The hidden cost of wind turbines

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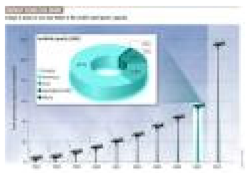

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Energy from the wind

It started with Turbine 68. On 16 October 2003, following excavations for the 49-metre tower's massive foundations, the peat bog above the village of Derrybrien in county Galway, Ireland, began to move. That night almost half a square kilometre of bog slid 2.5 kilometres down the hillside, engulfing an unoccupied farmhouse and blocking two roads. Journalists dubbed it the "bogalanche", and speculated about what might have happened had the weather been wet. Two weeks later they found out. Heavy rains washed peat soup into the Abhainn Da Loilioch river, where the sludge killed 50,000 fish and affected 50,000 more.

Anxious not to delay Ireland's renewable energy programme, politicians reassured local people that the bogalanche was an isolated incident. The operators were fined ¬1250 for polluting the river, they adopted new working practices, and completed construction of the 71-turbine project to create Ireland's largest wind farm. But the residents of Derrybrien were not prepared to leave it there. They felt ignored by the planning system and uncertain about what might happen next, so they commissioned their own report. The findings highlighted various shortcomings of the project, and concluded that the environmental impact assessment had failed to consider the implications of constructing major infrastructure on a peat bog. As a result, the European Union is now prosecuting the Irish government in the European Court of Justice.

What happened at Derrybrien was not a major environmental catastrophe, certainly not compared to the ravages of global warming, but it is a cautionary tale. If Ireland, and the rest of the world, is going to use wind energy to reduce greenhouse-gas emissions, there are going to have to be an awful lot more installations like Derrybrien. The problem is that in our haste to cash in on the obvious environmental benefits of wind power, we are largely ignoring the ecological damage that turbines can do. It is not simply a matter of sliding peat bogs. Some ecologists are warning that unless we think carefully about where wind farms are sited, they could disrupt fragile ecosystems and even contribute to global warming.

The stakes for wind energy are sky high. Seen by many as the major renewable alternative to fossil fuels, it is the world's fastest-growing source of power. In 2005, the world's installed wind power generation capacity increased by 43 per cent to almost 60,000 megawatts - that's more than 12 times Ireland's total electricity demand. Almost 70 per cent of this is in Europe, and while less than 20 per cent is in North America that figure is rising rapidly (see Diagram). Last year alone, US companies spent $3 billion on 2300 megawatts of new wind energy capacity, bringing its total to 9149 megawatts - a little more than 1 per cent of total US generating capacity. Other countries are also catching up fast. India is already fourth in the wind-energy league table, having overtaken Denmark, and China has plans to build 5000 megawatts of wind power capacity by 2010.

Worldwide, wind energy still accounts for little more than 0.5 per cent of total electricity generation, but expectations are high. The US government believes wind could supply up to 20 per cent of the country's electricity. Other estimates are even more impressive. Last year, Christina Archer and Mark Jacobson from Stanford University in California produced a global wind-energy resource map that estimated the global potential for wind-generated energy at 72 terawatts - that's 40 times the worldwide demand in 2000 (*Journal of Geophysical Research - Atmospheres*, DOI: 10.1029/2004JD005462). It is not surprising that governments have looked at growing electricity demand and the public's fears about global warming, and seen wind energy as part of the solution.

But there is a problem. Where do you put hundreds, if not thousands, of wind turbines? The obvious answer is a windy place in the middle of nowhere. In crowded Europe, at least, that often means taking the same option as the Derrybrien developers and building wind farms on peat bogs. In the UK, such farms include the 59-megawatt Cefn Croes in mid-Wales, which was the country's biggest wind farm when it opened last year, and a proposed 234-turbine, 702-megawatt installation on the Lewis Peatlands Special Protection Area in Scotland's Outer Hebrides. "Rolling hills near the sea offer the right kind of wind, and those are also the right conditions for bogs," says peat expert Richard Lindsay from the University of East London, who compiled the report for the Derrybrien residents along with colleague Olivia Bragg.

Lindsay is an advocate for renewable energy but has become concerned by the scale and number of wind-farm developments on peat bogs in Europe. "This is the Cinderella ecosystem," he says. "Peatland is busy performing a series of important functions for us and we just don't see it." Bogs often play a critical role in providing clean drinking water. More significantly in the context of renewable energy, they store three times as much carbon as is held in tropical rainforests. "We build wind farms in order to reduce carbon emissions," Lindsay says. "Yet peatlands represent the one land-based habitat in the world that is a major long-term carbon store. By building on peat, we release this carbon store as carbon emissions into the atmosphere."

This can happen in several ways. Peat dug out for foundations and service roads is stacked up and allowed to dry, and as it does so the carbon it contains - 55 kilograms per cubic metre - oxidises and is released into the atmosphere as CO_2. Construction on peat can also lead to widespread damage of a bog's integrity. Disruption of part of a bog can affect the whole ecosystem - in that respect, peatland acts more like a body of water than land, Lindsay explains. The results in this fluid environment are unpredictable, but can range from erosion of varying intensity to a catastrophic event like the one at Derrybrien.

Lindsay and Bragg calculated that the Derrybrien bogalanche released enough CO_2 to nullify the carbon savings during the lifetime of two of the turbines there. Even when the ecological impact of turbines is less dramatic, carbon emissions can still be substantial. Mike Hall from the Cumbria Wildlife Trust in north-west England has developed a formula to give a wind-energy CO_2 "budget" that balances the CO_2 savings that a project is expected to provide against the CO_2 costs from the manufacture and shipping of the turbines and construction work at the site.

The CO_2 costs are considerable even before accounting for emissions from peatland, primarily because of the energy required to produce the concrete in which turbines are embedded. The new generation of 140-metre turbines, need foundations the size of half a football pitch. Building on peat bogs contributes another large source of CO_2 that can add years to a turbine's CO_2 payback time. "The major CO_2 debt incurred by a wind turbine on a peat-rich site is not in its manufacture and installation but in the ongoing degradation of peat," Hall says.

Payback time

Hall has devised three scenarios for CO_2 emissions from degrading peat. The first is a baseline figure calculated simply from the amount of peat excavated in construction. The second "minimal scenario" includes emissions from degraded peat up to 50 metres around areas of disturbance such as foundations and service roads. This figure is being used by wind farm developer AMEC in Scotland. A third "high scenario" extends that range to 100 metres. Hall believes this is closest to the actual level of disruption, citing Lindsay's research, which indicates that damage to peat can extend for as much as 250 metres on either side of tracks or drainage ditches, as water drains from the affected area.

To calculate carbon savings, Hall uses the developers' own predictions, which generally give figures for overall electricity generation of about 30 per cent of the maximum rated capacity of a turbine. The average achieved output for existing wind farms is actually lower than this - 25.6 per cent according to industry figures. Using the conservative "minimal scenario", Hall calculates that a 2-megawatt turbine built on peat moorland 1 metre deep will take 8.2 years to pay back its CO_2 cost. The figure for the "high scenario" is a whopping 16 years. Even the minimal figure is a substantial portion of a turbine's normal lifespan of 25 years, and considerably higher than the industry's own figures, which range between three and 18 months.

Developers sometimes promise to avoid some of these emissions by, for example, using "floating roads". "I call them 'sinking roads'," Lindsay says, having witnessed the fate of floating roads at Derrybrien. Worse, he believes environmental impact assessments completed by developers on peat bogs are often either flawed or incomplete. "Should we be developing energy systems on the landscape that is our main carbon store and which releases carbon when you build on it?" he asks. Put that way, the proliferation of wind farms on peatland does seem somewhat foolhardy. But what are the alternatives?

In the US and Australia many wind farms are built in desert regions. The ecological impact in these environments is largely unstudied. Somnath Baidya Roy from Princeton University and his team have done research suggesting that rotating turbine blades lead to desiccation of the surrounding area, which may be particularly damaging in deserts (*Journal of Geophysical Research Atmospheres*, DOI: 10.1029/2004JD004763). In addition, a recent study of Californian ground squirrels reveals that those living close to wind farms are more edgy and cautious than those that inhabit areas of desert where there are no turbines. Lawrence Rabin from the University of California, Davis, and colleagues conclude that this is likely to have a knock-on effect within the ecosystem, affecting species including golden eagles, red-legged frogs and California tiger salamanders. They, like Lindsay, argue for greater care in siting turbines to minimise their ecological impact.

In Europe, the main alternative to peat bog sites is to go offshore. Denmark leads the way. By 2030, it will have an offshore capacity of 4000 megawatts - around 40 per cent of its total electricity requirement. The UK also has big ideas, with 13 projects of up to 30 turbines each already approved, and a goal of achieving half its renewable target for 2010 with offshore turbines. Research into the ecological impact of offshore renewable energy developments is even sparser than for onshore projects. Writing in the *Journal of Applied Ecology* last year (vol 42, p 605), Andrew Gill from the Institute of Water and Environment at Cranfield University in Silsoe, Bedfordshire, UK, noted that only 1 per cent of all papers on renewable energy published in the past 15 years considers environmental impacts onshore, and none offshore. We have very little idea how offshore installations will affect the marine environment and disrupt its wildlife through habitat damage, noise and vibration, electromagnetic fields and collisions with turbines, he warns. The marine ecosystem is largely uncharted territory, so wind farm developers often have no way of knowing which sites might be less vulnerable.

This lack of basic ecological information is also a major concern to Mark Avery, conservation director for the UK's Royal Society for the Protection of Birds. "You would think, with the industry being more advanced in other countries, that there would be papers you could just pull off the shelf," he says. Yet even figures on bird collisions with turbines, a long-standing bone of contention, is limited (see "Watch the birdie"). "Climate change is very bad news, and we're convinced we need to reduce greenhouse gas emissions," says Avery. "Renewables, including wind energy, have a part to play. The problem is where to put them."

We will need a lot more research to answer that question. In the meantime, though, there is an alternative to building huge wind farms in vulnerable habitats. We could all install our own personal turbines on the roofs of our houses. "I do believe that micro-generation has an important part to play," Lindsay says.

Watch the birdie

Bird deaths are one of the fiercest areas of dispute between wind farm developers and protesters. The ageing installation at Altamont Pass in California is often cited when it comes to showing the dangers turbines can pose to birds. Each year turbines there kill between 800 and 1300 birds of prey, including 75 golden eagles and several hundred red-tailed hawks, according to research carried out by the California Energy Commission. Wind-energy lobby groups, meanwhile, acknowledge the poor record of a few wind farms, but point out that only a tiny proportion of human-related bird deaths are caused by the wind-energy industry.

Hard evidence that could resolve the dispute is thin on the ground. Mark Avery from the UK's Royal Society for the Protection of Birds (RSPB) says it is large birds - eagles, vultures, storks and the like - that seem to be most vulnerable. "Large birds are not that nippy, and they can struggle to get out of the way of turbines, particularly in bad weather, or the dark, or if they're tired," he says. "We need to explore all this in more detail."

After re-analysing previous studies last year, researchers at the University of Birmingham, UK, concluded: "Available evidence suggests that wind farms reduce the abundance of many bird species at the wind farm site." But the most striking aspect of their report was how little evidence is available. The researchers found just 15 articles drawing on 19 datasets, of which only nine were complete. Lead author Gavin Stewart says that many studies are kept secret, sometimes for commercial reasons, with statistics on bird kills being kept from bird conservationists.

Ongoing research in Norway adds weight to the idea that turbines and large birds don't mix. The Smøla islands, 10 kilometres off Norway's north-western coast, have one of the highest breeding densities of white-tailed or sea eagles in the world. Smøla also has a new wind farm, most of whose 68 turbines started turning last summer. Between August 2005 and May 2006, researchers have found nine sea eagles killed by turbine strikes. The RSPB has been running a pilot study of eagle behaviour on Smøla, and has now stepped up its work to include checks on eagle deaths. "Breeding results on Smøla have been strikingly poor compared with the 30 years before the wind farm was built," says Arne Follestad from the Norwegian Institute for Nature Research. "We are not confident that white-tailed eagles will adapt to the turbines and return to the wind park area."