Pitfalls when Placing Electricity Pylons - The Influence of Age on Acceptance

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Abstract. The increasing penetration of renewable energies influences and changes the transmission task of electricity in Germany. However, the planning and construction of new lines is met with resistance from the public. To address public concerns adequately, a tailored information and communication concept is needed, for which knowledge about acceptance-relevant factors for different user groups is indispensable. In this paper we explore acceptance-relevant attributes in the context of electricity pylons contrasting attitudes of older and younger persons. Results of a conjoint study indicate that both age groups basically have comparable acceptance levels, but younger persons were found to be more sensitive with regard to distance of the pylon and possible health effects. Additionally, acceptance patterns similar to those for cell tower location were found, which implies that the analyzed attributes are not only stable across demographic groups but also across technologies.

Keywords: Energy infrastructure · Technology acceptance · Electricity pylons · User diversity · Renewable energies · Conjoint analysis

1 Introduction

The future high proportion of feature-dependent power generation as a consequence of the increasing penetration of renewable energies influences and changes the transmission task of electricity. Especially the high wind power capacity in the north of Germany requires an electricity transport from the north to the south of Germany. This is why the need for new transmission lines is a vital topic for the achievement of the ambitious aims of the energy transition.

But, the planning and construction of new lines is often met with resistance from the public, as they fear e.g. health problems due to radiation [1, 2] or criticize the visual impact on the landscape [3, 4]. Ignoring this criticism may lead to citizens' protests, which can cause delays and even cancelling of entire projects [5, 6]. Thus, public acceptance is a critical factor not only for the successful but also for the sustainable

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implementation of novel technologies. Often it is assumed that any novel technology naturally evokes concerns and criticism in the very beginning and that those concerns fade as the public gets attuned to it over time [7]. Nonetheless, there are some major arguments to actively address the concerns, for two reasons: First, technology acceptance is a complex phenomenon [8, 9] which needs a specific evaluation methodology [10]. Different from former studies on acceptance, in which a more or less static single factor evaluation was done, it is increasingly understood that reliable acceptance decisions include several factors at a time. Characteristically, negative factors and positive factors are weighed, related to each other and then built to a final decision. This is especially the case in large-scale technologies, in which many, some times contradictory motives on different (time)scales have to be considered. Thus, contemporary acceptance research must be directed to identifying the relevant factors, understand the nature of the weighing and factors compensating each other and learn which of the factors might be scalable. Second, public acceptance should be implemented as early as possible within the technology development in order to adapt technology decisions in line with public opinions. Understanding the fears and wishes of the citizens is the grounding to react adequately and to specifically tailor communication and information policies. A prerequisite for such a concept to be successful is the knowledge about which acceptance-relevant factors are important to which user groups [7]. Understanding aged persons seems to be an especially crucial cornerstone in the context of technology acceptance, as many European countries face a demographic change with an increasing penetration of life with technology. Multiple studies have therefore addressed the attitude towards technology of older adults [8, 11–13]. For renewable energies, age was found to also influence attitudes towards green energy, nuclear energy and micro-scale technologies [14]. In particular, it was for example found that older persons were less positive towards wind power [15] and were less willing to pay for renewable energy and energy efficiency [16].

As the grid expansion is a topic closely related to the turn towards more renewable energy sources, it is reasonable to assume that age also plays a role for the acceptance and preferences concerning pylon placement. Therefore, we focused on an age contrast with regard to acceptance-relevant factors of electricity pylon siting. Two research questions on this topic will be addressed in this study:

1. How do different acceptance-relevant attributes in the context of electricity pylons siting (health concerns, compensation payment, distance to housing, location of installment) relate to each other?
2. Can age-effects be found for the weighing of these factors?

To answer the research questions, we conducted an empirical study (conjoint analysis) which was designed as an online study. Our research contributes to the existing literature on acceptance of energy infrastructure, as well as the influence of user factors on acceptance patterns. It provides useful insights for energy providers, urban planners and energy policy makers into social acceptance patterns and possible pitfalls for the siting of power lines.

2 Grid Expansion in Germany and Specifications for Placements of Electricity Pylons

The transformation to a sustainable energy supply without the use of nuclear power and with low carbon emission in Germany leads to changing geographical electricity generation patterns and thus to changing electricity transmission needs. The transport of electrical energy over long distances is usually performed by voltage levels of 220 kV and especially 400 kV. Most lines at those voltages are built as overhead line as underground cabling as option is still lacking technical long-term experience at those voltage levels and is much more expensive.

To avoid unnecessary extension, the NOVA-principle[1] is applied in Germany. It implies that *prior* to the construction of new lines, the optimization as well as the reinforcement of the existing infrastructure (i.e. by mounting additional circuits on exiting poles) has to be carefully analyzed.

The need for reinforcement is usually identified on a point-to-point basis, which means that the concrete routing of the lines is not or only to a limited extent considered. Once the need for the new connection is determined by the system operator and confirmed by the national authority[2], it finds its way into the Federal Requirement Plan – still on a point-to-point basis. In the next steps the transmission system operator elaborates a first suggestion and possible alternatives for the routing of the line, initially in terms of an up to 1000 m wide corridor and later with precise positions for the pylons. In each case, the following process is led by the federal state authority or by the national authority, in case more than one federal state is concerned. Every citizen or organization is invited to get involved in the process which targets to identify a routing that considers technical, economic, environmental and social aspects. As a result, the system operator can be committed to analyze additional alternatives and obtain expert advice. The responsible authority eventually decides on the final routing.

With regard to technical aspects, it has to be considered that the length of a line determines its technical parameters. The isolation distance needs to be kept, so that vegetation in the closer surrounding of the line is only possible to a limited extent and the underground has to be suitable for the foundation of the pylons. The complexity of the construction of a line is also higher, if the route is twisty as the direction of the line has to chance often and more or different pylons have to be built. On the voltage level of 220 kV and above, no special need for closeness to residential areas exists as the supply of the consumers is performed with lower voltages. Nevertheless, at some points the closeness to residential areas cannot be avoided. In these cases, the knowledge

[1] NOVA means “Netzoptimierung vor Verstärkung vor Ausbau,” in English: “network optimization before reinforcement before extension”.

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about public preferences for siting scenarios is crucial at this point in order to timely react on possible concerns and to develop a solution that suits both, developers and citizens.

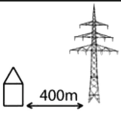
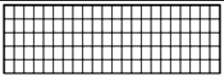
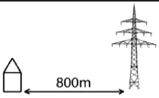
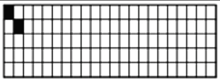
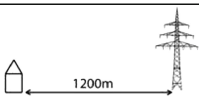
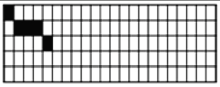
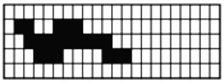
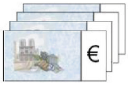
3 Methodology

A Choice-Based Conjoint (CBC) study was designed with Sawtooth Software as an online survey. Originating in market research, conjoint analysis is a measurement approach that allows for the determination of relative preferences and closely mimics decision processes of respondents. In conjoint analyses, participants are presented with a set of attributes that make up a product, or, in this case, a scenario. Participants compare different scenarios against each other, which are defined by the same attributes, but by different manifestations (or levels) of the attributes. This way, participants are forced to take into account bundles of characteristics for their choice rather than comparing isolated characteristics of scenarios. Because of this, the choice task models real-life decisions in a more realistic way than other types of questionnaire techniques. By analyzing the choice behavior of the participants, it is possible to calculate the importance of one attribute for the decision relative to the other attributes (relative importance), and furthermore, to calculate the value of a level of an attribute for the choice of a scenario relative to the others levels of an attribute (part-worth utility).

Questionnaire Design. The questionnaire included items on demographic information, living area, proximity to electricity pylons and the use of “green electricity”. Because earlier studies have shown that technical self-efficacy (TSE) [17] has an effect on technology acceptance and attitude towards energy related infrastructures, TSE was measured using eight selected items from Beier’s TSE-questionnaire [17] for which reliability had been previously tested [9]. All questions, with the exception of the demographic information, were answered on a six-point-Likert scale (“1 = do not agree at all” to “6 = fully agree”). Finally, participants were invited to leave comments on the topic.

Experimental Design/Selection of Attributes. For the conjoint task, the four attributes “location”, “distance to home”, “health effects” and “compensation payment” were chosen and were assigned appropriate levels (Table 1). Participants were presented with different infrastructure scenarios that differed concerning the frequency of health concerns, distance of the pylon to housing, location of pylon and amount of compensation payment. The attributes were chosen based on prior research on acceptance of technology infrastructure (mobile phone masts [10]) and the consultations of experts. They were adapted to the context of electricity pylons when necessary. This methodology additionally provides the opportunity to compare the same acceptance-relevant attribute across different technologies (mobile phone masts and electricity pylons) and identify possible generic fears and perceived threats that are stable across technologies. Levels were illustrated by pictures to enhance understanding (Table 1).

Table 1. Attributes and levels used in the conjoint study

Location	Distance to home	Frequency of health effects	Compensation payment
 near existing infrastructure	 400m	 never	 0€
 on an open field	 800m	 rarely	 250€
 in a forest	 1200m	 sometimes	 500€
		 often	 1000€

In an introduction before the conjoint tasks, the attributes, levels and mode of the survey were explained to the participants. For location, the levels "near existing infrastructure", "on an open field" and "in a forest" were chosen. These locations represent possible locations according to current policies for pylon siting in Germany. It is assumed that they are accepted differently, as they present a different degree of fit in a landscape: while the pylon on an open field is highly visible, a location in a forest disguises the lines, however, it comes at the cost of cutting down trees. Placing pylons near existing infrastructure has been favored in other studies on the subject, as it minimizes additional interferences with the environment. The "distance from home" is set at 400 m, 800 m and 1200 m. It was communicated to the participants in the introductory part of the study that even the nearest location (400 m) was in line with current regulations and fulfilled the security standard. Finally, possible subjective health risks such as dizziness, headaches etc. which are associated with EMF emitted from transmission lines were introduced at frequency levels ("never", "rarely", "sometimes" "often") [10]. The levels of the different attributes were combined into scenarios from which the participants had to chose the one they preferred most. For each choice task, the respondent was presented with three scenarios (Fig. 1). Because a full-factorial design would have yielded 144 (3 × 3 × 4 × 4) possible scenarios to judge, the amount of stimuli was reduced, so each participant only answered nine choice tasks, which were randomized across participants. To ensure design efficiency, a test for efficiency was applied (provided by Sawtooth Software). Taking into account 184 participants, the design was reported to have an efficiency of 100 % compared to the fully orthogonal design.

Data Collection. Data were collected in an online survey in Germany by distributing

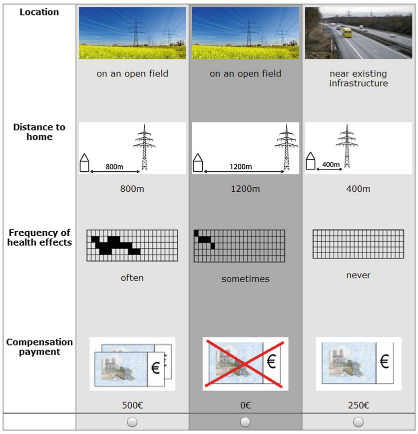


Fig. 1. Example of an original choice task from the conjoint study

the survey in social networks and online discussion forums. Citizen groups affected by the building of new power lines were especially invited to take part in the survey. The survey took approximately 15 min to complete.

3.1 Sample

231 participants took part in the survey. Because Sawtooth Software requires complete datasets for the conjoint analysis, all datasets with missing answers were excluded, so that 184 datasets remained for analysis. 44 % of the sample was female, 56 % male and the average age was 36.2 years (SD = 14.3). More than half of the participants (56.5 %) reported to hold a university degree, which shows that the sample was highly educated. The majority of the sample lived in the city center (41.3 %), followed by people living in the outskirts of a city (34.8 %), and the smallest group lived on the countryside (23.9 %). Most participants lived in an apartment house (60.9 %), further 26.1 % lived in a detached house.

On a scale of 1 (lowest) to 6 (highest), the average score for TSE was M = 4.6 (SD = 0.9). The self-reported knowledge about the grid expansion was low (M = 2.8, SD = 1.2). To control for effects of familiarity, participants were asked whether they lived within view of an electricity pylon (yes: 27.2 %, no: 72.8 %).

4 Results

The results of the conjoint analysis, average importances and part-worth utilities will be presented first for the whole sample and then contrasted for the two age groups.

Looking at the sample as a whole, an analysis of the average importances showed that health effects were by far the most important attribute for the choice of a scenario (Fig. 2) (54.8 %). It was followed by "location" (28.3 %), then by "distance" (11.0 %). A one-time compensation payment was the least important attribute (5.9 %).

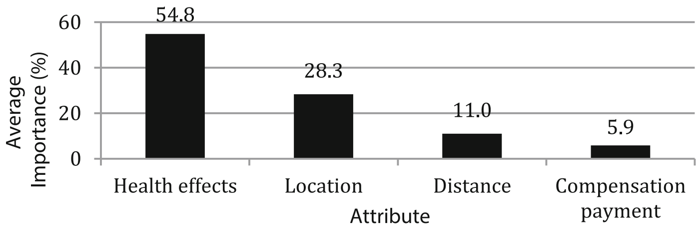


Fig. 2. Mean importances for attributes of pylon location scenarios (n = 184)

Next, the part-worth utilities for the different levels of the attributes are described (Fig. 3).

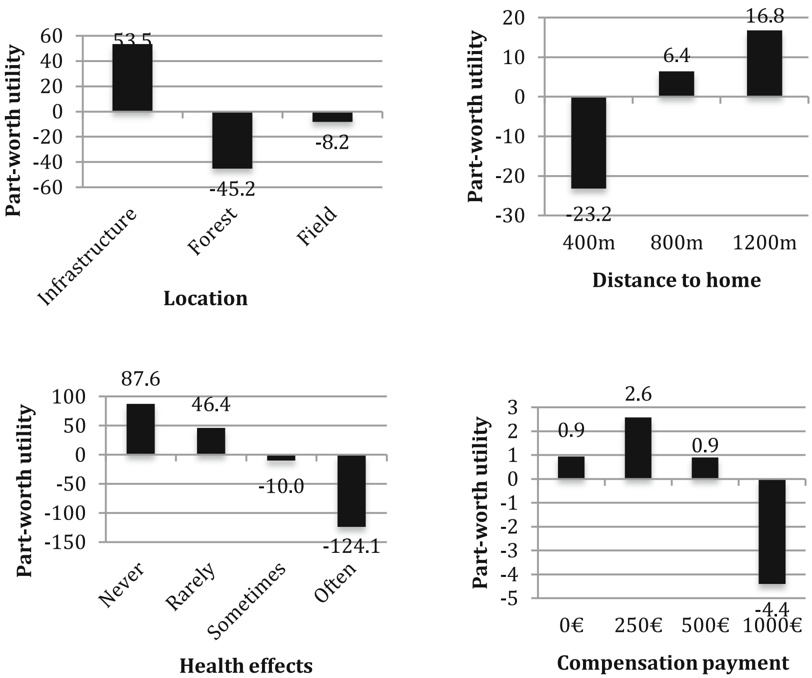


Fig. 3. Part-worth utilities for attributes location, distance to home, frequency of health effects, compensation payment (n = 184)

It was found that a pylon location near existing infrastructure was most accepted (53.5), while the location in a forest was the least accepted (–45.2). The location on an open field was less accepted than the placement near existing infrastructure, but more than the location "forest" (–8.2). Concerning the distance to home, the distances were accepted in descending order: the furthest away the pylon (1200 m), the more accepted the distance was (16.8). Next, the most important attribute "health effects" is examined. Participants accepted the most frequent health effects the least ("often": –124.1), and the least frequent health effects ("never": 87.6) the most. The opposition and acceptance were particularly strong for this attribute, as the large difference in utility values for the most and least accepted level showed (211.7), which is also reflected in the overall high average importance of this attribute. The compensation payment had almost no effect on the choice of the pylon placement scenario, which is illustrated by the very small differences in the part-worth utility values (difference between most and least accepted level: 7.0). Interestingly, the highest compensation payment of 1000€ was strongly rejected (–4.4), whereas 0€ and 500€ received the same, slightly positive rating (0.9). The most preferred compensation payment value was 250€ (2.6).

In the following, age effects were addressed. Participants were split into two age groups ("younger" group (<50 years), "older" group (50+ years)). The groups did not differ significantly in terms of gender distribution, however, the "older" group had a lower overall educational level ($p \leq 0.01$), lived on the countryside and in the outskirts of a city rather than in the city center ($p \leq 0.01$), and had a (slightly) lower TSE ($p \leq 0.01$). They did not differ in other possible influential factors on acceptance such as familiarity (living within view of pylons) or knowledge about grid expansion.

In a first step, the average importances for the young and old were compared (Fig. 4). It is evident that the groups did not differ greatly with regard to the most important attributes for the choice of the pylon-placement scenario. For both groups, possible health effects were the most important attribute when choosing a scenario, however, this was slightly less so for the older group (46.5 compared to 55.8). In contrast to this, the location was less important for the younger age group (26.6) than for the older participants (31.4). The distance had equally low importance for both groups (11.4 and 11.5). Compensation payment had an overall low importance, but its effect on the choice of a scenario was stronger for the old (10.5) than for the young group (6.2) (Fig. 4).

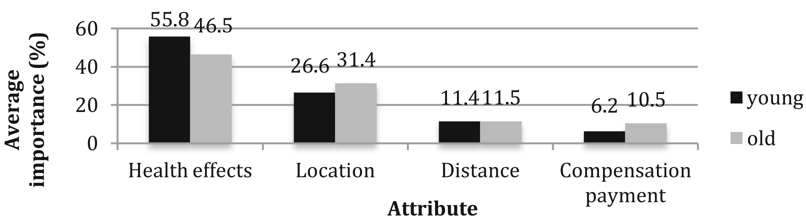


Fig. 4. Average importances for attributes of pylon location scenarios (younger: n = 141, older: n = 43)

Analyzing the attribute “location” for the two groups revealed that younger and older participants did not differ to a great extent in their preferences for the pylon setting. Both groups preferred a siting scenario in which the pylon is placed next to already existing infrastructure, followed by the placement on a field. The placement in a forest is most strongly rejected by both groups (Fig. 5).

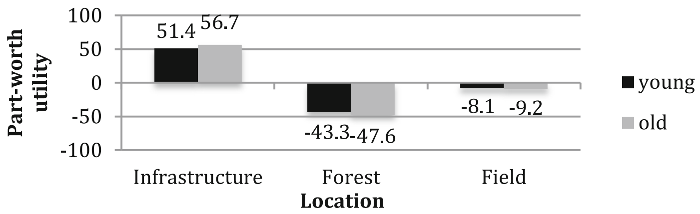


Fig. 5. Part-worth utilities for attribute “location” for age groups (young: n = 141, old: n = 43)

The preferences for the distance from the current place of living were more distinct between the two groups than for the location. The older and younger participants agreed in the fact that the closest location (400 m) was the least accepted. However, the young group preferred 1200 m over 800 m, while it was the other way around for the older participants. It is also noteworthy that the preference for 1200 m over 800 m by the young group was clearer (difference between the two levels: 15.9) than the preference of 800 m over 1200 m by the old group (difference: 7.0), indicated by the greater difference between the part-worth utility scores for the young group (Fig. 6).

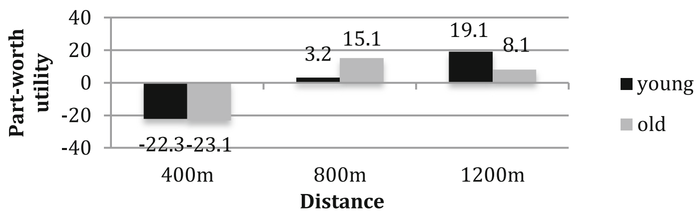


Fig. 6. Part-worth utilities for attribute “distance” for age groups (younger: n = 141, older: n = 43)

The preference patterns for the attribute “health effects” were the same for the two age groups: in both groups, acceptance declined with an increasing frequency of health effects. It is notable that health effects which occur “often” were much stronger rejected in comparison to “sometimes” by the young (–128.6) than by the old group (–92.7) (Fig. 7).

As already mentioned above, the compensation payment had only a very small effect on the choice of the pylon placement scenario, which is illustrated by the very small differences in the part-worth utility values. Differences between the groups exist, but they should not be overestimated because of the overall low effect on the choice of

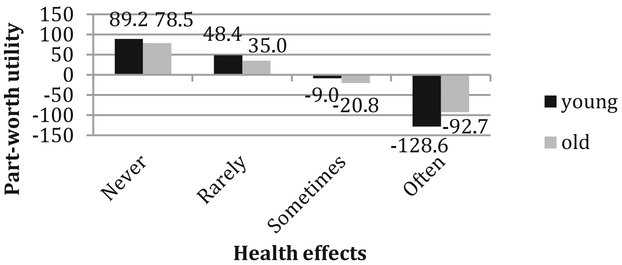


Fig. 7. Part-worth utilities for attribute "health effects" for age groups (younger: n = 141, older: n = 43)

the scenario. It is remarkable, however, that the highest compensation payment is not the best-accepted solution for either of the two groups (Fig. 8).

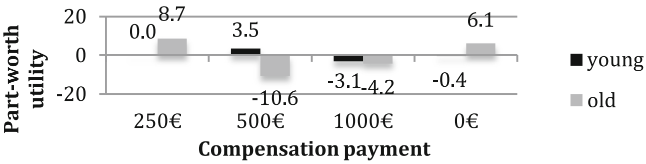


Fig. 8. Part-worth utilities for attribute "compensation payment" for age groups (younger: n = 141, older: n = 43)

Concluding, the best accepted scenario for the young participants would be a pylon placement near existing infrastructure, 1200 m away from their residential location, causing no health issues, with 500€ compensation payment. The scenario for the old participants looks similar: near existing infrastructure, with no health effects, but only 800 m away from their home with 250€ compensatory payment.

5 Discussion

Overall, the study was based on two different research questions. One was directed to the question if age of persons has an influence on the preference for a pylon placement scenario and the way the acceptance relevant criteria were evaluated. The results indicate that this is only partly true. It was found that the overall importance of the presented attributes was the same for young and old participants. The only noteworthy difference was found for the preference of the distance to home and frequency of health effects. Young participants presented themselves more sensitive than the older group: They favored a pylon location that was further away and were also more critical about possible health effects. A possible explanation could be that young people are generally in a better state of health than elders, and are thus more critical towards any impairment that could be caused. The overall more pronounced criticism of the young in combination with a higher technical self-efficacy compared to the older group could be an effect of them being better informed and thus also more informed about possible negative consequences.

Concerning the acceptance of compensation payments, it does not seem logical that the highest amount of compensation payment should have a similar part-worth utility value to "no compensation payment", and that 250€ are more accepted than 500€. Because of the minor differences in the part-worth utilities, the "preferences" for the different amounts of payment will be treated as pure chance. Given the fact that this attribute had hardly any significance at all and that the preferences were rather arbitrary, it seems that compensation payment does not have an effect on the acceptance of a siting scenario. Future studies will have to evaluate whether this is because the payment offered is too low, or because health effects cannot be compensated with money or if a compensation payment is rejected altogether in this context.

Another interesting finding is the striking parallel to the study with similar attributes on cell tower placement by Arning et al. [10]. In both studies, health effects were found to be the most important attribute for the choice of a scenario. Compensation payments, in contrast, were among the least important attributes. This suggests that these preference patterns are stable not only across different groups of people, but also across different technology contexts. With regard to the planning of any infrastructure, which could cause concerns related to health, this means that planners of such infrastructures should be aware of the power of these concerns.

There are of course further factors influencing acceptance of transmission lines which have not been treated in this study because of the special methodology chosen, for example fairness of the decision process and the influence of the sources of information, as mentioned by one participant in a comment:

> "(Acceptance of the new transmission line) depends on the objective necessity for the local electricity supply, which has not been proven by independent sources. (…) As long as we feel cheated by the economy and politics, there will be no acceptance of the new transmission lines." (female, member of citizen protest group)

Regardless of the results found in this study, the possibility remains that differences between groups based on user characteristics also exist in the case of pylon placement, bearing in mind that the sample was very well educated. It would be insightful to extend the research onto other target groups for communication and information concepts, also taking into account the role opinion leaders play for citizen protest against power line siting.

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References

1. Poortinga, W., Cox, P., Pidgeon, N.F.: The perceived health risks of indoor radon gas and overhead powerlines: a comparative multilevel approach. Risk Anal. **28**, 235–248 (2008)
2. Jay, S.: Pylons in the back yard: local planning and perceived risks to health. Environ. Plan. C Gov. Policy **25**, 423–438 (2007)

3. Atkinson, G., Day, B., Mourato, S., Palmer, C.: Amenity or eyesore? negative willingness to pay for options to replace electricity transmission towers. Appl. Econ. Lett. **11**, 203–208 (2004)
4. Devine-Wright, P., Batel, S.: Explaining public preferences for high voltage pylon designs: an empirical study of perceived fit in a rural landscape. Land Use Policy **31**, 640–649 (2013)
5. Neukirch, M.: Konflikte um den Ausbau der Stromnetze [Conflicts about the grid expansion]. Stuttgarter Beiträge zur Organisations- und Innovationsforschung (SOI) [Contributions to Organization and Innovation Research from Stuttgart]. Discussion Paper 2014-01 (1/2014), ISSN 2191-4990 (2014)
6. Cotton, M., Devine-Wright, P.: Putting pylons into place: a UK case study of public perspectives on the impacts of high voltage overhead transmission lines. J. Environ. Plan. Manag. **56**, 1225–1245 (2012)
7. Ziefle, M., Schaar, A.K.: Technical expertise and its influence on the acceptance of future medical technologies: what is influencing what to which extent? In: Leitner, G., Hitz, M., Holzinger, A. (eds.) USAB 2010. LNCS, vol. 6389, pp. 513–529. Springer, Heidelberg (2010)
8. Arning, K., Ziefle, M.: Different perspectives on technology acceptance: the role of technology type and age. In: Holzinger, A., Miesenberger, K. (eds.) USAB 2009. LNCS, vol. 5889, pp. 20–41. Springer, Heidelberg (2009)
9. Zaunbrecher, B.S., Kowalewski, S., Ziefle, M.: The willingness to adopt technologies: a cross-sectional study on the influence of technical self-efficacy on acceptance. In: Kurosu, M. (ed.) HCI 2014, Part III. LNCS, vol. 8512, pp. 764–775. Springer, Heidelberg (2014)
10. Arning, K., Kowalewski, S., Ziefle, M.: Health concerns vs. mobile data needs: conjoint measurement of preferences for mobile communication network scenarios. Int. J Hum. Ecol. Risk Assess. **20**(5), 1359–1384 (2013)
11. Arning, K., Ziefle, M.: Understanding age differences in PDA acceptance and performance. Comput. Hum. Behav. **23**, 2904–2927 (2007)
12. Mitzner, T.L., Boron, J.B., Fausset, C.B., Adams, A.E., Charness, N., Czaja, S.J., Dijkstra, K., Fisk, A.D., Rogers, W.A., Sharit, J.: Older adults talk technology: technology usage and attitudes. Comput. Hum. Behav. **26**, 1710–1721 (2010)
13. Wilkowska, W., Ziefle, M.: Which factors form older adults' acceptance of mobile information and communication technologies? In: Holzinger, A., Miesenberger, K. (eds.) USAB 2009. LNCS, vol. 5889, pp. 81–101. Springer, Heidelberg (2009)
14. Devine-Wright, P.: Reconsidering public attitudes and public acceptance of renewable energy technologies: a critical review. Manch. Sch. Environ. Dev. Univ. Manch (2007). http://geography.exeter.ac.uk/beyond_nimbyism/deliverables/bn_wp1_4.pdf
15. Ek, K.: Public and private attitudes towards green electricity: the case of Swedish wind power. Energy Policy **33**, 1677–1689 (2005)
16. Zarnikau, J.: Consumer demand for green power and energy efficiency. Energy Policy **31**, 1661–1672 (2003)
17. Beier, G.: Kontrollüberzeugungen im Umgang mit Technik [Locus of control when interacting with technology]. Rep. Psychol. **24**, 684–693 (1999)