

Rickover. In 1973, Heronemus testified before a nuclear licensing hearing that it would cost roughly \$2,400 per kW to build one of the U. S. Navy's nuclear reactors, compared with \$400 per kW for the commercial plant that was under review. (Note that at present, capital costs for commercial reactors are closer to the \$2,400 figure.) Heronemus also testified that he would have refused to approve the wiring and piping for the Navy that had been accepted and incorporated in the commercial nuclear facility.

### Advanced Reactor Considerations

According to Dr. Charles E. Till, a nuclear physicist at the Argonne National Laboratory (Illinois), a new generation of nuclear fission reactor, referred to as an "Integral Fast Reactor," has been under development by the U.S. Department of Energy for several years. This new liquid sodium-cooled reactor configuration is expected to be safer, minimize corrosion and be more efficient (i.e., it should be able to use 15 to 20 percent of the uranium fuel instead of the 1 to 2 percent with current reactors), and generate less radioactive wastes than the existing generation of light-water reactors in use in the U.S.

In addition, according to Jerry Griffith, an associate deputy assistant secretary for reactor systems development for the DOE, the Integral Fast Reactor is considered especially crucial to the future of nuclear power because it is the best technology for breeding plutonium. As the world's uranium reserves become scarce, plutonium will be needed as a substitute nuclear fuel.

Thus, the Integral Fast Reactor is the key to nuclear future and a "plutonium economy." However, there are three primary concerns with the advanced Integral Fast Reactor:

1. Nuclear physicists have had a relatively poor track record in predicting the engineering outcome of many theoretical calculations, and thus far, not even a prototype of the Integral Fast Reactor has been tested.
2. Liquid sodium is an extremely volatile substance that will burst into flames if it comes into contact with either air or water. Two liquid sodium-cooled U.S. prototype nuclear breeder plants were totally destroyed by liquid sodium fires.
3. Plutonium is an exceedingly difficult and dangerous material to handle. It is one of the most toxic elements known. Plutonium is 35,000 times more lethal than cyanide poison by weight. There is an equivalent of 20 million mortal doses in only 5 grams of plutonium, which is the weight of a 5-cent coin, and it will remain dangerous for hundreds of thousands of years. This long-term toxicity of plutonium, in and of itself, creates significant moral and ethical questions about producing such long-lived toxic substances that are invisible to human senses.

It is important to realize that in order to produce enough energy to displace fossil fuel resources, which now account for roughly 90 percent of the industrial world's energy supply, immense quantities of plutonium would have to be created. And given the extremely poor track-record of containing or properly disposing of the plutonium and other radioactive wastes that have already been created, the construction of the thousands of plutonium-fueled reactors that would be necessary for the "plutonium economy" to be viable would hardly seem to be an acceptable alternative. These serious problems underscore the importance of evaluating the renewable energy options that do not pose such long-term unknown environmental and economic risks.

### Nuclear Fusion

Nuclear fusion reactors, in contrast to nuclear fission reactors, do not split uranium

atoms. Rather, they are intended to fuse hydrogen atoms in a process similar to that which occurs in the Sun and other stars. Although fusion physics is a common occurrence in stars, it is well to remember that no biological organisms are able to live in such high-temperature environments. Billions of dollars have already been spent on this highest of high-tech energy technologies, which has been under development for decades by governments in the U.S., Japan, France, Germany, the Soviet Union, and other European countries. However, it has been as a result of this research that at least some fusion reactor advocates are now questioning whether such high-temperature (over 100 million degrees F) fusion energy systems will ever play any role in energy production during the next 50 to 100 years.

According to a recent nuclear fusion update article by John Horgan published in Scientific American, the initial hopes of having small, safe high-temperature fusion reactors burning cheap, abundant fuel have all but disappeared. It is now estimated that exotic and expensive fuels will be required, they will produce significant quantities of radioactive waste, and even the smallest fusion reactor would be comparable in size and complexity to the largest of today's fission reactors. Such high-temperature fusion technologies face staggering technical problems, and billions of additional dollars will be needed just to build a prototype. Even if the prototype plant works from a technical perspective, the really important question is whether nuclear fusion systems will ever be cost effective. As such, it would be irrational to predicate a nation's energy policy on such high-risk technologies.

### Nuclear Economics

The true cost of nuclear power has been confused by the quasi-public nature of the research and development. U.S. taxpayers are financially responsible for the "back-end" of the nuclear fuel cycle, which includes covering any costs not met by the utility for waste disposal and decommissioning. Billions of taxpayers dollars have also been spent for the "front-end" of nuclear research and development. These costs are not included in most nuclear cost totals. They include the construction and operation of the three U.S. uranium fuel enrichment facilities, that are at present shut down due to the extensive problems with respect to radiation spreading. When all three of these enrichment facilities were operating at full capacity, their electrical requirements were actually about the same as those used by the entire country of Australia. Other excluded costs include Federal regulation, long-term waste disposal, and the numerous health costs that are associated with people being exposed to radiation.

To comprehend the nuclear issue, it is necessary to put time in perspective. If toxic wastes, which will be deadly for 200,000 to 500,000 years, are generated, is it possible for anyone to comprehend the actual environmental or economic costs? The very first civilized groups of people in the Middle East appeared only about 8,000 to 10,000 years ago. How is it, then, that one generation could, or should, assume the right to create insidious radioactive hazards that will remain deadly for hundreds of thousands of years? How is it that we have allowed ourselves to do such things that cannot be comprehended or calculated in terms of cost or human death and disease?

The nuclear and other toxic waste problems are global in nature and have clearly transcended the capitalist or communist ideologies, as both political systems have developed nuclear technologies. It is interesting to note that both the U.S. and the Soviet Union -- as well as most other countries -- have up to now shown a complete disregard for the "human rights" of future generations. It seems difficult to imagine how so many "civilized" nations could have allowed the production of such deadly and

long-lived radioactive wastes to occur. Even more difficult to understand is how the citizens in the same countries can silently let the production of such long-lived toxic wastes continue. If the ovens of the prison camps in Nazi Germany are now viewed as a moral outrage, one can only wonder how future generations will view the actions of the present generation.

Never before has the human community been faced with such an awesome array of problems, and unlike most other environmental problems, acceptable solutions for the disposal of radioactive wastes are as yet unknown. This hard reality is underscored by the fact that after more than 30 years of concentrated effort by a wide-range of distinguished scientists from around the world, no one has yet demonstrated a solution to the radioactive waste problem. Indeed, a study done by the Jet Propulsion Laboratory of the California Institute of Technology for the President's Office of Science and Technology Policy concluded the following:

*"The problems of high-level nuclear waste management are so complex and have so many ramifications that no one person or group of persons can possibly have all the answers. The results of this study indicate that the U.S. program for high-level waste management has significant gaps and inconsistencies."*

As a result, it would seem that far from solving the diminishing fossil fuel problem, the nuclear power industry has only succeeded in creating a whole new range of technical and long-term environmental problems that will be inherited by our children and their children for thousands of generations into the future. This unfortunate reality brings to mind the observation that Albert Einstein made about nuclear technology:

*"The splitting of the atom has changed everything save our modes of thinking, and thus we drift toward unparalleled disaster."*

Dr. Barry Commoner made a similar observation in his book, *The Closing Circle*:

*"Our experience with nuclear power tells us that modern technology has achieved a scale and intensity that begins to match that of the global system in which we live. We cannot wield this power without deeply intruding on the delicate environmental fabric that supports us. It warns us that our capability to intrude on the environment far outstrips our knowledge of the consequences."*

Placing such an ominous issue as radioactivity into an evolutionary perspective is not easy. Kenneth and David Brower have expressed it as well as anyone in an article, "Miracle Earth" that was published in *Omni* magazine. In their article, they point out that when a beta particle, (a high-speed electron emitted from the nucleus of a radioactive atom) strikes living tissue, "it rips negatively charged electrons from the tissue's atoms, leaving positively charged ions in its wake." These liberated electrons in turn ionize other atoms in a cascading effect which tears apart tens of thousands of highly ordered biological molecules that serve as the structure of living cells. "This passage of such a particle leaves the city of the cell in ruins. Alpha, gamma, and X-rays all have this effect on biological molecules. Their entry hole is small, but their exit hole is spectacular."

### Conclusions

Because fossil fuels are nonrenewable and are being exponentially consumed, they will be unable to sustain an expanding global industrial economy. Even if the fossil fuels were inexhaustible, however, their unacceptable environmental impact would still dictate that alternative energy technologies and resources be developed.

Because nuclear energy systems do not produce greenhouse gases or acid deposition,

they are being touted as the logical solution to the problems created by burning fossil fuels. But nuclear fission technologies generate staggering environmental problems of their own that revolve around the radioactive wastes that have thus far proven to be unmanageable. Moreover, if nuclear power plants were to effectively replace the burning of fossil fuels, literally thousands of nuclear reactors would have to be built at a cost of trillions of dollars. In addition, since the existing uranium reserves will barely be able to keep the 109 existing reactors in the U.S. operating beyond the year 2000, a whole new type of untested breeder nuclear technology would have to be rapidly developed. For all of these reasons, if nuclear systems were the only energy alternatives to the burning of fossil fuels, there would be little reason to be optimistic about the future of the human community.

Fortunately, there are several viable renewable solar-hydrogen technologies that are capable of displacing the use of both fossil and nuclear fueled energy systems. While the political aspects of re-ordering national priorities are very real, most elected officials determine their issue priorities by finding out what the majority of their constituents think is important. Although elected officials are often criticized for tailoring their views to the whims of public opinion, they do have a responsibility to be aware of how the majority of the people they represent feel about issues. This essentially means it is necessary for the majority of voting citizens to be informed.

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