Powering Up: *Streamlining Wind Energy*

by Mikael Mulugeta

Corey Markfort, who earned a master's and PhD in civil engineering from the University of Minnesota, joined IIHR as an assistant research engineer in fall 2014.

EARLY ON A FRIDAY MORNING, MOHSEN Vahidzadeh stands under a radio tower in the southwest corner of the Kirkwood Community College campus. Overhead, more than a dozen sensors on the 350-foot tower track wind speed and direction, humidity, temperature, solar radiation, and even CO_2 concentration. Vahidzadeh, a second-year PhD student at IIHR, will collect the data and compare it to operational information from similar sensors affixed to Kirkwood's nearby 2.5 MW wind turbine.

Using these data, Vahidzadeh and IIHR's Corey Markfort, his faculty supervisor, hope to better understand how weather conditions affect the performance of wind turbines. That information will be crucial to build more accurate turbine flow models and optimize turbine operations. They plan to make the data publicly available online and use it in coursework for the University of Iowa's (UI) Wind Energy Certificate program.

ENVIRONMENTAL FLOWS

Markfort, who is also an assistant professor of civil and environmental engineering (CEE), studies environmental flows and wind energy. Environmental flows have two significant features that complicate measurements and forecasts. First, variations in topography and density because of varying temperatures at different depths cause a modeling challenge. Second, turbulence causes chaos. Markfort says we can see examples of turbulence in our daily lives, such as smoke rising from a smokestack or swirling flows in rivers. However, the technical problems stratified turbulence can produce are less obvious.

Turbulence is a recurring problem in physics and engineering, says Markfort. "My wind energy research, which is about capturing kinetic energy from natural flow, takes these other factors into account."

Markfort's focus on wind energy grew out of his PHD studies of the atmospheric boundary layer — the layer closest to the Earth's surface. While investigating how energy from the atmosphere mixes with lakes, he discovered a fascination with the complexities of harnessing wind energy. By understanding how land surface and complex terrain affect the wind, Markfort says we can better place wind turbines.

This is where the sensor data collected at Kirkwood comes into play. Understanding how weather affects turbines is one of several projects Markfort oversees. He hopes to improve wind power plant performance and forecasting, and to better understand and mitigate the environmental impacts of turbines.

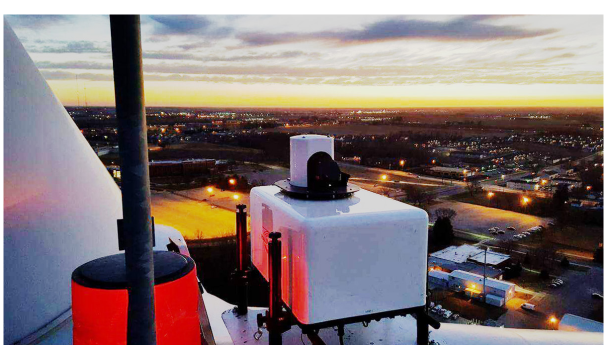
THE WIND ENERGY BOOM

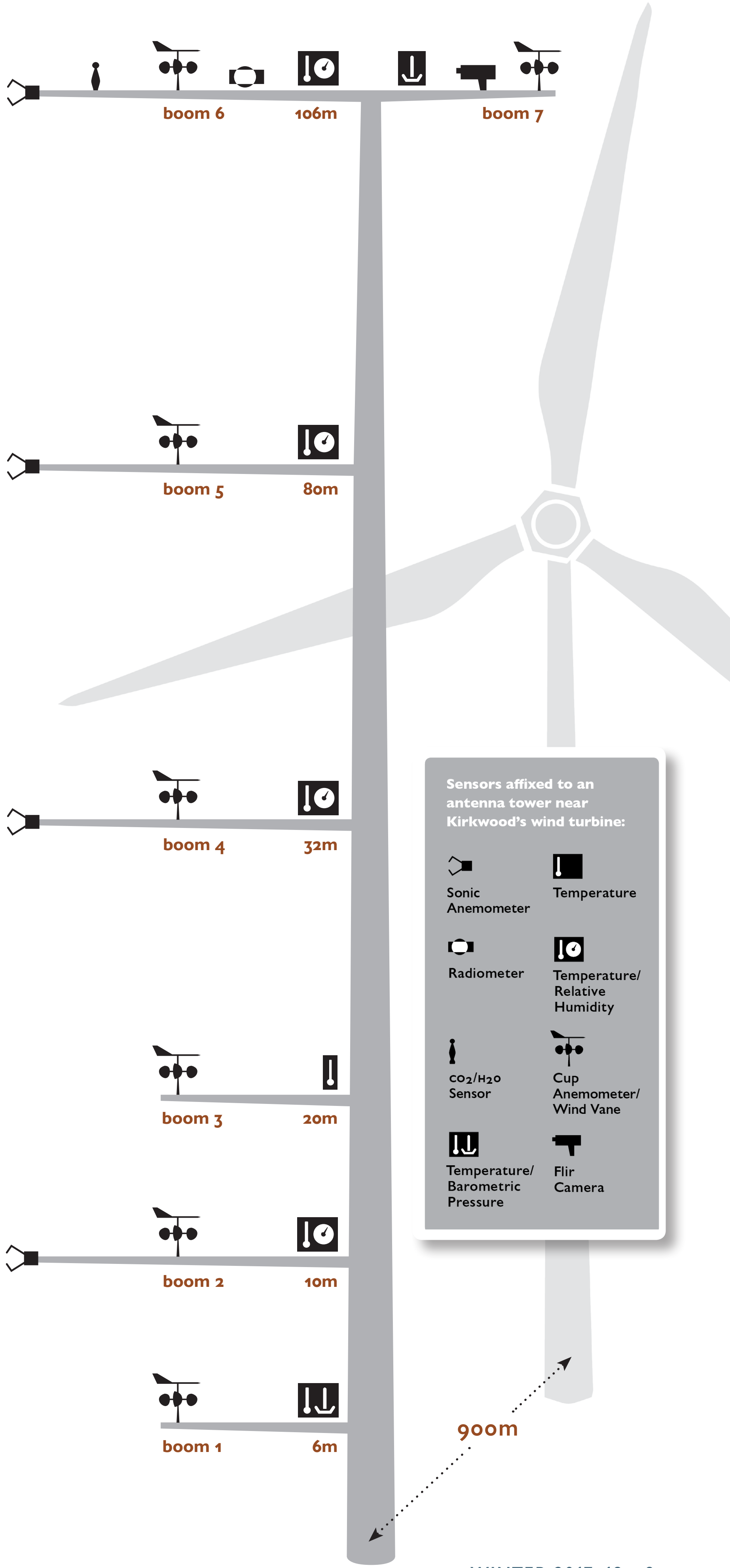
In 2008, the Obama administration set a goal to double renewable energy production in the United States. This spurred new funding for wind energy research. "That's a large part of what gave me the opportunity to research the interaction between wind and turbines, and how wind energy extraction affects the atmospheric boundary layer," Markfort says.

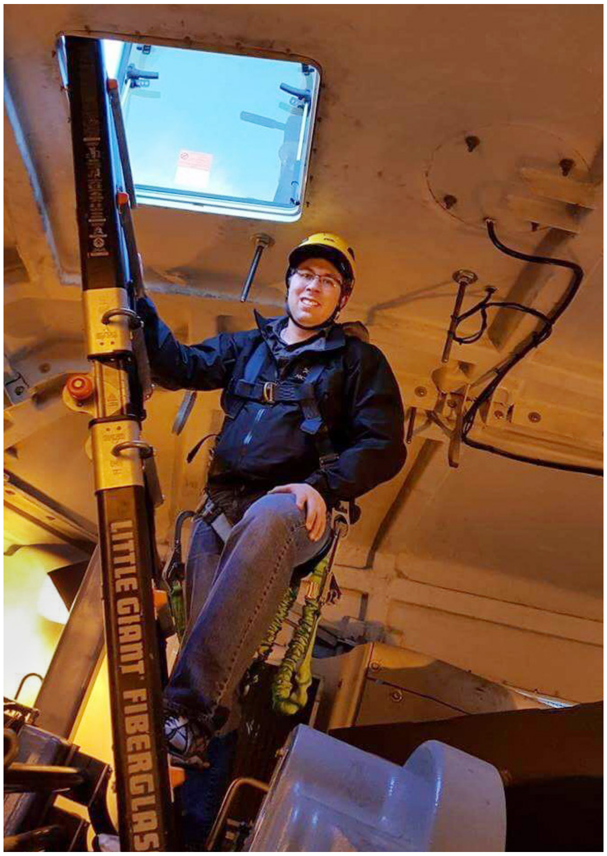
Iowa already produces more than a third of its electricity from wind, and the state's major electric utilities are on track to hit 80 percent within a decade. The national trend is also promising; the U.S. Department of Energy (DOE) projects that the United States will meet 20 percent of its electricity needs with renewable wind power by 2030. This will require a workforce of approximately 380,000, up from the current estimate of 73,000.

Markfort says scientists are rapidly overcoming the remaining challenges of wind energy. One of the most pressing issues is to prevent wind turbines at the front of a wind farm from reducing the effectiveness of turbines behind them. Utilities typically arrange wind turbines in rows. However, when wind flows past a turbine, the region behind it experiences lower wind speeds. Power generation depends on high wind speeds. This can lead

BELOW: The view of Cedar Rapids at sunset from the top of the turbine is stunning.







to significant losses. Markfort wants to understand why.

"Each turbine is designed to capture as much energy as it can, even to the detriment of neighboring turbines," says Markfort. "We're researching how to optimize the entire group so overall energy production is greater."

Another persistent issue is geographical. The strongest wind blows through the central United States, but the highest demand for energy is on the coasts. Although offshore wind energy potential is substantial, challenges persist, including the cost. Nevertheless, offshore wind is becoming a focus in the United States, especially off the East Coast and on the Great Lakes.

To study offshore wind farming, IIHR recently developed a new boundary layer wind-wave tunnel. In this facility, researchers conduct controlled experiments using state-of-the-art laser-based anemometry techniques to learn how offshore wind farms perform in the presence of surface waves and how they affect mixing at the Great Lakes and surface coastal oceans. Markfort is hopeful this research will help move offshore wind farming forward.

By most measures, the future looks bright for renewable energy — wind, hydro, bio, and solar. These energy sources offer opportunities for significant improvements in air and water quality, public health, and the reduction of carbon emissions. Renewable energy is also a booming industry requiring a skilled workforce. Institutions such as the UI play a critical role in training this workforce.

Markfort's research, and the work of others at IIHR and around the country, could help change how we generate electricity forever.

PHOTOS THIS PAGE: Markfort *(above; and center, below)* says that Kirkwood's 2.5-megawatt wind turbine, seen here, provided 5,600,000 KWH of clean electricity for the campus between 2012 and 2015, worth more than $1M.

Also pictured (*left to right*), IIHR team members Pablo Carrica, Marcela Politano, Markfort, Shivendra Prakash, and Ezequiel Martin.

Illustration Credit: enercast GmbH

Protecting Bats

by David Gooblar

IIHR HELPS MINIMIZE THE ENVIRONMENTAL IMPACT OF WIND TURBINES

ABOVE: IIHR researchers developed a model to help us understand how bats interact with wind turbines, with the goal of reducing bat fatalities.

We know wind turbines can be fatal to bats, but the exact number of bat fatalities at wind turbines is unknown. Because bats are an important part of our ecosystem—they are voracious insect eaters, saving farmers billions of dollars in pest control—and because some species of bats are threatened or endangered, the U.S. Fish and Wildlife Service (USFWS) and energy companies like MidAmerican are working to minimize the negative impact of wind farms on bats. That's where IIHR comes in.

Knowing of IIHR's long history of investigating the impact of hydropower on salmon, the USFWS and MidAmerican asked the institute for help in estimating the number of bats affected by wind turbines. IIHR's Corey Markfort, Pablo Carrica, Marcela Politano, and Ezequiel Martin took on the project. They've developed a model to map the expected distribution of bat carcasses around wind turbines so investigators can more accurately and efficiently estimate the number of bats killed around a turbine.

THE AERODYNAMICS OF BATS

According to Markfort, the interdisciplinary collaboration that IIHR is known for is perfectly suited to this project. "It's a classic interdisciplinary type of problem. You have the animals, who exhibit specific behaviors around wind turbines, and occasionally they are impacted by the rotating blades. And then they're being thrown into a very chaotic turbulent flow field." The researchers' model began with a situation relatively well-known to environmental fluid mechanics—the turbulent flow field around a wind turbine—and then introduced a living creature whose aerodynamic properties are mostly unknown. To develop a successful model, the researchers needed to know more about bats. Toward that end, the biological survey contractor collecting the bat carcasses brought some to the researchers so they could determine their aerodynamic and other physical properties.

From there, the researchers developed a two-part simulation using computational fluid dynamics: first modeling the flow field and then putting the bat-like particles into the flow. Although much is still unknown about bat behavior, Martin explained that the simulation can provide a good start on understanding what happens when a bat collides with a turbine's rotor. In the simulations, he says, "There are thousands of particles. They are hitting the blades at different heights, at different speeds, with different mass, and all that will give us a map of carcass distribution on the ground." With this map, researchers, regulators, and energy providers will be able to better understand the interaction between bats and turbines.

Counting every single bat carcass around a wind turbine would be impossible — expensive in both time and money. But a good model like the one the IIHR team has developed could let energy providers and regulators count just a sample of the bats and project accurately to calculate the total. "For threatened or endangered species," Markfort says, "ideally you don't want to have any adverse impact." On the path to that ideal, understanding and estimating how wind energy affects bats and birds is an important step to protect these creatures.