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Brief for Iowa Nuclear Energy Task Force

The State of Advanced Nuclear Technology and Policy

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1.0 Introduction

The purpose of this brief is to provide the Iowa Nuclear Energy Task Force with an overview of the current state of advanced nuclear technology and the policy framework that governs it. As of early 2026, energy production from fission is experiencing a renaissance due to technological advances in both light-water reactors like those used in the existing fleet of power generating reactors and in novel technologies that use coolants other than water, referred to as Generation IV reactors. These advances allow for a scaled down approach that may reduce risks and allow for serial manufacturing, resulting in significantly lower levelized costs of electricity.

In addition, other factors are making it increasingly likely that new reactors will be built in the United States. Public sentiment toward nuclear generation has improved[i], private investment and the demand for energy have increased, and state and federal governments have adopted policies to either lower barriers or create incentives for new nuclear.

There are also significant hurdles for the nascent advanced nuclear technology industry to clear. One set of challenges relates to the safety, security, and safeguards measures necessary even for the smallest reactors. Because both the reactor technology and the fuel itself are highly controlled to avoid proliferation, nuclear regulators employ inspection regimes to ensure that neither the intellectual property nor the fuel falls into the wrong hands. The current regime is designed to inspect the 94 active nuclear power reactors in the United States, which are large, static facilities employing similar technology. The advent of microreactors and SMRs will require new protocols and expertise related to novel technologies and to account for the possibility that reactors might be portable.

The other set of hurdles relates to the supply chains for both the reactors and fuel. In both cases, the industry will need to increase the pipeline of specialized workers from the skilled trades and professions to build and operate facilities throughout the supply chain, from mining to fuel production to generation to spent fuel management. Generation IV reactors do not use the same fuel as the current fleet of light-water reactors, and so fuel producers will need to build new production facilities both to meet increased demand and to produce new forms of fuel.

While the challenges are significant, they are not insurmountable. On the one hand, the latest generation of reactors are designed to be “walk-away safe.” The Department of Energy (DOE) describes passive safety as:

> “The ability of advanced reactors…or newer designs under development to shut down and remove excess heat without human intervention. In the unlikely event that a nuclear plant loses power, passive safety systems use the laws of physics to keep a reactor safe and cool the core such that fuel is not damaged. They take advantage of things like gravity or the natural circulation of coolant to move heat away from the reactor core without the need for external power sources, pumps, or operator action.”[ii]

Passive safety, once successfully demonstrated, would allow regulators to streamline the permitting process. A proven safety record could reduce insurance premiums and the need for expansive emergency planning zones, all resulting in lower development and operating costs.

Nuclear energy represents the potential for locally produced, firm energy to address the increasing demand for electricity from data centers, transportation electrification, and industrial users. Microreactors and small modular reactors (SMRs) could be sited near load, avoiding the bottlenecks in transmission. New nuclear will also have a much smaller physical footprint than other forms of new generation, like wind and solar, and will not impact air quality.

The remainder of the brief will provide a short summary of the state of advanced nuclear technology, an overview of the current policy framework around nuclear, and additional resources for learning more. Please note that the author used PNNL's internal artificial intelligence to draft outlines for the technology and policy sections of this brief.

2.0 Advanced Nuclear Technology

The 94 active reactors in the United States range in energy production from just over 500 MWe to approximately five gigawatts of power. These plants were massive construction projects, built over years, employing thousands of workers, after extensive siting and permitting processes. The next generation of reactors, known as advanced nuclear, are designed to simplify the process through standardization, downscaling, and offsite manufacturing of either the entire reactor or major components.

Small Modular Reactors (SMRs)

SMRs are compact nuclear reactors with capacities up to 300 MWe, designed for factory fabrication and modular deployment. Their smaller footprint and passive safety systems make them suitable for diverse applications, including integration into existing grids and remote installations.

Advantages

- Safety: Incorporation of passive safety features reduces reliance on active systems and human intervention.
- Economic Benefits: Lower upfront capital costs and shorter construction timelines compared to gigawatt-scale plants.
- Flexibility: Ability to scale incrementally and complement renewables for hybrid energy systems.

Current Status

- Global Development: There are 127 SMR designs worldwide, with seven designs operating or under construction and 51 in licensing stages.[iii]
- U.S. Progress: The U.S. Nuclear Regulatory Commission has certified NuScale's SMR design, marking a milestone for domestic deployment. DOE partnerships aim for first-of-a-kind reactors at Idaho National Laboratory by the late 2020s.
- Challenges: Fuel supply, particularly high-assay low-enriched uranium (HALEU), remains a critical barrier for many SMR designs.

Microreactors

Microreactors are ultra-small nuclear systems, typically producing 1–20 MWe, designed for portability and rapid deployment. Whereas SMRs would still require significant assembly onsite, microreactors are portable by design—small enough to be moved by truck, train, or barge. While the size limits their capacity to serve large, grid-scale loads, it makes them ideally suited for remote locations, temporary installations, and smaller sites.

Technological Innovations

- Design Features: Factory-built, transportable units with advanced heat pipe cooling and TRISO fuel for enhanced safety and longevity.
- Operational Flexibility: Capable of operating off-grid in "island mode," providing resilience during grid disruptions.
- Deployment Speed: Can be installed and operational within days, offering significant time and cost savings compared to conventional plants.

Recent Developments

- DOE Initiatives: Experiments at Idaho National Laboratory's DOME facility will begin as early as 2026, supporting commercialization by the end of the decade.
- Industry Projects:
    - Westinghouse eVinci: A 5 MWe microreactor using passive heat pipe cooling, designed for eight years of operation without refueling.
    - Radiant Kaleidos: A 1.2 MWe gas-cooled microreactor packaged in a single shipping container for rapid deployment.

Technology Types

The existing fleet of power generating reactors are light-water reactors (LWRs), in which water is used as the coolant. The newest reactor designs, known as Generation IV reactors, use something other than water as the coolant. They can be classified in three categories:

High-Temperature Gas-Cooled Reactors (HTGRs)

- Definition: Reactors using helium as coolant and graphite as moderator, operating at very high temperatures.
- Advantages: High thermal efficiency, hydrogen production capability, and inherent safety.
- Status: Demonstration projects underway globally, including China's HTR-PM pebble-bed reactor.

Liquid Metal-Cooled Reactors

- Definition: Fast reactors cooled by liquid sodium, lead, or other metals.
- Advantages: High power density, efficient fuel use, and potential for closed fuel cycles.
- Applications: Electricity generation and industrial heat.
- Status: Several designs in R&D and demonstration phases under DOE's ARDP program.

Molten Salt Reactors (MSRs)

- Definition: Reactors using liquid fuel dissolved in molten salt, enabling low-pressure operation and high safety margins.
- Advantages: Potential for continuous fuel recycling and high-temperature process heat.
- Status: Early-stage development with pilot projects planned for the 2030s.

Fission versus Fusion

While the focus of this brief is on fission energy, it's valuable to understand the difference between fission and fusion, a form of atomic energy that is also garnering interest as a promising form of new power generation.

Nuclear Fusion and Nuclear Fission are two distinct processes that release energy by altering atomic nuclei:

- Fusion combines two light atomic nuclei (usually isotopes of hydrogen like deuterium and tritium) into a heavier nucleus, such as helium. This process powers the sun and stars, requiring extremely high temperatures and pressures to overcome electrostatic repulsion. Fusion produces enormous energy with minimal long-lived radioactive waste, making it a promising energy source for the future.
- Fission, on the other hand, splits a heavy atomic nucleus (such as uranium-235 or plutonium-239) into two smaller nuclei, releasing energy and additional neutrons. These neutrons can trigger further fission events, creating a chain reaction. Fission is the basis

of current nuclear power plants but generates radioactive waste and requires robust safety systems.

Key Differences:

- Fuel: Fusion uses light elements (hydrogen isotopes); fission uses heavy elements (uranium, plutonium).
- Energy Output: Fusion releases more energy per reaction than fission.
- Waste: Fission produces long-lived radioactive waste; fusion does not.
- Conditions: Fusion needs extreme heat and pressure; fission can occur at much lower energy input.
- State of Technology: Fission power plants have been in operation for more than seventy years. Fusion is still in commercial infancy and there is no fusion power plant online producing net energy for consumption.

3.0 Regulatory and Policy Framework

The U.S. government regulates nuclear power generation through a comprehensive federal framework that prioritizes safety, security, and environmental protection.

Key Civilian Regulatory Agencies[iv]

- Nuclear Regulatory Commission (NRC): Established by the Energy Reorganization Act of 1974, the NRC is the primary independent regulator for civilian nuclear power. It licenses and oversees all commercial reactors, fuel cycle facilities, and waste management operations.[v]
- Department of Energy (DOE): DOE manages nuclear research, advanced reactor development, and safety at DOE-owned facilities. It also funds R&D for next-generation technologies and oversees nuclear material security.

Governing Laws

- Atomic Energy Act of 1954 (AEA): The foundational law for nuclear regulation, requiring civilian uses of nuclear materials to be licensed and empowering NRC to enforce safety standards. It also sets policies for promoting peaceful uses of atomic energy.
- Nuclear Waste Policy Act of 1982: Governs disposal and storage of high-level radioactive waste.
- Energy Policy Act of 2005: Provides incentives for new reactor construction, including loan guarantees and tax credits.
- ADVANCE Act 2024: Accelerates licensing and deployment of advanced reactors; reduces NRC fees; incentivizes first-mover projects.

Licensing and Oversight

- Licensing Process: NRC reviews reactor designs, construction permits, and operating licenses through a rigorous process that can take 3–5 years. Applicants must demonstrate compliance with safety, security, and environmental standards.
- Inspections and Enforcement: NRC conducts regular inspections and can impose fines or revoke licenses for non-compliance.
- Public Participation: NRC regulations require opportunities for hearings and judicial review.

Federal Preemption and Emerging Reforms

States may regulate economic aspects (e.g., cost, need for power) but cannot regulate radiological safety, which is exclusively under federal jurisdiction. Recent executive orders and DOE initiatives aim to modernize the regulatory framework for advanced reactors, streamline licensing, and accelerate deployment of small modular reactors (SMRs) and microreactors.

States' Role in Nuclear Regulatory Framework

States set land-use and economic policy for the nuclear industry. In Iowa counties have adopted zoning amendments to allow nuclear energy generation and waste storage, conditioned upon siting requirements and host community agreements.

4.0 Additional Resources

- US Department of Energy Videos on Nuclear:
  - Meet the largest nuclear power plant in the U.S.
  - Small Modular Reactors
  - What is a Microreactor?
  - What is a Fast Reactor?
  - What is High-Assay Low-Enriched Uranium (HALEU)?
  - Fusion vs. Fission

- Websites:
  - NARUC-NASEO Advanced Nuclear State Action Tracker
  - Primer on Accident Tolerant Fuels
  - Advanced Nuclear Reactors: Technology Overview and Current Issues

- Infographics/Illustrations (Graphics link to source website):

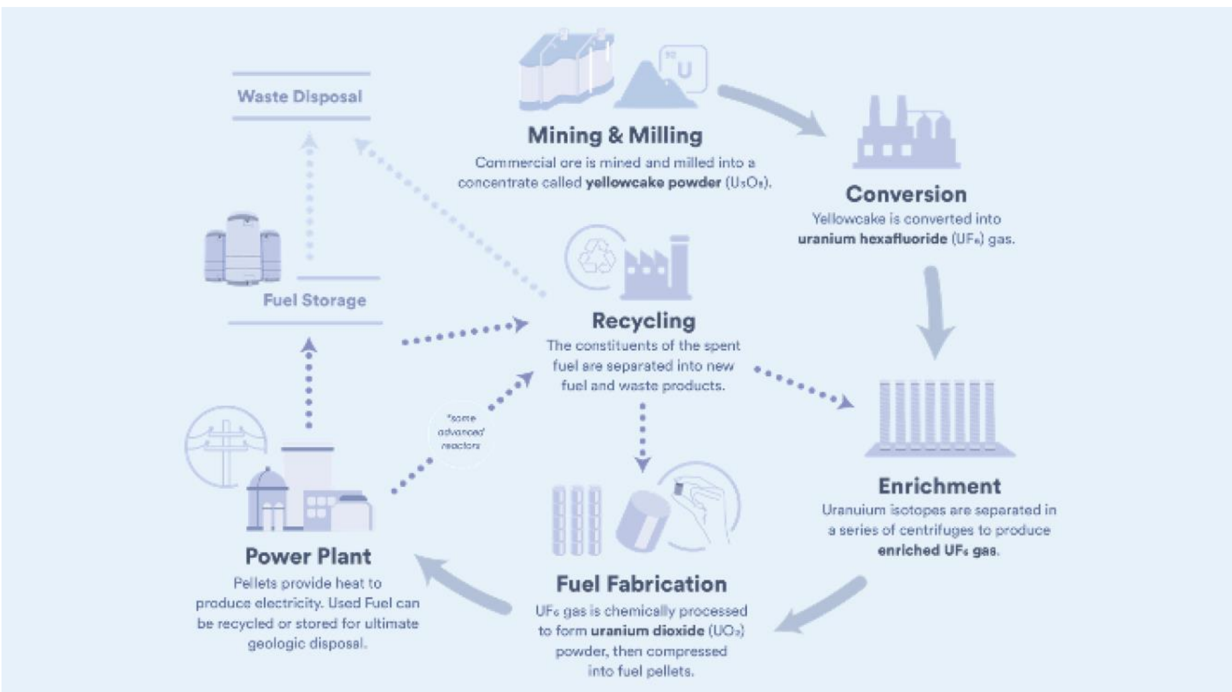

Figure 1: Nuclear Fuel Cycle

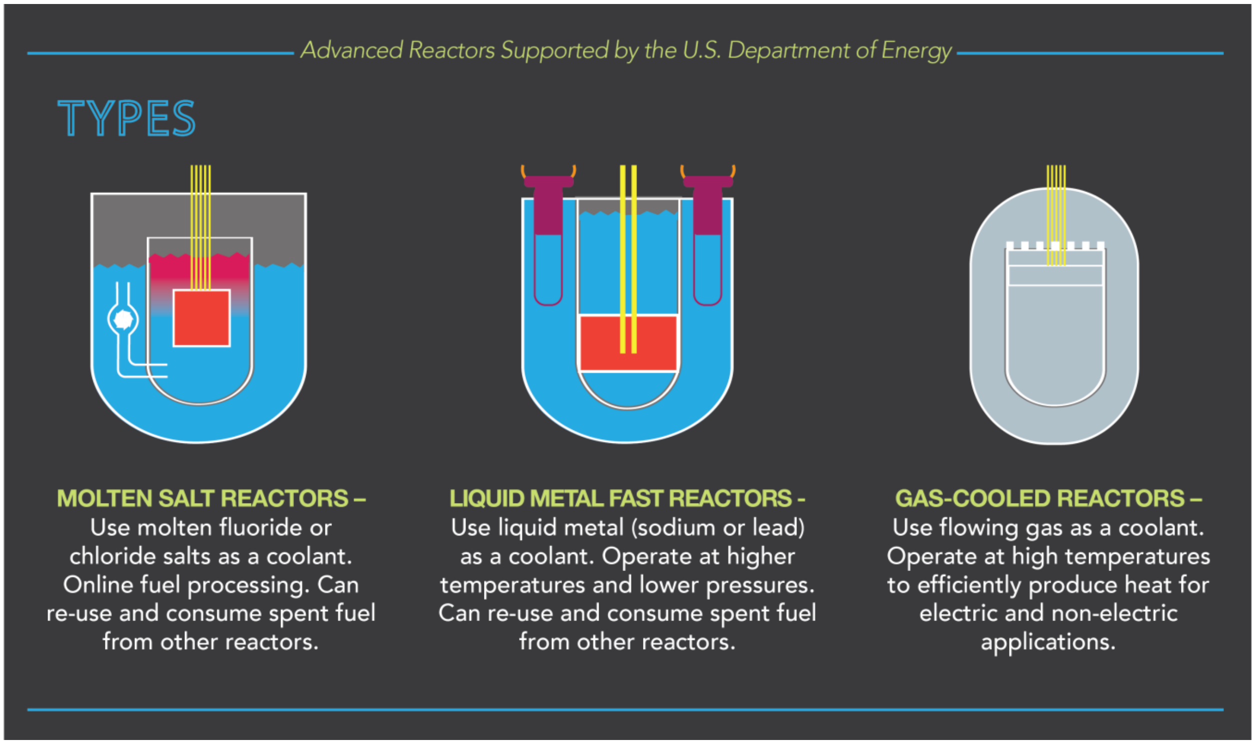

Figure 2: Advanced Reactor Types

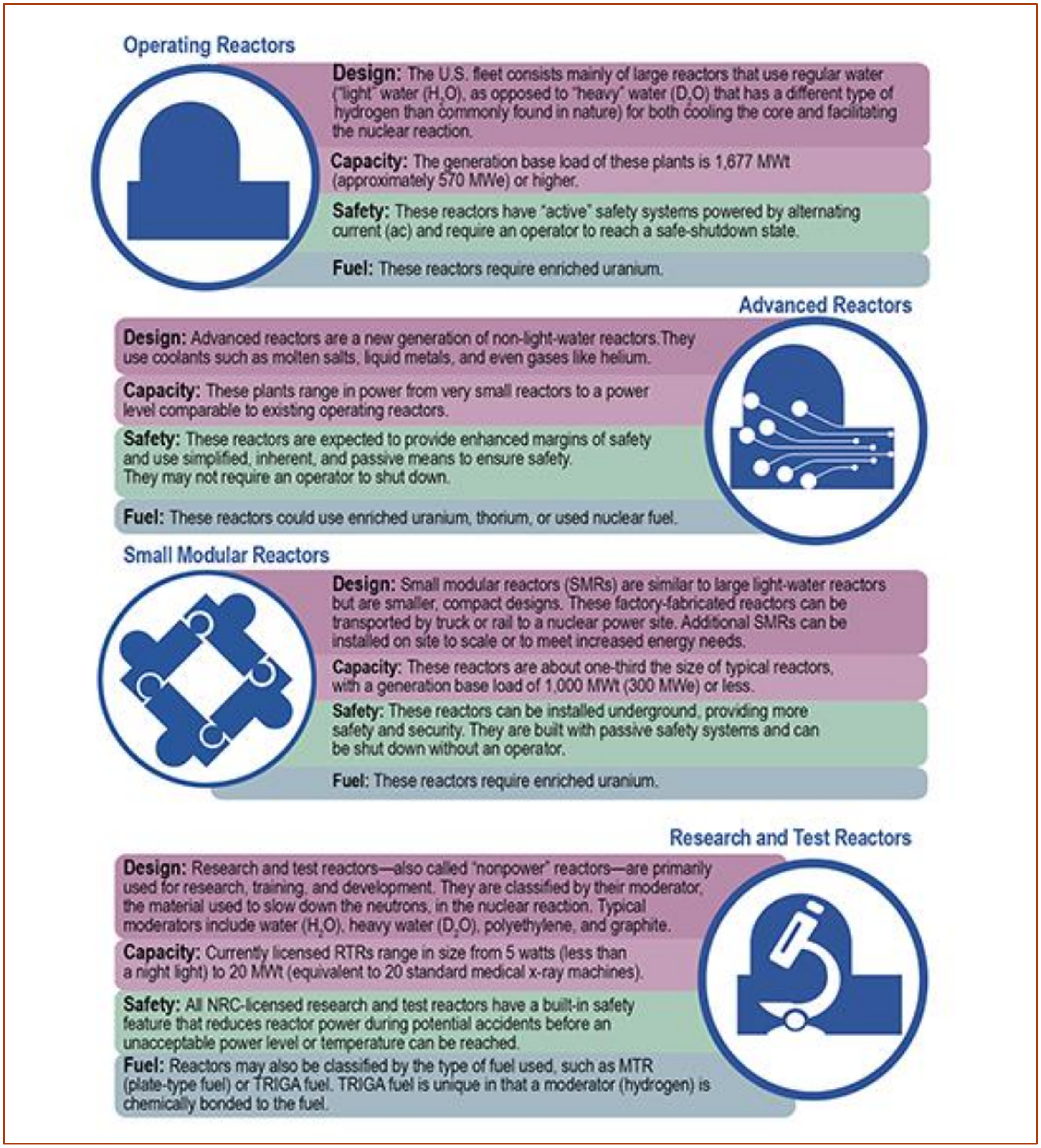

Figure 3: Nuclear Regulatory Commission Reactor Types

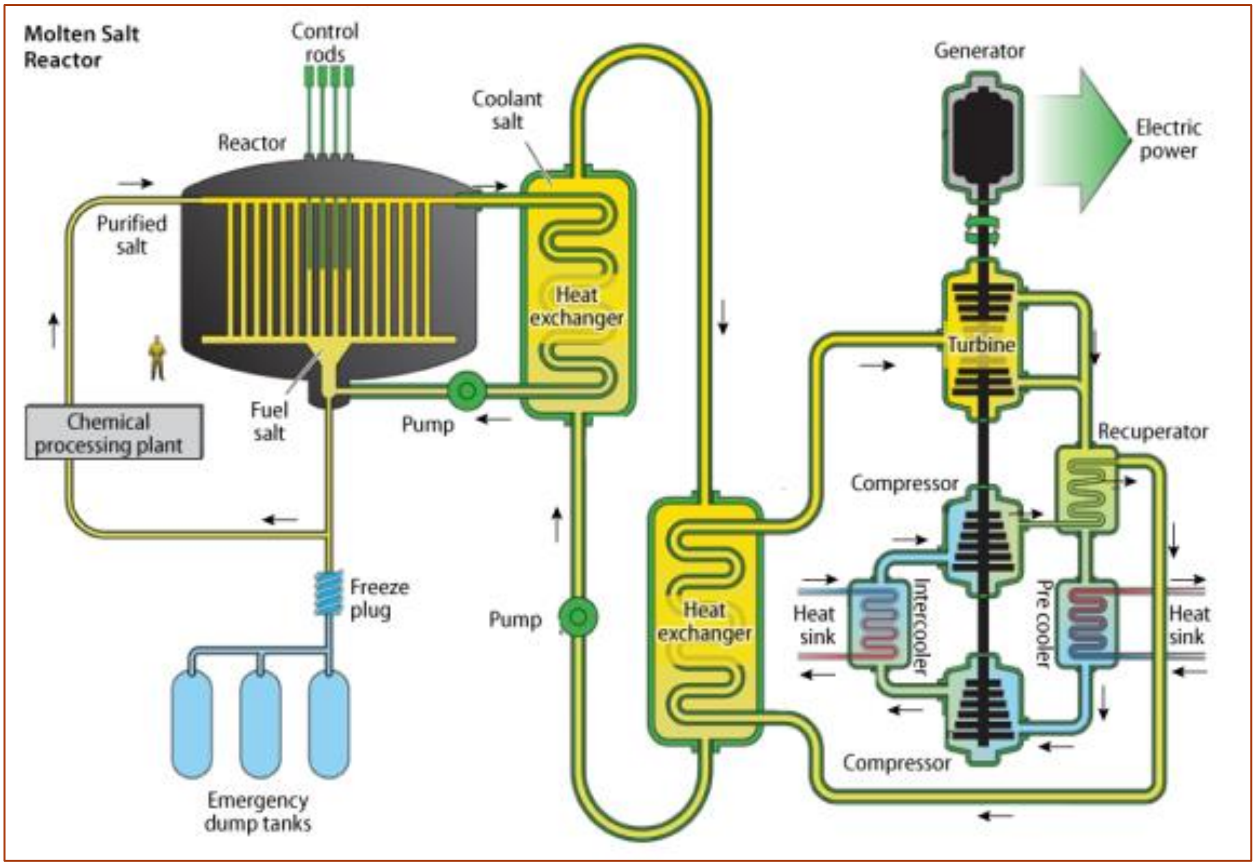

Figure 4: Molten Salt Reactor

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[i] https://www.pewresearch.org/short-reads/2025/10/16/support-for-expanding-nuclear-power-is-up-in-both-parties-since-2020/
[ii] US Department of Energy website, accessed 2/1/2026 https://www.energy.gov/ne/enhanced-safety-advanced-reactors
[iii] https://www.world-nuclear-news.org/articles/there-are-now-127-different-smr-designs-finds-nea-report
[iv] The Department of Defense/War (DoD/DoW) oversees reactors for military applications, exempt from NRC licensing under the Atomic Energy Act of 1954.
[v] NRC regulations are codified in Title 10 of the Code of Federal Regulations (10 CFR).