Uncovering the Impact of Trust and Perceived Fairness on the Acceptance of Wind Power Plants and Electricity Pylons

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Keywords: Trust, Fairness, General Acceptance, Local Acceptance, Electricity Pylons, Wind Power Plants.

Abstract: Success of the German energy transition towards renewables relies not only on technical and economic factors, but also on the public acceptance of the required energy infrastructure, e.g., wind power plants and power lines. In this paper, acceptance-relevant process characteristics (perceived fairness of project planning, trust in stakeholders, and trust in technology) were investigated by comparing users' acceptance for wind energy and power line planning, using an online survey in Germany (n = 70). Acceptance, trust, and perceived fairness were significantly higher for wind power plants than for electricity pylons. General acceptance of wind power plants and electricity pylons was affected by trust, with trust in technology playing a more important role than trust in stakeholders. Local acceptance was directly influenced by general acceptance and perceived fairness. Trust indirectly affected local acceptance through general acceptance. The results contribute to an improved planning of energy infrastructure by adequately addressing public requirements.

1 INTRODUCTION

The German "Energiewende" (energy transition towards renewable energy resources) requires a considerable expansion and restructuring of the current energy infrastructure to increase the share of energy from renewable resources in the electricity supply (Federal Ministry for Economic Affairs and Energy, 2015; n.d.). In addition to the construction of renewable energy generation facilities (e.g., wind farms or biomass power plants), new power lines are necessary to connect energy production facilities to the electricity grid (Federal Ministry for Economic Affairs and Energy, 2015; n.d.).

The success of planned projects is often challenged by local opposition seriously delaying or endangering the development, although citizens are in general supportive of the energy transition and associated renewable energy technologies (Jones and Eiser, 2009; Lienert, Suetterlin and Siegrist, 2015). Thus, a favorable reception of energy infrastructure technologies on a general and local level is an important precondition for successful energy infrastructure planning and, at a higher level, for achieving the energy transition (Sütterlin and Siegrist, 2017; Wüstenhagen, Wolsink and Bürer, 2007).

Reasons for local opposition to energy infrastructure such as wind farms or power lines are numerous. They include perceived visual impacts due to infrastructure elements (electricity pylons, wind turbines) that are visible from a great distance, but also concerns about negative consequences for human health and the environment (Baxter, Morzaria and Hirsch, 2013; Cotton and Devine-Wright, 2013). Siting conflicts can also arise from planning and decision making processes that are perceived as unfair (Gross, 2007; Zoellner, Schweizer-Ries and Wemheuer, 2008). This perceived unfairness of planning procedures and their outcomes was found to be related to trust in stakeholders involved in the planning (Devine-Wright, 2013; Huijts, Molin and Steg, 2012).

In the current paper, the influence of process characteristics (trust in technology and stakeholders and perceived fairness) on the acceptance of energy infrastructure technologies is empirically examined. By directly comparing perceptions of wind power plants and electricity pylons, it will be investigated whether acceptance-relevant process parameters are similar across technologies or whether they are indeed technology-specific. The results yield valuable insights for planners on how to achieve a socially accepted planning of energy infrastructure projects.

Linzenich, A. and Ziefle, M.
Uncovering the Impact of Trust and Perceived Fairness on the Acceptance of Wind Power Plants and Electricity Pylons.
DOI: 10.5220/0006696001900198
In *Proceedings of the 7th International Conference on Smart Cities and Green ICT Systems (SMARTGREENS 2018)*, pages 190-198
ISBN: 978-989-758-292-9

2 SOCIAL ACCEPTANCE OF ENERGY TECHNOLOGIES

The discrepancy between the often high general support for an energy technology and a lower local acceptance of specific implementations is known as the “social gap” in energy infrastructure planning (Bell, Gray and Haggett, 2005). Findings from past research on wind power projects show that local acceptance of a specific project is considerably affected by general support for the technology (Jones and Eiser, 2009; Walter, 2014). Among others, the following factors have been identified as vital for the acceptance of energy technologies: perceived benefits, barriers, and risks associated with the technology, trust in stakeholders responsible for the planning and implementation of projects, and perceived process fairness (Devine-Wright, 2013; Huijts et al., 2012; Visschers and Siegrist, 2014).

In previous studies, two dimensions of process fairness have been distinguished: procedural fairness of planning decisions and distributional fairness relating to how benefits, costs, and risks are shared among the population (e.g., Gross, 2007; Huijts et al., 2012). Planning procedures perceived as fair enable citizens to participate in the planning process and they take the interests of all citizens into account (Gross, 2007; Keir, Watts and Inwood, 2014). As found, opposition to energy infrastructure projects was not solely directed against the technology per se but also against planning processes and the distribution of benefits and costs that were perceived as unfair (Gross, 2007; Keir et al., 2014; Walker and Baxter, 2017). Distributional fairness refers not only to a fair distribution of benefits and risks or costs in the population in general but was also considered on a local level for residents living near proposed installation sites of energy infrastructure (Gross, 2007; Walker and Baxter, 2017). Perceived fairness, especially procedural fairness, was found to be related to trust in stakeholders (e.g., Devine-Wright, 2013).

When investigating the influence of trust on energy technology acceptance, recent studies mainly considered trust in stakeholders responsible for the technology such as energy companies and political actors (Bronfman, Jiménez, Arévalo and Cifuentes, 2012; Huijts et al., 2012; Visschers and Siegrist, 2014). In other technology contexts (e.g., AAL/medical technologies, e-commerce), also trust in technology was identified as acceptance-relevant parameter (Grabner-Kräuter and Kaluscha, 2003; Montague, Kleiner and Winchester, 2009). So far, studies investigating the relationship between trust in technology and acceptance of large-scale energy technologies are scarce (e.g., Achterberg, Houtman, van Bohemen and Manevska, 2010). As trust in stakeholders and trust in technology might not be the same, the influence of both trust types on acceptance should be investigated.

Studies examining the impact of process characteristics (trust and fairness) on energy technology acceptance have most often been limited to a single technology or compared technologies referring to the same part of the energy supply such as different energy sources (e.g., Bronfman et al., 2012; Visschers and Siegrist, 2014; Zoellner et al., 2008). But so far, it is still not understood if acceptance-relevant process parameters are similar across *different elements* of the energy supply system (e.g., electricity generation and transmission).

Taking wind power plants and electricity pylons as example for different elements in the energy supply chain, the research aims of the present study were: 1) A direct comparison of acceptance, trust in technology and stakeholders, and perceived fairness of project planning for wind power plants and electricity pylons. 2) An investigation of acceptance-relevant process characteristics for wind energy and power line planning.

3 METHOD AND MATERIAL

In the following, an overview of the online survey and the survey sample is given.

3.1 Questionnaire Design

The questionnaire items were chosen based on a literature analysis of previous acceptance studies in the energy infrastructure context. First, respondents were surveyed for demographic data and attitudinal variables: age, gender, technical self-efficacy (evaluated using four items from Beier, 1999), individual risk orientation, i.e., a person’s general attitude towards risk and safety (assessed by four items from Rohrmann, 2005), and self-assessed knowledge about the wind energy and power line technology (item “I feel well informed about the wind turbine [electricity pylon] technology”).

In the second part, participants were asked to rate electricity pylons and wind power plants in terms of general and local acceptance, trust in the underlying technology and involved stakeholders, and perceived fairness. To enable a direct comparison of both technologies, the same items were used to assess evaluations of wind power plants and electricity pylons.

General acceptance was measured using two items from Lienert et al. (2015) and Zoellner et al. (2008). *Local acceptance* was assessed by asking respondents to evaluate their reactions (supportive, happy, concerned) to the construction of a (hypothetical) wind power plant / electricity pylon in their neighborhood using three items from Lienert et al. (2015), O'Garra, Mourato and Pearson (2008), and Soland, Steimer and Walter (2013). To assess *trust* in wind energy and power line projects, participants had to indicate their trust in the underlying technology as well as trust in wind farm / grid operators and politics. The two items on *trust in actors* (one for companies, one for politics as a whole) were based on Bronfman et al. (2012) and Huijts, Midden and Meijnders (2007). *Perceived fairness* in wind energy and power line planning was assessed in terms of procedural and distributional issues. Covered *procedural fairness* aspects were perceived fairness and publicness of the siting process (two items based on Baxter et al., 2013, and results from Gross, 2007), the consideration of interests of all citizens, and opportunities for public participation during the planning process (two items based on Zoellner et al., 2008, and Soland et al., 2013). *Distributional fairness* was assessed by two items on the fair distribution of benefits and risks in the population, especially considering the benefit/risk-ratio for residents living near proposed installation sites (based on MacGregor, Slovic and Morgan, 1994, Wolsink, 2000, and results from Gross, 2007).

Like measures for individual characteristics, all items on wind power plant and electricity pylon perceptions were assessed on six-point Likert scales (1 = "do not agree at all", 6 = "fully agree"). Thus, values > 3.5 signify approval to and values < 3.5 indicate rejection of a statement. Results of reliability testing are depicted in Table 1.

Table 1: Results of reliability testing.

Construct	Technology	Number of items	α
General acceptance	Wind power plant	2	.82
	Electricity pylon	2	.81
Local acceptance	Wind power plant	3	.86
	Electricity pylon	3	.84
Trust in projects	Wind power plant	3	.81
	Electricity pylon	3	.68
Perceived fairness	Wind power plant	6	.82
	Electricity pylon	6	.82

3.2 Sample

The online survey was conducted in November 2016 in Germany. Respondents were invited to participate personally, via e-mail, discussion forums, and social media. 114 people took part in the study. The participants were volunteers who were not rewarded for their participation. After excluding incomplete data sets and internally inconsistent answering patterns, 70 data sets were used for further analysis, which corresponds to a response rate of 61%.

The mean age of the sample was 30.4 years (*SD* = 12.3, range: 15-62 years) with 52.9% females and 47.1% males. 21.4% of the participants reported to hold a university degree and an equal share of respondents had completed vocational training. Another 44.3% of participants had obtained a certificate for university entrance as highest educational achievement, while 8.5% reported to have a general certificate of secondary education or a lower secondary school qualification. 4.3% stated to have no educational attainment (yet).

The majority of respondents stated to live in the city center (58.6%), whereas 30.0% indicated to reside in the outskirts of a city or a suburb. 11.4% of the sample lived in a rural area. The sample reported to have a positive technical self-efficacy (M = 4.19, SD = 1.33) but self-assessed specific knowledge about the power line technology was rather low on average (M = 2.64, SD = 1.39). Participants felt significantly better but still not well informed about the wind turbine technology (M = 3.06, SD = 1.51; $F(1,69)$ = 15.65, p < 0.001, η^2 = .19). The risk orientation (general willingness to take risks) was medium (M = 3.33, SD = 1.01).

4 RESULTS

First, perceptions of wind power plants, electricity pylons, and process characteristics of wind farm and power line projects are reported. In a second step, the influence of trust and perceived fairness on the acceptance of wind power plants and electricity pylons is examined.

4.1 Perceptions of Wind Power Plants and Electricity Pylons

Mean values for perceptions of wind power plants and electricity pylons are depicted in Figure 1.

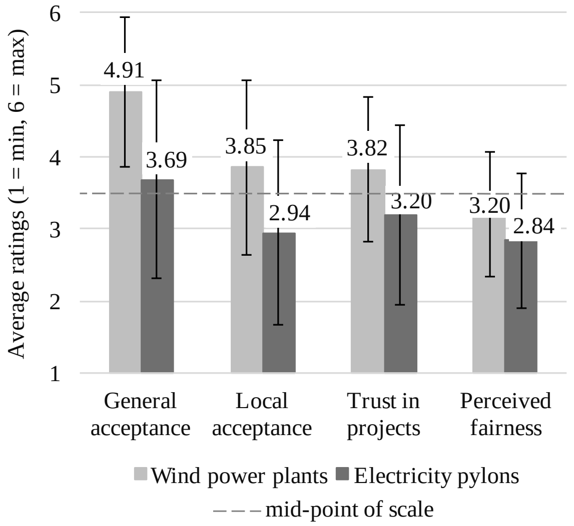

Figure 1: Ratings of general and local acceptance, trust in projects, and perceived fairness for wind power plants and electricity pylons (n = 70).

General acceptance of wind power plants was positive ($M = 4.91$, $SD = 1.04$), while electricity pylons were rated significantly lower and rather neutral ($M = 3.69$, $SD = 1.38$; $F(1,69) = 48.42$, $p < 0.001$, $\eta^2 = .41$). For both types of infrastructure, local acceptance was lower than general support (wind turbines: $M = 3.85$, $SD = 1.21$; electricity pylons: $M = 2.94$, $SD = 1.29$), but again wind power plants obtained a significantly higher rating ($F(1,69) = 27.75$, $p < 0.001$, $\eta^2 = .29$).

The general trust in power line projects (mean value summarizing trust in the underlying technology and stakeholders involved in project planning) was slightly negative ($M = 3.20$, $SD = 1.25$). In contrast, trust in wind power projects was significantly more positive ($M = 3.82$, $SD = 1.00$; $F(1,69) = 22.93$, $p < 0.001$, $\eta^2 = .25$).

Looking deeper into the different types of trust (Figure 2), trust in the technology itself was highest and trust in politics lowest for both technologies, while trust in wind farm and grid operators ranged in between. Comparing mean values for wind power plants and electricity pylons, participants had significantly more trust in the wind turbine ($M = 4.69$, $SD = 1.06$) than in the power line technology ($M = 3.64$, $SD = 1.35$; $F(1,69) = 34.36$, $p < 0.001$, $\eta^2 = .33$). A significant difference between electricity pylons and wind power plants was also found for trust in wind farm / grid operators: Respondents reported a slightly positive trust in wind farm operators ($M = 3.74$, $SD = 1.25$) but slightly rejected trust in grid operators ($M = 3.11$, $SD = 1.50$; $F(1,69) = 13.79$, $p < 0.001$, $\eta^2 = .17$). Trust in politics was rated on a similarly negative level for both technologies (wind turbines: $M = 3.04$, $SD = 1.52$; electricity pylons: $M = 2.83$, $SD = 1.56$).

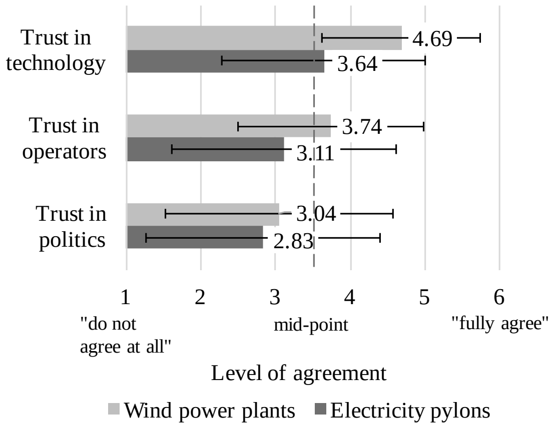

Figure 2: Descriptive statistics for different types of trust in wind farm and power line projects (n = 70).

Perceived fairness (Figure 1) was slightly negative for wind farm projects ($M = 3.20$, $SD = 0.86$) and significantly lower for power lines ($M = 2.84$, $SD = 0.93$; $F(1,69) = 12.07$, $p < 0.01$, $\eta^2 = .15$). Zooming into the different aspects of fairness (Figure 3), also the individual items were rated as rather negative to neutral. The two items respondents least agreed to were aspects of procedural fairness: consideration of interests of all citizens (wind turbines: $M = 2.93$, $SD = 1.21$; electricity pylons: $M = 2.49$, $SD = 1.29$) and participation opportunities in the planning process (wind turbines: $M = 2.96$, $SD = 1.17$; electricity pylons: $M = 2.53$, $SD = 1.26$). Compared with power line projects, wind power planning was perceived as more adequately but still not sufficiently considering interests of all citizens ($F(1,69) = 7.81$, $p < 0.01$, $\eta^2 = .10$) and providing opportunities for public participation ($F(1,69) = 8.13$, $p < 0.01$, $\eta^2 = .11$). Wind energy and power line projects did not significantly differ in perceptions of siting processes – both were regarded as similarly fair and open to the public – but in evaluations of distributional fairness. Respondents did rather not agree that risks and benefits were fairly distributed among citizens during the construction and operation of wind power plants ($M = 3.10$, $SD = 1.07$). For electricity pylons, respondents perceived an even higher level of unfairness ($M = 2.73$, $SD = 1.21$; $F(1,69) = 5.83$, $p < 0.05$, $\eta^2 = .08$). Distributional fairness on a local level (benefit-risk-ratio for residents compared to the public) was perceived slightly better but still not positive. Values were neutral for wind turbines ($M = 3.59$, $SD = 1.23$) and significantly more negative for pylons ($M = 3.03$, $SD = 1.25$; $F(1,69) = 13.47$, $p < 0.001$, $\eta^2 = .16$)

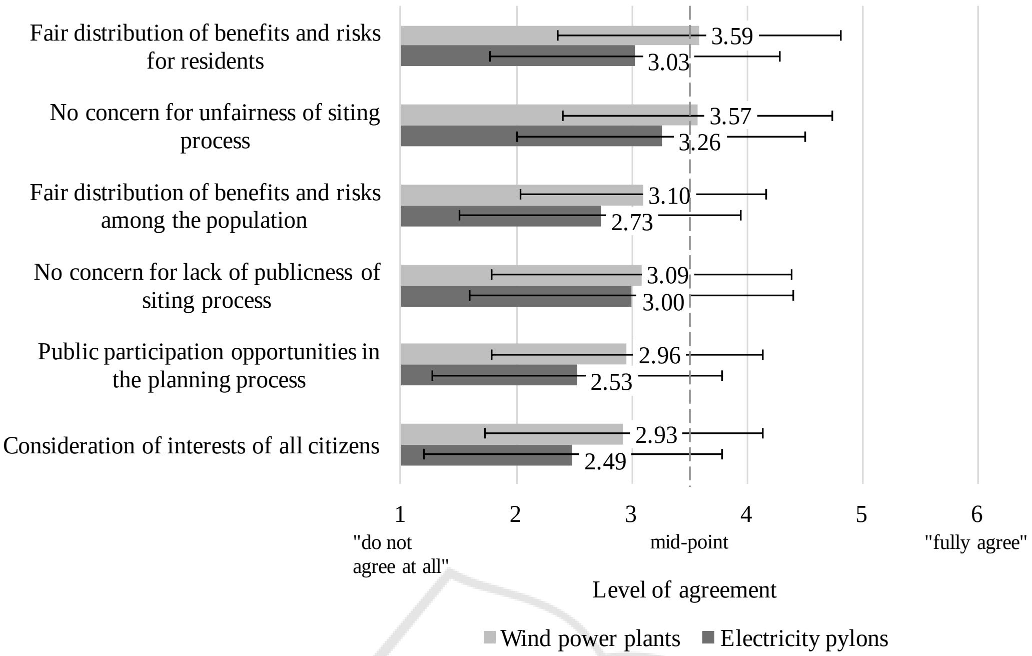

Figure 3: Descriptive statistics for aspects of perceived fairness related to wind farm and power line projects (n = 70).

4.2 Influence of Trust and Perceived Fairness on Acceptance

Standard multiple regression analyses were conducted to investigate the influence of trust and perceived project fairness on acceptance of wind power plants and electricity pylons. The enter method was used because trust and fairness have already been identified as acceptance-relevant parameters in past research. As a first step, mean values of the trust and perceived fairness scales were entered as independent variables and general acceptance as dependent variable.

The resulting regression models explained a similar amount of variance in general acceptance: 33.2% of variance for wind power plant acceptance ($F(2,67) = 18.19$, $p < 0.001$) and 33.7% of variance for electricity pylon acceptance ($F(2,67) = 18.56$, $p < 0.001$). In both cases, perceived fairness had no impact and only trust in projects contributed significantly to general acceptance (wind: ß = .60, p < 0.001; electricity: ß = .57, $p < 0.001$) – with a positive evaluation of trust increasing acceptance.

For the investigation of local acceptance, general acceptance was added as independent variable besides trust and fairness due to findings from past research on wind farms according to which general support considerably impacts local acceptance (e.g., Jones and Eiser, 2009; Walter, 2014). The model for wind power plants explained 38.9% of variance for local acceptance ($F(3,66) = 15.64$, $p < 0.001$) with general acceptance being the strongest predictor (ß = .53, $p < 0.001$), followed by perceived fairness (ß = .22, $p < 0.05$).

Both factors influenced acceptance positively: the higher general support and fairness ratings were, the more favorable was local acceptance. Trust in wind power projects did not directly influence local acceptance of wind turbines.

Strikingly, in the power line context general acceptance and process characteristics had a greater predictive power: 66.4% of variance in local acceptance were explained by general acceptance as strongest predictor (ß = .76, $p < 0.001$) and by fairness (ß = .30, $p < 0.01$; $F(3,66) = 46.45$, $p < 0.001$). Again, the two factors increased acceptance, whereas trust in projects had no impact.

To sum up so far, trust was found to impact general acceptance. General acceptance and process fairness were identified as promoters of local acceptance for both technologies. In a next step, the contribution of these factors was analyzed in detail by looking deeper into trust and fairness aspects. The aim was to find out which trust and fairness parameters were most acceptance-relevant for wind energy and power line projects by performing stepwise regression analyses.

First, the impact of trust items on general acceptance was examined. The resulting regression models are depicted in Tables 2 and 3.

Table 2: Regression model for the influence of trust types on *general acceptance* of **wind power plants**.

	B	SE B	β	T
Constant	1.32	.36		3.64
Trust in wind power plant technology	.77	.08	.78**	10.10

Adjusted $R^2 = 0.59$; ** $p < 0.01$; $n = 70$

Table 3: Regression model for the influence of trust types on *general acceptan*ce of **electricity pylons**.

	B	SE B	β	T
Constant	1.18	.36		3.32
Trust in electricity pylon technology	.69	.09	.67**	7.50

Adjusted $R^2 = 0.44$; ** $p < 0.01$; $n = 70$

For both wind power plants and electricity pylons, trust in the underlying technology was the sole trust variable that contributed significantly to general acceptance (wind: ß = .78, $p < 0.001$; electricity: ß = .67, $p < 0.001$). In the wind power context, trust in technology explained 59.4% of variance in general acceptance ($F(1,68) = 102.02$, $p < 0.001$), whereas for electricity pylons, the model had a slightly lower predictive power (44.4%; $F(1,68) = 56.21$, $p < 0.001$).

Subsequently, the influence of fairness parameters on local acceptance was investigated to identify the critical hotspots of planning. Results for wind power plants are depicted in Table 4.

Table 4: Regression model for the influence of fairness characteristics on *local acceptance* of **wind power plants**.

	B	SE B	β	T
Constant	2.44	.41		5.92
Fairness of benefit-risk distribution for residents	.39	.11	.40**	3.63

Adjusted $R^2 = 0.15$; ** $p < 0.01$; $n = 70$

The model for local acceptance explained 15.0% of variance in wind turbine ratings ($F(1,68) = 13.16$, $p < 0.01$) and only included the *fair distribution of benefits and risks for residents* (ß = .40, $p < 0.01$): the more positive evaluations of local distributive fairness, the higher was local acceptance. Fairness characteristics had a noticeably higher impact on the local acceptance of electricity pylons (see Table 5). 48.8% of variance in local acceptance were explained by fairness items ($F(3,66) = 22.95$, $p < 0.001$). Again, the *fair distribution of benefits and risks for residents* exerted the highest positive influence (ß = .69, $p < 0.001$). Also, the adequate *consideration of interests of all citizens* increased local acceptance (ß = .32, $p < 0.01$). In contrast, acceptance was lower for respondents who were less concerned about the siting process not being open to the public (ß = -.25, $p < 0.05$).

Table 5: Regression model for the influence of fairness characteristics on *general acceptance* of **electricity pylons**.

	B	SE B	β	T
Constant	.68	.34		1.97
Fairness of benefit-risk distribution for residents	.71	.10	.69**	6.97
Consideration of interests of all citizens	.32	.09	.32**	3.59
No concern for siting process being non-public	-.23	.09	-.25*	-2.46

Adjusted $R^2 = 0.49$; * $p < 0.05$, ** $p < 0.01$; $n = 70$

5 DISCUSSION AND CONCLUSION

To unveil whether requirements for a fair and trusted project planning are the same for *different parts* of the energy supply system or whether they are technology-specific, the present study took wind power plants and electricity pylons as examples and directly compared the impact of trust (meaning trust in stakeholders *and* trust in technology) and perceived fairness on acceptance.

In the present study, general and local acceptance were significantly higher for wind power plants than for electricity pylons, which indicates a comparably higher potential for opposition to power line projects and mirrors findings from Zaunbrecher et al. (2014).

Similar patterns *across* technologies were spotted for general trust and fairness ratings and their influence on acceptance. For wind energy and power line projects, trust in technology was evaluated more positively than trust in wind farm / grid operators. In contrast to past studies on large-scale technology acceptance (e.g., Huijts et al., 2007), the present results showed a lower trust in politics compared to companies regarding the planning and operation of wind power plants and power lines. This might reflect the current political and societal situation in November 2016 (e.g., the Edelman Trust Barometer found trust in politics and other established institutions to have decreased compared to the previous year in Germany and many other countries around the world; Edelman, 2017). Still, this finding underlines the importance for political actors to make transparent and consistent decisions that take account of environmental and citizen needs to successfully introduce energy infrastructure projects.

For wind power and power line projects, fairness parameters were (mostly) evaluated negatively. As the two fairness characteristics rated worst were the *consideration of interests of all citizens* and *public participation opportunities in the planning process*, planners should pay particular attention to interests from different citizen groups and offer the public better-suited ways to participate in the planning.

Corroborating findings from past research, (e.g., Devine-Wright, 2013; Visschers and Siegrist, 2014; Zoellner et al., 2008), trust and fairness were revealed as relevant to acceptance across technologies. But in this study, trust and fairness affected *different* acceptance levels. Trust in technology impacted general acceptance of wind turbines and electricity pylons, while general acceptance and perceived fairness were factors influencing local acceptance.

As a first study, the current research revealed that trust in the underlying technology had a significant impact on general acceptance of wind power plants and electricity pylons, indicating a general, overarching pattern across technologies and confirming results from Achterberg et al. (2010) for hydrogen technologies. This is interesting because previous studies have mainly focused on the role of trust in stakeholders for the acceptance of energy technologies, neglecting trust in the technology itself.

Technology-specific findings referred to the influence of individual fairness parameters on local acceptance of energy infrastructure projects. Fairness aspects were revealed to play a more important role for electricity pylon acceptance compared to wind power plants. For both electricity pylons and wind power plants, a fair distribution of benefits and risks for residents was relevant to local acceptance. But since this was also the best-rated fairness item, it might not be the most acceptance-critical point compared to procedural fairness issues. In the power line context, local acceptance was also found to be impacted by the consideration of interests of all citizens and the “publicness” (or rather “non-publicness”) of the siting process. Findings for “publicness” of the siting process seem at first contraintuitive: the less concerned respondents were about the planning process not being open to the public, the lower was local acceptance of power line projects. A possible explanation could be that people who perceive siting processes to be highly public might have been more frequently confronted with planned power line projects through media reports and public discussions. This could lead to feelings of ubiquity (i.e., “power lines are constructed everywhere”), resulting in a decreased acceptance. But this explanation remains speculative and needs to be investigated in future studies.

Some methodological issues of the current study should be considered in future research. In our study, hypothetical scenarios for wind energy and power line projects were compared. Hence, a direct comparison of case studies on actual projects is important for further insights into the relevance of process parameters for project acceptance. A further limitation is the small and skewed sample which was referred to in this study. For the adopted approach, the sample size is sufficient in a methodological and statistical sense. However, one should consider that participants volunteered to take part in the study and, in addition, were highly educated, thus the findings might not represent the “normal” population. Future studies should aim for a census representing sample to measure the view of an entire population on the topic and should seek for a replication of the findings with a larger and more balanced sample.

Another topic which needs a deeper focus in future research, regards the role of trust in technology for energy infrastructure acceptance by identifying the factors which constitute trust in large-scale energy technologies (e.g., perceived reliability, perceived safety, or an interplay of benefits and costs; Montague et al., 2009) and by investigating the relationship between trust in technology and trust in stakeholders.

The results of the present study can be used to inform project planning for energy infrastructure technologies. Planners need to be aware of: 1) the relevance of trust in stakeholders *and* (equally important but so far largely neglected) trust in the technology and 2) the need for a fair planning process with a just distribution of benefits and risks in the population.

ACKNOWLEDGEMENTS

The authors would like to thank Feyza Gölpinar for research support. This work had been inspired by the Excellence Initiative of German Federal and States Government (Project UFO, urban future outline) and has been funded by the European Institute of Technology & Innovation (EIT) within the EnCO2re flagship program Climate-KIC.

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