

Green innovations: The organizational setup of pilot projects and its influence on consumer perceptions

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Abstract

Pilot-, test- and demonstration-projects (PTDs) are a prominent policy tool to promote the adoption of smart, green technologies. However, as technology adoption is heavily dependent on the individual attributes and beliefs of potential adopters, it is important to understand the influence of a PTD's organizational setup on technology perception. By varying the information about a PTD's organizational setup in a survey experiment among a selected sample of potential PTD-participants, we gather first experimental evidence for the effect of different setups on the perception of green technologies. We show that the organizational setup has a significant impact on a product's perceived contribution to the energy transition, its establishment in the market, cost-reduction potential, innovativeness and environmental friendliness. In particular, full organizational cooperation between government, university and industry consistently improves perceptions compared to a partial setup. Regarding the willingness to participate in a PTD, we find that communication and support are the most imperative aspects and even more important than economic benefits. Our findings provide policy-makers with a more ample foundation on how PTDs should be designed to successfully transfer technologies to the market.

Keywords: Pilot projects, Organizational setup, Adoption decision, Quadruple Helix, Innovation diffusion

1. Introduction

Ambitious goals for decarbonisation and political commitment to a more sustainable use of natural resources have led to a fundamental questioning of the traditional ways energy is generated, transmitted and consumed (European Commission, 2018; IEA, 2017). As a result, energy systems around the world are currently undergoing a major transformation. The transfer of technological advances from the information and communication sector – widely referred to as the build-up of ‘smart energy systems’ (Lund et al., 2017) – is a central pillar of this comprehensive transition. In this regard, the widespread integration of smart devices like smart meters, heating systems, micro-grids or electric vehicles in all areas of the energy sector provides an opportunity to address many challenges that come along with a growing share of renewable energies. Most notably, smart devices could help to both reduce and balance demand and supply and make energy systems more efficient, reliable and sustainable in the future (European Commission, 2018).

The successful implementation of smart energy systems, however, is crucially dependent on research, development and – ultimately – market deployment of innovative technologies. In this complex process, one particular policy tool has gained rising attention over the last years: the application of pilot-, test- and demonstration-projects¹ (PTDs) (Bossink, 2017; Hellsmark et al., 2016; Neij et al., 2017). Policy initiatives around the world already devote a substantial amount of funding to PTDs, for various reasons.² In today’s complex systems, it has become virtually impossible to develop, test and introduce new energy products and innovations outside a real life context (Markard, 2018). PTDs offer the opportunity to bring together all stakeholders in a controlled, yet realistic environment that allows for learning about the holistic effects of market introduction (Bossink, 2017). By ‘bridging’ basic, small-scale knowledge generation in laboratories and large-scale industrial application and commercialization (Lager et al., 2013), PTDs enable learning not only on a technical but also on an organizational, policy and market level (Bossink, 2017). With their flexible customisability, they can furthermore contribute to all innovation phases from prototyping to market integration (Kivimaa and Kern, 2016). For market

¹ In this paper, we follow Bossink’s (2017) very broad definition of pilot-, test- and demonstration-projects as “settings wherein the authorities cooperate with academia and commercial firms to further test, understand and improve new sustainable energy technologies” (p.1349). An example for such a setting on a large scale are the PTDs within the SINTEG programme in Germany, e.g. WindNODE and C/sells, aimed at a digitalisation of the energy sector. Funded by the federal government, numerous companies and industrial partners are cooperating with a multitude of research institutes, universities and local communities in smaller ‘sub-PTDs’ to test flexible energy demand and supply technologies or a cellular network based on smart energy infrastructure and PV. For more on SINTEG and the funded projects see BMWi (2019).

² See e.g. the EU’s energy-related pilot-projects in the NER-300 program with a funding of €2.1bn, the MIC25 program in China with annual funding of ca. \$300bn, or Australia’s ARENA funding for pilot projects focused on the integration of renewable energy sources with annual funding of \$12.5m (European Commission, 2018, 2016; Australian Renewable Energy Agency, 2019; Sustainable Development Technology Canada, 2019; Zenglein and Holzmann, 2019). Similar approaches exist e.g. in the US and Japan (with annual funding of ca. €121m for solar photovoltaics PTDs in Japan, see e.g. Hellsmark et al., 2016; Hendry et al., 2010; Ikki and Matsubara, 2008).

uptake in particular, PTDs allow to form networks, reduce uncertainties, improve public awareness and expose potential system weaknesses (Hellsmark, 2010).

PTDs also address one of the key challenges arising from the progressing digitalisation and decentralisation in the energy sector: the reconceptualization of users as central stakeholders (Schot et al., 2016). While the global energy transition is changing traditional roles of all actors involved, the implications for consumers are especially pronounced. Due to the spread of micro-generation technology, private households are increasingly acting not only as consumers, but also as producers, (Parag and Sovacool, 2016). Furthermore, in digitalised and decentralized systems, uptake dynamics and the potential impact of promising technologies depend both on the number as well as the behavioural patterns of the individuals who choose to adopt and use them (Greening et al., 2000; Grimm et al., 2018; Huang et al., 2018; Zeng et al., 2014; Zhao et al., 2016). With more interconnected devices, behavioural reactions and direct feedback-loops with consumers are becoming ever more important for technology-assessment (Neij et al., 2017). Whether and how users engage with a new technology or service are fundamental questions, as unanticipated user-behaviour might counteract well-intended policy approaches.³ For the building of smart energy systems, it is thus elemental to understand the wants, needs and behavioural attributes of users (BMW, 2018).

Against this background, it is of increasing significance to focus on the following question: How should PTDs be designed and promoted to attract suitable participants? While detailed answers to this are highly context dependent, a general strategic decision is which institutional actors to involve in the governance of a PTD. We call this a PTD's organizational setup. Recent behavioural research has presented abundant evidence that individual decision-making is highly sensitive to contextual factors such as organizational framing and priming (Cornelissen and Werner, 2014). These findings indicate that a particular setup itself can be an important channel of influence on the perception of a product that is rolled out in a PTD. The setup could thus spur or hinder civic engagement by influencing participants' decisions to participate— independent of the actual attributes of the technology or service tested. Despite the resulting relevance of the accurate organizational setup of PTDs, the question whether and how it influences this ex-ante attraction of participants (and crowding-in or -out of main target groups) remains largely unaddressed up to now (Bossink, 2017; Hellsmark et al., 2016; Huang et al., 2018; Neij et al., 2017).

In order to develop a better understanding of how user-engagement in PTDs evolves, we focus on two aspects of project design in the following: Firstly, we test the influence of the organizational setup on the perception of potential participants and their evaluation of product characteristics in the context of a

³ Prominent examples for this are rebound-effects (see e.g. Sorrell and Dimitropoulos, 2008) or inefficient policy-support schemes due to unanticipated practical or psychological barriers, e.g. missing charging-infrastructure or the driving-range-paradox in case of electric vehicles (Franke and Krems, 2013; Jensen and Mabit, 2017).

field study. To do so, we conduct a survey experiment on a selected sample of households identified as potential PTD-first movers. By varying the information about the organizational setup, we present first experimental evidence for the effect of different organizational compositions on the perception of energy-related technologies. Secondly, we address the question whether other attributes of PTD-design such as communication channels and financial benefits for participants might help to engage potential users. We present data on the relative importance of such design features and compare it across financially and non-financially motivated user groups.

With this study, we contribute to a more coherent and thorough understanding of the underlying behavioural mechanisms that drive the participation in PTDs. Our results provide policy-makers with a more ample foundation on how PTDs should be designed in order to successfully transfer technologies to the market. In terms of policy implications, we highlight the need for policymakers to follow a systemic and targeted approach when creating PTD-related measures. In particular, we show that a progressive use of non-standard behavioural design elements can contribute to the creation of a PTD-setting that matches the requirements for the attraction of potential lead-users.

The remainder of the paper is structured as follows: In section 2, we briefly review the existing literature on the role of PTDs in research and development processes as well as the behavioural literature on framing and decision-making to motivate our research question. Section 3 provides a detailed description of our methodology and empirical strategy, including the experimental survey and the resulting dataset. We then present our main findings in section 4. Section 5 concludes with a discussion of possible policy implications.

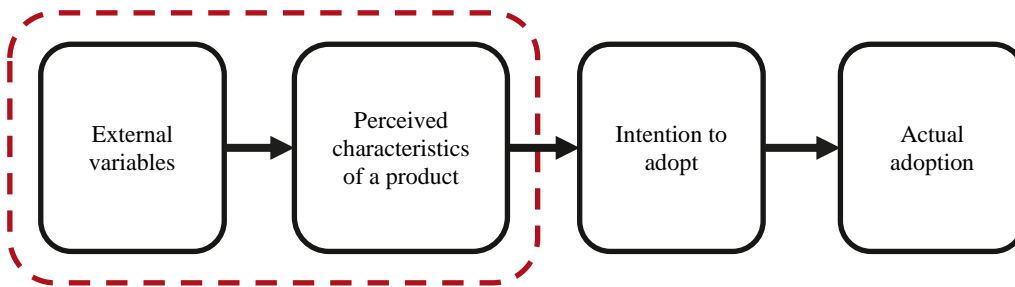
2. Related literature and research questions

In the following, we succinctly discuss the main findings in the related literature that mark the point of departure for this paper and serve as a motivation for our research question. The theoretical and empirical framework of this paper is based on two different strands of research: (1) behavioural research that investigates the rationales and heuristics of the adoption and diffusion of green innovations and (2) studies in economics of innovation that explore the role of PTDs in the process of research, development and deployment of these products and technologies.

In behavioural research on the adoption and diffusion of green technologies, it is widely acknowledged that the process leading to individual green technology adoption is complex and highly dependent on a multitude of factors. These factors range from the technological features of a product to external policy support, area of application and personal characteristics of potential adopters (for an overview see Faiers et al., 2007; Girod et al., 2017). Various approaches have been used to rationalise the decision-making process that leads to the adoption of new technologies. Yet prominent theories and models, such as Roger's 'Diffusion of innovations' (2010), the 'Technology Acceptance Model' and its modifications (Davis, 1989; Davis et al., 1989) or the 'perceived characteristics of innovations scale' by Moore and

Benbasat (1991), build on the assumption that adoption decisions are dependent on the individual perception of a product’s characteristics. This perception is in turn influenced by external variables. Figure 1 illustrates this reasoning in a condensed way. Given the relevance of individual perceptions, several studies call for a better incorporation of user profiles and preferences into research on technology adoption (Karakaya et al., 2015; Noll et al., 2014; Rai et al., 2016; Rai and Robinson, 2013; Sigrin et al., 2015; Ulsrud et al., 2011; Verhees et al., 2013).

Figure 1: Stylised model of decision-making and research focus



An important external variable that has been identified to have an impact on the perception of decision-makers is the organizational context in which a decision is made (Cornelissen and Clarke, 2010; Davidson, 2002; Kaplan, 2011, 2008; Kaplan and Tripsas, 2008; Kennedy and Fiss, 2009). On the individual level, specific organizational contexts might serve as a ‘cognitive frame’ (Benner and Tripsas, 2012; Walsh, 1995; Weick, 1995). This frame is defined as a “knowledge structure that directs and guides information processing” (Cornelissen and Werner, 2014, p. 184), or a ‘frame of reference’ (George et al., 2006; Henisz and Zelner, 2005), i.e. “a baseline expectation or reference point that provides a basis for decision-making” (Cornelissen and Werner, 2014, p. 184). Organizational contexts thus exert a decisive influence on the perceptions and behaviour of individuals.

In the economics of innovation research, PTDs are recognised to be of critical importance in building innovation processes and systems (Haase et al., 2013; Harborne and Hendry, 2012, 2009; Hellsmark et al., 2016; Hendry et al., 2010). They are seen as a means to test innovations and learn about interactions of the innovation and its context (Raven, 2007), changes in perceptions and practice (Brown et al., 2003) as well as societal change and public attitudes (Hellsmark et al., 2016; Hellsmark and Jacobsson, 2012). PTDs are hence key to developing an entire socio-technical system that is needed to transfer green energy innovations into widespread use (Hellsmark et al., 2016).⁴

In terms of organizational context, empirical studies show that sustainable energy PTDs are almost entirely rolled out as public-private partnerships (Bossink, 2017) that bring together institutional actors from three different sectors: government, university and industry. This default organizational setup, often referred to as ‘triple helix-combination’ (Etzkowitz and Leytesdorff, 1997), has been researched

⁴ A recent extensive and systematic overview of the application of PTDs in the R&D process of sustainable technologies has been provided by Bossink (2017).

intensively. Its merits for innovation systems on a national level are documented and reported in theoretical and applied work (Etzkowitz and Leydesdorff, 2000; Flanagan et al., 2011; Freeman, 1995; Hellsmark and Jacobsson, 2012; Kemp et al., 1998; Lundvall, 1992; Schot and Geels, 2008). However, this field of research has been conducted from a systems perspective and is solely focused on the innovation-outcome. The predominant role of public-private-partnerships in PTDs is so far merely justified by the underlying assumption “that the transition from a fossil fuel economy to a sustainable energy economy is often seen as a core responsibility of public organizations” (Bossink, 2017, p. 1354).

Potential benefits of intra-sector cooperation have also been explored extensively from a management perspective in the literature on ‘Open Innovation’ (Chesbrough, 2003). This strand of research revolves around the question under which circumstances research and development is best conducted in a cooperative and integrative environment, outside the boundaries of a firm. The advantages and disadvantages of cooperation for innovation output have been addressed from various perspectives (see e.g. Almirall and Casadesus-Masanell, 2010; Greco et al., 2015; Hossain and Kauranen, 2016), leading to the overall conclusion that opening up innovation processes is beneficial under many conditions, especially against the background of digitalisation. The optimal level of openness in the innovation process, however, can differ tremendously by context (Aghion et al., 2008; Heidenreich et al., 2015). Within this line of research, special attention has been given to the determinants of customer participation in innovation processes. To manage these successfully, matching the needs and requirements of users that can contribute productively to the innovation outcome is seen as immensely important (Gassmann et al., 2010; Perkmann and Walsh, 2007). Cui and Wu (2016) show that individual drivers to participate in innovation processes range from psychological benefits (such as feelings of enjoyment and accomplishment), the relationship with the institutional actors involved, social benefits, skills and knowledge attributes to economic benefits. Fernandes and Remelhe (2016) argue that these motives can be conceptualised in four domains: intrinsic motives (e.g. users driven by curiosity and interest in new ideas and innovation), the willingness to acquire knowledge about a new technology, social motives (e.g. sharing experiences with others who show similar interests) and financial motives. However, there seems to be discord regarding the relative importance of these factors for activating user engagement. While they find that customers tend to be mainly motivated by intrinsic and knowledge acquisition factors, other studies put larger weight on economic benefits (Franke et al., 2006; Meuter et al., 2005).

Recent studies on innovation systems thus point out the need for a systematic integration of the consumer perspective to meet the demands and needs of the general society (Höglund and Linton, 2018). In this respect, it has been emphasised that the “literature has not fully uncovered the interplay among actors, networks and institutions over time (...) as a technological field progresses” (Hellsmark et al., 2016, p. 1745). Consequently, it is called for a “more in-depth understanding of the actor networks surrounding [pilot and demonstration projects]” (Frishammar et al., 2015, p. 14).

In this paper, we combine the findings on individual decision-making, the adoption of new technologies and innovation research in a survey experiment to analyse their implications for PTD-design. Our main research questions are the following:

1. Does the organizational setup of a PTD – in terms of governmental, academic or industrial involvement – have an influence on the perceptions of potential participants regarding the product that is introduced?
2. If that is the case: What is the marginal contribution of a specific setup to the perception of different characteristics? Do certain organizational actors induce variation in the assessment of particular dimensions?
3. How important are additional features of PTD-design, such as communication channels, personal support and financial benefits, for potential participants regarding their decision about taking part in a PTD?

3. Data and Methodology

To explore this relationship between the organizational setup of a PTD and the ensuing perceptions of potential participants, we conduct a survey experiment among an elaborately selected sample of prosumers in the Nuremberg metropolitan area in Bavaria in the south of Germany. Survey experiments have a long tradition in the social sciences, as they combine advantages from two different approaches. An experimental setting – notably random allocation of treatments – allows for straightforward causal inference regarding the relationship of interest. A survey approach opens up the possibility to address a specific population in a realistic context, hence providing benefits in terms of generalisability and external validity of the data (for a methodological overview see e.g. Druckman et al., 2006; Mullinix et al., 2015; Mutz, 2011).

We exploit these advantages by assembling data on the perception of products that are introduced via a PTD among a specific subgroup, namely those households that are most likely to be addressed in the implementation of such projects.⁵ In our experiment, we randomly vary information about the organizational setup of a hypothetical PTD across the sample population. Differences in the assessment of the product that is rolled out in the PTD are then used to identify and analyse the effect of a particular organizational setup on potential participants' perceptions.

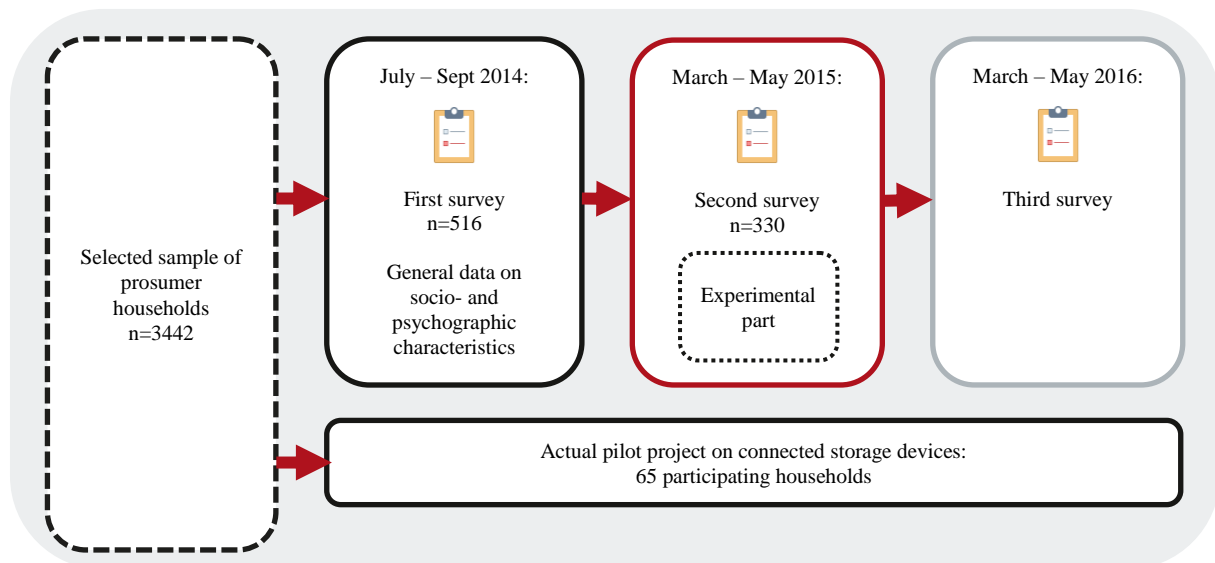
3.1 Survey procedure

The survey experiment was embedded in the second wave of a structured, three-part panel survey conducted in cooperation with a local energy provider. Figure 2 gives an overview of the panel structure.

⁵ For more information on the specific characteristics of such households, see section 3.1.

The panel study had been set up a year before to accompany an actual PTD dealing with virtually interconnected storage devices.⁶

Figure 2: Overview of panel structure



This setup ensures that the participants of our experiment correspond to the typical target group of PTDs: all are customers of the major local energy provider in the Nuremberg metropolitan area, have solar panels installed and have been targeted for recruitment into a PTD one year before during the first wave. This elaborate preselection and setting provides us with a sample already primed on and interested in green innovations as well as renewable energy, which constitutes a most suitable mindset for our experiment. Implemented at the very beginning of the second wave’s questionnaire, our experiment thus builds on a well-prepared context, which allows us to keep the experimental design itself neutral and independent of a specific product. In total, this setting enables us to gain detailed insight into the perceptions of a technological innovation by PTD participants and draw sound conclusions on the effects of varying organizational setups.

The second wave questionnaire consisted of two major parts. The first contained the experimental setting. The second, clearly separated from the experimental part, addressed the battery storage project of the local energy provider. Attached to the questionnaire was a cover letter describing the aim of the study as well as guaranteeing privacy and anonymity of the assembled data. To stimulate participation among recipients, those taking part in the survey had the chance to win one of three €100 prizes.⁷

⁶ The SWARM (Storage with amply redundant megawatt) project was a cooperation between two industrial partners, a university think tank and the state government in Bavaria. Its goal was to install 65 wirelessly interconnected battery storage units in private households in a metropolitan area as a virtual mass storage to provide balancing energy for the local distribution network. For more details about the first survey and the purpose of the project, please refer to U.S. Department of Energy (2019), Energy Campus Nürnberg (2019) and Grimm et al. (2018).

⁷ The full questionnaire is available on request.

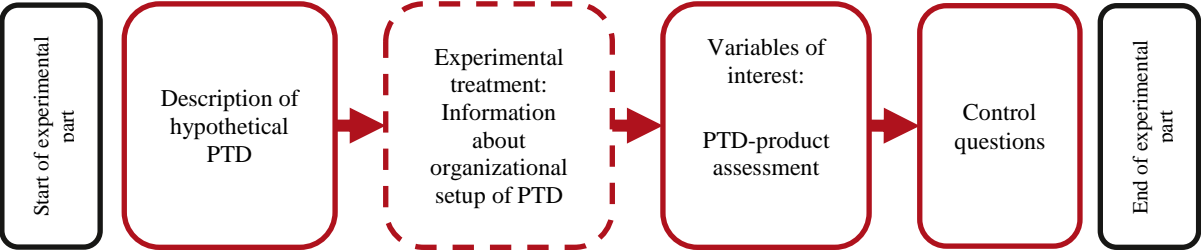
In February 2015, the survey was sent out to 516 households that had taken part in the panel study’s first wave in 2014 and had expressed their consent to being addressed repeatedly. Treatments were allocated randomly across the whole sample. Between March and May 2015, 330 questionnaires were returned, corresponding to a response rate of 64%. Due to the panel structure of our research, we were able to enrich our dataset with a variety of information collected during the first wave. This ranged from personal characteristics such as age, education, income, gender and household size to psychographic risk measures, attitudes towards environmentally friendly behaviour, the German energy transition and features of individual decision-making (for details see Grimm et al., 2018). Since the first survey was conducted a year in advance, we can safely assume independence between the treatment and these measures.

For further analysis, we excluded respondents that were inconsistent with respect to gender or year of birth across both surveys (n=62) and with missing items in the experimental part of the survey (n=33). The following analysis is based on 235 observations.

3.2 Experimental design

In detail, the experimental survey is designed as depicted in Figure 3 below.

Figure 3: Experimental design



At the beginning of the questionnaire, each recipient was provided with the same short description of a hypothetical scenario, explicitly mentioned as such. This description briefly stated that the local energy provider is planning to introduce a new product in the context of a PTD, without specifying product or technology any further. In order to examine the assessment of such a product under different organizational setups, we then varied the information about the PTD’s organizational setup. One group was told that “the project is accompanied by academic research” (university-industry collaboration (UI)), a second that “the project receives governmental support” (government-industry collaboration (GI)) and a third that “the project is accompanied by academic research and receives governmental support” (government-university-industry collaboration (GUI)).

We carefully checked that the wording was both as neutral and realistic as possible and therefore explicitly refrained from priming the absence of an entity (e.g. stating that the project does not receive governmental support or is not scientifically monitored).

These three treatments exemplify our organizational regimes of interest. While the treatments UI and GI cover partial organizational collaboration between industry and university as well as industry and government, the GUI-treatment describes a full institutional setup involving government, university and industry. Figure 4 shows the experimental part as presented in the questionnaire, where for each treatment group only one of the three statements was added directly after the introductory text.⁸

Figure 4: Description of hypothetical PTD and treatment variation

Please imagine your local energy supplier has developed a new product based on a new technology. You are given the opportunity to be among the first to use this product in the context of a pilot project. [**The project is accompanied by academic research.** / **The project receives governmental support.** / **The project is accompanied by academic research and receives governmental support.**

Without knowing more details about the project: What would you expect from product and technology?

Project description and experimental treatment were followed by an item battery containing pre-defined statements on different aspects and qualities of the aforementioned hypothetical product. Respondents were asked to signal their agreement with each statement on a 7-point-scale (marked 0-6). The scale endpoints were additionally coded as ‘Does not apply’ and ‘Does apply’. Items were identical over treatments, asking for the perception of product and technology in 10 different dimensions.

We presented recipients with a wide range of statements designed to capture the characteristics of a product in such a project from a broad perspective. Three items were directed at technical aspects, namely whether respondents expect the product (1) to represent the technological state of the art, (2) to be technically mature and (3) innovative. Two items were concerned with beliefs about general market performance, which would likely influence the decision of technology-adoption: whether (4) the product is going to be established in the market and if (5) prices are expected to decline in the future. Regarding the product’s features of direct utility for the customer, two other items addressed whether the product (6) is going to reduce the end users’ energy costs and (7) is primarily designed to serve end users’ needs. Finally, assessing the ‘green’ qualities of the product, we also asked whether (8) the product’s use is environmentally friendly, (9) contributes to the German energy transition and (10) should be supported by the general public.⁹ Following this section, we asked respondents in two additional item batteries to rate other aspects of PTD-design, such as communication channels, personal support or financial benefits, according to their importance for the decision to participate in a PTD. The complete list of

⁸ The original survey was conducted in German. In addition, the government level collaborating in the hypothetical PTD was not defined further. However, the original German wording for government support (“staatlich gefördert”) excludes the municipal level, i.e. respondents could only consider state or federal level government participation.

⁹ As a result of the industry context of our study and the interaction with actual customers, we faced limitations in the wording of the statements to comply with company-guidelines.

items is given in Table A1 in the Appendix. Respondents again indicated their agreement with each statement on a 7-point-scale (marked 0-6).

We closed the experimental part with control questions about the general attitude towards the adoption of new technologies, whether respondents think of a specific product and an option to voice critical remarks.

4. Results and Discussion

4.1 Balance tests and descriptive statistics

We ensured a random distribution of treatments across the sample by means of a computerised simple random allocation mechanism in the survey execution phase. Still we do not have full control over the survey response. We thus apply balance tests to our sample to assess whether we encounter differential attrition in form of systematic non-response, which we would have to control for in our further analysis. Table 1 provides descriptive statistics of the respondents' personal characteristics for the full sample and by treatment group, as well as the p-values of our balance tests for each of the variables.

Table 1: Descriptive statistics of survey sample

Variable	Treatment 1: UI (n=82)	Treatment 2: GI (n=77)	Treatment 3:GUI (n=76)	Full sample (n=235)	p- value
Age	54.10	53.78	52.95	53.61	0.80
Household size	3.65	3.4	3.35	3.4	0.31
Male	0.87	0.82	0.88	0.85	0.44
Energy saving measures	7.24	7.15	7.56	7.32	0.47
<i>Education</i>					0.23
Sec. school degree (H)	0.40	0.34	0.27	0.34	
Secondary school (R)	0.22	0.25	0.32	0.26	
University entrance diploma	0.13	0.13	0.22	0.16	
University degree	0.23	0.27	0.18	0.23	
<i>Employment</i>					0.99
Employed	0.63	0.65	0.66	0.65	
Self-employed	0.10	0.09	0.08	0.09	
Retired	0.27	0.25	0.26	0.26	
<i>Income level</i>					0.75
Low income (<30k)	0.14	0.15	0.15	0.15	
Middle income (30-60k)	0.47	0.36	0.43	0.42	
High income (60-90k)	0.24	0.36	0.27	0.29	
Very high income (>90k)	0.15	0.13	0.15	0.14	

Note: Average values for age, household size, male and energy saving measures. Proportion of sample for education, employment and income level. P-values of χ^2 - and LR-tests against H_0 that attributes are equally distributed over treatment groups.

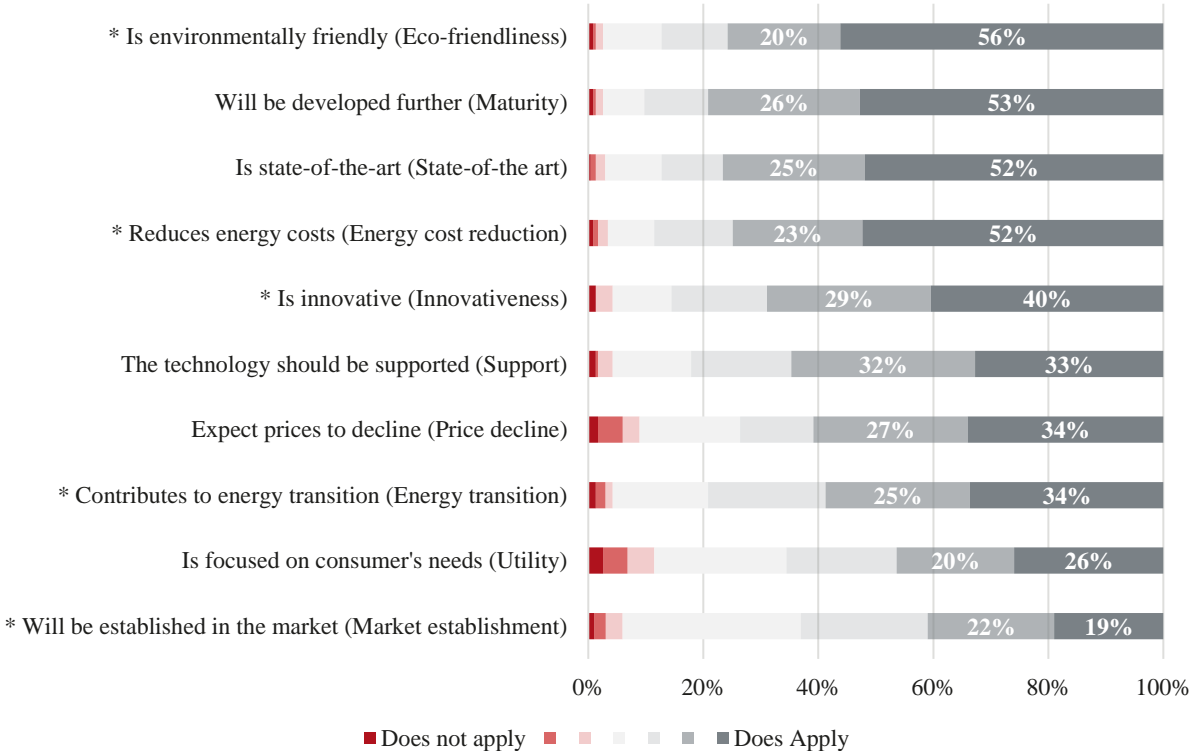
To check for non-randomness in distributions, we apply ordinal and multinomial regression with the treatment as the dependent variable for continuous and Chi² tests for categorical variables. We find no significant differences for either age (LR Chi²(2)=0.44, $p=0.80$), household size (LR Chi²(2)=2.37, $p=0.31$), being male (Chi²(2)=1.63, $p=0.44$), education (Chi²(6)=8.03, $p=0.23$), employment

($\text{Chi}^2(4)=0.23, p=0.99$) or income ($\text{Chi}^2(6)=3.45, p=0.75$) .¹⁰ We therefore assume independence of treatment, non-response as well as personal characteristics and attribute any systematic differences in the experimental part of the survey to the experimental intervention.

We also examine whether answers capture separate dimensions or can be condensed to a smaller number of underlying factors. First, we check for excessive correlation, which would indicate redundancy between items. However, no items show sufficient correlation so as to be treated as nearly identical within or between treatments. In addition, we conduct a principal component analysis commonly used for item reduction and scale building (Abdi and Williams, 2010). Again, we do not obtain meaningful results. We conclude that all items measure sufficiently distinct attributes and hence analyse them separately.

Next, we explore general attitudes towards PTD-products in the full sample. How do potential participants perceive the characteristics of a smart, green product that is launched in a pilot project? The distribution of answers to the 10 dimensions pooled across all treatments is shown in Figure 5.

Figure 5: Perception of characteristics of a PTD-product (full sample)



Note: Statements ranked by overall share of respondents that (fully) agree. * indicates items that show significant differences in agreement levels across treatment groups.

¹⁰ We also tested whether the respondents' thoughts about a specific product or project depended on treatment allocation, showing no significant results ($\text{Chi}^2(4)=2.10, p=0.72$).

The overall level of agreement is rather high with no full disagreement in any of the categories.¹¹ Nonetheless, we observe qualitative differences in answers that allow for a distinct interpretation. In five dimensions, affirmative answers seem to be particularly pronounced: Respondents perceive products in pilot projects to be environmental friendly (56% full agreement (FA), 76% high agreement (HA)), technologically state-of-the-art (52% FA, 77% HA) and innovative (40% FA, 69% HA) and they anticipate a reduction of energy costs (52% FA, 75% HA). However, they do not expect technological maturity. 79% of respondents (53% FA, 79% HA) express the belief that the product is going to be developed further, indicating that PTDs are not considered as a pure marketing instrument, but understood as a product-development environment. In the five remaining categories, variance in answers is higher, less concentrated in extreme points and respondents seem to be more divided on the issues. This includes the product's contribution to the German energy transition (34% FA, 59% HA), whether it is primarily designed to serve end users' needs (26% FA, 46% HA) and whether its introduction should be supported by the public (33% FA, 65% HA). Respondents still answer favourably in general, but answers are less concentrated in the right tail, showing less consensus compared to the first group of items. Both indicators of expected market performance, covering two important determinants of imminent adoption (Grimm et al., 2018), are among these items: Although 61% of all respondents agree with the statement that prices will decline in the future, only 41% are optimistic about the product's successful transfer to the market. In particular, this item shows the largest spread over answer categories and can hence be interpreted as the most disputed and uncertain aspect.

4.2 Analysis of treatment effects

We now turn to the analysis of our main research question: Does the stated organizational setup of the PTD – in terms of governmental, scientific or industrial involvement – have an influence on the perception of the product?

Although the overall distribution of agreement with the statements shows a tendency to be skewed to the positive extreme points, we find significant differences in answer levels across treatments, i.e. a treatment effect for five of the ten dimensions: The product's likelihood to be established in the market (KW, $\text{Chi}^2(2)=8.26$, $p<0.016$), its contribution to the German energy transition (Kruskal-Wallis-test (KW), $\text{Chi}^2(2)=7.28$, $p<0.026$), its innovativeness (KW, $\text{Chi}^2(2)=4.6$, $p<0.10$), its potential for energy cost reduction (KW, $\text{Chi}^2(2)=5.18$, $p<0.075$) and the environmental friendliness of its use (KW, $\text{Chi}^2(2)=5.55$, $p<0.063$). All five are assessed differently depending on the organizational setup of the PTD, which we analyse in more detail in this section.

Figure 6 shows the average assessment of these five items for each treatment group. It illustrates three aspects: Firstly, with respect to the overall agreement level, the same ranking of item categories as in

¹¹ This ceiling effect is partly due to the fact that compliance with company-guidelines limited wording of items to a predominantly positive domain.

the full sample statistics emerges. This ranking remains stable across treatment groups, indicating that the comparative perception of these five PTD-product-characteristics is unaffected by treatments.

Secondly, differences between treatments seem to be mainly driven by a ‘full vs. partial’ organizational setup effect. Under full organizational cooperation between government, university and industry, approval rates for all five items are significantly higher. Results of pairwise comparisons as shown in Table 2 support this impression. It is especially striking that the attenuating effect of the partial setups is mostly independent of the latter’s composition: Respondents’ answers in UI and GI are almost identical for every level. We do not observe any differing marginal contribution of either governmental or scientific participation in any dimension. Instead, the mere participation of all three institutional spheres induces changes in perception, without attributing any specific value to government or university participation per se.¹²

Figure 6: Perception of PTD-product characteristics by treatment group

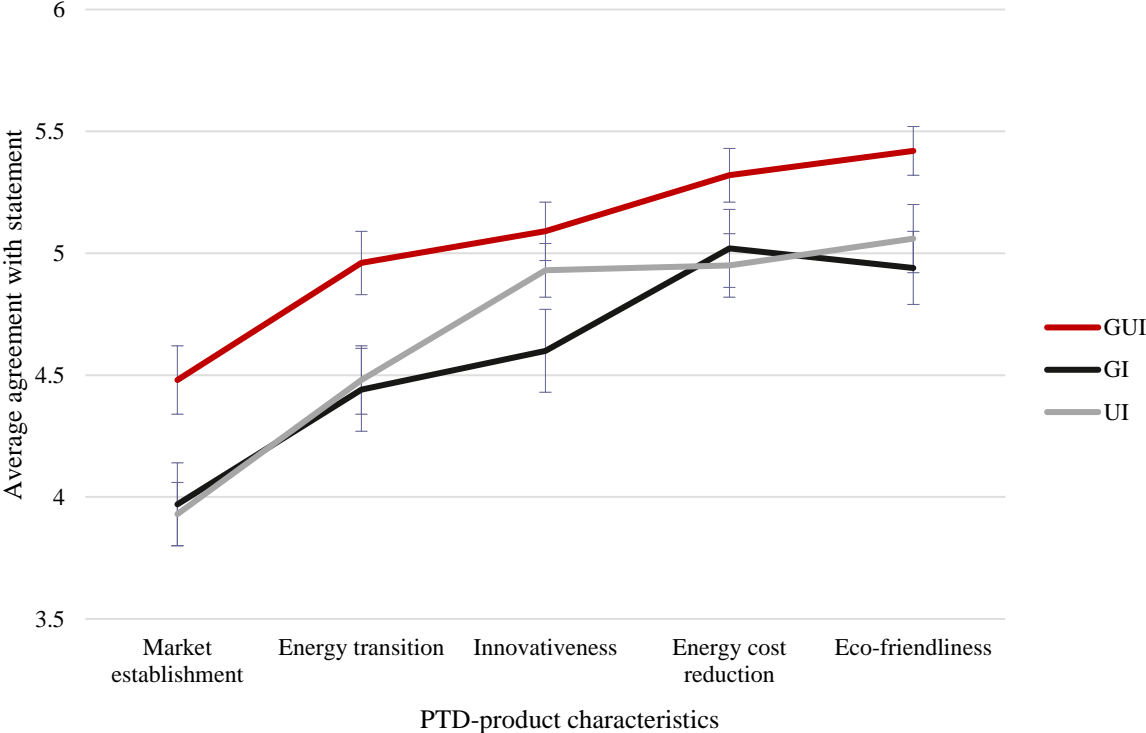


Table 2: Post-hoc pairwise comparisons of differences between treatments

Dependent Variable	Market establishment	Energy transition	Innovativeness	Energy cost reduction	Eco-friendliness
GI vs. UI	-	-	-	-	-
GI vs. GUI	GI < GUI**	GI < GUI**	GI < GUI**	-	GI < GUI**

¹² We are aware of the fact that it would be informative to test this against a partial organizational setup that features industry-only support of a PTD. However, since this – given the background of our survey study – is not feasible without specifically mentioning the absence of the other two sectors and we explicitly abstained from negative wording in this study, we have to postpone this to future research.

UI vs. GUI UI < GUI*** UI < GUI** - UI < GUI** UI < GUI*

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Bonferroni-Holm correction applied for significance of post-hoc test.

Thirdly, this full setup effect seems to be particularly pronounced for those items that face lower levels of agreement and the highest spread in answers, i.e. market establishment and (supporting the) energy transition. To analyse the treatment effect in more detail, Table 3 presents the results of OLS regressions for each of the five items as dependent variable.¹³

Table 3: OLS regressions with GUI-treatment as baseline

Dependent Variable	Market establishment	Energy transition	Innovativeness	Energy cost reduction	Eco-friendliness
<i>Variable of interest:</i>					
GI	-0.433**(0.207)	-0.465** (0.212)	-0.528*** (0.204)	-0.247 (0.193)	-0.490***(0.187)
UI	-0.550***(0.190)	-0.492** (0.193)	-0.168 (0.164)	-0.345** (0.177)	-0.395** (0.177)
<i>Sociodemographic controls:</i>					
Age	0.011 (0.007)	0.010 (0.007)	-0.008 (0.007)	-0.009 (0.007)	0.003 (0.007)
Education	0.035 (0.082)	-0.033 (0.084)	0.120 (0.076)	0.036 (0.076)	0.077 (0.073)
Income	-0.194** (0.083)	-0.047 (0.078)	0.125* (0.069)	-0.110* (0.066)	0.006 (0.074)
<i>Attitudinal controls:</i>					
Importance ET	0.086** (0.038)	0.127*** (0.040)	0.088** (0.035)	0.065** (0.033)	0.049 (0.035)
Energy saving measures	0.060 (0.039)	0.027 (0.040)	-0.014 (0.035)	-0.003 (0.039)	0.011 (0.039)
Imp. Environment	0.034 (0.145)	0.035 (0.161)	-0.115 (0.129)	-0.054 (0.129)	-0.019 (0.138)
Imp. Technology	0.201 (0.138)	0.126 (0.136)	0.374*** (0.109)	-0.014 (0.103)	0.214* (0.117)
Imp. Costs	0.031 (0.127)	-0.015 (0.136)	-0.125 (0.114)	0.142 (0.111)	-0.195* (0.116)
N	235	235	235	235	235
R ²	0.13	0.12	0.14	0.05	0.07

Note: Huber-White standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Attitudinal controls: Importance ET: scale measuring personal importance of German energy transition. Energy saving measures: scale measuring the number of measures taken for an environmentally friendly energy consumption. Imp. Environment: importance of contribution to energy transition for decision about investment in storage device. Imp. Technology: importance of innovativeness of technology for decision about investment in storage device. Imp. Costs: importance of energy cost reduction for decision about investment in storage device.

The results show highly significant negative effects of the GI and UI-indicators on all dependent variables compared to the GUI-baseline. The effects are particularly pronounced for the perception of the technology's establishment in the market, which is pivotal for reducing uncertainty among potential future adopters and driving widespread technology adoption. Similarly, the effects for the contribution

¹³ We also conduct ordered logistic regressions (dependent variables as ordinal variables) and a global level MANOVA to estimate treatment effects and account for potential alpha-error-accumulation due to multiple testing. Since the results are qualitatively very close to the OLS-estimates and interpretation is not straightforward, we report these results in Tables A2 and A3 in the Appendix.

to the German energy transition and environmental friendliness stand out. Both the UI- and the GI-setup induce significantly worse perceptions compared to the GUI-case in these three dimensions, with (only) minor differences in effect size.

While the university-industry setup scores slightly worse regarding the technology's future market establishment and its contribution to the energy transition, it spurs perceptions of its environmental friendliness comparatively more than the GI-setup (compared to the GUI-setting). Regarding a technology's innovativeness, university participation seems to drive the positive perceptions in this dimension: we see no statistically significant difference to the GUI treatment, while perceptions in the GI-treatment are significantly worse. Conversely, government support appears to be the momentum behind the perception of an energy cost reduction potential, with a treatment effect statistically indistinguishable from the GUI treatment, while the UI-setup comparatively worsens perceptions.

These results suggest that a cooperation between all institutional actors as in the GUI setting, i.e. between government, academia and industry, consistently improves participants' technology perceptions across various dimensions. There are several possible reasons for this. Firstly, the GUI-setup might convey that actors from all relevant institutional spheres are convinced of a new technology's potential and viability, its sustainability, relative matureness, future marketability and applicability, and are thus committed to contribute to its further development and diffusion. This impression may then incite more trust and certainty about these exact factors among potential PTD participants compared to a partial setup. Secondly, it could be that every institution adds a specific, individual reputation to the PTD, e.g. marking it as especially innovative, sustainable or fit for the future, thus appealing to potential participants. If this were the case, however, we should see a difference in perceptions between the GI and the UI treatment as a result of the reputations specific to academia and government. Thirdly, a combination of the first two channels might also be at work, i.e. that the impression conveyed by the PTD-setup is multiplied or enhanced by the specific reputation of the involved institutional actors. Lastly, the GUI-setting could be considered as the historically grown standard setup for PTDs in Germany. As such, any PTD with a partial UI or GI setup might be perceived as a 'poorer' version of PTD. Due to data constraints resulting from our survey design, we cannot provide a final assessment of the channels of influence at work here.

Of the sociodemographic controls, only the income level occasionally contributes to the answers, though to a smaller degree than the treatments: Respondents with higher income are associated with less optimistic perceptions regarding successful market establishment and energy cost reductions, yet are rather convinced of the technology's innovativeness.

In addition to sociodemographic characteristics, we also analyse the association with two groups of attitudinal controls collected during the first survey wave. Firstly, 'Importance ET' and 'Energy saving measures' indicate the respondents' attitude towards the German energy transition in general and actions they have taken to contribute to it (i.e. energy saving measures such as installing an environmentally

friendly heating system, house insulation, or green electricity contracts). We see that the more important the respondents deem the German energy transition, the more they expect new products to serve that goal, to reduce energy costs, to be innovative and to be established in the market. On the contrary, actual environmental measures taken have no significant effect on perceptions.

The second group of attitudinal covariates covers information on the role of particular product features as motivational factors for the adoption of a new smart technology: one's own contribution to the German energy transition (Imp. Environment), the use of an innovative technology (Imp. Technology) and financial aspects (Imp. Costs). Respondents who rate the innovativeness of a product as very important for their adoption decision tend to also have a more positive perception regarding the product's eco-friendliness and innovativeness in the context of a PTD. This suggests that the importance of innovativeness for the adoption of a new technology directly translates into the perception of a PTD product in the same domain, while the innovation is expected to address environmental concerns. The perception of eco-friendliness is negatively correlated with the importance of financial aspects regarding the individual adoption decision.

Finally, to analyse whether treatment effects are dependent on any of the covariates in our dataset, we integrate multiple interaction terms into the regressions. We do not find any evidence for heterogeneous treatment effects as interaction terms for neither sociodemographic nor psychographic variables show significant results. The treatment effect thus seems to be unaffected by and independent of personal characteristics.

4.3 Random forest analysis

To check the robustness of our results, we additionally estimate the average treatment effects of the different organizational setups by means of the generalised random forest algorithm developed by Athey et al. (2019). As outlined in Grimm et al. (2018), random forests provide superior analytical properties compared to many traditional regression methods. In particular, following Wager and Athey (2017) and Athey and Imbens (2016), we use causal forests, which allow for statistical inference and have proven to be more powerful than classical approaches in treatment effect estimation. We grow 2.000 causal trees as a basis for each of our causal forests that are 'honest' in addition, whereby the partitioning of the independent variables, i.e. the construction of the trees, is done using a different subsample of the data than when estimating the treatment effect, thus reducing bias.¹⁴

Due to random forests' capacity to handle a large number of covariates and identify complex interactions of higher order, we first verify whether our statistical analyses are set in the right variable space to prevent a potential omitted-variable bias. To do so, we run the causal forest algorithm with all available

¹⁴ Apart from the number of trees per forest, all tuning parameters are obtained using built-in cross-validation of the algorithm. Furthermore, we use debiasing weights to match expected moments and conduct the analysis several times using different random seeds to check the consistency of our results.

independent variables as input. Both for this full-variable setting as well as using the same specifications as in the regressions above, we obtain similar results in terms of effect size and significance as is shown in Table 4. These findings support the validity of our results.

Table 4: Average treatment effect with generalised random forest

Dependent variable	Treatment effect			
	GUI vs. GI		GUI vs. UI	
Eco-friendliness	0.498**	(0.197)	0.360**	(0.177)
Maturity	0.306	(0.206)	0.035	(0.155)
State-of-the-art	0.361*	(0.211)	0.131	(0.190)
Energy cost reduction	0.329	(0.210)	0.389**	(0.182)
Innovativeness	0.483**	(0.227)	0.138	(0.171)
Support	0.267	(0.212)	0.319	(0.202)
Price decline	0.364	(0.269)	0.087	(0.237)
Energy transition	0.571**	(0.234)	0.459**	(0.203)
Utility	0.244	(0.268)	0.144	(0.240)
Market establishment	0.533**	(0.241)	0.522***	(0.197)
N	235			

Note: Socio-demographic and attitudinal controls were used (see Table 3). Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

In a final step, we employ the causal tree algorithm to scan for significant relations and interactions between the treatment and control variables in order to assess whether the three treatments affect individuals with certain characteristics differently. Also using this explorative approach, we find no such interactions. This result suggests that all individuals are affected equally by the treatments based on their socio-demographic characteristics.

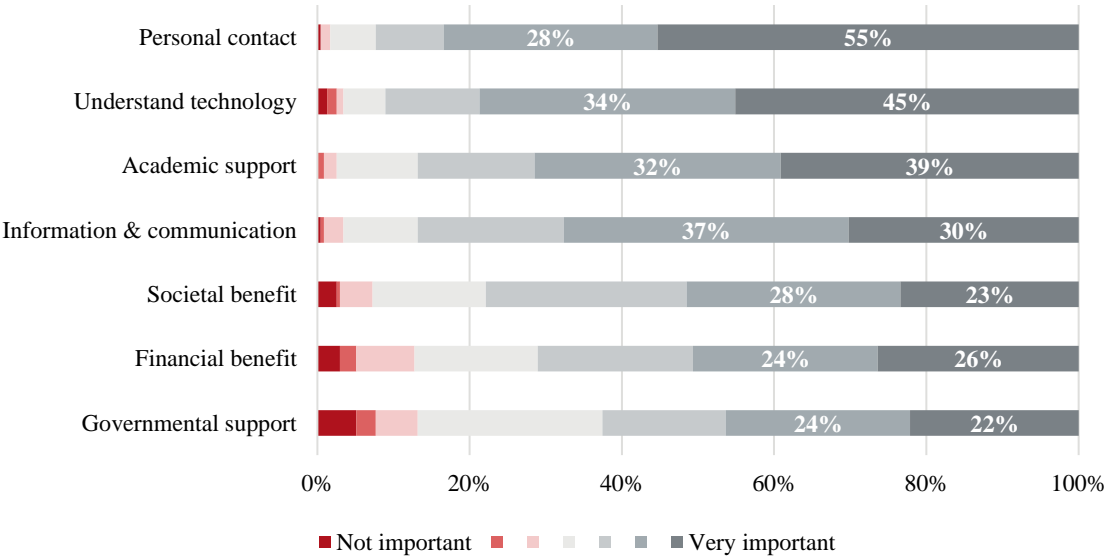
4.4 Additional aspects of PTD design

Civic engagement does not only require that product characteristics are matched with the needs of potential participants, but also that other factors of a PTD's design, i.e. the basic conditions that constitute the PTD-environment, are attractive for potential participants. Apart from a personal economic benefit this also includes softer factors like using an innovative technology, adequate information provision, generalised environmental benefits and community benefits (Gangale et al., 2013; Peters et al., 2018). In addition to the influence of the organizational setup, we therefore assess the importance of project design features in various domains such as communication, financial benefits or personal contact for project participation.¹⁵

¹⁵ A list of these items can be found in Table A1 in the Appendix.

Figure 7 shows the overall importance ranking of seven additional PTD design aspects for the full sample. Potential participants seem to especially value a personal contact person, understanding the technology behind the product they are using as well as being regularly updated about the project’s progress. This indicates that potential PTD participants want to be actively involved and be an integral part of the whole project. The very broad overall importance of academic accompaniment furthermore suggests that participants primarily understand and expect PTDs to be a means to promote the further development of an innovation, which they want to be actively involved in. Fostering technological progress thus appears to be the main motivation for participation; a direct financial benefit is rated as relatively less important. This suggests that ‘soft’ factors in a sense of fostering the common good are more decisive regarding PTD participation than ‘hard’ factors like price and cost reductions. The latter may become more important for adoption decisions at a later stage in a free market context, once a product has reached a sufficient level of maturity. This result is in line with Hoffman and High-Pippert (2010) and Peters et al. (2018), who find that the individual motivation to participate in a PTD on community energy is mainly driven by (abstract) perceived benefits for a community as well as general environmental benefit and not by actual personal benefits like lower electricity bills. In addition, they suggest that those potential PTD participants that end up volunteering to be an actual PTD participant are usually outstandingly enthusiastic, dedicated and well-informed citizens (Hoffman and High-Pippert, 2010). This characterisation also provides a reasonable explanation for the importance ranking we find in our study, as such persons would be more concerned with their contribution to the public good than their direct personal benefit. It is particularly striking that the importance ranking of these aspects is unaffected by our treatments, which underlines and solidifies their importance for all PTD projects on smart, green innovations irrespective of their organizational setup.

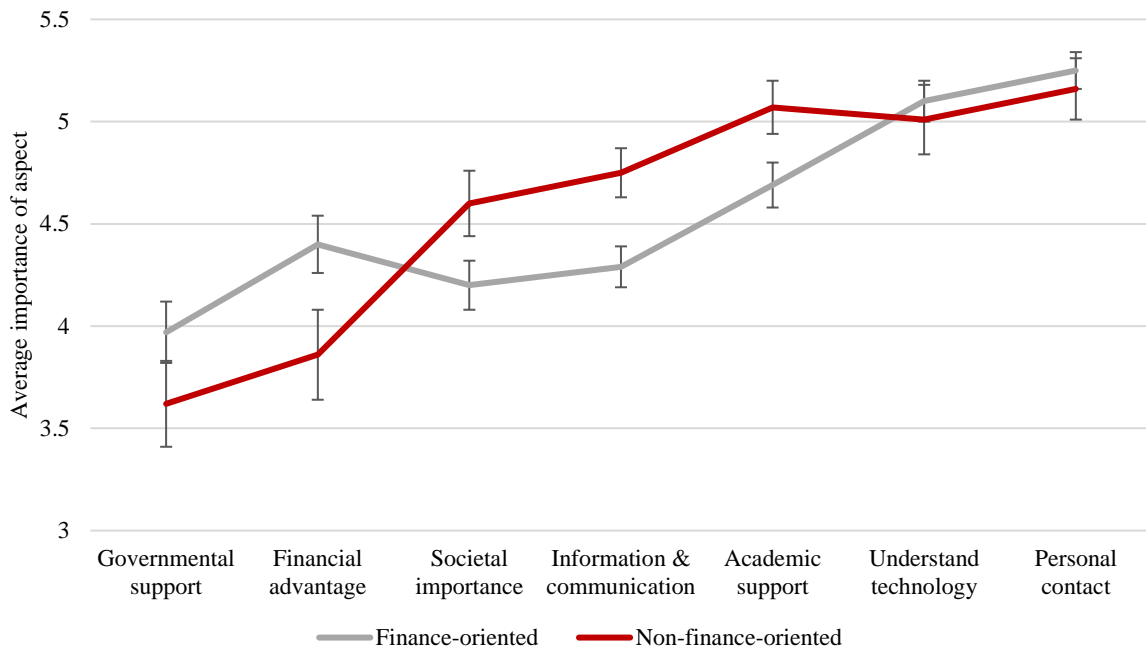
Figure 7: Importance of additional PTD design elements (full sample)



Note: Aspects ranked by overall share of importance.

Drawing on the findings in Grimm et al. (2018), we additionally compare the respondents' importance ranking for the presented PTD design aspects based on their individual motivational structure regarding the adoption of green innovations, i.e. based on whether they are mainly finance-oriented or not.¹⁶ While the organisational structure of a PTD seemingly has no influence on the PTD design aspect valuation, we find that the individual motivational structure, however, does play a role: Figure 8 illustrates the overall importance ratings for the finance- and non-finance-oriented respondents.

Figure 8: Importance of additional PTD design aspects by motivational structure



Non-finance-oriented respondents seem to care less about governmental support and financial benefits ($\text{Chi}^2(1) = 4.20, p < 0.036$) compared to finance-oriented ones. Instead, they value aspects such as the societal importance of the project ($\text{Chi}^2(1) = 3.08, p < 0.07$), information on and communication about the project ($\text{Chi}^2(1) = 6.16, p < 0.012$), e.g. via regular updates on project progress, as well as academic support ($\text{Chi}^2(1) = 3.58, p < 0.048$) more. However, we do not observe statistically different answers regarding the importance of a personal contact person and a basic understanding of the technology. The results of a global level MANOVA reported in Table 5 support this impression. It shows the marginal effect of a non-finance-oriented motivational structure on the importance rating ($F(1, 167) = 2.47, p < 0.019$; Wilk's $\Lambda = 0.902$).

Table 5: PTD design aspect valuation by motivational structure

Dependent Variable	Governmental support	Financial benefit	Societal importance	Information & communication	Academic support	Understand technology	Personal contact

¹⁶ To do so, we employ information about the individual adherence to a finance-oriented and two non-finance-oriented clusters, which is based on information from the first survey wave. A detailed characterisation of the different clusters can be found in Grimm et al. (2018).

Non-finance-oriented	-0.351 (0.273)	-0.528** (0.256)	0.396* (0.221)	0.461** (0.182)	0.377** (0.187)	-0.0845 (0.195)	-0.088 (0.171)
N	166	166	166	166	166	166	166
R ²	0.009	0.024	0.018	0.036	0.023	0.001	0.001

Note: Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

In sum, we find that understanding the technology at use and having a personal contact person are universally relevant aspects of PTD design, as they are generally valued irrespective of individual motivations and a PTD's organizational design. The importance of other aspects like academic support, information and communication, societal importance or financial benefits is in contrast dependent on the individual motivational structure regarding the adoption of new technologies. While none of these design features are influenced by a PTD's organizational structure, they should nevertheless be taken into account when designing a PTD in order to attract the desired target group.

5. Conclusion and Policy Implications

To successfully manage the transition of energy systems and spur the diffusion of green innovations, it is important to address all involved societal actors efficiently and effectively. In this complex process of research, development and market deployment, PTDs have become a prominent tool. Especially against the background of digitalisation, many smart innovations require the preceding adoption of an analogous technology as a basis, e.g. a smart meter, smart storage unit or smart home devices. In Germany, for instance, many smart energy applications are impossible without a smart meter or smart storage unit. In this context, PTDs provide a valuable opportunity to test innovative technologies and services in real-life ecosystems that enable learning for all relevant stakeholders.

To prevent a mismatch of the attributes and characteristics of technological solutions on the one hand and the needs, wants and perceptions of potential adopters on the other, it is of utmost importance to incorporate the perspective of individual participants in the design process of PTDs. In this paper, we therefore tested how the organizational setup of a PTD influences perceptions about products among a selected sample of potential PTD-first movers. In order to contribute to a more coherent and thorough understanding of the underlying behavioural mechanisms that drive participation in PTDs.

We find that the mere mentioning of a specific organizational setup – even in a vague and technologically unspecified context – triggers a pronounced effect on the perception of five different dimensions. We show that the organizational setup has a significant impact on a product's perceived establishment in the market, its contribution to the energy transition, innovativeness, cost-reduction potential and environmental friendliness. Concerning the marginal contribution of each involved institutional sphere, a full organizational cooperation between government, university and industry consistently improves perceptions compared to a partial setup. These treatment effects are robust across various estimation methods and independent of personal characteristics.

Regarding further design features that influence the attractiveness of PTD participation, we find that providing participants with the information and the means needed to actively participate in the project are paramount, e.g. via a personal contact person, regular updates about the project progress as well as detailed information on the product technology. Being actively involved in the product development is rated as even more vital than personal economic benefit. In addition, different design features gain relevance based on the individual motivation for technology adoption, which is especially relevant for the attraction of an adequate PTD target group.

From a policy perspective, these findings can be condensed into three main implications:

First, policy-makers should, in general, be aware of framing effects and hence take a holistic perspective when deciding on a PTD's organizational setup. As different organizational structures induce different perceptions, this is of clear practical relevance: It adds another dimension to the policy-measures at disposal and could be exploited strategically for the attraction of certain user groups. Such strategic attraction leads to increased differential selection into PTDs though (i.e. participants attracted by a particular setup might show specific behavioural characteristics), which has to be addressed and taken into account when interpreting the ensuing results and feedback.

Secondly, concerning the details of an organizational structure, full organizational cooperation (and its prominent communication) could prove beneficial in mitigating barriers to participation. The GUI-setup seems to send a powerful signal of commitment, technological maturity and future usability of a service or technology. As this reduces uncertainty in decision-making, upgrading a partial to a full cooperation setup might prove to be more efficient to promote a PTD compared to other measures. This non-monetary intervention could be particularly valuable for PTDs conducted in a market-learning or market-transfer context, in which policy-makers should be cautious to alter economic incentives for participants (e.g. via direct remuneration or other financial benefits to spur participation, see Benartzi et al. (2017)).

Thirdly, our results indicate that efficiently designed PTDs dispose of well-defined communication- and information-channels and focus on building a relationship with the participants. (Behavioural) feedback is not only paramount for technological learning in digital innovation systems – it also seems to be universally appreciated among potential participants and should hence be incorporated in an institutionalised way. Providing participants with a personal contact person, information about the technology tested, regular updates about the PTD's progress and uncomplicated feedback mechanisms can address the potential participants' needs and establish a transparent and continuous information flow between users and the executive institutions. These non-standard, behaviour-oriented design elements may pose a more flexible alternative to financial and regulatory incentive schemes when it comes to the attraction of potential participants.

Lastly, on a broader perspective, our results suggest that a more structured focus on research in this area is needed. While our findings pose a promising starting point, contrasting them to results from PTDs in other sectors and countries as well as testing them in actual PTDs would contribute to a more efficient application of PTDs in the future.

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References

- Abdi, H., Williams, L.J., 2010. Principal component analysis. *Wiley Interdiscip. Rev. Comput. Stat.* 2, 433–459.
- Aghion, P., Dewatripont, M., Stein, J.C., 2008. Academic freedom, private-sector focus, and the process of innovation. *RAND J. Econ.* 39, 617–635.
- Almirall, E., Casadesus-Masanell, R., 2010. Open versus closed innovation: A model of discovery and divergence. *Acad. Manag. Rev.* 35, 27–47.
- Athey, S., Imbens, G., 2016. Recursive partitioning for heterogeneous causal effects. *Proc. Natl. Acad. Sci. U. S. A.* 113, 7353–7360. <https://doi.org/10.1073/pnas.1510489113>
- Athey, S., Tibshirani, J., Wager, S., 2019. Generalized random forests. *Ann. Stat.* 47, 1148–1178. <https://doi.org/10.1214/18-AOS1709>
- Australian Renewable Energy Agency, 2019. Advancing Renewables - Advancing Renewables Program. <https://arena.gov.au/funding/advancing-renewables-program/> (accessed 11.19.19).
- Benartzi, S., Beshears, J., Milkman, K.L., Sunstein, C.R., Thaler, R.H., Shankar, M., Tucker-Ray, W., Congdon, W.J., Galing, S., 2017. Should Governments Invest More in Nudging? *Psychol. Sci.* 28, 1041–1055. <https://doi.org/10.1177/0956797617702501>
- Benner, M.J., Tripsas, M., 2012. The influence of prior industry affiliation on framing in nascent industries: The evolution of digital cameras. *Strateg. Manag. J.* 33, 277–302.
- BMW, 2019. The SINTEG Funding Programme. <https://www.sinteg.de/en/programme/> (accessed 11.21.19).
- BMW, 2018. Innovationen für die Energiewende. 7. Energieforschungsprogramm der Bundesregierung.
- Bossink, B.A.G., 2017. Demonstrating sustainable energy: A review based model of sustainable energy demonstration projects. *Renew. Sustain. Energy Rev.* 77, 1349–1362.
- Brown, H.S., Vergragt, P., Green, K., Berchicci, L., 2003. Learning for sustainability transition through bounded socio-technical experiments in personal mobility. *Technol. Anal. Strateg. Manag.* 15, 291–315.
- Chesbrough, H.W., 2003. *Open innovation: The new imperative for creating and profiting from technology.* Harvard Business Press.
- Cornelissen, J.P., Clarke, J.S., 2010. Imagining and rationalizing opportunities: Inductive reasoning and the creation and justification of new ventures. *Acad. Manag. Rev.* 35, 539–557.
- Cornelissen, J.P., Werner, M.D., 2014. Putting framing in perspective: A review of framing and frame analysis across the management and organizational literature. *Acad. Manag. Ann.* 8, 181–235.
- Cui, A.S., Wu, F., 2016. Utilizing customer knowledge in innovation: antecedents and impact of customer involvement on new product performance. *J. Acad. Mark. Sci.* 44, 516–538.
- Davidson, E.J., 2002. Technology frames and framing: A socio-cognitive investigation of requirements determination. *Mis Q.* 329–358.
- Davis, F.D., 1989. Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Q.* 319–340.
- Davis, F.D., Bagozzi, R.P., Warshaw, P.R., 1989. User acceptance of computer technology: a comparison of two theoretical models. *Manage. Sci.* 35, 982–1003.
- U.S. Department of Energy, 2019. Caterva SWARM. <https://energystorageexchange.org/projects/1537> (accessed 11.19.19).

- Druckman, J.N., Green, D.P., Kuklinski, J.H., Lupia, A., 2006. The growth and development of experimental research in political science. *Am. Polit. Sci. Rev.* 100, 627–635.
- Energy Campus Nürnberg, 2019. SWARM - Acceptance and Adoption in the Energy Transition [WWW Document]. URL <https://www.encn.de/en/reference-projects/energy-market-design/acceptance-and-adoption-in-the-energy-transition/> (accessed 11.19.19).
- Etzkowitz, H., Leydesdorff, L., 2000. The dynamics of innovation: from National Systems and “Mode 2” to a Triple Helix of university–industry–government relations. *Res. Policy* 29, 109–123.
- Etzkowitz, H., Leytesdorff, L., 1997. *Universities in the Global Economy: A Triple Helix of academic-industry-government relation*. London Croom Helm.
- European Commission, 2018. 10 Trends. Reshaping Climate and Energy.
- Faiers, A., Cook, M., Neame, C., 2007. Towards a contemporary approach for understanding consumer behaviour in the context of domestic energy use. *Energy Policy* 35, 4381–4390. <https://doi.org/10.1016/j.enpol.2007.01.003>
- Fernandes, T., Remelhe, P., 2016. How to engage customers in co-creation: customers’ motivations for collaborative innovation. *J. Strateg. Mark.* 24, 311–326.
- Flanagan, K., Uyarra, E., Laranja, M., 2011. Reconceptualising the ‘policy mix’ for innovation. *Res. Policy* 40, 702–713.
- Franke, N., Von Hippel, E., Schreier, M., 2006. Finding commercially attractive user innovations: A test of lead-user theory. *J. Prod. Innov. Manag.* 23, 301–315.
- Franke, T., Krems, J.F., 2013. What drives range preferences in electric vehicle users? *Transp. Policy* 30, 56–62. <https://doi.org/10.1016/J.TRANPOL.2013.07.005>
- Freeman, C., 1995. The ‘National System of Innovation’ in historical perspective. *Cambridge J. Econ.* 19, 5–24.
- Frishammar, J., Söderholm, P., Bäckström, K., Hellsmark, H., Ylinenpää, H., 2015. The role of pilot and demonstration plants in technological development: synthesis and directions for future research. *Technol. Anal. Strateg. Manag.* 27, 1–18. <https://doi.org/10.1080/09537325.2014.943715>
- Gangale, F., Mengolini, A., Onyeji, I., 2013. Consumer engagement: An insight from smart grid projects in Europe. *Energy Policy* 60, 621–628. <https://doi.org/10.1016/j.enpol.2013.05.031>
- Gassmann, O., Enkel, E., Chesbrough, H., 2010. The future of open innovation. *R&d Manag.* 40, 213–221.
- George, E., Chattopadhyay, P., Sitkin, S.B., Barden, J., 2006. Cognitive underpinnings of institutional persistence and change: A framing perspective. *Acad. Manag. Rev.* 31, 347–365.
- Girod, B., Mayer, S., Nägele, F., 2017. Economic versus belief-based models: Shedding light on the adoption of novel green technologies. *Energy Policy* 101, 415–426. <https://doi.org/10.1016/j.enpol.2016.09.065>
- Greco, M., Grimaldi, M., Cricelli, L., 2015. Open innovation actions and innovation performance: A literature review of European empirical evidence. *Eur. J. Innov. Manag.* 18, 150–171.
- Greening, L.A., Greene, D.L., Difiglio, C., 2000. Energy efficiency and consumption—the rebound effect—a survey. *Energy Policy* 28, 389–401.
- Grimm, V., Kretschmer, S., Mehl, S., 2018. Diffusion of Green Innovations: The Role of Consumer Characteristics for Domestic Energy Storage Adoption. *SSRN Electron. J.* <https://doi.org/10.2139/ssrn.3122235>
- Haase, R., Bielicki, J., Kuzma, J., 2013. Innovation in emerging energy technologies: A case study

- analysis to inform the path forward for algal biofuels. *Energy Policy* 61, 1595–1607.
- Harborne, P., Hendry, C., 2012. Commercialising new energy technologies: failure of the Japanese machine? *Technol. Anal. Strateg. Manag.* 24, 497–510.
<https://doi.org/10.1080/09537325.2012.674671>
- Harborne, P., Hendry, C., 2009. Pathways to commercial wind power in the US, Europe and Japan: The role of demonstration projects and field trials in the innovation process. *Energy Policy* 37, 3580–3595.
- Heidenreich, S., Wittkowski, K., Handrich, M., Falk, T., 2015. The dark side of customer co-creation: exploring the consequences of failed co-created services. *J. Acad. Mark. Sci.* 43, 279–296.
- Hellsmark, H., 2010. Unfolding the formative phase of gasified biomass in the European Union: The role of system builders in realising the potential of second-generation transportation fuels from biomass. Chalmers University of Technology.
- Hellsmark, H., Frishammar, J., Söderholm, P., Ylinenpää, H., 2016. The role of pilot and demonstration plants in technology development and innovation policy. *Res. Policy* 45, 1743–1761. <https://doi.org/10.1016/j.respol.2016.05.005>
- Hellsmark, H., Jacobsson, S., 2012. Realising the potential of gasified biomass in the European Union—Policy challenges in moving from demonstration plants to a larger scale diffusion. *Energy Policy* 41, 507–518.
- Hendry, C., Harborne, P., Brown, J., 2010. So what do innovating companies really get from publicly funded demonstration projects and trials? Innovation lessons from solar photovoltaics and wind. *Energy Policy* 38, 4507–4519.
- Henisz, W.J., Zelner, B.A., 2005. Legitimacy, interest group pressures, and change in emergent institutions: The case of foreign investors and host country governments. *Acad. Manag. Rev.* 30, 361–382.
- Hoffman, Steven M., High-Pippert, A., 2010. From private lives to collective action: Recruitment and participation incentives for a community energy program. *Energy Policy* 38, 7567–7574.
<https://doi.org/10.1016/J.ENPOL.2009.06.054>
- Hoffman, Steven M., High-Pippert, A., 2010. From private lives to collective action: Recruitment and participation incentives for a community energy program. *Energy Policy* 38, 7567–7574.
<https://doi.org/https://doi.org/10.1016/j.enpol.2009.06.054>
- Höglund, L., Linton, G., 2018. Smart specialization in regional innovation systems: a quadruple helix perspective. *R&D Manag.* 48, 60–72.
- Hossain, M., Kauranen, I., 2016. Open innovation in SMEs: a systematic literature review. *J. Strateg. Manag.* 9, 58–73.
- Huang, S.K., Kuo, L., Chou, K.-L., 2018. The impacts of government policies on green utilization diffusion and social benefits—A case study of electric motorcycles in Taiwan. *Energy Policy* 119, 473–486.
- IEA, 2017. *Digitalisation and Energy*. Paris.
- Ikki, O., Matsubara, K., 2008. National survey report of PV Power Applications in Japan 2007.
- Jensen, A.F., Mabit, S.L., 2017. The use of electric vehicles: A case study on adding an electric car to a household. *Transp. Res. Part A Policy Pract.* 106, 89–99.
<https://doi.org/10.1016/J.TRA.2017.09.004>
- Kaplan, S., 2011. Research in cognition and strategy: Reflections on two decades of progress and a look to the future. *J. Manag. Stud.* 48, 665–695.

- Kaplan, S., 2008. Framing contests: Strategy making under uncertainty. *Organ. Sci.* 19, 729–752.
- Kaplan, S., Tripsas, M., 2008. Thinking about technology: Applying a cognitive lens to technical change. *Res. Policy* 37, 790–805.
- Karakaya, E., Hidalgo, A., Nuur, C., 2015. Motivators for adoption of photovoltaic systems at grid parity: A case study from Southern Germany. *Renew. Sustain. Energy Rev.* 43, 1090–1098.
- Kemp, R., Schot, J., Hoogma, R., 1998. Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management. *Technol. Anal. Strateg. Manag.* 10, 175–198.
- Kennedy, M.T., Fiss, P.C., 2009. Institutionalization, framing, and diffusion: The logic of TQM adoption and implementation decisions among US hospitals. *Acad. Manag. J.* 52, 897–918.
- Kivimaa, P., Kern, F., 2016. Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions. *Res. Policy* 45, 205–217.
- Lager, T., Blanco, S., Frishammar, J., 2013. Managing R&D and innovation in the process industries. *R&D Manag.* 43, 189–195.
- Lund, H., Østergaard, P.A., Connolly, D., Mathiesen, B.V., 2017. Smart energy and smart energy systems. *Energy* 137, 556–565.
- Lundvall, B.-A., 1992. *National systems of innovation: An analytical framework*. London: Pinter.
- Markard, J., 2018. The next phase of the energy transition and its implications for research and policy. *Nat. Energy* 3, 628–633.
- Meuter, M.L., Bitner, M.J., Ostrom, A.L., Brown, S.W., 2005. Choosing among alternative service delivery modes: An investigation of customer trial of self-service technologies. *J. Mark.* 69, 61–83.
- Moore, G.C., Benbasat, I., 1991. Development of an instrument to measure the perceptions of adopting an information technology innovation. *Inf. Syst. Res.* 2, 192–222.
- Mullinix, K.J., Leeper, T.J., Druckman, J.N., Freese, J., 2015. The Generalizability of Survey Experiments. *J. Exp. Polit. Sci.* 2, 109–138. <https://doi.org/10.1017/XPS.2015.19>
- Mutz, D.C., 2011. *Population-based survey experiments*. Princeton University Press, Princeton.
- Neij, L., Heiskanen, E., Strupeit, L., 2017. The deployment of new energy technologies and the need for local learning. *Energy Policy* 101, 274–283. <https://doi.org/10.1016/j.enpol.2016.11.029>
- Noll, D., Dawes, C., Rai, V., 2014. Solar community organizations and active peer effects in the adoption of residential PV. *Energy Policy* 67, 330–343.
- Parag, Y., Sovacool, B.K., 2016. Electricity market design for the prosumer era. *Nat. Energy* 1. <https://doi.org/10.1038/nenergy.2016.32>
- Perkmann, M., Walsh, K., 2007. University–industry relationships and open innovation: Towards a research agenda. *Int. J. Manag. Rev.* 9, 259–280.
- Peters, M., Fudge, S., High-Pippert, A., Carragher, V., Hoffman, S.M., 2018. Community solar initiatives in the United States of America: Comparisons with – and lessons for – the UK and other European countries. *Energy Policy* 121, 355–364. <https://doi.org/10.1016/j.enpol.2018.06.022>
- Rai, V., Reeves, D.C., Margolis, R., 2016. Overcoming barriers and uncertainties in the adoption of residential solar PV. *Renew. Energy* 89, 498–505. <https://doi.org/10.1016/j.renene.2015.11.080>
- Rai, V., Robinson, S.A., 2013. Effective information channels for reducing costs of environmentally-friendly technologies: evidence from residential PV markets. *Environ. Res. Lett.* 8, 14044.

- Raven, R., 2007. Niche accumulation and hybridisation strategies in transition processes towards a sustainable energy system: An assessment of differences and pitfalls. *Energy Policy* 35, 2390–2400.
- Rogers, E.M., 2010. *Diffusion of innovations*. Simon and Schuster, New York.
- Schot, J., Geels, F.W., 2008. Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. *Technol. Anal. Strateg. Manag.* 20, 537–554.
- Schot, J., Kanger, L., Verbong, G., 2016. The roles of users in shaping transitions to new energy systems. *Nat. Energy* 1. <https://doi.org/10.1038/nenergy.2016.54>
- Sigrin, B., Pless, J., Drury, E., 2015. Diffusion into new markets: evolving customer segments in the solar photovoltaics market. *Environ. Res. Lett.* 10, 84001.
- Sorrell, S., Dimitropoulos, J., 2008. The rebound effect: Microeconomic definitions, limitations and extensions. *Ecol. Econ.* 65, 636–649. <https://doi.org/10.1016/j.ecolecon.2007.08.013>
- Sustainable Development Technology Canada, 2019. SDTC launches pilot project; partners with accelerators to provide seed funding to four potential game-changing technologies. <https://www.sdtec.ca/en/news/sdtec-launches-pilot-project-partners-with-accelerators-to-provide-seed-funding-to-four-potential-game-changing-technologies/> (accessed 11.19.19).
- Ulsrud, K., Winther, T., Palit, D., Rohracher, H., Sandgren, J., 2011. The Solar Transitions research on solar mini-grids in India: Learning from local cases of innovative socio-technical systems. *Energy Sustain. Dev.* 15, 293–303.
- Verhees, B., Raven, R., Veraart, F., Smith, A., Kern, F., 2013. The development of solar PV in The Netherlands: A case of survival in unfriendly contexts. *Renew. Sustain. Energy Rev.* 19, 275–289.
- Wager, S., Athey, S., 2017. Estimation and Inference of Heterogeneous Treatment Effects using Random Forests. *J. Am. Stat. Assoc.* 1–15. <https://doi.org/10.1080/01621459.2017.1319839>
- Walsh, J.P., 1995. Managerial and organizational cognition: Notes from a trip down memory lane. *Organ. Sci.* 6, 280–321.
- Weick, K.E., 1995. *Sensemaking in organizations*. Sage.
- Zeng, Z., Zhao, R., Yang, H., Tang, S., 2014. Policies and demonstrations of micro-grids in China: A review. *Renew. Sustain. Energy Rev.* 29, 701–718.
- Zenglein, M.J., Holzmann, A., 2019. *Evolving Made in China 2025*. China's industrial policy in the quest for global tech leadership.
- Zhao, Z.-Y., Chen, Y.-L., Chang, R.-D., 2016. How to stimulate renewable energy power generation effectively?—China's incentive approaches and lessons. *Renew. energy* 92, 147–156.

Appendix

Table A1: List of items in additional item batteries

Item	Item wording
<i>Perception of PTD and participants</i>	
Pioneers	Pilot project participants are pioneers.
Idealists	The project is targeted at idealists.
Societal benefit	Participating in the project generates a societal benefit.
Additional services	Participants of such projects receive additional services that later users do not receive.
Financial risk	There is no financial risk involved in participating in a pilot project.
Supervision	Pilot project participants are intensively taken care of.
Support progress	By participating in the project one supports progress.
Effort	Participating in the project equals effort without a reward.
<i>Important PTD design aspects for participation</i>	
Financial benefit	Participating in the project has to provide me with a financial benefit.
Understand technology	I have to understand how the technology works.
Societal importance	The project should be important for society.
Governmental support	The project should be government-funded.
Academic support	The project should be scientifically monitored.
Personal contact	I have a personal contact person.
Information & communication	
Exchange experiences	I have the opportunity to exchange experiences with other project participants.
Regular updates	I am regularly informed about the project's progress.
Report experiences	I am regularly asked about my experiences.
Only participation	Except for my consent to participate, nothing else is expected from me.

Alternative treatment effect analyses: MANOVA and ordered logit

A global multivariate analysis of variance test shows a statistically significant difference in perception based on treatment allocation ($F(2, 232) = 1.63, p < .096$; Wilk's $\Lambda = 0.932$).

Table A2: Treatment effect estimation using MANOVA

Dependent Variable	Market establishment	Energy transition	Innovativeness	Energy cost reduction	Eco-friendliness
GI	-0.506*** (0.211)	-0.513*** (0.213)	-0.485** (0.200)	-0.298 (0.195)	-0.481*** (0.193)
UI	-0.541*** (0.207)	-0.473** (0.209)	-0.151 (0.196)	-0.373** (-0.373)	-0.367** (0.190)
N	235	235	235	235	235
R ²	0.0349	0.0303	0.0259	0.0176	0.0284

Note: Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A3: Treatment effect estimation with ordered logistic regressions

Dependent Variable	Market establishment	Energy transition	Innovativeness	Energy cost reduction	Eco-friendliness
GI	-0.581** (0.306)	-0.612* (0.325)	-0.763** (0.334)	-0.286 (0.337)	-0.751** (0.329)
UI	-0.858*** (0.289)	-0.746** (0.298)	-0.365 (0.295)	-0.642** (0.299)	-0.610* (0.320)
Age	0.012 (0.011)	0.013 (0.011)	-0.012 (0.011)	-0.012 (0.011)	0.002 (0.012)
Education	0.030 (0.122)	-0.122 (0.122)	0.165 (0.125)	0.067 (0.118)	0.118 (0.127)
Income	-0.260** (0.125)	-0.008 (0.109)	0.251** (0.117)	-0.156 (0.115)	0.059 (0.119)
Importance ET	0.132** (0.059)	0.196*** (0.064)	0.120** (0.057)	0.104* (0.057)	0.074 (0.058)
Energy saving measures	0.087 (0.058)	0.045 (0.063)	-0.022 (0.057)	0.002 (0.062)	-0.013 (0.066)
Imp. Environment	0.005 (0.219)	0.073 (0.238)	-0.194 (0.195)	-0.100 (0.215)	-0.029 (0.240)
Imp. Technology	0.317 (0.210)	0.190 (0.196)	0.574*** (0.173)	0.029 (0.176)	-0.388* (0.208)
Imp. Costs	0.028 (0.188)	-0.031 (0.193)	-0.134 (0.184)	0.242 (0.173)	-0.310 (0.215)
N	235	235	235	235	235
Pseudo R ²	0.0416	0.0449	0.0479	0.0640	0.0900
BIC	796.362	768.149	715.257	684.552	655.810

Note: Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.