SMRs for Australia (Small is Beautiful)

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SMR NUCLEAR TECHNOLOGY

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Small Modular Reactors (SMRs)

- Reactors with a power output < 300 MWe (IAEA)
- Factory built reactor module

Technologies

- Gen III+ light water reactors (coolant and moderator)
- Gen IV
  - ➢High Temperature gas reactors
  - ➢Molten salt reactors
  - ➢Fast neutron reactors

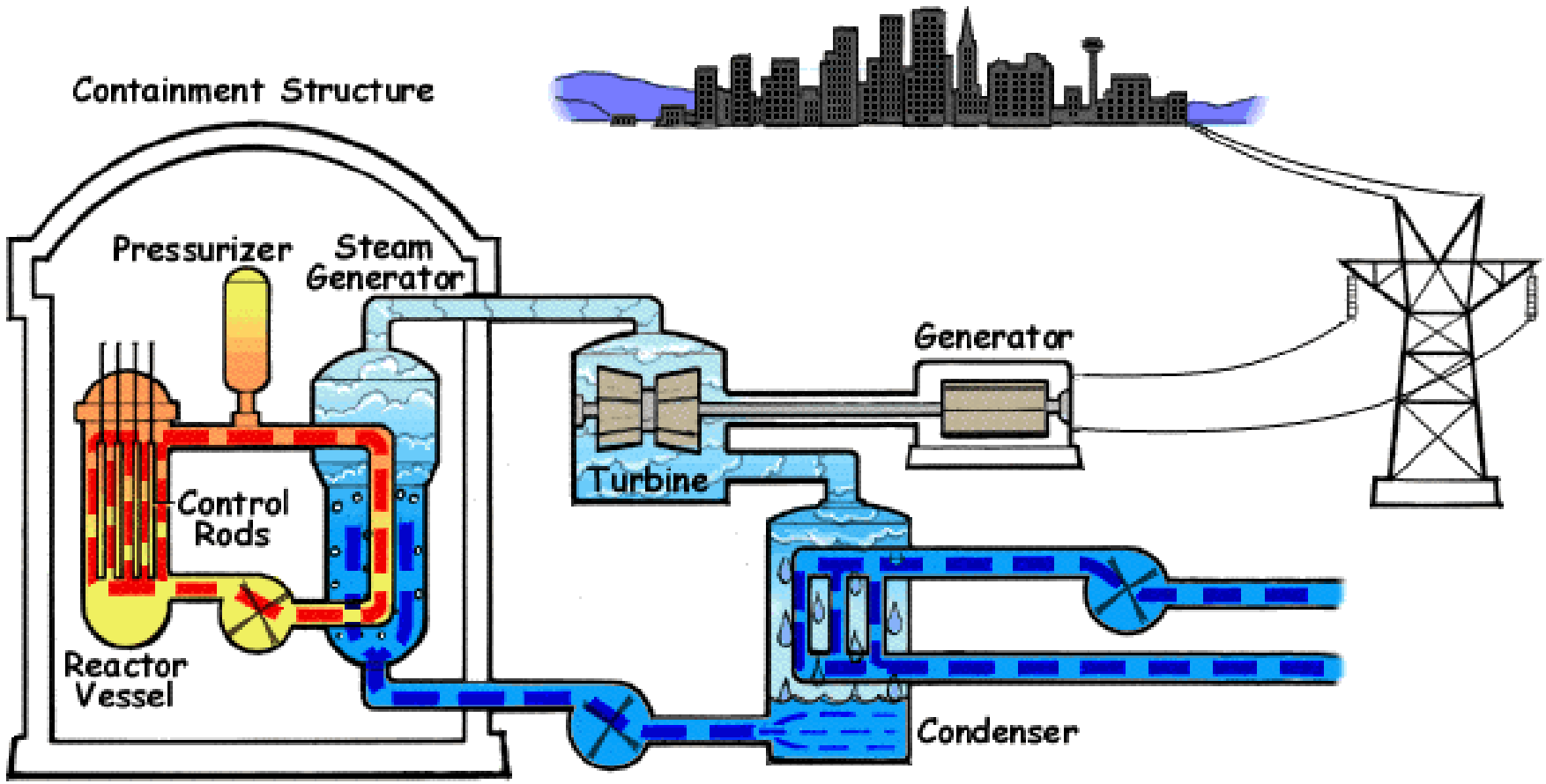
Advantages of SMRs

- Provide reliable, low emissions power in remote locations or for small grid systems
- Smaller quantity of nuclear materials - easier to design a high level of passive or inherent safety
- Reactor vessel can be installed below ground
- Factory built module, transported to site by road or rail – reduces risk of on-site construction delays
- Lower initial capital cost and scalable – modules can be added as required

Advantages of SMRs

- When one module is shutdown for refuelling the remaining modules are still producing power
- Simple to operate and maintain – passive safety systems require less maintenance
- Designed with load following capability to work in a system with VRE
- Do not need to be located near a large source of cooling water – turbine condenser can be dry cooled
- Multi-purpose – electricity, desalination and process heat
- Compact – 720 MWe on 18 hectare site

Pressurised water Reactor (PWR)



Primary circuit 15 MPa, inlet 294°C, outlet 325°C

Secondary circuit 6.2 MPa, inlet 224°C, turbine inlet 275°C

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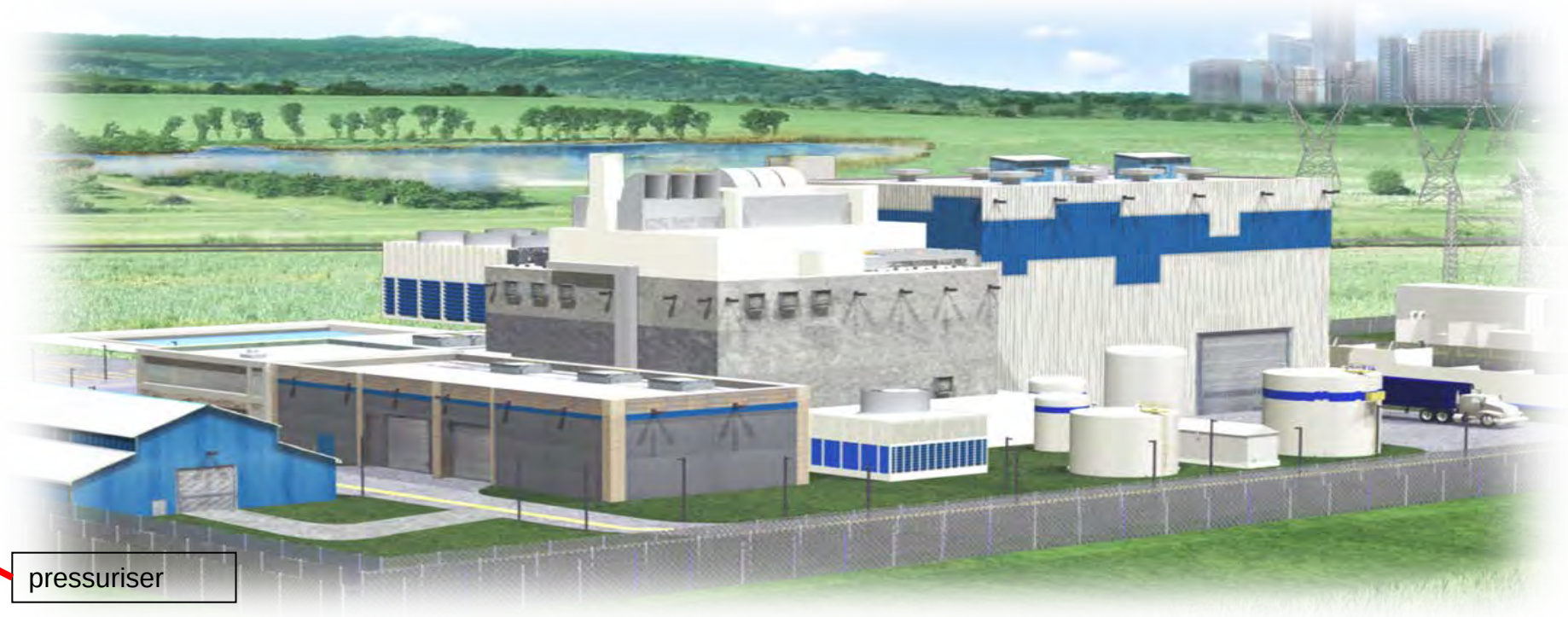
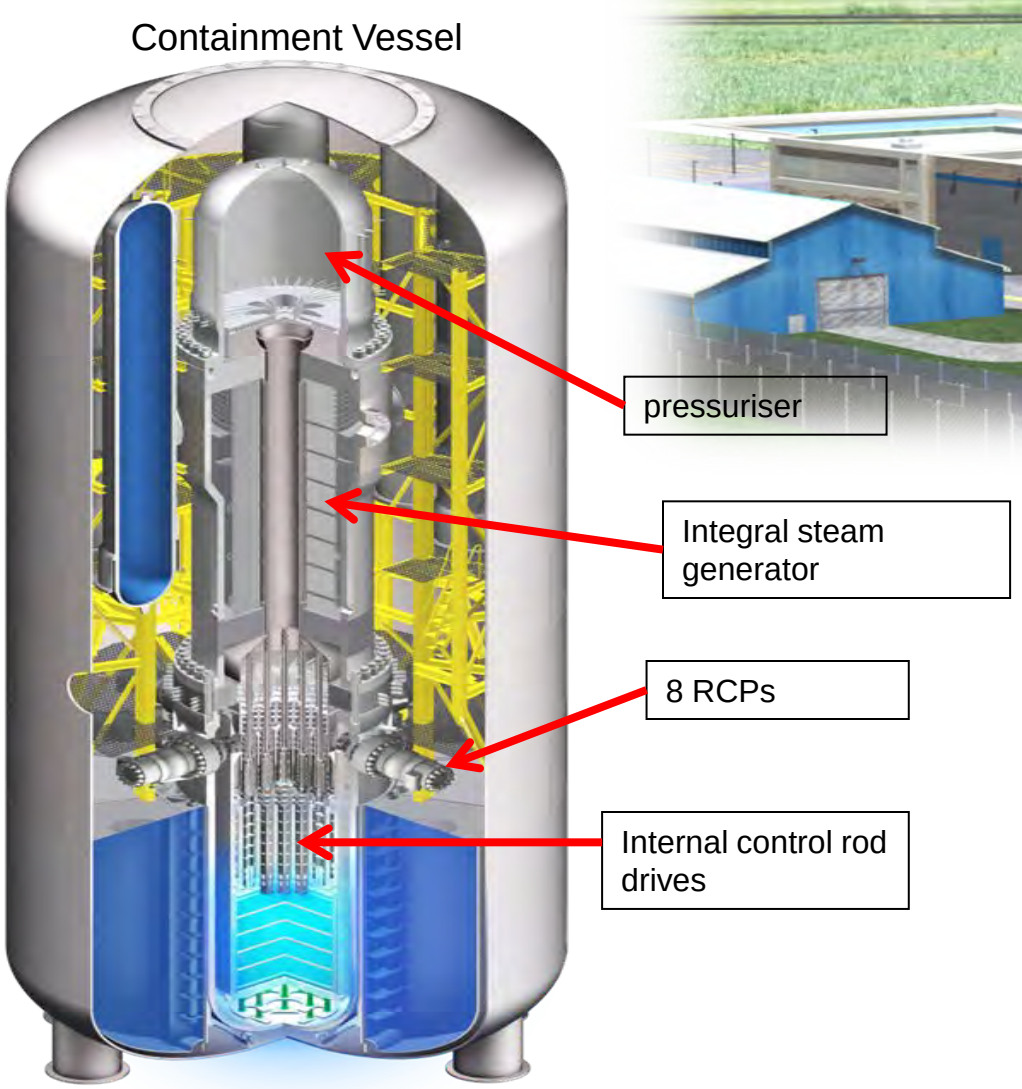
Westinghouse SMR





Westinghouse 225 MWe

Incorporates passive safety systems and proven components of the AP-1000

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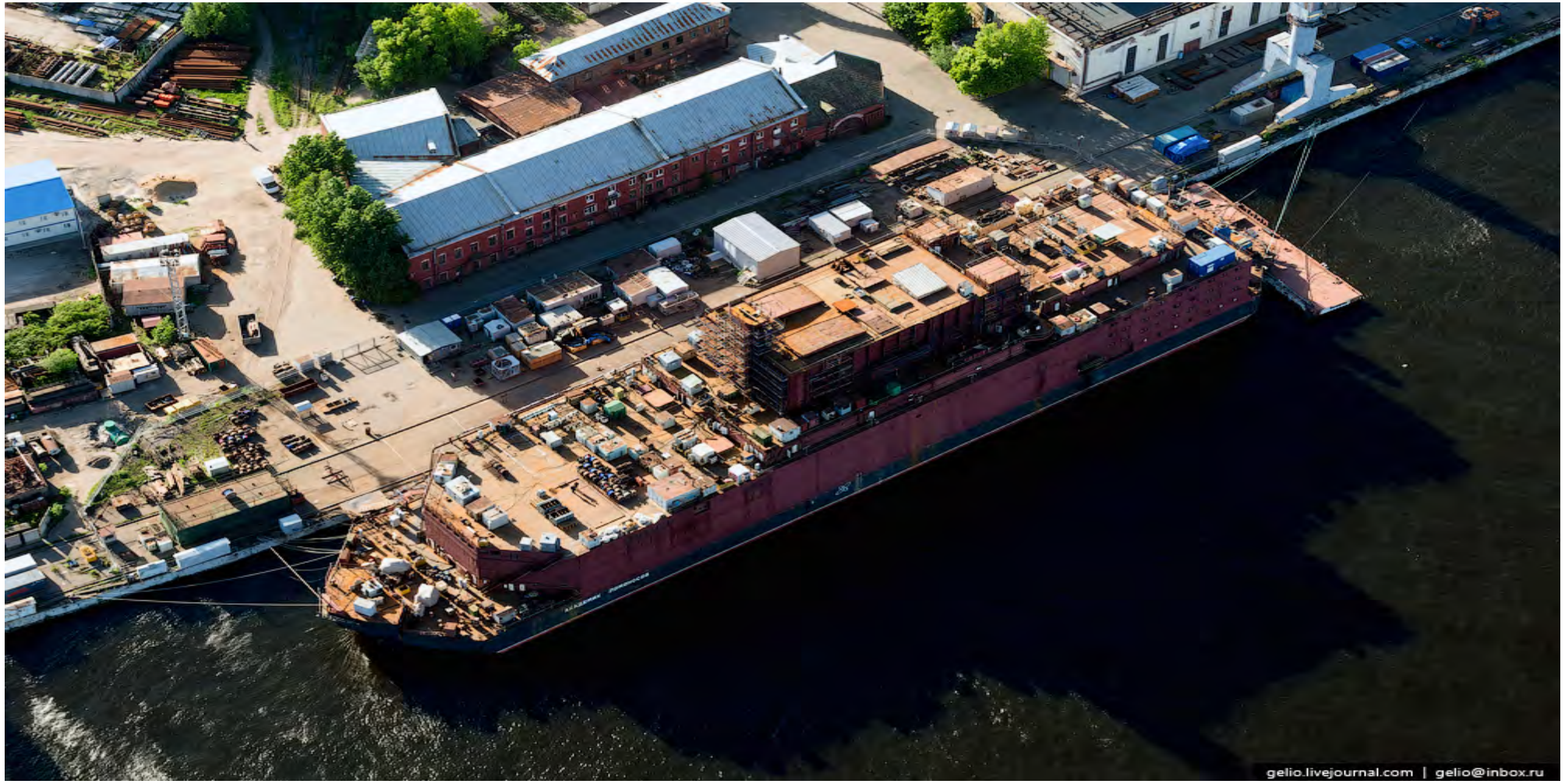
Russian 70 MWe floating nuclear power plant



2 x KLT-40S PWR reactors installed on non-self propelled barge, 140m long x 30m wide, 21,000t displacement

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Image: Rosenergoatom

Sept 2013 reactors installed.
2017 Trials completed at Baltic Shipyard, towed 4,000 km to Murmansk. Fuel loaded, first reactor started up November 2018.
August 2019 towed to Pevek.

Akademik Lomonosov Floating Power Unit

4 steam generators

Primary 12.7 MPa, inlet 280^{0}C, outlet 316^{o}C

Secondary 3.83 MPa, inlet 170^{o}C, outlet 290^{o}C

Akademik Lomonosov at Pevek

Image: TACC

19 December 2019 – connected to the grid, generating electricity

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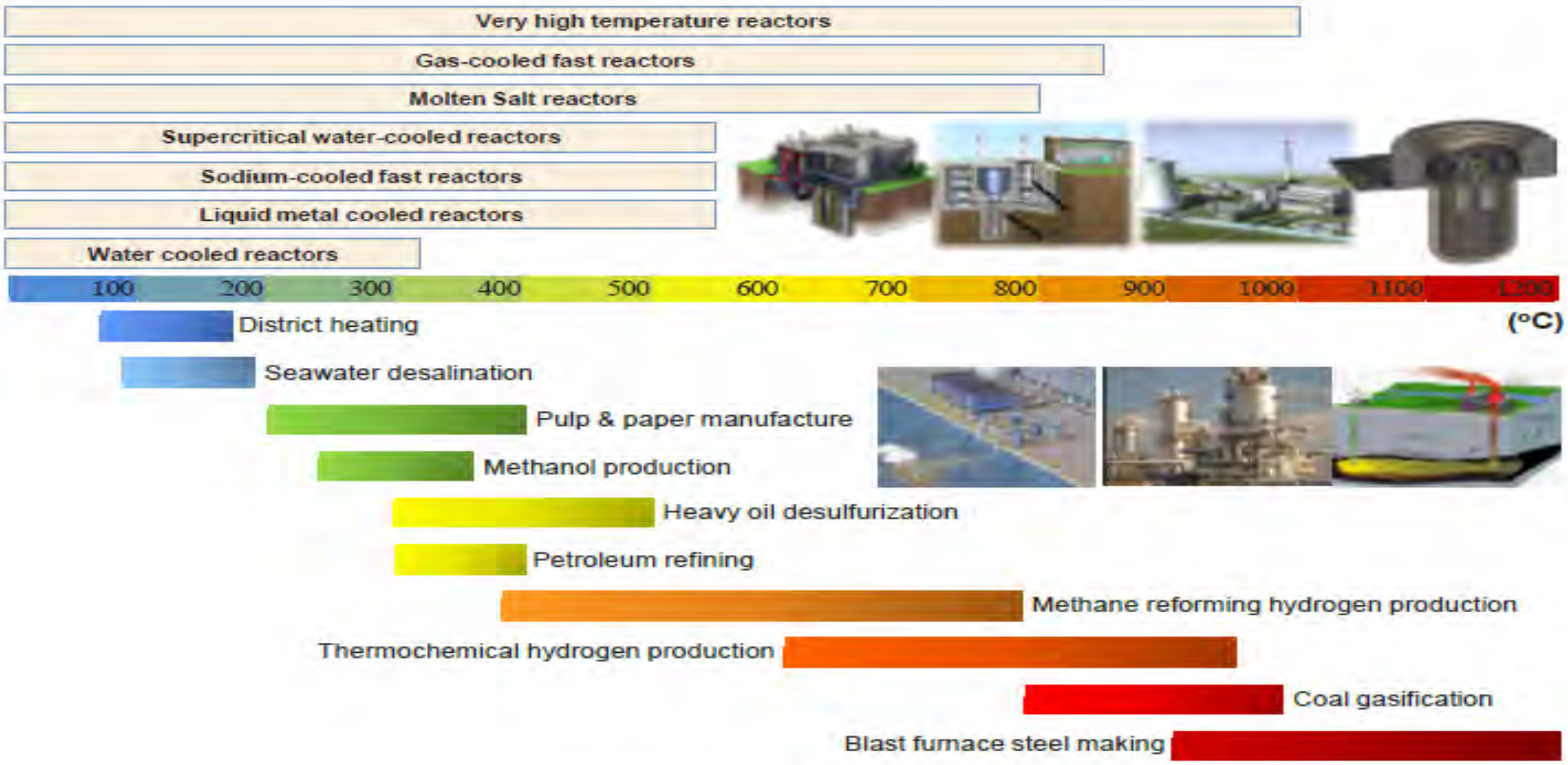
Opportunities for Process Heat



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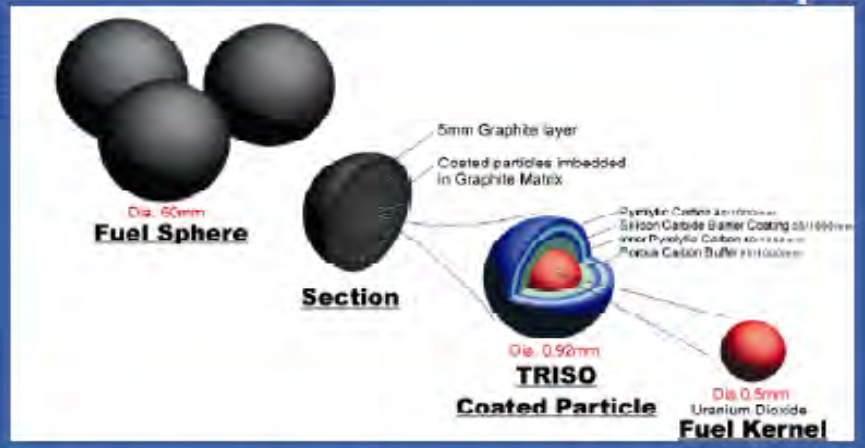
Source: 2016 IAEA SMR Book

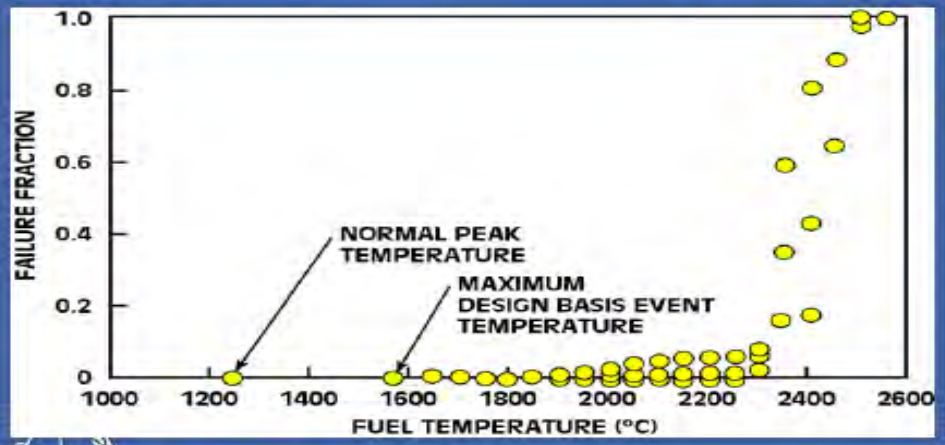
Inherent Safety Approach

VHTR

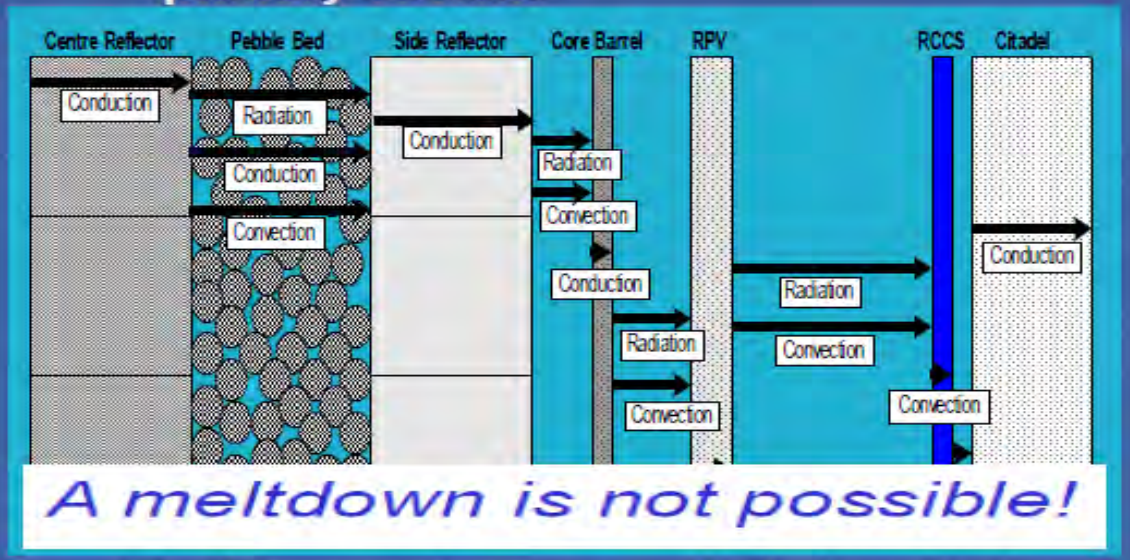
- Ceramic fuel retains radioactive materials up to ~2000˚C



- Coated particles stable to beyond maximum accident temperatures

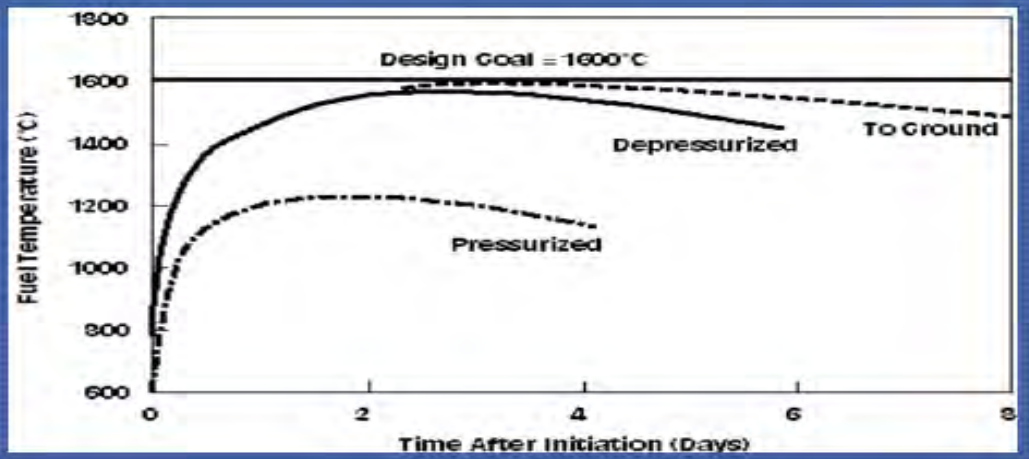


- Heat removed passively without primary coolant

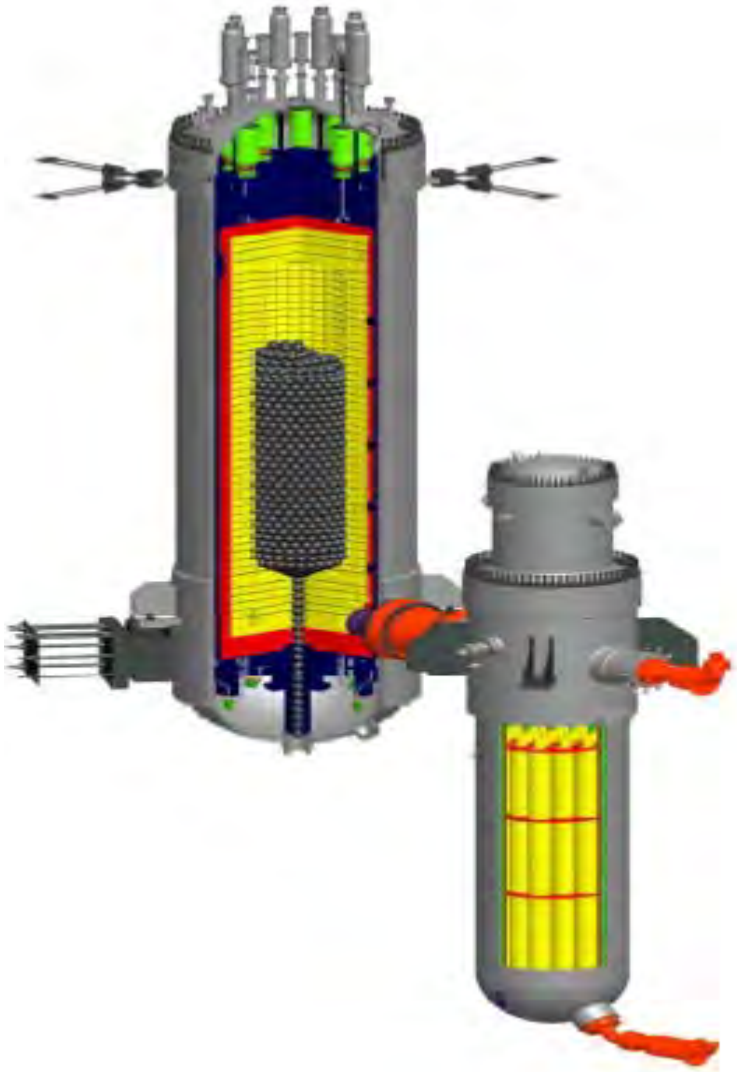


A meltdown is not possible!

- Fuel temperatures remain below design limits during loss-of-cooling events



IAEA



Shandong Shidaowan Plant

Construction commenced December 2012

VHTR

HTR-PM Designs Parameters

Plant electrical power, MWe	211
Core thermal power, MW	250
Number of NSSS Modules	2
Core diameter, m	3
Core height, m	11
Primary helium pressure, MPa	7
Core outlet temperature, ℃	750
Core inlet temperature, ℃	250
Fuel enrichment, %	8.9
Steam pressure, MPa	13.25
Steam temperature, ℃	567

INET

Image: INET

HTR-PM
March 2016

VHTR

Image: China Huaneng

Image: CNEC

HTR-PM reactor vessel
25m high, Weighs 700 tonnes
520,000 fuel spheres

April 2020 Reactor vessels and heat exchangers coupled.
Demonstration plant at Shidaowan, near Rongcheng, Weihai City

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Terrestrial Energy
Integral Molten Salt Reactor (IMSR)

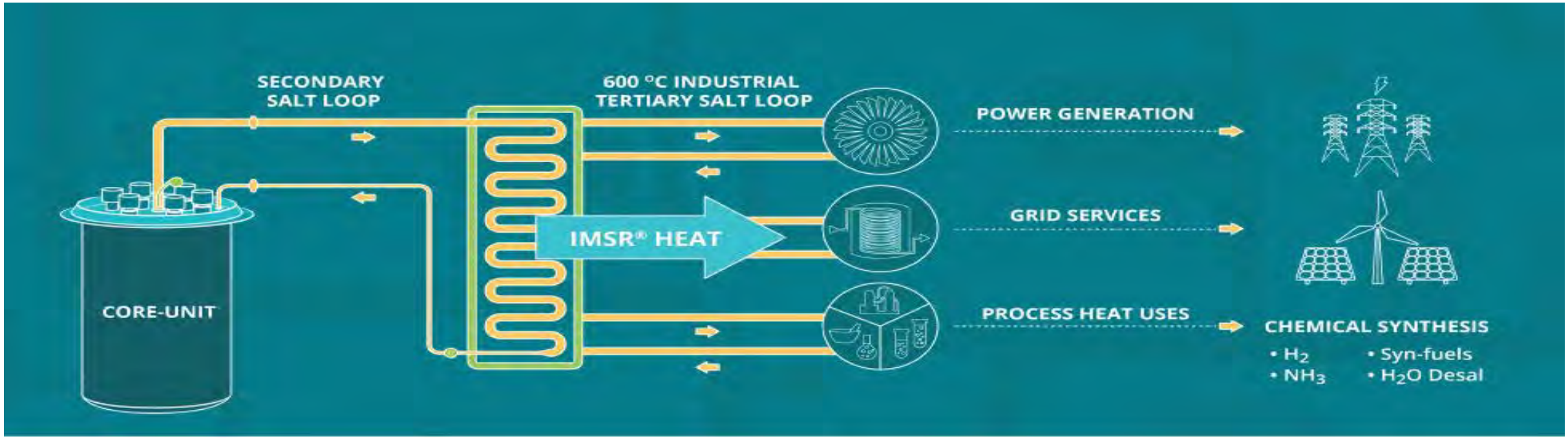

Image: Terrestrial

400 MWTh, 190 MWe, load following capable plus 600°C process heat .
Build in 4 years, 24 hectare site, first deployment 2020's.
Completed first phase of CNSC vendor design review.
LCOE US$50/MWh

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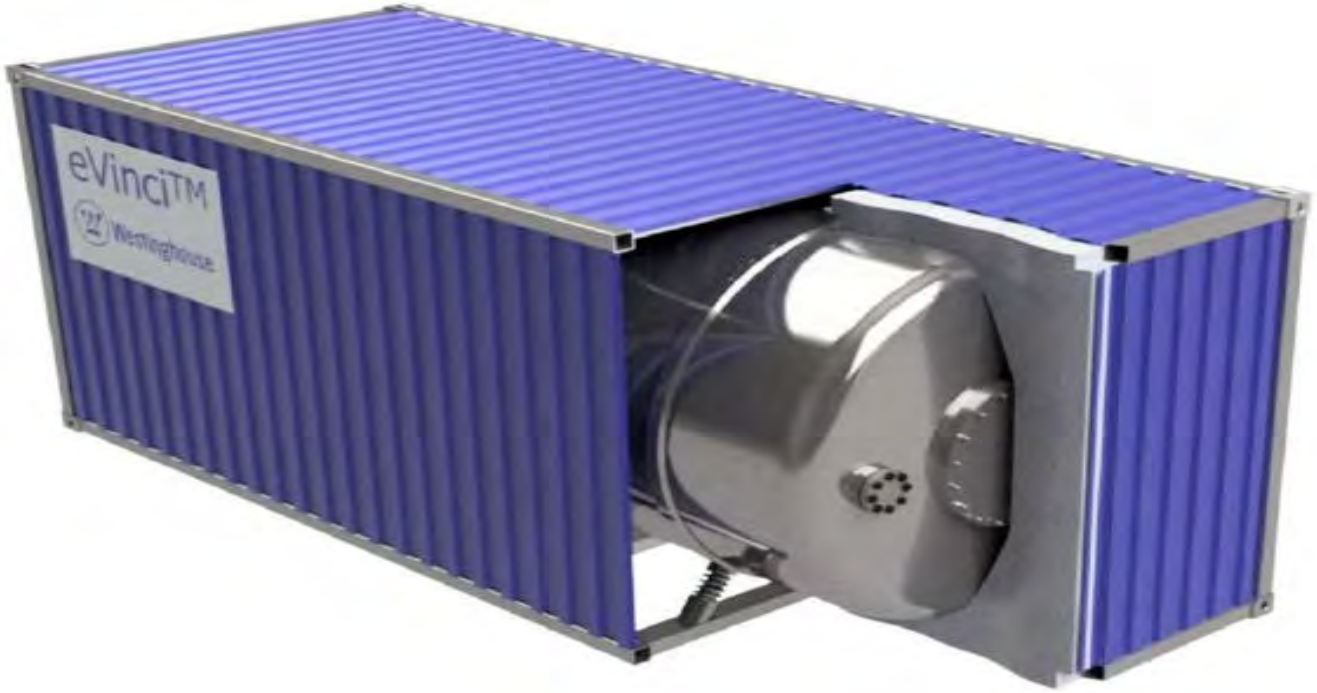
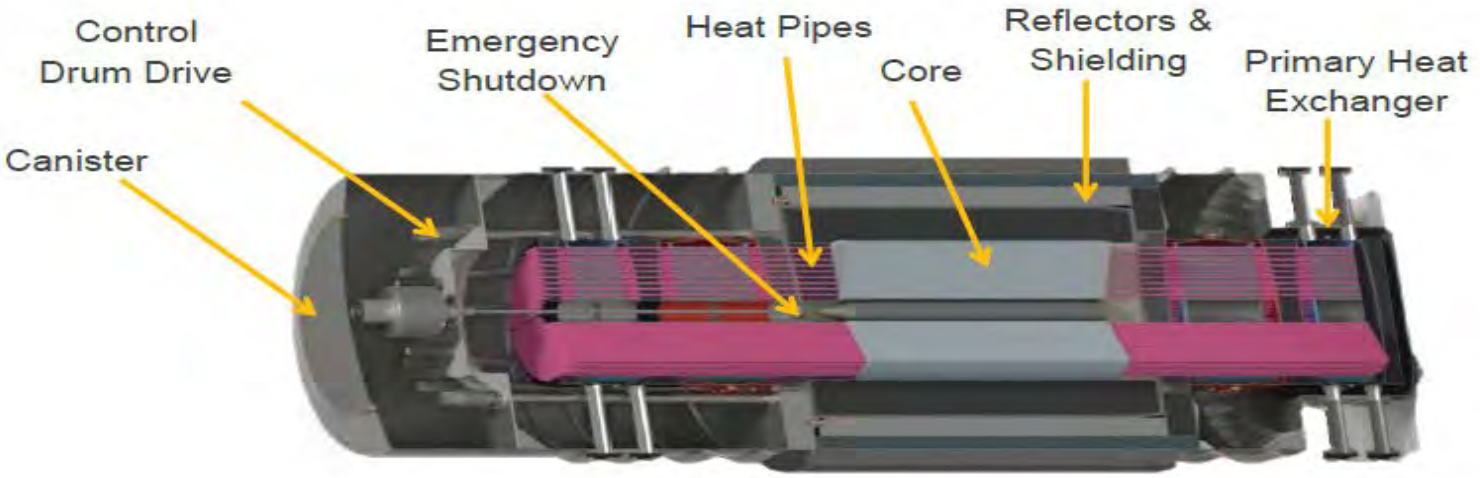
Micro-Reactor



Westinghouse eVinci 1 MWe – 5MWe



10 years without refuelling.
19.75% enrichment

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Images: Westinghouse

Micro-Reactor

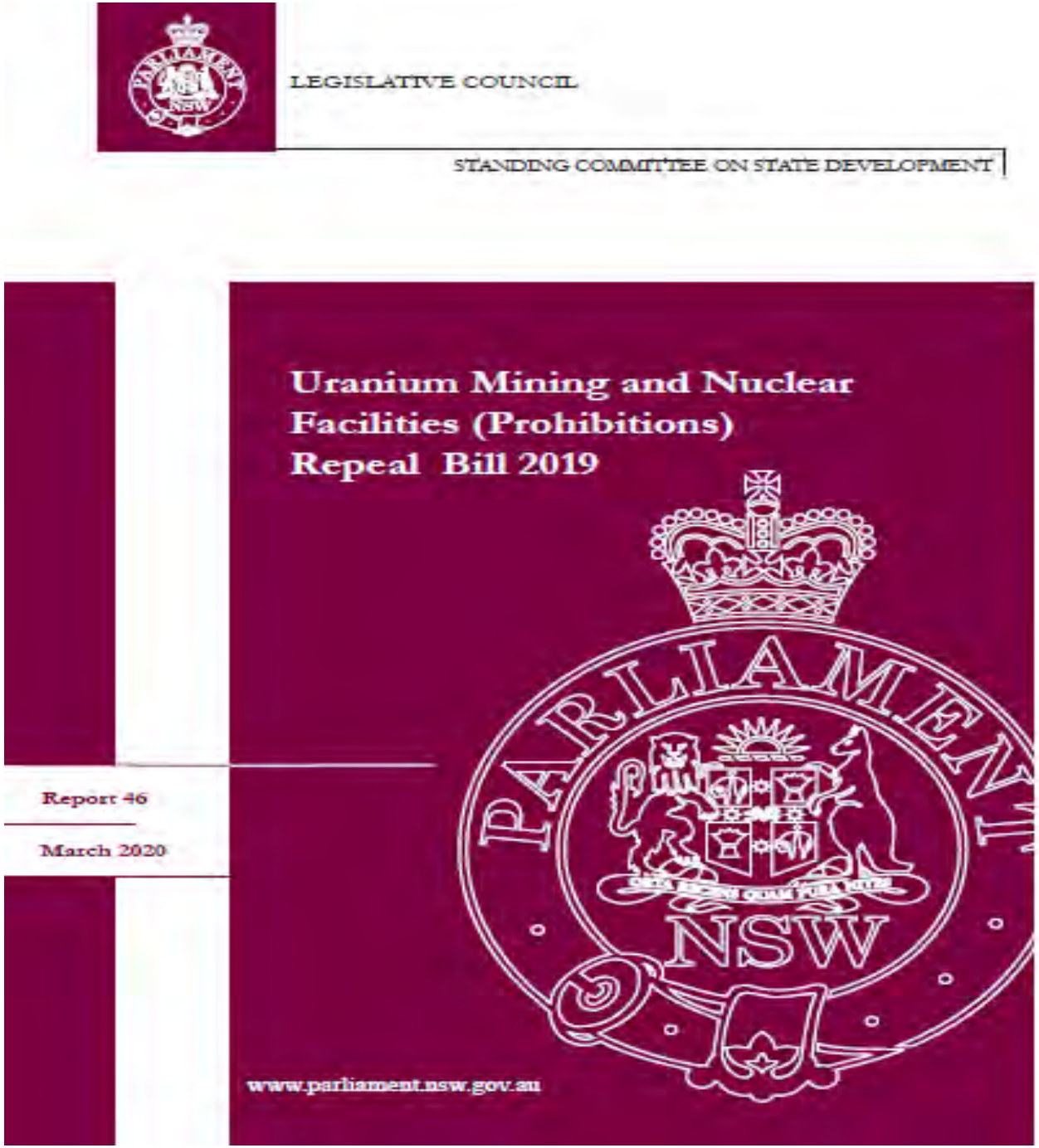
Oklo USA
1.5 MWe Aurora Powerhouse

Sodium cooled reactor, 20 years without refuelling.
Supercritical CO_2 power conversion system
Dec 2019 US DOE granted permit for a demonstration plant at INL
March 2020 – Oklo submitted COLA to NRC , accepted 5 June 2020

Image: Gensier

South Australia Nuclear Fuel Cycle Royal Commission Report 2016

- “The smaller capacity of SMRs makes them attractive to integration in smaller electricity markets such as the NEM in South Australia”
- “Nuclear power, as a low-carbon energy source comparable with other renewable technologies, may be required as part of a lower carbon electricity system.”



NSW Nuclear Inquiry

Prohibitions Act 1986
Repeal Bill 2019 – referred to NSW Standing committee on state development (June 2019).

Final Report (March 2020)
"The committee could find no compelling justifications from an environmental or human safety point of view which would warrant the blanket exclusion of nuclear energy, especially in its emerging small scale applications"

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Conclusions

Deployment pathways for SMRs in Australia:

- Reliable, low emissions electricity generation, independent of the weather
- Larger SMRs for coal-fired replacement
- System frequency control and inertia
- Load following VRE
- Smaller (micro SMRs) for remote locations
- Desalination
- Process heat particularly for hydrogen production

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