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Workshop on SHANTI Act 2025 : Enabling 100 GW Nuclear Power Roadmap

Supply Chain Localization & Implementation Approach

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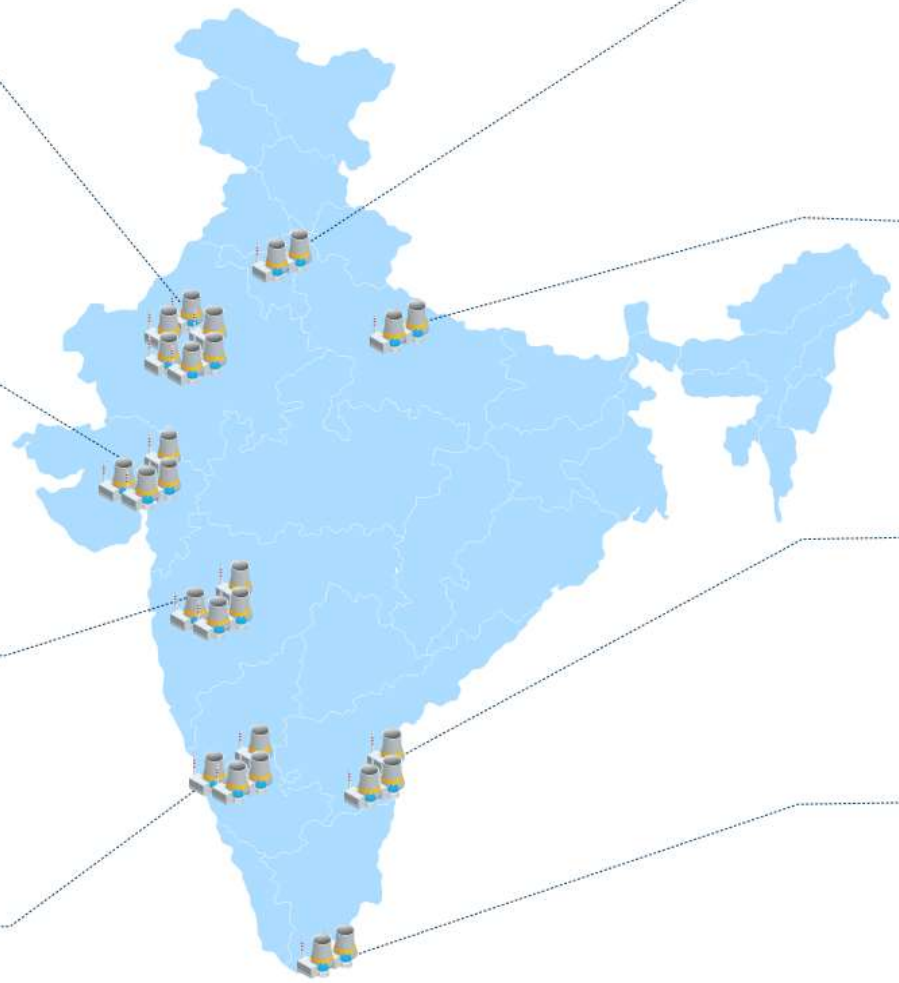
TCE’s association in Indian Nuclear Programme

Rajasthan Atomic Power Station
- Unit 1, PHWR CANDU 100 MWe (1972)
- Unit 2, PHWR CANDU 200 MWe (1980)
- Unit 5, PHWR IPHWR 220 MWe (2009)
- Unit 6, PHWR IPHWR 220 MWe (2010)
- Unit 7, PHWR IPHWR 700 MWe (2025)
- Unit 8, PHWR IPHWR 700 MWe (ongoing)

Kakrapar Atomic Power Station
- Unit 1, PHWR IPHWR 220 MWe (1992)
- Unit 2, PHWR IPHWR 220 MWe (1995)
- Unit 3, PHWR IPHWR 700 MWe (2021)
- Unit 4, PHWR IPHWR 700 MWe (2024)

Tarapur Atomic Power Station
- Unit 1, BWR 160 MWe (1969)
- Unit 2, BWR 160 MWe (1969)
- Unit 3, PHWR IPHWR 540 MWe (2006)
- Unit 4, PHWR IPHWR 540 MWe (2005)

Kaiga Atomic Power Station
- Unit 3, PHWR IPHWR 220 MWe (2007)
- Unit 4, PHWR IPHWR 220 MWe (2011)
- Unit 5, PHWR IPHWR 700 MWe (ongoing)
- Unit 6, PHWR IPHWR 700 MWe (ongoing)



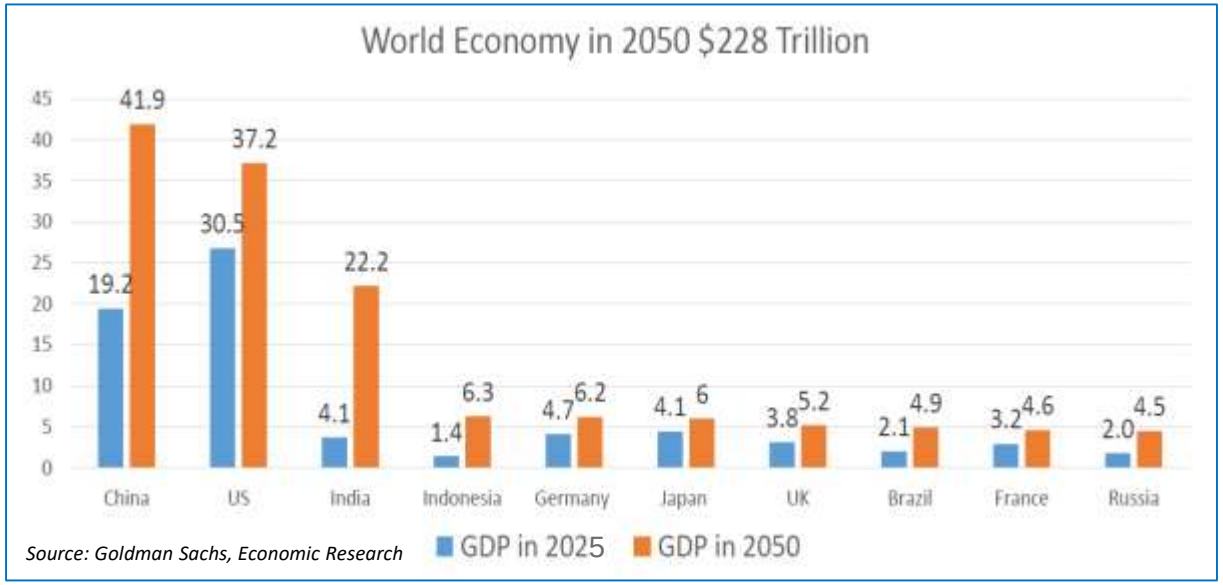
Gorakhpur Nuclear Power Plant
- Unit 1, PHWR IPHWR 700 MWe (ongoing)
- Unit 2, PHWR IPHWR 700 MWe (ongoing)

Narora Atomic Power Station
- Unit 1, PHWR IPHWR 220 MWe (1989)
- Unit 2, PHWR IPHWR 220 MWe (1992)

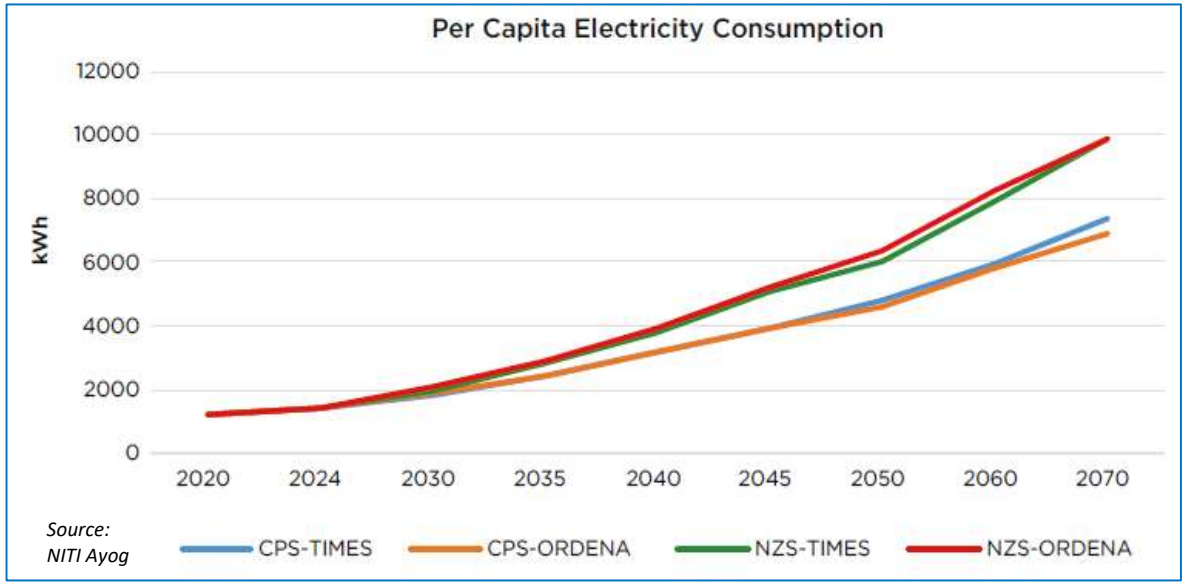
Madras Atomic Power Station
- Unit 1, PHWR IPHWR 220 MWe (1983)
- Unit 2, PHWR IPHWR 220 MWe (1985)
- Unit 3, FBR PFBR 500 MWe (ongoing)

Kudankulam Atomic Power Station
- Unit 1, PWR VVER 1000 MWe (2013)
- Unit 2, PWR VVER 1000 MWe (2016)

India's Growth Forecast

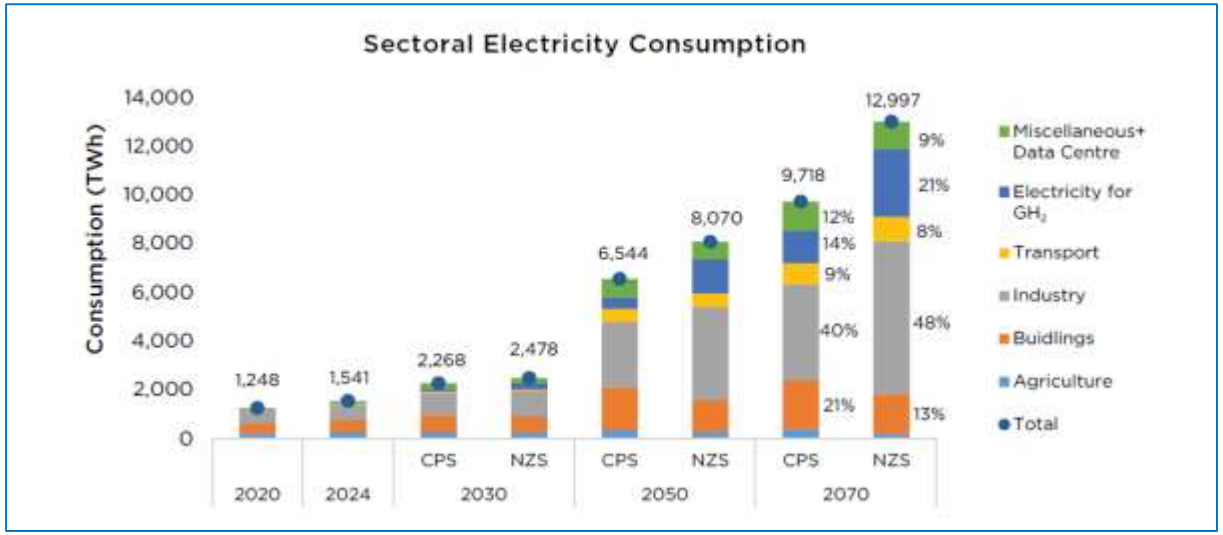


Source: Goldman Sachs, Economic Research



Source: NITI Ayog

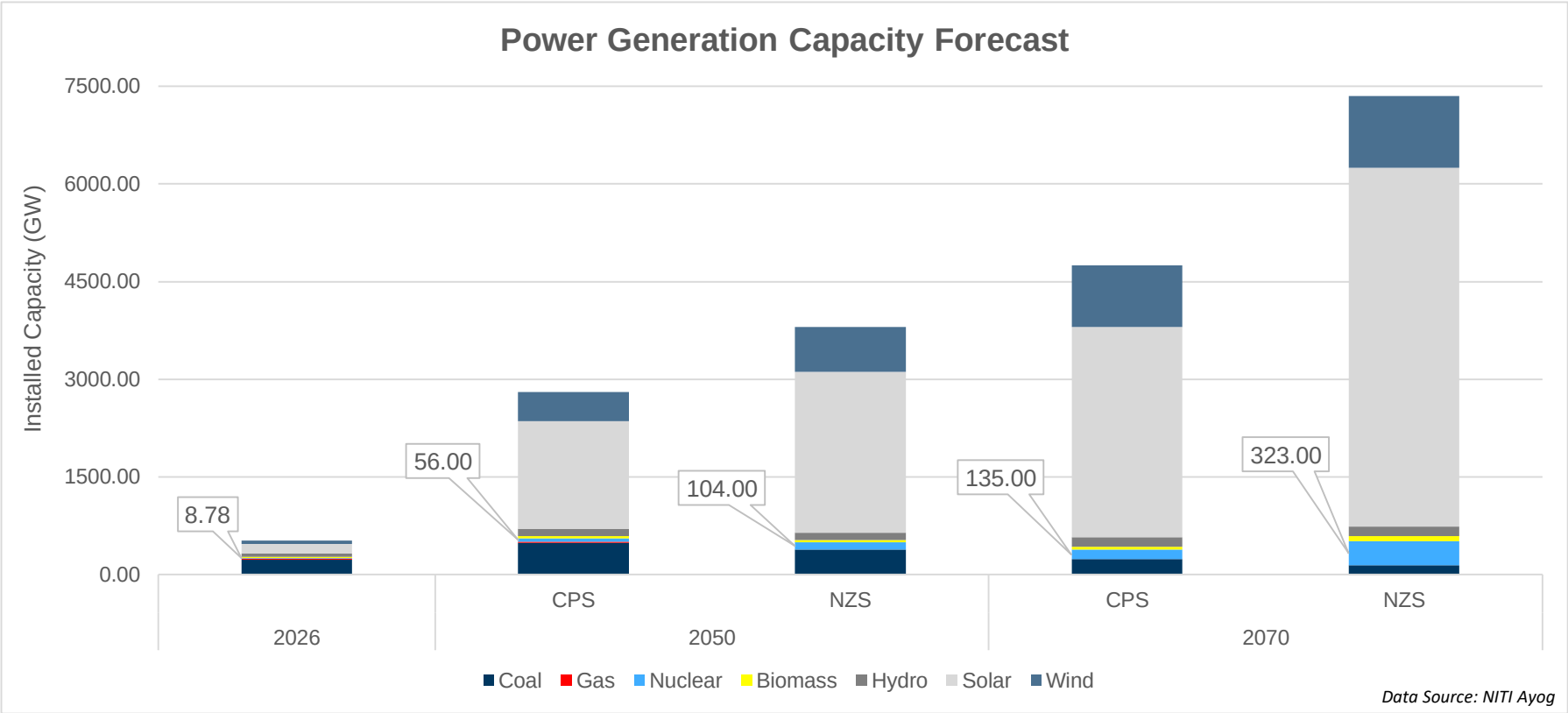
*- India Aspires to become US$30 Trillion by 2047



1. India's current HDI value 0.685, aiming to reach between 0.8-0.9
2. Per capita electricity consumption is set to reach 6,400 kWh by 2050 and 10,000 kWh by under Net Zero Scenario.
3. **CO_2 emission expected to be ~0.3 $kgCO_2$/kWh by 2050 & ~0.07 $kgCO_2$/kWh (CPS) & 0.00 $kgCO_2$/kWh (NZS) by 2070**

Simulation Models:
TIMES - The Integrated MARKAL-EFOM System ORDENA - ORigin-DEstiNAtion Data Exploration

Generation Capacity Addition Programme



CPS: Current Policy Scenario
NZS: Net Zero Scenario

Current Policy scenario

- Total installed capacity set to rise from ~500 GW in 2024-25 to **4,650-4,750 GW** (~9 times) in CPS by 2070.
- Total nuclear capacity projected to reach around **~135 GW by 2070.**
- Cumulative investment requirements reach approximately **USD 250 Billion (USD 5.5 Billion/year)** in Current Policy Scenario.

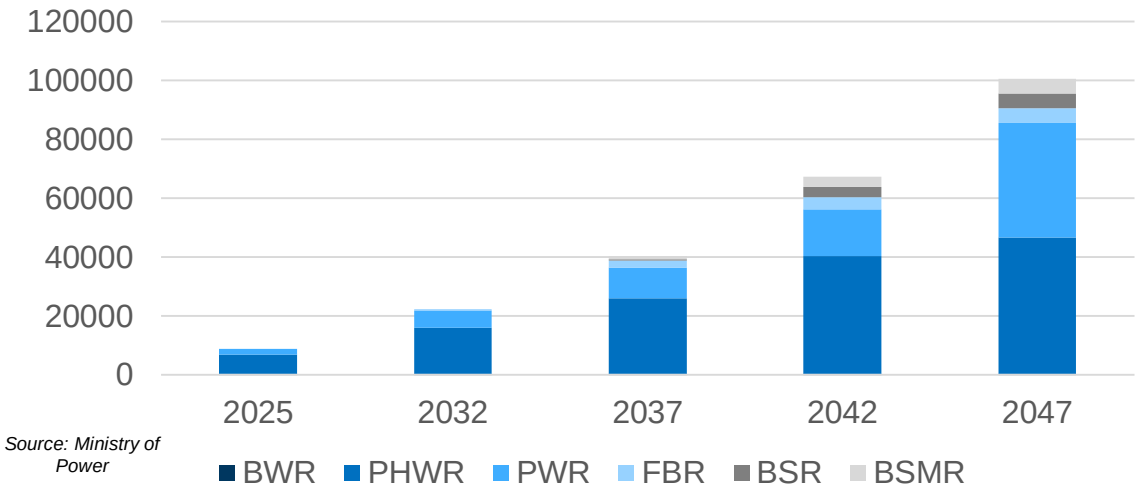
Net Zero Scenario

- Total installed capacity set to rise from ~500 GW in 2024-25 to **6,800 - 7,350 GW** (~14 times) in Net Zero Scenario (NZS) by 2070.
- The Net Zero Scenario reflects the achievement of India's nuclear mission target of **100 GW by 2047** and total nuclear capacity projected to reach around **323 GW by 2070.**
- Cumulative investment requirements reach approximately **USD 600 Billion (USD 13.5 Billion/year).**

100 GW Nuclear Power by 2047 – Broad Roadmap

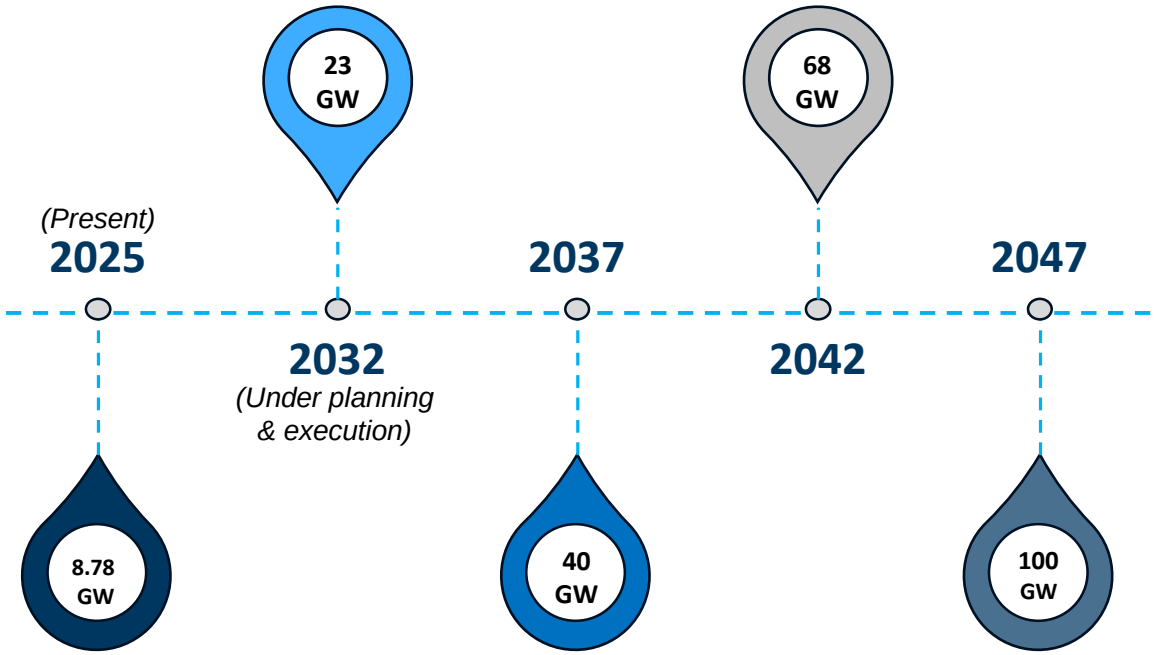
Nuclear Energy Mission for Viksit Bharat has set an ambitious goal to reach 100GW of Nuclear Power Generation by 2047 from its existing portfolio of 8.78 GW translating to an average capacity addition of ~ 4.14 GW per year pan India.

Technology-wise Capacity Addition Projection (in MW)



Source: Ministry of Power

Nuclear Energy Road Map till 2047



GoI has already initiated steps to increase the current Nuclear capacity to 22.48 GW by 2032

Possible options for achieving additional 75 GW capacity

1 3rd PHWR fleet of **10x700 MW**	4 2nd fleet of PHWR **(2x700 MW)** at existing sites of Kakrapar, Rajasthan, Narora	7 **4 PHWR (4x700 MW)** at Bhimpur, Madhya Pradesh
2 PWRs at Kovvada , Andhra Pradesh **(6x1208 MW)** & Jaitapur, Mahararashtra (**6x1730 MW)**	5 Small Modular Reactors **(SMR-55)** & **High Temperature Gas Cooled Reactor (5 MWth)** at off grid locations	8 **2x 500 MWe at FBRs** at Kalpakkam
3 Fast breeder reactors **(~ 3 GW)**	6 Foreign **LWR based power plants** (~ 17 GW)	9 **Private sector participation** for BSR, BSMR, foreign LWR/SMR based projects (~ 40 GW)

SHANTI Bill – An Enabler for Nuclear Power Expansion

Private Sector Participation | Tiered Licensing Model | Foreign Partnerships | Regulatory Enhancements | Governance Framework | Liability Reforms

Benefit Areas	Opportunities Unleashed	Relevance for Mission 100 GW
Private Sector Participation in New Builds	▪ Licenses can be granted to Indian private firms and JVs with govt. entities to build, own, operate & decommissioning nuclear plants.	▪ Would accelerate project development & capacity addition speed, scaling to 100 GW with higher capital access.
Foreign Partnerships (upto 49% FDI)	▪ Enables foreign companies to participate through joint ventures. ▪ Technology collaboration becomes easier with foreign entities.	▪ Access to advanced reactor designs (viz. PWR, SMRs), reduces technology gap. ▪ Boosts supply chain & investment towards manufacturing hubs.
Unified Legal Framework	▪ Consolidates regulation, licensing, safety and liability rules into one comprehensive law, reducing administrative friction.	▪ Would accelerate consenting & permitting process to faster deployment of new reactors.
Nuclear Liability Regime (Tiered Structure)	▪ Introduces graded operator liability ranging from ₹100 Cr. to ₹3,000 Cr. as per reactor capacity; central government covers excess liability. ▪ Eliminates supplier right-of-recourse liability, except in specific cases.	▪ Reduces financial risk for investors & suppliers, unlocking large-scale private and foreign capital needed for 100 GW expansion.
Statutory Status & Stronger Safety Oversight	▪ Grants legal backing to the Regulatory Board, mandating safety authorizations for radiation-related activities.	▪ Builds investor & public confidence, ensuring large-scale nuclear growth without compromising safety.
Policy Provision to boost Supply Chain	▪ Opening the sector to domestic private firms and foreign JVs expands manufacturing of components, reactor modules, fuel cycle facilities. ▪ Supplier liability relaxation improves vendor participation and policy also encourage modular manufacturing ecosystems.	▪ Strengthens domestic and global supply chains to support rapid, large-scale reactor construction. ▪ Would ensure availability of critical components, fuels, and technology to achieving the 100 GW nuclear mission.
Nuclear Governance Framework	▪ Establishes Atomic Energy Redressal Advisory Council to bring higher clarity in Govt. systems.	▪ Transparent regulatory environment improves investor confidence and reduces project risks & delays; key for mega-capacity targets.

Technology Segmentation & Localization Strategy

Reactor Type (India)	Capacity Additions by 2032 (MW)	Future Capacity Additions by 2047 (MW)		Current Localization	Nature of Localisation
		Site Identified	Site yet to be identified		
PHWR (220 / 540 / 700 MWe)	9100	7000	23800	~ 85–90%	Design and Manufacturing largely Indigenous with few specific imports (heavy forging, special alloy etc.)
PWR	4000	17628	15180	~ 20–30%	Civil works and auxiliaries localized; nuclear island, fuel, I&C, major equipment imported under turnkey model
Fast Breeder Reactor (FBR)	500	1000	3500	~ 70–75%	Indigenous design, niche imports
BSR	0	0	5060	–	Not yet implemented. However, largely indigenous same as 220MWe iPHWR
BSMR	0	0	5000	–	Not yet constructed

Supply Chain Indigenization – Implementation Approach

Phased Localization Strategy

Action - Start with low/medium complexity components, gradually move to critical systems

Outcome – Phased manufacturing program at par with Make-in-India guidelines

Regulatory Reform

Action - Simplify approval process, align liability framework with global standards

Outcome – Making cohesive environment for suppliers

Skilled Workforce Development

Action - Create training programs in nuclear engineering, execution and O&M

Outcome – Building specialized human capital for nuclear sector

Vendor Ecosystem Development

Action - Expand Tier-2 & Tier-3 suppliers, promote MSMEs, cluster-based manufacturing

Outcome - Expand industrial base and supply chain arrangement

Domestic Manufacturing Capability

Action - Develop heavy engineering & reactor components, control systems indigenous

Outcome - Reduce import dependence

Policy Integration

Action - Align with Make in India & industrial policy; incentivize localization

Outcome - Create a cohesive national strategy

Quality & Certification

Action - Support nuclear-grade certifications strengthen QA systems

Outcome - Ensure safety and global compliance

Upstream Supply Security

Action - Secure uranium; develop thorium cycle; strengthen materials supply

Outcome - Ensure long-term energy and resource security

Supply Chain Resilience

Action - Reduce dependence on critical imports; diversify sourcing

Outcome - Enhance resilience against geopolitical risks

Private Sector Participation

Action - Enable PPPs; allow private and foreign participation

Outcome - Scale up manufacturing & bring innovation

R&D and Technology Development

Action - Invest in SMRs, advanced fuels, digital control systems

Outcome - Achieve technological self-reliance

Fleet-mode Deployment

Action - Standardize reactor designs; enable bulk production

Outcome - Achieve economies of scale and cost efficiency

Supply Chain Localization - Phased Manufacturing Programme (PMP) steps

Reactor-Wise Localization Baseline

Value Chain Mapping (components wise)

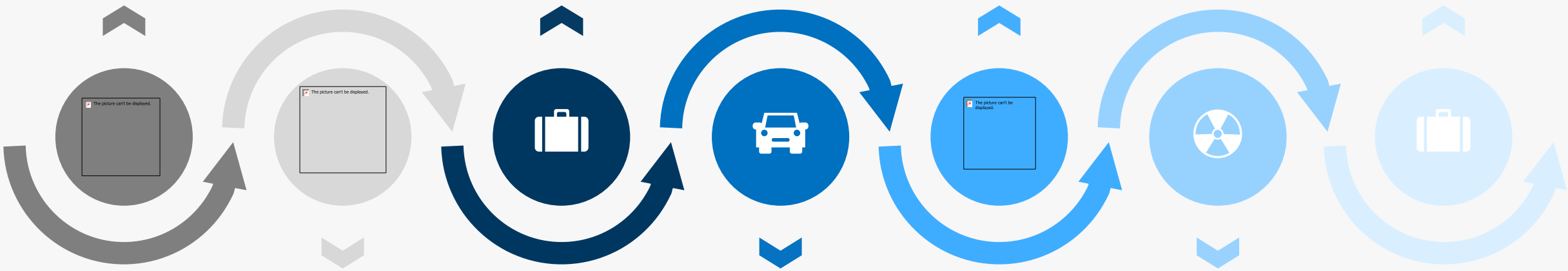
Phased Indigenization Approach

Vendor Development & Capacity Expansion

Long-Term Engagement for Suppliers/OEMs

QA/QC Programme and Verification

Strengthening of PMP (Make in India)



Collaborative Engagement for Advanced Reactor Deployment

Nuclear Energy Mission - 100 GW Nuclear Capacity by 2047

Comprehensive program to reinforce indigenous market

Development of Class-I suppliers, regulatory qualification

Engineering collaboration for 3D engg., modular design

1 2 3

4 5 6

Support in safety assessment, licensing

Joint programme for Workforce development,

Harmonization of Reactor deployment process

2x220 MWe PHWR Bharat Small Reactor (BSR)

Bharat Small Modular Reactors (BSMR-200 MWe)

Foreign Small Modular Reactors (SMR-55 MWe)

HT Gas Cooled Reactor (5 MWth)

Nuclear Value Chain – PSUs, Private Sector Engagement Opportunities

	Pre-Project Activities	Financing & Capital Investment	Plant Design & Engineering	R&D Activities	Supply Chain & Manufacturing	Construction & Commissioning Activities
Role of Govt. PSUs	• Lead candidate site selection process • Community engagement & land acquisition • Water allocation & grid integration planning	• Equity funding in public sector projects • Viability gap support • Nuclear investment fund, green financing	• Technology ownership for indigenous reactors • Engg. oversight for foreign technologies	• Lead nuclear R&D programs • Development & prototyping of BSMR technology. • Foundation for three stage deployment	• Qualification & regulation of nuclear vendors. • Expanding vendor ecosystem with investment in component manufacturing hub	• Lead construction activities for PSU projects. • Supervision, nuclear safety & quality compliance checks for all new builds
Role of Private Sector	• Participate in PFS & FS along with PSUs. • Support in site characteristics, environmental & radio-active assessment • Power demand assurance via PPAs	• Co-investment in SPVs, • Foreign investment under regulatory provisions • Raising capital via green bonds,	• Detailed engineering & balance-of-plant design, • 3D/4D engineering with design modularization • Plant design optimization & automation	• Support in SMR modularization, • Partnership in developing plant design for new technology options	• Expansion of nuclear-qualified private manufacturing firms, • Support in building indigenous manufacturing facility • Facilitating foreign technology through global supply chain	• Lead construction activities for private sector projects under supervision of regulators & SMEs • EPC execution, schedule optimization, cost control, project management systems

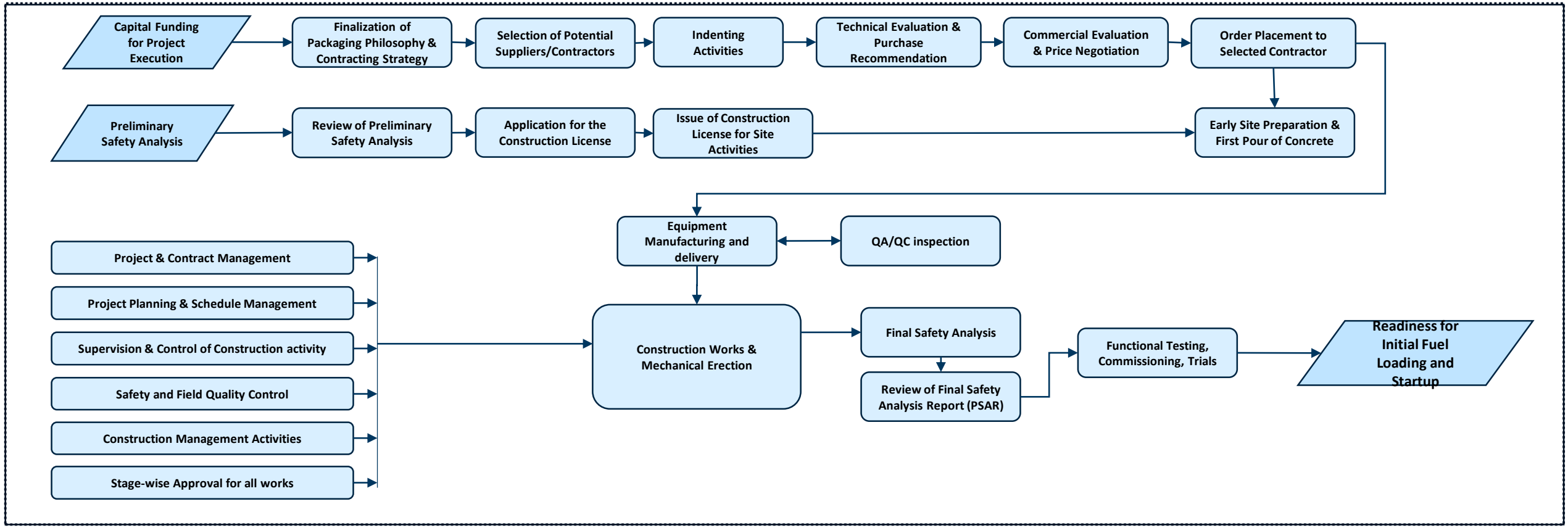
Nuclear Value Chain – PSUs, Private Sector Engagement Opportunities (Contd..)

	Plant O&M and Decommissioning	Fuel Cycle, HW, Waste Management	Human Resource Development	Risk & Liability Management	AI & Digital System Integration	Regulatory & Licensing Aspects
Role of Govt. PSUs	• Lead O&M activities • Control radioactive surveillance program & regulatory interface • Developing roadmap for decommissioning activities	• Expansion of mineral mining & fuel fabrication/ enrichment facilities • Development of alternate Th-based fuel cycle • Lead in radioactive waste management	• Development of national nuclear training institutes • Skill development & Regulatory certification programs	• Covering excess liability in addition to operators' liability • Strengthening nuclear insurance pools	• Mandating cyber-security standards • Implementing digital & smart systems in nuclear fleets/ installations	• Simplifying consenting & approval processes for large-scale expansion. • Interfacing with regulators during deployment and plant operations
Role of Private Sector	• O&M services support, (near term) and O&M handover (long term). • Developing optimal plant maintenance & asset management strategies.	• Partnership in fuel fabrication, fuel innovation and HW production • Support in logistics • Import from overseas countries	• Facilitating industry-academia collaboration to develop nuclear skilled workforce • Partnership in certified training programs	• Limited liability exposure at par with global practice • Risk sharing during project development & execution • Managing insurance pool	• Developing mechanism for AI/ML-based predictive maintenance, digital twins, advanced control systems and cyber-security solutions	• Compliance with nuclear safety and regulatory standards. • Structured interface through licensed operators • Obtaining licenses for build, own & operate

Strategic Approach for Nuclear Project Development

Strategies

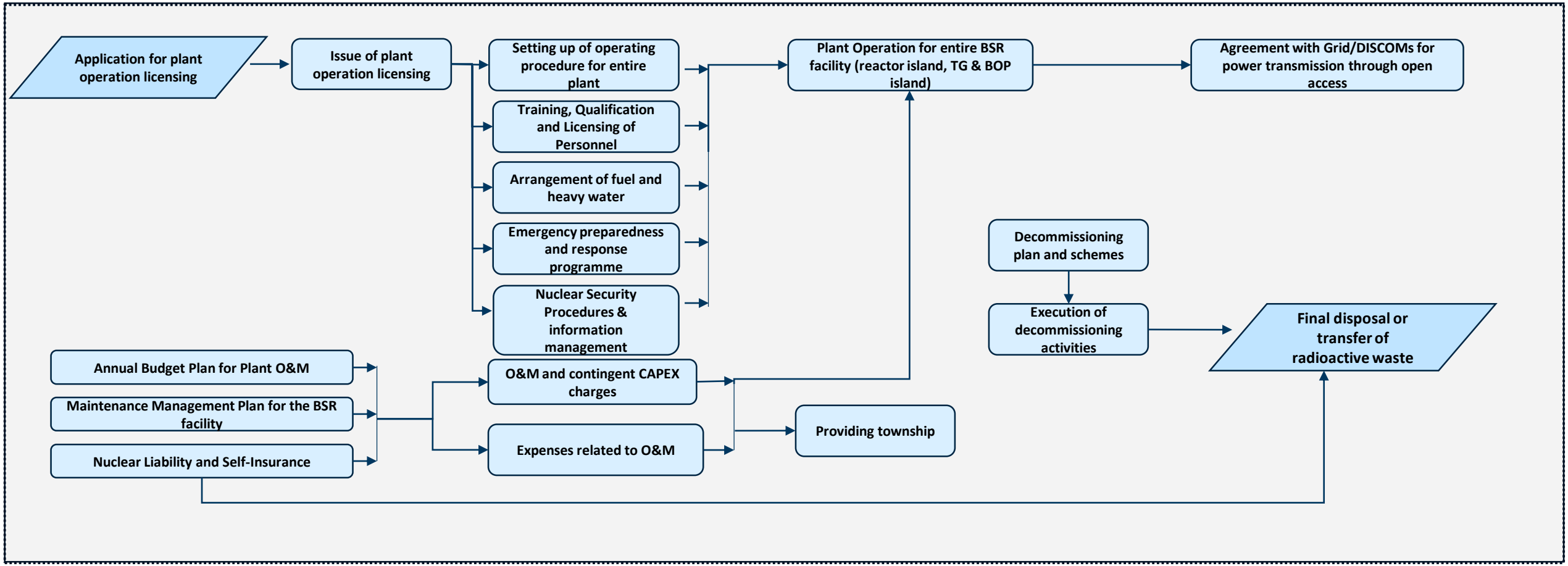
- Expanding domestic supply chain and manufacturing eco-system with necessary govt. support to both public/ private suppliers
- Developing indigenous manufacturing & delivery programs for large scale deployment of new reactor technologies
- Fleet mode implementation of nuclear plants and long-term order visibility for suppliers
- Enabling Foreign Direct Investment (FDI) in manufacturing and construction activities



Strategic Approach for Plant O&M Phase

Strategies

- Establish a Clear Spent Fuel & Waste Management Framework
- Enhance Vendor Ecosystem & O&M Supply Chain
- Strengthen Human Resources, Training & Licensing
- Developing AI/ML based maintenance & asset management strategies.
- Create a Robust National Decommissioning Policy + Corpus Fund
- Ensure Fuel Security including exploration of alternative Th fuel cycle



Concluding Remarks

Simplification of the licensing processes	Simplification of regulatory clearances and safety approval process at each stage for siting, construction, operation to avoid cost & time overrun and build investor confidence.
Indigenization of the manufacturing ecosystem	1. DAE -led vendor development and hand-holding should focus on building an indigenous, reliable manufacturing ecosystem and supply chain for nuclear reactor systems and equipment. 2. Committed focus on indigenous R&D for development of reactors suitable for Thorium – both large scale reactor and SMR.
Fleet Mode Execution	Provide 15–20-year advance visibility of a pipeline of nuclear projects and award bundled, multi-project contracts to enable vendor capacity ramp-up, cost reduction, and workforce stability.
Long-Term Engagement scheme	Requirement of next 15-20 years can be shared with manufactures/vendors, so that they can ramp up their capacity and consider hand holding interested and upcoming vendors with a view to expand the vendor base. .
Fuel Security and Scalability	Augmentation of heavy water & fuel processing facilities to assure fuel security and commitment on fuel price and heavy water charges. PSUs to lead the mining expansion, fuel fabrication/enrichment & development of alternate/new fuel options; Private sector to support logistics, innovation & studies for new options
Resource development	To develop National level nuclear training & skill development programs; Private sector to support industry-academia collaboration and large-scale pool of skilled resources

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