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Carol Hanlon
S&ER Products Manager
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Ms. Hanlon:

I request you include the three enclosures in the official record for consideration of the Preliminary Site Suitability Evaluation for the establishment of a national high-level radioactive waste disposal or storage site at Yucca Mountain. These documents highlight the national and international need for this facility.

I strongly recommend that Secretary Abraham make a positive recommendation on Yucca Mountain and proceeds with licensing and operating the facility for the interim storage and eventual disposal of high-level nuclear waste.

Sincerely,

Denis E. Beller

3 encl:
1. Statement Submitted to the U. S. Department of Energy on the Yucca Mountain Preliminary Site Suitability Evaluation.
2. "The Need for Nuclear Power," R. Rhodes and D. Beller, *Foreign Affairs*, Jan-Feb 2000.
3. "The Need for Nuclear Infrastructure," D. Beller, June 2001.

Statement Submitted to the U. S. Department of Energy,
Yucca Mountain Site Characterization Office
North Las Vegas, Nevada
on the

Yucca Mountain Preliminary Site Suitability Evaluation

by Denis E. Beller, Ph.D.
Harry Reid Center for Environmental Studies
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October 12, 2001

In January of 2000 the journal *Foreign Affairs*, which is widely considered most influential economic and foreign policy journal on Earth, printed an essay titled "The Need for Nuclear Power" (*Foreign Affairs* is a publication of The Council on Foreign Relations in New York City). Dr. Richard Rhodes, a Pulitzer-Prize winning historian and journalist, was one of the essay's authors. The essay has been entered in the Congressional Record, it has been widely cited in national and international publications, and it has been used as a reference for decisions by the U.S. Nuclear Regulatory Commission. I am the second author of that essay. Because it highlights the need for and worldwide environmental and health benefits of nuclear power, which places the need for these hearings in context with national and global energy needs, I have attached an annotated copy to my statement for entry in the official record.

The need for additional electricity supply was recently highlighted by an analysis of a report from the United Nations. They annually compile nation-by-nation values of a Human Development Index for almost the entire planet Earth. A low value of this index, which is found for most of the world's population, is associated with poor human conditions: illiteracy, poverty, poor health, and early death. Dr. Alan Pasternak of the University of California correlated this UN Index with per capita electricity use for 95% of the world's population. His correlation shows that human health and well being depend on electricity, and that the current alternative is worldwide suffering (Ref. Dr. Alan Pasternak, Lawrence Livermore National Laboratory, "Global Energy Futures and Human Development: A Framework For Analysis," presented at Global '01, Grenoble, France, Sep 2001).

For most of the people in the world, with minimal access to electricity, the Index increases rapidly with small increases of electricity supply. The average citizen of a nation with less than 1/4 of a threshold of 4000 kilowatt-hours per year can expect to die ten years earlier than citizens of nations with large supplies of electricity. Those with less than one-tenth die about 25 years early. Thus, the global lack of electricity means billions of people die decades before they should. We can conclude from this analysis that poverty is thousands of times more dangerous than explosions of natural gas, spills of oil, emissions from coal plants, or nuclear waste.

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Most practical people now understand that the less-fortunate peoples of the world must and will increase their electricity usage. The suppliers of that energy—and governments—will determine its impact on the economy and the environment. During the last decade, under deregulation, the U.S. nuclear industry has increasingly demonstrated that it is the cleanest, safest, and most environmental **major source** of electricity. It is also affordable, reliable, and sustainable. These six attributes—clean, affordable, reliable, environmental, safe, and sustainable—make up the acronym CARESS. Because these attributes characterize today's U.S. nuclear power industry, national leaders, the press, Wall Street, and business leaders widely recognize that we are in the midst of a renaissance. That is why Vice President Dick Cheney's energy studies group chose to CARESS nuclear power in its report: "Reliable, Affordable, and Environmentally Sound Energy for America's Future."

Recent publicity in the national press also tells us about the industry's plans for this nuclear renaissance, including when, where, and how the addition of new capacity is currently being and will be added. First, the operating "lifetimes" of most of the 103 commercial U.S. reactors will be extended by 20 years, taking existing U.S. nuclear power beyond the middle of the 21st Century. In addition, most of these existing nuclear reactors already have or will increase output in the next decade through upgrades to provide 10,000 megawatts of new capacity, which is equivalent to building 10 new nuclear plants. These two actions alone will increase the generation of used nuclear fuel from existing reactors by more than fifty percent.

In addition, the highly consolidated, privatized and de-regulated nuclear power industry is already making plans to begin construction of a variety of new nuclear reactors beginning in about 2005. They plan to add another 50,000 megawatts of new capacity, which means between 50 and 100 new reactors, at existing plants by 2020. We also expect the global nuclear power industry to build even more reactors in the U.S. and abroad through at least 2050. With at least sixty-year operational lifetimes, the newest of these reactors will still be operating, and generating used nuclear fuel, more than a hundred years from now.

But who will design, build, and operate this new generation of nuclear power plants that we need today? Recent reports in national paper and electronic media, such as Business Week and the Christian Science Monitor, have detailed a severe shortage of college graduates for the existing nuclear power industry. This is because the U.S. academic infrastructure for educating nuclear scientists and engineers declined precipitously during the 1990s. We have lost more than half of our nuclear engineering departments and those that remain graduate hundreds too few engineers for U.S. industry each year. A year ago undergraduate and graduate student populations were the lowest in more than three decades, and less than half our research reactors at universities are operating.

But those articles haven't told the whole story about our weakened infrastructure for all things nuclear--we need new nuclear scientists, engineers, and facilities for far more than just the nuclear power industry. We also need them for monitoring the activities of other nations and terrorist organizations, for stopping the proliferation of nuclear weapons,

for conducting nuclear science and R&D, and for industrial applications like oil exploration and irradiation of foods. Based on this situation, in June, during a panel discussion on Western energy issues in Idaho Falls, Idaho with Congressmen Craig and Simpson, I presented a statement titled "The Need for Nuclear Infrastructure." For entry in the official record, I have also attached to this statement a copy of "The Need for Nuclear Infrastructure."

In addition to the challenge of finding people to design, construct, and operate the nuclear power industry of the next two decades, the emerging global nuclear renaissance presents us with the challenge of greatly increased projections of used nuclear fuel generation. The result of the renaissance that I described, without a new management philosophy, is in excess of 120 thousand tonnes of used nuclear fuel by 2030 in the U.S. alone, and more than a million tons globally by the middle of this Century. We can thus expect to need a new repository somewhere in the world every couple of years. But students, faculty, and research scientists at the University of Nevada Las Vegas are already investigating a new technology and a different philosophy for the management of this valuable material. With the support of Senator Harry Reid to provide funding from the U.S. DOE, UNLV has begun research on accelerator-driven transmutation, a process of causing additional nuclear reactions in long-lived radioactive materials to turn them into short-lived or non-radioactive isotopes.

The three topics that I discussed herein--the need for nuclear power, the need for revitalizing our nuclear infrastructure, and the need for a national management capability for nuclear waste that will be created during the nuclear renaissance--offer the state of Nevada a unique opportunity. We must note that a national repository for high-level radioactive waste is a key element of that management capability for any nuclear energy future, including a nuclear close-out scenario.

Southern Nevada, led by the University in Las Vegas, can take this opportunity to become **the world leader** in insuring the safe, economical, and environmental management of used nuclear fuel. Nevada can create a new national nuclear science center: a national center of excellence for repository science, for recycling used nuclear fuel, for reusing this valuable resource, and for reducing the amount of waste that needs disposal as well as the radio-toxicity of that waste. We can create the science and technology necessary for recycling uranium, higher actinides like neptunium and plutonium, and other radioisotopes. We can reuse, rather than discard, the transuranium isotopes while extracting more vital electricity or other energy from the nuclear fuels. We can use other isotopes to conduct nuclear medical research in Nevada universities and to diagnose and treat diseases like osteoporosis and cancer in Nevada hospitals, and we can use other isotopes for an ever-expanding array of industrial radiation applications. These industrial applications include manufacturing, oil and gas exploration, irradiation to sterilize hundreds of consumer products and most medical equipment, and irradiation of food as well as livestock feed to eliminate pathogens like Listeria, Hoof-and-mouth, and e-Coli. Simultaneously with this recycling and reuse of nuclear materials, we can reduce the toxicity and the volume of waste, as well as quantities of materials that could be used for

proliferation of nuclear weapons centuries or millennia from now. Reduce, reuse, and recycle—but we need Yucca Mountain to optimize the application of this technology.

In conclusion, the citizens of Nevada are in a position to take the fullest advantage of this opportunity, to create a national center of excellence for management of this material, to reduce its legacy for our descendants, and to reduce its impact on the environment—all funded by the U.S. Government. The U.S. DOE should immediately begin to formulate a plan to create this program in Nevada.

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The following essay appears in *Foreign Affairs, Volume 79*, No. 1, January/February 2000, pp. 30-44. It has been edited here to include references and explanatory material.

The Need for Nuclear Power

Richard Rhodes and Denis Beller

A Clean Break

THE WORLD needs more energy. Energy multiplies human labor, increasing productivity. It builds and lights schools, purifies water, powers farm machinery, drives sewing machines and robot assemblers, stores and moves information. World population is steadily increasing, having passed six billion in 1999.[1] Yet one third of that number—two billion people—lack access to electricity.[2] 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. For the sake of safety as well as security, that increased energy supply should come from diverse sources.

"At a global level," the British Royal Society and Royal Academy of Engineering estimate in a 1999 report on nuclear energy and climate change, "we can expect our consumption of energy at least to double in the next 50 years and to grow by a factor of up to five in the next 100 years as the world population increases and as people seek to improve their standards of living."[3] Even with vigorous conservation, world energy production would have to triple by 2050 to support consumption at a mere one-third of today's U.S. per capita rate.[4] The International Energy Agency (IEA) of the Organization for Economic Cooperation and Development (OECD) projects 65 percent growth in world energy demand by 2020, two-thirds of that coming from developing countries.[5] "Given the levels of consumption likely in the future," the Royal Society and Royal Academy caution, "it will be an immense challenge to meet the global demand for energy without unsustainable long-term damage to the environment." That damage includes surface and air pollution and global warming.

Most of the world's energy comes from petroleum (39.5%), coal (24.2%), natural gas (22.1%),

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[1] US Census Bureau

[2] Bradley, Jr., Robert L., "Renewable energy: not cheap, not "green"," Cato Policy Analysis 280, Cato Institute, (www.cato.org/pubs/pas/pa-280.html), 1997, p. 22.

[3] "Nuclear energy--the future climate," Royal Society and Royal Academy, 1999, p. 3. (www.royalsoc.ac.uk/st_pol55.htm).

[4] Wolfe, B., "Why environmentalists should promote nuclear energy," *Issues in Science and Technology*, Summer 1996, pp. 55-60.

[5] "World Energy Outlook," International Energy Agency (IEA) of the OECD, Paris, 1998.

hydroelectric power (6.9%), and nuclear power (6.3%).[6] Although oil and coal still dominate, their market fraction began declining decades ago.[7] Meanwhile, natural gas and nuclear power have steadily increased their share and should continue to do so. Contrary to the assertions of antinuclear organizations, nuclear power is neither dead nor dying. France generates 79 percent of its electricity with nuclear power; Belgium, 60 percent; Sweden, 42 percent; Switzerland, 39 percent; Spain, 37 percent; Japan, 34 percent; the United Kingdom, 21 percent; and the United States (the largest producer of nuclear energy in the world), 20 percent.[8] South Korea and China have announced ambitious plans to expand their nuclear-power capabilities—in the case of South Korea, by building sixteen new plants, increasing capacity by more than 100 percent. With 434 operating reactors worldwide, nuclear power is meeting the electrical needs of more than a billion people.

In America and around the globe, nuclear safety and efficiency have improved significantly since 1990. In 1998, unit capacity factor (the fraction of a power plant's capacity that it actually generates) for operating reactors reached record levels. The average U.S. capacity factor in 1998 was 80 percent for about 100 reactors, compared to 58 percent in 1980 and 66 percent in 1990. Worldwide, reduced radiation exposure to workers and reduced high-level and low-level waste per unit of energy. Despite a reduction in the number of power plants, the U.S. nuclear industry generated nine percent more nuclear electricity in 1999 than in 1998.[9] Average production costs for nuclear energy are 1.9 cents per kilowatt-hour (kWh), while electricity produced from gas costs 3.4 cents per kWh.[10] Meanwhile, radiation exposure to workers and waste produced per unit of energy has hit new lows.

Because major, complex technologies take more than a half century to spread around the world, natural gas will share the lead in power generation with nuclear power over the next hundred years. Which of the two will command the greater share remains to be determined.[11] But both are cleaner and more secure than the fuels they have begun to replace, and their ascendance should be endorsed. Even environmentalists should welcome the transition and reconsider their infatuation with renewable energy sources.

CARBON NATIONS

AMONG SOURCES of electric-power generation, coal is the worst environmental offender. (Petroleum, today's dominant source of energy, sustains transportation, putting it in a separate category.) Recent studies by the Harvard School of Public Health indicate that pollutants from

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[6] "International Energy Annual 1997 Overview," U.S. Department of Energy, Energy Information Agency (DOE/EIA), 1997. (http://www.eia.doe.gov/emeu/ide/ overview.html)
[7] Marchetti, C., "Historical evolution of the primary energy mix for the world," *Technological Forecasting and Social Change 32*(4), 1987, Fig. 7(a).
[8] "Sustainable Development and Nuclear Power," International Atomic Energy Agency (IAEA), 1997, p. 12.
[9] "Short Term Energy Outlook," DOE/EIA, July and August 1999. (updated monthly on www.eia.doe.gov)
[10] "Nuclear Energy Insight," Nuclear Energy Institute, Washington, D.C., August 1998.
[11] Grübler, A., Nakicenovic, N., and Victor, D., "Dynamics of energy technology and global change," *Energy Policy 27*, 1999, pp. 247-280.

coal burning cause about fifteen thousand premature deaths annually in the United States alone.[12] Used to generate about a quarter of world's primary energy, coal-burning releases amounts of toxic wastes too immense to contain safely. Such waste is either dispersed directly into the air or solidified and dumped. Some is even mixed into construction materials. Besides emitting noxious chemicals in the form of gases or toxic particles—sulfur and nitrogen oxides (components of acid rain and smog), arsenic, mercury, cadmium, selenium, lead, boron, chromium, copper, fluorine, molybdenum, nickel, vanadium, zinc,[13] carbon monoxide and dioxide, and other greenhouse gases—coal-fired power plants are also the world's major source of radioactive releases into the environment. Uranium and thorium, mildly radioactive elements ubiquitous in the earth's crust, are both released when coal is burned. Radioactive radon gas, produced when uranium in the earth's crust decays and normally confined underground, is released when coal is mined. A 1,000 megawatt-electric (MWe) coal-fired power plant releases about one hundred times as much radioactivity into the environment as a comparable nuclear plant.[14] Worldwide releases of uranium and thorium from coal burning total about 37,300 tonnes (metric tons) annually, with about 7,300 tonnes coming from the United States. Since uranium and thorium are potent nuclear fuels, burning coal also wastes more potential energy than it produces.[15]

Nuclear proliferation is another overlooked potential of coal burning. The uranium released by a single 1,000-MWe-coal plant in a year includes about 74 pounds of uranium-235, enough for at least two atomic bombs.[16] This uranium would have to be enriched, which would be complicated and expensive. But plutonium could also be bred from coal-derived uranium. Moreover, "because electric utilities are not high-profile facilities," writes physicist Alex Gabbard of the Oak Ridge National Laboratory, "collection and processing of coal ash for recovery of minerals ... can proceed without attracting outside attention, concern or intervention. Any country with coal-fired plants could collect combustion byproducts and amass sufficient nuclear weapons materials to build up a very powerful arsenal."[17] In the early 1950s, when richer ores were believed to be in short supply; The U.S. Atomic Energy Commission actually investigated using coal as a source of uranium production for nuclear weapons; burning the coal, the AEC concluded, would concentrate the mineral, which could then be extracted from the ash.

Such a scenario may seem far-fetched. But it emphasizes the political disadvantages under which nuclear power labors. Current laws force nuclear utilities, unlike coal plants, to invest in expensive systems that limit releases of radioactivity. Nuclear fuel is not efficiently recycled in the United States because of proliferation fears. These factors have warped the economics of nuclear power development and created a politically difficult waste-disposal problem. If coal

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[12] Wilson, R., and Spengler, J., Eds., "Particles in Our Air: Concentrations and Health Effects," Harvard University Press, Cambridge, Mass., 1996, p. 212.
[13] Swaine, D., *Trace Elements in Coal*, Butterworth, London, 1990.
[14] Gabbard, A., "Coal combustion: nuclear resource or danger?," *ORNL Review*, Oak Ridge National Laboratory, 1993, p. 7.
[15] Ibid., p. 8.
[16] 74 pounds: Gabbard, 1993, p. 6. Critical mass for a U-235 sphere surrounded by a thick uranium tamper,15 kg: King, J. K., Ed., *International Political Effects of the Spread of Nuclear Weapons*, U.S. Government Printing Office, Washington, D.C., 1979, p. 7.
[17] Gabbard, 1993, p. 10.

utilities were forced to assume similar costs, coal electricity would no longer be cheaper than nuclear.

DECLINE AND FALL OF THE RENEWABLES

RENEWABLE SOURCES of energy—hydroelectric, solar, wind, geothermal and biomass—have high capital investment costs and significant, if usually unacknowledged, environmental consequences. Hydropower is not even a true renewable, since dams eventually silt in. Most renewables collect extremely diluted energy, requiring large areas of land and masses of collectors to concentrate. Manufacturing solar collectors, pouring concrete for fields of windmills, and drowning many square miles of land behind dams cause damage and pollution.

Photovoltaic cells used for solar collection are large semiconductors; their manufacture produces highly toxic waste metals and solvents that require special technology for disposal. A 1,000-MWe solar electric plant would generate 6,850 tonnes of hazardous waste over a 30-year lifetime. A comparable solar thermal plant (using mirrors focused on a central tower) would require metals for construction that would generate 435,000 tonnes of manufacturing waste, of which 16,300 tonnes would be contaminated with lead and chromium and considered hazardous.[18]

A global solar energy system would consume at least 20 percent of the world's known iron resources. It would require a century to build and a substantial fraction of annual world iron production to maintain. The energy necessary to manufacture sufficient solar collectors to cover a half-million square miles of the earth's surface and to deliver the electricity through long-distance transmission systems would itself add grievously to the global burden of pollution and greenhouse gas.[19] A global solar energy system without fossil or nuclear backup would also be dangerously vulnerable to drops in solar radiation from volcanic events such as the 1883 eruption of Krakatoa, which caused widespread crop failure during the "year without a summer" that followed. [This was an error in the *Foreign Affairs* essay, the "year without a summer" is the year following the 1815 Tambora eruption, which released 40 km^3 of ash into the atmosphere, double the amount released in the Krakatoa eruption. However, either would significantly reduce electricity production from a solar-electric system].

Wind farms, besides requiring millions of pounds of concrete and steel to build (and thus creating huge amounts of waste materials), are inefficient, with low (because intermittent) capacity. They also cause visual and noise pollution and are mighty slayers of birds. Several hundred birds of prey, including dozens of golden eagles, are killed every year by a single California wind farm; more eagles have been killed by wind turbines that were lost in the disastrous Exxon Valdez oil spill. The National Audubon Society launched a campaign to save the California condor from a proposed wind farm to be

The massive investment in renewables could have been better spent making coal plans and cars cleaner.

[18] Lehman, L., *Nuclear Fear: The Environmental Cost*, Technical & Regulatory Evaluations Group, Inc., Prior Lake, Minn., 1996, pp. 53-54

[19] Cf. Weingart, J., "The Helios strategy: an heretical view of the potential role of solar energy in the future of a small planet," *Technological Forecasting and Social Change 12*, 1978, pp. 273-315.

built north of Los Angeles. A wind farm equivalent in output and capacity to a 1,000-MWe fossil-fuel or nuclear plant would require about 4,000 windmills and occupy up to 1,000 square miles of land.[20] It would produce electricity at double or triple the cost of fossil fuels, even ignoring hidden pollution costs, and would require substantial subsidies to sell electricity competitively.[21]

Although at least one-quarter of the world's potential for hydropower has already been developed, hydroelectric power—produced by dams that submerge large areas of land, displace rural populations, change river ecology, kill fish, and risk catastrophic collapse—has understandably lost the backing of environmentalists in recent years. The U.S. Export-Import Bank was responding in part to environmental lobbying when it denied funding to China's 18,000-MWe Three Gorges project.[22]

Meanwhile, geothermal sources—which exploit the internal heat of the earth emerging in geyser areas or under volcanoes—are inherently limited and often coincide with scenic sites (such as Yellowstone National Park) that conservationists understandably want to preserve.

Because of these and other disadvantages, organizations such as the World Energy Council and the IEA predict that hydroelectric generation will continue to account for no more than its present 6.9 percent share of the world's primary energy supply, while all other renewables, even though robustly subsidized, will move from their present 0.5 percent share to claim no more than 5 to 8 percent by 2020.[23] In the United States, which leads the world in renewable energy generation, such production actually declined by 9.4% from 1997 to 1998: hydro by 9.5 percent, geothermal by 5.4 percent, wind by 50.5 percent, and solar by 27.7 percent.[24]

Like the dream of controlled thermonuclear fusion, then, the reality of a world run on pristine energy generated from renewables continues to recede, despite expensive, highly subsidized research and development. The 1997 U.S. Federal R&D investment per thousand kWh was only 5 cents for nuclear and coal, 58 cents for oil, and 41 cents for gas, but was $4,769 for wind and $17,006 for photovoltaics.[25] This massive public investment in renewables would have been better spent making coal plants and automobiles cleaner. According to Robert Bradley of Houston's Institute for Energy Research, U.S. conservation efforts and non-hydroelectric renewables have benefited from a cumulative 20-year taxpayer investment of some $30-$40 billion—"the largest governmental peacetime energy expenditure in U.S. history." And Bradley estimates that "the $5.8 billion spent by the Department of Energy on wind and solar subsidies" alone could have paid for "replacing between 5,000 and 10,000 MW of the nation's dirtiest coal capacity with gas-fired combined-cycle units, which would have reduced carbon dioxide emissions between one-third and two-thirds."[26] Replacing coal with nuclear generation would

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[20] "Meeting Our Clean Air Needs With Emission-Free Generation," Nuclear Energy Institute (NEI), Washington, D.C., Rev. May 1999, p. 14 (estimated from quadruple 150,000 acres). [author note: the text in the published essay said 2,000 square miles, a typographical error]

[21] Bradley, see Ref. 2, p. 8.

[22] Ibid., p. 21, citing the New York Times and the Wall Street Journal.

[23] IAEA, see Ref. 8, p. 10.

[24] Data from DOE/EIA online database, Annual Utility Electric Production Report 1998.

[25] NEI, see Ref. 20, p. 15.

[26] Bradley, see Ref. 2, p. 4 & 67.

have reduced overall emissions even more. Conservation has also been heavily subsidized, making saved power twice as expensive in the U.S. as generated power.[27]

Despite the massive investment, conservation and non-hydro renewables remain stubbornly un-competitive and contribute only marginally to U.S. energy supplies. If the most prosperous nation in the world cannot afford them, who can? Not China, evidently, which expects to generate less than one percent of its commercial energy from non-hydro renewables in 2025. Coal and oil will account for the bulk of China's energy supply in that year unless developed countries offer incentives to convince the world's most populous nation to change its plans.

TURN DOWN THE VOLUME

NATURAL GAS has many virtues as a fuel compared to coal or oil, and its share of the world's energy will assuredly grow in the first half of the 21st century. But its supply is limited and unevenly distributed, it is expensive as a power source compared to coal or uranium, and it pollutes the air. A 1,000-MWe natural gas plant releases 5.5 tonnes of sulfur oxides per day, 21 tonnes of nitrogen oxides, 1.6 tonnes of carbon monoxide, and 0.9 tonnes of particulates. In the United States, energy production from natural gas released about 5.5 billion tonnes of waste in 1994.[28] Natural gas fires and explosions are also significant risks. A single mile of gas pipeline three feet in diameter at a pressure of 1,000 pounds per square inch (psi) contains the equivalent of two-thirds of a kiloton of explosive energy; a million miles of such large pipelines lace the earth. [Energy equivalence calculated from Chem E Handbook. The U.S. has 190,000 miles of transfer pipelines, in addition to pipelines from distribution points to customers, per DOE/FE web site. A million miles is an estimate.]

The great advantage of nuclear power is its ability to wrest enormous energy from a small volume of fuel. Nuclear fission, transforming matter directly into energy, is several million times as energetic as chemical burning, which merely breaks chemical bonds. One tonne of nuclear fuel produces energy equivalent to 2 to 3 million tonnes of fossil fuel.[29] Burning 1 kilogram of firewood can generate 1 kilowatt-hour of electricity; 1 kg of coal, 3 kWh; 1 kg of oil, 4 kWh. But 1 kg of uranium fuel in a modern light water reactor generates 400,000 kWh of electricity, and if that uranium is recycled, 1 kg can generate more than 7,000,000 kWh. These spectacular differences in volume help explain the vast difference in the environmental impacts of nuclear versus fossil fuels. Running a 1,000-MW power plant for a year requires 2,000 train cars of coal or 10 supertankers of oil but only 12 cubic meters of natural uranium.[30] Out the other end of such fossil fuel plants, even those with pollution control systems, come thousands of tonnes of noxious gases, particulates, and heavy-metal-bearing (and radioactive) ash plus solid hazardous waste—up to 500,000 tons of sulfur from coal, more than 300,000 tons from oil, and 200,000 tons from natural gas.

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[27] Ibid., citing the EIA.
[28] Lehman, see Ref. 18, p. 32.
[29] Suzuki, A., "The plutonium issue and the environmental problem," *Proc. International Conference on Nuclear Waste Management and Environmental Remediation, Vol. 2*, Prague, Czech Republic, September 5-11, 1993. Cited in Lehman, see Ref. 18, p. 138.
[30] IAEA, see Ref. 8, p. 32.

In contrast, a 1,000-MWe nuclear plant releases no noxious gases or other pollutants[31] and much less radioactivity per capita than is encountered from airline travel, a home smoke detector, or a television set. It produces about 30 tonnes of high-level waste (spent fuel) and 800 tons of low- and intermediate-level waste—about 20 cubic meters in all when compacted (roughly, the volume of two passenger cars).[32] All the operating nuclear plants in the world produce some 3,000 cubic meters of waste annually. By comparison, U.S. industry generates annually about 50,000,000 cubic meters of solid toxic waste.

The high-level waste is intensely radioactive, of course (the low-level waste can be less radioactive than coal ash, which is used to make concrete and gypsum—both of which are incorporated into building materials). But thanks to its small volume and the fact that it is not released into the environment, this high-level waste can be meticulously sequestered behind multiple barriers. Waste from coal, dispersed across the landscape in smoke or buried near the surface, remains toxic forever. Radioactive nuclear waste decays steadily, losing 99 percent of its toxicity after 600 years—well within the range of human experience with custody and maintenance, as evidenced by structures such as the Roman Pantheon and Notre Dame Cathedral. Nuclear waste disposal is a political problem in the United States because of widespread nuclear fear disproportionate to the reality of risk. But it is not an engineering problem, as advanced projects in France, Sweden and Japan demonstrate. The World Health Organization has estimated that indoor and outdoor air pollution cause some three million deaths per year.[33] Substituting small, properly contained volumes of nuclear waste for vast, dispersed volumes of toxic wastes from fossil fuels would produce so obvious an improvement in public health that it is astonishing that physicians have not already demanded such a conversion.

The production cost of nuclear electricity generated from existing U.S. plants is already fully competitive with electricity from fossil fuels, although new nuclear power is somewhat more expensive. But this higher price tag is deceptive. Large nuclear power plants require larger capital investments than comparable coal or gas plants only because nuclear utilities are required to build and maintain costly systems to keep their radioactivity from the environment. If fossil fuel plants were similarly required to sequester the pollutants they generate, they would cost significantly more than nuclear power plants do. The European Union and International Atomic Energy Agency (IAEA) have determined that "for equivalent amounts of energy generation, coal and oil plants, … owing to their large emissions and huge fuel and transport requirements, have the highest externality costs as well as equivalent lives lost. The external costs are some ten times higher than for a nuclear power plant and can be a significant fraction of generation costs." In equivalent lives lost per gigawatt generated (that is, loss of life expectancy from exposure to pollutants), coal kills 37 people annually; oil, 32; gas, 2; nuclear, 1.[34] Compared to nuclear power, in other words, fossil fuels (and renewables) have enjoyed a free ride with respect to protection of the environment and public health and safety.

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[31] Uranium is refined and processed into fuel assemblies today using coal energy, which does of course release pollutants. If nuclear power were made available for process heat, or if fuel assemblies were recycled, this source of manufacturing pollution would be eliminated or greatly reduced.

[32] IAEA, see Ref. 8, pp. 32-34.

[33] Ibid., pp. 22-23.

[34] Ibid., table 4 and p. 44.

Even the estimate of one life lost to nuclear power is questionable. Such an estimate depends on whether or not, as the long-standing "linear no-threshold" theory (LNT) maintains, exposure to amounts of radiation considerably less than preexisting natural levels increases the risk of cancer. Although LNT dictates elaborate and expensive confinement regimes for nuclear power operations and waste disposal, there is no evidence that low-level radiation exposure increases cancer risk. In fact, there is good evidence that it does not. There is even good evidence that exposure to low doses of radioactivity *improves* health and lengthens life, probably by stimulating the immune system much as vaccines do (the best study, of background radon levels in hundreds of thousands of homes in more than 90 percent of U.S. counties, found lung cancer rates decreasing significantly with increasing radon levels among both smokers and nonsmokers).[35] So low-level radioactivity from nuclear power generation presents at worst a negligible risk. Authorities on coal geology and engineering make the same argument about low-level radioactivity from coal burning; a U.S. Geological Survey fact sheet, for example, concludes that "radioactive elements in coal and fly ash should not be sources of alarm." [36] Yet nuclear power development has been hobbled, and nuclear waste disposal unnecessarily delayed, by limits not visited upon the coal industry.

No technological system is immune to accident. Recent dam overflows and failures in Italy and India each resulted in several thousand fatalities. Coal-mine accidents, oil- and gas-plant fires, and pipeline explosions typically kill hundreds per incident. The 1984 Bhopal chemical plant disaster caused some 3,000 immediate deaths and poisoned several hundred thousand people. According to the U.S. Environmental Protection Agency, between 1987 and 1996 more than 600,000 accidental releases of toxic chemicals in the United States killed a total of 2,565 people and injured 22,949.

By comparison, nuclear accidents have been few and minimal. The recent, much-reported accident in Japan occurred not at a power plant but at a facility processing fuel for a research reactor. It caused no deaths or injuries to the public. As for the Chernobyl explosion, it resulted from human error operating a fundamentally faulty reactor design that could not have been licensed in the West. It caused severe human and environmental damage locally, including 31 deaths, most from radiation exposure. Thyroid cancer, which could have been prevented with prompt iodine prophylaxis, has increased in Ukrainian children exposed to fallout. More than 800 cases have been diagnosed and several thousand more are projected; although the disease is treatable, three children have died. LNT-based calculations project 3,420 excess long-term cancer deaths in Chernobyl-area residents and cleanup crews.[37] The Chernobyl reactor lacked a containment structure, a fundamental safety system that is required on Western reactors. Post-accident calculations indicate that such a structure would have confined the explosion and thus the radioactivity, in which case no injuries or deaths would have occurred.[35]

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[35] Cohen, B. L., "Perspectives on the high level waste disposal problem." *Interdisciplinary Science Reviews 23*(3), 1998, pp. 193-203; and Cohen, B. L. 1998, "Validity of the linear no-threshold theory of radiation carcinogenesis at low doses." *Proceedings of Uranium Institute Twenty Third Annual International Symposium*, 10-11 September 1998, London. (www.uilondon.org/sym/1998/cohen.htm).

[36] "Radioactive elements in coal and fly ash: abundance, forms, and environmental significance," U.S. Geological Survey Fact Sheet FS-163-97, 1997, p. 4.

[37] IAEA, see Ref. 8, Table 1, p. 25.

These numbers, for the worst-ever nuclear power accident, are remarkably low compared to major accidents in other industries. More than 40 years of commercial nuclear power operations demonstrate that nuclear power is much safer than fossil-fuel systems in terms of industrial accidents, environmental damage, health effects, and long-term risk.

GHOSTS IN THE MACHINE

MOST OF THE URANIUM used in nuclear reactors is inert, a non-fissile product unavailable for use in weapons. Operating reactors, however, breed fissile plutonium that could be used in bombs and therefore the commercialization of nuclear power has raised concerns about the spread of weapons. In 1977, President Jimmy Carter deferred indefinitely the recycling of "spent" nuclear fuel, citing proliferation risks. This decision effectively ended nuclear recycling in the United States, even though such recycling reduces the volume and radiotoxicity of nuclear waste and could extend nuclear fuel supplies for thousands of years. Other nations assessed the risks differently and the majority did not follow the U.S. example. France and the United Kingdom currently reprocess spent fuel, Russia is stockpiling fuel and separated plutonium for jump-starting future fast-reactor fuel cycles, Japan has begun using recycled uranium and plutonium mixed-oxide (MOX) fuel in its reactors and recently approved the construction of a new nuclear power plant to use 100-percent MOX fuel by in 2007.[38] [39]

Although power-reactor plutonium theoretically can be used to make nuclear explosives, spent fuel is refractory, highly radioactive, and beyond the capacity of terrorists to process. Weapons made from reactor-grade plutonium would be hot, unstable, and of uncertain yield. India has extracted weapons plutonium from a Canadian heavy-water reactor and bars inspection of some dual-purpose reactors it has built. But no plutonium has ever been diverted from British or French reprocessing facilities or fuel shipments for weapons production; IAEA inspections are effective in preventing such diversions. The risk of proliferation, the IAEA has concluded, "is not zero and would not become zero even if nuclear power ceased to exist. It is a continually strengthened nonproliferation regime that will remain the cornerstone of efforts to prevent the spread of nuclear weapons."[40]

> Ironically, burying nuclear waste only increases the risk of proliferation.

Ironically, burying spent fuel without extracting its plutonium through recycling would actually increase the long-term risk of nuclear proliferation, since the decay of less-fissile and more-radioactive isotopes in spent fuel after one to three centuries improves the explosive properties of the plutonium it contains, making it more attractive for weapons use. Besides extending the world's uranium resources almost indefinitely, recycling would make it possible to convert plutonium to useful energy while breaking it down into more shorter-lived, nonfissionable, nonthreating nuclear waste.

Hundreds of tons of weapons-grade plutonium, which cost the nuclear superpowers billions of dollars to produce, have become military surplus in the past decade. Rather than burying some of

[38] Japan: *Nuclear News*, Aug. 99, p. 116.
[39] "Uranium Institute News Briefing 99.32," August 1999, pp. 4-10. (http://www.uilondon.org/nb/nb99/ latestnews.htm)
[40] IAEA, see Ref. 8, p. 30.

this strategically worrisome but energetically valuable material—as Washington has proposed—it should be recycled into nuclear fuel. An international management system to recycle and manage such fuel would prevent covert proliferation. As envisioned by Edward Arthur, Paul Cunningham, and Richard Wagner of the Los Alamos National Laboratory, such a system would combine internationally monitored retrievable storage, the processing of all separated plutonium into MOX fuel for power reactors and, in the longer term, advanced integrated materials-processing reactors that would receive, control, and process all fuel discharged from reactors throughout the world, generating electricity and reducing spent fuel to short-lived nuclear waste ready for permanent geologic storage.[41]

THE NEW NEW THING

A NEW GENERATION of small, modular power plants—competitive with natural gas and designed for safety, proliferation resistance, and ease of operation—will be necessary to extend the benefits of nuclear power to smaller developing countries that lack nuclear infrastructure. The Department of Energy has awarded funding to three designs for such "fourth-generation" plants.[42] A South African utility, ESKOM, has announced plans to market a modular gas-cooled pebble-bed reactor that does not require emergency core cooling systems and physically cannot "melt down." ESKOM estimates that the reactor will produce electricity at around 1.5 cents per kWh, which is cheaper than electricity from a combined-cycle gas plant. [43]The Massachusetts Institute of Technology and the Idaho National Engineering and Environmental Laboratory are developing a similar design to supply high-temperature heat for industrial processes such as hydrogen generation and desalinization.

Petroleum is used today primarily for transportation, but the internal combustion engine has been refined to its limit. Further reductions in transportation pollution can come only from abandoning petroleum and developing nonpolluting power systems for cars and trucks. Recharging batteries for electric cars will simply transfer pollution from mobile to centralized sources unless the centralized source of electricity is nuclear. Fuel cells, which are now approaching commercialization, may be a better solution. Because fuel cells generate electricity directly from gaseous or liquid fuels, they can be refueled along the way much as present internal combustion engines are. When operated on pure hydrogen, fuel cells produce only water as a waste product. Since hydrogen can be generated from water using heat or electricity, one can envisage a minimally polluting energy infrastructure, using hydrogen generated by nuclear power for transportation, nuclear electricity and process heat for most other applications, and natural gas and renewable systems as backups. Such a major commitment to nuclear power could not only halt but eventually even reverse the continuing buildup of carbon in the atmosphere. In the

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[41] Arthur, E., Cunningham, P., and Wagner, R. Jr., "An architecture for nuclear energy in the 21st century," Santa Fe Energy Seminar, Santa Fe, New Mexico, 1998.

[42] Magwood, W. D., IV, "Looking toward generation four: considerations for a new nuclear R&D agenda," American Nuclear Society 1999 Summer Meeting, Boston, Mass., June 1999, p. 4.

[43] Kadak, A., "The Comeback of Gas Reactors," American Nuclear Society Annual Meeting, Boston, Mass., June 1999; "The American Nuclear Society's Role in Global Climate Change Mitigation," International Joint Meeting, The Role of Nuclear Power to Mitigate Climate Change, Acapulco, 1999.

meantime, fuel cells using natural gas could significantly reduce air pollution.

POWERING THE FUTURE

TO MEET THE WORLD'S GROWING need for energy, the Royal Society and Royal Academy report proposes "the formation of an international body for energy research and development, funded by contributions from individual nations on the basis of GDP or total national energy consumption." The body would be "a funding agency supporting research, development and demonstrators elsewhere, not a research center itself." Its budget might build to an annual level of some $25 billion, "roughly one percent of the total global energy budget."[3] If it truly wants to develop efficient and responsible energy supply, such a body should focus on the nuclear option, on establishing a secure international nuclear-fuel storage and reprocessing system, and on providing expertise for siting, financing, and licensing modular nuclear power systems for developing nations.

According to Arnulf Grubler, Nebojsa Nakicenovic, and David Victor, who study the dynamics of energy technologies, "the share of energy supplied by electricity is growing rapidly in most countries and worldwide."[11] Throughout history, humankind has gradually decarbonized its dominant fuels, moving steadily away from the more polluting, carbon-rich sources. Thus the world has gone from coal (which has one hydrogen atom per carbon atom and was dominant from 1880 to 1950) to oil (with two hydrogens per carbon, dominant from 1950 to today). Natural gas (four hydrogens per carbon) is steadily increasing its market share. But nuclear fission produces no carbon at all.

Physical reality—not arguments about corporate greed, hypothetical risks, radiation exposure, or waste disposal—ought to inform decisions vital to the future of the world. Because diversity and redundancy are important for safety and security, renewable energy sources ought to retain a place in the energy economy of the century to come. But nuclear power should be central. Despite its outstanding record, it has instead been relegated by its opponents to the same twilight zone of contentious ideological conflict as abortion and evolution. It deserves better. Nuclear power is environmentally safe, practical, and affordable. It is not the problem—it is one of the best solutions.

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The Need for Nuclear Infrastructure

Denis E. Beller, Ph.D.

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Idaho Energy Forum moderator U.S. Senator Larry Craig of Idaho (center), U.S. Representative Mike Simpson (Sen. Craig's left), also of Idaho, and Dr. Denis Beller of the Harry Reid Center for Environmental Studies.

The Report of the National Energy Policy Development Group that was recently released by the White House includes a considerable change in outlook for nuclear energy, a near 180-degree turnaround from the recent past. Just two years ago, Pulitzer-Prize winning historian Dr. Richard Rhodes and I began writing an essay titled "The Need for Nuclear Power," which was eventually published in the millennium issue of the international policy journal *Foreign Affairs*. At that time, nobody foresaw the impending nuclear renaissance.

Now, the need for nuclear power is taking on a new light because of unaffordable gas, unreliable renewable electricity, and rolling blackouts in California. Other states are scrambling to avoid the same fate this summer. The need for increased electricity supply is glaringly obvious except to a few who continue to believe we should stop using electricity—as former Secretary of Energy Bill Richardson told the National Press Club last Fall, "Just turn off the lights." But that doesn't meet the needs of millions of Americans and billions of our global neighbors.

A correlation between the Human Development Index that was tabulated by the United Nations and per capita electricity use shows that human well being and development depend on electricity, and the alternative is suffering: poverty, disease and death (Ref. Dr. Alan Pasternak, LLNL, Global Energy Futures and Human Development: A Framework For Analysis). A high Human Development Index value is associated with long life expectancy, higher

education, better health, and a higher all-around standard of living. For those with minimal access to electricity, the Index increases rapidly with small increases of electricity supply worldwide, and a high Index requires a per capita threshold of 4000 kilowatt-hours per year. This correlation also shows that the average citizen of a nation with less than 1/4 of this electricity threshold can expect to die ten years earlier, and those with less than one-tenth lose 26 years of their life expectancy. Thus, the global unavailability of electricity means billions of people die decades before they should. Thousands of times more danger results from poverty than from nuclear waste or emissions from coal plants.

Most practical people now understand that the less-fortunate peoples of the world must and will increase their electricity usage. The suppliers of that energy—and governments—will determine its impact on the economy and the environment. We would do well to note the actual title of the Vice President's Energy Policy Report: "Reliable, Affordable, and Environmentally Sound Energy for America's Future." That report includes a renaissance for nuclear energy because during the last decade, under deregulation, the U.S. nuclear industry has increasingly demonstrated that it is clean, affordable, reliable, environmental, safe, and sustainable.

The initials of these six attributes make up an acronym, CARESS, that I use to recall the major benefits of nuclear power. Thus, if the greens can hug a tree, this nature lover can CARESS Nuclear Energy.

The C in CARESS Nuclear Energy is for **Clean,** because nuclear power's wastes are safely, securely, and inexpensively sequestered at power plants; because nuclear power plants do not emit hazardous amounts of radioactive emissions or acid-rain precursors (SO_2, N0x, etc.); and because nuclear plants do not pollute our soil, air, or water. Secretary of Energy Abraham told reporters on May 25 that nuclear generation provides the cleanest form of electricity known.

The A is for **Affordability**--compared with many other sources of electricity the affordability of nuclear energy has recently been demonstrated all over the nation. The average marginal production cost of nuclear electricity last year, 1.8 cents per kW-hr, became less than coal and much less than oil or gas. I did not say that nuclear power is cheap, but it is affordable for most Americans.

The R is for **Reliability**. Nuclear power is the most reliable major source of electricity today, an attribute that makes it very valuable in an open market. Most nuclear plants run at 100% of capacity for more than a year before they are shut down to refuel, and that refueling now takes just a few weeks, as compared to a few months a decade ago. And the cost of nuclear power is also extremely reliable, because abundant fuel that is purchased today will be providing power at a steady, known cost five years from now (compare that to the cost of natural gas, which has taken daily roller coaster rides during the past year).

The E is for **Environmental**. As opposed to clean, this means it requires minimal land compared to water, wind or solar, it doesn't require cutting trees or native grasses to plant millions of acres of bio crops, and it requires minimal transportation of fuel and waste over our rails and highways. And then there's global warming—Vice President Cheney told an interviewer recently, "If you want to do something about carbon dioxide emissions, then you ought to build nuclear power plants, because they don't emit any."

The first S is for **Safe**—Secretary Richardson also said at the National Press Club last fall, "nuclear safety? I believe it is." Western-designed nuclear plants have never killed a private citizen in more than 40 years of operations in hundreds of plants worldwide. Yet tens of thousands of Americans die every year from emissions from fossil-fired generation, explosions of natural gas pipelines and from leaks in neighborhoods, fires and explosions at refineries and coal plants, coal-train collisions, and drowning behind hydro dams.

Finally, the last letter, and the second S, in CARESS Nuclear Energy is for **Sustainable**, at least for the 21st Century, using existing technologies and resources. Who knows how long it may last with the technologies that my new granddaughters, Maddison and Calalynn, could help invent twenty to fifty years from now while studying at the Idaho State University or while working at the Idaho National Engineering and Environmental Laboratory?

But who will design, build, and operate the new generation of nuclear power plants that we need today? Recent reports in national paper and electronic media, such as Business Week and the Christian Science Monitor, have detailed a severe shortage of college graduates for the existing nuclear power industry. They state this is because the

U.S. academic infrastructure for educating nuclear scientists and engineers declined precipitously during the 1990s. We have lost more than half of our nuclear engineering departments; and those that remain graduate hundreds too few engineers each year. The Nuclear Energy Research Advisory Committee reported to the U.S. Department of Energy a year ago that undergraduate and graduate student populations are the lowest in more than three decades. The same trends are reported for most of the world by the OECD in their recent report, "Nuclear Education and Training: Cause for Concern?" (Their answer is a resounding "YES" worldwide).

For nuclear energy to provide a considerable fraction of new generation, greater than the 20% share it now provides, the nation must stop the crash in our nuclear infrastructure that occurred in the previous administration. Our academic institutions today are not producing sufficient graduates for the existing industry, much less to provide our new nuclear capacity. The situation is much worse than the press has reported, though, for two reasons.

First, electricity generation is just a fraction of U.S. nuclear industry. The manpower needs of the existing nuclear power industry are less than one fourth of current and future requirements for nuclear scientists and engineers. During the next decade, we will need additional people for treatment, reduction, storage, and disposition of nuclear waste and used fuel. We need new scientists and engineers for national security programs like counter-proliferation, global monitoring activities, stewardship of our nuclear stockpile, and naval nuclear propulsion. We need more college graduates for design and federal regulation of next-generation reactors (the NRC has more staff in their sixties than in their twenties). We also need young people for nuclear medicine and medical research using radioisotopes and for our expanding industrial radiation applications such as manufacturing, oil and gas exploration, and irradiation to sterilize hundreds of consumer products and most medical equipment. In addition, we'll need a larger workforce for irradiation of food as well as livestock feed to eliminate pathogens like Listeria, Hoof-and-mouth, and e-Coli.

The other reason that the press is under-reporting the problem is that our disappearing infrastructure includes much more than just students and academic departments, it also includes facilities, laboratory equipment, and operating research reactors at our universities--down from a peak of 70 to about 25 today. Also, with the shut-down of federal research reactors and other facilities, our national nuclear laboratories and defense organizations are experiencing similar declines.

One major contribution to this decline has been a sharp reduction in Federal budgets for research in nuclear energy to near zero in the mid to late 1990s. However, nuclear research funding has increased in the past few years with the leadership of many members of Congress, including Senator Craig and Congressman Simpson. The increased budgets have been enough to slow, but not stop, the severe decline in our nuclear energy infrastructure. The FY2001 DOE/NE budget of about $120 million--a paltry sum compared to the importance of this technology to energy, medicine, national security, defense, and industry--can't address the ongoing decline.

To examine what the Administration and the U.S. Congress can do about the dismal state of the U.S. infrastructure, we must examine what attracts students and faculty. Most of us seek exciting things, new things, and opportunities to make a difference. New science attracts bright, young graduates to begin careers as faculty in healthy academic departments. This also makes it easier for faculty to recruit students into science and engineering. Employment opportunities, another requirement for attracting faculty and students, far exceed current supply—lack of jobs is definitely not a problem. The nuclear power industry has told the American Society of Engineering Education that they need hundreds more graduates per year than will be available in the next few years. Nuclear is one of the best-paid engineering disciplines in the U.S. because supply does not meet demand. Visibility and importance highlighted by the attention of national leaders are other highly important features that attract students. Recent publicity accompanying the introduction of several nuclear energy bills (education, research, and power) and the new Energy Policy Report are now providing that visibility.

New technology also attracts students to any field. In South Africa a new reactor design is being considered, the Pebble-bed Modular Reactor (PBMR), a compact, modular, ultra-safe design. An experimental reactor similar to this recently began operation in China. In Europe a multi-national collaboration for accelerator-driven transmutation of nuclear waste is preparing to conduct a Megawatt proton beam on target experiment called MEGAPIE. Another new multi-billion dollar facility is under construction in Japan for the economical and environmental recycling of used nuclear fuel. And the nuclear industry in Russia has recently decided, with government approval, to open an

international, monitored retrievable storage facility for high-level nuclear waste. How does U.S. nuclear research and development compare with these international programs?

Other than paper studies and small research projects that may lead to nowhere without strong national leadership and multi-year commitments, we have next to nothing. The last major nuclear energy experiment in the U.S. was built more than 20 years ago and has been mothballed; however, Secretary Abraham may decide to re-start this aged Fast-flux Test Facility (FFTF), reversing a Clinton-administration decision to permanently close it. Although critical to ongoing nuclear research, this is certainly not the way to attract faculty and students.

To stop the crash and reverse the decline in nuclear infrastructure, Congress and the Administration must provide substantial and sustained funding for academic and other research in nuclear science, engineering, and energy. To reinvigorate nuclear research and education, total budgets must reach several hundred million dollars per year for the Nuclear Engineering Education Research program, the Nuclear Energy Research Initiative, for research to recycle and transmute used nuclear fuel, and for other nuclear research. An additional several tens of millions of dollars per year will be needed to upgrade, maintain, and utilize existing university research reactors. In addition, both for nuclear research and for production of isotopes used in nuclear medicine and medical and other research, Congress should fund the restart of the FFTF in Washington--in addition to funding a program to begin the engineering design of new national nuclear research facilities and devices (accelerators and reactors).

These programs work to attract students into nuclear engineering and to reinvigorate nuclear academia. When Congress provides research funding for nuclear energy programs, we use that funding to support academia and national infrastructure. In the national Advanced Accelerator Applications Program, for instance, we are funding more than 70 students, from high school to doctorate, and 10 faculty from the FY01 budget, with Fellowships and research projects spread nationwide. If our representatives in Congress provide additional funding, we will expand the academic programs of the AAA project to reach more students and include more programs. For example, Professor Brey at Idaho State University is a Principle Investigator for a new intercollegiate research project that we are planning for the AAA Program. The same will happen in other DOE/NE and defense programs where Congress indicates that one reason for increased funding is to support academic infrastructure.

Strong national leadership will be required to provide this level of sustained research funding. Fortunately, that leadership appears to be forthcoming from the Administration and a surprising and substantial bi-partisan majority of Congress. More (nuclear) power to them.

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Bio

Dr. Denis Beller has a background in engineering design and analysis and in management of defense systems. He studied fusion engineering and reactor physics at Purdue University, where he was gradiuated in 1986 with a Ph.D.; he studied nuclear weapons effects at the Air Force Institute of Technology, where he earned a M.S. in Nuclear Engineering in 1981; and he received a B.S.in Chemical Engineering from the Univsity of Colorado in 1976. After graduation from Purdue in 1986, Dr. Beller began a seven-year stint as a professor at the Air Force Institute of Technology, where he taught graduate nuclear engineering and weapons effects to military officers. As a result of teaching, research, and professional activities, the faculty selected him as the first tenured military professor in AFIT's 70-year history. Dr. Beller's activities have included design and analysis of conceptual systems for nuclear effects testing with inertial confinement fusion, conceptual design of nuclear-pumped lasers, and formulation and testing of solid rocket propellants (including propellant formulations that were used in Operation Desert Storm). He also managed a rocket test facility, a nuclear detection laboratory that monitored radioactive emissions to support Safegaurd D of the Nuclear Test Ban Treaty, and an intelligence division that collected and disseminated foreign science and technology information. Immediately prior to joining the Technical Staff at the Los Alamos National Laboratory (LANL) in 1998, he designed, analyzed, and demonstrated a concept for a neutron effects test for the National Ignition Facility project. At LANL Dr. Beller concentrated in Nuclear Systems Analysis related to long-term national and global deployment of nuclear energy in conjunction with the DOE AAA/ATW program, the LANL Nuclear Vision Project, and the Nuclear Strategies Project (co-sponsored by SAIC, Los Alamos, Sandia, Livermore, and the Defense Threat Reduction Agency). Dr. Beller now serves in the Harry Reid Center for Environmental Studies at the University of Nevada, Las Vegas as Intercollegiate Programs Coordinator for the AAA University Participation Program, for "... research and development of technologies for economic and environmentally sound refinement of spent nuclear fuel ...." (Public Law 106-377). He is also an adjunct professor with the Department of Nuclear Engineering at Purdue University, and continues to be heavily involved in public information and academic education activities about nuclear science, technology, and energy.