Stanford Woods Institute for the Environment

Stanford | Precourt Institute for Energy

Innovation Brief

A New Approach to Wind Energy

Overview

Wind resources have the potential to power the world – the estimated 250 trillion watts of global wind power available is 20 times greater than the current total global power consumption – yet only 4 percent of electricity generated in the United States is derived from wind. Unlike fossil fuels, which have highly localized sources, wind is available for energy conversion in nearly every corner of the world. Still, however, nearly 1.5 billion people live without access to electrical service. Unfortunately, deployment of wind technologies that could fulfill the world's energy needs has been limited. To extend the reach of wind energy, we should focus technology development on large arrays of small, simplified wind turbines (vertical-axis wind turbines or VAWTs).

Problem Statement

Despite the global availability of wind resources, wind energy technology has had only a modest impact on power generation worldwide. A root cause of this paradox is the conventional, centralized approach for harvesting wind energy. In this approach, power generation relies on a few, increasingly large horizontal-axis wind turbines (HAWTs) that spark visual, acoustic and environmental concerns and must be placed in remote areas. By limiting ourselves to this centralized approach for harvesting wind energy, we have forfeited key advantages and opportunities afforded by the globally distributed energy source.

The Facts

Comparisons between renewable energy and conventional fossil fuels can be made using a variety of criteria, including carbon emissions, water use, operations, maintenance and cost. A common argument against renewable energy sources – primarily solar and wind – is that they are more diffuse than coal, oil and natural gas. However, wind offers a unique and potentially transformative advantage over fossil fuels: global availability. Coal, like other fossil fuels, is a highly localized source of energy, found underneath less than five percent of the world's land area. In contrast, wind resources are available for conversion to useful energy in nearly every corner of the globe (with the exception of heavily forested areas of the Amazon, Congo and Southeast Asia).

Although many economic, infrastructural, regulatory and cultural issues contribute to the limited adoption of existing wind energy technologies, a root cause is the historical trend of using a centralized approach to power generation. The approach arose after the Industrial Revolution as a consequence of the need to process highly localized fossil fuel sources. It was adopted for wind energy conversion, even though it does not mirror the physical resource itself. For tapping wind resources, the trend has exacerbated the use of conventional propeller-style wind turbines (HAWTs), which must be spaced far apart in order to avoid aerodynamic interference and fatigue-loading caused by interactions with the wakes of adjacent turbines.

John O. Dabiri
Department of Civil and Environmental Engineering and
Department of Mechanical Engineering; Stanford University

This requirement has forced wind energy systems away from high-energy demand population centers and toward remote locations, including offshore sites. It also has led to the need for increasingly large wind turbines, so the inefficiency of the wind farm as a whole, can be mitigated by accessing the greater wind resources available at higher altitudes. The approach has essentially blocked advantages and opportunities of the vast wind resource, such as the ability to generate energy close to its point of consumption; functional versatility in conversion devices; potentially lower barriers to adoption with distributed wind energy technologies; and expanded energy access for rural communities and the developing world.

An alternative to the status quo approach is the distribution of a new generation of small, simplified vertical-axis wind turbines (VAWTS) that can harvest wind energy at low altitudes with the help of new biology-inspired engineering. The approach can dramatically extend the reach of wind energy, as smaller wind turbines (one-tenth the height of modern structures) can be installed in many places incompatible to larger systems, especially in built environments. Moreover, they have lower visual, acoustic and radar signatures, and may pose significantly less risk to birds and bats. These features can be leveraged to attain cultural acceptance and rapid adoption of the technology.

Also, favorable economics can be obtained through the reduction in the number of components that make up each VAWT. Where a modern HAWT can have approximately 8,000 parts, a next generation, small VAWT can have fewer than a dozen parts. The new VAWT eliminates gearboxes and mechanisms to orient a wind turbine, and its size facilitates the use of cheaper structural materials. The simplicity and size also opens the door to utilizing point-of-use manufacturing technologies, such as 3D printing, to realize energy systems customized for use by individuals, families or small communities.

The Challenges

- Significant research is needed to achieve the full, global potential of wind energy with new generation VAWTs.
- Research on VAWTs in the 1980s demonstrated that their aerodynamics are more complex than HAWTs, a finding that makes VAWTs' response to fatigue loading less predictable.
- The best commercially available VAWTs suffer structural and/or electrical failure within months or even weeks of initial commissioning.
- For VAWTs, it is essential to complement lab-scale experiments and computer models with testing in the field.
- It remains unknown how co-located VAWTs and HAWTs will interact aerodynamically or how to optimize that interaction.

The Recommendations

In order to dramatically extend the reach of wind energy, new technology development for wind energy should be focused on large arrays of simplified, small VAWTs that can either replace conventional HAWTs or be used in locations and applications inaccessible to HAWTs.

- To address reliability issues related to VAWT design, advances in computational fluid dynamics, materials science, electrical engineering and experimental diagnostics should be harnessed in a coherent, multidisciplinary research program;

John O. Dabiri
Department of Civil and Environmental Engineering and
Department of Mechanical Engineering; Stanford University

- Technologies should be tested in remote locations, such as Alaskan villages, for a rigorous, real-world test of wind energy technologies;
- Field studies should be conducted, in areas like Altamont Pass, to better understand how co-located VAWTs and HAWTs will interact aerodynamically;
- Improvements to 3D printing systems should be supported in order to facilitate a do-it-yourself approach for making VAWT components;
- Existing wind resource maps should be updated to have sensors placed in areas where new distributed wind energy systems will most likely be sited.

This brief is based on research and findings by John O. Dabiri, Professor of Civil and Environmental Engineering and Professor of Mechanical Engineering in the School of Engineering at Stanford University.