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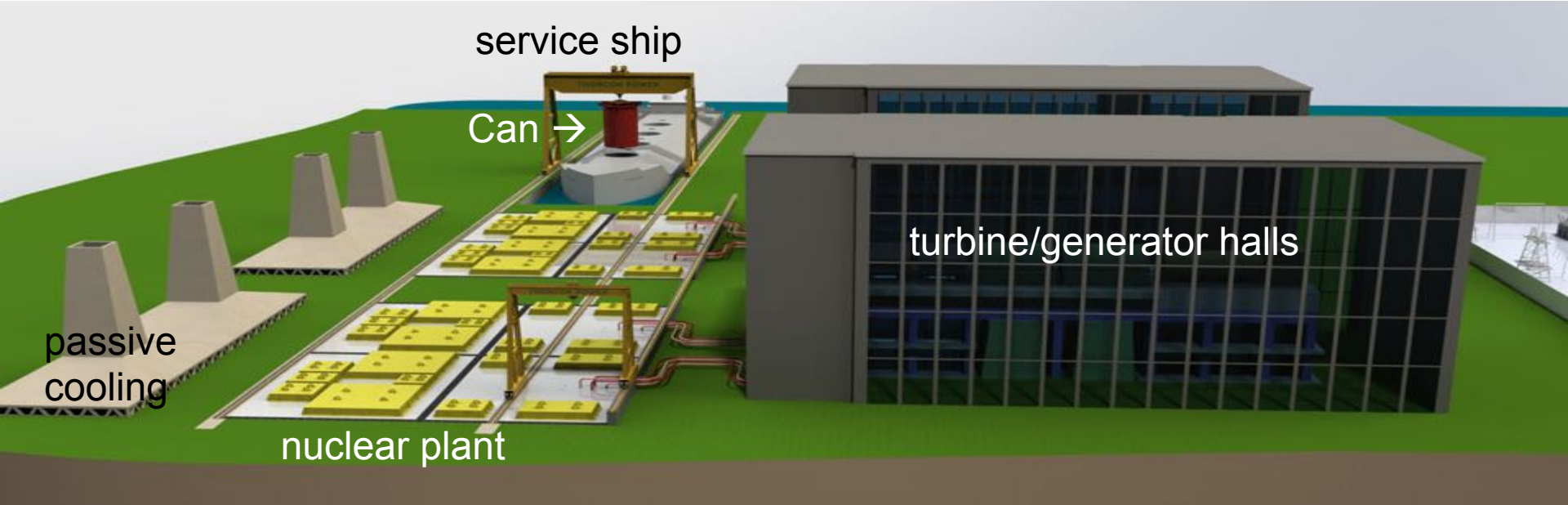
ThorCon

Technology: Passively safe, molten-salt nuclear power proven in the 1960s

Market: 800+ new coal plants planned in the developing nations

Advantage: Low-cost shipyard construction, no new technology



ORNL director Alvin Weinberg's interest in molten salt reactors led to a 1959 lab proposal for funding from the US Atomic Energy Commission to develop the MSRE. Construction began in 1962. The MSRE reactor core, shown during assembly, contained 69 cubic feet of graphite formed into 513 graphite core blocks. Passages between the blocks, called fuel channels, held molten salt fuel when the reactor was in operation.

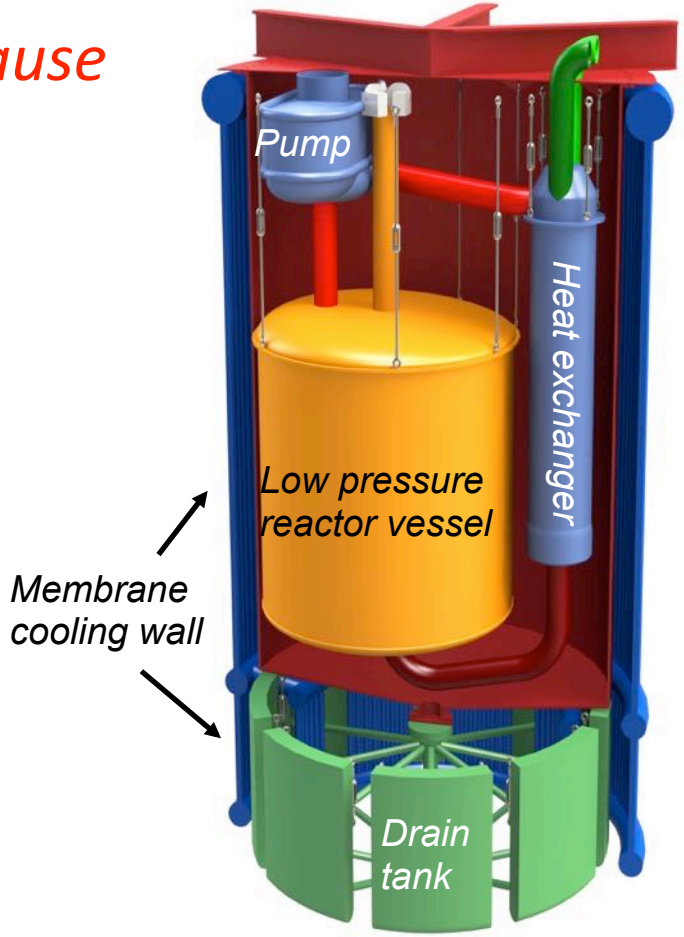
U.S. DEPARTMENT OF ENERGY

OAK RIDGE National Laboratory

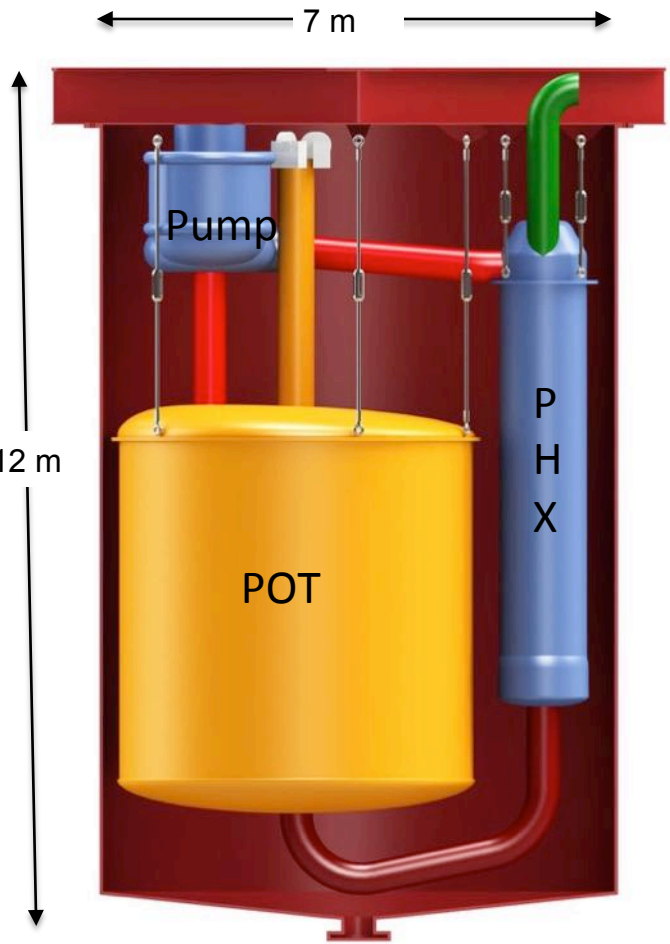
ThorCon is walk-away safe.

Safer than Fukushima and Chernobyl, because

- Safety is **intrinsic** from physics, not add-on safety systems; overheating stops chain reaction.
- Any break will **drain** reactor fuel to cold shutdown emergency drain tank.
- Decay heat is removed by membrane wall continuous **passive** water circulation, even in power blackout.
- Radioactive fuel salt at **low**, garden-hose pressure can't disperse in catastrophe.
- Fluoride salt chemically **locks up** hazardous fission products iodine-131, cesium-137, strontium-90.

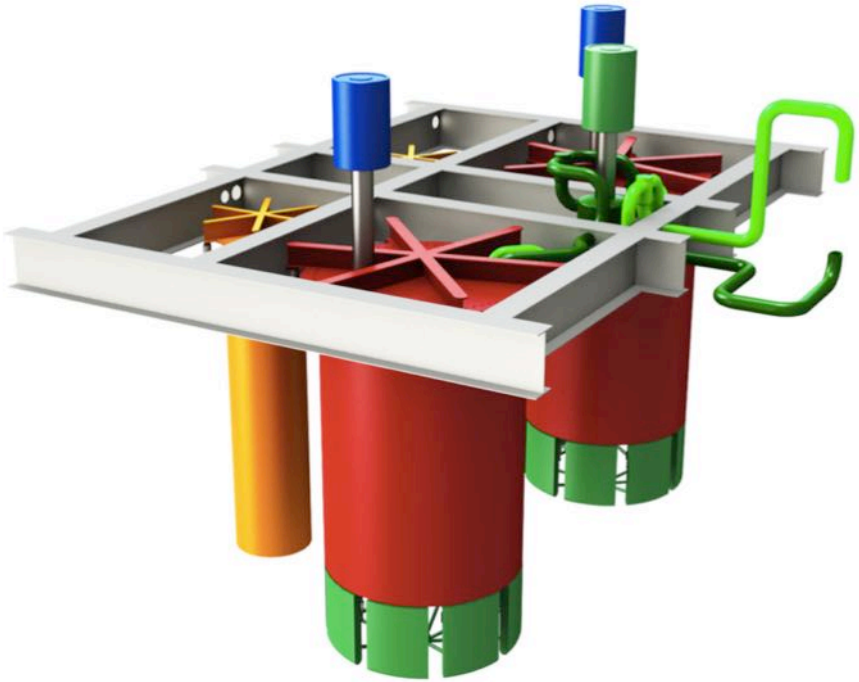


ThorCon's heart is the Can.



- **Pot** full of graphite slows neutrons produced by fission creating chain reaction which heats fuelsalt from 564C to 704C.
- Pump pushes fuelsalt around loop at just under 3000 kg/s. 14 sec loop time.
- Converts some Th to U-233, U-238 to Pu-239.
- Primary Heat Exchanger transfers heat to secondary salt cooling.
- One major moving part, the pump impeller.
- Pot pressure: 3.5 bar gage.
- Pump header tank extracts fission product gases.
- Pot → Pump → PHX is called the primary loop

Nuclear Island Modularity is 557MWt / 250 Mwe.



- Nuclear plant divided into underground power modules.
- Each module has two Cans housed in silos.
- Each Can contains a 557MWt reactor, primary loop pump, and primary heat exchanger.
- Cans are duplexed. To accommodate 4 year moderator life, Can operates for four years, then cools down for four years, and then is changed out.

ThorCon can steal the market from coal.

Cheaper than coal	ThorCon	Coal
Capital cost, $millions/GW	800	2000
Fuel cost, cents/kWh	0.53	2.27
Electricity, cents/kWh	3.1	5.6

- One GW increases GDP by $35 billion/year.
  Ayres & Warr, The Economic Growth Engine, p 346
- Rich nations can do what they want;
  poor nations do what they must.
  Joe Lassiter, Harvard Business School

- Developing nations **do choose** nuclear power
  50 under construction; 150 planned
- They **will choose** MSRs if they're available
  cheaper than LWRs; cheaper than coal

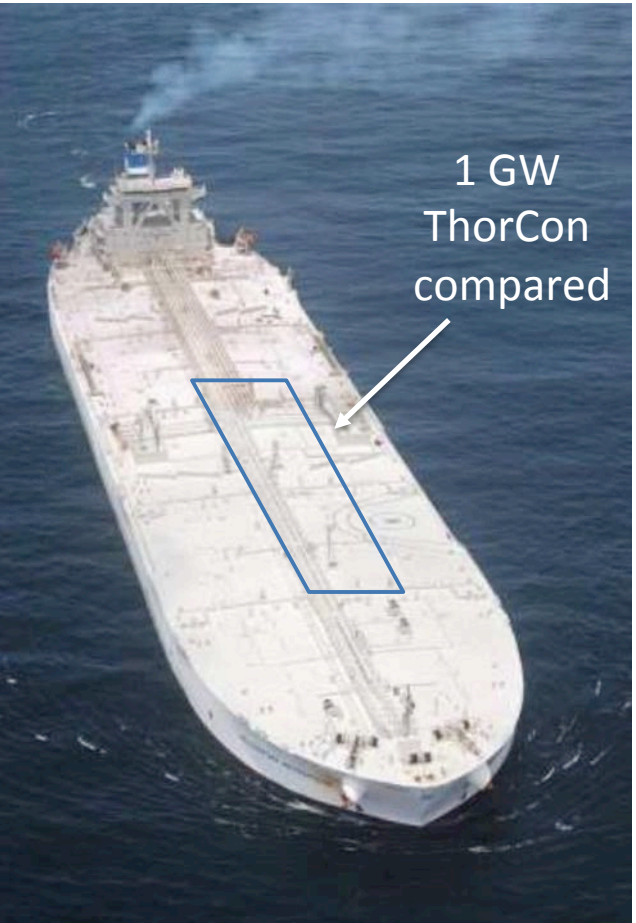
Energy density impact

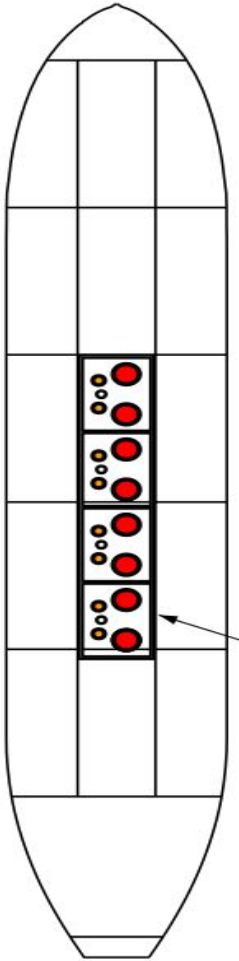
ThorCon uses low-cost, shipyard construction technology.

High-precision steel-fabrication builds ships for $2000 per ton.

A small shipyard can build ten 1-GW ThorCon power plants a year.

Thorcon will build nuclear power plants like supertankers.



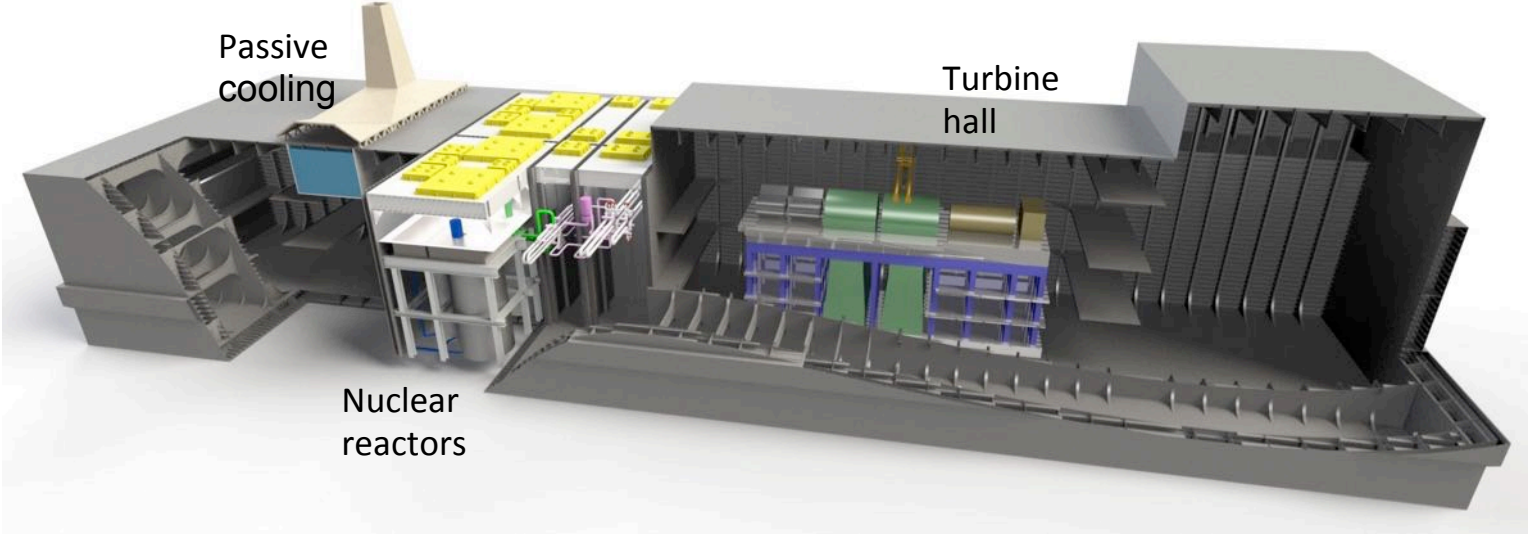


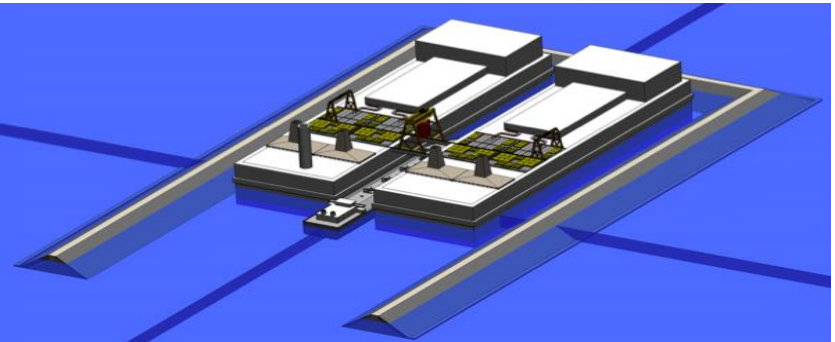
	ULCC	ThorCon
Overall Size(m)	380 x 68 x 35	121 x 23 x 32
Steel(MT)	67,591	18,300
Double curved plate	Lots	None
Coated area (m2)	350,000	30,000
Stainless steel(mt)	100	2,220
High nickel alloy(mt)	nil	253
Concrete(m3)	0	39,000
Excavation(m3)	0	182,000
Cargo capacity	445,000 tons oil	0
Ballast capacity	150,000 tons	0
Design Speed	16 knots	Just sits there
Design Criteria	Hurricane at sea	0.6g earthquake
Throughput	Discharge 15,000 m3 oil per hour	Heat 14,000 m3 salt per hour
Biggest component	35MW low speed diesel	500t SWL crane
Construction time	10 months	
Price(2001)	$89,000,000	

Devanney Ultra Large Crude Carrier cost $89 million, in 10 months

ThorCon: ¼ the steel, simpler construction

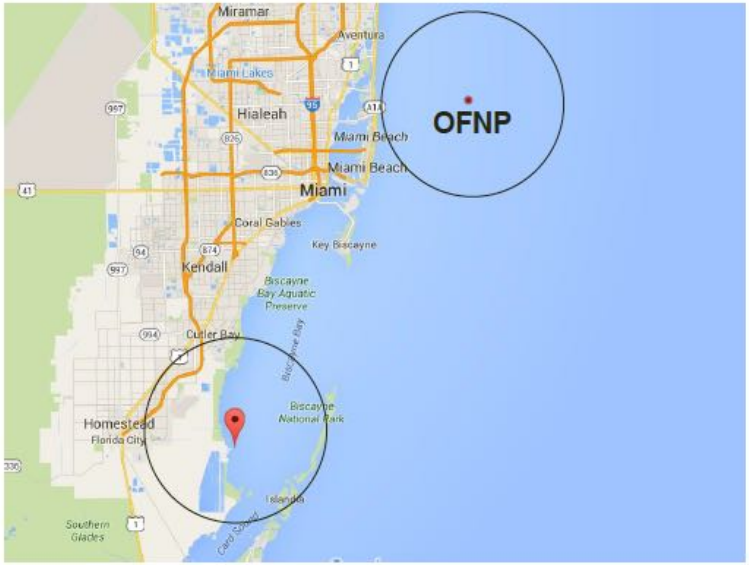
ThorCon prototype will be built on a hull, pretested, towed to testing site, settled shoreside, and powered up.





- Canship shown between two 500 MW ThorCons
- Water depth 5-10 m.
- Sand ballast protects against ship, airplane strikes.
- Hull version allows changes to be made to prototype at shipyard, provides siting flexibility.
- Production versions to be land-based, cheaper.

Designed for Superior Safety



Plant	Population within 10-mi radius	Evacuation plan	Distance from major load center
Indian Point	~270,000	Yes	25 mi from NYC
OFNP NYC	0	No	<15 mi from NYC
Turkey Point	~160,000	Yes	21 mi from Miami
OFNP Miami	0	No	<15 mi from Miami

Indonesia signed an MOU with ThorCon.

PT Industry Nuklir Indonesia (INUKI) is the state-owned nuclear fuel processing company.

PT PLN is the state-owned power generation company.

PT Pertamina is the state oil and gas giant which is now looking at nuclear and other forms of energy.

Lars Jorgensen, CEO, ThorCon; Yudiutomo Imardjoko, CEO, INUKI; Nicke Widyawati, Director, PLN; Rachmad Hardadi, Refinery Director, Pertamina; Dave Devanney, Director, ThorCon

To supplement its coal power plans, Indonesia wants energy from nuclear.

Compelling ThorCon Advantages

Liquid fuel: simple fuel handling, higher temperature efficiency, no cladding.

ORNL R&D. ORNL built two MSRs then designed DMSR guiding ThorCon.

No new technology: standard, available, affordable materials.

Complete power plant design: not just another fission reactor idea.

Shipyard construction: bidding out reduces cost, controls quality, scales to make 100 GW of power plants per year.

Small modular reactor: 250 MW module has economy of scale and simplifies safety.

Full scale prototype: No scale-up surprises or delays; only design once.

Maintenance by replacement: CanShip moves Can and fuel to recycling facilities.

Thorium: cuts uranium consumption, improves proliferation resistance.

Test then license: Indonesia will create final regulations as prototype is tested.

ThorCon avoids three costly LWR issues:
low temperature, high pressure, solid fuel.

- Thanks to **high temperature**, ThorCon uses the same, competitively-sourced, $500/kW supercritical steam turbine-generator as a modern coal plant.

- Thanks to **low pressure**, ThoCon avoids reinforced concrete mausoleum and 9-inch-thick forgings.

- Thanks to **liquid fuel**, ThorCon can move fuel around with a pump. No exacting fuel pin fabrication. No complex reshuffling refueling systems.

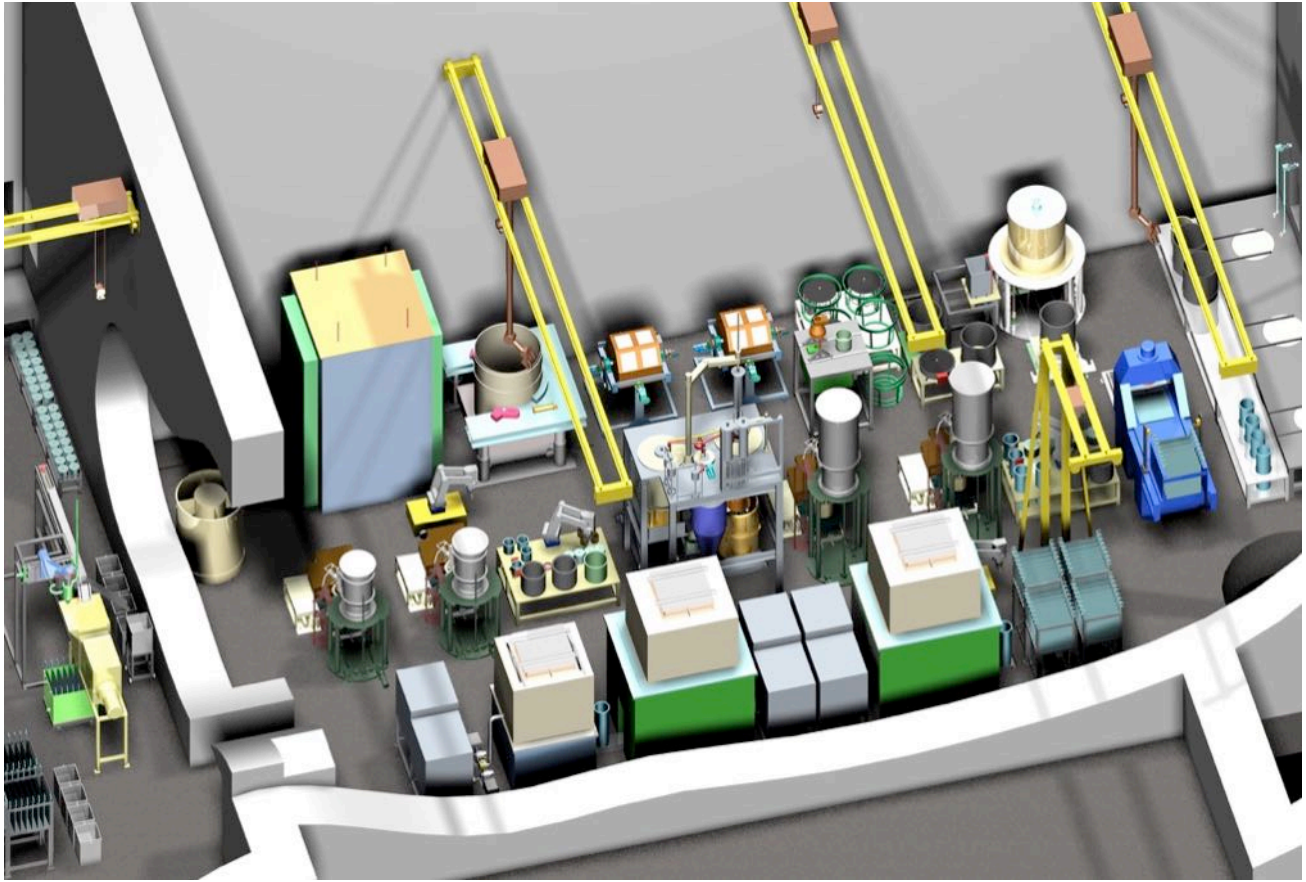
Industrial contenders for power plants.

Contender	Comment	ThorCon advantage
Supercritical pulverized coal	High CO2 emissions	cost
Natural gas CC turbine	½ CO2 emissions of coal	gas more costly outside US
Wind, solar	Need subsidies, backup power	cost, load-following design
Westinghouse AP1000 LWR	8 under construction	cost
China Inc AP1400	China uses all IP of AP1000	future competitor?
Rosatom LWR	$100 billion book of business	Indonesia declined
Areva EPWR	costly overruns, vessel weakness	cost, new technology
GE ESBWR, Prism reactors	possible UK sales	cost
Korea APR1400	4 under const in Korea, 4 in UAE	cost, modularity

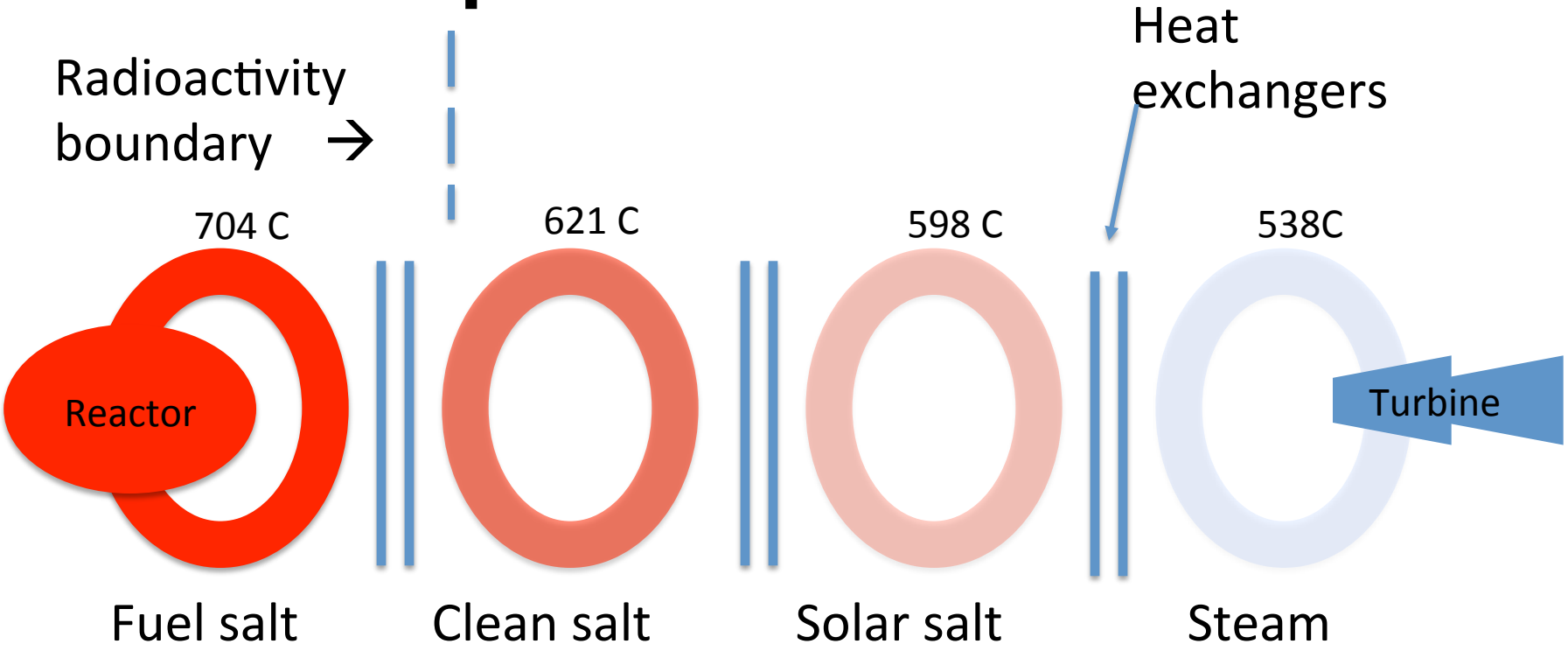
Spent fuel generation, before processing

- Each 250MWe module fuel salt lasts 8 years (2 GWe-yrs) and generates 20m^3 spent fuel.
- Spent fuel is stored on-site to cool for four years. 85kW at end of 4 years.
- This is shipped in one fuel cask (11m high x 3 m diameter).
- 80 years operation of demonstration plant produces 20 such casks.
- Picture to the right is a dry cask storage area for a 620 MWe power plant after 28 years.

LWR Pyroprocessing Facility (100 T/yr)



ThorCon converts energy via four heat transfer loops.



Tritium Control

- Tritium is a weak beta emitter that migrates through hot metal unless it is chemically combined to form a larger compound (like HTO).
- Tritium production with fresh NaBe salt averages 6 grams/GWe-yr - using FLiBe production is initially higher but settles out to around 50 grams/GWe-yr
- Beryllium is the source of tritium in MSR via
  $^{9}Be(n,alpha) \rightarrow {}^{6}Li(n,alpha) \rightarrow {}^{3}H + alpha$
- Tritium production is higher than LWR but 34 times lower than Candu
- Each gas tight space has a tritium getter until walls are cold.
- Challenge in the main heat path is stopping tritium migration to the steam cycle.
- Solar salt (60% NO_3, 40% KO_3 by weight) in the third loop will capture tritium as water.
- Canadian limits are 7,000 Bq/L. International Commission on Radiological Protection limits are 10x higher.