Energy Research & Social Science 91 (2022) 102755

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

Original research article

Competent, trustworthy, and likeable? Exploring which peers influence photovoltaic adoption in Germany

Fabian Scheller [a,b,*], Sören Graupner [b], James Edwards [c], Jann Weinand [d,e], Thomas Bruckner [b]

[a] Energy Economics and Modelling, Sustainability, Society and Economics Division, Department of Technology, Management and Economics, Technical University of Denmark (DTU), Denmark
[b] Institute for Infrastructure and Resources Management (IIRM), Leipzig University, Germany
[c] SINUS Markt- und Sozialforschung GmbH, Berlin, Germany
[d] Chair of Energy Economics, Institute for Industrial Production, Karlsruhe Institute of Technology (KIT), Germany
[e] Institute of Energy and Climate Research – Techno-Economic Systems Analysis (IEK-3), Forschungszentrum Jülich, Germany

ARTICLE INFO

Keywords:
Peer effects
Communication behaviour
Solar photovoltaic
Decision-making
Quantitative survey

ABSTRACT

Little is known about the role of active peer effects (interpersonal contact) compared to passive peer effects (noticing or seeing) regarding residential photovoltaic (PV) diffusion. Recent literature suggests that peer effects are determined by the perceived credibility of one's active peer connections regarding PV and passive peer effects. Utilising data from a survey of German house owners who either own a PV or indicate purchase intention (N = 1,165), this paper explores the underlying mechanisms of active peer effects during different stages of PV adoption decision-making. Our findings suggest that the perceived credibility of peers on PV related issues is positively associated with the reported number of adopters in the decision-maker's peer group (passive peer effect) and also with the progress in the PV adoption decision process. Furthermore, we find a relationship between the perceived credibility of peers regarding PV and the reported influence strength of peer interactions throughout the decision-making processes of German householders, suggesting that subjective evaluations of peers play a role in active peer effects. Finally, we observe an association between the rate of self-initiated peer interactions about PV for respondents with a higher reported number of peers that have adopted PV, suggesting that passive effects (knowing peer PV adopters) play a role in initiating active peer interactions. These results are significant for all sub-groups, regardless of the decision progress. From a policy-making perspective, "bottom-up" efforts such as peer consultation and community-led outreach should be promoted in Germany to empower potential adopters.

1. Introduction

1.1. Active peer effects in residential photovoltaic diffusion

Reducing greenhouse gas emissions requires advances in all parts of the economy and society. Individual households can contribute to the required socio-economic transformation by adopting low-carbon consumption patterns [1]. On an individual household level as well as an infrastructural level, importance should thus be attached to the adoption of technical innovations that reduce carbon emissions. By reducing emissions, low-carbon innovations for households help mitigate anthropogenic climate change and thus contribute to the public good [2]. This makes the diffusion of such innovations desirable from a societal point of view, and also explains why their adoption is currently pursued as a public policy goal. However, "top-down" strategies to accelerate the societal uptake of such innovations have not yet been successful on a sufficiently large scale [3–6]. On the one hand, the requisite technologies might be insufficiently attractive from a consumer point of view: they tend to require a large initial investment and are sometimes perceived as risky or uncertain with respect to performance due to their relative novelty [5]. On the other hand, research indicates that a range of cultural, institutional, and social barriers could inhibit low-carbon innovation uptake on a more significant level than perceived technical feasibility and economic viability alone [7].

Solar energy represents one of the main drivers of global growth in the market share of renewable energies [8,9]. Alongside large-scale renewable energy sources like wind and solar farms, decentralised rooftop photovoltaic (PV) systems offer a significant and viable contribution to the energy transition. While the residential uptake of

* Corresponding author at: Energy Economics and Modelling, Sustainability, Society and Economics Division, Department of Technology, Management and Economics, Technical University of Denmark (DTU), Denmark.
E-mail address: fjosc@dtu.dk (F. Scheller).

https://doi.org/10.1016/j.erss.2022.102755
Received 3 May 2021; Received in revised form 18 May 2022; Accepted 20 July 2022
Available online 10 August 2022

PV systems has been approached from various angles [10–12], the importance of peer effects in significantly shaping residential adoption decisions has been recognised by a number of studies [11,13–18]. According to Wolske et al. [19], within the energy context, the term "peer effects" encompasses the impact of peer attitudes, values, behaviours, and interactions on the attitudes, values, or behaviours of individual decision-makers. In other words, "peer effects are the influence of a person's peers [...] on his or her behaviour" [20]. Across the literature, peer groups are often defined in terms of spatial or geographic proximity: for instance, all private households within a neighbourhood or a district can be defined as "peers" [11,13,15,21]. Such definitions implicitly assume an objective or outsider viewpoint. However, it is quite possible that residential decision-makers themselves might not consider all spatially proximate households to be "peers" [19]. From a subjective or insider viewpoint, "peers" might be defined as members of a decision-maker's social network or individuals who share their interests or values, regardless of spatial proximity [12,20,22,23]. "Peers" as defined subjectively, based on shared social networks and/or shared interests or values, are more likely to be connected with and known by one another than "peers" as defined based on geographical proximity alone [19]. For the rest of this paper, "peers" are defined from a subjective viewpoint as people who are connected with, known by, or regarded as "similar" by residential decision-makers themselves. This comprises family members, relatives, friends, acquaintances, co-workers but also neighbours.

Peer effects can be further distinguished into two types: passive peer effects (i.e., homeowners become more likely to adopt PV when they see residential PV panels in their geographic proximity [14]) and active peer effects (i.e., homeowners become more likely to adopt PV when they engage in peer interactions about PV [14]). According to Bollinger and Gillingham [13], peer effects on potential PV adopters develop as a consequence of both the visibility of PV panels and interactions about PV. Researchers often assume passive peer effects to represent a substantial part of the entire peer effect, as the visibility of PV systems is generally high [11,13,14]. Bollinger et al. however, demonstrate that a higher level of word-of-mouth communication between peers is associated with a higher adoption rate [24]. Likewise, decision-makers interviewed qualitatively by Palm [20] assessed active peer effects as more important than passive peer effects. Mundaca and Samahita [18] support such findings with a quantitative survey: while "a higher frequency of seeing or hearing about PV raises the likelihood of adopting [...] the effect of visibility is extremely small and not statistically significant". Jager [25] and Noll et al. [26] also demonstrate the comparative efficacy of PV-related engagements by contacts that are personally known to decision-makers, within the context of well-connected communities.

Despite the stated importance of active peer effects in accelerating residential PV adoption, comparatively little research has been done on the underlying social mechanisms [14,19,20]. To begin with, the interrelationship between passive and active peer effects is not clear. Working with a dataset from the residential PV market in Texas (United States), Rai and Robinson [14] assume (but do not prove) that active peer effects may arise from passive peer effects, whereas in Sweden, Palm [20] could not find qualitative evidence that the mere existence of PV systems in decision-makers' peer groups motivated them to make contact with previous adopters who they did not already know personally (though the author suspects that it is possible that decision-makers themselves underestimated the influence of having seen PV systems).

Secondly, there is a gap in empirical work on how decision-makers' perceptions of and interactions with specific peers mediate active peer effects [12,20]. Based on data on different parts of the United States, Wolske et al. [23] assume that the quality of a given peer connection is more important than the geographical proximity of the peer, and advocate conducting research to form a more reliable picture of how active peer effects influence behaviour [19]. Prior qualitative research by Palm [20] in Sweden and Scheller et al. [10] in East Germany shows that peers who are less well-known or emotionally close to decision-makers exert less influence on them, suggesting that active peer effects are determined in part by the strength of established relationships (e.g., peers who are perceived as trustworthy [26] (United States) and familiar [20] (Sweden) exert more influence). Similarly, while Mundaca and Samahita [18] demonstrate that hearing about PV from a personally-known source significantly improves the likelihood of adoption by decision-makers in Sweden, there is no further specification of what "personally known" really means from the perspective of the decision-maker.

Thirdly, there is an indication that peer influences are dynamic on several levels, potentially changing over the course of the decision-making process [27]. According to both our literature review and focus group discussions we conducted in Germany, proximity and ordinary communication on a regular basis play a central role at the awareness stage, while trustworthiness and expertise are of greater importance during the interest and the planning stages; however, as decision-makers have no choice but to rely on commercial stakeholders during the planning stage, the perceived trustworthiness of these stakeholders seems to become less important [10,28]. Unfortunately, few quantitative studies delve into the way peer effects may vary during different stages of PV decision-making and adoption [20].

In conclusion, it is clear that research remains to be done on the interrelation of active and passive peer effects, the role of decision-makers' perceptions of and interactions with peers in mediating peer effects, and the way peer effects modulate over the course of the decision-making process. Addressing such gaps would contribute significantly to our understanding of peer effects. It could also provide an impetus for more effective policymaking.

1.2. Research objectives, scope and contributions

The present study explores to what extent PV-specific peer interactions are related with residential PV adoption decision-making among German householders. Special attention is given to the dynamism of peer effects over the course of the decision-making process (e.g., respondents at different decision making stages), the role of existing peer adopters (e.g., number of peers with PV systems) and perceived peer attributes (e.g., trustworthiness, competence, closeness, likeability) in relation to peer interaction (e.g. active initiation of interactions), and the interrelation of perceived peer attributes to perceived peer influence (e.g., influence strength of the peer interaction). Thereby, the responses of different sub-groups of decision-makers with different progress in the decision-making process are compared. The following research questions are used as a guideline:

- What is the relationship between the reported decision making stage of household decision-makers and PV-relevant perceptions of different groups of peers?
- What is the relationship between the number of PV adopters in decision-makers' social circles and their PV-relevant perceptions of different groups of peers?
- What is the relationship between PV-relevant perceptions of peers and the perceived strength of influence of peer interactions throughout different stages of the PV decision-making process?
- What is the relationship between the attributes ascribed by German householders to peer groups and the self-initiation of interactions with peers by residential decision-makers?
- What is the relationship between the number of PV adopters in decision-makers' social circles and the self-initiation of interactions with peers by residential decision-makers?

This study takes a quantitative approach to these questions. A nationwide survey was conducted in Germany, focusing on residential decision-makers' interactions with various peer groups on the topic of

PV, their perceptions of these peer groups' PV-relevant attributes, and their assessments of these peer groups' influence on the PV decision-making process. Decision-makers' positions in the decision-making process and general statements towards PV were also measured, as were passive peer effects with the help of the number of peers in the social circle. To ensure robust insights, respondents needed to indicate ownership of their house, indicate decision-making power over their rooftop, demonstrate awareness of PV technology, and report at least some interest in installing residential PV. Building on the conceptual idea of different decision-making stages [29,30], as well as source credibility theory [31,32], this paper demonstrates how the qualities of peer relationships enable and intensify active peer effects in different ways at different stages in the adoption decision process.

Besides the theoretical research gap, our choice of Germany as a research site can be justified by the fact that PV has tremendous potential in Germany, but residential adoption hesitancy remains a barrier to the full realisation of this potential. An analysis commissioned by the German Federal Environment Agency has shown average greenhouse gas reduction potentials for PV electricity for a system operation in Germany between 35 and 57 g CO2-eq./kWh [33]. In 2020, PV accounted for 9,3% of the gross electricity consumption [34]. The deployment of solar power in Germany has increased greatly from 114 MWp in 2000 to a total of 1.8 million PV systems and an accumulated installed capacity of 49.02 GWp in 2019 [35]. In a scenario where 0.5% of land is covered in ground-mounted PV and the full potential of rooftop PV is exploited, Matthes et al. [36] estimate an installed PV capacity of 313 GWp by 2050 in Germany. Some federal states have furthermore decided, in various legislative resolutions, to introduce an obligation to install rooftop solar systems [37]. Furthermore, the coalition agreement between the newly-elected governing parties in Germany states that "all suitable roof areas will be used for solar energy in the future" [38]. The implementation of PV systems may well become mandatory in the future for both newly constructed and renovated residential and non-residential buildings.

The remaining gap in PV coverage at this point would be existing buildings that are not due to be retrofitted. Outreach to the owners of such buildings is thus necessary to close this gap and bring Germany closer to its de-carbonisation goals. Despite technological improvements and availability at a cost-neutral level due to feed-in tariffs [39], the majority of house owners in Germany (as in many developed markets) still hesitate when faced with the decision of whether they should purchase PV. For instance, in Germany, market research estimates that 11.7 million one- and two-family houses are suitable for PV [40]. By the end of 2020, 1.3 million installations had been reported [40], equating to an adoption rate of around 11%. It should be noted that the feed-in tariff for selling excess PV energy and not self-consuming it is currently at 7.36 cents € per kWh for residential rooftop systems smaller than 10 kWp. Taking into account that the adoption of PV systems is subject to a particularly large number of barriers compared to other pro-environmental behaviours [41] (ranging from high investment costs [42] to information barriers [25] to technical barriers like poor roof orientation [43]), the estimated adoption rate of 23% by Mattes et al. seems to be a more profound number [44]. In order to overcome these barriers and raise adoption rates, outreach to house owners must be grounded on a more granular understanding of their adoption decision-making processes. In exploring the decision-making processes of current and potential adopters, the present study seeks to establish the foundation of such understanding.

2. Related work

2.1. Active peer effect relationships

Research to date has demonstrated that active peer influences play a role in the PV decision-making process, with decision-makers often going out of their way to establish contact with PV-owning peers. Mundaca et al. [18] and Petrovich et al. [45] found for Sweden and Switzerland that the presence of PV systems in a decision-maker's local environment (neighbours) and personal social circle (friends and family) drive their likelihood of adopting to a significant degree. In a meta-study, Schulte et al. [41] demonstrated that the perceived benefits of PV are important drivers of intention to adopt, and that these benefits are driven in part by subjective norms. Among decision-makers in Sweden studied by Palm [20], the strongest active peer effects resulted from personal contacts such as friends, acquaintances, or relatives, leading Palm to conclude that "established social connections [are] more important than geographical proximity". Geographically proximate peers categorised by decision-makers as "neighbours", without any other personal relationship, were rarely perceived as influential, especially in comparison to local peers with whom decision-makers had some kind of personal relationship [22].

This is in line with social network analyses, which tend to show that the persuasiveness of word-of-mouth communications depends on the quality of the relationship between the interlocutors [19]. Trust clearly plays a role here: with regard to the United States, Wolske et al. [23] found a positive correlation between decision-makers' trust in their social networks, their interest in learning about PV systems owned by their peers, and their belief that theirs social network supports PV adoption. This may be because insight shared by trusted personal contacts can reassure decision-makers of their competence to make an informed decision. Palm interprets such insight as "a confirmation from a trustworthy source (e.g., a person that the respondents knew and that was in a similar situation as themselves) that the technology worked as intended and without hassle" [20]. Rode and Müller's [11] findings support Palm's conclusion as to the importance of personal contacts [20]. They additionally hypothesise that neighbours are more likely to have close personal relationships in rural areas than in urban areas, and are therefore more likely to communicate with each other [11]. It follows that peer effects had less of an effect in areas with a higher diffusion rate [11,15].

Contrary evidence appears in Rai et al. [12], who found that less than a fifth of the respondents from Northern California mentioned "conversation with friend/family/work" as a primary spark event for PV adoption, and that the median response regarding the importance of information from family, acquaintances, and co-workers was rather low [12]. The quality of personal relationships between decision-makers and their PV-owning peers is clearly not the only factor influencing PV decisions; indeed, interactions between a range of factors likely come into play. Mundaca and Samahita [18], for instance, showed that while learning about PV systems from personal contacts increased decision-makers' likelihood of adoption, even stronger peer effects arose from interactions with peers identified as both geographically proximate and likeable. Palm [20] added that the relative contributions of various factors to the overall strength of peer effects may differ between cultural contexts: for instance, "Swedes might be less prone to talk to their neighbours than are people in the U.S. or Germany". Testing this assumption requires research in multiple countries and contexts.

Although community energy organisations do not match this paper's narrow definition of "peers" as "people who are connected with, known by, or regarded as 'similar' by residential decision-makers themselves", research on such organisations can shed light on the drivers of active peer effects. According to Noll et al. [26] community solar energy organisations in the United States are unique in their ability to influence decision making because of the trust networks they hold. In cities in the United States and United Kingdom, the information provided by community energy organisations appears to be perceived as particularly credible, in part because it is backed up by the technical knowledge and experience of previous adopters who belong to these organisations [26,46] (note that according to Schulte et al. [47], technical and administrative support can proactively reduce the perceived initial effort required to adopt low-carbon technology; cf. [25]). In the Netherlands, Sloot et al. [48] found that engagement with community energy

organisations that also targeted photovoltaic update could uniquely explain intentions and behaviours towards PV adoption, over and above personal environmental motivations. Similarly, in Germany, Dewald and Truffer [49] found that such organisations were key intermediaries for "understanding early market formation success". Noll et al. [26] emphasise that in areas with low PV deployment, community initiatives play a greater role as a trustworthy source of information than in markets with a high number of adopters. Focus group discussions conducted in Eastern Germany by Scheller et al. [28] point in the same direction. It can be assumed that as adoption rates rise, community energy organisations may lose importance. However, as pointed out by Dewald and Truffer [49], solar initiatives operating in less mature markets (e.g., eastern parts of Germany and some middle and northern regions) still perceive their role as pivotal. We can conclude that a better understanding of active peer effects requires more comprehensive evaluations of the social, psychological, geographical, organisational, and other factors in play.

2.2. Importance of peer credibility

Considering that active peer effects are based on information gathered through different kinds of actively-triggered social influences, Berlo et al. [50] point to the fact that "an individual's acceptance of information and ideas is based in part on 'who said it'". Wolske et al. [19] add that the persuasiveness of a word-of-mouth exchange depends on the "quality" of the connection between the interlocutors. Within the context of PV adoption, decision-makers appear significantly more likely to be influenced by interlocutors to whom they ascribe certain positive attributes, summarised here under the heading of "credibility" [28].

Several authors have operationalised credibility in different ways [32]. Here, multiple dimensions of credibility are posited. Firstly, empirical evidence indicates that a message is perceived as most credible when the communicator is regarded as both an expert and trustworthy [51]. Expertise is defined as having "adequate knowledge, experience or skills" [52]. Trustworthiness is related to "the degree of confidence in, and level of acceptance of, the [peer] and the message" [32], as well as the communicator's "honesty, integrity and believability" [52]. The findings of Lui and Standing [53] and McGinnies and Ward [51] suggest that trustworthiness is at least as important for effective communication as expertise. A third factor that bears upon the persuasiveness of messages is power, defined here as the perceived legitimate right of the communicator to influence the decision-maker and obtain their compliance [54]. Power and credibility are often intertwined [31]. Early research on innovation diffusion furthermore suggests that geographical proximity conditions the likelihood of social influence [55]: the closer (and more available) the communicator, the higher the likelihood and strength of influence [56]. Finally, in addition to rational and objective factors, affective factors come into play. Specifically, communication tends to be more effective when the communicator is perceived as likeable; likeability, defined as "affective intimacy between source and its receiver" [53], might indeed be seen as a mediator between various other attributes.

2.3. Procedural decision-making

An innovation decision or adoption process "examines the individual and the choices an individual makes to accept or reject a particular innovation" [57]. It is analytically helpful to break such processes down into stages. Rogers' [29] adoption model, for instance, consists of five sequential stages. Similarly, Wilson et al. [30] propose a three-stage process for home refurbishments. Various events, such as stakeholder interactions, can "spark" movement from one stage to another, for instance from the stage of awareness of PV to consideration or adoption [12]. While stage models have been criticised for being overly linear and excluding contextual variation [27,58,59], the literature has consistently indicated their utility [23,60,61].

Accordingly, the present study builds upon an abstract four-stage process model for residential PV decision-making and adoption, the stages of which are Awareness (stage I), Interest (stage II), Planning (stage III), and Implementation (stage IV) [10,28]. The applied decision-making process consists of the first three stages, while the fourth stage, implementation, completes the adoption process. The first stage is characterised by initial awareness of PV and by passive exposure, and a lack of intrinsic motivation to engage with the topic. At the second stage, individuals begin to perceive the product as interesting, and start to actively seek and evaluate information from various sources. If the information search leads to a sufficiently positive attitude, the individual will collect object-specific information in the planning stage. The decision-making process ends when an irreversible decision has been made: i.e., in the case of PV, when a contract is signed. Although a strict separation of the process stages is hardly realistic, the applied four-stage model provides a framework to classify the progress of different decision-makers regarding their adoption decisions and analyse how decision-makers accumulate information through interactions, building more object-specific knowledge over time.

3. Methodology

3.1. Form of data acquisition and design of the survey

Since this investigation aims to quantify perceptions representative of the population of residential PV decision-makers in Germany, a non-experimental design was chosen. Due to near-universal internet penetration within the target population of house owners with at least some affinity for advanced technology, a nationwide structured online survey was conducted in German. The questions are provided in English translation in the Supplementary Material Part A (see file in Appendix D). The survey was designed in collaboration with the institute SINUS Markt- und Sozialforschung GmbH.[1] An overview of relevant terms with respect to the survey are outlined in Table 1.

In order to ensure a tight focus on the target population of current and potential residential PV decision-makers, the survey questionnaire opened with a screener battery. Respondents who indicated that they owned a house capable of hosting a PV system (i.e. a single-family home or duplex) and were solely or jointly responsible for major technological or renovation investments were invited to proceed through the rest of the survey. These respondents were then sorted into two groups: those who had already acquired a PV system (current adopters) and those with a moderate or strong intention of purchasing a PV system (potential adopters) which needed to be indicated by the respondents without an own PV system (ten-point Likert scales; only respondents with an intention greater or equal 3 were allowed to continue with the survey). Potential adopters were asked to indicate their perceived stage in the adoption decision process using a slider (100-point scale) matched to a graphic showing and describing the four decision-making process stages: (I) awareness stage; (II) interest stage; (III) planning stage; (IV) implementation (adoption) stage. The stages were described as in Table 1. Current adopters were automatically placed in (IV) implementation stage. The indication of their actual stage was later used for the sub-group analysis of the residential decision makers.

The main parts of the questionnaire addressed passive (proxy: through number of PV adopters in the different peer groups) and active peer effects (proxy: strength of interaction and number of self-initiated interactions with peer groups about PV). Questions were asked

[1] SINUS (https://www.sinus-institut.de/en/) is an independent institute operating in the field of social science research and consultancy.

Table 1
Definition of the terms as used and presented in the survey. The first section of the table describes the different stages of decision-making. The middle and the end sections describe the relevant peer and stakeholder groups and peer group attributes, respectively. The survey respondents represented the group of residential PV decision-makers (current and potential adopters).

Term	Description
Decision-making process stages	
Awareness	I am aware of the existence of residential PV systems (stage I)
Interest	I find residential PV systems interesting and I want to know more about them (stage II)
Planning	I plan to install a residential PV system in my home (stage III)
Implementation	I have signed a contract for a residential PV system (stage IV)
Residential decision-makers	
Potential adopters	Respondents who are interested in PV and find themselves in stage I–III
Current adopters	Respondents who have already acquired or signed a contract for a PV system and find themselves in stage IV
Peer groups	
Family and relatives	Private persons among the decision-maker's family and relatives
Friends	Private persons within the decision-maker's immediate social circle
Acquaintances and co-workers	Private persons within the decision-maker's wider social circle
Neighbours	Private persons living in the decision-maker's neighbourhood
Peer group attributes	
Trustworthiness	Peers offer honest and transparent statements and information about PV systems
Competence	Peers are very competent with regard to PV systems.
Power	Peers have the power to stand in the way of my decisions regarding PV systems
Independence	Peers would not profit from my decision to acquire a PV system
Availability	Peers are always available for discussions or to provide information on PV systems
Closeness	Peers are located near my place of residence and home
Integrity	Peers behave in the way that I would generally expect
Likeability	Peers are likeable to me
Reliability	Peers keep their promises and honour contracts
Contact directions	
Active initiations	I initiated contact with the peer group
Passive experiences	The peer group initiated contact with me

about four peer groups: family and relatives, friends, acquaintances and colleagues, and neighbours for which detailed definitions as indicated in Table 1 were provided.

First, respondents were asked to indicate the approximate number of PV systems: (1) within their neighbourhoods; (2) among their family and relatives; and (3) among their friends, colleagues, and acquaintances (single choice per group: none; one to two; three to four; five or more). As no questions about active contact had yet been asked, the aggregate number of PV adopters within these three groups is interpreted in this study as an indicator of passive peer effects.

Second, respondents were asked to indicate their perception of the peer groups with regard to nine attributes defined in Table 1 (sliding scale from 1 = the selected attribute does not apply at all to the respective peer group to 10 = the selected attribute applies completely to the respective peer group; additional option of "I don't know or can't judge"). Relevant stakeholders and attributes were identified via literature review and a prior phase of focus-group-based research [10,28].

Third, respondents (which could have indicated a different decision making stage and thus could belong to different decision maker subgroups) were asked to provide information about the peer contacts that influenced them during each stage of the PV adoption process (termed as decision stages in the analysis) that they had completed. Per relevant stage, respondents indicated which peer groups they had contact with; whether each contact was unidirectional or bidirectional (i.e. receiving information only vs. engaging in an exchange); whether each contact was initiated by the respondent or the peer; and whether each contact exerted influence on the respondent's PV adoption decision. For each contact to which respondents ascribed influence, the perceived strength of influence was then measured (sliding scale from 1 = the selected peer group had very weak influence in the respective decision stage to 10 = the selected peer group had a very strong influence in the respective decision stage). The questions were created specifically for the objectives of the questionnaire.

The final section of the survey comprised several personal questions used to compare different decision-making adopter segments: education level; income level; household status and composition; area of residence; perceived neighbourhood cohesion. In contrast, the variable political ideology [62] was not included. Since all of the participants needed to show interest in the technology to be included in the survey we think that the variable has not the significant effect as completely at the beginning of the decision-making process.

3.2. Procedure of recruitment and sourced sample

Data were obtained from single- or two-family house owners (residential decision-makers) who either own a PV system or are in advanced stages of the adoption decision process. House owners who did not locate themselves in at least decision stage II — Interest or who reported not a certain intention to purchase a PV system were excluded from the survey (c.f., Section 3.1). Considering the exploratory nature of the survey, the main reason for this decision was to focus on house owners who had already been involved with the technology in order to identify the ascribed attributes for active peer effects in Germany while many decision-makers who stay in stage I - Awareness experience passive influences only. The sample was sourced from the Ipsos Online Access Panel[2] using a specialised sampling tool that makes a random selection of potential respondents.

Comprehensive plausibility and consistency checks were conducted during the programming process. The questions and answers were furthermore checked for comprehensibility during pretests and were modified according to the feedback. After that, survey respondents were invited to participate in the survey by personal e-mail. During the field time, the addressees received a maximum of two reminders. The final sample consists of 1165 completed questionnaires. Data collection was completed on Tuesday, December 17th 2019. During this timeframe, 535 respondents did not finish the questionnaire and dropped out. Furthermore, 151 respondents were automatically excluded from the final sample due to speeding and/or straight-lining total.

[2] More information can be found here: https://www.ipsos.com/en/sample-access.

Table 2
Demographic structure of the total sample population (N) and the sample population with respect to the information concerning gender (Male; Female), net income (≤ €2340 low net income (Low); €2341–3200 lower-middle net income (L.-M.); €3201–4840 upper-middle net income (U.-M.); ≥ €4841 high net income (High), and residence (City; Suburb; Country). The final sample consisted of 1165 respondents. According to their own indicated position, the sub-groups for potential adopters are divided into stage II and stage III. The sub-group of decision-maker in stage IV adopted already a PV system. Due to the same decision-making process, stage IV respondents included in the contact and influence analysis were restricted to those who installed and thus adopted a PV system after house purchase (Retrofit = Retrofitting) and did not adopt it with the purchase of the house or with the building with the house (Bundle).

Decision-maker	N (%)	Gender			Income[a]				Residence		
sub-group		Male	Female	Other	Low	L.-M.	U.-M.	High	City	Suburb	Country
Stage II	602 (51.7)	305	297	0	132	135	153	115	154	169	279
Stage III	169 (14.5)	98	71	0	32	40	45	34	70	38	61
Stage IV (Retrofit.)	235 (20.2)	131	103	1	30	44	58	67	61	72	102
Stage IV (Bundle)	159 (13.6)	96	63	0	18	23	58	51	108	25	26
Total	1165 (100)	630	534	1	212	242	315	267	393	304	468

[a]Study respondents without an indication are not shown.

Table 3
Socio-demographic characteristics of the sample compared to the population of house owners in Germany. The comparison has been based on structural data on house owners in Germany available in the best for planning tool (b4p) (https://mds.mds-mediaplanung.de/). A complete overview of the comparison is outlined in the Supplementary Material Part B (see file in Appendix D).

Characteristic	Category	House owner	Study sample
Home	Single-family home	65.7%	65.7%
	Duplex	18.4%	16.2%
	Row house	16.5%	13.5%
	Apartment complex	0%	4.6%
Region	South	30.6%	21.9%
	East	28.9%	29.2%
	West	21.4%	32.5%
	North	19.1%	18.8%
Gender	Female	52.3%	45.8%
	Male	47.7%	54.1%
Age	Under 40	25.9%	23.3%
	40 to 59	40%	49.1%
	60 and older	34.1%	27.6%
Income	Mean	3712 €	4202 €

An overview of the sample in absolute numbers is outlined in Table 2. Further insights into the relative sample compositions are provided in Supplementary Material Part B (see file in Appendix D). The respondents are distributed between the sample decision-maker sub-groups stage IV - Implementation (current adopters; $n = 394$) and potential adopters ($n = 771$). Among potential adopters, around 75% located themselves in stage II — Interest ($n = 602$), while the remainder located themselves in stage III — Planning ($n = 169$). In this survey, stage II and stage III decision-maker sub-groups already own a house and are subsequently deciding afterwards to install a PV panel in terms of retrofitting. The sub-group of decision maker in stage IV-Implementation adopted already a PV system. To have the same decision-making process for each decision-maker sub-group as a basis for the analysis, stage IV respondents included in the analyses were restricted to those who installed a PV system independent of house purchase (retrofitting the own house with a PV system). A comparison of the total sample at hand with structural data on house owners in Germany is outlined in Table 3.

In order to determine how well the sample matches the population, one-sample χ^2-Tests were conducted for the different socio-demographic variables. While all tests indicated that the sample differs somewhat from the population on these variables, the descriptive comparison shows that the sample is comparable in terms of age, marital status, and the type of house owned. Regional distributions regarding the different states also differ only modestly. Men are slightly over-represented within the sample, and respondents are more likely to have a high household income and to be highly educated than house owners in general. This is especially true for the sub-group of current adopters. Since PV systems are cost-intensive and can be assumed to appeal to house owners with some technical affinity, these findings are consistent with expectations.

3.3. Model specifications and statistical analyses

To investigate the relationship between the stage progress in the decision-making process (self-indication of the decision progress; Section 4.1) or the number of PV adopters in respondents' peer groups (here used as proxy for passive peer effects; Section 4.2) and respondents' perceptions of peer groups bivariate statistical inference methods like Spearman's rank correlation coefficient were applied. Furthermore, multivariate analysis of variance (MANOVA) were applied to investigate statistically significant differences. Subsequently, in Section 4.2 parametric t-tests and non-parametric Mann-Whitney U tests were used to identify whether attributed peer attributes differed between the three sub-groups (decision-makers in stage II, stage III, and stage IV) as outlined in Table 2. The median of PV adopters in the peer groups was found to be six adopters allowing to divide respondents into (sub-) groups with a low number of PV adopters (less than six) and a high number of PV adopters (equal or more than six). The aim was to see if we find the same pattern between all of the stage related sub-groups and thus can see an effect for all respondents independent of their decision-making progress.

To explore whether and how the nine ($a = 1, \dots, 9$) perceived attribute ratings $Attr_{a,s}$ of the peer groups in each decision stage $s = I, II, III$ (the ratings were given by the different decision maker sub-groups for the indicated completed stages) were related to the strength of the influence attributed to each peer initiated interaction with the decision-maker ($1 \leq Infl_s^{PC} \leq 10$) and self-initiated peer interaction by the decision-makers ($1 \leq Infl_s^{SC} \leq 10$), linear regression analyses were conducted (see Section 4.3). A separate linear regression model was utilised for each decision stage. We controlled for the number of adopters among peers (n_{adopt}) and four ($c = 11, \dots, 14$) further variables: gender, income level, age, and area of residence ($control_c$). The dependent variable was aggregated over all indicated influence-strengths for all self-initiated contacts by the decision-makers in a certain decision-making stage to all peer groups (family and relatives; friends, colleagues, and acquaintances). Thereby, the data sheet was transposed and the reported attributes of the peer groups were directly set in relation to the reported influence strength of each peer group. The resulting model is provided in Eq. (1):

$$Infl_s^{SC|PC} = \beta_{0,s} + \sum_{a=1}^{9} \beta_{a,s} Attr_a + \beta_{10,s} n_{adopt} + \sum_{c=11}^{14} \beta_{c,s} control_c + \epsilon_s \quad (1)$$

For the linear regressions, the OLS (ordinary least squares) method was used, for which the sum of squared error distances was minimised. In line with the literature, outliers with studentised residuals greater than +/−2 should not occur in the sample [63,64]. Thus, outliers, defined as observations with a modulus of the studentised residual greater than 2 were removed iteratively. We justify this procedure by noting that the assessment of the attributes and influences

in numerical form might have provided difficulties to the respondents. Nevertheless, the share of useful observations seems ample to provide meaningful insights against the explorative background of the survey. Multicollinearity, and model performance were checked, as were the normality of the residuals and the homogeneity of variance of the residuals [63,65]. The model performance was also tested for goodness-of-fit using the Pearson likelihood ratio χ^2. R^2 and were used to explain the proportion of the variance in each dependent variable explained by the independent variables in the model.

Subsequently, in Section 4.4, we analysed whether respondents who self-initiated contact with peers assessed their peers differently regarding the perceived attributes. T-tests and Mann-Whitney U tests were used to check whether there is a relationship between the level of ascribed attributes and the self-initiation of PV-related interactions. For this, again, peers were aggregated, and respondents of the different stage-related sub-groups were divided into two groups: those who had self-initiated contact with peers (of any group) and those who had not self-initiated contact. We also checked with the ANCOVA method if there is an interrelation between the reported number of peer adopters and the indicated stage progress on the number of self-initiated PV-related interactions. Finally, we tested with T-tests and Mann-Whitney U tests if respondents with a higher reported number of PV adopters also indicated a higher number of PV-related self-initiated interactions. This is shown for each decision-maker sub-group in Section 4.5.

4. Findings

4.1. Perceptions of peer groups for different sub-groups at different stages of decision-making

As outlined in Table 2, for the purpose of this study, respondents allocated themselves to one of three independent decision-making sub-groups stage II, stage III, and stage IV. In order to analyse the relationship of the ascribed attributes and the influence strength, we initially seeked to understand if there was a relationship between the reported decision making stage of household decision-makers and the respondent's PV-related perceptions of each of the four peer groups (family and relatives; friends; colleagues and acquaintances; as well as neighbours). The nine peer group attributes as described in Table 1 were assessed: trustworthiness, competence, power, independence, availability, closeness, integrity, likeability, and reliability.

Examining each of the peer groups according to the nine PV-specific attributes of interest, the results showed that respondents that are further along in the decision-making stage reported higher mean attribute ratings for each peer group. For example, respondents in stage IV reported a higher perceived trustworthiness of their peer groups than respondents in stage II. The means including the observations are outlined in Table A.7 for family and relatives, in Table A.8 for friends, in Table A.9 for colleagues and acquaintances, as well as in Table A.10 for neighbours. To test if these differences were significant, a MANOVA was run. Here we determined a statistically significant difference between the reported decision-making stage and respondents' combined PV-related perceptions for each of the four peer groups. The F-statistics for Wilks' lambda were as follows for the peer groups: family and relatives ($F(2626) = 4.24$, $p < .001$); friends ($F(2621) = 4.29$, $p < .001$); colleagues ($F(2601) = 4.53$; $p < .001$), and neighbours ($F(2580) = 4.15$, $p < .001$).

To understand if the progress in the decision-making is significantly associated with a higher PV-related perception of the peer group or if a higher determination of adopting PV drives the peer group rating levels, a Spearman's rank correlation test was run. A low correlation was found between reported intention to adopt by decision-making sub-groups in stage II or III and the respondent's perception of each of the peer groups according to the nine attributes of interest. For the decision-making sub-group in stage II the highest correlation was found between the intention to adopt and the reported competence perception ($\rho = .239$, $p < .001$). For the decision-making sub-group in stage III the highest correlation was found between the intention to adopt and the reported trustworthiness perception ($\rho = .209$, $p < .001$).

4.2. Perceptions of peers groups for different numbers of PV adopters among peer groups

Spearman's rank correlation coefficients were also used to test the relationship between the reported number of PV adopters among respondents' peer groups (neighbours; family and relatives; friends, colleagues, and acquaintances) and their indicated perceived attributes. The strongest statistically significant positive correlations were found between the number of PV adopters among respondents' neighbours and respondents' ratings of neighbours' trustworthiness ($\rho = .328$, $p < .001$) and competence ($\rho = .308$, $p < .001$). Similar results were obtained for the other peer groups (family and relatives; friends, colleagues, and acquaintances). An overview of the observations, means, and the standard deviations are given for the different peer groups in Tables B.11, B.12, B.13, and B.14. The means indicated that with a higher reported number of peer adopters in the respondent's peer group, they also ascribed a higher level of attributes to each peer group. This time, the four independent groups were based on the responses of no peers with PV systems, one to two peers with PV systems, three to four peers with a PV system, and five or more peers with a PV system. The subsequent used MANOVA again, demonstrated a statistically significant difference between the number of PV adopters in the respective peer group the on the combined dependent variables for the peer group family and relatives ($F(3755) = 4.74$, $p < .001$), friends ($F(3748) = 6.65$, $p < .001$), colleagues ($F(3724) = 7.13$, $p < .001$), and neighbours ($F(3706) = 9.93$, $p < .001$).

For further insights, we tested for differences between the reported number of peer adopters and indicated peer group perception separately. This was done individually for each decision-maker sub-group. In other words, we checked within each sub-group related either to stage II, stage III, or stage IV, whether the mean attribute ratings were higher for respondents with a high number of PV peer adopters than for those with a low number of PV peer adopters. Respondents within each stage were divided into two groups: those with fewer than six adopters among all groups of peers (stage II: n = 337; stage III: n = 59, stage IV: n = 69), and those with six or more adopters among all groups of peers (stage II: n = 265; stage III: n = 110, stage IV: n = 166). For the distinction of the stage specific sub-groups, we chose the median of the reported number of adopted PV systems in the social circle of the peers. Across all three decision stages (stage I — Awareness, stage II — Interest, stage III — Planning) (stages which were completed) and all peer groups, respondents with more than six peer adopters for all different decision maker sub-groups were found to perceive their peers as more competent on average at a statistically significant level of 5% when using t-tests but also non-parametric Mann-Whitney U tests. Thus, independently of the progress of the decision-maker (different sub-groups), they reported a significantly higher attribute rating for competence with respect to all of the peer groups (family and relatives, friends, acquaintances and acquaintances, as well as neighbours) when they also reported a high number of PV adopters. A Cohen's d effect size statistic of d = .44 to d = .78 across the different peer groups and decision-making stages shows this effect to be medium to large. All other attribute ratings did not show a significant difference for all sub-groups and stages.

Similar to the decision-making stage progress of the respondents, we also determined a significant difference between the number of PV adopters in the peer groups and the peer perceived attributed of the peer groups. Additionally, the results for each of the sub-groups even points towards the existence of a plausible relationship between having a large number of adopters in one's social circle and rating the peer group as more competent. Nevertheless, there is also the possibility that knowing a few peers with these attributes leads to learning from other people who also have PV.

4.3. Perception of peer groups and peer group influence strength

This study seeks to understand whether specific PV-related peer interactions are more positively correlated with influence strength in residential PV adoption among German householders. By doing this, for each peer group with whom respondents reported contact in one of the stages, they were asked to indicate whether the contact was influential, and to what degree. Given the relationships found between respondents' decision-making stage progress or number of peer adopters and ascription of positive attributes to peers (c.f., Sections 4.1 and 4.2), it is conceivable that there are also relationships between ascribed peer attributes and perceived influence strength of an interaction. As indicated in Section 3.2, linear regression models were designed to explore these relationships. The four peer groups were aggregated according to the definition of peers provided in Section 1.1.

An overview of the explanatory power and the statistically significant coefficients of the linear regression models are given in Table 4 for self-initiated interactions and in Table 5 for peer initiated interactions. The β−coefficients allow an estimate of the relationship between attribute levels and strength of influence in each decision-making stage. The R^2 demonstrate that with regard to respondent-initiated peer contacts, the perceived positive attributes of peers can largely explain their perceived influence in all regression models.

Note that outliers were removed iteratively. This led to Cook's distances below .0466 and leverage observations below 1.999. The link test revealed no problems with our specification, and all VIFs (Variance Inflation Factors) are lower than 3. The distribution of the residuals is slightly leptokurtic compared to the normal distribution; this is related to the heteroscedasticity of the residuals, wherein the variance of the residuals becomes smaller for high independent and dependent variable values. A possible cause lies in the left-skewed distribution of respondents' assessments, given using a slider scale. Since there are no severe outliers and the distribution seems fairly symmetric, this left-skewed distribution might be traced to the initial decision to exclude residential decision-makers with little or no PV awareness or low intention to purchase. We assume that the distribution is valid for our intended explanatory analysis of peer effects within the group of potential and current adopters.

As all regression models in Tables 4 and 5 indicate, peers with higher positive attribute ratings were perceived as more influential. The number of peer adopters had no significant relationship in the explanatory model for the influence strength. This was also supported by further parametric (t-test) and non-parametric (Mann-Whitney U test) tests. While respondents with a higher number of peer PV adopters did rate their peers as slightly more influential, only a few statistically significant differences were found (at a level of 5%) between respondents with fewer than six peer adopters vs. six or more peer adopters.

The control variables also showed minimal effects, except for gender in stage III in the self-initiated interactions. Statistically significant associations were found between strength of influence and various perceived attributes. More specifically, the following attributes were found to have the highest relationship with the influence strength per stage in terms of the self-initiated interactions (c.f., Table 4):

- Stage I: likeability (β = .303), availability (β = .291), integrity (β = .212);
- Stage II: availability (β = .319), likeability (β = .145), trustworthiness (β = .128);
- Stage III: availability (β = .423), trustworthiness (β = .156), competence (β = .126).

In terms of peer initiated interactions, the following attributes were found to have the highest relationship with the influence strength per stage (c.f., Table 5):

- Stage I: closeness (β = .205), availability (β = .200), likeability (β = .195);
- Stage II: reliability (β = .245), power (β = .212), likeability (β = .175);
- Stage III: independence (β = .269), likeability (β = .258), availability (β = .257).

We can interpret these findings to mean that the perceived attributes of peers are associated with the influence strength in terms of PV interactions. According to that, active peer effects are influenced by different peer-related attributes mentioned in the literature. There were also stage-specific differences. Additionally, different attributes demonstrated a higher relationship depending on whether the PV-related interaction was initiated by the decision-maker or by the peer group. For this, we want to further investigate if there are recognisable relationships with the reasons that decision-makers start PV-related interactions. This could be substantial for a stronger active peer effect in the future.

4.4. Perceptions of peer groups and self-initiation of PV-related interactions

In order to get further insights into the self-initiation of PV-related interactions, we examined whether there was a relationship between respondents' perceptions of their peers' and the self-initiation of interactions with peers. In the survey, respondents were asked whether they came into contact with each peer group on the topic of PV, and, if so, who initiated the contact. This was done again for each decision-making stage. First, the four groups of peers were aggregated as also shown in Section 4.3, and respondents were divided into two groups: those who had self-initiated contact with peers (of any group) and those who had not self-initiated contact. T-tests and non-parametric Mann-Whitney U tests were then used to determine whether statistically significant differences occurred between the average attribute levels ascribed to peers by respondents who had self-initiated contact in contrast to respondents who had not. The results are displayed in Table 6.

Respondents who had self-initiated contact with peers assessed their peers more positively than respondents who had not self-initiated contact, at a significance level of 5% across all decision-making stages. The only notable exception is the attribute independence, for which the t-test shows no significant distinction. For all sub-groups across all stages, the mean differences were especially large for the attributes availability and competence (meaning that respondents whom self-initiated interactions with peers tended to assess their peers as more available and more competent). The calculated effect size statistic was again medium to large.

Due to the relationships found in Section 4.1 for stage progress and ascribed level of PV-related attributes and in Section 4.2 for the number of peer adopters and ascribed level of PV-related attributes, we also investigated whether the reported stage progress or the number of PV adopters is related with the self-initiation of peer interactions. We observed differences in the means across the rates of self-initiated interactions as shown in Table C.16 for the stage I — Awareness, in Table C.17 for the stage II — Interest, and in Table C.18 for the stage III — Planning. The higher the mean number of reported PV peer adopters, the higher the number of self-initiated interactions. An ANCOVA was used for each stage to test for whether the number of peer adopters has a relationship with the number of self-initiated contacts. We controlled for the indicated stages of the respondents. The number of peer adopters was significantly related to the number of self-initiated peer interactions throughout all three decision-making stages ($p < .001$).

4.5. Number of PV adopters among peer groups and self-initiated PV-related interactions

Given the relationships found between respondents' number of peer adopters and the ascription of positive attributes to peers 4.2 and the

Table 4
Relationship of perceived peer attributes (trustworthiness, competence, power, independence, availability, closeness, likeability, integrity, reliability), number of peer adopters, and of control variables (gender, residence, income, age) on the perceived peer influence on residential PV adoption decisions. The dependent variable of the linear regression model 'influence strength of the self-initiated peer exchanges' comprises the influence exerted by the peers on the decision-maker as a result of these self-initiated interactions.

Dependent variable: Influence strength of self-initiated peer interactions									
Explanatory variables	Stage I — Awareness			Stage II — Interest			Stage III — Planning		
	beta coeff	95% CI lower	upper	beta coeff	95% CI lower	upper	beta coeff	95% CI lower	upper
Trustworthiness	.183***	.159	.207	.128***	.095	.161	.156***	.123	.189
	(.012)			(.017)			(.017)		
Competence	.062***	.046	.078	.121***	.103	.139	.126***	.101	.151
	(.008)			(.009)			(.013)		
Power	.020***	.010	.030	−.022***	−.034	−.010	.025***	.011	.039
	(.005)			(.006)			(.007)		
Independence	−.030***	−.040	−.020	.024***	.014	.034	−.040***	−.052	−.028
	(.005)			(.005)			(.006)		
Availability	.291***	.269	.313	.318***	.291	.345	.423***	.394	.452
	(.011)			(.014)			(.015)		
Closeness	.009	−.007	.025	.032***	.014	.050	.006	−.012	.024
	(.008)			(.009)			(.009)		
Likeability	.303***	.276	.330	.145***	.114	.176	.107***	.072	.142
	(.014)			(.016)			(.018)		
Integrity	.212***	.188	.236	.053***	.024	.082	.020	−.007	.047
	(.012)			(.015)			(.014)		
Reliability	−.049***	−.069	−.029	.067***	.043	.091	.125***	.092	.158
	(.010)			(.012)			(.017)		
Adopters	−.005**	−.009	−.001	−.000	−.006	.006	−.008***	−.014	−.002
	(.002)			(.003)			(.003)		
Income	.051***	.039	.063	.007	−.007	.021	.021***	.005	.037
	(.006)			(.007)			(.008)		
Residence	.099***	.072	.126	.024	−.007	.055	−.017	−.052	.018
	(.014)			(.016)			(.018)		
Age	.002**	.000	.004	−.001	−.003	.001	−.005***	−.007	−.003
	(.001)			(.001)			(.001)		
Gender	−.054**	−.095	−.013	−.001	−.050	.048	.116***	.065	.167
	(.021)			(.025)			(.026)		
Constant	−.574***	−.770	−.378	1.245***	.996	1.494	.484***	.233	.735
	(.100)			(.127)			(.128)		
Observations	427			484			382		
R^2	.977			.947			.971		

*$p < .050$, **$p < .010$, ***$p < .001$; Standard errors in parentheses.

significant differences between the reported number of PV adopters in the social-circle and the self-initiated interactions about PV in Section 4.4, we finally checked if each of the sub groups is showing the same pattern. In other words, we tested whether there is a relationship visible between the number of peer adopters and the self-initiation of interactions for each of the sub-groups. Respondents were able to report a maximum of four self-initiated contacts (one per peer group) per decision-making stage they had passed through. The maximum of contacts was four due to the four relevant groups family and relatives, friends, acquaintances and co-workers, and neighbours. In line with the previous analyses in Section 4.2, respondents' sub-groups within each stage were divided into two groups: those with fewer than six peer adopters (stage II: n = 337; stage III: n = 59, stage IV: n = 69), and those with six or more peer adopters (stage II: n = 265; stage III: n = 110, stage IV: n = 166).

Again as outlined in Table B.15, respondents with six or more peer adopters reported more self-initiated contacts in all stages at a statistically significant level of 5% regardless of the position of the decision-making sub-group in the PV adoption decision-making process. (regardless of the respondent's current stage). The effect size statistics ranged from d = .39 to d = .68, showing the effect to be medium to large. This pattern is visible throughout all stage-related sub-groups and all passed decision-making stages. While we cannot conclude any causal statement, the results demonstrated a similar pattern of all three decision-making sub-groups independent of the progress again.

5. Research implications

5.1. Results discussion

Our results suggested that decision-makers who progressed further in the decision-making process also rated their peers with a higher level of positive PV-related attributes. While it is possible that the progress in the decision-making process is driven by a more positive PV-related perception of the peer group, it is also possible that the peer group rating levels are driven by a higher determination to adopt PV. At the same time, we see a similar relationship between the number of PV adopters in the respondent's social circle and the ascribed peer group attributes. Additionally, for all different decision-maker sub-groups located in stage II, stage III, and stage IV, the reported number of peer PV adopters was found to have a positive interrelation with the rating of the attribute competence. While we see positive interrelations which can go in both directions, it is also important to mention that respondents were asked to rate their peers, and we cannot know if the ratings were given in retrospect or from current perspective. Nevertheless, we can also assume that similarly to Rai et al. [12], Mundaca et al. [18], and Petrovich et al. [45], the study demonstrated that the presence of PV adopters in decision-makers' might motivate them to consider PV more seriously.

The study also demonstrated that the perceived attributes of peers contribute to influencing effect strength at different decision-making stages. Our analyses showed a positive relationship between the level of ascribed attributes to their peers and the reported influence by respective peer interactions. This suggests that decision-makers' subjective evaluations of peers play a role in active peer effects. While

Table 5
Relationship of perceived peer attributes (trustworthiness, competence, power, independence, availability, closeness, likeability, integrity, reliability), number of peer adopters, and of control variables (gender, residence, income, age) on the perceived peer influence on residential PV adoption decisions. The dependent variable of the linear regression model 'influence strength of peer initiated peer exchanges' comprises the influence exerted by the peers on the decision-maker as a result of these peer initiated interactions.

Dependent variable: Influence strength of peer initiated interactions									
Explanatory variables	Stage I — Awareness			Stage II — Interest			Stage III — Planning		
	beta coeff	95% CI lower	upper	beta coeff	95% CI lower	upper	beta coeff	95% CI lower	upper
Trustworthiness	.177***	.173	.182	.171***	.168	.174	.130***	.126	.134
	(.033)			(.021)			(.030)		
Competence	.048*	.045	.052	.033*	.030	.036	−.191***	−.196	−.186
	(.026)			(.019)			(.032)		
Power	.012	.010	.014	.212***	.210	.214	.150***	.147	.153
	(.017)			(.014)			(.022)		
Independence	−.001	−.003	.001	.026**	.024	.028	.269***	.265	.273
	(.018)			(.012)			(.028)		
Availability	.200***	.197	.203	.048***	.046	.050	.257***	.253	.261
	(.025)			(.017)			(.029)		
Closeness	.205***	.202	.208	−.019	−.021	−.017	−.147***	−.152	−.142
	(.022)			(.016)			(.031)		
Likeability	.195***	.191	.199	.175***	.171	.179	.258***	.252	.264
	(.030)			(.026)			(.039)		
Integrity	−.033	−.037	−.029	.154***	.151	.157	.091**	.086	.096
	(.032)			(.024)			(.036)		
Reliability	.181***	.177	.186	.245***	.242	.248	.233***	.228	.238
	(.035)			(.024)			(.036)		
Adopters	.004	.003	.005	−.039***	−.040	−.038	−.011	−.012	−.010
	(.009)			(.005)			(.008)		
Income	.012	.010	.015	.008	.006	.010	.015	.012	.018
	(.019)			(.012)			(.019)		
Residence	.028	.021	.035	−.023	−.027	−.019	.152***	.145	.159
	(.053)			(.032)			(.048)		
Age	.000	.000	.001	.004*	.004	.004	−.007*	−.008	−.006
	(.004)			(.003)			(.004)		
Gender	.029	.020	.039	−.231***	−.238	−.224	−.052	−.063	−.041
	(.074)			(.050)			(.074)		
Constant	−.004	−.038	.034	.088	.062	.114	−.313	−.350	−.276
	(.272)			(.189)			(.246)		
Obeservations	252			201			171		
R2	.892			.959			.940		

*$p < .050$, **$p < .010$, ***$p < .001$; Standard errors in parentheses.

likeability, integrity, and availability demonstrated a higher correlation with the influence strength for self-initiated peer interactions at the beginning of the decision-making process, availability, trustworthiness, and competence show the highest correlation with the influence strength at the end of the decision-making process. This again is in line with past studies such as Mundaca and Samahita [18], Wolske et al. [19], and Scheller et al. [10,28]. A possible explanation for the changing importance of different attributes throughout the decision-making process could be that "consumers employ different evaluative criteria in alternative stages of their decision-making process" [27]. It also confirms and quantifies our prior qualitative finding [10,28]. At the same time, the results showed that the underlying mechanism of self-initiated interactions is different than with respect to peer initiated interactions about PV.

Additionally, the reported higher number of peer adopters is positively correlated with rate of self-initiated interactions about PV. It is important to mention again that because respondents were asked to assess the peers and interactions in retrospect, their assessments do not necessarily reflect what they thought of peers before self-initiating contact with them or being influenced by them. It is equally possible that respondents self-initiated contact with certain peers and were influenced by these peers because they perceived these peers as credible, or that respondents assessed certain peers as more credible because they had self-initiated interactions with. Nevertheless, the finding can also point towards some relationship between passive and active peer effects as stated in Rai et al. [14]. Finally, the analyses revealed an intriguing distinction: while active initiations of peer exchanges were positively related to the number of peer adopters and the perceived attributes of peers, the influence ratings of these exchanges were almost entirely explained by the perceived attributes of peers.

5.2. Policy recommendations

The results suggest that to promote PV adoption in a municipality, policymakers need to put socially well-connected residents at the centre of attention. Self-organised and participatory solar initiatives and interest groups can provide crucial support by cultivating relationships of trust between current and potential adopters. The availability of contacts is also necessary.

From a community angle, residential adopters could be recruited to participate in information campaigns such as neighbourhood seminars. In a German context, this could be done by mediating community college courses for adult education (Volkshochschulkurse), which enjoy widespread public awareness and participation. It would be advisable for such courses to involve previous adopters and make use of in-depth discussions, rather than relying on lecture-based pedagogy (as is often currently the case). In addition, university students or participants in college groups (Hochschulgruppen) could receive degree credit points for carrying out practical peer counselling work on-site with interested citizens, collecting qualitative insights and discussing problems and solutions.

Further community-based measures could include municipally sponsored peer counselling centres and 'office hours' during which actual adopters are available to answer questions about rooftop PV and share details about their adoption journey (to whatever extent they feel comfortable). Such models are already practised in Germany in health counselling and could be adopted in the field of low-carbon residential energy technology. Finally, from an individual angle, social incentive programmes (such as 'recruit-a-friend') could be launched by PV providers in Germany. Targeting such actions on the sub-municipal

Table 6
Comparison of respondents who had self-initiated contact with peers (of any group) vs. those who had not, with regard to the average attribute levels ascribed to peers per decision stage. The table includes descriptive statistics (N = Observations, M = Mean, SD = Standard Deviation), two-tailed t-test results (Diff = Difference, Sig = Significance), the results of the non-parametric Mann-Whitney U test (z = z statistics, Sig = Significance), the probability that a random draw from the first sample is larger than a random draw from the second sample (pord), and Cohen's d effect sizes. Statistical significance is indicated using asterisks (*$p < .050$, **$p < .010$, ***$p < .001$). Except for few isolated attributes, across all decision stages, respondents who self-initiated contact with peers were more likely to ascribe positive attributes to peers.

Decision-stage	Ascribed attributes to the peer groups	Decision-makers in decision-making stage II										Decision-makers in decision-making stage III										Decision-makers in decision-making stage III									
		Passive experienced peer contacts			Self-initiated peer contacts			Group comparisons			Effect size	Passive experienced peer contacts			Self-initiated peer contacts			Group comparisons			Effect size	Passive experienced peer contacts			Self-initiated peer contacts			Group comparisons			Effect size
		N	M	SD	N	M	SD	Diff/Sig	z/Sig	pord	d	N	M	SD	N	M	SD	Diff/Sig	z/Sig	pord	d	N	M	SD	N	M	SD	Diff/Sig	z/Sig	pord	d
Stage 1 - Awareness	Trustworthiness	1406	6.86	2.34	573	7.68	2.12	.82***	−7.67***	.39	.36	392	7	2.08	218	8	1.69	1***	−6.36***	.34	.52	523	7.81	2.03	285	8.47	1.62	.66***	−4.55***	.4	.35
	Competence	1353	4.36	2.31	564	5.63	2.36	1.27***	−1.27***	.35	.54	396	5.48	2.52	216	6.49	2.3	1.01***	−5.15***	.37	.41	496	5.12	2.39	284	7.43	2.24	2.31***	−12.41***	.23	.99
	Power	1583	2.74	2.4	569	3.48	2.83	.74***	−5.22***	.43	.28	432	3.43	2.86	217	3.83	3.08	.4	−1.75	.46	.13	572	2.61	2.52	296	5.04	3.56	2.43***	−9.62***	.31	.78
	Independence	1556	7.34	3.37	558	6.6	3.61	−.74***	4.89***	.57	−.2	411	7.14	3.12	216	7.28	3.15	.14	−1.01	.48	.04	568	7.31	3.53	279	7.21	3.26	−.1	3.29**	.57	−.0
	Availability	1444	5.51	3.03	573	7.14	2.42	1.63***	−1.84***	.35	.59	376	6.04	2.88	218	7.11	2.43	1.07***	−4.4***	.39	.40	546	5.32	3.13	293	7.72	2.34	2.4***	−10.46***	.28	86
	Closeness	1716	7.22	2.86	592	8.05	2.25	.83***	−5.28***	.43	.32	441	7.48	2.5	219	8.3	1.84	.82***	−3.46***	.42	.37	612	7.43	2.91	298	8.47	1.81	1.04***	−2.97**	.44	.42
	Likeability	1719	7.78	2.22	594	8.51	1.79	.73***	−7.48***	.4	.36	440	7.7	2.09	220	8.54	1.57	.84***	−4.9	.38	.45	609	8	2.09	298	8.74	1.55	.74***	−4.5***	.41	.40
	Integrity	1599	7.78	2.22	592	8.37	1.85	.59***	−5.53***	.42	.28	409	7.46	2.15	219	8.31	1.57	.85***	−4.57	.39	.45	567	7.96	2.01	286	8.52	1.78	.56***	−3.7***	.42	.29
	Reliability	1326	7.45	2.31	530	7.92	2.24	.47**	−4.75***	.43	.20	372	7.08	2.24	197	7.67	2.14	.59**	−3.35***	.41	.26	479	7.6	2.19	266	8.67	1.41	1.07***	−6.29***	.36	.58
Stage 2 - Interest	Trustworthiness	1276	6.72	2.37	703	7.77	2.04	1.05***	−10.08***	.36	.47	343	7	2.05	267	7.81	1.85	.81***	−5.61***	.37	.41	496	7.77	2.1	312	8.48	1.5	.71***	−4.47***	.41	.38
	Competence	1229	4.28	2.28	688	5.55	2.39	1.27***	−10.84***	.35	.54	347	5.55	2.5	265	6.22	2.44	.67***	−3.63***	.41	.27	466	5.09	2.38	314	7.25	2.33	2.16***	−11.72***	.25	.91
	Power	1461	2.75	2.43	691	3.34	2.71	.59***	−4.79***	.44	.22	381	3.49	2.85	268	3.67	3.05	.18	−.9	.48	.06	547	2.56	2.47	321	4.93	3.55	2.37***	−9.93***	.31	.77
	Independence	1435	7.32	3.38	679	6.76	3.56	−.56**	3.45***	.55	−.1	356	6.83	3.21	271	7.66	2.95	.83**	−4.19***	.4	.26	535	7.25	3.55	312	7.33	3.26	.08	2.56	.55	.02
	Availability	1315	5.32	3.02	702	7.19	2.41	1.87***	−13.3***	.32	.68	329	5.82	2.83	265	7.2	2.5	1.38***	−6.24***	.35	.51	521	5.22	3.2	318	7.68	2.2	2.46***	−10.59***	.28	.89
	Closeness	1586	7.13	2.89	722	8.08	2.24	.95***	−6.86***	.41	.36	392	7.31	2.5	268	8.4	1.9	1.09***	−5.72***	.37	.49	586	7.43	2.9	324	8.39	1.96	.96***	−3.03**	.44	.38
	Likeability	1589	7.69	2.25	724	8.57	1.75	.88***	−9.55***	.38	.43	389	7.51	2.13	271	8.66	1.48	1.15***	−7.28***	.33	.62	583	7.97	2.14	324	8.73	1.47	.76***	−4.16***	.42	.41
	Integrity	1473	7.69	2.26	718	8.45	1.77	.76***	−7.83***	.4	.37	359	7.23	2.15	269	8.46	1.53	1.23***	−7.5***	.33	.65	539	7.95	2.03	314	8.49	1.76	.54***	−3.44***	.43	.28
	Reliability	1224	7.33	2.33	632	8.06	2.18	.73***	−7.58***	.39	.32	328	6.83	2.26	241	7.9	2.01	1.07***	−6.12***	.35	.50	462	7.63	2.22	283	8.56	1.45	.93***	−5.04***	.39	.49
Stage 3 - Planning	Trustworthiness											328	6.95	2.11	282	7.83	1.77	.88***	−5.62***	.37	.45	468	7.64	2.14	340	8.6	1.41	.96***	−6.4***	.37	.52
	Competence											331	5.54	2.54	281	6.19	2.39	.65**	−3.33***	.42	.26	441	5.18	2.44	339	6.97	2.41	1.79***	−9.67***	.3	.73
	Power											362	3.56	2.9	287	3.57	2.99	.01	−.16	.5	.00	517	2.65	2.57	351	4.61	3.5	1.96***	−8.15***	.34	.63
	Independence											339	7.07	3.08	288	7.32	3.17	.25	−1.65	.46	.07	505	7.38	3.48	342	7.14	3.4	−.24	3.51***	.57	−.0
	Availability											316	5.77	2.85	278	7.18	2.48	1.41***	−6.37***	.35	.52	488	5.16	3.13	351	7.54	2.46	2.38***	−10.72***	.28	.84
	Closeness											371	7.28	2.52	289	8.37	1.91	1.09***	−5.64***	.37	.48	556	7.39	2.94	354	8.37	1.95	.98***	−3.25**	.44	.39
	Likeability											369	7.51	2.13	291	8.57	1.57	1.06***	−6.7***	.35	.56	553	7.91	2.19	354	8.76	1.39	.85***	−4.99***	.4	.46
	Integrity											345	7.25	2.16	283	8.38	1.59	1.13***	−6.87***	.34	.59	512	7.87	2.09	341	8.57	1.64	.7***	−4.51***	.41	.37
	Reliability											311	6.82	2.3	258	7.84	1.98	1.02***	−5.6***	.36	.47	429	7.55	2.21	316	8.58	1.51	1.03***	−6.09***	.37	.54

(neighbourhood) level could be particularly beneficial in Germany, as active initiations of peer exchanges are dependent in part on spatial proximity. The comparatively good state of neighbourly relations in many areas of Germany would be beneficial in this regard.

6. Conclusion

This paper contributes to the literature on peer effects in residential PV adoption by exploring the underlying mechanisms of active peer interactions. A survey approach was taken in order to enable the comparison of residential PV decision-makers in Germany (N = 1165). A three-stage model of the PV decision-making process of German householders was furthermore employed to shed light on the way such mechanisms might change over the course of the adoption journey. Our findings suggest that the perceived credibility of peers on PV related issues is positively associated with the number of adopters in the decision-maker's peer group (passive peer effect) and also with the progress in the PV adoption decision process. We also find a relationship between the perceived credibility of peers regarding PV and the reported influence strength of peer interactions throughout the decision-making processes of German householders, suggesting that subjective evaluations of peers play a role in active peer effects. Finally, we observe an association between the rate of self-initiated peer interactions about PV for respondents with a higher reported number of peers that have adopted PV, suggesting that passive effects (reported number of peer PV adopters) play a role in initiating active peer interactions. These results are significant for all sub-groups, regardless of the decision progress.

An inherent limitation of survey-based research is that respondents may assess their own perceptions, intentions, and behaviours differently at different times and in different contexts [19]. In the case of the present study, respondents from Germany were asked to describe perceptions and interactions during past stages in the decision-making process, as well as during their current stage. In some cases, a significant amount of time may have passed, and past perceptions and interactions may not be remembered accurately. Subsequent events may also colour the memory of past perceptions and interactions: for instance, a tendency exists to assess one's own decisions positively once they have already been made [12]. Furthermore, decision-makers can be influenced by peers or other stakeholders without recognising this influence at the time [5,66]. In the case of the present study, it is conceivable that some respondents were more or less influenced by certain peer groups than reported, either in general or at given stages in the decision-making process.

Another limitation of the present study is that social networks were investigated on the level of peer groups rather than the level of individual peers, as was done for instance by Palm [20]. Thus, the relationship between peer attributes and peer effects can only be quantified on an aggregate level; analyses of the type outlined in Graziano and Gillingham [15] and Rode and Müller [11] are not possible. Survey formats are also ill-suited to capturing granular information on the context of peer interactions, which socio-technical transition researchers such as Geels et al. [5] identify as important to peer effects. Due to the aggregated peer groups, we also did not differentiate if the survey respondents contacted a previous adopter or a potential adopter. While we used peer adopters as proxy for existing adopters in the social circle of the respondents, our variables allowed not to measure whether potential adopters searched or received information from no PV-owner peers. Such a differentiation would provide even a more deeper understanding of the active peer effect.

Additionally, the exclusion of early-stage potential adopters and PV rejecters from the sample limited the range of comparative analyses that could be performed, as well as the analysts' ability to account for self-selection bias (as late-stage potential adopters and current adopters are, by definition, more interested in PV). Finally, investigating multiple stages in the decision-making process meant that limited time could be dedicated to each stage; it follows that a detailed view of the effect of active exchanges on the final decision itself, as provided by Rai and Robinson [14], was not possible. Additionally, our study did not examine all possible causes of influences. Due to time constraints, some attitudes and beliefs were evaluated using single-item measures that may be prone to measurement error, and might thus have impacted our conclusions. This was deemed acceptable because other studies have comprehensively explored the impact of decision-makers' attitudes towards PV, whereas very few have explored their perceptions of stakeholders; accordingly, the latter research aim was prioritised.

The present analysis has been performed as an intermediate step for the parametrisation of an agent-based model (cf. [67–69]) that aims to simulate residential PV adoption decisions in specific spatial–temporal contexts. Future research needs to validate the exploratory findings but could also build on these exploratory findings to further clarify the role of peers adopters and attribute perception in the adoption process in general and the contact initiation and influence strength in particular, which could in turn improve policymakers' ability to harness peer effects to support individual decision-making. In particular, future research could further investigate the processes by which peer influence operates. Further data could also be gathered in different countries to establish the generalisability of the findings across different populations or cultures. A more detailed investigation of the proposed peer and relational attributes, expertness, trustworthiness, power, likeability and closeness, could also be helpful.

Declaration of competing interest

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

Acknowledgments

The authors wish to thank Sinus Markt- und Sozialforschung GmbH for the cooperation in conducting the survey. Furthermore, we thank Prof. Karyn Morrissey and the reviewers for critical reading and thoughtful suggestions, which helped us to improve the quality of the manuscript. This survey was financed by the Saxony State government out of the State budget approved by the Saxony State Parliament within the framework of the project SUSIC no. 100378087. Furthermore, Fabian Scheller also kindly acknowledges the financial support of the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement no. 713683 (COFUNDfellowsDTU). Jann Weinand was supported by the Helmholtz Association under the program "Energy System Design".

Appendix A. Attribute ratings and decision-maker sub-groups

See Tables A.7–A.10.

Appendix B. Attribute ratings and number of PV adopters

See Tables B.11–B.15.

Appendix C. Number of PV adopters or decision stage progress and self-initiated interactions

See Tables C.16–C.18.

Appendix D. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.erss.2022.102755. The supplementary material consists of the survey questions, sample overview, and descriptive statistics of the answers.

Table A.7
Attribute ratings for the peer group family and relatives. The table includes descriptive statistics (N = Observations, M = Mean, SD = Standard Deviation) for decision-maker sub-group in stage II, stage III, and stage IV.

Decision maker sub-group	Statistics	Attribute ratings								
		Trustworthiness	Competence	Power	Independence	Availability	Closeness	Likeability	Integrity	Reliability
Stage II	N	498	492	542	534	513	578	580	556	488
	M	7.600	4.714	3.445	6.504	6.359	7.040	8.741	8.469	8.273
	SD	2.424	2.503	2.969	3.621	3.100	3.121	1.901	1.974	2.195
Stage III	N	152	155	163	159	151	165	166	159	148
	M	7.639	5.779	3.845	6.582	6.670	7.721	8.482	8.159	7.706
	SD	2.083	2.650	3.025	3.306	2.862	2.413	1.884	1.943	2.261
Stage IV	N	206	201	218	210	212	228	228	215	194
	M	8.477	6.018	3.832	6.611	6.550	7.420	8.833	8.551	8.473
	SD	1.845	2.633	3.299	3.646	3.124	3.116	1.664	1.813	1.804
Total	N	856	848	923	903	876	971	974	930	830
	M	7.818	5.218	3.607	6.542	6.459	7.245	8.718	8.435	8.219
	SD	2.266	2.628	3.063	3.570	3.066	3.020	1.847	1.935	2.135

Table A.8
Attribute ratings for the peer group friends. The table includes descriptive statistics (N = Observations, M = Mean, SD = Standard Deviation) for decision-maker sub-group in stage II, stage III, and stage IV.

Decision maker sub-group	Statistics	Attribute ratings								
		Trustworthiness	Competence	Power	Independence	Availability	Closeness	Likeability	Integrity	Reliability
Stage II	N	505	485	537	528	508	580	582	555	483
	Mean	7.420	4.798	2.917	7.387	6.190	7.237	8.711	8.317	7.938
	SD	2.183	2.438	2.495	3.337	3.011	2.656	1.778	2.000	2.170
Stage III	N	156	154	162	156	149	165	165	158	145
	Mean	7.486	5.944	3.581	7.466	6.738	7.719	8.489	8.080	7.670
	SD	1.960	2.535	3.029	3.038	2.722	2.327	1.865	1.911	2.106
Stage IV	N	207	196	217	212	209	227	226	214	190
	Mean	8.175	6.061	3.396	7.481	6.398	7.718	8.768	8.446	8.230
	SD	1.748	2.562	3.062	3.308	3.026	2.371	1.693	1.766	1.866
Total	N	868	835	916	896	866	972	973	927	818
	Mean	7.612	5.306	3.148	7.423	6.335	7.431	8.687	8.307	7.958
	SD	2.070	2.554	2.749	3.277	2.971	2.547	1.774	1.935	2.097

Table A.9
Attribute ratings for the peer group colleagues and acquaintances. The table includes descriptive statistics (N = Observations, M = Mean, SD = Standard Deviation) for decision-maker sub-group in stage II, stage III, and stage IV.

Decision maker sub-group	Statistics	Attribute ratings								
		Trustworthiness	Competence	Power	Independence	Availability	Closeness	Likeability	Integrity	Reliability
Stage II	N	488	476	537	527	500	572	572	541	453
	Mean	6.686	4.700	2.593	7.386	5.713	6.613	7.467	7.626	7.103
	SD	2.210	2.302	2.211	3.363	2.811	2.661	2.039	2.122	2.238
Stage III	N	152	152	162	155	148	165	165	157	141
	Mean	7.261	5.843	3.351	7.335	6.301	7.073	7.678	7.502	7.028
	SD	1.910	2.354	2.843	3.012	2.713	2.395	1.903	1.972	2.188
Stage IV	N	202	194	217	212	210	227	225	211	183
	Mean	7.851	5.913	3.230	7.479	5.940	6.859	7.887	7.900	7.727
	SD	1.794	2.493	3.031	3.390	3.045	2.752	1.957	1.894	2.010
Total	N	842	822	916	894	858	964	962	909	777
	Mean	7.069	5.197	2.878	7.399	5.870	6.749	7.601	7.668	7.236
	SD	2.119	2.427	2.563	3.308	2.859	2.643	2.003	2.048	2.192

Table A.10
Attribute ratings for the peer group neighbours. The table includes descriptive statistics (N = Observations, M = Mean, SD = Standard Deviation) for decision-maker sub-group in stage II, stage III, and stage IV.

Decision maker sub-group	Statistics	Attribute ratings								
		Trustworthiness	Competence	Power	Independence	Availability	Closeness	Likeability	Integrity	Reliability
Stage II	N	488	464	536	525	496	578	579	539	432
	Mean	6.653	4.715	2.794	7.303	5.598	8.820	6.945	7.322	6.895
	SD	2.266	2.347	2.343	3.385	2.836	1.848	2.241	2.256	2.338
Stage III	N	150	151	162	157	146	165	164	154	135
	Mean	7.023	5.793	3.476	7.369	6.012	8.512	7.262	7.278	6.669
	SD	2.032	2.437	2.845	3.078	2.747	1.974	1.962	2.065	2.168
Stage IV	N	193	189	216	213	208	228	228	213	178
	Mean	7.637	5.848	3.301	7.543	5.731	9.080	7.487	7.689	7.457
	SD	2.205	2.658	3.110	3.367	3.141	1.580	2.148	2.181	2.216
Total	N	831	804	914	895	850	971	971	906	745
	Mean	6.948	5.184	3.035	7.372	5.702	8.828	7.126	7.401	6.989
	SD	2.245	2.498	2.647	3.327	2.900	1.818	2.184	2.211	2.293

Table B.11
Attribute ratings for the peer group family and relatives. The table includes descriptive statistics (N = Observations, M = Mean, SD = Standard Deviation) for respondents with different reported number of peer adopters.

Number of peer adopters	Statistics	Attribute ratings								
		Trustworthiness	Competence	Power	Independence	Availability	Closeness	Likeability	Integrity	Reliability
No peer adopters	N	142	142	168	166	148	178	179	171	157
	Mean	6.741	3.961	3.202	5.952	5.140	6.693	8.213	8.003	7.948
	SD	2.592	2.409	2.843	3.732	3.252	3.268	2.373	2.298	2.428
One to two peer adopters	N	413	419	453	440	429	471	473	450	405
	Mean	7.743	5.393	4.213	6.698	6.379	7.139	8.502	8.309	8.023
	SD	2.164	2.578	3.154	3.314	2.907	2.868	1.851	1.929	2.124
Three to four peer adopters	N	263	253	266	264	266	283	283	275	247
	Mean	8.134	6.056	3.831	6.947	7.214	7.480	8.877	8.436	8.395
	SD	2.078	2.679	3.253	3.401	2.797	2.842	1.643	1.932	1.921
Five and more peer adopters	N	182	176	186	183	181	191	192	183	167
	Mean	8.628	6.557	4.820	7.039	7.550	8.070	9.124	8.852	8.620
	SD	1.823	2.706	3.727	3.565	2.762	2.823	1.441	1.539	1.934
Total	N	1000	990	1073	1053	1024	1123	1127	1079	976
	Mean	7.865	5.564	4.065	6.702	6.624	7.312	8.656	8.385	8.207
	SD	2.219	2.716	3.272	3.462	3.002	2.948	1.856	1.948	2.108

Table B.12
Attribute ratings for the peer group friends. The table includes descriptive statistics (N = Observations, M = Mean, SD = Standard Deviation) for respondents with different reported number of peer adopters.

Number of peer adopters	Statistics	Attribute ratings								
		Trustworthiness	Competence	Power	Independence	Availability	Closeness	Likeability	Integrity	Reliability
No peer adopters	N	213	212	266	255	235	277	281	260	235
	Mean	6.339	3.907	2.761	7.380	4.913	6.622	8.280	7.958	7.500
	SD	2.491	2.503	2.505	3.277	3.276	2.862	2.171	2.283	2.471
One to two peer adopters	N	460	434	467	456	445	496	495	477	414
	Mean	7.733	5.630	3.527	7.420	6.528	7.477	8.697	8.284	7.999
	SD	1.880	2.414	2.849	3.145	2.726	2.395	1.662	1.832	1.873
Three to four peer adopters	N	202	199	200	201	200	212	212	203	192
	Mean	8.139	6.150	3.921	7.356	7.344	7.893	8.595	8.384	8.076
	SD	1.549	2.307	3.088	3.150	2.298	2.161	1.745	1.776	1.957
Five and more peer adopters	N	138	133	133	134	133	139	138	134	121
	Mean	8.646	7.202	5.180	7.793	7.737	8.567	8.991	8.654	8.321
	SD	1.408	2.323	3.735	3.143	2.402	1.921	1.321	1.564	1.971
Total	N	1013	978	1066	1046	1013	1124	1126	1074	962
	Mean	7.645	5.576	3.616	7.446	6.473	7.480	8.610	8.270	7.933
	SD	2.049	2.603	3.022	3.177	2.908	2.497	1.794	1.921	2.077

Table B.13
Attribute ratings for the peer group colleagues and acquaintances. The table includes descriptive statistics (N = Observations, M = Mean, SD = Standard Deviation) for respondents with different reported number of peer adopters.

Number of peer adopters	Statistics	Attribute ratings								
		Trustworthiness	Competence	Power	Independence	Availability	Closeness	Likeability	Integrity	Reliability
No peer adopters	N	204	209	269	254	231	276	276	254	213
	Mean	5.699	3.746	2.501	7.337	4.549	5.811	7.110	7.166	6.531
	SD	2.433	2.384	2.254	3.307	3.034	2.863	2.264	2.384	2.501
One to two peer adopters	N	445	427	467	455	441	490	490	467	401
	Mean	7.334	5.650	3.300	7.446	6.122	6.908	7.675	7.749	7.455
	SD	1.909	2.284	2.775	3.198	2.695	2.512	1.933	1.942	1.972
Three to four peer adopters	N	199	196	199	200	198	211	211	202	186
	Mean	7.717	6.084	3.799	7.455	6.905	7.228	7.824	7.923	7.617
	SD	1.575	2.286	3.075	3.108	2.326	2.199	1.818	1.755	1.956
Five and more peer adopters	N	137	133	133	134	133	139	137	134	120
	Mean	8.342	7.130	5.057	7.893	7.592	8.186	8.410	8.332	8.045
	SD	1.558	2.375	3.711	3.114	2.438	2.126	1.583	1.677	2.051
Total	N	985	965	1068	1043	1003	1116	1114	1057	920
	Mean	7.213	5.530	3.411	7.479	6.109	6.856	7.654	7.716	7.351
	SD	2.100	2.544	2.946	3.197	2.851	2.604	1.997	2.024	2.165

Table B.14
Attribute ratings for the peer group neighbours. The table includes descriptive statistics (N = Observations, M = Mean, SD = Standard Deviation) for respondents with different reported number of peer adopters.

Number of peer adopters	Statistics	Attribute ratings								
		Trustworthiness	Competence	Power	Independence	Availability	Closeness	Likeability	Integrity	Reliability
No peer adopters	N	441	432	512	496	462	547	548	500	405
	Mean	6.451	4.491	2.688	7.293	5.090	8.798	6.976	7.275	6.834
	SD	2.449	2.467	2.407	3.447	2.999	1.897	2.234	2.270	2.315
One to two peer adopters	N	365	346	386	381	363	404	403	388	323
	Mean	7.324	5.842	3.715	7.513	6.248	8.803	7.167	7.418	7.083
	SD	1.859	2.265	2.893	3.011	2.624	1.740	2.106	2.167	2.184
Three to four peer adopters	N	103	99	101	100	104	105	105	101	91
	Mean	7.612	6.767	4.295	6.905	6.918	8.395	7.530	7.706	7.345
	SD	1.966	2.164	3.160	3.147	2.381	1.817	1.893	1.947	2.145
Five and more peer adopters	N	66	66	66	66	66	66	66	66	65
	Mean	8.773	8.542	7.811	8.282	8.333	8.492	8.624	8.500	8.508
	SD	1.530	1.833	2.950	2.580	2.042	1.941	1.704	1.543	1.827
Total	N	975	943	1065	1043	995	1122	1122	1055	884
	Mean	7.058	5.509	3.530	7.399	5.919	8.744	7.193	7.445	7.101
	SD	2.233	2.590	2.971	3.223	2.897	1.839	2.163	2.182	2.256

Table B.15
Comparison of respondents in each sub-group with fewer than six peer adopters vs. six or more peer adopters, with regard to the mean number of self-initiated contacts per relevant stage. The table includes descriptive statistics (N = Observations, M = Mean, SD = Standard Deviation) the results of the two-tailed t-tests (Diff = Difference, Sig = Significance), the results of the non-parametric Mann-Whitney U test (z = z statistics, Sig = Significance), the probability that a random draw from the first sample is larger than a random draw from the second sample (pord), and the Cohen's d effect size. Asterisks indicate the significance level with $*p < .050$, $**p < .010$, $***p < .001$.

Decision maker subgroup	Decision stage	Low number of PV peer adopters			High number of PV peer adopters			Group comparisons			Effectsize
		N	M	SD	N	M	SD	Diff/Sig	z/Sig	pord	d
Stage II	Stage I — Awareness	337	.66	1.18	265	1.4	1.49	.74***	−6.93***	.35	.55
	Stage II — Interest	337	.77	1.25	265	1.76	1.6	.99***	−8.05***	.32	.68
	Stage III — Planning										
Stage III	Stage I — Awareness	59	.93	1.34	110	1.5	1.53	.57*	−2.52*	.39	.39
	Stage II — Interest	59	1.05	1.33	110	1.9	1.66	.85***	−3.22**	.36	.56
	Stage III — Planning	59	1.17	1.38	110	2.02	1.63	.85***	−3.25**	.35	.56
Stage IV	Stage I — Awareness	69	.81	1.28	166	1.46	1.57	.65**	−2.83**	.39	.45
	Stage II — Interest	69	.75	1.17	166	1.64	1.65	.89***	−3.69***	.36	.62
	Stage III — Planning	69	.94	1.16	166	1.75	1.61	.81***	−3.21**	.37	.57

Table C.16
Reported number of peer adopters and reported decision-making stage in relation to the rate of self-initiated interactions about PV. The table includes descriptive statistics (N = Observations, M = Mean, SD = Standard Deviation) for respondents with different rate of self-initiated interactions with respect to the interactions of stage I - Awareness stage.

Statistics	Self-initiated interactions about PV																	
	None			One			Two			Three			Four			Total		
	N	M	SD	N	M	SD	N	M	SD	N	M	SD	N	M	SD	N	M	SD
Peer adopters	567	5.034	3.824	182	6.451	3.665	143	7.776	4.293	117	9.641	5.110	156	9.282	5.049	1165	6.623	4.551
Decision stage	533	2.576	0.825	161	2.640	0.818	109	2.651	0.821	79	2.772	0.905	124	2.782	0.861	1006	2.635	0.836

Table C.17
Reported number of peer adopters and reported decision-making stage in relation to the rate of self-initiated interactions about PV. The table includes descriptive statistics (N = Observations, M = Mean, SD = Standard Deviation) for respondents with different rate of self-initiated interactions with respect to the interactions of stage II — Interest stage.

Statistics	Self-initiated interactions about PV																	
	None			One			Two			Three			Four			Total		
	N	M	SD	N	M	SD	N	M	SD	N	M	SD	N	M	SD	N	M	SD
Peer adopters	534	4.903	3.758	142	5.915	3.818	158	7.418	4.127	139	9.137	5.102	192	9.458	4.622	1165	6.623	4.551
Decision stage	496	2.575	0.823	125	2.816	0.919	125	2.504	0.747	96	2.677	0.814	164	2.756	0.859	1006	2.635	0.836

Table C.18
Reported number of peer adopters and reported decision-making stage in relation to the rate of self-initiated interactions about PV. The table includes descriptive statistics (N = Observations, M = Mean, SD = Standard Deviation) for respondents with different rates of self-initiated interactions with respect to the interactions of stage III — Planning stage.

Statistics	Self-initiated interactions about PV																	
	None			One			Two			Three			Four			Total		
	N	M	SD	N	M	SD	N	M	SD	N	M	SD	N	M	SD	N	M	SD
Peer adopters	180	6.167	3.971	95	6.084	3.338	90	8.489	4.648	85	11.012	5.216	113	10.531	5.057	563	8.131	4.883
Decision stage	151	3.603	0.491	67	3.657	0.478	62	3.516	0.504	41	3.610	0.494	83	3.518	0.503	404	3.582	0.494

References

[1] H.-Y. Lin, M.-H. Hsu, Using social cognitive theory to investigate green consumer behavior, Bus. Strategy Environ. 24 (5) (2015) 326–343, http://dx.doi.org/10.1002/bse.1820.

[2] W. Sierzchula, S. Bakker, K. Maat, B. van Wee, The influence of financial incentives and other socio-economic factors on electric vehicle adoption, Energy Policy 68 (2014) 183–194, http://dx.doi.org/10.1016/j.enpol.2014.01.043.

[3] P.-C. Lin, Y.-H. Huang, The influence factors on choice behavior regarding green products based on the theory of consumption values, J. Clean. Prod. 22 (1) (2012) 11–18, http://dx.doi.org/10.1016/j.jclepro.2011.10.002.

[4] J. Clausen, K. Fichter, W. Winter, Theoretische grundlagen für die erklärung von Diffusionsverläufen von Nachhaltigkeitsinnovationen, 2011, URL https://www.borderstep.de/wp-content/uploads/2014/07/Clausen-Fichter-Winter-Theoretische_Grundlagen_fuer_die_Erklaerung_von_Diffusionsverlaeufen_von_Nachhaltigkeitsinnovationen-2011.pdf.

[5] F.W. Geels, T. Schwanen, S. Sorrell, K. Jenkins, B.K. Sovacool, Reducing energy demand through low carbon innovation: A sociotechnical transitions perspective and thirteen research debates, Energy Res. Soc. Sci. 40 (2018) 23–35, http://dx.doi.org/10.1016/j.erss.2017.11.003.

[6] A. Huber, S. Girard, Y. Thomas, On the way to a post-carbon society: Assessing the personal carbon footprint of french social milieux to develop targeted intervention strategies, Int. Sci. Conf. November (2011) 1–14, URL https://www.ademe.fr/sites/default/files/assets/documents/way-post-carbon-society-assessing-personal-carbon-footprint-french-social-milieux-develop-targeted-intervention-strategies-2009-summary.pdf.

[7] J. Barnes, The local embedding of low carbon technologies and the agency of user-side intermediaries, J. Clean. Prod. 209 (2019) 769–781, http://dx.doi.org/10.1016/j.jclepro.2018.10.258.

[8] IEA, World Energy Outlook 2020, International Energy Agency, Paris, 2020.

[9] J. Rogelj, D. Shindell, K. Jiang, S. Fifita, P. Forster, V. Ginzburg, C. Handa, H. Kheshgi, S. Kobayashi, E. Kriegler, et al., Mitigation pathways compatible with 1.5 C in the context of sustainable development, in: Global Warming of 1.5°C, Intergovernmental Panel on Climate Change, 2018, pp. 93–174.

[10] F. Scheller, I. Doser, E. Schulte, S. Johanning, R. McKenna, T. Bruckner, Stakeholder dynamics in residential solar energy adoption: findings from focus group discussions in Germany, Energy Res. Soc. Sci. 76 (2021) 102065, http://dx.doi.org/10.1016/j.erss.2021.102065.

[11] J. Rode, S. Müller, I spot, I adopt! a discrete choice analysis on peer effects in solar photovoltaic system adoption of households, 2019, http://dx.doi.org/10.2139/ssrn.3469548, URL https://EconPapers.repec.org/RePEc:dar:wpaper:119280.

[12] V. Rai, D.C. Reeves, R. Margolis, Overcoming barriers and uncertainties in the adoption of residential solar PV, Renew. Energy 89 (2016) 498–505, http://dx.doi.org/10.1016/j.renene.2015.11.080.

[13] B. Bollinger, K. Gillingham, Peer effects in the diffusion of solar photovoltaic panels, Mark. Sci. 31 (6) (2012) 900–912, http://dx.doi.org/10.1287/mksc.1120.0727.

[14] V. Rai, B. Sigrin, Diffusion of environmentally-friendly energy technologies: buy versus lease differences in residential PV markets, Environ. Res. Lett. 8 (1) (2013) 014022, http://dx.doi.org/10.1088/1748-9326/8/1/014022.

[15] M. Graziano, K. Gillingham, Spatial patterns of solar photovoltaic system adoption: The influence of neighbors and the built environment, J. Econ. Geogr. 15 (4) (2015) 815–839, http://dx.doi.org/10.1093/jeg/lbu036.

[16] H.C. Curtius, S.L. Hille, C. Berger, U.J.J. Hahnel, R. Wüstenhagen, Shotgun or snowball approach? Accelerating the diffusion of rooftop solar photovoltaics through peer effects and social norms, Energy Policy 118 (2018) 596–602, http://dx.doi.org/10.1016/j.enpol.2018.04.005.

[17] J. Rode, A. Weber, Does localized imitation drive technology adoption? A case study on rooftop photovoltaic systems in Germany, J. Environ. Econ. Manage. 78 (2016) 38–48, http://dx.doi.org/10.1016/j.jeem.2016.02.001.

[18] L. Mundaca, M. Samahita, What drives home solar PV uptake? Subsidies, peer effects and visibility in Sweden, Energy Res. Soc. Sci. 60 (2020) 101319, http://dx.doi.org/10.1016/j.erss.2019.101319.

[19] K.S. Wolske, K.T. Gillingham, P.W. Schultz, Peer influence on household energy behaviours, Nat. Energy 5 (3) (2020) 202–212, http://dx.doi.org/10.1038/s41560-019-0541-9.

[20] A. Palm, Peer effects in residential solar photovoltaics adoption—A mixed methods study of Swedish users, Energy Res. Soc. Sci. 26 (2017) 1–10, http://dx.doi.org/10.1016/j.erss.2017.01.008.

[21] L.-L. Richter, Social effects in the diffusion of solar PV in the UK, 2013.

[22] A. Palm, Local factors driving the diffusion of solar photovoltaics in Sweden: A case study of five municipalities in an early market, Energy Res. Soc. Sci. 14 (2016) 1–12, http://dx.doi.org/10.1016/j.erss.2015.12.027.

[23] K.S. Wolske, P.C. Stern, T. Dietz, Explaining interest in adopting residential solar photovoltaic systems in the United States: Toward an integration of behavioral theories, Energy Res. Soc. Sci. 25 (2017) 134–151, http://dx.doi.org/10.1016/j.erss.2016.12.023.

[24] B. Bollinger, K. Gillingham, S. Lamp, T. Tsvetanov, Promotional Campaign Duration and Word-of-Mouth in Durable Good Adoption, NYU Stern School of Business, 2019, http://dx.doi.org/10.2139/ssrn.3500933.

[25] W. Jager, Stimulating the diffusion of photovoltaic systems: A behavioural perspective, Energy Policy 34 (14) (2006) 1935–1943, http://dx.doi.org/10.1016/j.enpol.2004.12.022.

[26] D. Noll, C. Dawes, V. Rai, Solar Community Organizations and active peer effects in the adoption of residential PV, Energy Policy 67 (2014) 330–343, http://dx.doi.org/10.1016/j.enpol.2013.12.050.

[27] J.W. Arts, R.T. Frambach, T.H. Bijmolt, Generalizations on consumer innovation adoption: A meta-analysis on drivers of intention and behavior, Int. J. Res. Mark. 28 (2) (2011) 134–144, http://dx.doi.org/10.1016/j.ijresmar.2010.11.002.

[28] F. Scheller, I. Doser, D. Sloot, R. McKenna, T. Bruckner, Exploring the role of stakeholder dynamics in residential photovoltaic adoption decisions: A synthesis of the literature, Energies 13 (23) (2020) 6283, http://dx.doi.org/10.3390/en13236283.

[29] E.M. Rogers, Diffusion of Innovations, 5th ed., Free Press, New York, 2003.

[30] C. Wilson, H. Pettifor, G. Chryssochoidis, Quantitative modelling of why and how homeowners decide to renovate energy efficiently, Appl. Energy 212 (2018) 1333–1344, http://dx.doi.org/10.1016/j.apenergy.2017.11.099.

[31] M.S. Nesler, H. Aguinis, B.M. Quigley, J.T. Tedeschi, The effect of credibility on perceived power, J. Appl. Soc. Psychol. 23 (17) (1993) 1407–1425, http://dx.doi.org/10.1111/j.1559-1816.1993.tb01040.x.

[32] R. Ohanian, Construction and validation of a scale to measure celebrity endorsers' perceived expertise, trustworthiness, and attractiveness, J. Advert. 19 (3) (1990) 39–52, http://dx.doi.org/10.1080/00913367.1990.10673191.

[33] A.E. Energien-Statistik, Erneuerbaren Energien in Deutschland Daten zur Entwicklung im Jahr 2017, Dessau-RoßLau: Umweltbundesamt, 2018.

[34] H. Wirth, Aktuelle fakten zur photovoltaik in deutschland, 2020, URL https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/aktuelle-fakten-zur-photovoltaik-in-deutschland.pdf.

[35] Bundesministerium für Wirtschaft, Energie, Erneuerbare Energien in Zahlen: Nationale und internationale Entwicklung im Jahr 2019, 2020.

[36] F.C. Matthes, F. Flachsbarth, C. Loreck, H. Hermann, H. Falkenberg, V. Cook, Zukunft Stromsystem II Regionalisierung der erneuerbaren Stromerzeugung, WWF Deutschland Berlin, 2018, URL https://www.oeko.de/fileadmin/oekodoc/Stromsystem-II-Regionalisierung-der-erneuerbaren-Stromerzeugung.pdf.

[37] S. Enkhardt, Solar mandatory on new buildings in Berlin from 2023, pv magazine, 2021, URL https://www.pv-magazine.com/2021/06/18/solar-mandatory-on-new-buildings-in-berlin-from-2023/.

[38] S. Enkhardt, New German government coalition wants to deploy another 143.5 GW of solar this decade, pv magazine, 2021, URL https://www.pv-magazine.com/2021/11/25/new-german-government-coalition-wants-to-deploy-another-143-5-gw-of-solar-this-decade/.

[39] J.-B. Eggers, M. Behnisch, J. Eisenlohr, H. Poglitsch, W.-F. Phung, M. Muenzinger, C. Ferrara, T. Kuhn, PV-ausbauerfordernisse versus Gebäudepotenzial: Ergebnis einer gebäudescharfen analyse für ganz Deutschland, 2020.

[40] pv Europe, Germany: Huge solar potential for residential rooftop installations still unexploited, 2021, URL https://www.pveurope.eu/markets-money/eupd-research-germany-huge-solar-potential-residential-rooftop-installations-still.

[41] E. Schulte, F. Scheller, D. Sloot, T. Bruckner, A meta-analysis of residential PV adoption: the important role of perceived benefits, intentions and antecedents in solar energy acceptance, Energy Res. Soc. Sci. 84 (2022) 102339, http://dx.doi.org/10.1016/j.erss.2021.102339.

[42] A. Jacksohn, P. Grösche, K. Rehdanz, C. Schröder, Drivers of renewable technology adoption in the household sector, Energy Econ. 81 (2019) 216–226, http://dx.doi.org/10.1016/j.eneco.2019.04.001.

[43] R. Galvin, I'll follow the sun: Geo-sociotechnical constraints on prosumer households in Germany, Energy Res. Soc. Sci. 65 (2020) 101455, http://dx.doi.org/10.1016/j.erss.2020.101455.

[44] J. Mattes, A. Huber, J. Koehrsen, Energy transitions in small-scale regions–What we can learn from a regional innovation systems perspective, Energy Policy 78 (2015) 255–264, http://dx.doi.org/10.1016/j.enpol.2014.12.011.

[45] B. Petrovich, S.L. Hille, R. Wüstenhagen, Beauty and the budget: A segmentation of residential solar adopters, Ecol. Econ. 164 (2019) 106353, http://dx.doi.org/10.1016/j.ecolecon.2019.106353.

[46] Y. Parag, J. Hamilton, V. White, B. Hogan, Network approach for local and community governance of energy: The case of Oxfordshire, Energy Policy 62 (2013) 1064–1077, http://dx.doi.org/10.1016/j.enpol.2013.06.027.

[47] E. Schulte, F. Scheller, W. Pasut, T. Bruckner, Product traits, decision-makers, and household low-carbon technology adoptions: moving beyond single empirical studies, Energy Res. Soc. Sci. 83 (2022) 102313, http://dx.doi.org/10.1016/j.erss.2021.102313.

[48] D. Sloot, L. Jans, L. Steg, Can community energy initiatives motivate sustainable energy behaviours? The role of initiative involvement and personal pro-environmental motivation, J. Environ. Psychol. (2018) http://dx.doi.org/10.1016/j.jenvp.2018.06.007, URL https://linkinghub.elsevier.com/retrieve/pii/S027249441830330X.

[49] U. Dewald, B. Truffer, The local sources of market formation: Explaining regional growth differentials in german photovoltaic markets, Eur. Plan. Stud. 20 (3) (2012) 397–420, http://dx.doi.org/10.1080/09654313.2012.651803.

[50] D.K. Berlo, J.B. Lemert, R.J. Mertz, Dimensions for evaluating the acceptability of message sources, Public Opin. Q. 33 (4) (1969) 563–576, http://dx.doi.org/10.1086/267745.

[51] E. McGinnies, C.D. Ward, Better liked than right: Trustworthiness and expertise as factors in credibility, Personal. Soc. Psychol. Bull. 6 (3) (1980) 467–472, http://dx.doi.org/10.1177/014616728063023.

[52] D. Van der Waldt, M. Van Loggerenberg, L. Wehmeyer, Celebrity endorsements versus created spokespersons in advertising: A survey among students, South Afr. J. Econ. Manage. Sci. 12 (1) (2009) 100–114.

[53] L. Lui, L. Standing, Communicator credibility: Trustworthiness defeats expertness, Soc. Behav. Personal. Int. J. 17 (2) (1989) http://dx.doi.org/10.2224/sbp.1989.17.2.219.

[54] I.E. Steiner, M.E. Fishbein, Current Studies in Social Psychology, Holt, Rinehart and Winston: New York, New York, 1965.

[55] T. Hägerstrand, A Monte Carlo approach to diffusion, Eur. J. Soc./Arch. Eur. de Soc./Eur. Arch. Soz. 6 (1) (1965) 43–67, http://dx.doi.org/10.1017/S0003975600001132.

[56] J. Meyners, C. Barrot, J.U. Becker, J. Goldenberg, The role of mere closeness: How geographic proximity affects social influence, J. Mark. 81 (5) (2017) 49–66, http://dx.doi.org/10.1509/jm.16.0057.

[57] E.T. Straub, Understanding technology adoption: Theory and future directions for informal learning, Rev. Educ. Res. 79 (2) (2009) 625–649, http://dx.doi.org/10.3102/0034654308325896.

[58] C. Wilson, H. Dowlatabadi, Models of decision making and residential energy use, Annu. Rev. Environ. Resour. 32 (1) (2007) 169–203, http://dx.doi.org/10.1146/annurev.energy.32.053006.141137.

[59] J. Axsen, K.S. Kurani, Social influence, consumer behavior, and low-carbon energy transitions, Annu. Rev. Environ. Resour. 37 (1) (2012) 311–340, http://dx.doi.org/10.1146/annurev-environ-062111-145049.

[60] P.-C. Sun, H.-M. Wang, H.-L. Huang, C.-W. Ho, Consumer attitude and purchase intention toward rooftop photovoltaic installation: The roles of personal trait, psychological benefit, and government incentives, Energy Environ. 31 (1) (2020) 21–39, http://dx.doi.org/10.1177/0958305X17754278.

[61] J.R. Parkins, C. Rollins, S. Anders, L. Comeau, Predicting intention to adopt solar technology in Canada: The role of knowledge, public engagement, and visibility, Energy Policy 114 (2018) 114–122, http://dx.doi.org/10.1016/j.enpol.2017.11.050.

[62] Z. Clulow, M. Ferguson, P. Ashworth, D. Reiner, Comparing public attitudes towards energy technologies in Australia and the UK: The role of political ideology, Global Environ. Change 70 (2021) 102327.

[63] A. Field, Discovering Statistics using IBM SPSS Statistics, Sage, 2013.

[64] S. O'Halloran, Econometrics, II - lecture 5: Model checking, in: Sustainable Development U, Vol. 99611, Columbia University, 2005.

[65] R.A. Gordon, Regression Analysis for the Social Sciences, Routledge, 2015.

[66] J.M. Nolan, P.W. Schultz, R.B. Cialdini, N.J. Goldstein, V. Griskevicius, Normative social influence is underdetected, Personal. Soc. Psychol. Bull. 34 (7) (2008) 913–923, http://dx.doi.org/10.1177/0146167208316691.

[67] S. Johanning, F. Scheller, D. Abitz, C. Wehner, T. Bruckner, A modular multi-agent framework for innovation diffusion in changing business environments: conceptualization, formalization and implementation, Complex Adapt. Syst. Model. 8 (1) (2020) 1–32, http://dx.doi.org/10.1186/s40294-020-00074-6.

[68] F. Scheller, S. Johanning, T. Bruckner, Review of designing empirically grounded agent-based models of innovation diffusion, 2019, URL http://hdl.handle.net/10419/191981.

[69] D.G. Reichelt, S. Kühne, F. Scheller, D. Abitz, S. Johanning, Towards an infrastructure for energy model computation and linkage, in: INFORMATIK 2020, 2021.