What makes consumers adopt to innovative energy services in the energy market?

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Abstract: The paper discusses the incentives and barriers of the successful adoption of the innovative energy services in the energy market. The literature review of the outcomes from field experiments and research surveys is enhanced by the results from a pilot study regarding willingness to pay for green energy and by an agent-based model of diffusion of innovative dynamic electricity tariffs. It was found out that to achieve large market penetration rates of the innovative energy services, the consumers must be aware of them. They must be also supported by the access to reliable information and advice to limit their confusion of choice. The perceived difficulty of adoption should be reduced to encourage consumers to get interested in the energy services. Also the distribution channels of the innovation, namely social influence in the consumers’ social networks and advertisement in mass-media should be effectively used to boost the diffusion. The great attention should be put on the negative word of mouth, which may limit or even stop the diffusion of innovation.

Key-words: diffusion of innovation, incentives and barriers of adoption, energy market, willingness to pay, agent-based modeling and simulation

1. Innovations in the energy market

The power system of the future has to be more sustainable, built on a greater energy efficiency and a high share of renewable energy with decreased production of CO₂ emissions. These goals are strongly correlated with the new approach towards the power system, namely the concept of the Smart Grids (SG). Smart grids use modern communication technologies to exchange information between market agents, like generators, market operators and end-users, in order to improve the efficiency of energy production and consumption [1-6]. The rapid increase of renewable energy and a need to increase the energy efficiency at production, transmission and consumption level led to development of some innovative services in the energy market. Among these services we can distinguish in particular:

- technologies based on renewable energy sources (RES): used for local production of electricity and heat; some of them, like PV, solar panels or small wind generators can be installed at consumers’ households,
- green energy tariffs: a voluntary or mandatory electricity tariff that includes some share of green energy and is usually more expensive than a typical tariff including only conventional power,
- dynamic tariffs: called also dynamic pricing, which belong to one of the most crucial demand side management and demand response tools (DSM/DR) and involves a price volatility, flattening demand curve by shifting electricity consumption from on-peak to off-peak hours,
- smart metering information systems (SM platforms): include smart meters, internet widgets and platforms, smart phone applications, in-home displays designed to share the information about the current electricity prices and its consumption between the household and the energy supplier,
- enabling technologies: like, smart plugs, smart appliances or home area networks that optimize and automatize the electricity consumption according to its market price and consumers’ requirements.

A successful diffusion of these innovative services is needed to assure the reliable, sustainable and efficient power system in the future. A diffusion is a process in a social system where an innovative idea or concept is spread by members of the social group through certain communication channels [7]. Further, a successful implementation of these innovative solutions require high consumer adoption rates: the number of members of a society who start using a new technology or innovation during a specific period of time. It induces that consumers play a crucial role in the innovation adoption process [5, 8-10].

In the energy market the consumers’ role in the power system has recently radically changed [11,12]. The importance of the demand side of the energy market has increased, mainly because of its rapid growth all over
the world and the challenges with balancing increased demand with a limited supply. The concept of activating energy consumers by a wide range of demand side management & demand response tools (DSM/DR) was thought to create some incentives for efficient energy consumption and better adjustment between demand and supply of electricity. The development of renewable energy sources could be one of the cures to increase the supply and to make it more flexible, located closer to the consumers in the distribution networks. By massive education the consumers learned that they may now invest in the renewables and produce electricity and heat for their own needs. They may also sell the electricity surplus to the energy supplier. In such a way they may become prosumers (i.e. consumers who produce and consume energy at the same time). In some countries, the governments and local institutions offer subsidies to encourage consumers to invest in solar panels, photovoltaic, small wind or hydro generators. Such incentives increase consumers’ interest in this sector of the energy market. Moreover, consumers may also choose the energy supplier they like, that offer them e.g. green or dynamic electricity tariffs. By choosing green tariffs consumers support development of the renewables [13-15]. Further, when they decide for dynamic electricity tariffs, they increase energy efficiency of the power system. It is achieved by reduction of energy consumption and its adjustment to the pricing incentives from the energy supplier [16,17]. Consumers may also decide to participate in the energy market by choosing another demand response tools, like incentive-based programs [18,19]. The innovations in the IT sector opened a wide range of products and services that enable consumers access to the information about their current energy consumption and electricity prices. By using a wide range of smart metering information systems (SM platforms), they may learn which of their home appliances are mostly energy-intensive and how to adjust the electricity demand to the current electricity prices. They may also decide to invest in enabling technologies that allow optimization and automatization of the electricity consumption in their households.

As shown, the range of innovative energy services is quite broad and may bring some benefits for the consumers, and the power system itself. Although this prospect seems optimistic, but the research surveys, field experiments and pilot programs show that most of consumers are unaware of all the opportunities they now have in the power system [2,16,17,20]. Moreover they are disengaged and uninterested in the energy sector [6,11,21-23]. As some authors prove, consumers’ disinterest in energy services have various origins some of them are afraid of change (they do not want to complicate their lives) or they need more information [6,23]. Consumers usually do not voluntary decide for green or dynamic electricity tariffs and they are reluctant to use SM platforms [12,15,24-26]. Even if the consumers claim to be pro-environmental and eager to save energy, they do not want to change their habits and take some effort to use new energy services. A great gap between consumers stated preferences and attitudes towards innovative energy services and their actual actions has been empirically proved [23,27-29]. For example, according to the current data, the actual take-up of green electricity tariff in most countries, where choice exist is quite low. As [27] emphasizes, in the US average rates are estimated to be at or below 2%, though some of the best performing regional programs have achieved penetration rates between 5% and 17%. In Europe only modest levels of green electricity tariff adoption by consumers have been observed, with the Netherlands providing a notable exception. The same problem is observed in case of dynamic electricity tariffs. Only a small amount of participants of the pilot programs decide to sign up for the dynamic tariffs [23]. As the report of AT Kearney reveals 60-75% of consumers are not aware of the existence of smart grids and are not willing to shift their consumption to off-peak hours [21].

Why the consumers do not smoothly adopt to the innovative energy services? What barriers of adoption are mostly important? What would encourage consumers to adopt to these products more eagerly? These and other questions will be answered within this paper, based on the literature review and two case studies. In the next chapter the literature regarding adoption of the innovative products in the energy market will be reviewed. The main barriers of adoption as well as conditions of consumer acceptance towards innovations will be presented based on the findings from pilot programs and research surveys. The wide range of research considering willingness to pay and willingness to adopt to innovative energy services will be mentioned. Then, to illustrate the problem of consumers’ adoption, two case studies will be presented. The first one is based on the pilot study and shows what encourage consumers to pay more for green electricity and to invest in green technologies (RES). The second one makes a usage of a simple agent-based model to show how social influence on one hand, and difficulty of adoption on the other, may impact the diffusion of the dynamic tariffs in the energy market. Finally, some conclusions and recommendations for further increase of the market share of the innovative energy services will be reported.
2. Adoption of the innovative products – a review of the literature

2.1. Process of innovation diffusion

A diffusion to be successful typically follows some regular, sequential steps: (1) gaining knowledge about the innovation, (2) forming an opinion (attitude) towards it, (3) deciding whether to accept or reject an innovation, (4) implementing the decision (e.g. signing up for green or dynamic tariff, becoming a prosumer, using SM platform), (5) confirming the decision, which shows whether the consumer is satisfied with the innovation and wants to continue using it or is rather disappointed and will discontinue the adoption [7].

Generally innovative energy services, like green or dynamic tariffs diffuse slowly into markets [6,14,30,31]. As [14] indicates slow diffusion can be explained by both: market failures and systemic character of innovations. In case of market failures it is not easy to get the prices right. The consumers, in the early adoption process, compare the prices of the innovative product or service with products which are already present in the market [9,32]. The price difference between old and new products and services in most cases reduce consumers’ interest towards innovation. People generally, as [32] points, are not in favor of paying a price premium for increased use of renewable energy sources in the future. That’s why to increase consumers’ engagement in investment in renewable energy technologies, the government and other institutions use price control, by the means of taxes and subsidies. The main problem with this solution is to define where those subsidies should go and what their level should be [14]. Then, the environment in which innovations are developed influences strongly the success of the diffusion. This environment consist of socio-technical configurations of actors, rules, physical infrastructures and their relations. Various systemic problems (like e.g. lack of continuity and long-term regulations, ‘misalignment’ between policies on sector and governmental levels, i.e. EU, national, regional level, no access to new entrants, etc.) are broadly reviewed in [14]. Further, as [4] emphasizes, there is often some misconception between consumers and energy service designers or suppliers. It can be easily observed in case of smart meters. Consumers expect more benefits from smart meters than they are really likely to have, at least in the immediate future, and also think that they will be exposed to more risks than are really likely. For example, customers may be less likely to support SM implementation with the knowledge that enabling technologies would require additional investment costs to the customer. The authors suggest electric utilities to scale back the consumers’ expectations, so that consumers do not expect more than SM can deliver [4]. Secondly technology should be implemented in line with expectations, by adding useful SM thermostats and in-home displays to show consumers them real-time electricity use and help them to save money [11,18,33,34].

Moreover, as many experts indicate, innovative energy services do not diffuse successfully because of the lack of awareness and knowledge and a high level of consumers’ indifference and disengagement towards these services [11,20,22,29,35]. As [36] notices, promoting innovative energy services can be difficult, because electricity differ from other consumer goods. Energy is an abstract commodity: invisible and untouchable and it is consumed indirectly by related activities. That is why the first stage of gaining knowledge about the innovation is essential, as the consumers must be aware of the innovation [6,20,29]. According to [20], most of the surveys and researches assume that consumers are aware of the existence of the innovative products, like green energy or dynamic tariffs. However, as the authors emphasize, it doesn’t have to be always true. Many consumers might not have spent much time considering these green innovations or, more importantly, are not aware of their existence at all. Consumer awareness generally depends on the backgrounds or market segment of the consumers and the specific technology in question. Learning about substitution towards more energy efficient consumption and other energy related services is usually delayed by perceptions of risk and procrastination [3,6,20,29]. Moreover, each innovation diffuses through certain communication channels over time among the members of the social system and via mass-media. That is why the social influence within the consumer’s social network is so vital for the outstanding diffusion and high market penetration rates. As [37] marks, influence of interpersonal communication channels is so far rarely examined in the diffusion of the energy innovations. But it is empirically proved that information shared within a social network, is one of the crucial elements, in addition to action and feedback, which can influence householders to adopt to the innovation [33,37]. Recently, the presence of the energy-relative issues in the social media was checked. The authors confirm that studying Twitter of Facebook communication channels provide information regarding engagement, identifying influencers, word of mouth communities that my support and accelerate a change in energy related behaviors [37,38].
The challenge to increase adoption rates of innovative energy goods is high, because most of the consumers are not motivated enough to get interested in these products. People do not talk about them, do not exchange experiences. These goods are also not commonly advertised in the mass-media. However there are some incentives that may motivate consumers to use energy services. As research surveys prove consumers increase their engagement once because of the economic reasons (they find a certain investment in renewables, energy efficient technologies to be costly effective, promising savings on electricity bill, high return on investment or extra incomes from selling domestically produced energy to the energy retailer), and secondly because of the social pressure from their peers and neighbors who have already adopted a certain product, service or behavior [12,39-42]. Environmental motivations are found to be helpful in convincing people to adopt, but they do not seem to play a major role in diffusion of innovative energy services [32,41]. Finally, a lot of authors mention that psychological factors, to which individual and collective values belong, affect evaluations of the innovative energy service alternatives, e.g. among renewable technologies [24,28,32,43,44]. As [32] stresses, the strength of the effects of values and the processes through which they influence evaluations and acceptability might differ depending on the unique characteristics of each innovative energy service (which is likely to depend on the contextual factors, like, e.g. price, availability, service).

The summary of the main incentives and barriers of adoption towards innovative energy services is placed in table 1. Apart from the issues mentioned in the table, the adoption is highly influenced by some factors on the demand side, like: the consumer attitudes towards environmental protection issues, perceived difficulty of switching one’s electricity supplier, customer’s expectations that their behaviors are ethically proper, perceived differences between offerings, an access to the reliable data about substitutes (e.g. comparison of pros and cons of various tariffs), see [4,11,24,27]. On the supply side among factors influencing diffusion the typical aspects of marketing-mix can be defined, like e.g.: price level, distribution channels, service and promotion of new offers [26,45].

Table 1.
Incentives and barriers of consumers’ adoption towards innovative energy services

<table>
<thead>
<tr>
<th>Incentives</th>
<th>Barriers</th>
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<tbody>
<tr>
<td>financial savings (e.g. lower electricity bill, price differential between e.g. conventional and renewable electricity)</td>
<td>difficulty of adoption (perceived non-financial cost-benefit analysis, in particular: obstacles of getting used to new conditions, change in the daily routine, discomfort of usage)</td>
</tr>
<tr>
<td>extra incomes (from selling energy)</td>
<td>cost (e.g. investment, service and maintenance cost)</td>
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<tr>
<td>“being like others” (adopting social norms and peers’ behavior)</td>
<td>lack of awareness and knowledge</td>
</tr>
<tr>
<td>satisfaction from being pro-environmental</td>
<td>confusion of choice (lack of professional advice)</td>
</tr>
<tr>
<td>personal values, beliefs and attitudes towards environmental protection issues</td>
<td>negative word-of-mouth (i.e. negative information shared within a social network about the innovation)</td>
</tr>
<tr>
<td>government subsidies and other financial support</td>
<td>lack of appropriate long-lasting financial and legal support</td>
</tr>
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Some aspects of consumer behavioral change regarding adoption in the energy market will be briefly discussed below.

2.2. Consumer behavior in the energy market

Since many years there are a lot of scientific attempts to explain the phenomena of the consumer behavior in the energy market. The authors usually base their research on the theoretical socioeconomic models, explaining the consumer’s environmental behavior and individual decision making process. Among these models, one may distinguish e.g.: cognitive behavioral models, like the Theory of Planned Behavior [46], normative models for pro-environmental behavior, like The New Environmental Paradigm [47], Values-Belief-Norm model [48] or the Attitude-Belief-Context model [35] and many other consumption or utility-based theory models of behavioral economics. These models are reviewed and described in the context of environmental or energy behavior in (e.g. [5,11,44,49]. To verify the theories the authors usually use methods popular in social science, like contingent valuation methods, field experiments, survey questionnaire, semi-structured interviews and online surveys.

Apart from socioeconomic theories and field experiments, some authors use also modeling and simulation tools to observe how and under which condition the products or services diffuse in the market. Recently among modeling techniques agent-based models (ABM) are gaining attention and interest, mainly because of their bottom-up approach, from micro to macro behaviors of the agents, societies and populations. Such an approach
allows to simulate adoption of individual consumers towards various products and to define how social influence, network topologies and external factors, like e.g. mass-media advertisement impact the diffusion. ABM are also used for simulating diffusion of energy relative products, like: smart meters [2,5,6,50,51], SM platforms [52], dynamic tariffs [53], storage devices [54], PV systems [55] or novel biomass fuel [56].

The main conclusion from all these surveys is that consumers' environmental behavior is influenced by motivational, contextual and habitual factors. Environmental behavior is strongly connected not only with consumers' general environmental beliefs and attitudes, but also with environmental norms, drivers and barriers, perceived financial and non-financial costs and benefits, individual and collective values, social and community influence (moral and normative concerns), government policy and affection [see, e.g. 3,13,16,25,28,29,32,35,36,39,42,43,49,57-59]. The authors underline that these different perspectives are not mutually exclusive and all of them should be considered to predict environmental behaviors. Below, some most important antecedents of behavioral change regarding energy conservation are summarized.

Environmental attitudes concern a person’s belief regarding the consequences of undertaking a specific behavior as a function of the person’s valuation of the consequences in terms of environment protection. Therefore, attitudes, whether favorable or unfavorable, are produced by behavioral beliefs [46]. In [15] the investigation of the factors that encouraged UK consumers to sign up for green electricity proved that positive attitudes towards green electricity lead to adoption intention. But attitudes to be effective in transferring into the certain behavior cannot be too general. They must be quite precise and constant over time [53]. As [60] emphasizes, individual environmental preferences and attitudes will be affected by differences in age, gender, education, socio-economic status and political views. When people decide to adopt an innovation, they consider not only functionality, usability, costs and intended outcomes, but also what the innovation means to them, how it reflects their identity, image, values and norms [15]. The influence of norms on the attitudes and behavior is emphasized in the value-belief-norm theory of Stern [35,48]. According to this theory, normative beliefs have a positive effect on the intention to adopt environmental behavior. As Ozaki argues, recycling is a good example how an environmental issue can become a normative behavior. The more consumers are convinced that waste segregation is good for the environment and start doing it, the higher is the probability that such a behavior will become a norm and that other people will adopt this practice [15].

There is also a wide range of contextual (e.g. price level) and psychological factors, including both individual and collective values that may influence the evaluation of decision’s alternatives regarding e.g. green energy technologies [32]. Those, whether a consumer cares more about well-being of a whole society (collective, self-transcendence values) or rather about the wealth of herself (individual, self-enhancement values) decides about the decision making process and the evaluation of the innovative energy services. The appraisal of a certain innovative energy service may differ while being investigated from individual or collective perspective. In most cases, people evaluate energy services more positively from the collective than individual point of view. As [9] points, individual values are considered important drivers of early adoption, because they constitute motivational forces to pursue goals and intentions relevant in the early adoption process.

Then, environmental drivers include procedural knowledge and understanding which is necessary to turn attitudes and beliefs into concrete actions, consumer feelings of guilt or moral obligation, sense of social responsibility, ease of adoption and personal relevance [29,35]. On the other hand, the strongest environmental barriers include large initial investment costs, expected long pay-back time, insufficient information, lack of professional help and advice and lack of time [28,53,61]. People make more or less consciously a cost-benefit analysis of the alternatives, weigh pros and cons, to maximize their benefits [49]. If the perceived costs exceed benefits, people usually refuse to adopt the innovation.

Further, the literature suggests that consumers are favorably influenced by the opinions and actions of their family, friends and associates and also by cultural values [8,10,16,37,46,61-63]. Many studies have shown that normative social influence has a positive effect on the intention to engage in environmental behaviors, like the acceptance of green energy or energy conservation behavior [15,39,42,53]. In the work of [8] social interaction through so called peer effects are recognized as a potentially important factor in the diffusion of new products. In that study, the impact of peer effects on household decisions about the installation of solar photovoltaic (PV) panels has been shown [3]. The more PV were installed on average in the certain area, the higher was the probability of the adoption and further increase of new installations. The impact of the neighbors behavior has been also revealed in the studies of [39,40]. Both studies report on the large-scale program, run by the
OPOWER, who sent so called Home Energy Report Letters to residential utility customers comparing their electricity use to that of their neighbors. By the means of this action, the energy consumption has been reduced by 2%. It was shown that combining the descriptive and injunctive messages (in this case, the emoticons: happy or sad faces) lowered energy consumption and reduced the undesirable boomerang effect (that those who occurred to use less energy in comparison with the neighbors started to increase their consumption), see [39]. According [40] learning that neighbors consume less (more) energy could increase (decrease) feelings of guilt about contributing to social problem and thereby impact private preferences and motivations to conserve [3]. Alternatively, learning the behavior of neighbors might provide information about the possibility of alternative consumption choices and the relative benefits of those choices. Finally, Nolan et al. has argued that a social norm has a greater impact that other non-normative motivations like: protection of environment, benefiting society or even saving money. Moreover, in that study the inconsistency between stated motivation and actual behavior has been revealed. On one hand “because others are doing it” was judged to be the least important reason at the self-reported motivation stage. But, on the other hand, the highest correlation between actual conservation behavior and a person’s belief whether or not their neighbors were doing it, was proved, see [3,42].

Finally, financial incentives, grants, discounts, subsidies, and other intrinsic and extrinsic rewards etc., can be helpful in changing consumer behavior, but they are not enough [25,28,41,57]. They should go along with some of the other factors: pro-environmental attitudes, social influence and lack of environmental barriers [35]. As [28] reveals, some research has shown that government policies and subsides does not influence environmental beliefs. It may indicate that green consumers do not trust governments to deliver on promises for better policies and subsides that will offset their costs. The trust in policies, its fairness and rightness is also found crucial in convincing consumers to invest in a certain renewable energy technologies [25,32]. That is why government policies to be effective should assure consumers that in the long run benefits will outweigh the cost from engaging in positive environmental behavior [28]. To avoid institutional failures, it is necessary to focus on specific technological products or services, which require appropriate policy measures. As [14] reports, differences in policy needs are determined by the phase the innovation system is in, the specific problems related to the technology, acquisition of financial resources, distance to market, strength of the networks, international playing field, etc. This implies that ‘one model fits all’ is not likely to work. The consequence is that innovation policy makers need to develop the appropriate capabilities to evaluate the specific circumstances of an individual innovation system and the specific problems that are related to specific technological fields [14].

To summarize what pushes people from intention to adopt to actual adoption is: a combination of perceived personal benefits as a consequence of adopting to the innovative energy service, compatibility with consumer’s values, identity and social references, strong social influence and normative beliefs, a sense of control over costs and associated inconveniences attached to switching over, no perceived risk or uncertainty and finally good information [13,15,28,43,64].

2.3. Barriers of adoption of innovative products in the energy market

The main difficulty in understanding the energy behavior is to realize how humans attitudes and beliefs and consumer’s willingness-to-pay for certain products are correlated with their actual behaviors. The basic observation of psychology is that people’s attitudes towards some ideas or products do not have to be followed by actual decisions and behaviors. As proved in many surveys, pro-environmental intentions (attitudes) do not always translate into actual actions [15,28,62]. Also the knowledge about the innovation and the benefits of environmental actions is not enough to make people engage in these actions [60]. A survey done in Italy showed that whilst 70% of respondents are willing to increase energy savings, only 2% are currently reducing their use [29]. In U.S. 78% of Americans oppose gasoline tax and 60% oppose business energy taxes. At the same time 52% of Americans claimed to support Kyoto Treaty. But if they had to pay an extra 50$ per month, then they would oppose it [29]. So, people are in favor of some idea as long as it has no consequences for themselves. The same problem can be noticed in case of dynamic tariffs, while in UK only about 5% of consumers opt for a simple dynamic time-of-use (TOU) tariff with peak and off-peak prices [64]. In US higher recruitment rates were for default offer (78 to 87%) in contrast to opt-in offers (5% to 28%). Consumers, generally, do not want to shift consumption [22]. In Poland consumers are neither willing to shift their consumption by themselves (51%) nor automatically (71%) [21]. 57% claim that they will not respond to the information about energy costs. The discrepancy between opinions and actions has been also observed in case of green energy [27]. For example, in Finland 30% of households claimed to be interested in green energy, while only 0.2% demonstrated purchasing behaviors. In the UK 25% are interested in green energy, and only 0.07% decide to purchase it [65].
This social phenomenon is called **intention-behavior-gap** and has been the subject of many studies [5,15,27,28,53,62]. [27] as well as [15] argue that among factors that may cause stated preferences to diverge from the actual behavior the following can be mentioned: unstable consumers’ opinions, lack of knowledge of the green power availability, confusion generated by the complexity of tariffs, lack of guidelines and advice, lack of sufficient supply, a hesitancy to switch from one electricity supplier to another, distrust of energy product suppliers and cost concerns, search cost involved in switching and free rider problem [3].

Most of the reasons of the intention-behavior gap can be recognized as **adoption barriers**, among which we can distinguish: lack of awareness and knowledge, lack of motivation, disengagement, indifference, confusion of choice, perceived difficulty of adoption and discomfort of usage (see, also Table 1). Below, some of them will be shortly discussed.

A lot of environmental behavior takes place under conditions of bounded rationality. Strict rationality is prevented by information and cognitive constraints. Due to several factors such as lack of time to analyze, limited information about issues and options, limited processing capacity or just lack of interest and laziness, consumers may not behave rationally all of the time and could look for options until they find the one, which looks satisfactory rather than making an optimal choice, see [60]. **Knowledge deficits** may explain a lot of environmental inactions [29,35]. [29] distinguishes three main obstacles to behavior change: perception, self-interest and limits to knowledge, where knowledge includes: awareness, understanding and procedural knowledge (see also [35]). Awareness of the innovation, as already mentioned, is a fundamental condition of the adoption of the product or service.

Then, **cost** is a strong barrier to adopt some of environmental behavior. Generally, people are not eager to bear extra investment cost or to pay a price premium, especially when there are cheaper alternatives already available in the market. Some surveys proved that socio-economic status (whether a household depends on benefits or not), number of children, the age of housing, etc. were insignificant suggesting that poverty does not constrain environmental action [60]. On the other hand, according to the other surveys, people on lower incomes are less willing to incur monetary costs and richer people are less willing to sacrifice living standards and comforts [44]. As Ozaki indicate, cost belongs to one of the most important controllability factors. Control factors (beliefs) are people’s perceptions of how easy or difficult it is to perform the behavior in relation to their abilities, resources and opportunities, which will encourage or hinder the performance [15,46]. Cost of adoption can be also analyzed from non-financial perspective, as a **difficulty of adoption** [66]. Perceived difficulty of adoption can be a result of an individual judgement regarding pros and cons of the innovation. If the disadvantages of the adoption are larger than potential benefits, the consumers may be reluctant to adopt. The consumers usually don’t like to change their habits and do not accept any reduction in comfort of living [32,34]. In the extreme situation, the perceived difficulty of adoption is so high, that some consumers may found an innovation redundant and unnecessary, or user-unfriendly and they will refuse using it.

### 2.4. WTP for the innovative products

To measure consumers’ evaluation of the product the concept of willingness to pay (WTP) is commonly used. In case of the energy, WTP is often used to evaluate consumers’ engagement and a willingness to contribute (by paying more for green energy, by becoming a prosumer, by switching to the dynamic tariffs program). In case of early adopters, so consumers who are firstly interested in a new innovative good, [9] considers also **innate willingness to pay for innovations** (IWTP), for which large number of factors influence. Among these factors there are: demography, financial situations (income, financial expectations and savings orientation) and personal values (uncertainty avoidance, importance of status symbols). IWTP is also effected by country and cultural context (population size, macroeconomic parameters, cultural values, e.g. individual vs. collective decision making). In the consequence a consumer final decision regarding an innovative product or service depends on consumer’s satisfaction that consist of: perceived quality, competitive advantages, values, initial quality expectations, public brand image and social recognition. In many cases the prices for new products and services are higher than for established ones, that is why high willingness to pay is a precondition for early adoption of innovations, see [9].

The table below gathers the results of some studies, exploring the correlation between willingness to pay and socioeconomic characteristics of the consumers, mainly regarding green energy and dynamic tariffs, [3,9,13,15,32,59,65,67,68], see Table 2.
Table 2. 
Correlation between willingness to pay and socio-economic factors

<table>
<thead>
<tr>
<th>Willingness to pay for green energy and dynamic tariffs is correlated</th>
<th>negatively with:</th>
</tr>
</thead>
<tbody>
<tr>
<td>positively with:</td>
<td></td>
</tr>
<tr>
<td>- positive attitudes towards green energy or energy conservation</td>
<td>- non-voluntary programs</td>
</tr>
<tr>
<td>- self-transcendence values (interest on the welfare of others)</td>
<td>- self-enhancement values (interest on the oneself happiness and comfort)</td>
</tr>
<tr>
<td>- income level</td>
<td>- electricity cost</td>
</tr>
<tr>
<td>- educational level</td>
<td>- household size</td>
</tr>
<tr>
<td>- knowledge about energy issues and awareness of the climate issues</td>
<td>- extra cost of supporting technologies (smart meters, in home displays) in case of dynamic tariffs</td>
</tr>
<tr>
<td>- concern about environmental problems</td>
<td>- age</td>
</tr>
<tr>
<td>- experience in investing in green energy</td>
<td>- rural population</td>
</tr>
<tr>
<td>- urban population</td>
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</table>

A lot of research has indicated the discrepancy between declared WTP or stated willingness to adopt (SWA) and actual adoption [15,27,67,69]. Despite the relatively high level of customer intent, the actual take-up of green or dynamic electricity tariffs is relatively low in most countries where the choice exist. On one hand WTP or SWA for green energy are quite high in Europe and in U.S. (WTP between 40-60% and SWA between 30-60%), see [27]. On the other hand the actual number of consumers switching to green tariffs is low (average adoption rate in U.S. is below 2% and in Europe even lower).

The WTP estimates vary substantially across countries due to significant differences in the levels of economic development and environmental awareness as well as social customs and cultural backgrounds. The actual value of the WTP is also usually higher if the consumers are asked about the particular energy source (like, wind generators or solar panels) or particular DSM/DR tools or technologies (like, smart meters) than, when they are asked about generic renewable energy sources or generic DSM/DR [17,67,68].

3. Case studies

In this part of the paper the above discussed issues enhancing or reducing successful diffusion will be illustrated with two case studies. Firstly, the results of the pilot study regarding factors that encourage consumers to adopt to green electricity will be discussed. Secondly, a simple agent-based model that simulates the impact of the social influence on one hand, and difficulty of adoption on the other, on the diffusion of the dynamic tariffs in the energy market will be presented.

3.1. WTP for green energy – results of the pilot study

In April 2016 a pilot study was conducted among Polish electricity consumers to discover which economic and psychological factors determine their willingness to pay for green energy. The online questionnaire was completed by 151 respondents.

3.1.1. Respondents

The research sample consisted mainly of well-educated people, owing a house or a flat, living in small cities or in villages (see, Table 3). 97% of the respondents were aware how much they monthly pay for electricity.

Table 3.  
Sample description

<table>
<thead>
<tr>
<th>Sample size</th>
<th>151 respondents</th>
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<tbody>
<tr>
<td>Participant gender</td>
<td>44% male</td>
</tr>
<tr>
<td></td>
<td>56% female</td>
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<tr>
<td>Participant age</td>
<td>60% 18-30 years old</td>
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<tr>
<td></td>
<td>28% 31-45 years old</td>
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<td></td>
<td>12% above 45 years old</td>
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<tr>
<td>Education</td>
<td>70% university degree</td>
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<tr>
<td>Mean household size</td>
<td>3 persons</td>
</tr>
<tr>
<td>Type of a house</td>
<td>52% live in own house</td>
</tr>
<tr>
<td></td>
<td>28% live in own flat/ apartment</td>
</tr>
<tr>
<td></td>
<td>14% rent a flat/ apartment</td>
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<td>6% others options</td>
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3.1.2. Willingness-to-pay for RES

To evaluate the level of WTP for RES a following question was asked: How much are you willing to pay more for green energy in comparison to your current electricity bill? In response, c.a. 60% of the respondents claimed that they are willing to pay more for the energy if it is green. Among them 30% is willing to pay less than 10% more in comparison with their current electricity bill, 20% would be able to pay more between 10%-25% than currently, 6% declare to be willing to pay 25-50% more and only 3% is willing to pay more than 50% than now (see, Fig. 1).

![Fig. 1. WTP for green energy in comparison with current electricity bills.](image1)

The results were than compared with respondents’ preferences regarding: reliability of electricity supply, type of energy sources and electricity price (Fig. 2).

![Fig. 2. Respondents’ preferences regarding: reliability of electricity supply, energy source and electricity price.](image2)

The respondents were asked to mark on the scale how important for them these three parameters are when compared with each other. It was found out that for most of the respondents electricity price (68%) and reliability of supply (67%) are much more important than the energy source. Comparing electricity price with reliability of electricity supply shows slightly advantage of the latter. It shows that the declared WTP for green energy cannot be taken for granted. Actually only around 30% of the respondents would be really ready to pay more for green electricity, as they declare that energy source is for them more important than the price and...
reliability of the supply. The similar results were obtained in the large, national survey in 2014, where the energy source, as more important than price and reliability of supply, was marked by only c.a. 25% of respondents [70].

For the given sample size no correlation between WTP and income level (V-Cramer coefficient = 0.053) as well as monthly electricity bill (V-Cramer coefficient = 0.107) has been found. The lack of correlation can be explained by the size of the sample and distribution of the sample attributes.

3.1.3. Functional, social and knowledge values

In the pilot study consumers’ motivations to invest in RES (e.g. install solar panels) were investigated. Most of the respondents claimed to be willing to invest in RES. Among possible technologies most of them declared to invest in solar panels or photovoltaic (93%), then in wind (52%), in geothermic (28%), in hydro (17%) and in biomass (13%).

According to the received answers, for 31% respondents the cost of the installation is very crucial. Secondly, for 27% the operational cost (maintenance, service) and for 25% the effectiveness of the installation were important. Environment protection was marked by 15% and the support from the family and neighbors only by 2%. Surprisingly, 62% of respondents claimed that the opinions of their social network have no impact on their decisions regarding RES. On the other hand, 23% of respondents confirmed that they care about social opinions and acceptance. For 11% the advertisement of RES in mass-media is inspiring enough to invest in RES.

The Figure 3 shows the distribution of answers regarding the most important factors enhancing a consumer’s decision about investing in RES and their relation to the respondents’ WTP (Fig. 3). It can be observed that those who do not declare willingness to pay for RES and whose WTP is rather low (< 10%) are very sensitive to all kind of costs (investment & operational) and they care about effectiveness of investment. The environment protection and social influence are mainly important for the respondents with higher willingness to pay for RES.

Further, the respondents were asked to mark 2-3 issues that could convince them to invest in RES. The answers reveal that 28% of them chose functional values of renewables (meaning their cost, effectiveness and user-friendliness), 30% marked the satisfaction from being a prosumer and 30% an opportunity to get some financial support from various national and European programs. 12% claim that investing in RES is a good business. While comparing these answers with consumers’ WTP for RES, it was found out that financial support was mainly marked by the consumers with higher WTP (Fig. 4).
Fig. 4. Declarations regarding factors enhancing positive decisions of investing in RES with positive WTP towards RES, where FSU: financial support, GBI: good business, SAT: satisfaction, BEN: functional benefits, OTH: other factors.

No matter what their WTP was, the consumers cared about functional values of renewables and satisfaction of being a prosumer (only for consumers with WTP 25-50%, the satisfaction was on a relatively lower level).

It was also interesting to check how consumers already support RES (they could choose max. 3 answers). Most of them (89%) do not support renewables at all (even if their WTP for renewables is above 10%)! It is a clear example of the intention-behavior gap, when the declarations (willingness to pay for RES understood as positive evaluation of RES) is not transformed into any action. Then, 32% of respondents chose a green electricity tariff, and 16% was already a prosumer. 8% supported financially some NGOs devoted to renewables and some of the respondents work in the RES sector or was a member of Greenpeace (Fig. 5).

Fig. 5. Respondents’ preferences regarding the way of supporting RES.

Even though the pilot study has a lot of limitations, like: small size of the sample and internet bias (connected with rather young age of the respondents), it was possible to observe that although 60% of consumers declared willingness to pay a higher price for electricity if it would be green, actually only c.a. 30% would be really ready to pay more. The lack of smooth transformation from beliefs into actions is even more visible while looking at the fact, that c.a. 90% of respondents do not support green energy at all (even if they claim to have positive appraisal of renewables, and WTP> 0). It is a typical example of intention-behavior gap, when consumers declare some positive attitudes towards a product, but do not transform their opinions into actions. The respondents were sensitive to all kind of costs. They also claimed that satisfaction from being a prosumer would be important for them. Surprisingly, the consumers were not aware of the impact of their social network on their opinions and decisions (however, similar results were also obtained in the surveys by [39,42].

3.2. ABM for adoption of dynamic tariffs

Agent-based models are a useful tool to simulate and observe the impact of various parameters on the diffusion time and schedule [6,51,71,72]. In [53] by the means of a simple ABM the authors discuss the gap between consumers attitudes and behaviors towards dynamic electricity tariffs. The main conclusion is such that an intention-behavior gap is mainly caused by the instability of the consumers’ opinions (one day the consumer may be in favor of the dynamic pricing and a few days later she may be against it). Secondly, the higher is the level of consumers’ indifference and disengagement towards energy, the larger is the gap: even the positive opinions about the tariffs do not make consumers switch from a traditional flat tariff to the dynamic one, see [53,71,72].
Here, the extended version of this agent-based model is used to capture the issues regarding economic willingness to pay and its influence on the demand curve for a dynamic tariff. The model is widely described in [73]. Generally, this agent-based model is based on the concept of the reservation (marginal) prices. The reservation price is strongly related with the consumer’s willingness to pay, as it describes the appraisal of the product by the consumer. It is assumed that the consumers (agents in the model) will decide for a dynamic tariff, only if their reservation price (tariff’s appraisal) is higher than the actual market price of the tariff. Here, for simulating purposes, the market price of the dynamic tariff as well as its market share, is uniformly distributed on the interval from 0 to 1, where 1 indicates the highest market price and the highest market share.

In this model the evolution of the consumers’ reservation price is governed by two different processes: individual judgment (\(f\)) and social network (\(p\)) with mass-media influence (\(h\)). As shown in the model framework (Fig. 6) each agent behaves independently with some probability \(p\) and forms her opinion solely on the basis of individual judgment (see, [52]). With probability \(f\) the agent perceives high difficulty of adoption or finds the product unneeded and redundant (non-financial costs exceed benefits, e.g. adoption requires possessing some new skills or is connected with discomfort of usage, change of daily routine, etc.), see left panel of the Fig. 6. In the extreme situation, the agent will not be interested in the dynamic tariff at all (reservation price \(P_i=0\)).

![Model Flowchart]

Fig. 6. A model flowchart presenting the evolution of an agent’s reservation price within a single time step \(\Delta t\). \(P_i\) denotes the agent’s reservation price at time \(t\), whereas \(P_i^+\) the reservation price at time \(t + \Delta t\). Parameters: \(p\), \(f\), \(h\) and \(P\) denote probabilities of opinion dynamics. Notation e.g. \(P_i^+ \in U(P,1)\) indicates that reservation price takes a random value from the uniform distribution on the interval \((P,1)\), see [73].

On the other hand, if non-financial benefits of the adoption are higher than costs, then the agent evaluates the product positively and with probability \((1-f)\) the agent may assign a new reservation price. The update of the reservation price is possible only if the agent’s opinion about the tariff has been changed. The probability of the opinion change depends here solely on the market price \(P\) of the good. In this particular case, the market price of the tariff can be understood as its relative cost (both financial and non-financial) in comparison to other similar offerings (i.e. green or flat tariffs). The model assumes that the consumer is more likely to switch to a positive opinion, when the market price is low than when it is high [52,73].

Secondly, with probability \((1-p)\) the agent is exposed to social influence and advertising (see right panel of the Fig. 6). In the model it is assumed that the agent interacts with a group of close neighbors (here limited to \(q=4\)). If this group unanimously share the same (positive or negative) opinion about the product, the agent will conform and choose a new reservation price, higher or lower than before. What distinguishes this approach is that social influence, in particular word of mouth (WOM), can act in both directions: increasing or decreasing the reservation price, depending on the unanimous positive or negative opinion of the group about the product. The idea of the group’s unanimity is explained in [71,72]. If the group of neighbors is not unanimous, the agent will be exposed to advertising. In the model it is assumed that advertising can only increase the consumer appraisal of the product, by rising the reservation price of the agent, with some probability \(h\). The results are calculated analytically by the
method called mean-field analysis for complete graphs. This method allows to calculate the stationary values of adoption rate. Complete graph is such a network topology, where each agent is connected with every other agent and therefore they are all neighbors. The model’s parameters and the method are described in details in [73].

3.2.1. Impact of individual judgement and advertisement on the demand curves

In the Fig 7. the demand curves for constant value of parameter \( p \) (here, \( p=0.4 \)) are presented. The demand curves illustrate the law of demand, which says that the lower is the price of the good, the higher is the quantity demanded by the consumers. Here, the impact of the individual judgment \( (f) \) and advertisement \( (h) \) on the demand curve is examined.

![Graph](image)

**Fig. 7. Demand curves for model with \( p=0.4 \) and different values of parameters \( p, f \) and \( h \).**

The solid line shows the basic case with no perceived difficulty of adoption and no advertisement (both \( f=h=0 \)). Then, the dashed line represents the situation when the consumer perceives more non-financial costs than benefits \( (f>0) \) of switching into the dynamic tariff. The value of the parameter \( f \) indicates that consumer perceives with probability e.g. \( f=0.4 \) more non-financial cost (obstacles) than benefits of adoption and with probability \( (1-f=0.6) \) more benefits than costs. It such a case the demand curve shifts downwards in comparison to the initial model with \( f=h=0 \), no matter what the market price of the dynamic tariff is. Finally, the demand curve denoted in dash-dot line shows the model with advertising \( h>0 \) and \( f=0 \). If an advertising effect is positive, the demand curve shifts upwards in comparison to the initial model. That is why, the advertisement effect \( (h) \) increases the market share even for higher market prices. So far, in case of dynamic tariffs consumers rather do not evaluate them positively (low reservation prices). Most of the consumers perceive high difficulty of adoption (high \( f \)), because of lack of knowledge, advice, confusion of choice and discomfort of usage. There is almost no education and positive mass-media advertisement of these services, so \( h \) is close to 0. It explains why so far the high market penetration rates of dynamic tariffs as well as high adoption rates cannot be achieved.

Now let’s examine how social influence (WOM) will change the shape of the demand curves, for various values of parameters \( f \) and \( h \). Is it possible to increase the market share of the dynamic tariffs, if people start talking and sharing information about the tariffs? Does it matter whether the word-of-mouth is positive or negative?
3.2.2. Impact of social influence on the demand curves

As the upper panel in Fig. 8 indicates, for $f=h=0$, on one hand, if the parameter $p$ is low (e.g. $p=0.1$ or $0.2$), the impact of WOM (here, $1-p$) is strong. It means that agents, with high probability, follow the opinions of their social network. On the other hand, if $p=1$, there is no WOM and the demand curve has a linear shape (see, a dotted line). It can be also seen that for high market prices of the dynamic tariffs (e.g. $P=0.6$ and more), the smaller is the parameter $p$, the lower is the quantity demanded (demand curve shifts downwards, what decreases the market share). For low market prices (e.g. $P=0.3$ or less), the smaller is the parameter $p$, the higher is the quantity demanded (demand curve shifts upwards, what increases the market share). In other words, dependent on the market price of the good, WOM shifts the demand curve in opposite directions. Strong WOM reduces the demand for high market prices and increases the demand for low market prices.

In the middle panel of Fig. 8 for $f=0.4$ and $h=0$, the perceived difficulty of adoption combined with a strong WOM (e.g. $p=0.1$) may limit or even stop the diffusion of the product. The quantity demanded is very low or equals zero, even if the product is offered for free. Such a situation is often observed for dynamic tariffs, when consumers usually perceive much more costs than benefits (like, e.g. discomfort of usage, change in the daily routine, limited financial savings, etc.). In the bottom panel of Fig. 8 the positive effect of the advertisement ($h$) is combined with WOM. Similarly to the upper panel, we may observe two price regimes: for high market prices strong WOM decreases the demand curves and for low market prices it boosts the diffusion.

A simple agent-based model has been used to investigate how consumers’ individual judgement of the perceived non-financial cost and benefits of adoption of dynamic tariffs as well as social influence (WOM) and mass-media advertisement impact the shape of the demand curves and the market penetration of the dynamic tariffs. As the results show, WOM may change the impact of individual judgement and advertising. The effect depends strongly on the market prices of the dynamic electricity tariffs (in relation to other types of tariffs: green or flat). If the prices are high, WOM reduce positive impact of advertising and strengthens the impact of
adoption difficulty. For low market prices the effect of WOM acts in opposite directions by weakening the effect of adoption difficulty and strengthening the effect of advertising.

4. Conclusions and policy recommendations

The papers deals with the incentives and barriers of adoption of innovative energy services, like: green energy technologies, green or dynamic tariffs or smart metering information systems. The successful diffusion of these services and gaining large market penetration rates require consumer engagement and interest. As the literature review indicates there is a wide range of factors that influence consumer behavior and decision making process in the energy market. Without any doubt, the awareness of the innovation, access to information and advice are extremely crucial and fundamental. Then, the social influence plays a great role, even if its impact is not so obvious to the consumers (they claim, that they do not pay any attention to what their neighbors are saying and doing). The rest of the factors, like e.g. consumers’ attitudes, values and beliefs or their perceived difficulty of adoption also influence the consumers’ willingness to adopt and their final actions.

Currently, the diffusion of the innovative energy services is still at the beginning. Even if the usage of most of these services is in social interest (because these services increase energy efficiency and environment protection), people generally are not interested in using them. They perceive more obstacles and disadvantages than benefits from adoption. The pilot study, as well as other surveys prove that even declared willingness to pay for green energy (so positive appraisal of these energy sources) does not necessarily transfer into certain behaviors (in this case e.g. choosing green tariff or investing in RES). So called, intention-behavior gap exists and it is not easy to eliminate it.

Then, as the results of the agent-based model point, social influence (mainly WOM) can either increase or decrease adoption and the market share of the product, dependent on the market price of the good. If the market prices are high (e.g. dynamic tariffs are more expensive than flat tariffs), people more probably share negative information about the tariff, so WOM will strengthen the negative impact of the perceived difficulty of adoption and weaken the positive effect of the advertisement. If the market prices are low, WOM strengthens the positive effect of advertisement and reduces the negative impact of difficulty of adoption. This knowledge should be used by energy suppliers while designing a new kind of a tariff. Conditional on a targeted market penetration level and a market price of the good, they should aim on strengthening or weakening the WOM effect, in particular by encouraging the individualistic (to minimize the impact of WOM) or collective (to maximize the social influence) decision making and market behavior of the consumers.

To overcome the barriers of adoption and to increase the adoption rates, the following actions should be taken:

- Increase awareness and understanding by messaging via all possible communication channels (using also social media, social events or friend referral programs).
- The positive word of mouth (e.g. recommendation from already adopted friends and neighbors) and some confident information from mass-media would be also helpful. Creating of strong social norms and critical mass to boost adoption rates are needed.
- Information should be displayed in an easy and clear way to reduce confusion. A good feedback system for the users and suppliers is needed. Such a feedback system could play a motivational role, informing whether e.g. after signing to dynamic pricing program consumers’ energy efficiency has increased or not; how well they are doing in comparison to their neighbors, etc.
- To reduce perceived difficulty of adoption, like fear of change and disinterest, designers of the innovative energy services should focus on access to information and advice, ease of usage and potential financial savings. In case of the latter, as most of the innovative energy services offer neither fast payback periods nor high savings or incomes, it is very important to emphasize all other potential gains on societal and personal levels. The designers of the innovative services should also care about educating consumers and teaching them how to use modern innovative energy services. Consumers could be also offered some trial products for free (e.g. in-home displays).
- The innovative energy services should not be promoted generically. As the literature suggests, the individual promotion of the certain e.g. green technologies, particular DSM/DR tools or enabling technologies is much more efficient in creating consumers’ willingness to pay and to adopt.
- A process of signing up, while deciding on green or dynamic tariffs should be fast and easy.
- In case of SM platforms the attention on data privacy and security is needed.
To summarize, the enrollment percentage and the market share of the innovative energy services will rise as a byproduct of increasing awareness, understanding and interest. The goal is to increase perceived benefits and to reduce adoption barriers. It must be underlined that people differ in terms of their thresholds for benefits and barriers. Hence, to promote the innovative energy services in a right way, a segmentation of the consumers would be needed regarding their level of awareness, knowledge, values, beliefs, motivations and other socioeconomic parameters. In the future research such a segmentation of the consumers is planned in order to propose right marketing strategies to boost diffusion of the innovative energy services.

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References


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