Energy Efficiency (2014) 7:973–985
DOI 10.1007/s12053-014-9271-9

ORIGINAL ARTICLE

Factors that influence consumers' acceptance of future energy systems: the effects of adjustment type, production level, and price

Fenna R. M. Leijten · Jan Willem Bolderdijk · Kees Keizer · Madelijne Gorsira · Ellen van der Werff · Linda Steg

Received: 12 May 2014 / Accepted: 29 May 2014 / Published online: 8 June 2014

Abstract To promote the successful introduction of sustainable energy systems, more insight is needed into factors influencing consumer's acceptance of future energy systems. A questionnaire study among 139 Dutch citizens (aged 18–85) was conducted. Participants rated the acceptability of energy systems made up of four varying system attributes: type of energy (renewable or fossil), price (remains stable vs. 25 % increase), adjustments in use (convenience technology or consumers themselves decide on what to change), and production level (energy is produced at a central vs. community vs. household level). Conjoint analyses were conducted to determine the overall acceptability of future energy systems, the relative importance of the various attributes for acceptability, and preference for levels within each attribute. Interesting patterns were uncovered: participants preferred making adjustments in use themselves (autonomous), rather than relying on technology to make the changes for them. Consumers did not exhibit a clear preference for any of the presented production levels, indicating that they would be open to change in this energy system attribute. Because participants preferred energy systems in which adjustments in use are made autonomously and because adjustment type was very important for overall acceptability of energy systems, technological developers and policy makers should take this into consideration.

Keywords Energy systems · Consumer acceptance · Conjoint analyses · Autonomous · Convenience

Introduction

The combustion of fossil fuels causes detrimental environmental problems, mainly through the emission of greenhouse gases. Carbon dioxide emission can be largely accounted for by the use of (primarily fossil) energy sources (Abrahamse et al. 2005). Furthermore, the future of the use of fossil energy sources is made uncertain both by the exhaustion of resources and the dependence on politically unstable countries for the remainders. Even with the growing societal awareness of energy sources depletion and environmental devastation, energy-use continues to increase due to economic and developmental expansion (Abrahamse et al. 2005). In order to keep up with energy demands and to meet international agreements on emissions, a transition to the use of renewable energy sources and efficient use of these resources is necessary.

It is therefore essential to better understand how to promote the transition towards a sustainable energy system at the macro and meso (e.g., political, technological, institutional) levels and at the micro (e.g., individual, household) level. At the macro and meso levels changes include, among others, technological progress towards efficient production and distribution of

F. R. M. Leijten · J. W. Bolderdijk · K. Keizer · M. Gorsira · E. van der Werff · L. Steg (✉)
Faculty of Behavioural and Social Sciences, University of Groningen, Grote Kruisstraat 2/1, 9712 TS Groningen, The Netherlands
e-mail: e.m.steg@rug.nl

renewable energy sources, changes in institutional and legal arrangements, the introduction of prosumers (who produce and use their own energy) and establishment of new companies that trade energy, and (inter) national policies that stimulate such a transition. Research on both requirements and feasibility of energy transitions, for example, on alternative energy sources such as solar, geothermal, and wind energy (Martins and Pereira 2011; Burkhardt et al. 2011; Grothe and Schnieders 2011) have shown that different renewable energy sources can be employed to meet energy demand. Additionally, research points towards the potentials of smart grids in advancing the energy transition (Gellings and Samotyj 2013; Clastres 2011; Oldfield 2011). Smart grids aim to manage energy flows, e.g., via automated technology and incentives delivered via ICT systems, by optimally matching energy demand and supply at a given moment. Hence, future energy systems are likely to differ in many different respects from the current energy system.

If the advantageous effects of macro and meso levels changes and smart grids are to be realized, it is essential to consider the substantial and hopefully malleable role that consumers, at the household [micro] level, have in the total energy transition. Individual consumers should find the expected changes in energy systems acceptable and be willing to adopt such new energy systems in order for them to be effective. Therefore, it is crucial to better understand how individual consumers evaluate different characteristics of future sustainable energy systems, which affect the overall acceptability of such energy systems. The current research aims to address a central question for the successful energy transition on the micro level: how acceptable do individual consumers find possible future energy systems and specific attributes of such systems? Answers to these questions will provide knowledge on which attributes are deemed most acceptable, relative to one another, for consumers and how future energy systems can best be designed to enhance consumer acceptability. Further, the findings can add to the discussion of the individual consumer [household]-technology interaction that will become increasingly important in the energy transition.

Individual consumers play a key role in energy transitions, as they are responsible for a substantial part of total energy consumption. For example, of total energy consumption in the USA and the European Union, household use accounts for 42 and 29 %, respectively (Palmer et al. 2013; Hansla 2011). In a recent Danish study, it was concluded that [household] energy consumers' behavior is at least equally as important as efficient technology for household energy consumption reductions (Hanssen-Gram 2013); yet the authors note that energy-efficient technology should be acceptable, making the role of individual consumers even more significant. Research on acceptability of novel energy systems and technologies has typically focused on specific facets at the micro level, such as: what do consumers think of green renewable energy, and how much are they willing to pay for it? (Marcus and Jean 2009; Gerpott and Mahmudova 2010; Whitehead and Cherry 2007; Bolsen and Cook 2008; Niemeyer 2010; Laroche et al. 2001), are consumers willing to change their energy-use behavior to reduce overall energy demand? (Abrahamse et al. 2005; Press and Arnould 2009), which strategies are effective to reduce household energy use? (Abrahamse and Steg 2013; Abrahamse et al. 2005; Steg and Abrahamse 2010), and what do consumers think about smart grids or owning solar panels? (Wood and Newborough 2003; Faiers et al. 2007). These lines of research provide valuable insights about consumer attitudes towards specific parts of energy systems. The current study expands upon this by incorporating different attributes simultaneously and focusing on how acceptable consumers find certain possible future energy systems in general, and determining the relative importance of specific attributes for the overall acceptability of energy systems. We aim to study the unique contribution of different attributes while controlling for possible confounding factors. Four attributes of energy systems were assessed that are likely to change in the transition to sustainable energy systems, namely: type of energy (green or gray), how adjustments in energy use are made in order to increase the efficiency of the system (autonomously or via technology), the level of energy production (central, small community, or household), and price (stable or 25 % increase). Each of these energy system attributes and their respective levels are explained in further detail below (see Table 1 for an overview).

Type of energy

A transition to green energy—energy obtained from renewable sources—has been slowly developing since the early 1990s. Most energy suppliers now offer consumers a choice between green and “gray” energy (the latter being obtained from traditional fossil fuel

Table 1 Energy system attributes and their levels

Attribute	Level	Symbol	Definition
Type of Energy: What is the source of the energy?	Gray		Produced from raw materials such as oil, coal or natural gas
	Green		Produced from renewable and sustainable resources such as sun and wind
Price: How much will the energy cost?	Stable	=	
	Increase by 25 %	^	
Adjustment: How will adjustments in energy use be made?	Autonomous	A	Individuals will adjust usage behavior manually to adjust demand to available supply
	Convenience technology	C	Technological devices will adjust demand to match available supply
Production Level: Who will provide the energy?	Central	O	Energy providers will continue supplying energy
	Small community	X	Community of households will produce and use energy together
	Household	*	An individual household will produce and use its own energy

= Stable, ^ 25 % Increase, *A* Autonomous, *C* Convenience Technology, * Household, *X* Community, *O* Central

sources), and increasingly, consumers started to produce their own energy (and hence become prosumers), either individually or in local collectives. Green energy sources—particularly energy from solar, wind, and geothermal energy—are renewable and have less negative effects on the environment, because they generally emit less CO_2 and are thus more sustainable than traditional fossil energy sources. In this research, we studied the relative impact of individual consumers' preference for green versus gray energy for overall energy system acceptability.

Adjustment type

The current energy system requires abundant energy production to accommodate for high peaks in energy demand at certain times. Production capacity is now directed towards these peak demands. If peak demands can be leveled out, less capacity will be necessary. This will improve efficiency of the system and will have beneficial outcomes for the environment, and in turn will be likely to reduce energy prices. Further, adjustments in time of use may be even more needed if green energy sources, such as wind and solar energy, are more widely used because these sources may not be readily and equally available at all times of the year or day. In order to promote modifications of demands to available supply, individual consumers can adjust their energy use, for example by shifting the use of certain appliances to times of the day when much energy is available rather than using these appliances at times where energy demand is already high. Adjustment type thus refers to adjustments in energy use, i.e., how energy demand in households is managed. Individuals can make these adjustments themselves by continuously monitoring whether their demand does not exceed the momentary supply, and adapt their demand in line with the available supply at that moment. They can do so voluntarily, but in addition, different incentives can be implemented to motivate people to make these adjustments themselves. For example, time-dependent energy price, e.g., cheaper energy in the evening when demand is low, is an example of an incentive for individuals to make changes in use autonomously. Another option is the implementation of convenience technology, which can switch apparatuses on and off automatically at specific times to automatically balance demand and supply. In this case, consumers do not have to monitor energy use and decide when to switch appliances on and of, as this is delegated to convenience technology. Such a technology is already being tested in pilot smart grid projects, as to regulate energy demand for a community of households in order to efficiently use energy and eliminate peaks in demand (Clastres 2011). It is hypothesized that different considerations may play a role when opting for either autonomous changes in use (e.g., a sense of control and exercising influence over own use behavior) or convenience technology changes in use (e.g., ease, time-saving for other activities) (e.g., De Groot and Steg 2008; Steg et al. 2012). It is important to know whether consumers will accept and utilize such convenience technology, or whether they prefer to remain autonomous in making adjustments in energy use. This knowledge will offer guidelines for how technology should be designed or implemented in order to accommodate user preferences and thus create acceptability for such new systems.

Production level

Increased energy system efficiency can be further achieved through local production of energy. Currently, energy is largely produced and provided for at a central level: large energy suppliers bring energy to households. This process is relatively inefficient, as primary energy is lost in transport due to a large distance between energy production and consumption. An alternative to this central production is local or home-based production and distribution of energy, for instance via small communities owning a windmill, individual households placing solar panels on their roofs to provide for their own energy, or micro-combined generators. So, it is important to know to what extent consumers prefer energy production on a central, local or household level, and how important production level is for acceptability of energy systems relative to the other attributes described above.

Price

One drawback of the use of green energy is that it is currently often (perceived to be) more expensive than fossil energy. We studied the role of price in overall energy system preferences, because past research has indicated that price is very important to consumers (Whitehead and Cherry 2007). However, little is known about how important price of energy is for consumer acceptability of different energy systems relative to other system attributes. Although it is highly likely that consumers will prefer a stable price over an increase, we included price in the energy system scenarios because price, as it is so important to consumers, would then determine their preferences for other energy system attributes on the basis of assumptions they have. For example, if consumers believe that convenience technology is very expensive they will be less likely to accept an energy system including convenience technology, not because they do not like the technology as such, but because they think it would be expensive. By including price level in the scenario, we aim to prevent such possible confounding. In addition, we studied the importance of price levels relative to the other factors included in our study, as we believe it is vital to compare the importance of price in relation to other attributes of energy systems, to get insight into consumer's priorities.

The current study

The goal of the current research was to uncover which energy systems consumers find acceptable, which attributes are important in determining this acceptability, and which levels within the attributes consumers prefer. Specifically, the two main research questions in this study are:

1. What is the relative importance of type of energy, adjustments in use, production level, and price for overall energy system acceptability?
2. To what extent do consumers prefer:

   (a) autonomous or convenience adjustments in use?
   (b) central, local or household production level?
   (c) an increased or stable price?

The identification of which attributes are most and least important in determining consumer energy system acceptability can give direction for the future development and implementation of the energy transition. If certain energy system attributes, and changes herein, on the micro level are more easily accepted than others, decisions on future expenditures and research at the macro level can be made in accordance.

Methods

Respondents and procedure

The current research was carried out in the Netherlands in November of 2010. A questionnaire was posted on ThesisTools, an online questionnaire host. ThesisTools contacted, via email, a random sample from their panel to participate in the study. In total 139 questionnaires were completed. Participants were 87 males and 47 females; 5 did not indicate their gender. Aged ranged from 18 and 85 (M=55.5, SD=14.47). Our sample was representative of the Dutch population with respect to monthly income, completed education level and household compilation (compared to information from Statistics Netherlands; statline.cbs.nl accessed 2010).

Participants first read a general text on future energy systems in the Netherlands that will use relatively more energy from renewable sources and have less detrimental effects on the environment:

> It is likely that in the future more sustainable energy will be used. Sustainable energy is produced from renewable sources, such as the sun or the wind, and as a result emits little CO_2. Partly because of the greater portion of sustainable energy, the way in which energy will be supplied to households will change. Your opinion on future energy systems is very important for how this new system will take form. The new energy facilities can take many forms, depending on, for example, the price of energy or who is responsible for the production and supply of energy. Important decisions need to be made about these aspects of energy.

Hereafter, they read about the four energy system attributes that were discussed in the "Introduction" section, and their respective levels (for an overview, see Table 1). We first provided a more extensive description of the attributes, and indicated levels of these attributes that we distinguished (i.e., which choices have to be made regarding each attribute). Next, we indicated how we referred to these attributes in the remaining parts of the questionnaire.

The first attribute, price, was described as follows: "The price of energy in the future can 1) stay the same, 2) slightly increase". The levels of price were described as follows: "stable price: price of energy remains stable" and "slight increase: price of energy increases with 25 % in the next five years".[1]

The second attribute described was adjustments in energy use, and was described as follows:

> There are certain times in the day (for example around dinner time) when many people use a lot of energy at the same time, while at other times (for example at night) much less energy is used. In order to keep up with energy demand at peak times more energy has to be produced that is not needed at non-peak times. In order to make the production of energy more efficient, it is necessary that the demand for energy is spread out throughout the day. Thus it is necessary that certain devices, such as washing machines, are only used during non-peak times. There are two ways in which future energy use can be spread out across the day: 1) technology turns certain devices on during non-peak times (when energy demand is low), or 2) you yourself decide which devices you don't turn on until non-peak times. In both cases it will not be possible to use all household devices at once during peak times.

Hence, two levels of adjustments in energy use were included: convenience technology or autonomy. Convenience technology was described as follows: "Convenience technology turns on devices during non-peak times: Convenience technology (for example a grid in the house) turns devices (for example your washing machine) on only when there is a large supply of energy, you don't have to do anything yourself. You do not have control over which devices will be turned on during non-peak times." Autonomy was described as follows: "You yourself decide which devices you will use during non-peak times: You have to make decisions yourself about which devices you will wait to use until there is a large supply of energy (for example your washing machine). You have control over which devices will be turned on at non-peak times."

The third attribute, production level, was described as follows:

> The way that energy is delivered can be done in different ways in the future: 1) the energy company is responsible for the supply of energy, 2) you are, together with your community, responsible for the supply of energy, 3) you yourself are responsible for the supply of energy. For all options the supplied energy can be **green** or **gray**.

Next, three levels of production level were described as follows: "Energy company: The energy company takes care of the supply of energy (for example in a park with solar panels)", "Community: You, together with people in your community, are responsible for the supply of energy (for example by placing solar panels on the roof of a local school)", and "Individual: You yourself are responsible for the supply of energy (for example by placing solar panels on the roof of your house)".

[1] After discussion with various market parties (energy distribution companies), we decided that 25 % would constitute a plausible price increase.

The fourth attribute, type of energy, was described as: "Green energy is generated by renewable sources, such as the sun or wind. Green energy emits little CO_2 and thus has a less negative effect on the environment than gray energy, which is generated from fossil fuels (for example gas or coal). Currently in the Netherlands mostly gray energy is used." Hence, two levels of energy systems were included, green and gray.

After reading about the energy system attributes, two tasks were presented that measured the importance of the different attributes for overall energy system acceptability in a direct and indirect way. In the direct method, participants rated the importance of four energy system attributes separately for overall energy system acceptability. In the indirect method, through a conjoint analysis, information was also obtained on participants' acceptance of these energy system attributes. This was done through scenarios that were based on systematic combinations of variations in the four attributes. The two measures will be described in further detail below. We used the indirect method alongside a direct method in order to check for social desirable answers in the direct method; for example, persons may not directly admit they do not want to pay more for sustainable energy systems. Also, using both methods allowed us to check for the robustness of our findings. Hereafter, participants filled in demographic information. The questionnaire took about 20 min to complete.

Throughout this article, we discuss the direct measurement prior to the indirect measurement, because this provides basic information that is expanded upon by the indirect measurement. In the questionnaire, the indirect measurement preceded the direct measurement so that participants would not try to be consistent in filling in the indirect task with their answers in the direct measurement.

Measures and analyses

Direct measurement

The direct measurement assessed what role the four attributes had in energy system preferences; including green or gray energy (this attribute was not included in the indirect measurement). Participants were asked "What role do the following aspects play in *your* preference for future energy systems?" concerning type of energy, way of adjusting energy use, production level of energy, and price on a 7-point Likert scale from "1: No role at all" to "7: Very large role".

Indirect measurement

Participants evaluated different scenarios describing possible future energy system with systematically varied levels within the attributes as was explained above and can be seen in Table 1. We varied these levels within the attributes order to gain insight into what is important for consumers in accepting energy systems, that is, which specific aspects of the attribute attract or deter consumers from these systems. A pilot study showed that incorporating all four attributes with their respective levels made the conjoint experiment too extensive and overwhelming ($2\times2\times2\times3=24$ scenarios). Therefore, we choose to leave out type of energy (green or gray) because it is highly likely that future energy systems will mainly use renewable sources, and thus this is less controversial and open for discussion. Hence, the indirect method incorporated three of the attributes that are particularly important *within* a green energy system: price, adjustments, and production level, resulting in 12 ($2\times2\times3$) energy system scenarios. Participants were asked to rate the acceptability of the 12 energy systems on a seven-point Likert scale. A score of "1" on the scale meant that the participant found the system very unacceptable and a score of "7" meant that the system was very acceptable. This provided us with basic descriptive information on which energy system was the most, to least, preferred.

The following instructions were presented to participants:

> Below 12 different energy systems are described that vary with regard to the three aspects of energy that are described above. Mark for each energy system how acceptable you think it is if an energy system would take form in this way. It is important that you give your opinion about all 12 energy systems, because this is the only way that we can gain an insight into what you find important for the facilities of energy. Do not take too much time to think, we are interested in your first reactions. Judge each energy system independently; it is not necessary to take into account what you filled in earlier.

Participants had already read extensive descriptions of the energy system attributes and their levels, and thus in the scenarios only brief descriptions were given, for example: "Energy system 1: Price of energy will remain stable/Convenience technology turns devices on/You provide the supply of energy yourself."

We compared the importance of each attribute for energy system acceptability and assessed the preferences for the different levels within the attributes using a Conjoint Analysis in SPSS 16. Conjoint analyses are frequently used in market research to assess how important specific attributes of a product are for consumers (Green and Srinivasan 1990; Louviere 1988). Individuals' preferences for products are presumed to be compiled of preferences for discrete aspects of the product. Product choices are thought to be made up of multiple trade-offs in attribute levels. By means of a Conjoint Analysis, we could make comparisons between the importance of attributes in relation to one another in energy system acceptability (importance values). Further, we could point out the preferred levels within each attribute (utility estimates).

A Conjoint Analysis yields two relevant statistics: average importance values (I.V.) and utility values. I.V.'s are calculated for each attribute separately, and reflect the relative importance of each attribute (i.e., price, adjustment, and production level) in overall energy system acceptance relative to one another. An attribute's I.V. represents a percentage (the sum of all attribute I.V.s is 100), thus an I.V. represent the importance of an attribute relative to the other attributes being varied. The higher the I.V. of an attribute, the more weight that attribute carries in the total acceptability of the relevant energy system. Utilities come forth from a regression formula that a Conjoint Analysis produces for each participant. These regression formulas include one constant and utility values for each attribute. Utility values, also called part-worth scores, indicate a valuation of a level *within* an attribute, compared to other levels within that same attribute, in making a choice. Utilities thus give the direction of the preference: for example, a large utility value for an increase in price indicates that this specific level within the attribute price plays a large role in an individual's overall acceptability of an energy system scenario. Averaged utility values also provide information about which level within each attribute (for example for price: stability or 25 % increase) is preferred across the sample.

Design

The experimental approach used in the current study, specifically the conjoint analysis, is a well-established method that is frequently used in different disciplines (i.e., "discrete choice experiments"). This is a rigorous method that enables a researcher to exercise much control over the choice situation in order to determine the effects of independent variables on dependent variables when all other variables are kept constant (and are thus controlled for). The method enabled us to examine weighted preferences and partially eliminates social desirability effects. As in any study, high control over a situation (high internal validity), which gives key insights in which general principles play a role (so that results can be generalized to other situations), comes at a price: we do not take into account the full complexity of the real world (Pelham and Blanton 2012).

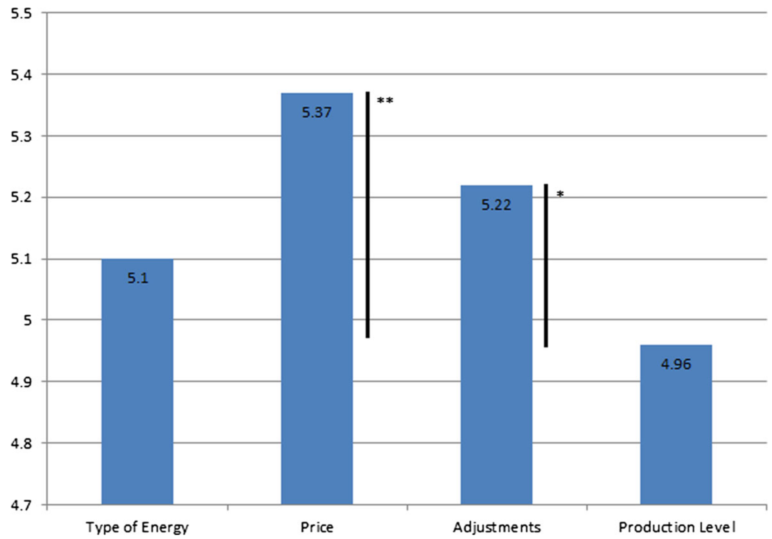
Results

The results from the direct, self-reported preference, analyses are presented first, hereafter the indirect conjoint analyses findings are reported.

Direct measurement

By comparing the mean scores on the importance ratings of the four attributes in the direct measurement, we could examine the relative importance of each of the attributes. Not surprisingly, we found that, on average, price was considered to be the most important attribute (M=5.37) in determining overall energy system preference. The importance of price was followed closely by how adjustments in energy use were made—either autonomously by the individual household, or through convenience technology (M=5.22). Hereafter, whether the energy being provided was green or gray (type of energy) played a slightly smaller role (M=5.10) in future energy system preferences. However, the self-reported importance of these three attributes in energy system preferences did not significantly differ from one another (all $p>0.05$). The least important attribute for future energy system preferences was production level (M=4.96). The role that production level played was significantly lower than the role that price and adjustment played (respectively, $p<0.01$ and $p<0.05$, see Fig. 1). All four attributes had mean scores above the

Fig. 1 Mean Importance of Attributes for Energy Systems Preferences. Note: Scores could vary from 1, "no role in energy system preferences" to 7 "large role in energy system preferences". Price and adjustments compared to production level. *Significant at $p<0.05$. **Significant at the $p<0.01$



half-way mark of 3.5 on the scale, suggesting that all factors are deemed to be important in future energy system preferences.

Indirect measurement

Whereas the direct assessment provided insight in attribute importance for overall energy system preferences, the Conjoint Analysis provides details on what attribute trade-offs individuals made when rating overall energy system acceptability, as the different system characteristics are evaluated simultaneously. From the indirect acceptability assessment of the 12 energy systems, three interconnected findings are reported: descriptives of preferences, importance values, and utility scores.

Descriptives: acceptability of specific energy systems

Prior to conducting the conjoint analysis, we ordered the 12 energy system scenarios on the basis of their average acceptability ratings (range 1–7; see Table 2). From these ratings, it is apparent that the six most acceptable systems (*M* ranges from 4.20–6.50) all have a stable energy price rather than a 25 % price increase. Moreover, the three most acceptable systems all also included autonomous adjustments rather than convenience technology adjustments. The six least accepted systems (*M* ranges from 2.94–4.00) include a 25 % increase in price and involved adjusting energy use via technological devices. From this preliminary table of acceptability ranking, acceptability ratings seem to most strongly depend on price and the way in which adjustments in energy use are made, whereas production level shows less consistent acceptability patterns. This finding is similar to the findings from the direct assessment.

Conjoint analysis

The I.V.s from the conjoint analysis indicate the relative influence, in the form of a percentage, an attribute has in

Table 2 Energy systems ordered based on their average acceptability ratings

System acceptability rank	Mean acceptability	Energy system attribute		
		Price	Adjustment	Production level
1	5.50	=	A	O
2	5.35	=	A	*
3	5.07	=	A	X
4	4.36	=	C	O
5	4.28	=	C	X
6	4.20	=	C	*
7	4.00	^	A	O
8	3.70	^	A	X
9	3.69	^	A	*
10	3.17	^	C	O
11	2.95	^	C	X
12	2.94	^	C	*

= Stable, ^ 25 % Increase, *A* Autonomous, *C* Convenience Technology, * Household, *X* Community, *O* Central determining overall energy system acceptability (100 %). This analysis (see Table 3) revealed that price, with an importance value of 53.06, was considered to be the most important in determining overall energy system acceptability. This was followed by how adjustments were made (I.V.=35.27). Production level was considered least important (I.V.=11.67). Hence, the order of the ranking of the importance of the attributes found here was the same as found in the direct assessment (refer back to Fig. 1), although the differences in importance values are more pronounced in the indirect task.

The utility estimate results (see last column Table 3) provide further details on the trade-offs individuals make in. The utility estimates (U.E.) indicate which levels within each attribute are most acceptable. Not surprisingly, we see that a stable price is largely preferred (U.E.= 0.70) over an increase in price (U.E.=−0.70). Furthermore, participants preferred to make adjustments in energy use themselves (autonomous, U.E.=0.47) as opposed to having convenience technology do this (U.E.=−0.47). Moreover, a central production level was most preferred (U.E.=0.17), followed by household's producing energy themselves (U.E.=−0.03) and lastly producing energy at the community level (U.E.=−0.14).

Discussion

Summary of the findings

Understanding consumers' acceptability of future energy systems is highly relevant and should incorporated in the development of new policies and technology aimed at changing current preferences in order to further the energy transition. In the direct method, all mean scores were above the half-way mark, indicating that type of energy, adjustment type, production level, and price were all deemed to be important for acceptability of future energy systems. Answering our first research questions, on the robust basis of both the direct and indirect method, we conclude that after price, adjustment type is considered the most important factor, while production level is the least in determining energy system preference and acceptability. Concerning the second research question, autonomous adjustments in use, central production level, and a stable price were the preferred levels within the energy system attributes.

Table 3 Results of the conjoint analysis of energy system acceptability

Attribute	Average importance value	Level	Utility estimate
Price	53.06	Equal	0.70
		Increase by 25 %	−0.70
Adjustment	35.27	Autonomous	0.47
		Convenience technology	−0.47
Production Level	11.67	Central	0.17
		Community	−0.14
		Household	−0.03
Constant			4.03

Adjustments in use

How adjustments are made was found to be an important aspect in overall energy system acceptability with making autonomous changes largely being preferred over convenience technology. It seems that consumers prioritize autonomy above convenience in use and comfort. This is an interesting finding, because convenience seems to be an important consideration in decisions people make in other consumer domains, such as an automatic timer on a heating system in the winter that turns the heat lower during working hours. This finding has also important practical implications, as large portions of research and development on sustainable energy systems is expended on technological advancements to develop convenience technology as an ideal instrument to match energy demand and supply efficiently. Our finding implies that such technological advancements should pay special attention to the level of (perceived) control provided by the relevant systems. Also, convenience technology is likely to be more effective in managing energy demand and supply compared to autonomous changes, as the latter involve changing well-established energy-use habits and continuous monitoring of one's energy use, which may prove difficult to realize. Yet, our findings indicate that consumers may not yet be ready or open for these types of advances.

Further research needs to be conducted to discover what the main concerns related to the use of convenience technology are, and under which circumstances individual consumers accept and are willing to make use of such convenience technology, in order to tailor the development of such devices in this direction. Also, such studies could examine how convenience technology can best be designed to meet consumer concerns and wishes, for example, by allowing consumers to overrule the system when needed which may meet their need for autonomy. Thus, although convenience technology may sound attractive from a purely hedonic perspective, technicians should not forget that people also have other motives, such as feeling competent and autonomous (Deci and Ryan 1985), which may lead them to favor technologies which offer them more (perceived) control. The relatively strong preference for autonomous adjustments depicts how essential it is to consider consumer preferences in the construction of future energy systems. Technology that is convenient in that demand is automatically adjusted to supply to some extent and at the same time safeguards feelings of autonomy in behavioral choices would possibly suit consumer preferences.

Production level

Production level was the least important energy system attribute. The findings from the direct assessment task were in accordance with the results from the indirect task, that revealed that scenarios in which production level was varied were not consistently evaluated as very high or low on acceptability (see Table 2), and the conjoint analysis revealed that its importance value was much lower than that of the type of adjustment and price. This suggests that consumers' acceptability of overall energy systems is not substantially determined by production level and thus consumers will be less opposed and more open to changes herein. This finding is surprising as previous studies suggest that consumers are keen to participate in local initiatives, which suggests that they would strongly prefer to produce energy themselves or in their local community. Future research should explore preferences for production level in more detail as to make sure that consumer preferences are optimally addressed in the specific design of the relevant systems. Developers and policy makers can already make use of the fact that consumers do not have such strong preferences for production level.

Price

This study revealed that price is the most important factor in energy system preference and acceptability, which is not a very surprising finding. Yet, even the most seemingly obvious research hypotheses need to be empirically validated, as research shows that common sense knowledge may prove not to be true when examined rigorously (e.g., Noppers et al. 2014), and that prices may sometimes be less important than often assumed (Bolderdijk et al. 2013). Interestingly, the indirect method revealed that a low price was even preferred when consumers did not favor the other system characteristics. For example, results revealed that consumers rather accepted convenience technology than accepting a higher price. Incorporating price in the scenarios in the current study did allow us to control for (perceptions of) price and it allowed us to draw more valid conclusions about the other attributes' importance. If price had not been included, findings on preferences for adjustment type and production level could have been confounded because consumers may have preconceptions that, for example, convenience technology and local energy (e.g., solar panels), are more expensive. Thus, by incorporating price in all scenarios, this possible unmeasured confounding could be controlled for. Future research should assess whether price always plays such a prominent role, at which levels of price increase it perhaps does not play such a role, and whether opinions change when people actually experience new systems (Schuitema et al. 2010). Future research could also explore the role of individual differences in preferences for different attributes and attribute levels.

Strengths and considerations

The complexity of energy systems and of consumers' preferences for them with regard to the different attributes highlights the value of conducting this research by means of a conjoint analysis alongside a direct measurement. Not only does the scenario method reduces the chance of socially desirable answers, it also enables researchers to incorporate several attributes at once which reveals the relative importance of different attributes and eliminates unmeasured confounding. Especially with regard to price this is an important advantage of conducting a conjoint analysis because if consumers have to rate their preferences of, for example, convenience technology, without any specification of the price of this entire energy system their preconceptions about the cost of convenience technology may influence their opinion on this, and thus be an unmeasured confounder that challenges the validity of the results. Furthermore, the relative importance of the attributes can be compared in a comprehensive way. For example, we found that relative to the importance of adjustment type, production level was much less important to consumers.

The most acceptable energy system was found to be one in which price remained stable, individuals adjusted their energy use autonomously, and energy was produced and provided for on a central basis. A status quo effect could apply here: this is exactly the system that individuals are accustomed to (Samuelson and Zeckhauser 1988). Accordingly, the least preferred energy system was one that varies from the current situation on all aspects: in which price would increase by 25 %, convenience technology would adjust use, and energy would be provided for on a household basis. Furthermore, the status quo bias in the current study could be an underestimation because participants read information on the different attributes of energy systems and may thus be better informed than the average consumer.

Because we focused on innovative future energy systems that are not in place yet, we relied on participants' projected, rather than actual, preferences. Although we do not know what type of energy systems participants currently use or are familiar with, it is very likely that most of them have no experience with the innovative energy system attributes we included in our study. This may have enhanced the status quo effect. Hence, our results are particularly relevant for predicting consumers' attitudes prior to experience when a status quo bias is most likely. Research suggests that people are not good at predicting their future preferences (Mitchell et al. 1997; van Boven and Ashworth 2007), and their preferences tend to shift and adapt to new circumstances (Samuelson and Zeckhauser 1988; Jost et al. 2004). This is related to the possible status quo effect, which can be overcome through experience, such as occurred, for example, with the Stockholm congestion charge (Börjesson et al. 2012; Schuitema et al. 2010). It would be interesting to also study preferences for future energy systems among participants that already use these systems, and to examine whether the importance of attributes of energy systems changes when people have experience with the relevant energy systems, and why such changes may occur.

In the current study, the reality of complex energy systems was simplified into measurable and quantifiable energy systems with specific carefully defined attributes. As such, as in any scientific study, the energy systems that were evaluated by participants reflect a simplification of reality, which enabled us to draw firmer conclusions on the relative significance of energy system attributes. As described in the "Design" section of the Methods, this differs from studying real-life situations in all their complexity. The latter would reveal how people evaluate specific things in a particular situation, but would have a weaker internal validity, as it would not be possible to determine which factor caused the issue at stake. Also, it would be much more difficult to derive implications for which processes and variables may play a key role in a different situation. Yet, it is important to try to replicate our findings using complementary research designs, as the use of different types of approaches will increase our insight and confidence into a phenomenon, thereby balancing strengths and weaknesses of different research methods. Of course, any single study cannot possibly combine both methods, and reveal general processes while considering the full complexity of real-life at the same time (Pelham and Blanton 2012). In the current study, we opted for a method that is strong in internal validity, thereby realizing that our stimulus materials do not reflect the world in its true complexity. Future studies are needed to address this issue, as in the end, studying similar phenomena in a research program relying on different research methods, each having their strengths and weaknesses but together giving a comprehensive picture, would provide the most solid evidence.

The energy system attributes in the conjoint analysis scenarios are not all-encompassing—many other relevant attributes were not included because this would have made the questionnaire too extensive. Future research can expand upon the current study and examine (a) additional attributes, and (b) further and different specifications of the attributes included. First, it would also be interesting in future research to incorporate other attributes, such as how energy is stored (e.g., battery at home or in the neighborhood, gas system), and ownership of energy providers (e.g., private or public). Second, the attributes we included can be further specified, for example, by including type of green energy (e.g., wind, solar) and gray energy (e.g., coal, fossil fuel) in order to explore where consumers' exact preferences lie. Attribute specifications can also be varied, for example, the price increase assessed in this study was set at 25 % on the basis of discussions with market parties. Yet, incorporating different price levels (e.g., 10 and 50 %) would allow for more detailed information on the cutoff point at which consumers' are no longer willing to pay more for different types of energy systems. Because all scenarios were shown to all participants, adding more attributes with multiple dimensions would have made the questionnaire too long. Thus, three attributes of energy systems and their respective dimensions were selected on the basis of discussions with market parties; these attributes were expected to change in upcoming years and had been assessed separately in past research. Future studies could include other attributes and dimensions to extend our knowledge on this issue.

Another important question for future research is which factors predict preferences for and importance of attributes and attribute levels of future energy systems. Individual differences in values, motivations and experience may play a role in this respect. For example, consumers with strong environmental values may evaluate the source of energy as relatively more important, while consumers with strong egoistic values may prioritize the price of energy. Similarly, as discussed earlier, preferences may change when consumers have more experience with innovations in energy systems, or become more knowledgeable of important features of such energy systems.

A potential limitation in the current study concerns the representativeness of the sample as we recruited participants from a panel. Some studies suggest that data collected using such panels may differ from data collected using traditional means of data collection (e.g., Yeager et al. 2011), whereas others show that these differences are small to non-existent (e.g., Sanders et al. 2007). We believe it is unlikely that using a panel influenced our findings in important ways, as we were primarily interested in relations between variables rather than the comparison of absolute numbers, which makes potential problems (if any) with non-representativeness of participants in the opt-in panel used here are less pressing than they would otherwise be (Schultz et al. 2005).

Concluding remarks

By focusing on the relative significance of general system characteristics for overall preferences and acceptability of such systems we were able to study which attributes and attribute levels are more and less important for the acceptability of new energy systems, which is a novel contribution to the literature, and complements earlier studies on acceptability of energy systems and energy system components. Yet, these general characteristics can be further specified in many different ways, which may have important implications for system preferences and acceptability. This is an important topic for future research. Our findings were that participants valued a stable price most, hereafter making autonomous adjustments in use, and lastly a central production level. These findings have implications for what policies and innovators should target when stimulating an energy transition.

References

Abrahamse, W., & Steg, L. (2013). Social influence approaches to encourage resource conservation: a meta-analysis. *Global Environmental Change, 23*, 1773–1785.

Abrahamse, W., Steg, L., Vlek, C., & Rothengatter, T. (2005). A review of intervention studies aimed at household energy conservation. *Journal of Environmental Psychology, 25*(3), 273–291.

Bolderdijk, J. W., Steg, L., Geller, E. S., Lehman, P. K., & Postmes, T. (2013). Comparing the effectiveness of monetary versus moral motives in environmental campaigning. *Nature Climate Change, 3*, 413–416.

Bolsen, T., & Cook, F. L. (2008). The polls—trends: public opinion on energy policy: 1974–2006. *Public Opinion Quarterly, 72*(2), 364–388.

Börjesson, M., Eliasson, J., Hugosson, M. B., & Brundell-Freij, K. (2012). The Stockholm congestion charges-5 years on. Effects, acceptability and lessons learnt. *Transport Policy, 20*, 1–12.

Burkhardt, J. J., III, Heath, G. A., & Turchi, C. S. (2011). Life cycle assessment of a parabolic trough concentrating solar power plant and the impacts of key design alternatives. *Environmental Science and Technology, 45*(6), 2457–2464.

Clastres, C. (2011). Smart grids: another step towards competition, energy security and climate change objectives. *Energy Policy, 39*(9), 5399–5408.

De Groot, J., & Steg, L. (2008). Value orientations to explain beliefs related to environmental significant behavior: how to measure egoistic, altruistic, and biospheric value orientations. *Environment and Behavior, 40*(3), 330–354.

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. New York: Plenum.

Faiers, A., Cook, M., & Neame, C. (2007). Towards a contemporary approach for understanding consumer behaviour in the context of domestic energy use. *Energy Policy, 35*(8), 4381–4390.

Gellings, C. W., & Samotyj. (2013). Smart Grid as advanced technology enabler of demand response. *Energy Efficiency*. doi:10.1007/s12053-013-9203-0.

Gerpott, T. J., & Mahmudova, I. (2010). Determinants of green electricity adoption among residential customers in Germany. *International Journal of Consumer Studies, 34*(4), 464–473.

Green, P. E., & Srinivasan, V. (1990). Conjoint analysis in marketing: new developments with implications for research and practice. *Journal of Marketing, 54*(4), 3–19.

Grothe, O., & Schnieders, J. (2011). Spatial dependence in wind and optimal wind power allocation: a copula-based analysis. *Energy Policy, 39*(9), 4742–4754.

Hansla, A. (2011). Value orientation and framing as determinants of stated willingness to pay for eco-labeled electricity. *Energy Efficiency, 4*(2), 185–191.

Hanssen-Gram, K. (2013). Efficient technologies or user behavior, which is the more important when reducing households' energy consumption. *Energy Efficiency, 6*(3), 447–457.

Jost, J. T., Banaji, M. R., & Nosek, B. A. (2004). A decade of system justification theory: accumulated evidence of conscious and unconscious bolstering of the status quo. *Political Psychology, 25*(6), 881–919.

Laroche, M., Bergeron, J., & Barbaro-Forleo, G. (2001). Targeting consumers who are willing to pay more for environmentally friendly products. *Journal of Consumer Marketing, 18*(6), 503–520.

Louviere, J. J. (1988). *Analyzing decision making: metric conjoint analysis*. Newsbury Park: Sage.

Marcus, A., & Jean, J. (2009). Going green at home: the Green Machine. *Information Design Journal, 17*(3), 235–245.

Martins, F. R., & Pereira, E. B. (2011). Enhancing information for solar and wind energy technology deployment in Brazil. *Energy Policy, 39*(7), 4378–4390.

Mitchell, T. R., Thompson, L., Peterson, E., & Cronk, R. (1997). Temporal adjustments in the evaluation of events: The "Rosy View". *Journal of Experimental Social Psychology, 33*(4), 421–448.

Niemeyer, S. (2010). Consumer voices: adoption of residential energy-efficient practices. *International Journal of Consumer Studies, 34*(2), 140–145.

Noppers, E., Keizer, K., Bolderdijk, J. W., & Steg, L. (2014). The adoption of sustainable innovations: driven by symbolic and environmental motives. *Global Environmental Change, 25*, 52–62.

Oldfield, E. (2011). Addressing energy poverty through smarter technology. *Bulletin of Science, Technology and Society, 31*(2), 113–122.

Palmer, K., Walls, M., Gordon, H., & Gerarden, T. (2013). Assessing the energy-efficiency information gap: results from a survey of home energy auditors. *Energy Efficiency, 6*(2), 271–292.

Pelham, B. W., & Blanton, H. (2012). *Conducting research in psychology: measuring the weight of smoke*. Belmont: Wadsworth.

Press, M., & Arnould, E. J. (2009). Constraints on sustainable energy consumption: market system and public policy challenges and opportunities. *Journal of Public Policy and Marketing, 28*(1), 102–113.

Samuelson, W., & Zeckhauser, R. (1988). Status quo bias in decision making. *Journal of Risk Uncertainty, 1*, 7–59.

Sanders, D., Clarke, H. D., Stewart, M. C., & Whiteley, P. (2007). Does mode matter for modeling political choice? Evidence from the 2005 British Election Study. *Political Analysis, 15*, 257–285.

Schuitema, G., Steg, L., & Forward, S. (2010). Explaining differences in acceptability before and acceptance after the implementation of a congestion charge in Stockholm. *Transportation Research-A: Policy and Practice, 44*(2), 99–109.

Schultz, P. W., Gouveia, V. V., Cameron, L. D., Tankha, G., Schmuck, P., & Franzek, M. (2005). Values and their relationship to environmental concern and conservation behavior. *Journal of Cross-Cultural Psychology, 36*, 457–475.

Steg, L., & Abrahamse, W. (2010). How to promote energy savings among households: Theoretical and practical approaches. In V. Corral-Verdugo, C. H. Garcia-Cadena, & M. Frias-Armenta (Eds.), *Psychology approaches to sustainability: current trends in theory, research and applications* (pp. 61–80). New York: Nova Science Publisher.

Steg, L., Perlaviciute, G., Van der Werff, E., & Lurvink, J. (2012). The significance of hedonic values for environmentally-relevant attitudes, preferences and actions. *Environment and Behavior*. doi:10.1177/0013916512454730.

van Boven, L., & Ashworth, L. (2007). Looking forward, looking back: anticipation is more evocative than retrospection. *Journal of Experimental Psychology: General, 136*(2), 289–300.

Whitehead, J. C., & Cherry, T. L. (2007). Willingness to pay for a Green Energy program: a comparison of ex-ante and ex-post hypothetical bias mitigation approaches. *Resource and Energy Economics, 29*(4), 247–261.

Wood, G., & Newborough, M. (2003). Dynamic energy-consumption indicators for domestic appliances: environment, behaviour and design. *Energy and Buildings, 35*(8), 821–841.

Yeager, D. S., Krosnick, J. A., Chang, L., Javitz, H. S., Levendusky, M. S., Simpser, A., et al. (2011). Comparing the accuracy of RDD telephone surveys and internet surveys conducted with probability and non-probability samples. *Public Opinion Quarterly, 75*, 709–747.