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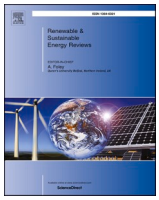

Segmenting household electricity customers with quantitative and qualitative approaches

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ABSTRACT

Understanding private electric utility customers is essential given their central role in the sustainability transition of the electricity system. Socio-economic attributes, environmental attitude, and electricity consumption are not enough to take the new technological, economic and regulatory bases of the residential electricity markets in many industrialized countries into account. Further attributes can help to obtain a more holistic understanding of the private electricity customer. We conduct three studies and find a good correspondence of the customer segments resulting from a survey of the literature, an expert workshop, and a survey of Swiss electricity customers. Five key customer segments are distinguished: 1) affluent and quality-oriented, 2) ecologically aware, 3) technophile, 4) regionally rooted, and 5) stable and uninterested. Due to their unique energy preferences, these customer segments represent critical boundary conditions for technology adoption driven sustainability transitions. Assessment of the strengths and weaknesses of the segmentation methods suggest that with sufficient resources a combination can produce reliable and valid segments.

1. Introduction

Four interwoven developments have raised the insecurity of electricity markets and above all among electrical utilities, at least in European countries, over the past 10–20 years: *First*, the ongoing regional and national sustainable energy transitions[1] [1] challenge European electric utilities to innovate their business models [4–6]. *Second*, policies of electricity market deregulation and related liberalization raise the freedom of private electricity customers to choosing their electricity providers and generate a largely new situation of competition for electric utilities in many countries [7–9]. *Third*, the emergence and diffusion of new technologies for electricity generation [10,11], transmission and distribution [12–14] and storage [15–17] have created new possibilities and functions for private electricity customers. Electric utility customers are increasingly taking on a far more diverse and active engagement with the generation, distribution, storage, and consumption of electricity, in contrast to their earlier role in regulated markets as recipients of largely commoditized electricity product offerings. *Fourth*, due to the previous three developments electricity customers today can participate in decentralized electricity production (prosumption), individually and collectively, often in neighborhood or community initiatives [18,19]. Household customers have also begun to adopt individual and shared local decentralized electricity storage solutions [20], and generally their electricity usage and management behavior has undergone significant changes in the last 10 years [19,21].

As their relationships with their private electricity (household) customers have become central to their strategic responses to the ongoing changes in electricity markets, electric utilities are seeking to recognize the more complex and diverse nature of their relationship to the contemporary private electricity customer. Utilities need to know their customers better in order to retain them. Retention, to a large extent, depends on how customers perceive service quality [22] and how satisfied they are [23] with the utility. It has a significant impact on utilities' profitability [24]. Utilities also need to know the preferences of their current and potential future customers to introduce market offers which these customers will find attractive, and they need to tailor their marketing and advertisement to customers' needs [25].

Previous research that has tried to understand electricity and renewable energy consumption has to a large extent relied on

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[1] Sustainable energy transitions are defined as the increasing regional, national and local adoption of renewable energy technologies in the generation of energy with the goal of reducing carbon emissions in response to climate change [1,2], thereby ensuring that energy consumption "meets the needs of the present without compromising the ability of future generations to meet their own needs" [3], p. 16].

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List of abbreviations

ANOVA	Analysis of Variances
BMI	Business Model Innovation
CHF	Swiss Francs
CVIs	Cluster Validity Indices
F	Factor
KMO	Kaiser-Meyer-Ohlkin
MSA	Measure of Sampling Adequacy
NAS	Neighborhood Attachment Scale
NEP	New Environmental Paradigm
OLS	Ordinary Least Squares
PCA	Principal Component Analysis
PCE	Perceived Consumer Effectiveness
PV	Photovoltaics
S	Segment
TWh	Terawatt-hours

quantitative methods: modelling the consumption of electricity or renewable energy products through regression analyses has shed light on the important influencing factors [25–28]. This line of work has stressed that attitudinal variables mediate socio-economic characteristics such as gender, age, education, and income [27]. Above all, opinions on environmental protection and ecological attitudes in general have been found to explain a higher degree of sustainability and acceptance of renewable energy consumption [25–27,29]. Moreover, perceived consumer effectiveness (PCE), that is the degree to which consumers believe their decisions actually have an impact on environmental matters, are important [27,30,31].

However, more recent and qualitative work has found that other unexpected attitudes can also influence the adoption of renewable energy technologies and subsequent behavior change towards sustainable energy consumption: Schelly points to an "interest in technical innovation and enjoyment of the technical aspects of energy systems" as a driver for solar electricity adoption [32]. Palm finds that the influence of peers on the adoption of PV-based electricity production comes primarily from direct interpersonal contacts and social exchange and not mere observation of installed systems in a neighborhood [33]. Thus, the attitude and openness of consumers to social relationships matter. However, as we will show below, previous segmentations of energy customers predominantly relied on socio-economic variables and environmental attitudes. At the same time other attitudes, such as openness to and interest in new technology, sociability and communicativeness, or regional identification, have become increasingly important with the changes of the electricity system and its position in societies, but they have been under studied in electricity customer segmentations. So, a first aim of this paper is to generate a more holistic understanding of the electricity customer, by going beyond socio-economic variables and environmental attitudes.

In regulated electricity markets electric utilities had to worry very little about their value proposition to residential customers and their business models. Even after market liberalizations started, utilities reaching out to their residential customers struggled with their position in the electricity market, offering a commodity, which was not well understood by most consumers, fairly standardized, and difficult to differentiate and brand. In the words of Rundle-Thiele et al. [31, p. 182]: "Marketing renewable power is a challenge." In addition, for the average households in most industrialized countries electricity supply was and still is below the price perceptibility threshold. Even though customer-centric innovation efforts have been conceptualized in a number of frameworks and literatures over the years, integrating customers into value proposition design or even new product development [34–38], they have hardly been used among electrical utilities. A defining feature of this literature is a more nuanced understanding of the customers' values and attitudes and the reasons behind their behavior, to offer attractive value propositions to customers [34,38,39] or even involve the customers themselves in their development [37]. It draws on more hands-on qualitative approaches such as workshops, participative observation, ethnographic and other qualitative methods. For instance, Hankammer et al. [40] apply Clayton M. Christensen's jobs-to-be-done framework [36] and use a mixed-methods design to identify consumer needs along the lifecycle of television sets. In the paper, identifying unmet consumer needs was perceived as a first step to generating new value propositions, which are attractive for consumers and include the provision of services that complement or replace the provision of products. In the view of the authors, knowledge of these needs constitutes an empirical boundary condition to steering the industry towards a circular economy.

Such customer-centric concepts and frameworks have been little used in the electricity industry, but this is changing, as the role of residential households and the value propositions for them have become more complex. A second aim of this paper is to go beyond a purely quantitative approach and include the knowledge of electricity suppliers about their customers via qualitative methods. We followed what Machauer and Morgner [41] called a "hybrid approach" which identified segments in a workshop and then applied clustering techniques using attitudinal data which were collected in a survey of electric utility customers. Combining quantitative and qualitative methods and embedding quantitative segmentation in the practical business context helps us to learn about the methodological strengths and limitations of both and combine them in a way that increases the robustness of the results and their relevance for management.

The paper contributes in several ways: 1) Methodologically, by combining results from innovation workshops with electrical utilities with survey data on the customers of these utilities. 2) In terms of content, through the synthesis of customer segments in the residential private electricity business. 3) Conceptually, by including a more comprehensive set of customer-related characteristics that go beyond socio-economic variables, environmental attitudes and behavior, and electricity consumption. This can be perceived as an extension of the boundary conditions of the conceptualization of consumer decisions, with a particular focus on renewable energy. Such establishment of boundary conditions has been argued to be a key contribution of literature reviews [42] and empirical studies [43,44] to advancing theory. 4) Last but not least, we make a practical contribution providing insights for electrical utilities seeking to adjust their value propositions and marketing to reach out to household customers. The results also contribute to the broader energy transition and electric utility BMI [45] research agendas. These contributions are of value not only to local and national actors in Switzerland seeking to advance the Swiss sustainable energy transition, but also to scholars seeking to realize a more customer centric approach to strategic responses by business to societal transitions.

The paper is structured as follows: In section 2 we briefly describe the context of the study and the three approaches pursued to synthesize the literature, collect data from utility managers and scientists on the local electricity consumers, and collect data from electricity consumers themselves. Section 3 presents the results of each of the three approaches (literature, workshop, survey) to understanding customer segments and section 4 discusses them. Section 5 draws conclusions for management and research.

2. Methods and data

The findings of this paper are based on three independent and concurrent efforts to segment the private household customers of electric utilities (see Fig. 1):

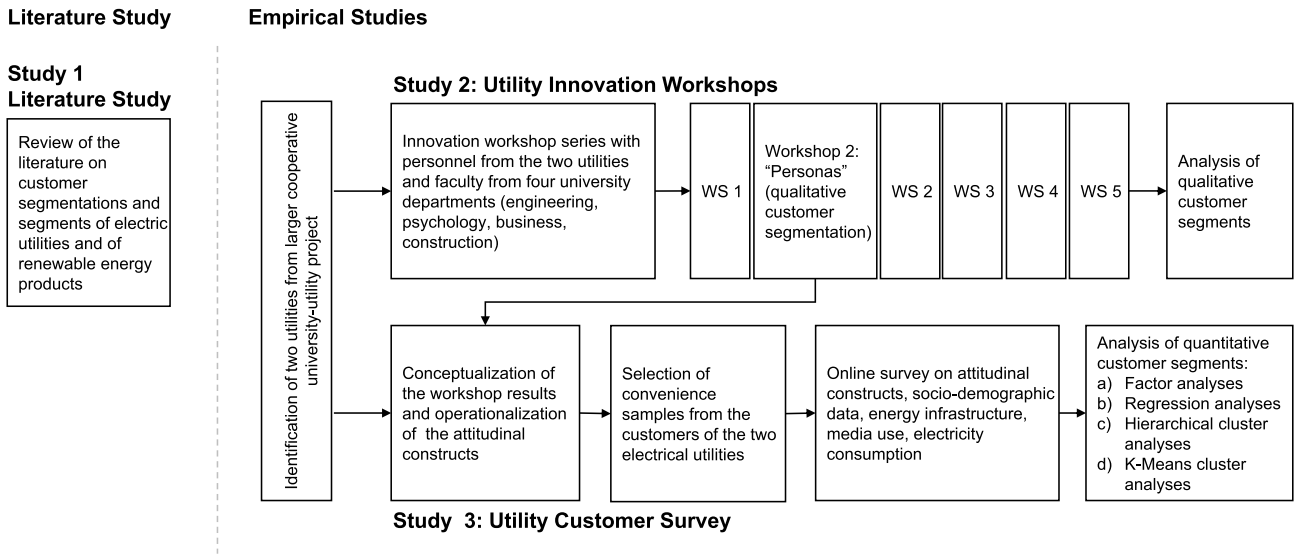

Fig. 1. Overview of the multi-study research design (Source: Authors.).

- *first*, a systematic review of the literature on customer segments of electric utilities and customers of renewable energy products more generally,
- *second*, an expert workshop-based approach, within the context of a broader business model innovation project,
- *third*, a customer survey-based approach.

2.1. Context of the study

The empirical setting of the study is the Swiss electricity system. In 2019 the total Swiss annual electricity production of 67.8 TWh included 56% from hydropower, 35% nuclear power plants, 3% conventional thermal power and district heating plants, and 6% renewable energy sources [46]. Households consumed approximately one third of the electricity. Switzerland is one of the few Western European countries with a partially deregulated electricity market: only large customers can choose their electricity supplier freely; households need to buy it from their local or regional utility, of which close to 700 exist in a country of approximately 8 million inhabitants. These utilities are almost all (89%) owned by the Swiss public sector, with 8% having private owners and slightly less than 3% have foreign owners [46]. Following the Fukushima disaster in 2011, the Swiss Federal Council drew up a strategy that includes the phase-out of the nuclear power plants, a reduction of per capita energy consumption, and an expansion of energy production from new renewable sources (wind, solar energy, biomass and geothermal energy). The Federal Act on a Secure Electricity Supply with Renewable Energies (2021) also aims to fully open up the electricity market to competition and create incentives to invest in domestic renewable energies [47]. Hence, the Swiss electricity sector continues to be confronted with fundamental changes.

2.2. Literature synthesis

A semi-systematic approach was adopted to identify the most appropriate literature for this study [48]. The search for articles focused on electric utility business models relied on a systematically collected database of references for energy research created as part of a larger innovation project. The articles were then supplemented by a purposeful search of major energy (e.g., Energy, Energy Policy and Energy, Sustainability and Society) and strategy (e.g., Strategic Management Journal, Long Range Planning) journals, to identify business model innovation studies, searching for the terms business model and business model innovation. A further search for articles focused on electricity customer segmentation was also conducted, starting with a general search via Google Scholar, followed by searches of the major journals for marketing (e.g., Journal of Marketing Research and Journal of Marketing), renewable energy, sustainability and environment (e.g., Energy and Environmental Sciences and Advances in Energy Materials), and psychology (e.g., Personal Psychology and Journal of Applied Psychology), which resulted in a very limited number of results. This search was then adapted, and major energy journals were included. The search terms used to identify customer segmentation papers included customer, preferences, segmentation, segments, clusters, energy, and electricity. In both the business model innovation and customer segmentation searches the approach was one of seeking articles that explicitly addressed the focal interests of electric utility business models, BMI and customer segmentation as explicit part of the study. Results were classified according to two criteria:

1) *Type of variables used in the customer segmentation.* Wedel and Kamakura [49] distinguish between general and product-specific characteristics, which can be directly observable or unobservable (i.e., inferred), as the bases for segmentations. *General observable* characteristics, such as geographic, demographic, and socio-economic variables, are easy to measure, comparatively stable over time, and readily available to companies. However, market segments resulting from such variables might be too generic to be meaningful for business decisions and group together customers with inhomogeneous demand, limiting their value for predicting demand [49,50]. *Product-specific observable* (also "behavioral" [50]) characteristics, such as purchase or use frequency or brand loyalty, have many advantages with regard to segmenting customers for existing products and brands. However, in the case of new products, they are challenging to observe [49,50]. *General unobservable* characteristics can be grouped into personality traits, personal values and lifestyle [49]. It is well understood that such measures can be used to detect general behavioral patterns, but not the selection of one specific brand. *Product-specific unobservable* characteristics, i.e., psychographics, perceptions, attitudes, preferences, or behavioral intentions related to one product or brand can produce highly responsive market segments [49]. However, they can only be collected through dedicated and expensive empirical work and not be simply transferred to other products.
2) *Resulting customer segments.* Nine different customer segments were identified in more than one of the reviewed studies, see Table 3 and

Appendix 1, and a set of further segments appeared in only one study, suggesting considerable heterogeneity among household electricity customers.

2.3. Qualitative electricity market segmentation: expert workshops

Customer segmentation was pursued within a larger workshop-based business model innovation project [51], in collaboration with two electric utilities. Workshop participants included industry experts, electric utility managers and academics from diverse disciplinary backgrounds, but with a shared focus on energy and electrical utilities. The second workshop of the collaboration adopted an approach that sought to develop "personas" [52] for focal private (household) electric utility customers in Northwestern Switzerland.

The personas workshop was attended by five representatives of the two partner electric utilities and eight academic participants from four disciplines and focused on developing as broad a range of electric utility private (household) customers which were then evaluated on the attractiveness of their ascribed attributes for the electric utilities.

The workshop started with two exemplary electric utility customer personas, in an attempt to create a shared understanding of the goal and format of the collaborative effort. It resulted in a further 34 customer personas being suggested in a brainwriting [53] session by the participants. The 36 personas were then aggregated in an open plenum discussion, leading to a final set of twelve distinct customer personas representing the typical household customers of the electric utilities. The results are summarized in Table 4, below.

2.4. Quantitative electricity market segmentation: customer survey

The second empirical segmentation relied on data obtained through a survey of the utilities' customers and subsequent regression and cluster analyses.

2.4.1. Survey design and sample

The survey was conducted among private household customers of two Swiss utilities participating in the innovation project. Both utilities are regional multi-product firms, catering to business customers and private household customers of several communities.

The default product for both utilities is electricity from predominantly Swiss hydropower plants. Both offer more expensive "green" electricity products, with a new renewable component (PV or wind energy) and/or contributions to ecological measures. Utility A offers one green product and Utility B three slightly different products. Utility A also offers a slightly cheaper electricity product with a nuclear power component ("grey" electricity). Neither utility offers a specific regional product: Utility A does not include the origin of the electricity in its product descriptions and Utility B characterizes all green products as regional.

The customer survey was conducted in March and April 2017 online. The link to the questionnaire was printed on a flyer inviting customers to participate in the study. A total of 12,000 Utility A customers received the flyer as a supplement to their quarterly accounts, and 35,000 Utility B customers as a supplement to a customer magazine. A total of 464 persons completed the survey in full; 203 of them were utility A customers (response rate: 1.7%) and 261 Utility B customers (response rate: 0.75%).

Among the respondents of Utility A we find only a small share of 6% of green electricity consumers (see Appendix 2), for Utility B this share is notably higher (25%). The grey electricity product has been purchased by 30% of the survey respondents from Utility A. Furthermore, the survey responses differed significantly, between the two utilities, with regard to the estimated annual electricity costs as well as some socio-economic and attitudinal characteristics (see Appendix 2).

2.4.2. Constructs and indicators

2.4.2.1. Approach. Socio-economic characteristics are easily observable and therefore widely used indicators in segmentations [50]. However, it has long been known that the correlation between socio-economic traits and consumption decisions is at best weak [41,49,50,54,55]. Personality traits, personal values and lifestyle indicators, subsumed under the headline of "general unobservable characteristics" [49] have been found to predict purchase behavior better. This follows Homer and Kahle's [56], cf. [57], cognitive hierarchy model which conceptualizes human behavior as influenced by cognition in a hierarchical structure: values are considered as the most general cognitions which influence more specific cognitions like attitudes. Attitudes in turn influence behavioral intentions and behavior. Homer and Kahle [56] used nine values to explain favorable attitudes towards nutrition. Above all individuals who rated the values of fun and enjoyment in life, self-fulfillment, and self-respect more highly had more favorable attitudes toward nutrition and were more often frequent natural food shoppers, as well as spending more on natural foods. Machauer and Morgner [41] used 11 attitudinal constructs to segment bank customers. They showed that the individuals in the identified attitudinal clusters show more distinctive attitude profiles, above all with regard to the attitudes towards information and towards technology, than those of customer groups defined by simple socio-economic criteria.

Following the latter approach, we conducted guided discussions prior to the survey, in six focus groups of private energy consumers, living in the German-speaking part of Switzerland. The results of the focus groups were fed into the development of an electronic online questionnaire. Using this questionnaire we then obtained data on attitudes by means of a survey among the customers of the two utilities.

2.4.2.2. Measures. The questionnaire was divided into the following parts: socio-economic data, data on energy infrastructure (e.g., type of heating/domestic hot water system), media use, electricity consumption, and evaluation of different electricity scenarios. From these questions we used only the socio-economic data and selected variables on electricity consumption. Moreover, to cover the attitudes towards the topics of the environment, social affairs, money, regional identification, and technology, we employed 22 questionnaire items and used 6-point Likert response scales (see Appendix 3).

2.4.2.3. Survey data processing. Two groups of variables from the survey had to be processed before the analyses: the attitudinal variables and the electricity costs.

Attitudinal variables. The answers to attitudinal questions might be prone to response styles which reduce the variance in the responses and introduce a uniform response bias. In the context of energy-related attitudes, Van der Velde et al. [58] have suggested to apply the ipsative measurement method [59] to resolve this problem. We followed this suggestion and produced ipsative values for the attitudinal variables by subtracting the mean response across all attitudinal questions from each individual value. This procedure essentially converts the rated variables into relative, ranked variables in which the extreme opinions and attitudes are revealed.

Moreover, Dibb and Stern [60] suggested to conduct a principal component analysis (PCA), in order to reduce the influence of correlated variables and outliers on the segments resulting from customer segmentations. In our dataset, the Measure of Sampling Adequacy (MSA) for the 22 ipsative attitudinal variables was mostly very low (<0.5) and the KMO-measure reached only 0.133. After stepwise excluding eight variables, the MSA was in no case below 0.5 and the KMO-measure of 0.71 described the dataset as well suited for the PCA (see Appendix 3, only 14 italicized variables were kept for the PCA). We extracted six factors based on two criteria as suggested by Everitt & Hothorn [61]: an eigenvalue greater than 0.7 and an "elbow" in the scree plot of the

logged eigenvalue. The components explain 73% of the total variance, with the first factor (Varimax rotated) contributing 23.8% and the sixth factor 5.3% (factor loadings are shown in Appendix 4).

Estimated annual electricity costs. The costs in Swiss Francs as provided in the survey were highly skewed and not normally distributed according to Kolmogorov-Smirnov tests. We eliminated two extreme outliers of (at household level) implausible electricity costs of 20′000 and 15′000 CHF per year. Furthermore, we calculated natural logarithms and used this in the regression analyses as the dependent variable.

2.4.2.4. Regression analyses. Variables are meaningful for segmentations if they can explain consumer behavior. We conducted regression analyses to evaluate the relationship between attitudes, socio-economic characteristics and electricity consumption, i.e., the self-assessed annual electricity costs and the choice of the green and grey electricity products. We conducted stepwise regressions, which retained only the variables with significant coefficients $p < 0.05$. Table 1 shows the results of OLS-regressions on the estimated annual electricity costs (natural logarithms). The goodness-of-fit measure is acceptable for this type of analysis, indicating that we can explain 36.3% of the variance of the annual electricity costs. As we would expect, the higher ecological consciousness, the lower the electricity bill, suggesting that ecological consciousness raises energy saving behavior. Respondents with a high value for the social networking dimension tend to have higher electricity costs, however, the factor slightly misses the chosen significance threshold of 5%. Several control variables have been added in the regression: respondents from Utility A have higher electricity costs. Employed respondents have lower electricity bills, which might be due to the fact that they spend less time at home than retired and self-employed respondents; in addition, self-employed respondents might work at home more often using more electricity in the process. Household size, the size of the living space, and the housing type "living in own house" correlate with higher annual electricity costs as well.

The results of the stepwise logistic regressions on the choice of a green electricity product (utilities A and B) and a grey electricity product with a nuclear power component (utility A) are not shown. The results confirm that both, attitudinal and socio-economic variables matter. However, the set of variables that are retained in the regressions differs: Ecological consciousness is a strong predictor of the choice of the green and grey product, but with the expected opposing signs: positive for the green product, negative for the grey product. Technological competencies also explain product choice, with customers of the green product having lower and customers of the grey product having higher self-assessed competence levels. Moreover, customers of the green product have a lower inclination to social networking and customers of the grey product are less concerned about financial losses. Lastly, age and education also contribute to explaining product choice. In sum, several of the attitudinal constructs and socio-economic characteristics contribute to explaining the different measures for electricity consumption. It is notable that the configuration of significant variables differs between the regressions. This confirms the expectation that a broad set of attitudes and characteristics should be considered to obtain meaningful customer segments which indeed relate to consumption.

Table 1
Estimated annual electricity bill in CHF (OLS regression).

	Beta Coefficient	T	Sig.
Attitude constructs			
F1 Ecological consciousness and economic disinterest	−0.132	−2.800	**
F2 Regional identification	.003	0.055	
F3 Economic loss avoidance	-.018	−0.374	
F4 Social networking	.088	1.805	+
F5 Technological competencies	-.006	−0.126	
F6 Technological curiosity	.037	0.792	
Control variables			
Intercept		62.361	**
Utility A	0.099	2.086	*
Employed	−0.126	−2.650	**
Household size	0.176	3.353	**
Lives in own house	0.322	5.911	**
Living space (in sqm)	0.229	4.213	**
Goodness-of-fit (adjusted R squared)	0.363		
Observations	355		

**p < 0.01, *p < 0.05, + p < 0.1.

2.4.3. Segmentation techniques

Wedel and Kamakura [49] identify the selection of the appropriate segmentation methods, which produce "true" market segments, as a key challenge when performing market segmentation analysis. Previous work has suggested that the combination of hierarchical and non-hierarchical clustering methods, starting with a hierarchical minimum variance clustering (Ward's method) which can then be subjected to some non-hierarchical clustering, like the k-means clustering, produces good results [49,62].

We first ran hierarchical cluster analysis (using Ward's method) of the six factors resulting from the PCA. Determining the number of clusters that represents best the underlying cluster structure of a dataset is not trivial. Cluster Validity Indices (CVIs) have been suggested as a solution. A comparative study of 30 CVIs by Arbelaitz et al. [63] found that the Silhouette index performs best with real world datasets. The Silhouette index as well as visual analyses of the increase of within-cluster variance in the agglomeration process suggested an 11-cluster solution as optimal for the dataset.

We then conducted another analytical step and submitted the cases to a k-means cluster analysis, for which we used the 11 clusters obtained in the hierarchical clustering and the cluster centers as the initial values. Approximately two third of the cases remained and one third was reassigned to a different cluster in this step.

The paper employs a common and wide-spread approach to the clustering of survey-data, and its purpose is not to evaluate the influence of methodological variations, but to compare across clustering approaches (literature-based, workshop-based, survey-based).

3. Segmentation results

This section presents the results of the three approaches separately before engaging in a comparison.

3.1. Synthesis of customer segments from the energy literature

Customer centric approaches are increasingly being promoted for generating effective responses to the sustainable energy transition [64–66], understood as the increasing regional, national and local adoption of renewable energy technologies in the generation of energy with the goal of reducing carbon emissions in response to climate change [1,2]. We review two streams of literature, the energy related BMI and broader energy literatures.

The business model approach has been mobilised in a diverse range of areas related to the ongoing electricity sustainability transition, with a focused on generic electric utility business model evolution [5,66]. Three of these studies focused either exclusively on Switzerland [45,67] or included Switzerland [64], the national context of our study.

The customer segmentations in electric utility business model studies remain general, typically distinguishing only between private/household and commercial customers [4,13,68–70]. Facchinetti and Sulzer [67] and Hannon et al. [69] identify four customer categories of residential, commercial, industrial and farms (agricultural). Customers are also often categorized by the degree to which they consume and/or produce electricity [68,70] and whether they own the generation

capacity [45,68]. Only a small number of studies have also proceeded to describe specific customer characteristics, including:

- how demanding they are and their expectations vis-a-vis the electric utility [68],
- the nature of their electricity consumption [45,64,70],
- their desired degree of control over their electricity consumption [68],
- how active they are in relation to their electricity related activities [66,68],
- their awareness of environmental/sustainability themes [68,70],
- their needs and desires [69–71] and preferences [45,71],
- their degree of flexibility [71],
- the changing nature of their relationship with electric utilities [6],
- their spending power, degree of social engagement [66], and
- how driven they are by environmental or economic missions [66].

Work that seeks to move beyond the more generic segmentations and customer characteristics identified above is rare (see Table 2). According to our knowledge Curtius et al. [64] is the only example where a typology of customer segments was developed, for smart grids (Supporters, Ambiguous and Sceptics), that subsequently allow four generic business models (Saver, Smart+, Smart Camouflage, Trader) with unique value propositions for different customer segments to be developed. In this work the perceived advantages and costs of smart metering by potential consumers played an important role in developing the customer segments.

Research on customer segmentation in the broader energy literature also continues to remain limited, although it does show increasing convergence. Recent research in major energy journals has addressed household energy behavior in terms of energy use and savings [72–77]. Others focused on customer preferences for different electricity products (e.g., renewable vs. non-renewable) [30,78], and the related willingness to pay [80], the interaction and preferences of electricity customers with smart metering systems, in-home displays, and web-based feedback [81–83], and the perceived importance and beliefs regarding biofuels [56].

A range of approaches was applied to describe different customer types (see Table 3). Most of the studies based their customer segmentation approach on general observable characteristics, such as socio-economic (e.g., income level or education level), pro-environmental behavior (e.g., energy savings or building improvements), dwelling attributes (e.g., dwelling type or residency duration) or regional factors (e.g., urban vs rural or different climate zones). Product-specific observable characteristics are also actively used, including energy consumption patterns (e.g., renewable vs non-renewable energy or the quantity and variability of electricity consumption) and the use of smart metering attributes (e.g., remote reading and remote steering). In contrast product specific unobservable characteristics are rarely included, while three types of general unobservable characteristics are beginning to emerge as increasingly adopted, namely environment-related (e.g., environmental awareness), financial (e.g., responsiveness to financial incentives) and technology (e.g., technology affinity) related values and attitudes. A diverse range of other value and attitudinal characteristics have also been used, but have not to date contributed further distinct categories of general unobservable characteristics.

In the studies that combine different types of characteristics (general and product-specific, observable and unobservable), commonly one type of characteristic is used to cluster the data and a second one to describe the resulting clusters (see Appendix 1). Whereas most of the studies used quantitative data collected through surveys or smart meter data, a few cases that also use qualitative approaches (interviews, focus groups) have been applied for the characterization of customer clusters [78,83]. The studies encompassing quantitative data vary in their analysis methods: The majority applied a (hierarchical) clustering analysis [56,72,75,81,82,84,87]. The number of final clusters (i.e., customer

Table 2
The use of observable and unobservable characteristics in customer/market segmentation in the energy literature.

General observable characteristics

Socio-economic	Pro-environmental behavior	Dwelling	Regional
• Income level • Respondent age • Gender/Gender roles • Education • Family type/ characteristics • Employment status • Language	• Pro-environmental behavior • Energy saving/ efficiency-related • Energy management • Acquisition of energy related knowledge • Environmental organization member • Building improvement	• Dwelling types • Residency duration • Relocated place of living • Energy types • Conditions in building • Occupancy Duration • Construction Date • Impact on resale value • Energy label	• Urban (developed)/ Rural Zone (undeveloped) • Climate Zone

General unobservable characteristics

Environment-related values & attitudes	Financial values & attitudes	Technology Related values & attitudes	Other values & attitudes
• Environmental awareness • Ascription of responsibility • Willingness-to-pay for eco-friendly products • Support for eco-taxes • Awareness of green electricity labels • Consumption (reduction) convictions	• Financial/ investment motivation • Responsiveness to financial incentives • Controlling and reducing costs	• Technological affinity • Appeal of home energy monitor to Consumer	• Supply risk tolerance • Self-efficacy/ Consumer efficacy • Response efficacy • Personal efficacy • Personal norms • Attitude to contextual forces • Personal security • Complexity tolerance • Personal comfort & convenience • Cultural and Creative • Traditional Values • Self-realization, careerist • Legitimate practices/norms • Trust in science • Responsiveness to feedback frequency

Product-specific observable characteristics		Product-specific unobservable characteristics	
Energy consumption	**Smart Metering and Home Energy Monitoring**	**Energy Meter User Acceptance**	**Energy-related values & attitudes**
• Technology Renewables/Non-renewables • Energy Mix Renewable/Non-renewable • Type of grid connection • Energy consumption quantity	• Remote Reading • Reading Accuracy • Real Time Consumption Feedback	• Consumer familiarity with home energy monitor	• Well informed on energy matters • Willingness-to-pay for sustainable electricity

(continued on next page)

Table 2 (*continued*)

General observable characteristics	
• Energy consumption variability • Electricity costs to consumer • Estimate of cost of green electricity • Switched tariff • Appliance ownership • Owns PV (solar) • Product bundling – home security • Pricing tariff (low/high) • Pricing monthly fee • Price guarantee • Contract length/cancelation terms • Location of electricity generation • Supplier • Eco Certification • Other	• Remote steering services • Ownership of Home energy monitor (HEM)

Sources: Yang et al. [30]; Van der Velde et al. [58]; Gouveia, Seixas [72]; Grey, Bean [73]; Hache et al. [74]; Kwac, Flora, Rajagopal [75]; Nachreiner, Matthies [76]; Li et al. [77]; Hübner et al. [78]; Tabi, Hille, Wüstenhagen [79]; Zhang, Wu [80]; Gölz, Hahnel [81]; Kaufmann, Künzel, Loock [82]; Murtagh, Gatersleben, Uzzell [83]; Sanguinetti et al. [84], Slupik et al. [85]; Han et al. [86]; Suetterlin et al. [87].

segments) varies between 3 and 24, 3–5 being the most common result (see Appendix 1).

Regardless their different approaches, the studies obtain partially consistent customer segments (see Appendix 1 and Table 3 for an overview over the segments in each study).

- Several studies have identified a *price-sensitive customer segment* featured by low income [30,72,74,80], and a low willingness to pay for renewables [30,82]. Their choice of energy products and feedback systems are driven by the motivation to reduce financial costs [81,82,86,87]. The price-sensitive customer segment feels no moral obligations to contribute to the expansion of renewable energy, but rather perceives it as a common good [30,80].
- A second is the passive, *neutral or uninterested customer segment*, that seeks to keep the energy systems' impact on their lives as low as possible [81,85,87], but do engage in energy saving behaviors, preferably (or even only) if it is incentivized by financial benefits [73,81,83].
- The third customer segment is the *environmentally aware/"green" energy customer*, that shows a high indication of pro-environmental behaviors [30,73,85] and a high interest in saving electricity [73,83]. Customers in this segment choose energy products based on environmental-friendly characteristics [30,56,78,85], a strong interest in renewable energy [78], or their high willingness to pay higher prices for it [30,80]. According to Grey & Bean [73] and Yang et al. [30], this group is motivated by a sense of personal responsibility and moral obligation.
- The fourth customer segment commonly identified covers "modern" and *technology-minded customers*, who are likely to take on innovations as early adopters [84,85] and have a high interest in new technologies and preferences for steering, programming, and monitoring services [78,82,83].
- The fifth consistent customer segment includes customers that emphasize the *quality of energy products and their comfort* [72,85–87], resulting in high demand for which they have a high willingness-to-pay [74,75].
- The sixth customer segment, the traditional/conservative, includes elderly customers with a limited interest in renewable energy [76,78,79], technology use, and innovations [84].
- The seventh customer segment is the hedonic or entertainment-oriented segment, motivated by fun and learning experiences [78,81].
- The eighth customer segment has been labelled the reluctants, a customer segment that is principally resistant to changing their energy/electricity consumption, with low levels of pro-environmental behavior, some responsiveness to incentives [73], but lower levels of motivation, opportunity and ability to conserve energy [77].
- The nineth customer segment is the knowledgeable/well educated, typically has a higher education entry qualification or university degree, tends towards two person households and undertakes pro-environmental behaviors related to electricity consumption via appliances [76]. Although the pro-environmental behavior of the segment is not a primary influence on energy consumption for the segment [85–87].

A central question for understanding and practically identifying customer segments is what types of variables can best be used to undertake segmentation. In Table 3 we cross-tabulate variable types and the nine frequent segments. If more than 60% of the segmentations use a characteristic type to identify a segment, we would classify the approach as "strong", if 40–60% identified a segment it is "average" and if less than 40% identified a segment with a characteristic type, it is a "weak" attribute for that segment.

Our review suggests that general observable characteristics are strongest at identifying the most common or well understood of the 9 labelled segmentations in Table 3. Socio-economic characteristics are strong predictors of price sensitive, passive and uninterested, and environmentally aware segments. While the lack of pro-environmental behavior is a strong predictor of price sensitive, and passive and uninterested segmentations and the presence of pro-environmental behavior is an average classifier of environmentally aware, and quality and comfort-oriented segmentations. Dwelling characteristics and regional attributes are average to strong in the segmentation of price sensitive, and quality and comfort-oriented customers.

General unobservable characteristics provide the strongest approach for identifying the environmentally aware segment, followed by the traditional conservative segment, while providing an average to strong approach for identifying the price sensitive, passive uninterested, technology affine, and the quality/comfort-oriented segments. Environment-related values and attitudes being central to identifying the passive, environmentally aware and traditional customer segments. Financial values and attitudes are a strong approach for the environmental and quality/comfort-oriented segmentations and average at segmenting price sensitive, passive and traditional conservative customers. While technology related values and attitudes are a strong approach for identifying the environmental, technology affine and traditional segmentations.

Product-specific observable characteristics are average to strong at the segmentation of the most common or well understood of the 9 labelled segmentations, namely price sensitive, passive and uninterested, environmentally aware, technologically affine early adopters, and quality and comfort-oriented segments. Product-specific unobservable characteristics are average to strong at identifying the same segments, but additionally have average strength for segmenting traditional conservative, and knowledgeable and well-educated customer segments, using energy-related values and attitudes.

All in all, this tells a clear story: The price sensitive and the passive and uninterested segments are very well detected through clustering general or product-specific observable characteristics of the customers. For the environmentally aware, modern and technology affine, and the traditional & conservative customer segments the inclusion and use of general unobservable characteristics (psychographics, values, attitudes)

Table 3
Frequent customer segments from previous segmentations by variable type.

	Price-sensitive		Passive / neutral / uninterested		Environmentally aware / "green"		Modern / technology minded / early-adopters		Quality- / comfort-oriented		Traditional / conservative		Hedonic/ entertainment oriented		Reluctants		Knowledgeable / well educated		Other		No. of Unique Papers
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N
General observable characteristics																					
Socio-economic	9	69	9	69	9	69	4	31	6	46	5	38	1	8	1	8	4	31	3	23	13
Pro-environmental behavior	6	75	5	63	4	50	2	25	4	50	2	25	-	-	2	25	3	38	1	13	8
Dwelling	5	83	3	50	1	17	1	17	3	50	2	33	-	-	1	17	2	33	1	17	6
Regional	2	67	1	33	-	-	-	-	2	67	-	-	-	-	-	-	-	-	1	33	3
General unobservable characteristics																					
Environment-related values & attitudes	3	50	4	67	5	83	3	50	2	33	4	67	1	17	-	-	2	33	1	17	6
Financial values & attitudes	3	50	3	50	4	67	2	33	4	67	3	50	1	17	-	-	2	33	-	-	6
Technology Related values & attitudes	-	-	-	-	2	67	3	100	-	-	2	67	1	33	-	-	1	33	1	33	3
Other values & attitudes	4	50	3	38	6	75	3	38	4	50	4	50	2	25	-	-	3	38	2	25	8
Product-specific observable characteristics																					
Energy Consumption	6	75	4	50	4	50	3	38	5	63	2	25	1	13	-	-	1	13	4	50	8

	Price-sensitive		Passive / neutral / uninterested		Environmentally aware / "green"		Modern / technology minded / early-adopters		Quality- / comfort-oriented		Traditional / conservative		Hedonic/ entertainment oriented		Reluctants		Knowledgeable / well educated		Other		No. of Unique Papers
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N
Smart Metering and Home Energy Monitoring	1	33	2	67	-	-	3	100	-	-	1	33	-	-	-	-	-	-	2	67	3
Product-specific unobservable characteristics																					
Energy-related values & attitudes	3	75	2	50	3	75	2	50	2	50	2	50	-	-	1	25	2	50	-	-	4
Energy Meter User Acceptance	1	33	2	67	2	67	1	33	-	-	1	33		-	1	33	-	-	2	67	3
Total segments	12	67	10	56	7	39	7	39	8	44	6	33	2	11	2	11	5	28	7	39	18

Key: Strong Approach | Average Approach | Weak Approach

provides for better segmentation results. The quality, comfort-oriented segment is similarly common for general observable and general unobservable variable configurations. There are, however, several other segments for which both the observable and unobservable general and product-specific characteristics that would represent the strongest approach for identifying the segmentations remain poorly understood. The characteristics that best describe the technology affine customer segment arguably remain poorly understood in the literature, but seem to likely be unobservable. While little to no evidence of an understanding of the four types of characteristics of the hedonic, reluctants, and knowledgeable and well-educated customer segments is found in the literature.

3.2. Workshop-based customer segmentation

The first phase of the personas workshop conducted with experts from electrical utilities and a university in Northwestern Switzerland resulted in a total of 36 customer types being identified during the

brainwriting session, including the two initial persona examples of the provided by the organizers (marked with * in Table 4). The university participants and the representatives of the electric utilities respectively contributed 18 and 16 new customer descriptions. Each of these suggestions included several attributes, as identified and described by the workshop participants. The 36 personas exhibited significant overlap, which was addressed in a second phase of the workshop, resulting in the final 12 customer segments (see Table 4). The customer types were described by the participants to the workshop using 18 characteristics and behaviors (see rows in Table 4). Participants adopted some of the attributes suggested by the workshop organizers for the two exemplary customer types, when describing other customer types, but also suggested several new attributes: these attributes are in part specifically related to electricity/energy and in part general characteristics. They include ecological, technological, and social attitudes, as well as behavioral characteristics (e.g., being mobile, adopting innovations, owning a house).

The attribute-persona matrix is shown in Table 4. A few general patterns can be observed:

- General observable characteristics were hardly used for describing customer segments. Not even the "Poor Payer" (segment 09) was described with an observable characteristic like income. An unobservable electricity-specific marker was used instead, namely low willingness to pay for electricity. This reflects that data on most of the observable characteristics is not readily available to utilities (e.g., income, education, family type, or employment status).
- The most commonly used general characteristics, 3–8, relate to technological, social, ecological attitudes and behavior, and regional orientation. Experts seem to perceive those as most relevant to describe electricity customers. Other attitudes and traits, such as independence, innovativeness, or having fun matter less. University and electric utility representatives identified several categories to an equal degree, but utility managers emphasized more strongly, "evangelism" (i.e., the drive to convince others) and communicativeness, either personally or digitally. Workshop participants from the university referred more often to technological affinity, concern for the environment, and the importance of having fun.
- In addition to the five electricity-specific observable and unobservable categories (rows marked with an asterisk *) which were already included in the examples provided to start the workshop, only one further specific characteristic was added by the workshop participants (compared to eleven additional general characteristics). While for the most frequent types with three or more mentions in the workshop, above all electricity-specific variables were used, this applies only to one of the less frequently named types, the stable customer, which was contributed by the workshop organizers.
- All in all, the workshop participants found it easiest to use general unobservable characteristics to describe customer segments. University staff placed more emphasis on electricity-related attributes (e.g., time and commitment to energy, extent of trust in electricity producers and utilities, high interest in electricity and energy topics, and own production of electricity), utility managers on general unobservable characteristics. This comes as a surprise and we would have expected the opposite, that people from industry rely more strongly on categories from their immediate context. This finding might be interpreted as a sign that utility managers do not know a lot about the relationship of their customers to electricity.
- The descriptions of the customer segments contributed by utility managers and academic experts are generally in line and we do not find any contradictions. However, the richness of the descriptions from academic experts is higher than from corporate workshop participants which in most cases used fewer attributes to describe the customer types.
- In the results positive evaluations dominate, above all among the general characteristics (except for the segments 02, 08, & 09). High customer interest in technology, high ecological awareness, high interest in social status and inclination to communicate (traits 4 and 5) are frequent customer attributes. This raises the question whether the opposite attributes were below the awareness threshold of the workshop participants and are therefore missing in the results. Only one of the suggested customer types was featured by low interest in technology and there were no suggestions for technologically phobic customer types. This shows a tendency to suggest customer types that are described with positive rather than negative attributes. Only among the electricity-specific variables we find two attributes that have predominantly negative values, the extent of trust in electricity and utilities (trait 18) and the stability of customer contracts in the electricity sector and frequency of supplier changes (trait 14).
- Those customer segments that are associated with high engagement with their electricity supply and produce their own electricity (segments 01, 02, 05 & 07) received significant attention despite their relatively small numbers in the overall electricity user population. The academic participants emphasized them even more than the utility representatives. This could be of interest if these customer segments are seen as indicating future trends.

3.3. Customer segmentation by means of a survey

3.3.1. Segmentation with factor and cluster analyses

The second segmentation consisted in a principal component analysis of a matrix of 14 variables and 464 observations, which resulted in six factors (see section 2.4.3 on the methods and Appendix 4 on the results), which were then subjected to cluster analyses. The clustering resulted in 11 market segments which have between 25 (S4) and 63 (S2) members (see Table 5). Fig. 2 shows the factor profiles of the segments. A black column indicates that the cluster mean is for this factor above zero, a white column indicates that it is below. The larger the black (white) columns, the bigger (smaller) the cluster means. The cells in the figure are ordered: clusters and factors were submitted to a permutation with the banded anti-Robinson criterion creating local optima in the Bertin plot, i.e., clusters and factors most similar to each other were placed next to each other in the figure [88].

First, we see that factors differ regarding their contribution to the differences between the segments. Regional identification contributes only little and above all with a large negative value (= virtually no regional identification) in S11, whereas technological competence contributes to many segments, both positively and negatively. Second, two market segments are characterized by strong negative values for most factors, S2 and S4, and one segment by predominantly positive values (S7). Third, financial affluence is a strong factor in the segments, both in a positive way (S3–S5) as well as in a negative way of little tolerance of financial losses (S6, S7, and S11). The three affluent segments are not strong on ecological interest or regional identification, all characteristics often used by utilities to market "green" electricity products. However, two segments consist of tech-savvy and technologically curious respondents, of which one segment has a very low value for sociability (S3) and the other a moderate to high value (S5). The third segment with financially secure customers that would also tolerate losses with their investments is the abovementioned S4, that has virtually no positive values for any of the constructs. Fourth, it came to us somewhat as a surprise that demonstrating basic technological competencies (factor 5) is distinct to showing curiosity for and having fun with new electronic devices (factor 6). Even more, three segments have at the same time high values for one construct and low values for the other (S1, S8 and S9). S9 is primarily described by these two factors, and S10 has also high values for social and ecological interest. Hence, the latter seems to be a lot more amenable for marketing measures appealing to these two factors. S1 is probably the most difficult to explain, and why people with little technological competence still might be curious about new technologies.

Fifth, only S8 is characterized by a strong regional identity, plus a

Table 4
Overview of the outcome of the personas workshop.

Characteristics and behaviors of electricity consumers	01 (Partly) Self-sufficient prosumer		02 Cost Optimizer*		03 Technophile		04 Early Adopter		05 Ecologically Aware Customer		06 Digital Shopper		07 Ecologically Aware Prosumer		08 Stable Customer*		09 Poor payer		10 "Conrad" Tinkerer		11 Neighborhood / Facility Manager Energy		12 Private Home Builder / Renovator	
No. of customer types in the workshop, origins in brackets (corporate/ academic)	6 (1/5)		6 (3/3)		5 (3/2)		4 (1/3)		4 (2/2)		3 (2/1)		2 (1/1)		2 (1/1)		1 (1/0)		1 (0/1)		1 (1/0)		1 (0/1)	
General observable characteristics																								
1. Mobile customer						+																		
2. Property ownership																				+				+
General unobservable characteristics																								
3. Technological affinity and knowledge		+			++	++	+	+		-	+	+								+				
4. Social status and recognition seeking								++		+	+						-			+	+			
5. Communicativeness (personally or digitally)*					+					+	+		+		-	-				+				
6. Ecological awareness, environmental concern		+	-	-		+			++	+			+	+										
7. Evangelist, wants to convince others					+			+					+								+			
8. (Home) regional orientation			-	-					+	+											+			
9. Importance of independence/ autonomy	+	++																		+				
10. Innovativeness, early adoption of innovations						+	+	+																
11. Importance of entertainment and fun factor				+								+												
12. Importance of practical constraints																								+
Electricity/energy specific observable characteristics																								
13. Own production of electricity*	+	++		+						-			+	+	-	-				+				
14. Stability from utility perspective*				-	--							-			+	+								
Electricity/energy specific unobservable characteristics																								
15. Time for and	+	o		+	+	+		+		-		-			-	-				+	+			+

commitment to energy*																							
16. Willingness to pay for electricity/energy services*		+	--	--	+	+	+	+	o	+			+	+	+		-						
17. Interest in electricity & energy topics*		+		o		+								+		-							
18. Trust in electricity sector actors, utilities	-	-				-				-													

+ Ratings of corporate workshop participants + Ratings of academic workshop participants

*These rows and columns include the exemplary customer types and attributes provided at the beginning of the workshop by the organizers.

++ Strong positive characteristic of the segment, + positive, o neutral, - negative, -- strong negative.

high value for the social networking construct (F4). Combining this insight with the characteristics of technophiles as described in this paragraph, it seems that marketing measures should either appeal to technological curiosity or to regional identity, but not to a combination of both. Sixth, there is a segment with rather little interest in ecological and technological topics, and additionally a high value for the avoidance of financial losses which we interpreted as few financial resources (S6). This type will probably be challenging to reach with electricity marketing measures, except for offers helping them to reduce costs. Seventh, S11 stands out because of its low value for regional identification and intolerance of financial losses. The low value for regional identification might reflect that this is a cluster of customers with potentially high mobility. They show above average concern for the environment and social networking and average technological interest. For this segment, flexible and short-term offers could be of interest, stressing low costs and environmental "correctness".

Even though several segments differ significantly regarding socio-economic characteristics (see Table 5), the pattern is complex, and the segments cannot be reduced to simple socio-economic differences. Electricity consumption can be approximated in the dataset through the type of product obtained from the utility and the annual electricity costs. The shares of new renewable ("green") electricity customers are highest in S1, S2, and S10, and lowest in S3–S5; the latter segments have above average shares of "grey" electricity customers. The attitudinal characteristics map fairly well on these shares with a few attributes sticking out:

- Ecological consciousness is high in the three segments which buy "green" electricity products (Table 5 and Fig. 2), as we would expect. Also, in S11, which consists of renting families with children, ecological interest is present and green energy has more often been chosen than grey energy.
- Financial affluence is the common characteristic of the three segments that consist of large shares of consumers of "grey" electricity products. The degrees of interest in technology and sociability vary across these clusters, but their relative wealth and good education are remarkable.
- Strong regional identification (S7, S8) goes hand in hand with below average education (i.e., many vocationally and few academically trained respondents) and average selection of green energy products.

4. Discussion

4.1. Comparison of the approaches and results

This section discusses the similarities and differences between the three independent parallel studies with regard to the categories used for segmenting and the resulting customer segments.

4.1.1. Segmentations: variables and approaches

Previous customer segmentations have predominantly used three groups of variables: general observable characteristics including socio-economic attributes, environmental behavior and/or conditions of dwellings or housing, attitudes towards the environment, and observable measures of energy consumption. Segmentations drawing on general observable characteristics and on energy consumption fared well with identifying several segments, but they performed worse with identifying the segments of technology minded (early-adopter) consumers, conservative energy consumers, and hedonic, entertainment-oriented consumers. These were discovered well by general attitudinal variables and energy-related attitudes which, however, were less common in the segmentations, beyond environmental, energy-related and financial attitudes.

The segments obtained from our attitudinal constructs in the customer survey data correlate with socio-economic differences and help explain electricity consumption. Ecological consciousness, social networking, technological competencies, and the attitude towards financial constraints differ across the segments and relate to electricity consumption. In particular, the attitudes towards technology and socializing and communicating are thus valuable additions, which describe aspects of energy consumers that have become more important in recent years. The workshop-based segmentation confirms this as the participants also placed a higher importance on unobservable characteristics when describing residential electricity consumers. We thus confirm earlier qualitative evidence on influences on electricity consumption decisions and the adoption of renewable energies [28,32]. As the involved utility managers demonstrated only limited understanding of their customers' attitudes towards electricity in the workshop, this suggests that such categories would not be considered sufficiently in internal and qualitative approaches, e.g., as part of business model innovation projects, to segmenting customers. This reminds of Rundle-Thiele et al.'s [31] Australian case study, where they found that

Table 5
Socio-economic characteristics and electricity consumption of the customer segments.

	N	Socio-economic characteristics								Electricity consumption		
		Average age	Share females	Share basic vocational training	Share w. Academic degree	Share of pensioners	Share w. income >100′000	Share of tenants	Share households w. children	Share "grey" energy	Share "green" energy	Est. Annual elect. bill in CHF (median)
S1: Ecologically conscious, technologically curious, but not tech-savvy	25	60	28%	28%	40%	28%	38%	36%	8%	0%	52%	800
S2: Customer with some ecological and low technological and social interest	39	69	33%	39%	23%	54%	19%	15%	5%	9%	39%	900
S3: Financially secure and markedly unsociable technophiles	39	69	3%	18%	51%	59%	48%	21%	10%	27%	6%	1′200
S4: Financially secure and technologically disinterested customer	48	61	15%	21%	42%	31%	51%	10%	15%	31%	10%	1′000
S5: Financially secure and sociable technophiles	44	49	21%	9%	46%	11%	61%	43%	30%	31%	6%	800
S6: Low resource and low interest customer	38	57	29%	38%	5%	34%	38%	32%	18%	8%	24%	1′150
S7: Financially cautious technophile with strong regional identification	63	55	19%	38%	30%	38%	42%	22%	27%	16%	24%	1′000
S8: Strong regional identity and sociable, with some ecological awareness and little technological interest	52	59	58%	39%	25%	28%	29%	29%	21%	21%	21%	860
S9: Technologically competent	49	54	27%	18%	37%	22%	51%	39%	18%	14%	19%	1′050
S10: Technologically competent, with strong social and ecological interest	35	51	40%	14%	46%	15%	42%	26%	37%	4%	29%	800
S11: No regional identification and financially very cautious, with some social and ecological interest	31	43	45%	23%	50%	0%	50%	52%	42%	4%	23%	600
Total	463	56	28%	26%	35%	30%	42%	29%	21%	17%	21%	1000

a utility might introduce new products without segmenting the market at all or even without defining the target customers.

All in all, we find that not all categories have been taken into account equally well and that both time, comparing the literature and our recent analysis, and segmentation methods influence what attributes, attitudes and behavior are being considered as crucial for understanding the consumption decisions of energy consumers. The greater the degree to which a customer segment diverges from the well understood customer segments, the less likely we are to understand the appropriate observable and unobservable characteristics to meaningfully identify them.

4.1.2. Segments of electricity customers

The findings show that both empirical analyses, the clustering and the workshop approach, identified customer segments established in the literature, but that the workshop resulted in a less differentiated segmentation (see Table 6). Drawing on the literature, the specific customer segments have been grouped into five segment categories, which at least partially have distinct socio-economic characteristics, attitudes, and electricity consumption patterns. The drivers behind these consumption patterns have been confirmed in the regression analyses.

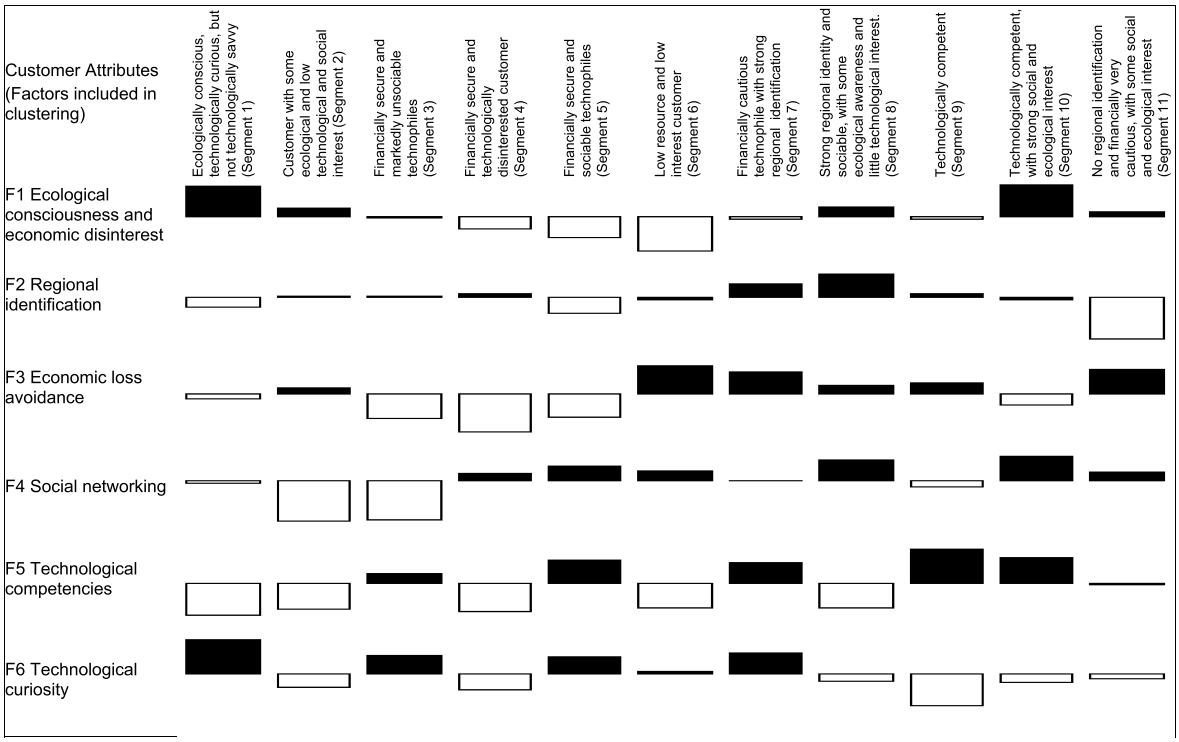

Fig. 2. Customer segments resulting from clustering of the survey results (Source: Authors.).

(i) *Affluent and quality-oriented customer segment.* Customers which have a strong focus on the quality of the products and services which they consume and the financial means to pay for this were identified in the literature [74,75] and in the empirical cluster analysis. They vary on several socio-economic characteristics and include sub-segments of (mainly) pensioners, households owning real estate, as well as younger tenant households with children. However, they have in common that they are well educated with above-average percentages of academic degree holders, have more than average shares of high-income households, and, most importantly for our purposes, more than average consumption of the grey electricity product, i.e., a product that is cheaper than the standard product and includes a nuclear power component. At first glance this might seem counterintuitive, but the average to low values for ecological consciousness are in line with the consumed electricity product. The estimated annual electricity bill is either above or below the overall average. In a nutshell, the characteristics identified in the clustering suggest that the willingness-to-pay more than necessary for electricity and to subsidize renewable energy products are low in this segment, due to low ecological consciousness and different consumption preferences. Financial restrictions would not matter. This segment was identified in the workshop as well and classified as "cost optimizer", stressing the key characteristic combined with the low ecological awareness.

(ii) *Ecologically aware segment.* The two empirical analyses identified a number of sub-segments where ecological awareness was a defining feature, as has been established in both the business model innovation [66,68,70] and broader energy literatures. Interestingly, both empirical approaches to segmentation identify these sub-segments and the key discriminator between them is identical as well, namely technological affinity [78,82,83] – in the workshop this was translated into an inclination to engage in electricity production and become a prosumer (high technological affinity). For the sub-segments identified in the cluster analysis ecological consciousness is the overarching commonality. The sub-segments show clear differences with regard to the technological and social dimensions. Ecological consciousness also translates into a different electricity consumption pattern, with above-average shares of green electricity consumers which pay a higher price and purchase electricity products with an additional component of new renewables and/or an environmental funding scheme. The sub-segments still have 10–20% lower estimated annual electricity bills than the median respondent, suggesting that electricity saving behavior is more widespread in the segment.

(iii) *Technology-savvy customer segment, technophiles.* Both empirical analyses identified technophile customer segments, with strong technological knowledge, reflecting previous energy research [78,82,83]. The cluster analysis detected two sub-segments of technology-minded customers that were similar on almost all dimensions except for technological curiosity, one having a high and the other a very low value for this factor. They have in common that they identify with the region, are economically cautious, but neither very concerned ecologically nor socially integrated. Their energy consumption is close to the average, with average shares of grey and green electricity consumers, as are their annual electricity bills.

In the workshop, several sub-segments with strong technological interests were suggested, mostly also characterized by some degree of financial affluence. The presence of so many sub-segments can be explained by established attributes, such as the degree to which the customers are likely to be early adopters [84] and having high interest in new technologies [78,82,83]. In the workshop, technological interest was equated to interest in electricity and energy technologies. Neither the financial affluence of the segment nor its interest in electricity technologies were confirmed in the clustering, however. Both are rather below the average in this segment. This limits the adoption of ecologically motivated electricity offers and the likely contribution of this segment to the sustainability transition.

Table 6
Comparison of segments resulting from the three approaches.

Literature	Cluster Analysis	Workshop Analysis	Logic for Alignment
Affluent and quality-oriented Segment	3 Financially secure and markedly unsociable technophiles 4 Financially secure and technologically disinterested customer 5 Financially secure and sociable technophiles	02 Cost Optimizer	Low willingness-to-pay for energy and very stable from the perspective of the utility. The cluster analysis finds the desire to avoid economic losses as the strongest criterion binding the three subsegments.
Ecologically Aware Segment	1 Ecologically conscious, technologically curious, but not technologically savvy 2 Customer with some ecological and low technological and social interests 10 Technologically competent, with strong social and ecological interest	05 Ecologically Aware Customer 07 Ecologically Aware Prosumer	The approaches identified different customer segments with high ecological awareness which mainly differ with regard to their interest or savvy for technology. The more technologically competent segment tends towards prosumption. The survey suggests the prosumers may also be more social.
Technophile Segment	7 Financially cautious technophile with strong regional identification 9 Technologically competent	03 Technophile 10 ″Conrad" Tinkerer (singular) 06 Digital Shopper 04 Early Adopter	Low willingness-to-pay for energy and very stable from the perspective of the utility. The cluster analysis suggests that these customers may be technologically competent, but not very curious. Interestingly the workshop identified the most sub-categories of customer segments for those customers that are social, technologically competent and interested. All the customer segments here are featured by financial security, but low interest in the ecological environment or regional identification. The workshop suggests there may be an interest in energy.
Not covered (Regionally rooted Segment)	8 Strong regional identity and sociable, with some ecological awareness and little technological interest	11 Neighborhood/ Facility Manager Energy (singular)	Strong expressions of regional and local identification and the social dimension
Stable and Uninterested Segment	6 Low resource and low interest customer 11 No regional identification and financially very cautious, with some social and ecological interest	09 Poor payer (singular) 08 Stable Customer	The approaches identify multiple related customer segments that are featured by stability, that have low interest in the topic of energy and can further be distinguished by their financial means and their degree of interest in adopting new technologies.

Note: The workshop identified two customer segments (01 (Partly) Self-sufficient prosumer and 12 Private Home Builder/Renovator) that could not be matched to the survey-based segmentation approach, as the survey did not include the relevant descriptors.

(iv) *Regionally rooted customer segment.* This segment does not have a good expression among the segments identified in the literature (see section 3.1). The customers in this segment can be characterized by a strong level of regional identification, a new attribute that was not included in earlier studies, but arguably represents an unobservable counterpart to the previously adopted general rural/urban distinction or climate zone observable characteristics [74,75,80]. Their energy consumption pattern is similar to that of segment (iii). We still consider it to be a separate segment, as it differs, in part notably, from the previous cluster in the other dimensions. Above all, the survey respondents from this segment consider themselves as not very tech-savvy, the defining criterion of segment (iii), but they place a high value on the social dimension, i.e., social networking. The workshop participants identified one segment that bears some resemblance to this segment, namely segment 11 "Neighborhood/Facility Manager Energy". It shares the regional and social features but differs somewhat regarding the role of technology, respectively shows more interest in energy. Notably, a strong regional identification does not translate into a particular electricity consumption pattern (as revealed by our measures). However, it needs to be kept in mind that neither utility in our sample offers a specific regional product, with Utility B classifying all its new renewable products at the same time as "regional".

(v) *Stable and uninterested customer segment.* Both the cluster analysis and workshop identified different stable and uninterested customer segments, defined by a low interest in energy issues, an attribute observed previously in the business model innovation [66,68] and broader energy literatures [81]. The two sub-segments from the cluster analysis and the two from the workshop are aligned in terms of the role of willingness-to-pay [30,82], with the clusters characterized by a pronounced focus on the avoidance of economic losses. Whereas in sub-segment 6 ecological awareness and technological competence are low, in sub-segment 11 regional identification is absent. Socio-economically, these sub-segments have few things in common, but sub-segment 11 is notable being the one with the highest shares of tenants, households with children, and youngest respondents. The electricity products consumed are very similar, but sub-segment 11 has the lowest estimated electricity costs 40% below the median. All in all, the cluster analysis especially shows the diverse and complex nature of the stable and uninterested category of customer segments, which is critically important, as these customer segments represent most likely a large share of electricity customers in a regulated market.

The workshop made clear that the degree to which the utilities view these customer segments favourably is highly related to their stability as customers, i.e., an assumed low propensity to change the provider after

market liberalization. With regard to their economic resources the workshop participants distinguished sub-segments, however, of which one was even labelled "poor payers".

4.2. Methodological considerations

The results discussed in the previous section suggest a few methodological lessons for segmenting electricity consumers. The largely coherent segmentation of the electric utilities' customers by the two empirical segmentation approaches was unexpected. Unsurprisingly the statistical analysis of a larger sample of data generally provided more nuance in distinguishing customers from each other. The only occasion where the workshop produced more fine-grained results than the cluster analysis was for the technophile segment. However, the effort needed to obtain these detailed results was considerable and the success only moderate: if one takes the financially comparatively cheap way of online survey, the response rate that can be achieved in a survey is low – in our case only about 1% of the gross sample. This small net sample is then very likely to be biased, for example regarding interest in the topic of energy, affinity to responding to computer-assisted surveys or educational level. Identifying customer segments in this (biased) dataset, for instance through cluster analyses, requires a number of further decisions between different options for which the decision criteria are rather fuzzy: in particular whether variables or factors should be used, how the influence of response patterns can be reduced, which clustering techniques (hierarchical versus non-hierarchical) and clustering algorithm should be chosen, and which number of clusters represents best the underlying structure of the dataset.

However, the cluster analysis is able to distinguish customer segments with greater specificity and in combination with regression analyses the key attributes that should be included are easier to identify. This is rarely likely to be the case with the workshop approach. Overall, our results suggest that expert-based workshops are going to broadly generate similar results as the survey and subsequent quantitative data analyses. The advantage of the quantitative approach is, however, that it also may generate results on the frequency of attributes and size of customer segments, and on the covariates of consumption decisions (electricity costs, type of electricity product). However, as the dataset is most certainly biased, the numbers need to be treated carefully and it is not clear to what extent they should actually be trusted and form the basis of costly decisions on strategy, product development and new offerings to electricity customers. What is interesting with the segments developed in the workshop is that they are all to some degree associated with personal behavior or activities in the neighborhood. This suggests that workshop participants may have been able to draw on personal experiences and their information-rich understanding of the local contexts. This introduces some degree of subjectivity into the process which might not be desirable, as it could also lead to biased results depending on who participates in the workshop. In sum, a wholesome approach mixing qualitative and quantitative empirical methods and adding a review of the literature seems to be most suitable for identifying robust customer segments and their key features and differences.

5. Conclusions

Our findings have implications for analyzing and understanding renewable energy consumers and their influence on the sustainability transition of the electricity system, as well as for management practice in electrical utilities.

The first goal of this paper is to contribute to a more holistic understanding of the electricity consumer. Our findings are relevant for defining and extending the boundary conditions of the conceptualization of the role of residential customers in the electricity system in a conceptual and empirical sense. Conceptually we learned that even though large sets of variables have been used to explain residential electricity consumption and describe and segment private household consumers, the technological, regulatory, and economic bases of the industry have shifted to such an extent, that new markets and products have appeared, which cannot be understood by applying the previous, older categories used in segmentations. Socio-economic differences and differences in environmental awareness remain important, but other attitudinal constructs are central to identifying emerging electricity customer segments, which apply different criteria to evaluating new electricity products and services.

Segmentations and analyses which explain consumer choices for renewable products should therefore go beyond the set of established variables and consider further observable and unobservable general and (if available) product-specific characteristics. Technological interest, sociability and communicativeness, regional identification, and preoccupation with financial constrains have mattered in our own empirical analyses. Others before us have pointed to the attitude towards risk [30], comfort and convenience [84], self-realization and hedonism [78,81], and conservative/traditional (political) views [78]. In sum, we see a strong need for researchers to continue working on a richer picture of the residential electricity customer, taking into account further attributes to produce a deeper understanding of the influences on electric utility customer consumption decisions. From the empirical perspective we extended the known customer segments of affluent and quality-oriented, ecologically aware, technophile, and stable and uninterested customers by adding a regionally rooted customer segment. It is characterized by strong expressions of regional and local identification, and a strong social dimension, i.e., sociability and integration into regional networks.

This also strongly suggests that, also in regulated markets, utilities should develop specific offers for specific customer segments, as this will allow the maximal expansion of sustainable energy consumption. This also raises the degree to which customers' differing attitudes and preferences and the resulting intentions and behavior are being met and reduces the risk of losing the customers when the electricity market is liberalized. This means that attracting new customers to renewable offerings must find the right incentives and associations, that correspond to customers' opinions and preferences. Put differently, technologically interested consumers will not be convinced to adopt sustainable energy technologies by appealing to their environmental conscience. Instead, marketing efforts should stress the technological aspects of new product offerings that are more sustainable.

Even though we find some patterns with regard to socio-economic characteristics, it is not possible to replicate these segments by using socio-economic variables only. Above all ecological consciousness and technological competencies and to lesser extent other attitudes, are fairly strong predictors of electricity consumption or prosumption. Moreover, the attitudinal differences and patterns in the analyses point to potentially underserved customer segments. They also point to challenges that utilities must overcome when reaching out to their customers with new offers:

- The cluster patterns across both utilities indicate that financially affluent customers are not necessarily also ecologically conscious, nor do they necessarily perceive themselves as technologically competent. Hence, offering new renewable electricity products requires the identification of other incentives, e.g., regional origin of electricity, or avoiding unnecessary follow-up costs in the long run and raising efficiency of electricity consumption.
- Our empirical evidence suggests that environmentally aware customers of both utility A and B tend to consider themselves as not very tech-savvy and their interest in technology is predominantly low. Offers that involve them more actively in electricity production and require more than very basic technological understanding, e.g., PV, electrical mobility, or battery storage, might have to overcome technological fears. Customers will need accompanying services or "all-round carefree packages" to ensure they are able to contribute to their full potential to the energy sustainability transition.

– Finally, we find that a sizable share of the survey participants from Utility A identifies with the region, however, the utility does not offer any electricity products which stress the regional origin of the electricity. There might be an untapped customer segment that could be bound more strongly to Utility A through such a product.

The correspondence of the findings of the two different segmentation approaches raises our confidence in the reliability and validity of the resulting segments and reduces the risk of basing decisions on artifacts, i.e., faulty segments, which could result from imperfect or biased data and unfounded methodological decisions and are hard to detect by managers [89]. Hence, if time and resources permit, a combination of quantitatively segmented survey data and qualitatively generated workshop data would be optimal, as it produces results with the highest level of granularity and robustness.

Using a purely workshop-based approach can however be a good solution when time and other resources are too scarce to perform customer segmentation by survey. To reduce the risk of biased results and blind spots due to group think, utilities should seek a mix of internal and external participants. The variety of backgrounds and perspectives provides for a richer understanding of the electricity consumer. While internal participants from utilities bring knowledge of customers' reactions towards products and marketing activities, academia and consulting firms can provide a structured bird's eye view of electricity customers and knowledge of the context in which electricity customers operate. Customers with divergent attitudes towards energy, technology, the environment, society and economic issues themselves can represent different currents in society and contribute to a greater balance of workshop results. Such characteristics can be relatively easily identified in telephone screening interviews and taken into account when selecting participants. In addition, an analysis of the literature on segmentations of customers of comparable products helps to ground the results and better evaluate the driving variables and key characteristics which influence consumption behavior.

These findings thereby suggest clear avenues for future research and managerial practice in the segmentation of utility customers in pursuit of realizing the energy sustainability transition.

Credit author statement

Franz Barjak: Conceptualization, Methodology, Formal analysis, Investigation, Visualization, Writing – original draft, Writing – review & editing, Project administration, Johan Lindeque: Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing, Julia Koch: Conceptualization, Investigation, Writing – original draft. Martin Soland: Conceptualization, Investigation, Writing – original draft,

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Appendix 1
Overview of the electricity customer segmentation literature

Authors	Focus	Country	Data source(s)	Segmentation methods	Sample size	Segmentation variables	Specific variables used for segmentation	Outcome (customer segments)
One type of segmentation variables								
Hache et al. [74]	Household classification to provide recommendations to improve energy efficiency programs	France	National housing survey	Multiple Correspondence Analysis, hierarchical splitting by means of Chi Square Automatic Interaction Detection (CHAID)	26′004 households	General observable characteristics	Household, dwelling and geographic characteristics, and energy source for heating	4 aggregated segments: 1) Fuel poor 2) High income - high consumption 3) Rich sober 4) Poor sober
Kwac, Flora, Rajagopal [75]	Household Energy Consumption Profiles	USA	Electricity consumption data at 1 h intervals	K-means and hierarchical clustering	123′150 households with 44′949′750 24-h load profiles	Product-specific observable characteristics	Magnitude and timing of electricity consumption (load shape) based on smart meter data	9 segments in households, based on two characteristics: a) Quantity: heavy, light, or moderate b) Variability: stable, moderate, and variable
Grey,Bean [73]	Likelihood to conserve electricity	Australia	Online survey	Quartiles of an index on 12 pro-environmental behaviors	188 individual electricity consumers	General unobservable characteristics	Pro-environmental behavior (citizenship, purchasing, and household)	4 segments in customers: 1) Committeds 2) Middles 3) Privates 4) Reluctants

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Appendix 1 (*continued*)

Authors	Focus	Country	Data source(s)	Segmentation methods	Sample size	Segmentation variables	Specific variables used for segmentation	Outcome (customer segments)
Kaufmann, Künzel, Loock [82]	Customer preferences in smart metering	Switzerland	Survey	Hierarchical clustering with minimum variance algorithm (Ward)	87 households	Product-specific unobservable characteristics	Preference of specific attributes and levels for smart metering in a choice-based conjoint study	4 segments in customers: 1) Risk-averse 2) Technology minded 3) Price sensitive 4) Safety-oriented
Murtagh, Gatersleben, Uzzell [83]	Qualitative examination of household experience and behavior in response to In-home displays	United Kingdom	Interviews	Typology based on participation in sustainability projects (plus a control group)	21 households	Product-specific unobservable characteristics	social-psychological aspects of household experience and behavior in response to electricity use feedback	3 segments: 1) The Monitor Enthusiasts 2) The Aspiring Energy Savers 3) The Energy Non-active
Gölz,Hahnel [81]	Examination of underlying goals which motivate people to use web-based feedback on their own electricity consumption	Germany	actual feedback usage based on log files, accompanied by an online panel survey	Model-based cluster analysis (mixture modelling), fitting data by maximum likelihood estimation, using expectation-maximisation algorithm & Bayesian information criterion. ANOVA and MANOVA	310 electricity consumers using a smart meter and a feedback system for a one-year trial	Product-specific unobservable characteristics	goals towards feedback usage (having fun, learning how to save electricity, controlling and reducing costs, and avoiding inconvenience due to perceived negative impacts of feedback usage)	3 segments in customers: 1) pragmatic view on feedback systems; 2) hedonic-oriented; 3) doubt-oriented (strive to save electricity, but also aim at keeping the systems' impact on their lives as low as possible)
Słupik et al. [85]	Assess the potential for engaging and motivating consumers to change their behavior to be more energy efficient	Catalonia (Spain) and Germany	CAWI survey	Respondent allocation to ideal customer segments based on an algorithm	Germany (572) Spain (522) UK (512) utility customers	General unobservable characteristics	Segmentation based on environmental awareness and financial orientation, moral obligation and social pressure.	5 segments in customers: 1) Ecological idealist 2) Aspiring ecologist 3) Opportunists 4) Dedicated savers 5) Indifferent
Two types of segmentation variables								
Gouveia,Seixas [72]	Household Energy Consumption Profiles	Portugal	survey and smart meter data	Hierarchical clustering with squared Euclidean distance (Ward) of smart meter data. Survey data for cluster characterization.	265 households	General observable characteristics + product-specific observable characteristics	Household characteristics, dwelling's physical characteristics, electrical equipment ownership and use + energy consumption patterns	3 segments in households: 1) Fuel poverty (lack of fulfillment of thermal comfort levels), 2) Standard comfort, 3) "Fat energy" (potential for reduction of electricity consumption)

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Appendix 1 (*continued*)

Authors	Focus	Country	Data source(s)	Segmentation methods	Sample size	Segmentation variables	Specific variables used for segmentation	Outcome (customer segments)
Nachreiner, Matthies [76]	Assessing the energy saving potential in households	Germany	Online survey	Discriminant analysis (Fisher's functions) to determine most relevant variables and weightings, two-step cluster analysis	1254 individual electricity consumers	General observable characteristics + product-specific observable characteristics	Household characteristics, type and use of household appliances	5 segments in households: 1) Family households 2) Pensioner households 3) High-saving-potential households 4) Low-income households 5) Higher-educated households
Li et al. [77]	Identifying building occupants' energy use characteristics and their relevant behaviors to adopt energy reduction strategies	USA	online survey	k-means clustering analysis	177 occupants in a 32-story mixed use building in Chicago	Product-specific observable characteristics + product-specific unobservable characteristics	Segmentation based on motivation (needs, goals, values, level of involvement), opportunity (availability and accessibility to the energy saving information), ability (knowledge)	5 segments in building occupants: 1) Prone 2) Mildly unable 3) Unable 4) Mildly resistant 5) Resistant… to change the energy use behavior
Zhang,Wu [80]	Willingness to pay for green electricity among urban residents	China	Online and paper-based survey	Mlogit model	1139 individual electricity consumers	General observable characteristics + product-specific unobservable characteristics	Segmentation based on consumers' willingness to pay for green electricity and description along sociodemographic variables	6 segments in customers, in terms of their bid amount
Hübner et al. [78]	Customer segmentation regarding potential adoption of green electricity	Germany	Online survey	Cluster analysis (not specified)	632 current or prospective house owners that are interested in the use of renewables	General observable characteristics + general unobservable characteristics	Demographic characteristics, personal values and lifestyle	5 segments in customers that already purchase green electricity: 1) modern mothers 2) green women 3) modern fathers and mothers 4) traditional fathers 5) "guardians of empty nests" 5 segments in customers that do not purchase green electricity: 1) traditional mothers 2) urban modernists 3) urban individualists 4) career-oriented fathers 5) "guardians of empty nests"

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Appendix 1 (*continued*)

Authors	Focus	Country	Data source(s)	Segmentation methods	Sample size	Segmentation variables	Specific variables used for segmentation	Outcome (customer segments)
Three types of segmentation variables								
Yang et a. [65]	Preference regarding different energy products among energy customers	Denmark	survey with choice experiment	Latent Class Analysis using the Minimum Akaike Information Criterion (AIC), the minimum Bayesian Information Criterion (BIC), the modified Akaike Information Criterion (AIC3), and Akaike's p2	1012 individual electricity consumers	General observable characteristics + product-specific observable characteristics + product-specific unobservable characteristics	Segmentation based on their product choice (percentage of renewables, source of energy, price, contractual term, supplier), description along sociodemographic characteristics and attitudes towards green energy	3 segments in customers: 1) Value-seeking 2) Green 3) Price-sensitive
Han et al. [84]	Investigation of an intervention strategy to stimulating energy-saving behavior to achieve energy neutral urban development	Eindhoven region of the Netherlands	Online survey	A latent class model	309 households responded	-General observable, general unobservable and product unobservable characteristics	Segmentation based on social-demographic characteristics, knowledge, motivation and context factors	4 segments in customers: 1) cost driven residents 2) conscious residents 3) ease driven residents 4) environment minded residents.
Integration of all four segmentation types								
Van der Velde et al. [44]	Perceived importance and beliefs about biofuels	Belgium	survey	Ipsative measurement method for response standardization, Ward's hierarchical cluster method and K-means cluster method	363 car drivers at randomly selected gas stations	Integration of all four approaches	Customer segmentation in terms of subjective importance of different biofuel characteristics. Clusters are described in terms of sociodemographic variables, vehicle use and lifestyle, and beliefs about biofuel	4 segments in customers: 1) Performance-oriented 2) Society-oriented 3) Environment-oriented 4) Convenience-oriented
Tabi, Hille, Wüstenhagen [79]	Choice experiment about adoption of green electricity	Germany	survey with choice experiment	Latent Class Analysis, best model fit determined by means of Percent Certainty (Pct Cert), Consistent Akaike Information Criterion (CAIC), Chi-square and relative Chi-square	414 households	Integration of all four approaches	Socio-demographic, psychographical characteristics (e.g. sensitivity to environmental issues, trust in science, awareness of green electricity labels) and behavioral characteristics (e.g. switching of electricity tariff during the last 5 years, willingness to pay)	5 segments in customers: 1) Adopters 2) Potential adopters - truly greens 3) Potential adopters - price sensitive greens 4) Potential adopters - local patriots 5) Likely non-adopters
Sanguinetti et al. [84]	Assess the current market and barriers to adoption of home energy management systems	USA	survey	Two-step cluster analysis, hierarchical binary logistic regression model for each cluster, Chi-squared and one-way ANOVA tests.	709 utility customers	Integration of all four approaches	Segmentation based on awareness, interest, and ownership of home energy management systems and description along sociodemographic variables, housing characteristics, and technology adoption and use, perceived smart home benefits and barriers	4 segments in customers: 1) Unfamiliar 2) Unpersuaded 3) Persuaded 4) Owners

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Appendix 1 (*continued*)

Authors	Focus	Country	Data source(s)	Segmentation methods	Sample size	Segmentation variables	Specific variables used for segmentation	Outcome (customer segments)
Sütterlin et al. [87]	The study seeks to better segment energy consumers	Switzerland	Mail-in survey	Cluster analysis	1292 Swiss households participated	Integration of all four approaches	Segmentation based on energy saving behavior, acceptance of policy measures, beliefs and attitudes, and general attitudes related to energy-saving behaviors	6 segments in customers: 1) Idealistic 2) Selfless inconsequent 3) Thrifty 4) Materialistic 5) Convenience-oriented/ Indifferent 6) Problem-aware well-being-oriented

Appendix 2

Variables in the multivariate analyses by utility

	Utility A	Utility B	Total	F-value (ANOVA)	Obs.
Dependent variables					
Est. Annual electricity bill (in CHF)	1431.47	1097.78	1244.00	11.37**	356
Ln(est. Annual electricity bill)	7.04	6.78	6.89	13.36**	356
Green elec. product	0.06	0.25	0.17	29.65**	464
Grey elec. product	0.30	n/a	0.30	n/a	201
Attitudinal factors					
F1 Ecological consciousness and economic disinterest	−0.08	0.06	0.00	2.22	463
F2 Regional identification	0.14	−0.11	0.00	7.38**	463
F3 Economic loss avoidance	−0.04	0.03	0.00	0.48	463
F4 Social networking	0.16	−0.12	0.00	8.80**	463
F5 Technological competencies	−0.01	0.01	0.00	0.02	463
F6 Technological curiosity	−0.05	0.04	0.00	1.05	463
Socio-economic control variables					
Age	55.80	55.71	55.75	0.00	464
Gender (share females)	0.30	0.27	0.28	0.46	464
Share w. income >100′000 CHF p.a.	0.38	0.46	0.42	2.23	386
Compulsory education	0.02	0.02	0.02	0.01	464
Professional education, apprenticeship	0.27	0.25	0.26	0.30	464
Commercial college, technical college, grammar school	0.08	0.07	0.07	0.21	464
Higher vocational training	0.34	0.25	0.29	4.74*	464
University	0.27	0.41	0.35	9.76**	464
Employed	0.52	0.58	0.55	1.42	464
Self-employed	0.10	0.09	0.09	0.09	464
Other employment situation	0.06	0.04	0.05	1.72	464
Retired	0.31	0.29	0.30	0.43	464
Household size	2.34	2.26	2.30	0.56	464
Control variables for type of housing					
Tenant	0.24	0.32	0.28	2.89	464
Lives in a condominium	0.11	0.19	0.16	5.70*	464
Lives in own house	0.65	0.49	0.56	10.96**	464
Age of building, years since last major renovation	42.58	50.76	47.26	1.08	421
Living space (in sqm)	145.46	130.63	137.06	4.83*	463

Differences between utilities significant at level $p < 0.01$ (**) and $p < 0.05$ (*).

Appendix 3

Operationalization of attitudes*

Attitude towards environment (revised NEP after [90])
Eco1 To what extent would you personally be prepared to cut back on your standard of living in order to protect the environment?
Eco2 Modern science will solve our environmental problems with little change in our way of life.
Eco3 People worry too much that human progress will harm the environment.
Eco4 I do what is right for the environment, even if it costs me more money and time.
Eco5 For someone like me, it is just too difficult to do much for the environment.
Attitude towards new technology (technology acceptance model according to Ref. [91])
Tech1 I love owning new electronic devices.
Tech2 I enjoy trying out an electronic device.
Tech3 It's easy for me to learn how to use an electronic device.
Tech4 I know my way around electronic devices.
Attitude towards social contacts (derived from expert workshop, see section 3.2)
Soc1 I like to get involved in associations (clubs, parties, associations or similar).
Soc2 It is very important to me that others consider me to be competent.
Soc3 Good social relationships help me to achieve my goals.
Soc4 People who do not abide by the rules of a community should expect consequences.
Regional identity (Neighborhood Attachment Scale (NAS) according to Ref. [92])
Reg1 Region XY is the ideal place to live for me.
Reg2 There are places in region XY with which I feel very much connected internally.
Reg3 It would be hard for me to move away from region XY.
Reg4 For me it is important that the electricity I receive is produced in the region.
Attitudes towards financial investments (derived from expert workshop, see section 3.2):
Fin1 When it comes to recurring costs (e.g. health insurance, telephone, Internet), I always make sure that I have the offer with the best price-performance ratio.
Fin2 I am prepared to take out a loan for a larger purchase (e.g. car, heating, kitchen).
Fin3 I like to deal with the question of how I should invest my money.
Fin4 I can live with the possibility that my financial investments (e.g. shares, real estate, etc.) can also bring losses.
Fin5 When investing money, I always take care to make a profit as quickly as possible.

*Note: Only italicized items were kept for the cluster analysis.

Appendix 4

Rotated factor loadings from the principal component analysis (cut-off value: 0.4)

	F1 Ecological consciousness and economic disinterest	F2 Regional identification	F3 Economic loss avoidance	F4 Social networking	F5 Technological competencies	F6 Technological curiosity
Eco1	0.782					
Eco4	0.757					
Fin3	−0.497					
Reg1		0.749				
Reg2		0.752				
Reg3		0.758				
Reg4			0.679		−0.406	
Fin4			−0.78			
Soc2				0.703		
Soc3				0.838		
Tech3					0.852	
Tech4					0.861	
Tech1						0.870
Tech2						0.774

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