Introduction and Summary 1

In September 1993, the Office of Technology Assessment (OTA) published *Dismantling the Bomb and Managing the Nuclear Materials, a* report on the technical and policy issues involved in dismantling nuclear warheads in the United States and Russia as well as the long-term care of the materials extracted from these warheads. OTA concluded, and several other recent reports have confirmed *(48,* 27, 37), that disposing of plutonium from warheads is one of the more intractable problems that remain as a legacy of the Cold War nuclear arms race. In addition, the OTA report stressed the need to formulate national policy goals on plutonium control and disposition prior to adopting major technical paths.[1]

Although few readily available methods, other than long-term storage, currently exist for plutonium disposal, many proposals have been put forward to develop. adapt, or apply new advanced technologies for this purpose. One such technology that has been proposed is the so-called advanced liquid metal reactor/integral fast reactor (ALMR/IFR, or ALMR system). OTA reviewed the merits of this system briefly in its dismantlement report. The Department of Energy (DOE) has been supporting a research program to develop this system for many years. Basic research on liquid metal reactor systems began more than four decades ago. The work supported by DOE's Office of Nuclear Energy in the 1970s and 1980s was part of a major effort to develop breeder reactors that would produce plutonium and power at the same time. More

[1] In fact, in early 1994, the Department of Energy established a department-wide initiative for control and disposition of surplus fissile materials as well as a new office to plan and implement a long-range strategy.

recently, the developers of this technology have claimed that essentially the same concept could be used to consume plutonium and meet such goals as disposing of surplus plutonium from nuclear warheads.

This paper evaluates the ALMR program, its current status and potential for plutonium disposal, and certain key questions that have been raised about what benefits or risks this technology may offer if it is fully developed and deployed in the future. The program itself has a long and complicated history. The technology for plutonium disposal would include a nuclear reactor, a fuel manufacturing and reprocessing system, and many ancillary components. Some of these components are already developed, while others are in the early testing phase or have not yet been designed. In general, the overall technology is still in the research stage, and many claims about its potential are based on assumptions about the successful outcome of future development and testing work.

Since the ALMR system has been promoted for a variety of purposes, the features and subsystems of the total project have necessarily changed to fit each purpose. Therefore, any analysis of the advantages or disadvantages of this technology should be made separately for each purpose proposed. OTA has attempted to conduct this evaluation in such a way as to limit its analyses primarily to the newly proposed objectives, without making judgments about the future of nuclear power in general.

During FY 1992 and 1993, DOE supported the ALMR research program at a level of approximately $40 million to $43 million annually. These funds were allocated to the Argonne National Laboratory, which received almost 80 percent of the budget, and to the General Electric Company (GE), which received about 20 percent. Argonne has conducted this work at its laboratory and research offices in Chicago, as well as at its test facility known as "Argonne West," which is located in the Idaho National Energy Laboratory. Recently, Argonne's work focused on the development of the reactor fuel reprocessing portion of the total system, which is one of the important and necessary components for the plutonium disposal application. GE efforts, however, have focused on a total commercial power generating system that is not closely related to the key development needs for plutonium disposition applications.

In 1993, Congress debated whether continued funding for this program could be justified. Issues were raised about the most appropriate goals for the program and whether there was sufficient justification for funding the program at various levels. The final FY 1994 appropriation for the program was about $30 million. In the President's FY 1995 budget as submitted to Congress in January 1994, the Administration proposed to cut almost $100 million from Nuclear Energy research and development (R&D) programs in general and to terminate the ALMR project.

FOCUS OF OTA'S ANALYSIS

This paper, which presents OTA's evaluation of the ALMR project, first reviews the history of government programs and recent program goals for developing 1 liquid metal fast reactors, and then focuses on four key questions that have been posed about the technology's potential for specific purposes:

1. What is the potential for this technology in disposing of surplus weapons plutonium?
2. What is its potential for processing spent fuel from light-water reactors and for destroying plutonium and other actinides?
3. What is its potential for processing other radioactive wastes that are currently stored under marginal conditions?
4. What risks and benefits, in terms of plutonium proliferation, might be associated with large-scale deployment of this technology in the future?

Throughout the history of this program, the development of an advanced reactor system for large-scale nuclear power generation has consistently been an overriding goal. However, that goal has not been put forth as primary in recent program justifications. As such, this OTA paper does not address the role of advanced reactors in future energy supply scenarios, the risks and benefits of nuclear power in general, or the advantages or disadvantages of this particular technology in terms of the future of nuclear power.[2]

SUMMARY OF ALMR EVALUATION

OTA's analysis shows that the DOE ALMR project is clearly in the research phase and, as such, cannot provide conclusive results regarding its potential for newly identified uses other than power production. The following summarizes OTA's analysis.

I Disposing of Weapons Plutonium

ALMR technology is one of several advanced reactor or converter systems that theoretically could convert substantial portions of a given amount of plutonium to other fission products by processing the materials through the system repeatedly over a long period. In one hypothetical system, for example, after fissioning, fuel would be removed from each reactor and reprocessed approximate] y every 2 years for a total of 50 years in order to destroy about two-thirds of the total plutonium material fed into the system. To deploy a working system that will perform effective y and efficiently would require a great deal more research and testing of several key components, as well as of the total system. Therefore, it is important to make sure that there is a clear and pressing need for such a capability and that the cost and time required to implement it are justified.

Plutonium isotopes can potentially be eliminated completely within the reactor of a future ALMR systems Thus, according to ALMR supporters, it should be favored over options that would simply produce a material with difficult-to-extract plutonium still in it. This distinction, however, becomes less important when one considers the fact that plutonium exists in all spent reactor fuel currently stored worldwide. Also, even though its percentage is small, the total quantity of plutonium now contained in all spent reactor fuel is much larger than the current stockpile of plutonium extracted from weapons. This fact has led some researchers to take the position that it is more important to put weapons plutonium into a form that is as proliferation-resistant as spent fuel as soon as possible, than it is to wait (perhaps many decades) to prove the effectiveness of a system such as the ALMR, which may be able to eliminate it.

The Department of Energy and other responsible agencies are currently developing policies and strategies with regard to the disposition of weapons plutonium. These policies will probably put a high priority on methods that can be implemented quickly to control weapons-usable material and make it more resistant to proliferation. Most policymakers recognize the urgency of dealing with materials that are now in the former Soviet Union and would also put a high priority on methods that could be implemented quickly there.

Given the above priorities, the ALMR technology would be less appropriate for plutonium disposition than more near-term technologies that would not require as long a development time (such as mixing with high-level waste and vitrification or fissioning in existing light-water reactors). However, if a policy is adopted at some future date that favors complete elimination of plutonium in all forms, ALMR technology has the potential to be one of several options that could be evaluated after more development work has been done.[4]

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[2] For an overall assessment of the relative merits of this and other nuclear reactor technologies for future energy supply, see U.S. Congress, Office of Technology Assessment, *Energy Technology Choices: Shaping Our Future*, OTA-E-493 (Wash ington, DC: U.S. Government Printing Office, July 1991).

[3] It should he noted, however, that current ALMR reactor designs must always maintain some amount of plutonium within the reactor core in order to function and that this material w III remain even after many decades of operation.

[4] The other elimination options, advanced reactors and converters, are discussed in references 27 and 48.

Processing Spent Reactor Fuel

Current difficulties with progress toward an underground repository for spent fuel from commercial nuclear reactors have led proponents of the ALMR to suggest that this technology could be used to process spent fuel and thus make it more suitable for repository disposal. With technical additions for handling spent fuel, ALMR technology could potential y reprocess the spent fuel rods and, over many cycles, transform the actinides (uranium plus elements with higher atomic weights) to other materials. If all actinides were removed, proponents claim that the remaining waste would have to be isolated and contained for no more than a few centuries because the actinides are elements with very long half-lives that require repository integrity for tens of thousands of years or longer.

The above claims of complete actinide removal and transformation, however, are somewhat uncertain at the current stage of ALMR development. Less work has been accomplished on this aspect of the technology than on most other aspects. Also, although actinide removal is theoretically feasible, in practice it would add many more fission products to the waste stream. Some of these products also have long half-lives (equivalent to or greater than plutonium). Until more complete design analysis and testing work is done, it is not clear whether ALMR technology can offer much of an advantage, if any, to the commercial nuclear waste management dilemma. In addition, problems in establishing a nuclear waste repository may not be solved with purely technical approaches. A long history of public policy and regulatory issues related to repository planning and siting has dominated technical issues in the past and will probably continue to do so in the future.

Another proposed advantage of actinide (particularly plutonium) removal from spent fuel is that material suitable for weapons would thus be destroyed. Since the plutonium present in small quantities in all reactor spent fuel does present some level of proliferation risk, removing it could alter that risk. Recent studies have discussed the risk and approaches to managing it (26, 27). Whether ALMR technology has a place in nonproliferation strategies with regard to the processing of spent fuel will depend on comparisons with other approaches and will need to be evaluated in an international context because all countries with nuclear reactors have some spent fuel that requires management.

Processing Other Radioactive Wastes

The ALMR has also been proposed for processing certain radioactive wastes that cannot be stored or treated safely with any existing technologies. In particular, DOE has a large inventory of special spent fuel assemblies, some of which are stored under marginal conditions and require treatment or packaging to ensure adequate protection for the future. Parts of the ALMR technology may be suitable for processing such wastes, but more analysis will be needed to match the existing problems with the capabilities of the system. Very little research on this application has been conducted to date.

Another issue that requires further exploration and development is the question of what additional types and volumes of wastes from a total ALMR system may be generated that will need treatment, storage, and disposal, On the one hand, it may be possible with careful and efficient design to minimize waste. On the other hand, each step of a complex process can create its own waste stream. While an overall goal of the ALMR system is to eliminate long-lived radioactive acti-n ides from the waste stream, new fission-products and wastes will be generated. A more complete determination of the wastes streams produced by this technology must await the results of prototype testing.

Risks and Benefits in Terms of Plutonium Proliferation

Developers of the ALMR technology have worked to create technical barriers to prevent the diversion of weapons material that would be present within the reactor and the fuel reprocessing systems. However, critics of the program continue to stress that any technology that concentrates and separates plutonium would be a proliferation concern because it could be modified, once developed, for weapons purposes. Although technical barriers incorporated in the ALMR design may prevent material diversion when adequate inspection systems and controls are in place, they may not suffice to deter a state or a group that did not honor safeguard agreements, Most experts agree that any separated plutonium from reactors could be used to produce weapons. Whether or not the ALMR technology is proliferation-resistant thus depends more on its deployment, control and success of outside inspection, than on the technology itself.

If the ALMR technology were developed and then exported to a number of other countries, the United States should be concerned about adequate control of plutonium to prevent its diversion for weapons. Even if the system were designed to be a plutonium consumer, it would not be mechanical-1 y difficult for an owner with technical expertise to convert it to a "breeder" (plutonium producer). The difficulty of converting the ALMR system from a '"burner" to a "breeder" is related to the stage of its development and whether the conversion possibility was a factor in the initial design of a reactor. Since the technology is currently in the R&D stage, one could easily complete a specific design to fit requirements for either an easy or a difficult conversion. Nevertheless it would be difficult or impossible to design a reactor core that could be guaranteed to not work as a plutonium breeder. In addition, the ALMR technology has certain components such as a hot cell that could be used to support other equipment to concentrate, separate, and purify plutonium. Technical systems could be built, and inspection procedures adopted, to monitor operations and protect against proliferators, but the technology itself could not be a guarantee against misuse.

Compared with other older technologies that have been used to reprocess spent reactor fuel and to separate plutonium,[5] the ALMR system may offer more proliferation advantages because of technical barriers that could be designed into the system. However, these possible advantages must be weighed against the risks of widely deploying systems that could be later modified if the owners had the proper technical capability and weapons-building motives.

CONCLUSION

In summary, ALMR technology will not be available for application to plutonium disposition for many years. Substantial research, development. and testing work is needed to demonstrate the performance of specific portions of the total system necessary for fuel reprocessing and waste handling. Even though ALMR technology has potentially beneficial features such as the elimination of plutonium isotopes, concerns about possible proliferation problems still have to be resolved. Whether the development of this technology should be pursued also needs to be considered in the context of plutonium disposition policy objectives as well as overall energy policy. Any subsequent development work on ALMR technology would benefit from clearly stated policy goals and specific objectives by which to measure future accomplishments.

[5] Such as the PUREX system, which is a chemical separation process commonly used in producing weapons materials and in strew commercial operations in France and the United Kingdom.