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Workshop on Climate Effects of Wind Turbines

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Citation: Emanuel, Kerry et al. "Workshop on Climate Effects of Wind Turbines." Bulletin of the American Meteorological Society 97.3 (2016): ES57-ES58. © American Meteorological Society

As Published: <http://dx.doi.org/10.1175/bams-d-15-00231.1>

Publisher: American Meteorological Society

Persistent URL: <http://hdl.handle.net/1721.1/108552>

Version: Final published version: final published article, as it appeared in a journal, conference proceedings, or other formally published context

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MEETING SUMMARIES

WORKSHOP ON CLIMATE EFFECTS OF WIND TURBINES

BY KERRY EMANUEL, FRAUKE HOSS, DAVID KEITH, ZHIMING KUANG, JULIE LUNDQUIST, AND LEE MILLER

A workshop was held at Harvard University in June 2015 for the purposes of assessing the state of research on possible climate effects of wind turbines and identifying important outstanding issues and possible means by which they might be addressed.

The issue was considered as one part of the broader issue of the environmental effects of all sources of energy. Such environmental considerations are an important part of the matrix of issues that must be considered in designing an optimal mix of power sources for the future.

Early in the workshop, it was recognized that the fraction of incoming solar radiation that is converted to kinetic energy in the atmosphere represents an upper bound of about 1000 terrawatts (TW) of available wind energy, which corresponds to a maximum global potential wind power extraction by turbines on and near land on the order of 100–300 TW. The projected global energy demand of 20–30 TW in 2050 is a small fraction of this total.

Some simulations using global climate models have investigated the extraction of 5 to several hundred

WORKSHOP ON CLIMATE EFFECTS OF WIND TURBINES

WHAT: About 25 attendees representing scientific, policy, and industrial expertise met to assess the state of research on possible climate effects of wind turbines and identify important outstanding issues and possible ways they might be addressed.

WHEN: 24–25 June 2015

WHERE: Cambridge, Massachusetts

TW including the extreme case of deploying enough wind turbines around the globe to tap this entire resource. In exploring such extreme scenarios, previously published results suggest that zonally averaged surface temperature may change by several degrees Celsius and the poles may cool by as much as 10°C. Such results clearly require further understanding and likely relate to wind turbines inducing a damping effect on baroclinic disturbances via the boundary layer. Other associated differences such as the reduction in surface wind may increase the surface temperature but reduce the temperature and humidity of the troposphere, leading to a reduction of the contribution of water vapor to longwave trapping. While extreme wind power scenarios are unlikely to ever be realized, understanding the underlying mechanisms for the climatic differences provides guidance to evaluate more realistic smaller-scale deployment scenarios. Given the present variability between global climate model results for both the extreme and more realistic scenarios, participants agreed that standardized modeling intercomparisons to evaluate approaches to representing wind turbine impacts could be beneficial. An important goal should

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DOI:10.1175/BAMS-D-15-00231.1

In final form 27 August 2015

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be a quantification of climate impacts per TW power generated for comparison to climate effects of other power sources.

Climate effects of wind farms also need to be considered for local- to regional-scale deployments. For example, satellite data and field campaigns suggest slightly higher nocturnal temperatures within and downwind of presently operational wind farms during select time periods. Although wind turbine wakes are the focus of much active research, we do not yet have a good understanding of the downstream effects of individual wind turbines or wind turbine arrays, beyond general understandings of wind speed reductions and increases in turbulence directly within turbine wakes. In particular, the propagation and dissipation of wakes over a full range of turbine configurations and atmospheric conditions are not well understood. Further, because wake effects (and therefore production by waked turbines) vary over the course of a diurnal cycle, regional estimates of wind power availability must also account for this diurnal variability.

Research should be directed toward optimizing wind power arrays not only to maximize production and distribution, but also to minimize disturbances to the environment, including local and regional climate. However, much uncertainty remains in delineating the local and regional climate effects of wind turbine arrays. Future research should be directed toward better characterizing such climate effects, not only on mean values, but also on fluctuations, including the variability of wind itself.

Workshop participants agreed that a better delineation of both the local and remote effects of wind turbines requires an improved understanding of how such turbines affect the boundary layer, including surface fluxes. To this end, it would be desirable to mount a set of field measurement campaigns at the sites of wind farms representing a variety of environmental conditions—for example, in flat relatively featureless landscapes on one extreme to highly inhomogeneous landscapes on the other. Such campaigns, spanning several seasons, would provide measurements that would improve our understanding of how turbines affect momentum and, indirectly, heat, moisture, and tracer fluxes at the surface and aloft. These measurements would support the design and validation of more accurate representations of wind turbine arrays in regional and global models used to assess local and regional climate effects of wind power generation. Once accurate representations of wind turbine effects for regional- and global-scale models are defined, coordinated intercomparisons of specific deployment scenarios could explore likely climate effects.

Progress in understanding the local, regional, and global environmental effects of wind turbines should be clearly placed within the broader context of understanding the environmental effects of power generation, including conventional fossil fuels as well as rapidly developing technologies such as solar power. A coupled and comprehensive understanding of power generation and associated environmental effects is a necessary input to discussions regarding the optimal mix of energy sources.