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THE PLUTONIUM ECONOMY

Why we should wait and why we can wait

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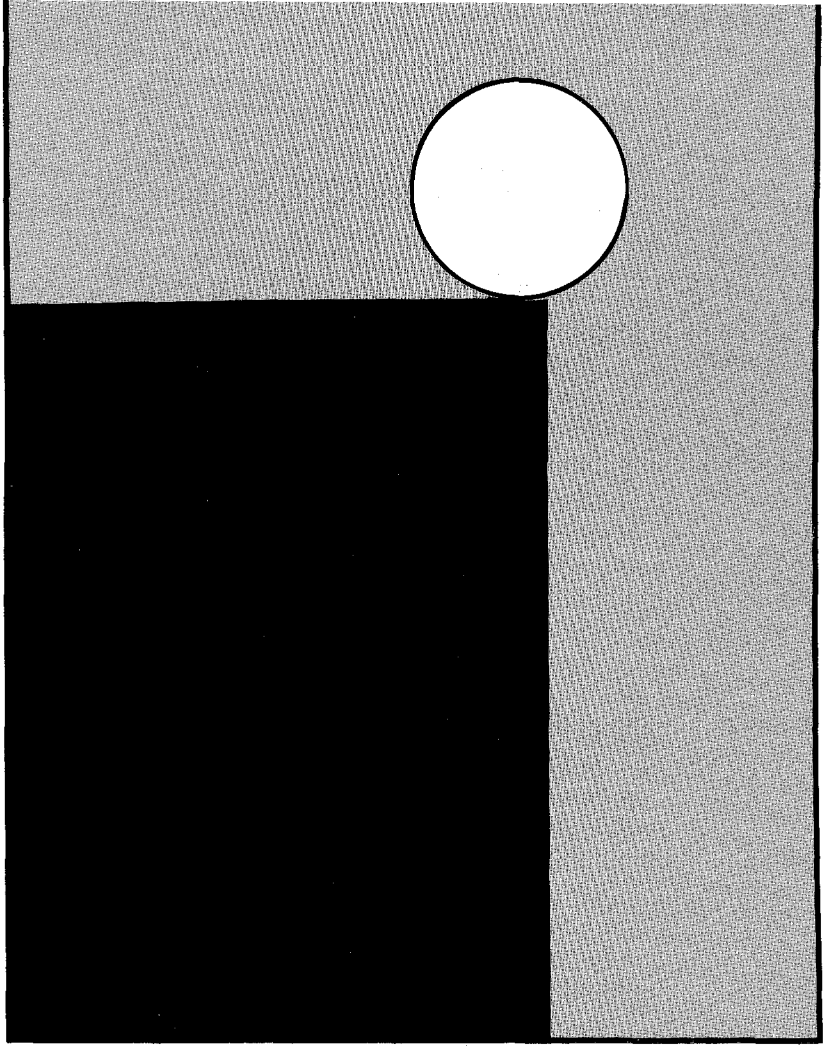


The debate over nuclear energy has become so polarized that it has stifled public consideration of options other than the two extremes of full speed ahead or a shutdown of the nuclear industry. In the offing, however, are some far-reaching governmental decisions that for the time being at least can be separated from the final decision on nuclear power.

Specifically, the world is on the brink of a commitment to the widespread use of recycled plutonium as a nuclear fuel.

To date, virtually all the plutonium which has been produced in the uranium fuel of current nuclear power plants has been left there—mixed with the highly radioactive fission products in the spent fuel. In the proposed "plutonium economy," however, the plutonium would be recovered from the spent fuel by "reprocessing" and then recycled—first as fuel for today's reactors and subsequently as fuel for breeder reactors.

These plutonium breeder reactors provide the ultimate rationale for the recycle of plutonium. Although current reactors produce some plutonium, even with plutonium recycle their principal fuel would be the rare naturally occurring chain-reacting isotope uranium-235. This isotope represents no greater an economic energy resource than petroleum.

Plutonium breeder reactors would effectively exploit the energy content of the relatively abundant "fertile" isotope of uranium, uranium-238, by converting most of it into the chain-reacting isotopes of plutonium. The resulting hundredfold increase in the energy released from natural uranium would make uranium a viable energy resource for the long term. It is for this reason that plutonium breeder reactors are now under development in several industrialized countries, including the United States, the Soviet Union, France, the United Kingdom, West Germany and Japan.

The most imminent plutonium economy decisions relate, however, not to the breeder, but to the recycling of plutonium in contemporary reactors. The U.S. Nuclear Regulatory Commission (NRC) hopes to make its decision on the desirability of such plutonium recycle in the United States in 1977.

From an economic point of view the decision on whether or not to recycle plutonium in today's reactors is of no great moment to the consumer. The cost of uranium and uranium enrichment will be such a small component of the total delivered cost of electricity from nuclear power plants in the 1980s (about 10 percent) that plutonium recycle could reduce this total cost by only a small percentage at most. The economic incentives for the industry, however, depend not on the percentage reduction of the cost of electricity delivered to the consumer, but rather on whether recycled fuel is cheaper than fresh fuel.

A decade ago it appeared that the "reprocessing" business would be quite profitable. Today, in the light of experience in the United States and abroad, and because of increasingly stringent regulatory requirements relating to occupational hazards, radioactive waste disposal, and the safeguarding of plutonium against theft, plutonium recycle appears to be a much more marginal economic operation.*

Despite the decline in its near-term economic attractiveness, however, plutonium recycle in today's reactors still has many advocates who feel that it would be a major advance in establishing an industrial base for the plutonium breeder reactor. A decision by the Nuclear Regulatory Commission to go ahead with plutonium recycle would also be of symbolic significance to many in the nuclear industry who feel that such a decision would firmly establish a long-term commitment to nuclear power by the United States.

The advent of a plutonium economy holds the promise of a virtually inexhaustible energy resource. But it brings with it disturbing questions of risk—above all, the potential that the plutonium, which today is left in the highly radioactive spent fuel, by being put into commercial circulation would become vulnerable to diversion for nuclear weapons purposes through theft by terrorist and criminal groups, or through appropriations by governments of nations not currently in the nuclear "club."

The following article, "Security Implications of Alternative Fission Futures," discusses these risks and the difficulties involved in coping with them. It argues that there may be alternatives to the present course of nuclear power development which are inherently less vulnerable to diversion.

One of the possibilities which is discussed would involve the substitution of thorium-232 for most of the uranium-238 as the principal "fertile" isotope for breeding new chain-reacting isotopes in reactors. The bred material would then be the artificial isotope uranium-233, mixed with enough uranium-238 to "denature" it, that is, render it unsuitable for weapons purposes without further isotope enrichment. This

*A commercial reprocessing plant did operate in the United States at West Valley, New York, between 1966 and 1972. Not much fuel was reprocessed however, and the recovered plutonium was not recycled on a commercial basis. Plutonium recycle has been conducted on a pilot project basis in both the United States and elsewhere. Of course plutonium has been extracted on a large scale for the manufacture of nuclear weapons from the fuel of special reactors by members of the nuclear "club."

The role of plutonium in nuclear power

Plutonium-239 is produced in reactor fuel by neutron bombardment of the isotope uranium-238, which makes up 99.3 percent of natural uranium. Like the isotope uranium-235, which makes up the other 0.7 percent of natural uranium, plutonium-239 can sustain a fission chain reaction and therefore has fuel value.

Uranium-235 is the primary fuel for today's reactors. As this fuel fissions in a reactor, however, a small fraction of the uranium-238 is converted to plutonium, which then also begins to fission. Some of the plutonium produced and some unfissioned uranium-235 remain in the spent fuel when it is withdrawn for replacement. It has been proposed to extract and recycle these isotopes into new fuel. Over the lifetime of the reactor the resulting reduction in the requirements for fresh uranium-235 would be perhaps 25 percent, with roughly equal contributions to the savings coming from the plutonium and the recycled uranium-235.

Plutonium breeder reactors would be able to convert more than half of the uranium-238 into chain-reacting plutonium and thus make possible the release of about 100 times as much energy from a pound of uranium as is being achieved with current reactors. A breeder of some kind is required if fission is to be a major energy source for the indefinite future, because known deposits of high-grade uranium ore are rather small. But the commercial recycle of plutonium would expose this material to the risk of diversion for nuclear weapons purposes. The purpose of these articles, therefore, is to examine alternatives to a "plutonium economy" and how long a decision on a commitment to plutonium recycle could be delayed.

While the major breeder programs throughout the world today are focused on breeding plutonium, it is also possible to breed the artificial chain-reacting isotope uranium-233 from thorium-232. Thorium-232, like uranium-238, is abundant enough worldwide to support a large fission economy indefinitely. And, as explained in the article "Security Implications of Alternative Fission Futures," a fission economy based primarily on thorium might be made more resistant to subversion for nuclear weapons purposes than one based primarily on uranium.

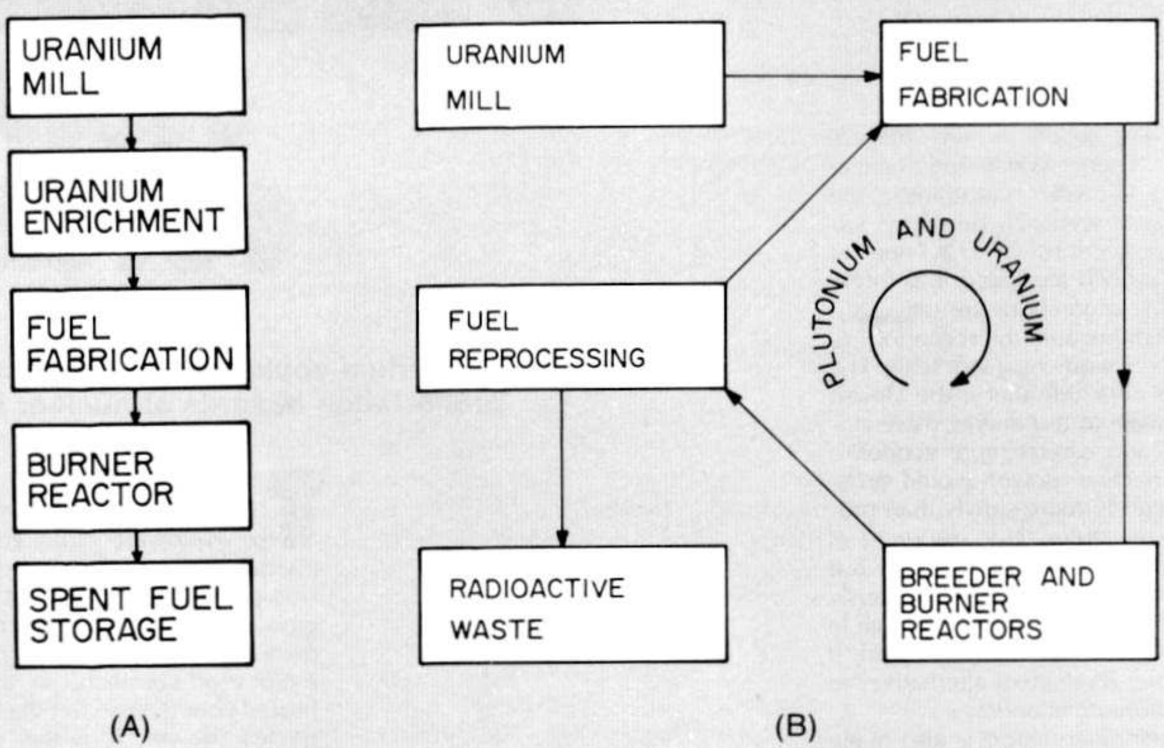
cannot be done with plutonium. Thorium-232, like uranium-238, is abundant enough worldwide to support a large fission economy indefinitely.

Perhaps the most remarkable thing about this proliferation resistant alternative is that it has not even been considered seriously in the course of the development of fission power. Billions in public funds and the energies of thousands of talented people have been devoted to solving the technological problems encountered during the deployment of fission power; but little attention has been devoted to designing the technology in a manner which takes into account the dangers of proliferation in a world of imperfect institutions. We believe that alternative fission futures and, perhaps, even more urgently, non-fission futures based on solar and possibly on fusion energy must be examined before the world proceeds with plutonium recycle.

It has long been assumed that we would go ahead with plutonium recycle. *Indeed this has been the underlying assumption of the fission research and development programs of the developed nations for more than a decade. Does this mean, however, that it is too late to avoid plutonium recycle? We think not,* principally for two reasons:

- The parts of the fuel cycle uniquely associated with plutonium recycle, namely plants for reprocessing and for fabrication of fuels containing recycled plutonium, represent only a tiny fraction of the total capital investment in nuclear power.
- There is not yet any wide-scale deployment of plutonium recycle

Current once-through and proposed plutonium breeder fuel cycles



These figures show the contrast between the current "once-through" fuel cycle of commercial power reactors in the United States (see A) and the proposed plutonium breeder fuel cycle (see B).

In the once-through cycle the uranium is mined; a large fraction of the uranium-238 is removed, thus enriching the uranium by raising the percentage of uranium-235 from its natural level of 0.7 percent to approximately 3 percent; the "enriched" uranium is used to make reactor fuel; the fuel is used to sustain a chain reaction in the reactor until most of the uranium-235 has been consumed; and, then the "spent" fuel is stored. This spent fuel contains some plutonium which has been produced by neutron bombardment of the uranium-238 in the fuel.

In the proposed plutonium-breeder economy, the primary fuel is derived from the element uranium-238, which makes up 99.3 percent of natural uranium. Breeder reactors would produce more chain-reacting plutonium out of this uranium-238 than they consume. Since uranium-235 is not the primary fuel, no enrichment plant is required. Natural uranium is mixed with plutonium in the reactor fuel. After being irradiated for some time the fuel is removed from the reactor core, processed chemically, and the uranium and plutonium are recycled into fresh fuel.

technology in the United States or abroad.

Once a commitment to plutonium recycle is made, however, much flexibility will be lost: the nuclear industry can be expected to hold governments to arrangements within which the industry has learned to work, and governments will fear that their regulatory authority would be eroded even further if they changed their minds.

Can we afford to delay plutonium recycle? Must we not commit ourselves now to the plutonium economy if we are to be sure of adequate fuel supplies for our nuclear reactors beyond the next few decades? Such questions are prompted by projections of nuclear energy growth and estimates of uranium resources made by the U.S. Energy Research and Development Administration (ERDA) and the International Atomic Energy Agency.

The last article in this *Bulletin* report, "Energy Waste and Nuclear Power Growth," examines the energy-use scenarios on which ERDA's projections of U.S. nuclear power growth are based. It is found that these projections are unrealistically high because the scenarios entail energy waste on a vast scale. The authors conclude that if the United States were to use energy more efficiently and capital more economically, nuclear power would grow considerably more slowly than projected by ERDA. U.S. resources of "cheap" uranium would then last considerably longer than previously projected—certainly long enough to allow the nation to explore and, if desirable, implement alternatives to the plutonium economy.

A preliminary effort is also made in this article to explore the uranium supply-demand situation on the international level. Here it is pointed out that the United States, in the role of a uranium exporter, could influence the timing of the plutonium recycle decision in some important uranium-poor nations.

Together these articles support a simple proposition: Large-scale commercial plutonium recycle should be discouraged worldwide until the alternatives have been carefully assessed. □

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SECURITY IMPLICATIONS OF ALTERNATIVE FISSION FUTURES

Use of thorium could reduce the security and proliferation hazards of nuclear breeders

The worldwide rapid growth of civilian nuclear power is exposing a rising and potentially staggering amount of plutonium to the risk of its diversion to nuclear weapons by nations or criminals. In the often heated controversy over the future of nuclear power, it is this risk that appears to be the one most intractable to technical resolution and, as well, most insistently fundamental to the way people feel about nuclear power. It is the issue which should, in our view, most determine the character of the next stage in the development of nuclear power in the United States and abroad.

The information and non-nuclear materials needed to make fission explosives are now widely distributed and available to the general public. Dozens of nations have or could