

Nuclear Waste: A Pragmatic Approach to a Manageable Challenge



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About the Author

Joshua A. Tolbert, Ph.D., P.E., is a seasoned engineer with four engineering degrees, including a doctorate in mechanical engineering. He has extensive experience in power generation, including coal, natural gas, biomass, and nuclear, as well as leadership roles such as CTO and VP of Engineering for a commercial developer of small-scale nuclear power plants. Dr. Tolbert has worked with nuclear regulators domestically and internationally, including the UK ONR, Poland's PAA, Argentina's ARN, Romania's CNCAN, and Turkey's NDK.

In the private sector, Dr. Tolbert has identified the major obstacles to nuclear power development, including regulatory, technical, and economic challenges. He has a deep commitment to participating in the revitalization of the nuclear industry by implementing practical solutions to these obstacles.

His technical expertise includes the full design of a small-scale pressurized water reactor (PWR), encompassing the primary loop, secondary loop, and auxiliary systems, all utilizing advanced modularization techniques to enhance constructability and reduce costs. This hands-on experience positions Dr. Tolbert to offer unique insights into the challenges and opportunities facing the nuclear industry today.

Introduction

Few topics in energy policy provoke as much concern — and as much misunderstanding — as nuclear waste. For decades, waste has served as a rhetorical centerpiece for opposition to nuclear power, often portrayed as an unsolved, existential hazard. Yet the reality is far more grounded: nuclear waste is one of the most scientifically characterized, tightly controlled, and technically manageable byproducts of any major energy sector.

This is not to minimize its complexity. Spent nuclear fuel is highly radioactive when removed from the reactor and demands careful handling. But the narrative that nuclear waste is an unmanageable crisis ignores the layers of engineering, regulation, and operational experience accumulated over more than 60 years of commercial reactors. In truth, the challenge of nuclear waste is less about technology and more about political and institutional will.

This paper clarifies what nuclear waste is, how it is managed today, and why a pragmatic, phased approach — one that leverages proven technical solutions while allowing room for future innovation — is the most responsible path forward.

Understanding What Nuclear Waste Really Is

The term *nuclear waste* conjures images of unbounded toxicity, but in practice, it refers to a finite set of well-characterized materials. The most significant category is spent nuclear fuel (SNF) from light-water reactors. A typical fuel assembly, after approximately five years in the core, contains:

1. unused uranium
2. fission products
3. plutonium
4. transuranic elements

The volume of this material is small. The lifetime SNF output for a single person's entire electricity consumption — assuming nuclear energy provided all of it — would fit in a soda can. All of the spent nuclear fuel ever produced in the United States — roughly 86,000 metric tons — would fit on a single football field stacked about 20–25 feet high.

Contrary to public perception, spent nuclear fuel is not an amorphous, uncontained material. It is a solid ceramic, encased in metal cladding, stored within multiple engineered barriers. Its radioactivity decreases predictably over time, and its decay heat follows well-understood exponential curves. This precision makes nuclear waste one of the most predictable industrial byproducts ever produced.

The Effectiveness of Existing Storage Methods

The nuclear industry already employs two robust and highly successful methods of storing SNF: wet storage and dry cask storage. Together, they form a complete near-term management system.

Wet Storage: The First Stage

When fuel is removed from the reactor, it is placed in deep pools filled with borated water. These pools:

1. cool the fuel through convection
2. shield radiation
3. and provide redundant barriers against release

The design basis for fuel pools is conservative and backed by decades of empirical data. After several years, when decay heat has diminished, fuel assemblies are ready for dry storage.

Dry Cask Storage: Proven, Scalable, and Durable

Dry cask storage represents a remarkable engineering success story. Each cask is a heavily shielded, steel-and-concrete structure designed to withstand:

1. floods
2. earthquakes
3. tornado-driven projectiles
4. extreme temperatures
5. impacts
6. and long-term material degradation

Some casks have been in service for more than 30 years with excellent performance. The system is modular, standardized, and readily expandable. For the foreseeable future, dry storage provides a safe, low-cost, and reliable solution capable of housing all existing and future SNF.

In short: the United States is not scrambling for a place to put nuclear waste. It already has a system that works.

The Misalignment Between Waste Policy and Technical Reality

The central challenge in nuclear waste management is not technical — it is political. The Nuclear Waste Policy Act envisioned a permanent geological repository at Yucca Mountain, but the project became a casualty of political resistance, not scientific deficiency.

While other countries (Finland, Sweden, South Korea) successfully move forward with repositories based on similar geologic principles, the U.S. remains stalled. The irony is striking: the country most capable of building a repository is prevented from doing so not by engineering limitations, but by a failure of national consensus.

This political impasse has created a myth that waste management is technologically unresolved, when in fact:

1. interim storage is safe and stable
2. repositories have been extensively validated
3. and future fuel cycles may reclaim significant portions of SNF

The disconnect between perception and reality has few parallels in modern engineering policy.

Reprocessing and Advanced Reactors: Turning Waste into a Future Resource

Nuclear waste contains substantial quantities of potential fuel. Plutonium and uranium in spent fuel assemblies can be reprocessed and used in fast reactors or other advanced systems. Several countries, including France and Japan, already do this today.

The U.S. discontinued commercial reprocessing partly for nonproliferation reasons and partly due to cost considerations at the time. But as new reactor designs emerge — particularly fast-spectrum reactors and molten salt systems — the value proposition of reprocessing may change. Many advanced reactor developers explicitly target transuranic consumption as part of their fuel cycle strategy.

Importantly, adopting reprocessing is not a prerequisite for solving waste management. But its potential means that today's "waste" may be tomorrow's energy asset. A pragmatic approach maintains this optionality without tying current deployment to speculative future fuel cycles.

What Responsible Waste Policy Actually Looks Like

A practical nuclear waste strategy does not require breakthrough science. It requires the discipline to follow a phased, technically grounded approach:

1. Continue safe wet and dry storage, which can support the industry for many decades.
2. Develop consolidated interim storage solutions to streamline management and reduce site-by-site duplication.
3. Re-establish a national pathway toward a permanent repository, whether at Yucca Mountain or an alternative site.
4. Maintain the ability to adopt reprocessing in the future as reactor technologies evolve.
5. Ensure regulatory predictability, enabling utilities to plan investment and manage existing inventories effectively.

None of these steps are speculative. They reflect technologies and practices that already exist and already work.

Conclusion

The challenge of nuclear waste has long been exaggerated in public discourse. While it is politically complex, it is technically straightforward: we know how to store it safely, how to monitor it effectively, and how to contain it for as long as necessary. The limiting factor is not engineering capability but policy alignment and institutional follow-through.

A pragmatic, staged approach — grounded in existing storage technologies and open to future fuel cycle advancements — is sufficient to manage all waste generated by the U.S. nuclear industry for decades to come. Far from being an unsolved crisis, nuclear waste stands as evidence of a system that works: predictable, secure, and governed by deeply mature science.

If the United States is serious about revitalizing nuclear power, it must recognize that waste is not an obstacle to deployment. It is a manageable responsibility — one the industry has handled successfully for nearly 70 years and is prepared to handle for many more.