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India Smart Utility Week 2025 Conference

20th March 2025 (Thursday)

NUCLEAR RENAISSANCE AND THE ROLE OF SMR FOR THE NET ZERO POWER SYSTEMS

C P Tiwari, Head – BD, Services and Technology
TATA Power Company Limited

Lighting up Lives!

Message from Visionary and TATA Power as Lead Adaptor of Technology

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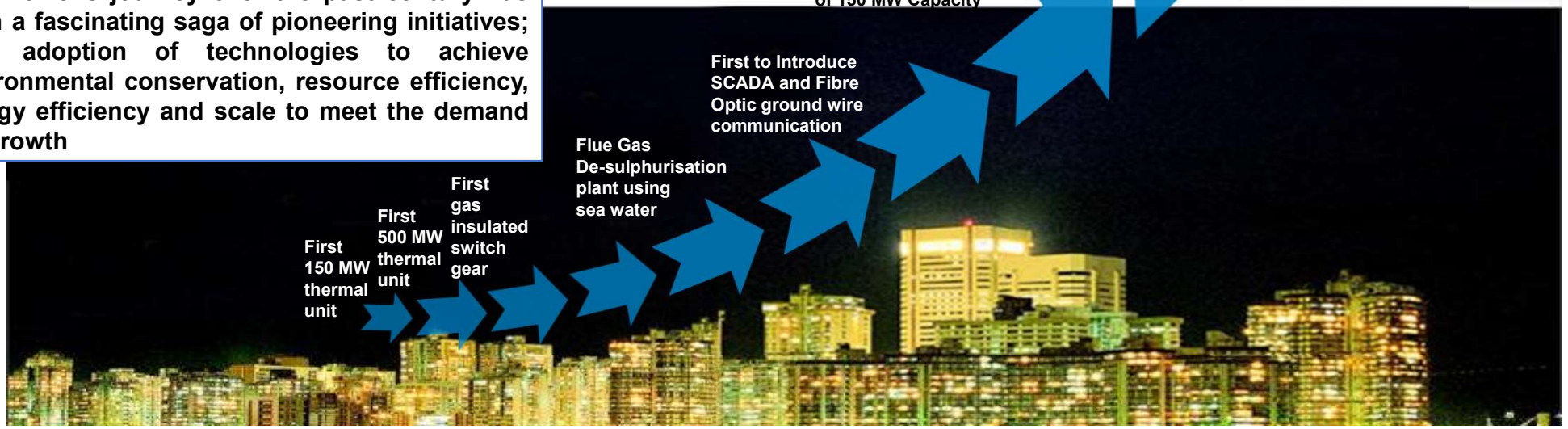
Message from Visionary

"**Clean, cheap and abundant** power is one of the basic ingredients for the economic progress of a city, state or country."

Lead Adaptor of Technology

Tata Power's journey over the past century has been a fascinating saga of pioneering initiatives; lead adoption of technologies to achieve environmental conservation, resource efficiency, energy efficiency and scale to meet the demand for growth



TATA Power | India's largest vertically-integrated power company

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Generation

~25.6 GW
Total Capacity
(Operational + Under construction)

~16.8 GW
Clean & Green Energy
(Including 10.1 GW Under Construction)

~8.9 GW
Thermal energy generation
(Installed capacity)

Transmission

4,633 Ckm
Operational Transmission lines

2,414 Ckm
Transmission line under construction

Distribution

12.6 Mn
Customers in Distribution

New-age Energy Solutions

~4.9 GW
Manufacturing capacity for Cell & Module each (including 0.3GW Cell Capacity under commissioning)

2.8 GW
MoU signed for Pumped Hydro Project (PSP)

5,500
Public EV charging points energised across 580+ cities and towns

New-age Energy Solutions

Generation

Renewables

Transmission & Distribution

Generation, Transmission and Distribution assets spread across India

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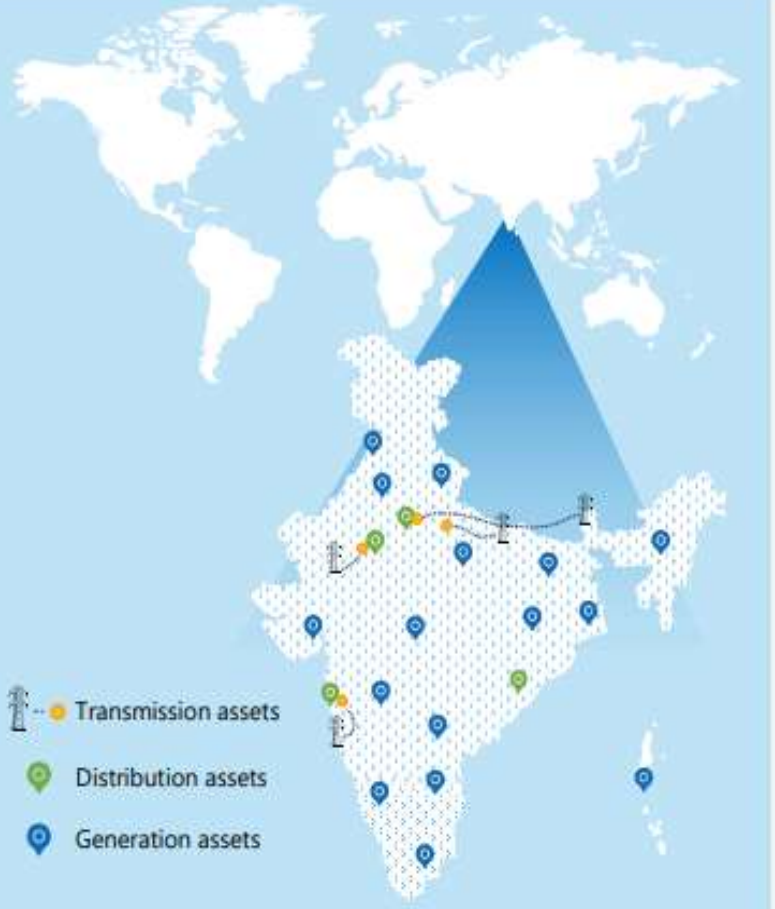


Capacity Mix (Domestic + International)

25,620 MW
Total capacity
(Operational + Under construction)

8,860 MW
Thermal

1,034 MW
Wind

880 MW
Hydro

443 MW
Waste Heat Recovery /BFG

4,350 MW
Solar

10,053* MW
Clean & Green capacity under construction

Distribution of installed capacity (Domestic & International) (%)

Transmission and Distribution

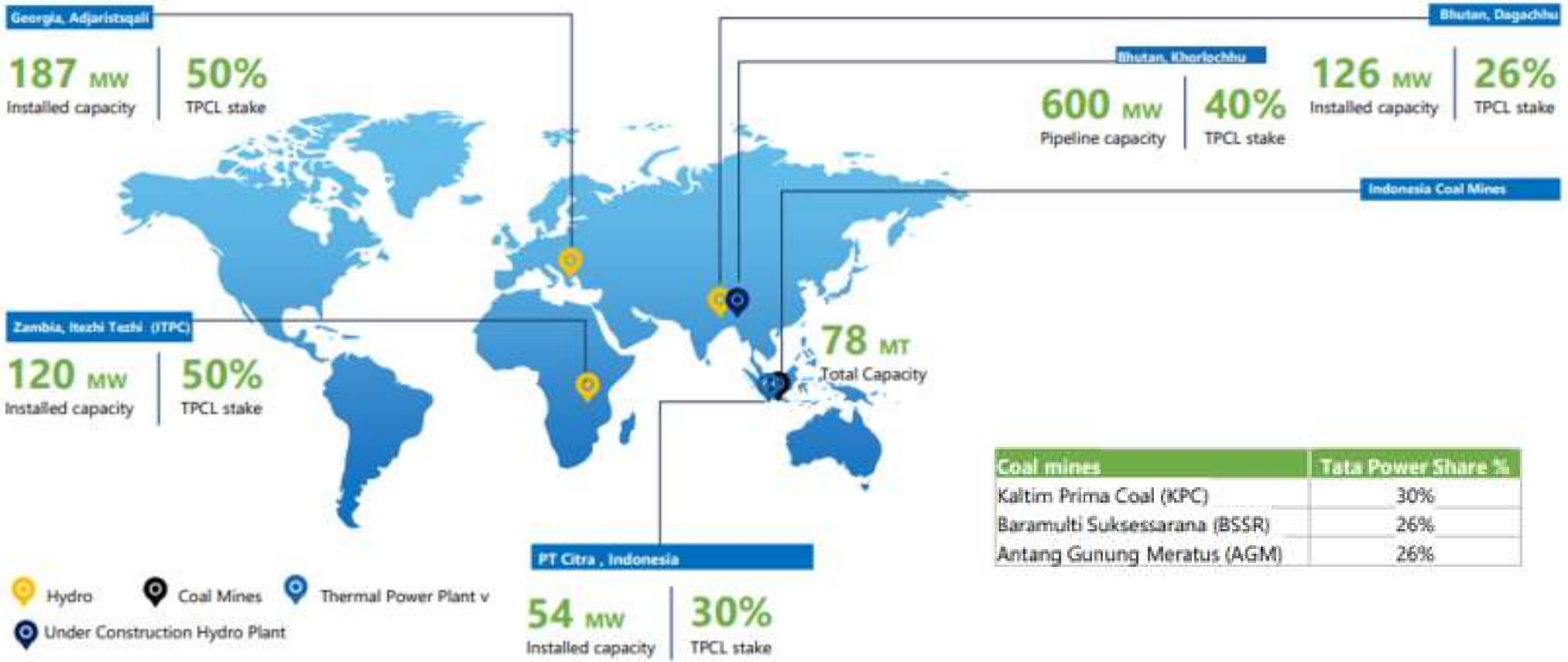
12.6 Mn
Customers in Distribution

4,633 Ckm
Operational Transmission lines

2,414 Ckm
Transmission pipeline under construction

*Includes 15MW of IEL and excludes Rooftop under -pipeline capacities

TATA Power | Assets located outside India



Coal mines	Tata Power Share %
Kaltim Prima Coal (KPC)	30%
Baramulti Suksessarana (BSSR)	26%
Antang Gunung Meratus (AGM)	26%

BSR | Approach by GoI

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Efforts for Energy Security

- To come up with a **policy document on appropriate energy transition pathways** that balances employment growth & environmental sustainability
- **PM Surya Ghar Muft Bijli Yojana,** which has seen more than 1.28 crore registrations, to be further encouraged
- **Policy for promoting pumped storage projects** will be brought out for electricity storage & facilitating smooth integration of growing share of renewable energy
- **R&D of Small and Modular Nuclear Reactors :** Govt will partner with private sector for – setting up **'Bharat Small Reactors';** R&D of **'Bharat Small Modular Reactor';** and R&D of Newer technologies for Nuclear energy

#BudgetforViksitBharat

Union Budget 2024-25

Budget 2024-25

Nuclear energy is expected to form a very significant part of the energy mix for Vikshit Bharat. Towards that pursuit, our government will partner with the private sector for:

1. Setting up Bharat Small Reactors
2. Research and development of Bharat Small Modular Reactors
3. Research and development of newer technologies for nuclear energy

The R&D funding announced in the Interim Budget will be made available for this sector as well.

BSR | Proposed business model

Focus of Government on developing and deploying Small Modular Reactor (SMR) with the participation of private players presents opportunities for venturing into Nuclear power generation

Bharat Small Reactor (BSR) – India's version of SMR

- India has significant **expertise in 220 MW Pressurized Heavy Water Reactor (PHWR)** with 14 such reactors deployed in current Nuclear plant fleet of India
- Bharat Small Reactors (BSRs) are **small-scale nuclear reactors based on India's proven 2 x 220MWe PHWR** technology, with Steel containment to **reduce exclusion zone to 0.5 km (Presently 1 km)**

Clean Energy | **Smaller Size**

Modular Design | **Improved Safety**

Proven Technology

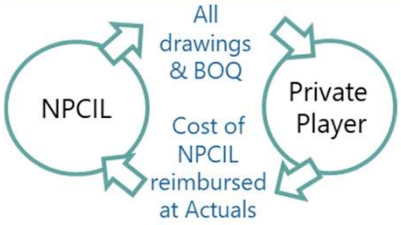
Government has invited participation of private players in deploying this capacity in the country

Government has outlined model for enabling participation of private players while avoiding nuclear and civil liability on them

Project Development Phase

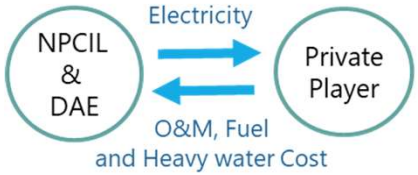
- Non-committal MoU for Site selection
- Land reclassification & Sub Lease to NPCIL, post Site approval by GoI
- Definitive agreement for project implementation

Construction Phase



- Procurement & construction by private player under NPCIL Guidance
- Statutory clearances by NPCIL.
- Asset transfer to NPCIL on lease

Operations Phase



- O&M agreement and Tripartite Agreement (Private Player, NPCIL & DAE) for Fuel & Heavy Water
- NPCIL operates the plant
- Private Player will have exclusive right for off take of electricity
- O&M expenditure including fuel and heavy water cost by Private Player
- Private Player to pay NPCIL for services (including PHWR expertise)

BSR | Market context and the potential

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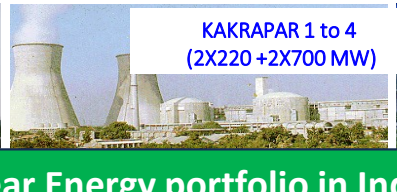
24 Operational Nuclear units (8180 MW)



Nuclear Energy portfolio in India

Project Under Construction

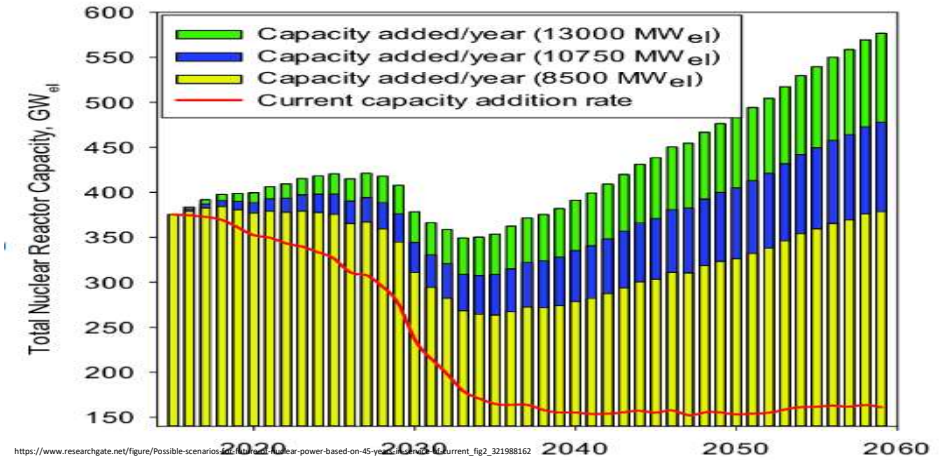
***14300 MWe** capacity addition planned. This also includes* 10 reactors with 700 MW each, to add by 2031-32 in fleet mode and 01 number of 500 MW FBR under commissioning.

World Total and Nuclear Electrical Generating Capacity GWe

Electrical Capacity	2023	2030		2040		2050	
		Low	High	Low	High	Low	High
Total	8 992	10 042	10 042	13 747	13 747	20 329	20 329
Nuclear	372	414	461	491	694	514	950
Nuclear as % of Electrical Capacity	*4.1%*	*4.1%*	*4.6%*	*3.6%*	*5.0%*	*2.5%*	*4.7%*

https://www-pub.iaea.org/MTCD/Publications/PDF/RDS-1-44_web.pdf

Possible scenarios for future of nuclear power; based on 45 years in service of current reactors and adding new reactors with rate of ~21 reactor per 5 years



https://www.researchgate.net/figure/Possible-scenarios-for-future-of-nuclear-power-based-on-45-years-of-service-of-current_fig2_321988162

BSR | The Key Success Factors

Technical :

- **Safety:** Uncompromising safety record is paramount. BSR must demonstrate robust safety features and a high level of operational reliability
- **Partial Modular Construction:** Standardized, modular components can streamline construction, reduce costs, and accelerate deployment.
- **Proven Compact Design with high reliability :** BSR's compact size offers advantages in terms of transportation, construction, and siting, making it suitable for various locations.

Economic Viability:

- **Cost Competitiveness:** BSR must be cost-effective to compete with other energy sources. This includes minimizing construction costs, fuel costs, and operating expenses.
- **Financing:** Attracting investors and securing financing for BSR projects will be critical for market penetration.
- **Lifecycle Management:** Efficient and cost-effective fuel cycle management, including waste disposal, is essential for long-term economic viability.

Longest Continuous Days of Operation (Worldwide)

Reactor	Location	Days
KGS-1	**India**	962
Heysham II	UK	940
Pickering-7	Canada	894
Torness-2	Scot,UK	825
RAPS-3	**India**	778
RAPS-5	**India**	765
LaSalle 2	US	739

Longest Continuous Days of Operation (India)

KGS-1	KGS-2	KGS-3	KGS-4
962	698	712	550

Market Strategy :

- **Strategic Partnerships:** Collaborations with utilities, OEM, Vendors, Industry Experts and regulatory bodies can facilitate early technology adoption and completing the BSR project in time, making the tariff competitive.
- **Regulatory Compliance:** Ensuring BSR meets all relevant safety and regulatory requirements is essential for licensing and deployment.
- **Public Acceptance:** Building public trust and addressing concerns about safety and environmental impact is critical for successful market adoption

Additional Considerations:

- **Innovation and R&D:** Continued investment in research and development to enhance BSR's performance, address technological challenges, and explore new applications.
- **Supply Chain Development:** Establishing a robust and reliable supply chain for BSR components and materials is crucial for timely and cost-effective deployment.

100GW Nuclear Energy by 2047-is it too ambitious or too little?

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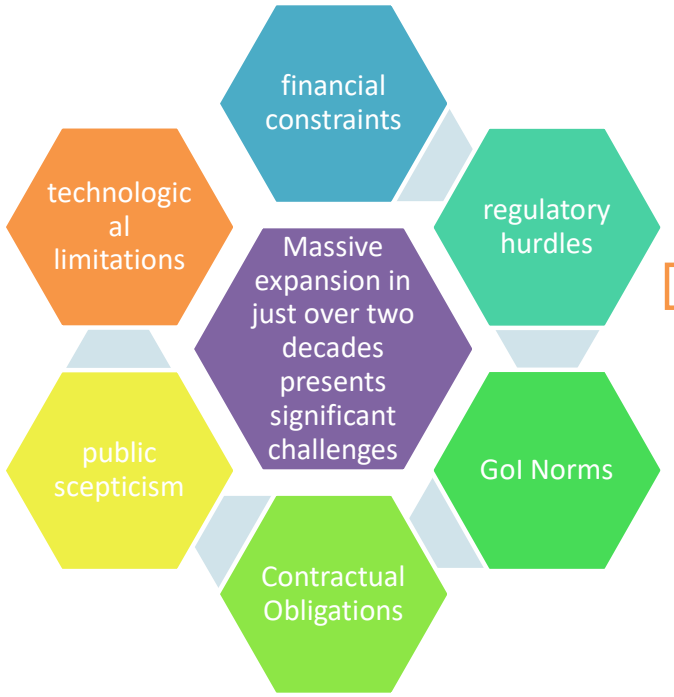
The Union Budget 2025-26 | Significant push towards nuclear energy as part of India's long-term energy transition

- The government has set an target of 100 GW nuclear power capacity by 2047, positioning nuclear energy as a major pillar in India's energy mix.
- Nuclear Energy Mission for Viksit Bharat. This initiative aims to enhance domestic nuclear capabilities, promote private sector participation, and accelerate the deployment of advanced nuclear technologies such as Small Modular Reactors (SMRs).
- **Small Modular Reactors (SMRs) and R&D Initiatives | Launch** of a **Nuclear Energy Mission,** which is focused on research and development (R&D) of **Small Modular Reactors (SMRs).** The government has allocated **₹20,000 crore** for this initiative, aiming to develop at least **five indigenously designed and operational SMRs by 2033.**
- **Nuclear Energy Mission for Viksit Bharat |** To facilitate the implementation of the **Nuclear Energy Mission**, amendments to the **Atomic Energy Act** and **Civil Liability for Nuclear Damage Act** will be taken up by the parliament. These amendments are expected to encourage **private sector investments** in nuclear power projects.
- The mission aligns with India's commitment to achieving **100 GW** of **nuclear energy capacity** by **2047**
- The government will enter into partnerships with the private sector with the motive of:
  - Setting up **Bharat Small Reactors,**
  - Research & development of **Bharat Small Modular Reactor**, and
  - Research & development of **newer technologies** for nuclear energy.
- The Budget also proposes that states will be incentivized for electricity distribution reforms and augmentation of intra-state transmission capacity. The Minister informed that additional borrowing of 0.5 per cent of GSDP will be allowed to states, contingent on these reforms

https://pib.gov.in/PressReleasePage.aspx?PRID=2099244#:~:text=The%20government%20is%20actively%20expanding,partnerships%20with%20the%20private%20sector.u

India has set an ambitious goal of increasing its nuclear power capacity from the current 8.2 gigawatts (GW) to 100 GW by 2047—a nearly 12-fold expansion.



While nuclear energy can play a role in India's energy future, a more realistic approach may be needed.

For Better Result

strong policy reforms → increased investment → technological advancements → Private Public Partnership

Potential Users of Nuclear Power

Supply of Clean Power to Industries (Steel, Chemical, Cement, Aluminium) with intent to decarbonise their operation

Supply of Clean Power to ***Data Centres & other Commercial & Industrial consumers*** who intend to use clean power.

Bundling with other renewable power like Solar & Winds. However, load variation in IPHWR is not possible.

Clean Power supply to ***Distribution Companies*** with long terms PPA under section-62 with pass through fuel cost.

Economic Viability of SMRs including cost, financing models, and the potential for integrating SMRs with other energy sources and industrial applications to optimize energy systems

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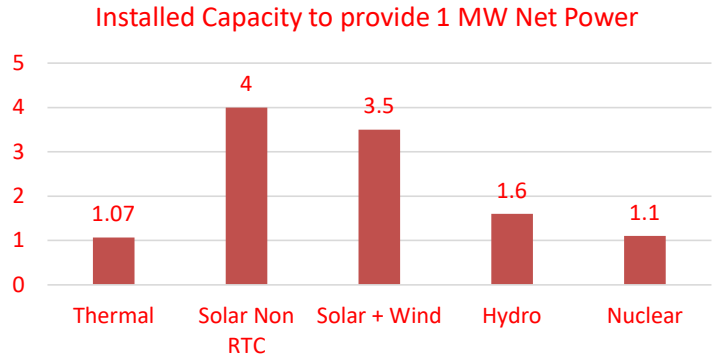
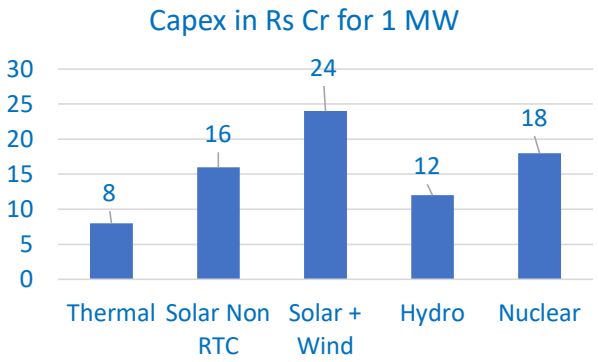
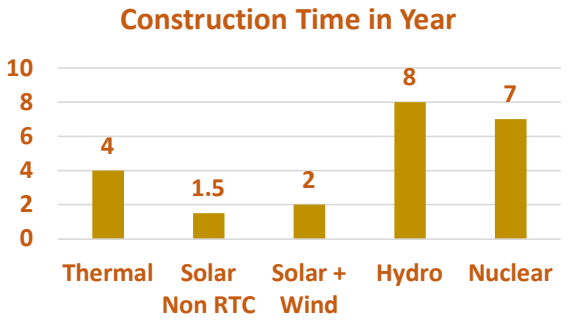
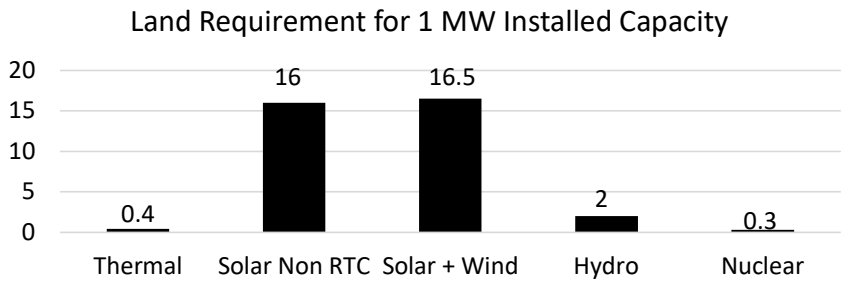
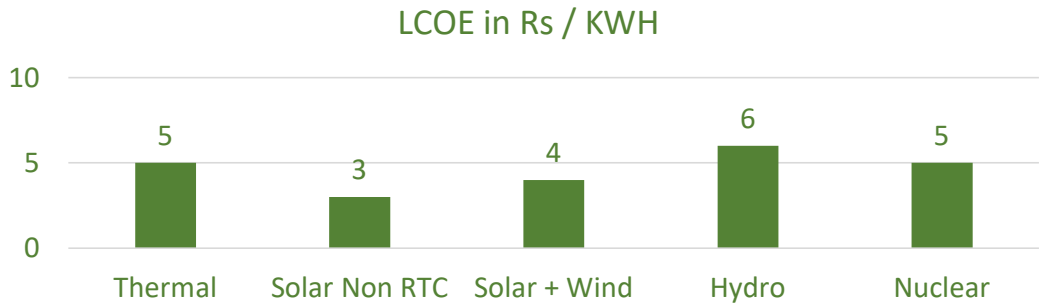








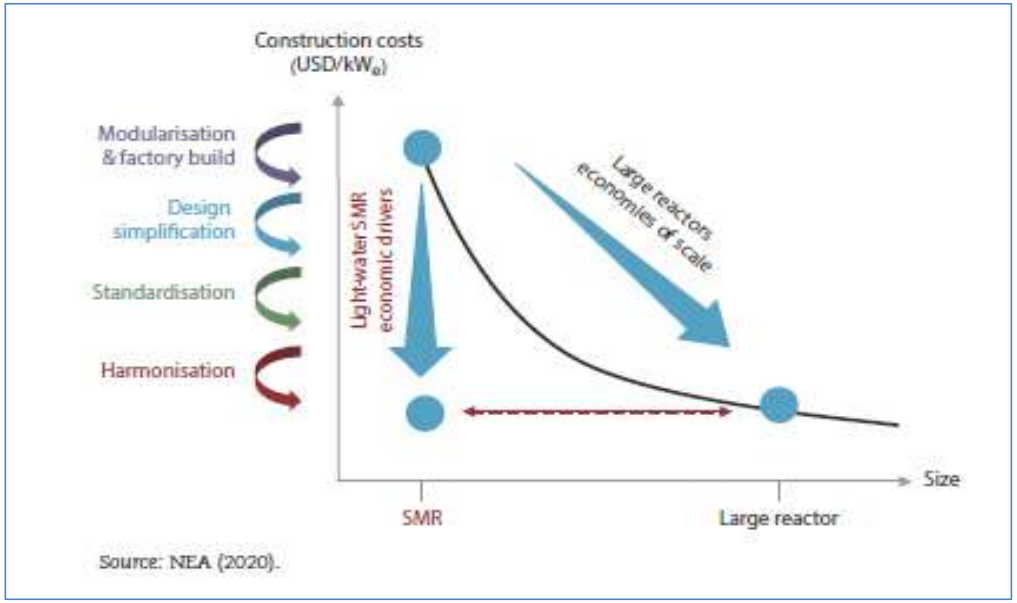


- **Nuclear similar to thermal in terms of land requirement, but is significantly lower than thermal including land use for mining**
- **Cost per MW of nuclear is ~2x of thermal power, but LCOE is comparable with thermal.**
- **LCOE of Nuclear is higher than solar or solar + wind combination, Nuclear Power is dispatchable.**
- **IAEA reports lifecycle emissions of only 5.1-6.4 g/kWh of nuclear power, which is ~1% of thermal and less than 50% of Wind & Solar emissions**

Economic Viability of SMRs including cost, financing models, and the potential for integrating SMRs with other energy sources and industrial applications to optimize energy systems

Key Economic Drivers of SMR

1. **Simplification** – Passive mechanism improvements, greater design integration, reduced number of components
2. **Standardization** – Lower output means lesser site dependency and more standardization
3. **Modularization** – techniques tailored to logistics and transportation standards; 60~80% factory fabrication; advanced manufacturing techniques including additive manufacturing
4. **Harmonization** – regulatory and industrial harmonization provides access to global markets



- ❑ Small modular reactor (SMR) technology has been attractive on paper, but difficult to realize in practice.
- ❑ Despite high investments into SMR development, no SMRs are yet in commercial operation.
- ❑ However, as the world struggles with the immense challenges of transitioning away from fossil fuels, OEMs across the globe are extensively working on development of SMRs.

Economic Viability of SMRs including cost, financing models, and the potential for integrating SMRs with other energy sources and industrial applications to optimize energy systems

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Issues & Challenges in BSRs

1) Fuel security & Fuel cost
2) Heavy water cost
3) Nuclear waste storage – Away from reactor facility by DAE common for multiple users
4) O&M cost and NPCIL expertise charges
5) Business Model Proposed – issues like if asset will be on User books, claiming depreciation etc.
6) Availability of skilled manpower, capability building at NPCIL end so that design engineering, supervision etc. can be completed without delay.
7) Supply chain – for TG and other critical components, only few vendors. Quick approval of new vendors.
8) State government supports in land and water allocation and permitting for installation of BSRs
9) Design of BSRs for seismic zone IV and above
10) Design of BSRs system for minimizing water consumption
11) Reduction of Exclusion zone to 0.5 km
12) Capital cost of BSR and LCOE

Government support required for BSRs

Benefit of green power to be extended & MoP, GoI and State Govt shall waive off ISTS and State Transmission charges for power generated from BSRs.

GoI shall provide following financial incentives and shall waive off following taxes and duties:

- **GoI allow framework for raising capital via Clean Bonds. These Clean Bonds should enjoy tax benefits like the Green Bonds and / or Mega Projects. Shall provide Green loans below GoI rate with moratorium of PPA period**
- **Concession in taxes & duties like GST, Customs, Imports and all kind of taxes and duties in relation to Construction and Operations for life span of the project.**
- **Single window fast track statutory clearance for BSR adoption.**
- **Power generated from BSR shall be treated as Base load.**
- **Assistance from NPCIL for the USER in securing financing for the project under any master tripartite agreement with banks - at competitive interest rates.**
- **Waiver of electricity duty and other charges.**
- **Mandating Discoms for use of clean power from nuclear sources similar to renewable power obligation.**

Amendment to Atomic Energy Act and Civil Liability for Nuclear Damage Act

Amendment in AEA and CLND act will enable Private players to work with SMR OEM's and implement their design in Indian Market

Amendment of the Atomic Energy Act:	**Current Status:** The Atomic Energy Act of 1962 restricts private sector participation in nuclear power generation.
	Proposed Change: The government plans to amend this Act to allow private entities to build and operate nuclear power plants.
Amendment of the Civil Liability for Nuclear Damage Act:	**Current Status:** The existing law holds both operators and suppliers liable for nuclear accidents, which restricts foreign suppliers from participating in the Indian market.
	Proposed Change: The government intends to amend this Act to reduce supplier liability, aligning with international standards.

New Opportunities :

- ❑ Private companies can now invest in and manage nuclear power projects,
- ❑ Increased competition and innovation in the sector.
- ❑ Collaboration with SMR OEMs for indigenous development for cost reduction
- ❑ Using SMRs for TATA Power clean energy portfolio.
- ❑ Collaboration with fuel manufacturer for development of thorium based nuclear fuel.

The Union Budget 2025-26 outlines a significant push towards nuclear energy as part of India's long-term energy transition strategy. The government has set an ambitious target of 100 GW nuclear power capacity by 2047, positioning nuclear energy as a major pillar in India's energy mix. This development aligns with the broader objectives of Viksit Bharat, ensuring energy reliability and reducing dependency on fossil fuels. To achieve this goal, strategic policy interventions and infrastructure investments are being undertaken, with an emphasis on indigenous nuclear technology and public-private collaborations.

Key risks in NPP Business

Category	Potential Risk	Mitigation measure
Policy & Regulatory Risk	1) Absence of Policy for Private Participation in Nuclear Power Generation	1) Govt. support in formulation of policy framework for private participation 2) Govt. to allow installation of NPPs in Industrial areas with exclusion zone as 0.5km
Operational & Safety Risk	1) Non availability of fuel & heavy water 2) Waste Management 3) Health and Environment concerns 4) Hazard associated with natural events 5) Limited O&M Resource availability 6) Security Risk	1) Fuel security to be ensured. Since heavy water is being produced within India, Govt. shall guarantee for supply of heavy water with agreed cost escalation. 2) Spent fuel management will be by DAE 3) Adherence to proven NPCIL design and construction methodology. 4) NPCIL Design shall consider all such natural events in design 5) NPCIL shall train Private user team for supporting O&M activities 6) DAE / NPCIL norms for access control and security shall be followed.
Design & Implementation Risk	1) Design of 220 MW Reactor 2) Large scale of investment 3) Delay in inspection and certification during manufacturing and construction 4) Delay in supply of critical components 5) Delay in construction and commissioning	1) NPCIL has proven design of 220 MW Reactor. Only few design changes required like provision of steel containments which shall be completed within agreed schedule 2) Govt support in funding like clean bond etc. 3) NPCIL / AERB to agree for schedule of inspection and certification & comply agreed schedule 4) Critical components shall be ordered by NPCIL in advance 5) LD and Bonus provisions shall be kept in contract for timely completion. Also, NPCIL shall complete stage inspections as per project schedule.'
Tariff & Financial Risk	1) High tariff compared to coal-based power and renewable power 2) Increase in tariff due to change in fuel and heavy water cost 3) Credit risk from off taking customers	1) Firm clean power to captive users with intent of decarbonization or govt supported long term PPA with distribution companies with pass through cost. 2) Govt to give assurance for escalation rate in heavy water cost. For Fuel security, either govt to give assurance for escalation or fuel security shall be ensured as suggested by DAE like stocking of fuel, owing uranium mines or permission for manufacturing & use of alternative fuel like ANEEL. 3) MoP already has notification for timely payment by DISCOM.
Public Perception / Brand Risk	1) Stalling of project due to negative public sentiments	1) Public campaign to create awareness and break social stigma for acceptance of NPP in neighborhood.

Safety Overview | Multiple Barriers

A series of successive barrier against the release of radioactivity to atmosphere is provided. This includes:

1. **First Barrier** - Fuel: UO_2 is a ceramic with high melting point and inert to water. As long as ceramic fuel does not melt, it will keep large fraction of fission product entrapped in its matrix. Several back-up cooling system is provided to avoid melting of fuel.
2. **Second Barrier** - Fuel Sheath: Sheath is made of Zircoloy-2 and seals UO2. This forms second barrier.
3. **Third Barrier** - Primary Heat Transport System: This is closed system and form third barrier.
4. **Fourth Barrier** - Containment: Primary containment of pre-stressed concrete is enveloped by secondary containment of reinforced concrete. The annulus between inner and outer containment is maintained at a slightly negative pressure with respect to atmosphere to minimize ground level activity releases to the environment during accident conditions. Also in new units, steel containment will be added before primary containment.
5. **Fifth Barrier -** Exclusion Zone: Presently exclusion zone of 1.6km is provided. With steel containment, it will be changed to 0.5km.

Regulatory and Safety Considerations for SMRs including licensing processes, regulatory challenges, and public perception issues

India has a mature nuclear ecosystem, primarily controlled by the govt

Central Government agency for nuclear energy policy; owner of fuel

Regulator of the nuclear industry; formulation of rules & compliance monitoring

Designer, Integrator, Manufacturer and Licensor of Nuclear Reactors
- *More cost effective than global players*

Operator of nuclear plants

Govt is actively working for private participation in Nuclear Power Generation

Thank You!

Website: www.tatapower.com

Email Id: Chandra.tiwari@tatapower.com

Contact: +91 9312072156/7678237415