Wide-scale adoption of wind energy poses social and conservation challenges.

LETTERS

Edited by **Jennifer Sills**

Wind energy: A human challenge

In their Review "Grand challenges in the science of wind energy" (25 October, p. eaau2027), P. Veers *et al.* outline an "integrative" vision centered on three legs they contend are "critical to realizing the full potential of wind energy": improving understanding of the physics of flow in and around wind power projects, engineering of large machines, and integration of wind into the electricity grid. However, large-scale wind power implementation is unlikely to succeed without the social sciences. Although wind power deployment on a massive scale is a technical question, it is even more so a public issue.

Persuading people to adopt new technology requires an understanding of the relationships people have with places and landscapes and an appreciation of how they perceive risk (*1*–*3*). Conflict resolution strategies will have to be put in place to moderate the competing uses of land and sea, such as offshore wind power and commercial fishers (*4*). Institutions and developers will have to build trust (*5*). Public participation must be encouraged to ensure that those affected are given a voice and some influence over the outcome (such as the number of turbines or the project layout) (*5*). The transition to renewable energy ought to be implemented in a way that considers those communities long reliant on fossil fuel development (*6*). The inequitable burden placed on those living near transmission lines must be addressed so that needed transmission can actually be built (*7*). Without a thorough understanding of the human context (*8*–*10*), society may fall well short of "realizing the full potential of wind energy."

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COMPETING INTERESTS

J.F. for the University of Delaware serves as managing director of a private joint venture between the University and Siemens Gamesa that owns and operates a 2MW wind turbine that supplies energy to the campus and town of Lewes, Delaware, and uses revenues to fund research and student fellowships. He also consults for Lawrence Berkeley National Laboratory.

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Wind energy: An ecological challenge

In their Review "Grand challenges in the science of wind energy" (25 October, p. eaau2027), P. Veers *et al.* identify three grand challenges in the science of wind energy based in atmospheric physics, material science, and electrical engineering. However, other crucially important challenges include understanding the effects of wind energy production on ecological systems and developing and deploying tools to mitigate negative environmental effects.

Wind energy production affects species and ecological systems in three ways. Collisions with wind turbines kill volant organisms, such as birds and bats, sometimes causing population-level consequences (*1*, *2*). Wind facilities and associated infrastructure transform the landscape, contributing to habitat loss, degradation, and fragmentation (*3*, *4*) and altering species behavior (*5*, *6*). Finally, wind turbines alter microscale and possibly macroscale weather (*7*–*9*).

Globally, environmental issues cost wind developers and operators millions of dollars and halt construction of facilities [e.g., (*10*, *11*)]. Wildlife fatalities and habitat loss are the foundation of legal prosecutions [e.g., (*10*, *11*)]. The build-out goals outlined by Veers *et al.* require an increase in the number of turbines and expansion into new sites, potentially exacerbating these problems. Moreover, the engineering-related developments required to meet Veers *et al.*'s grand challenges will result in taller, larger wind turbines, with longer, faster-moving blades that produce more energy but may also increase adverse effects on the environment.

Engineers, atmospheric scientists, and industry representatives are working collaboratively with conservation scientists to develop research, applied science, best practices, and management actions aimed at reducing the environmental impacts of wind energy. Efforts include modeling wildlife movements, fatalities, and risk to individuals and populations; developing technologies to deter bats and birds from wind turbines;

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and deploying automated shutdown technologies that stop turbines in the presence of target species (*12*). Fortunately, many of the integrated and cross-disciplinary research efforts in atmospheric, physical, computational, and data science that Veers *et al.* identify contribute to the collaborative science required to address the environmental challenges as well.

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COMPETING INTERESTS

D.M.N. is a science adviser for the American Wind Wildlife Institute. A.E.D. has been paid as a consultant by wind energy companies. A.E.D., M.A.B., and T.A.M. have received research funding from wind energy companies and the American Wind Wildlife Institute. T.A.M. has also provided paid expert testimony in a hearing regarding golden eagle use of a wind energy facility in New York State. T.J.C. is a member of the Alameda County (California) Wind Repowering/Avian Protection Technical Advisory Committee.

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Protecting Patagonian peatlands in Chile

In their Letter "Seeing Chile's forest for the tree plantations" (27 September, p. 1388), A. P. Durán and O. Barbosa explain how Chile's current proposal for reducing greenhouse gas emissions (*1*) inadequately addresses forest management with exotic tree plantations. We agree, but we are even more concerned that the proposal overlooks other ecosystems entirely. Chilean Patagonian peatlands cover 3.1 million hectares (*2*) and contain approximately 4800 million tons of carbon accumulated over 18,000 years (*3*, *4*). This is 4.7 times more carbon than the aboveground biomass of forests in Chile (*4*, *5*). Peat in Chile is classified as a fossil resource, allowing it to be exploited by the Ministry of Mining (*6*). Chile should invest in the protection of this important ecosystem.

Because of the slow peat accumulation in sub-Antarctic regions (less than 1 mm per year) (*4*), exploitation of peatlands compromises their carbon sequestration capacity, shifting peatlands from net carbon sinks into net carbon sources (*7*). Protecting Chile's Patagonian peatlands would help the country achieve carbon neutrality by 2050 (*8*, *9*). To protect the peatlands, Chile must end their classification as fossil resources. Instead, Chile should present peatland preservation as part of its greenhouse gas reduction contributions at the 2019 United Nations Climate Change Conference (COP25) (now planned for Madrid, Spain, instead of Chile). Patagonian peatlands should also be recognized as overlooked carbon sinks of regional importance in Chile's new Climate Change Law (*10*).

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TECHNICAL COMMENT ABSTRACTS

Comment on "The role of electron-electron interactions in two-dimensional Dirac fermions"

S. Hesselmann, T. C. Lang, M. Schuler, S. Wessel, A. M. Läuchli

Tang *et al*. (Research Articles, 10 August 2018, p. 570) report on the properties of Dirac fermions with both on-site and Coulomb interactions. The substantial decrease, up to ~40%, of the Fermi velocity of Dirac fermions with on-site interaction is inconsistent with the numerical data near the Gross-Neveu quantum critical point. This results from an inappropriate finite-size extrapolation.

Full text: dx.doi.org/10.1126/science.aav6869

Response to Comment on "The role of electron-electron interactions in two-dimensional Dirac fermions"

Ho-Kin Tang, J. N. Leaw, J. N. B. Rodrigues, I. F. Herbut, P. Sengupta, F. F. Assaad, S. Adam

Hesselmann *et al*. question one of our conclusions: the suppression of Fermi velocity at the Gross-Neveu critical point for the specific case of vanishing long-range interactions and at zero energy. The possibility they raise could occur in any finite-size extrapolation of numerical data. Although we cannot definitively rule out this possibility, we provide mathematical bounds on its likelihood.

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EDITOR'S NOTE

"Joint statement on EPA proposed rule and public availability of data (2019)" by H. Thorp, M. Skipper, V. Kiermer, M. Berenbaum, D. Sweet, R. Horton, *Science* **366**, eaba3197 (2019). Published online 6 December 2019 (First Release 26 November 2019); 10.1126/science.aba3197

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