Nature
Comment

"A US nuclear future?"

Counterpoint

Not wanted, not needed*

J. Doyne Farmer *of the Santa Fe Institute and* Arjun Makhijani *of the Institute for Energy and Environmental Research.*

The costs of nuclear power, from the cash investment to the risks of proliferation, disaster and environmental harm, are simply too high — especially when one considers that many of the true costs are obscured by government subsidies. Fortunately there are plenty of workable alternatives with low-to-zero carbon dioxide emissions. The current total power requirements of the United States could theoretically be supplied by solar power plants covering about 36,000 square kilometres of land in the desert southwest, an area an eighth the size of the state of Nevada. Wind energy could produce about nine times the current annual US electricity generation.

Although both resources currently provide only a tiny proportion of US energy, they can be ramped up quickly. Annual installation of wind-energy capacity in the United States has quadrupled from about 2,500 megawatts in 2006 to about 10,000 megawatts in 2009. Multiple groups have shown that wind-power capacity could grow to provide 30–40% of US electricity supply within 30 years. In 2008, a US Department of Energy report concluded that using wind energy to meet 20% of energy needs by 2030 "while ambitious, could be feasible".[1] One comprehensive study of the potential of solar energy showed that it "has the technical, geographical, and economic potential to supply 69% of the total electricity needs and 35% of the total (electricity and fuel) energy needs of the US by 2050".[2] None of this will be easy: it will require energy and carbon policy capable of redirecting the massive capital investment in fossil fuels and planned nuclear power. But the difficulties are political, not technological.

Wind power and solar power are often criticized for being too intermittent and unreliable. Solutions to these problems are available today. Compressed-air energy storage is cost effective, and has been used commercially with coal-fired plants since 1978 to smooth out peaks in demand. In addition, the technique of using molten salt to store the heat energy produced by concentrating solar thermal power plants is now being commercialized. A large 280-megawatt plant with six-hour salt-storage is planned in Arizona, with a tentative completion date of 2013. Existing hydropower could be used to even out remaining gaps in the power supply.

---

* This article first appeared as one of two parts of: Charles D. Ferguson, Lindsey E. Marburger, J. Doyne Farmer, and Arjun Makhijani. "A US nuclear future?", Comment, *Nature*, v. 467 (23 September 2010) pp. 391-393. doi:10.1038/467391a. On the Web at http://www.nature.com/nature/journal/v467/n7314/full/467391a.html#a4.

BETTING THE FARM

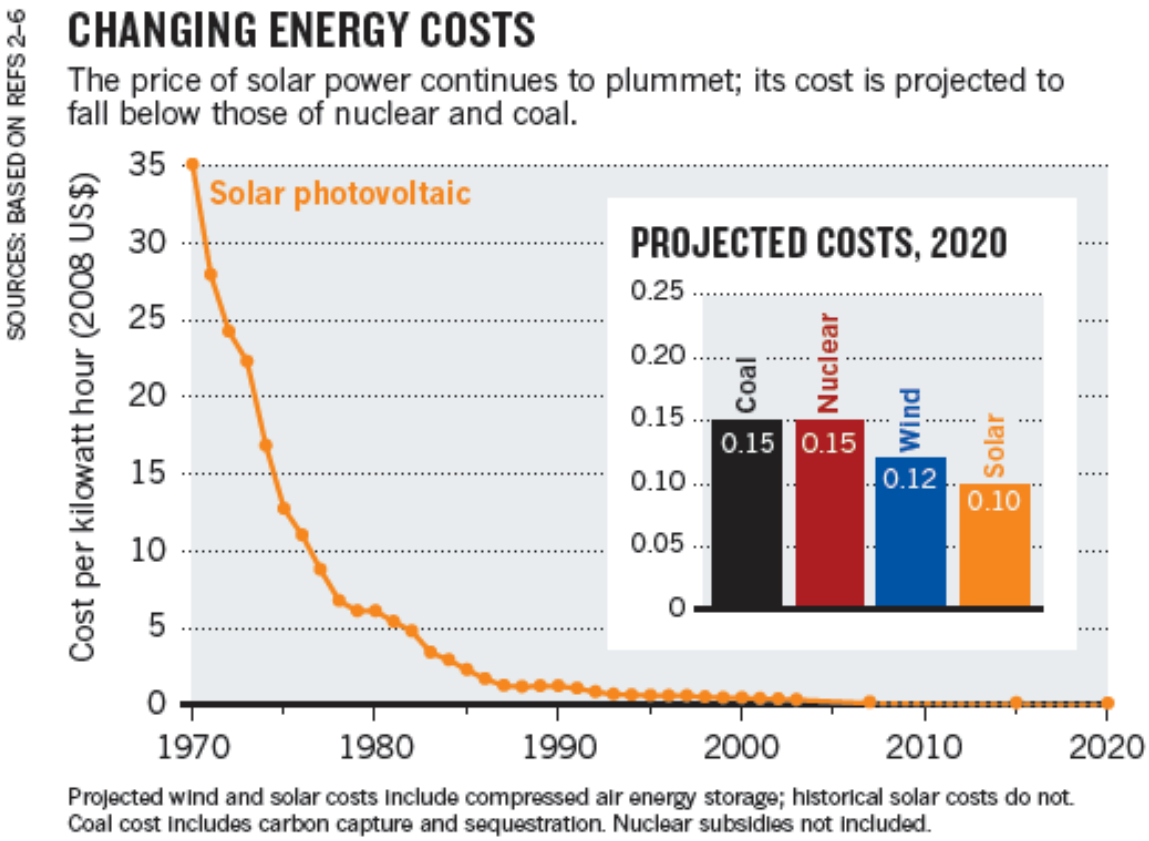
The cost of a nuclear reactor is often so large — US$8 billion to $10 billion — as to be comparable to the market capitalization of the company proposing the project. As a result they are considered a ‘bet the farm’ risk by Wall Street, which refuses to finance them.

The history of the US nuclear industry has been rife with construction delays, cost overruns and cancellations. The last reactor to come online, completed in 1996, took 23 years to build. Capital costs rose from about $1,000 per kilowatt in 1970 to $5,000–9,000 per kilowatt in the 1990s (ref. 3). The reasons are debated, but include loss-leader pricing in the early years, expensive design changes required by regulators in later years for safety, and interest-rate fluctuations. The enormous cost of reactors makes learning very expensive. Estimates over the past few years have shown that there is little reason to expect reactor construction costs in the United States to fall.

By contrast, between 1981 and 2001 the capital cost of wind power dropped by a factor of about four. Over roughly the same period (see graph), solar photovoltaic energy costs decreased by a factor of almost ten.[3] Since about 2003, increases in the costs of materials, due in part to the dramatic growth in demand in China, have pushed up the capital costs of all energy-generation technologies except solar.

Nuclear currently costs from about 12 cents to more than 20 cents per kilowatt-hour, and coal just 7–8 cents per kilowatt-hour, without the cost of carbon capture and sequestration. Wind is already generally cheaper than nuclear: we calculate that the full cost, including capital, fuel, operation and maintenance, is 11–14 cents with compressed-air energy storage. Large-scale solar photovoltaic energy without storage is currently at about 16 cents. By our estimate, only about $100 billion of additional built capacity (equivalent to the cost of a dozen nuclear reactors) is needed before solar energy will be cheaper than coal.[4]

Current price estimates for nuclear energy ignore important hidden costs. The US Price– Anderson Act caps the liability of the nuclear power industry at a few hundred million dollars per plant. By law the nuclear industry also maintains an ‘insurance pool’ that would pay up to about $11 billion in case of an accident. This is a meagre sum compared with the estimated damages of the most severe accidents, which could run into hundreds of billions of dollars. Clearly the Price–Anderson Act needs to be amended so that the cost of nuclear power reflects the full risks.



SCALED-UP DANGERS

There are also undesirable side effects of using nuclear power. To make a large dent in CO2 emissions, 2,000–3,000 reactors would be needed worldwide by 2050 to replace an equivalent coal capacity and to increase the share of nuclear electricity to about 30%. This poses a huge proliferation hazard. Two medium-sized uranium–enrichment plants would need to be built every year to fuel so many nuclear reactors, increasing the risk that some fuel would be diverted and enriched to weapons grade material. A major US push for nuclear power will make developing countries more likely to demand the capacity to enrich their own fuel, vastly hampering efforts to clamp down on nuclear proliferation.

In addition, each 1,000-megawatt reactor generates about 30 nuclear-bombs' worth of plutonium each year. There is still no long-term solution for the safe disposal of nuclear waste. This year, the office managing the US Yucca Mountain storage project is being closed down, leaving the discussion potentially back at square one after a 30-year and $12-billion effort.

Finally, each 1,000-megawatt nuclear plant loses between 40 million and 80 million litres of water a day through evaporation. Wind, solar photovoltaic and concentrating solar thermal power plants (if they are air-cooled) consume little by comparison. Switching from coal and nuclear sources to renewable energy could save about 7 trillion litres of water a year in the United States.

The nuclear power industry survives thanks to government lifelines. By its own reckoning, the US nuclear industry cannot be revived without massive loan guarantees, continued insurance subsidies and government guarantees to do something with the waste. Nuclear power cannot stand on its own feet after half a century. There are cheaper, quicker and better solutions at hand. President Barack Obama

needs to abandon the government lifelines for nuclear energy, and instead push for 30–40% renewable-electricity production by 2025. Such a course would convert cheap talk about US leadership into a reality. ■ see news p.376

J. Doyne Farmer *is a professor at the Santa Fe Institute, Santa Fe, New Mexico 87501, USA, and* **Arjun Makhijani** *is president of the Institute for Energy and Environmental Research in Takoma Park, Maryland 20912, USA.*

e-mail: jdf@santafe.edu

END NOTES

1. *20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply* (Doe, 2008); available at go.nature.com/ow33a4
2. Fthenakis, V., Mason, J. E. & Zweibel, K. *Energy Policy* **37,** 387–399 (2009).
3. Cooper, M. *The Economics of Nuclear Reactors: Renaissance or Relapse?* (2009).
4. Farmer, J. D. & Trancik, J. *Dynamics of Technological Development in the Energy Sector* (London accord, 2007).
5. *Report of the Interagency Task Force on Carbon Capture and Storage* (2010); available at go.nature.com/BrBvQ2
6. Mason, J. *Wind with CAES Power Plant Model: Base Load Capacity Option* (renewable energy research Institute, 2009)

"Nuclear power cannot stand on its own feet after half a century."