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Abstract

In this paper, we propose and apply the design of a sequential discrete choice experiment to examine homeowner preferences regarding the adoption of micro-generation systems and willingness to cooperate in sustainable energy infrastructure. Adoption and cooperation decisions of private households in the energy sector are complex, interlinked, and assumably sequential. A common design with single choice tasks reflecting both adoption and cooperation decisions is assumed as cognitively too burdensome for survey respondents. The objective of the proposed sequential choice task design is twofold. Firstly, reducing complexity for respondents. Secondly, reflecting a step-wise decision process as is appropriate for the studied decisions. Our application from the energy sector is motivated by the need for innovative business models for non-industrial prosumers providing flexibility services in (local) distribution grids, due to an increasing amount of volatile and decentrally generated electricity. Results indicate that respondents reveal more pronounced preferences when dealing with their decision in sequential steps and that the task design has a lasting effect on respondents' choices. By estimating latent class logit models, five consumer classes are identified and labeled by their distinguished motivational foci: costs (1), climate protection (2), self-supply (3), local reference (4), and other (5).

Keywords: **choice experiment, micro-generation, renewable energy, community energy, energy transition**

JEL Classification No.: **C25, D12, Q42**

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[1] This working paper is also listed in the FCN Working Paper Series see www.fcn.eonerc.rwth-aachen.de.

1. Introduction

A discrete choice experiment is an attribute-based stated preference method used across various research fields, including energy and environmental economics (Hoyos, 2010, Hanley, 2001), and relates to the random utility theory by Thurstone (1927) and McFadden (1974). Choice experiments can take inter-linked behaviors into account and enable analysts to test hypotheses on preferences for goods and services in consumption and investment decisions or aspects of business models and public policy (for details on choice experiments see for example Train, 2009, or Hoyos, 2010). The choice-experimental setting provides information on chosen and non-chosen alternatives from a controlled environment with independently varied attribute levels. The advantage of using a choice experiment to analyze adoption and cooperation decisions on innovations in the dynamically transforming energy sector is the possibility to investigate preferences for products and services that are not yet established on the market with little to no observable real consumer decisions.

The decisions to adopt micro-generation technologies and to cooperate in sustainable energy infrastructure (e.g. energy networks) certainly qualify as complex consumer decisions. Designing a choice experiment only for the adoption decision of micro-generation technologies is challenging due to its complexity. It is both an energy service decision and an investment decision, where options in reality consist of a large bundle of characteristics. Respondents are often unfamiliar with adoption of micro-generation technologies and even if they are familiar, it is unlikely to be a frequently repeated decision. Therefore, the formulation of the choice setting regarding the adoption of micro-generation technologies, on the one hand, needs to be rather detailed to avoid unobserved assumptions by the respondents, but on the other hand should not exceed a manageable amount of attributes. Carlsson and Martinsson (2008) point out that the number of attributes has a detrimental effect on the ability to choose among alternatives. The subsequent decisions on how to use the micro-generation technologies and how to cooperate with them in sustainable energy infrastructure such as a renewable energy community, massively increase the complexity of an already complex decision setting.

We assume that private individuals use a step-wise decision process of adoption and cooperation decisions in sustainable energy infrastructure, either separately over time in isolated acts or conceptually in basically two subsequent decisions at one point in time. The mutual dependency and potentially different frequency of these two assumably subsequent household decisions may be illustrated by analogous examples from the housing market: first choosing the residential location (e.g. a certain city for job or school reasons) and then the dwelling, or first buying a house and subsequently deciding on the usage of rooms. Another analogy is choosing the hardware and operating system for a personal computer and subsequently the software applications.[2] A step-wise decision process in two isolated acts on sustainable energy infrastructure is to be expected particularly in Germany, where in the last decade

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[2] Two-stage (i.e. investment and operation) decision modeling of residential energy demand has a long tradition in the energy econometrics literature that can be traced back at least to Fisher and Kaysen (1962); cf. Madlener (1996).

a large number of micro-generation PV systems was installed, about 800,000 up to 2013 (cf. Oberst and Madlener, 2014).[3] These distributed micro-generation systems are connected with the public grid and are affected by the same conditions, but usually do not cooperate (yet) in production, storage, and consumption. A cooperative integration of those micro-generation systems in energy networks is an option to provide some of the very much needed flexibility in the system. Faiers et al. (2007a) raise the question whether consumers assess product attributes in a step-wise process for the case of adopting domestic solar power systems. Faiers et al. (2017a) and related studies (cf. Harmsen – van Hout et al., 2013a) regard the step-wise assessment of attributes within one selection decision, while we focus on a step-wise decision process of the two interlinked but at least theoretically separate selection decisions of adoption and cooperation. Faiers et al. (2017a) show that complexity itself is an important adoption barrier for innovative and pragmatic customers. Faiers et al. (2007b) summarize the literature, stating that "*It has been demonstrated that consumers assess attributes in a stepwise process, commencing with relative advantage, then compatibility and complexity. These three attributes have been shown to hold the most influence over the purchase choice*" and refer to Rogers (2001), Dunphy and Herbig (1995), Mohr (2001), and Martinez et al. (1998).

The motivation for the specific energy application is the need for new business models of non-industrial consumers providing (local) flexibility services in the distribution grid (low and medium voltage). With pursuing the green energy transition in Germany, electrical grids face the challenge to integrate higher shares of volatile renewable energies, with a substantial amount supplied by decentral generation units (Echternacht et al., 2015). The demand for flexibility and local electricity system services in low and medium voltage grids arises due to an increasingly volatile electricity supply based on renewable energies (mainly solar and wind) and micro-generation systems. Hirth and Ziegenhagen (2013) estimate that each installed GW of wind or solar power capacity requires 30-70 MW of additional control power. Whether prosuming contributes to local grid stability or worsens it depends on the consumption and supply patterns, cooperation, and local technology concentration, which in turn depend on the legal framework and market conditions (cf. Oberst et al., 2016). Energy cooperations consisting of or integrating prosumer households are conceivable business models for modern energy supply comprising electricity generation, collective storage, controllable demand response, and therefore possibly the provision of electrical system services. Prosumer households could provide their storage capacities to external control and might adjust their load demand at particular times. Concepts of non-industrial consumers providing flexibility services to the grid are currently receiving more attention, see for example Biegel et al. (2014) on the integration of flexible consumers in ancillary service markets.[4] However, little is known about the determinants of prosumer households' willingness to participate in

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[3] Micro-generation systems defined as 10 kWp and smaller (based on data provided by transmission system operators). Since 2014 data is published by the regulator Bundesnetzagentur (URL: https://www.bundesnetzagentur.de/). However, due to a change in reporting style a direct comparison with former data is not possible. Note, the (adoption) rate of new installation of micro-PV systems is declining.

[4] Of course, integration of consumers is not the only discussed option. Glensk and Madlener (2016) discuss for example the flexibility options for lignite-fired power plants with a real options approach.

such an energy cooperation and the potential for cross-industrial energy cooperations with prosumer households.

To evaluate household preferences regarding adoption and cooperation decisions in energy technology and networks, we constructed a sequential discrete choice experiment that is adapted for the assumably step-wise nature of the decision process. The proposed sequential approach has the advantage of being relatively straightforward given the complexity of the setting. For comparison we randomly assign respondents either to a series of sequential choice tasks or to a comparable series of simultaneous choice tasks. Afterwards, we have respondents reply to holdout questions of the opposite type to investigate the persistence of effects.

The modeling of the adoption decision of micro-generation technologies relates to choice experiments on micro-generation systems and primary heating systems by Scarpa and Willis (2010) and Oberst and Madlener (2014). Scarpa and Willis find for the UK in 2007 that renewable energy sources are significantly valued by households, but that this value is not sufficiently large for the vast majority to cover the higher investment costs of renewables. Oberst and Madlener find for homeowners in Germany in 2014 a perceived utility of electricity self-supply and conclude that "prosuming" (producing and partly self-consuming electricity) involves more than just a profitable energy investment and using green electricity. Further, they conclude from the respondents' evaluation of the clarity of attributes in the choice tasks that energy policies and business models should avoid the introduction of overly complex measures. This recommendation to avoid overly complex measures also in surveys is empirically tested in the present paper.

Less is known about the willingness to cooperate of prosumer households and the mutual dependency of adoption and cooperation decisions. There is a related literature on willingness to participate in local and community-based renewable energy projects. Kalkbrenner and Roosen (2016), for example, find that the general attitude toward community energy is positive, that the willingness to volunteer is higher than willingness to invest money, and that both ownership of a renewable energy system and living in a rural community increase the likelihood to participate in community-based renewable energy projects. Regarding preferences for electricity tariffs, Kalkbrenner et al. (2017) find a positive valuation by citizens of energy supply by a local cooperative, high share of local production (66 %), and regional provider.

For our sequential choice experiment we are methodologically inspired by three streams of choice-experimental literature on complex consumer decisions. The literature on hierarchical information integration (HII), as reviewed by Molin & Timmermans (2009), develops and applies a method to reduce cognitive respondent burden when many attributes are involved, by classifying the large number of potentially influential attributes into fewer decision constructs, and designing separate experiments for each of these. In our case, the choices for system and cooperation are clearly distinguished, so there is no need for attribute classification, but the design part of the method is applied. From the HII literature, Van Helvoort-Postulart et al. (2009) are particularly influential, since they illustrate how this method can be combined with recent advances in logit modeling. The literature on consumer choices of product component packages (Dellaert et al., 2007) suggests how consumer choices of modularized products can be modeled and measured using conjoint choice experiments. They find that models of consumer choices of separate modules have lower random errors than choices between packages. We interpret the choices for system and cooperation as potential modules in the package sustainable energy infrastructure. Therefore, in both our choice-experimental designs, simultaneous and sequential, the system and cooperation attributes are also orthogonalized across alternatives and not only across choice sets. Finally, the literature on structural choice modeling (Rungie et al., 2011) proposes a way to jointly analyze data from separate but related choice experiments by integrating them with structural equation modeling (SEM), which groups related variables in latent constructs. In our case, we do not use SEM to combine our related choice experiments on system choice and cooperation choice, but account for the correlation between for example the impact of the environmental attribute on system choice and the impact of the environmental attribute on cooperation choice by interactions.

The paper proceeds as follows. Section 2 discusses the design of the discrete choice experiment, the attribute selection and attribute levels, and the structure of the entire survey. Section 3 briefly describes the estimation models used. Section 4 reports results of the empirical analysis and Section 5 concludes.

2. Design of the discrete choice experiment

2.1 Choice task structure and attributes

Table 1 presents the considered attributes and attribute levels in the choice experiment, together with a short description as provided to respondents.[5]

The modeling of the first step, i.e. the adoption decision of micro-generation technologies, relates to labeled choice experiments on micro-generation systems and primary heating systems by Scarpa and Willis (2010) and an unlabeled choice experiment on generic micro-generation systems by Oberst and Madlener (2014). Both studies model the trade-off between investment costs (capital costs) and repeated financial benefits (annual energy saving or changes in monthly electricity bills). In this study, we summarize costs related to the micro-generation system and electricity procurement costs in one attribute of average monthly electricity costs with system (*Costs System*), and consider as a second financial attribute the monthly savings or additional costs by joining an energy cooperation (in the second step). For both attributes, respondents are shown the new hypothetical absolute value of electricity costs after installing the system and the percentage this constitutes from their current electricity costs. For example, if a respondent reported 50 euros of electricity costs, then with the level of 90 %, the values of 45 euros and 90 % are displayed.[6] The financial attribute of the cooperation

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[5] Note that the survey was carried out in German and here the translation is provided.

[6] Stated household electricity costs are calculated at the beginning of the survey based on stated living area and number of household members. Subsequently, respondents are asked if the estimation is a realistic assessment of their electricity costs or if they would like to state their

decision is modeled as savings or additional costs by the cooperation (*Costs Cooperation*) and also based on stated household electricity costs. *Costs System* and *Costs Cooperation* are to be understood as average user costs and net-benefit indicators for installing a micro-generation system and joining an energy cooperation. In related choice-experimental studies, financial attributes have a strong negative influence on the selection probability.

The description of self-supply potential of the system (*Self-Supply System*) resembles the respective attribute in Oberst and Madlener (2014), but here with attribute levels 0 %, 20 %, and 40 %. Oberst and Madlener find with a larger attribute scale that private households attribute a significant weight in their decision process on adopting a micro-generation system towards self-supply (more strongly than for environmental benefits). For the cooperation decision, the self-supply attribute is mirrored as the share of electricity supplied by cooperation partners (*Supply Cooperation*), which consists of three levels (0 %, 30 %, and 60 %). The attribute levels are chosen in a way that a cooperation-supported self-sufficient situation ("autarchic") with 100 % "self"-supply potential is only possible if respondents choose an alternative with the maximum level of both supply attributes (which is not possible in all choice tasks). We hypothesize that a higher self-supply potential is generally valued positively by respondents (by system or cooperation), but the valuation is higher for the self-supply by system than for the supply by cooperation partners.

The attribute supplier of the system (*Type Supplier System*) has no directly comparable attribute in discussed related literature, but in its concept and mechanism might be compared to an attribute as "recommended by" (none, friend, plumber, etc.) in Scarpa and Willis (2010), which reflects trust in specific suppliers. The attribute cooperation type (*Type Cooperation*) is comparable to the attribute "partner companies" in Kalkbrenner and Roosen (2016). By including the attribute cooperation type in the choice experiment we evaluate preferences for different forms of cooperation (virtual or local, households or cross-industrial energy cooperations). We hypothesize that respondents have a preference for systems and cooperations with local reference.

Since the adoption and market diffusion of renewable energies is driven by the motivation of climate protection, we include attributes for contributing to climate protection by the system and the cooperation. We hypothesize that both *Climate System* and *Climate Cooperation* are valued positively by respondents, but that respondents' willingness to pay for the change to the next higher level for *Climate System* is higher than for the same change in *Climate Cooperation*.

We further control for effort with attributes for user effort of the system (*Effort System*) and time effort to participate in the cooperation (*Effort Cooperation*). Based on results in related studies, e.g. for the attribute "inconvenience of the system" on the choice of primary heating by Scarpa and Willis (2010), and for the attribute "user effort" on the choice of energy-saving measures by Harmsen – van Hout et

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monthly electricity costs manually. If respondents choose manually, the estimated value is overwritten. This procedure is applied to obtain comparable responses on households' current electricity costs, even if respondents are unaware or uncertain about their electricity costs.

al. (2013), we hypothesize that both higher *Effort System* and higher *Effort Cooperation* are valued negatively by respondents.

Table 1: Attributes used in discrete choice experiment[7]

Attribute	Description	Levels
Costs System Average monthly electricity costs with system	Considers the investment, operating, and financing costs of the micro-generation system as well as electricity procurement costs for not self-generated electricity, revenues from electricity feed-in, and other savings.	80 %, 90 %, 100 %, 110 %, 120 %
Self-Supply System Self-supply potential of the system	Proportion of the electricity consumption that you can cover with the installed system through to the year and do not need to purchase from the grid. It can be increased by installing a storage device. If 100 % of the produced electricity is fed into the grid (public or cooperation), then this is tantamount to **no** self-supply.	0 % (no self-supply), 20 % (middle), 40 % (high)
Type Supplier System Supplier of the system	Type of supplier from which the system is sourced.	local handicraft business, online merchant, private energy company, energy cooperative
Climate System Contribution to climate protection with system	With the system, for example CO_2 emissions can be reduced, which are related to electricity consumption and feed-in. A high contribution reduces CO_2 emissions by 100 % and more, while a middle contribution reduces CO_2 emissions by about 50 % (both related to the average CO_2 emissions of a unit of electricity (kWh) in Germany.	low to none, middle, high
Effort System User effort of the system	The average expected time effort for operation and maintenance of the system. Low effort (30 min. per year) is comparable to the reading of the electricity meter without own system.	low (30 min. per year), middle (30 min. per month), high (30 min. per week)
Costs Cooperation Monthly savings or additional costs by energy cooperation	Additional cost savings or extra costs by integration in the cooperation. Savings for example by means of a more efficient usage of the own system within the cooperation (e.g. storage) or a more profitable marketing of the produced electricity. Extra costs may be attributed to transaction costs.	-10 % (savings), -5 % (savings), 0 % (no changes), +5 % (extra costs), +10 % (extra costs)
Supply Cooperation Share of electricity from energy cooperation partners	Proportion of the electricity consumption that you can cover with electricity supplied by the cooperation (additional to self-supply of the system). The proportion can for example be increased by using a collaborative storage. A 100 % self-supply is in the present decision setting only possible, if you already chose a system with a self-supply potential of 40 % and here choose a high share (60 %) of electricity from cooperation partners.	0 % (no own usage of electricity by cooperation), 30 % (low), 60 % (high)
Type Cooperation Type of the energy cooperation	Virtual network means connecting electricity production units (of the partners) at different locations. In a local network, the cooperation partners are located in the neighborhood (physical connection possible).	virtual network with other private households, local network with neighboring private households, local network with neighboring industry and business companies, virtual network with private energy companies
Climate Cooperation Contribution to climate protection by energy cooperation	With the cooperation, for example more CO_2 emissions can be saved, e.g. due to a more efficient usage of the electricity produced in the cooperation. The contribution is additional to the contribution to climate protection with the own system.	low to none, middle, high
Effort Cooperation Time effort to participate in the energy cooperation	Time effort associated with the membership in the energy cooperation.	low (30 min. per year), middle (30 min. per month), high (30 min. per week)

2.2 Sequential discrete choice experiment

After an introduction to the setting including screening questions, respondents were randomly assigned to either the treatment group, with ten randomized sequential choice tasks followed by two fixed simultaneous choice tasks, or the control group, with ten randomized simultaneous choice tasks and two fixed sequential choice tasks. For the choices, respondents were asked to assume themselves in the position to purchase a micro-generation system for electricity and to join an energy cooperation. In

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[7] The original attribute description in German can be found in VI Transformation NRW (2017), p.42.

sequential choice tasks the decisions on system and cooperation were made sequential, each alternative described by five attributes, while a simultaneous choice task was described by all ten attributes (see Figure 1). By modeling two alternative decision-making structures, we are able to investigate the effect that the decision complexity can have on technology adoption and cooperation.

Sequential choice task (treatment)

Which system would you rather choose?

	A	**B**
Costs System		
Self-Supply System		
Type Supplier System		
Climate System		
Effort System		
	○	○

Which cooperation would you rather join?

	A	**B**
Costs Cooperation		
Supply Cooperation		
Type Cooperation		
Climate Cooperation		
Effort Cooperation		
	○	○

Would you really purchase the system and join the cooperation?

- **Yes**, I would purchase system and join cooperation
- **No**, I would **not purchase system**
- **No**, I would **not join cooperation**
- **No**, I would **neither purchase system nor cooperate**

Underlying set of alternatives

	1	**2**	**3**	**4**
System	A	B	A	B
Cooperation	A	B	B	A

Simultaneous choice task (control group)

Which system and cooperation would you rather choose?

	A	**B**
Costs System		
Self-Supply System		
Type Supplier System		
Climate System		
Effort System		
Costs Cooperation		
Supply Cooperation		
Type Cooperation		
Climate Cooperation		
Effort Cooperation		
	○	○

Would you really purchase the system and join the cooperation?

- **Yes**, I would purchase system and join cooperation
- **No**, I would **not purchase system**
- **No**, I would **not join cooperation**
- **No**, I would **neither purchase system nor cooperate**

Underlying set of alternatives

	1	**2**
System	A	B
Cooperation		

Note: Attributes in random order among respondents with fixed order per respondent. Same order for cooperation attributes as for system attributes.

Figure 1: Sequential and simultaneous choice tasks

On the distribution of attributes levels in choice tasks, we created an “alternative-specific complete enumeration design”[8] in Sawtooth[9] for the simultaneous treatment, and presented this same design in two steps for the sequential treatment. The alternative-specificity made sure that attributes were not only orthogonalized across choice sets, but also across alternatives. Therefore, the design became comparable between treatments, even though in the sequential treatment there are four alternatives per choice task compared to two in the simultaneous choice tasks.[10]

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[8] See Chrzan and Orme (2000).

[9] Orme (2014).

[10] Four alternatives in sequential treatment: (i) first system / first cooperation, (ii) second system / second cooperation, (iii) first system / second cooperation, and (iv) second system / first cooperation.

The survey was concluded by a debriefing questionnaire with questions on (1) household background (socio-demographics, energy situation, and general attitude), (2) clarity, importance, and attendance of attributes, and (3) quality, effort, and affinity with respect to participation.

3. Estimation model

The basic estimation model we use is the conditional logit model. It is based on random utility theory (McFadden, 1979) and assumes an individual's utility from a choice alternative U to linearly depend on attributes of the alternative X, characteristics of the individual Y (in this study: whether the individual was assigned to the sequential or the simultaneous treatment), and a random term drawn from a Gumbel distribution ε:

$$U = V(X, Y) + \varepsilon \qquad (1)$$

This last assumption makes sure that the probability P of an individual j selecting an alternative i (i.e., when its utility is higher than those from the other alternatives) is following a logistic distribution:

$$P(i) = \frac{\exp(X_i * \beta + Y_j * y)}{\sum_i \exp(X_i * \beta + Y_j * y)} \qquad (2)$$

of which the parameters β, γ can be estimated with maximum likelihood. For further information about this standard logit model, see for example Hensher et al. (2005).

The choice for system and cooperation is allowed to depend on whether it is the first system in the task and on all ten attributes, and for the sequential treatment additionally on whether it is the first cooperation in the task and on the interaction between a treatment dummy variable - equal to 1 for the sequential treatment and 0 for the simultaneous treatment - and all other explanatory variables. The system and cooperation types are coded as dummy variables, whereas all other attributes are coded as ordinal variables with the lowest level as 1, the second-lowest level as 2, etc.

In the more recent econometrics literature (e.g. Greene and Hensher, 2003) there are two different ways of generalizing the above-mentioned conditional logit model in order to explicitly account for parameter heterogeneity among individuals. The first approach is the mixed or random parameter logit model, which assumes each parameter to be drawn from a specific distribution. The analysis requires simulation methods and provides the analyst apart from the point estimates with estimated standard deviations of all parameter distributions. The latent class logit model, in contrast, models heterogeneity discretely with a predetermined number of latent classes. The analysis provides separate point estimates for all parameters for each class.

We use the software NLOGIT 6,[11] where we implement 1,000 Halton draws in the Monte Carlo simulations and a normal distribution for all parameters with the mixed logit estimation. The model selection criterion is log likelihood.

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[11] Greene (2016).

4. Empirical results

4.1 Sample characteristics

For all estimations, we use data from an internet-based survey with 2,071 respondents. The survey was carried out in December 2016 among homeowners in North Rhine-Westphalia (NRW) (about 3.5 million households in NRW), the most populous state in Germany. The sample consists only of respondents who live in owner-occupied houses (homeowners), because prosuming is mainly relevant for them. One factor is that homeowners do not face the investor-user dilemma of tenants, which sets additional high adoption barriers and restrictions for installing micro-generation systems based on property rights, decision-making independency, and house characteristics, cf. Gillingham et al. (2012). Further, only respondents stating that they make decisions on energy matters in the household (e.g. choosing electricity provider or type of heating system) were considered for the survey. This target group is in line with related literature (e.g. Scarpa and Willis, 2010, Achtnicht, 2011, Oberst and Madlener, 2014). Besides performing the choice experiment, the survey collects cross-sectional information on socio-demographic and energy-related characteristics of the households, respondents' general attitude, and perception of the choice experiment. The sample is demographically representative as stratified by age and gender. For the stratification, ten quota groups were formed with five age groups for female and male respondents. The minimum size of these quota groups was set to 120 respondents. By differentiating between treatment and control group this quota size is reduced to a minimum of 54 respondents (the number of men between 18 and 29 in the treatment group). A more detailed summary of the sample structure and characteristics is given in Table 2, with sample proportions of respondents' gender, age group, the number of actual prosumers, and selected building and household characteristics.

The mean age of respondents is 50.2 years, with about equal shares of women and men. On average, women in our sample are slightly younger than men (by about 3 years). The majority of the surveyed homeowners lives in single or two-family houses (76 %), though a relevant share of 24 % lives in in multi-family houses. The average household size in the sample is 2.6 persons and the share of 1-person households is 14 %. Of all respondents in multi-person households, 32 % state that they take decisions on energy matters in the household alone, 62 % together with partner, and 6 % with the ownership community (in 1-person households 11 % take decisions with ownership community). Differences in sample characteristics between treatment and control group are negligible as expected. Most pronounced are differences between prosumer and consumer households (see Oberst et al., 2016, for a detailed discussion). Other differences are that men and prosumers have a higher tendency to state that they take energy decisions alone. Energy decisions with the owner community are only relevant for the youngest age group of homeowners (18 to 29). The proportion of electrical water heating decreases with older age groups (except the group above 60 years). Gender differences are mainly shown for the questions regarding household's decision maker on energy matters: while 42 % of the men in multi-person households' state to make such decisions alone, only 21 % of the women state that they take such decisions alone.

Table 2: Sample structure and characteristics

	Sample	Female	Male	Prosumer*	Consumer	18 - 29 years	30 - 39 years	40 - 49 years	50 - 59 years	60 years and older
Group size (number)	2,071	1,040	1,031	347	1,724	253	250	422	472	674
Structure in %										
Treatment	50.6	51.3	49.8	47.8	51.1	49.4	50	49.3	53.2	50.1
Quota										
Women 18-29	6.4	12.8	0.0	8.6	6.0	52.6	0	0	0	0
Women 30-39	6.3	12.5	0.0	11.5	5.2	0	52	0	0	0
Women 40-49	11.6	23.2	0.0	9.8	12.0	0	0	57.1	0	0
Women 50-59	12.1	24.1	0.0	11.0	12.4	0	0	0	53.2	0
Women >60	13.8	27.4	0.0	8.6	14.8	0	0	0	0	42.3
Men 18-29	5.8	0.0	11.6	9.2	5.1	47.4	0	0	0	0
Men 30-39	5.8	0.0	11.6	7.8	5.4	0	48	0	0	0
Men 40-49	8.7	0.0	17.6	10.4	8.4	0	0	42.9	0	0
Men 50-59	10.7	0.0	21.4	10.1	10.8	0	0	0	46.8	0
Men >60	18.8	0.0	37.7	13.0	20.0	0	0	0	0	57.7
Characteristics in %										
Owner micro-generation system	16.8	16.5	17.0	100.0	0.0	24.5	26.8	16.6	15.5	11.1
House type										
Single-/two-family	76.0	75.7	76.2	87.9	73.5	75.1	76.8	78.2	78.0	73.1
Multi-family	24.0	24.3	23.8	12.1	26.5	24.9	23.2	21.8	22.0	26.9
Household size										
1-person	14.4	16.5	12.2	14.1	14.4	15.4	12.4	10.9	15.3	16.3
2-person	44.2	40.6	47.8	34.0	46.2	21.3	27.2	30.6	45.6	66.6
3 or 4-person	35.2	36.2	34.2	43.5	33.6	51.4	50.8	49.5	34.1	15.3
5 or 6-person	5.8	6.2	5.4	8.4	5.3	10.7	8.8	9.0	5.1	1.5
Household energy decision (in multi-person households)										
Alone	31.6	20.9	42.0	31.2	31.7	24.3	32.4	34.6	33.8	30.7
With partner	62.3	73.3	51.8	63.4	62.1	50.5	61.2	62.8	63.8	66.0
With owner	6.0	5.9	6.2	5.4	6.4	25.2	6.4	2.7	2.5	3.4
Water heating										
Electric	39.9	41.1	38.8	44.1	39.1	49.4	44.4	37.4	32.6	41.4
Non-electric	58.7	56.8	60.5	54.8	59.5	46.6	52.4	60.9	67.2	58.2
Unknown	1.4	2.1	0.7	1.2	1.5	4.0	3.2	1.7	0.2	0.4
Conf. estimate elect.	53.5	56.3	50.6	63.7	51.5	74.3	59.2	52.8	53.0	44.4
Characteristics in means										
Living space heated	131.7	129.2	134.2	145.5	128.9	133.4	132.3	136.5	129.2	129.6
Household size in persons	2.6	2.6	2.6	2.7	2.5	3.0	3.0	2.9	2.5	2.1

Notes: * Prosumer = Owner micro-generation system

The sample is sufficiently geographically diversified, but not stratified, across regions in NRW. All regions are sufficiently covered and the proportion is largely in accordance to the population size (see Figure 2 for the geographical distribution).[12]

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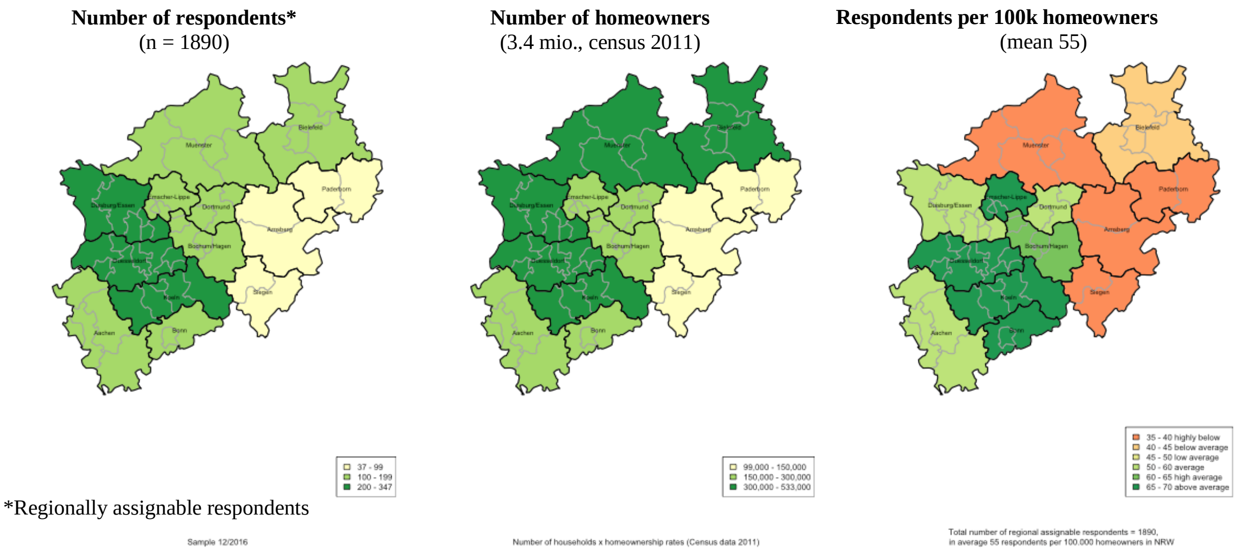
[12] For about 6 % of the respondents we observe no matching zip code and for 2 % the zip code matches to regions outside of NRW (probably due to moving, secondary residence, etc.). The data on zip codes were collected from standing panel providers four months after the survey.


Number of respondents*
(n = 1890)

Number of homeowners
(3.4 mio., census 2011)

Respondents per 100k homeowners
(mean 55)

*Regionally assignable respondents

Sample 12/2016

Number of households x homeownership rates (Census data 2011)

Total number of regional assignable respondents = 1890,
in average 55 respondents per 100.000 homeowners in NRW

Figure 2: Geographical distribution of respondents and NRW households according to planning region (ROR)

The choice experiment described in Section 2 provides 20,710 observations (choices) from 10 choice situations per respondent. Respondents were randomly assigned to the treatment group with per situation two sequential choice tasks with five attributes each, *n* = 1,047 (50.6 %), or to the control group with simultaneous choice tasks with ten attributes, *n* = 1,024 (49.4 %). In the estimation analysis, we consider the two parts of the sequential choice for the treatment group as one choice situation. Holdout choice tasks (with the alternative setting of sequential or simultaneous choices) included are discussed in Section 4.5.

In the evaluation questionnaire of the choice experiment, most respondents considered the two financial attributes *Costs System* and *Costs Cooperation* as principal decision-relevant attributes in the modeled choice situation, with 49 % and 41 %. That no attribute was primarily relevant was stated by 9 % of the respondents. The most ignored attributes were the two label attributes *Type Supplier System* (30 %) and *Type Cooperation* (26 %), as well as *Climate Cooperation* (27 %). About 26 % of respondents state that they did not ignore any attribute in the choice experiment. 43 % of respondents state that no attribute was unclear, followed by 22 % that the attribute *Effort Cooperation* was unclear.

4.2 Model selection

Table 3 presents the proportion of respondents' answers to the follow-up question "*Would you buy the chosen system in reality and would you join the cooperation according to your choice?*" according to treatment and control group. It is clear that these proportions are not significantly influenced by the treatment. Therefore, we perform all subsequent analyses only with the data on system and cooperation choices and neglect the data on the follow-up question.

Table 3: Descriptive statistics on follow-up question on reality

	Control		Treatment	
	10 simultaneous	2 sequential fixed	10 sequential	2 simultaneous
Yes, both	25 %	25 %	23 %	23 %

No, not system	23 %	22 %	24 %	23 %
No, not cooperation	13 %	11 %	13 %	11 %
No, neither	39 %	42 %	40 %	43 %

The log likelihood values from estimating the model variants as described in Section 3 are plotted in Figure 3. Both heterogeneity options appear to be strong improvements as opposed to the standard conditional logit model. With at least four classes, latent class logit, moreover, outperforms random parameters logit. With at least seven classes, latent class logit becomes inestimable, while with six classes, the log likelihood increases less (cf. Cattell, 1966) and the standard errors of the estimated coefficients are relatively large (cf. Greene, 2016). Therefore, the results of the latent class logit model with five latent classes are presented in the next section.

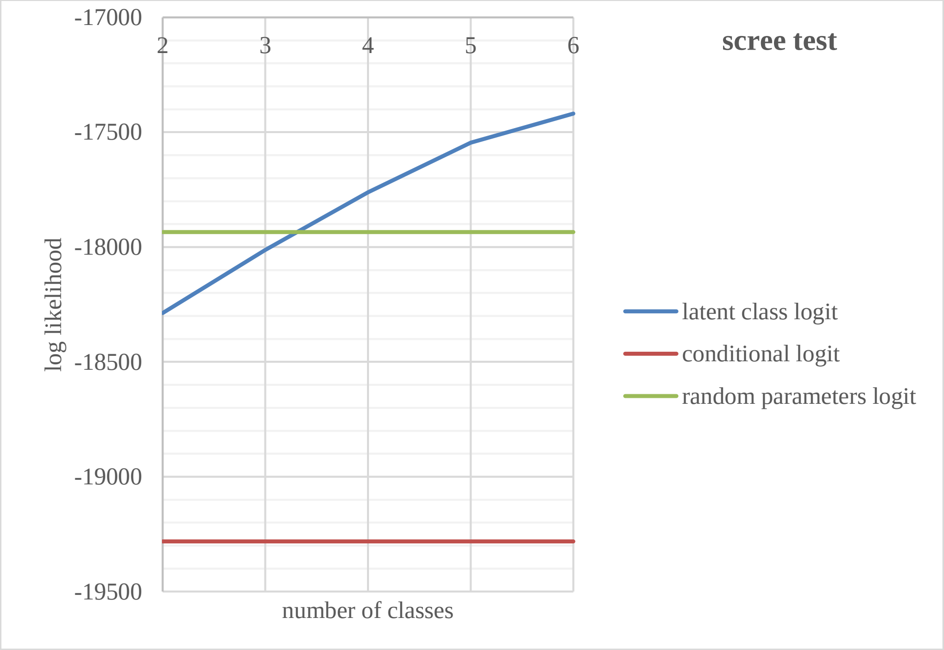


Figure 3: Logit model selection

4.3 Results latent class logit model

Table 4 reports the estimation results for the latent class logit model with five classes. Coefficients with their significances and standard errors are reported column-wise for each latent class (for the attribute coding see Section 3). We label the columns by their distinguished motivational foci: costs (1), climate protection (2), self-supply (3), local reference (4), and other (5) based on the coefficient results. The first 15 variables show the effects estimated for simultaneous choice tasks. The other 16 variables show the estimates for interactions effects of the sequential choice tasks ("*seq.*") with attributes. These effects show the difference of measured coefficients between the two choice task designs. All five attribute coefficients of the system adoption decision are significant at the 5 % level for at least one class for the simultaneous treatment. For the cooperation decision, *Supply Cooperation* is shown to be insignificant for all classes in the simultaneous choice task design. For the treatment group with sequential choice tasks of adoption and cooperation, however, many of the estimated effects in the simultaneous choice task are significantly strengthened or weakened, sometimes even reversed, with the result that more attribute coefficients become significant. This implies that respondents reveal more pronounced preferences when dealing with their decisions in sequential steps.

As an addition to Table 4, Figure 4 provides a graphical overview of significant coefficients for the latent class logit model with five classes. In the first block, joint attribute effects for sequential choices show preferences of respondents in the treatment group. The joint effects are calculated by adding the significant coefficients of attribute effects in simultaneous choices and interaction effects of attributes with sequential choices. The second block shows attribute effects for the simultaneous choices and, therefore, the measured preferences of the control group. In a standard choice-experimental setting we would only observe these preferences of simultaneous choices. The third block shows significant interaction effects of attributes with the treatment sequential choice, which indicates significant differences in selection choices between the sequential and the simultaneous choice task design. For example, for class 1 the joint effect for costs system of -1.76 results from adding the attribute effect "*Costs System*" (-3.00) and the interaction effect "*sequential * Costs System*" (1.24). The coefficients show that respondents of latent class 1 value a decrease in electricity costs with system installation as highly positive. The positive interaction effect shows that the price effect is stronger for simultaneous than for sequential choice tasks, which can be interpreted as the mitigating effect of the sequential choice task design on an otherwise dominating attribute effect (in that class). For class 2 and climate contribution by system and cooperation it shows that the joint effect is based only on the interaction effect, meaning that for simultaneous choice we cannot identify a significant importance in the selection decisions for these two attributes. In general, we see that in the sequential choice more attributes are significant, providing a more differentiated picture in line with general assumptions of choice experiments. This leads us to the conclusion that in overly complex choice tasks respondents tend to focus on a few dominated aspects.

Table 4: Results latent class logit model with five classes

Variable \ Latent class	1 costs	2 climate protection	3 self-supply	4 local reference	5 other
first system	-0.445** (0.194)	0.813*** (0.147)	-0.213** (0.099)	0.237** (0.106)	-0.513*** (0.084)
costs system	-3.004*** (0.236)	-0.019 (0.031)	-0.157*** (0.036)	-0.421*** (0.041)	-0.172*** (0.034)
self-supply system	0.141 (0.110)	-0.025 (0.052)	0.109* (0.058)	0.573*** (0.056)	-0.195*** (0.054)
supplier system type 2	0.100 (0.304)	-0.108 (0.121)	0.135 (0.127)	-0.340** (0.134)	-1.199*** (0.129)
supplier system type 3	0.344 (0.279)	0.015 (0.124)	0.106 (0.134)	-0.296** (0.138)	-0.460*** (0.130)
supplier system type 4	0.253 (0.300)	-0.072 (0.121)	0.166 (0.139)	0.003 (0.138)	-0.527*** (0.124)
climate system	-0.224* (0.130)	0.021 (0.047)	0.010 (0.053)	0.435*** (0.058)	0.024 (0.052)
effort system	-0.188 (0.116)	-0.053 (0.047)	-0.01 (0.056)	-0.053 (0.055)	-0.222*** (0.049)
supply cooperation	-0.034 (0.116)	-0.012 (0.049)	-0.083 (0.059)	0.038 (0.053)	0.023 (0.052)
cooperation type 2	1.240*** (0.337)	0.155 (0.128)	-0.068 (0.131)	-0.082 (0.148)	0.003 (0.133)
cooperation type 3	0.652** (0.298)	0.203 (0.131)	-0.117 (0.122)	0.098 (0.140)	-0.205 (0.128)
cooperation type 4	0.872*** (0.285)	0.041 (0.128)	-0.035 (0.136)	0.084 (0.149)	-0.211 (0.135)
climate cooperation	0.118 (0.119)	0.025 (0.044)	-0.004 (0.049)	0.211*** (0.051)	0.182*** (0.048)
costs cooperation	-0.29*** (0.072)	0.003 (0.037)	-0.527*** (0.033)	-0.104** (0.041)	0.046 (0.038)
effort cooperation	-0.158 (0.115)	0.065 (0.045)	-0.097* (0.050)	-0.083 (0.054)	-0.147*** (0.056)
seq. * first system	0.675*** (0.216)	-0.906*** (0.197)	0.252** (0.122)	-0.509*** (0.130)	1.356*** (0.093)
(seq.) first cooperation	0.036 (0.058)	-0.008 (0.136)	-0.066 (0.062)	-0.091 (0.059)	0.342*** (0.036)
seq. * costs system	1.241*** (0.246)	-0.081 (0.060)	-0.387*** (0.053)	0.278*** (0.050)	0.026 (0.042)
seq. * self-supply system	0.047 (0.130)	0.427*** (0.120)	0.820*** (0.086)	-0.558*** (0.079)	0.194*** (0.066)
seq. * supplier system type 2	-0.297 (0.341)	-0.576** (0.262)	-0.710*** (0.171)	-1.087*** (0.180)	1.127*** (0.156)
seq. * supplier system type 3	-0.418 (0.327)	-0.366 (0.287)	-0.231 (0.18)	-0.356** (0.18)	0.467*** (0.157)
seq. * supplier system type 4	-0.402 (0.342)	-0.273 (0.298)	0.002 (0.181)	-0.462*** (0.178)	0.491*** (0.154)
seq. * climate system	0.387*** (0.144)	1.590*** (0.136)	0.296*** (0.074)	-0.400*** (0.074)	0.012 (0.066)
seq. * effort system	0.003 (0.133)	-0.161 (0.113)	-0.159** (0.072)	-0.481*** (0.074)	0.330*** (0.065)
seq. * supply cooperation	0.021 (0.122)	0.184* (0.110)	0.497*** (0.070)	0.009 (0.070)	-0.125** (0.062)
seq. * cooperation type 2	-1.323*** (0.350)	-0.108 (0.290)	0.026 (0.173)	0.644*** (0.191)	0.039 (0.159)
seq. * cooperation type 3	-0.696** (0.312)	-0.427 (0.269)	0.008 (0.157)	0.307* (0.173)	0.082 (0.15)
seq. * cooperation type 4	-0.861*** (0.301)	-0.118 (0.254)	-0.074 (0.173)	0.069 (0.189)	0.077 (0.158)
seq. * climate cooperation	-0.078 (0.125)	1.37*** (0.112)	0.265*** (0.066)	-0.255*** (0.070)	-0.144** (0.058)
seq. * costs cooperation	-0.522*** (0.076)	-0.026 (0.065)	0.216*** (0.042)	0.034 (0.051)	-0.043 (0.042)
seq. * effort cooperation	-0.069 (0.121)	-0.228** (0.100)	0.068 (0.065)	-0.372*** (0.069)	0.135** (0.065)
probability class	0.281*** (0.017)	0.079*** (0.011)	0.223*** (0.021)	0.166*** (0.019)	0.252*** (0.020)

Notes: ***, **, *: significance at 1 %, 5 %, 10 % level; seq. = sequential.

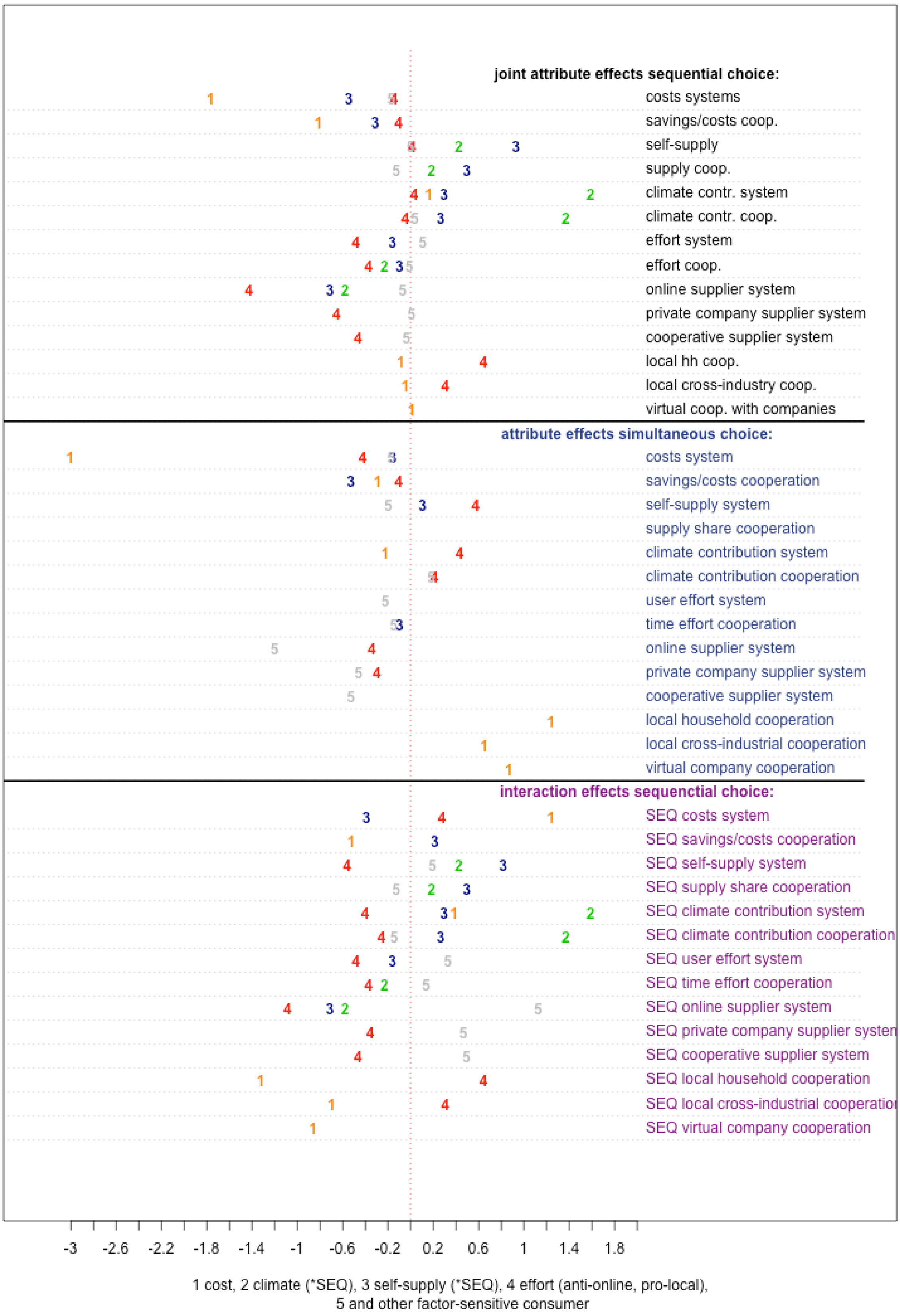


Figure 4: Graphical overview coefficients latent class logit model with five classes

To illustrate the results (see Table 5), we can calculate for scenarios the probability of choosing an alternative A over B based on the logistic distribution given in Equation (2) (see Section 3) and the estimation results given in Table 4. The selection probability for an alternative A over B, *P*(A), is modeled by the ratio of the exponential value of the estimated utility for alternative A and the sum of exponential values for the estimated utilities of each available alternative (A and B). In other words, the numerator of the ratio is the sum of attribute effects for alternative A, and the denominator is the summed value of (joint) attribute effects for attribute levels for both alternatives (all terms in exponential values).

For example, by assuming the same conditions for alternative A and B, the model yields a selection probably of 50 % for both alternatives. If we assume a decrease of C*osts System* A from 100 % to 90 %, this results in a new selection probability for a respondent of latent class 1 (costs) in the sequential choice tasks of 85.4 % with all other conditions remaining equal. The smaller coefficients for other latent classes show that this effect is accordingly weaker; for example, for class 3 (self-supply) leading to a selection probability of 63.3 % (see joint effect *Costs System* of -0.55 = -0.16 + – 0.39). Table 5 provides a scenario example with attribute assumptions for two alternatives (A and B). An application on the website: https://coberst.shinyapps.io/vi_dce2017/ allows to build one's own scenarios.[13]

Table 5: Examplary choice task

Attributes	Alternative A	Alternative B
Costs System	90 %	100 %
Self-Supply System	40 %	20 %
Type Supplier System	local handicraft business	energy cooperative
Climate System	middle	high
Effort System	low	middle
Costs Cooperation	0 %	-10 %
Supply Cooperation	0 %	60 %
Type Cooperation	virtual network with private energy companies	local network with neighboring industry and business companies
Climate Cooperation	high	middle
Effort Cooperation	low	middle

Class	***P*(A) seq**	***P*(A) sim**	***P*(B) seq**	***P*(B) sim**
1	73.3	96.4	26.7	3.6
2	61.3	48.2	38.7	51.8
3	52.2	35.1	47.8	64.9
4	78.2	64.7	21.8	35.3
5	57.2	74.5	42.8	25.5

Notes: *P*(A) seq = selection probability alternative A with sequential choice task and *P*(A) sim analogues with simultaneous choice task. Same notation for alternative B.

We used the application to review our energy-economic hypotheses as described in Section 2.1, considering the sequential choice task design to be the better representation of households' preferences. The results show that financial attributes have a negative influence on the selection probability, but the effect is more moderate for sequential choice tasks and mostly relevant for latent class 1 (costs). The hypothesis that higher self-supply potential is generally valued positively by respondents (by system or cooperation) can also be confirmed but is limited to latent classes 3 and 2 (self-supply and climate protection) with sequential choice and class 4 (local reference) with simultaneous choice tasks. The

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[13] The application was made with R shiny (see Chang et al. 2017) and is also available from the authors upon request.

hypothesis that self-supply by system is valued higher than by cooperation can be confirmed, but the differences in valuations are small. The hypothesis that respondents have a preference for systems and cooperations with local reference can be confirmed. Surprisingly, the strongest positive impact is shown for class 1 (costs); however, it is mainly in association with neighboring private households and not with neighboring industries. In contrast, for the virtual network, class 1 (costs) prefers the cooperation with private energy companies, while other classes are shown to be mainly indifferent. The hypotheses that both *Climate System* and *Climate Cooperation* are valued positively, and that a change to the next higher level for *Climate System* is valued higher by respondents than the same change in *Climate Cooperation* can be confirmed with results of sequential choice tasks. The higher valuation of climate contribution by system than by cooperation is particularly true for latent classes 2 and 1 (climate protection and costs). This difference in preference for contributions to protect the climate is particularly noteworthy if you consider the global aspect of climate change. Therefore, we can conclude that it is an important aspect for the success of business models for cooperative prosumer solutions, to show households their own climate contribution. The hypotheses that both higher *Effort System* and higher *Effort Cooperation* are valued negatively by respondents can be confirmed. Additional user effort of the system is associated with higher inconveniences than time effort to participate in energy cooperation for latent classes 3 (self-supply), 4 (local reference), and to a small extent 2 (climate protection), while for latent class 1 (costs) the effort to cooperate is seen to be slightly more inconvenient than for the own system.

The observed effects for latent class 1 (costs) illustrate the virtues of the sequential choice tasks. For the control group with the complex simultaneous choice task, the attribute effect of *Costs System* is highly negative and dominating in the choice decision. A dominant attribute is a violation of assumptions of a choice-experimental design. Even though the effect of the second financial attribute *Costs Cooperation* is significantly negative, the coefficient's magnitude, as for all other attributes, is much smaller. With the sequential choice task we see that, while the attribute *Costs System* remains an important negative factor, its effect is mitigated by the sequential choice setting (indicated by the positive interaction effect), whereas the negative effect *Costs Cooperation* is elevated (see negative interaction effect). Further, we can observe that the label variables for the *Type Cooperation* only have a significant effect in the more burdensome simultaneous choice situation.

4.4 Interactions of system and cooperation attributes

To find out whether there are any complementarities between system and cooperation, we re-estimate the models as described in Section 3, and we include interactions between the related ordinal explanatory variables (*Costs System* and *Costs Cooperation*, *Self-Supply System* and *Supply Cooperation*, *Climate System* and *Climate Cooperation*, and *Effort System* and *Effort Cooperation*). The latent class logit model with six latent classes is now inestimable, whereas among the remaining models, latent class logit with five latent classes achieves the highest log likelihood, though slightly lower than the latent class logit model with five latent classes without the interactions.

It appears that in the first class, which largely coincides with the first class in the model without the system/cooperation interactions (see Table 7), no interaction is significantly influencing choice. For the classes 2, 3, and 4, it appears that there are two, one, and one significant interaction effects respectively in the simultaneous treatment. However, these effects are cancelled out in the treatment with two sequential steps, where consumers could consider their choices better. In class 5, there is a consistent significantly negative effect of the effort interaction in both treatments, and a significantly positive effect of the climate interaction in the sequential treatment. Thus, if effort is already high for the system, these consumers especially dislike high effort for the cooperation, and if climate protection is already high from the system, these consumers especially appreciate high climate protection from the cooperation in the sequential treatment, where they could consider their choices better. This is not surprising given that class 5 largely coincides with the second class in the model without the interactions (see Table 7), who were described as especially environmentally concerned before. Furthermore, these findings confirm once more the relevance of a two- vs. one-step decision framing.

Table 7: Comparison between classes for the models with and without additional system/cooperation interactions

With\without	1	2	3	4	5	Sum
1	427	4	3	8	13	455
2	61	36	259	133	87	576
3	0	22	14	255	125	386
4	1	17	158	17	189	382
5	0	211	3	20	38	272
Sum	489	290	437	403	452	2071

4.5 Holdout tasks analysis

Table 8 provides the frequency distributions of the observed outcomes in the two fixed holdout tasks that were presented to all respondents. If respondents participated in the simultaneous treatment, then the holdout tasks were sequential and vice versa. Table 9 provides the frequency distributions of the outcomes for the holdout tasks as predicted by the latent class logit model of Table 4. Thus, we can see that the prediction power of a model estimated on how individuals choose in a simultaneous or sequential task is not high if we apply it to the other task type. Moreover, this prediction power is even lower for the case that individuals first performed ten simultaneous tasks and then two sequential tasks (p-value of χ^2 difference test: $8*10^{-8}$ for simultaneous and $2*10^{-29}$ for sequential). Apparently, the higher complexity of the simultaneous tasks strongly and lastingly affects individuals' decisions.

Table 8: Observed frequency distributions with fixed holdout tasks

Simultaneous

choice\task	1	2
A	379	772
B	645	252
	1024	1024

Sequential

choice\task	1	2
A (A, A)	190	516
B (B, B)	401	81
C (A, B)	297	234
D (B, A)	160	217
	1048	1048

Table 9: Predicted frequency distributions for fixed holdout tasks by latent class logit model with five classes

Simultaneous

answer\task	1	2
A	432	710
B	592	314
	1024	1024

Sequential

answer\task	1	2
A (A, A)	231	455
B (B, B)	270	115
C (A, B)	389	192
D (B, A)	158	286
	1048	1048

4.6 Effects on survey perception

In order to investigate the effects of a sequential choice-experimental design on how participants perceive their participation in the survey, we included a German translation of the scale items for Effort, Response Quality, and Topic Salience from Deutskens (2006) in the debriefing questionnaire. The twelve items were ordered randomly per respondent and measured on a 5-point Likert scale where 1 indicates ‘totally agree’ and 5 denotes ‘totally disagree’. The responses to the four items per concept were averaged as to provide us with one measure for the effort each respondent claims to have put into the survey, one measure for the quality each respondent evaluates her answers to the survey, and one measure for how much affinity each respondent has with the topic of the survey. Table 10 presents the averages of these three measures for the sequential and the simultaneous treatment. From Table 10 we can conclude that, on average, the 1,024 respondents who answered their choice questions in two steps reported to have put more effort in the survey, their response to have higher quality, and to experience a higher topic salience than the 1,048 respondents in the more complex, traditionally simultaneous control treatment. On response quality, this positive effect of the sequential treatment is significant at the 10% level.

Table 10: Average respondent effort, quality, and affinity in the two treatments

treatment / average	effort	quality	affinity
sequential	1.791	2.109	2.308
simultaneous (control)	1.818	2.153	2.345
difference between treatments	0.028	0.044	0.037
p-value of 1-sided independent sample t-test under equal variances	0.179	0.092	0.190

5. Conclusion

Results indicate that respondents reveal more pronounced preferences when dealing with their decision in sequential steps (we find that respondents' value more attributes as (highly) relevant). This effect did not disappear when we subsequently changed the task design (simultaneous or sequential choice) to the alternative setting. Also, participants' self-perceived quality of their survey answers is higher with the sequential choice tasks. We conclude that for policy or marketing applications, presenting choices in either a simultaneous or a sequential way may be an effective intervention to affect consumers' preferences. Furthermore, for choice-experimental application in research it is crucial to identify first the "true" decision process type (simultaneous or sequential) in order to investigate consumers' preferences. In future research, the impact of the order of adoption and cooperation decisions on respondents' valuation could be investigated by reversing the order in an alternative treatment. Further, it would be interesting to test, similar to Faiers et al. (2007b), whether households consider attributes in different order between adoption and cooperation choices as well as between simultaneous and sequential choices.

For the application case of business models and energy cooperations with non-industrial prosumers in Germany, we conclude that it is important to show households their contribution to their own and neighbors' electricity supply and their contribution to climate protection in order to increase the willingness to adopt and participate. However, the positive consumer preference for self-supply cannot be extrapolated to supply within a cooperation. On the motivation of current prosumer households (MGT-owners) we find that they are more likely to be found in the latent class of climate protectors and self-suppliers (+6 %-points) and less likely in the class of price-sensitive consumers (-6 %-points). Compared with the strong effect of prices in related choice experiments (and the control group of simultaneous choice tasks in this study), this finding suggests that price effects can be overestimated due to overly complex choice tasks.

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Appendix

Table 11: Latent class composition

	Sample	**5LC_1**	**5LC_2**	**5LC_3**	**5LC_4**	**5LC_5**	**5iLC_1**	**5iLC_2**	**5iLC_3**	**5iLC_4**	**5iLC_5**
Sample in n	2071	489	290	437	403	452	455	576	386	382	272
Sample	100	23,6	14	21,1	19,5	21,8	22	27,8	18,6	18,4	13,1
Treatment (sequential)	50,6	37,2	72,4	47,8	58,8	46,2	42,2	33,7	63,7	50	82,4
Quota Women 18-29	6,4	4,5	10,3	4,6	6	8,2	4,8	4,2	7	9,7	8,5
Quota: Women 30-39	6,3	4,9	7,2	6,2	5,5	8	4,4	6,2	6,2	7,1	8,5
Quota: Women 40-49	11,6	9,8	10	14	10,9	13,1	11	12,8	11,9	12	9,2
Quota: Women 50-59	12,1	12,5	11	11,4	15,1	10,4	12,7	12,7	13,7	8,9	12,1
Quota: Women >60	13,8	12,7	14,5	15,1	16,1	11,1	12,7	14,8	17,9	9,4	13,6
Quota Men 18-29	5,8	3,5	7,2	4,3	5,2	9,3	3,7	4,7	4,1	9,9	8,1
Quota: Men 30-39	5,8	4,9	5,9	6,2	4,7	7,3	4,4	4,2	5,4	10,5	5,5
Quota: Men 40-49	8,7	11	7,6	8,2	6,2	9,7	9,7	8,9	7,3	8,4	9,6
Quota: Men 50-59	10,7	13,7	9	12,1	11,2	6,6	14,1	11,3	10,1	8,6	7,4
Quota: Men >60	18,8	22,5	17,2	17,8	19,1	16,4	22,4	20,3	16,3	15,4	17,6
LMR Aachen	4,5	5,1	4,1	5,3	5	2,9	5,1	4,3	2,8	5,5	4,8
LMR Bielefeld/Pad.	9,1	8	7,9	9,4	9,4	10,4	7,7	12,2	8,3	7,6	8,1
LMR Duessel.-Ruhr	49,4	51,5	52,4	43,9	51,4	48,7	51,9	46,7	49,7	50	49,6
LMR Koeln	20,1	19,4	17,9	24,3	18,1	20,1	19,6	21	22	18,1	19,5
LMR Muenster	6,4	6,7	4,1	7,8	5,7	6,6	6,2	7,5	6	6,8	4,4
LMR Siegen	1,8	1,8	3,1	1,1	3,2	0,4	2,2	0,9	2,6	1,3	2,9
LMR Other	2,1	1,2	1,7	2,5	3,5	1,8	1,3	3,1	2,8	1,6	1,1
missing ZIP code	6,6	6,1	8,6	5,7	3,7	9,1	6,2	4,3	5,7	9,2	9,6
ROR Duesseldorf	16,8	15,5	21,7	14,6	13,9	19,5	15,6	13,9	16,8	19,6	20,6
ROR Koeln	12,9	11,7	12,1	15,3	11,4	13,7	12,1	13,4	14,8	11,3	12,9
ROR Duisburg/Essen	10,1	10	9,3	9,6	11,4	10	10,3	10,6	10,1	10,5	8,1
ROR Aachen	7,7	7,8	6,2	7,6	9,4	7,1	7,7	8	7,5	7,9	7
ROR Bochum/Hagen	7,6	7,2	6,9	6,2	10,4	7,3	7,5	7,1	8,8	7,1	7,7
ROR Bielefeld	7,2	6,7	5,9	7,3	7,7	8,2	5,9	10,2	6,2	6	6,2
ROR Muenster	6,4	6,7	4,1	7,8	5,7	6,6	6,2	7,5	6	6,8	4,4
ROR Bonn	6,1	6,7	5,2	8,5	5,2	4,6	6,2	6,8	5,2	6,3	5,9
ROR Emscher-Lippe	5,5	8,6	5,2	5,5	5	2,7	9,5	4,7	4,4	2,9	5,5
ROR Dortmund	5,1	6,5	5,5	3	5	5,3	6,4	4,5	4,7	5	4,8
ROR Arnsberg	2,4	2	2,4	3,2	2,7	1,5	1,3	3,1	2,3	3,1	1,5
ROR Paderborn	1,8	1,2	2,1	2,1	1,7	2,2	1,8	1,9	2,1	1,6	1,8
ROR Siegen	1,8	1,6	3,1	1,1	3,2	0,4	2	0,9	2,6	1,3	2,9

5LC = Logit model with 5 latent classes, 5iLC = Logit model with interactions with 5 latent classes

Table 12: Selected class characteristics (5iLC)

	5iLC_1	5iLC_2	5iLC_3	5iLC_4	5iLC_5
Sample, prop. in *n*	455,0	576,0	386,0	382,0	272,0
Age in years	52,5	51,8	50,5	45,7	48,4
Gender male	54,3	49,3	43,3	52,9	48,2
Owner micro-generation system	9,9	17,0	16,1	22,5	20,6
HH decision maker: alone	41,1	37,8	36,0	44,0	34,9
HH decision maker: with Partner	51,9	56,6	57,5	49,2	55,9
HH decision maker: with owner community	7,0	5,6	6,5	6,8	9,2
Single-/two-family house	76,5	76,9	74,6	76,2	74,6
Multi-family house	23,5	23,1	25,4	23,8	25,4
Living Space heated in m2	127,5	134,6	131,9	130,0	134,7
Household size in persons	253,8	260,8	248,2	262,6	264,7
Estimated electricity costs (mean), in euro p.m.	84,1	85,6	84,5	87,0	87,3
Confirmation estimate elect. costs, in %	44,2	50,7	58,5	54,5	66,5
Diff. estimated & stated elec. costs (mean)	-49,9	-35,9	-9,0	-28,9	-12,4
Diff. estimated & stated elec. costs (median)	-14,0	-10,5	4,0	-14,5	-6,0
Water heating electric	38,2	36,6	38,6	48,4	39,7
Water heating non-electric	60,4	62,2	59,8	50,3	58,5
Water heating unknowing	1,3	1,2	1,6	1,3	1,8

Table 13: Respondents and latent class evaluation choice experiment

	Sam-ple	5LC _1	5LC _2	5LC _3	5LC _4	5LC _5	MGT	No MGT.	Fem.	Male	Fem. 18-29	Fem 30-39	Fem. 40-49	Fem 50-59	Fem. 60-99	Male 18-29	Male 30-39	Male 40-49	Male 50-59	Male 60-99
Sample, in *n*	2071	489	290	437	403	452	347	1724	1040	1031	133	130	241	251	285	120	120	181	221	389
Important																				
Costs.Sys	48,9	69,3	32,8	49,0	47,1	38,7	42,9	50,1	47,0	50,8	53,4	42,3	46,5	48,2	45,6	37,5	47,5	54,1	52,0	53,7
Self-Supply.System	23,5	15,7	23,8	30,7	27,8	20,8	33,4	21,5	22,2	24,7	23,3	20,8	24,9	21,1	21,1	23,3	23,3	28,2	27,6	22,4
Suppliertype.Sys	18,3	9,2	21,0	15,3	21,8	26,1	22,8	17,4	18,7	17,9	21,8	16,9	14,9	19,9	20,0	18,3	15,8	15,5	17,6	19,8
Climate.Sys	26,8	13,9	40,0	29,1	32,5	25,2	33,1	25,6	29,4	24,2	32,3	20,8	27,4	33,5	30,2	30,0	20,8	22,7	23,5	24,7
Effort.Sys	20,5	15,1	21,0	23,1	24,8	19,7	21,3	20,4	19,7	21,3	20,3	18,5	17,4	19,5	22,1	20,8	25,0	23,2	20,4	20,1
Supply.Coop	11,0	7,4	12,4	13,5	10,9	11,5	18,7	9,4	9,5	12,4	12,8	4,6	8,7	10,4	10,2	16,7	17,5	12,2	14,9	8,2
Type.Coop	11,8	7,8	14,5	10,8	13,2	14,2	16,1	10,9	11,1	12,5	8,3	10,8	10,0	13,5	11,2	13,3	8,3	12,7	14,0	12,6
Climate.Coop	18,5	9,6	29,3	19,7	23,1	16,2	27,4	16,8	20,7	16,4	21,8	19,2	16,6	23,5	21,8	17,5	15,8	17,1	14,9	16,7
Costs.Coop	41,4	56,0	25,9	54,0	35,0	29,2	36,0	42,5	39,0	43,8	46,6	30,0	38,6	41,0	38,2	34,2	45,8	45,9	44,8	44,7
Effort.Coop.	19,6	18,4	15,9	20,6	25,1	17,3	21,9	19,1	18,6	20,6	18,8	20,0	22,0	16,7	16,5	15,8	15,0	24,9	26,2	18,5
No attribute	9,3	7,2	10,7	8,2	9,4	11,7	8,1	9,6	9,8	8,8	4,5	10,0	10,0	9,6	12,3	7,5	8,3	5,5	9,0	10,8
Ignored																				
Costs.System	6,1	3,9	7,6	5,0	6,5	8,2	9,2	5,5	5,5	6,7	3,0	6,2	5,0	6,0	6,3	8,3	11,7	2,8	6,8	6,4
Self-Supply.System	10,8	11,9	10,3	8,2	12,2	11,3	11,2	10,7	10,0	11,6	11,3	9,2	8,7	12,0	9,1	18,3	11,7	12,7	8,1	11,1
Suppliertype.Sys	30,3	38,9	23,4	34,3	28,3	23,2	28,2	30,7	27,4	33,2	28,6	25,4	30,3	27,5	25,3	30,8	33,3	35,4	32,6	33,2
Climate.Sys	26,8	13,9	40,0	29,1	32,5	25,2	33,1	25,6	29,4	24,2	32,3	20,8	27,4	33,5	30,2	30,0	20,8	22,7	23,5	24,7
Effort.Sys	14,6	18,4	11,7	14,4	12,9	13,9	19,6	13,6	13,5	15,7	9,0	9,2	12,0	18,7	14,0	8,3	15,8	17,1	18,1	15,9
Supply.Coop	14,8	18,6	9,7	14,2	16,9	12,6	13,3	15,1	13,5	16,1	12,8	10,8	12,9	16,3	13,0	20,0	19,2	16,6	12,7	15,7
Type.Coop	26,1	32,7	18,3	29,1	29,0	18,6	24,8	26,4	25,2	27,1	24,8	29,2	26,6	25,5	22,1	21,7	29,2	30,9	25,3	27,2
Climate.Coop	15,4	21,3	11,4	14,0	13,2	15,0	14,7	15,5	12,8	18,0	14,3	12,3	13,7	13,1	11,2	12,5	22,5	24,3	16,7	16,2
Costs.Coop	5,9	4,3	7,9	4,3	6,2	7,7	10,1	5,1	5,5	6,4	6,8	3,1	3,3	8,4	5,3	10,0	7,5	4,4	8,1	4,9
Effort.Coop	20,4	23,3	21,4	20,6	17,9	18,8	20,5	20,4	19,6	21,2	17,3	13,1	13,7	25,9	23,2	19,2	17,5	21,0	22,2	22,6
No attribute	25,8	22,5	30,3	26,8	26,8	24,8	25,6	25,9	29,4	22,2	25,6	25,4	27,8	29,9	34,0	15,0	20,0	20,4	22,6	25,7
Unclear																				
Costs.Sys	8,5	8,0	6,6	9,4	7,9	10,2	10,1	8,2	7,5	9,6	3,8	10,8	5,4	10,0	7,4	10,8	12,5	8,3	7,2	10,3
Self-Supply.Sys	15,8	14,1	15,2	14,4	16,9	18,4	15,9	15,8	16,6	14,9	21,8	12,3	17,0	13,9	18,2	15,0	17,5	14,9	13,1	15,2
Suppliertype.Sys	11,8	10,0	13,1	11,7	9,2	15,5	13,3	11,5	10,3	13,4	9,0	13,8	10,0	8,0	11,6	19,2	14,2	7,7	12,2	14,7
Climate.Sys	11,4	10,0	12,1	8,5	13,9	13,1	14,1	10,8	10,2	12,6	11,3	6,9	11,6	8,4	11,6	19,2	15,8	8,8	11,8	11,8
Effort.Sys	17,9	17,2	17,9	16,9	18,4	19,0	19,6	17,5	16,7	19,0	18,8	16,2	15,8	18,7	15,1	15,0	26,7	19,3	14,9	20,1
Costs.Coop	11,4	12,5	7,6	10,5	13,6	11,7	14,1	10,9	10,7	12,2	11,3	13,8	7,1	13,9	9,1	12,5	16,7	9,4	10,4	13,1
Supply.Coop	13,9	15,3	10,3	16,7	13,9	11,9	14,4	13,8	13,6	14,3	15,0	16,2	14,1	9,6	14,7	14,2	12,5	13,8	14,5	14,9
Type.Coop	16,2	15,1	13,8	17,2	17,6	16,8	17,9	15,9	16,3	16,1	11,3	17,7	16,6	17,5	16,8	15,8	16,7	16,0	18,6	14,7
Climate.Coop	10,0	9,8	9,7	8,7	9,7	11,9	11,0	9,8	9,7	10,3	6,8	10,8	6,2	9,6	13,7	8,3	11,7	8,8	10,0	11,3
Effort.Coop	22,4	21,3	18,6	22,0	25,8	23,2	21,9	22,4	23,3	21,4	21,1	22,3	22,0	23,9	25,3	12,5	21,7	19,3	24,9	23,1
All attributes clear	43,3	47,0	41,7	46,2	44,7	36,1	40,3	43,9	43,5	43,1	44,4	36,2	44,8	45,4	43,5	34,2	35,8	47,5	47,1	43,7
Further relevant																				
Manufactoring location sys.	25,1	20,2	28,3	25,6	30,8	22,6	26,2	24,8	25,9	24,2	18,8	17,7	23,2	27,5	33,7	19,2	18,3	17,7	23,5	31,1
Recommendation installer	15,0	13,9	12,1	15,1	15,1	17,9	17,6	14,5	15,3	14,7	13,5	14,6	12,9	16,3	17,5	15,0	14,2	13,8	14,0	15,7
Minimum contract period	41,2	46,0	34,8	43,0	42,9	36,7	34,3	42,6	42,8	39,6	37,6	33,1	44,0	45,8	46,0	34,2	30,8	36,5	45,7	41,9
Expected operating life	42,9	47,2	36,6	48,1	45,2	35,4	36,9	44,1	41,7	44,1	42,1	35,4	39,8	44,6	43,5	30,8	35,8	41,4	52,5	47,3
Technical efficiency system	34,4	36,4	26,9	37,5	39,0	29,9	36,6	33,9	31,7	37,1	28,6	21,5	30,3	38,2	33,3	29,2	32,5	37,6	42,5	37,5
Opinion indep. energy consultant	21,5	20,9	22,4	20,8	22,6	21,2	19,0	22,0	22,9	20,1	20,3	13,8	17,8	29,1	27,0	10,0	15,0	18,8	22,6	23,9
warranty period	41,9	45,0	36,6	45,1	45,2	35,8	40,1	42,2	40,5	43,3	39,1	33,8	39,0	41,8	44,2	33,3	40,0	38,1	48,4	46,8
Data protection, digitalization/automatization	13,5	12,5	13,1	14,4	12,9	14,6	14,1	13,4	13,4	13,7	14,3	10,0	11,6	15,5	14,0	13,3	14,2	11,6	15,8	13,4
Expected power outages at home	29,3	32,3	25,2	30,7	28,5	27,9	23,3	30,5	31,2	27,3	30,1	21,5	30,3	34,7	34,0	21,7	22,5	28,2	26,2	30,6
Impact on local biodiversity	8,2	3,9	12,4	8,0	7,2	11,1	12,7	7,3	8,9	7,4	11,3	7,7	8,3	10,4	7,7	5,8	10,0	6,1	6,8	8,0
Ownership structure (e.g. leasing/rent system)	34,5	39,9	28,3	36,4	36,0	29,4	32,0	35,0	33,4	35,6	22,6	23,8	36,1	37,1	37,2	23,3	20,0	31,5	42,1	42,4
Extension option system	15,5	15,3	15,5	16,2	16,1	14,2	21,0	14,3	15,0	15,9	15,0	13,8	19,5	14,7	11,9	14,2	15,0	16,0	20,4	14,1
Impact on elec. grid	17,8	17,4	18,3	20,4	17,6	15,7	21,3	17,1	19,9	15,7	21,8	13,8	19,5	18,7	23,2	15,0	12,5	13,3	16,3	17,7
Funding (public or private)	30,1	33,5	21,4	33,0	36,2	23,9	28,5	30,5	31,2	29,0	19,5	29,2	28,6	37,5	34,4	22,5	20,8	27,6	31,7	32,6
Space requirements	43,0	47,9	35,5	46,9	46,4	35,6	33,1	45,0	45,1	40,8	40,6	33,8	48,5	46,6	48,1	28,3	33,3	40,3	46,2	44,2
Investment risk (e.g. guaranteed or variable payment)	31,0	42,5	26,6	31,4	29,0	23,0	25,6	32,1	30,0	32,1	24,1	24,6	31,1	30,3	34,0	20,8	22,5	30,9	38,5	35,5
Other	1,8	2,5	1,7	2,3	1,7	0,7	1,4	1,9	1,4	2,1	0,8	0,8	1,2	1,2	2,5	0,0	0,8	2,8	2,3	2,8
All relevant attributes incl.	10,1	9,8	11,0	10,5	8,4	10,8	10,4	10,0	10,6	9,6	10,5	11,5	11,6	10,4	9,5	8,3	8,3	11,0	10,0	9,5