Technology options for long term nuclear power development

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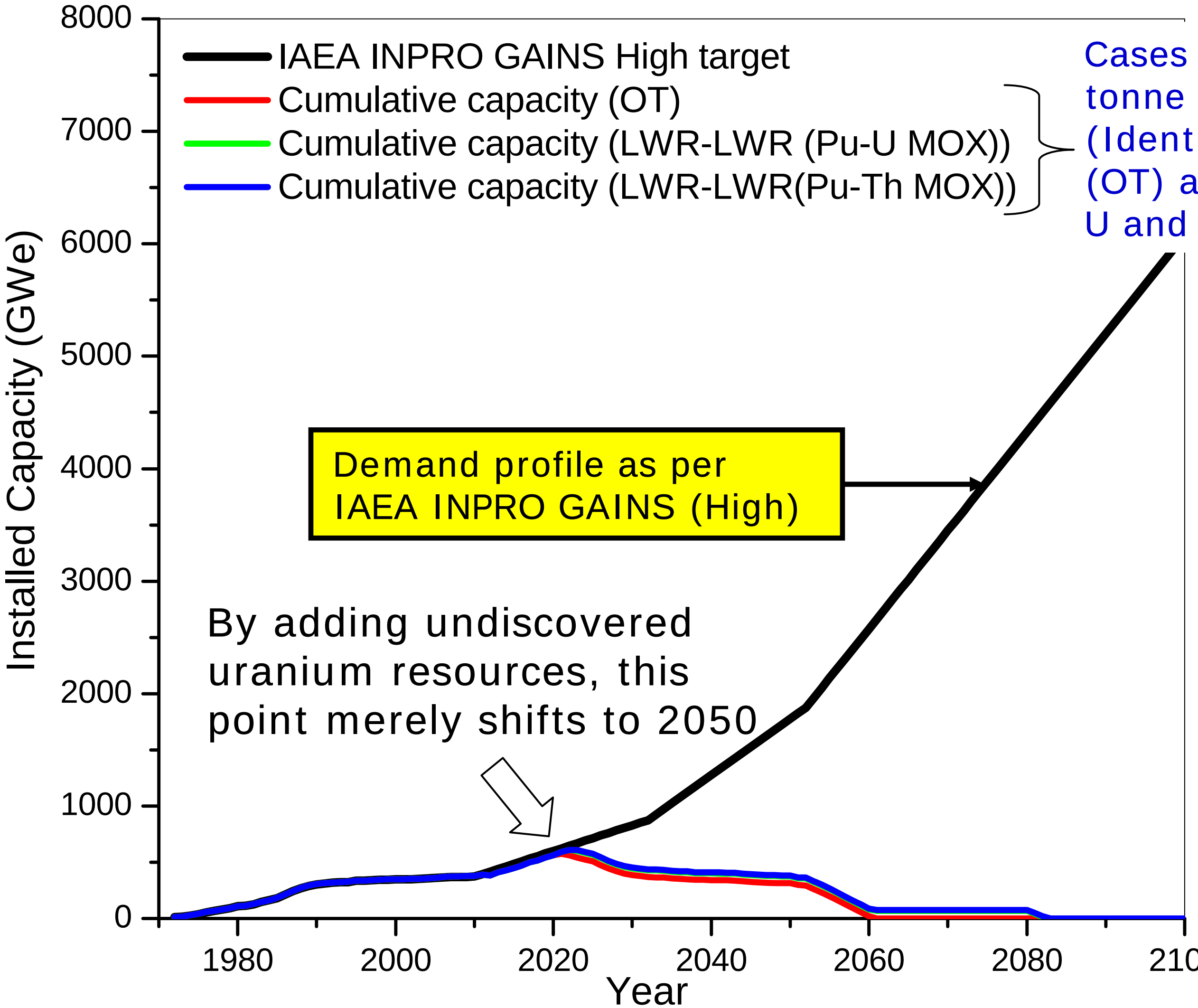
Long term nuclear power development
- The challenge of the numbers.

- A per capita electricity use of about 5000 kWh/year appears to be needed for reaching a state of reasonably high human development. Considering the progressive depletion of fossil fuel reserves, and the urgent need for addressing the global warming related concerns, nuclear energy is expected to substantially contribute to meeting the future global energy requirements.

- Assuming that at least half of the total energy demand may need to be met with nuclear, the world will need between 3000 to 4000 nuclear power reactors of different capacities for electricity generation. The number may at least double with the use of nuclear energy to provide an alternative to fluid fossil fuels.

- A large number of these reactors may need to be located in regions with high population densities and modest technological infrastructure with their sizes consistent with local needs.

Identified resources of uranium in once-through mode will be inadequate to support growth.



Cases with use of 5.469 million tonne natural uranium metal (Identified resources)* in LWR (OT) and LWR-MOX (both Pu-U and Pu-Th)

*:Total resources (Identified + Undiscovered) are 15.969 million tonnes

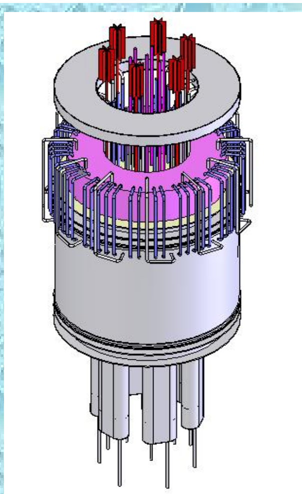
Ref: Uranium 2007: Resources, Production and Demand-The joint report by OECD Nuclear Energy Agency and the International Atomic Energy Agency (RED Book 2008)

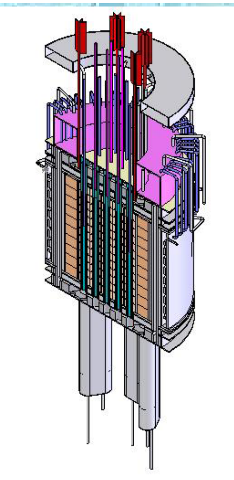
Uranium in open cycle is unsustainable. Recycle of nuclear fuel in high conversion-ratio reactors has to be brought in soon enough.

Selection of technology options for Nuclear Reactors

Near-term	■ Economic competitiveness ■ Proven technologies
Mid/Long-term (Additional considerations)	■ Technology consistent with fuel cycles that support fuel resource sustainability ■ Enhanced levels of safety ■ Technological solutions to address security issues including proliferation concerns ■ Additional, non-power applications

Advanced Heavy Water Reactor



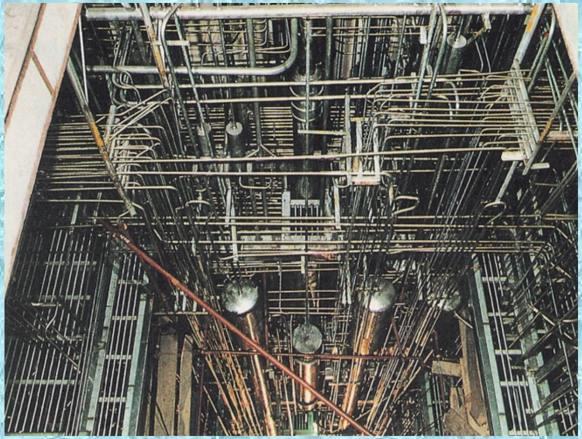


Compact High Temperature Reactor

Selection of technology options for Nuclear Fuel Cycle

Near-term	■ Domestic facilities/reliable supply ■ Economic viability ■ Protection of technologies
Mid/Long-term (Additional considerations)	■ Fuel resource sustainability ■ Environmental sustainability through waste minimisation and disposal strategies

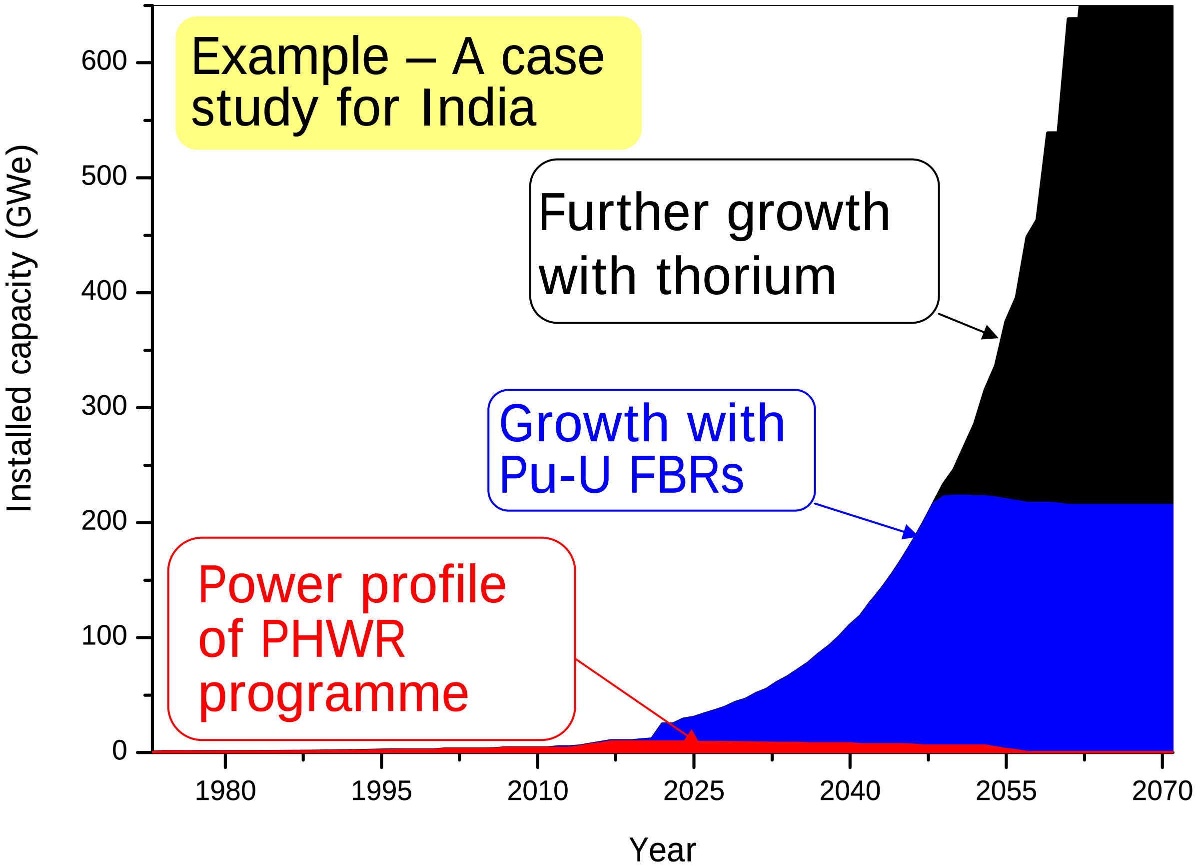
Solid Storage Surveillance Facility



Kalpakkam Reprocessing Plant- in-cell process piping

Cold Crucible Induction Melter : Engineering demonstration facility

Thorium represents at least three times larger energy resource than uranium. Its exploitation requires a proper sequencing of reactor-fuel cycle technologies in the overall programme.



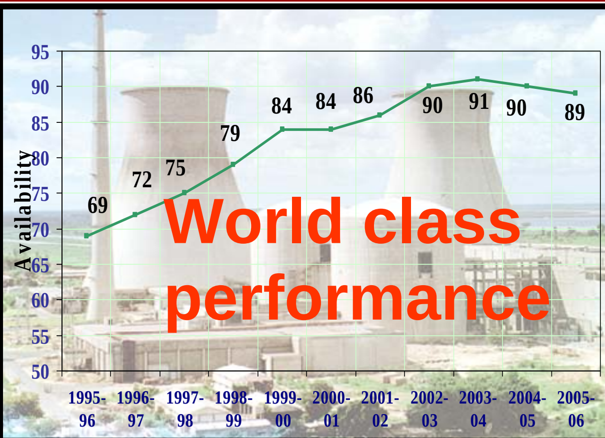
Important attributes of thorium

- Effective burner of Pu, produces ^{233}U
- ^{233}U with ^{232}U, high intrinsic proliferation resistance
- Lower generation of minor actinides
- Thoria – better retention of fission gases, high thermal conductivity, higher melting point

A strategy to achieve required growth profile can be supported through timely deployment of appropriate reactor technologies including FBRs and thorium

The Indian experience

Status of the Indian Three Stage Nuclear Power Programme



Stage – I

PHWRs

- 15 – Operating
- 3 - Under construction
- Several others planned
- Scaling to 700 MWe
- Gestation period has been reduced
- POWER POTENTIAL ≅ 10 GWe

LWRs

- 2 BWRs Operating
- 2 VVERs under construction

Stage - II

Fast Breeder Reactors

- 40 MWth FBTR - Operating since 1985 Technology Objectives realised
- 500 MWe PFBR- Under Construction
- TOTAL POWER POTENTIAL ≅ 530 GWe (including ≅ 300 GWe with Thorium)

Stage - III

Thorium Based Reactors

- 30 kWth KAMINI- Operating
- 300 MWe AHWR- Under Development

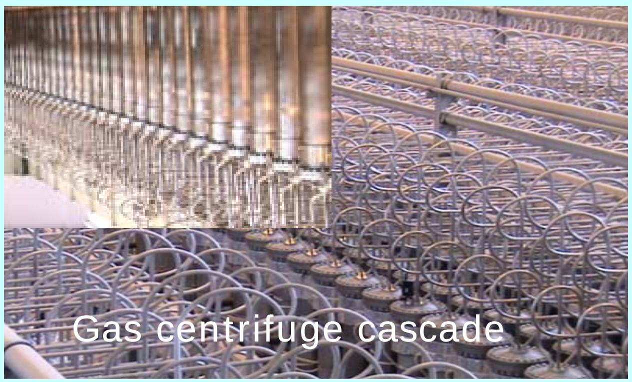
POWER POTENTIAL IS VERY LARGE

Availability of ADS can enable early introduction of Thorium on a large scale

Infrastructure for front and back end including heavy water


Uranium mining

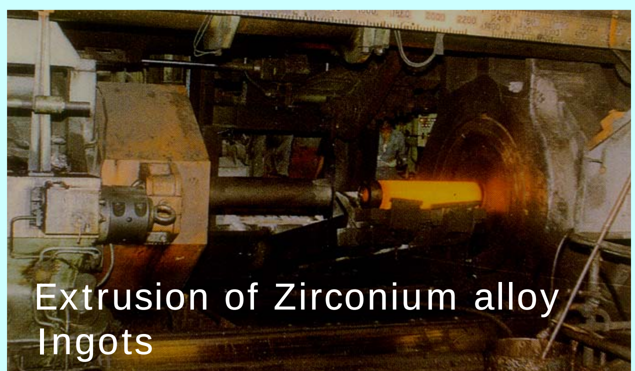

Uranium purification through Slurry Extraction System


Gas centrifuge cascade


Assembling of PHWR Fuel Bundles

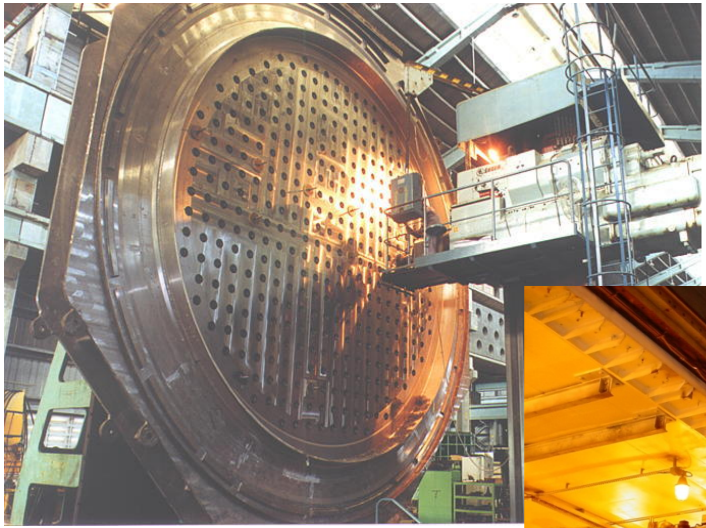

Pu-U Carbide Fuel Fabrication Facility (for FBTR)

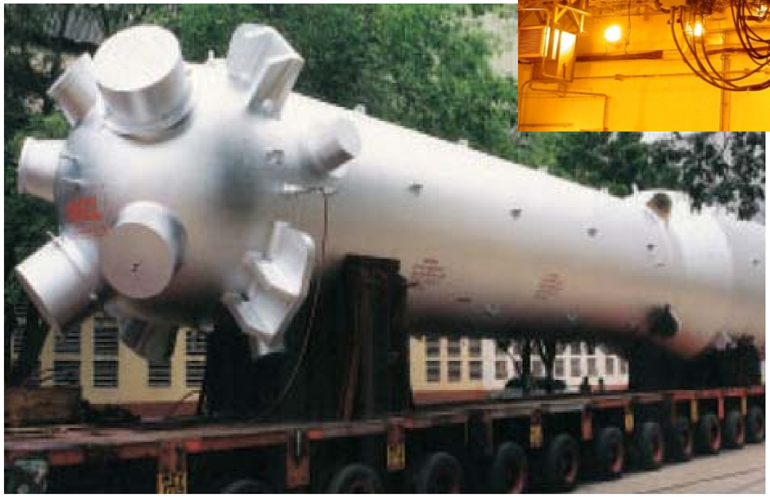
Spent fuel storage

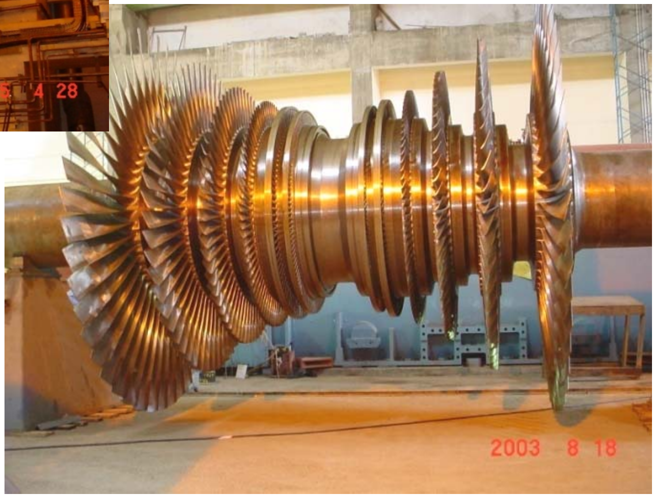

Extrusion of Zirconium alloy Ingots


Heavy water plant Manuguru

Equipment supply chain







Erection of major equipment for PHWRs

Steam Generator Erection

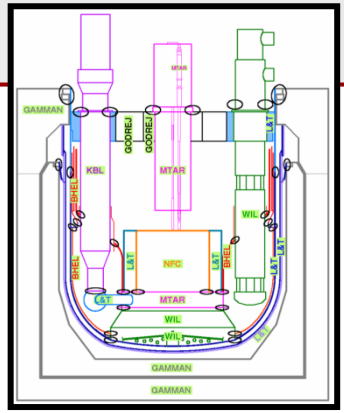
Erection of

Turbo Generator

End Shield Erection

Calandria Erection

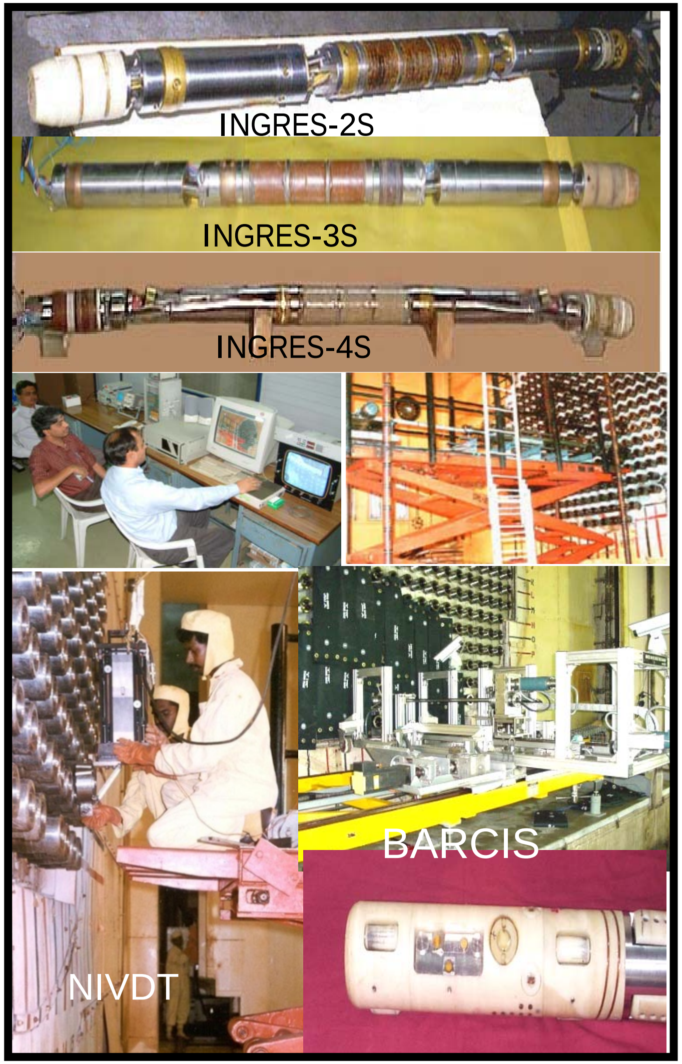
Construction of the PFBR: Status



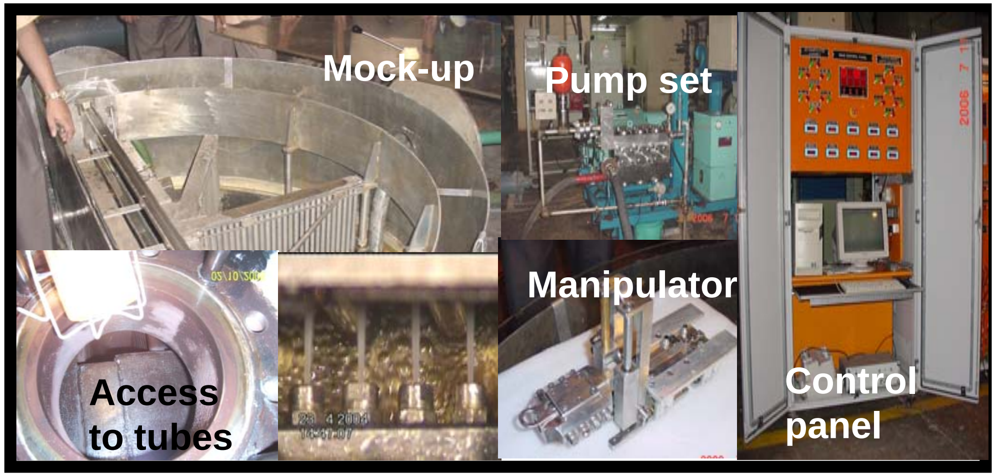
- Technology with strong R&D backup
- Manufacturing technology development completed prior to start of project
- Capability of Indian industries to manufacture high technology nuclear components demonstrated (main vessel, safety vessel, steam generator, grid plate)

PFBR will be commissioned by Sept 2010

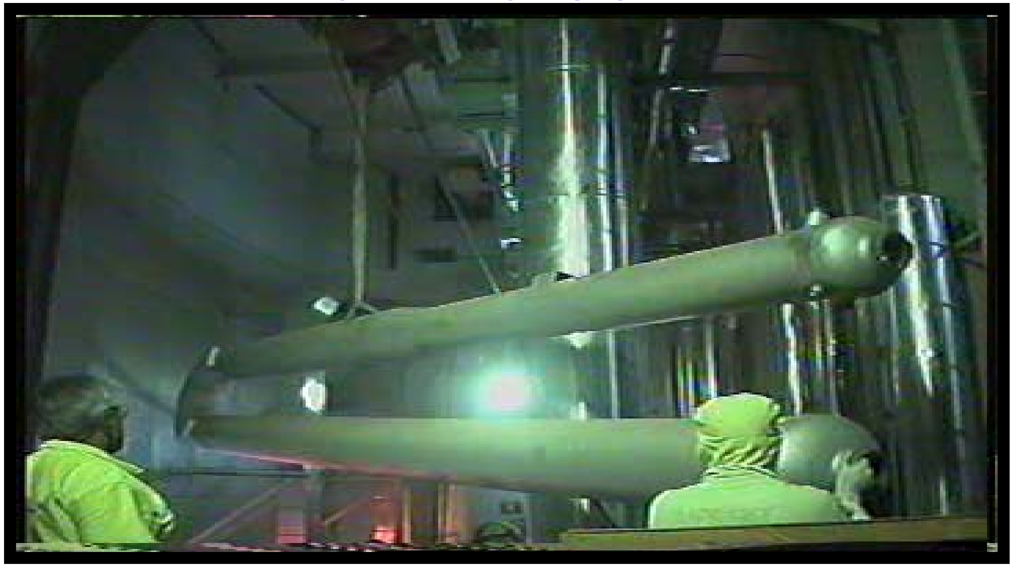
Inspection, maintenance and replacement of major equipment and components



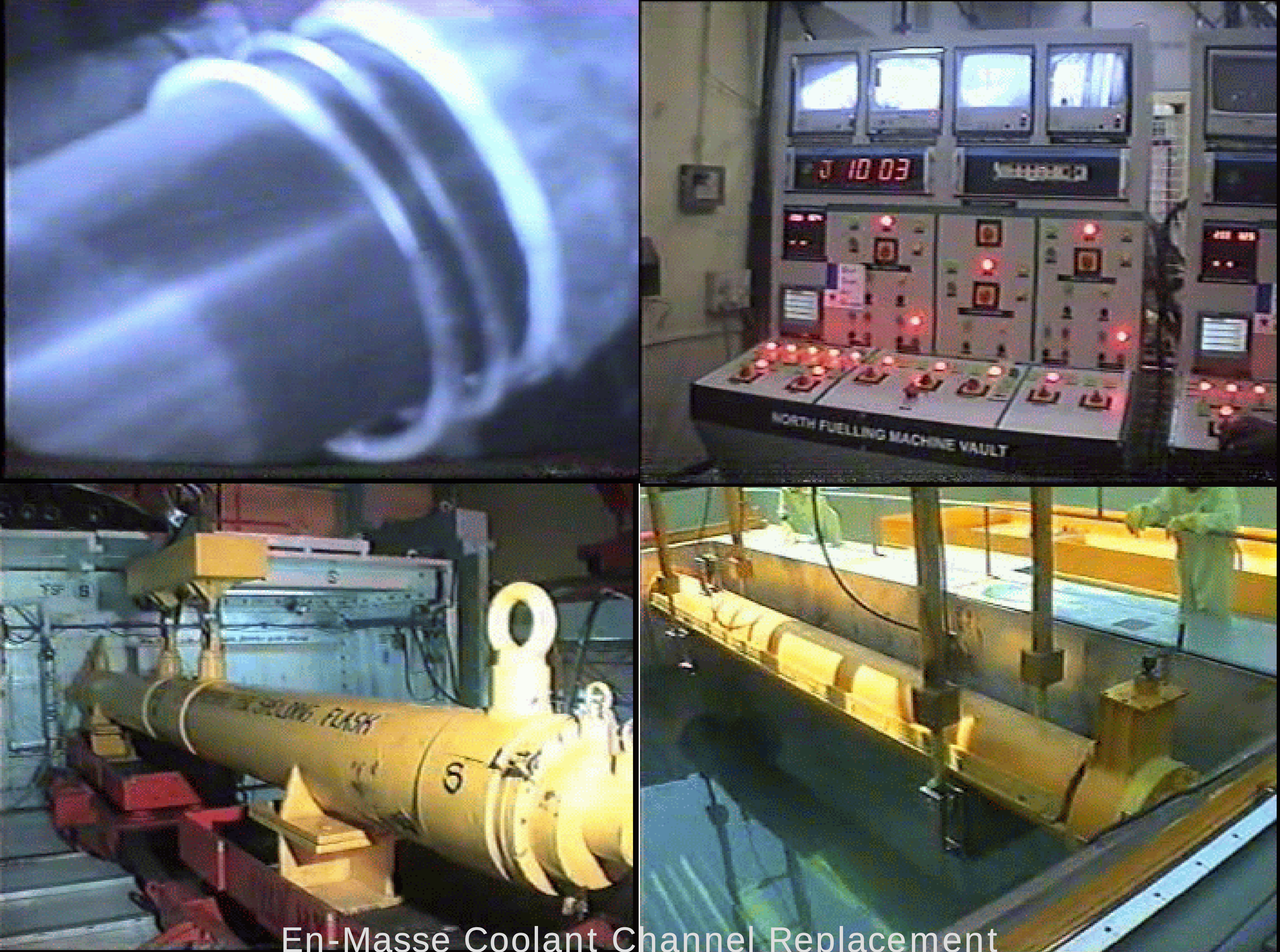
Tools for life management of coolant channels



Sludge lancing equipment



Replacement of Steam Generator- Hair pin heat exchanger in MAPS

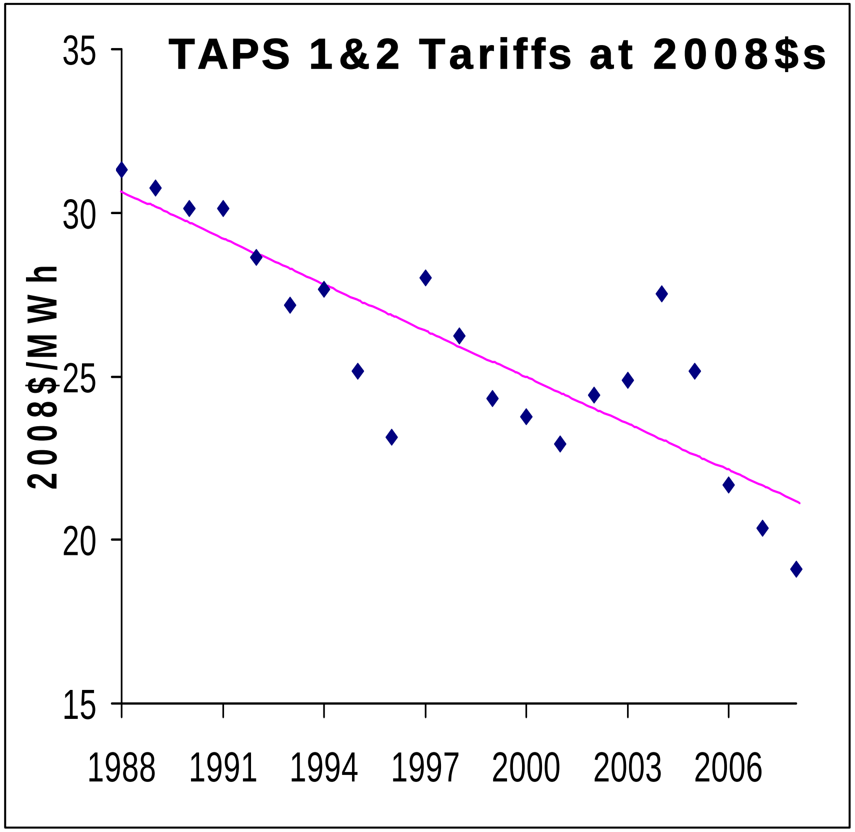


En-Masse Coolant Channel Replacement

Competitive economics of Indian reactors

	Indian PHWRs (700 MWe)	Global range
Capital Cost	1700* $/kWe	2000-2500 $/kWe
Construction period	5-6 years	5-6 years
UEC $/MWh	60	60 - 70

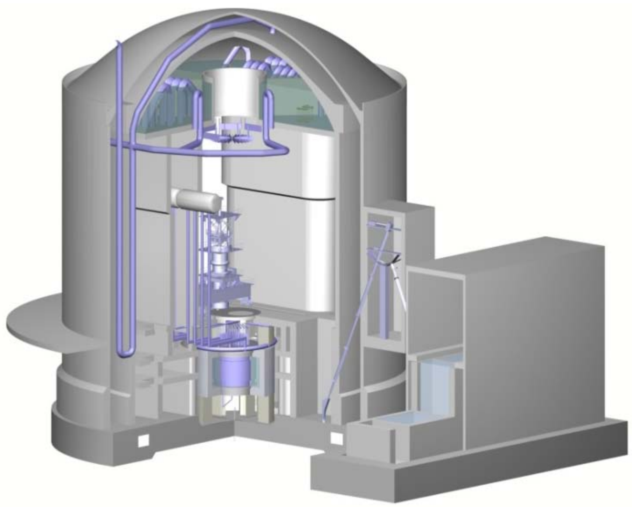
Capital Cost of recently completed units	
TAPS – 3 & 4 (540 MWe)	Rs. 58850* million ~ 1200* $/kWe
Kaiga – 3&4 (220 MWe)	Rs. 26000* million ~ 1300* $/kWe



** Cost figures pertain to the Indian domestic context. In the international context these figures will be location dependent.*

The Indian Advanced Heavy Water Reactor (AHWR)

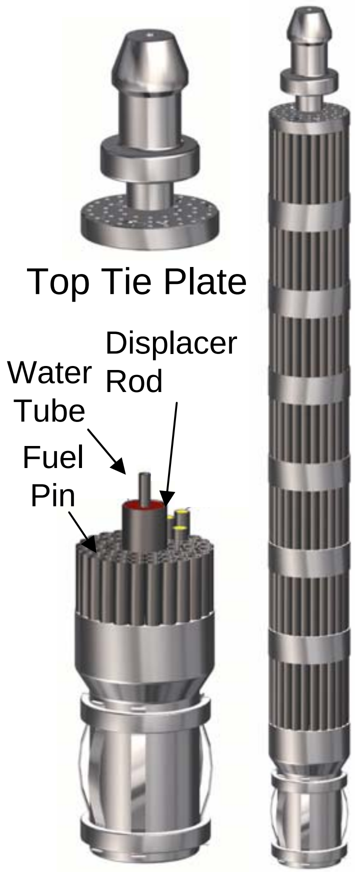
AHWR is a 300 MWe vertical pressure tube type, boiling light water cooled and heavy water moderated reactor using ^{233}U-Th MOX and Pu-Th MOX fuel.



AHWR can be configured to accept a range of fuel types including enriched U, U-Pu MOX, Th-Pu MOX, and ^{233}U-Th MOX in full core

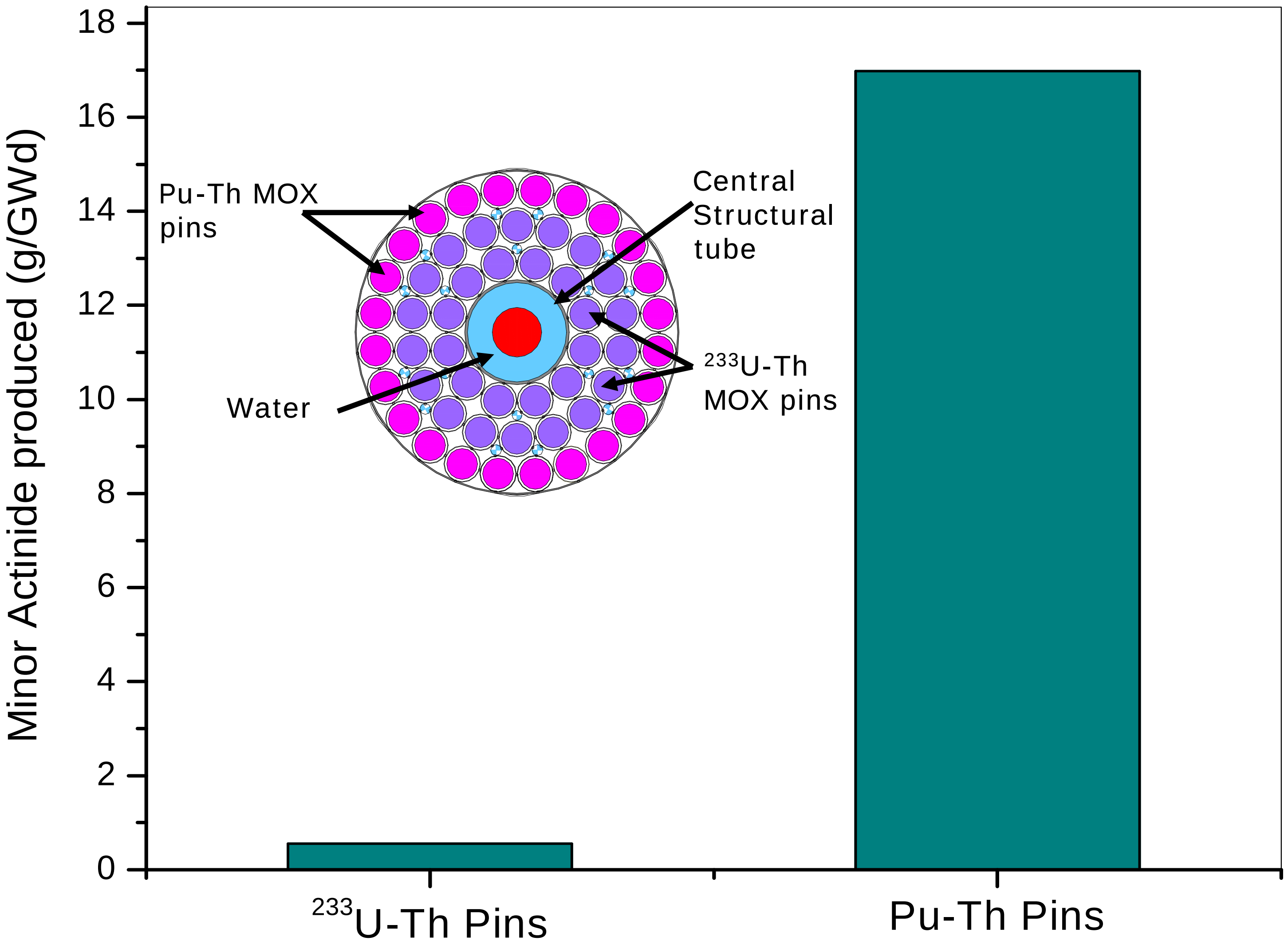
Major design objectives

- 65% of power from Th
- Several passive features
  - 3 days grace period
  - No radiological impact
- Passive shutdown system to address insider threat scenarios.
- Design life of 100 years.
- Easily replaceable coolant channels.

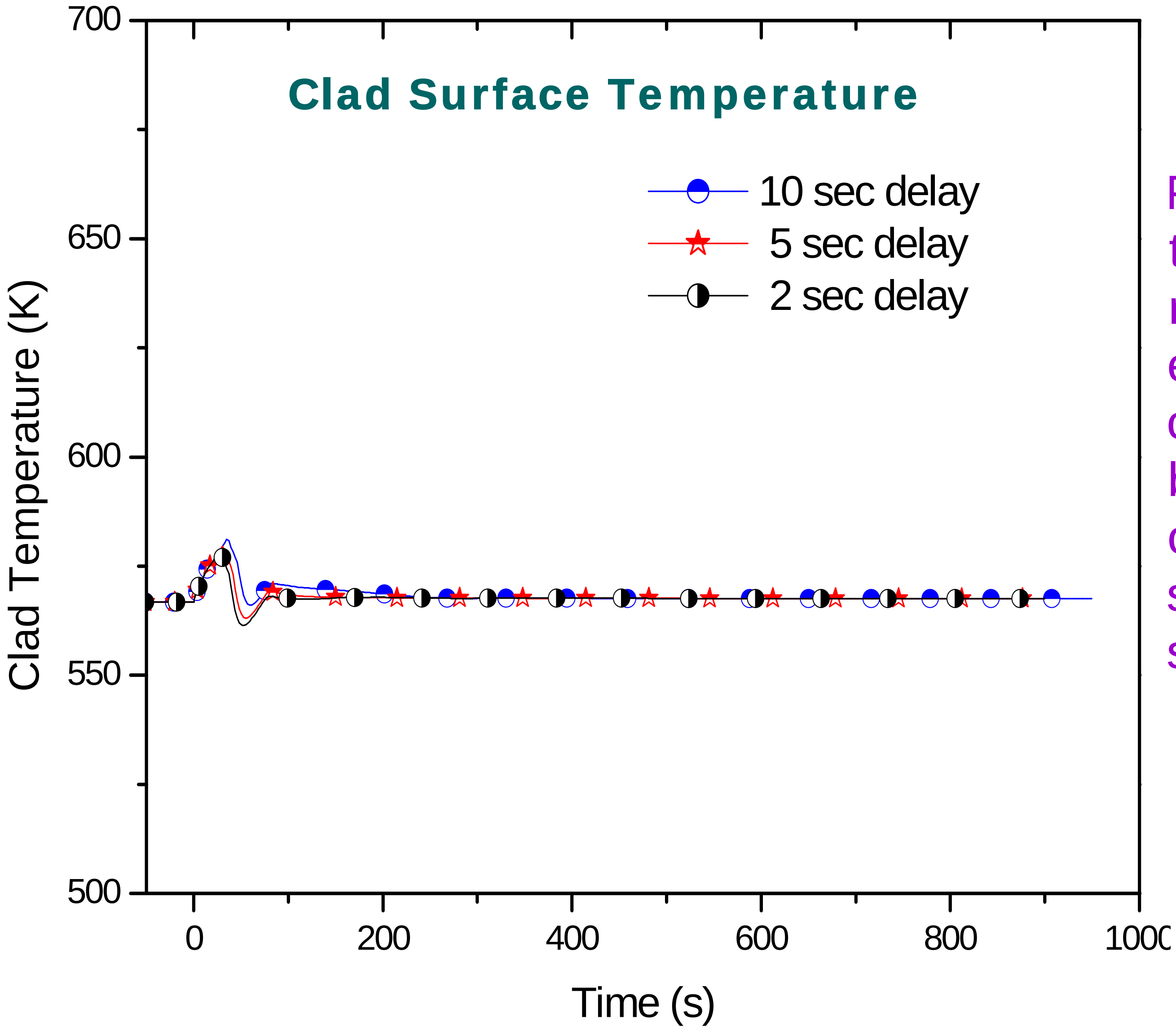


AHWR Fuel assembly

Minor actinide production in the Pu-Th and the ^{233}U-Th bearing pins of fuel used in the current design of AHWR



Transients following station black-out and failure of wired shut-down systems



Peak clad temperature hardly rises even in the extreme condition of complete station blackout and failure of primary and secondary shutdown systems.

Conclusion (1/2)

- Globally, the technology options for long-term nuclear power development need to be based on a scientific approach to attain sustainability of nuclear fuel resources and environment even while addressing, enhanced global reach and volume of deployment of nuclear energy.

- Similarly, concerns relating to safety, security and proliferation issues also need to be handled through technological means. This, perhaps, is the only way for sustainable management of these issues.

- The Indian nuclear programme is consistent with the above objectives.

Conclusion (2/2)

- At present, India has robust technologies in all aspects of nuclear energy.
- India is operating the world's smallest power reactors. The performance of these reactors is competitive with the larger sized reactors inspite of the latter having the benefit of economics of scale.
- The Indian industry has adequate resources and expertise and India can become a manufacturing hub for the nuclear industry. This could include not only reactors but also supply of fuel.

Thank you for your attention.