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Fluctuations in the wind energy supply do not impair acceptance of wind farms

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Abstract

With the growing contribution of wind power to the electric energy supply, fluctuation in available wind energy might increasingly become part of public debate. Fluctuation influences energy prices and might lead to acceptance problems. As a first step to gauge potential communication strategies, we investigated in an experimental study if acceptance is influenced by being made aware of fluctuation. Participants either answered questions on acceptance before or after judging fluctuation and predictability for 30 days of wind energy input. To test for potentially biased cognition, we additionally checked if judgments were affected by whether or not it was transparent that the graphs showed wind energy input. Mean acceptance did not differ between the groups. Directing attention to the fluctuation of power generated by wind does not have an impact on acceptance. Additionally, presence or absence of labels on the graphs and thus knowing that the graphs depicted wind energy supply, did not affect fluctuation and predictability ratings.

Keywords Climate change, Communication, Renewable wind energy, Acceptance, Attitudes

Introduction

Global warming is strongly determined by the increased concentration of greenhouse gasses in the atmosphere. The natural greenhouse effect keeps earth warm by trapping the heat from the sun and makes the planet habitable for many different species (IPCC, 1990). However, the elevated concentration of greenhouse gasses, due to human activities, facilitate excessive absorption of solar energy and leads to the earth's surface overheating (Forster, et al., 2008; IPCC, 1990). Anthropogenic climate change, induced by greenhouse gasses, can affect our environment and human well-being in many ways. For instance, the increase of global annual mean temperature led to agricultural drought and flooding (Arnell et al., 2019), negatively affected biodiversity (Nunez et al., 2019), and elevated risk of infectious diseases (Butler, 2018) as well as health impairments (Patz et al., 2014). Anthropogenic climate change will also harm the global economy in the long term, especially in poor countries (Tol, 2018). Phasing out of fossil fuel consumption and consequently reducing the atmospheric concentration of greenhouse gasses can attenuate the global temperature increase (IPCC, 2014). Global CO_2 emissions should reach zero by 2060–2080 in order to adhere to the Paris Climate Agreement (Clémençon, 2016). The major contributor to the increase of annual greenhouse gas emissions between 2000 and 2010 was energy supply, its share made up 47% (IPCC, 2014). Subsequently, renewable energy sources, along with the energy efficiency, are considered to be a key component in addressing this issue, as they have the potential to fulfil the required reduction of emissions (Gielen et al., 2019). In 2018, more than 26% of global electricity was generated by renewable energy and the number of countries relying on renewables is increasing gradually (REN21, 2019).

The crucial role of renewable energy in the reduction of greenhouse gasses has become increasingly apparent (see Gielen et al., 2019 for a review). However, the

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practical deployment of renewable energy technologies, especially wind energy plants, faces low public acceptance (Devine-Wright, 2007). Therefore, the factors determining this low acceptance should be examined carefully in order to facilitate further development of wind energy. Wide implementation of renewable energy systems strongly depends on public acceptance (Devine-Wright, 2007). Generally, public attitudes toward renewable energy are mainly positive (Liu et al., 2013; Ntanos et al., 2018; Stokes & Warshaw, 2017). According to Eurobarometer (2019), about 92% of respondents rate the implementation of renewable energy systems as important and think that the portion of renewable energy used should increase. Yet, public attitudes and acceptance are not the same for different forms of renewable energy. Citizens have a more positive attitude towards solar energy than to wind energy (Liebe & Dobers, 2019). Despite the acceptance of wind farms in the general sense and acknowledgment of its crucial role in the process of climate change mitigation, the practical deployment of wind plants still faces considerable public resistance, especially, on the local community level (Olson-Hazboun, 2018; Sharpton et al., 2020). This paradoxical attitude is often described by Not In My Backyard (NIMBY) phenomenon. According to NIMBY, some citizens, who generally have positive attitudes toward wind power plants, resist the installation in their vicinity (Larson & Krannich, 2016). However, there is also evidence that almost 75% of U.S. citizens supported the deployment of a wind farm within 25 miles from their home (Ansolabehere & Konisky, 2009).

Apart from the territorial proximity of wind plants, acceptance of wind energy is affected by various factors including early participation of locals in the planning and implementation processes, perceived fairness of decision-making process and its results, expected benefits, trust in policymakers, as well as perceived risks and disadvantages (Aitken, 2010; Bell et al., 2005; Jones & Eiser, 2009; Sonnberger & Ruddat, 2016). Negative effects, associated with wind energy plants, may also shed light on low public acceptance. One of the main reasons for resistance to wind plants is the visibility of wind turbines from the home (Ladenburg, 2014; Pedersen et al., 2009). Strong visual intrusion of wind plants may decrease property values significantly (Jensen et al., 2018; Sunak & Madlener, 2016). Another reason for resistance is noise produced by the turbines (Pedersen et al., 2009). Some scientists argue that low-frequency noise and infrasound coming from the turbines can be harmful to health, whereas many others do not share this view (see Knopper et al., 2014 for a review). Potentially, wind farms can also pose a threat to biodiversity by increasing bird fatalities (Panarella, 2014; Rollins et al., 2012).

Alongside the local effects of wind plants, there are other potentially important factors influencing public acceptance. The reliability of wind energy, for instance, is one of them. Reliability is mainly determined by two characteristics: (a) whether energy generation is consistent over time without large fluctuation and (b) whether it is highly predictable (Rohrig et al., 2013). With a larger contribution of wind energy, fluctuation might have a more dominant effect on the availability of electricity in the grid. Fluctuating availability and low predictability will be mirrored by fluctuation in energy prices at the level of stock exchange. It is therefore conceivable that the successful implementation of wind energy at a larger scale endangers acceptance because fluctuation in supply becomes a relevant factor. Fluctuation in the wind electricity supply due to the high variations of wind speed are quite common (Shafiullah et al., 2013; Watson, 2014). This fact makes wind energy less predictable. One of the main challenges the wide implementation of wind plants faces is fluctuation in energy generation as well as energy demand. There are times, when the amount of generated power and demand may not match—for instance, an increase in seasonal demand for electricity and a decrease in wind speed. Such fluctuation and mismatched demand–supply patterns lead to price variations (Badyda & Dylik, 2017) and can even cause the negative price spikes, for instance, when supply exceeds demand significantly (Brandstätt et al., 2011). To compensate for gaps in wind energy generation, countries fill the demand by using coal-fired power plants (OIST, 2016) or other sources of renewable electricity as a backup (Vivas et al., 2018). Nevertheless, compensating for fluctuation through battery storage and energy control systems seems increasingly conceivable (Katoh et al., 2014).

Although lay people have their opinions and views regarding climate change and renewable energy, they may have limited knowledge and information about the topic (Assefa & Frostell, 2007). Thus, public opposition toward renewable energy and especially toward wind energy may be characterized by a deficiency in knowledge and information regarding the pros and cons of renewable energy sources. In a study by Bidwell (2016), participants who gained more information about wind energy showed higher support for it, compared to the other participants. Therefore, providing additional information about wind energy supply could lead to the reconsideration of attitudes and acceptance. The present study aimed to investigate whether bringing fluctuation of wind energy supply to mind would reduce acceptance. If this was the case, communication strategies highlighting the potential for flexible energy usage by industry and consumers

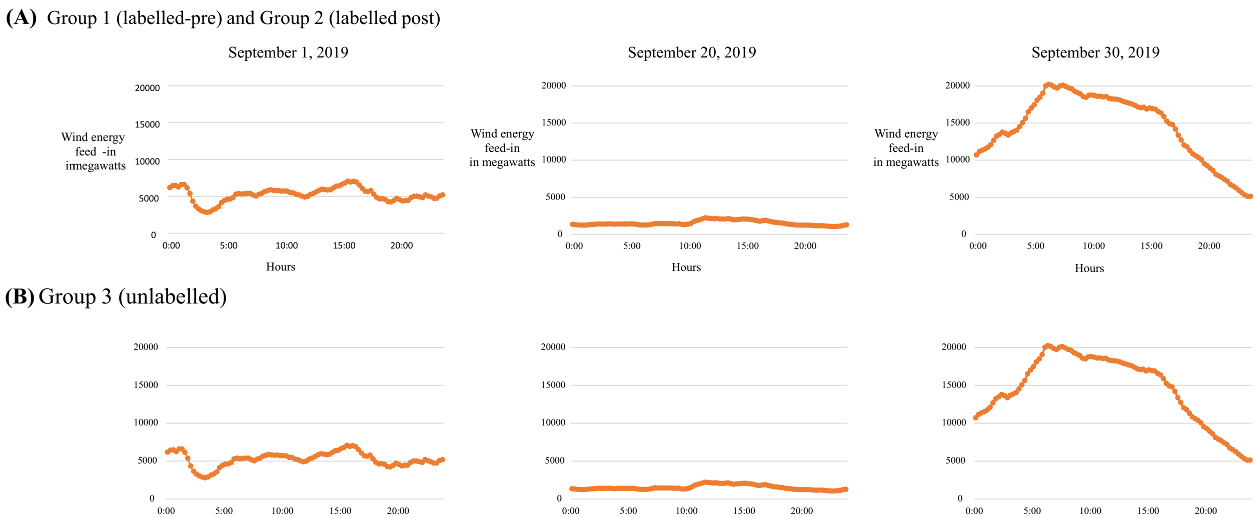

Fig. 1 Examples of the graphs presented in each group

might be warranted in order to prevent stances regarding fluctuation and predictability from threatening acceptance. In order to make sure that participants processed data on fluctuation and predictability, we had them rate these characteristics for 30 data graphs charting the generated wind energy (30 days, from 0:00 to 24:00 with 5 h intervals; see Fig. 1A for labelled groups). We had an additional group of participants (see Fig. 1B) rate the graphs in an unlabelled variant. This allowed us to check whether stances towards wind energy would bias the rating of predictability and fluctuation (cf. Lewandowsky et al., 2016).

Methods

The present study allowed for two different tests with respect to acceptance of wind energy. Group 1 (labelled-pre) reported on wind energy acceptance after rating predictability and fluctuation for 30 data graphs (see Fig. 2). Group 2 (labelled-post) ran through the online experiment in reverse order. By comparing the acceptance of wind energy between these two groups, we could test whether bringing fluctuation of wind energy to mind would have a negative impact on acceptance. Furthermore, we were able to compare the rated predictability and fluctuation for the graphs depending on whether they were labelled or not. This should allow detecting biases in judgments that are driven by the stance towards the domain (cf. Lewandowsky et al., 2016). Participants were randomly assigned to one of the three groups ($n1=71$, $n2=74$, $n3=73$). Groups 1 and 2 received 30 labelled graphs one at a time. Design, content, and layout of graphs were identical and each graph was followed by fluctuation and predictability ratings in both groups. The only difference between these groups was the position of acceptance items. Participants in group 1 received the acceptance items after presenting all 30 graphs. Group 2 received the same acceptance items right before seeing the graphs. All nine items were presented on the same page and the order of the items was fixed in both groups. Group 3 (unlabelled) only received the unlabelled graphs and did not receive the acceptance items. Thus, participants in this group had to make fluctuation and predictability ratings without knowing the domain of the presented graphs. The amount of graphs shown was equal in all three groups. They all depicted the same content, which was the veridical data about the wind energy supply (in Megawatts) and all of them were followed by the same items (fluctuation and predictability ratings).

Participants

Overall, we recruited 252 participants. Thirty-four were excluded from further analysis. Exclusion criteria were low proficiency in German language, self-reported lack of seriousness, and very short duration (<300 s) of participation. Data from 218 subjects (74% female) were included in the final analysis (age $M=34.30$, $SD=11.90$, range 19–73 years).[1] Participants were either native German speakers (85%) or fluent in German (15%). Students received one course credit for their participation in the

[1] Group 1—$M_{age}=36.31$, $SD=12.31$ ($n=71$; 77% female; 82% native German speakers).
Group 2—$M_{age}=35.14$, $SD=12.69$ ($n=74$; 65% female; 86% native German speakers).
Group 3—$M_{age}=31.51$, $SD=10.18$ ($n=73$; 81% female; 86% native German speakers).

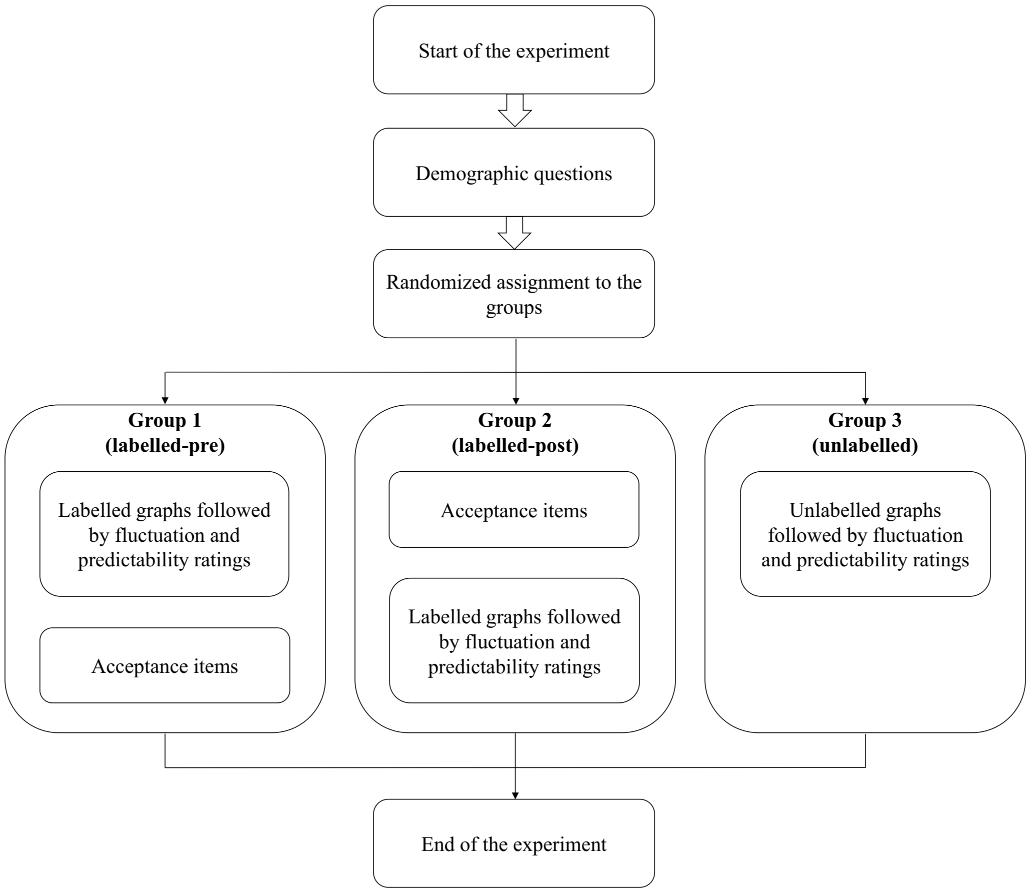

Fig. 2 Design and procedure of the experiment

online survey. The study was approved by the ethics committee of FernUniversität in Hagen.

Material and procedure

The present experiment was conducted entirely online. Participants were randomly allocated to the three experimental conditions. They received the instruction that they would be presented with different graphs to rate predictability and fluctuation. While the instruction for two of our three conditions clarified that the graphs were about daily wind energy production (and the graphs were labelled accordingly), the domain was not disclosed to the third group and the graphs were not labelled. After a short introduction, participants were to give informed consent and answer some demographic questions (age, gender, and proficiency in the German language). Participants received 30 graphs (either labelled or unlabelled) showing fluctuation in wind energy feed-in on daily basis in September 2019 (TenneT TSO, 2019). All graphs were created in Microsoft Excel. If labelled, X-axes of the graph depicted the amount of produced Megawatts and Y-axes depicted the time of the day with 5 h intervals (0:00, 5:00, 10:00, 15:00, 20:00, see Additional file 1).

In the unlabelled condition, graphs were presented without any information about the content of data or axes. Each graph was followed by two items. In the first one, participants had to rate the fluctuation (*the fluctuation in the course of the day is very large*) of the trend-line on the graph from 1 (*strongly disagree*) to 5 (*strongly agree*). In the second one, participants had to rate the predictability of trend fluctuation (*the fluctuation in the course of the day is well predictable*) from 1 (*strongly disagree*) to 5 (*strongly agree*). Participants in the labelled conditions also received nine items measuring the acceptance of wind energy (see Table 1). They were modified version of acceptance items previously used by other studies (Diller et al., 2017; Sonnberger & Ruddat, 2016). Participants had to rate each item statement from 1 (*strongly disagree*) to 5 (*strongly agree*). Between the labelled conditions, we varied, whether the acceptance items were provided before or after the task of rating predictability and fluctuation of the 30 wind energy supply graphs. In this task, graphs were presented one-by-one in

Table 1 Acceptance items presented in group 1 (after the graphs) and group 2 (before the graphs)

1	In my opinion, the advantages of wind energy dominate over disadvantages
2	Wind energy should make a significant contribution to securing energy supply
3	I would agree to new nearshore wind farms being built
4	I would agree to new wind farms being built in my region
5	I would agree to new wind farms being built in my neighbourhood
6	I would agree to a new wind farm (with more than 15 turbines) being built 5 kms away from my house
7	Despite the fluctuation in the amount of produced wind power, wind energy can make a significant contribution to securing energy supply
8	Because of the fluctuation in the amount of produced wind power, wind energy is not worthwhile for securing the energy supply
9	The fluctuation in the produced wind power is problematic for the wind energy supply

Item 8 and item 9 were later inverted for the further statistical analyses. Cronbach's α = .86 (for all nine items). See Additional file 1 for the German version of the material used in data collection

randomized order. The time participants had to complete the online experiment was not limited. At the end, participants were asked to give final informed consent, declare whether their participation was serious or not, leave comments, share their experience and opinion about the experiment.

Results

Acceptance of wind energy

As main issue of the analysis, we tested whether prior exposure to data graphs conveying information on fluctuation and (lack of) predictability of wind energy supply would affect acceptance ratings. An independent samples *t*-test revealed no significant difference in mean acceptance of the group that had reported on acceptance after vs. prior to rating fluctuation and predictability of wind energy supply (group 1 vs. group 2), $t(143) = -0.86$, $p = .390$, $d = -0.14$ (see Table 2). According to the Bayesian independent samples *t*-test (van Doorn et al., 2020), the null hypothesis predicts the data almost four times better ($BF_{01} = 3.98$) than the alternative hypothesis ($BF_{10} = 0.25$). Thus, there was substantial evidence that bringing fluctuation in wind energy supply to mind did not affect acceptance. We exploratively analysed the distribution of the group means on the single item level (see Fig. 3) to check whether the some acceptance items would show ceiling- or floor-effects. As this was not the case, we could rule out that the robustness of acceptance with respect to information on fluctuation and predictability was due to such a measurement problem.

Fluctuation

We checked how participants processed the data graphs in order to (1) test whether they indeed had attended the material which implemented the experimental manipulation and to (2) check whether labelling the data as related to wind energy influenced judgments. In a first step, we checked whether fluctuation ratings were affected by potential stances towards wind energy. For this, we compared fluctuation ratings across the experimental groups with labelled vs. unlabelled data graphs. Univariate ANOVA showed no significant effect of graph format on fluctuation ratings, $F(2, 215) = 1.46$, $p = .235$, $\eta_p^2 = .013$ (see Table 2). Bayesian ANOVA revealed that predictive strength of the null hypothesis is almost six times higher ($BF_{01} = 5.78$) compared to the alternative hypothesis ($BF_{10} = 0.17$).

Predictability

An equivalent analysis was performed on predictability ratings. According to the results of univariate ANOVA, groups differed significantly regarding their ratings of predictability of energy supply on daily basis, $F(2, 215) = 3.12$, $p = .046$, $\eta_p^2 = .028$ (see Table 2). As a post hoc *t*-test (corrected with Games–Howell because the assumption of homogeneity of variances was violated) showed, this effect was carried by the difference between

Table 2 Descriptive statistics for dependent variables

	M	*SD*
Acceptance		
Group 1	3.74	0.63
Group 2	3.84	0.77
Fluctuation		
Group 1	3.06	0.42
Group 2	3.02	0.54
Group 3	2.92	0.48
Predictability		
Group 1	3.05	0.39
Group 2	2.81	0.73
Group 3	2.91	0.59

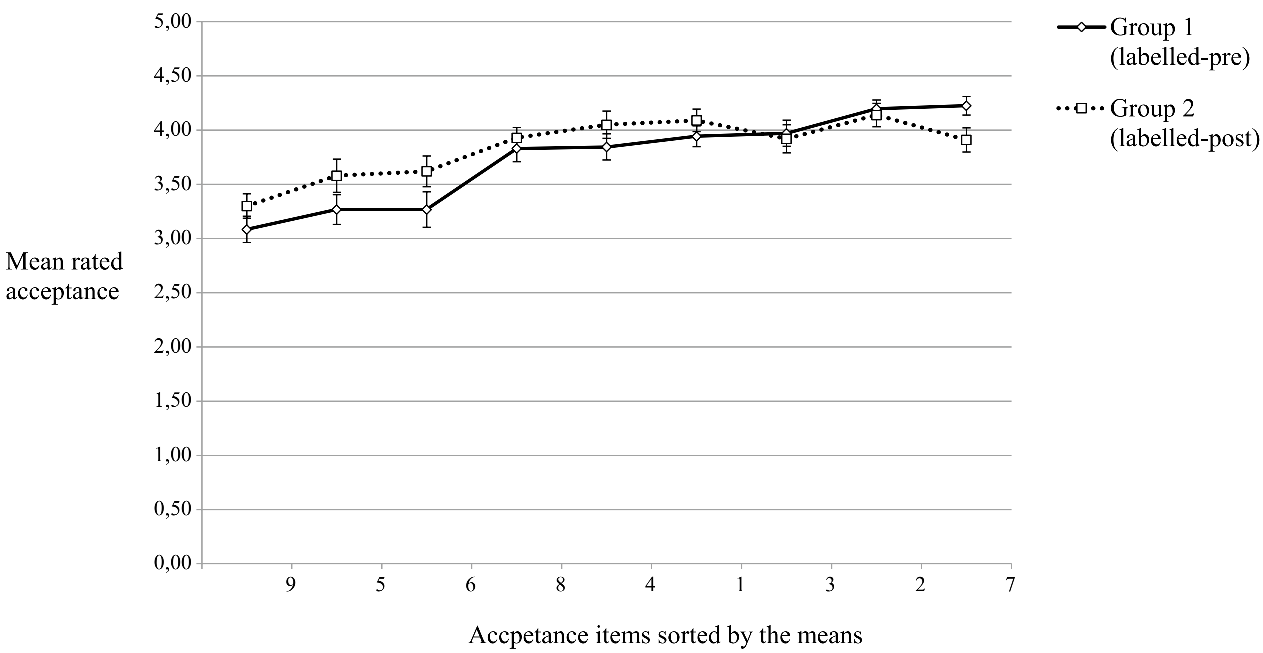

Fig. 3 Means of acceptance items within each group. Ascending order of items is based on the mean ratings in the group 1. Error bars depict the standard errors in rating of each individual item in one specific group

group 1 and group 2 ($p = .041$). Group 3 (the unlabelled group) did not differ from group 1 or group 2 significantly ($ps \geq .395$), which means that predictability ratings were not significantly influenced by the presence or absence of labels on the graphs. Despite the significant main effect revealed by univariate ANOVA, according to the Bayesian ANOVA, data are about 1.3 times more likely to occur under the null hypothesis ($BF_{01} = 1.34$) than under the alternative hypothesis ($BF_{10} = 0.75$).

Consistency in the ratings

In a final step, we analysed how consistent the ratings across participants were (see Fig. 4). High consistency across participants would suggest that participants worked on the data graphs attentively and judged them based on similar features. To explore consistency, we sorted the mean ratings of fluctuation and predictability for the 30 graphs. Lack of consistency across participants would present a shallow slope (lack of substantial rating differences among the graph that on average was rated lowest vs. highest). If participants were consistent, there should be differences spanning more than a rating point among the low-rated and top-rated graphs. Accordingly, this analysis served as a manipulation check securing that the experimental manipulation of bringing participants in contact with data graphs conveying information on predictability and fluctuation of wind energy supply had indeed been achieved. Figure 4 suggests that the manipulation was successful. The group means of lower-rated vs. higher-rated data graphs spanned a large part of the scale implying that participants showed high consistency in ratings based on processing the data graphs.

Discussion

With the growing share of wind power in the electric energy supply, fluctuation in wind energy supply might increasingly become part of public debate as they influence energy prices. Here we explored whether this might lead to acceptance problems that should be taken into account by developing appropriate communication strategies. Our results suggest that acceptance of wind energy is robust and not perturbed by salient information on fluctuation of wind energy supply. Participants' acceptance of wind energy plants was not compromised by making information on fluctuation in wind energy salient. Furthermore, mean scores of fluctuation and predictability ratings were not different for groups working on labelled data graphs vs. participants working on unlabelled data graphs (not knowing that the data was about wind energy supply). Thus, potential stances towards wind energy did not affect judgment of fluctuation and predictability (cf. Lewandowski et al., 2016).

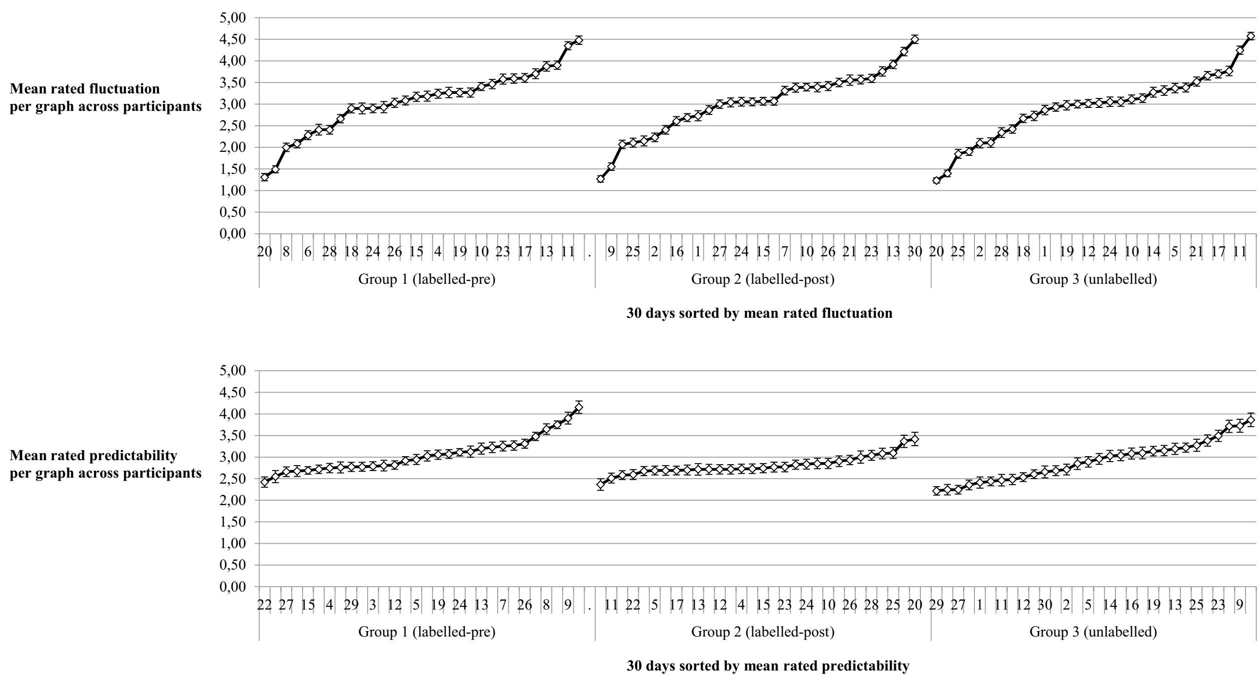

Fig. 4 Consistency of fluctuation and predictability ratings across the participants for each individual graph. Error bars depict the standard errors in the ratings of each individual graph in one specific group

Our study contrasts work suggesting that reliability, predictability, and stability of wind energy supply are considered to be important elements of wind energy acceptance (Rohrig et al., 2013; Schubert et al., 2014). Different from prior work we experimentally manipulated the availability of information on predictability and fluctuation. The divergence in results might hint that in other studies reliability, predictability, and stability were used as arguments by citizens to support a negative stance towards wind energy (rather than this actually being the basis of their position). Many studies emphasize that the resistance toward wind energy plants mainly exists on the local level (Hammami et al., 2018; Olson-Hazboun, 2018; Sharpton et al., 2020). For instance, according to the studies, distance from wind turbines, locals' engagement in the planning and implementation process, perceived benefits, equity, fairness (see Ellis & Ferraro, 2016 for a review), and community co-ownership (Musall & Kuik, 2011) can effectively attenuate resistance. Acceptance of wind farms is further determined by socio-political, environmental, and personal attitudes (Huijts et al., 2012; Kempton et al., 2005). Thus, factors affecting the acceptance of wind power technologies are manifold.

According to Assefa and Frostell (2007), lay people are not well equipped with relevant information about climate change or renewable energy sources. They constantly seek the balanced information (Dütschke & Wesche, 2015). This underlines the importance of studies checking which aspects (do not) lead to acceptance problems. Moreover, the fact that enhancing knowledge about renewable energy can improve acceptance (Liu et al., 2013) may be indirect evidence that uncertainties about this innovative technology underlie the local resistance. Citizens might not feel affected by fluctuation in the supply as other sources of electricity can compensate (Vivas et al., 2018; World Nuclear Association, 2020). Future studies might test whether we can also count on robust levels of acceptance when the costs of this strategy are made transparent. Importantly, fluctuation in supply can place strong incentives on consumers and industry to flexibly shift the use of energy towards peaks in supply. Thus, charting the economic and ecologic potential of flexible energy usage might substantially increase the acceptance of renewable energy sources.

The current work used an experimental approach optimized to secure that differences between conditions (or lack of differences) could be attributed to the impact (or lack of impact) of the independent variable (cf. Shadish et al., 2002): participants were randomly assigned in a blind way. We secured (see Fig. 4) that they attentively processed the data graph material so that we can be sure that they took notice of the high variability in wind energy. Thus, this manipulation check secured that the independent variable was varied successfully. Together with the high statistical power (large sample), this makes us quite confident to conclude that varying information on fluctuation in wind energy has indeed no effect on acceptance. Furthermore, the generalizability of the findings is likely high given that we tested an age- heterogeneous sample of students most of whom are working. The current work can serve as a basis for addressing questions on the acceptance of energy change in studies using panel data from representative samples including more information on the economic and sociodemographic background of the participants.

Conclusion

Overall, results of the present study suggest that showing how fluctuating the wind energy supply can be, does not affect whether or not participants accept wind energy farms. Thus, fluctuation in wind energy supply can be directly addressed without compromising acceptance. As the successful implementation of wind energy systems, which is one of the most promising sources of renewable energy, highly depends on public acceptance (Devine-Wright, 2007), it is crucial for climate change mitigation to investigate factors facilitating acceptance of wind energy.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40807-022-00071-8.

Additional file 1. Fluctuations in the wind energy supply do not impair acceptance of wind farms

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Author contributions

All authors contributed to the development, revision and finalization of the article. All authors read and approved the final manuscript.

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Availability of data and materials

All raw data and the study related material can be found at: https://osf.io/v7cwg/?view_only=d98404f4135f4354a712e110f40432f6.

Declarations

Ethics approval and consent to participate

Ethics approval was granted by the institutional review board of the School of Psychology at FernUniversität in Hagen on August, 8th, 2019. All procedures performed in the present study that involved human participants were conducted in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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References

Aitken, M. (2010). Wind power and community benefits. *Energy Policy, 38*(10), 6066–6075. https://doi.org/10.1016/j.enpol.2010.05.062

Ansolabehere, S., & Konisky, D. M. (2009). Public attitudes toward construction of new power plants. *Public Opinion Quarterly, 73*(3), 566–577. https://doi.org/10.1093/poq/nfp041

Arnell, N. W., Lowe, J. A., Challinor, A. J., & Osborn, T. J. (2019). Global and regional impacts of climate change at different levels of global temperature increase. *Climatic Change, 155*(3), 377–391. https://doi.org/10.1007/s10584-019-02464-z

Assefa, G., & Frostell, B. (2007). Social sustainability and social acceptance in technology assessment: A case study of energy technologies. *Technology in Society, 29*(1), 63–78. https://doi.org/10.1016/j.techsoc.2006.10.007

Badyda, K., & Dylik, M. (2017). Analysis of the impact of wind on electricity prices based on selected European countries. *Energy Procedia, 100*(105), 55–61. https://doi.org/10.1016/j.egypro.2017.03.279

Bell, D., Gray, T., & Haggett, C. (2005). The 'Social Gap' in wind farm siting decisions. Explanations and policy responses. *Environmental Politics, 14*(4), 460–477. https://doi.org/10.1080/09644010500175833

Bidwell, D. (2016). The effects of information on public attitudes toward renewable energy. *Environment and Behavior, 48*(6), 743–768. https://doi.org/10.1177/0013916514554696

Brandstätt, C., Brunekreeft, G., & Jahnke, K. (2011). How to deal with negative power price spikes?—Flexible voluntary curtailment agreements for large-scale integration of wind. *Energy Policy, 39*(6), 3732–3740. https://doi.org/10.1016/j.enpol.2011.03.082

Butler, C. D. (2018). Climate change, health and existential risks to civilization: A comprehensive review (1989–2013). *International Journal of Environmental Research and Public Health, 15*(10), 2266. https://doi.org/10.3390/ijerph15102266

Clémençon, R. (2016). The two sides of the Paris climate agreement: Dismal failure or historic breakthrough? *The Journal of Environment & Development, 25*(1), 3–24. https://doi.org/10.1177/1070496516631362

European Commission. (2019). Special Eurobarometer 490—Climate Change. ec.europa.eu/public_opinion/archives/ebs/ebs_364_en.pdf. Accessed 10 Oct 2020.

Devine-Wright, P. (2007). Reconsidering public attitudes and public acceptance of renewable energy technologies: A critical review. In M. Grubb, T. Jamasb, & M. Pollitt (Eds.), *Delivering a low carbon electricity system: technologies, economics and policy* (pp. 443–461). Cambridge University Press.

Diller, C., Gardt, M., & Litmeyer, M. L. (2017). Neutrale Akzeptanzerhebungen? Einflussmöglichkeiten der Forschung am Beispiel von Windenergieanlagen. *TATuP Zeitschrift Für Technikfolgenabschätzung in Theorie Und Praxis, 26*(3), 58–63. https://doi.org/10.14512/tatup.26.3.58

Dütschke, E., & Wesche, J. P. (2015). Status quo of social acceptance strategies and practices in the wind industry. *Fraunhofer I. S. I.* http://wisepower-project.eu/wp-content/uploads/20150319_WISE_Power_Deliverable_2-2_final.pdf. Accessed 17 Sept 2020.

Ellis, G., & Ferraro, G. (2016). The social acceptance of wind energy: Where we stand and the path ahead. *JRC Science for policy report. European Commission, Brussels* https://doi.org/10.2789/696070.

Forster, P., Ramaswamy, V., Artaxo, P., Berntsen, T., Betts, R. & Fahey, D et al. (2008). Changes in atmospheric constituents and in radiative forcing. In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC.* http://www.cambridge.org/catalogue/catalogue.asp?isbn=9780521705967. Accessed 20 Sept 2020.

Gielen, D., Boshell, F., Saygin, D., Bazilian, M. D., Wagner, N., & Gorini, R. (2019). The role of renewable energy in the global energy transformation. *Energy Strategy Reviews, 24*(1), 38–50. https://doi.org/10.1016/j.esr.2019.01.006
Hammami, M. S., Chtourou, S., & Al Moosa, H. (2018). A holistic approach to understanding the acceptance of a community-based renewable energy project: A pathway to sustainability for Tunisia's rural region. *Business Strategy and the Environment, 27*(8), 1535–1545. https://doi.org/10.1002/bse.2211
Huijts, N. M. A., Molin, E. J. E., & Steg, L. (2012). Psychological factors influencing sustainable energy technology acceptance: A review-based comprehensive framework. *Renewable and Sustainable Energy Reviews, 16*(1), 525–531. https://doi.org/10.1016/j.rser.2011.08.018
IPCC. (1990). *Climate change: The IPCC scientific assessment*. Cambridge University Press.
IPCC (2014). Climate Change: Synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K. and Meyer, L.A. (eds.)]. IPCC, Geneva, Switzerland, 151 pp.
Jensen, C. U., Panduro, T. E., Hedemark, T., Lundhede, T. H., Elberg Nielsen, A. S., Dalsgaard, M., & Thorsen, B. J. (2018). The impact of on-shore and off-shore wind turbine farms on property prices. *Energy Policy, 116*, 50–59. https://doi.org/10.1016/j.enpol.2018.01.046
Jones, C. R., & Eiser, R. (2009). Identifying predictors of attitudes towards local onshore wind development with reference to an English case study. *Energy Policy, 37*(11), 4604–4614. https://doi.org/10.1016/j.enpol.2009.06.015
Katoh, S., Ohara, S., & Itoh, T. (2014). Technologies for mitigating fluctuation caused by renewable energy sources. *International Power Electronics Conference*, 850–856. https://doi.org/10.1109/IPEC.2014.6869687.
Kempton, W., Firestone, J., Lilley, J., Rouleau, T., & Whitaker, P. (2005). The offshore wind power debate: Views from Cape Cod. *Coastal Management, 33*(2), 119–149. https://doi.org/10.1080/08920750590917530
Knopper, L. D., Ollson, C. A., McCallum, L. C., Whitfield Aslund, M. L., Berger, R. G., Souweine, K., & McDaniel, M. (2014). Wind turbines and human health. *Frontiers in Public Health, 2*, 63. https://doi.org/10.3389/fpubh.2014.00063
Ladenburg, J. (2014). Dynamic properties of the preferences for renewable energy sources—A wind power experience-based approach. *Energy, 76*, 542–551. https://doi.org/10.1016/j.energy.2014.08.050
Larson, E. C., & Krannich, R. S. (2016). "A great idea, just not near me!" Understanding public attitudes about renewable energy facilities. *Society and Natural Resources, 29*(12), 1436–1451. https://doi.org/10.1080/08941920.2016.1150536
Lewandowsky, S., Ballard, T., Oberauer, K., & Benestad, R. (2016). A blind expert test of contrarian claims about climate data. *Global Environmental Change, 39*, 91–97. https://doi.org/10.1016/j.gloenvcha.2016.04.013
Liebe, U., & Dobers, G. M. (2019). Decomposing public support for energy policy: What drives acceptance of and intentions to protest against renewable energy expansion in Germany? *Energy Research and Social Science, 47*, 247–260. https://doi.org/10.1016/j.erss.2018.09.004
Liu, W., Wang, C., & Mol, A. P. J. (2013). Rural public acceptance of renewable energy deployment: The case of Shandong in China. *Applied Energy, 102*, 1187–1196. https://doi.org/10.1016/j.apenergy.2012.06.057
Musall, F. D., & Kuik, O. (2011). Local acceptance of renewable energy—A case study from southeast Germany. *Energy Policy, 39*(6), 3252–3260. https://doi.org/10.1016/j.enpol.2011.03.017
Ntanos, S., Kyriakopoulos, G., Chalikias, M., Arabatzis, G., & Skordoulis, M. (2018). Public perceptions and willingness to pay for renewable energy: A case study from Greece. *Sustainability, 10*(3), 687. https://doi.org/10.3390/su10030687
Nunez, S., Arets, E., Alkemade, R., Verwer, C., & Leemans, R. (2019). Assessing the impacts of climate change on biodiversity: Is below 2 °C enough? *Climatic Change, 154*, 351–365. https://doi.org/10.1007/s10584-019-02420-x
Okinawa Institute of Science and Technology Graduate University—OIST (2016). New insights into fluctuations of wind energy, with implications for engineering and policy. *Science Daily*. www.sciencedaily.com/releases/2016/12/161231184935.htm. Accessed 13 Oct 2020.
Olson-Hazboun, S. K. (2018). "Why are we being punished and they are being rewarded?" Views on renewable energy in fossil fuels-based communities of the U.S. west. *The Extractive Industries and Society, 5*(3), 366–374. https://doi.org/10.1016/j.exis.2018.05.001
Panarella, S. J. (2014). For the birds: Wind energy, dead eagles, and unwelcome surprises. *Hastings West-Northwest Journal of Environmental Law and Policy, 20*(1). https://ssrn.com/abstract=2954647. Accessed 10 Sept 2020.
Patz, J. A., Frumkin, H., Holloway, T., Vimont, D. J., & Haines, A. (2014). Climate change: Challenges and opportunities for global health. *JAMA, 312*(15), 1565–1580. https://doi.org/10.1001/jama.2014.13186
Pedersen, E., van den Berg, F., Bakker, R., & Bouma, J. (2009). Response to noise from modern wind farms in The Netherlands. *The Journal of the Acoustical Society of America, 126*(2), 634–643. https://doi.org/10.1121/1.3160293
REN21 (2019). *Renewables 2019 Global Status Report.* Paris: REN21 Secretariat. http://www.ren21.net/gsr-2019/pages/foreword/foreword/. Accessed 5 Oct 2020.
Rohrig, K., Richts, C., Bofinger, S., Jansen, M., Siefert, M., Pfaffel, S., & Durstewitz, M. (2013). Energiewirtschaftliche Bedeutung der Offshore-Windenergie für die Energiewende. *Fraunhofer Institut Für Windenergie Und Energiesystemtechnik (IWES)*, 1–21.
Rollins, K. E., Meyerholz, D. K., Johnson, G. D., Capparella, A. P., & Loew, S. S. (2012). A forensic investigation into the etiology of bat mortality at a wind farm: Barotrauma or traumatic injury? *Veterinary Pathology, 49*(2), 362–371. https://doi.org/10.1177/0300985812436745
Schubert, D. K. J., Meyer, T., & Möst, D. (2014). Messung und Integration der gesellschaftlichen Akzeptanz für ein Energiesystem. *13. Symposium Energieinnovation,* 1–21. Graz, Austria.
Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). Experimental and quasi-experimental designs for generalized causal inference. Boston: Houghton Mifflin. https://www.alnap.org/system/files/content/resource/files/main/147.pdf.
Shafiullah, G. M., Oo, A. M., Ali, A. B. M., & Stojcevski, A. (2013). Influences of wind energy integration into the distribution network. *Journal of Wind Energy*, 1–21. https://doi.org/10.1155/2013/903057.
Sharpton, T., Lawrence, T., & Hallb, M. (2020). Drivers and barriers to public acceptance of future energy sources and grid expansion in the United States. *Renewable and Sustainable Energy Reviews, 126*, 109826. https://doi.org/10.1016/j.rser.2020.109826
Sonnberger, M., & Ruddat, M. (2016). Die gesellschaftliche Wahrnehmung der Energiewende: Ergebnisse einer deutschlandweiten Repräsentativbefragung. Stuttgart: Institut für Sozialwissenschaften, Abt. für Technik- und Umweltsoziologie, Universität Stuttgart. https://doi.org/10.18419/opus-8894.
Stokes, L., & Warshaw, C. (2017). Renewable energy policy design and framing influence public support in the United States. *Nature Energy, 2*, 17107. https://doi.org/10.1038/nenergy.2017.107
Sunak, Y., & Madlener, R. (2016). The impact of wind farm visibility on property values: A spatial difference-in-differences analysis. *Energy Economics, 55*, 79–91. https://doi.org/10.1016/j.eneco.2015.12.025
TenneT TSO. (2019). Tatsächliche und prognostizierte Windenergieeinspeisung. https://www.tennet.eu/de/strommarkt/transparenz/transparenz-deutschland/netzkennzahlen/tatsaechliche-und-prognostizierte-windenergieeinspeisung/. Accessed 16 Dec 2019.
Tol, R. S. J. (2018). The economic impacts of climate change. *Review of Environmental Economics and Policy, 12*(1), 4–25. https://doi.org/10.1093/reep/rex027
van Doorn, J., van Den Bergh, D., Bohm, U., Dablander, F., Derks, K., Draws, T., et al. (2020). The JASP guidelines for conducting and reporting a Bayesian analysis. *Psychonomic Bulletin and Review, 28*, 813–826. https://doi.org/10.31234/osf.io/yqxfr
Vivas, F. J., De las Heras, A., Segura, F., & Andújar, J. M. (2018). A review of energy management strategies for renewable hybrid energy systems with hydrogen backup. *Renewable and Sustainable Energy Reviews, 82*, 126–155. https://doi.org/10.1016/j.rser.2017.09.014
Watson, S. (2014). Quantifying the variability of wind energy. *Wiley Interdisciplinary Reviews: Energy and Environment, 3*(4), 330–342. https://doi.org/10.1002/wene.95
World Nuclear Association (2020). Renewable energy and electricity. https://world-nuclear.org/information-library/energy-and-the-environment/renewable-energy-and-electricity.aspx. Accessed 8 Apr 2021.

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