Characteristics of innovation in adopting renewable residential energy system

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Abstract

Purpose – This paper investigates the criteria influencing the adoption of innovation in the empirical context of renewable residential energy solutions, particularly the wood pellet heating system.

Design/methodology/approach – The study carried out an extensive literature review on Rogers' characteristics of innovation theory and then complemented it with a content analysis on empirically perceived characteristics on wood pellet heating systems.

Findings – The literature review shows that most of the previous studies employ the characteristics of innovation but do not confirm the usability of the Rogers framework as a whole. In addition, our empirical results demonstrate that relative advantage is the predominant characteristic in the adoption of residential energy systems.

Research limitations – The limitations of the literature review and the biases of empirical findings are discussed. For instance, there are limitations that the study is based on single country data and its theoretical approach relies on only one theory, Rogers' characteristics of innovation.

Practical implications – In order to achieve sustainable strategic advantage, firms providing renewable energy solutions should attempt to communicate clearly the relative advantages instead of attempting to, for instance, offer an opportunity for trialling such green energy systems.

Originality/value – The paper highlights the use of characteristics of innovation and further empirically examines the perceived characteristics of an innovation considering green investments in residential heating systems. Due to the exploratory nature of the study, the results provide a gateway to a number of possible avenues for future research.

Keywords - Innovation; characteristics of innovation; wood pellet heating system; review; assessment; content analysis

Paper type – Research paper

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Introduction

A recurring theme in the literature concerning sustainable energy sources is the observation that whenever a cleaner or a cost-reducing technology is available on the market, its uptake across households takes several years and sometimes even decades (Battisti, 2008). The technology itself and the bundles of services and additional features wrapped around the basic technology affect its acceptance and adoption in the market. Rogers (2003) has proposed that from 49% to 87 % of the variance in adoption can be explained in terms of five characteristics of innovation (hereafter referred to as Rogers' framework): relative advantage, compatibility, complexity, trialability, and observability. The role that these characteristics of innovation play in the adoption of an innovation in general has been studied extensively (E.g. Martins *et al.,* 2004; Lee, 2004; Al-Gahtani, 2003; Hayati and Jowkar, 2008), and also with specific regard to energy issues (Faiers *et al.,* 2007b; Völlink *et al.*, 2002; Kaplan 1999a; Kaplan 1999b) and homeowners' choice of a heating system (Mahapatra and Gustavsson, 2008). Previous studies have suggested that further research should focus on the refinement, redefinition, and elaboration of characteristics of innovation (Faiers *et al.*, 2007; Völlink *et al.*, 2002) in order to further our understanding of the attributes of innovations influencing their adoption in the marketplace.

The purpose of this study is to address the characteristics of innovation and thereby contribute to the existing literature in two ways: investigating the existing body of knowledge to highlight the use of characteristics of innovation and, further, empirically examining the perceived characteristics of an innovation in the particular context of green investments in residential heating systems. In recent years, the characteristics of innovation concept has been employed increasingly by scholars in analyses of various technological systems and, in the context of this study, energy issues as well (Völlink *et al.*, 2002; Mahapatra and Gustavsson, 2008; Labay and Kinnear, 1981). Combating climate change and the increased demand for energy have together prompted the development of new technologies for more sustainable energy production. The use of wood pellets, particularly in domestic heating solutions, is one of the new, alternative ways to produce renewable energy (Heinimö, 2008). Wood pellets are small cylindrical, compressed chips of wood that are burnt in stoves and boilers in order to tackle residential heating needs (Fiedler, 2004) and which are more expensive than regular wood residues requiring extra processes and transportation (Chau *et al.,* 2009). This study investigates empirically the characteristics of innovation in the context of wood pellet heating systems in relation to the Rogers' framework.

We start our investigation by setting out the theoretical background to the characteristics of innovation. Next, we review the literature for the period from 1986 to 2008 to understand to what extent the Rogers (2003) framework for characteristics of innovation is used in the literature in assessing innovation adoption. Then, after presenting our empirical methodology and data, we investigate what perceived criteria are presented by potential adopters as influencing the decision to acquire wood pellet heating systems and, via content analysis, how such perceived criteria can be classified according to the five characteristics of innovation. Our results demonstrate that relative advantage is the predominant characteristic, at least in the context of long-term investments. In order to achieve sustainability from an economic and environmental point of view (Parnell, 2008), a firm should attempt to communicate clearly the relative advantages instead of attempting to offer an opportunity for trialling such green energy investments.

Characteristics of innovation explaining the technology's adoption

The technology itself and the bundles of services and additional features wrapped around the basic technology affect its acceptance in the market. Further, the nature of the technology, whether novel or evolved, and the market, whether concentrated or scattered, are all important considerations when firms employ technical or institutional strategies (Das *et al.*, 2000). This is the case especially when a firm aims towards a sustainable strategy from both environmental and market perspectives (Parnell, 2008).

The theoretical premises of this study are based on theories of the adoption of innovation (Moore, 1999), especially concentrating on the characteristics of innovation (Rogers, 2003). The term innovation can refer to the inventive process by which new things, ideas and practices are created; it can mean a new thing, idea, or practice itself; or it can describe the process whereby an existing innovation becomes a part of an adopter's cognitive state and behavioural repertoire (Goldsmith and Foxall, 2006). In short, innovation concerns the metamorphosis from present practice to something new, probably an improved practice. In this paper, we adopt a view of innovation which refers to a new technological entity that is used for improving its adopters' processes.

The adoption of innovation has traditionally been divided into phases from initial slow growth to accelerating growth, and finally to maturity and decline (Rogers, 2003; Bass, 1969; Gort and Klepper, 1982). Each phase might independently determine innovation adoption. Importantly, customers in the innovation adoption phases differ dramatically in their characteristics (Moore, 1999). Categories in the diffusion of innovation succeed each other at an increasing rate until the critical mass is formed. One of the major factors promoting adoption from one category to another is the mutual influence between category members, i.e., adopters. Rogers (2003) has defined the development in which innovation proceeds through specific channels of communication and members of a social system over time as 'diffusion'.

In addition, the innovation adoption decision can be regarded as a process (Rogers, 2003; Mahapatra and Gustavsson, 2008; Bass 1969). The process includes stages of knowledge, persuasion, decision, implementation, and confirmation in which persuasion refers to a stage when a person or group has an attitude with positive or negative attributes to the innovation. Attributes affect attitude, and thus, attributes affect the adoption decision; previous adoption can lead to continued adoption, or a previous rejection decision can lead to a later adoption decision (Rogers, 2003). The effects are characterized in various ways (Christensen, 1997; Veryzer, 1998) in different or even within the same contexts.

According to Rogers (2003) from 49% to 87 % of the variance in adoption can be explained in terms of five characteristics: relative advantage, compatibility, complexity, trialability, and observability. Relative advantage, compatibility, and complexity represent the advantages and disadvantages of an innovation, while trialability and observability represent uncertainty as to the value of the innovation that in turn lowers the perceived risks to adoption (Narayanan, 2001). However, there are only a few studies on the differences between the importance ascribed to these characteristics in the innovation adoption decision (e.g. Tapaninen *et al.,* 2009).

Literature review

In the literature review, our purpose is to analyze the characteristics of innovation (Rogers, 2003) used in the existing literature in assessing innovation adoption in order to review the existing evidence on the influence and importance of characteristics of innovation. As of November 5, 2008 E. M. Rogers' Diffusion of Innovation had over 1238 citations at the ISI Web of Science, which highlights the extensive use and therefore the relative importance of Rogers' research outcomes (233 citations to the 1962 edition, 373 citations to the 1983 edition, and 632 citations to the 1995 edition).

In order to shed light on the overall usage of Rogers' framework, our search of existing publications was designed to cover all languages, all document types, and all databases at the ISI Science Citation Index, the Social Sciences Citation Index and the Arts and Humanities Citation Index. The period covered is from 1986 to the last updating in October 4, 2008. Our search was limited to the search string, which includes all possible combinations of three of the five characteristics. We present the search procedure in Appendix 2, in order to ensure repeatability of our results.

The combination in the search terms considering the characteristics of innovation was confined to include three of the five characteristics because we wanted to find the existing articles that actually consider Rogers' framework holistically, that is, the articles that employed all or most of its characteristics. Further, a combination of only two of the five characteristics of innovation produced 573 results. However, many of these papers used these characteristics in a different meaning than the Rogers' (2003) definition and therefore majority of these papers would lie outside the scope of our interest. Our search resulted in 85 publications in October 8, 2008, which include one publication in German and two in French with English abstracts. This represents a relatively low number compared to the number of citations of Rogers' Diffusion of Innovations (7%, 85/1238). This might indicate that the characteristics of innovation have been used rather scarcely as a framework in previous studies.

Next, in order to limit our analysis to essential publications regarding the use of the Rogers framework, we first read through all the publications to establish their relevance. Then we cross-checked the entire body of texts to ensure that at least three of the five characteristics of innovation (Rogers, 2003) were present and also that the short explanations of the characteristics of innovation followed Rogers' definitions. This procedure narrowed our data to 57 publications. We then confirmed our observations by a search of references in these publications for citations of E.M. Rogers' book on the Diffusion of Innovations. This search produced evidence for citations in 52 publications. Though the remaining five publications contained no explicit mention of Rogers' work, we included them all since they involved closely at least three of the five characteristics of innovation. Primary methodologies of data collection methods comprised 21 surveys, 3 field studies, 3 cases, 2 literature reviews, 6 interviews, 11 questionnaires, 10 practical discussions, and one that combined interviews and questionnaires. In 34 publications, the method used was described explicitly. However, the identification of the method in 18 publications was not straightforward since, for instance, the difference between literature review and practical discussion was somewhat vague.

The number of subject areas in the 57 publications is presented in Table 1. A single paper is classified into as many as three subject areas; hence, the total count is more than the number of publications in our data. In only two of 57 papers did the subject discuss the category of energy and fuels; both publications dealt with renewable energy issues (Faiers *et al*., 2007; Mallet, 2007). However, the number and definition of subject areas (based on ISI classification) affects the classification results; for instance, there is quite a variety of medical subject areas and only one computer science subject area which receives multiple counts. Further, we cannot say exactly how and why a particular paper has been included in subject area, thus we have to be rather careful in drawing conclusions here. Nevertheless, we can conclude from Table 1 that Rogers' framework has been applied in a variety of subject areas and, therefore, despite the low number of references, its general applicability to research is validated.

Table 1. Number of subject areas in characteristics of the innovation publications

Subject areas	Count
Agriculture, Multidisciplinary	1
Anesthesiology	1
Business	4
Communication	2
Computer Science, Cybernetics	10
Dentistry, Oral Surgery & Medicine	1
Economics	2
Education & Educational Research	5
Energy & Fuels	2
Engineering, Electrical & Electronic	2
Engineering, Industrial	2
Engineering, Manufacturing	1
Environmental Sciences	2
Environmental Studies	4
Ergonomics	1
Genetics & Heredity	1
Health Care Sciences & Services	4
Health Policy & Services	1
Information Science & Library Science	5
Management	6
Medical Informatics	3
Medicine, General & Internal	3
Nursing	2
Operations Research & Management Science	1
Pharmacology & Pharmacy	1
Planning & Development	2
Psychology, Applied	1
Psychology, Experimental	1
Psychology, Multidisciplinary	3
Public, Environmental & Occupational Health	6
Rehabilitation	1
Social Work	1
Substance Abuse	1
Telecommunications	2
TOTAL	85

These 57 publications included the characteristics as defined according to Rogers in the following number of cases: relative advantage 53, compatibility 54, complexity 54, trialability 44, and observability 41. In addition, we found eight instances of trialability and six of observability which were excluded in the actual assessment in those studies. Additional characteristics of innovation or adoption attributes, such as ease of use, visibility, simplicity, playfulness, and operational novelty were also mentioned in the studies (Shih, 2008; Cale and Eriksen, 1994; Weiss and Dale, 1998; Atkinson, 2007)

The results show that not all characteristics of innovation were assessed as being important or influential in survey- and questionnaire-based studies. Variance in the use of the characteristics of innovation in survey and questionnaire studies is consistent with the result of use of characteristics of innovation in all studies in our data, because, as mentioned before, 57 publications included the characteristics of innovation in the following order of number of cases: relative advantage, compatibility, complexity, trialability, and observability. Varying usage of characteristics of innovation indicates that not all characteristics are observed as useful in every case.

The results of the literature review can be summarized as follows: First, Rogers' Diffusion of Innovation is cited widely; however, the search results show fluctuations in the characteristics of innovation publication counts. Secondly, not all the characteristics were mentioned in every selected publication or in all the survey and questionnaire-based studies. This might indicate that not all characteristics are considered useful or that the meaning of the characteristics is not used in the same way in all study contexts. References to trialability and observability, in particular, are less frequent than to other characteristics of innovation. Interestingly, there were only two studies relating to energy and fuel. Therefore, we can conclude that existing studies view the characteristics of innovation as applicable in various field but at the same time do not confer the usability of Rogers' framework as a whole as applicable in explaining the adoption. This leads us to investigate further what perceived criteria adopters use in evaluating innovations and how these might relate to Rogers' framework empirically.

Collection of empirical data and methodological choices

The empirical context of this paper is renewable energy sources for domestic heating. Domestic heating systems are durable technologies which customers evaluate based on perceived characteristics and decide to either adopt or reject the system (Berkowitz and Haines, 1982). In addition, domestic heating system markets may be divided in to two categories: new homes and systems for existing homes. In order to gain access to both users and potential users, a survey was conducted at a public housing exhibition in summer 2007, which was attended by both types of potential customer.

The study was carried out in two parts. Firstly, the initial design of the survey was pre-tested (Czaja and Blair, 2005) on a sample of twenty randomly selected adult respondents. Based on the results of the pre-test, a few minor changes were made to clarify the wording of the questionnaire. For this study, all the survey items have been translated from the original language. The survey was conducted in a country with a cold climate in which there is an obvious need for residential heating systems. Secondly, the final survey (N=154) was performed at a Housing Expo between July 13, 2007 and August 12, 2007. This had over 195,000 visitors, corresponding to 3.8% of the national population. The example was a single-family house with a wood-pellet heating system installed in the utility room, and there was at least one expert representative demonstrating the system.

Visitors to such exhibitions are typically those interested in housing and house building technologies and, thus, likely potential customers for wood pellet heating. The Housing Expo was considered a suitable venue for the survey of this study since the event provides a showcase for companies to exhibit their products and services and also to attract customers and gain feedback.

Overall, the aim of the survey was to obtain views on wood pellet heating technology and services. As an inducement to participate, each respondent received a wood pellet brochure worth five Euros. A total of 157 respondents answered a six-page questionnaire which was divided into four thematic sections and which contained at total of 35 questions, both open and closed. We accepted to our sample all respondents regardless of having already installed any type of heating system, because according to Rogers (2003) previous adoption can lead to continued adoption, or a previous rejection decision can lead to a later adoption decision. Three responses were eliminated because they were unclear. In terms of the subject of the present paper, we consider only part of the main survey, namely the following question: *"In your opinion, what are the most important selection criteria for acquiring a wood pellet heating system?"*

The freely written answers were arranged alphabetically (in the original language) and the spoiled responses were discarded. Next, only unique factors were populated as a primary data set; our main interest was in gathering a complete list of the different factors mentioned by respondents.

Hence, we do not present the number of responses for any particular perceived criteria but treat each one equally. As a result, we obtained a list of 96 different perceived criteria.

Next, we employed a content analysis that can be briefly defined as a systematic, objective, quantitative analysis of message characteristics (Bryman and Bell, 2007, p.302). We used an interpretative technique of the content analysis that targets a formation of theory from the observation of messages and the coding of those messages (Neuendorf, 2002, p.6). The coding instructions of perceived factors were designed based on Rogers' definition for characteristics of innovation. Each factor was evaluated in terms of the following five perceived characteristics of the innovation: relative advantage, compatibility, complexity, trialability, and observability, all of which are aspects of persuasion (Rogers, 2003). Each criterion was classified independently and no empty classifications were allowed.

Seven researchers evaluated the 96 perceived criteria. As human coders are used in evaluations of perceived factors, establishment of intercoder reliability becomes a crucial issue in ensuring the validity of the results. To assess the reliability of multiple coders' evaluations, we used Krippendorff's alpha (hereafter, K-alpha) method. This describes the extent to which independent intercoders evaluate each item (i.e., factor) and reach the same conclusion (Krippendorff, 1980; Krippendorff, 2004). In this study, K-alpha indicates the extent to which the different classifiers tend to ascribe the same factor to the same category (that is, to Rogers' characteristics). In the content analyses, a closer examination of reasons why classifiers disagree is usually needed (Neuendorf, 2002). Therefore, we conducted a follow-up study in order to analyze, in detail, possible reasons why classifiers classified perceived criteria into a particular category. We were especially interested if the classification was ambiguous or not. To conduct the follow-up, we asked firstly, why a classifier classified the factor into a certain category. Secondly, we asked if the classification had been ambiguous to complete. Finally, following from the second question, we inquired as to what was the perceived reason for ambiguity.

Empirical results

There were 95 responses to the question: *"In your opinion, what are the most important selection criteria for acquiring the pellet heating system?"* These answers amount to 96 different perceived criteria for evaluation. The whole list of perceived criteria and agreement percentages of categorisation are in Appendix A. Despite attempts to retain all nuances of the original language, certain subtleties of expression may have been lost in translation. Overall, 22 perceived criteria received full agreement (100%) in the classifications, see Table 2. Of these, 17 were considered to be perceived criteria assessing the relative advantage of the pellet heating system. This category includes primarily factors relating to cost, such as *initial investment, profitability, and costs.* Five of the unanimously agreed 22 perceived criteria fell into the compatibility category and included, for instance, *environmental issues*.

Table 2. The 22 perceived criteria showing the greatest agreement

Perceived criteria	Relative advantage	Compatibility	Complexity	Trialability	Observability
initial investment	100 %	0 %	0 %	0 %	0 %
initial costs	100 %	0 %	0 %	0 %	0 %
affordable, budget, economical, inexpensive, low cost	100 %	0 %	0 %	0 %	0 %
affordabilty	100 %	0 %	0 %	0 %	0 %
setting up costs	100 %	0 %	0 %	0 %	0 %
affordable energy	100 %	0 %	0 %	0 %	0 %
profitability	100 %	0 %	0 %	0 %	0 %
heating efficiency (in monetary sense)	100 %	0 %	0 %	0 %	0 %
energy efficiency (in monetary sense)	100 %	0 %	0 %	0 %	0 %
price, charge, rate, price tag, cost	100 %	0 %	0 %	0 %	0 %
price-quality ratio	100 %	0 %	0 %	0 %	0 %
expenses, costs	100 %	0 %	0 %	0 %	0 %
expence, cost, outlay	100 %	0 %	0 %	0 %	0 %
expences of operation	100 %	0 %	0 %	0 %	0 %
reliable, trustworthy, dependable, trusty, authentic	100 %	0 %	0 %	0 %	0 %
reliability, dependability, trustworthiness, credibility	100 %	0 %	0 %	0 %	0 %
heating cost effectiveness	100 %	0 %	0 %	0 %	0 %
setting, surroundings, environment, neighborhood	0 %	100 %	0 %	0 %	0 %
environmental issues	0 %	100 %	0 %	0 %	0 %
environmental factors	0 %	100 %	0 %	0 %	0 %
environmentally friendly, ecological, ecologically compatible	0 %	100 %	0 %	0 %	0 %
environmental friendliness	0 %	100 %	0 %	0 %	0 %

Examples of factors classified in two categories (27), were those assessing *ease of installation* and *future prices.* Other perceived criteria classified in two categories, with lower agreement rates, were *quality, simplicity,* and *expected length of residence*. *Automated, domestic* and *versatility* were also mentioned. Most of the perceived criteria (36) were classified in three categories including service issues such *operating functions, personal preferences, system simplicity.* Additionally, the price and the quality of wood pellets were mentioned. Finally, the ten factors displaying the strongest disagreement (i.e. factors classified in four categories) comprise factors such as *knowledge*, *repayment,* and *availability of raw material,* see Table 3. To conclude, agreement rates were less than 60% for half of the factors, which indicate mixed interpretations of these perceived criteria. Moreover, in the final classification, no factors were assigned to the trialability category.

Table 3. The eleven perceived criteria showing the greatest disagreement

delivery, shipment	57 %	14 %	14 %	0 %	14 %
functionality, functioning	57 %	14 %	14 %	0 %	14 %
space	14 %	43 %	29 %	0 %	14 %
supply of wood pellets	29 %	14 %	43 %	0 %	14 %
high price of electricity	43 %	14 %	14 %	0 %	29 %
repayment, refund, reimbursement	43 %	14 %	14 %	0 %	29 %
knowledge, information, piece of information, data	14 %	43 %	14 %	0 %	29 %
convenience of use	29 %	14 %	29 %	0 %	29 %
automatic operation	14 %	29 %	29 %	0 %	29 %
knowledge of benefits	14 %	29 %	14 %	0 %	43 %
availability of raw material	0 %	29 %	29 %	0 %	43 %

As mentioned earlier, we used the K-alpha method to assess the reliability of the evaluations. Table 4 interprets the significance of the alpha value as was suggested by Landis and Koch (1977).

Table 4. Interpreting the value of Krippendorff alpha

K	Interpretation
< 0	Poor agreement
0.0 – 0.20	Fair agreement
0.21 – 0.40	Slight agreement
0.41 – 0.60	Moderate agreement
0.61 – 0.80	Substantial agreement
0.81 – 1.00	Almost perfect agreement

K-alpha reliability estimates were calculated using SPSS software and a macro provided by Hayes and Krippendorff (2007). For all classifiers, the K-alpha has a value of 0.2771, indicating only slight agreement. Because K-alpha indicates only slight agreement between classifiers, we carried out a follow-up. Of 96 perceived criteria, 11 were classified into four different categories, which indicated major disagreement between the researchers. In order to understand the phenomena behind the disagreement, the researchers were asked some questions during interviews. Despite the fact that K-alpha indicates only slight agreement between classifiers, our results show that at least from one classifier's perspective 88 of the factors (i.e., 91%) were considered to be perceived criteria assessing the relative advantage of the pellet heating system (see Appendix 1). In the other words, only eight perceived criteria were not classified to the relative advantage category by any of the classifiers.

Discussion

General findings

The paper reviews the current literature in order to shed light on how the perceived characteristics of innovation have been used in the literature to assess the adoption of innovation. First, our results show that Rogers' diffusion of innovation theory is widely cited. However, the ways in which the characteristics are employed vary considerably; the characteristics in their entirety were not at all mentioned in each publication, survey, or questionnaire-based study examined in our data. This indicates that not every characteristic was considered useful by scholars and that the characteristics could be assessed in different ways depending on the particular study context. Trialability and observability, in particular, were employed with much less frequency than the other characteristics of innovation. Further, additional characteristics or attributes have been added to the frameworks of previous studies, which might suggest shortcomings in the use of Rogers' framework in different contexts. The content analysis and K-alpha test demonstrate possible weaknesses in Rogers' framework. Only 22 of 96 perceived criteria received perfect agreement (100%) in our classification, of which 17 perceived criteria assessed relative advantage and five assessed compatibility.

Our results indicate that the relative advantage is clear, especially with monetary issues since costs and profitableness criteria can be used to compare prices of heating systems against others and relative advantage seems to be the easiest characteristic to apply for such comparisons. According to Rogers (1962), a new idea may be emphasized by a crisis. Therefore, climate change may be an example of a current crisis that emphasizes the relative advantages of innovation. In addition, our results show that, at least from one classifier's perspective, 91 percent of the factors were considered to be assessing the relative advantage of the wood pellet heating system in comparison to other energy sources (see Appendix 1). Our results show that relative advantage seems to be the easiest characteristic of innovation to be used in comparing innovations with each other. Naturally, however, all characteristics can be used to assist a general comparison of innovations. Therefore, our results demonstrate that relative advantage seems to be a predominant characteristic of innovation influencing adoption in the context of long-term investments. However, our observation of predominance has its limitations, which are described in the following section.

Interestingly, in the compatibility category the most agreed perceived criteria are related to environmental issues, which indicates the suitability of the wood pellet heating system's use in a social sense and its usefulness to the potential adopter's ecological values. Our observation reciprocates the work of Faiers, *et al.* (2007b) requesting a re-definition of compatibility. Therefore, we propose that Rogers' framework does not explicitly allow for the fact that customers also have an ecological, green perspective. Hence, customers may also adopt or reject an innovation because of an ecological response.

In addition, 27 factors were classified in two categories and most of the criteria (36) were classified in three categories. Finally, ten factors were classified in four categories, indicating strong disagreement between researchers. This illustrates that utilizing Rogers' (2003) framework of innovation's characteristics is a somewhat complicated procedure. We believe that the observed complexity relates to the nature of the technology or to the evolution phases of various technologies. The nature of the technology, relating to either consumer or durable goods, affects observed complexity since the amount of costs incurred in the adoption decision varies and therefore creates barriers to entry and exit for a customer. Further, the evolution phase (Bass, 1969; Gort and Klepper, 1982) influences adoption since customer segments and customer needs are different in each adoption phase. Wood pellet heating technologies are gaining a foothold in the well-established heating systems market. Careful identification of the evolution phase aids in formulating the theoretical as well as practical implications.

Follow-up study results

The results of the follow-up study to analyze in more detail why the classifiers disagreed with each other, revealed some interesting insights. Table 5 represents the results in figures.

Table 5. Ambiguity in classifying perceived criteria. The greener colour indicates the greater agreement

	CRITERIA		CHARACTERISTICS OF INNOVATION			
Perceived criteria	***Unambiguous***	***Ambiguous***	***Relative advantage***	***Compatibility***	***Complexity***	***Observability***
Functionality, functioning	67 %	33 %	67 %	17 %	17 %	17 %
Delivery, shipment	57 %	43 %	71 %	14 %	0 %	14 %
High price of electricity	50 %	50 %	67 %	17 %	0 %	33 %
Repayment, refund, reimbursement	50 %	50 %	50 %	17 %	17 %	33 %
Knowledge, information, data	29 %	71 %	14 %	43 %	14 %	29 %
Space	17 %	83 %	17 %	50 %	33 %	17 %
Availability of raw material	14 %	86 %	0 %	29 %	29 %	43 %
Knowledge of benefits	14 %	86 %	14 %	29 %	14 %	43 %
Convenience of use	0 %	100 %	33 %	17 %	33 %	33 %
Supply of wood pellets	0 %	100 %	40 %	20 %	60 %	20 %
Automatic operation	0 %	100 %	17 %	50 %	17 %	33 %

First, the observed complexity in perceived criteria might be caused by overlapping definitions of characteristics of innovation. In our study, the most straightforward characteristic to use was relative advantage, which is illustrated in the first four categories in Table 5. From 50 percent to 67 percent of classifiers considered these categories unambiguous, and these perceived criteria were also considered most often as representing relative advantage.

Second, the definitions of particular perceived criteria were perceived as ambiguous by classifiers; one- to three-word criteria offer several different interpretations to a classifier, thus creating the possibility for several suitable categories. For instance, all classifiers considered the following perceived criteria ambiguous: convenience of use, supply of wood pellets, and automatic operations. Table 6 shows that these perceived criteria were distributed quite evenly over all four categories of characteristics of innovation.

Third, a general observation as to why a categorisation might be difficult to classify is that a categorisation might be more related to the characteristics of the macro-environment than to the characteristics of the actual innovation. The predominance of the relative advantage supports this notion since all characteristics can be used to compare innovations with each other, and relative advantage seems to be the easiest characteristic to apply for such comparisons.

Limitations of the study

Our research has certain strengths and limitations which merit attention. One limitation is the selected search terms. The search terms excluded other potentially related articles that did not contain this exact terminology (Rogers, 2003). In addition, if particular characteristics receive no mention in the abstract, they might play a minor part in the accompanying study (Abrahamson and Fairchild, 1999) and therefore are of only marginal interest for our study. Moreover, as described in the methodology section, 'characteristics of innovation' was used to describe the level of the technology, concealing five distinct underlying terms of characteristics of innovation. Further, the terms describing the characteristics, such as relative advantage, can be used differently to Rogers' definition and thus fall outside the scope of our interest. This, however, could provide a topic for future research since here it shows that much care is required in the selection of vocabulary and advanced search terms. We sought to overcome the limitations of our search terms by systematic formulation and empirical testing.

In addition, the study is limited by its use of the innovation decision theory (Rogers, 2003). Rogers' framework does not explicitly allow for the fact that customers also have an emotional perspective. Instead of making a rational adoption decision, customers may also adopt or reject an innovation, in this case in the context of domestic energy use, on the basis of an emotional response (Faiers *et al.*, 2007a). In this study we did not consider emotional perspectives – though they might be included in perceived factors – but we attempted to provide a comprehensive overview of perceived factors influencing customers' adoption decisions in the early phases of renewable energy utilization.

Our empirical assessment was also subject to certain limitations. The results may be influenced by the fact that the study was conducted in a single country, thus restricting the generalizability of the results. Additionally, the results may be viewed as biased because they were conducted at an exhibition. However, despite these limitations, the group of Housing Expo visitors forming the empirical sample were likely to be interested in and conversant with domestic energy issues. The study was restricted to customers, but one of its strengths is that the customers freely reported the perceived criteria. A larger and more heterogeneous sample might have given more specific information. The results might also have been biased by the fact that the respondents were able to view a working wood pellet heating system in the Housing Expo before answering the questionnaire. Conversely, a strength of the study is the respondents' interest to learn more about the system.

In addition, only unique factors were populated as a primary data set. However, different factors might be only slightly different. In other words, factors could mean similar or almost similar perceived criteria. Factors with similar meaning could be classified with a large number of classifiers in future studies. The reliability of the content analysis carried out by seven researchers might be enhanced by increasing the number of evaluators. However, the strength of the content analysis is that all evaluators are members of the same research centre with prior knowledge of and interest in innovation management theories.

Conclusions

The first objective of this study was to determine the extent to which perceived characteristics of innovation are used in the literature for assessing innovation adoption. Demonstrating the innovative concept's present utility through a review of the literature provides an important insight into the current understanding of characteristics of the innovation. It also identifies more specific levels of research where the framework potentially can be used. We propose that the characteristics of innovation concept can be put to good use in innovation management research into the increasingly important areas of energy and bio-fuels.

The second objective was to determine which criteria are perceived as affecting the acquisition of wood pellet heating systems and how such perceived criteria can be classified into the categories of characteristics of innovation. Based on the empirical results, we propose guidelines for managerial decision-making with regard to the adoption of long-time investments in residential energy markets. Information on the technological solution, its usage, advantages, and overall economic and social aspects need to be addressed to market these solutions successfully. In particular, firms should first prioritize communicating the relative advantages of the green energy investments over other strategies such as offering customers the chance to trial the systems. Second, compatibility with the expectations of the markets such as ecological and domestic resource utilization should be used to inform potential customers of the benefits of the technology over the alternatives. With proposed guidelines, firms might accomplish the sustainable strategies and therefore manage their external recourses, minimise potential losses from unexpected crises or, on the other hand, neither succumb to nor invite government regulation (Parnell, 2008).

This study is among the first to investigate the empirical aspects of the characteristics of innovation of green residential heating systems, particularly wood pellet heating systems, and general decision-making in this field. Due to the exploratory nature of the study, the results provide a gateway to a number of possible avenues for future research. For example, further qualitative research on the content of the published articles can lead to more detailed analysis of the characteristics of the innovation. Finally, further research could contribute to our understanding of end-user adoption of long-time investments and energy technologies based on renewable energy sources.

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Appendix 1. Perceived criteria and their distribution to five classes of characteristics.

	DISTRIBUTION BETWEEN CLASSIFIERS				
Perceived criteria	**Relative advantage**	**Compatibility**	**Complexity**	**Trialability**	**Observability**
initial investment	100 %	0 %	0 %	0 %	0 %
initial costs	100 %	0 %	0 %	0 %	0 %
affordable, budget, economical, inexpensive, low cost	100 %	0 %	0 %	0 %	0 %
affordabilty	100 %	0 %	0 %	0 %	0 %
setting up costs	100 %	0 %	0 %	0 %	0 %
affordable energy	100 %	0 %	0 %	0 %	0 %
profitability	100 %	0 %	0 %	0 %	0 %
heating efficiency (in monetary sense)	100 %	0 %	0 %	0 %	0 %
energy efficiency (in monetary sense)	100 %	0 %	0 %	0 %	0 %
price, charge, rate, price tag, cost	100 %	0 %	0 %	0 %	0 %
price-quality ratio	100 %	0 %	0 %	0 %	0 %
expenses, costs	100 %	0 %	0 %	0 %	0 %
expence, cost, outlay	100 %	0 %	0 %	0 %	0 %
expences of operation	100 %	0 %	0 %	0 %	0 %
reliable, trustworthy, dependable, trusty, authentic	100 %	0 %	0 %	0 %	0 %
reliability, dependability, trustworthiness, credibility	100 %	0 %	0 %	0 %	0 %
heating cost effectiveness	100 %	0 %	0 %	0 %	0 %
setting, surroundings, environment, neighborhood	0 %	100 %	0 %	0 %	0 %
environmental issues	0 %	100 %	0 %	0 %	0 %
environmental factors	0 %	100 %	0 %	0 %	0 %
environmentally friendly, ecological, ecologically compatible	0 %	100 %	0 %	0 %	0 %
environmental friendliness	0 %	100 %	0 %	0 %	0 %
energy price	86 %	14 %	0 %	0 %	0 %
prices when in use	86 %	14 %	0 %	0 %	0 %
future prices	86 %	14 %	0 %	0 %	0 %
easy to maintain	14 %	0 %	86 %	0 %	0 %
easy to use	14 %	0 %	86 %	0 %	0 %
ease of maintenance, easy maintenance, manageability	14 %	0 %	86 %	0 %	0 %
user-friendliness, ease of use	14 %	0 %	86 %	0 %	0 %
easy to install	29 %	0 %	71 %	0 %	0 %
simple	43 %	0 %	57 %	0 %	0 %
automated	57 %	0 %	43 %	0 %	0 %
investment and operating costs in relation to alternatives	57 %	0 %	43 %	0 %	0 %
ease of use	57 %	0 %	43 %	0 %	0 %
simplicicity, usabilty	57 %	0 %	43 %	0 %	0 %
coefficient of efficiency, efficiency	57 %	0 %	43 %	0 %	0 %
flexibility of use (compared to electricity)	71 %	0 %	29 %	0 %	0 %
versatility	71 %	0 %	29 %	0 %	0 %
ecology of use	71 %	29 %	0 %	0 %	0 %
expected length of residence	71 %	29 %	0 %	0 %	0 %
domestic fuel	57 %	43 %	0 %	0 %	0 %
domestic	57 %	43 %	0 %	0 %	0 %
cost efficiency, cost-effectiveness	57 %	43 %	0 %	0 %	0 %
operating costs	57 %	43 %	0 %	0 %	0 %
environmental friendliness	43 %	57 %	0 %	0 %	0 %
user experience	43 %	0 %	0 %	0 %	57 %
quality, grade, standard	43 %	0 %	0 %	0 %	57 %
ease of use (effortless)	0 %	0 %	43 %	0 %	57 %
nature conservation, environmental protection, conservation	0 %	57 %	0 %	0 %	43 %
minor maintainence costs	14 %	0 %	57 %	0 %	29 %
ease of mainteneance	29 %	0 %	57 %	0 %	14 %
practicality, viabilty	43 %	0 %	43 %	0 %	14 %
ease of use	43 %	0 %	43 %	0 %	14 %
user friendliness, convenience	43 %	0 %	43 %	0 %	14 %
annual energy storage	43 %	0 %	43 %	0 %	14 %
ease of maintenance	57 %	0 %	29 %	0 %	14 %
system simplicity	57 %	0 %	29 %	0 %	14 %
availability, accessibility	29 %	0 %	29 %	0 %	43 %
ease of maintenance/cleaning	14 %	0 %	29 %	0 %	57 %
upkeep, maintenance, care	71 %	0 %	14 %	0 %	14 %
service/maintenance requirements	71 %	0 %	14 %	0 %	14 %

Appendix 2. The search terms for the ISI Web of Science. The search was carried out in October 8, 2008

In our search, *TS* in field tags contains title, abstract, keyword and author keywords. We included the topic and abstract in our study since they mostly relate to the main idea of the study (Abrahamson and Fairchild, 1999). Here AND and OR are Boolean operators.

```
TS=(Rogers AND ("relative advantage" OR compatibility OR complexity OR trialability OR observability))
OR
TS=("relative advantage" AND compatibility AND complexity AND trialability AND observability)
OR
TS=("relative advantage" AND compatibility AND complexity)
OR
TS=("relative advantage" AND compatibility AND trialability)
OR
TS=("relative advantage" AND compatibility AND observability)
OR
TS=("relative advantage" AND complexity AND trialability)
OR
TS=("relative advantage" AND complexity AND observability)
OR
TS=("relative advantage" AND trialability AND observability)
OR
TS=(compatibility AND complexity AND trialability)
OR
TS=(compatibility AND complexity AND observability)
OR
TS=(compatibility AND trialability AND observability)
OR
TS=(complexity AND trialability AND observability)
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