Relative Risk: Global Warming and Imported Fossil Fuels vs. Nuclear Power

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Understanding relative risk is at the heart of America's current debate over a revival of nuclear power. "Nuclear power is dangerous," say the critics. "Dangerous compared to what?" should be the reply.

Commenting in early 2007, the president of Stanford University, John Hennessy, said, "Nuclear power has to be part of the solution [to global warming]. Can we really understand the notion of risk? Nuclear plants versus carbon emissions – which will kill and has killed more people?"[1] To this we should append a question about the relative risk of nuclear power versus America's reliance on fossil fuels. Imported oil and natural gas can fluctuate wildly in cost or may be embargoed by hostile nations while domestic coal remains far from clean and burning any type of fossil fuel contributes to greenhouse gas emissions.

All energy comes with risks. Coal mining is a deadly occupation – burning coal emits thousands of tons of radioactive particles, damages the lungs of tens of thousands of people a year, and releases billions of tons of carbon dioxide. Natural gas presents somewhat less of a carbon problem than coal, but it is highly explosive. Hydroelectric dams can burst, causing flooding that can be detrimental to communities and the environment. Dams also damage fisheries, while inundating large swaths of carbon-impounding forests. Burning biomass for power spews particulates and other pollutants into the air and competes with food and cash crops for limited farmland. Wind power consumes ten times the amount of cement and steel to produce the same amount of power as does nuclear, which it does only when the wind is blowing, and kills

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1. John Hennessy, President, Stanford University, Address at Alternative Energy Conference in Sunnyvale, California, *in Corn Fakes*, INVESTOR'S BUS. DAILY, July 18, 2007, at A12.

raptors and bats in the process. Photovoltaics are made with toxic materials, such as arsenic and mercury, and are still far more expensive than competing sources of energy. As a source of peaking power, solar thermal has become competitive with natural gas, mainly due to the latter's increasing costs and price volatility. Still, because of their capricious nature, solar and wind require the construction and maintenance of backup power plants, typically powered by natural gas, to ensure grid reliability. Thus, solar and wind cannot provide reliable on-demand baseload power.

THEN THERE'S NUCLEAR.

In spite of the limitations of other energy sources, for the last 30 years Americans have been reluctant to invest their support in nuclear power, but this attitude is beginning to shift.

America's 104 nuclear reactors produce about 20 percent of our nation's electricity. By comparison, France's 59 reactors produce 78 percent of its electricity while Sweden has 10 reactors that provide 48 percent of its power.[2] The first applications in 30 years for the building of new nuclear reactors were recently received by the Nuclear Regulatory Commission (NRC). Over the next two years, the NRC expects applications for 19 new reactors[3] with a total of 30 anticipated.[4]

In spite of a U.S. nuclear energy safety record that would be the envy of the coal, gas, or oil industry, the future of nuclear power is clouded by split public opinion, the majority of which unrealistically sees wind and solar as both reliable and affordable mainstays of the U.S. power grid. Good intentions from politicians and wishful thinking from the public will not power the grid, however.

Nowhere in America is this more apparent than in California, where 54 percent of residents told the Public Policy Institute that "global warming poses a very serious threat to the state's future economy and quality of life."[5] In 2006, in response to the publics' desire to do something, the California legislature passed, and Governor Schwarzenegger signed, a sweeping greenhouse gas law (Assembly Bill 32

2. Nuclear Energy Institute, World Nuclear Plants in Operation (Nov. 2007), http://www.nei.org/resourcesandstats/documentlibrary/reliableandaffordableenergy/graphicsandcharts/worldnuclearpowerplantsinoperation/; Nuclear Energy Institute, World Statistics (Mar. 2008), http://www.nei.org/resourcesandstats/nuclear_statistics/worldstatistics/.

3. Nuclear Plant Application Filed, Oil Daily, Aug. 3, 2007.

4. Rebecca Smith, Power Producers Rush to Secure Nuclear Sites, Wall St. J., Jan. 29, 2007, at A1.

5. Mark Baldassare, Dean Bonner, Jennifer Paluch and Sonja Petek, Public Policy Institute of California Statewide Survey: Californians and the Environment, July 2007 (Sept. 2007), http://www.ppic.org/content/pubs/survey/S_707MBS.pdf.

or AB 32).[6] AB 32 mandates a 25 percent reduction in greenhouse gas (GHG) emissions by 2020, returning emissions to their 1990 levels – all while the state's population is projected to grow 20 percent to 44 million people.[7] By 2050, AB 32 requires an 80 percent reduction in GHG emissions below 1990 levels.[8] A separate California law passed last year effectively phases out the use of conventional coal power over 20 years.[9] Coal now provides about 16 percent of California's power.[10]

Implementing these laws while growing the state economy may prove Californians right for the wrong reason when they agreed that global warming threatens the State's economy.[11]

The transportation sector produces 41 percent of California's GHG emissions.[12] Short of using government edicts to radically alter people's lives, the only way to meaningfully reduce these emissions is to offload them on an expanded and cleaner electrical sector. If electricity is affordable, this can be done with electric and hydrogen-powered vehicles at costs competitive with gasoline and diesel.

Electrical generation accounts for 22 percent of California's GHG emissions. More than half of these emissions come from burning natural gas, which provides 42 percent of California's electricity.[13] Yet reducing

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6. California Global Warming Solutions Act of 2006 (Assembly Bill No. 32), Cal. Health & Safety Code § 38500 (2008), available at http://www.leginfo.ca.gov/pub/05-06/bill/asm/ab_0001-0050/ab_32_bill_20060927_chaptered.pdf.

7. Id.; Public Policy Institute of California, California's Future Population (Sept. 2006), http://www.ppic.org/content/pubs/jtf/JTF_FuturePopulationJTF.pdf.

8. Assembly Bill No. 32, supra note 6

9. Cal. Pub. Util. Code § 8340 (2008), available at http://info.sen.ca.gov/pub/05-06/bill/sen/sb_1351-1400/sb_1368_bill_20060929_chaptered.pdf.

10. California Energy Commission, 2006 Gross System Electrical Production (Apr. 16, 2007), http://www.energy.ca.gov/electricity/gross_system_power.html; California Energy Commission, 2005 Gross System Electrical Production (Sept. 7, 2006) http://www.energy.ca.gov/electricity/2005_gross_system_power.html.

11. Baldassare, supra note 5 at 13.

12. Gerry Bemis, California Energy Commission, Inventory of California Greenhouse Gas Emissions and Sinks: 1990 to 2004, Fig. 3 (Dec. 22, 2006) at 23, available at http://www.energy.ca.gov/2006publications/CEC-600-2006-013/figures/FIGURE-3.PDF. The California Energy Commission's Greenhouse Gas Inventory for December 2006 estimates transportation sector GHG emissions at 40.7 percent and electrical at 22.2 percent, but these figures are for emissions only and do not include total lifecycle factors such as manufacturing, construction, maintenance, and disposal. EPA, CO2 Emissions from Fossil Fuel, http://www.epa.gov/climatechange/emissions/downloads/CO2FFC_2004.pdf (last visited April 1, 2008). The U.S. EPA's 2004 estimate for GHG emissions for California is 393.83 million metric tons with 222.95 MMT from the transportation sector (56.6 percent) to 47.16 MMT from the electrical sector (12.0 percent). This estimate does not take into account imported electricity nor total lifecycle factors. Accounting for imported electricity would almost double electricity's portion of GHG emissions in the EPA survey, making it more in line with the California Energy Commission's Greenhouse Gas Inventory. According to a conversation the author had with a California Air Resources Board staffer, the ARB will adopt rules that account for total lifecycle emissions rather than simple "smokestack" emissions.

13. California Energy Commission, 2006 Gross System Electrical Production, supra note 10. The percentage of power from natural gas comes from California Energy Commission's 2006

California's dependence on natural gas, which is increasingly imported from abroad, will be impossible without a major change in state energy policy.

California law favors wind, solar, biomass, geothermal, and small hydroelectric, but they are costly or unreliable and do not make much of a dent, if any, in GHG emissions.[14] That leaves nuclear power as the sole source of power that is scalable, reliable and affordable. At a cost of about $4 billion for a 1,600 mW reactor, each new reactor built would save about $1 billion in burned natural gas per year[15] and about 8 million metric tons of GHG emissions,[16] all while using about $30 million in uranium.

Yet, any discussion about nuclear power immediately turns to the question of what to do with the spent nuclear fuel created in power generation. And there it stops. Many environmental groups claim that they would not oppose nuclear power if the nuclear waste issue could be solved. But any discussion of what to do with spent nuclear fuel makes one quickly realize that many nuclear opponents are not being honest about their opposition, as nothing can satisfy their concerns.

The anti-nuclear argument is an airtight but circular argument focused on the isotope of nuclear fission: plutonium-239. Each

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Gross System fact sheet. The GHG calculation comes from the author's own work reviewing several studies of lifecycle CO2/kWh for nuclear. See Joseph V. Spadaro et al., Assessing the Difference: Greenhouse Gas Emissions of Electricity Generating Chains, 42 IAEA Bulletin 2000, at 19, 21 chart ("The range of total greenhouse gas emissions from electricity production chains"); Australian Uranium Association, Comparative Carbon Dioxide Emissions from Power Generation (May 2007), available at http://www.uic.com.au/ComparativeCO2.htm; Uranium Information Center, Energy Balances and C02 Implications (March 2006), available at http://www.uic.com.au/nip100.htm.

14. See supra note 13; Hans Holger Rogner & Arshad Khan, Comparing Energy Options: Progress Report on the Inter-Agency DECADES Project, 40 IAEA Bull. 1998, at 2, 5 chart, available at http://www.iaea.org/Publications/Magazines/Bulletin/Bull401/bull401.pdf.

15. See Southern California Edison, San Onofre Nuclear Generating Station, http://www.sce.com/PowerandEnvironment/PowerGeneration/SanOnofreNuclearGeneratingStation/ (last visited April 1, 2008). The fact sheet shows that the two reactors producing 2,254 megawatts of power save the equivalent of 188 billion cubic feed of natural gas each year. Southern California Edison, SONGS Fact Sheet, http://www.sce.com/PowerandEnvironment/ PowerGeneration/ SanOnofreNuclearGeneratingStation/SONGSFactSheet.htm (last visited April 1, 2008). One modern 1,600 megawatt reactor would therefore save about 71 percent as much natural gas as the two reactors at San Onofre, or about 133 billion cubic feet of natural gas. The wellhead price (less transportation and storage) for natural gas in September 2007 was $5.61 per thousand cubic feet at which 133 billion cubic feet would be valued at $749 million. Energy Information Administration, U.S. Natural Gas Wellhead Price (Dollars per Thousand Cubic Feet), http://tonto.eia.doe.gov/dnav/ng/hist/n9190us3M.htm (click "Monthly" under "View History") (last visited April 1, 2008). The value of 133 billion cubic feet of natural gas delivered would sometimes be more, sometimes less than $1 billion, depending on market conditions and contract terms.

16. Based on author's own calculations of lifecycle CO2 emissions, as extrapolated from the averaged output values, 599g/kWh for natural gas and 20g/kWh for nuclear. See Chuck DeVore, Electricity Cost and CO2 Model for California, Power for California (2007), http://www.powerforcalifornia.com/images/Electricity_Cost_and_CO2_Model.xls.

commercial nuclear reactor creates about 500 pounds of plutonium every year of operation.[17] This plutonium is the main argument against nuclear power. With a half-life of 24,110 years, plutonium-239 must either be reprocessed and used to make electricity, or placed in geologic storage for 200,000 years – the time needed for it to decay to radioactively safe levels.

The opposition to reprocessing is rooted in the Cold War-era fears of anti-nuclear activists. They argue that extracting the fissionable plutonium from spent fuel rods renders that plutonium available for making nuclear bombs (the second nuclear bomb used in warfare was a plutonium bomb). It was this rationale that caused President Jimmy Carter to ban U.S. nuclear fuel reprocessing in 1977. The thought was that this action would inspire other nations to do the same. Opponents of reprocessing speak of "plutonium-in-commerce" to define their fear that the extracted plutonium will fuel a new nuclear arms race. This line of reasoning leads us back to long-term geologic storage and the circular argument.

But the Gordian knot of plutonium has already been cut by the French. The French reprocess their spent nuclear fuel. By recycling usable fuel, including plutonium and unburned uranium back into their reactors, the French reduce the volume of used nuclear material by about 96 percent.[18] This slightly increases the cost of electricity, but it eliminates the need to safely store large amounts of plutonium-239 and other materials, saving money on the back-end by making geologic storage needed for a few hundred years, rather than two-hundred thousand years.

Eventually, America will have to settle on a method to deal with the nuclear material generated by its civilian and defense programs. That this material exists is an established fact. That methods are already being used around the world to deal with this material is also established. The only remaining issue is making the political decision to deal with it. This is why the proposed site in Nevada to store spent nuclear fuel is called the "Yucca Mountain Repository" and not the "Yucca Mountain Nuclear Waste Dump," since reprocessing renders any spent fuel stored there a valuable source of fuel for commercial nuclear reactors.

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17. Roger Dunstan, *Benefits and Risk of Nuclear Power in California*, California Research Bureau, California State Library (Apr. 2002), at 25; *available at* http://www.library.ca.gov/crb/02/08/02-008.pdf.

18. Todd P. Lagus, *Reprocessing of Spent Nuclear Fuel: A Policy Analysis*, at 2, in 9 WISE J. ENGINEERING & PUB. POL'Y 2005, *available at* http://www.wise-intern.org/journal/2005/Lagus.pdf. ("Spent fuel contains 96% uranium (mostly 238U), 1% plutonium, 0.1% minor actinides (neptunium, curium, and americium), and 3% fission products. Only a small portion (about 1%) of the fission products poses long terms hazards. The uranium, which can be separated from the rest of the products, still has most of its energy content and could be either reused or disposed of as low-level waste (LLW).").

Meanwhile, greenhouse gas emissions continue to pile up while foreign supplies of oil and natural gas gets more expensive – which brings us back to California. Unless California figures out a way to change the laws of physics and of supply and demand, electricity costs will likely soar, perhaps doubling in real terms as cheap coal is phased out and natural gas supplies tighten on world markets. The volatility of natural gas prices directly led to a Southern California Edison (SCE) 15 percent rate increase in 2006.[19] It also drove Northern California's Pacific Gas and Electric (PG&E) to announce a residential electricity rate increase of 4.1 percent in early 2008, then rescind it for a 0.8 percent cut.[20] Meanwhile, the Los Angeles Department of Water and Power approved a 9 percent electricity base rate hike, its first in 17 years, hitting the average-sized business with an added monthly cost of $1,043.[21]

These price increases will be exacerbated by pressures to comply with California's landmark Global Warming Solutions Act, AB 32. This in turn will put political pressure on a future legislature and governor to revisit the law. Possible scenarios include:

1) Regulations to reduce greenhouse emissions threaten to be "a very serious threat to the state's future economy,"[22] so future politicians decide to delay the reduction mandate or to simply rescind it allowing greenhouse gas emissions to grow.

2) A carbon cap and trade scheme is implemented, enriching traders on the floor of the Chicago Climate Exchange and serving as a substantial fossil fuel tax, leading to economic harm and the reversal of the law.

3) Regardless of the economic consequences, politicians and regulators extract a 25 percent carbon emissions reduction out of the California economy at the cost of economic pain, leading voters to throw them out of office, whereupon their successors reverse the law.

4) California gets serious about greenhouse gas emissions, lifts its ban on building new nuclear power plants, constructs four new reactors, and sees a large reduction in carbon emissions from the electrical sector and a small overall reduction in GHG emissions.

Note that every scenario posited countenances failure, except the last one. I do not see a reasonable path to success because, when it comes to government and economics, there are no miracles.

But, the last scenario requires a change of state law. California's ban on new nuclear power has been in effect for 32 years. Signed into law by

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19. *Edison Proposes Additional Customer Rate Relief*, CITY OF SAN MARINO NEWSL. (Oct. 2006) at 5, *available at* http://www.ci.san-marino.ca.us/pdf_forms/citycouncil/archive_communityNewsletters/CommunityNewsLetter_1006.pdf.

20. David R. Baker, *Tiny Drop in Power Bills for PG&E Residential Customers*, S.F. CHRON., Dec. 27, 2007, at A1, *available at* http://www.sfgate.com/cgi-bin/article.cgi?f=/c/a/2007/12/27/MN7MU503D.DTL&hw=pg&sn=011&sc=259.

21. Duke Helfand, *DWP Power, Water Rate Hikes OKd*, L.A. TIMES, Oct. 3, 2007, at B7.

22. *See* Baldassare, *supra* note 5.

then-Governor Jerry Brown in 1976 soon after voters overwhelmingly rejected a ballot initiative to make the state nuclear free, the ban prevents the approval of new nuclear power plants by the California Energy Commission (CEC) until a long term storage method or place for spent fuel rods is approved by the federal government. Even if the CEC does certify that a way to dispose of spent fuel is in place, the legislature may still overturn the CEC's findings. The likelihood of the current legislature ever repealing the nuclear power ban or even agreeing with an affirmative CEC finding that would permit the construction of a new nuclear power plant in California is slim to none. However, unless this law is repealed soon enough to allow nuclear power plants to be licensed and constructed, a six to eight year process, California is destined to fail in its attempts to lead by example on the global warming front. This leaves the ballot initiative as the only practical route to success.

California's four nuclear reactors furnish about 13 percent of the state's electricity,[23] saving some $2.6 billion per year in natural gas[24] and about 22 million metric tons of greenhouse gas emissions.[25] Adding four modern reactors would allow the electrical sector to reduce greenhouse gas emissions by 40 percent, returning the sector to 1990 levels.[26] Building an additional four reactors would provide enough lower cost electricity to replace a substantial portion of fossil fuel burned in the transportation sector – the main challenge in actually making AB 32 successful.

One last point about AB 32 and the laws of economics: California is not an island. When we act to increase the cost of doing business here, whether through higher taxes or more burdensome regulations, capital and labor have the choice to move elsewhere. California is the most electrically efficient state in America and the third most energy efficient state overall. Our environmental laws are world-class. The result is that a unit of goods or services produced in California does less harm to the environment here than it would were it produced in almost any other place on earth. But making California less competitive has the unintended impact of moving economic activity to other states or nations with less environmentally friendly economies. Many Californians concerned about air and water pollution were fine with the loss of

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23. California Energy Commission, *2006 Gross System Electrical Production*, *supra* note 10.

24. Based on cost to deliver 376 billion cubic feet of natural gas (188 billion cubic feet of natural gas from San Onofre's two reactors times 2 for what are virtually identical reactors at Diablo Canyon). *See supra* note 14.

25. *See* DeVore, *supra* note 16.

26. California Energy Commission, *1983-2006 California Electricity Generation* (2007), http://www.energy.ca.gov/electricity/ELECTRICITY_GEN_1983-2006.XLS. Electrical sector GHG emissions calculated by author based on historical figures for gross system electrical production in California, 1990 compared to 2006. *See* DeVore, *supra* note 15.

manufacturing jobs in exchange for improving California's environment. But to the extent that global warming is caused by greenhouse gas emissions, this California-centric strategy fails miserably. Any production of goods or services lost to Nevada or Arizona sets us back in the struggle to reduce global GHG emissions – and a loss to coal-fired China or India is far, far worse.

We gain nothing by setting standards for GHG emissions, only to see those emissions effectively moved out of California due to our state becoming a prohibitively expensive place to do business. To make a truly lasting impact on GHG emissions, California needs to secure a reliable and lower-cost source of baseload power. Today's technology dictates that the only source of such power is nuclear. Is it worth the risk relative to that posed by global warming driven by manmade greenhouse gas emissions?