After studying the photographs and reference 2, interested readers should be able to supply their own answer to Archer's rhetorical question "why not?"

References

1. US Bureau of Land Management, Wind Energy Development Programmatic Environmental Impact Statement FAQs, http://windeis.anl.gov/faq.
2. US Department of Energy, Wind and Hydropower Technologies Program, State Wind Resource Maps, http://www.eere.energy.gov/windandhydro/windpoweringamerica/wind_maps.asp.

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As a free-standing, reliable, and stable source of energy, wind power is totally inadequate; even as a secondary, supportive source, it has serious limitations. Due to the character of wind, power is not produced in a steady stream over a long period but in a succession of spikes between zero and full power. The fluctuation makes reliable management of the power grid very risky. Moreover, wind power generation delivers only a modest fraction (20% to 25%) of the installed power capacity. For example, a 150-MW wind farm planned for the Gulf of Mexico outside Galveston, Texas, at a cost of $310 million would realistically deliver at an average rate of 30 MW. This will provide power for less than one extra minute per day for the state. To keep up with a 1.5% annual increase in electrical usage in Texas, one would have to build about 25 of these wind farms every year. So one 150-MW wind farm is small potatoes for Texas's electrical supply.

Germany is half the size of Texas but has more than twice the installed wind power capacity of the entire US, namely 16 400 MW, producing 4.9% of Germany's electricity (1.25% of its total energy). The problems created by the large investment Germany has made in wind power are discussed in the *Wind Report 2005*[1] from E.ON Netz, Germany's second largest electrical utility. The report concluded that the possibility of wind energy replacing conventional energy sources is quite limited. For instance, the country's 16 400 MW wind-energy system can actually only contribute 8% of its output capacity (1312 MW) as secure power production. So an extra, conventional generating capacity of about 90% of the wind capacity has to be added to the grid as backup, which would require an enormous additional investment.

The report also stated that the feed-in capacity for wind energy can change often and dramatically. "On Christmas Eve 2004, wind production in Germany fell 4000 MW in 10 hours, representing the capacity of eight 500 MW coal-fired power plants! This created an enormous challenge for the operators of the grid and it could easily have led to a vast blackout in central Europe."

For people thinking "the more wind energy the better," *Wind Report 2005* should be required reading.

Reference

1. E.ON Netz GmbH, *Wind Report 2005*, English translation available at http://www.eon-netz.com/EONNETZ_eng.jsp.

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Cristina Archer is quoted in the PHYSICS TODAY story as saying of wind energy, "We should really try to switch to wind power as much as possible. . . . It's an amazing source of energy—it's free, there's no fossil fuel involved, why not?" The story also notes that seven times as much energy is available as is currently consumed, from which I infer that the "possible" may include complete conversion to wind energy.

How much of this energy can be diverted without affecting climate and weather? Bird kills by wind turbines are dismissed as currently being less than 0.1% of wild bird deaths due to human causes, but the possibility that increasing use of wind energy could increase that rate by a factor of thousands is not considered. I'm sure other concerns—such as the effects of globally diminished wind speeds on ocean waves and currents—will arise when the matter is considered carefully.

Archer and Mark Jacobson are to be commended for their efforts in acquiring interesting and valuable information regarding wind speeds and distributions. However, I remain dismayed by the continuing efforts over the last three decades to identify desirable sources of energy without lucid analyses of the undesirable feedback and side effects they all must generate when scaled up from their experimental and marginal initial development.

Hints have appeared recently that even hard-core environmentalists are beginning to recognize that only nuclear energy can easily fulfill a major portion of current and projected energy needs, and that it would do so with the least amount of negative impacts—except for the criminally irresponsibly designed Soviet reactors—of all current energy sources. As Edward R. Murrow said, "The obscure we see eventually; the completely apparent takes longer."

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Archer and Jacobson comment: Kenneth Perry suggests that wind turbines interfere with nature's beauty. We believe, though, that the correct comparison is not with nature's beauty but with the visual, health, and climate impacts of coal, natural gas, and nuclear power plants (see, for example, http://www.fotosearch.com/photos-images/coal-burning-plant.html), which is what wind turbines would be replacing. No one wants to add a new facility of any type to the landscape, but so long as society demands energy, it must come from somewhere. Coal, natural gas, and nuclear power all have visual and health-risk externalities that we believe exceed those of wind power.

Frits de Wette contends that the intermittency of wind makes power management of a wind-energy-dominated grid risky. This is true when wind farms are not linked together in an organized manner through the transmission grid, but not true if they are. We have shown in a new study that interconnecting up to 19 wind farms several hundred kilometers apart converts an intermittent wind resource to one that produces about one-third of its electric power at the same reliability as the average US coal-fired power plant—which has a 12.5% outage rate. Remaining electricity can be firmed with hydroelectric, geothermal, solar, or other power. The website for Red Eléctrica, which operates Spain's electric power system (http://www.ree.es/ingles/i-index_de.html), further shows, as an example, that linking most of Spain's wind farms through a common grid would eliminate minute-by-minute fluctuations that occur at a single wind farm.

Whereas older wind turbines produce capacity factors of 20% to 25%, modern turbines (for example, producing 1500 kW, with 77-meter blades and 80-meter hub height) placed where mean annual wind speeds exceed 6.9 m/s at hub height have capacity factors greater than 35%. The Galveston project will generate approximately 40% of 150 MW, or 60 MW of electric power. California's electric power from fossil-fuel sources could be replaced by 6280 5-MW turbines offshore or onshore in wind speeds greater than 8.5 m/s. This is only 3.3 times the current number of smaller turbines in California. We believe wind can provide a large portion of electric power and energy if wind