Small & Micro Nuclear Reactors for Vikshit Bharat

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100 GW N-Power is a Gateway to Vikshit Bharat

Total energy requirements for Vikshit Bharat will be around or even more than 30000 TWh/year.

100 GW is hardly (~800 TWh/year)

It is an excellent starter – before the Main Course – Let us plan the Main Course also

Strategic Planning for Nuclear Electricity for 100 GW

- Large number of Coal Plants to Retire – assuming no replacement of coal to coal to safeguard against climate change

- Captive Power plants in India have increased from 40 GWe in 2012 to almost 80 GWe in 2020 (~2 times in 8 years). It is envisaged that steel will grow by 8 times and cement by 3 times in next 20 years. Thus, energy demand through captive power plants is estimated to be approx. 400 to 500 GW by 2070.

- Energy Security from home to mobility:

LPG to Nuclear Electricity – Oil to Nuclear Evs (today nuclear electricity cost is comparable to oil & LPG)

- 7300 cargo Ships of India account for over 50% of the total fuel consumption in the maritime industry.

- By 2047, India's data center capacity is projected to require approximately 35 GW of power to support rapid AI and cloud infrastructure growth,

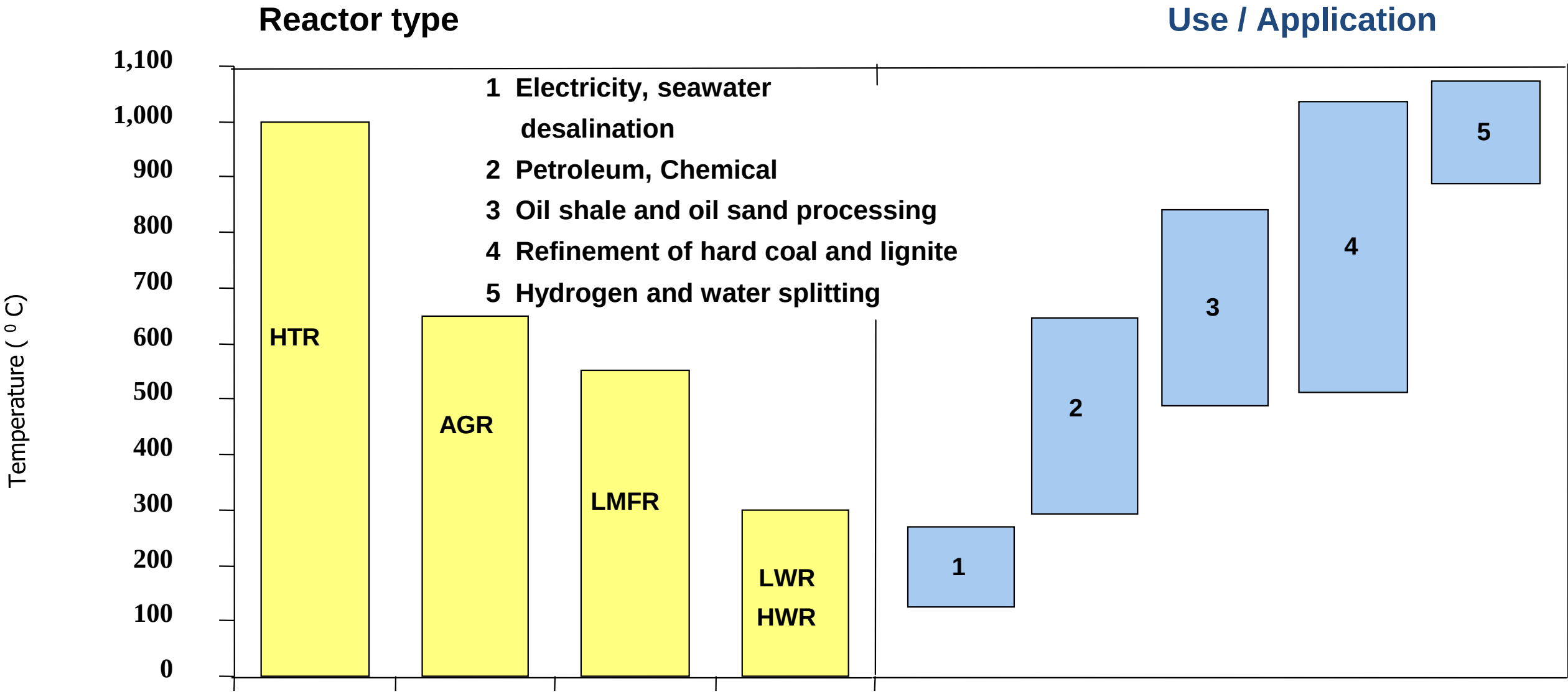
What are the Limitations of Large Size Gen III & Gen III plus technologies?

- **Cost – Capex – too large for many utilities to step into nuclear**
- **LCOE – unknown – everytime there is debate**
- **Public Acceptance for Safety – Chernobyl & Fukushima –Core melt & hydrogen issues still remain**
- **Fuel supply security – Who will assure**
- **Supply chain – Who will invest to establish**
- **700 MW PHWRs – Today only Government Organisations such as NFC or HWB make supply critical nuclear equipment and heavy water– when private & PSUs will enter – how this will be established?**
- **Management of waste – each gram of irradiated uranium to be stored for several years at the plant site before DAE takes it back– PHWR volume of waste is very large**

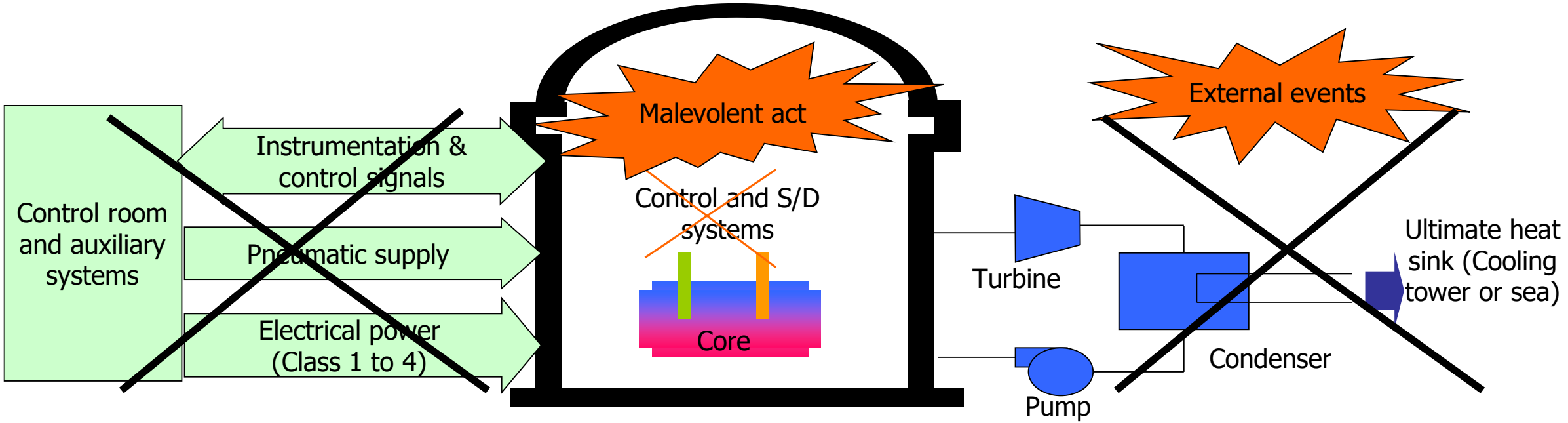
Getting a Green Site – Biggest Challenge

- **Acquiring green sites in India – qualifying seismic conditions - no seismic fault for 5 km radius – where to get???**
  - large population density of India
  - Requirement of ExZ (1 km rad), EPZ (16 km rad) to meet dose criteria of large plants
  - Coastal sites – availability is poor
  - Interior India – water availability, seismic zone qualification, seismic faults

Nuclear power: Looking for temperatures not just electricity



Are Small & Micro Reactors the Answers – The Most Important Call - Safety & Security against external & internal threats

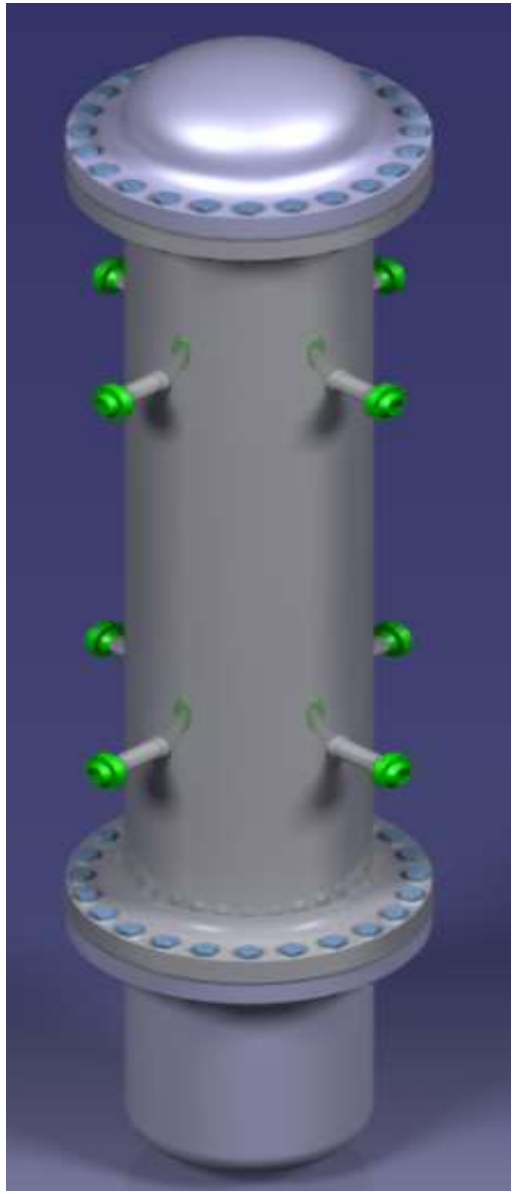


- No unacceptable radiological impact outside the plant boundary with
  - (a) Failure of all active systems, and
  - (b) Failure of external infrastructure to provide coolant, power and other services, and
  - (c) Malevolent acts by an insider, one of the consequences of which is the failure of instrumentation signal initiated shutdown actions, and
  - (d) Inability of plant operators to manage the events and their consequences, for a significantly long time.

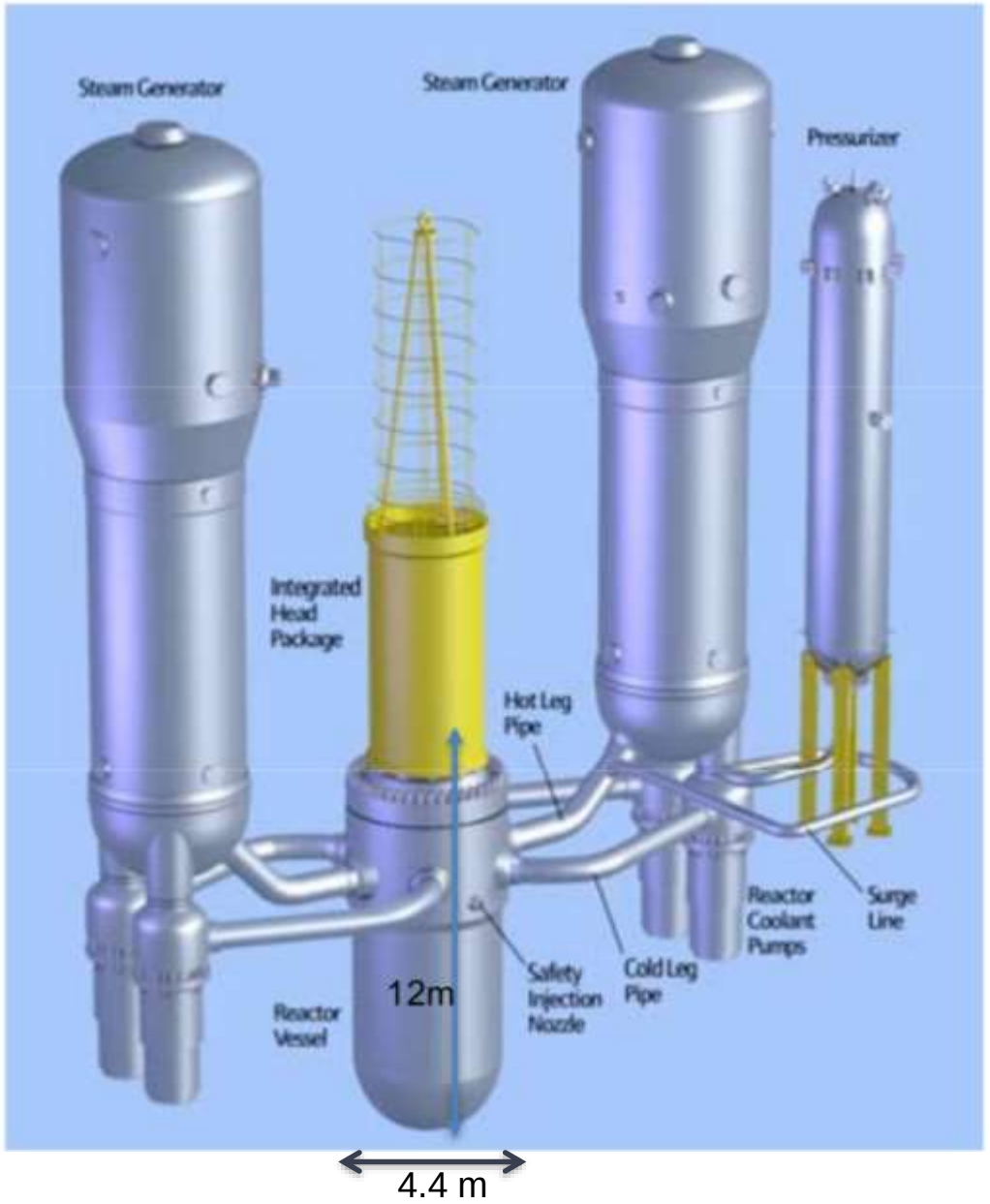
What SMRs We look for?

Integral SMR – a single product from factory – very critical for inherent safety & accelerated deployment

- **Every reactor below 300 MWe is not an SMR**
- **Has to be resilient against internal or external sabotage**



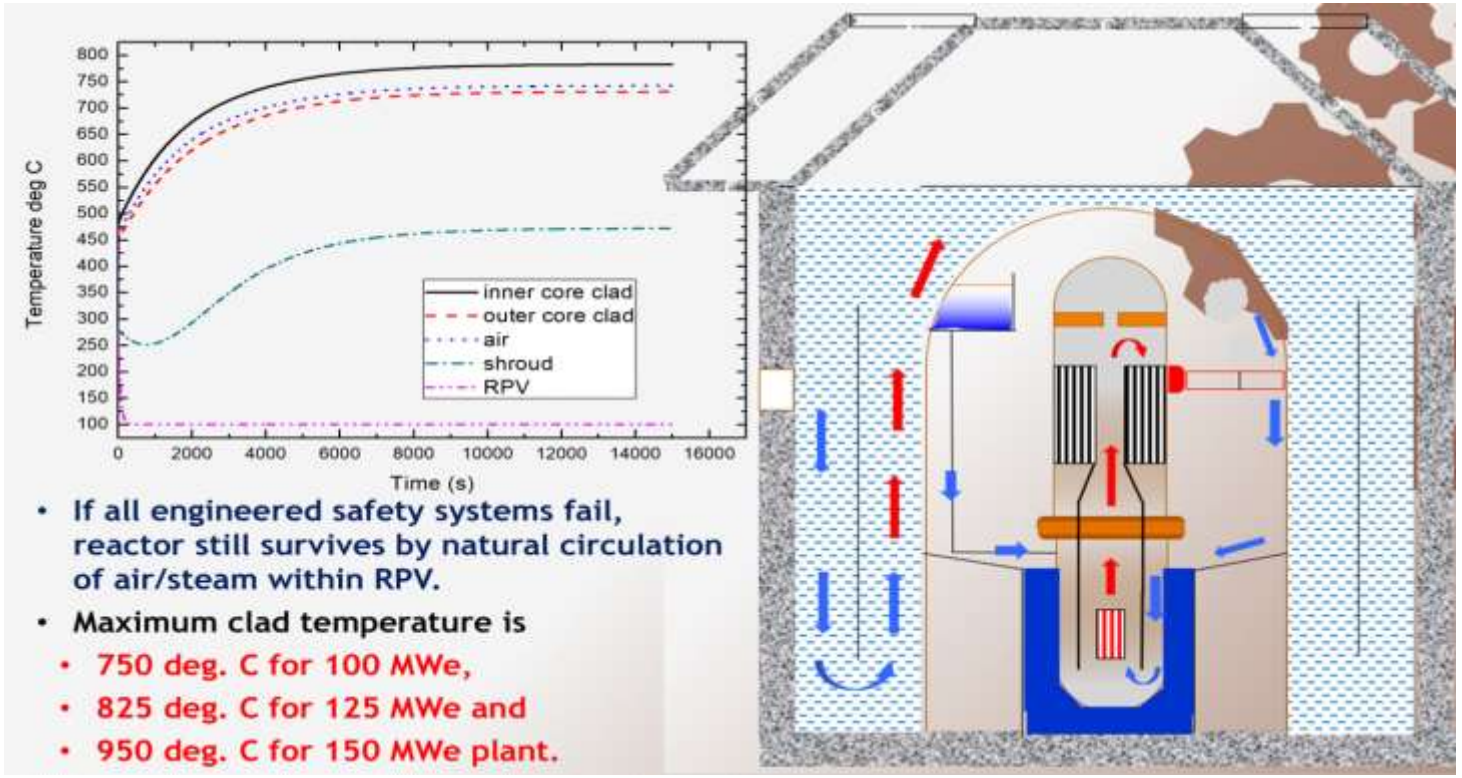
SMR – PWR technology based



Conventional PWR

Enhanced Safety & Security to accomplish no ExZ or EPZ requirement:

- Proof of Plant Boundary as ExZ Boundary and no EPZ - is required to qualify to put in a public domain such as in a Captive Plant
- Proof of no core melt or hydrogen production in extreme event



SMRs for India - Whether Imported or Domestic

- Domestic manufacturing – 100% localization
- Possible to transport by rail or road – FOR INTERIOR INDIA
- Minimum site work, mass production – target 36 months from FPC to Grid connection

SMRs for India - Whether Imported or Domestic

- **Should qualify to be sited anywhere (high Seismic design basis)**
- **Dry cooling**
- **Flexibility to use Thorium fuel**
- **Complying to Closed fuel cycle**

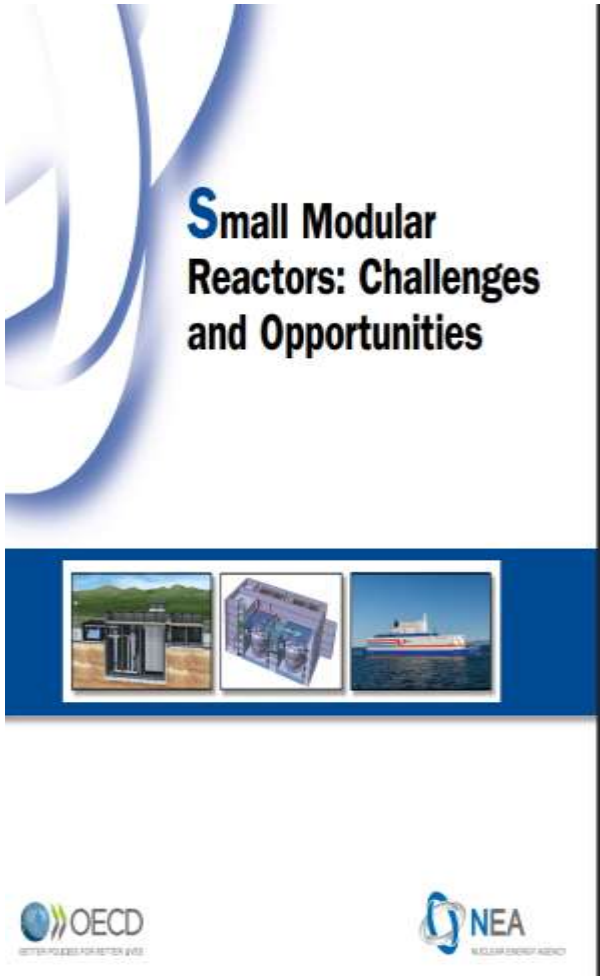
SMRs third party liability – May be excluded

5.2. Nuclear third party liability and SMRs

The international conventions governing nuclear third party liability are:

- the Paris Convention on Third Party Liability in the Field of Nuclear Energy ("Paris Convention" or PC),[11] which will soon be amended by a 2004 Protocol yet to enter into force ("Revised Paris Convention" or RPC);[12]
- the Vienna Convention on Civil Liability for Nuclear Damage ("Vienna Convention" or VC);[13]
- the Vienna Convention as amended by the 1997 Protocol ("Revised Vienna Convention" or RVC);[14]
- the Convention on Supplementary Compensation for Nuclear Damage (CSC).[15]

SMRs are included in the definition of "nuclear installation" provided in the conventions, which covers "reactors other than those comprised in any means of transport".[16] Having regard to the nature of the nuclear installation involved and to the likely consequences of a nuclear incident originating therefrom, the conventions (except for the Vienna Convention) allow countries to establish a lower amount of liability for that installation, provided that in no event shall any amount so established be less than the amounts provided in the conventions for low-risk installations.[17] The aim of this option is to avoid burdening the nuclear operators concerned with unjustified insurance or financial security costs.[18] Therefore, SMRs may be considered as low-risk installations if the installation states' applicable convention(s) and national laws allow for such a case.



Saving Factors by Choosing Existing Coal Sites for Nuclear Power

Sr. No.	Activity	Savings		Remarks
		Time	Cost	
1	Land acquisition for Plant	2-5 Years	Nil	Already at utility possession
2	Water Source	2-3 Years	Nil	Already at utility possession with higher capacity than SMR requirement
3	Site survey	2-5 Years	Nil	DPR of Plant already exist only revalidation required
4	Transport facility (Rail and Road connectivity)	1-2 Years	5 % of site activity	Already Exists Only security needs to improvise
5	De-commissioning of Boiler and turbine		NIL	
6	Trained Manpower	--	Scrap value of plant is a asset	Except nuclear operation the BOP operation already available
7	Township for Employees and local facilities	1-3 Years	--	Majority exists only capacity enhancement and modernization required
8	Sewage treatment plant	2-5 Years	10 % of Project cost	Already available

*The timeline is indicative and taken from open literatures and engineering thumb rules

Coal to Nuclear Transition - The American Strategy

COAL *to* NUCLEAR

Repowering coal plants with advanced nuclear reactors can help unlock **new job, economic, and environmental opportunities** for energy communities across the country as the United States shifts toward cleaner energy sources. Here's how it works.

Retire **Reuse** **Re-Power**

30%
of the nation's coal plants are expected to retire by 2035

more than 300
existing and retired coal plants are suitable to host advanced nuclear plants and technologies

up to 35%
can be saved on plant construction costs by reusing existing coal plant infrastructure

650+
high-paying nuclear jobs would be created or converted in the region

up to 86%
drop in emissions in the surrounding region by replacing coal with nuclear plants

$275m
added annual economic activity in nuclear-sector communities

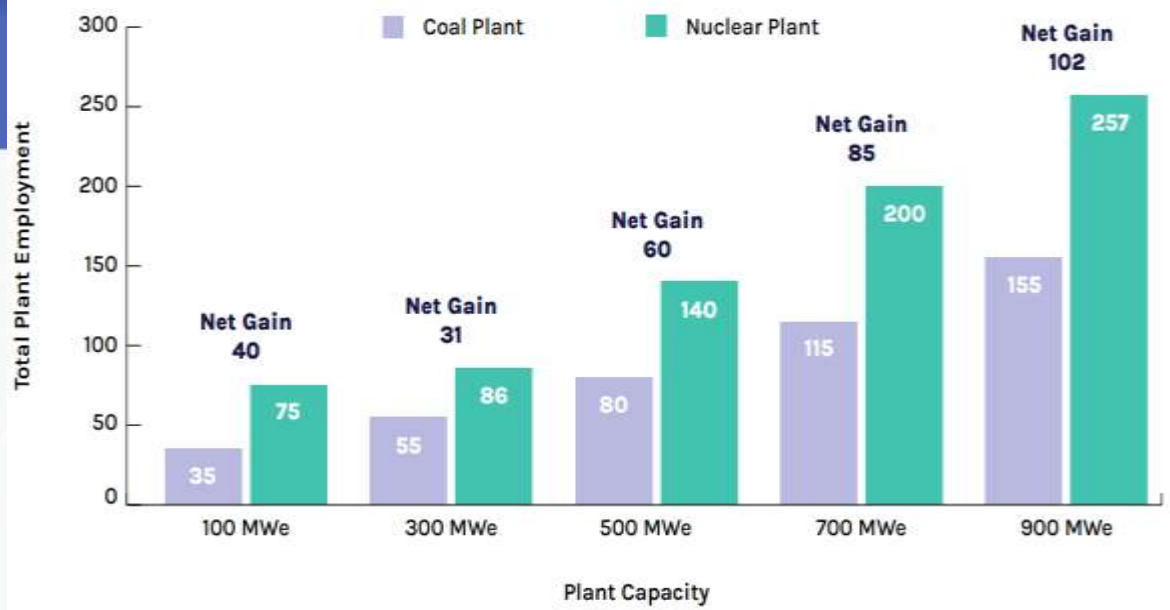
POWER & OPERATIONS

Nearly 400 coal sites could be home to the next 250 GW of U.S. nuclear capacity

Thu, Sep 15, 2022, 8:00PM | Nuclear News

The Naughton coal-fired power plant near Kemmerer, Wyo., has two units set to retire in 2025 and be replaced by a TerraPower Natrium reactor. (Photo: PacifiCorp)

ESTIMATED EMPLOYMENT BY GENERATION

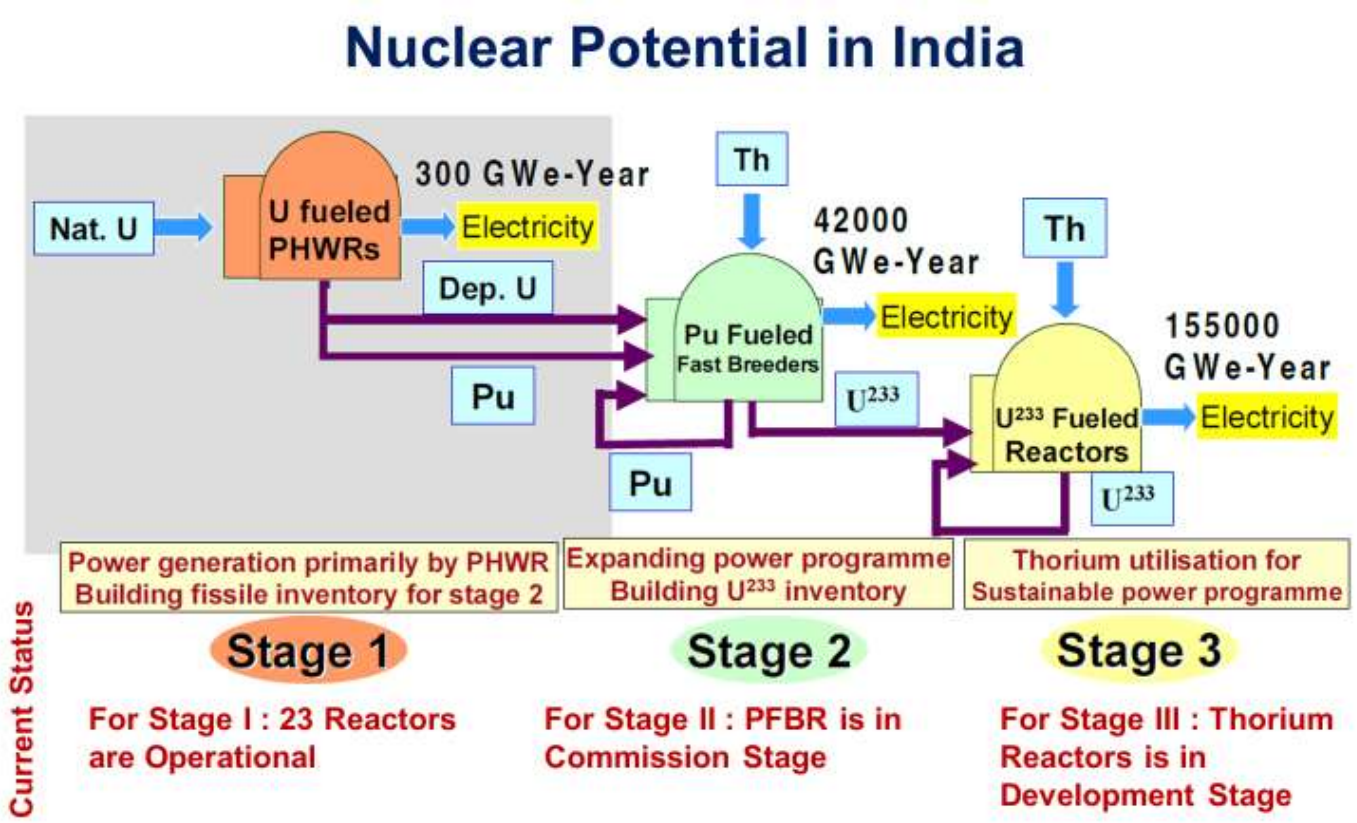


Potential of Micro Modular Reactors for Hydrogen Production and Rapid Deployment in NE Region, Data Centres, Maritime industries, Isolated regions, Malls, Hospitals, Airports, etc. for Uninterrupted Power Supply

- Power less than 20 MWe
- Drive Cargo Ships – Several hundreds in India and thousands globally
- Data Centres – Compact Uninterrupted Power Supply
- Small Captive Power Plants require clean/ green energy for production of Hydrogen/ localized electricity supplu
- High temperature MMRs- ideal for Hydrogen production - for Transport and Industry energy consumption:
  - Typically, per MWe, around 480 kg of hydrogen can be generated per day using standard low temperature electrolysis. If high temperature steam electrolysis is used, 630 kg of hydrogen can be generated per day per MWe by dedicated SMRs/Micro Reactors.

Nuclear Potential in India through Domestic Fuel Reserves

Fuel



- The first stage targets to generate close to 10 GW electricity through NU.
- The second stage envisages generating close to 42000 GWe-years (~4,00,000 TWh) through Pu FBR.
- The final stage is the development of advanced nuclear power reactors targeting energy production of 155000 GWe-years (~14,00,000 TWh) through thorium fuel.
- If we consider the need for 100 years, the second and third stage combined can provide nearly 18000 TWh/year.
- Further can be enhanced through imported fuel.

Accelerating Thorium Deployment

- **PHWRs (BSR & 700 MWe) – ANEEL fuel needs qualification & testing - reduced spent fuel volume which can have direct impact on economics**
- **AHWR (LEU-Th) –design ready- (has potential to be converted to a true SMR) – designed to be put in public domain with power from thorium**
- **ADS – through international collaboration**
- **LEU-Thorium spent fuel will be high Gamma active – needs technology for reprocessing**

Establish the thorium front end & back end –by DAE institutions

Deploy Advanced SMRs/MMRs using thorium in different platforms :

- **MSBRs**
- **GCRs**

In a CANDU reactor, the single-pass, Th-LEU fuel cycle increases uranium utilization by up to 30% relative to natural uranium fuel, and would provide a low-cost insurance policy against future shortages of uranium as well as provide a bridge to the closed thorium cycles of the future.

Wilfrid Bennett Lewis - recognized as the **"Father of the CANDU reactor"**

Task Ahead (1) - Technologies & Vendors Establishment

Task Ahead (2) - Fuel Supply

Task Ahead (3) – Establishment of fuel fabrication facilities

Task Ahead (4) - Supply Chain Development

Task Ahead (5) - Financing

Task Ahead (6)- Licensing aspects

Task Ahead (7) - Human Resources Development

SMR & MMR Deployment – Mission Mode

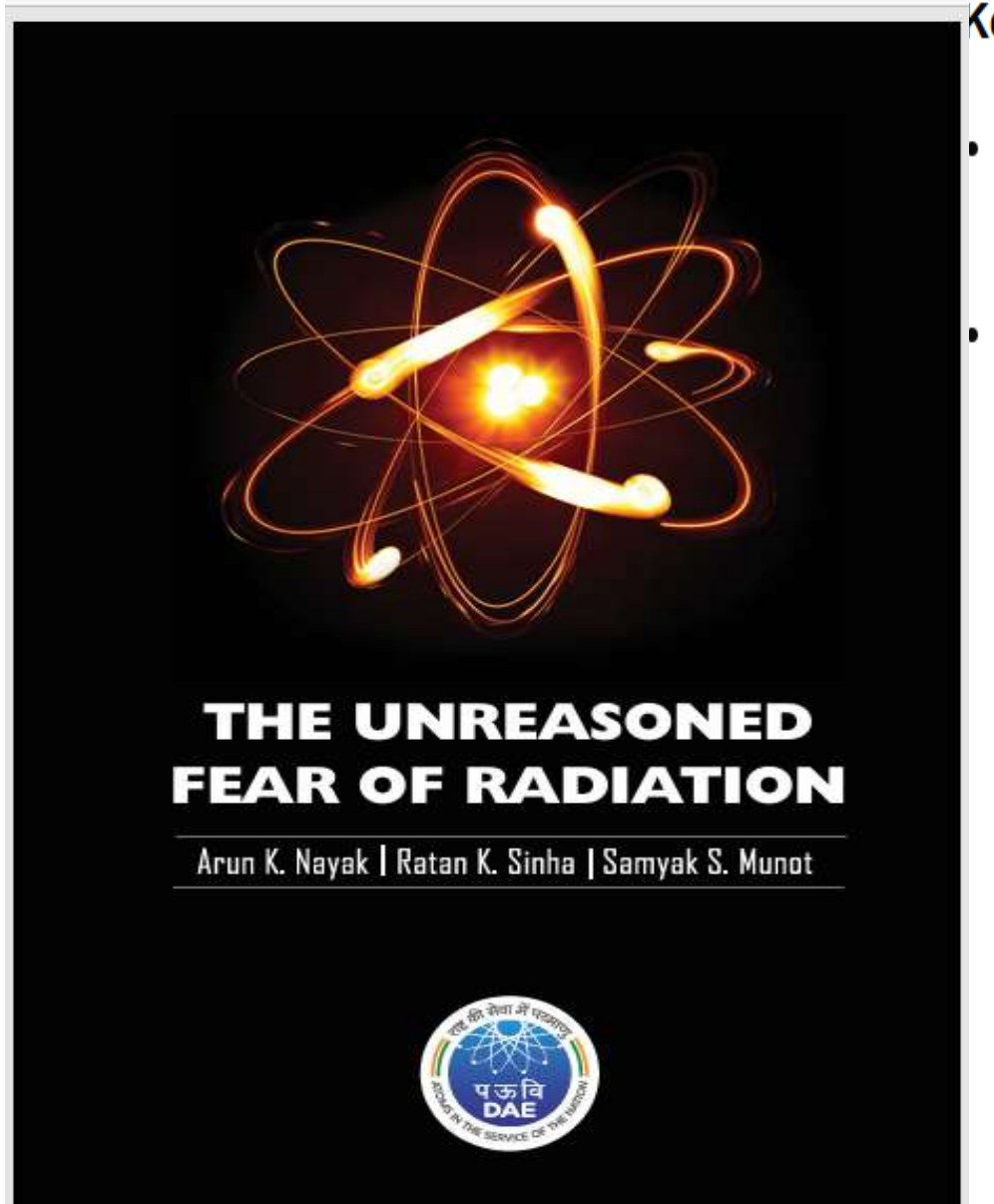
How SHANTI Act will help for accelerated deployment

- Private, Central/State PSUs allowed to build, own, operate including decommission NPPs – a dramatic change in nuclear power expansion
- Private funding including foreign investment to accelerate n-power growth
- any industry can import/fabricate the fuel – burden on DAE & NFC removed
- Collaboration with foreign entities to deploy reactors of Gen III+, Gen IV, SMRs and MMRs in accelerated manner
- Safety, Security & Safeguards remain in Government Control – so public concerns eliminated
- Licensing remain in Government Control – only those licensed to enter into n-power business – public concerns eliminated

How SHANTI Act will help for accelerated deployment

- Rad waste to be handled by operator under AERB safety REGULATION – public concerns eliminated
- AERB now established by ACT – concerns of independent functioning of AERB eliminated
- Civilian Nuclear energy research & development opened up – many start-ups, collaborations expected soon
- Third party liability simplified by removing ambiguities in 17(b) & 46 of CLND Act; Liability amounts layered according to the size of nuclear power plants & facilities

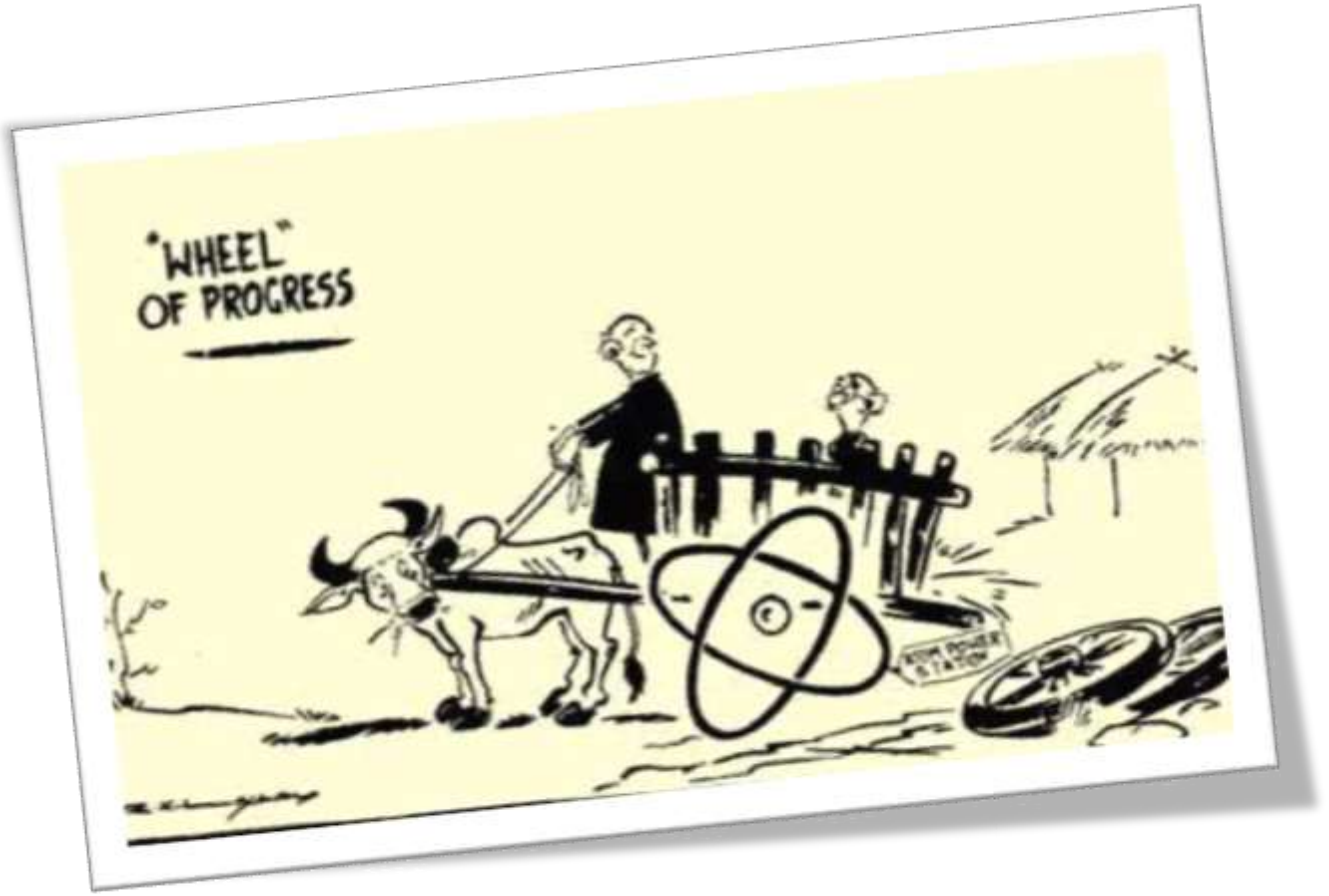
Revisiting Dose Criteria



Key Aspects of the ALARA Decision:

- **The Change:** The DOE is removing ALARA from directives, including DOE Order 458.1 and 10 CFR 835, which will alter long-standing safety-first protocols.
- **Reasons for Removal:** The policy was viewed by the administration as overly burdensome to the nuclear industry with minimal safety benefits, aiming to align regulations with current, less conservative scientific evidence.

Thank you



R. K. Laxman's famous cartoon depicting Pandit Nehru driving the common man on a bullock cart with a nuclear wheel – on the eve of the dedication of the first nuclear research reactor APSARA (1957)