The Energy-Climate Crisis is Your Business

Part IV: Is Nuclear Power a Viable Solution?[1]

James A. Cusumano, PhD

"... finances are not unlimited, and you can only spend the money once. How can anyone justify spending it on something that is not proven to be economical, not going to deliver for two decades – and then will only provide a limited solution? Michael Brooks, "Is It All Over For Nuclear Power?""
New Scientist, April 22, 2006

Oil prices are sky high and predicted to rise; some say beyond $250 per barrel within the next 18 months. Increasing greenhouse gases are changing the planet's climate and driving temperatures up around the world. As a result, a growing number of politicians and power company executives are beginning to overlook the challenges associated with nuclear power, highlighted by events at Three Mile Island and Chernobyl, and touting nuclear power as the solution to global climate change and energy security. Is it? You be the judge.

There are four critical factors to consider in answering this question: 1. Economics, 2. Commercial Potential, 3. Health and Safety, 4. Waste Management and Nuclear Proliferation.

ECONOMICS

We are faced with the emergence of a global climate-energy crisis, perhaps the most significant issue to face humankind since we first appeared on the face of the planet. Is nuclear power cost effective compared to other alternatives that could address this challenge? The nuclear industry thinks so, and points to the low operating cost of a nuclear reactor. But this distracts from the exorbitant capital costs in building a plant, decommissioning it after 30 years, and managing large volumes of resultant radioactive waste over a period of many millennia. One might call this "voodoo" economics. It's akin to you buying a new car and calculating transportation costs over your ownership period, simply by calculating the fuel costs, and omitting the cost of the car and its maintenance. As is done in all well run businesses and projects, the cost of capital and financing must be included in the economics. When this is done, several studies by knowledgeable and respectable institutions find nuclear power to be the most expensive source of energy (see Table 1). Furthermore, these calculations do not include the costs for decommissioning a plant at the end of its life, as well as those for transport and storage of highly radioactive nuclear waste. When these costs, which so far have been the burden of taxpayers, are included in the economic calculations, nuclear power costs are way off the chart.

Table 1: Cost of Newly delivered Electricity (2007 Cents per kWh)[2,3,4]

Nuclear Power	>14
Combined-Cycle Gas Plant	10
Coal Plant	9
Wind Farm	7
Building-Scale Cogeneration	6
Combined-Cycle Industrial Cogeneration	5.5
Recovered-Heat Industrial Cogeneration	3
End-Use Efficiency	0

In Table 1, a combined cycle gas plant is a system wherein a gas-fired-turbine generates electricity and the resultant waste heat is used to make steam to generate additional electricity via a steam turbine; this last step enhances the efficiency of power generation. Cogeneration refers to simultaneous generation of electricity and heat, using the heat to increase overall efficiency of operation. Increased efficiency means cheaper energy and lower greenhouse gas emissions.

One study looked at the accumulated costs of nuclear power in the U.S. from 1950 through 1990, and found that commercial nuclear power has thus far cost $492 billion, $97 billion of which was in the form of federal subsidies, i.e. billed to taxpayers[5]. This means that nuclear electricity cost the consumers at least 9 cents per kilowatt-hour, and a lot more when other factors are accounted for. These figures, which are far higher than the power costs for other readily available fuels, are conservatively low as they do not include costs for health effects of radiation, accidents, adequate insurance, plant decommissioning, and nuclear waste disposal. It is estimated that these factors would add at least an additional $375 billion, bringing the consumer price to at least 16 cents per kilowatt-hour. In contrast, other major fuel sources have costs in the range of 4 to 8 cents per kilowatt-hour.

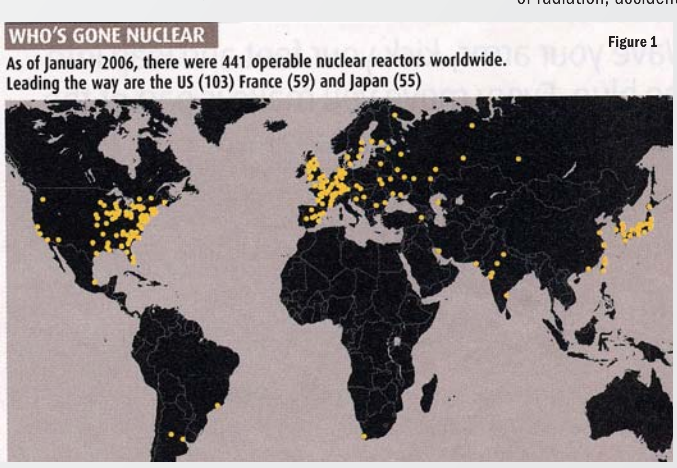

Figure 1

The economic challenges for nuclear power are likely to increase with time. Current reactor prices are already in the stratosphere, projected by the nuclear power industry to range from $5 billion to 12 billion per plant[6]. Non-industry calculations suggest that the latest proposed nuclear plant in the U.S. at Turkey Point, Florida is estimated to cost between $12 billion and $24 billion[7]. Capital costs have escalated with increase in the price of construction materials such as cement, copper, steel, and also with the demise over the last 20 years of the nuclear infrastructure to manufacture, manage and operate nuclear reactors. By comparison a 500 megawatt state-of-the-art coal combustion power plant costs about $ 650 million, and gas-fired power plants cost even less.

The nuclear industry does not have a good record of financial management. For 75 reactors built in the U.S. between 1966 and 1986, the average cost was $3 billion, or more than triple early estimates[8]. The advanced nuclear power plant under construction in Finland by the French company, Areva is already more than 24 months behind construction and $2 billion over budget. Industry sources also report that "Areva has been so anxious to showcase its technology that it has offered [Finland] a price that might not be sustainable to get the plant built[9]." Part of the problem is that nuclear plants are almost always built by central planning governmental bureaucracies using taxpayers' money. Wall Street will not invest in nuclear plants unless their risk is minimized by government loan guarantees, capping insurance liabilities, and providing numerous other subsidies. This year, the U.S. will provide more than $30 billion in subsidies to the nuclear power industry[10].

In the U.S., taxpayers insure plant operators against legal or regulatory delays and over the years have subsidized nuclear plants by ~1–5 cents per kilowatt-hour. In 2005, these subsidies were raised to ~5–9 cents per kilowatt-hour for new plants. This is - ~60–90 % of their entire power cost[11].

International energy expert, Amory Lovins summarizes his view of the economics of nuclear power this way:

The chief obstacle was and remains nuclear theology. This fervently held belief system asserts that nuclear power will become cost-effective if enough of it is bought; that its competitors, however laudable and successful, are and will always be inadequate; and that whatever its costs, and however unwilling the private capital market is to finance it, nuclear power must be bought anyway, because... well, just because... I'm unmoved by nuclear theology. In God we trust; all others bring the data. Show me the numbers[12].

COMMERCIAL POTENTIAL

Today, some 31 countries have 441 reactors producing 16% of the world's electricity, worth annually about $125 billion (see Figure 1). Essentially all of these power plants were built with large government subsidies using taxpayers' money, and would never have been funded by private capital markets because they are fundamentally uneconomic to build, especially when compared to alternative energy possibilities. In the U.K. and U.S., the arguments for a nuclear renaissance, although touting nuclear power as part of the solution to the climate-energy crisis, are really based on the fact that the nuclear reactors now generating electricity are coming to the end of their lives, and this will cause a precarious and dangerous energy gap if not replaced by some power source.

The largest projected growth for nuclear power is in Asia, in particular in China and India. However, even if China were to build all 30 of its planned nuclear plants, nuclear power would still only generate 5% of its electricity by 2030.

Nuclear advocates suggest that there is no way that other competitive alternative energy technologies could ever fill the growth gap that is projected in the power industry. This is a peculiar and specious argument as renewable low- or no-carbon electricity generation technologies have already surpassed the production of nuclear power, and are projected to grow rapidly (see Figure 2). These technologies are part of what is the early stage of the Micropower Revolution, generating power locally at the point of use instead of in large centralized plants and then shipping electricity hundreds of miles with attendant power losses. It is therefore not surprising that in 2006, new nuclear

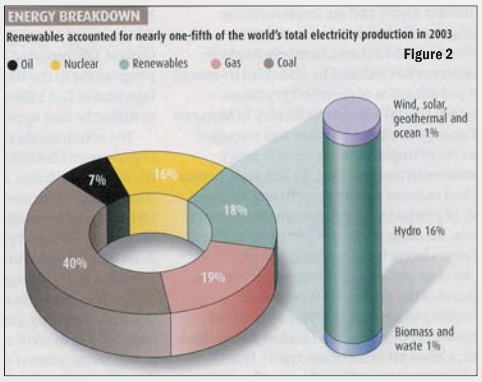

Figure 2

power generation accounted for 2 % of the increase in world wide electricity capacity generation, while micropower increased by 28 %[13]. Spain and Germany's venture into wind power alone, added as much power capacity in 2004 as the entire global nuclear industry will add from 2000 to 2010. By 2010, renewable and low-carbon power sources will provide 177 times as much added capacity as nuclear power[14].

Could nuclear power make even a modest contribution to addressing climate change? With the trivial goal of avoiding just 0.2 ºC of global warming[15] by 2100, Thomas Cochran, a physicist at the Natural Resources Defense Council, calculated that relying on nuclear power for this benefit would require increasing the number of reactors in the world from the current 441 to at least 700 by mid-century and holding the number steady for 50 years. Allowing for closure of old plants, this would require 1200 new plants, installed at the rate of 17 per year[16]. This is not remotely possible under current circumstances.

HEALTH AND SAFETY

On March 28, 1979, partial meltdown of the nuclear reactor core at Three Mile Island in the U.S. posed a significant early warning to the nuclear power industry. But the final nail in the nuclear power coffin was driven on April 26, 1986, when Chernobyl reactor number 4 in the Ukraine was ripped apart by an explosion, and burned out of control for 10 days spewing a massive amount of radioactive materials over Europe and the rest of the world. A recent report by U.K. radiation scientists says that the number of people who have died plus those that will die from the Chernobyl accident is as high as 60,000, fifteen time more than the number originally reported by the International Atomic Energy Agency and the World Health Organization[17].

Recent studies by researchers in the U.S. and Germany, analyzing data from 136 nuclear sites in the U.K. Canada, France, the U.S. Germany, Japan and Spain found an increased incidence of leukemia in children less than 9 years of age living close to these sites by as much as 21%[18]. Death rates were raised to as high as 24%, depending on proximity to the nuclear facilities. The study in Germany was by far the most troubling. These researchers found a 60% increase in solid cancers, and 117% increase in leukemia among young children living near all 16 large German nuclear facilities between 1980 and 2003.

In other recent studies in the U.S., subsequent to 1987, eight nuclear power plants located at least 113 km from other reactors ceased operations due to ageing reactors. Strontium -90, which is a lethal radioactive isotope, and is legally emitted at low levels by most nuclear power plants, was found to sharply decline in local sources of milk. Strontium is similar in structure to calcium and therefore can incorporate into children's bones and teeth. Deaths among infants who had lived downwind and within 64 km of each plant were found to decline in direct parallel to the decline in strontium -90[19].

WASTE MANAGEMENT AND NUCLEAR PROLIFERATION

A typical nuclear power plant generates 1000 megawatts of electrical power, and can supply the power needs of a city the size of Amsterdam (750,000 people). Such a plant produces 300 m^3 of low and intermediate level radioactive waste per year, and 30 tons of high level solid packed radioactive waste. Each year, nuclear power plants worldwide produce 200,000 m^3 of low and intermediate level radioactive waste, and 10,000 m^3 of high level radioactive waste[20]. The high level waste contains radioactive isotopes such as plutonium, which has a half-life of 24,000 years[21]. Many of these isotopes are highly toxic. For example, a person simply standing next to 1 gram of unshielded plutonium for 1 minute would be subject to certain death[22].

Some countries such as the UK reprocess their waste to recover radioactive materials (usually plutonium) that can be used again. This is a highly expensive process and severely debits the economics of nuclear power. Also, it provides a pure source of plutonium, which is relatively easy for a terrorist to steal and then incorporate in a nuclear bomb. Other countries such as the U.S., have stored their waste in swimming pools over several decades at nuclear power facilities, waiting for a government-approved storage facility for this waste.

No country in the world has solved the problem of how to safely store highly radioactive waste for millennia. For example, in the U.S., nearly $100 billion dollars has been spent over the last 25 years studying the possibility of burying nuclear waste deep within the earth at Yucca Mountain in Nevada. For safety, technical and political reasons, it is doubtful that this site will ever open for nuclear waste storage. And even if it did open in 2020 as currently scheduled, the Department of Energy says that it will be full to capacity within 2 years, and that taxpayers would owe the power companies more than $35 billion for the storage of radioactive waste on their premises over the past several decades.

And what of nuclear terrorism? The 9/11 Commission Report disclosed that Mohammad Atta, the pilot of the first plane to hit the World Trade Center, had considered targeting the Indian Point nuclear power plant he had observed during a reconnaissance flight over Manhattan[23]. General Electric and a recent study in Germany concluded that nuclear plants could not withstand a direct hit by a 737 or larger airplane[24]. The Union of Concerned Scientists study estimates that a terrorist-caused meltdown at the Indian Point nuclear power plant, located 30 miles north of New York City, could kill as many as 44,000 people from initial radiation poisoning, with more than 500,000 people eventually dying from cancer and millions more requiring permanent relocation. Direct economic losses could exceed $12 trillion, and the damage to the U.S. and global economies caused by the loss of New York's international financial center are essentially incalculable[25].

IF NOT NUCLEAR THEN WHAT?

The details for more cost-effective, environmentally-friendly solutions to the energy-climate crisis are contained in Part III of this series[26]. However, let's summarize a few key points.

- There is no "silver bullet." No single energy source currently known can solve our global energy-climate challenge in a timely manner. It will take a mix of clean technologies to do so.
- There are huge possibilities and opportunities in energy efficiency. In the Western World to save the equivalent of one barrel of oil on average currently costs $12. With oil hovering at $140 per barrel, that is a huge saving in both current power usage and in capital. The Electric Power Research Institute, which represents the U.S. power industry, estimates that the U.S. could save 75% of its current electricity use by increased energy efficiency measures. Similar possibilities exist in Europe and elsewhere in the world.
- Combined heat and power cogeneration technologies have carbon emissions which are as much as 80% less than conventional large-scale natural gas-fired plants.
- We have yet to capture the full potential of clean power from geothermal energy and heat pipes. The latter is an excellent component for micropower, i.e. power generated at the site it is used.
- New wind turbines are so efficient and falling in cost that they will provide numerous opportunities for energy generation. The largest turbines currently produce more than 7 megawatts of electricity (see Figure 3). Billionaire oilman T. Boone Pickens is building the world's largest wind farm in West Texas, producing 4,000 megawatts of electricity[29]. That's equivalent to 4 nuclear power plants, enough to power more than 1 million homes. Global installed wind capacity in 2007 was 94 gigawatts. At the projected annual global growth rate of 20%, this would result within 6 years in more than 280 gigawatts of capacity, the equivalent of 280 nuclear plants. This can be compared with the current global number of 441 nuclear plants, which were built over nearly 60 years. Even if the wind farms operated 30% of the time (New technologies operate at more than twice this rate.), they would generate the electricity of nearly 100 nuclear plants.
- Significant opportunities exist for advanced thermal biomass plants generating energy from wood waste[30].
- Cellulosic biofuels will shortly provide a low-cost, carbon-friendly route to replace part of our petroleum-based fuels.
- Plug-in hybrid cars, which will be launched in 2009 will diminish the need for oil, and in combination with low- or non-carbon based power such as wind or biomass, would help alleviate the climate change issue.
- Within 5 years, advances in solar technology, both photovoltaics (direct electricity generation) and thermal solar (solar heat to generate electricity) will help launch the Micropower Revolution[31].


Figure 3: The World's Largest Wind Turbine Generates over 7 Megawatts of Power

AND THE LIST GOES ON

Is nuclear power the solution to the challenges we face in the climate-energy crisis? You be the judge.

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[1] Parts I and II of this series outline the Global Energy Security and Climate Change issues, respectively, and Part III provides a summary of a workable solution. See Prague Leaders Magazine, Nos. 1, 2 & 3, 2008.
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[6] Rebecca Smith, "The High Cost to Go Nuclear," Wall Street Journal, May 13, 2008.
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[13] Amory Lovins, Ibid.
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[24] http://www10.antenna.nl/wise/index.html?http://www10.antenna.nl-wise/terrorism/112001gre.html.
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[26] James A. Cusumano, "The Energy-Climate Crisis is Your Business: Part III. A Workable Solution," Prague Leaders Magazine, No. 4, July, 2008.
[27] Amory Lovins, "The World in 2007: Getting Off Oil," http://www.rmi.org/images/PDFs/Energy/E06-08_GettingOffOil_World2007.pdf
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[31] "The Power and the Glory," The Economist, June 21, 2008, pp. 12–14.

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