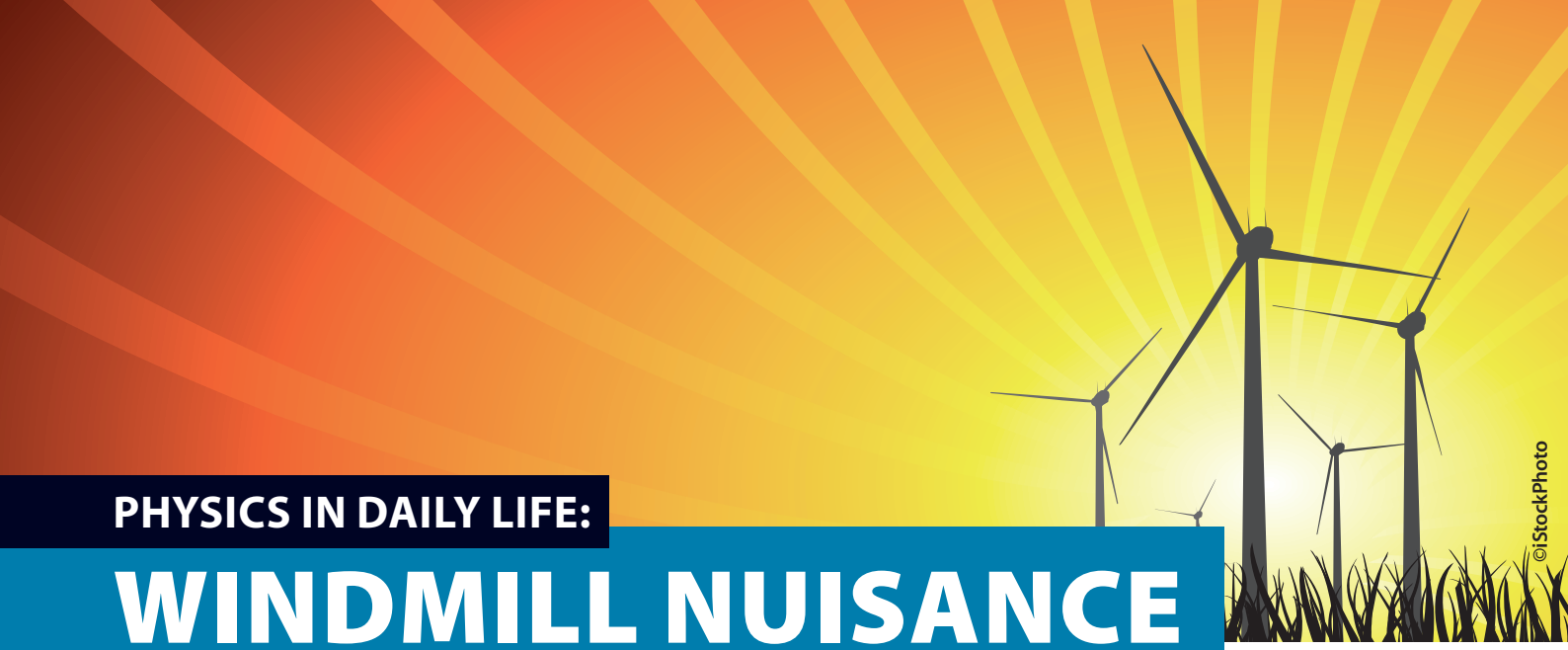

PHYSICS IN DAILY LIFE:

WINDMILL NUISANCE

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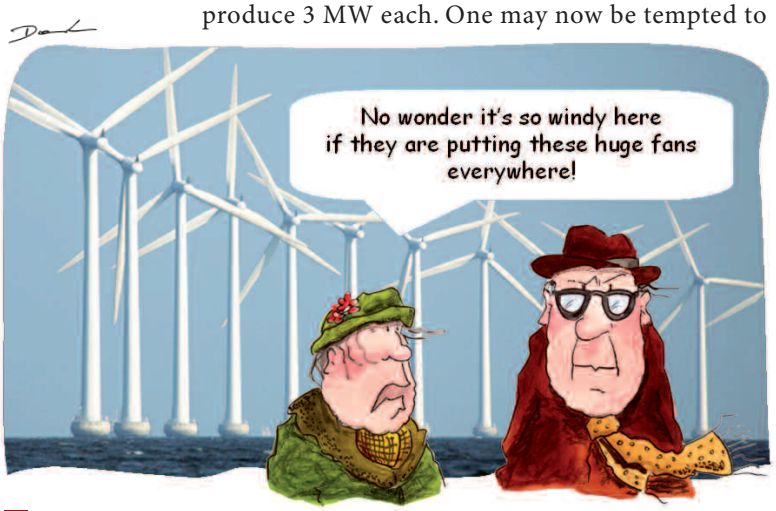
Many people dislike them, and some find them downright awful: it's the wind turbines scattered all across Europe these days. And let's be frank: there is nothing quite like the relentless droning of rotor blades to spoil the peace and tranquility of the countryside. Why do we put those things all over the place? As physicists we realize that wind power is proportional to v^3, with v the wind speed. So it may not be such a great idea to put those turbines on land, let alone in the middle of continental Europe where wind speeds are typically low. Why not put them off-shore where winds are strong, in the North Sea or the Baltic, for example? A few off-shore wind farms have already been put into operation recently, and a number of others are planned. Shouldn't we forget those monsters on shore altogether?

Let us have a closer look at the two options. First: wind turbines at sea. How many do we need, to begin with? Let us assume we want to have the equivalent of, say, 1500 MW, which is typically the electricity output of a large conventional or nuclear power plant. Modern wind turbines with a rotor diameter of 90 meters can produce 3 MW each. One may now be tempted to conclude that we need 500 turbines. Wrong. We have to include the load factor, *i.e.*, the average output divided by the maximum output. This is 30 to 33 % for wind turbines at sea (and up to 25 % on shore). So we need about 1500 turbines of this type for 1500 MW.



How much space would such a large number of turbines take? Here we have to account for the fact that a reasonable spacing is required. If wind turbines are too close, they will spoil each other's wind profile. This not only decreases the power of the wind turbines downstream, it also puts extra strain on the construction as a result of turbulence. It turns out that a spacing of 7 rotor diameters is a reasonable rule of thumb for wind farms. So the total area required is about 800 km^2. This is consistent with a rule of thumb saying that wind farms at sea generate, on average, between 1 and 2 MW per km^2, depending on type and location. This is, in first approximation, independent of the rotor diameter, since both turbine power and spacing scale with the square of the diameter. Large turbines obviously take advantage of the fact that the wind speed increases with altitude. Given the size of the seas around Europe, 800 km^2 does not sound unreasonable. So we should opt for off-shore wind power? Perhaps, but off-shore wind turbines have a drawback: building and maintaining them at sea is cumbersome. This makes them roughly twice as expensive as turbines on land. Economically speaking, we would be better off with wind power on shore. Such turbines, if placed wisely, are almost comparable to traditional power plants. And their 'energy pay-back time' is less than a year. Sounds great, but it does not address our aesthetic objections.

One may wonder: How did our 17th century ancestors perceive the windmills that we find so charming in the Dutch landscape today? Interesting question. But the answer… is blowing in the wind. ■