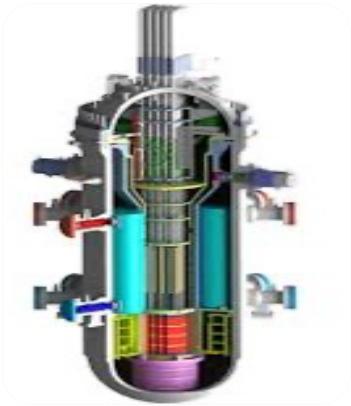


India Smart Utility Week 2024

14th Mar 2024

New Delhi, India

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

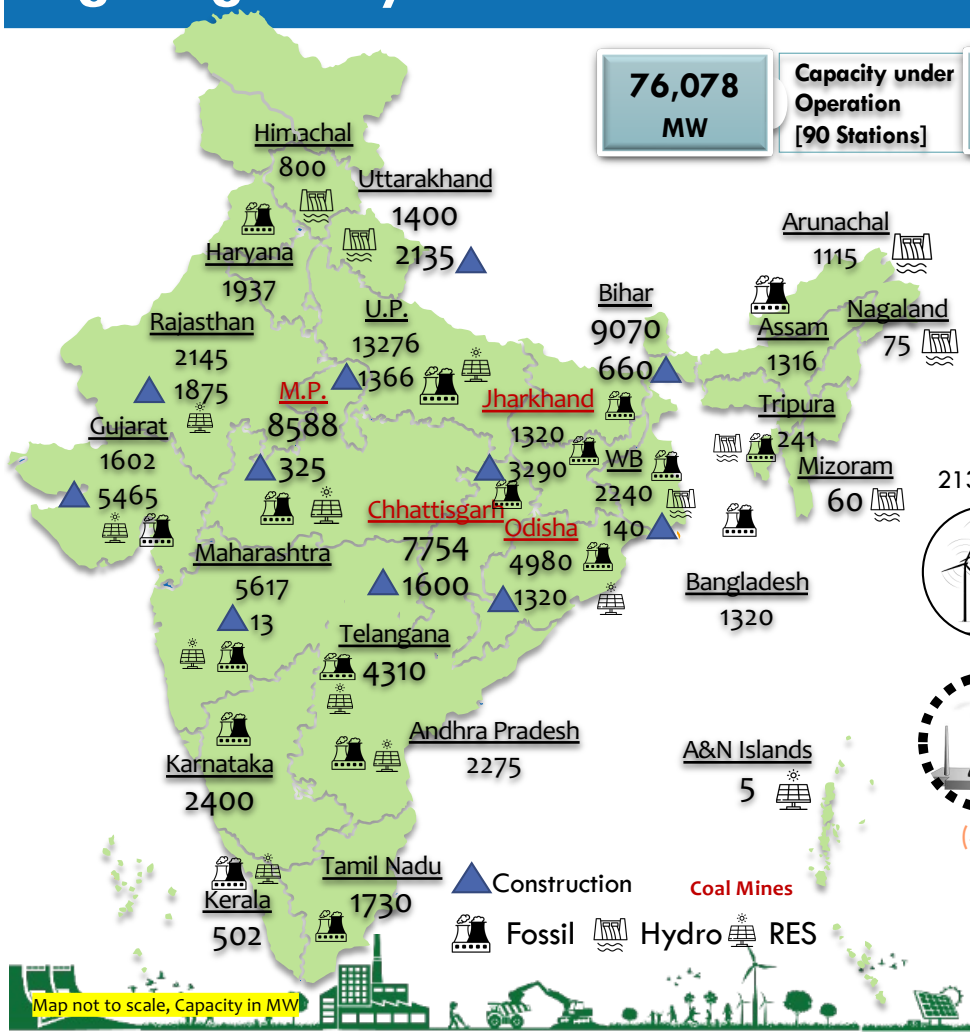
Transition to cleaner, more sustainable energy solutions for net-zero power systems aims to mitigate the impact of traditional energy sources on the environment.

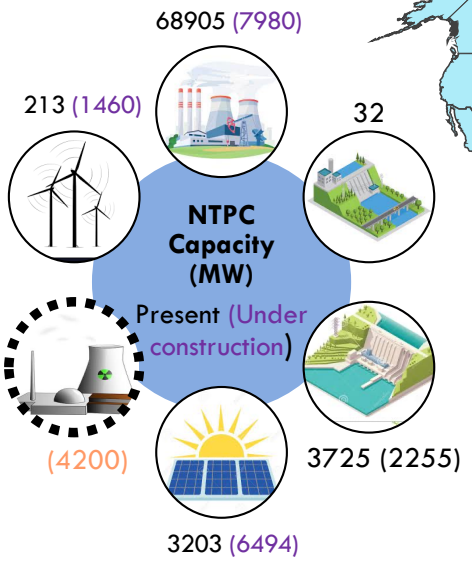
Follow us on: /ntpc1 /ntpcltd1 /ntpclimited /Company/ntpc /ntpclimited

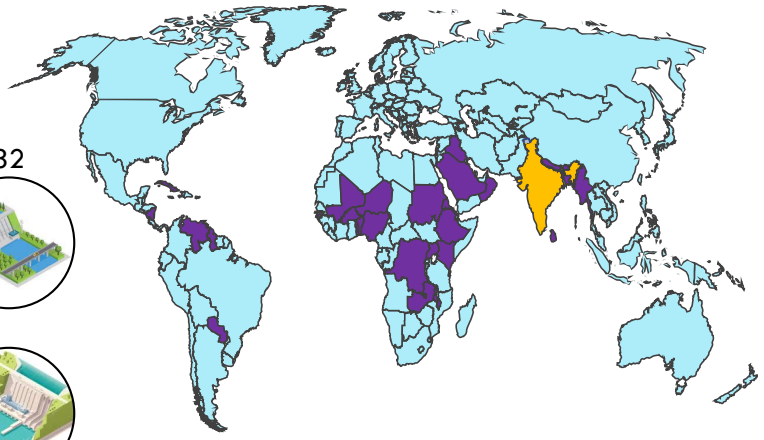
Lighting every 4th bulb in India since last 25 years

76,078 MW	Capacity under Operation [90 Stations]	18,189 MW	Capacity under Construction [31 Projects]	71 MMTPA	Coal Mining Capacity [7 Mines]	29 Companies	10 Subsidiaries 19 Joint Ventures

17000+ Employees







International Proj 1.72 GW (incl 0.4 GW Solar)

Long term O&M in GT plants in Bangladesh

PMC in ISA member countries 6555 MW

NTPC for Conservation of Environment

Biomass Firing

CCU & Methanol

Adapting more efficient thermal cycles
From 38% (in 90's) to 42% (in ~2010) & aiming for 46% (AUSC)

Electric & Hydrogen Bus

Combustion Tuning

FGD

Blending H_2 in PNG

Low-NOX Burners

3 GW Completed
60.6 GW under execution
1.5 GW under tendering

NTPC Kawas PNG +H_2

Afforestation

20 million trees till date

Ash Utilization

> 700 LMT ash utilized in last year

Optimum land usage

ACC, ZLD, HIGHER COC, AWRS, STP

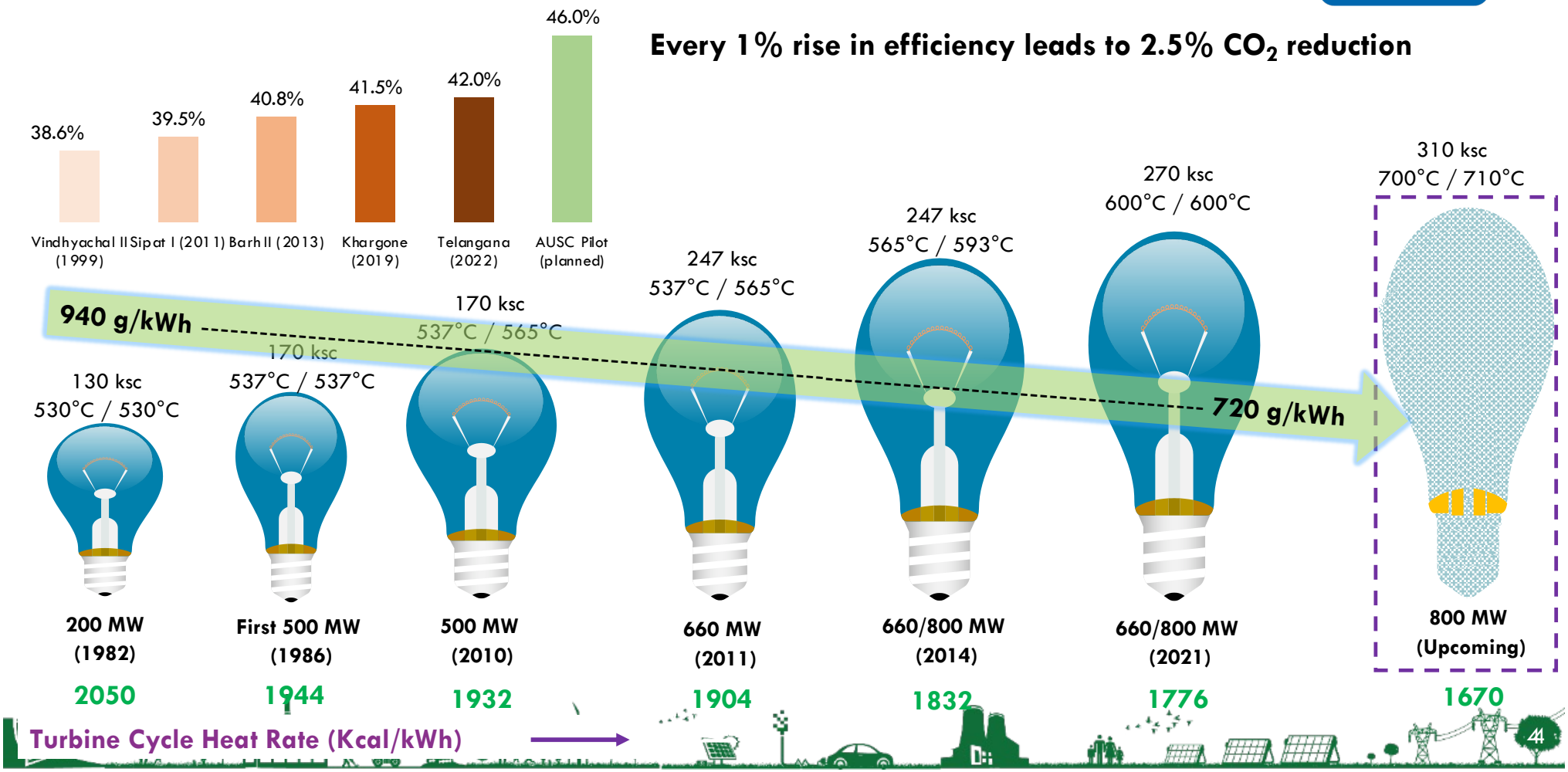
2.69 Litres** (fresh water) per kWH in last year against norms of **3.5 L/kWh

DESALINATION OF SEA WATER

Desalination of Sea Water at Simhadri

NTPC - Moving towards Efficient Operations

Every 1% rise in efficiency leads to 2.5% CO_2 reduction



Move towards flexibility

Renewable infusion, needs flexibility

Higher Ramp Rate, Lower Technical Min load

NTPC initiatives **Live schedule monitoring**, **Part-load optimization**, **Compliance to AGC (Automatic Generation Control) and RGMO/FGMO**.

APC

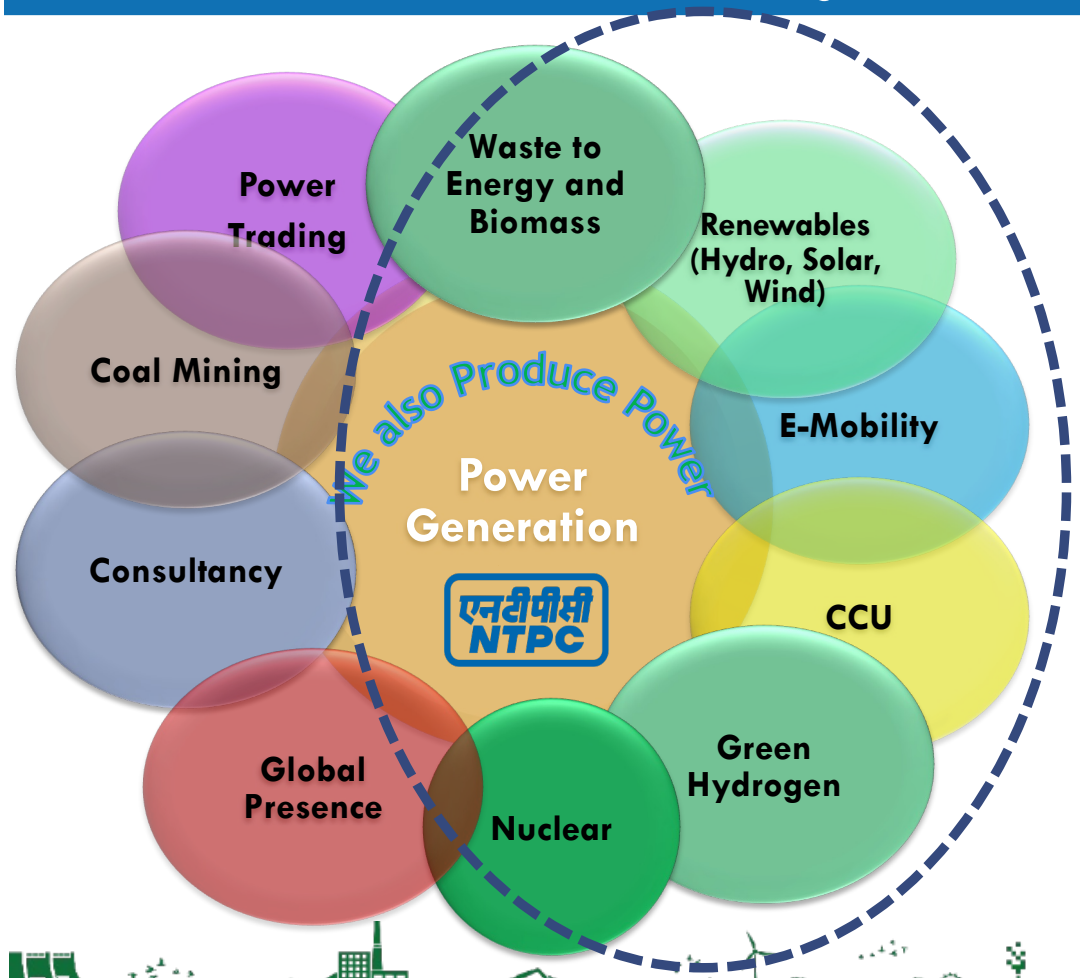
Auto Mill Scheduler

Two prominent ones Advanced Process Control and Automatic Mill Scheduler

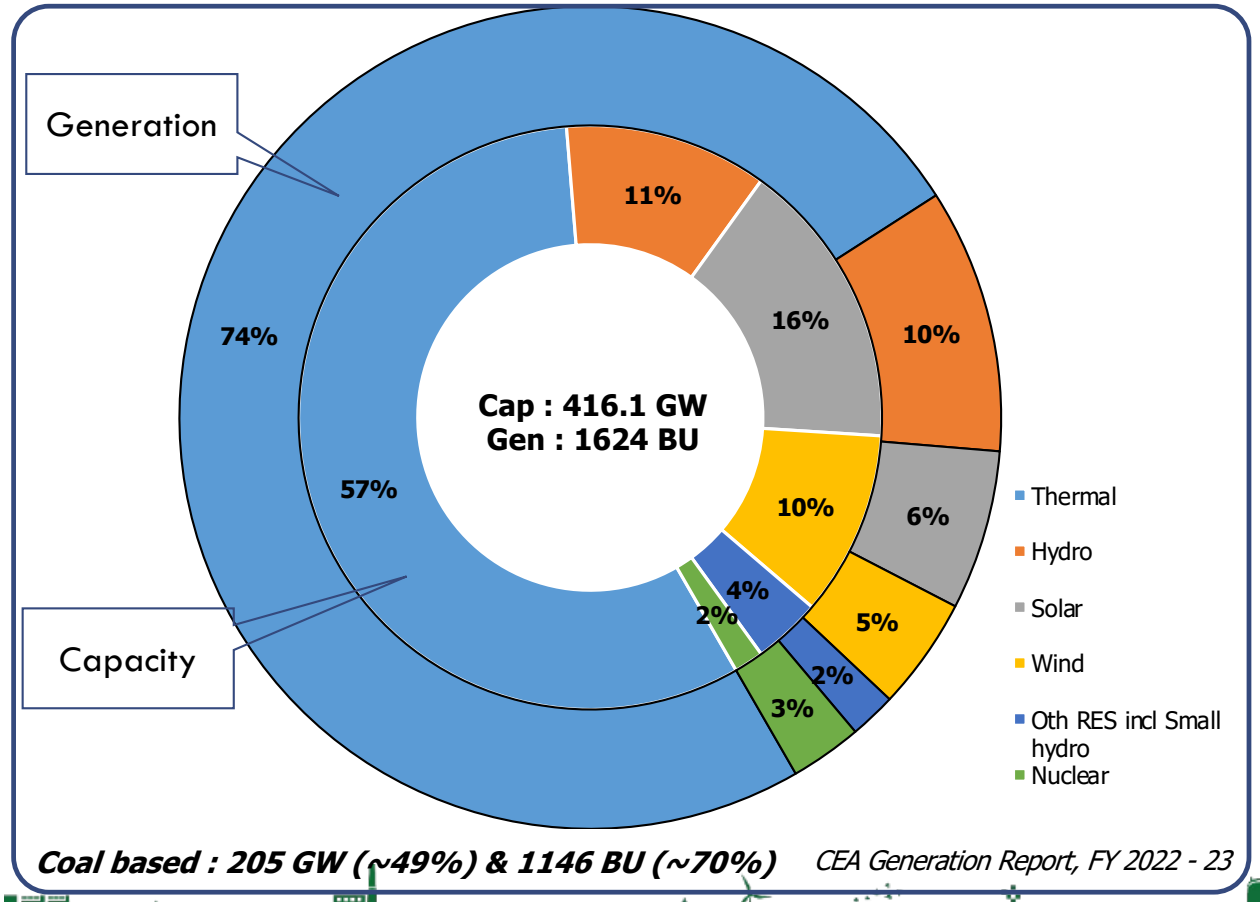
- ❑ Implemented in 2020 at NTPC Simhadri TPP
- ❑ State Variable Control - Model Predictive Control
- ❑ Neural Network Control

- ❑ Implemented in 2022 at NTPC Vindhyachal TPP
- ❑ Ramp Rate optimization and Schedule deviation minimization

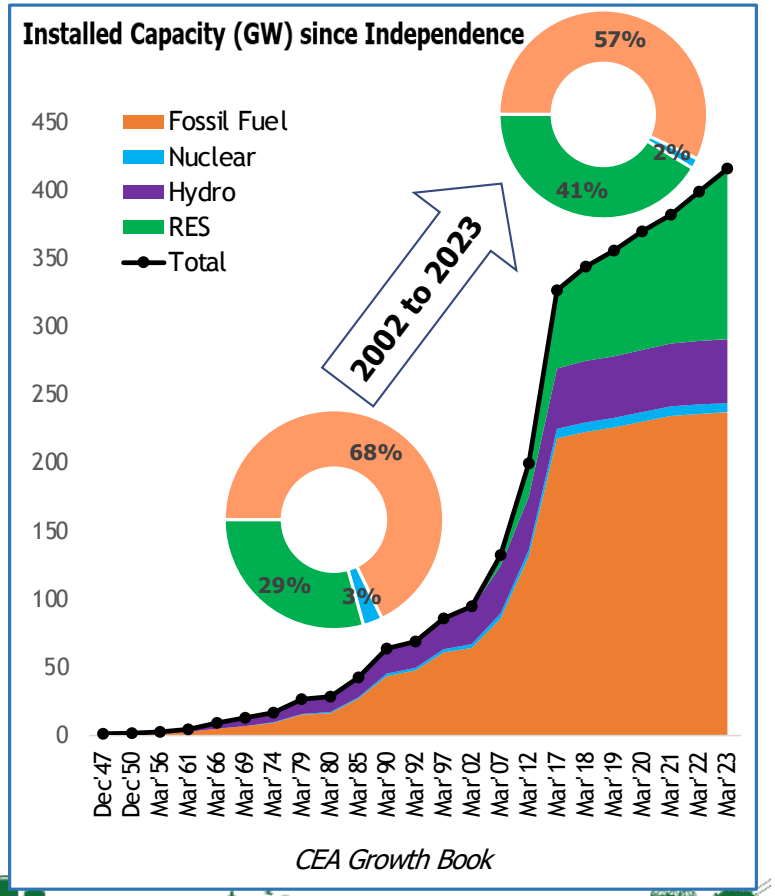
NTPC Diversified Sectors & Strength



India Energy Mix – Capacity & Generation

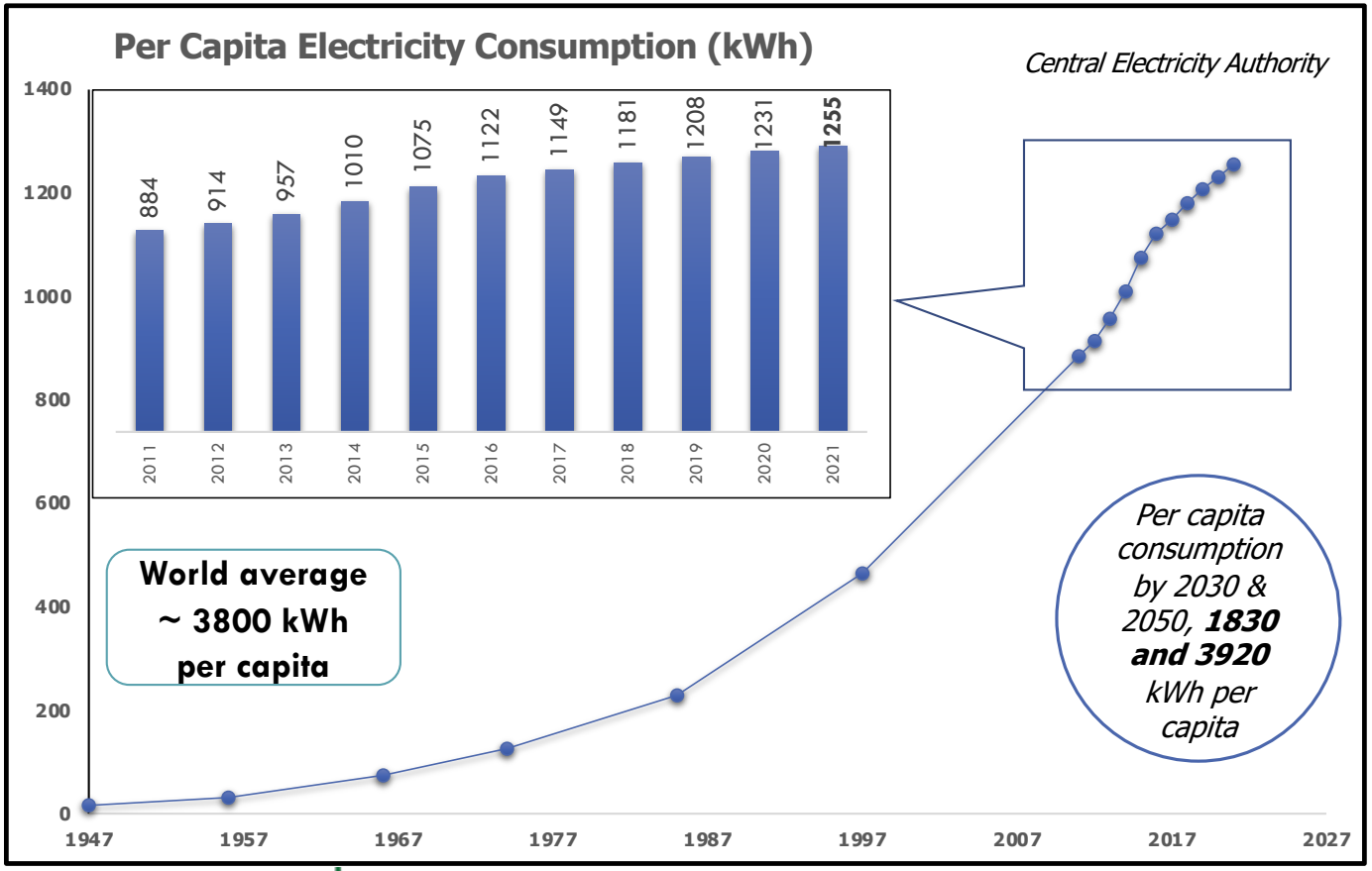


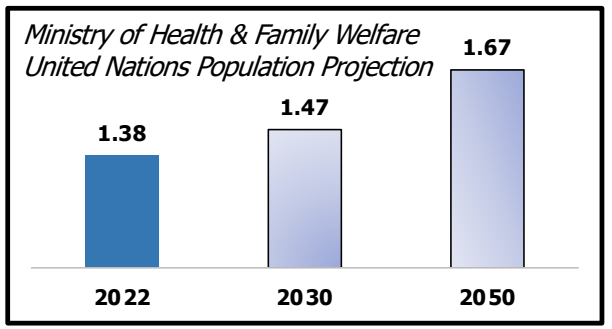
Coal based : 205 GW (~49%) & 1146 BU (~70%) *CEA Generation Report, FY 2022 - 23*

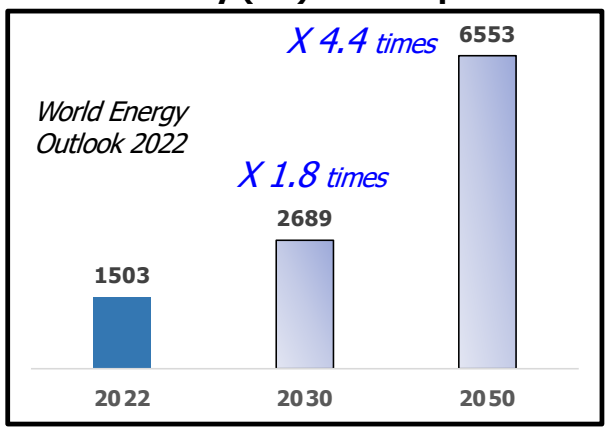


CEA Growth Book

India - Electricity Consumption



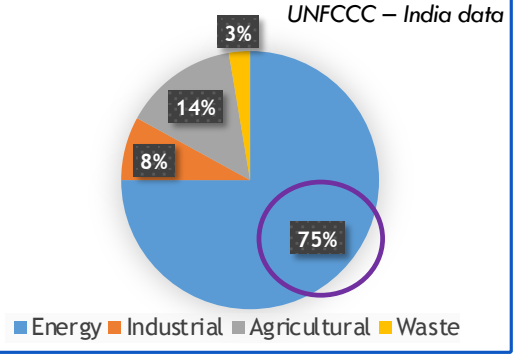




NEED FOR DECARBONIZATION & NUCLEAR ENERGY

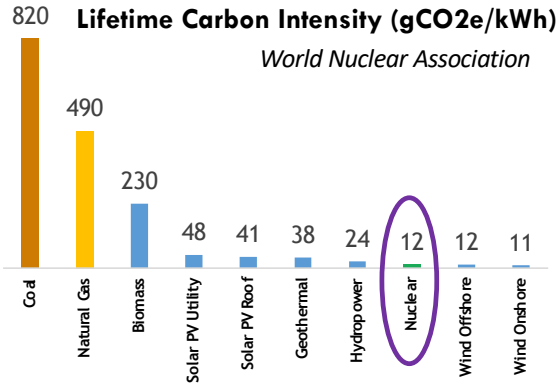
SECTOR WISE EMISSION (%)

UNFCCC – India data



Lifetime Carbon Intensity (gCO2e/kWh)

World Nuclear Association



Energy Storage systems have limitations.

Hence, requirement for dispatchable power to supplement renewable sources.

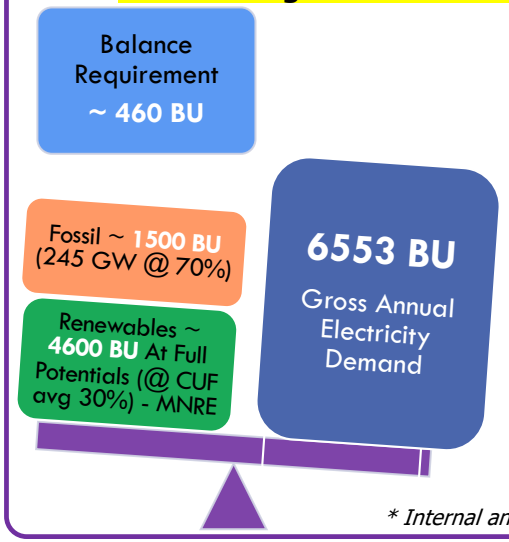
Globally, IEA & IAEA have expressed this.

INDIA's PANCHAMRIT

- ❑ Carbon Net-zero by 2070
- ❑ To increase non-fossil fuel energy capacity to 500 GW by 2030.
- ❑ Increase the share of renewables in the energy mix to 50% by 2030.
- ❑ Reduce the emissions intensity of its economy by 45%.
- ❑ Reduce emissions by 1 billion Tonnes of CO2.

Nuclear fits into 4 out of above 5 Amrits!

India Emergent Situation - 2050



- ❑ IAEA Projection 78 GW (South Asia)
- ❑ Based on the WEO 2022 Outlook projections
- ❑ Assumption of utilization of total RE potential of India
- ❑ Retirement of old Fossil based plants (after two R&M cycles)
- ❑ Addition of 80 GW Fossil based plants

** Internal analysis based on data available*

Potential RE by MNRE

Solar : 850 GW (Roof Top Solar 102 GW)
Wind : 765 GW (Offshore 70 GW)
Small Hydro : 21 GW ***Biomass*** *: 20 GW* ***Waste*** *: 5.7 GW*

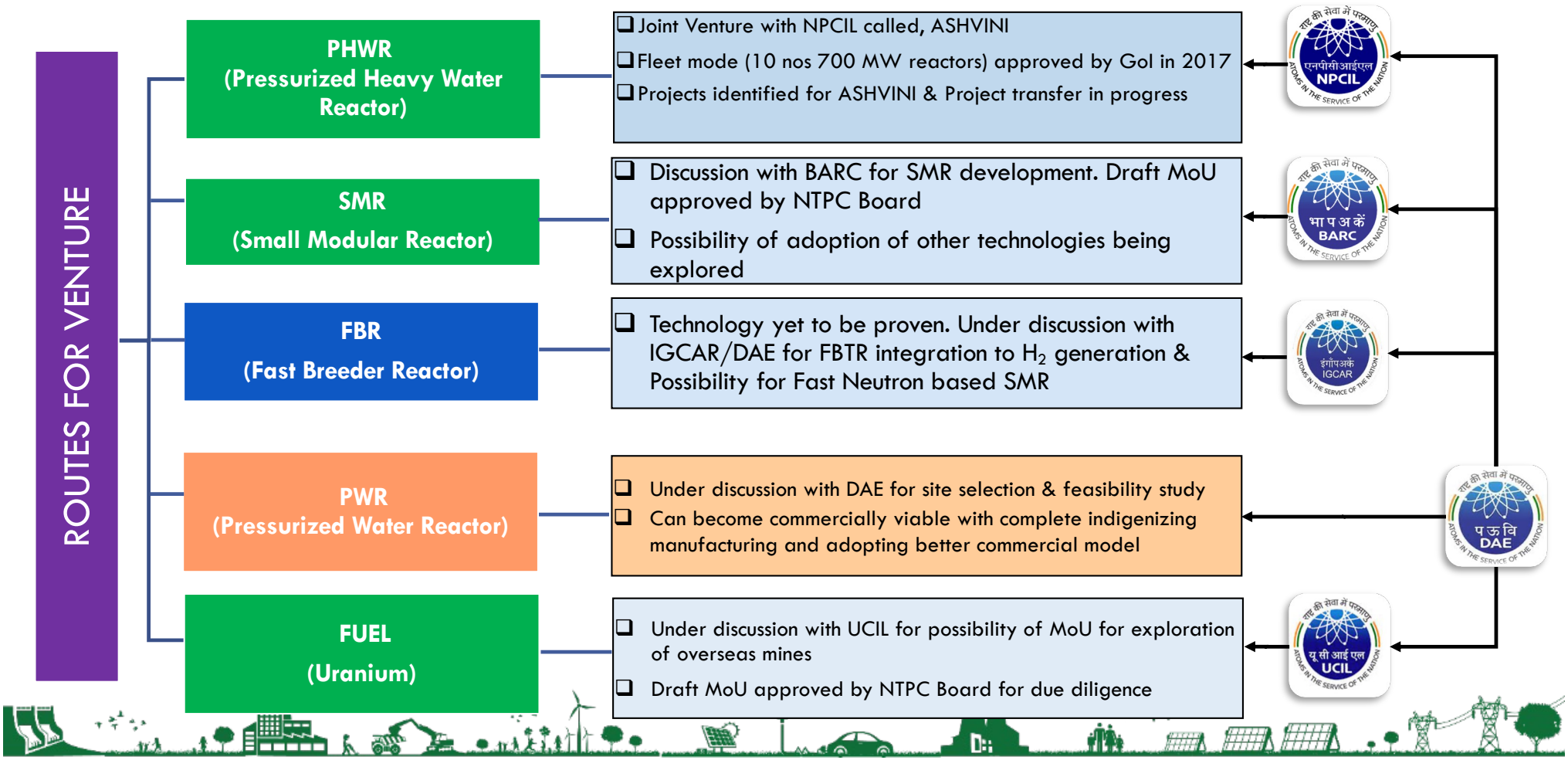
India's Present Electricity consumption 1624 BU (2022-23)

Expected Electricity Consumption 6553 BU (2050) *estimated by WEO 2022*

Total renewable energy potential 4600 BU (30% CUF)

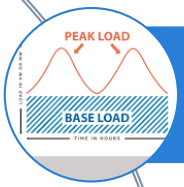
For meeting base load demand, Nuclear energy is among the best alternatives – recognized worldwide

Exploring Avenues for Nuclear venture



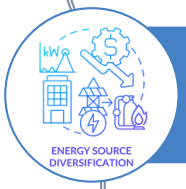
Role of SMR

While the utilization of traditional nuclear reactors has limitations, SMRs present a compelling solution with diverse applications and significant environmental benefits.



Reliable Baseload Electricity

SMRs, as a part of nuclear power, offer a dependable source of low-carbon baseload electricity, aligning with global efforts to reduce greenhouse gas emissions.

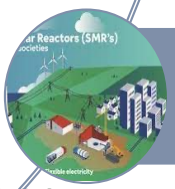


Diversifying Energy Mix

Enhancing energy security, SMRs play a significant role in diversifying the energy mix, reducing reliance on fossil fuels and mitigating potential supply disruptions.

Off-Grid Power Supply

SMRs serve as a viable solution for providing consistent power supply to remote communities, bolstering economic development without extensive grid infrastructure.

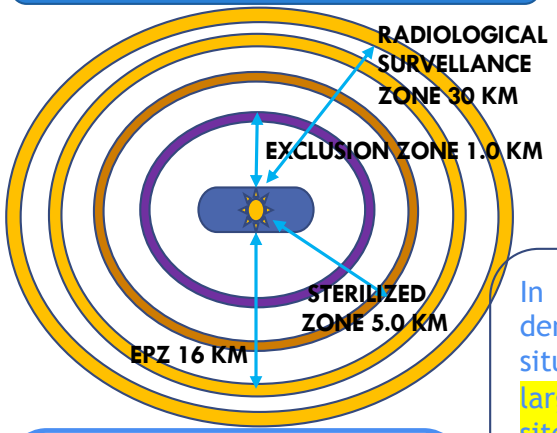


Industrial Implementations

SMRs can be utilized for industrial processes such as desalination, hydrogen production, and district heating, contributing to the reduction of carbon emissions.

SMR CUTTING EDGE OVER CONVENTIONAL REACTORS

CONVENTIONAL LARGE SCALE REACTORS



Thick growth of population around the retiring coal plants for job & livelihood Emergency preparedness involves relocating of people & development of large infrastructures

In the current demographic situation, can such large number of sites meeting the safety criteria be identified ??

Adopting conventional large reactors in retired coal plants

SMALL MODULAR REACTORS

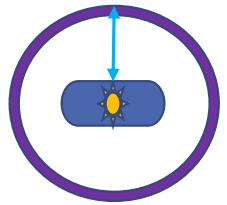
PASSIVE COOLING SYSTEM & INFINITE COOLING THROUGH DESIGN

ENSURES CORE COOLING FOR > 7 DAYS WITHOUT OPERATOR INTERVENTION

RULES OUT CORE MELTDOWN & REDUCES CORE DAMAGE FREQUENCY DRASTICALLY

WALK AWAY SAFE

✓ PARTIAL PORTION OF SMR UNDERGROUND CONSTRUCTION FOR BRINGING DOWN EXCL ZONE BELOW 1 KM



EXCLUSION ZONE LESS THAN OR EQUALS 1.0 KM

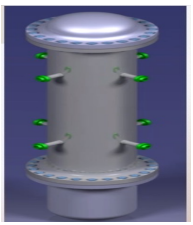
- ❑ Minimum public disturbances, with its EPZ boundary as plant boundary
- ❑ Modular design with maximum factory construction & enhanced quality standards
- ❑ Low gestation period
- ❑ Lesser footprint
- ❑ Potential to decarbonize industrial and transportation sector
- ❑ Repurposing of existing brownfield projects
- ❑ Suitable for Micro grid and isolated grid operation

Small Modular Reactors

- Reactors with power output between **10 MWe and 300 MWe**
- **Modular** design saves construction time

BLOCK

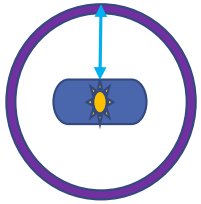
INTEGRAL



PASSIVE COOLING SYSTEM & INFINITE COOLING THROUGH DESIGN

ENSURES CORE COOLING FOR > 7 DAYS WITHOUT OPERATOR INTERVENTION

RULES OUT CORE MELTDOWN & REDUCES CORE DAMAGE FREQUENCY DRASTICALLY



EXCLUSION ZONE SHOULD BE LESS THAN OR EQUALS 1.0 KM

SMR Basic Design Approach

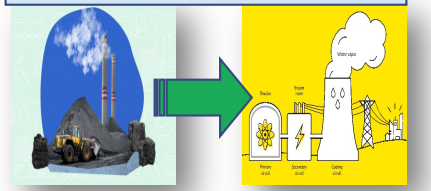
- To meet the dozing criteria at plant boundary.
- Load follow capability
- Lesser quantum of spent fuel.

- **Water cooled land based**
- **Water cooled Marine Based**
- **Gas cooled**
- **Molten Salt Cooled**

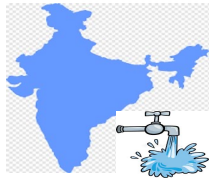
Majority of SMRs based on PWR design

Trending Technology
NuScale (USA),
ROSATOM (Russia),
Holtec (USA),
EDF (France),
SMART (Korea)

Retired CPP to NPP



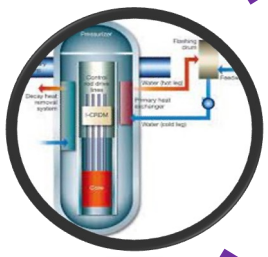
Desalination & Water Grid

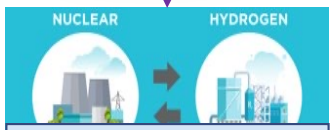


Industrial applications

Textile
Chemicals
Fertilizers
Refinery
Food process
Paper

APPLICATIONS



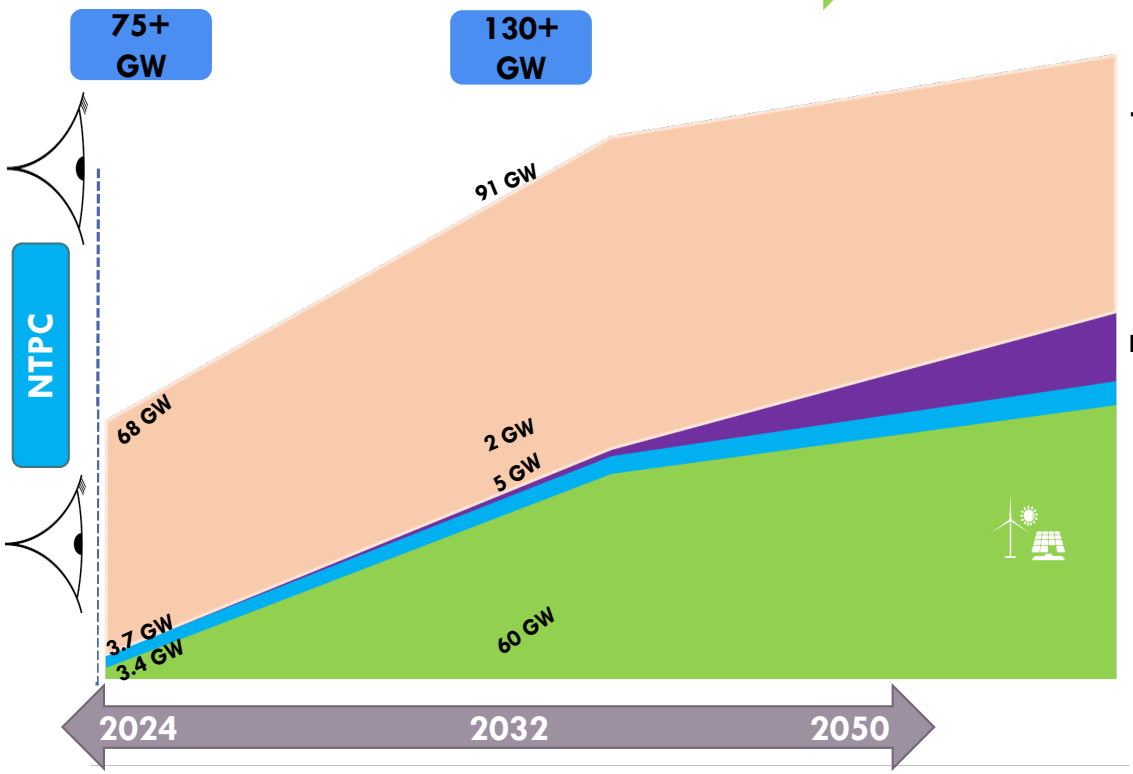


Hydrogen Generation

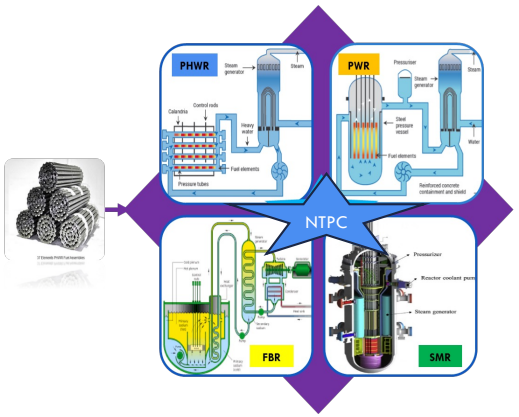
Cooling & Refrigeration

NTPC pursuing Energy Transition

Fossil Energy Major >>>>> **Green Energy Major**



NUCLEAR ENERGY



RENEWABLE ENERGY

Thank You

Future Outlook for Enabling advanced reactor technologies

Policy Frameworks	Global Dynamics	Innovative Research	Market Integration	Industrial Applications	Renewable Energy Integration	Environmental Contribution
Comprehensive policy frameworks, integrating regulatory standards, energy security, and long-term sustainability goals.	Geopolitical influences and international cooperation in policy development.	Exploring cutting-edge research and development in advanced nuclear technologies	Assessing economic feasibility and commercial growth potential.	Assessing the applications of nuclear energy in industrial sectors	Examining the synergy between nuclear energy and renewable	Highlighting environmental benefits and emissions reduction through the integration of nuclear energy

Repurposing Opportunities of retired thermal plants

Source	Potential Capacity	Annual CUF(%)	Capital Cost	Variable Cost	CO2 Emissions (g/kWh)	Remarks
Coal with CCU	☒ ~ 70 GW Additional land for CCU,H2 & Methanol	☑ 60-70	☒ **High**	☒ High Fuel consp	☒ Has to be mitigated through CCU	Electricity for hydrogen production will be higher than the generated for 100% carbon capture and conversion to methanol.
Solar	☒ ~ 10 GW	☒ 20-25	☑ Moderate	☑ Small	☑	Cannot meet the required demand. Lower capacity utilization – varies through region, season
Wind	☒ ~ 2 GW	☒ 30-35	☑ Moderate	☑ Moderate	☑	Cannot meet the required demand. Wind potential is not available in pit-head stations. Lower capacity utilization – varies through region, season.
Nuclear	☑ > 100 GW	☑ 80-90	☒ **High**	☑	☑	Potential available - Best fit solution for the current demography – cost is primarily capital nature can be optimized – economies of series **(Among Nuclear, SMR has cutting edge over conventional NPP in terms of Radiological safety requirement)**

Different SMR Technologies World Wide

S.N	Design	Output (MWe)	Type	Config.	PHT circulation	Designer	Country	TRL > 5
1)	CAREM	30	PWR	Integral	Natural	CNEA	Argentina	✓
2)	ACP100	100	PWR	Integral	Forced	CNNC	China	✓
3)	NuScale	77	PWR	Integral	Natural	NuScale Power	USA	✓
4)	SMART	107	PWR	Integral	Forced	KAERI	Korea	✓
5)	CAP200	200	PWR	Block	Forced	SPIC	China	✓
6)	NUWARD	170	PWR	Integral	Forced	EDF	France	☒
7)	IMR	350	PWR	Integral	Natural	MHI	Japan	☒
8)	RITM-200	53	PWR	Integral	Forced	JSC	Russia	✓
9)	VK-300	250	BWR	Integral	Natural	NIKIET	Russia	✓
10)	BWRX-300	270-290	BWR	Integral	Natural	GE-Hitachi	USA, Japan	☒
11)	SMR-160	160	PWR	Semi Integral	Natural	Holtec	USA	✓