Supported by
Ministry of Power
Ministry of Heavy Industries
Government of India

ieema
your link to electricity

15th Edition
ELECRAMA
Powering the Future of Energy

eTECH nxt
20-21 February, 2023
ELECRAMA, Hall 2 & Hall 4

NUCLEAR BUSINESS PLATFORM

Nuclear Power

ESSENCE AND NECESSITY OF NUCLEAR FOR CLEAN ENERGY TRANSITION

Vinay Khanduri ,
Head- India ,
Nuclear Business Platform

INDIA
NUCLEAR BUSINESS PLATFORM

Agenda

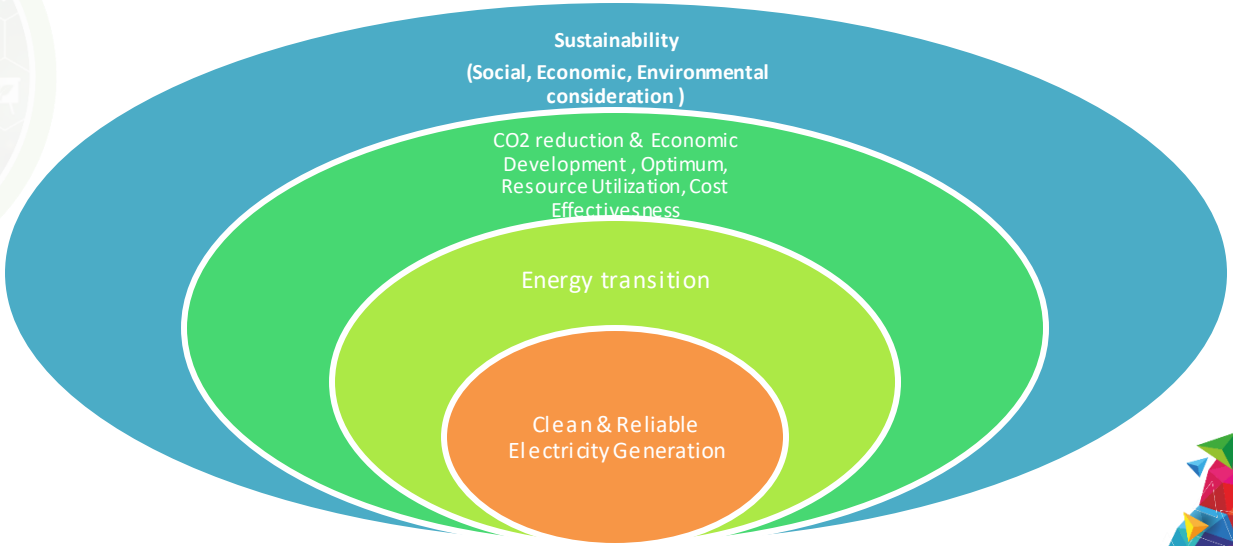
- Exploring the climate change initiatives and clean energy capacity build up in India
- Evaluating adequacy and efficacy of current drive
- Essence of a diversified energy mix with adequate clean base load capacity
- How nuclear fits into the overall scheme
- Nuclear Scale-up & Opportunities
- Gearing up for #NuclearIndustry2.0

Climate Change is real!

Long dry spell, Torrential rains, change of weather phenomenon, Melting of glaciers, Abnormal conditions in ecological sensitive regions are normal experiences now

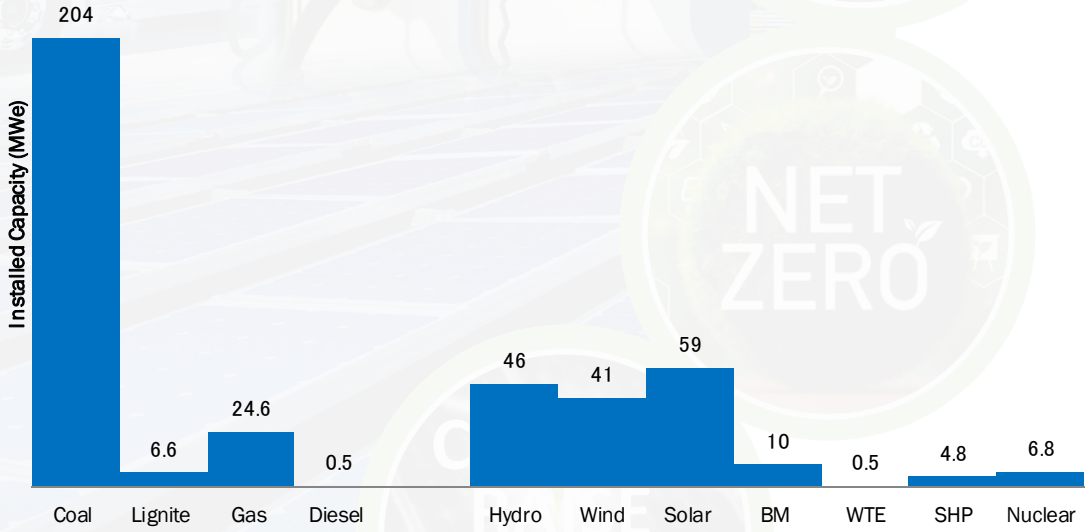
Taking actions against climate change is not an option but a questions of human survival and civilizational existence

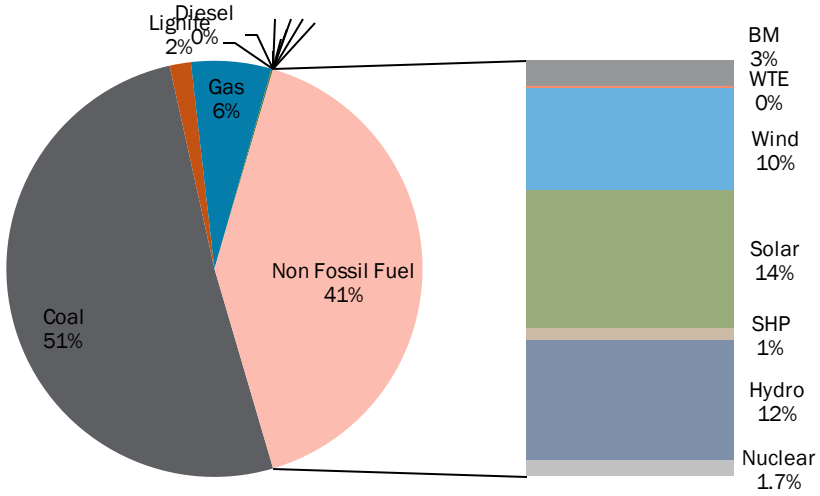
This has mobilized global community take necessary actions, not just mere exchange of ideas and deliberations, on climate change mitigation and sustainable future. Global initiative taken under UNFCCC and acted through COP deliberations and IPCC research works is playing a major role in enabling clean energy transition across different countries

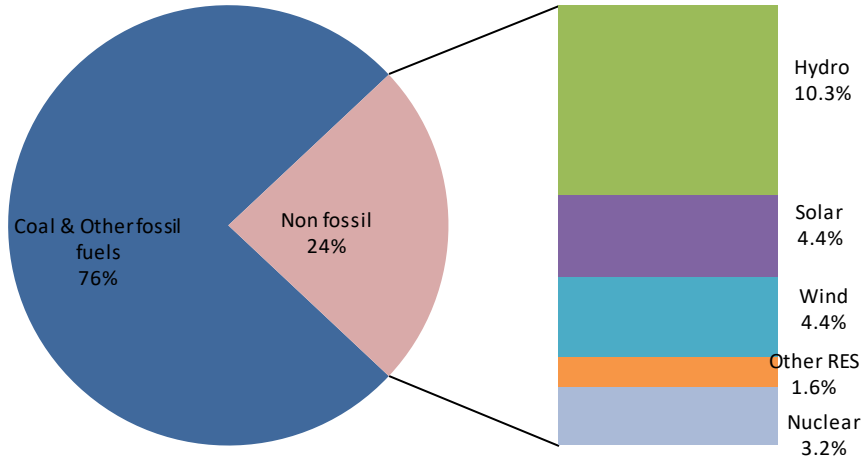


India Power Mix

Currently, electricity makes up around **15% of energy** consumption



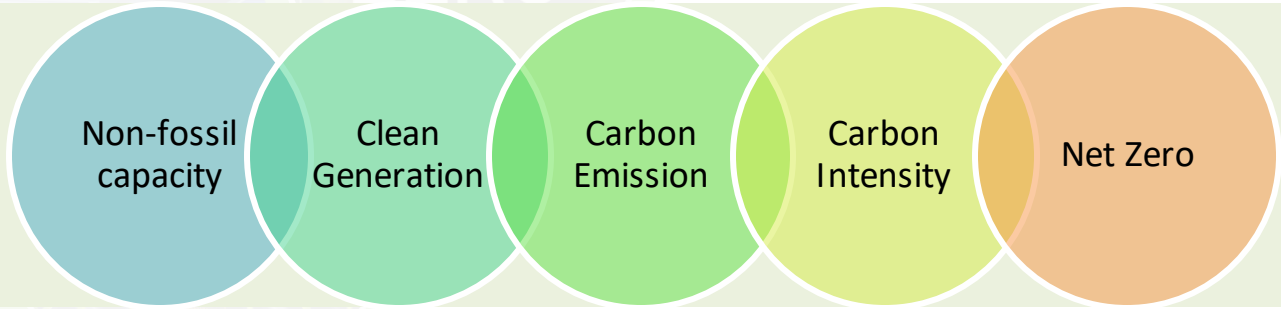




India's Climate Commitment

India's commitment for climate change mitigation is reflected through PM Modi's **Panchamrit Mission** announced at Glasgow Summit of COP26.

India will get its non-fossil energy capacity to 500 GW by 2030
India will meet 50% of its energy requirements till 2030 with renewable energy
India will reduce its projected carbon emission by one billion tonnes by 2030
India will reduce the carbon intensity of its economy by 45% by 2030
India will achieve net zero by 2070

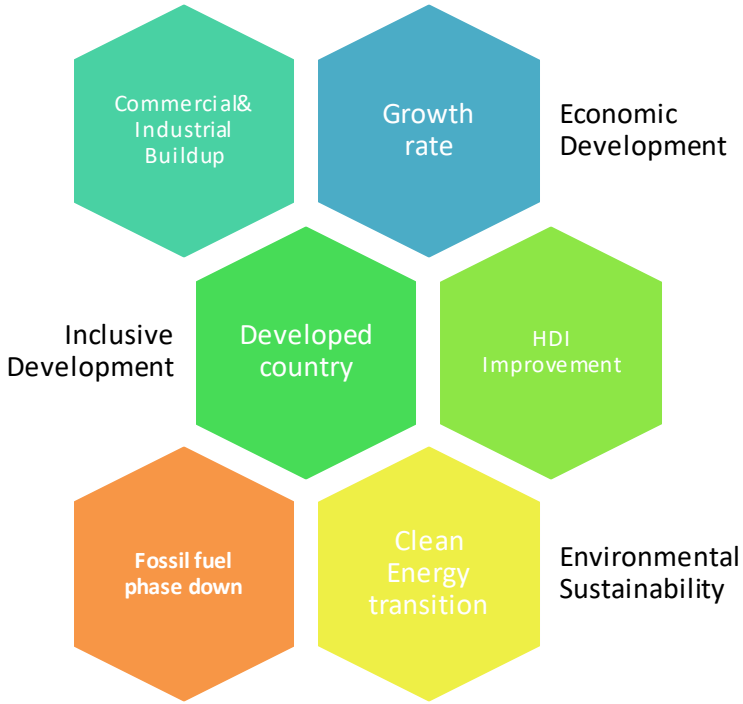


India's Developmental Aspirations

- To be 3rd largest economy by 2027 and sustain its further growth
- Maintain momentum of its economic rate over 7%
- To be a developed country by 2047
- Improve HDI of its billion+ population
- Meet climate commitments and net zero targets

To achieve these goals, **Electricity/ Energy demand** in the country would go further high.

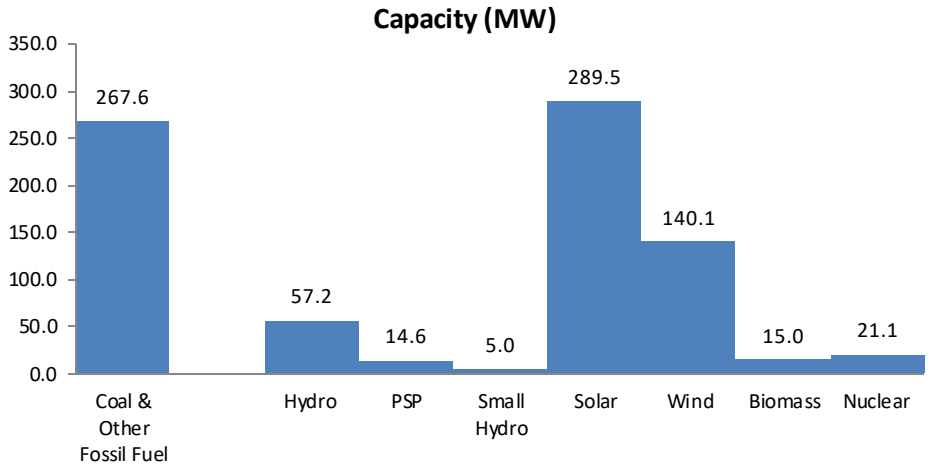
Developing a **reliable and sustainable clean power infrastructure** is central to achieve India's developmental and economic goals

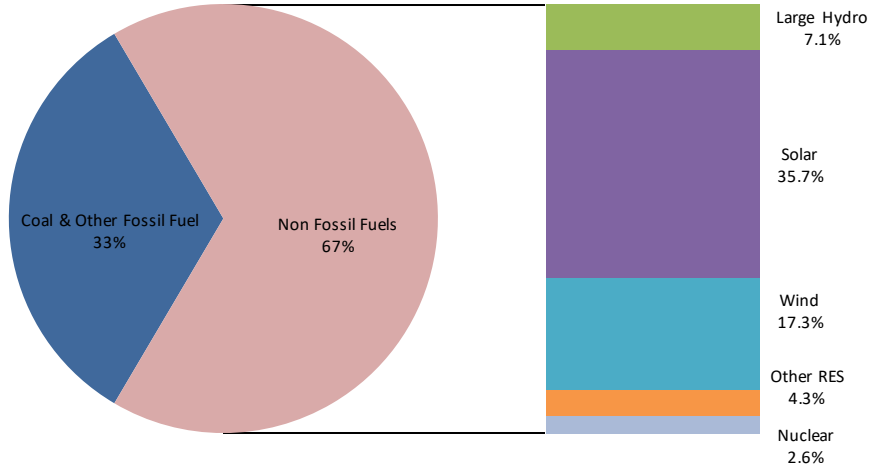


Power Capacity Build-up

Electricity Capacity Addition

	Capacity in 2022 (MW)	Capacity in 2030 (MW)	Capacity Change (MW)	Capacity Change (%)
Coal & Other Fossil Sources	236110	267551	31441	13%
Non-Fossil Sources	168861	542455	373594	221%
Solar	59197	289473	230276	389%
Wind	40358	140117	99759	247%
BM +WTE	10954	15000	4046	37%
Small Hydro	4849	5000	151	3%
Pumped Storage		14566-	-	
Large Hydro	46723	57219	10496	22%
Nuclear	6780	21080	14300	211%
Total	**404971**	**810006**	**405035**	100%





Adequacy & Efficacy of Current Drive?

As clean energy transition unfolds, we find that the share of electricity in the energy mix of the country will go up. It is estimated to rise from current level of 15% to **42% by 2050**

Major power of commercial, residential (electricity supply), transportation, industry (Steel, Cement, Hydrocarbon / Petrochemical /Refineries, fertilizers, etc.) will be fulfilled through the grid

As a result, **reliable power generation** becomes utmost crucial for **grid stability**, business certainty, reducing **price volatility**, and to support economic growth and consumers' comfort

Current drive is primarily focused on REs (which is good for its own reason) and it should continue

However, is it adequate? Perhaps, not

Will it obviate the country's reliance over fossil fuels for power generation and help emission reduction at faster rate? Possibly, not in the foreseeable future

Issues with Current Climate Drives

Current focus is surely far sighted, still **Energy Mix** need to be diversified to ensure energy security, sustainability and affordability. This calls for equal emphasis on other energy options, particularly clean base load sources

Variability of generation (Daily, seasonal, and unforeseeable), Integration, Inertia and grid stability, Material constraint, Quantum of waste generation, high land requirement, technological maturity, project life (just 25 years), Low efficiency systems (17-30%), Performance degradation after 10-12years of operation are key issues with REs

The clean energy transition will be lot slower and far costlier without deployment of a comparable clean base load alternative for coal such as nuclear and hydro

It doesn't mean that RE and Nuclear are mutually exclusive options. Rather, they need to be nurtured as complementary to make energy transition faster and more cost-effective

Case-in-point: Germany's over-reliance on variable REs and neglect of nuclear resulted not just in terms of high electricity prices in Germany but Germany landed up being one of the countries with highest carbon intensity in the EU.

India with its massive grid system, 3x electricity consumption and increasing demand, just can not rely on such lopsided energy policy. A broad based policy with due consideration for Clean base load capacity is essentially required to support developmental and decarbonization goals

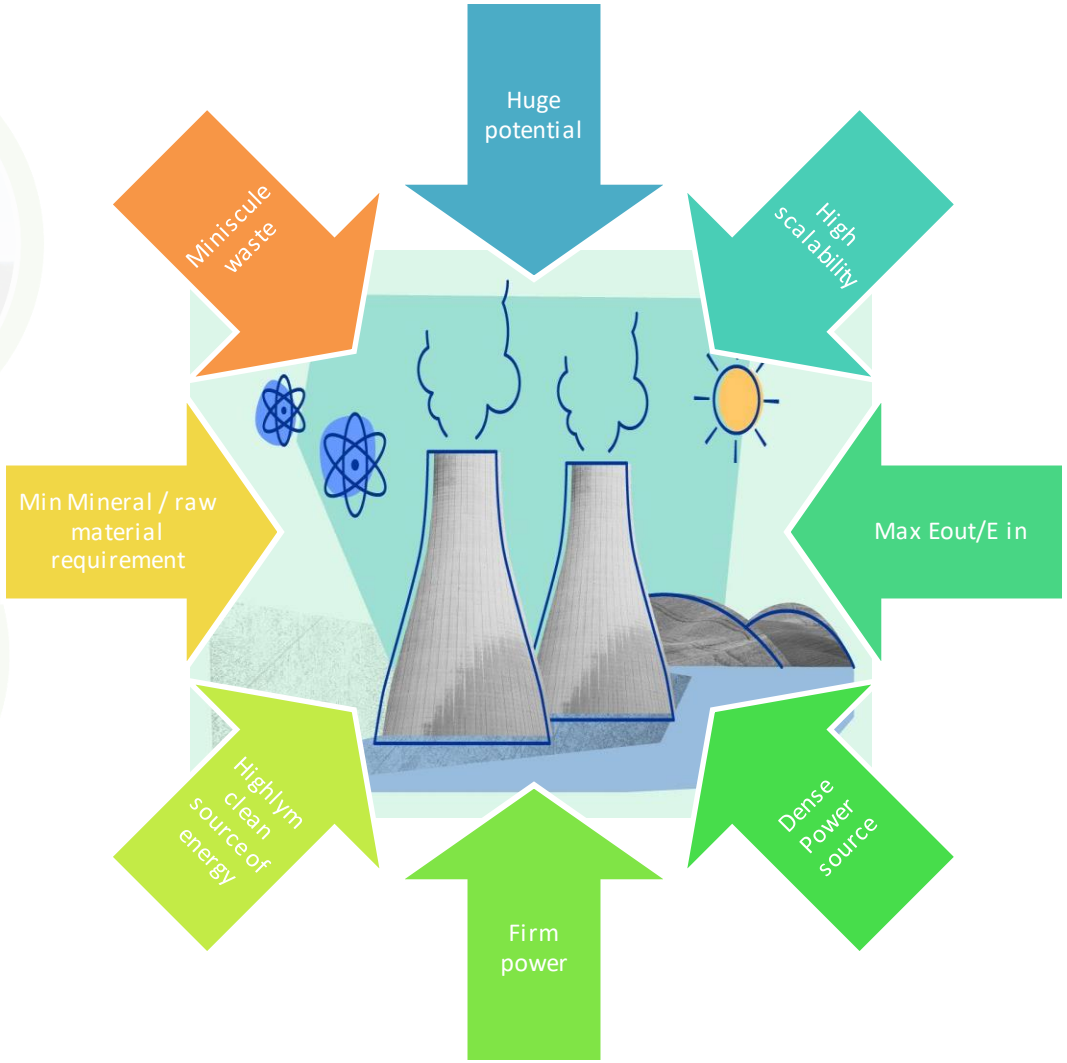
A diversified clean energy mix with around 50% clean base load sources such as nuclear and hydro is need of the hour

Looking Ahead

All energy options must be explored, deployed and mainstreamed to enable a **diversified clean energy mix** that can address the current and future challenges of energy security, affordability, sustainability and economic development of India.

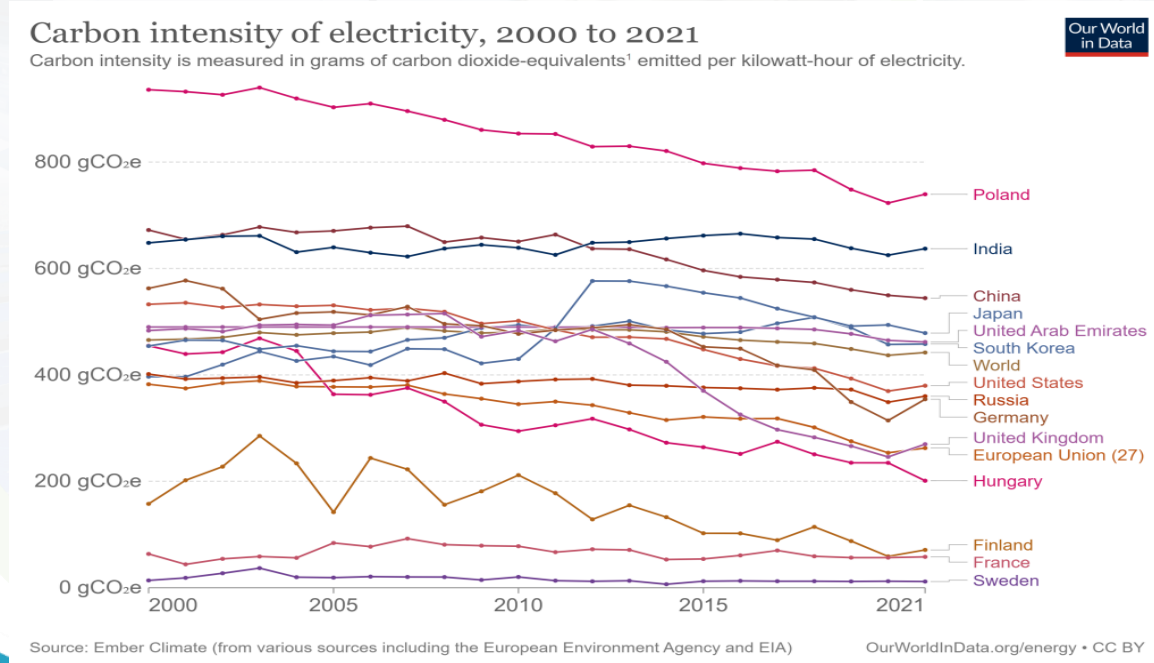
Nuclear is surely one of the most reliable options for its

Abundant potential and high scalability,
Firm nature,
Highly condensed form of energy,
High clean credentials,
Minimum Land requirement,
Minimum material requirement
High Eout/Ein,
Highest investment multiplier
High job generation potential
Miniscule waste
Accountable waste management across the value chain

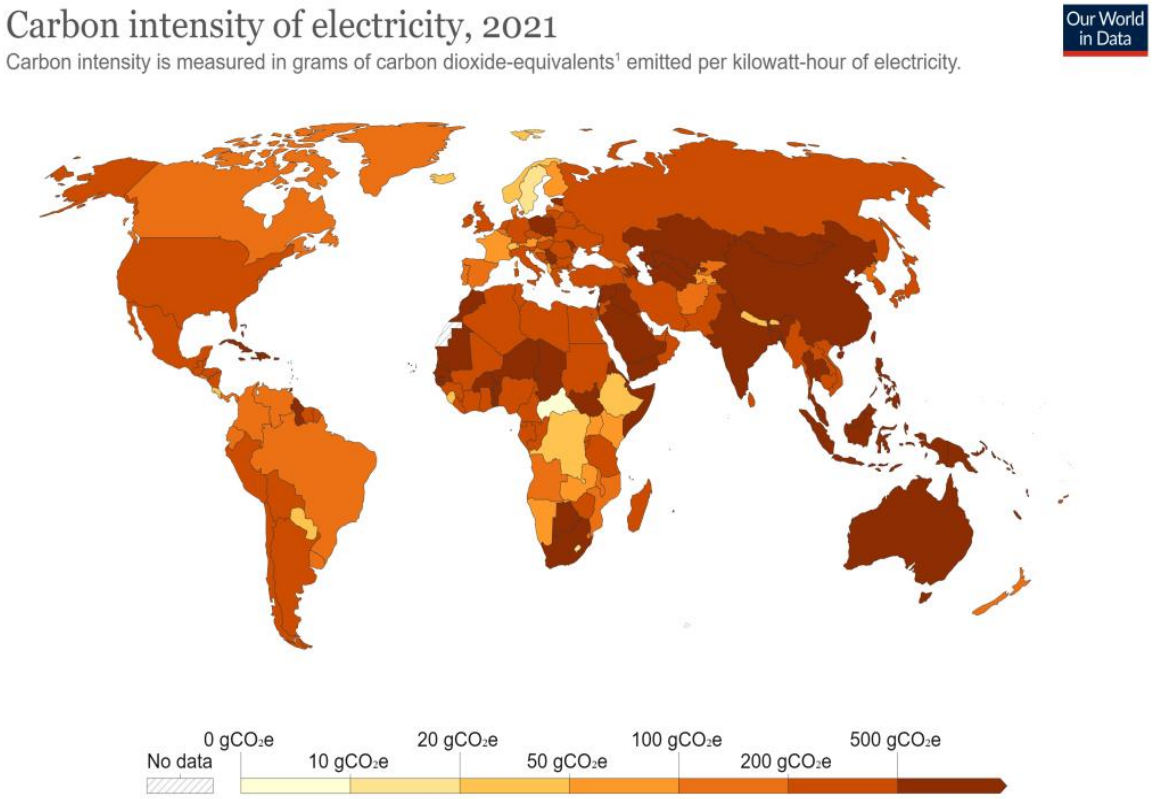


Why Nuclear?

To enable faster reduction in carbon intensity and draw tangible results on carbon emission reduction



1. Carbon dioxide-equivalents (CO_2eq): Carbon dioxide is the most important greenhouse gas, but not the only one. To capture all greenhouse gas emissions, researchers express them in 'carbon dioxide-equivalents' (CO_2eq). This takes all greenhouse gases into account, not just CO_2. To express all greenhouse gases in carbon dioxide-equivalents (CO_2eq), each one is weighted by its global warming potential (GWP) value. GWP measures the amount of warming a gas creates compared to CO_2. CO_2 is given a GWP value of one. If a gas had a GWP of 10 then one kilogram of that gas would generate ten times the warming effect as one kilogram of CO_2. Carbon dioxide-equivalents are calculated for each gas by multiplying the mass of emissions of a specific greenhouse gas by its GWP factor. This warming can be stated over different timescales. To calculate CO_2eq over 100 years, we'd multiply each gas by its GWP over a 100-year timescale (GWP100). Total greenhouse gas emissions – measured in CO_2eq – are then calculated by summing each gas' CO_2eq value.

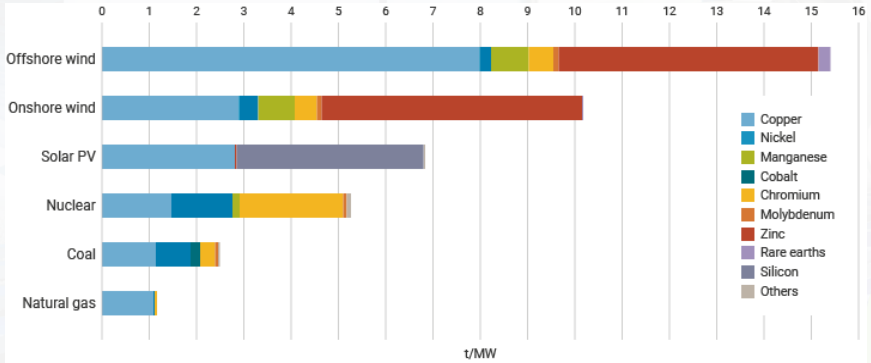


1. Carbon dioxide-equivalents (CO_2eq): Carbon dioxide is the most important greenhouse gas, but not the only one. To capture all greenhouse gas emissions, researchers express them in 'carbon dioxide-equivalents' (CO_2eq). This takes all greenhouse gases into account, not just CO_2. To express all greenhouse gases in carbon dioxide-equivalents (CO_2eq), each one is weighted by its global warming potential (GWP) value. GWP measures the amount of warming a gas creates compared to CO_2. CO_2 is given a GWP value of one. If a gas had a GWP of 10 then one kilogram of that gas would generate ten times the warming effect as one kilogram of CO_2. Carbon dioxide-equivalents are calculated for each gas by multiplying the mass of emissions of a specific greenhouse gas by its GWP factor. This warming can be stated over different timescales. To calculate CO_2eq over 100 years, we'd multiply each gas by its GWP over a 100-year timescale (GWP100). Total greenhouse gas emissions – measured in CO_2eq – are then calculated by summing each gas' CO_2eq value.

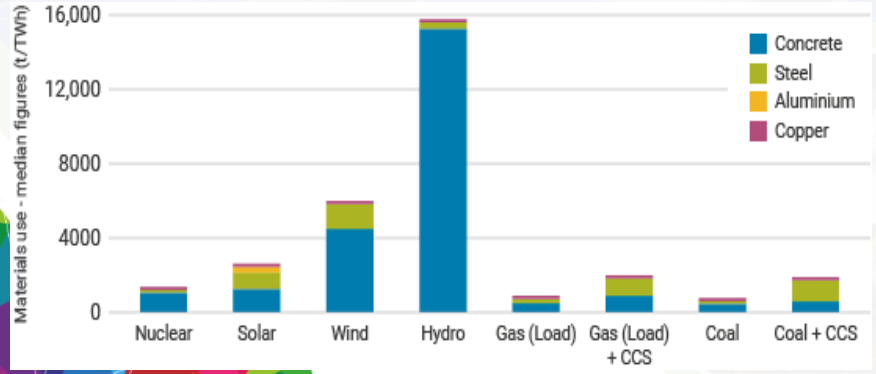
Why Nuclear?

To ensure sustainability of ecosystem and avoid over dependence and over exploitation of mineral resources

Critical mineral requirement (tonne/MW)

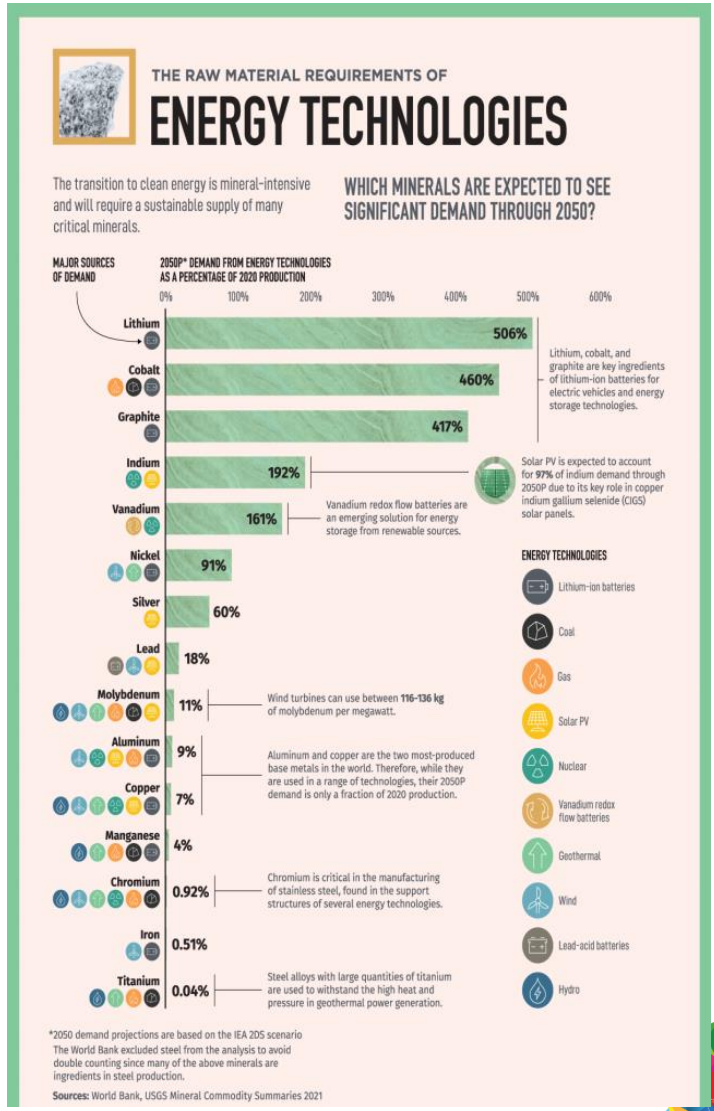


Bulk material requirement (tonne/TWh)



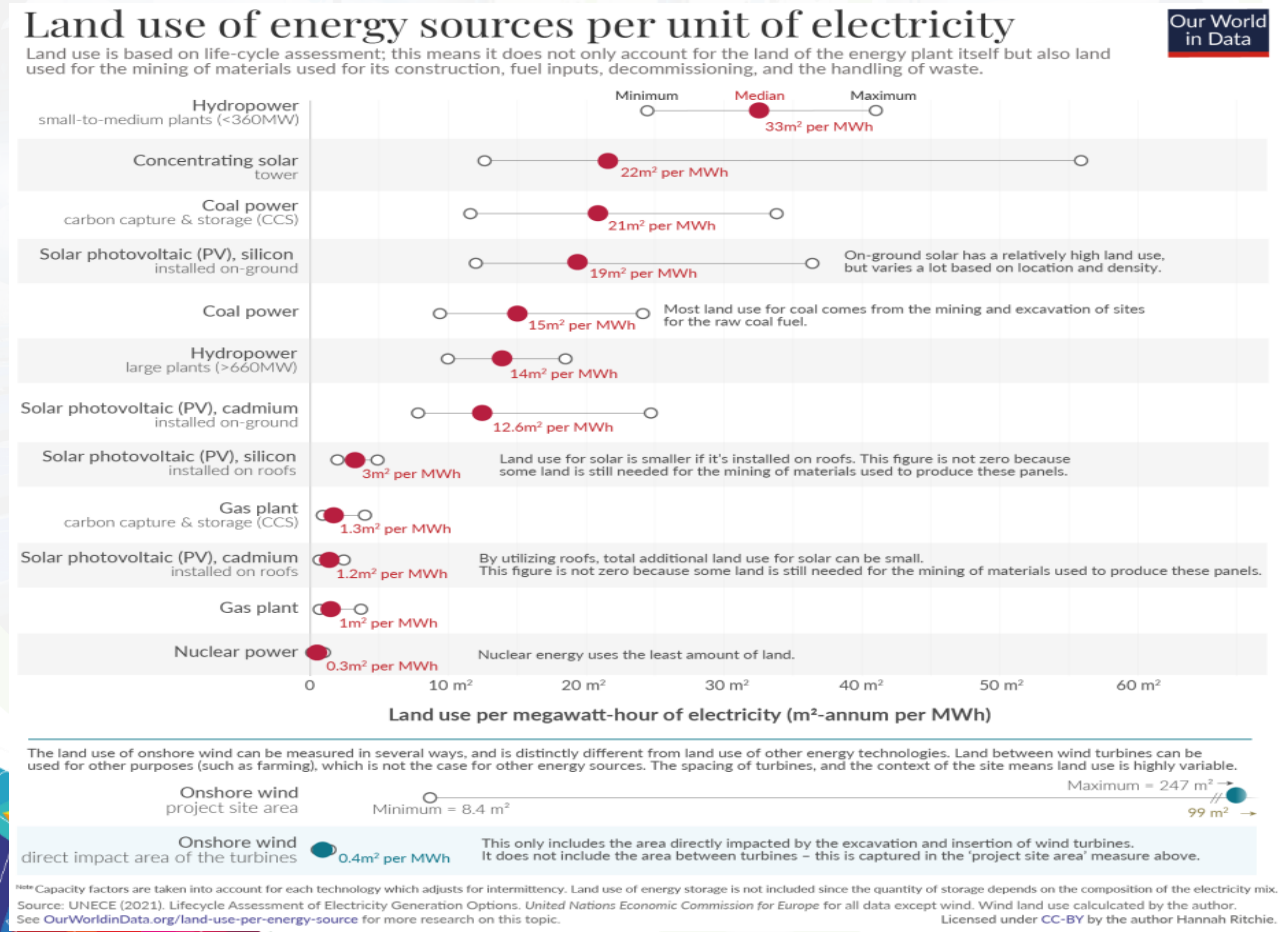
According to the IEA, per MW of capacity, offshore wind requires about 15.5 tonnes of critical minerals. Onshore wind is less mineral intensive, requiring about 10 t/MW, followed by solar photovoltaics (PV) at about 7 t/MW. The report notes that nuclear, along with hydropower and biomass, have comparatively low critical mineral requirements. High-carbon sources such as coal and gas require much less of those critical minerals.

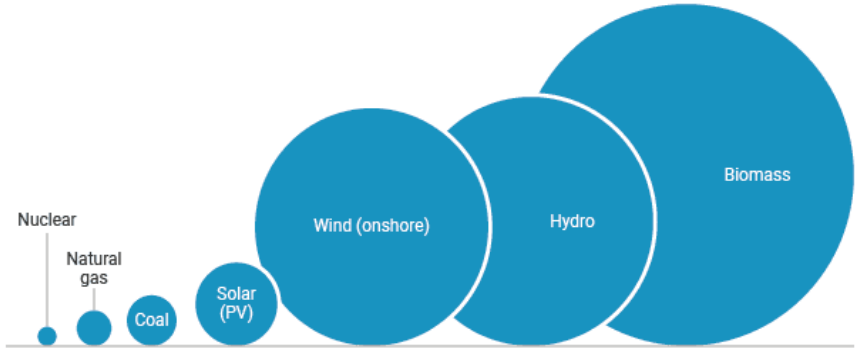
Lithium, nickel, cobalt, manganese and graphite are crucial to battery performance, longevity and energy density. The demand for each of these increases hugely by 2040. Rare earth elements are essential for permanent magnets that are vital for wind turbines and EV motors and they show a very large increase in demand to 2040. “The shift to a clean energy system is set to drive a huge increase in the requirements for these minerals, meaning that the energy sector is emerging as a major force in mineral markets.” Nuclear power is shown to need mainly copper, nickel and chromium.

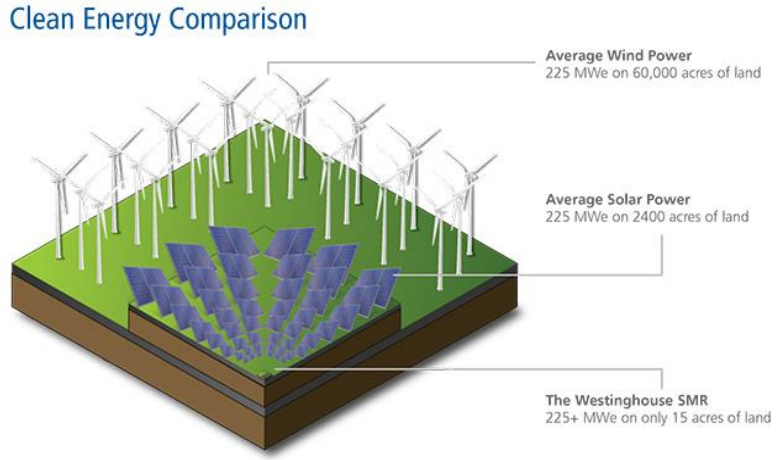


Why Nuclear?

To enable optimum use of available land; India does not have unlimited land







Why Nuclear?

To enable employment generation and economic growth in the country

In generating 10% of the world's electricity, nuclear power plants and a sophisticated supply chain support 250,000 jobs in operation and maintenance with another half a million in the supply chain.

Employment: For every €1 invested, the nuclear industry indirectly contributes €4 in GDP, and every direct job creates 3.2 jobs in the EU as a whole.

Hinkley point-C : 18 billion £ into the UK economy & 71000 (direct, indirect and induced) jobs across the UK

Jaitapur EPR Nuclear Project: 25,000 jobs created during the 15 years of construction of a pair of EPR • 2,700 permanent jobs created the 60-year operation lifetime. Numerous induced jobs for the local economy

International Monetary Fund (IMF) found nuclear energy investment spending has a large economic output multiplier effect.

Horizon	Nuclear Energy Investments Multiplier	Renewable Energy Investments Multiplier	Fossil Fuel Energy Investments Multiplier
Impact	4.11	1.19	0.65
1 Year	3.97	1.20	0.64
2 Years	3.88	1.19	0.62
3 Years	3.83	1.17	0.59
4 Years	3.80	1.14	0.55
5 Years	3.78	1.11	0.52

Source: *IMF Working Paper, 2021, Building Back Better: How Big Are Green Spending Multipliers? by Nicoletta Batini, Mario Di Serio, Matteo Fragetta, Giovanni Melina, and Anthony Waldron / WNA*

Misconceptions & Miscommunication about Nuclear

Nuclear has no scope in sustainability business ?

Lifecycle emission : As per IPCC report, Lifecycle emission of nuclear power 12 gCO2/ kWh. For Solar PV, lifecycle emission is 48 gCO2/kWh.

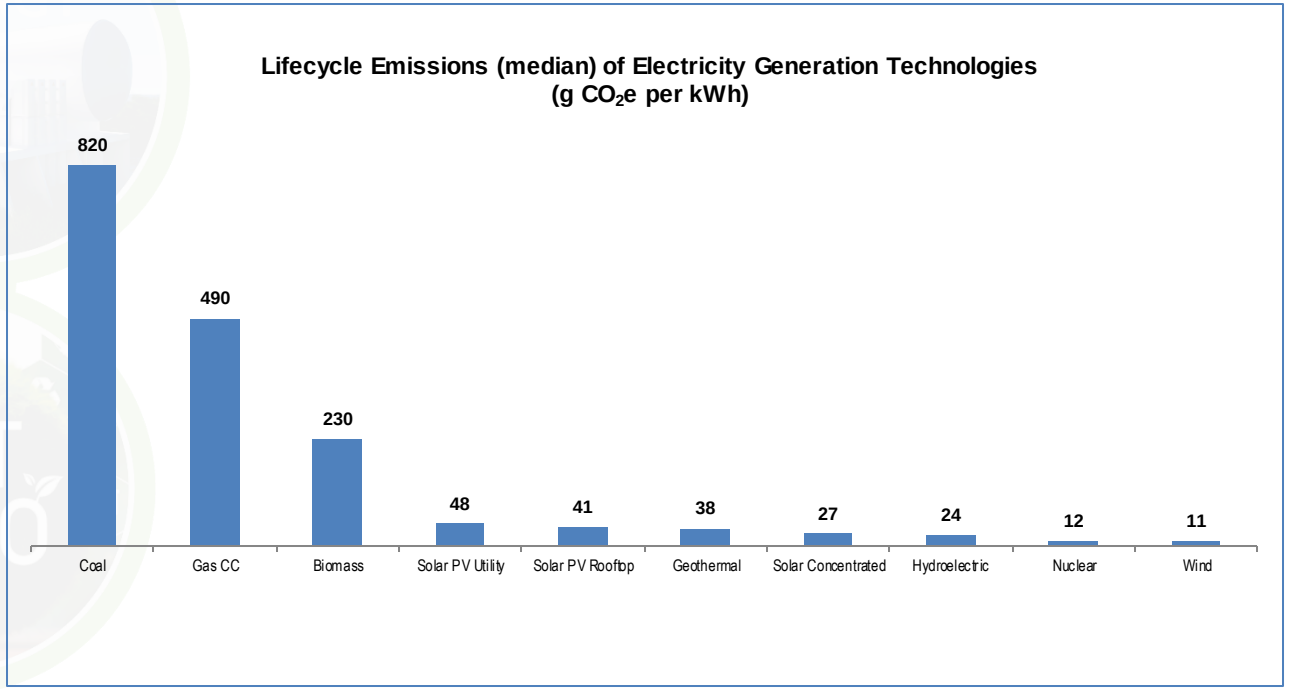
Nuclear power is 4 times cleaner than solar in terms of lifecycle emission

Highly efficient system : Capacity utilization of nuclear plant is ~90% as compared to 17% solar.

For same installed power, nuclear infuses 4.5 times more clean energy than that from a solar plant

Longer plant life: Nuclear plants are designed for 60 years and beyond that. Solar /RE are designed for 25 years and that too their efficiency degrades after 8-10 years in operation.

Ensuring most optimum utilization of earth's natural resources



Source: Annexe III Technology Specific Cost and Performance Parameters. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)

Misconceptions & Miscommunication

Accident Prone?

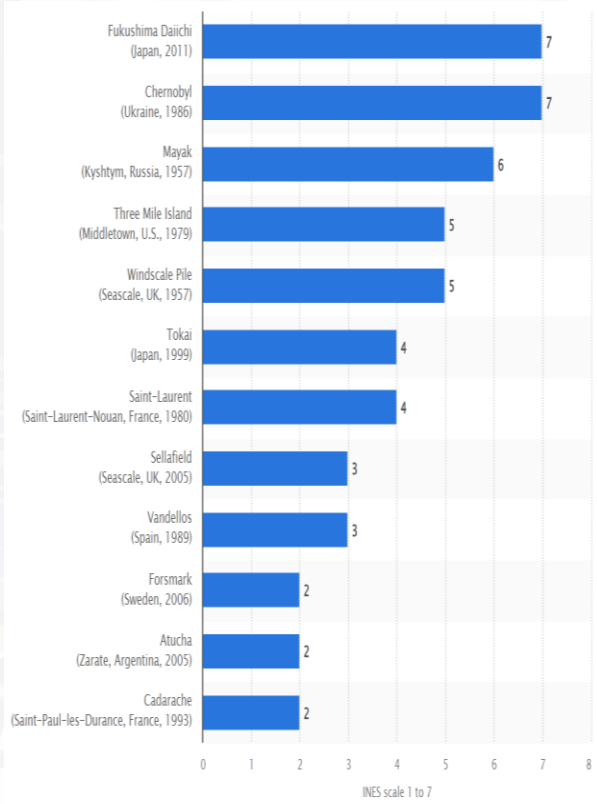
In the 70 year history of nuclear power operation, Indian nuclear plants have an impeccable safety record.

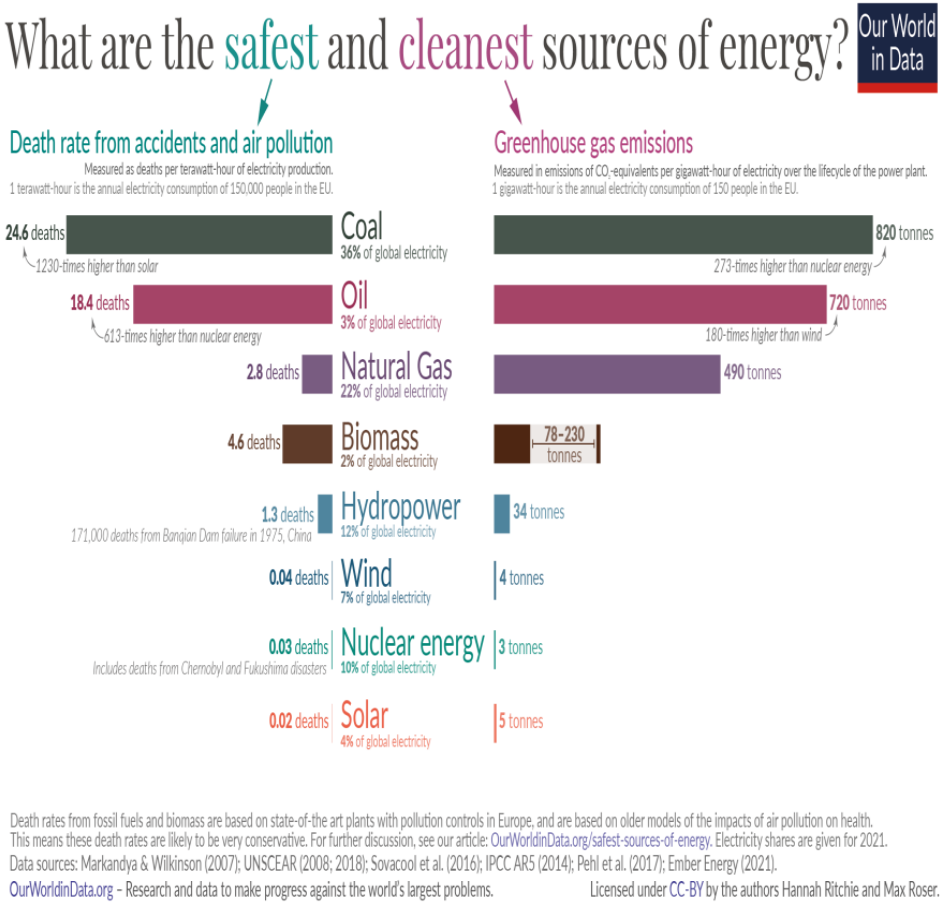
Globally also, it is hard to count any major accident except for Fukushima and Chernobyl:

Fukushima: Direct death due to nuclear plant management- 0, Deaths due to radiation- 1, Evacuation related deaths- 2202, Non fatal radiation

Chernobyl: Direct Deaths due to nuclear plant management-31, Radiation induced effect: 4000;

TMI: No deaths, Partial core meltdown





In 2013, two years after the incident, the WHO indicated that the residents of the area who were evacuated were exposed to so little radiation that radiation induced health impacts are likely to be below detectable levels.

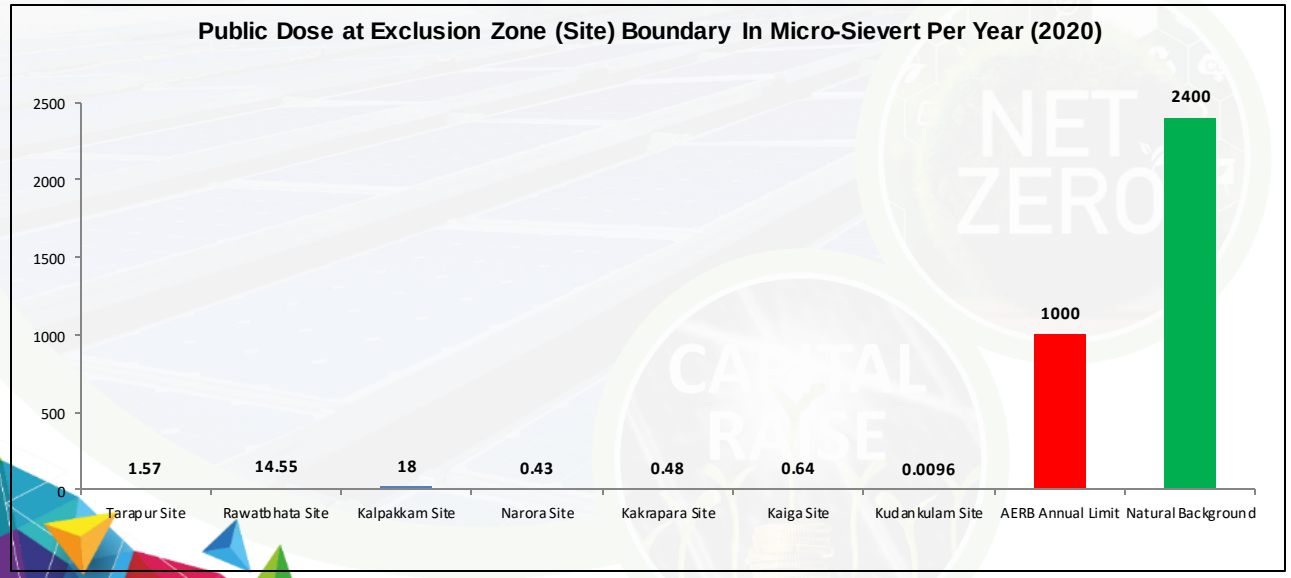
To give a perspective: Annual road accidents globally: Deaths: 1.3 Million people, As per a WHO report, about three million people die each year due to air pollution

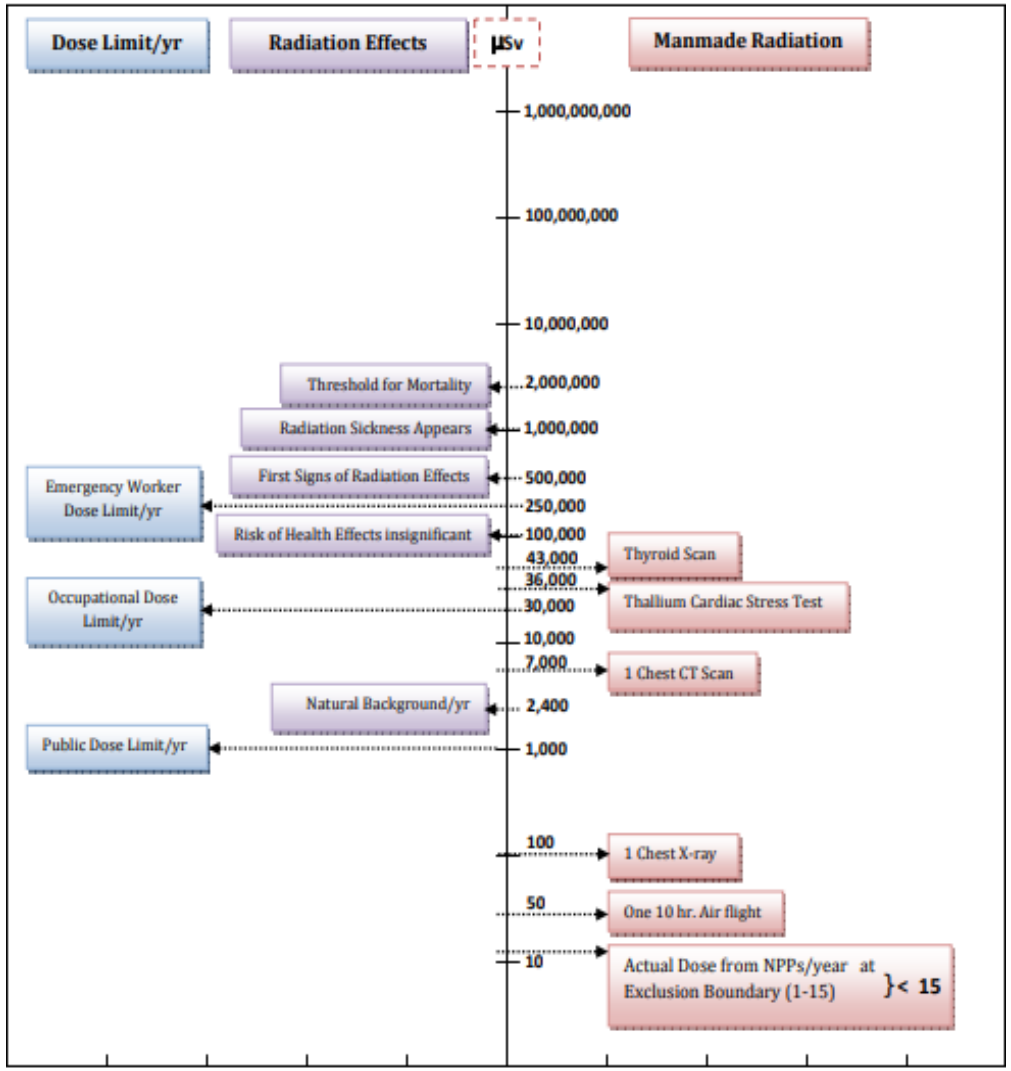
Misconceptions & Miscommunication

Radiation Effect?

Radiation is everywhere

However for Nuclear, Environmental Survey Labs are set up before any major nuclear facility is established. These laboratories continue to monitor the surrounding environment throughout the period of the existence of the facility.





Misconceptions & Miscommunication

Nuclear Waste ?

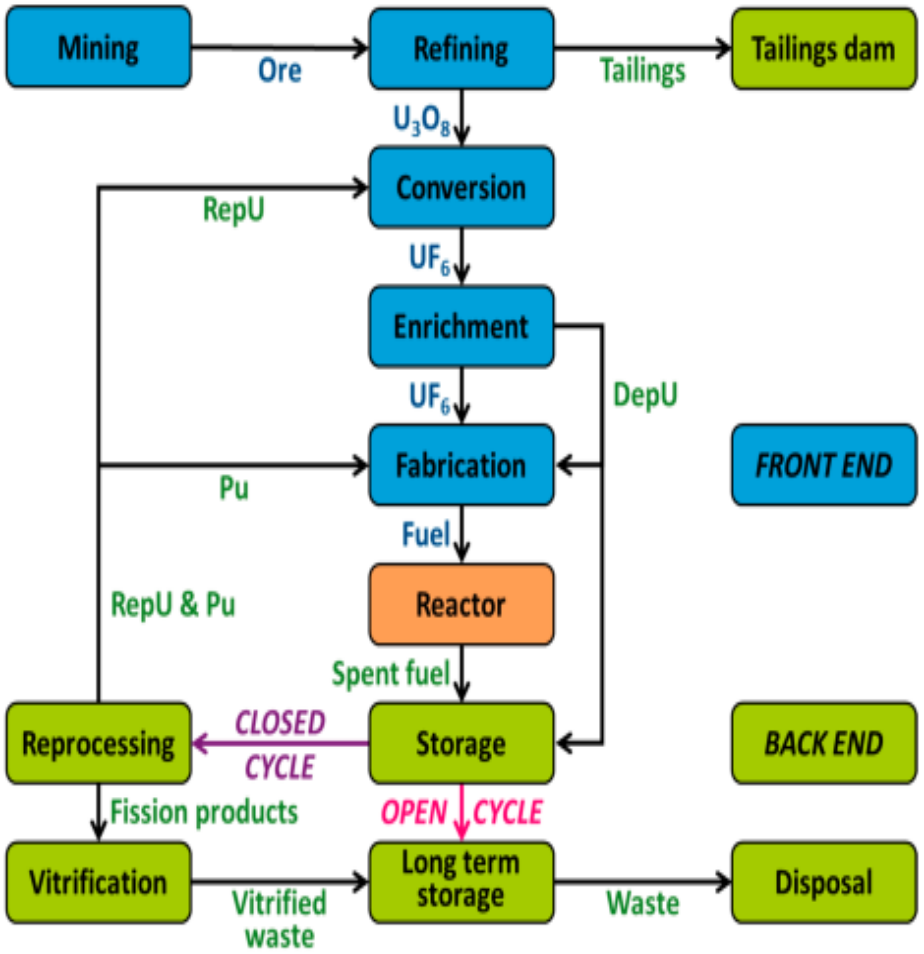
Many a times it is commented that nuclear waste is an insoluble problem- a permanent and accumulating environmental hazard.
The reality is that of all the energy forms capable of meeting the world's expanding energy needs, nuclear power yields the least and most easily managed waste.

What it is

Spent fuel – Well contained
Recyclable and re-used:
India follows **closed loop fuel cycle**
Only 95% energy is used when fuel is in the core.
It is recycled for further use in stage-2 reactors
Useful fission product such as ^{137}Cs, ^{90}Sr, ^{106}Ru etc have many industrial as well as medical applications. Cs-137 is prominent alternate to Co-60 for irradiaton

How much is it?

All of the used fuel ever produced by nuclear plants globally for the past 70 years can fit into a **football field** of the height of 10 yards



Misconceptions & Miscommunication

Costly ?

Electricity is a **unique product** - It has to be consumed when it is produced

Installed capacity or project cost/LCOE has meaning when electricity is produced in a reliable manner over a long period in a year

Life of Nuclear Plants:
Over 60 years as compared to solar or wind (meant for 25 years)

Capacity factor of Nuclear: Around 90% capacity factor as compared to 17-20% CF of solar

Availability factor: Nuclear plants have very high availability factor over 90%,: High uncertainty involved with solar/wind plants

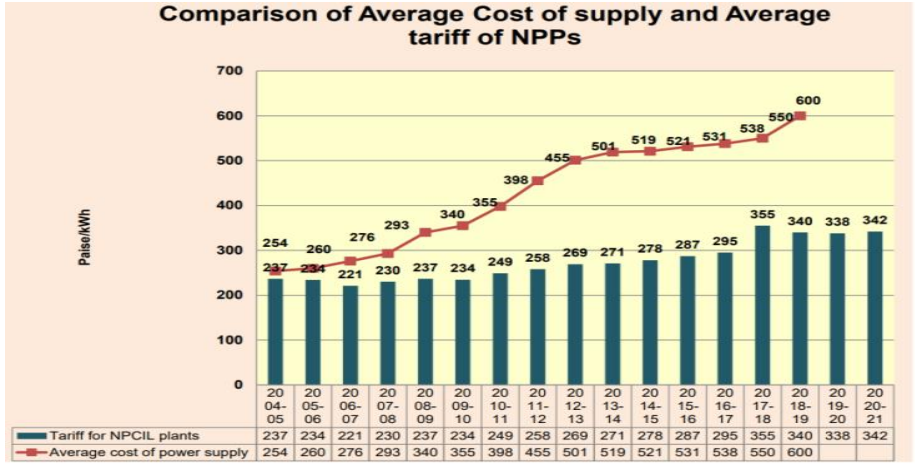
Backup requirements : Nuclear is a complete electricity source in itself for RTC power generation over the years: RE will require costly battery backups with high degree of involvement for demand and supply management for smooth grid operation

For the past 10-12 years the tariff of nuclear power is almost 50-60% of the average cost of the power supply in the country.

Tariff of nuclear power plant has been steady without much fluctuation against the continuously rising average cost of power supply, indicating that nuclear is a good option to insulate customers from electricity price fluctuations

LCOE makes sense only if energy is produced. Nuclear is highly cost-competitive (LCOE) and improves markedly when system costs/externalities accounted for REs.

Electricity Tariff: For nuclear projects cost is front loaded, resulting into higher tariff during initial 5-6 years, but tariff becomes equal to that of other sources during next 5-6 years and goes down below that for balance 40-50 years of plant life



Executive Summary on Power Sector – July 2021 (page 31)
Source:- PFC Reports on the performance of State Power Utilities

भारत सरकार
Government of India
विद्युत मंत्रालय
Ministry of Power
केन्द्रीय विद्युत प्राधिकरण
Central Electricity Authority
वित्तीय एवं वाणिज्यिक मूल्यांकन प्रभाग
Financial &Commercial Appraisal Division
SEWA BHAWAN, R.K. PURAM, NEW DELHI-110066
सेवा भवन, आर० के० पुरम, नई दिल्ली–110066

Tariff for sale of power from various Atomic Power Stations of NPCIL for the period from 01.04.2017 to 31.03.2022 (Notified by DAE on 22.03.2018)

A Sl.No	B Name of Power Stations	C Capacity (MWe)	D Tariff @ (P/kWh)	E Water charges (in P/kWh for every Rs 1 Crore of water charges/ cess/ levies paid by respective Atomic Power Station)	F Insurance Charges (in P/kWh for every Rs 1 Crore of premium paid by respective Atomic Power Station per annum)
1	Madras Unit-1&2	2x220	260.71	0.42318	0.42318
2	Narora Unit-1&2	2x220	299.14	0.42918	0.42918
3	Rajasthan Unit-2,3,4	1x200+ 2x220	334.39	0.29376	0.29376
4	Rajasthan Unit-5,6	2x220	392.48	0.42918	0.42918
5	Tarapur Unit-1,2	2x160	192.39	0.5723	0.5723
6	Tarapur Unit-3,4	2x540	290.58	0.17183	017183
7	Kaiga Unit 1 to 4	4x220	348.52	0.2116	0.2116

Nuclear Scale-up & Opportunities

Project Pipeline:
- Operating capacity: 6.78 GW
- Under construction projects: 15.7 GWe
- Proposed projects: 25.8 GWe

Business potential: USD 125 Bn

SMR for Retrofitting at Retiring Coal Sites:
- Available capacity: 150 GWe by 2050, / Total cap- 205 GW

Business potential: USD 375 Bn by 2050

SMR for Clean H2 Generation:
- Estimated capacity: 100 GW at 1345 odd islands

Business potential: USD 250 Bn within next 20-30 years

PHWR Export Potential
- IPHWR is **cheapest nuclear technology** across the globe
- Several countries in Africa, Asia and other parts of the world are looking for **cost-effective nuclear solutions** to meet their clean energy transition objectives
- India exploring to be **a net export economy** in nuclear power. Good opportunities for private stakeholders to get involved in nuclear supply chain

Indian Nuclear Capacity and Business Potential

	Reactor Type	Rx Electrical Capacity (MWe)	No. of Reactors	Total Electrical Output (MWe)	Total Business Potential
Reactor under Construction	IPHWR-700	700	16	11200	USD 30.8 Bn (INR 2461 Bn) *Kakrapar-3 of 700 MW capacity is already connected to grid*
	PFBR-500	500	1	500	
	VVER-1000	1000	4	4000	
			21	15700	
Reactors with Principle Approval / Under Consideration	EPR-1650	1650	6	9900	USD 94.4 Bn (INR 7076 Bn)
	AP1000	1208	6	7248	
	VVER-1000	1200	6	7200	
	FBR-600	600	2	1200	
	AHWR-300	300	1	300	
			21	25848	
Reactors under Operation	IPHWR-220	220	14	3080	Business opportunties pertaining to Operation & Maintenance, Annual Contracts, Equipment/Spare Supplies, Quality Assurance, Plant Life Extension, Fuel & Systems, Simulator, Digital Twin,, Digital Transformation, Automation & AI, Health Physics, Waste management etc
	IPHWR-540	540	2	1080	
	CANDU-200	200	1	200	
	BWR-160	160	2	320	
	VVER1000	1000	2	2000	
			21	6680	
Reactor Under Extended Shutdown	CANDU-100	100	1	100	Pre-decommissioning /decommisioning related business opportunities

Supported by
Ministry of Power
Ministry of Heavy Industries
Government of India

ieema
your link to electricity

15th Edition
ELECRAMA
Powering the Future of Energy

eTECH nxt
20-21 February, 2023
ELECRAMA, Hall 2 & Hall 4

#NuclearIndustry2.0: Nuclear Scale-up

Pre-project | Design & Development | Project management & Commissioning | Operations | Life cycle management | Decommissioning

Mining | Fuel Processing | Fuel Fabrication | Power Generation | Spent Fuel | Waste management

Key Organizations Involved in Nuclear Scale-up: **NITI Aayog, DAE, NPCIL, NTPC, AERB, NFC, UCIL, BHAVINI, BARC, IGCAR** etc

Domestic Nuclear Scale-up : Large Reactors & SMRs

Nuclear Supply chain:
- Component manufacturing
- Electrical / mechanical / control & instrumentation
- Digital / AI / IIoT
- Technology development
- EPC
- Engg / Design
- Law
- Insurance
- Testing inspection & certification

Export Economy

- PHWR value chain
- Global nuclear programs based on large reactors & SMRs

Energy transition

- Clean hydrogen value chain through nuclear
- Batteries powered through nuclear
- H2 for industrial purpose & transportaion
- Microreactors

To explore further and get involved in the nuclear sector,

Ensure your participation at **INBP Conference-2023**: International Industry Conference on Indian nuclear Market ;
10-11th October 2023, **Mumbai**

Let's connect: vinay@industry-platform.com I +91-8777805565; LinkedIn: https://www.linkedin.com/in/vkhanduri;

Supported by
Ministry of Power
Ministry of Heavy Industries
Government of India

ieema
your link to electricity

15th Edition
ELECRAMA
Powering the Future of Energy

eTECH nxt
20-21 February, 2023
ELECRAMA, Hall 2 & Hall 4

Thank You!