

KILLING WILDLIFE IN THE NAME OF CLIMATE CHANGE

*Written remarks for a hearing of the Senate Committee
on the Environment and Public Works, USA*

by Robert Bryce



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Robert Bryce – Senior Fellow, Manhattan Institute for Policy Research*

Good afternoon.

The focus of this hearing is on the economic benefits of ecosystems and wildlife and how they “are valuable to a wide range of industries,” including tourism. The purpose is also to examine “how the Administration is preparing to protect” ecosystems “in a changing climate.”

The facts show that federally subsidized efforts that are being undertaken to, in theory, address climate change, are damaging America’s wildlife. Furthermore, those same efforts have, for years, been allowing an entire industry to avoid federal prosecution under some of America’s oldest wildlife laws.

My discussion will focus largely on the wind-energy sector, an industry that has been getting federal subsidies since 1992, and the impact that the wind-energy business is having on wildlife.ⁱ

There are two key questions that must be addressed:

- * Are all energy providers getting equal treatment under the law when it comes to wildlife protection? The answer to that question is no.
- * Is widespread deployment of wind turbines an effective climate-change strategy? The answer, again, is no.

Energy companies are not being treated equally when it comes to enforcement of federal wildlife laws.

I have been writing about the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act since the late 1980s.ⁱⁱ In the late 1980s and early 1990s, the US Fish and Wildlife Service brought hundreds of enforcement cases against the oil and gas industry in Texas, Oklahoma, and New Mexico, for violations of those laws. And rightly so.

At that time, the Fish and Wildlife Service estimated that about 600,000 birds per year were being killed after coming in contact with illegal or improperly maintained pits in the oil fields.ⁱⁱⁱ In 2009, I resumed writing about the enforcement of the Migratory Bird Treaty Act, (enacted in 1918)^{iv} and Bald and Golden Eagle Protection Act (enacted in 1940)^v after groups like the American Bird Conservancy began calling attention to the threat that wind turbines were posing to birds and bats.^{vi}

A July 2008 study of bird kills by wind turbines at Altamont Pass, California, estimated that the massive wind farm was killing 80 golden eagles *per year*. Those birds are protected by the Bald and Golden Eagle Protection Act.^{vii} In addition to the eagle kills, the study, funded by the Alameda County Community Development Agency, estimated that about 2,400 other raptors, including burrowing owls, American kestrels, and red-tailed hawks – as well as about 7,500 other birds, nearly all of which are protected under the Migratory Bird Treaty Act – were being killed every year at Altamont.^{viii}

In 2009, a biologist with the Fish and Wildlife Service estimated wind turbines were killing some 440,000 birds per year.^{ix}

The bird-kill studies in 2008 and 2009 underscored the pernicious double standard at work. In the late '80s, the Fish and Wildlife Service, found widespread violations of the Migratory Bird Treaty Act by the oil and gas industry. In response, it launched a multi-state, multi-jurisdictional crackdown on the oil and gas industry.

By 2009, the agency's own biologists were finding that the wind industry was causing similar levels of wildlife mortality to what had occurred two decades earlier in the oilfield, and yet there were no prosecutions. There were no multi-state law-enforcement actions. Instead, there was widespread silence on the issue and what appeared to be the Interior Department's issuance of a *de facto* get-out-of-jail-free-card for the wind industry because it had been deemed "green" by some advocates.

At the same time the wind industry was getting a free pass on bird kills, the Fish and Wildlife Service continued prosecuting traditional energy companies for violating the Migratory Bird Treaty Act. On July 10, 2009, Oregon-based PacifiCorp agreed to pay \$1.4 million in fines and restitution for killing 232 eagles in Wyoming over a two-year period. The birds were electrocuted by the company's power lines.^x

In 2011, the Fish and Wildlife Service filed criminal indictments against three drillers who were operating in North Dakota's Bakken field. One of those companies, Continental Resources, was indicted for killing a single bird, a Say's phoebe. Brigham Oil & Gas was charged with killing two mallards and Newfield Production was indicted for the deaths of two mallards, one northern pintail, and one red-necked duck.^{xi}

In 2012, investigators found that the Pine Tree wind project in California had killed at least six golden eagles.^{xii} In early 2013, Jill Birchell, a special agent in charge with the Division of Law Enforcement of the Fish and Wildlife Service, told me that a total of nine golden eagles had been killed at the Pine Tree project.^{xiii} A biological assessment of the Pine Tree project estimated that the wind project was killing some 1,595 birds, or about 12 birds per megawatt of installed capacity, per year.^{xiv}

Given the number of dead eagles being found at Pine Tree, and the projections of other bird mortality, the obvious question is this: Why haven't the owners of the Pine Tree project been prosecuted for violating the Migratory Bird Treaty Act and the Eagle Protection Act?

I can only speculate as to why there hasn't been a prosecution. But it's worth noting that the Pine Tree project is owned by the Los Angeles Department of Water and Power. Prosecuting such a high-profile governmental entity for repeatedly violating some of America's oldest wildlife-protection laws would be politically embarrassing. On its website, the LADWP claims that the Pine Tree facility is the "largest municipally owned wind farm in the US." The agency also says the Pine Tree project "displaces at least 200,000 tons of greenhouse gases" per year.^{xv}

In March 2013, a peer-reviewed study published in the *Wildlife Society Bulletin*, estimated that in 2012 alone, US wind turbines killed 888,000 bats and 573,000 birds. Those bird kills included 83,000 raptors.^{xvi} In September 2013, some of the Fish and Wildlife Service's top raptor biologists reported that the number of eagles being killed by wind turbines has increased dramatically over the last few years, going from two in 2007 to 24 in 2011. In all, the biologists found that wind turbines have killed some 85 eagles since 1997. And Joel Pagel, the lead author of the report, told me that that the eagle-kill figures they used are "an absolute minimum." Among the carcasses: six bald eagles.

Pagel's study was published just five months after the Fish and Wildlife Service issued a report which said flatly "there are no conservation measures that have been scientifically shown to reduce eagle disturbance and blade-strike mortality at wind projects."^{xvii}

The Pagel study is key because it shows that as more wind projects have been built, more birds have been killed. In 2007, the US had about 17,000 megawatts of installed capacity. By 2011, that figure had nearly tripled to about 47,000 megawatts.^{xviii} Over that time period, the number of documented eagle kills increased by a factor of 12.

Furthermore, when I interviewed Pagel by phone shortly after his report was published in the *Journal of Raptor Research*, he told me that since he completed his report, he and his colleagues have documented additional eagle kills by wind turbines in Idaho, Montana, Nevada, and North Dakota. Pagel refused to say how many additional eagle-kills they'd confirmed, but said, "it's quite a few." Pagel went on to say that there are now "14 states where eagles have been killed" by wind turbines. "That's a very large geographical area," he said, adding that more than half of the eagle carcasses "were found incidentally," and that there were "no systematic surveys" of the wind projects by people who had been trained to look for dead birds.^{xix}

To clarify that last comment: Pagel said that most of the dead eagles that have been killed by wind turbines were found by people who were not looking for them. Therefore, the actual total of dead eagles is likely far higher than what Pagel and his colleagues are reporting. "We don't know how many eagles are being killed at wind farms," Pagel said, "but it's definitely more than what we have reported."

The September report from Pagel and his colleagues appears to have embarrassed federal law enforcement authorities into finally take action against the wind industry. On November 22, the Justice Department announced that it had reached a \$1 million settlement with the owner of two Wyoming wind projects which had illegally killed golden eagles and other federally protected birds. The plea deal, with Duke Energy, marks the first time that the federal

government has enforced the Migratory Bird Treaty Act against the wind industry. By bringing criminal charges against Duke – for killing 14 golden eagles and 149 other protected birds – the Justice Department ended the legal double standard on enforcement of the Act.^{xx}

It's not at all clear what happens next. Although the Fish and Wildlife Service says it has several active bird-kill investigations on other wind projects, no prosecutions have been announced.

The situation got even murkier in December, when the Interior Department announced that it would consider granting some wind-energy companies permits that may allow them to kill or injure bald and golden eagles for up to 30 years without penalty. A number of environmental groups oppose the 30-year permit deal, including the American Bird Conservancy, Conservation Law Center, and the National Audubon Society.^{xxi}

Immediately after the deal was announced, Audubon issued a statement with the headline "Interior Dept. Rule Greenlights Eagle Slaughter at Wind Farms." The statement calls the permit deal "a stunningly bad move." It also quotes the group's president and CEO, David Yarnold: "Instead of balancing the need for conservation and renewable energy, Interior wrote the wind industry a blank check." He went on, saying "It's outrageous that the government is sanctioning the killing of America's symbol, the Bald Eagle."^{xxii}

Let me be clear: there is no such thing as a free lunch, particularly when it comes to energy production. Every form of energy comes with positives and negatives. What is problematic is the selective enforcement of our wildlife laws. If we are going to have a protected class of energy producers who are exempt from federal laws, then the Interior Department should make that policy clear. If the Justice Department and Interior Department are not going to enforce the law equally – if justice is not going to be blind – then perhaps policymakers should consider repealing our wildlife laws altogether.

Before moving on, let me briefly mention the issue of bat kills. Earlier this month, I interviewed Merlin Tuttle, one of the world's foremost experts on bats. He told me "Anyone familiar with bat population biology is deeply concerned about the impact of wind turbines on the long term viability of a number of bat species."

Tuttle, who is the founder of Bat Conservation International, as well as the Bats and Wind Energy Cooperative, said that bats have slow reproductive rates.^{xxiii} And while some wind-energy companies have been conscientious in their efforts to mitigate the impact of their facilities on bats, other companies have not. The result: "We are at great risk of needlessly creating new endangered species. We risk losing the benefits of bats to natural systems and agriculture."^{xxiv}

Widespread deployment of wind turbines is not an effective climate-change strategy.

In discussing energy sources, we must cast aside the social marketing of renewable energy and discard pre-conceived notions as to what qualifies as "green." Instead, we must focus on basic physics and math.

I am an ardent proponent of nuclear energy because of its negligible carbon dioxide emissions and its incredibly high power density. No other form of energy production can produce as much energy from such a small footprint as a nuclear reactor. This is due to basic physics. Allow me to explain this by using a common metric in physics: power density, which is a measure of the energy flow that can be harnessed from a given area, volume, or mass.

The concept of power density can be understood by looking at the San Onofre Nuclear Generating Station in Southern California. SONGS has a capacity of about 2,200 megawatts (2.2 billion watts.)^{xxv} The plant, which is slated for closure, covers 214 acres or 866,027 square meters.^{xxvi} Therefore, the nuclear plant has a power density of about 2,500 watts per square meter.^{xxvii}

Now let's compare that to the power density of wind energy, which is 1 watt per square meter. And I can back up that number with a half dozen studies.^{xxviii}

Therefore, to replace the San Onofre plant with wind energy would require setting aside 2.2 billion square meters of land. That's 2,200 square kilometers. Put another way, if we wanted to replace the San Onofre Generating Station solely with wind energy, California policymakers would have to set aside a land area nearly as large as Sacramento County.^{xxix} And because of the low-frequency noise and infrasound that wind turbines make, no people could live on that county-sized piece of land.

It is essential to understand the concept of power density because it is directly related to the wildlife-kill issue. To produce significant quantities of energy with wind energy requires vast swaths of land to be covered with wind turbines. And the more wind turbines that are installed, the more birds and bats will be killed. That can be seen by the Pagel study mentioned above, which shows that as wind-energy installations in the US have increased, so have the verified numbers of eagle kills.

When we look at the main justification for renewable energy projects, and wind energy in particular, climate change is nearly always mentioned. For instance, the Global Wind Energy Council claims "The greatest benefit of wind power is its contribution to reduction of carbon dioxide emissions."^{xxx} On its website, the American Wind Energy Association says "Mitigating climate change poses an immediate need to reduce greenhouse gas pollution. Fortunately, wind energy can play a major role in reducing CO₂ emissions."^{xxxi} And in a December 6, 2013 press release that focused on the bird-kill issue, the American Wind Energy Association claimed that wind energy "is one of the cheapest, fastest, most readily scalable ways available now to address climate change."^{xxxii}

Those claims are among many similar ones that have been made over the past few years by renewable-energy advocates. Here's the reality: Wind turbines are nothing more than climate-change scarecrows.

The proliferation of wind turbines over the past few years has not, and will not, result in statistically significant reductions in global carbon dioxide emissions. That is not an opinion. It is simple math.

In 2012, the American Wind Energy Association claims that wind energy reduced domestic carbon dioxide emissions by 80 million tons.^{xxxiii} That sounds significant. It's equal to about 1.4 percent of US carbon dioxide emissions in 2012. But the issue isn't US carbon dioxide emissions. As President Obama said in his State of the Union speech on January 28, "Over the past eight years the United States has reduced our total carbon pollution more than any other nation on Earth."^{xxxiv}

The daunting challenge we face is global carbon dioxide emissions. In 2012, those emissions totaled 34.5 billion tons.^{xxxiv} Thus, in 2012, the 60,000 megawatts of domestic wind-generation capacity reduced global carbon dioxide emissions by about two-tenths of 1 percent.

Since 1982, global carbon dioxide emissions have been increasing by an average of about 500 million tons per year.^{xxxv} If we take the American Wind Energy Association's claim that 60,000 megawatts of wind-energy capacity can reduce carbon dioxide emissions by about 80 million tons per year, then simple math shows that if we wanted to stop the growth in global carbon dioxide emissions by using wind energy alone, we would have to install about 375,000 megawatts of new wind-energy capacity every year. If we assume each turbine has a capacity of two megawatts, that would mean installing 187,500 wind turbines every year, or nearly 500 every day.

How much land would all those wind turbines require? Again, the math is straightforward. As I noted earlier, the power density of wind energy is 1 watt per square meter.

Therefore, attempting to halt the growth in carbon dioxide emissions with wind energy alone would require covering a land area of about 375 billion square meters or 375,000 square kilometers -- an area the size of Germany -- *and we would have to do so every year.*

What would that mean on a daily basis? Using wind alone to stop the growth in carbon dioxide emissions would require us to cover about 1,000 square kilometers with wind turbines -- a land area about 17 times the size of Manhattan Island -- *and we would have to do so every day.*^{xxxvi} Given the ongoing backlash against the wind industry that is already underway here in the US, as well as in Canada, Europe, and Australia, the silliness of such a proposal is obvious.

The hard but unavoidable truth about wind energy is that it not even a viable option to *stop the growth in global carbon dioxide emissions, much less make a significant dent in existing demand for carbon-based fuels.*

If we are going to agree that carbon dioxide is a problem, and that we must reduce carbon dioxide emissions in order to protect wildlife, then we must embrace the technologies that are most effective at reducing our production of that gas. And that means N2N, natural gas to nuclear.

A surge in availability of low-cost natural gas has been a key driver of the recent reductions in US carbon dioxide emissions. Furthermore, it is beyond argument that that if we are going to be serious about making further reductions in emissions, we will have to get serious about nuclear energy, not just on a national basis, but on a global basis.

That point was made in November, when some of the world's top climate scientists, including James Hansen, a former NASA scientist, Kerry Emanuel of the Massachusetts Institute of Technology, Tom Wigley of the University of Adelaide in Australia, and Ken Caldeira of the Carnegie Institution, wrote an open letter that was clearly aimed at anti-nuclear groups like the Sierra Club, Greenpeace, and the Natural Resources Defense Council. The letter says that while renewables "like wind and solar and biomass" are growing, those sources "cannot scale up fast enough to deliver cheap and reliable power at the scale the global economy requires." It went on, saying that "in the real world there is no credible path to climate stabilization that does not include a substantial role for nuclear power." The four concluded their epistle by saying that if environmental activists have "real concern about risks from climate change" then they should begin "calling for the development and deployment of advanced nuclear energy." ^{xxxvii}

Rather than get serious about nuclear, the US and other countries have been subsidizing the paving of vast areas of the countryside with 500-foot-high bird-and bat-killing whirligigs that are nothing more than climate talismans. Wind turbines are not going to stop changes in the earth's climate. Instead, they are token gestures -- giant steel scarecrows -- that are deceiving the public into thinking that we as a society are doing something to avert the possibility of climate change.

Even though wind energy has not been, and cannot be, an effective strategy to address global climate change, the US government and state-level policymakers are continuing to pursue this failed strategy through tax breaks, mandates, and subsidies. Those policies are leading the deployment of still more bird-and bat-killing wind turbines. According to the latest projections from the Energy Information Administration, domestic wind-energy capacity is expected to increase by about 25 percent, to about 75 gigawatts, by the end of 2015. ^{xxxviii} And most, perhaps all, of that additional 15 gigawatts of wind-energy capacity, will be getting taxpayer money in the form of the production tax credit, the 2.3 cent per kilowatt-hour subsidy that is given to the owners of qualifying wind projects.

Given the studies already done on wind energy's deleterious impact on wildlife, combined with the "energy sprawl" that will come with the industry's continuing expansion, it is virtually certain that as the wind sector adds more turbines, more federally protected wildlife – including more bald eagles, an animal that has been on the Great Seal of the United States since 1782 – will be killed. ^{xxxix} And thanks to the production tax credit, taxpayers will be subsidizing the slaughter.

The question at hand is obvious: why are policymakers implementing an energy policy that is a known killer of wildlife in exchange for what are infinitesimally small reductions in carbon dioxide emissions?

If the federal government is going to be serious about addressing climate change and in protecting this nation's wildlife, it must focus on the energy sources that have small footprints, are able to provide large amounts of dispatchable energy at reasonable cost, and can provide significant reductions in carbon dioxide emissions when compared to the two sources that dominate our current energy mix: oil and coal.^{xi}

Those energy sources are natural gas and nuclear energy.

Thank you.



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- ⁱ Department of Energy, "Renewable Electricity Production Tax Credit," undated, <http://energy.gov/savings/renewable-electricity-production-tax-credit-ptc>.
- ⁱⁱ See Robert Bryce, "Crackdown Due on Foul Water Holes: Birds Fall Victim to Slime in 3 States," *Tulsa Tribune*, November 17, 1989, <http://www.robertbryce.com/articles/440crackdown-due-on-foul-water-holes-birds-fall-victim-to-slime-in-3-states>. See also, Robert Bryce, "Oil Waste Pits Trap Unwary Birds," *Christian Science Monitor*, March 19, 1990, <http://www.csmonitor.com/1990/0319/apit.html>.
- ⁱⁱⁱ Robert Bryce, "Oil Waste Pits Trap Unwary Birds," *Christian Science Monitor*, March 19, 1990, <http://www.csmonitor.com/1990/0319/apit.html>.
- ^{iv} <http://www.fws.gov/laws/lawsdigest/migtrea.html>.
- ^v <http://www.fws.gov/midwest/midwestbird/eaglepermits/bagepa.html>.
- ^{vi} Robert Bryce, "Windmills Are Killing Our Birds," *Wall Street Journal*, September 7, 2009, <http://online.wsj.com/news/articles/SB10001424052970203706604574376543308399048>.
- ^{vii} Fish and Wildlife Service data. Available: <http://www.fws.gov/midwest/Eagle/guidelines/bgepa.html>.
- ^{viii} Alameda County Community Development Agency, "Altamont Pass Wind Resource Area Bird Fatality Study," July 2008, 1-3. Available: http://www.altamontsrc.org/alt_doc/m30_apwra_monitoring_report_exec_sum.pdf.
- ^{ix} Albert M. Manville II, "Towers, Turbines, Power Lines, And Buildings—Steps Being Taken By The U.S. Fish And Wildlife Service To Avoid Or Minimize Take Of Migratory Birds At These Structures," Proceedings of the Fourth International Partners in Flight Conference: Tundra to Tropics 262–272, undated (2009), http://www.partnersinflight.org/pubs/mcallenproc/articles/pif09_anthropogenic%20impacts/manville_pif09.pdf, 268.
- ^x Fish and Wildlife Service data. Available: <http://www.fws.gov/news/newsreleases/showNews.cfm?newsid=750629CF-E286-4B51379292C1D9377C411>.

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- xi Christopher Helman, "Judge Throws Out Criminal Case Against Oil Companies for Killing Birds at Drilling Sites," *Forbes*, January 18, 2012, <http://www.forbes.com/sites/christopherhelman/2012/01/18/judge-throws-out-criminalcase-against-oil-companies-for-killing-birds-at-drilling-sites/>.
- xii Louis Sahagun, "US probes golden eagles' deaths at DWP wind farm," *Los Angeles Times*, February 16, 2012, <http://articles.latimes.com/2012/feb/16/local/la-me-eagles20120216>.
- xiii Author phone interview with Birchell, March 4, 2013.
- xiv Center for Biological Diversity press release, http://www.biologicaldiversity.org/news/press_releases/2011/wind-energy-project-10-202011.html.
- xv Los Angeles Department of Water and Power news release, undated, <http://www.ladwpnews.com/external/content/document/1475/248767/1/Pine%20Tree%20Fact%20Sheet.final.pdf>.
- xvi K. Shawn Smallwood, "Comparing bird and bat fatality-rate estimates among North American wind-energy projects," *Wildlife Society Bulletin*, March 26, 2013, <http://onlinelibrary.wiley.com/doi/10.1002/wsb.260/abstract>.
- xvii <http://www.fws.gov/windenergy/PDF/Eagle%20Conservation%20Plan%20GuidanceModule%201.pdf>, iv.
- xviii BP Statistical Review of World Energy 2013.
- xix Author phone interview with Pagel, September 16, 2013.
- xx <http://www.justice.gov/opa/pr/2013/November/13-enrd-1253.html>.
- xxi http://www.abcbirds.org/abcprograms/policy/collisions/pdf/Groups_opposed_30yr_eagle_take_permits.pdf.
- xxii <http://www.audubon.org/newsroom/press-releases/2013/interior-dept-rule-greenlightseagle-slaughter-wind-farms-says-audubon>.
- xxiii For more on the BWEC, see: <http://www.batsandwind.org/index.php>.
- xxiv Author interview with Tuttle by phone, February 17, 2014.
- xxv <http://www.songscommunity.com/docs/DecommissioningSanOnofreFactsheet.pdf>.
- xxvi Tetra Tech, "California's Coastal Power Plants: Alternative Cooling System Analysis," undated, http://www.opc.ca.gov/webmaster/ftp/project_pages/OTC/engineering%20study/Chapter_7N_San_Onofre_Nuclear_Generating_Station.pdf, N-3.
- xxvii $2.2 \text{ billion watts} / 866,027 \text{ m}^2 = 2,558 \text{ W/m}^2$.
- xxviii For instance, see:
1. David J.C. MacKay, "Illuminating the Future of Energy," *New York Times*, August 28, 2009, <http://www.nytimes.com/2009/08/29/business/energyenvironment/29iht-sustain.html?pagewanted=all>, which puts the power density of wind at 2 to 3 W/m².
 2. Jesse Ausubel, "Renewable and Nuclear Heresies," *International Journal of Nuclear Governance, Economy, and Ecology*, Vol 1., No. 3, 2007, 233, <http://phe.rockefeller.edu/docs/HeresiesFinal.pdf>, which puts wind's power density at 1.2 W/m².

3. Vaclav Smil, "Power Density Primer: Understanding the Spatial Dimension of the Unfolding Transition to Renewable Electricity Generation, (Part V – Comparing the Power Densities of Electricity Generation) " Vaclavsmil.com, May 14, 2010, <http://www.vaclavsmil.com/wp-content/uploads/docs/smil-article-power-densityprimer.pdf>, which puts wind's power density at 0.5 to 1.5 W/m².
4. Todd A. Kiefer, "Twenty-First Century Snake Oil: Why the United States Should Reject Biofuels as Part of a Rational National Security Energy Strategy," Waterloo Institute for Complexity and Innovation, January 2013, <http://wici.ca/new/wp-content/uploads/2013/02/Kiefer-Snake-Oil2.pdf>, 33, 68, note 119. Kiefer puts wind's power density at 1.13 W/m².
5. Amanda S. Adams and David W. Keith, "Are global wind power resource estimates overstated?" *Environmental Research Letters*, February 25, 2013, http://iopscience.iop.org/1748-9326/8/1/015021/pdf/1748-9326_8_1_015021.pdf, which put wind's power density at 1 W/m².
6. Author's own calculations, based on data on 16 different projects that ranged in size from 40 megawatts to more than 2,000 megawatts. The projects were geographically diverse – Texas, Pennsylvania, Wyoming, Kansas, Ontario, and Australia --and totaled more than 5,000 megawatts of capacity. Author's finding: the power density of wind energy is 0.89 watts per square meter.

In summary, the power-density calculations of wind energy are as follows:

Jesse Ausubel: 1.2

David J.C. MacKay: 2

Vaclav Smil: 1

Todd Kiefer: 1.13

Adams/Keith: 1

Robert Bryce: 0.89

Add those figures together and divide by six, and you get an average power density for wind energy of 1.2 watts per square meter --exactly what I reported in my 2010 book, *Power Hungry: The Myths of "Green" Energy and the Real Fuels of the Future*. If we toss out the high and low estimates (MacKay's 2 watts per square meter, and my 0.89 watts per square meter) then the average power density of wind is 1.08 watts per square meter.

xxix Sacramento County covers 2502 square kilometers. See: http://en.wikipedia.org/wiki/List_of_counties_in_California.

xxx Global Wind Energy Coalition, <http://www.gwec.net/faq/how-much-co2-emissionscan-wind-avoid/>.

xxxi American Wind Energy Association, <http://www.awea.org/Issues/Content.aspx?ItemNumber=854>.

xxxii American Wind Energy Association, <http://www.awea.org/MediaCenter/pressrelease.aspx?ItemNumber=5910>.

xxxiii American Wind Energy Association, <http://awea.rd.net/Resources/Content.aspx?ItemNumber=5097>.

xxxiv Full text available here: http://www.nytimes.com/2014/01/29/us/politics/state-of-theunion-address-text.html?_r=0.

xxxv BP Statistical Review of World Energy 2013.

xxxvi Manhattan Island covers about 59 square kilometers. See: <http://en.wikipedia.org/wiki/Manhattan>.

xxxvii <https://plus.google.com/104173268819779064135/posts/Vs6Csiv1xYr>.

xxxviii Capacity at the end of 2012 was roughly 60 gigawatts. See: BP Statistical Review of World Energy 2013. For the latest EIA projections, see EIA, Short-Term Energy Outlook, February 11, 2014, http://www.eia.gov/forecasts/steo/report/renew_co2.cfm.

xxxix <http://www.greatseal.com/committees/finaldesign/>.

xi Together, oil and coal provide about 63 percent of global energy consumption. See: BP Statistical Review of World Energy 2013.

Cover photo by Bret Stewart.

