The Good, the Bad and the Ugly: Affect and its Role for Renewable Energy Acceptance

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Abstract: To foster a socially accepted energy transition, it is essential to gain insights into motives for acceptance or rejection of technologies related to renewable energies. The study aims to shed light on the emotional evaluation of renewable energy technologies and in how far the affective responses are correlated with the acceptance of those technologies. An empirical study is conducted in which a semantic differential is used to assess emotional evaluation of wind power, solar power (PV) and biomass for electricity production. Furthermore, general acceptance of the technologies was assessed. It was found that not only did the technologies differ in terms of emotional responses they evoked, but that those responses also varied significantly between groups of high and low levels of acceptance concerning the respective energy technology. By analyzing spontaneous associations with the three energy sources, possible reasons for the affective evaluations were identified, which can provide essential topics for the communication about those technologies. Overall, the three renewable energy technologies revealed different emotional evaluations which might considerably impact the overall acceptance. It is argued that knowledge about such affective perceptions is useful to tailor energy technology development in early phases and to steer public information and communication strategies.

1 INTRODUCTION

By decentralizing energy production infrastructure in the course of the energy transition, it is moving closer to residential areas. This often causes opposition in the public, as people fear, e.g., health risks (Crichton et al., 2014), spoiled landscapes (Johansson and Laike, 2007; Upreti and van der Horst, 2004), and, as a consequence, reduced property values (Elliott and Wadley, 2002). Other reasons to oppose are related to the project planning, for example, a lack of trust in developers, planners, and policy makers, alongside with perceived unfairness of the decision making process (Rösch and Kaltschmitt, 1999; Gross, 2007; Zoellner et al., 2008). It has been shown that opposition leads to negative consequences for the planned infrastructure projects, but that early and systematic participation of the public can help to decrease these negative effects (Dütschke et al., 2017). In order to support this participation with targeted information and communication concepts, it is essential to understand how the public forms attitudes towards energy infrastructure to be able to address the issues raised. From a technical point of view, an energy source is often evaluated along objective criteria, such as costs (Benitez et al., 2008; Klaiß et al., 1995) or CO2 footprint (Sims et al., 2003). From a social science point of view, the public attitudes towards renewable energy technologies can additionally be influenced by subjective factors, such as affect (Huijts et al., 2012) and emotional connotations of the energy source and its infrastructure, such as the perception of risks and uncertainty (Frewer et al., 2002).

Affect is defined as "[t]he specific quality of "goodness" or "badness" (i) experienced as a feeling state (with or without consciousness) and (ii) demarcating a positive or negative quality of a stimulus." (Slovic et al., 2007, p. 1333). Affect has a powerful influence on risk perception and decision making by providing mental "short cuts" which people rely on for their assessment (Slovic et al., 2005). The importance of affect is underlined by findings which suggest affective evaluations can even "overrule" cognitions: "When cognitions and affect point in the same direction (e.g., are both positive or both negative), they equally contribute to attitude, but when they contradict, then feelings tend to dominate over cognitions in the formation of attitudes. This shows the importance of including both cognitions and affects as antecedents for attitudes." (Huijts et al., 2012, p. 528).

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Despite its potential influence on attitudes and decision making, affect has, to the best of our knowledge, not yet been profoundly studied in the context of renewable energy technologies. This applies in particular to a quantified measurement of affective responses to renewable energies and an attempt to analyze the relation between affective responses and acceptance. The paper aims at uncovering both, affective responses to renewable energies on the one hand, and the relation between those responses and acceptance. To this end, first, studies on affect in the context of energy will be reviewed and the remaining research gap will be identified. The method of the study is then pointed out, followed by detailed results on affect and general acceptance of the energy technologies. In the discussion, the results are critically analyzed with regard to their contribution to acceptance research and policy implications. Finally, the methodological approach is discussed.

2 ACCEPTANCE AND AFFECT IN THE CONTEXT OF ENERGY SUPPLY

Affect and emotional connotations of energy sources play a particularly interesting role in the context of the energy transition. First of all, their relevance in the context of renewable energies is given by the complexity of the topic of energy supply. Affect and underlying emotional connotations have been shown to play a key role in decision making, especially when the context is complex and uncertain (Slovic et al., 2007). It is therefore likely that affect will also play a role for forming attitudes about renewable energies. The complexity here arises, for example, due to a generally positive image in the public (sustainability), but, at the same time, possible negative effects on the environment (“green on green conflicts”, (Warren et al., 2005)), leading to conflicting viewpoints. This makes it difficult for laypersons to come to an informed decision (Frewer et al., 2002).

Second, it has been shown that communicative measures are desperately needed to integrate the public in renewable energy planning, as this can help to overcome opposition, and, as a result of this opposition, overcome delays of projects and dissatisfaction in the public (Dütschke et al., 2017). It is argued that there is a need to increase the public understanding by involving the public in early phases of technology development and local infrastructure planning and addressing the public’s specific information and communication needs. In order to tailor those communicative measures, “it is crucial to gain insights into the mental representations of renewable energy systems and their specific affective evaluation.” (Sütterlin and Siegrist, 2017, p. 362). Exploring affect and mental representations can, for example, help to uncover seemingly paradox attitudes among laypersons (Leiserowitz, 2006).

For these reasons, the study of affect in the context of energy and climate change has gained importance in recent years. A number of studies focused on the influence of affect on attitudes towards nuclear energy, in order to understand reasons for opposition and support. In a study by Finucane et al., it was investigated how risks and benefits of nuclear energy were perceived when affect as influential factor is taken into account (Finucane et al., 2000). By providing biased information to the participants, it was observed how an altered overall impression changed assessment of risks and benefits of the technology and it was concluded that affect moderates both, perceived risks and benefits. While Leiserowitz’ and Finucane’s studies provided a more conceptual approach to the affect heuristic, other studies pursued more content-driven approaches, in order to uncover the motives behind attitudes towards different energy sources. In Keller et al., the influence of affect, assessed through spontaneous associations, on acceptance of nuclear power plants was analyzed, also taking user factors (gender) into account (Keller et al., 2012). There was a relationship between the affective representation of nuclear power plants and the acceptance of a new generation of nuclear power plants: significant differences were found between the associations of those who opposed to nuclear power plants and those who were more accepting towards them. Beyond the affective evaluation, it was shown that also the content of the associations is worth investigating to come to a thorough understanding of acceptance.

Comparative approaches, in which more than one energy source is investigated with regard to affect, have also been undertaken. Sütterlin and Siegrist investigated attitudes towards hydroelectric power, solar power, wind power, and, as a contrast, nuclear power, but only elicited affective imagery for solar power (Sütterlin and Siegrist, 2017). For the latter, they found positive affective connotations. They also found that affect influences abstract acceptance more than concrete acceptance. In the study by Truelove et al., nuclear energy was compared to wind energy, natural gas and coal with regard to implicit associations and policy support (Truelove et al., 2014). It was found that not only negative, but also positive, implicit associations persisted. They had, however, only moderate impact on policy support. Truelove et al. also pointed out that the reference against which an energy source is compared should be carefully chosen (in this study, nuclear energy was for example evaluated more positive than coal, but not preferred over natural gas). Most similar to our approach, Renn (1982) compared "the emotional component of an attitude" (p. 251) towards nuclear energy, coal and PV on a semantic differential scale (Renn, 1982). In the majority of dimensions, though not in all, PV was evaluated most positively.

Finally, it has been shown that the influence of the affect heuristic is not limited to decision making of laypersons, but can also be found for experts. Chassot et al. investigated how implicit cognition is related to the investment behavior of energy investors (Chassot et al., 2015), and, also for this target group, a link between positive associations and decision making could be observed. In the context of the energy transition, they highlight the necessity to look beyond rational arguments: "Implicit associations may hinder investment in new energy technologies in ways that are not obvious to the observer, and sometimes inaccessible to the decision-maker himself." (p. 291).

It is important to note that in none of the studies, associations were evaluated for technical accuracy or logic. Rather, "[the] intention was merely to measure the structure of attitudes, to find common types of reasoning in this matter and to investigate the processes involved in making up one's mind (...)" (Renn, 1982, p. 243). Thus, although the mental representations might not correspond to technical realities, they are, nevertheless, important and decisive, because they reflect laypersons' realities and perceptions, which, in turn, influence the decision for or against a specific energy supply solution. In this sense, they are no less "valid" than technical facts when it comes to decision making for laypersons as they can even overrule technical "truths". This calls for an open-minded communication with the public from a planning and policy perspective, in which laypeople's concerns are taken seriously.

Even though the studies used different methods, focused on different technologies and different target variables, they provide strong evidence for the assumption that the affect heuristic plays a major role for the acceptance of different types of energy and in the energy transition in general. So far, a comparison between different renewable energies with regard to affect and attitude is still lacking, although especially in this context, public perceptions are important to understand in order to better understand acceptance and opposition and react in apporpriate ways.

3 EMPIRICAL EVIDENCE

In order to illustrate the interplay between affect and attitudes towards renewable energies, an empirical study was designed in which three renewable energy sources (wind, solar power (PV), biomass) were analyzed with regard to affective attitudes (implicit) and acceptance (explicit). In addition, a word association task served as means to closer examine underlying motifs, reflecting mental concepts and cognitions as part of the affective evaluation.

3.1 Methodological Approach

Data were collected using a quantitative approach for which an online questionnaire was designed. It was distributed via mail and social networks to an interested German audience. Participation was not gratified and was voluntary. Participants were ensured that their personal data and all of the results are treated confidentially and in accordance with the high privacy standards of the research institution. The questionnaire consisted of two major parts: the first section assessed demographic information and user characteristics. Regarding the demographic information, age, gender, education level, occupation, area of living, and other energy infrastructure in the vicinity were asked for. The user characteristics examined in the study were general technical attitude (5 items, as used and tested in (Himmel et al., 2014)) and environmental attitude, (combined from attitude towards renewables (adapted from (Siegrist, 1996)) and environmental awareness (selected items from NEP scale (Dunlap et al., 2000))[1]. Attitude towards technologies in general and environmental attitude have been found to influence acceptance of technology in general and of renewable energy infrastructure in particular (Zaunbrecher et al., 2014). Both attitudinal traits were therefore hypothesized to also influence emotive responses to energy infrastructure and thus needed to be controlled for. Cronbach's Alpha for general attitude towards technology was measured at 0.86, and for attitude towards the environment at 0.79, the scales were thus considered reliable.

The second section of the questionnaire assessed attitude towards wind energy, PV and biomass. For all questions, 6-point Likert scales were used as answering format to measure agreement (1= do not agree at all, 6= fully agree). Participants were asked for their (subjective) knowledge about wind energy, PV and biomass ("I feel well informed about" and "I know how a (windpower plant/PV plant/biomass

[1]Detailed questionnaire available from the authors by request.

plant) works"). These questions were used to examine influence of knowledge on emotive responses on the semantic differential scale. In addition, participants were asked five questions on each renewable energy technology to determine general acceptance of the technologies (Items see Table 2).

The emotional assessment of wind energy, biomass and PV was measured using a semantic differential scale (Osgood, 1952) for each of the three technologies . It is described as especially useful to measure "meanings that are based on emotions" (Bergler, 1975, p. 69). The semantic differential consisted of 13 adjective-pairs which had previously been tested by five independent participants for their suitability in the context of energy-related infrastructure (for dimensions see Figure 1). Furthermore, participants were asked to note down spontaneous associations with the three energy technologies to enrich the quantitative with qualitative data and uncover acceptance-relevant aspects which had not been treated in the questionnaire so far. For statistical evaluation of the results, SPSS (Version 21) was used. The significance level was set at 5%. Missing percentages adding up to 100% are due to missing answers from some participants.

3.2 Sample

329 of originally 389 participants were included in the sample for analysis (excluded participants had not completed any of the questions on demographics or user characteristics). 55.3% were female, 42.9% male. The mean age was 33.7 years (SD= 15.7), with respondents up to 30 years of age accounting for around two thirds of the sample. The educational level was high, 57.1% of the respondents held a university degree and further 27.1% school degrees that qualify for university entrance ("Abitur"). 10.0% had completed vocational training, and 3.3% had obtained a basic school leaving certificate. 58.4% lived in the city center, while around 27.7% lived in suburbs, 12.5% lived in a village. To control for exposure to (energy) infrastructure in their daily lives, participants were asked which (energy) infrastructure was within view of their homes (multiple answers possible). 13.4% reported to have transmission lines in view of their homes, 8.2% wind power plants, 1.5% biomass plants, 21.3% PV installations. Further 26.4% had a mobile phone base station in view of their home and 54.4% indicated that none of the above could be seen from their home. Regarding user diversity, participants showed an overall openness towards technology (general attitude towards technologies: M=4.7, (Maximum: 6), SD=0.9) and a high environmental awareness (M=4.8 (Maximum: 6), SD=0.7).

3.3 Results

First, the knowledge about and the general acceptance of renewable energies will be reported. Afterwards, results from the semantic differential as well as qualitative results are presented.

Participants reported overall average perceived knowledge with mean values between 2.8 and 4.1 (Maximum: 6) (Table 1). They reported highest scores for knowledge about and functionality of wind power plants (M=3.6 and M=4.1, respectively) and lowest perceived knowledge for biomass plants. Values for the feeling of being informed and perceived knowledge of function correlated highly (PV: r=0.77, $p \leq 0.01$, Wind: r=0.68, $p \leq 0.01$, Biomass: r=0.75, $p \leq 0.01$) and the two respective items are thus combined (mean value) for subsequent analyses to one factor ("knowledge").

Table 1: Perceived knowledge about renewable energy infrastructure (N=326-328, Scale: Min: 1, Max: 6).

	Feel informed	**Know about functionality**
PV	3.3 (SD=1.4)	3.6 (SD=1.5)
Wind	3.6 (SD=1.2)	4.1 (SD=1.3)
Biomass	2.8 (SD=1.2)	3.0 (SD=1.4)

Regarding general acceptance of the technologies (Table 2), PV was overall most favored. Participants were least unhappy if it would be built nearby, found it least dangerous, accepted it most within view of their house, expected least health risks and welcomed it most for energy supply of their hometown. Biomass, on the other hand, was least favored by the participants. People were most unhappy at the thought of a biomass plant nearby or in view of their house, found it most dangerous and thus also expected the most health risks and support was weakest for their home town to be supplied by this form of renewable energy. Wind energy was rated worse than PV, but better than biomass on all dimensions of acceptance.

While these first questions asked for specific attitudes towards different renewable energy sources, the semantic differential required participants to indicate their intuitive rating of renewable energies with regard to different dimensions. Results are depicted in Figure 1. The semantic differential shows distinct profiles for each renewable energy source. Biomass was consistently rated worse than PV and wind energy. Ratings for biomass were especially negative ($\leq$ 3.5) for the dimensions "ugly-beautiful", "disturbing-

Table 2: Acceptance of renewable energy infrastructure.

	PV			Wind energy			Biomass		
	N	M	SD	N	M	SD	N	M	SD
I would be unhappy if X was built nearby.	313	2.4	1.4	314	2.9	1.3	302	3.2	1.3
I find X dangerous.	311	1.9	0.9	312	2.2	1.0	298	2.5	1.0
I would accept X in view of my house.	314	4.7	1.3	315	4.2	1.4	305	3.4	1.2
I fear that X could cause health risks.	312	1.8	1.0	313	2.1	1.2	300	2.5	1.0
I would support it if my town decided to use X for energy supply	314	5.0	1.1	315	4.9	1.2	300	4.1	1.2

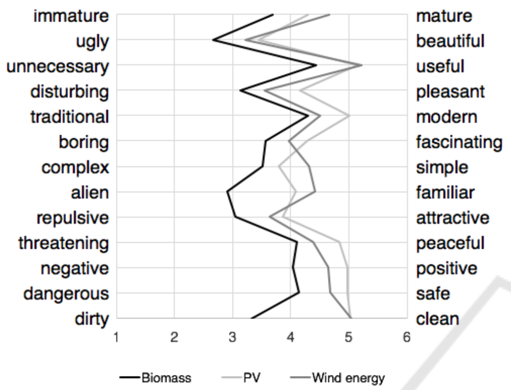

Figure 1: Semantic Differential for renewable energy infrastructure (N=292-315).

pleasant", "alien-familiar", "repulsive-attractive" and "dirty-clean". Biomass received the most positive rating for usefulness. For wind energy and PV, the picture was less distinct than for biomass. In some dimensions, PV was rated more positive than wind energy, in others, the opposite occurred. While wind energy was rated more mature than PV, PV was rated more beautiful. There were only minor differences in the rating of their usefulness with high overall values ($\geq$ 5.0). PV was rated more pleasant, modern and fascinating than wind energy. Regarding complexity and familiarity, wind energy was rated to be simpler and more familiar. PV reached higher values for attractiveness, peacefulness, and was perceived more positive and safer. Regarding cleanliness, both energy sources were rated almost equally positive ($\geq$ 5.0).

In a next step, to investigate the relation between ratings on the semantic differential and acceptance, the participants were split according to the levels of general acceptance towards the respective technologies to compare semantic differential evaluations between the two groups. For each participant, a "general acceptance" score was calculated for each technology using the mean score of the acceptance items (Table 2, negatively worded items were recoded), taking M=3.5 as cut-off value between the "high acceptance" (HA) and the "low acceptance" (LA) group. This was done with reference to the 6-point Likert scale, for which 3.5 presented the midpoint of the scale and the tipping point between agreement and rejection. Participants who had not answered all questions related to acceptance of the respective energy sources did not receive a "general acceptance" score and were therefore excluded from the group analysis.

For all energy sources, the HA groups scored higher than the LA groups on all dimensions of the semantic differential (Figure 2 to 4). This indicates that affective ratings are related to the explicitly stated acceptance, supporting the assumption that the affect heuristic holds true for the context of the renewable energy sources. Depending on the specific energy source, the differences between the groups, as well as groups sizes and characteristics varied (Table 3, Appendix). For biomass, differences between the LA group (n=73) and the HA group (n=236) were largest for the dimensions "positive-negative", "safety" and "threatening-peaceful" (Figure 2). The two groups differed significantly in terms of gender distribution, attitude towards technologies and knowledge about biomass: In the HA group, there were more male participants and group members had a more positive attitude towards technologies as well as higher reported knowledge about biomass. For PV, the differences between the groups (LA group: n=16, HA group: n= 299) were the larger than for biomass, with the largest differences occurring on the same dimensions ("positive-negative", "safety" and "'threatening-peaceful") (Figure 3). The groups according to PV-acceptance differed significantly in gender distribution, attitude towards technology and knowledge about PV: The HA group had a higher share of male participants, a more positive attitude towards technology and reported better knowledge about PV. For wind energy, the two groups (LA group: n=41, HA group: n= 275) produced extreme differences with respect to the rating on the semantic differential similar to the PV groups (Figure 4). The largest differences occurred on the dimensions "positive-negative", "threatening-peaceful", and "disturbing-pleasant". The two groups differed significantly in age, educational level and environmental attitude:

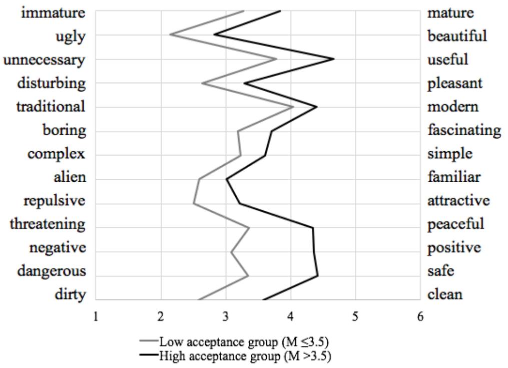

Figure 2: Semantic differential for biomass for high acceptance and low acceptance groups.

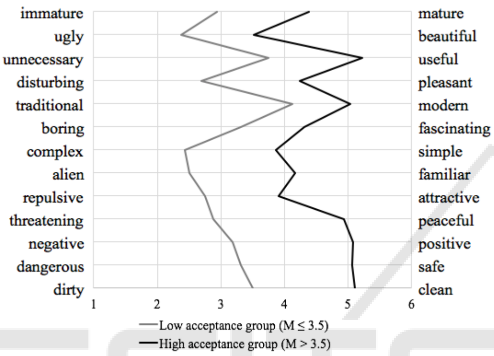

Figure 3: Semantic differential for PV for high acceptance and low acceptance groups.

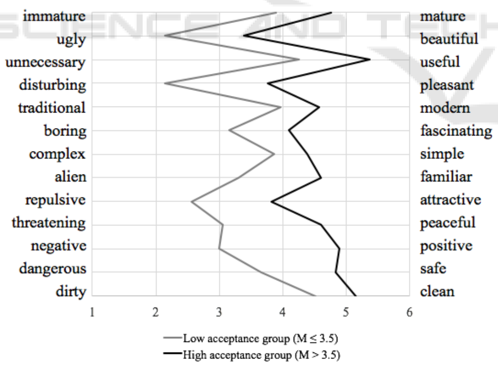

Figure 4: Semantic differential for wind power for high acceptance and low acceptance groups.

The HA group was younger, better educated and had a more ecologically oriented attitude.

Summarizing results for the three different renewable energy sources, feelings of danger or threat were most distinguishing between the HA and LA groups for all energy sources. For wind energy, the visual appearance of wind turbines (evoking feelings of being "pleasant" or "disturbing") was an additional distinguishing factor. These findings show the underlying affective evaluations which can help to explain explicit acceptance ratings.

In addition to rating renewable sources on semantic differential scales, participants were asked for their spontaneous associations with PV, wind energy and biomass. Associations and remarks were categorized, summarizing those associations which were similar to each other in one category (e.g.: "unknown", "not enough information", "no knowledge about it" and similar associations were summarized in "lack of knowledge"). Association categories with four or more mentions are depicted in Figures 5 to 7[2].

For PV, 251 participants produced 458 associations (Figure 5). The two most dominant associations were "sun", referring to the source of the energy, followed by the typical location in which PV panels are found ("roofs"). Further frequent associations included references to the type of energy (heat/electricity), as well as general favorable evaluations of PV as a type of renewable energy (e.g., "clean", "useful", "modern"), with the exception of "expensive" and "ugly". Participants also frequently referred to the dependence on the weather, as well as unfavorable climatic conditions in Germany for PV as a general problem. In contrast to biomass and wind power, PV was seen as a renewable energy "for everyone", referring to the possibility of installing it at one's own home. In general, PV was seen as a rather unobtrusive technology, with the downsides of price and weather-dependency.

In the case of wind energy, 263 participants produced 535 associations (Figure 6). From the results, the bigger impact of wind power plants on their environment, in contrast to PV, is clearly visible: although considered to be "clean", the "size","noise emissions" and "shadows" of wind power plants are frequently cited. Besides, there is evidence that the "green on green" conflict (Warren et al., 2005) concerning possible harm to animals (birds, bats, etc.) as well as "landscape impact", is deeply anchored in peoples' minds. In contrast to PV, however, there were also very positive statements, in which wind power plants were described as "majestic" or even "elegant". This ties in with the findings from the semantic differential results, revealing that HA and LA groups produced extreme results using almost the entire width of the scale, which reflects extremely opposing viewpoints.

For biomass, 232 participants produced 356 associations (Figure 7). The most striking result is that – among the 22 most frequently mentioned categories– only two (!) are clearly positive ("ecological" and "useful"). "Odor/stench" was the most dominant association, which is coined negatively. This is in strong

[2]Full list of associations available upon request from the authors.

contrast to wind power and PV, for which "clean" was among the most frequent associations. Further negative associations contained references to ecological ("monocultures") as well as ethical concerns ("waste of food"). Besides, the difference to PV and wind power was that no specific infrastructure was among the most frequent associations for biomass, in contrast to, e.g., "wind turbines" or "solar panels".

Summarizing, the results from the direct acceptance measurement (using items), the semantic differential and the word association task uncovered a differentiated acceptance-pattern for biomass, wind power and PV. According to the results, PV was most accepted, while wind power was seen more controversial, and biomass was least accepted. While the items to measure acceptance already brought this pattern to light, the semantic differential helped to systematically compare the three renewable energies along affective dimensions. Based on the theory of the affect heuristic, the semantic differential and the spontaneous word associations helped to uncover the hidden drivers of these attitudes: while PV was valued for its unobtrusiveness, wind power was seen more critical because of its high impact on landscapes and fauna. Biomass was frequently associated with negative concepts (dirt, manure, stench), thus receiving an overall more negative evaluation. Besides, the relation between affective ratings and acceptance was shown.

4 DISCUSSION

In this research, the public acceptance of three different renewable energy sources, wind power, solar power and biomass, was empirically studied. The overall aim was to gain insights into motives for acceptance or rejection of technologies related to renewable energies. Previous studies (Joffe, 2003; Renn, 1982; Slovic et al., 2005; Slovic et al., 2007) have shown that –apart from "objective" or "factual" arguments, such as costs, known sustainability effects, or CO2 footprints– acceptance of the public also relies on implicit affective evaluations. In order to shed light on these hidden emotional evaluations of renewable energy technologies and to understand in how far the affective responses are related to the acceptance of those technologies, mental models and associations of participants were investigated and analyzed in relation to acceptance groups. The study revealed that, overall, the technologies differed distinctly in terms of emotional responses they evoked. In addition, the affective evaluations varied significantly between LA and HA groups, supporting the theory that affect influences attitudes. The analysis of the spontaneous associations revealed possible reasons for attitudes towards the energy sources, which might contribute to future information strategies for the respective technologies directed at laypersons. Following, key findings are summarized as well as their policy implications, followed by a discussion of the effectiveness of the methodology. The section closes by outlining some limitations and future research duties.

4.1 Key Findings: Perceptions of Energy Technologies

The results support the hypothesis that there exists a link between the affect heuristic and perceptions of renewable energies: the energy sources with positive ratings on the semantic differential and in word association tasks were perceived more positive regarding risks and acceptability than the one with negative ratings and negative associations. Biomass received, overall, the most negative evaluation, PV the most positive. This is reflected in the acceptance-judgments: Biomass was seen as bearing the largest risk (most dangerous, most fear of health risks), PV as being least dangerous and bearing the least health risks, as well as being supported most for communal energy supply. Wind power, for which results were in the middle of the answering-scales on most affective dimensions, showed the lowest distances between the risk and benefit items. This corresponds to results by Alhakami and Slovic, who found on the one hand that "items with intense positive or intense negative evaluations had the largest distance between risk and benefit judgments.[3]" and that "items in the middle of the evaluation scale were associated with smaller distances." (Alhakami and Slovic, 1994, p. 1095).

From the results of the semantic differential and the acceptance groups, it can be deduced that PV represents the overall most "agreeable" renewable energy. It is thus not only more positive evaluated than fossil sources (Renn, 1982), but also than the renewables it was compared against. From the associations, the reasons for this can be assumed: it does neither have an impact on landscape, nature, nor humans through emissions of any kind. The group separation according to acceptance showed large differences on the semantic differential scales for PV, however, the LA-group comprised of only 16 participants, as the overall acceptance of PV was high. The very selective group could therefore account for the extreme views. Wind power, according to the associations, provoked equally strong feelings in the two groups,

[3]"Item" is to be understood here as "artefact under study", rather than "question".

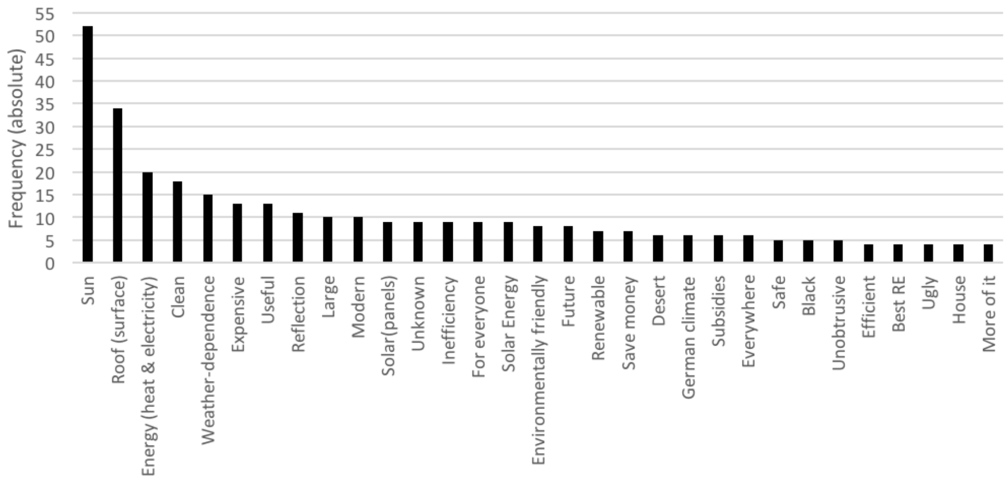

Figure 5: Associations with the term "photovoltaics", total: 460 associations.

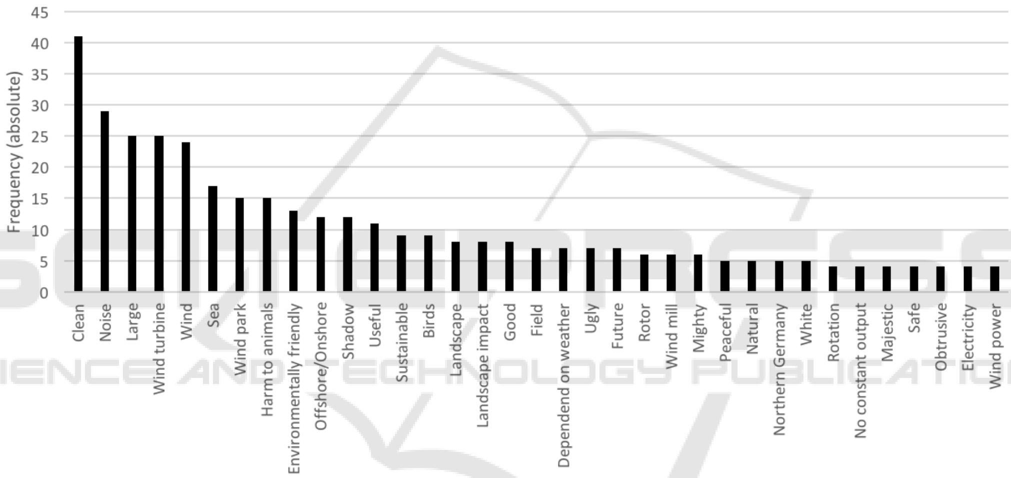

Figure 6: Associations with the term "wind energy", total: 535 associations.

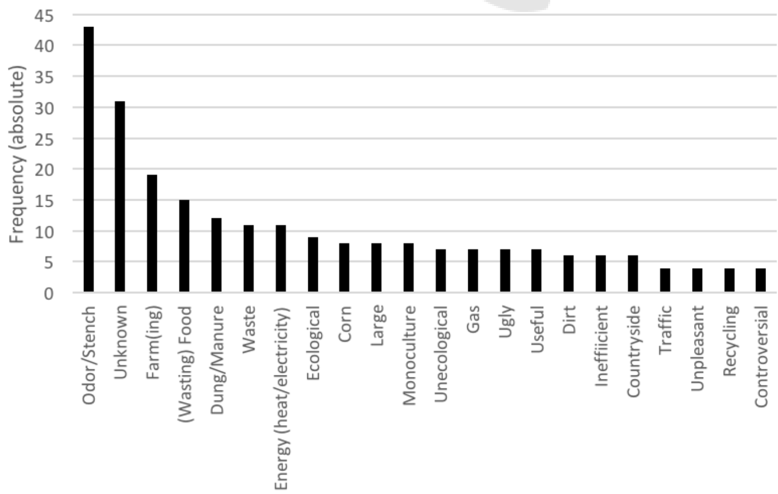

Figure 7: Associated with the term "biomass", total: 357 associations.

on the positive as well as on the negative end of the scale. From the group comparison and the associations it can be inferred that it is the most debated of the energy sources, this will be especially true for people with concerns for the welfare of animals and those sensitive towards landscape change. Biomass represents the renewable energy source on the most negative end of the scale from the perspective of social acceptability. Besides scoring comparably negative on the affect-scales (semantic differential), the word associations were mostly unfavorable. Besides odor emissions, negative associations contained references to ecological (monocultures) as well as ethical concerns (waste of food). These barriers are in line with other studies on the acceptance of biomass (Rösch and Kaltschmitt, 1999; Kortsch et al., 2015). According to the associations, biomass did not provoke many positive associations, which could explain the overall hesitant attitude towards it, in contrast to other studies, in which positive aspects such as job security were frequently mentioned (Kortsch et al., 2015). Concerning the impact of user diversity, no clear pattern emerged in which one demographic variable or user factor was similarly influential in all technology contexts. It thus seems that next to a differentiated acceptance pattern on the level of content, also the influence of user characteristics is different for each technology. These results should, however, be treated with care and need further evidence, as some of the groups observed were only small.

4.2 Methodological Discussion

As in this study, qualitative and quantitative measures were used to uncover users' attitudes and affective drivers of energy technology acceptance, the methodology needs a thorough discussion regarding its strengths and reliability. The application of the semantic differential had the advantage that a direct, quantitative comparison between the three energy sources was possible in terms of affect, as they were rated on the same scales. In combination with free associations, the method was useful for a comparative view on affect in the domain of energy supply. Other studies have compared affect related to wind and solar energy with coal, nuclear and energy from gas (e.g., (Lee, 2015)), while we focused specifically on a comparison between renewables only. Methodologically, this approach was chosen because even renewables, although generally having a positive image, have considerable drawbacks, which might have been diminished when comparing them to fossil fuels. In contrast to quantitative approaches, in which attitudes are measured and used to make predictions following a theoretical model, the use of qualitative measures and the findings might leave, though insightful, a fuzzy and somewhat elusive impression behind in terms of arbitrariness and randomness of the findings. One might argue that these qualitative and indirect measures to uncover affective evaluations might miss the "numerical" rigor in comparison to quantitative analyses which use inferential statistics to validate findings. Even if we cannot fully rule out this justifiable argumentation, only by such "unregulated" and "free" methodology it is possible to uncover the hidden drivers that underlie affective evaluations which impact acceptance and decision making.

Thus, the combination of qualitative and quantitative methods is mandatory to detect affective acceptance drivers, at least in early phases of acceptance modeling. In the next step, a cross validation with a more detailed quantitative model is needed. Regarding policy, appealing to the "conscious level of decision making", e.g. by presenting technical facts on new renewable energy projects, may not be the most effective way of promoting renewable energy infrastructure. This also highlights the need for an interdisciplinary approach to such projects which takes the human factor into account rather than base decisions on technical parameters only.

4.3 Implications for Policy and Communication

Considering the implications of the results for public communication and policy, different topics are relevant for the communication about the different energy sources. For wind, the impact on landscape and nature was frequently associated, indicating that perceived fit within the landscape and visual intrusion are topics which need to be addressed. This is in line with other acceptance studies on wind energy, some of which have even found that perceived negative landscape impact can "spill over" to evaluations of efficiency (Waldo, 2012). Biomass was not well-known among the participants, indicating a need for more information on this energy source. This is supported by the lack of a specific, symbolic infrastructure as part of the mental model of biomass of laypersons (in contrast to, e.g., wind turbines for wind power or solar panels for PV). It can be assumed that a widespread diffusion of biomass plants will be difficult to achieve on the basis of the current level of knowledge of the public, as participants spontaneously had mostly negative associations concerning various aspects (ecological, ethical and health concerns). PV, on the other hand, seemed most agreeable, some participants even demanded that it should be "obligatory for every house owner". The concerns regarding dependence on weather conditions could be addressed by better informing the public about storage possibilities. From a social acceptance point of view, results indicate that PV is likely to provoke the least opposition. Apart from the implications of the findings on public information strategies, a final note is directed at a metaperspective of the utility of the mental models prevailing in the public. Naturally, mental models and affective evaluations of energy sources of the uninformed public might be "illogical" or even "incorrect" from experts' points of view. Not considering these mental models seems ill-advised from a social science point of view. If experts take those affective evaluations as a starting point to integrate the public, giving them the chance to participate in an open and transparent discourse, this might help to overcome affective barriers and to shape public knowledge systematically. In this case, uncovering implicit mental models and addressing them deliberately in an open discourse between experts, planners, and citizens, represents a kind of discourse instrument and an educative tool to negotiate accepted renewable and sustainable energy transition processes.

4.4 Limitations

Regarding the influence of the affect heuristic on acceptability of renewable energy sources, it should be further analyzed how stable the mental models of the participants are, for example by giving biased information. In the case of biomass, for which a lack of specific information was identified, the influence of biased information could be different than for wind power or PV. Additionally, the extent of the influence of affect on acceptance was not quantified in this study. Comparative research on the three energy sources showed tendencies for affect having a different influence on acceptance depending on the energy source (Zoellner et al., 2008). Furthermore, user factors and their influence on affect were not analyzed in detail in this study, however, Sütterlin and Siegrist found that affective images for solar power are influenced by gender, so it is likely that this is also the case when comparing across different energy sources (Sütterlin and Siegrist, 2017). They also suggest a cultural influence on affect. Future studies should therefore include more countries, concentrating on user diversity and the question which individual factors might impact affective responses towards energy technologies (e.g., extent of risk tolerance, interest in innovation, extent of ecological awareness). In addition, out sample was quite young and –in comparison to the German population – highly educated. As education levels, social norms and cultural traditions also impact the environmental awareness and the consciousness about societal welfare, a more detailed look into user factors is needed (Kollmuss and Agyeman, 2002). Finally, electricity production is only one part of the grid which needs to be adapted to the energy transition. Storage facilities for electricity also play an important role for securing sustainable electricity supply, also here, mental models can help to uncover possible barriers to acceptance (Zaunbrecher et al., 2016).

5 CONCLUSIONS

The study showed that emotional responses to renewable energies can, next to cognitive responses, explain attitudes and uncover hidden motivations. Investigating those affective responses can thus help to improve understanding for attitudes of laypersons towards energy infrastructure. As research has shown that an integrative approach which values public opinions and participation can influence the success of such projects, it is advisable to integrate public mental models and perceptions into early phases of energy infrastructure planning and communication strategies.

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APPENDIX

Table 3: Demographics and user characteristics of acceptance groups (WP: wind power plant, BM=biomass plant), *sign. differences (p≤ 0.05)

	Biomass-acceptance groups	
	HA group (n=73)	**LA group (n=236)**
Gender*	female: 52.4% male: 47.6%	female: 68.5% male: 30.1%
Age	M=33.3 (SD=15.5)	M= 35.2 (SD=17.1)
University degree	59.70%	47.90%
Place of residence	City center: 57.2%, Suburbs: 28.8% Village: 12.3%	City center: 57.5%, Suburbs: 30.1% Village: 12.3%
Infrastructure within view	WP: 8.9%, BM: 2.1%, PV: 19.9%	WP: 5.5%, BM: 0%, PV: 27.4%
Environmental attitude	M=4.9 (SD=0.7)	M=4.8 (SD=0.6)
Attitude towards technology*	M=4.8 (SD=0.8)	M=4.5 (SD=0.9)
Knowledge biomass*	M=3.0 (SD=1.2)	M=2.5 (SD=1.3)

	Windpower-acceptance groups	
	HA group (n=275)	**LA group (n=41)**
Gender	female: 56.0% male: 42.9%	female: 61.0% male: 36.6%
Age*	M=32.7 (SD=15.1)	M=40.2 (SD=16.8)
University degree*	60.70%	39.00%
Place of residence	City center: 58.9%, Suburbs: 28.4% Village: 11.3%	City center: 53.7%, Suburbs: 29.3% Village: 17.1%
Infrastructure within view	WP: 8.7%, BM: 1.5%, PV*: 18.9%	WP: 4.9%, BM: 2.4%, PV*: 34.1%
Environmental attitude*	M=4.9 (SD=0.7)	M=4.5 (SD=0.8)
Attitude towards technology	M=4.7 (SD=0.9)	M=4.7 (SD=0.9)
Knowledge wind power	M=3.9 (SD=1.1)	M=3.7 (SD=1.2)

	PV-acceptance groups	
	HA group (n=299)	**LA group (n=16)**
Gender*	female: 54.8% male: 43.8%	female: 81.3% male: 18.8%
Age	M=33.9 (SD=15.8)	M=31.5 (SD=15.7)
University degree	60.20%	25.00%
Place of residence	City center: 57.5%, Suburbs: 28.8% Village: 12.4%	City center: 62.5%, Suburbs: 31.3% Village: 6.3%
Infrastructure within view	WP: 8.4%, BM: 1.3%, PV: 21.49%	WP: 6.3%, BM: 6.3%, PV: 12.5%
Environmental attitude	M=4.8 (SD=0.7)	M=4.9 (SD=0.7)
Attitude towards technology*	M=4.8 (SD=0.7)	M=3.9 (SD=1.0)
Knowledge PV*	M=3.5 (SD=1.3)	M=2.2 (SD=1.5)