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Where the wind blows: Mapping our wildest gusts

A new wind atlas will help turbines avoid the doldrums – and solve some of wind's enduring mysteries

Michael Cogliantry/Getty

By **Joseph Calamia**

THE town of Watzerath in western Germany is a small, attractive sort of place, its white houses sitting prettily against rolling, lightly forested hills. But on the outskirts of town there is trouble.

Here, set among fields and clumps of trees, is a scattering of wind turbines. They are the focus of a dispute – one centred not on the usual Nimbyism but on a commercial fiasco. A few years ago, the wind farm's investors learned that the turbines were producing only a little more than half the energy they were forecast to generate, prompting a protracted legal fight last year between these backers and the farm's developers.

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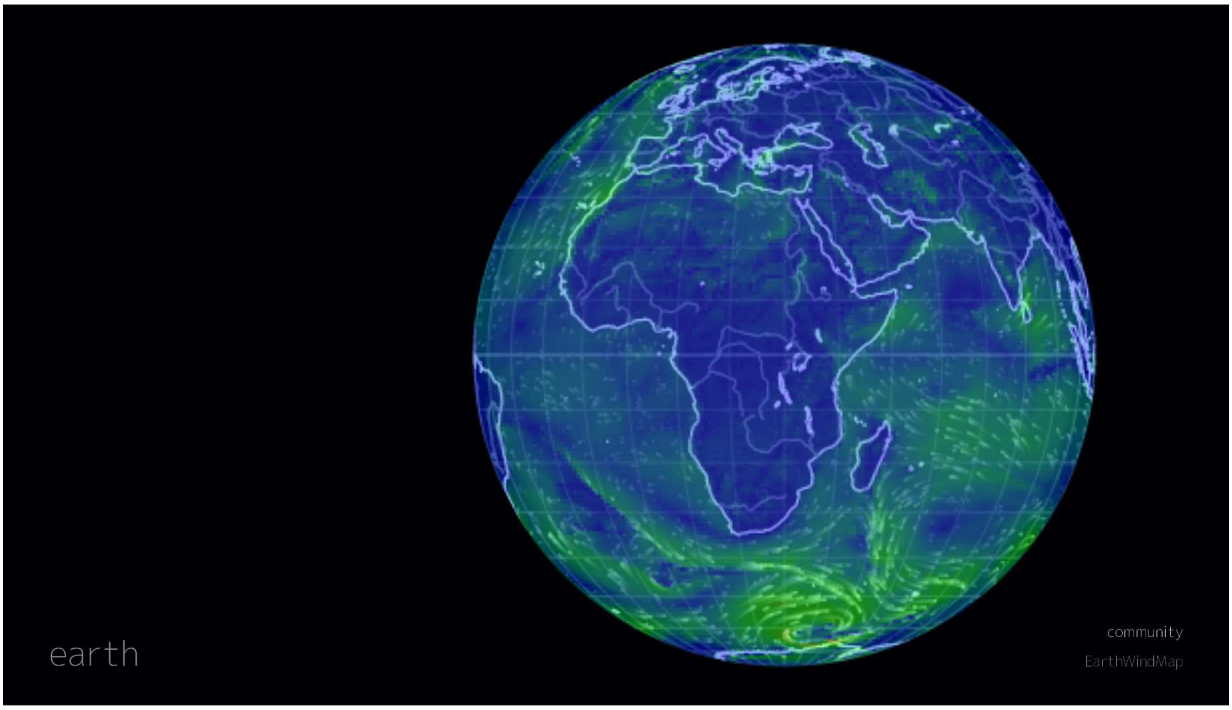
This was more than a business squabble. It illustrates a strange truth with implications far beyond the borders of Watzerath: we don't always know where and how the wind will blow. Sure, the weather forecast will tell you the general direction and speed to expect tomorrow. But pick a specific spot on the map and we're hard pushed to say how breezy it generally is there.

That's why efforts are afoot to map the wind better than ever before. Getting answers will mean venturing to some of Europe's most windswept places – but it will be worth it. The prize isn't just a surer footing for renewable energy, but also answers to some of the enduring mysteries of the wind.



Although we can't predict the wind perfectly in complex local terrain, we do have a good idea of how the wind blows on a global scale. This visualisation shows the US National Oceanographic and Atmospheric Administration's wind forecast, which is updated every 3 hours.

The grand plans come at a time when wind energy is more important than ever for Europe. Last year, it overtook coal to become the continent's second largest source of power after natural gas. Wind now provides about a tenth of the energy Europeans use, and that could rise to a fifth by 2030. Achieving that will mean roughly doubling our current wind capacity. That means a lot of new turbines.

But where to put them? Potential sites must avoid homes and conservation areas, but be close to the electricity grid and enjoy steadfast winds. With many of the prime spots already taken, competition is fierce.

That makes mapping the wind more crucial than ever, but it's hardly a new endeavour. Efforts began as long ago as the 16th century, when map borders often featured heads with puffed-up cheeks, each representing a prevailing wind. Their placement was based largely on superstition, however, and it was only in the late 17th century that maps began to reflect measurements, after Edmond Halley, of comet fame, began charting wind directions during voyages.

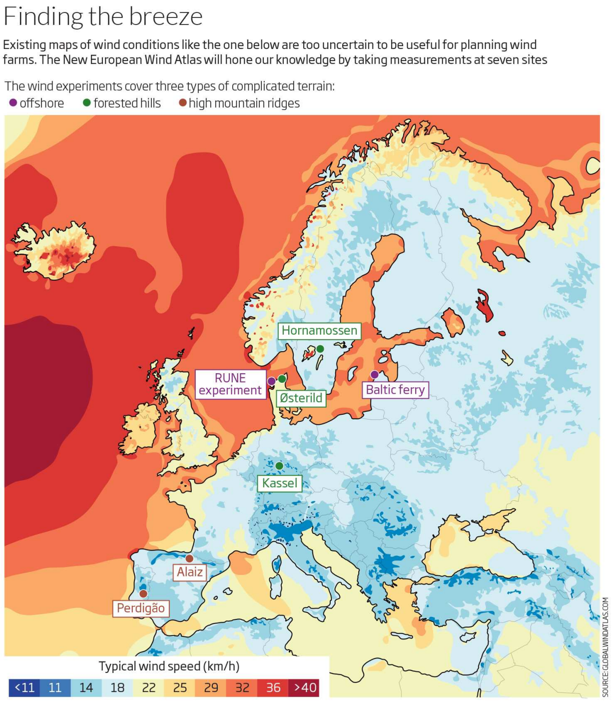
Surf's up

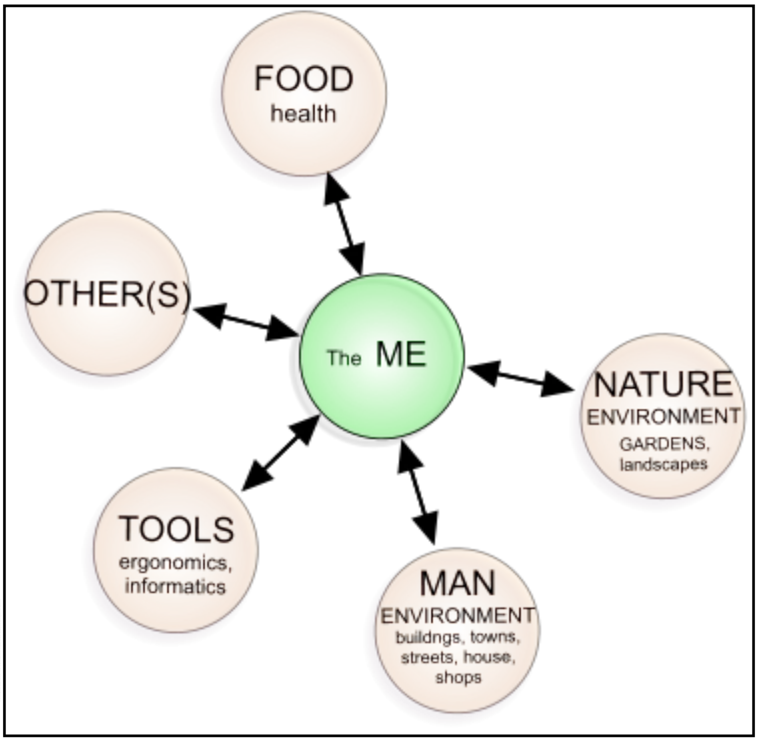
Modern efforts got going in the 1980s when Erik Lundtang Petersen, then at the Risø National Laboratory in Denmark, led the European Wind Atlas project. His team used temperature, atmospheric pressure and wind records from 220 meteorological stations across Europe to break down the continent into broad wind speed zones. These first appeared in a printed atlas in 1989, around the time a similar atlas was released covering the US. Once available online, the work attracted a broad audience: "I once read that surfers used it to find good sites in the Mediterranean," Petersen says.

The zones themselves were pretty crude: they couldn't give a decent sense of the gustiness of a specific hillside. But the atlas-makers had also developed handy computer models, released as the Wind Atlas Analysis and Application Program (WAsP). This meant anyone could plug in a location, together with a few weather observations, and WAsP would spit out predictions for wind velocity and the energy yield if there had been turbines there. These days the calculations have been generalised, and combined with data from weather stations and satellites, to yield an online Global Wind Atlas showing typical speeds (see map).

Simple models such as those used in WAsP are fine for plains. But predictions for more complex terrain can be out by as much as 50 per cent. The irregular shape of hills, mountain ridges and sea cliffs can whip up turbulence that those models find tough to capture. That's enough to put the wind up any potential turbine investor.

Frustratingly, such sites can see incredibly strong winds, but it's hard to tell which ones will do so regularly. For instance, the simple models routinely used in assessments say that the steeper a slope, the faster the wind will blow over the top of it. We know that's not always the case in reality, but we don't know precisely what factors cause this prediction to go awry. One of the hardest sorts of terrain to model is forested hills – like the ones on the outskirts of Watzerath – where the trees baffle the air in myriad ways from all sides.





"Simple models cannot cover forested areas," says Julia Gottschall at the Fraunhofer Institute for Wind Energy and Energy System Technology in Germany. "This wasn't so relevant 30 years ago, because you had many good sites for wind projects." But now, with most of the easy-to-model sites already in use, some new turbines are going to have to sit on terra incognita.

"Forested hills are enough to put the wind up any turbine investor"

That's why researchers are striving to create models that can capture more nuances. In the US, for example, fieldwork funded by the Department of Energy is characterising wind flow over the undulating hills of the Columbia river basin near Portland, Oregon.

But Gottschall and her peers across Europe are embarking on something more ambitious: the New European Wind Atlas (NEWA), an improved descendant of the 1989 original. "We would like to upgrade significantly," says project leader Jakob Mann at the Technical University of Denmark. Crucially, NEWA will, for the first time, attach uncertainties to its wind energy estimates, helping wind farmers gauge the risk of ending up in the doldrums.

Making the atlas means setting up camp in the windiest locales of Europe and measuring the finest details of factors that influence winds, from the way the ground heats and cools to the way vegetation conveys water vapour into the atmosphere. For more than a year, the NEWA collaboration has been collecting data at a constellation of seven experiments (see map). They employ a suite of instruments, including scanning lidar, which uses lasers to measure wind speed by tracking the movement of aerosol particles. By concentrating many sensors in complex terrains, the researchers can construct a detailed picture of wind flows.

Several of the experiments are in forests, and one is aboard a Baltic Sea ferry – the passengers none the wiser. But the most sophisticated is near Perdigão, Portugal, where an unprecedented array of instruments will track the wind as it crosses two parallel, 4-kilometre-long ridges. Some sensors here are set atop 54 meteorological towers up to

100 metres tall, approximating the heights of wind turbines. “It’s like climbing a ladder but there’s nothing at the top,” says Orson Hyde, a technician at the University of Notre Dame, Indiana, who helped to install the equipment.

Blowy up here: one of the 54 meteorological masts at Perdigao
New European Wind Atlas

After a pilot last year, Perdigão will really spin into action this month with a full complement of instruments. And it’s not just wind turbine developers taking note. For the next round of experiments, the core team will be joined by other interested parties, including Christopher Hocut from the US Army Research Laboratory. The work is especially interesting to Hocut because it’s at “army scale”, or approximately the size of a soldier’s immediate surroundings. “We want to understand everything that happens in the environment that’s on that scale,” says Hocut. Models will come in handy when flying drones, or to understand how toxic gas is dispersed by the wind in complex terrain.

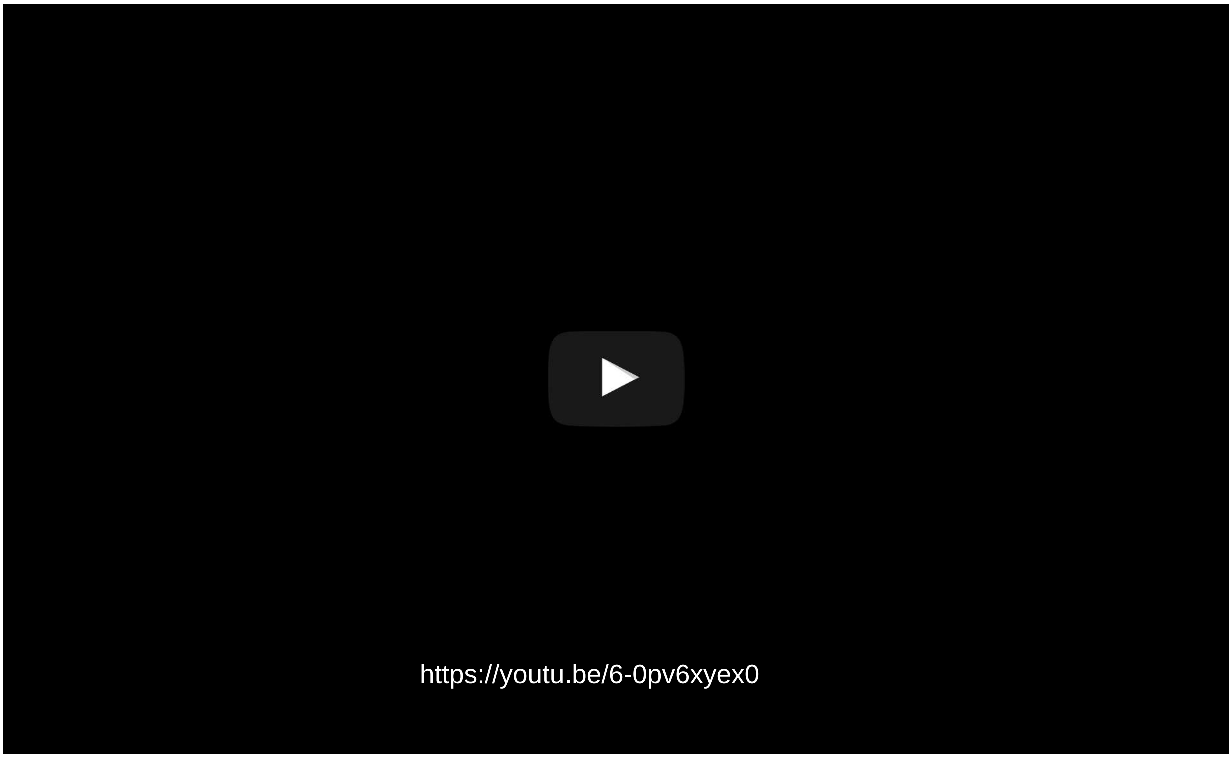
There are more fundamental mysteries to unravel too, says Julie Lundquist, an atmospheric scientist at the University of Colorado and co-leader of the Perdigão experiment. Take gravity waves, patterns in wind speed and temperature that crop up in the stratified night air, and can extend over 500 to 2000 metres. When the flow of wind is disturbed by something – a steep hill, say – waves form as a result of a balancing act between gravity, which pulls the densest air down, and a mix of other drivers including the air’s buoyancy. Some gravity waves seem to have a mind of their own, moving in different directions at different altitudes. Lundquist hopes the dense array of sensors at Perdigão will record these movements and allow researchers to figure out the waves’ behaviour. “They are not a smoking gun for any of the big questions in wind energy,” Lundquist says. “They’re just some of the cool phenomena that occur at night.”

Much like the original atlas, NEWA’s clout will lie in the models that power it, and their benefits will extend beyond Europe. Some of the findings will be transferable to US efforts to better understand the wind, says Mann. Plus, there is a growing demand for wind energy in Africa and South America. Nicolas Fischaux at the International Renewable Energy Agency says the models will help countries there spot potential wind farm sites.

When the new atlas is complete in 2020, the aim is to have wind energy predictions that are no more than 10 per cent out, far more precise than the 1989 atlas.

None of this can help Watzerath's lacklustre turbines. "Something really went wrong with this wind farm," says Petersen, who offered an expert assessment to the dismayed investors, who eventually lost their case. The nearby terrain is very complicated, so more measurements than usual should have been made to understand it.

On the flip side, Petersen says Watzerath is an ideal test site for the new atlas. "There's a hope," he says, "that we will be able to calculate Watzerath's wind farm production again – and reproduce it correctly".



Go fly a kite

Wind turbines can end up standing idle for uncomfortably long periods if they're sited in the wrong place (see main story). But you can quite literally get on top of the problem. Soar to a few times the height of a turbine and the wind blows strongly and consistently – that's why a few firms are betting on kite power.

The idea has been around since at least 2003, but lately it seems to have taken off. In 2013, Google X, the firm's research arm, bought a company called Makani that generates power using kite-mounted rotors, with the electricity transmitted down a tether to a ground station. "Energy kites fly above disturbances introduced by local terrain, so can be sited in valleys and other onshore sites unsuitable for conventional wind turbines," says Julie Lydon, a company spokesperson. The kites also use far fewer materials than turbines, the firm says.

Kite Gen, a company based in Italy, and the Kite Power research group at the Technical University of Delft in the Netherlands are taking a different tack: using the spooling in and out of the kite's cables to turn an electricity turbine.

One challenge is scaling up. That involves finding ways to control the kite automatically so it can be pulled inwards during lulls in the wind, minimising the power needed. But master that and it paves the way to one of Kite Gen's grand visions: a tens of kilometres-wide carousel turned with the power of many kites. That could generate some serious energy.

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