

Nuclear Fission and the Technology Choices Shaping the Future

A Practical Look at the Reactor Options — and the
Engineering Realities That Will Determine the Winners



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PEOPLE | EXPERIENCE | REAL PROGRESS

Why Fission, **Why Now?**



AI AND DATA CENTERS

Explosive growth in AI and cloud computing is driving unprecedented, continuous electricity demand.



GRID RELIABILITY

A stronger, more resilient grid requires always-on generation to complement intermittent renewables.



INDUSTRIAL HEAT

Hard-to-abate industries need high-temperature, low-carbon heat for chemicals, steel, hydrogen, and more.



ENERGY DENSITY

Nuclear fuel contains millions of times more energy per kilogram than fossil fuels, enabling compact, reliable power.

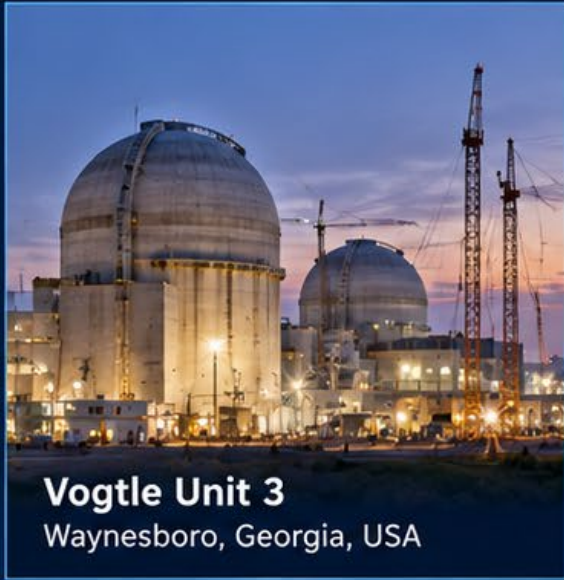
A SMALL AMOUNT
OF NUCLEAR FUEL
GOES A VERY
LONG WAY.

The world needs large amounts of clean, reliable, high-density energy.

NUCLEAR FISSION CAN MEET THAT NEED.

Pressurized Water Reactors (PWRs)

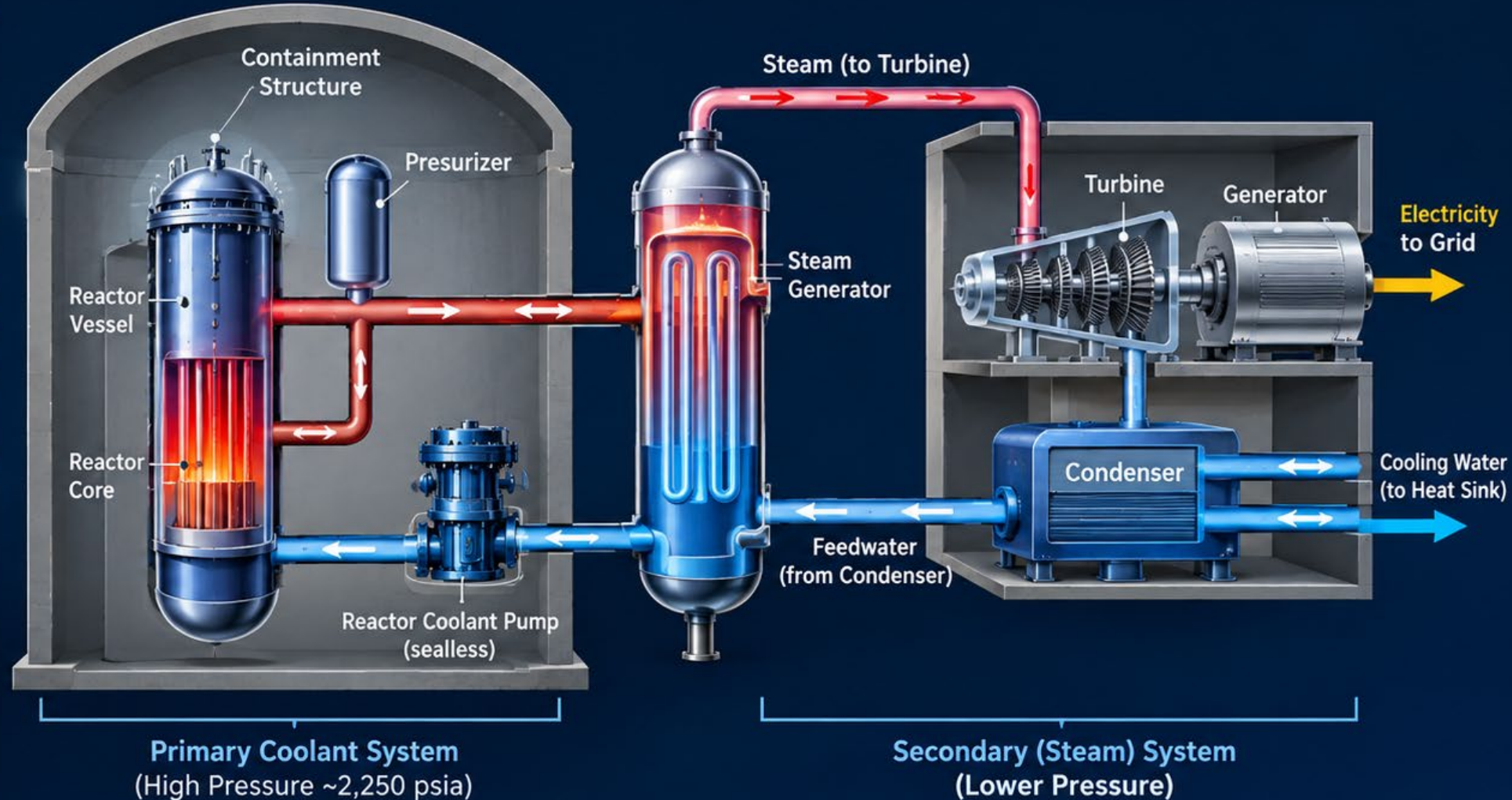
Proven technology. Global experience. Large-scale, reliable power.



Vogtle Unit 3

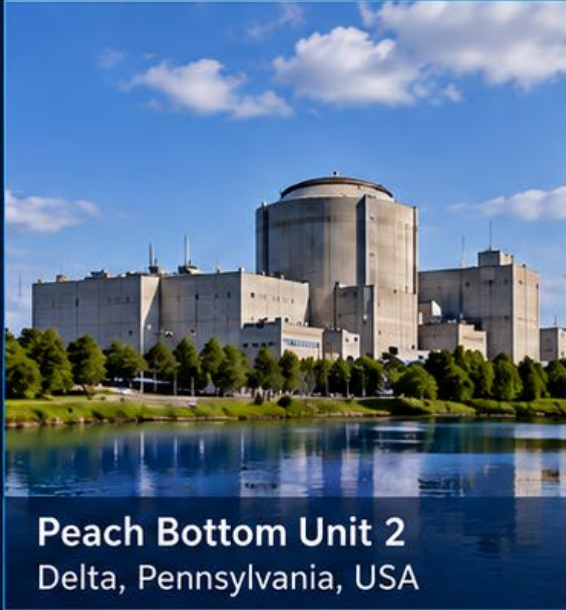
Waynesboro, Georgia, USA

In a PWR, water in the primary system is kept under high pressure so it stays liquid. Heat from the reactor is transferred to a separate steam cycle to produce electricity.

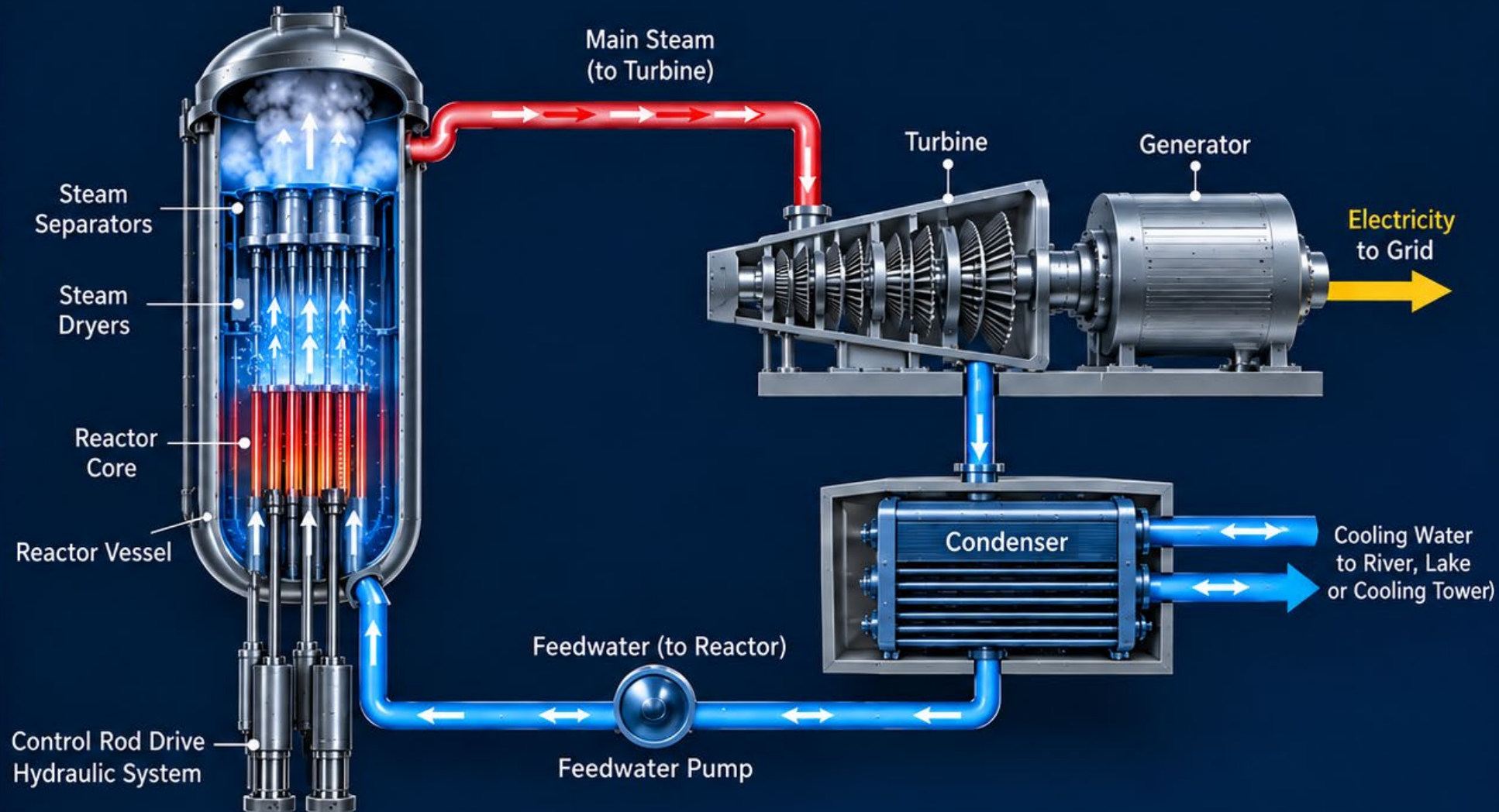


Boiling Water Reactors (BWRs)

A simpler design that generates steam directly in the reactor vessel.



In a BWR, water is boiled directly in the reactor vessel. The steam is sent directly to the turbine, eliminating steam generators and simplifying the plant design.



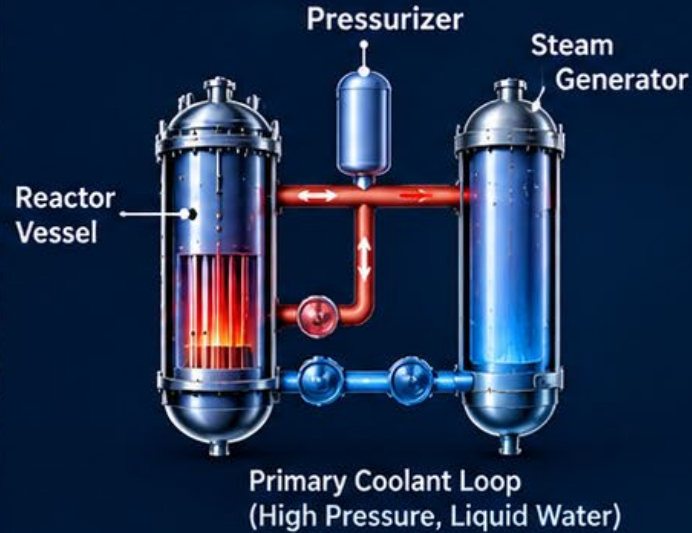
PWR vs BWR — Engineering Tradeoffs

Two proven designs. Different solutions. Real tradeoffs.



Vogle Unit 3
Waynesboro, Georgia, USA

Pressurized Water Reactor (PWR)



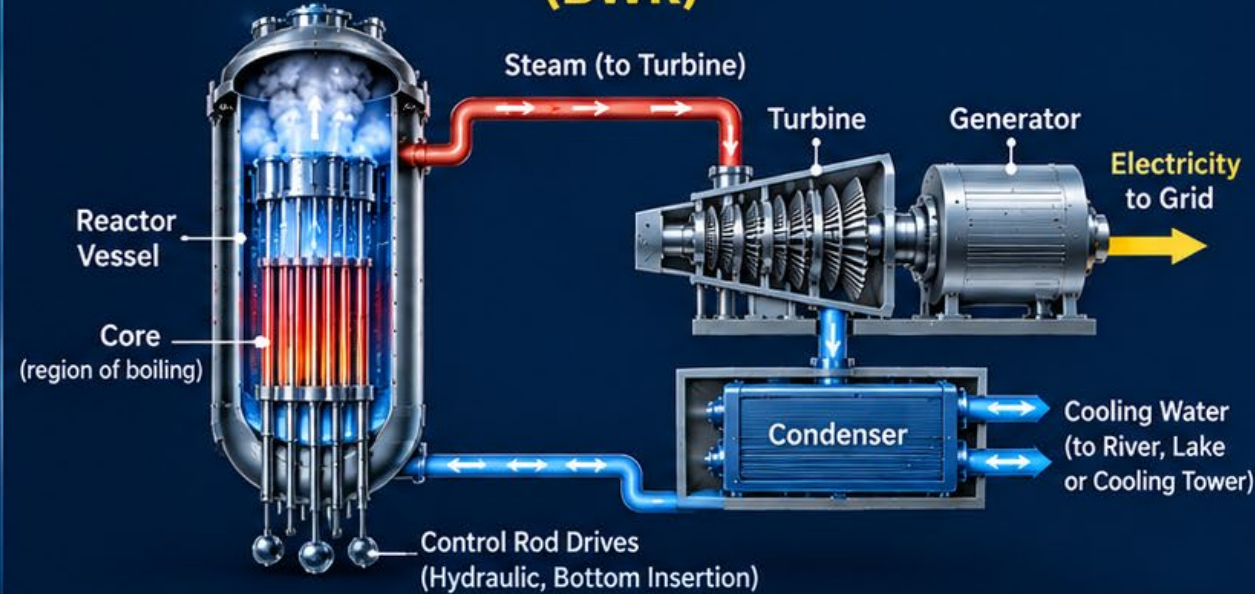
PWR – Key Benefits

- 1 Established, proven technology with decades of operating experience
- 2 Separate turbine cycle keeps radioactivity out of the turbine system
- 3 Large global fleet and licensing base

PWR – Key Challenges

- 1 High-pressure primary system (~2,250 psia)
- 2 Steam generators add complexity, size and cost
- 3 More components and larger balance-of-plant

Boiling Water Reactor (BWR)



BWR – Key Benefits

- 1 Simple, direct steam cycle
- 2 Fewer major heat-transfer components (no steam generators)
- 3 Proven, reliable design with strong operating performance

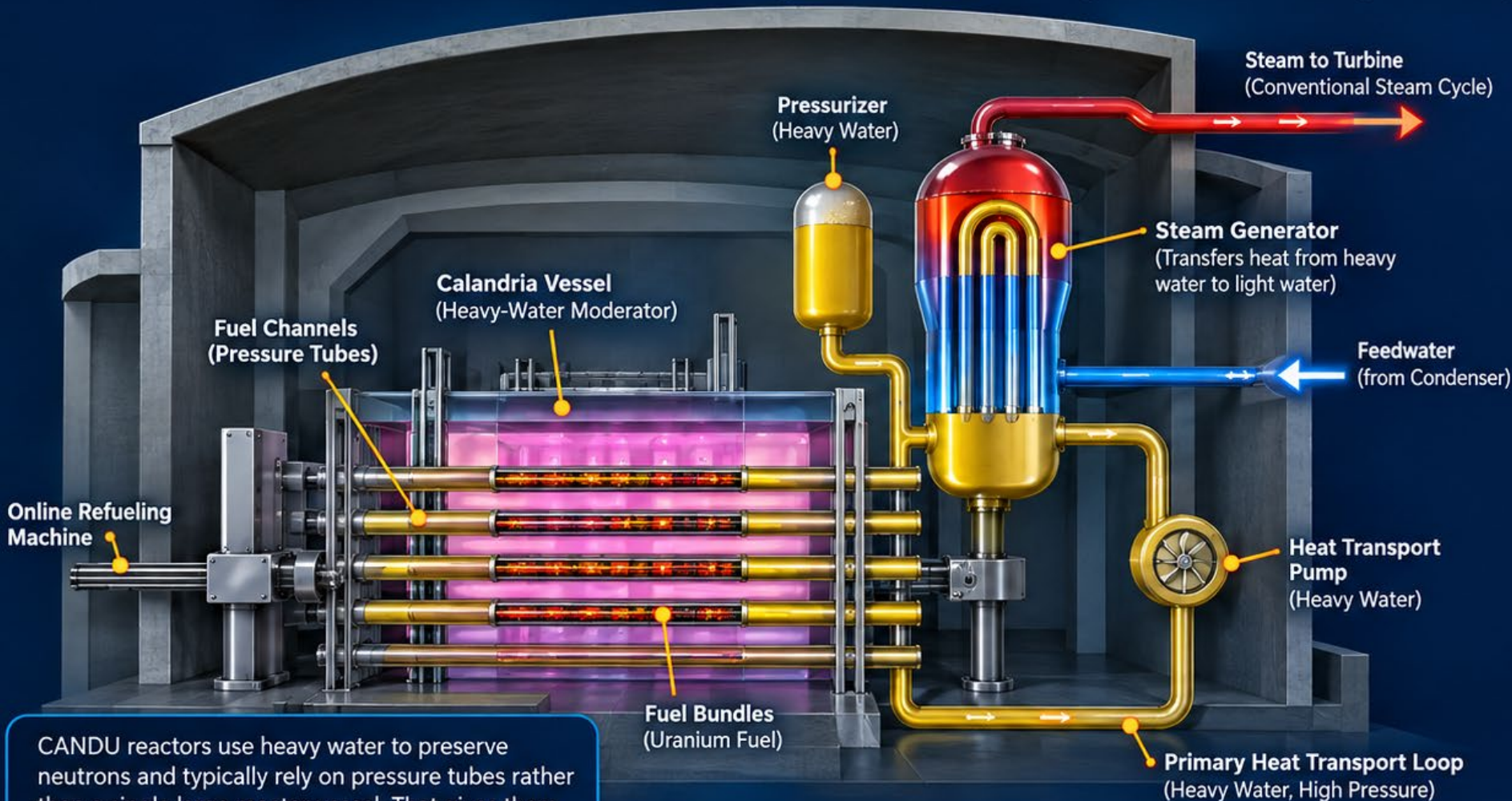
BWR – Key Challenges

- 1 Radioactive steam in turbine system requires robust radiological controls
- 2 Two-phase flow in the core is more complex to manage
- 3 Turbine and condenser systems must be designed for radioactive service

Different approaches. Same mission. Safe, reliable, economic electricity.

CANDU / Heavy-Water Reactors

Excellent neutron economy. Online refueling. Distinctive engineering tradeoffs.



CANDU reactors use heavy water to preserve neutrons and typically rely on pressure tubes rather than a single large reactor vessel. That gives them excellent fuel flexibility and the ability to refuel online, but it also adds equipment and maintenance complexity.

Key Benefits

- 1 Excellent neutron economy
- 2 Can use natural uranium fuel
- 3 Online refueling supports high availability

Key Challenges

- 1 Heavy water is expensive and must be carefully managed
- 2 Many pressure tubes and feeders add complexity
- 3 Inspection and maintenance are more involved

Heavy water and pressure tubes create real advantages — but they also create a more complex plant.

Sodium Fast Reactors — Pros and Cons

Unique capabilities. Real engineering challenges.

Key Benefits

1

Excellent Heat Transfer

liquid sodium removes heat very efficiently, enabling compact, high-power designs.

2

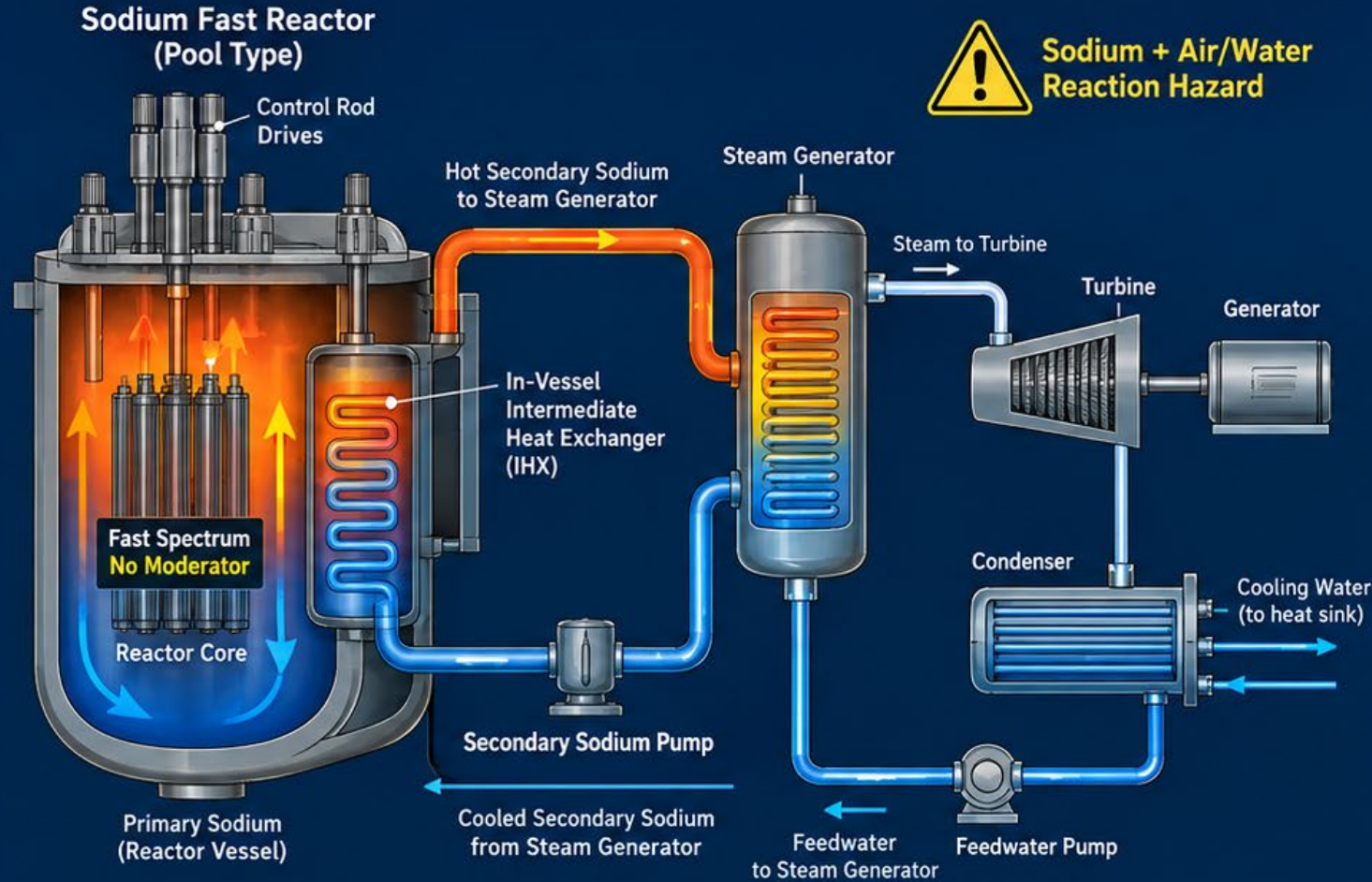
Low Operating Pressure

sodium's high boiling point permits high-temperature operation at near-atmospheric pressure.

3

Fuel-Cycle Flexibility

fast-spectrum reactors can support a wide range of fuel-cycle options, including recycling and breeding potential.



Key Challenges

1

Sodium Chemical Reactivity

sodium reacts vigorously with air and water, requiring careful isolation and leak management.

2

Difficult Inspection

opaque sodium complicates in-service inspection and maintenance.

3

Demanding Maintenance and Economics

specialized systems, materials, procedures, and staffing can increase cost and complexity.

Excellent heat transfer and low pressure are real advantages — but sodium's chemistry and system complexity are serious engineering challenges.

High-Temperature Gas Reactors (HTGRs) — How They Work

Helium cooling. Graphite moderation. High-temperature process-heat potential.

HOW IT WORKS

An HTGR uses helium gas to remove heat from a graphite-moderated core. Heat from the primary helium loop is transferred in a steam generator to a secondary water/steam loop that drives a turbine generator. The design delivers high-temperature heat and supports process heat applications in addition to electricity generation.

KEY FEATURES



Helium coolant

Chemically inert, single-phase gas cooling.



Graphite moderator

Slows neutrons to sustain fission reactions.



High outlet temperature

Typically 700–950°C (enables process heat).



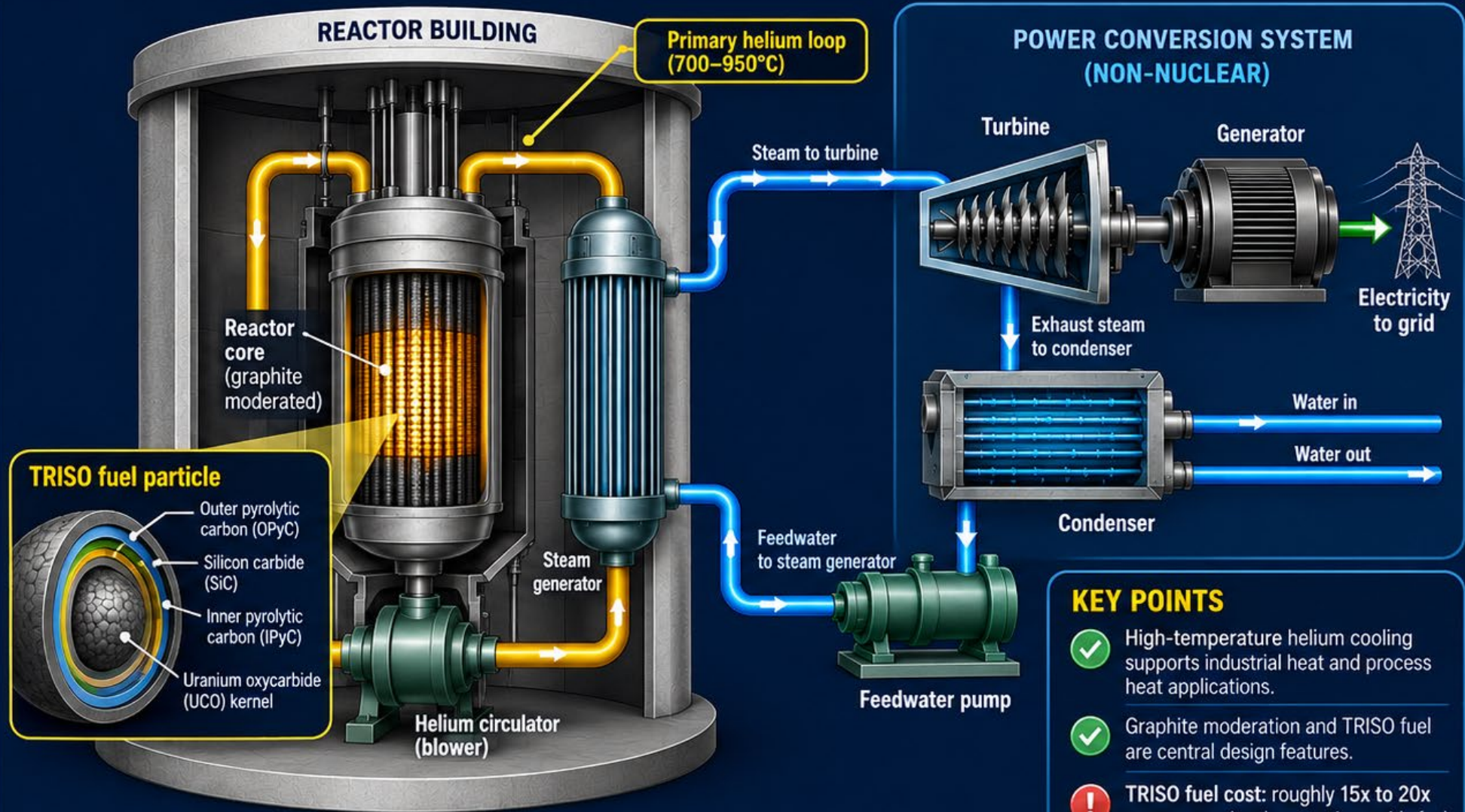
TRISO fuel

Robust, multi-layer coated fuel particles.



Process-heat potential

Supports industrial heat, hydrogen, and other applications.



KEY POINTS

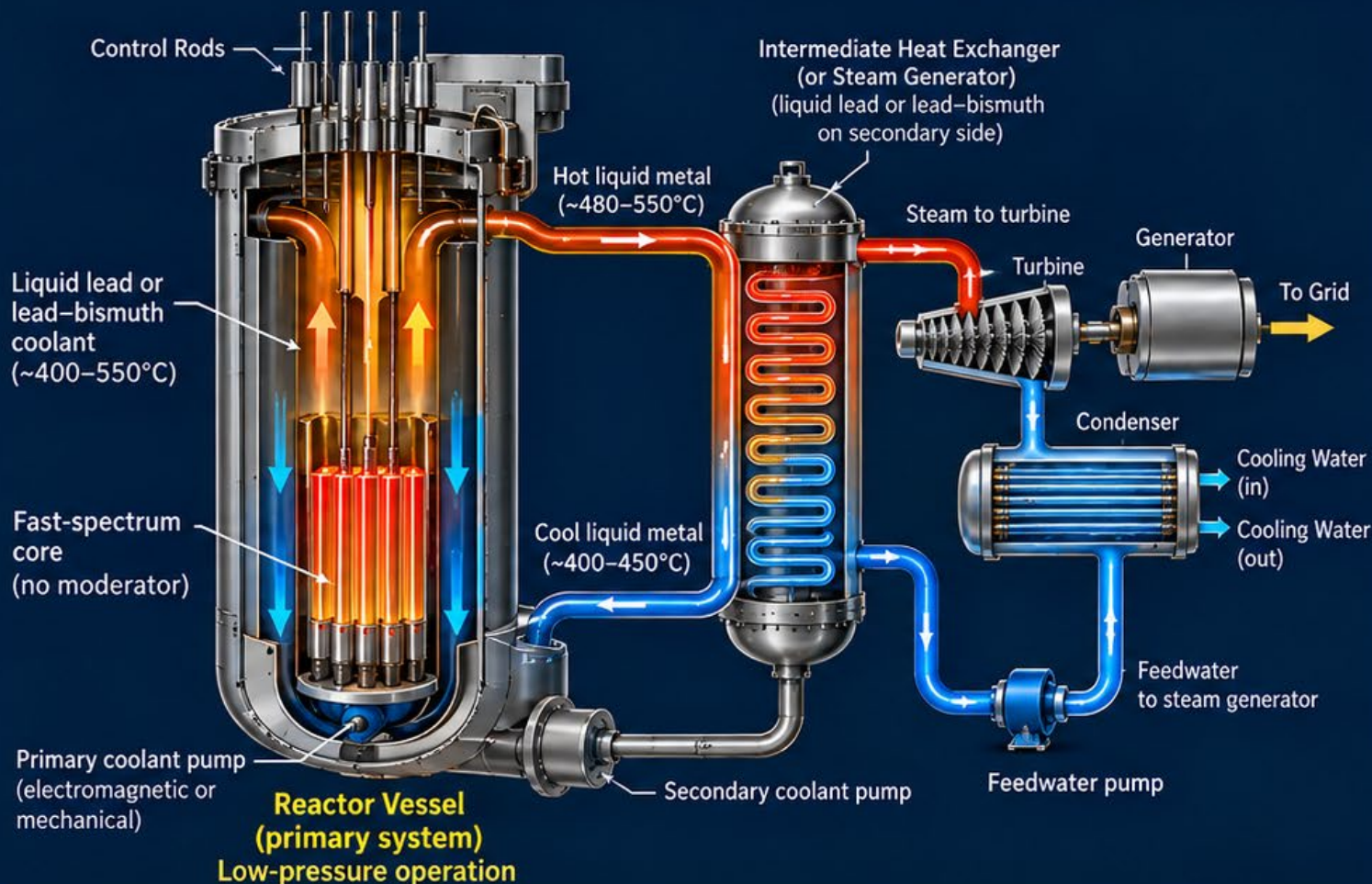
- ✓ High-temperature helium cooling supports industrial heat and process heat applications.
- ✓ Graphite moderation and TRISO fuel are central design features.
- ! TRISO fuel cost: roughly 15x to 20x more expensive than uranium oxide fuel.



High-temperature helium cooling creates process-heat potential — but TRISO fuel performance and cost are central to the design.

Liquid Lead & Lead-Bismuth Fast Reactors

Low-pressure cooling — but very limited reactor operating experience.



KEY BENEFITS

1 High Boiling Point / Low Pressure

Very high boiling point (~1,670°C for lead; ~1,670°C for LBE) allows high-temperature operation at low pressure.



2 Less Reactive with Air and Water

Lead and lead-bismuth are far less reactive with air and water than sodium (reduced risk of fires or explosions).



3 Potential for High Temperatures

Can enable high thermal efficiency and flexible plant configurations (e.g., electricity and process heat).



KEY CHALLENGES

1 Corrosion and Oxygen Control

Liquid lead and LBE can be highly corrosive; requires tight control of oxygen chemistry and advanced materials.



2 Freezing / Solidification and Heavy Coolant

Relatively high melting points (lead 327°C, LBE ~125°C) require careful thermal management and heat tracing. Coolant is very dense (high structural loads).



3 Inspection, Maintenance and Economics

Opaque coolant makes in-service inspection difficult. Specialized maintenance techniques are required. Economics remain uncertain due to limited operating experience.



NO COMMERCIAL LEAD OR LEAD-BISMUTH POWER PLANTS HAVE OPERATED.

Limited operating experience: mainly Soviet lead-bismuth submarine reactors and land-based prototypes (~80 reactor-years). Pure-lead reactor operating history is even more limited.

Soviet Alfa-class nuclear submarine (historical application)

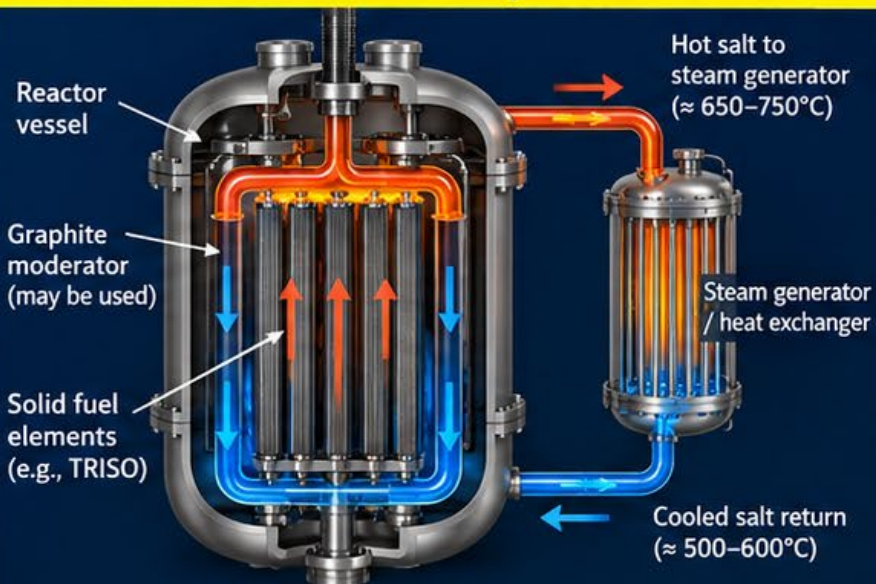


Molten Salt Reactors — Two Different Families

High-temperature potential — but major chemistry, materials, and commercialization challenges.

Molten salt describes more than one reactor architecture. Do not confuse the coolant with the fuel.

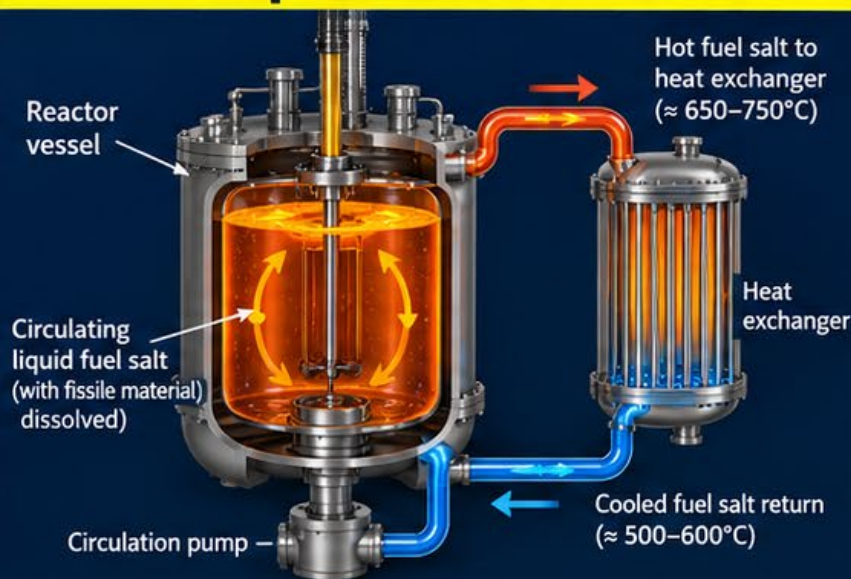
Salt-Cooled, Solid-Fuel Reactor



**Fuel is solid.
Salt is the coolant.**

- Graphite or other moderator may be used.
- Sometimes called FHR / salt-cooled concepts.

Liquid-Fueled Molten Salt Reactor



Fuel is dissolved in the salt.

- Circulating liquid fuel.
- May require online chemistry / fuel management.

Potential Advantages

-  High-temperature operation
-  Relatively low-pressure primary system
-  Potential for efficient electricity production and industrial heat

Major Challenges

-  Molten salts are highly corrosive and demand careful materials selection
-  Salt chemistry control is difficult and central to performance
-  Tritium management is a concern in some concepts
-  Liquid-fuel versions may require fuel processing / cleanup systems
-  Licensing, maintenance, and component replacement remain challenging



Only a handful of molten salt reactors have ever operated — none commercially.

Operating history is limited. Corrosion, chemistry control, maintenance, and commercial deployment remain unresolved challenges.



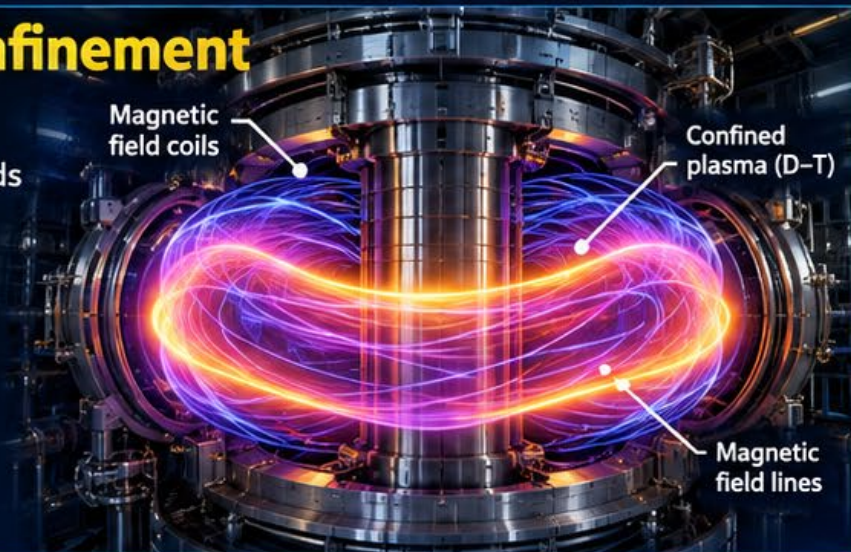
IEEE

Fusion — Promising Physics, Brutal Engineering

Fusion remains a possible long-term energy option — but the engineering challenges are enormous.

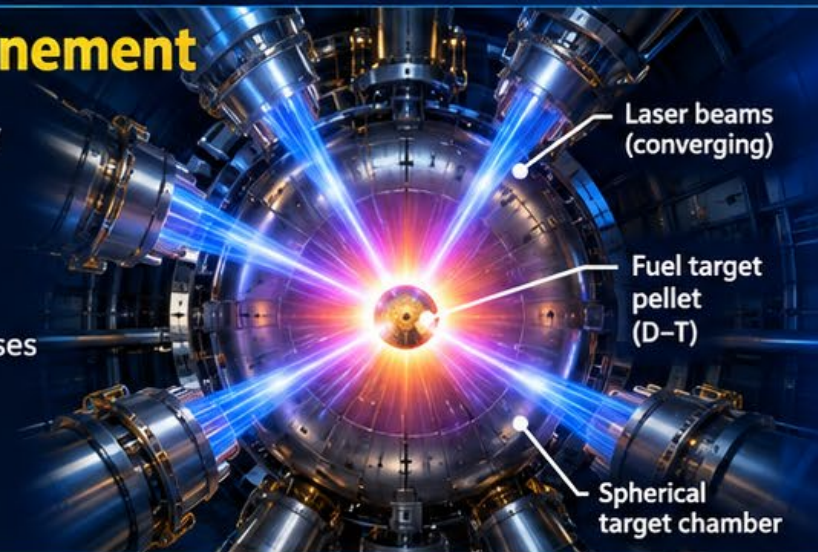
Magnetic Confinement

- Plasma confined by powerful magnetic fields
- Tokamak / stellarator concepts
- Challenge: sustained plasma performance and maintainability



Inertial Confinement

- Lasers compress a tiny fuel target
- Excellent physics experiments
- Challenge: turning pulses into a practical power plant



14 MeV neutrons = the First Wall Problem

High-energy neutrons damage materials, activate structures, and create one of fusion's hardest engineering barriers.

Why fusion is still hard



Very high-energy neutron damage (first wall / blanket materials)



Complex integrated systems



Materials and tritium-management challenges



No meaningful operating experience on a fusion power plant



Reliability growth curve still lies ahead



Commercial electricity production remains unproven

Bottom line



Fusion may become important — but today it is still an engineering development challenge, not a commercially demonstrated power technology.

Physics progress is real. Commercial fusion is still a long way from proven.

STATE OF THE NUCLEAR POWER INDUSTRY

A nuclear renaissance — and a crowded field of competing reactor designs

156

SMR & MICROREACTOR
PROJECTS IDENTIFIED WORLDWIDE

OECD NEA Digital Dashboard, Edition 4.0, September 2026

120+

PARTICIPATING
DEVELOPERS

95

INCLUDED IN
DETAILED DASHBOARD

SELECTED DESIGNS IN IAEA 2024 CATALOGUE — NOT A BREAKDOWN OF THE 156

Numbers are design counts from the IAEA 2024 catalogue.
They do not sum to the OECD total above.

WATER-COOLED REACTORS
(LWRs – PWR, BWR, etc.)



21

15 land-based
6 marine-based

**HIGH-TEMPERATURE
GAS REACTORS (HTGRs)**



14

FAST REACTORS
(Sodium, Lead, Lead-Bismuth)



10

MOLTEN SALT REACTORS



12

MICROREACTORS
(≤ 20 MWe, any technology)



13

OTHER / NICHE CONCEPTS
Heat-pipe, NaK-cooled, hybrid, and
other non-mainstream designs



eVinci —
heat-pipe
microreactor

MARVEL —
NaK-cooled
microreactor

Additional designs

Microreactors can use any coolant technology (water, gas, sodium, lead, salt, etc.), so size and technology categories overlap.

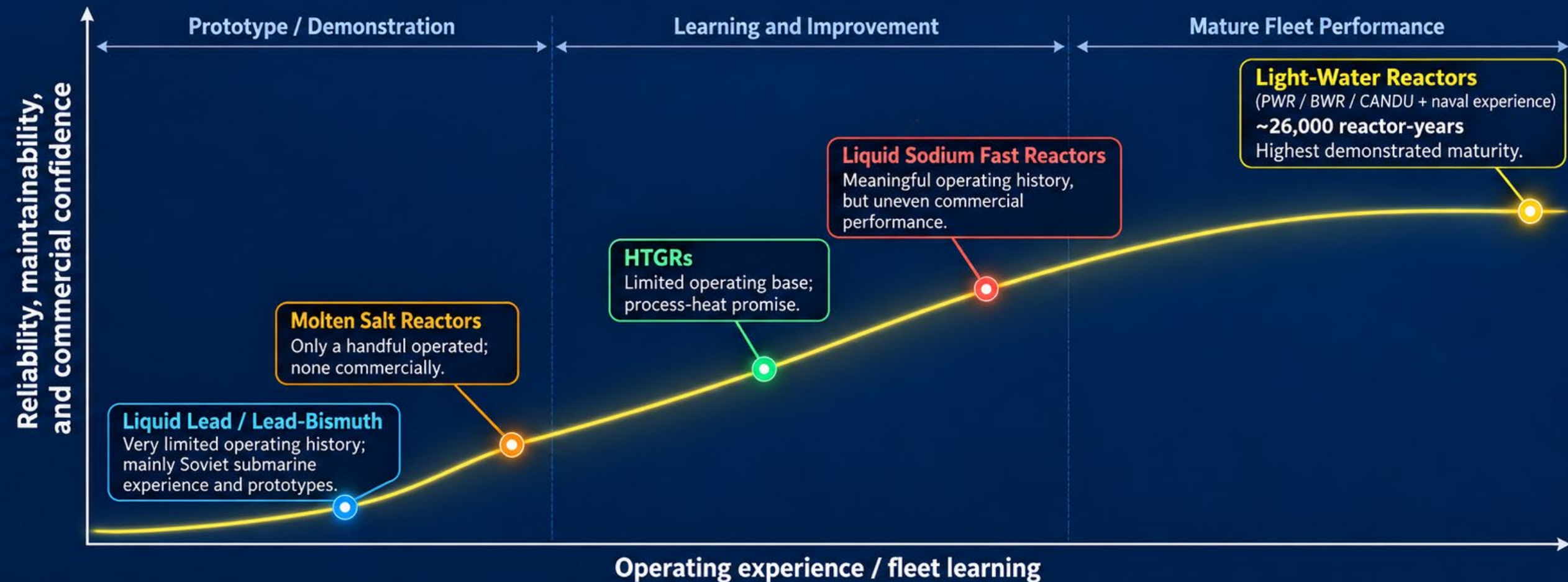


SATURATION PRECEDES SELECTION.

A promising concept is not yet a
licensed, maintainable, cost-competitive power plant.

Reliability Growth Curve — Reactor Technology Maturity

Operating experience is the ultimate teacher.



The unspoken assumption in many advanced reactor discussions:
future designs will perform reliably and cost-effectively on par with LWRs.

Experience matters. Reliability is not declared — it is earned.

Where Is the Industry Going? — The Great Culling

Many Concepts Enter the Commercial Funnel

LWRs

SMRs / MMRs

HTGRs

Liquid Sodium

Liquid Lead / LBE

Molten Salt

Fusion

(longer-horizon path)

Commercial Feasibility Filters
(Narrowing the Field)



Fuel Availability

Scalable, secure, affordable supply



Licensing

Achievable, predictable, timely approvals



Buildability

Proven designs, constructible, repeatable



Operability

Safe, reliable, high availability



Supply Chain

Mature, resilient, scalable



Capital Cost

Competitive total lifecycle cost



Customer Demand

Real contracts, sustained markets

A Few Bankable, Deployable Outcomes



Deployed Plants



Repeatable Projects



Bankable Nuclear Products

(e.g., LWRs and LWR-based SMRs/MMRs where economics work)



Near-term advantage: proven LWR foundations.

Advanced systems must prove more than core physics.

Fusion is a distinct longer-horizon path, not part of the near-term commercial field.

Distinct longer-horizon path
(not part of near-term commercial field)

Selection will be driven by licensing, construction, operation, and economics — **not by reactor physics alone.**

Questions & Answers



**Any
questions?**

Let's talk about what actually works.