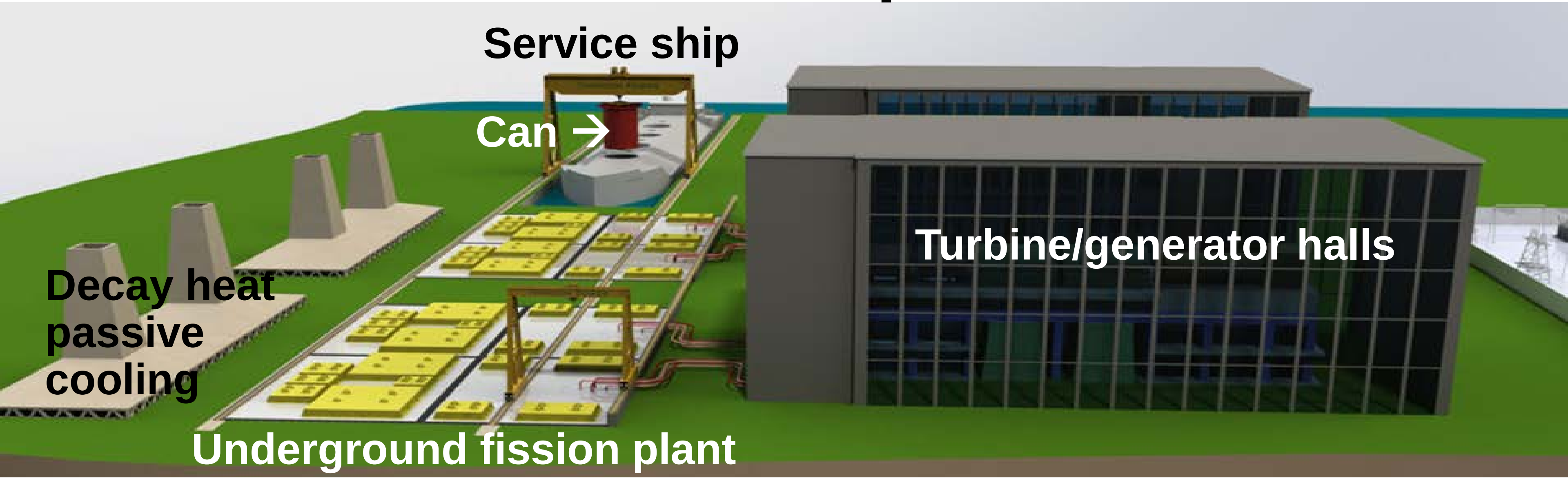
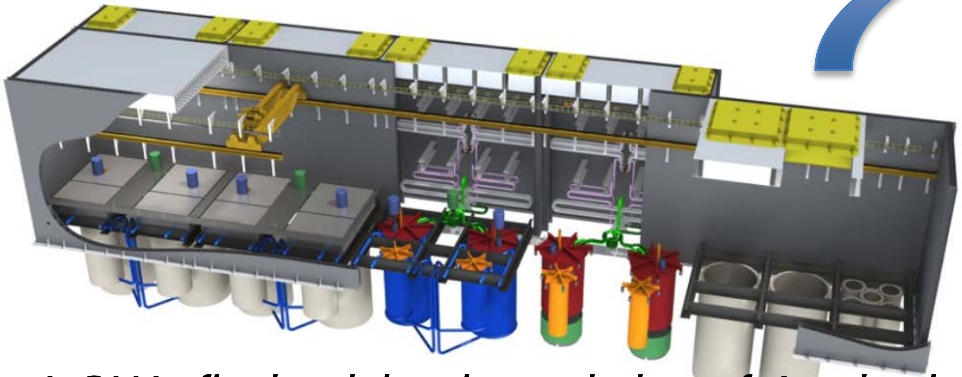
ThorCon: *Powering Up Our World*
Status Report



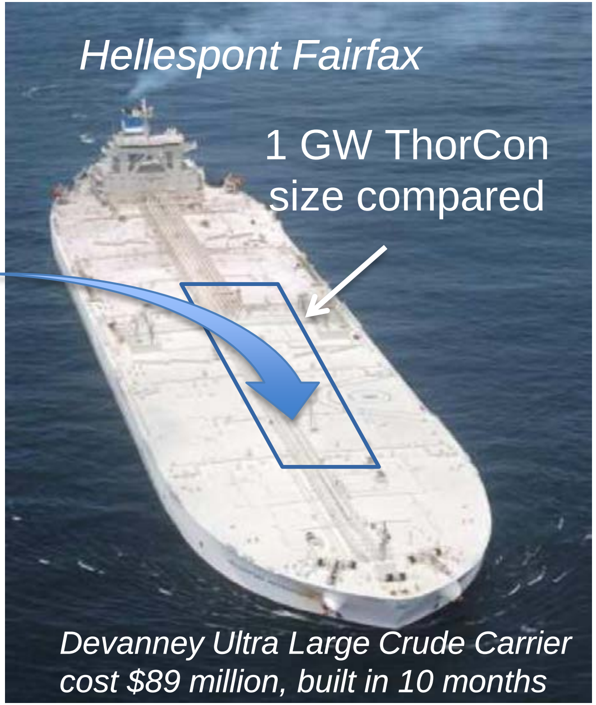
ThorCon, http://thorconpower.com/, info@thorconpower.com
Dane Wilson presenting
October 5, 2016
Molten Salt Reactor Workshop 2016

ThorCon Is a Block Constructed, Passively Safe, Molten-Salt, Fission Power Plant

- Based on MSR technology, proven in the 1960s
- Uses low-cost shipyard block construction



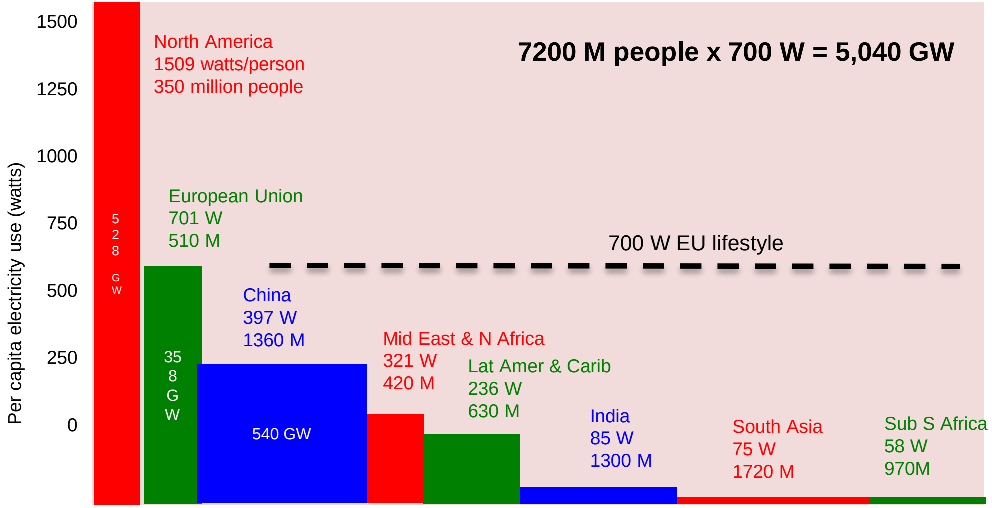
1 GWe fission island consisting of 4 paired Cans



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

Low Cost, Rapid Construction Is Essential To Meeting Growing Electricity Consumption

- Power needs of 5,040 GW
- High-precision steel-fabrication builds ships for $2,000 per ton
- A small shipyard can build 10 1-GW ThorCon power plants a year



World Bank data

World population 7200 million people

Base Cost* Is Estimated To Be Less Than For Coal

Electricity Project	Westinghouse AP1000	ThorCon	Coal (high)	Coal (low)
Interest rate	8.00%	8.00%	8.00%	8.00%
Capital cost, $millions	16000	1200	2200	1800
Generating capacity, MW	2200	1000	800	1200
Lifetime, years	40	40	40	40
Capacity factor	0.9	0.9	0.8	0.8
Capital cost per kWh**	**$0.077**	**$0.013**	**$0.033**	**$0.018**
Operating cost estimate	0.01	0.0056	0.0049	0.0049
Fuel cost	0.007	0.005	0.0145	0.0145
Total cost per kWh	**$0.094**	**$0.024**	**$0.052**	**$0.037**

* Base cost: power only; excludes fees, taxes, licenses, R&D, corporate management, investor return, …

** Excel PMT function (interest rate, lifetime, cost) / capacity factor

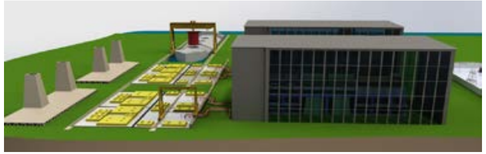
Riau 800-1200 MW coal plant $1.8-2.2 billion www.thestar.com.my/business/business-news/2015/11/10/indon-coal-plant-for-msia/

"Can" Modularity (250 MWe) Is Integral To ThorCon And Allows Materiel Transport

- Shipyard builds new power plants (PP)

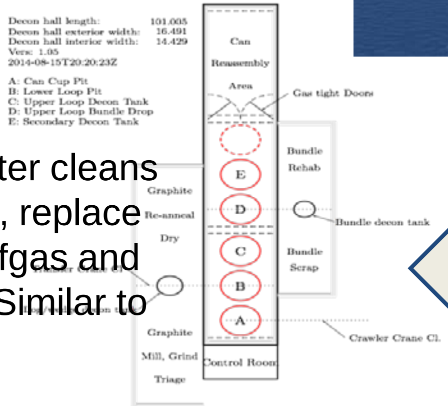
- Barge to PP site (around 20 barge loads per GW)

- PP sites (1 GW site shown) 1,000-20,000 GW total



- Canship delivers new Cans and takes old Cans back for recycling. Also transports new fuel and returns spent fuel. One round trip every four years to each 1GWe site.

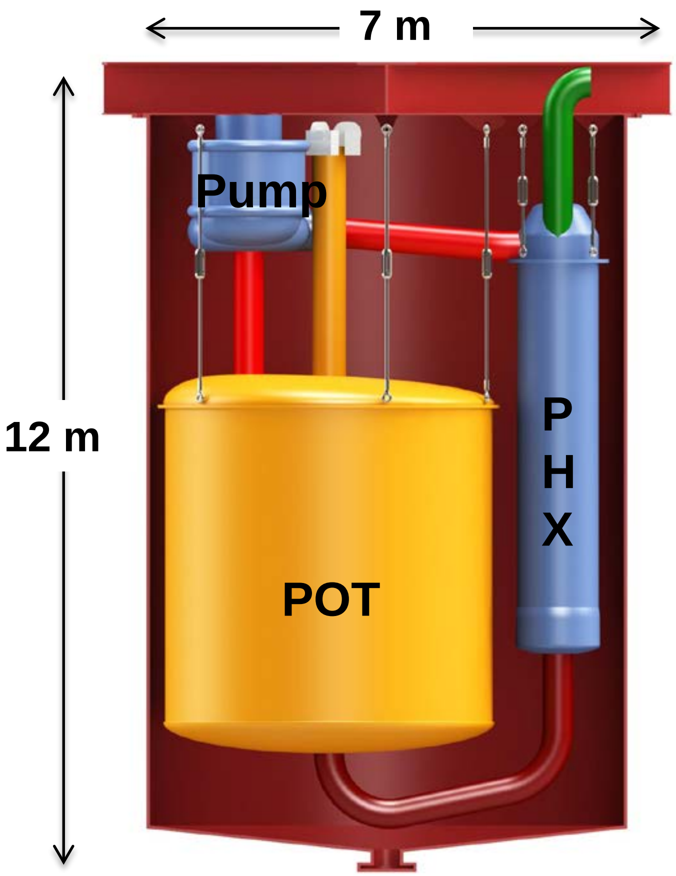
- Can recycling center cleans and inspects cans, replace graphite, stores offgas and graphite wastes. Similar to a shipyard.



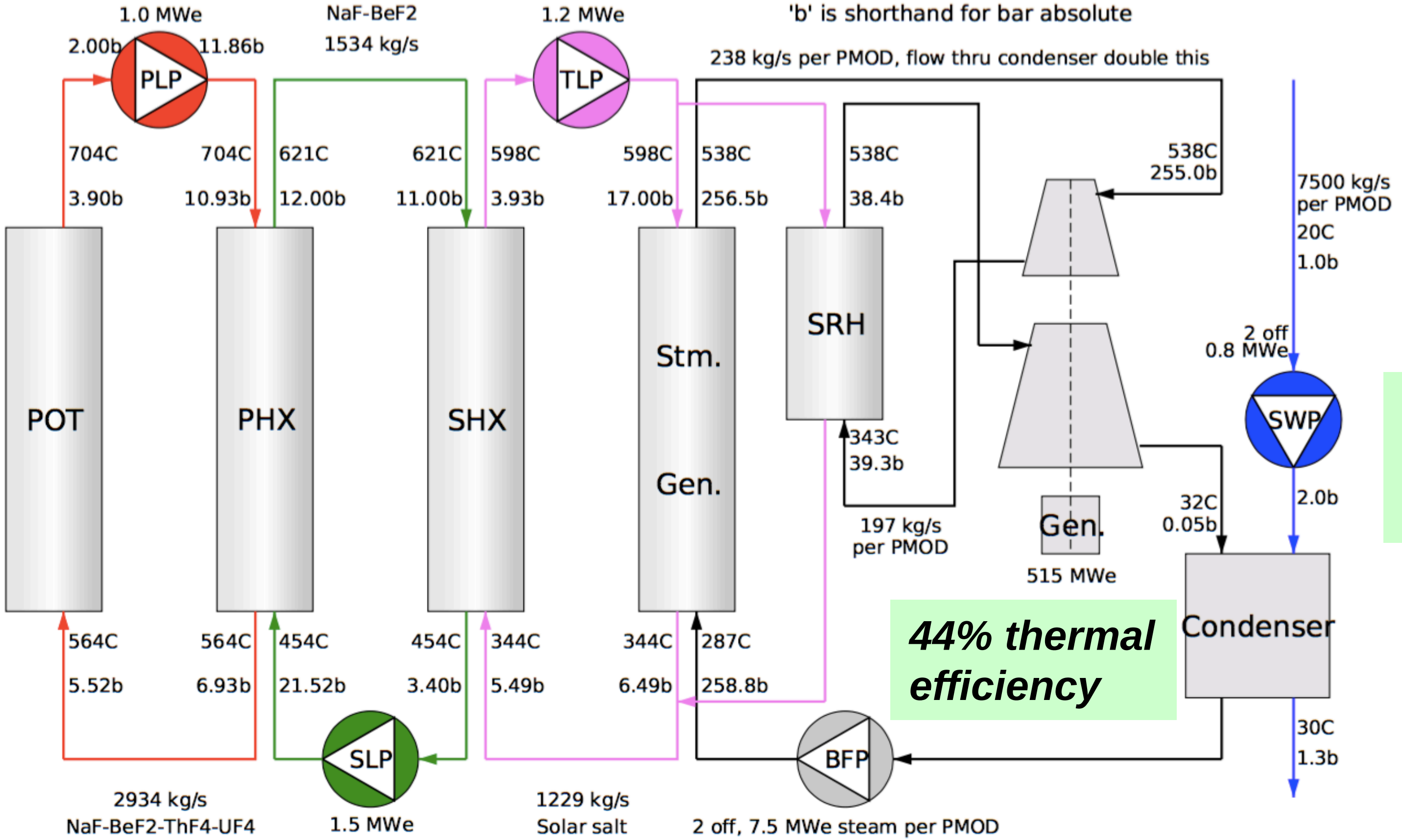
- Secure site stores spent fuel (dry cast) for possible future processing.

ThorCon's Heart Is The Can Which Contains:

- Pot
  - Pressure: 3.5 bar
  - Temperature: inlet of 564°C and outlet of 704°C
  - Graphite moderator
  - Some Th converts to U-233, U-238 to Pu-239
- Pump
  - Fuelsalt pumped at ~ 3000 kg/s
    - 14 sec loop time
- Primary Heat Exchanger (PHX)



ThorCon Employs Three Salt Loops



44% thermal efficiency

super-critical turbine

ThorCon Is Fuel And Salt Flexible

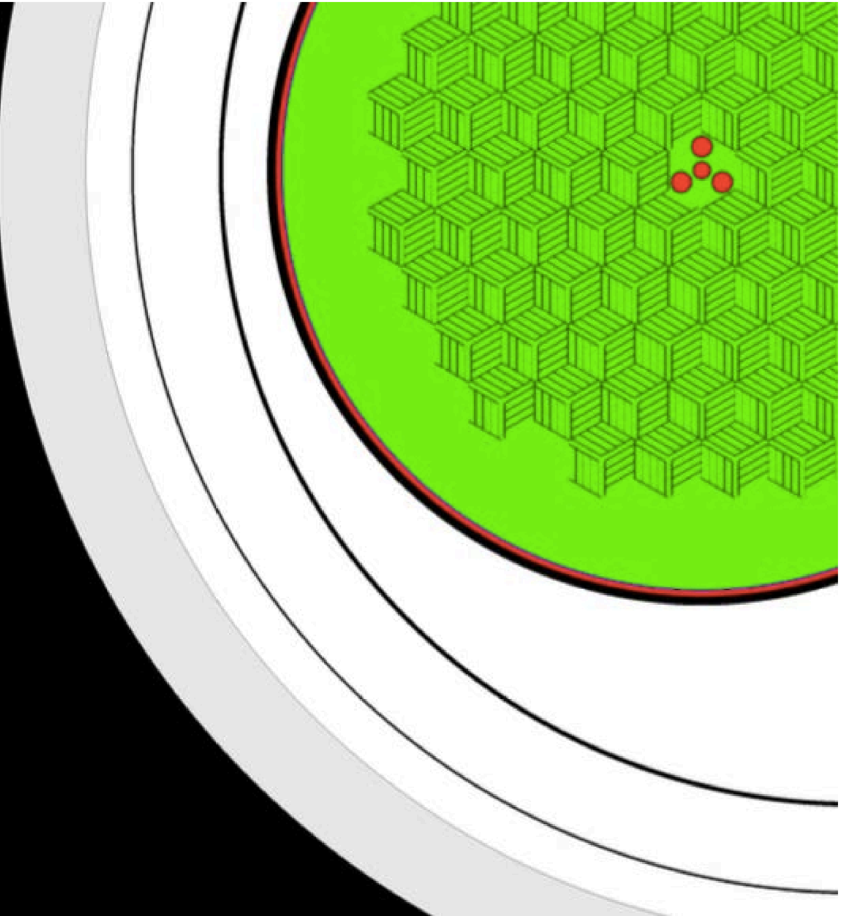
Mission	Salt 12% HM	Startup					Makeup Th plus			Self generated fuel (%)
		Heavy metal (%)		U distribution (%)			U distribution (%)			
		Th	U	U233	U235	Other	U233	U235	U238	
1) Initial tests	NaBe	0	100	0	3	97	0	5	95	30
2) Economic baseline	NaBe	82	18	0	20	80	0	20	80	50
3) Better fuel utilization	FLiBe	82	18	0	20	80	0	20	80	60
4) Best fuel utilization *	FLiBe	82	18	12	0	88	12	0	88	Almost 100

Near future. No changes to system.

More distant future. Changes to system required.

* Possible future: Separate of seeker fission products + Pu, Am, Cm. Plutonium goes to a fast reactor and LEU U233 returns. Makeup is almost all thorium.

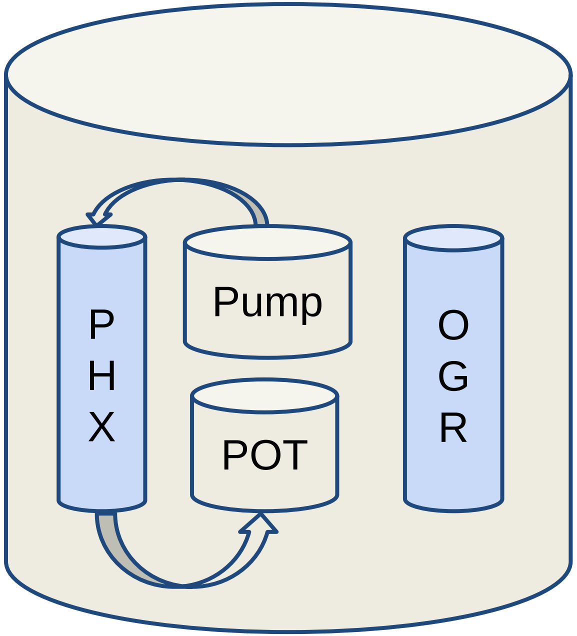
Neutronics Modeling Is In A State Of Flux



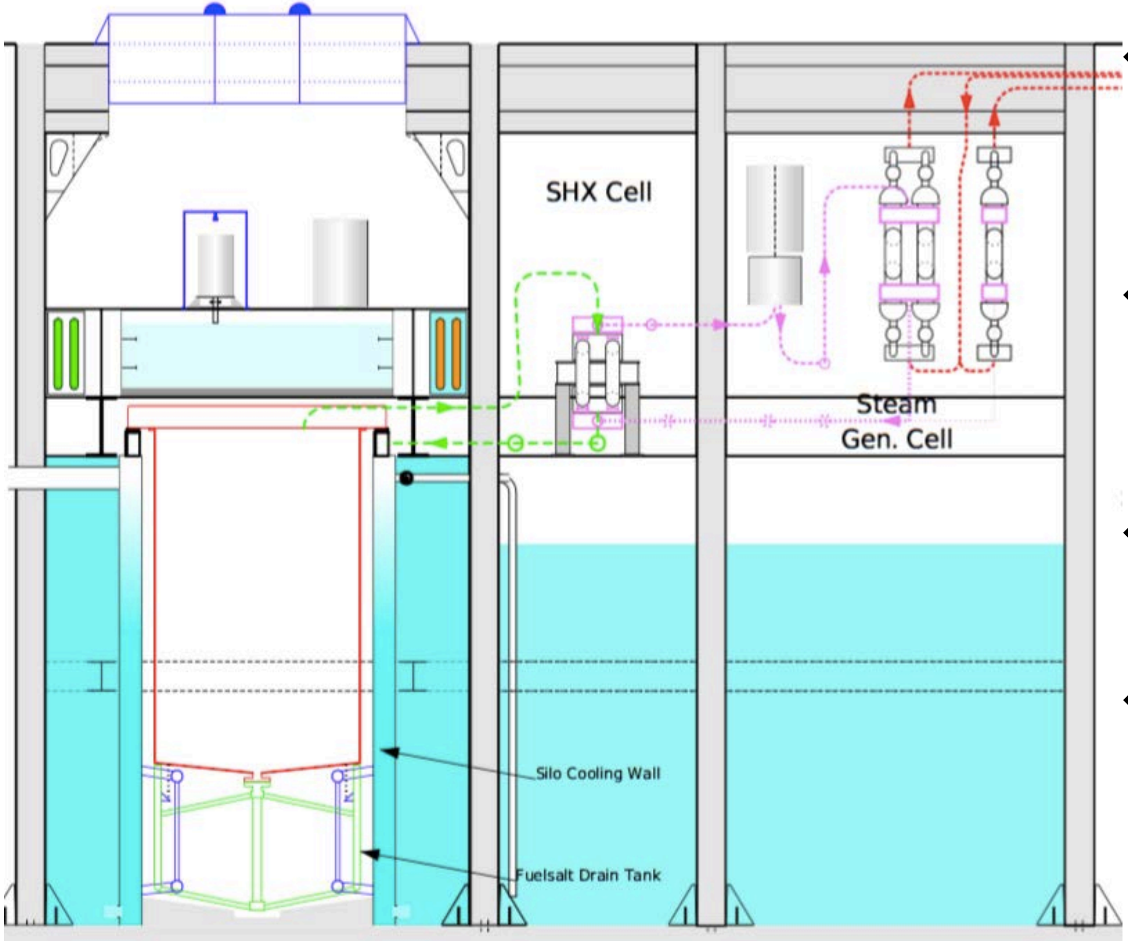
- ❖ Neutronics and burnup modeled with both MCNP and Serpent
- ❖ ThorCon DNA design control system allows changes to flow to documentation and model preprocessors, facilitating design experimentation
- ❖ Moderator mounting system allows graphite changes with temperature and fluence
- ❖ Strongly negative temperature coefficient throughout fuel cycle, even on NaBe
- ❖ Load response via pump speed confirmed

Fission Product Removed Via Off-gas System

- Recovery involves He sweep, hold-up tanks, charcoal delay
  - Low turbulence flows
- Gases (Kr, Xe)
  - Removed by spray bubbling
  - 216 kg/GWe-yr
- Noble metals (Nb-Te)
  - Plate out into OGR and PHX
  - 234 kg/GWe-yr
- Solubles (Rb, Sr, Y, Zr, Cs-Gd, Pu-Cm)
  - Stay in the salts
  - 409 kg/GWe-yr
- Trifluorides approach saturation in fuel salt after 8 years



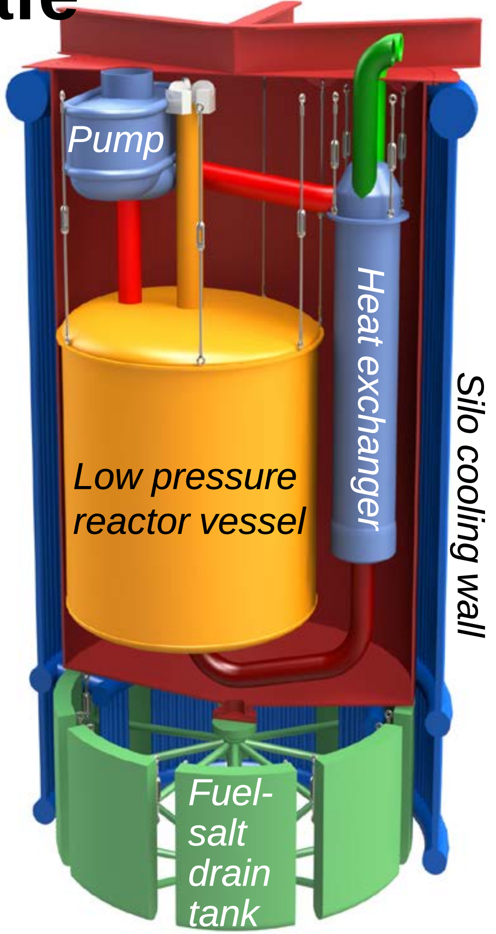
ThorCon Design Allows For Tritium Control



- Beryllium is the tritium source: $^{9}Be(n,alpha) \rightarrow {}^{6}Li(n,alpha) \rightarrow {}^{3}H$ + alpha
- Tritium migrates through hot metal surfaces such as the PHX
- Tritium is gettered in each sealed gas space
- Solar salt ($NaNO_3$, KNO_3) third loop will capture the last of the tritium

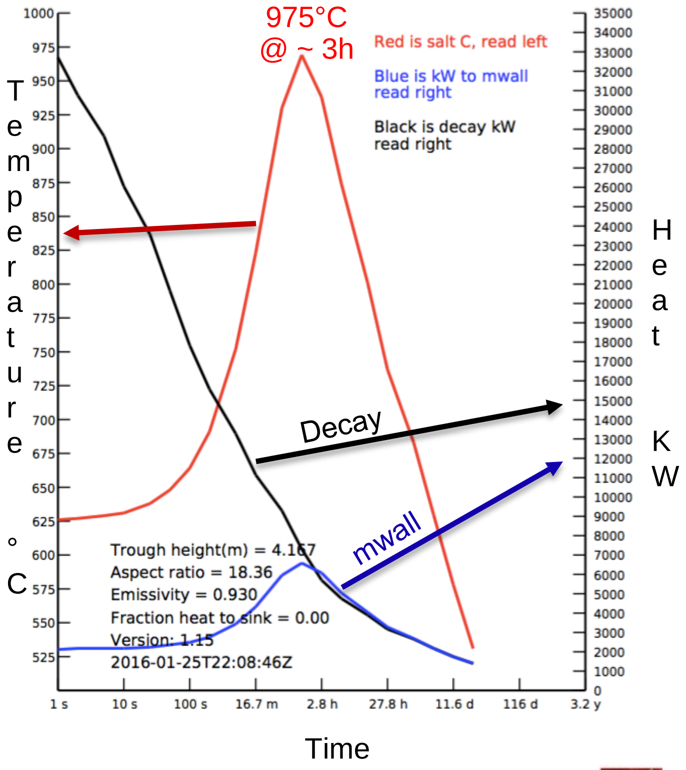
ThorCon Is Walk-away Safe

- Safety is **intrinsic** from physics, not add-on safety systems
  - Overheating stops chain reaction
- Any break will **drain** reactor fuel to cold shutdown Fuelsalt Drain Tank (FDT)
- Decay heat is removed by silo cooling wall continuous **passive** water circulation
  - Even in power blackout
- Radioactive fuel salt at **low** pressure
  - No energy for significant dispersion
- Fluoride salt chemically **locks up** hazardous fission products Cs-137, Sr-90



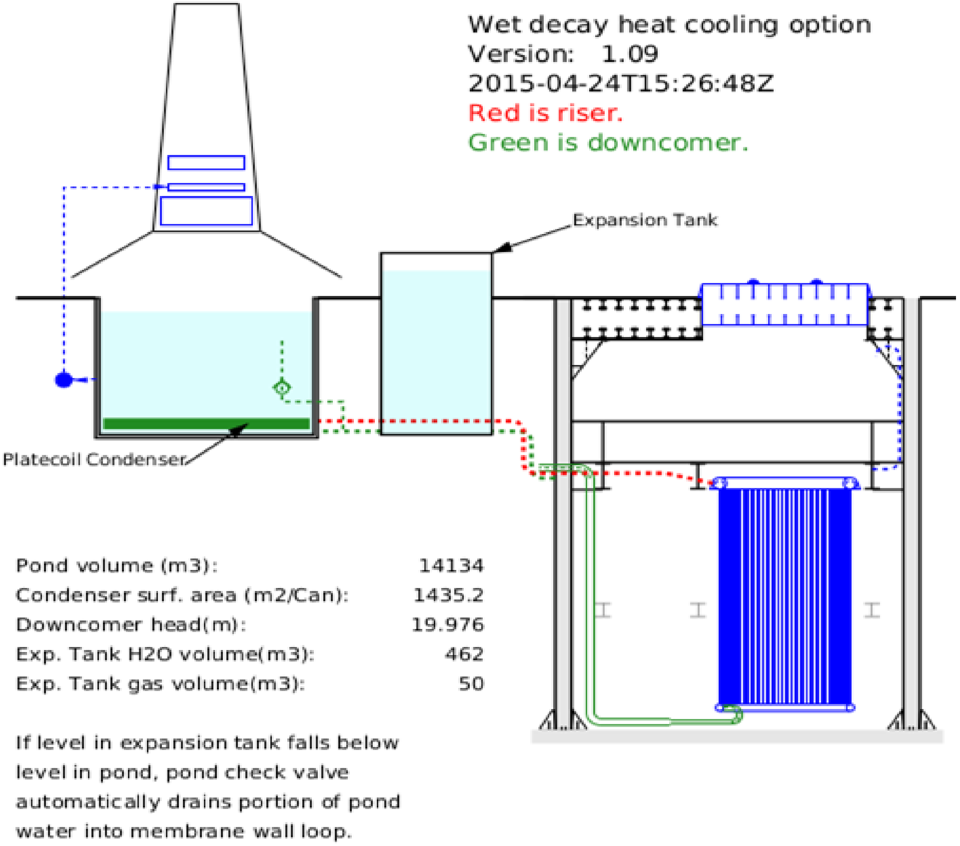
Layered, Passive Decay Heat Cooling Is Employed

- On station black-out
  - Sentry turbine handles decay heat
    - Avoids drain
- On Sentry turbine failure
  - Loop overheats, fuse valve thaws, primary loop drains to FDT
- On drain at full power to FDT
  - Always-on membrane wall cools
    - After ~3h, temperature peaks at 975°C
      - 450°C below boiling point
- ***Nothing the operator can do to prevent the drain and cooling***



Additionally, The Silo Wall Is Continuously Passively Cooled

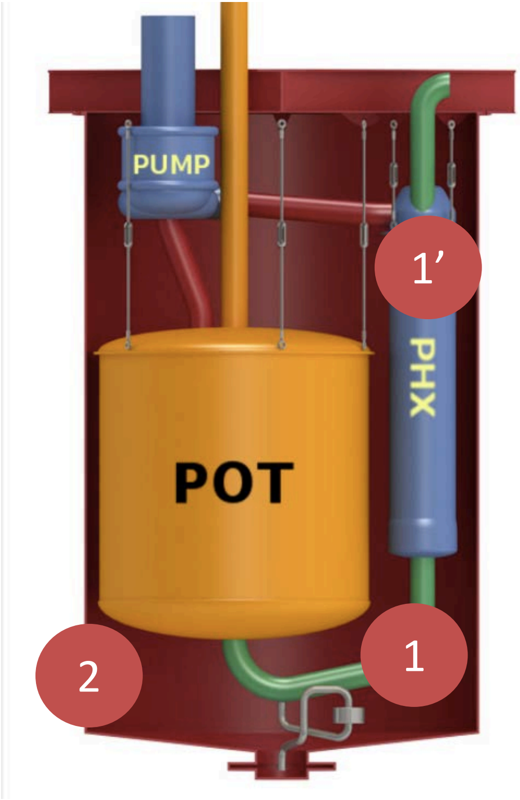
- ❖ Silo wall can cool 30 MWt
  - ♦ Max decay heat is 5 MWt
- ❖ Pond has 72 days worth of water
  - ♦ 180 days with wet towers
- ❖ Basement water adds over a year of walkaway safety

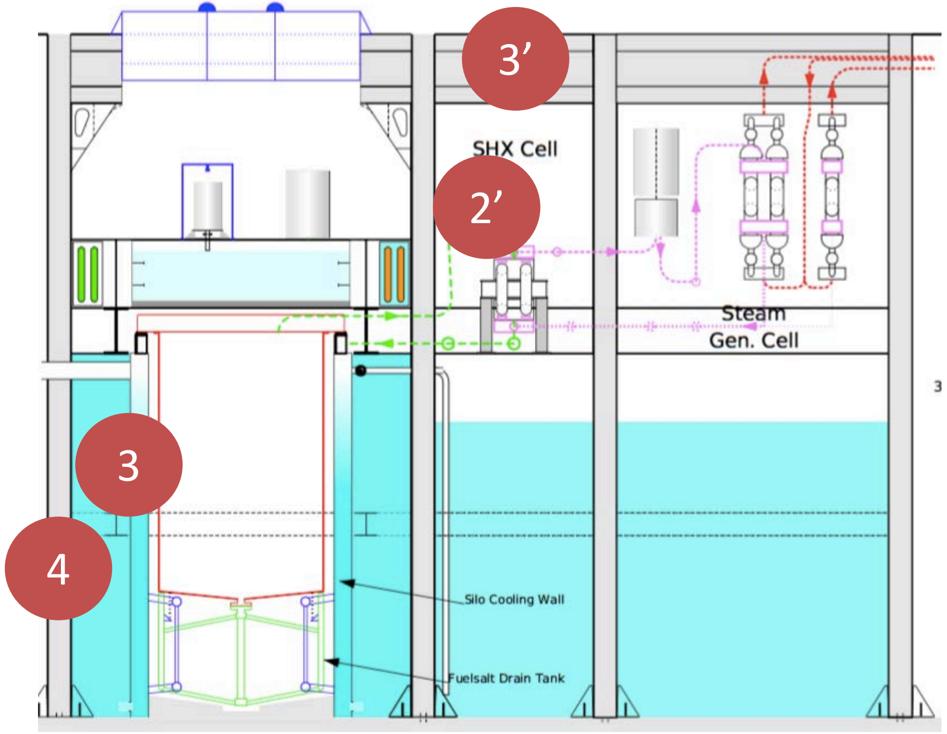


ThorCon Has 3 To 4 Radioactivity Transport Barriers

1. Primary Loop Piping
2. Can/Drain Tank
3. Silo Cavity
4. Silo Hall

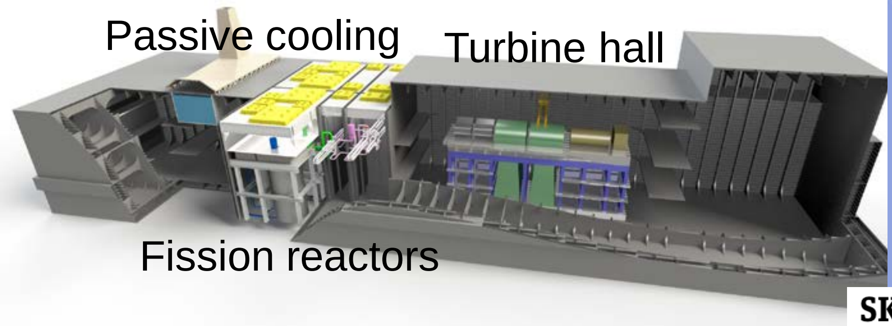
1’ Primary HX
2’ SHX Loop
3’ SHX Cell

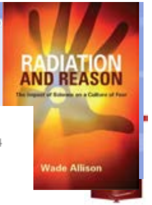




Likely Demonstration Site Is Indonesia

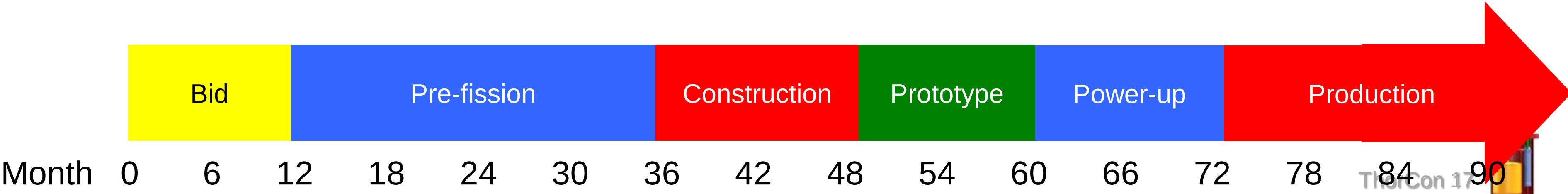
- ThorCon discussing test-then-license with regulator
- Site selection initiated by Indonesia
- ThorConIsle prototype will be built on a hull, pretested, towed to Indonesia, settled near shore, and powered up
  - Water depth 5-10 m
  - Allows for changes to prototype at shipyard and siting flexibility
  - Lower-cost land-based version will be available





The ThorCon Indonesia Project Has 6 Phases

Phase	Task	Milestone	Investments
Bid	Complete engineering	Bids in hand	$10 million
Pre-fission	Build, test unfueled prototype on hull in shipyard	Tests complete	$120 million
Construction	Add turbine-generator, switchgear, Cans; contract fuel	Ready to tow hull	$520 million
Prototype	Tow to Indonesia, fuel, test	Power to grid	$65 million
Power-up	Increase power to 250+ MW	License for +3 GW	$65 million
Production	Build 3 GW more plants	Revenue from +3 GW	borrowing



Summarizing As Two 500 MW ThorConIsles Are Serviced by a CanShip