. Moreover, there is a general interest among the population towards novel technology such as ICT solutions [see Ref. [32]], but at the time of the survey new energy services had not yet managed to intrigue many users.

This article addresses two questions. First, what non-use is in the area of smart energy services. Here, we examine consumer attitudes and apply Satchell and Dourish's non-use typology [27]. Second, we ask which background features (sociodemographic background, assets and housing) relate to non-use. Based on our findings, we contemplate how the markets should regard non-use and what the results might mean for smart energy service policies and for the restructuring, facilitated by the rollout of smart metering, of the electricity market.

2. Non-use and the adoption of smart energy services

According to Everett M. Rogers [9], the success or failure of new technology depends on its ability to move across a market characterized by qualitatively different customer segments. *Diffusion* is thus defined as the spread of innovation through a market and *innovation diffusion* as the process of market penetration by new products and services, which is driven, with or without consumers' explicit knowledge, by social influences [33]. Customer segments differ in terms of their relationship with technology, their need for recommendations and their use of communication channels, which are all factors that cause these segments to respond to marketing in a specific way. Research has uncovered individual differences in inherent inclinations to resist new ideas as well as products [34], which may manifest as late- or non-adoption of innovations [30]. Looking at laggards, the last adoption segment in Rogers' theory [9], as the sole group where non-adoption is embodied ignores the fact that non-use can be something other than delayed consumption: it can be a deliberate choice, and it can be caused by exterior factors (see, for example, Wyatt et al.'s critique of the concept of laggardness in the digital divide debate [35]).

Table 1
Forms of non-use.

Form of non-use	Definition
Lagging adoption	Temporary non-use that will disappear over time.
Active resistance	A steadfast refusal to adopt technology because of concerns over privacy, lack of time, preference for other forms of technology or varied moral considerations.
Disenchantment	Non-use explained by reluctant or partial use of technology often explained by nostalgic reasons.
Disenfranchisement	Non-use explained by lack of physical or cognitive availability.
Displacement	Non-use explained by having someone else in the household or nearby adopt the innovation.
Disinterest	Non-use explained by lack of interest in or ignorance of new technology.

The non-use typologies employed in previous non-use studies offer an apt solution for conceptualizing non-use in the case of energy markets. These studies suggest that non-use can be motivated by myriad factors, some of them associated with resources, some with attitudes and some with a consumer's level of knowledge.

In their account of the forms of non-use, Satchell and Dourish [27] suggest that non-use can manifest in six forms (Table 1).

The first form, lagging adoption is simply defined as a temporary condition where some consumers have yet to adopt a particular innovation. Consequently, it is difficult to study the segment with cross-sectional data, and it remains largely undefined in research. The second form of non-use is active resistance, a considered and steadfast refusal to adopt a technology [see also Refs. [30,32]]. Potential reasons for active resistance can be seen in concerns over privacy, lack of time and preference for alternative modalities of engagement, or in a plethora of other potential factors, ranging from ideas of corporate responsibility to educational, environmental and health considerations. The third form of non-use, disenchantment, stands for reluctant or partial use of technology, which is often intertwined with nostalgic wistfulness. The fourth form is disenfranchisement, which is linked to the physical and cognitive availability of new products. The fifth form of non-use is displacement, which suggests that the adoption of services can be done by someone else. The sixth form of non-use is simply called disinterest – an apathetic attitude towards embracing new technologies. The consumer data used in the present study allow for the examination, at least to some extent, of all the six types of non-use.

The most challenging task in studying non-use is the investigation of active resistance, a particular effort to resist new technology [27]. Here, we understand active resistance as opposing certain concrete consumer choices. In the survey, questions on the adoption of smart energy services included the answer option "I do not want this service under any circumstances". In addition, however, active resistance can be seen in a number of attitudinal questions. Concern over autonomy is an integral part of the technology experience [36]; resistance can spring from a fear that dependence on technology might leave consumers with less choice and freedom (e.g. [37,38]). In Satchell and Dourish's non-use typology [27], the writers posit that the reasons for active resistance of HCI (Human-Computer Interaction) lie in concerns over privacy and consumer autonomy and also in educational, environmental and health considerations. In the case of smart energy services, consumers often express concerns about losing control over their electricity usage and violation of their privacy through audits and surveillance [39]. New innovations can also raise concerns about their environmental effects. This type of resistance also manifests as lack of trust in the chain of actors providing the innovation [37], which, in the case of the smart grid and smart meters, is well-documented. Consumers tend to be sceptical of energy companies' willingness to actually reduce their customers' energy consumption (see Ref. [40]). Several authors suggest

that consumers might have carefully considered reasons for resisting innovation, either personal or related to a broader social or societal context [30,37,38,41].

Disenchantment also appears to be a relevant type of non-use when studying smart energy services. It may, on one hand, be associated with age and entrenched habits. Heiskanen et al. [37] argue that non-use can include opposition to the instrumental view inherent in many new smart technologies. Such technologies are presented as rational ways to manage activities with intrinsic, aesthetic or social values, such as cooking or dining. Nye et al. [42] claim that energy consumption is not a conscious act; rather, it is driven by habits and deeply embedded routines which are influenced by identity (e.g. in the case of lighting), lifestyles (comfort, home appliances) and subjective norms (ideas about the quality of life). Sometimes, non-use may also be linked to expectations of the improvement of technologies over time. In the case of smart energy services, one might speculate that some non-adopters have their eye on future innovations; some consumers might in fact consider the offerings of energy companies to be too conservative. Peres et al. [33] present evidence that products evolve in the form of successive product generations that satisfy the same need but through a different technology [43,44]. Reluctant first generation consumers may warm slowly to the need for a product innovation and finally, when they are ready to adopt, it is reasonable to skip a generation or two and adopt the newest version on the market, a phenomenon termed leapfrogging [45].

Disenfranchisement is linked to consumers lacking the resources necessary for adoption. Helsper and Reisdorf [46] have examined ICT non-use, and they divide the reasons behind non-use into lack of resources, including lack of access, money and skills. Rogers [9] also argues that a precarious economic position may force consumers to be extremely cautious about adopting novel technologies and experimenting with new solutions. Although Rogers refers to such consumers simply as laggards, the notion of disenfranchisement may be useful for explaining non-use at a more general level. Claudy et al. [47] also argue that consumer resistance to green innovation is mainly related to perceptions of cost.

Disinterest is also a form of non-use to be expected when examining the adoption of new services. Helsper and Reisdorf [46] consider interest one of the key resources that explain the use of ICT. Non-use of smart energy services may thus be explained by apathy and ignorance. Oreg's [34] research suggests that consumers who are routine-seeking and cognitively rigid are the most resistant to change. Consequently, lack of interest and knowledge is also a likely reason for the non-use of smart energy services, since many consumers have a low engagement with energy technology and know little about effective ways to save energy or reduce carbon dioxide emissions (e.g. [48]). Moreover, disinterest may be linked to displacement – the consumer outsourcing the consideration and purchase of smart energy technologies to someone else. In the case of smart energy services, this someone else is likely to live in the same household.

3. Methods

3.1. Data and statistical methods

The article draws on a nationally representative [Energy Efficiency in Finland 2013] survey. The survey questionnaire included questions on housing, housing-related purchases and the adoption of new technologies in terms of energy-efficiency services, the providers of these services and general attitudes towards energy. The questionnaire was sent to a random sample of 5000 Finnish citizens aged 18–70. The final response rate was 24.8% (N = 1240), which is typical for postal surveys. The data represents the whole population quite well, but men were slightly overrepresented in the sample (50.6%) as compared to the whole population (49.2). Moreover, comparison with the 2013 population census showed that 45–64-year-olds were slightly overrepresented and younger age groups slightly underrepresented in the data [49]. Furthermore, the respondents' level of education was somewhat higher than in the population as a whole. Only 18.8% of the survey respondents reported having no more than a basic level of schooling, whereas for the entire population above 15 years old, the respective proportion was 30.6% in 2013. In the data the proportion of respondents with a technical education (37.6% of respondents who had completed further or higher education) is higher than in the population as a whole (29.7%) [50].

Variables representing the adoption of particular smart energy services allow comparison between consumers who have purchased these services or are open to acquiring them, those who are resisting their adoption and those who are merely disinterested in them. The smart energy services we used to operationalize non-use include energy audits, installation and maintenance of real-time home electricity displays for monitoring energy consumption, services for the purchase or instalment of equipment enabling energy saving (such as LED and heat pumps) and equipment for the micro-production of energy (such as solar panels or small-scale wind power plants). The services are all novel: although a number of companies offer them, they are still emerging in the Finnish market.

First, in order to underline the complexity of non-use, we look at simple distributions of the variables representing smart energy service adoption and investigate the role of active resistance in service adoption. Thereafter, we examine the relevance of other types of non-use (late adoption, disenchantment, displacement, disinterest) [27] and how these are reflected in consumer attitudes. Second, we build factor scores for different types of non-use through Principal Component Analysis (PCA). In light of earlier research, we expect non-use to be also connected to the physical assets of the consumer. Third, we look more closely at disenfranchisement, including the relationship between non-use, socio-economic and geographic variables, assets (education and income) and housing. Here we apply a basic General Linear Model (GLM). The analysis was performed with the statistical package R.

3.2. Measures of non-use

We examined non-use through questions about perceived interest in purchasing smart energy services and gadgets, assuming the services would pay off as energy savings within 1–5 years. These services included *energy audits and/or personal guidance at a reasonable price*, installation and maintenance of *real time home electricity displays for monitoring energy consumption*, installation and maintenance of *home electricity guiding equipment (timing gadgets for heating and technical equipment)*, *services for the purchase or instalment of equipment enabling energy saving (such as LED and heat pumps)* and services related to *micro-production technology for energy production (such as solar panels or small-scale wind power plants)*. The response options were 1 = I have already purchased the service; 2 = I am considering purchasing the service; 3 = I am interested in getting more information about the service; 4 = I am not interested in the service; 5 = I am not willing to get the service under any circumstances; and 6 = I couldn't say.

Different attitudes related to non-use and their interrelations were examined through a variety of variables with response options measured on a conventional 5-point Likert scale ranging from 1 = I completely disagree to 5 = I totally disagree.[1] First, lagging adoption was measured with two items: "I would only purchase the service only if free giveaway for another product", and "I would only purchase products from established companies". Second, active resistance was mapped out with five items related to consumers concerns: "I do not trust in privacy and information security" (representing a lack of trust felt towards the electricity company), "I do not trust in getting a fair

[1] For the analysis, option 6, "I could not say", was combined with option 3, "neither agree or disagree".

deal from the company", "I do not trust in the quality of the equipment and appliances" (from the electricity company), "Novel smart energy services might cost more than they save" and "Natural resources cannot be saved through novel services". Social influence was measured with two items: "I do not need help in saving electricity" and "I only acquire a new product if there are successful examples of use nearby". Third, disenchantment was measured with three statements: "I dislike trying out new technology", "I am not keen on following technology news in newspapers/on TV", and "I have no interest in internet forums or blogs about energy issues". Finally, disinterest was measured with one statement: "I have no longstanding interest in energy issues".

The fifth and sixth forms of non-use, disenfranchisement and displacement, were examined through survey items on the respondents' background. The variables used in the analysis to examine disenfranchisement included socioeconomic variables (gender, age), assets (education, income) and variables representing housing (number of people in the household, household size and type of dwelling and type of area), the latter variables being closely related to the financial benefits obtained from the services. Displacement was investigated through a dichotomous variable representing the person responsible for making the decisions on energy issues in the respondents' household (1 = the respondent, 2 = other).

We first examined the variables representing lagging adoption, active resistance, disenchantment and disinterest through Principal Component Analysis. Next, we used the General Linear Model to further analyse the components produced by the analysis. Thereafter, we examined the connection between other forms of non-use and variables representing disenfranchisement and displacement.

4. Results

4.1. Patterns of non-use

The distributions of the items pertaining to particular services deserve some consideration at this point (Table 2). From the perspective of non-use, the negative answers are the most interesting. The response options "not interested in the service" and "couldn't say" express disinterest, which is one form of non-use. Choosing the option "not willing to get the service under any circumstances" instead reflects active resistance and steadfast refusal.

Table 2 shows that only a small number of respondents had purchased the services investigated in this study. Moreover, interest in purchasing smart energy services in general was quite low. In each of the questions, more than 10% of respondents had no opinion on the service, and more than one-third of respondents reported having no interest in the service. However, the share of respondents who were openly against purchasing a particular service was rather low. Table 2 demonstrates that non-use is most likely to manifest as disinterest rather than as active resistance. Depending on the service, the share of non-users among the survey respondents was 40–70%. Frequencies for the attitudinal variables (thirteen altogether) reflecting different types of non-use are presented in Table 3.

The three variables used to indicate lagging adoption were distributed in the following way: few respondents agreed that they would only purchase smart energy services if they were free giveaways. Two statements on acquiring and trying out new technology revealed that more than half of the respondents wanted to wait until the services had become established and there were successful examples of service adoption nearby. The six statements linked to active resistance indicate that only one-fourth of respondents felt they needed no help in saving electricity. Moreover, the respondents expressed little distrust in privacy safeguards or the quality of the equipment provided by the electricity company. However, it was common for them to be suspicious of receiving a fair deal from the electricity company. Furthermore, they questioned the extent to which novel services saved natural resources or money. One-fourth of respondents did not like trying out new

Table 2
Interest in purchasing smart energy services and gadgets (per cent).

	Has already purchased the service	Considers purchasing the service	Interested in more information about the service	Not interested in the service	Not willing to get the service under any circumstances	Could not say
Energy audits and/or personal guidance at a reasonable price	1.2	4.9	25.1	47.6	6.4	14.7
Installation and maintenance of real time home electricity displays for monitoring energy consumption	7.2	15.5	33.9	29.6	3.0	10.8
Installation and maintenance of home electricity guiding equipment (timing gadgets for heating and technical equipment)	7.3	14.6	32.9	31.4	3.8	10.1
Services for the purchase or instalment of equipment enabling energy saving (such as LED and heat pumps)	13.9	19.0	25.6	24.8	2.8	13.9
Services related to micro-production technology for energy production (such as solar panels or small-scale wind power plants)	2.0	16.8	24.2	33.1	8.6	15.5

Table 3
The distribution of attitudes linked to adoption of energy services in the data (per cent).

	Agree		Could not say	Disagree		
	Fully agree	Somewhat agree	Neither agree or disagree	Somewhat disagree	Totally disagree	Total (N)
I would only purchase the service only if free giveaway for another product	1.7	9.5	47.5	18.1	23.2	100 (1240)
I would only purchase products from established companies	17.8	41.0	19.1	17.4	4.6	100 (1240)
I do not trust in privacy and information security	3.8	10.6	22.7	37.6	25.3	100 (1240)
I do not trust in getting a fair deal from the company	16.9	40.1	27.0	11.5	4.7	100 (1240)
I do not trust in the quality of the equipment and appliances	2.1	6.3	50.7	27.9	13.0	100 (1240)
Novel services might cost more than they save	15.8	38.4	35.1	8.1	2.7	100 (1240)
Natural resources cannot be saved through novel services	17.9	28.7	19.9	22.5	11.0	100 (1240)
I do not need help in saving electricity	10.8	13.1	36.9	28.3	10.8	100 (1240)
I only acquire a new product if there are successful examples of use nearby	18.9	39.7	20.2	15.8	5.4	100 (1240)
I dislike trying out new technology	6.9	19.0	25.8	31.7	16.7	100 (1240)
I am not keen on following technology news in newspapers/on TV	11.8	12.0	17.4	38.3	20.6	100 (1240)
I have no interest in internet forums or blogs about energy issues	34.4	25.2	20.4	13.7	6.2	100 (1240)
I have no longstanding interest in energy issues	9.4	14.0	26.4	31.9	18.3	100 (1240)

technology, almost one-fourth reported not following technology news in newspapers or on TV and over half the respondents reported being uninterested in internet forums or blogs about energy issues. A fourth of respondents also reported having no longstanding interest in energy issues.

An interesting feature in the distribution of the attitudinal variables is an overall cautiousness in opinions concerning smart energy services. Thus, a large proportion of respondents had no opinion on their personal service need (need for complementary services, need for help in saving energy, trustworthiness of the devices). Moreover, a negative stance towards smart energy services was manifested in respondents' distrust of the ability of smart energy services to save natural resources and costs. However, active resistance seemed most evident in the respondents' general disinterest in energy issues.

4.2. Associations between attitudinal variables

We used principal component analysis (PCA) to examine connections between the attitudinal variables. The analysis produced five components with eigenvalues greater than 1. Together these five components accounted for 60.1% of the variance, which is a reasonably high share. We included variables with a factor loading greater than 0.5 in the analysis. The statement "Natural resources cannot be saved through novel services", with a factor loading of slightly less than 0.5 (0.48) was also included, as it covers the environmental aspects of adopting smart energy services, which the other variables do not (Table 4).

The five components do not fully resonate with Satchell and Dourish's [27] non-use typology. The first component (*Disinterest and disenchantment*) connects four variables that reflect disenchantment with and disinterest in technology, energy issues and ultimately innovation adoption. The second component (*Lagging adoption*) connects two variables indicating lagging adoption and the need for successful demonstrations before purchase. The third component (*Mistrust towards companies*) entails mistrust towards technology and service solutions and the fourth (*Suspicion of the costs and benefits*) suspicion of the perceived costs of these services. The fifth component (*Dependence*) connects two variables: the first, with negative loading, indicating the need for help in energy saving, and the second, with positive loading, measuring the perceived involuntariness of investing in smart energy services, which could reflect the respondents' lack of competence in smart energy services.

We found that disenchantment (the reluctance to adopt new technology) and disinterest in energy issues were interlinked and were, moreover, pivotal forms of non-use alongside lagging adoption. However, the items measuring mistrust towards technical solutions offered by electricity corporations and suspicion of the costs and benefits of the services can also be seen as components of non-use.

Table 4
Principal Component Analysis (PCA) for attitudinal questions related to non-use.

	Component					Communality (h2)
	I	II	III	IV	V	
I am not keen on following technology news in newspapers/on TV	**0.76**	−0.01	0.15	−0.07	0.09	0.62
I have no longstanding interest in energy issues	**0.76**	−0.01	0.09	−0.12	−0.07	0.60
I have no interest in internet forums or blogs about energy issues	**0.66**	0.05	−0.07	0.14	−0.03	0.47
I dislike trying out new technology	**0.55**	0.37	−0.07	0.18	0.13	0.49
I would only purchase products from established companies	0.05	**0.87**	−0.05	0.07	0.06	0.77
I only acquire a new product if there are successful examples of use nearby	0.05	**0.86**	0.06	0.03	0.08	0.75
I do not trust in privacy and information security…	−0.03	0.00	**0.82**	0.12	−0.07	0.69
I do not trust in the quality of the equipment and appliances	0.13	−0.01	**0.81**	0.02	0.02	0.67
Novel services might cost more than they save	−0.04	0.07	0.01	**0.79**	−0.20	0.67
I do not trust in getting a fair deal from the company	0.00	−0.01	0.35	**0.65**	0.17	0.57
Natural resources cannot be saved through novel services	0.17	0.17	−0.08	**0.48**	0.40	0.45
I do not need help in saving electricity	0.21	0.00	−0.10	0.15	**−0.73**	0.61
I would only purchase the service only if free giveaway for another product	0.18	0.13	−0.11	0.14	**0.61**	0.45
Eigenvalue	2.03	1.68	1.52	1.41	1.17	
% of variance explained	15.61	12.92	11.66	10.87	9.02	

Note: N = 1240. Rotation method: Varimax with Kaiser normalization.

Table 5
Attitudinal components by background variables (parameter estimates (β) for standardized models, with standard errors in parentheses, F-values from GLM).

	I: Disinterest and disenchantment	II: Lagging adoption	III: Mistrust towards companies	IV: Suspicion of the costs and benefits	V: Dependence
Gender					
Male	(a)			(a)	(a)
Female	**−0.583 (0.057)*****			**0.249 (0.058)*****	**−0.259 (0.058)*****
Age group					
18–24	(a)	(a)	(a)	(a)	
25–34	−0.049 (0.127)	0.064 (0.127)	−0.133 (0.130)	−0.169 (0.131)	
35–44	−0.051 (0.123)	−0.163 (0.123)	0.048 (0.125)	**−0.305 (0.126)****	
45–54	0.105 (0.108)	**−0.336 (0.108)*****	−0.174 (0.112)	**−0.244 (0.112)****	
55–64	**0.184* (0.105)**	**−0.491 (0.107)*****	−0.038 (0.108)	**−0.278 (0.108)** ***	
65–70	0.156 (0.113)	**−0.705 (0.116)*****	0.186 (0.115)	**−0.346 (0.116)*****	
Education					
Basic level	(a)	(a)		(a)	(a)
Upper secondary/vocational	0.072 (0.083)	**−0.023 (0.084)***		0.009 (0.086)	**0.161 (0.083)***
BA level	**0.267 (0.085)*****	0.104 (0.084)		0.96 (0.086)	**0.271 (0.087)*****
MA level or higher	**0.236 (0.106)****	**0.303 (0.102)*****		**0.256 (0.105)****	**0.256 (0.107)****
Income					
0–24 999 €/year	(a)				(a)
25 000–44 999 €/year	0.093 (0.085)				0.058 (0.086)
45 000–59 999 €/year	0.058 (0.103)				**0.227 (0.102)****
60 000–79 999 €/year	0.088 (0.106)				**0.277 (0.103)*****
80 000 €/year –	**0.230 (0.117)****				**0.303 (0.112)*****
No information on income	0.017 (0.099)				**0.257 (0.101)****
Persons in the household					
1–2 persons		(a)			
3 persons or more		0.073 (0.072)			
Type of house					
Apartment block		(a)			
A terraced house or a row-house		−0.131 (0.085)			
Single-family house		−0.044 (0.077)			
Area					
City centre		(a)		(a)	
Suburb		0.050 (0.082)		0.001 (0.081)	
Small town/village		−0.147 (0.107)		−0.129 (0.104)	
Countryside		−0.083 (0.107)		**−0.236 (0.097)****	
Size of the dwelling					
−60 m^2	(a)		(a)		
61–80 m^2	0.023 (0.089)		0.100 (0.091)		
81–120 m^2	0.066 (0.081)		**0.221 (0.082)****		
121 m^2 –	**0.162 (0.084)*****		**0.175 (0.081)****		
Constant	**0.483 (0.153)*****	**0.248 (0.154)**	**−0.111 (0.099)**	**−0.131 (0.160)**	**0.045 (0.123)**
F, sig.	**10.019*****	**9.179*****	**3.316*****	**4.724*****	**6.548*****
R squared adj.	0.116	0.089	0.016	0.037	0.041

Note: The score for the reference category (a) equals 0.00, significance: * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

The components revealed by PCA were saved as factor score variables (indices of specific forms of non-use). All the five variables are in standard units (mean = 0, standard deviation = 1). The variable scores ranged from −2.74 to 2.79 (component 1), −2.01 to 2.97 (component 2), −3.58 to 2.67 (component 3), −2.86 to 3.64 (component 4), and −3.29 to 2.93 (component 5). Because we used Varimax as a rotation method, the variables are not correlated with each other.

4.3. Non-use by social background, assets and housing

According to previous research, some non-use can be characterized as disenfranchisement. In other words, some non-use can be explained by lack of resources (access, cost, skills). Next, we turn to how the respondents' social background (gender, age, education and income) and housing-related factors are linked to the principal component analysis results. In Table 5 we use the General Linear Model (GLM) to examine the link between forms of non-use and its possible causes, such as disenfranchisement (lack of assets) and displacement (having someone else to make the decisions on use). The standardized models were built on the basis of examination of main effects of individual variables on different forms of non-use.[2] Although the explanatory rates for the standardized models remain low, we can still see that different forms of non-use relate to social background, assets and housing differently.

It emerged that socio-demographic and housing-related background variables had unforeseen connections to the components representing disinterest and disenchantment (Table 4). Education was expected to have a negative impact on disinterest because pioneering users of smart

[2] By looking at the main effects of individual variables, we found that gender, age group, education, income and size of the apartment were the best predictors of disinterest and disenchantment (with adjusted R-squared 0.095, 0.010, 0.009, 0.005, and 0.025 respectively). For lagging adoption, the most important explaining variables were age group, education, number of persons in the household, type of house and area (adj. R-squared 0.079, 0.002, 0.015, 0.003 and 0.005 respectively). Mistrust towards companies could be explained by age group (adj. R-squared = 0.003), and size of the apartment (adj. R-squared = 0.004). Suspicion of the cost and benefits could be explained by gender, age, education and size of the apartment (adj. R-squared for the variables 0.018, 0.013, 0.008 and 0.009). Dependence could be explained by gender (adj. R-squared = 0.018), education (adj. R-squared = 0.013), and income (adj. R-squared = 0.017). Other variables we tested proved statistically insignificant.

energy services have been found to have higher than average education [16]. Nevertheless, in our analysis the effects of education and income revealed that a high level of education and high income were associated with a higher level of disinterest and disenchantment towards smart energy services. Woen and older age groups also scored higher on this component. Moreover, disinterest also corresponded with the size of the dwelling: on average respondents living in larger dwellings scored higher on the disinterest component than their counterparts in smaller dwellings. The results seem contradictory, as we expected that those with more resources and concrete opportunities to make energy technology choices would be more interested in the issue. These unexpected findings perhaps partly reflect a structure found by MacKenzie [51] and Woolgar [52], who, in their *certainty through* model, suggested that a higher degree of uncertainty occurs in two groups when accepting technology: the group closely involved with the technology and the group alienated from the technology and the producing institution. Our findings suggest that disinterest is associated with having more resources and opportunities.

The second component represents lagging adoption. The youngest age group scored highest on this component, whereas the middle-aged and the old were far less likely to be lagging adopters. With regard to the oldest age groups, this finding could be explained by their having more settled lifestyles. In other words, the form and functionality of their homes have already become established, thereby having the opportunity to acquire additional services or new technical appliances. The theory of the diffusion of innovations suggests that late adopters may be in precarious financial positions, thus explaining their reluctance to adopt novel technologies (cf. [9,30,53–55]). We suspected that the same might apply to non-users in general. However, contrary to our expectations, a high level of education explained lagging adoption. Some differences relating to housing were also found: those not living in blocks of flats scored lower on lagging adoption. A difference was also detected between areas: On average those living in sparsely populated areas scored lower on lagging adoption than their counterparts living in city centres or suburbs. The results – especially those relating to housing – may arise from a concrete need to consider energy consumption and adopt new technology in sparsely populated areas and detached houses. By contrast, questions of energy use are less often considered by those dwelling in blocks of flats. We suggest, however, that lagging adoption does not merely result from a lack of resources. Moreover, the relationship between the lagging adoption component and housing related factors may reflect ideological differences rather than the actual need or opportunity to adopt the technology.

The third component (Mistrust towards electricity companies) is a form of resistance that can be partially explained by age, although the relationship between age and mistrust is not linear. Instead, the most important individual background variable linked to mistrust is size of dwelling, with those living in larger dwellings being less trusting. In larger dwellings, mistrust may be related to higher electricity costs and the potential consequences should energy-saving technologies fail.

The fourth attitudinal component (Suspicion of the costs and benefits) was found to be stronger among men and the youngest age group. Moreover, the highly educated questioned the costs and fairness of electricity deals more often than those with a basic level education. Again, respondents living the countryside were less suspicious of getting a fair deal from their energy company. Previous research in Finland has indicated that there is a generally high level of trust in local electricity providers, and inhabitants of detached rural houses are their most typical customer group. Traditionally, local electricity companies have been municipally owned (although their ownership structure is now changing), which has contributed to higher levels of trust [56]. This is also reflected in the fact that only half of Finns responsible for their household's electricity issues have changed their electricity provider through competitive tendering. We also initially suggested that adopting smart energy services may be less popular in city centres than in the countryside. Our findings indicate why this is so: in the countryside, the adoption of smart energy technologies is seen as an energy and cost-saving measure.

The fifth component (Dependence) resonates weakly with the independent background variables. Nonetheless, female respondents, those with a higher level of education and those with a higher income scored higher on the dependence variable. Again, it may be that the wealthy can better afford to depend on the solutions offered by energy companies compared to the less affluent.

To summarize, disenfranchisement in terms of assets and availability is most strongly linked to disinterest and disenchantment, lagging adoption and mistrust towards electricity companies as well as suspicion of the costs and the benefits of these technologies. Displacement (relying on someone else in the household to make decisions on household energy issues), did not explain any of the non-use components, which may reflect the fact that consumption of electricity can be considered as a personal choice just as well as a household decision.

5. Discussion

5.1. Theoretical implications

In this article, we have challenged the unidimensional approach to non-use, building our analysis of interest in smart energy services on a typology by Satchell and Dourish [27], who suggest that non-use is a diffuse phenomenon encompassing much more than lagging adoption. Our findings suggest that some concepts presented in this non-use typology are relevant in the context of smart energy services, whereas other components, contrary to expectations, seemed to be differently structured and overlap. In Table 6 we summarize the different forms of non-use derived from the data.

Disinterest and disenchantment, which Satchell and Dourish [27] suggest are separate forms of non-use, seem to go together in our data. Examining the connection between these factors and the respondents' background provided some counter-intuitive results in the light of previous research: disinterest and disenchantment were more typical for female respondents, older age groups, respondents with higher levels of education and income, and also for respondents living in detached houses. What is striking is that this form of non-use seems typical for the very consumer segment that is thought to have the highest proportion of pioneering users [16], the segment for which smart energy services are usually targeted, and the very segment that could most benefit from novel services.

Thus, the reason behind their disinterest and disenchantment may well be that these services are not sufficiently interesting or established. The novelty of the services calls into question whether the concept of non-use can be integrated into innovation diffusion theories with a deterministic view on the evolvement of markets. Hence, it seems innovation adoption does not merely entail the simple and gradual transformation of the consumer into a user of a certain technology. Moreover, thinking about non-use as a multifaceted concept may well challenge the evolutionary idea that becoming a user of a novel technology is a gradual process of identity formation and adjustment (see for example Ref. [37]). In line with Satchell and Dourish [27], thinking of non-use as a combination of several components implies that use and non-use do not develop linearly; instead, non-use may involve various (re-)considerations of different values and knowledge.

In the case of smart energy services, lagging adoption was found to be a relevant type of non-use alongside disinterest and disenchantment. Both forms of non-use correlated positively with the respondents' level of education and disinterest and disenchantment also with income. Recent research has found that hedonic factors are important in hindering innovation adoption, as some consumers want to preserve their experience of comfort [7]. Forms of non-use such as disinterest and disenchantment may therefore overlap with lagging adoption – the active decision to delay the adoption of a certain technology. Thus, non-

Table 6
Summary of different aspects of non-use in the data.

Attitudinal components	Segment
Disinterest and disenchantment	Males and older respondents Respondents with high education and income Respondents living in the countryside and in a detached house
Lagging adoption	The youngest respondents Highly educated Households with 3+ persons Respondents in urban settings
Mistrust towards companies	Respondents living in larger dwellings
Suspicion of the costs and benefits	Male respondents and younger respondents The most educated Urban city dwellers
Dependence	Female respondents Highly educated Respondents with high level of income
Stratificational components	
Disenfranchisement	Respondents with assets (physical and educational) different in terms of non-use attitudes Importance of housing-related factors
Displacement	Minor impact on (non-)use

users may become the early adopters of the next generation of products or services (cf. leapfrogging by Goldenberg and Oreg [45]).

The most difficult form of non-use to operationalize, active resistance, also seems to overlap with the multiple attitudinal non-use components we found in our data. Satchell and Dourish [27] define active resistance as "a steadfast refusal to adopt technology, because of concerns over privacy, lack of time, preference of other forms of technology or varied moral considerations". Our findings suggest that the attitudinal components of mistrust towards companies, suspicion of the costs and benefits of new services, as well as the component of consumer (in-)dependence, are dimensions of active resistance to smart energy services. By contrast, a positive perception of the consequences of the adoption of smart grid services is likely to result in use [7].

What seems surprising, however, is the effect of socioeconomic differences and housing, which are often used to explain differences in consumer choices. In our findings, the way in which factors representing disenfranchisement related to other components of non-use was somewhat counter-intuitive. We operationalized disenfranchisement by using variables representing physical and educational assets and housing. We found a clear link between non-use and these assets and between non-use and housing characteristics: a high level of education and income and living in a detached house correlated positively with some forms of non-use. Moreover, lagging adoption was less typical of respondents living in detached houses in countryside – in other words among those respondents towards whom new services are primarily marketed and who could benefit the most from adopting smart energy services.

5.2. Limitations of the study and future research needs

Emerging smart energy services provide an appropriate empirical context for an analysis of non-use, since consumers' relationship with technology can be better articulated in the case of novel services than in the case of well-established technologies. Finland offers a suitable context for such an analysis, since smart meters are installed in every household; hence, the findings indicate future development paths for countries where smart meter roll out is still in progress.

The most important limitation of the study is that the data were collected through a postal survey with the whole population as the target group. Energy is a special kind of commodity, and it fails to arouse much interest among the vast majority. This may result in a larger proportion of responses from the most cutting-edge and the most sceptical of users, in the absence of other fora in which to voice an opinion. It seems likely that the majority of the population, who find energy issues distant, incomprehensible and uninteresting, were underrepresented among the respondents. As mentioned, men and respondents with a technical education were slightly overrepresented in the data. Hence, in the whole population, non-users may be more prevalent than in the data used in the present study.

Although we use data that is some years old, it still offers some valuable insight on non-use. The reason for the validity of the results is that in many other countries the market development today is in the same or earlier phase as it was in Finland, a leading country in smart grid development in 2013. Moreover, the services under scrutiny have not evolved much during the last years nor are there novel service innovations in the market. What is evident is that there is a higher number of companies currently offering the same services. Besides, as the contribution of our article is explorative account on the diversity of the concept of non-use, it is not so much dependent on a specific technology or a service.

Our data do not allow for an investigation of patterns of communication among consumers. However, communication is central to the diffusion of innovations hypothesis [57]. It is usually assumed that social influence flows from innovators and pioneers to the rest of the population. Nevertheless, communication might also flow in the other direction: from non-users to the majority. Thus, an interesting topic for further research would be how much non-users influence other customer segments.

In future research, it would be interesting to conduct a more careful investigation of potential acceptable providers of smart energy services, thereby providing energy companies with insights into partnership candidates that would help improve the demand for smart energy services and promote transformation of the sector. In addition, it would be interesting to study the peer effects of the most cutting-edge users, on the one hand, and actively resistant consumers, on the other. For instance, it would be important to know if they influence the majority of

users in the same way and with similar intensity and whether one enjoys more trust than the other among the majority. It would also be useful to gain more insight into the different forms of non-use presented in this study.

6. Conclusions and practical implications

Energy is a difficult subject to the consumers due to its invisible and abstract nature [1]. Academia and policy makers alike widely recognize the need for energy conservation, and businesses acknowledge the need for new kinds of business models. The goal of distributing renewable energy technology and smart energy services could be achieved by creating easily obtainable service packages and financing for these technologies and their investment costs, building on trust through regulations guaranteeing, for instance, free access to an electricity network and a reasonable price for feed-in electricity and by providing reliable advice to consumers.

There seems to have been an oversimplification in the theorization of how technologies and socio-cultural contexts interact to affect energy-using practices, leading to unwarranted optimism about the adoption of novel technologies [58]. If the aim is to engage the majority of consumers as active players in the energy market, non-use should be approached as a multifaceted concept, which can be seen in different forms of non-use, some of which depend on attitudinal factors and some on factors relating to respondents' background. Some of non-use seems to be characteristic to a certain customer segment (males, younger and more educated respondents with higher income), which may in fact describe the first group to adopt. This supports the finding that leapfrogging may indeed be a reasonable reaction in novel services adoption and should be kept in mind in further service development.

Although the dissemination of technological knowledge may not entirely dispel disinterest and disenchantment, clear service packages and communication of information about costs may encourage innovation adoption. Reasonable service pricing is, on the other hand, essential in tackling disenfranchisement. Consumer mistrust and criticism towards electricity companies, as well as active resistance, may, in turn, be reduced by making corporate operations and responsibility questions more transparent. Accordingly, we recommend a shift in sustainable energy policy away from technology, technical efficiency and the production of solely technical solutions towards the support of user-oriented practices and service provision and the facilitation of networking between different stakeholders.

The presence of non-users in the novel smart-energy service market does not only have implications for marketing; it is a far wider issue. In line with Devine-Wright [59], we suggest that a zero-carbon economy should be situated within a wider zero-carbon society, which can be attained through a change in the business logic of complete sectors, such as the electricity sector. The goal requires policy makers and practitioners to go beyond technological fixes and awareness-raising campaigns to consider the wider aspects of socio-technical change.

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