Atomic Myths, Radioactive Realities:
Why Nuclear Power Is a Poor Way to Meet Energy Needs

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Journal of Land, Resources, & Environmental Law, Vol. 24 No. 1 2004
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"It is not too much to expect that our children will enjoy in their homes electrical energy too cheap to meter, will know of great periodic regional famines in the world only as matters of history, will travel effortlessly over the seas and under them and through the air with a minimum of danger and at great speeds, and will experience a lifespan far longer than ours ... . This is the forecast for an age of peace." Lewis Strauss, AEC Chairman, 1954[1]

"It is safe to say ... that atomic power is not the means by which man will for the first time emancipate himself economically, whatever that may mean; or forever throw off his mantle of toil, whatever that may mean. Loud guffaws could be heard from some of the laboratories working on this problem if anyone should in an unfortunate moment refer to the atom as the means of throwing off man's mantle of toil. It certainly is not that! ...At present, atomic power presents an exceptionally costly and inconvenient means of obtaining energy which can be extracted much more economically from conventional fuels... . The economics of atomic power are not attractive at present, nor are they likely to be for a long time in the future. This is expensive power, not cheap power as the public has been led to believe." C. G. Suits, Director of Research, General Electric, 1951[2]

Atomic power was born of self-deception as well as deliberate deception. There were messianic pronouncements of paradise on Earth that began at the end of World War II. Alvin Weinberg, a nuclear reactor designer and the first director of Oak Ridge National Laboratory, said in retrospect, in 1981, that he had "a little bit of the same spirit as the Ayatollah [Khomeini] has at the moment."[3]

Such fervent and self-deceptive excitement seemed to slide seamlessly into deliberate propaganda that the government knew was false. For by 1954, when Lewis Strauss made his famous statement that nuclear power would be "too cheap to meter" in the foreseeable future, a number of government and corporate studies had concluded the contrary.[4] None showed that it would be cheap, let alone "too cheap to meter."[5] The assessment of C. G. Suits of General Electric, quoted above, was distinguished from many others only in that it was more blunt.

Nor was there any reasonable prospect based on basic engineering considerations that nuclear power could be so cheap that any task, no matter how energy intensive, would have negligible energy costs. In the most optimistic scenario for nuclear power, it might be assumed that the fuel cost would be nearly zero. But that would still leave eighty-five percent of the costs of electricity for residential and small business consumers and sixty percent for the largest industrial users intact. The reason is that the bulk of the costs of electricity are related not to the fuel and the boiler (the functions served by the nuclear fuel and nuclear reactor), but by the power generating equipment, and the transmission and distribution network. Moreover, it was clear even then that (i) nuclear reactors would cost far more than coal-fired boilers, and (ii) it would be difficult to manage and dispose of nuclear waste. And of course, nuclear fuel was not free. Uranium was thought to be a scarce resource in the 1950s and fuel costs then were expected to be an important part of the costs of generating nuclear power.

The West knows the costs of uranium fuel well. This is especially so in the Colorado Plateau, which is dotted with about two hundred million tons of radioactive mill tailings[6] and possibly a comparable amount of uranium mine waste. These wastes have injured health, polluted precious water supplies, and resulted in billions of dollars in clean-up costs.[7] And the liabilities will extend into the future for tens of thousands of years. The half-life of thorium-230, the radionuclide that drives the radioactivity content of mill tailings, is about 75,000 years. Thorium-230 decays into radium-226, which has a half-life of 1,600 years.[8]

Yet the propaganda continues in the face of this radioactive mess. In a recent article in *Foreign Affairs*, which is an advocacy piece for nuclear power, Richard Rhodes and Denis Beller stated that the annual output of waste from a nuclear power plant was only a tiny twenty *cubic meters* (compacted). They then compare this to a weight measure - compared to half a million *metric tons* of waste for a coal-fired plant.[9]

The figure of twenty cubic meters for nuclear power plant waste completely ignores the largest volume of waste, which is generated at uranium mines and mills. When that component is taken into account, the waste associated with coal is typically only about five or ten times that of nuclear power-related waste, a far cry from ratio of about ten thousand implicit in the Rhodes and Beller article. Rhodes and Beller therefore have exaggerated the volume of waste produced by coal relative to nuclear power by roughly one thousand times.

The biggest current argument for nuclear power that has been put forth with considerable vigor by the nuclear industry is that it is the solution to the problem of severe climate change. Nuclear power does not emit carbon dioxide (CO_2), which is the most important greenhouse gas, or at least not very much at all compared to a coal-fired power plant. Coal and oil burning are the principal sources of CO_2 emissions that threaten serious climate change.

The new push for nuclear power also contains a messianic element - that it will make for a peaceful world. In this view, the world needs a vastly greater supply of energy to meet the needs of a growing world population, most of which has still to taste the kind of material consumption levels that are routine in the United States and other industrialized countries. This rising energy consumption in developing countries is crucial to national security. According to Rhodes and Beller,

> Development depends on energy, and the alternative to development is suffering: poverty, disease, and death. Such conditions create instability and the potential for widespread violence. National security therefore requires developed nations to help increase energy production in their more populous developing counterparts.[10]

I. Energy Supply, Use, and Needs

The assertion that "development depends on energy" conflates energy supply, prevailing energy use patterns, and energy needs. These are very different concepts. Energy, other than in the forms of sunshine and food, is not a need in itself. Our needs are not for oil or electricity or coal.

Rather we need to be able to see things at night, to cook, to go from one place to another with reasonable speed, safety, and comfort, etc. It takes some supply of energy to accomplish these things. But how much? The amount of fuels that we use to accomplish these tasks depends centrally on how efficiently the primary source of energy, the energy supply, is used to perform the given task.

The efficiency of use of energy even in industrialized countries is pathetically low. For instance, a typical "high-efficiency" gas-fired furnace has an efficiency of less than ten percent, when evaluated by strict physics criteria. Electric resistance heating is even more inefficient. The average efficiency of electric lighting systems is about one percent - that is, only about one percent of the energy in the fuel used to generate the electricity comes out as visible light energy. The rest is wasted as heat either at the power plant or in the light bulb. Even high-efficiency lamps have an efficiency of only about three percent.[11]

Passenger transportation efficiency is similarly dismal. The useful work done when a car weighing 1.5 tons transports one person weighing 150 or 200 pounds is typically about one percent or less of the energy content of the fuel input, even if one does not take into account the fact that much of the driving is typically done to earn the money needed to purchase and maintain the vehicle.[12]

The scope of increasing the efficiency of energy use with currently available technology is vast. Two-thirds of U.S. energy use per unit of economic output could be eliminated using available technology, while still maintaining all the functions present-day fuel use performs.[13] With a sensible program of energy research and public policy, it is quite possible to achieve energy use per unit of economic output at one-tenth present levels within a few decades.

While energy use in Western Europe and Japan is somewhat more efficient than in the United States, energy use in developing countries is less efficient. For instance, hundreds of millions of poor people still use candles and kerosene wick lamps for lighting because they have no electricity. The amount of light output that they can avail themselves of can be increased a hundred-fold or more without any change in energy input by going to efficient electric lighting.

Moreover, the most important components of energy use for the rural poor, who are the majority of the world's poor, are not even counted in energy data as it is normally compiled. For instance, wood and crop residues are rarely considered when arguments that large increases in energy supply are needed for development. Further, the energy used by draft animals, which provide the main source of energy for agricultural work for hundreds of millions of peasants in Asia, is not compiled in energy data or considered in development discussions. Such traditional energy sources are far more important energy inputs than non-traditional fuels like oil or natural gas. In rural Nepal, for instance, these traditional energy sources provide over fifty times the energy input of modern energy sources and the efficiency of their use is typically lower than that of modern fuels.[14]

In sum, it is quite possible to greatly improve material standards of living without increasing energy input in developing countries, and while actually reducing energy input in industrialized countries. Yet, the use of electricity, if done properly, can be one crucial element in increasing energy use efficiency. Hence, the issue of the fuel source for increased electricity production is not resolved by the efficiency argument. So it is still important to consider the pros and cons of electric power systems and the energy sources that can power them.

II. Comparing Energy Systems

Nuclear power brings its own severe vulnerabilities that are not related to climate change or the severe routine pollution often associated with coal mining and oil production. These vulnerabilities relate to:

- *Nuclear weapons proliferation*: Nuclear power technology has a large overlap with nuclear weapons technology. Nuclear power plants create weapons usable materials - plutonium in current designs.
- *Severe accidents*: Severe accidents on the scale of Chernobyl can occur with nuclear power plants, even though the details of accident mechanisms and accident probabilities vary with design, care of construction, and degree of independent oversight and regulation.
- *Nuclear waste management*: Wastes associated with nuclear power, from mill tailings to spent fuel, are very long-lived and threaten essential resources, notably water resources.

If the world continues to use oil for transportation (and oil accounts for about forty percent of carbon dioxide emissions from fossil fuel use today, most of it in the transport sector),[15] a very large number of nuclear power plants will have to be built in the next four decades to mitigate carbon dioxide emissions. Most existing coal-fired power plants would have to be replaced with nuclear ones, and present-day nuclear power plants (over 400 in all) will have to be retired and replaced with new ones. In order to make a significant dent in CO_2 emissions, at least one-third, and perhaps one-half or more of the global growth in electricity demand must be supplied by nuclear power. In any scenario involving two percent or greater global electricity growth, the use of nuclear power will mean the construction of thousands of nuclear power plants in the next four decades. Consider for instance, an electricity growth rate of two percent, which is far less than that occurring in China and India, but more or less typical of recent U.S. trends. To make a substantial contribution to reducing greenhouse gas emissions, we might hypothesize that (i) all present day nuclear power plants will be replaced by new ones, (ii) half the electricity growth will be provided by nuclear power, and (iii) half of the world's coal-fired plants will be replaced by nuclear power plants. This would mean that about two thousand large (1,000 megawatts each) nuclear power plants would have to be built over the next four decades. That is a rate of about one per week. If small plants, like the proposed Pebble Bed Modular Reactor were built instead, the required rate of construction would be about three reactors every two days.

The proliferation implications of building so many plants and supplying them with fuel are stupendous. Inspecting them, enriching the uranium, ensuring that materials are not diverted into weapons programs would present challenges that would make today's proliferation concerns look like the proverbial Sunday school picnic. We already have confrontations between the United States and other countries over alleged nuclear weapons aspirations from far more modest programs involving a handful of power plants. The risk of losing a city once in a while to nuclear bombs should be an unacceptable part of an energy strategy.

Similarly, it would be difficult to inspect, regulate and maintain such a vast number of plants properly. Even the U.S. regulatory system is currently under considerable strain. In fact, oversight and safety are deteriorating. There have been unexpected leaks and severe corrosion problems missed by inadequate regulation. Nuclear power plant owners are operating their plants at very high capacity factors, churning out profits, while the Nuclear Regulatory Commission allows them to service some safety backup equipment while the power plants are still running.[16] That makes no sense from a safety point of view. Backup systems are there in case the normal systems break down. If a break down occurs while the back system is being maintained, it will not be available in case of emergency.

Consider an analogy with commercial aircraft. Commercial airlines in the United States have a reasonably good safety record. It would be unacceptable for commercial airlines to service backup equipment while in the air (if it could be arranged to save money). Yet, the present regulatory system for nuclear power allows on-line servicing of backup equipment, even though many more lives are at stake. If that is the situation today in the wealthiest country in the world, one might imagine and shudder at the problems of nuclear safety with one large plant a week coming on line around the world. Such a world might not be a pleasant place even for nuclear boosters.

The vulnerability of nuclear power plants, spent fuel storage, and plutonium storage facilities to terrorist attack, were revealed by the violent tragedy of September 11, 2001, as never before. Studies in the past had hypothesized the potentially catastrophic effects of accidents, war, or terrorist attacks on certain portions of the nuclear energy infrastructure.[17] They can no longer be ignored as they have been.

The crash of one of the airliners in Pennsylvania, not far from the Three Mile Island nuclear power plant, as well as statements by a prisoner held in Afghanistan showing his awareness of nuclear power plants as potential targets,[18] should greatly heighten serious concerns about nuclear vulnerabilities. Most spent fuel storage sites as well as storage sites of other nuclear materials, notably plutonium, have serious vulnerabilities to terrorist attack. A breach of spent fuel containment or a meltdown in a nuclear reactor could cause catastrophic releases of radioactivity and immense disruption of energy, environmental, and financial systems.

Despite these vulnerabilities, the Nuclear Regulatory Commission has been lax and has not required hardened storage of spent fuel on site. It has not required power plant owners to postulate a September 11 type attack in evaluating where the public might be safe from catastrophic radioactivity exposure in case of attack. It is extending the licenses of power plants without allowing consideration of terrorism risks.

III. Commercial Plutonium

The problems with nuclear power don't stop there. The romance with nuclear power has, from the start, been strongly associated with the use of plutonium as a fuel. This is because the most abundant uranium isotope in nature is uranium-238 - more than ninety-nine percent of natural uranium is U-238, which cannot sustain a chain reaction and is therefore not useful as a reactor fuel. The starting reactor fuel must necessarily be uranium-235, which is fissile but constitutes only about 0.7 percent of natural uranium. But U-238 has another property - when placed in a reactor, it absorbs a neutron, undergoes nuclear reactions, and gets transmuted into plutonium-239, which is fissile. Like uranium-235, plutonium-239 can be used to make bombs and fuel reactors. Converting uranium-238 into plutonium-239, in a kind of reactor called a "breeder reactor," can create more fuel than the reactor uses in its power generation mode. This is the "magical" aspect of nuclear power that has fascinated physicists and propagandists alike.

About $ 100 billion have been spent worldwide over half a century in the effort to commercialize plutonium fuel and reactors that will "breed" it from uranium-238.[19] The effort has been a vast economic and technical failure. Plutonium fuel is used to supply part of the fuel of less than three dozen reactors, most of them in France, out of a world total of more than 400 commercial reactors. The fuel is subsidized by ratepayers and taxpayers to the tune of about one billion dollars per year in France alone.

Surplus commercial plutonium extracted from spent fuel rods is piling up in enormous quantities at several nuclear sites. The largest stores are at the sites in Britain and France where plutonium is separated chemically from the rest of spent fuel in vast factories known as reprocessing plants, to the point that the separated commercial plutonium stock now rivals the military one and is in more locations. The Sellafield site in Britain and the La Hague site in France each store about eighty metric tons of separated commercial plutonium stored. The combined stock is enough to make more than twenty thousand nuclear bombs. More than thirty metric tons of commercial plutonium is stored at the Mayak site in the Southern Urals in Russia, where both military and commercial nuclear activities take place. The United States and Russia have worked together to improve security at Mayak, but the weak economic conditions in Russia, including at the nuclear weapons sites, the rapidly fluctuating tensions in an unstable world, and the spread of the idea that nuclear weapons can change a power equation all by themselves, has resulted in a situation where the dangers of diversion of plutonium into the non-state terrorist arena are now considerably higher than they were during the Cold War.

While nuclear weapon states may not use commercial plutonium to make weapons (since most also have military plutonium, which nuclear weapons designers prefer for its somewhat different mix of plutonium isotopes), separated commercial plutonium is an ever-present temptation for non-nuclear states that want to make weapons. For instance, the leader of the Liberal Party in Japan said in April 2002 that "if (China)gets too inflated, the Japanese people will become hysterical in response," and that "we have plenty of plutonium in our nuclear power plants, so it's possible for us to produce 3,000 to 4,000 nuclear warheads."[20] Japan owns enough plutonium to accomplish this, though some of it is currently stored at the British and French reprocessing sites, where almost all Japanese commercial reprocessing takes place. Japan is also building a large new reprocessing plant at home.

The risks of commercial plutonium diversion to military purposes has led the United States to adopt a bi-partisan policy against use of plutonium as a commercial fuel in the United States. It was initiated during the Ford administration in 1976 and then consolidated during the Carter administration. The fact that such fuels were also uneconomical (and remain so) also helped decide the issue. Unfortunately, the trend since 2001, when the energy plan created by Vice-President Cheney's task force was published, is towards lifting that taboo and re-opening the question of possible use of plutonium fuel in commercial reactors in the United States.[21]

Figure 1: History of cumulative global military and commercial plutonium stocks since 1945, in metric tons.[22]

Type	1945	1950	1960	1970	1980	1990	2000
Total military	0.1	2	45	130	200	250	260
Unseparated commercial	0	0	0	1	145	530	1,200
Separated commercial	0	0	0	5	40	120	210
Total commercial	0	0	0	6	185	650	1,410
Total, military and commercial	0.1	2	45	136	385	900	1,670

IV. Reducing Greenhouse Gas Emissions

So where will the added electricity generating capacity come from? Clearly, coal has its problems, and the world needs also to reduce its consumption of oil, if only to reduce CO_2 emissions. Table 2 below shows a comparison of the environmental effects of fossil fuel and nuclear power dominated energy systems.

If we keep in mind the basic economic fact that the amount of money that we have to address the problem of reducing greenhouse gas emissions is limited, the answer begins to emerge even apart from the proliferation problems with nuclear power.

Of the fossil fuels, natural gas is the least polluting. If it is used in highly efficient "combined cycle" power plants, it emits only about one fourth as much CO_2 per unit of electricity than coal. The cost of such natural gas-fired power plants is also quite low, so that for a fixed number of dollars, combined cycled plants can reduce CO_2 emissions by forty percent more than nuclear power plants when used to replace coal-fired plants. This disparity exists even if we assume that nuclear power plants and their associated systems emit no CO_2 whatsoever. The reason is that nuclear power plants are much more expensive.

Natural gas represents a good transition energy source. But much of the growth in electricity must come from renewable energy sources - wind, solar, and sustainably produced biomass. In developing countries, the efficiency of use of biomass can be greatly increased. Wind power is available in plentiful supply. Large wind power plants are cheaper than new nuclear power stations today. That is part of the reason why many countries, like Germany, Denmark, and the United States are building new wind power plants, but not nuclear power plants. Nuclear power plants now tend to be concentrated in countries where direct government programs decree them, or where there is a strong element of government or ratepayer subsidy. This is even more true of plutonium fuel programs, none of which are economical.[23]

In the United States, where Wall Street has had a big say in whether and what kind of power plants get built, investors are not willing to put up money for nuclear plants. None have been ordered since 1978. While nuclear companies say they want to order such plants, in practice they appear to want the government to provide loan guarantees. A Congressional Budget Office (CBO) analysis of proposed U.S. government loan guarantees for new nuclear power plants said that the "CBO considers the risk of default on such a loan guarantee to be very high" and that if the power plant were complete "we expect it would financially default soon after beginning operations ... ."[24] That doesn't necessarily mean the plants would shut down - just that the taxpayers would wind up paying for much of the nuclear generated electricity.

We have the technologies to economically phase out nuclear power, drastically reduce greenhouse gas emissions, and improve material standards of living in the United States and the world. It is not difficult to demonstrate that. One reasonable estimate of the possibilities using the same economic and demographic assumptions as the Cheney energy plan is shown in Figure 2, taken from my November 2001 study, *Securing the Energy Future of the United States*.[25]

It is the political will to accomplish these goals that is lacking. Or rather, the political will is forcefully present in increasing oil supply and nuclear power, while being tepid when it comes to actually tapping the immense potential of efficiency, natural gas, and renewable energy sources. The political and institutional problems in tackling the problems of energy security and greenhouse gas emissions are actually far more severe than the technological challenges.

Figure 2: Comparison of Fossil Fuels and Nuclear Power - Tabular Sketch*[26]

	Nuclear, with plutonium economy	**Nuclear, once-through uranium use**	**Fossil Fuels, present approach**	**Fossil Fuel, moderated use, and Renewables**
Resource Base, present economics	indefinite future	50 to 100 years, possibly more	a few hundred years	indefinite future
Resource Base, including very low-grade resources	not required	indefinite future	thousands of years	not required
Incremental Climate Change Risk	none**	none	potentially catastrophic	none if fossil fuels are largely phased out
Potential Consequences of catastrophic accidents	severe: long-lasting effects over large regions	severe: long lasting effects over large regions	no consequences for large regions but may be locally severe; effects generally short term	no consequences for large regions but may be locally severe; effects generally short term
Air Pollution, routine	relatively low	relatively low	severe to moderate, depending on	moderate to low, depending on

operations			control technology	control technology
Water Pollution, routine operations	potentially serious at mines and mills, but limited due to low uranium requirements; potentially serious at waste disposal sites	often serious at mines, mills, and uranium processing sites (includes non-radioactive and radioactive pollutants); potentially serious at waste disposal sites	often serious at coal mines; serious at some oil fields (includes non-radioactive and radioactive pollutants, notably radium-226 near many oil-wells)	potentially very low
Risk of Nuclear Weapons Problems	yes	yes, but less than with a breeder reactor economy	none	none
* These are incremental risks, assuming facilities are run with reasonable attention to environmental protection. ** Questions have been raise about the effect of krypton-85 from extensive reprocessing necessary for a breeder reactor system on cloud formation and hence potential climate change. However, krypton-85 can be removed from exhaust gases by cyrogenic cooling.				

FOOTNOTES:

* President of the Institute for Energy and Environmental Research in Takoma Park, Maryland. This paper was adapted from an oral presentation given at the Eighth Annual Wallace Stegner Center Symposium titled "Nuclear West: Legacy and Future."

1. Daniel Ford, The Cult of the Atom: The Secret Papers of the Atomic Energy Commission 50 (1982) (quoting Lewis L. Strauss, Address to the National Association of Science Writers (Sept. 1954)).

2. C.G. Suits, Power from the Atom - An Appraisal, Nucleonics, Feb. 1951, at 3-4.

3. Ford, supra note 1, at 25 (quoting Alvin Weinberg (1981)).

4. These early studies are reviewed in Arjun Makhijani & Scott Saleska, The Nuclear Power Deception: U.S. Nuclear Mythology from Electricity "Too Cheap to Meter" to "Inherently Safe" Reactors (1999). This article draws on technical details and analysis of these studies in this book, where additional references and explanations may be found.

5. Id. at 53-69.

6. Nuclear Wastelands: A Global Guide to Nuclear Weapons Production and its Health and Environmental Effects 122 (Arjun Makhijani et al. eds., 2000) (the figure includes mill tailings attributable to both commercial and military activities).

7. Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons Since 1940, 378 (Stephen I. Schwartz ed., 1998)

8. These are standard half-lives and require no reference. They can be found in any radiochemistry text and in some periodic tables.

9. Richard Rhodes & Denis Beller, The Need for Nuclear Power, 79 Foreign Affairs No.1 30, 32 (2000) (the volume of coal waste would likely be between 200,000 and 300,000 cubic meters, depending on the density of the wastes. Rhodes and Beller do not specify densities of various wastes so an exact comparison is not possible).

10. Id. at 30.

11. These are efficiencies based on fuel input. For light output per unit of electricity input, see http://www.wikipedia.org/wiki/Light bulb (last visited Dec. 4, 2003). To get an efficiency based on fuel input (overall efficiency), the figures for lumens per watt in this source must be divided by three, since about two-thirds of the fuel energy is typically rejected in thermal electricity generation (mainly coal and nuclear).

12. These are my calculations based on average car performance of 15 percent efficiency, vehicle weight of 3000 pounds and passenger weight of 175 pounds - that is the useful load is only about 6 percent of the overall weight of the car and efficiency with which the fuel is converted into the mechanical motion of the car is about 15 percent. The engine efficiency itself is somewhat higher, but one must account for losses in the transmission and tires also. The efficiency is better for advanced engines, of course, but 15 percent or so would be typical for the car and 20 percent is typical for the engine. For the latter figure see http://courses.washington.edu/me341/oct22v2.htm (last visited Dec. 4, 2003). Therefore, taking into account that the useful load is only about six percent of the total load, we get 0.060.15 = 0.009 or about 0.9 percent overall.

13. Arjun Makhijani, Securing the Energy Future of the United States: Oil, Nuclear, and Electricity Vulnerabilities and a Post-September 11, 2001 Roadmap for Action, at 15 fig.4 (Nov. 2001), at www.ieer.org/reports/energy/bushrpt.pdf (last visited Dec. 4, 2003).

14. Arjun Makhijani, Draft Power in South Asian Foodgrain Production, at ch. 2 tbl.5 (Sept. 1990), at www.ieer.org/reports/energy/2-ovrvw.html (last visited Dec. 4, 2003).

15. World Resources Institute, Greenhouse Gas Emissions by Source, at http://earthtrends.wri.org/datatables/index.cfm?theme=3&CFID=375636&CFTOKEN=84012239 (last visited Dec. 4, 2003).

16. Nuclear Energy Agency Committee on Regulatory Activities, Organization for Economic Cooperation and Development, Inspection of Maintenance on Safety Systems During NPP Operation NEA/CNRA/R(2001)6, 19 (Aug. 16, 2001), available at http://www.nea.fr/html/nsd/docs/2001/cnra-r2001-6.pdf (last visited Dec. 4, 2003).

17. See generally Federal Emergency Management Agency, Dispersed, Decentralized and Renewable Energy Sources: Alternatives to National Vulnerability and War (1980) (this study was prepared by the Energy and Defense Project); Amory B. Lovins & L. Hunter Lovins, Brittle Power: Energy Strategy for National Security (1982) (2001 updated version is available at http://www.rmi.org/images/other/S-BrPwr-Parts123.pdf (last visited Dec. 4, 2003)).

18. William Branigin, In Afghan Jail, a Terrorist Who Won't Surrender: Bin Laden Disciple Held by N. Alliance Would Attack U.S., Washington Post, Oct. 30, 2001, at A13.

19. Arjun Makhijani, Plutonium End Game: Managing Global Stocks of Separated Weapons - Usable Commercial and Surplus Nuclear Weapons Plutonium, at 28 (Jan. 2001), at http://www.ieer.org/reports/pu/peg.pdf. The data and analysis on plutonium in this and the following paragraphs are drawn from this report.

20. Ichiro Ozawa, Japan Can Counter China with Nuclear Weapons, Mainichi Shimbun, Apr. 7, 2002, available at http://mdn.mainichi.co.jp/news/archive/200204/07/20020407p2a00m0fp022000c.html (last visited Dec. 4, 2003).

21. Makhijani, supra note 13, at 39-41.

22. Estimates by Arjun Makhijani from various sources.

23. Makhijani, supra note 19, at 19-30.

24. Congressional Budget Office, Cost Estimate, S. 14 Energy Policy Act of 2003 12 (May 7, 2003), available at http://www.cbo.gov/ftpdoc.cfm?index=4206&type=3 (last visited Dec. 4, 2003).

25. Makhijani, supra note 13.

26. Estimates by Arjun Makhijani from various sources.