Leveraging Conventional Power Supply Chains for Nuclear Energy

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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

Nuclear power's cost challenges are often attributed to its technical complexity or regulatory intensity, but a more subtle structural issue plays a defining role: nuclear energy has become isolated from the broader world of industrial power generation. In the United States, modern nuclear plants increasingly rely on a narrow, bespoke supply chain governed by ASME Section III and nuclear-specific qualification requirements. Meanwhile, the larger ecosystem of conventional power — boilers, turbines, heat exchangers, pumps, piping systems — operates within an enormous, mature, globally competitive industrial marketplace under ASME Section I, Section VIII, B31.1, and similar standards.

This divergence was not inevitable. Early nuclear plants relied heavily on commercial and fossil-industry components, integrating nuclear-specific standards only where the consequences of failure justified them. Over time, however, regulatory expectations drifted toward an assumption that "nuclear" must be synonymous with "Section III," even when PRA and engineering judgment do not support that level of rigor across the entire plant. The result is a supply chain constrained by scarcity, long lead times, and inflated costs — not because nuclear technology requires it, but because the regulatory framework encourages it.

Rebalancing nuclear design to better leverage conventional power supply chains is one of the most impactful steps that can be taken to restore the competitiveness of nuclear energy. This does not mean compromising safety; rather, it means aligning component classification with actual safety significance, integrating probabilistic insights into design decisions, and rebuilding nuclear within the context of the industrial power landscape that has manufactured reliable equipment at enormous scale for over a century.

The Drift Toward Nuclear Exceptionalism

From the 1960s through the early 1970s, the U.S. built dozens of reactors on timelines and budgets that would be inconceivable today. Those plants did not rely on a boutique supply chain. Their balance-of-plant systems — feedwater heaters, steam generators, piping networks, pumps, valves — were largely sourced from the same manufacturers serving coal, gas, and industrial steam facilities. The nuclear-specific components were relatively limited, and the overall design philosophy emphasized containment and robust passive barriers rather than extreme qualification of every subsystem.

As PRA matured, however, the industry began to quantify accident scenarios and identify systems whose failure could contribute to core damage. While PRA provided invaluable insight, regulatory interpretation sometimes leapt from "this system contributes marginally to risk" to "this system must therefore meet full nuclear safety classification," even when the connection was indirect or low-consequence. In this way, nuclear plant design slowly shifted from a defense-in-depth emphasis — where containment was the ultimate safety assurance — toward a prevention-first philosophy that demanded near-perfect performance of upstream components.

The consequence was a gradual expansion of nuclear-grade classification beyond its original intent. The supply chain narrowed. Costs rose. Lead times expanded. The industry began relying on vendors who, because of nuclear-specific qualification requirements, operated in a sheltered market with limited competition. The very standards designed to protect the public quietly undermined nuclear's ability to compete economically.

The Case for a Risk-Informed Supply Chain

A central principle of PRA is that risk should guide engineering decisions. Yet in nuclear design, PRA often informs only part of the process, while component classification remains anchored in deterministic rules. A risk-informed approach would reverse the default assumption: components should be treated as conventional industrial equipment unless PRA and safety analysis clearly justify nuclear-specific treatment.

This philosophy does not diminish safety. On the contrary, it refocuses safety investment where it truly matters.

A conventional pump may not be designed to the same hypothetical stress limits as a Section III pump, but if its failure does not meaningfully increase core damage frequency or large early release frequency, imposing nuclear requirements adds cost without reducing public risk. Conversely, where PRA demonstrates that equipment failure could contribute significantly to accident progression, nuclear-grade requirements remain appropriate and necessary.

By aligning component classification with actual safety significance, nuclear plants regain access to the vast, high-quality industrial supply chain that powers much of the global economy. This alone has the potential to reduce capital cost and construction timelines dramatically.

Containment as the Ultimate Safety Boundary

One of the strongest arguments for integrating conventional components is that containment — properly sized and designed — already limits radiological consequences even in severe core damage scenarios. A strong containment system acts as a final barrier, allowing upstream systems to be designed with realistic expectations rather than aspirational perfection.

In practical terms, this means:

1. Equipment that does not meaningfully affect containment integrity or accident progression need not meet nuclear-specific standards.
2. Safety analysis should quantify where containment provides sufficient mitigation to allow for more flexible upstream design.
3. Emphasis on containment shifts investment away from proliferating redundancies and toward structural robustness where it matters.

This balanced approach mirrors the safety philosophy of earlier nuclear generations — a philosophy that produced some of the most reliable and well-understood reactors ever built.

Reconnecting Nuclear With the Industrial Marketplace

Tapping into the conventional power supply chain is not merely a cost-control exercise; it is a return to design rationality. The industrial sector has spent decades refining manufacturing processes, building high-volume production capacity, and developing components with exceptional reliability and performance. By contrast, the nuclear supply chain has become specialized to the point of fragility.

A risk-informed design that uses:

1. commercial-grade heat exchangers where appropriate
2. industrial-grade turbines and generators
3. B31.1 piping for non-safety systems
4. Section VIII pressure vessels in balance-of-plant applications
5. standard industrial valves, pumps, and instrumentation

...would dramatically expand supplier availability and reduce procurement risk. It would also make nuclear deployment more compatible with standardized construction practices, modularization strategies, and emerging advanced manufacturing techniques.

Most importantly, it would allow nuclear projects to regain predictability — something the nuclear construction sector has lacked for decades.

A Practical Path Forward

Achieving this rebalancing does not require rewriting the rulebook; it requires using existing regulatory tools as they were intended. The NRC already recognizes the legitimacy of risk-informed design. PRA insights can and should drive component classification. Defense-in-depth principles still endorse containment as a key safety barrier.

What is needed is a unified design philosophy that treats nuclear plants not as exotic, bespoke machines, but as industrial facilities differentiated by their core nuclear island — not by every support system that surrounds it.

Future reactor developers, especially those pursuing standardized small modular or mid-sized designs, are well-positioned to implement this philosophy from the outset. By baking risk-informed classification into the earliest stages of plant architecture, they can:

1. reduce capital cost
2. shorten construction timelines
3. broaden supplier qualification pools
4. and improve design simplicity

All while maintaining — and in some cases enhancing — plant safety.

Conclusion

Nuclear energy does not need to reinvent the entire industrial supply chain to succeed. It needs to reconnect with it. The economic viability of nuclear power depends on recognizing that not every component requires nuclear-grade treatment, and that PRA-driven, risk-informed design is the most rational way to match engineering rigor with real-world safety significance.

By embracing a balanced safety philosophy centered on containment, and by restoring access to proven industrial supply chains, the nuclear industry can reduce unnecessary cost, accelerate deployment, and align itself with the scale and efficiency that modern clean energy demands.

If the U.S. is serious about revitalizing nuclear power, then leveraging the conventional power supply chain is not merely an option — it is an operational necessity and one of the most immediate actions that can meaningfully bend the cost curve downward.