

# Nuclear Resurgence after COP28 pledge to #TRIPLE-NUCLEAR



ORGANIZER  
**ISGF**  
India Smart Grid Forum

India  
SMART UTILITY  
Week 2025

www.isuw.in



11<sup>th</sup> International Conference  
and Exhibition on Smart Energy  
and Smart Mobility

18 – 22 March 2025

Hotel Lalit, New Delhi

## Supporting Ministries



MINISTRY OF POWER  
CENTRAL ELECTRICITY AUTHORITY



NITI Aayog



MINISTRY OF POWER  
GOVERNMENT OF INDIA



MINISTRY OF NEW AND  
RENEWABLE ENERGY  
GOVERNMENT OF INDIA

“RISE OF REALISM”... (Dec. 2024)

We're witnessing what I call a return to realism in energy policy. As nations face the urgent need to decarbonize, strengthen energy security, and ensure sustainable growth, nuclear is uniquely positioned to meet such challenges.

[https://www.linkedin.com/posts/rafael-mariano-grossi\\_were-witnessing-what-i-call-a-return-to-activity-7273332904514965505-CGgz](https://www.linkedin.com/posts/rafael-mariano-grossi_were-witnessing-what-i-call-a-return-to-activity-7273332904514965505-CGgz)



Grossi  
at IAEA

## Nuclear Resurgence and the Role of SMRs for RELIABLE Net Zero Power Systems

20 March 2025

Crystal 2 10:00-13:00

Coordinator: Bala Subramanyam |  
bala.k@indiasmartgrid.org

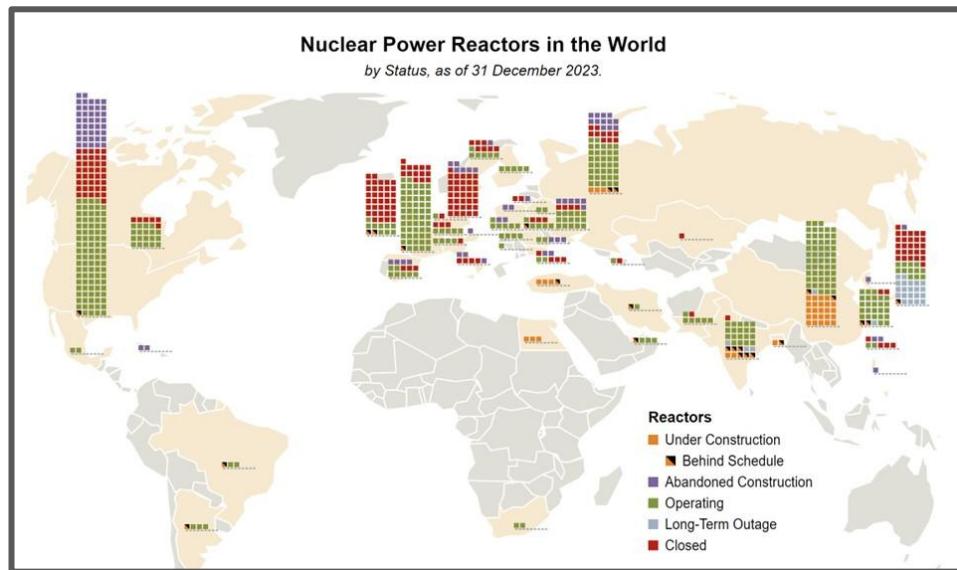
<https://www.isuw.in/conference-agenda-and-program-2025>

## Andrew D. Paterson (USA)

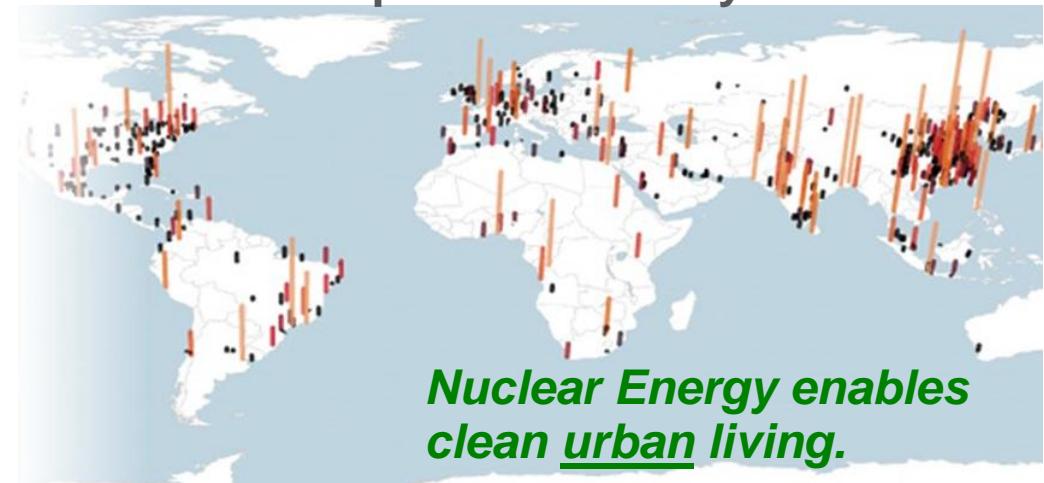
Board Member at Environmental Business Int'l  
and **Senior Fellow, US Nuclear Industry Council**  
Former senior analyst at DOE for Policy & Finance.  
*Advisor to Allied Nuclear Partners, led by IP3.*

## from Briefing to US House Nuclear Caucus

Jan. 31,  
2024



## Urban Population Density - 2020



## A. Tripling Nuclear by 2050 from COP28... WHY? Will take 1,000 GWs+

- Now India wants to move toward 100 GWs by 2050-ish
- Plenty of Capital (>\$300 Trillion) circles the planet each day

## B. Nuclear Energy is only source to power Cities in 21<sup>st</sup>C, 6 Billion people

- “Always-on, Zero emissions, on a small footprint.” Not wind and solar
- How will electric vehicles be charged at night. Plus, Mass Transit.
- The Energy Transitions we face are EXPONENTIAL in nature. Govts are incremental.

## C. Govts now **cannot** fund the investment needed from Budget alone.

*Nature of Govt participation in Financing New Nuclear will shift to PPP Investments*  
No country can mount the construction campaign needed *alone*. Including USA.

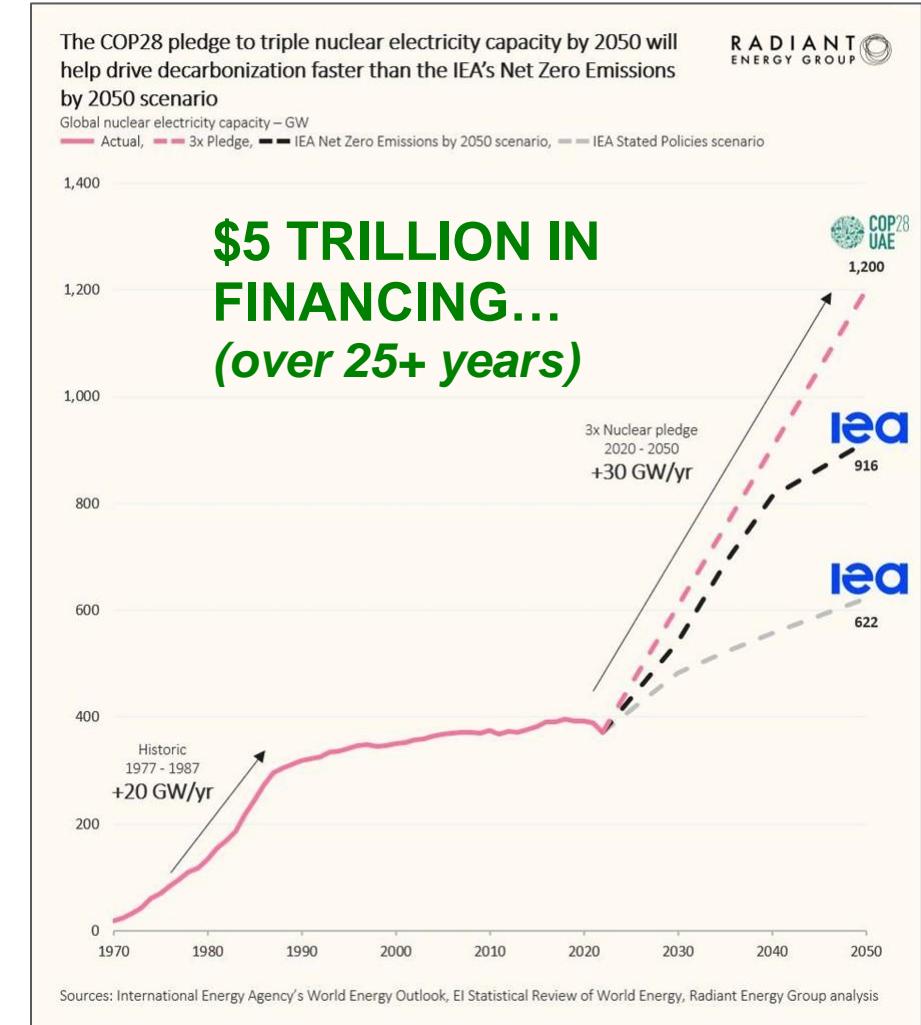
- **So, who will the Super-Powers be that attract investment? HOW? Deals...**

## D. Since 2024, Energy for Data Centers / AI changes the Demand Outlook

# COP28: 25 Countries Pledge to TRIPLE Nuclear Capacity by 2050 (1200 GWs)

India  
SMART UTILITY  
Week 2025

This is a LARGE, SERIOUS COMMITMENT... HOW? Where are China, Russia (not on stage)?

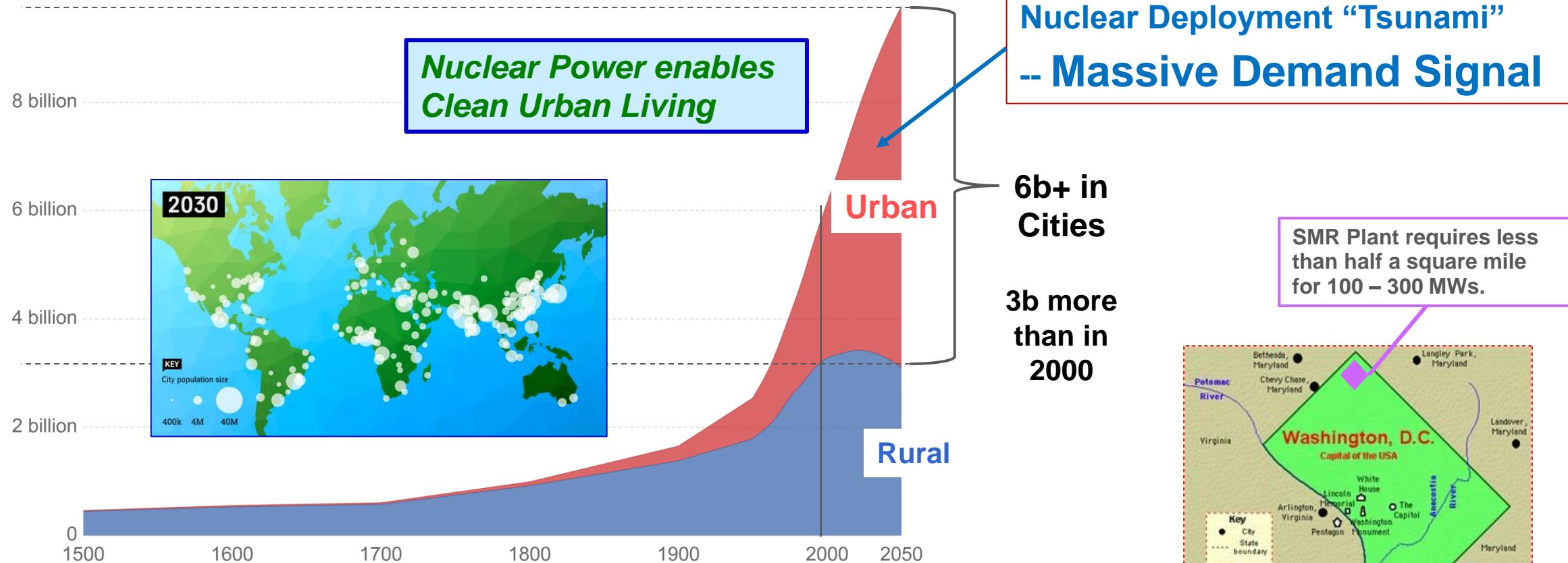


# URBAN Growth & Reliability as Top Driver for new nuclear capacity globally

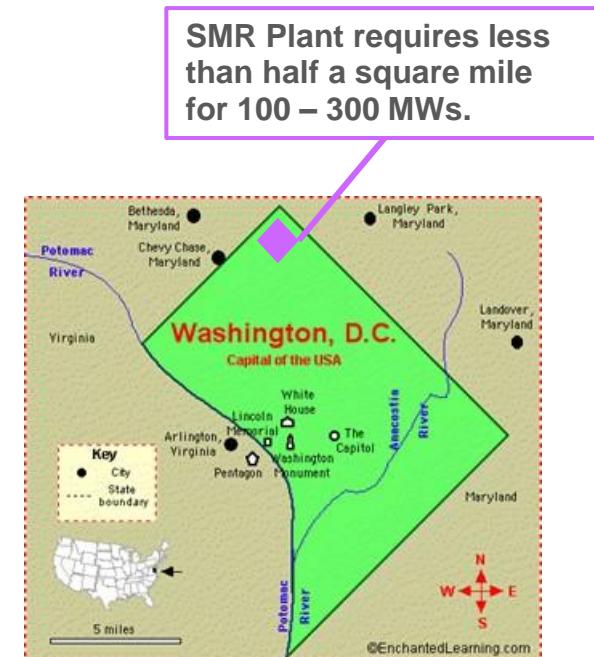
## Urban and rural population projected to 2050, World

Total urban and rural population, given as estimates to 2016, and UN projections to 2050. Projections are based on the UN World Urbanization Prospects and its median fertility scenario.

Our World  
in Data



<https://ourworldindata.org/urbanization>



# Urban demand strains power grids. RE is inadequate

Market for Nuclear Energy is URBAN -- for Power, Clean Water, Transport



UK Blackout – August 2019



Where to put wind and solar?



San Francisco in wildfire ash, Sept. 2020



Japan has restarted 12 reactors (of 33 GWs)

# Mega-Cities use Millions of Clean Reliable MegaWatt Hours

**Mega-Cities cannot be powered by Wind and Solar – physically.**

**What are the costs of OUTAGES?**



**THORCON** – Coastal cities  
Ship-based thorium reactors

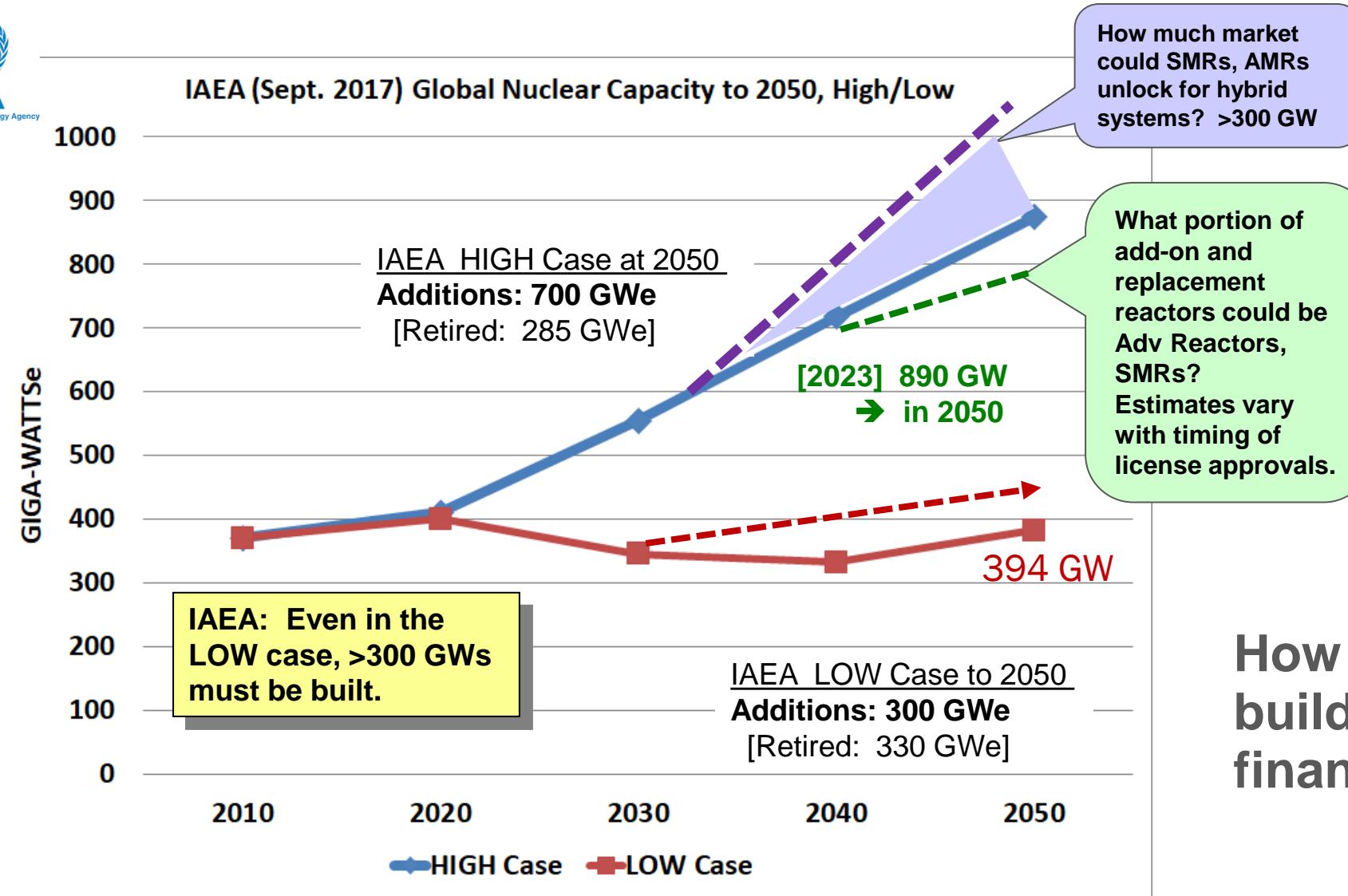


**MUMBAI**



**NEW YORK CITY**

# IAEA (Sept 2017 & 2023) – High & Low World Estimates of Projected Nuclear Capacity PLANNED in 2030, 2040, 2050



How can this buildout be financed?

**CNBC** Search quotes, news & videos WATCHLIST

MARKETS BUSINESS INVESTING TECH POLITICS VIDEO INVESTING CLUB JOIN PRO

CLIMATE

## Amazon goes nuclear, to invest more than \$500 million to develop small modular reactors

PUBLISHED WED, OCT 16 2024 8:45 AM EDT | UPDATED 3 HOURS AGO

Diana Olick @IN/DIANAOLICK @DIANAOLICKCNBC @DIANAOLICK

SHARE f X in e

**KEY POINTS**

- AWS announced it has signed an agreement with Dominion Energy, Virginia's utility company, to explore the development of a small modular nuclear reactor, near Dominion's existing North Anna nuclear power station.

### Oracle to build nuclear SMR-powered gigawatt data center

Quarterly revenues reach \$13.3bn, up 7% YoY

September 10, 2024 By: Georgia Butler Have your say



Oracle is planning to build a gigawatt-scale data center powered by three small nuclear reactors (SMRs), according to founder Larry Ellison.

CTO and chairman Ellison told investors during an earnings call this week that Oracle currently has 162 cloud data centers in operation or under construction globally, the largest of which has a capacity of 800MW and is set to house Nvidia GPU clusters.

News

## Microsoft and Constellation sign PPA for Three Mile Island restart

The tech giant is looking to power its data centres with nuclear energy.

Alfie Shaw | September 23, 2024

DIVE BRIEF

## Microsoft, Google, Nucor partner on initiative to spur emerging 24/7 clean power technologies

The Advanced Clean Electricity initiative aims for widespread commercial deployment of advanced nuclear, next-generation geothermal and long-duration storage by the early 2030s.

Published March 21, 2024

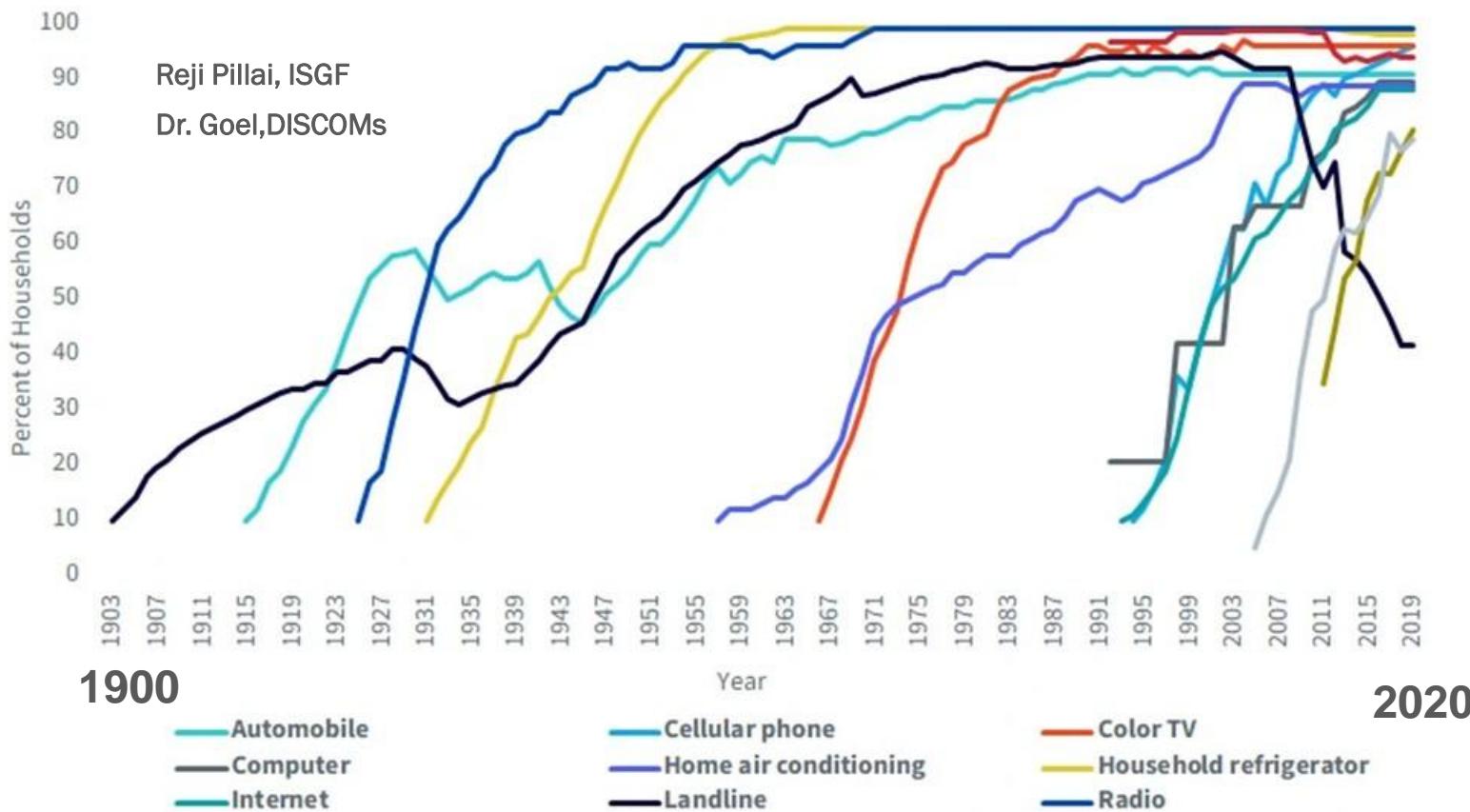
**OKLO TEAMS WITH OPENAI, and SWITCH IN DATA CENTER BUILDOUT... 12 GWs (2025)**



# Technology Adoption Curves are NOT LINEAR... Govts tend to be.

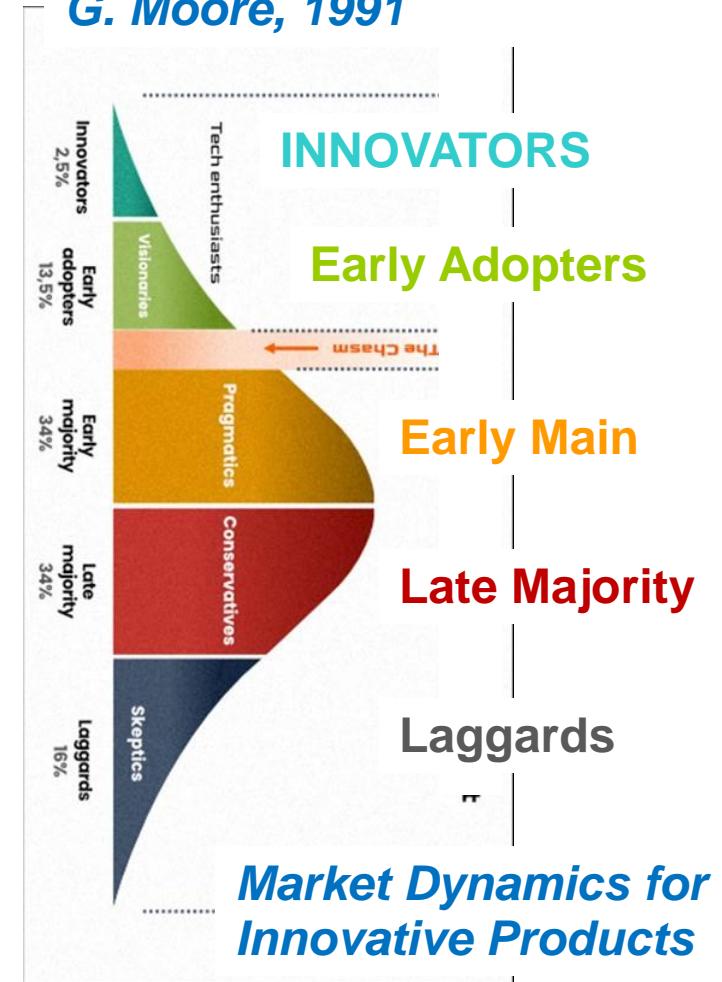
Govt budgets move at incremental pace. Technology Innovation moves at an Exponential pace.

Smart Cities are a vehicle for more rapid adoption...



Sources: Horace Dediu; Comin and Hobijn (2004); other sources collated by Our World in Data OurWorldinData.org/technological-change (2017).

*"Crossing the Chasm",  
G. Moore, 1991*



20 Oct. 2024



**Global economy**

## IMF warns over ‘unforgiving’ conditions for state finances

SAM FLEMING — LONDON

The head of the IMF has warned of an “unforgiving” economic backdrop for government finances around the world as she highlighted a widespread reluctance among politicians to rein in spending and raise taxes.

Kristalina Georgieva, the fund’s managing director, said rising levels of borrowing meant a growing share of government revenues was being used to cover interest payments, while “lacklustre” growth heightened the challenge of curbing debts.

“Our forecasts point to an unforgiving combination of low growth and high debt — a difficult future,” said Georgieva. Countries faced “high and rising public debt — way higher than before the pandemic”, she added, even after a fall in debt-to-GDP levels as inflation lifted nominal growth.

The managing director’s remarks ahead of next week’s IMF and World Bank annual meetings come as global

public debt heads to a record \$100tn by the end of 2024. Borrowing surged during the early stages of the coronavirus outbreak as economies were locked down. Many governments, including those of the world’s largest economies, are yet to bring spending under control.

The US is still running substantial budget deficits, while China’s government has recently pumped funds into the economy in an effort to support weak growth.

The IMF confirmed the world’s two largest economies were driving the global rise, in findings published this week. But in prepared remarks, Georgieva also highlighted a “frightening evolution” in emerging and low-income countries, as more government income is set aside to honour debt-servicing commitments.

Georgieva said governments needed to lower debt and rebuild fiscal buffers to cope with potential economic shocks — something the managing director said “will surely come, and maybe sooner than we expect”.

## *Tripling Nuclear Capacity by 2050 with only Public Finance is IMPOSSIBLE.*

**IMF chief warns of ‘unforgiving’ debt backdrop and low growth**  
**Kristalina Georgieva says governments’ reluctance to rein in spending heightens public finances challenge**

**“Our forecasts point to an unforgiving combination of low growth and high debt — a difficult future,” said Georgieva. Countries faced “high and rising public debt — way higher than before the pandemic”, she added, even after a fall in debt-to-GDP levels as inflation lifted nominal growth.**

**The managing director’s remarks ahead of next week’s IMF and World Bank annual meetings come as global public debt heads to a record \$100tn by the end of 2024. Borrowing surged during the early stages of the coronavirus outbreak as economies were locked down. Many governments, including those of the world’s largest economies, are yet to bring spending under control.**

The two leaders agreed that energy security was fundamental to economic growth, social well-being and technical innovation in both countries and "re-committed to the **US-India Energy Security Partnership, including in oil, gas, and civil nuclear energy**". 12 Feb. 2025



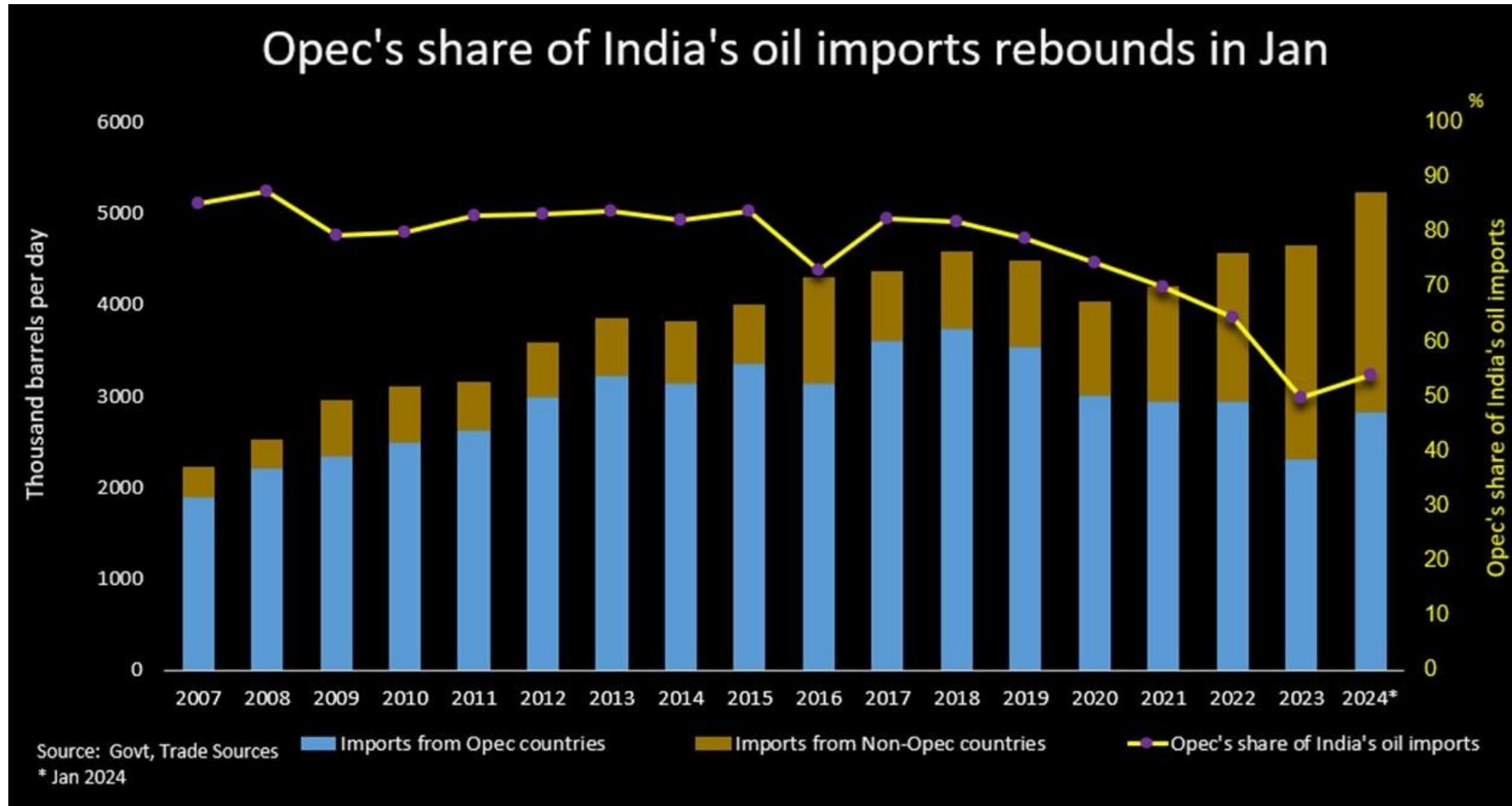
# India's Oil Imports still on the Rise after COVID, less from OPEC

India  
SMART UTILITY  
Week 2025

Energy Partnership...



“MEGA”



# India's Gas Imports will rise to 50% of Consumption by 2050

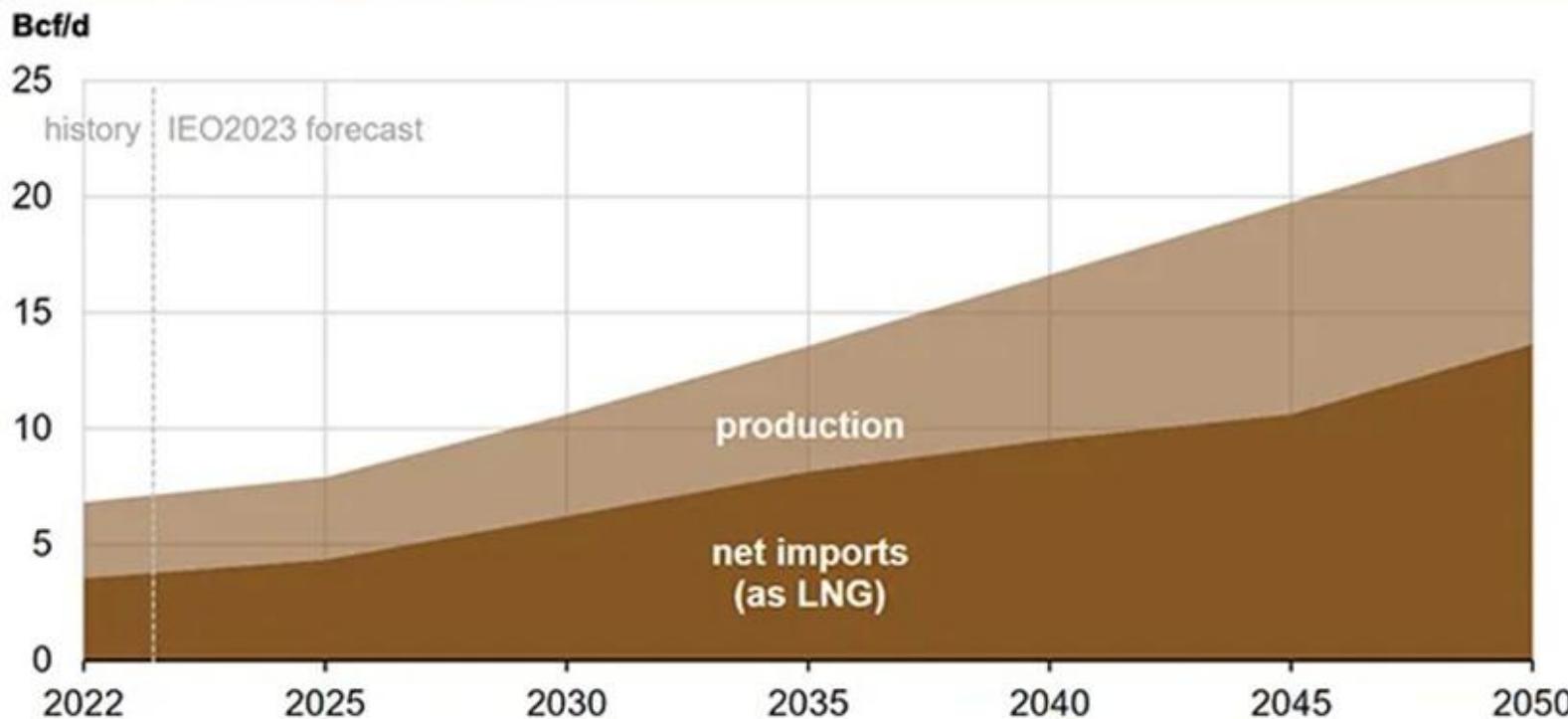
Energy Partnership...



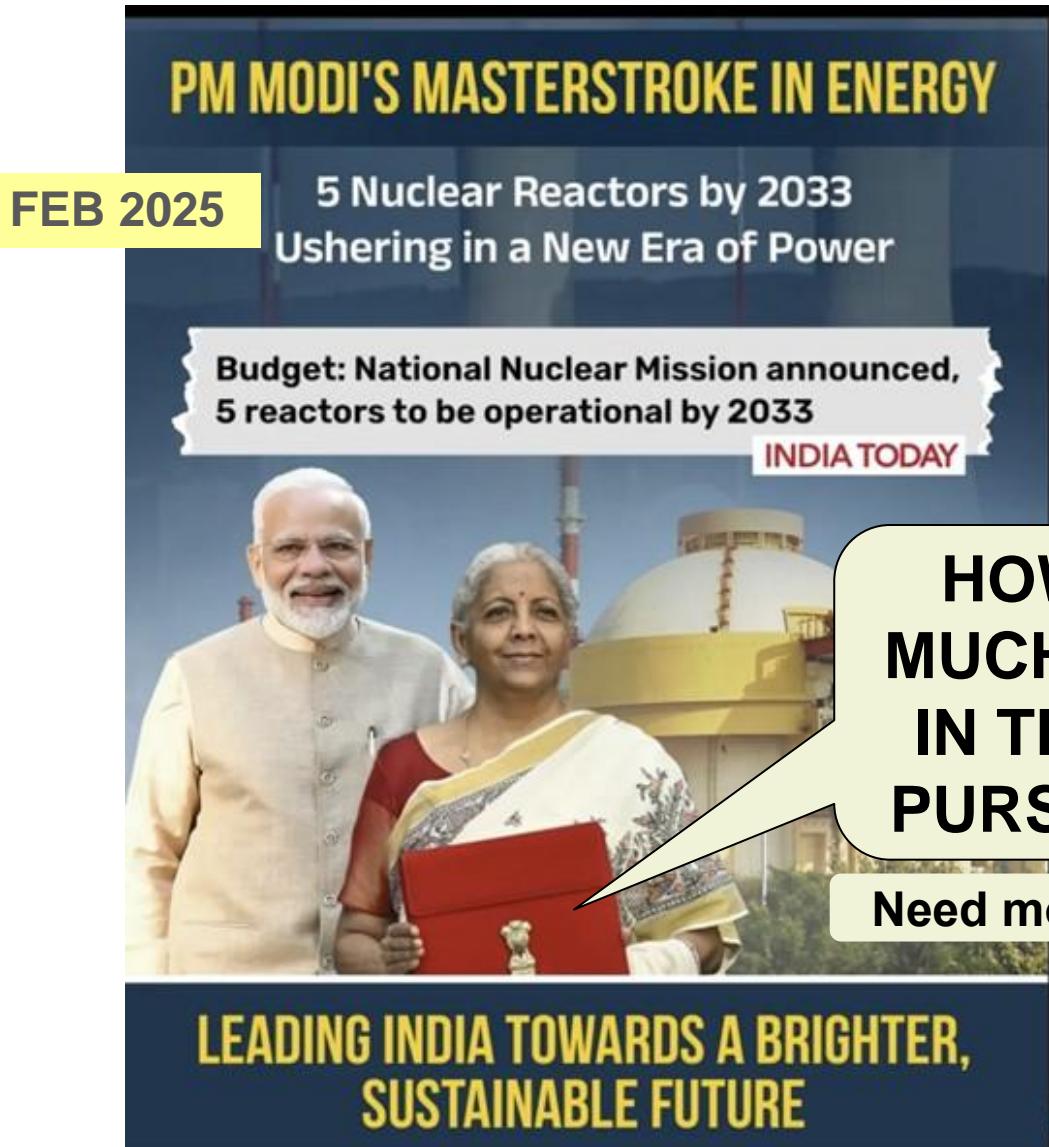
"MEGA"

## Annual Natural Gas Domestic Production & Net Imports in India

NGI



Source: Energy Information Administration



## "RISE OF URBAN ENERGY REALISM"...

3 Feb. 2025 -- In her budget speech, **Finance Minister Nirmala Sitharaman** announced the Nuclear Energy Mission for Viksit Bharat (Viksit Bharat is the government's strategy to make India into a completely developed nation by 2047).

"Development of at least 100 GW of nuclear energy by 2047 is essential for our energy transition efforts. For an active partnership with the private sector towards this goal, amendments to the Atomic Energy Act and the Civil Liability for Nuclear Damage Act will be taken up," Sitharaman said.

"A Nuclear Energy Mission for research & development of Small Modular Reactors (SMRs) with an outlay of INR20,000 crore will be set up. **At least 5 indigenously developed SMRs will be operationalized by 2033.**"

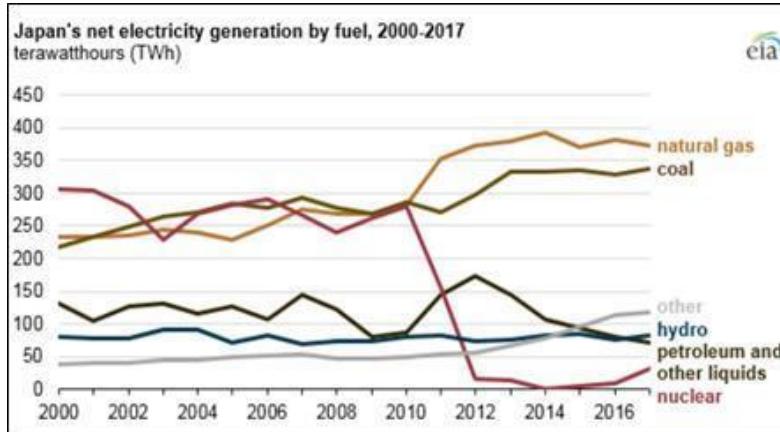
INR20,000 crore is around USD2.3 billion (1 crore is 10 million).

India is already working to expand its nuclear capacity from 8180 MW today to 22,480 MW by 2031-2032, including the construction and commissioning of ten units totalling 8,000 MW across Gujarat, Rajasthan, Tamil Nadu, Haryana, Karnataka, and Madhya Pradesh, the DAE said. Pre-project activities for a further ten reactors are under way,

# Fukushima, Chernobyl, TMI -- STILL USING NUCLEAR!



Japan restarted 12 of 33 reactors, since 2011 to reduce gas imports



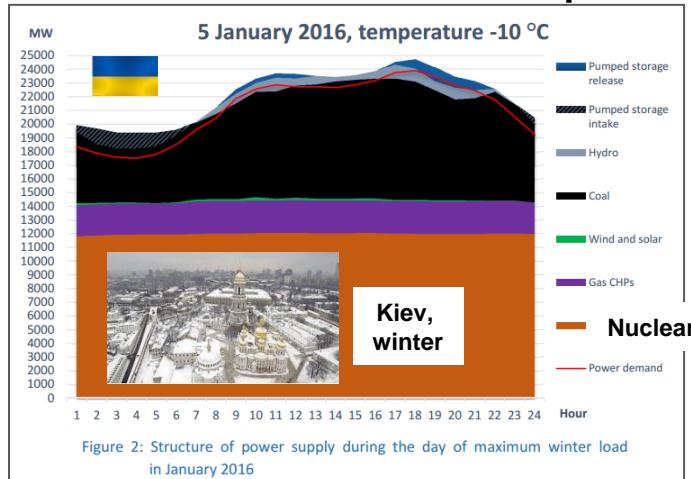
The OTHER TMI Reactor ran for 40 years !



Countries with most severe nuclear accidents still use nuclear. WHY?

*Because...  
Nuclear Energy enables clean urban living.*

Ukraine TONIGHT relies on 15 Nuclear Plants for HALF of power



Current US Nuclear plants by location



Breaking News this week...

Trump proposes US ownership of Ukraine's nuclear plants  
by Laura Kelly - 19/03/25

RUSSIA-Ukraine WAR  
Ukraine's nuclear electricity production

In 2021, more than half of Ukraine's electricity was produced with nuclear power. Its Zaporizhzhia Nuclear Power Plant - Europe's largest facility - was captured by Russian forces in March. The UN's IAEA warns that damage to the plant could lead to a nuclear disaster.



- ✓ At COP28, >24 Countries vowed to Triple Nuclear Capacity by 2050 (+1000 GWs)
- ✓ India followed suit in 2025 by announcing ambitions for 100 GWs by 2047
- ✓ The severity of Air & Water **pollution** in India offers the greatest cleanup project in the *history of civilization*. *For 1.5 billion people by 2030.*
- ✓ By 2050, more than SIX billion people will live in Cities, double that in 2010  
City-dwellers use mass transit and electric transport, office towers
- ✓ The “*Great Game*” has shifted: Russia & China are using Nuclear projects to gain spheres of influence globally, across Eurasia, into Europe, Africa.
- ✓ More capital is available than ever before in history... >\$300 TRILLION
- ✓ NOW, Industrial and Commercial uses of SMRs expand demand greatly

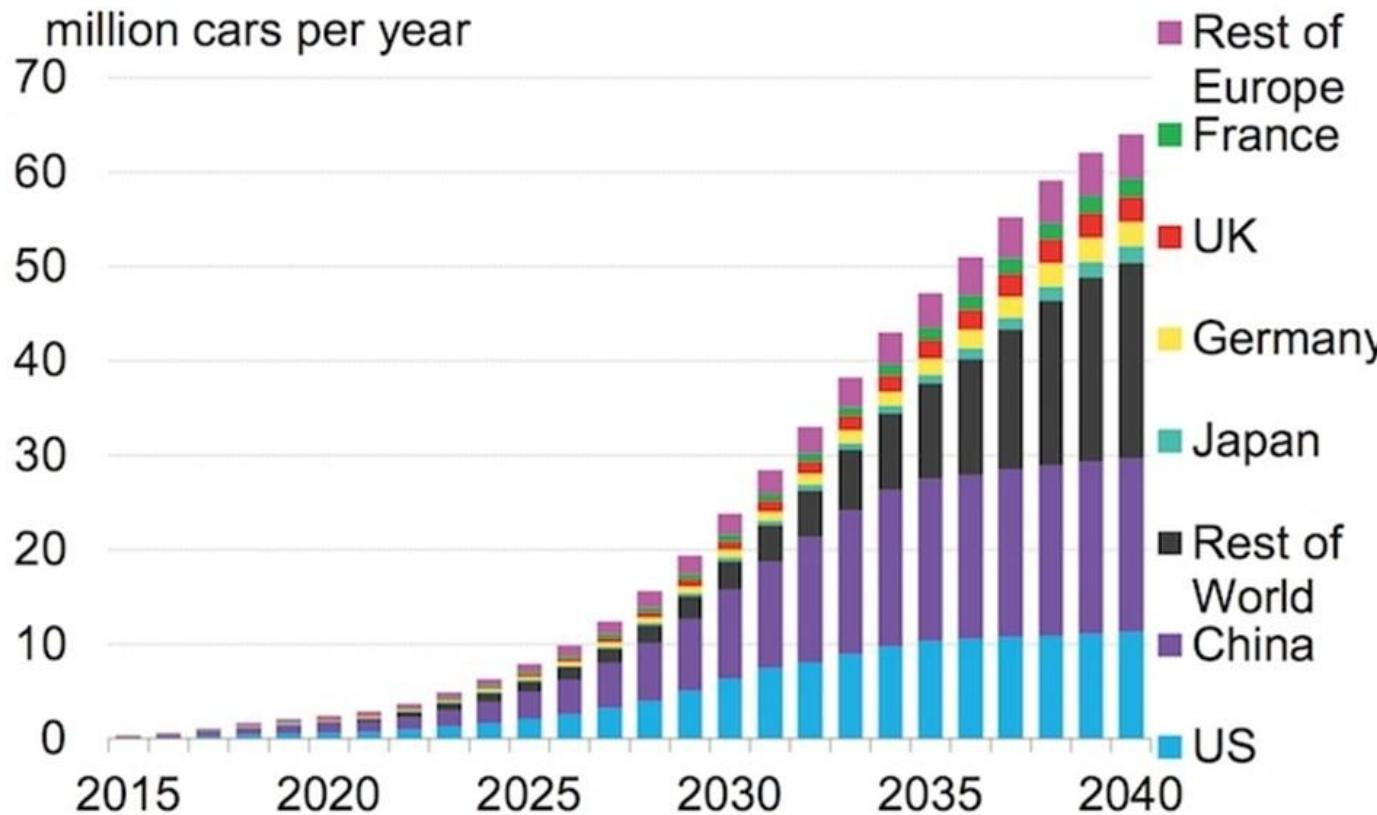
# Curbing emissions is a big priority for Global Mayors, since 2016

## Nuclear Energy enables Clean Urban Living

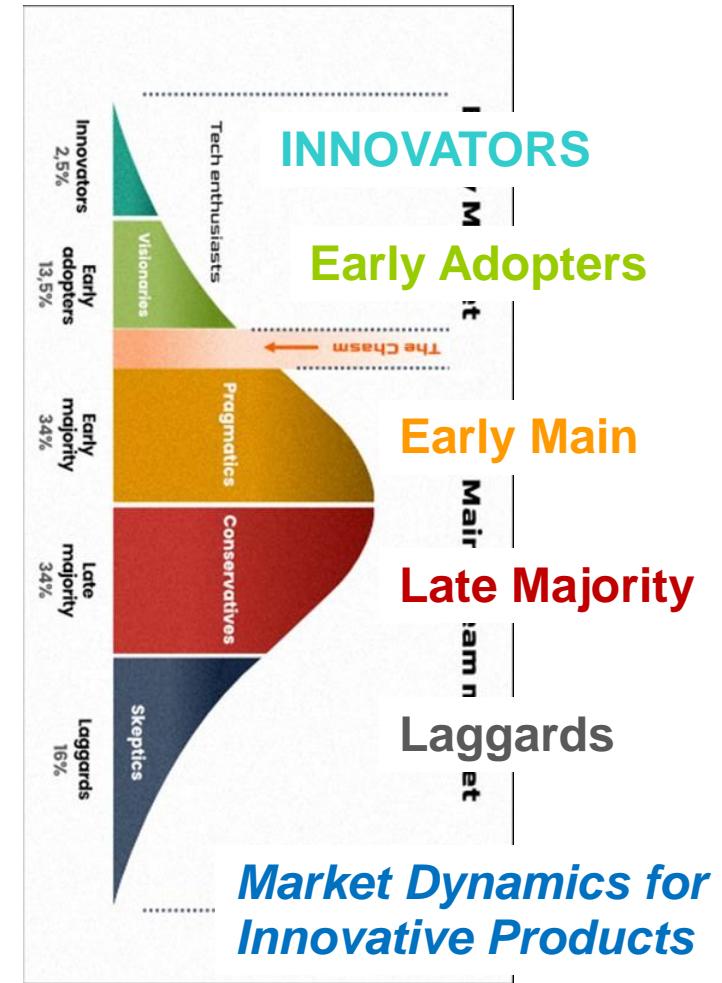


# Concentrated in Urban Areas: Ramping Electric Vehicle production Globally for Net Zero

Passenger electric vehicle sales are set to jump more than 80% in 2021 to 5.6 million units, up from 3.1 million in 2020 (and 2.1 million in 2019), according to the Zero-Emission Vehicles Factbook, a special report published today by BloombergNEF (BNEF).



[www.climatecentral.org/news/world-electric-car-revolution-21597](http://www.climatecentral.org/news/world-electric-car-revolution-21597)



## TACTICAL OBSERVATIONS

- The new National Mission Statement for India is a start at 100 GWs
- There is plenty of capital OUTSIDE India looking for opportunity.  
It will not be donated... it must be negotiated. **India can attract FDI.**
- India cannot build 100 GWs **ALONE**... Innovate in Deployment  
-- Partnering means *sharing* CONTROL, using Market Dynamics  
**Can India share control and ownership to gain financing?**
- India can still Regulate and Operate in a JV... for local interests
- Private capital will NEGOTIATE Ownership (rights to profit-sharing)
- Move on Industrial Applications with SMRs *sooner* – to garner EXPORT Earnings in Hard Currencies (more than domestic revenues on grid).  
**SMRs for Industrial use is a GAME-CHANGER. Exponential growth.**
- China will be aggressively cost-competitive  
– do you want a Chinese Reactor on your soil?

## For Urban Planners... WHY NUCLEAR?

$$E = mc^2$$

Energy =  $\Delta$  Mass x Speed of Light SQUARED  
For nuclear reactions

Speed of Light Squared: 90 Quadrillion

90,000,000,000,000 per square meter per  
second-squared

$\Delta$  Mass x 90 Quadrillion square-meters  
per second squared

(or City-scale: 90 Billion KM-squared / s<sup>2</sup>)

Nuclear Energy is the only EXPONENTIAL Energy Source  
by its very nature... Best suited for DENSE Urban Demand

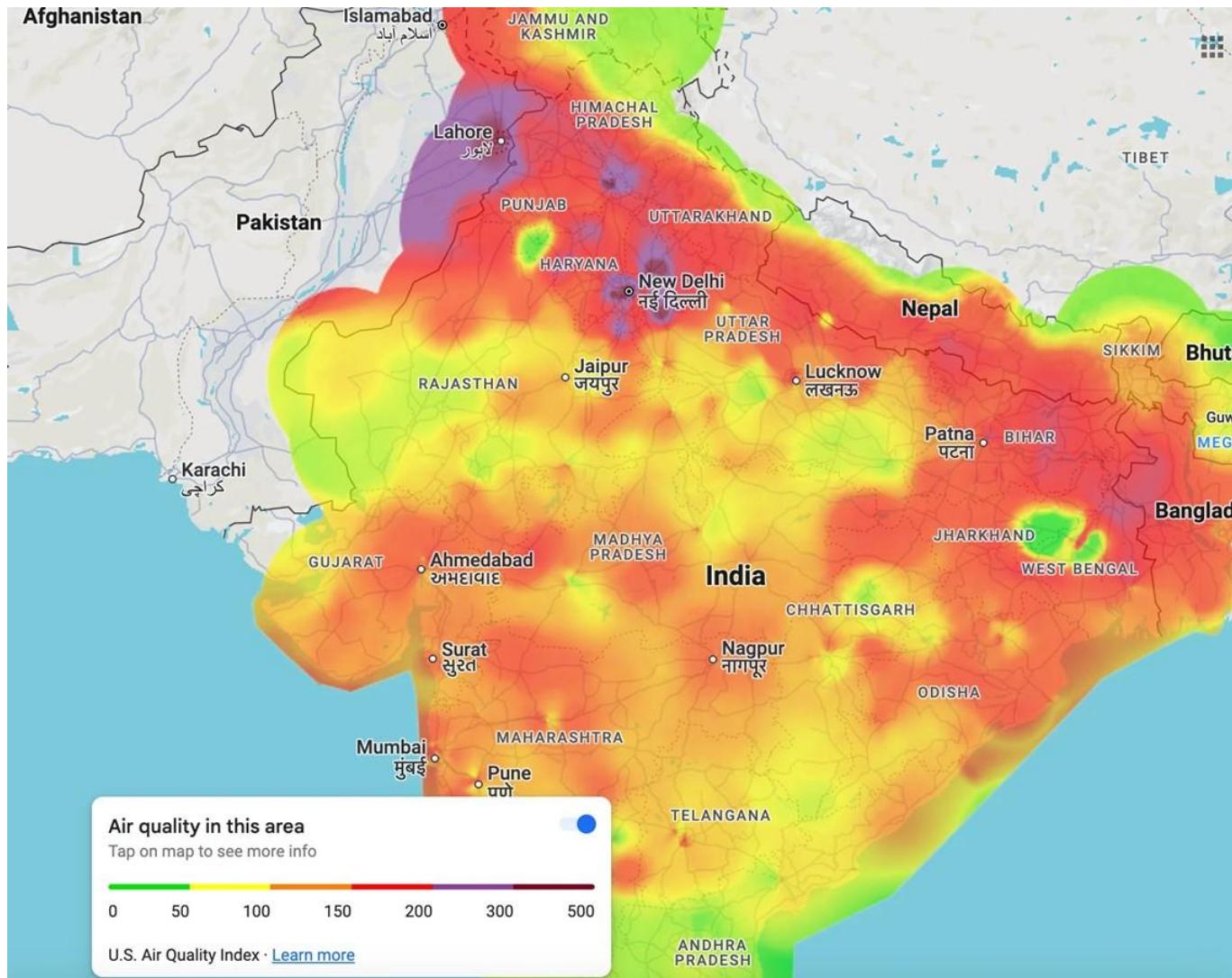
## DO YOU WANT TO POWER THIS?



With these – at night ?



# Air Pollution in India – 2023



**Starting point:**

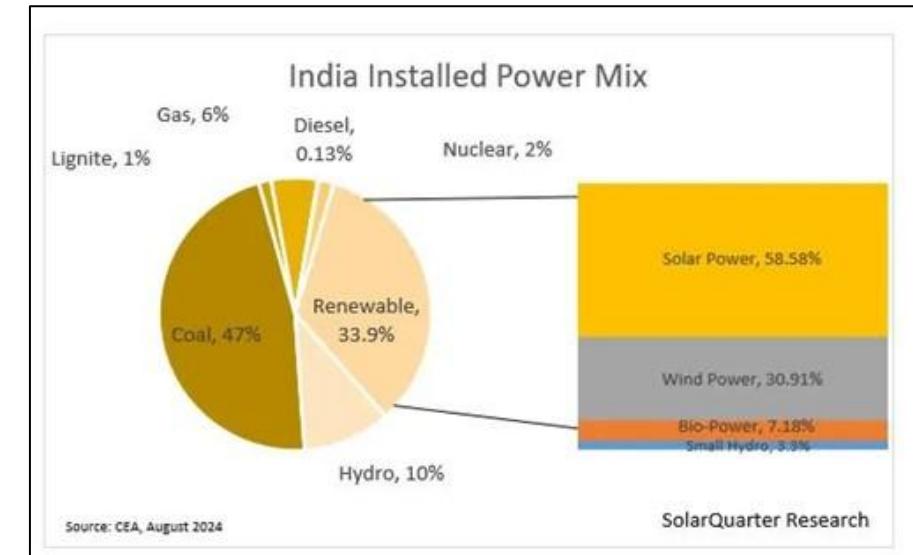
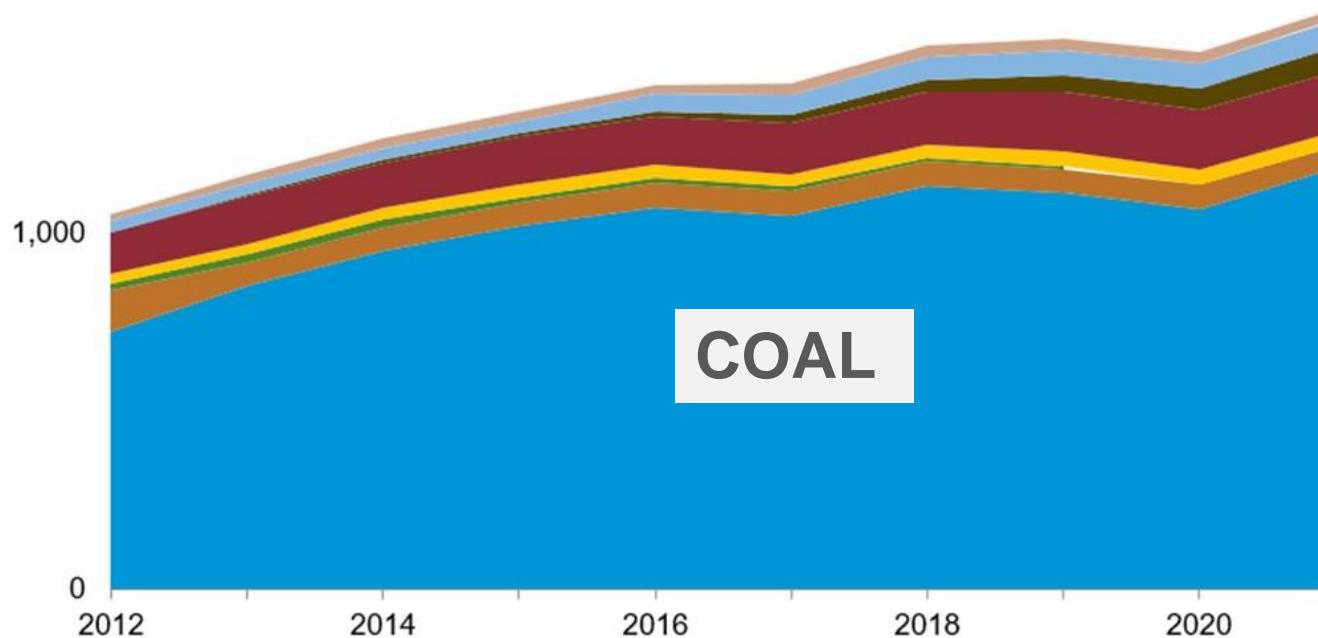
**AIR & WATER POLLUTION IN INDIA FOR 1.4 BILLION PEOPLE IS SO SEVERE THAT IT PROVIDES THE WORLD'S LARGEST OPPORTUNITY FOR NUCLEAR ENERGY**

# India Electricity Generation, 2012 – 2021

Figure 8. India's net electricity generation by fuel type, 2012–2021

terawatthours (TWh)

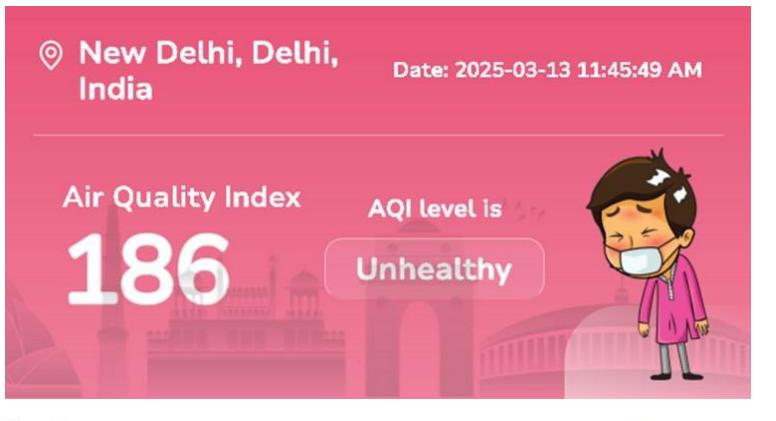
2,000      coal    natural gas    oil    nuclear    hydro    solar    wind    biomass and waste



Data source: U.S. Energy Information Administration, *International Energy Statistics and Estimates*

# Polluted Air kills 1 million+ people in India prematurely EVERY YEAR

India has six of the world's 10 most polluted cities, report shows



Written by [Cherry Gupta](#)  
New Delhi | December 19, 2024 11:11 IST

4 min read



As Delhi's AQI has reached a 'severe' level once again, here's a look at the air quality status in the NCR

## Delhi Pollution: Deadlier Than You Think

**BASIS OF STUDY** | Fine particulate pollutants (PM1) grow bigger by absorbing moisture and exceed cut-off size, which is the basis for their detection by sensors. This leads to underestimation of PM1 concentrations



### WHAT STUDY FOUND

- There's up to 20% underestimation of PM1 levels in Delhi, the highest among world's megacities
- Higher the pollution and humidity in air, bigger the underestimation of PM1 levels
- Highest underestimation (20%) happens during morning rush hours in winter, when pollution levels are high & so is relative humidity (typically around 90%)
- Severe pollution episodes in Delhi-NCR during winter are actually more severe than what is currently estimated

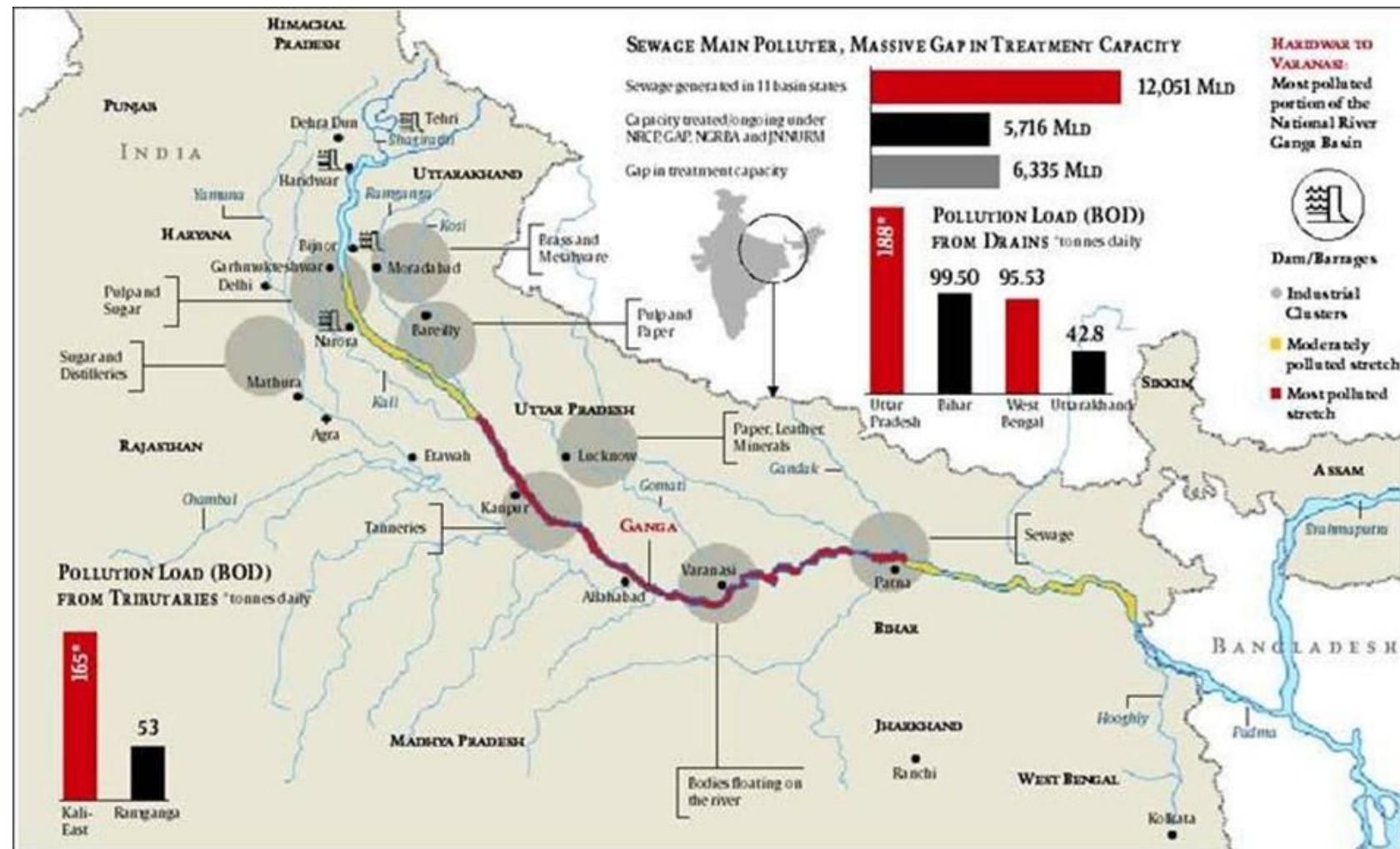


### WHY IS IT SIGNIFICANT?

- Fine particulate matter is one of major pollutants in Delhi. It's also among the deadliest, with severe health impacts
- Underestimation of PM1 levels has implications not just for health of Delhiites but also for policies targeting the region's air pollution



# Severe Water Pollution in the Ganges River Basin -- 40% of India's people



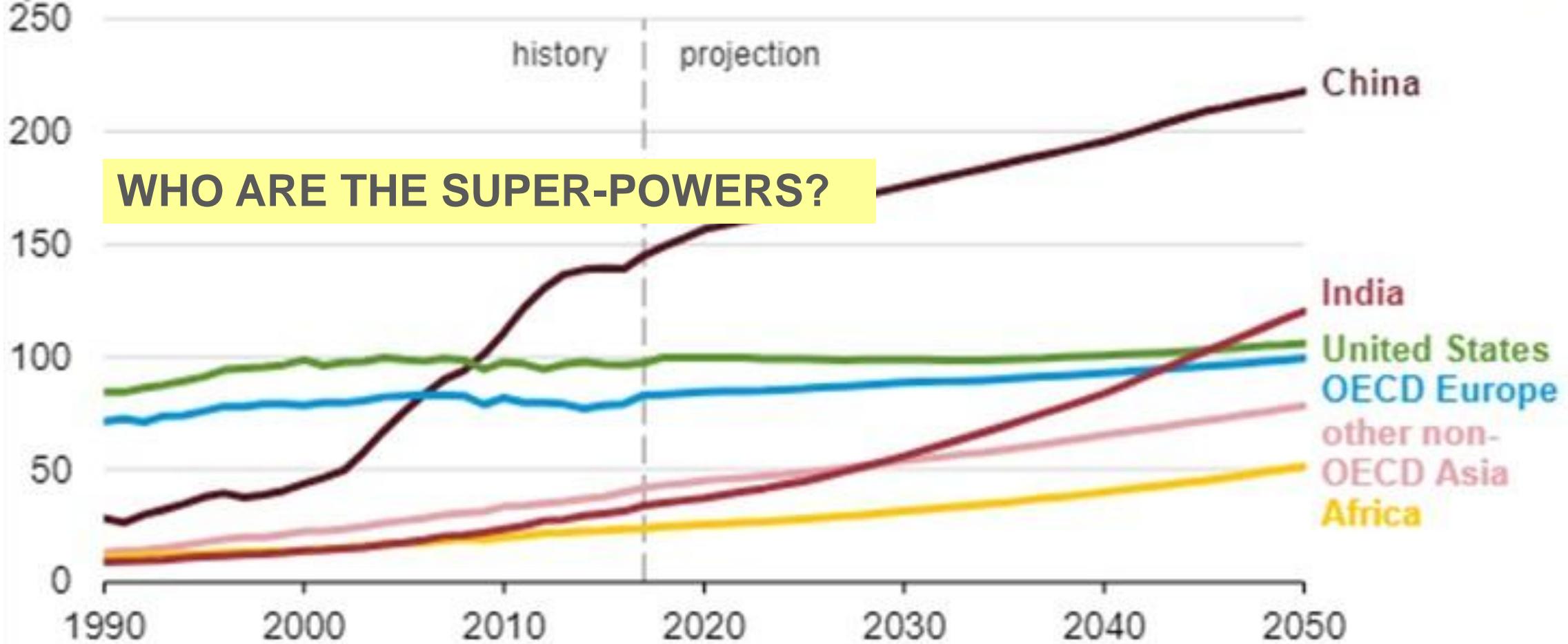
**WHAT CAN BE DONE?**  
**Will require exponential energy amounts.**



2023: <https://believersias.com/pollution-of-the-ganges/>

# Energy Consumption to 2050

Total energy consumption in selected countries and regions (1990-2050)  
quadrillion British thermal units

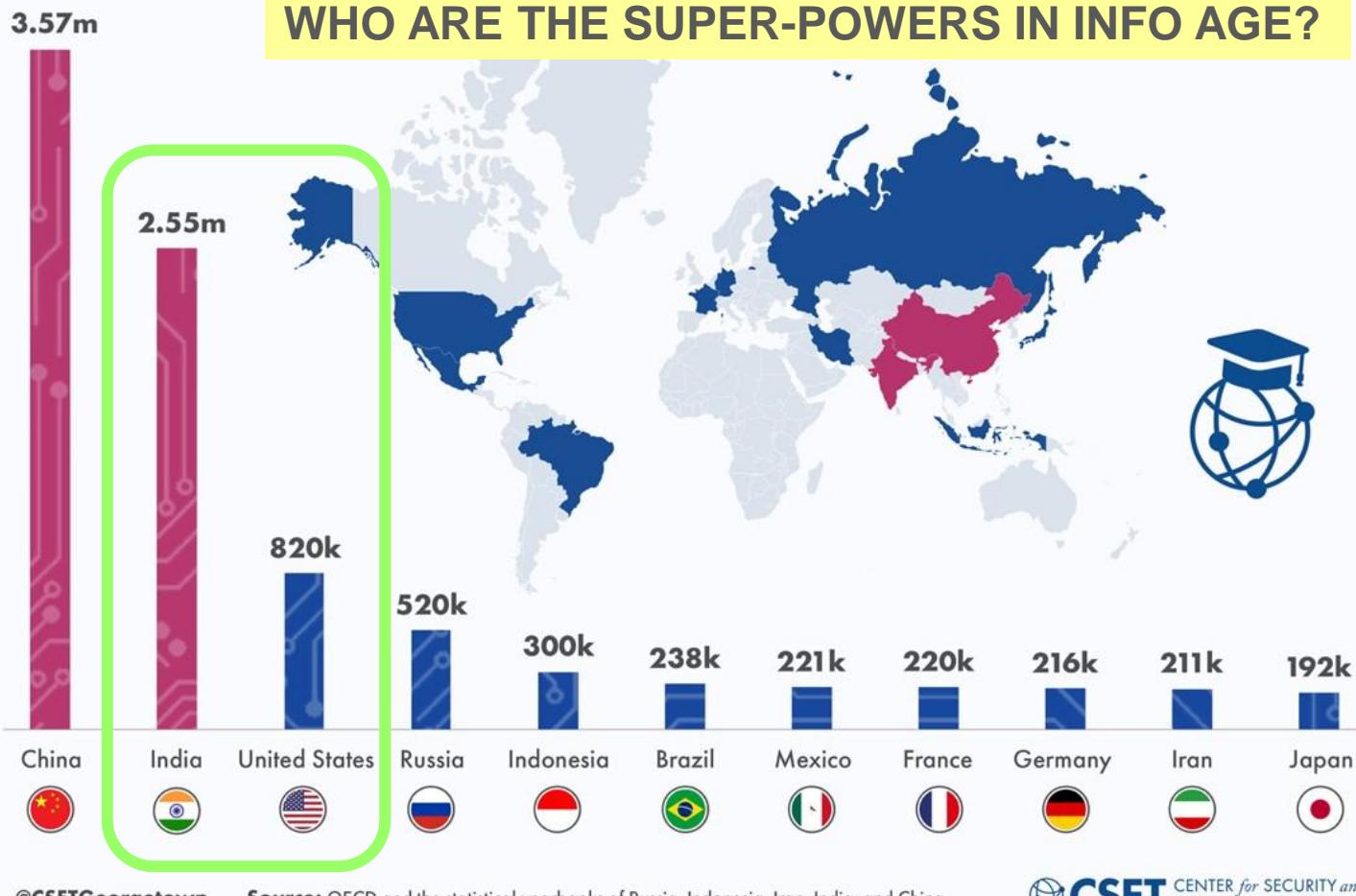
 eia

<https://www.eia.gov/todayinenergy/detail.php?id=42295>

# MAGA + MIGA = “MEGA”. WHO ARE THE SUPER-POWERS?

## Top Countries by Number of STEM Graduates

Graduates in Science, Technology, Engineering, and Mathematics in 2020



How many STEM grads are fluent in English?

NBC NEWS: Indians become biggest international student group in U.S., surpassing Chinese for first time since 2009

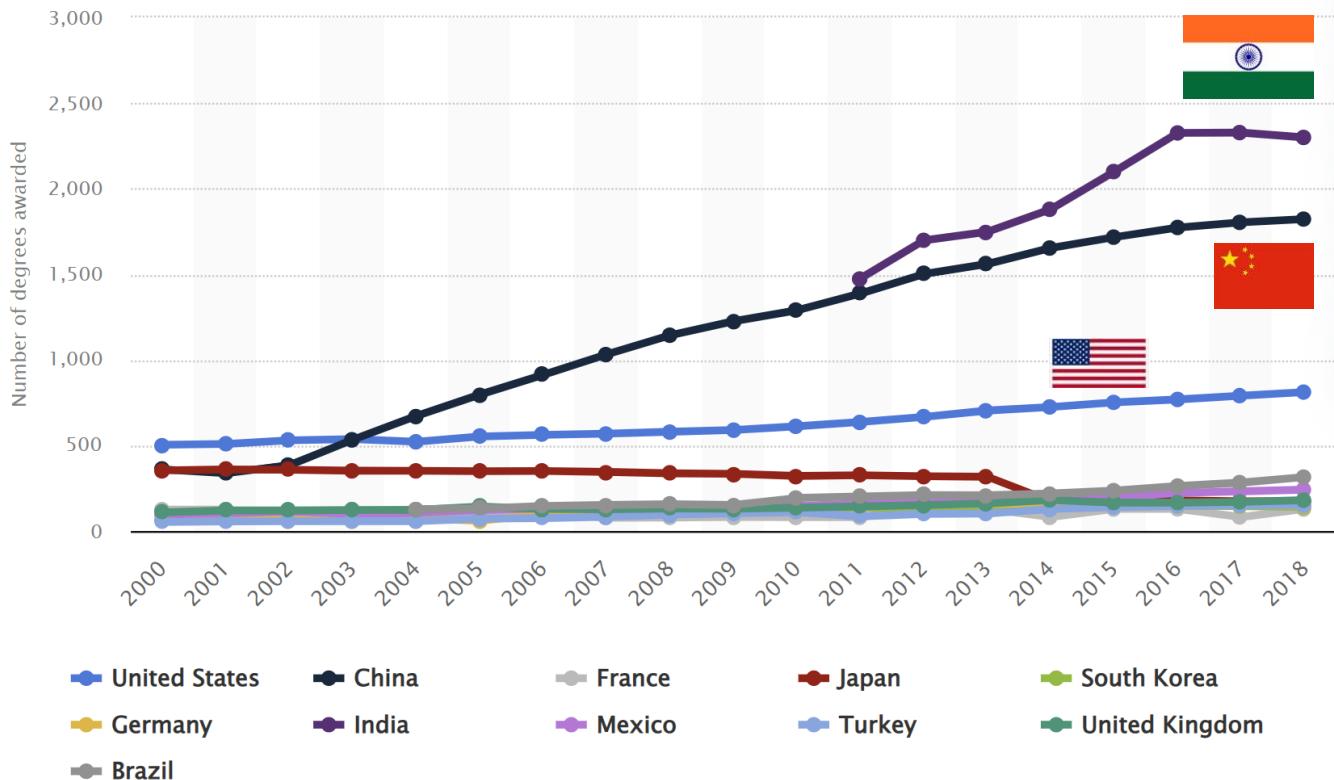
Experts say the lingering effects of Covid and strained tensions with China have caused India to become the new biggest sender of students .

There are now **331,602 Indian international students in the U.S.** (a 23% growth from last academic year), compared with 277,398 Chinese international students (a 4.2% decline).

# INDIA SURGES PAST CHINA ON STEM GRADUATES... 2025



↗ Zoomable Statistic: Select the range in the chart you want to zoom in on.



... And all the India STEM graduates speak English

Russia is losing population

Additional Information

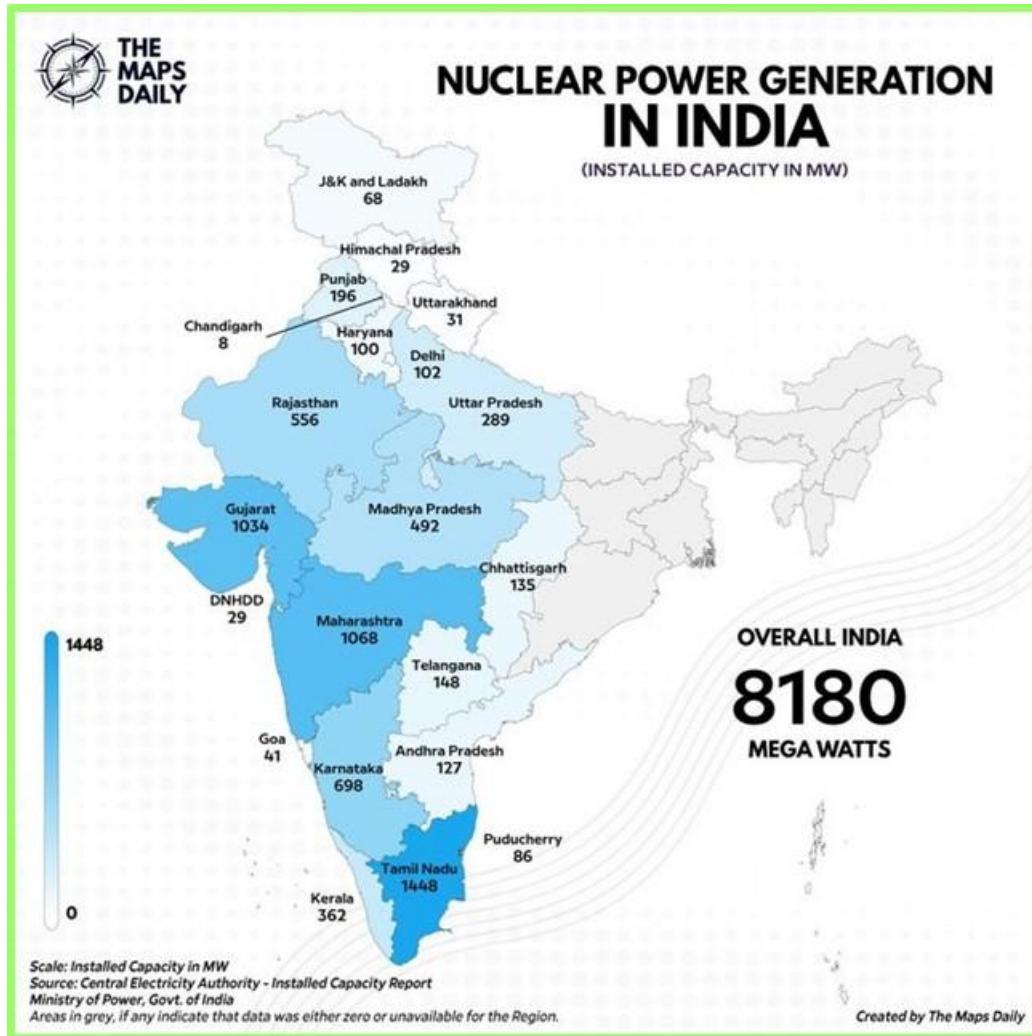
© Statista 2025

Show source

## WHO ARE THE SUPER-POWERS IN INFOTECH AGE?



# Nuclear Power Generation in India, heading to 22 GWs



## Nuclear Power Plants In India

The list below highlights the Nuclear Power Plants in India that are planned to be constructed.

### Nuclear Power Plants in India – Planned (Future projects)

Name Of Nuclear Power Station	Location	Capacity
Tarapur	Maharashtra	300
Madras	Tamil Nadu	1,200
Kaiga	Karnataka	1,400
Chutka	Madhya Pradesh	1,400
Gorakhpur	Haryana	2,800
Bhimpur	Madhya Pradesh	2,800
Mahi Banswara	Rajasthan	2,800
Haripur	West Bengal	4,000
Mithi Virdi (Viradi)	Gujarat	6,000
Kovvada	Andhra Pradesh	6,600
Jaitapur	Maharashtra	9,900

# WNISR: Nuclear Reactors Under Construction by Host Country - July 2023



**58 GWs**

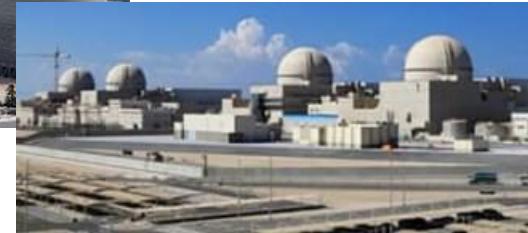
Table 2 · Nuclear Reactors “Under Construction” (as of 1 July 2023)<sup>38</sup>

Country	Units (Domestic Design)	Other Vendor	Capacity (MW net)	Construction Start	Grid Connection	Units Behind Schedule
China	<b>23</b>	Russia: 4	24 408	2016 – 2023	2023 – 2028	1
India	8 (4)	Russia: 4	6 028	2004 – 2021	2024 – 2027	6 <sup>(a)</sup>
Russia	5 (5)	-	2 810	2018 – 2022	2025 – 2027	2
Turkey	4 (0)	Russia: 4	4 456	2018 – 2022	2024 – 2027	1
Egypt	3 (0)	Russia: 3	3 300	2022 – 2023	2028 – 2030	-
South Korea	3 (3)	-	4 020	2013 – 2018	2024 – 2025	3
Bangladesh	2 (0)	Russia: 2	2 160	2017 – 2018	2024	1
U.K.	2 (0)	France: 2	3 260	2018 – 2019	2027 – 2028	2
Argentina	1 (1)	-	25	2014	2027	1
Brazil	1 (0) <sup>(b)</sup>		1 340	2010	2028?	1
France	1 (1)	-	1 630	2007	2024	1
Iran	1 (0)	Russia: 1	974	1976	2024	1
Japan	1 (1)	-	1 325	2007	2025?	1
Slovakia	1 (0)	Russia: 1 <sup>(c)</sup>	440	1985	2024	1
UAE	1 (0)	South Korea: 1	1 310	2015	2023	1
U.S.	1 (1)	-	1 117	2013	2023	1
<b>Total</b>	<b>58</b>		<b>58 GWs</b>	1976 – 2023	2023 – 2030	24
<b>Total per Vendor Country:</b>						
Russia: 24 - China: 19 - India: 4 - South Korea: 4 - France: 3 - U.S.: 1 - Argentina: 1 - Japan: 1						



Teams at Plant Vogtle  
have safely completed  
initial synchronization  
to the grid for Unit 4.

**Large Reactors  
in the ARENA**



**Barakah for  
UAE with  
KEPCO,  
5600 MWs**



**Rosatom at Akkuyu**



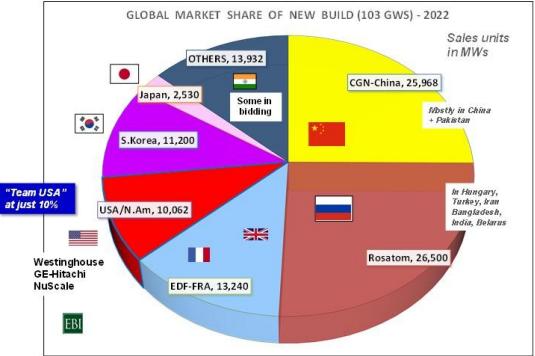
**CEG repowering  
TMI for MSFT?**



Sources: Various, compiled by WNISR, 2023

# Opening Viewpoints from USA...

Today, Nuclear Energy is not a “market”, it is an ARENA...  
 of “Nation-State Gladiators”, like CGN, Rosatom, EDF  
 Russia and China command >50% of total construction today; USA <5%  
 Govts are heavily involved in financing new nuclear projects.



Not an LCOE Arena



## 1) Look at Industrial Applications First – Steam, Heat, then Power

Take advantage of rising Demand Signals for New Nuclear:

Sharp increase in electricity needs for Data Centers / AI, Chemicals, Steel suddenly enables more private capital *negotiated*.

## 2) Financings must employ an “Allied Model” (NATO) + INDIA working with other countries

## 3) Get to “FLEETS” of SMRs sooner... *on the BUY-side* Fleets, not “onesies” pull forward the supply chain -- Look to “building airplanes, more than airports”



Ship a manufactured reactor to the site

# FLASH OVERVIEW at ISUW: KEY TOPICS TO DISCUSS...

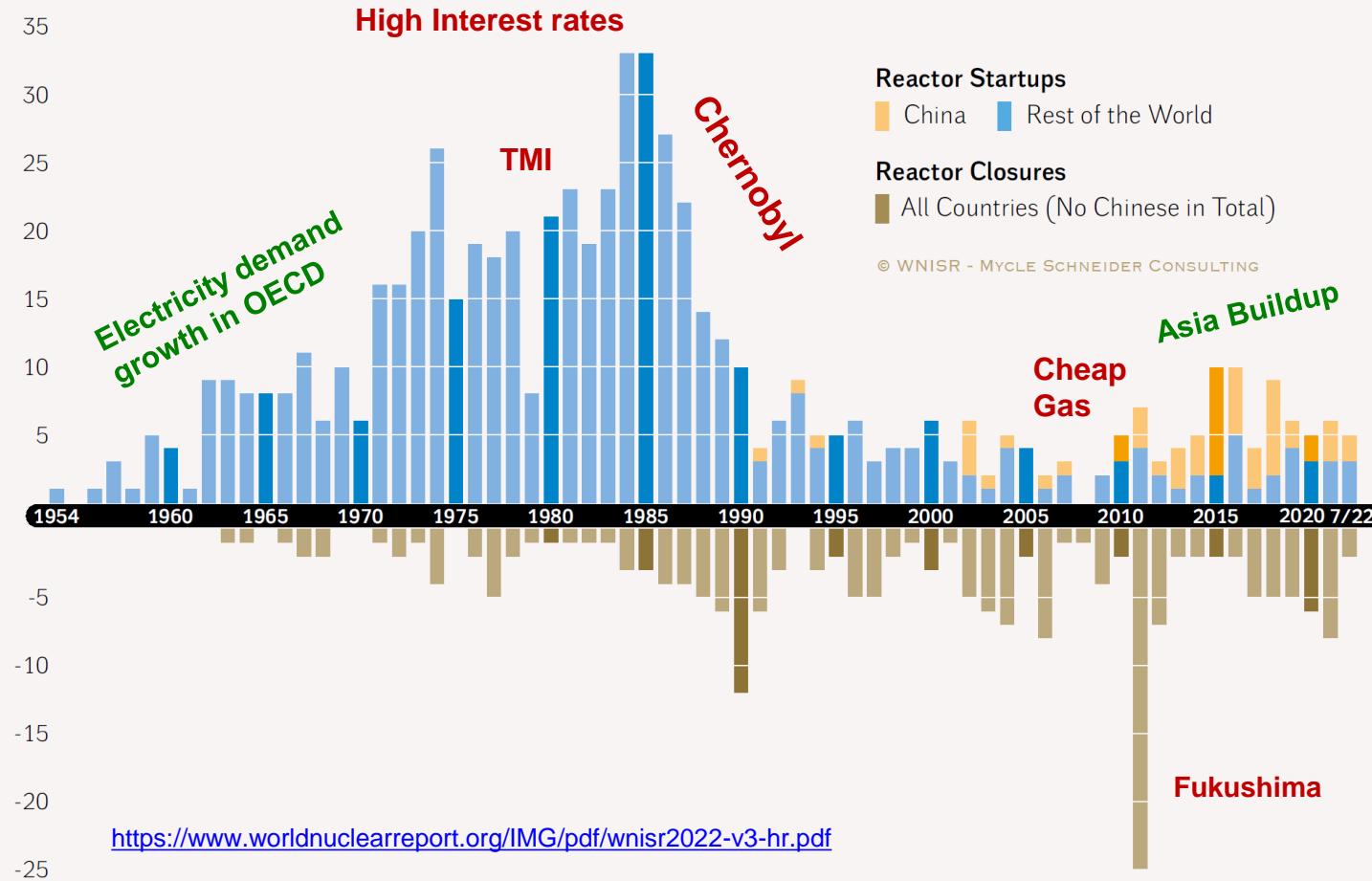
KEY TOPICS TO DISCUSS...	INITIAL BLAST COMMENT
1. 100GW Nuclear Energy by 2047- is it too ambitious or too little?	A decent start as a <b>minimum...</b>
2. Development of 5 SMRs indigenously by 2033	<b>Laughably small. Must be 20+</b>
3. ₹20,000 crore (\$2.3 billion) allocation for the Nuclear Energy Mission and its expected impact on India's energy landscape.	India must draw EXTERNAL Private Capital. Multiply this number as equity
4. Roadmap for 100 GW Nuclear Energy by 2047 and indigenous development of Five SMRs by 2033 – <i>Any foreign vendors allowed? How?</i>	Important – Think “ALLIED MODEL” <b>India working ALONE will FAIL.</b>
5. Advancements in SMR Technology – latest developments in SMR design, improved safety features, modular construction, operational efficiencies	<b>These are coming faster outside India</b>
6. Economic Viability of SMRs including <b>cost</b> , <b>RISK-BASED</b> financing models, and the potential for integrating SMRs with other energy sources and <b>INDUSTRIAL APPLICATIONS</b> to optimize energy systems	Focus on Industrial Applications FIRST, in <b>EXPORT</b> industries. <b>Not grid first.</b> <b>Lowest cost will not deliver best results.</b>
7. Regulatory and Safety Considerations for SMRs including licensing processes, regulatory challenges, and public perception issues	<b>Other countries will license SMRs first.</b>
8. International Collaboration and Best Practices – the role of global collaboration in advancing SMR technology, sharing lessons learned from international entities involved in SMR development and deployment	<b>How will India PARTNER? Joint Venture means sharing OWNERSHIP.</b>
9. Thorium Reactors and Alternative Nuclear Technologies – evaluating the potential of thorium-based nuclear reactors, and current development	<b>OK. Do Thorium. Show us. BEAT CHINA!</b>
10. Workforce training framework; role of AI/ML and Predictive Analysis	Important, useful. Essential
11. Amendment to Atomic Energy Act & Civil Liability for Nuclear Damage	<b>Must do; nothing without this.</b>

# Historically Nuclear Plants are built in Waves... since the 1960s



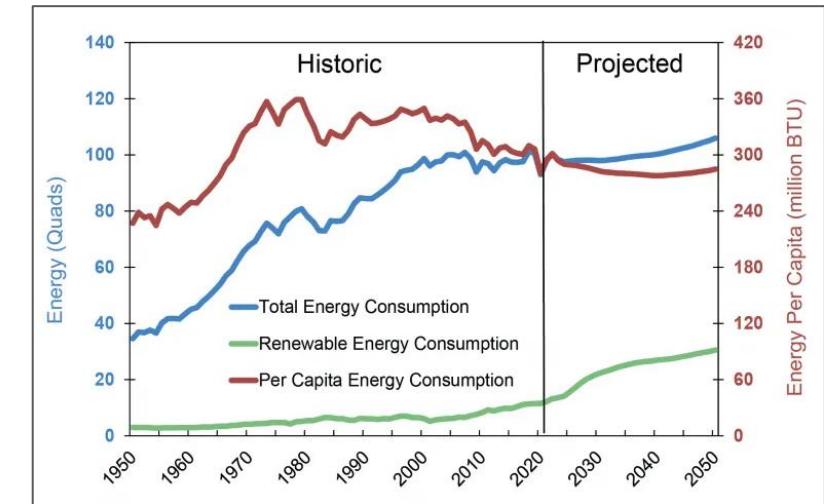
## Reactor Startups and Closures in the World

in Units, from 1954 to 1 July 2022

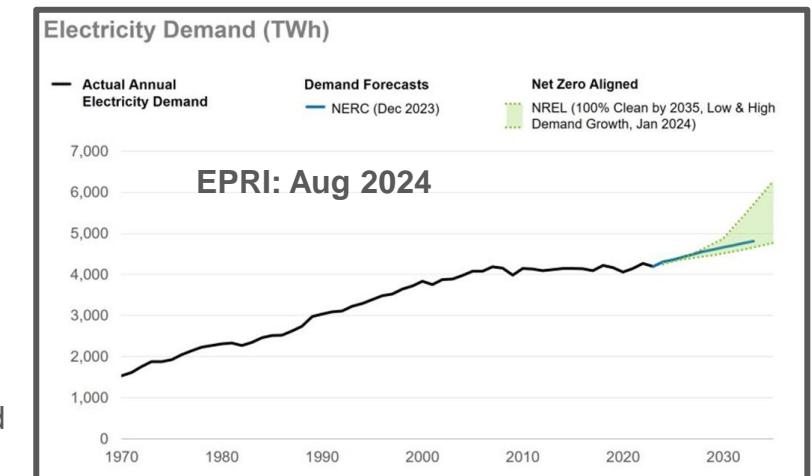


<https://www.energy.gov/policy/articles/clean-energy-resources-meet-data-center-electricity-demand>

Not much Energy Growth forecasted to 2050

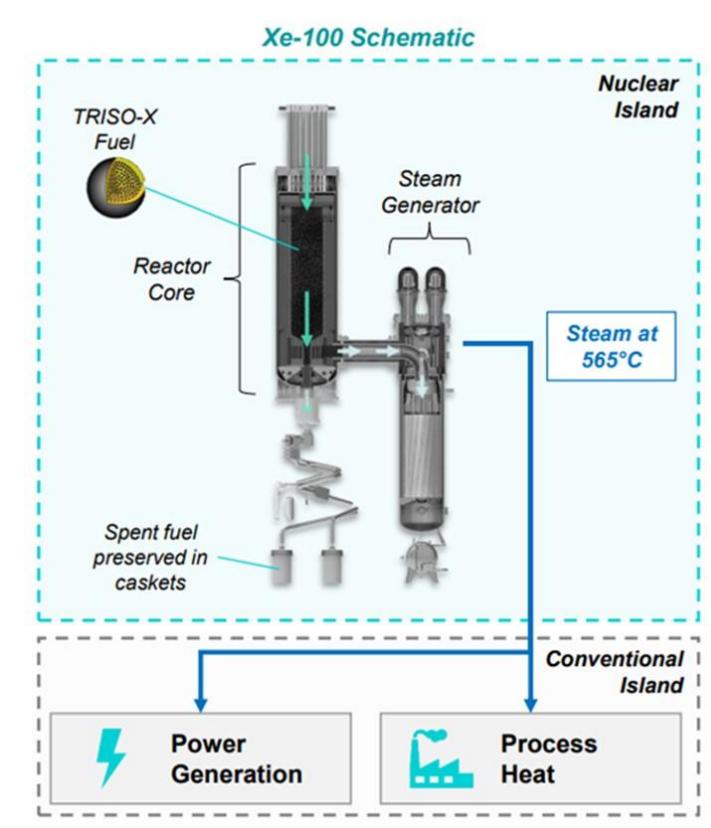


... until this year with Data Center growth



# INDUSTRIAL: DOW & X-energy collaborating in Texas

The project will reduce the Seadrift site's emissions by approximately **440,000 metric tons of carbon dioxide per year**, which is equivalent to removing more than 97,000 cars from the road. X-energy's Xe-100 nuclear reactor will be among the first operational grid-scale INDUSTRIAL reactor plants in the continent. The Seadrift site encompasses 4,700 acres and manufactures more than 4 billion pounds of materials annually. <https://c3newsmag.com/dow-and-x-energy-collaborate-on-grid-scale-smr-project/>



# Global SMRs in “Discussion” now nearing \$85 Billion in total value, 2022

Stage of Development	
China or Russia	5
Fuel load / Ops	4
Under Constr	3
Financing signed	2
Siting selected	
JV Formed	1

China & Russia lead deployment of SMRs ... Industrial and Arctic applications  
What will USA and Europe do to recover leadership?

Locale	Expected SMR Project	SMR Site	Reactor	Operating by		MWs	[Reactors]	Total	\$Billions	\$Millions
				Average	Average	Units	MWs	Total Cost	Cost per MW	
				2029	190	60	9,168	\$85.60 B	\$9.3 M	
USA, Utah	UAMPS	INL, ID	NuScale LWR	2030	77	6	462	\$8.00 B	\$17.3 M	
USA, several	NUCOR EAFs	Several: KY, WV	NuScale LWR	2030	77	12	924	\$12.00 B	\$13.0 M	
CAN, Ontario	OPG	Darlington, ON	GE LWR	2028	300	1	300	\$1.80 B	\$6.0 M	
UK Site	RR SMR	Wales, UK TBD	Rolls Royce	2030	470	3	1410	\$9.00 B	\$6.4 M	
UK Site	RR SMR	Moreside, UK	Rolls Royce	2032	470	2	940	\$6.00 B	\$6.4 M	
CAN, NB	NB SMR	Pt. LePreau, NB	Moltex AMR	2029	300	1	300	\$2.50 B	\$8.3 M	
CAN, Ontario	CNL	Chalk River, ON	USNC Micro	2027	5	1	5	\$0.40 B	\$80.0 M	
USA, Alaska	US Air Force SMR	Eielson base, AK	AMR Micro	2027	5	1	5	\$0.50 B	\$100.0 M	
USA DOE ARDP	TerraPower	Kemmerer, WY	Natrium AMR	2032	345	1	345	\$3.50 B	\$10.1 M	
USA DOE ARDP	DOW Chem	Freemont, TX	X-e 100	2032	80	4	320	\$4.20 B	\$13.1 M	
USA DOE ARDP	X-energy	Hanford, WA	X-e 100	2032	80	2	160	\$2.40 B	\$15.0 M	
Poland	PKN Orlen	Multiple sites	GE-BWRX	2030	300	4	1200	\$8.00 B	\$6.7 M	
Poland	SYNTHOS	Oświęcim, PL	LWR SMR	2030	300	1	300	\$2.50 B	\$8.3 M	
Bulgaria	Industrial AMR	Maritsa Iztok, BG	AMR	2028	80	6	480	\$7.20 B	\$15.0 M	
Slovenia	Krško-2	Krško site, SLO	LWR SMR	2030	300	2	600	\$4.00 B	\$6.7 M	
Romania	Cernavoda SMR	Cernavoda, ROM	NuScale LWR	2028	77	6	462	\$6.00 B	\$13.0 M	
CH, Shanghai	China NNC AMR	Shandong AMR	HTR-PM	2024	210	1	210	\$1.40 B	\$6.7 M	
RU, Siberia	Seversk Chemical + Rosatom MOX	Seversk, RU	TVEL BREST Lead-cooled	2027	300	1	300	\$2.00 B	\$6.7 M	
RU, Arctic Circle	Arctic Port	Pevek, RU	2 x KLT-40C	2020	35	2	70	\$0.50 B	\$7.1 M	
CH, Hainan	CNNC	Changjiang	ACP100 PWR	2026	125	1	125	\$1.50 B	\$12.0 M	
CH, Floating	CNNC	Floating SMR	ACP100 PWR	2028	125	1	125	\$1.20 B	\$9.6 M	
CH, Jiangxi	CNNC	Ningdu	ACP100 PWR	2028	125	1	125	\$1.00 B	\$8.0 M	

SMR Projects in the Global “Arena” top \$80 billion in estimated project value (20+ projects)

At various stages of development, SMR projects announced by vendors, engineering partners and governments (either for siting or investment) have reached near \$85 billion in projected capital investment – more than 20 projects including at least 40 reactors for a combined total topping 8-9 GWs. Most of that capital investment lies in the future, as projects are still at various stages of development: from 1) Announced plan and JV by a Government; 2) Selected site with permits in view; 3) Financing signed -- the biggest hurdle it seems; 4) Under construction; 5) Fuel loading and operation in a few cases. Each of these five stages represent a significant milestone with multiple stakeholders and a clear decision point.

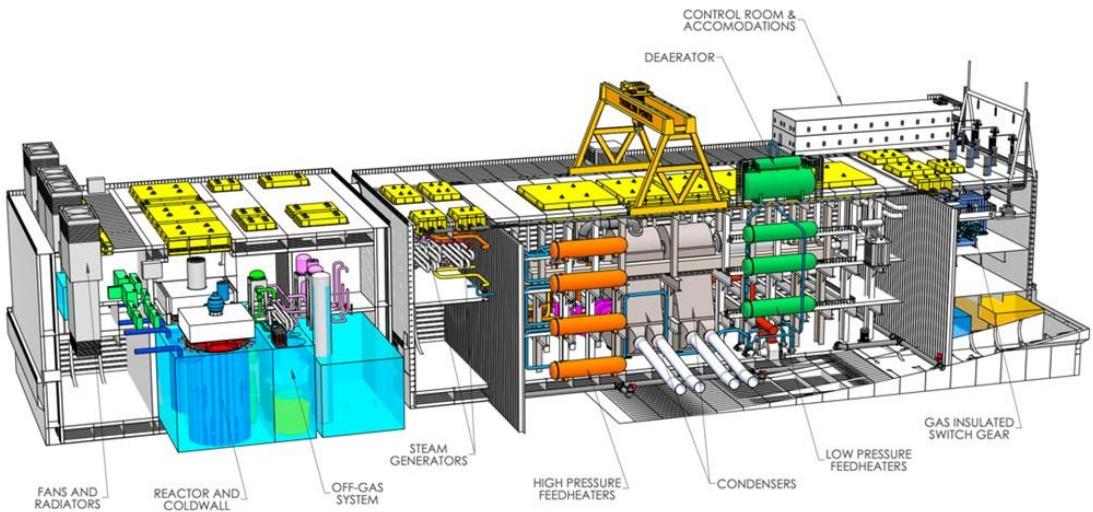
Cost estimates are still moving around due to the earlier stage of projects; some estimates are high and some are low, so the combined list should be near an expected value.

The table notes the Stage of Development of a project and highlights China & Russia versus allied actors. Also, whether the reactor design is a conventional LWR (either a BWR or PWR, Gen III) vs a more advanced “AMR” reactor with designer shown. Micro-reactors (sub-20 MWs) are for specialty applications and remote facilities (e.g., Arctic ports and stations). ADPaterson

© ADPaterson (from PhD work)



# ThorCom also in Nuclear Sweepstakes with Shipyard building



**Two year to build and install**

**Nuclear module to generate  
Hot solar salt. 570C, 1114MW**

**Production cost is 1.2 cents/kWth-hr**

**Price is to be negotiated**

**Fuel is LEU so commonly available on the market**

**Existing supply chains can support initial builds. Scaling up supply chain to meet market demands is very possible. (Uranium and beryllium mining, conversion, enrichment).**

**First fission 2028**

**Commercial license 2030**

**Current plan is for electricity production in Indonesia  
Nuclear module is identical**

# THORCON Modular Design

2 years to build and install

Nuclear module to generate  
Hot solar salt.

570C, 1114MW,  
production cost is 1.2 cents/kWth-hr  
Price is to be negotiated

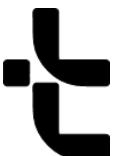
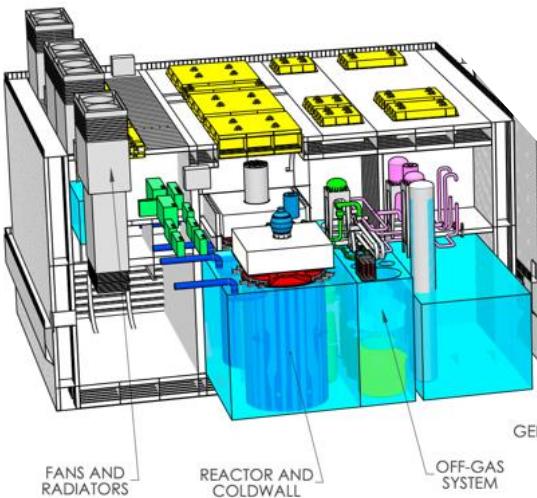
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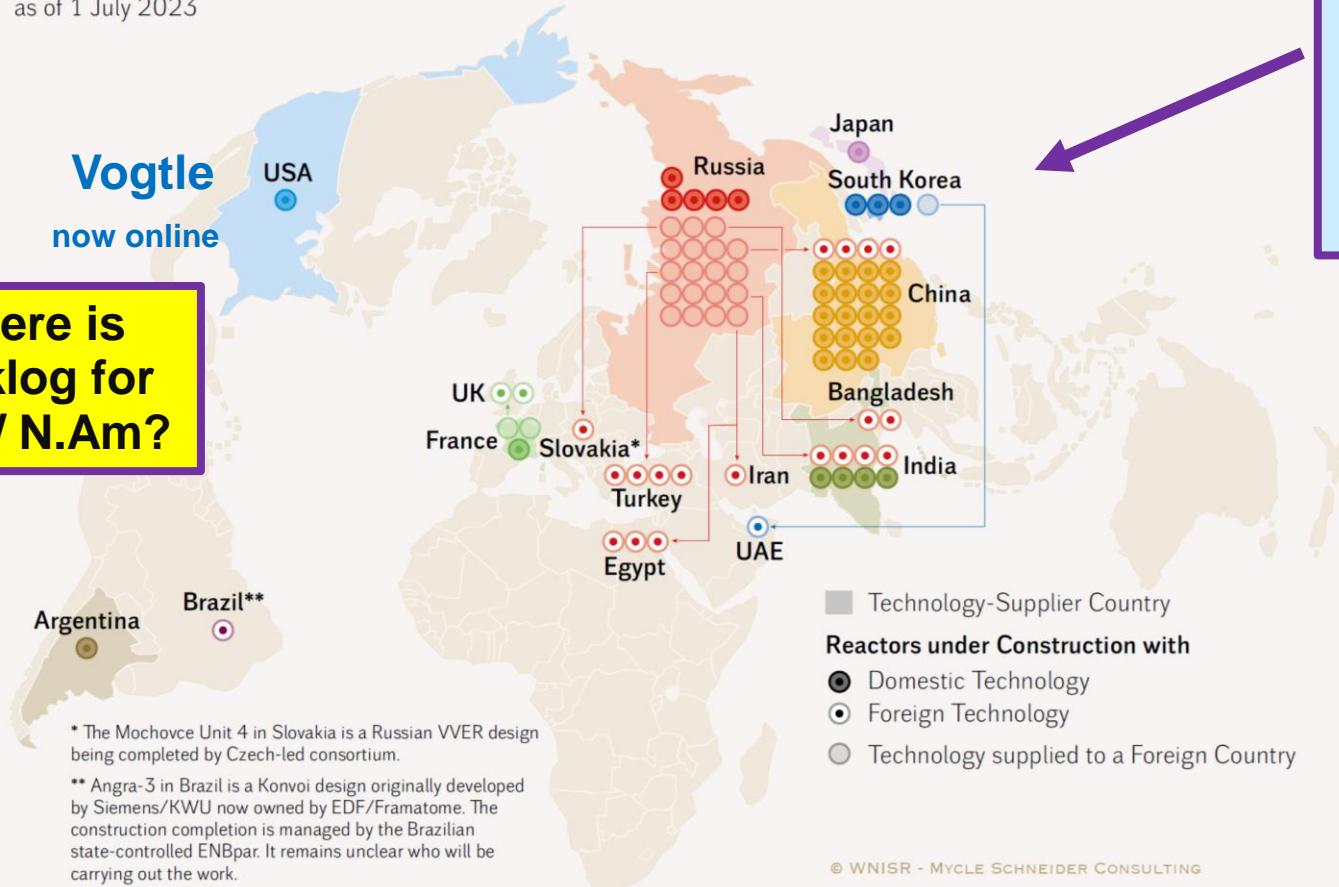


## Nuclear Power Reactors under Construction in the World

Units by Technology-Supplier Country and Construction Country  
as of 1 July 2023

**Vogtle**  
now online

Where is  
backlog for  
USA / N.Am?



New Construction  
for Nuclear Plants  
is concentrated in  
MacKinder's  
“HEARTLAND”

WHY?

Possible backlog in N.Am:

- TMI redo for MSFT (PA)
- Restart at Palisades, MI
- Diablo Canyon (CA)?

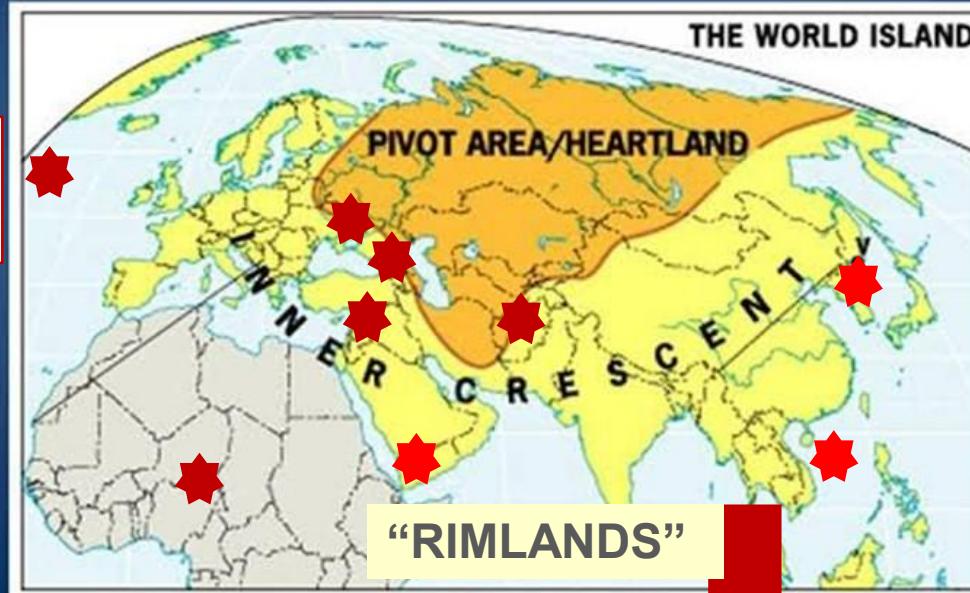
- ❖ SMR at OPG (CAN)
- ❖ SMR at TVA (Tenn)
- ❖ SMR at Kemmerer, WY
- ❖ Kairos with Google
- ❖ AWS with X-energy

1904

## Mackinder's Heartland Theory:

"Who rules East Europe commands the Heartland  
 Who rules the Heartland commands the World Island  
 Who rules the World Island commands the world"

Cyber-  
attacks  
In N.Am



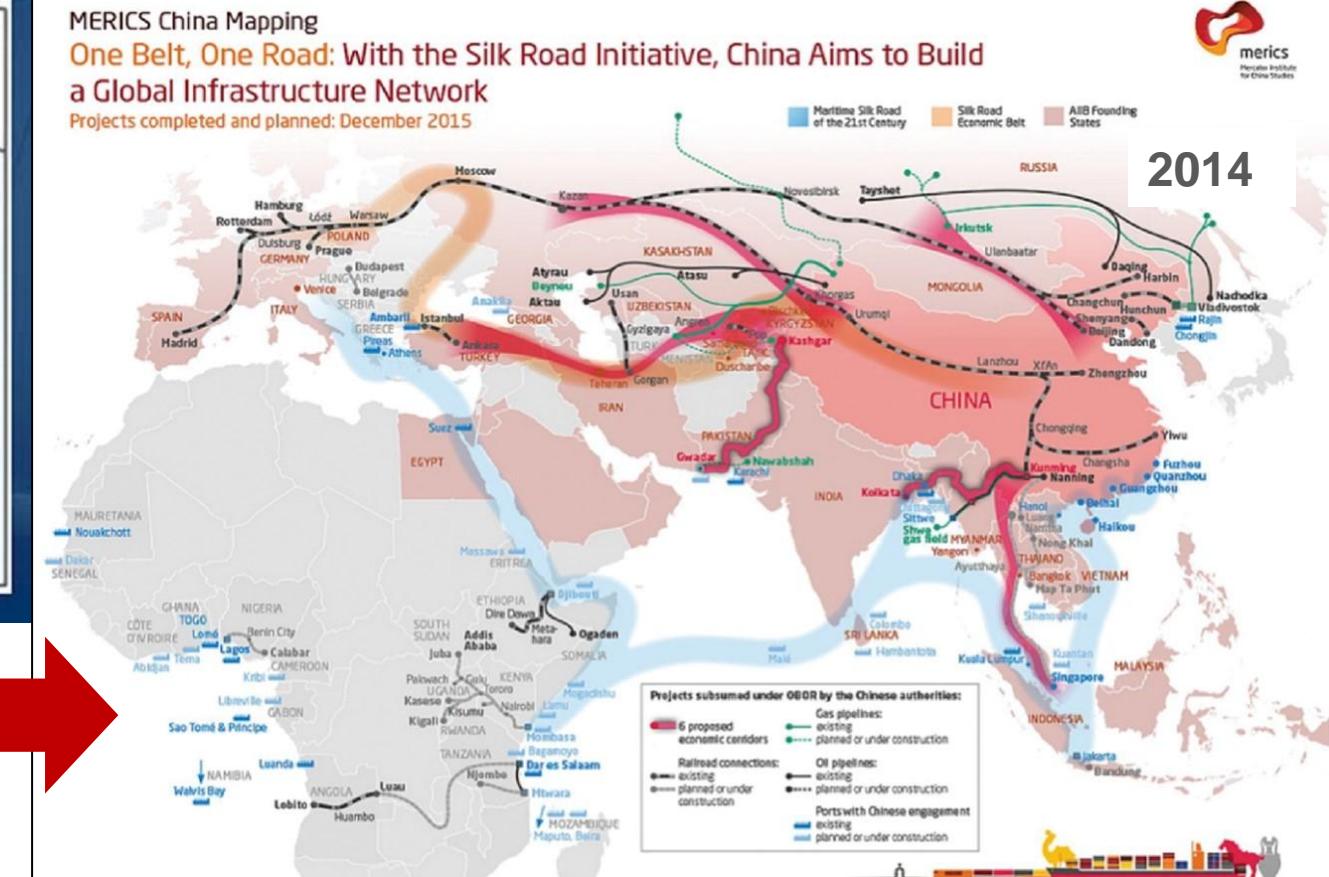
**"RIMLANDS"** – where  
more conflicts will arise

CFR: [www.cfr.org/report/conflicts-watch-2024](http://www.cfr.org/report/conflicts-watch-2024)

China - Russia Belt & Route Initiative  
 brings Mackinder's Prophecy (from LSE) to Life –  
 Russia and China look to consolidate Eurasia;  
**Conflicts will spring up along Crescent Border region**

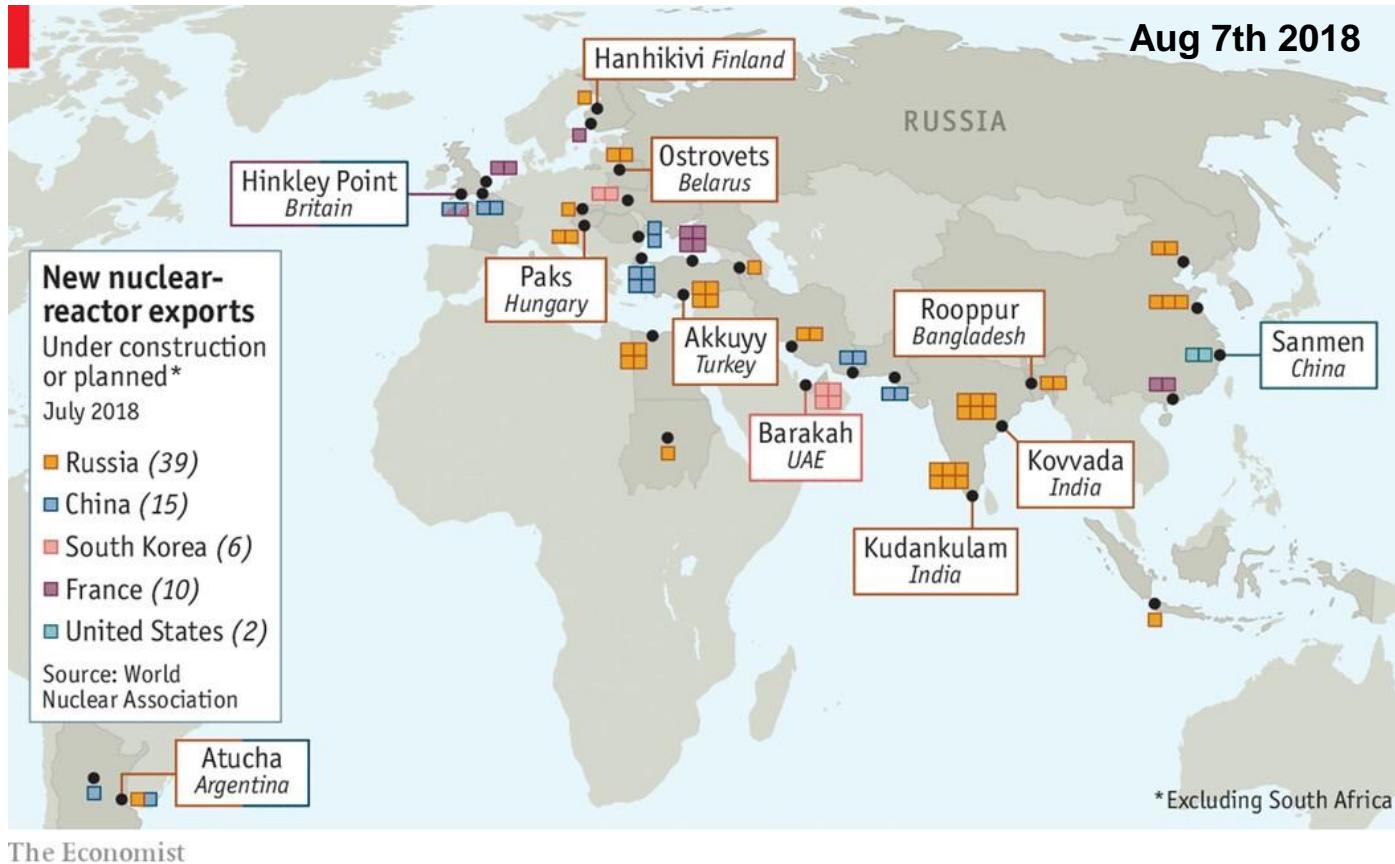
MERICS China Mapping

One Belt, One Road: With the Silk Road Initiative, China Aims to Build  
 a Global Infrastructure Network  
 Projects completed and planned: December 2015



# Economist 2018: Russia leads world in International Reactor Projects...

“China is its only real competitor”... or as some believe – They are working as a TANDEM.



<https://www.economist.com/graphic-detail/2018/08/07/russia-leads-the-world-at-nuclear-reactor-exports>

## Russia leads the world in Reactor Projects (Aug 2018)

*The Economist: “China is its only real competitor...*

Russia's nuclear programme has endured for two main reasons. Its designs are cheap, and Rosatom enjoys the backing of the state, which helps it absorb hard-to-insure risks like nuclear meltdowns. Its competitors trail hopelessly: France's Areva (now Orano) has started building only two plants in the past ten years, in Finland and China; both are delayed and over budget. KEPCO, South Korea's energy company, is facing a domestic backlash against nuclear power, while Westinghouse, in America, is only now emerging from bankruptcy.

Russia's only real competitor is China, another country where government and business are tightly entwined. Until recently China has focused on meeting soaring demand for electricity at home. But importing raw materials and exporting technology is a better long-term bet, and so it has started to look abroad. A Chinese state-backed firm is partly funding Hinkley Point in Britain, and others are involved in plants in Argentina and Turkey. Yet although

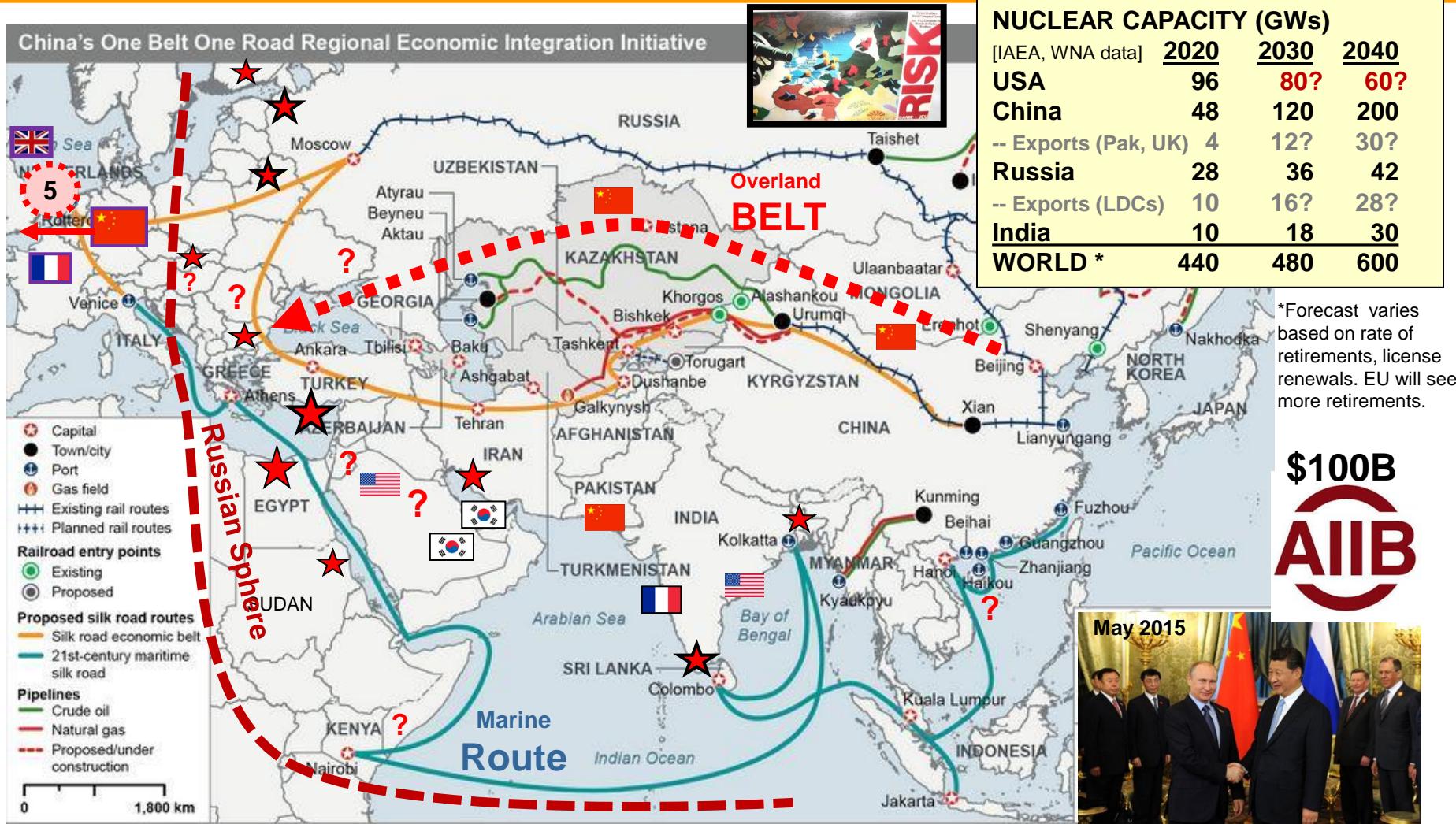
**China will surely catch up, for now Russia has no serious rivals in the export of nuclear technology.**

In a world that needs to generate much more electricity from nuclear power if it is to take de-carbonisation seriously, that is a sobering thought.

**China using nuclear units to reinforce BELT-ROUTE INITIATIVE (BRI) with Russia**  
**Russia actively locking up Marine Route sites (ports), with Military Basing Rights**

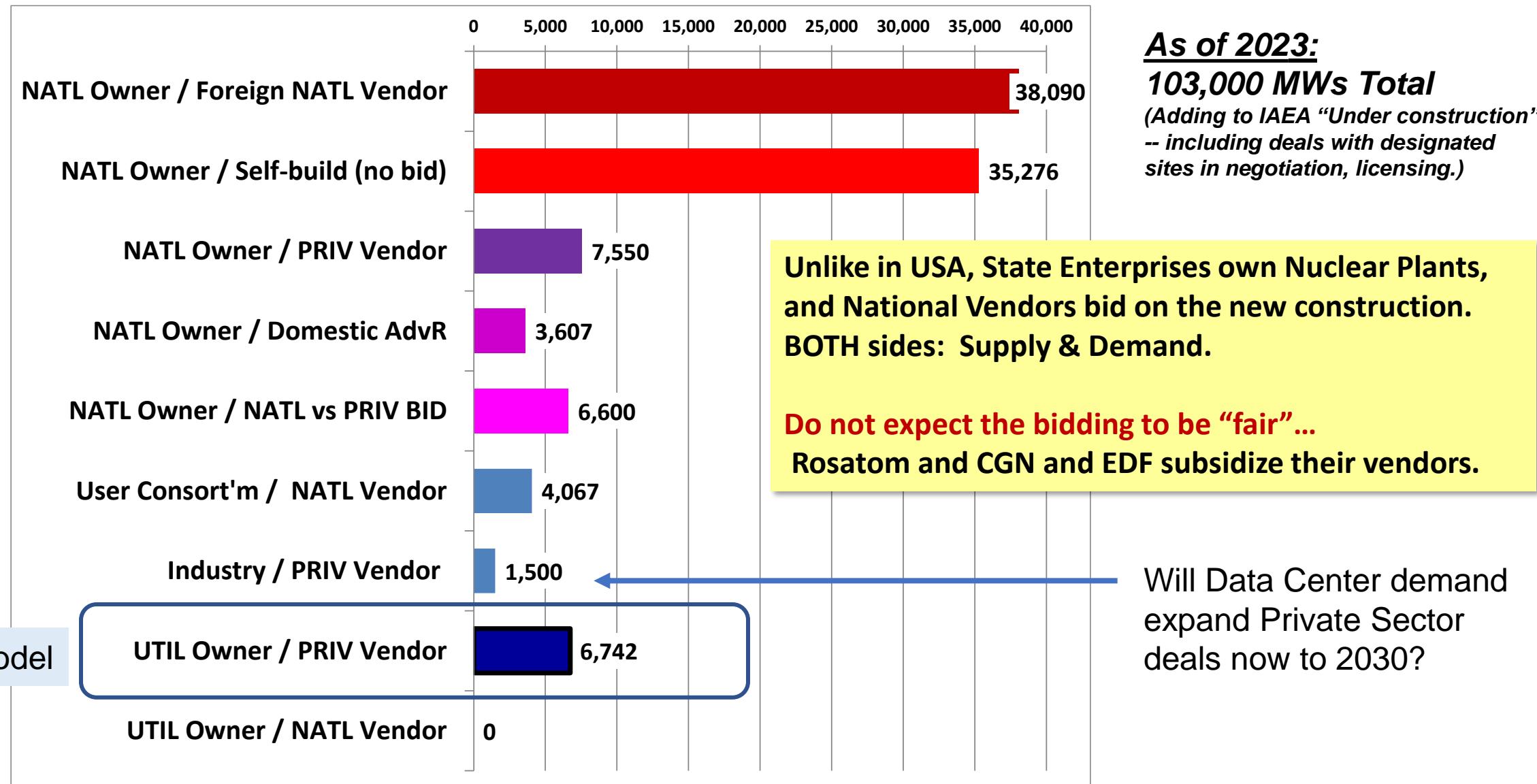
Is Russia  
winning  
projects by  
focusing on  
LCOE?

No, they  
focus on the  
BUY-side  
with client  
Govts.



**Active Russian Nuclear Project...** most bolstering global trade hubs for BRI  
 Chinese nuclear plants along BELT path have not been sited yet (proposed)

# State Owners & National Vendors Dominate



# Nation-States are being forced to change their nature...

Bobbitt on his constitutional diagnosis:

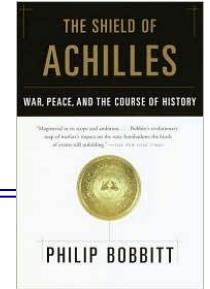
"Market States are not the ideal, but since 1990 they are emerging."

**"Market States seek roles to *enable* rather than *provide*, to expand or optimize *opportunities* for their citizens, to reduce transaction costs rather than provide services directly, in contrast to Nation-States looking to maximize social welfare. They are umpires, not judges. They set rules for market operators more than decide outcomes."**

**"Mercantile Market States** (Asia) are more consensual and more protectionist, and keep control over capital both monetary and human." Less immigration. Cities drive policy.

**"Managerial Market States** (EU), Government planning, more sensitive to egalitarianism, attempt through long-range planning to give more weight to posterity, sustainability."

**"Entrepreneurial Market States** (N.Am) reflect a broadly libertarian view, tend to less intervention in markets, focused on providing public goods, and favoring pluralism and innovation." More functions are privatized. Wealthy suburbs.



[http://www.law.columbia.edu/fac/Philip\\_Bobbitt](http://www.law.columbia.edu/fac/Philip_Bobbitt)

***Nation-States face stresses now that exponential in nature***

### Threats to Nation-States (Bobbitt):

Triggering shift to Market-States

- 1) WMDs in hands of Terrorists eroding force monopoly (9/11)
  - 2) International pressures for democratization, human rights
  - 3) Global trade, communications (competitiveness pressures)
  - 4) Global media encroaching on cultural norms and narratives
- 
- 5) NOW: Sovereign debt crisis, fiscal strains, and dependence on external financing
  - 6) **More pressure for Energy Transition**

# IMF Chief warns on Debt Overhang for Many Countries

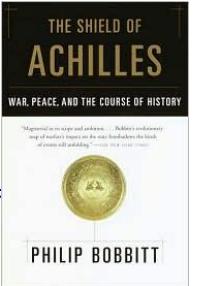


## ***Tripling Nuclear Capacity by 2050 with only Public Finance is IMPOSSIBLE.***

IMF chief warns of ‘unforgiving’ debt backdrop and low growth  
Kristalina Georgieva says governments’ reluctance to rein in spending heightens public finances challenge

**“Our forecasts point to an unforgiving combination of low growth and high debt — a difficult future,” said Georgieva. Countries faced “high and rising public debt — way higher than before the pandemic”, she added, even after a fall in debt-to-GDP levels as inflation lifted nominal growth.**

**The managing director’s remarks ahead of next week’s IMF and World Bank annual meetings come as global public debt heads to a record \$100tn by the end of 2024. Borrowing surged during the early stages of the coronavirus outbreak as economies were locked down. Many governments, including those of the world’s largest economies, are yet to bring spending under control.**



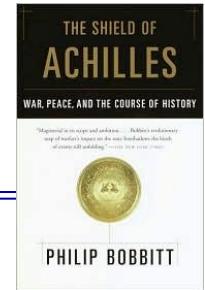
# Nation-State (1600-1990) → Market State (1990 -- )

Market States seek roles to enable rather than provide – as Umpire, not Judge.

Funding for nuclear power may evolve toward more public-private financing. Negotiated

TRAITS	<b>NATION – STATE</b> [since Peace of Westphalia, 1638]	<b>“MARKET STATE”</b> [since End of Cold War (Long War), 1990]
Main mission	Welfare, security, Sovereignty	Opportunity, access, growth
Means	<b>Provider, public function, Judge</b> [Judges determine outcomes]	<b>Limited functions; “Umpire”</b> [Referees ensure fair competition]
Culture	Nationhood, a “folk”	Less community; more Functionality
Organization	Institutions; Hierarchies	Networks; Project management TEAMS
Communication	State media, TV / Radio	Open media, Internet
Political process	Limits on campaign contributions	Market donations, disclosure
Orientation	Regulation, compliance	Competitiveness, innovation
Military	Mandatory conscription, draft	Volunteer Army; Mercenaries
Labor	Industry, Public employee unions	Contractors; Privatization
Promotion	Seniority, social standing	Meritocracy, performance
Nuclear technology	Military power; State leadership	Reliable energy; Public goods

## Market States: Mercantile, Managerial, Entrepreneurial



	Pre-cursor => Metaphor	Imperial / Dictatorial [social stability] "Garden"	Socialist [social equality] "Park"	Liberal Parliamentarian [freedom, opportunity] "Meadow"
	[per Bobbitt, SofA]	Market State TYPE		
Ref.	ATTRIBUTE	Mercantile	Managerial	Entrepreneurial
A	<b>Central Government</b>	Strong (one-party)	Leading	Constrained
B	<b>Socially</b>	Stable	Cohesive	Multi-cultural
C	<b>Trade</b>	Primary, global	Regional	Secondary
D	<b>Military</b>	Supports trade	In Alliances	Unilateral / Autonomous
E	<b>Capital</b>	Controlled	Public-Private	Risk-oriented
F	<b>Consumers</b>	Secondary	Tax base	Primary
G	<b>Labor Unions</b>	Not strong	Active Partners	Not favored
H	<b>Regulation</b>	Selective	Favors	Dislikes
I	<b>Population Growth</b>	Static or less	via Immigrants	Native growth
J	<b>Immigration</b>	Discouraged	Guest workers	Mixed

# Nuclear Strategy & “Market States”

Capacity and Strategy of Governments, of “Market States”, is shifting with financial crisis. ... indeed, the financial crisis is rooted more in a shift in the nature and “RESIZING” of government.

19<sup>th</sup> / 20<sup>th</sup> Century

**Nation-States** →

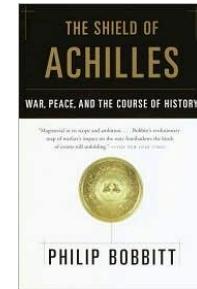
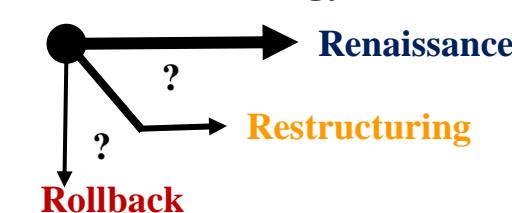
- Autocratic Dictatorship
- Socialist planned society
- Liberal Democracy

21<sup>st</sup> Century; post-Cold War

**“Market-States”** →

- Mercantile
- Managerial
- Entrepreneurial

**Nuclear Strategy**



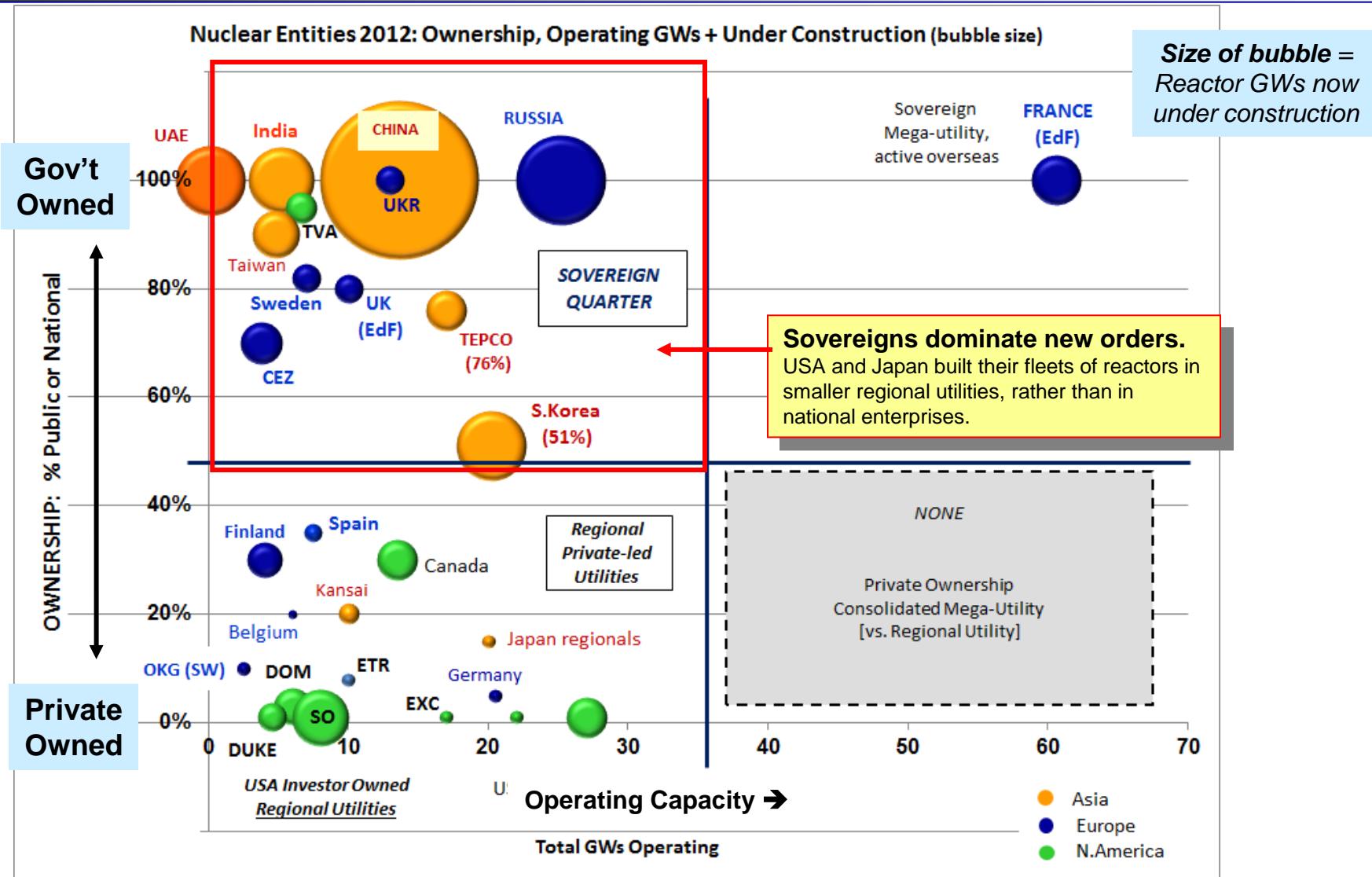
## SUMMARY

Market State TYPE			
<b>Nuclear Strategy</b>	<b>Mercantile</b>	<b>Managerial</b>	<b>Entrepreneurial</b>
<b>Renaissance</b>	China, Russia, South Korea, UAE	France, Finland, India; UK (2014)	Canada, UK
<b>Restructuring</b>	UK, Japan? (2012) Taiwan, Vietnam	Sweden, CzechR, Poland, Romania	USA
<b>Rollback</b>	Japan (2011)	EU: Germany, Italy Spain, Belgium	[none]

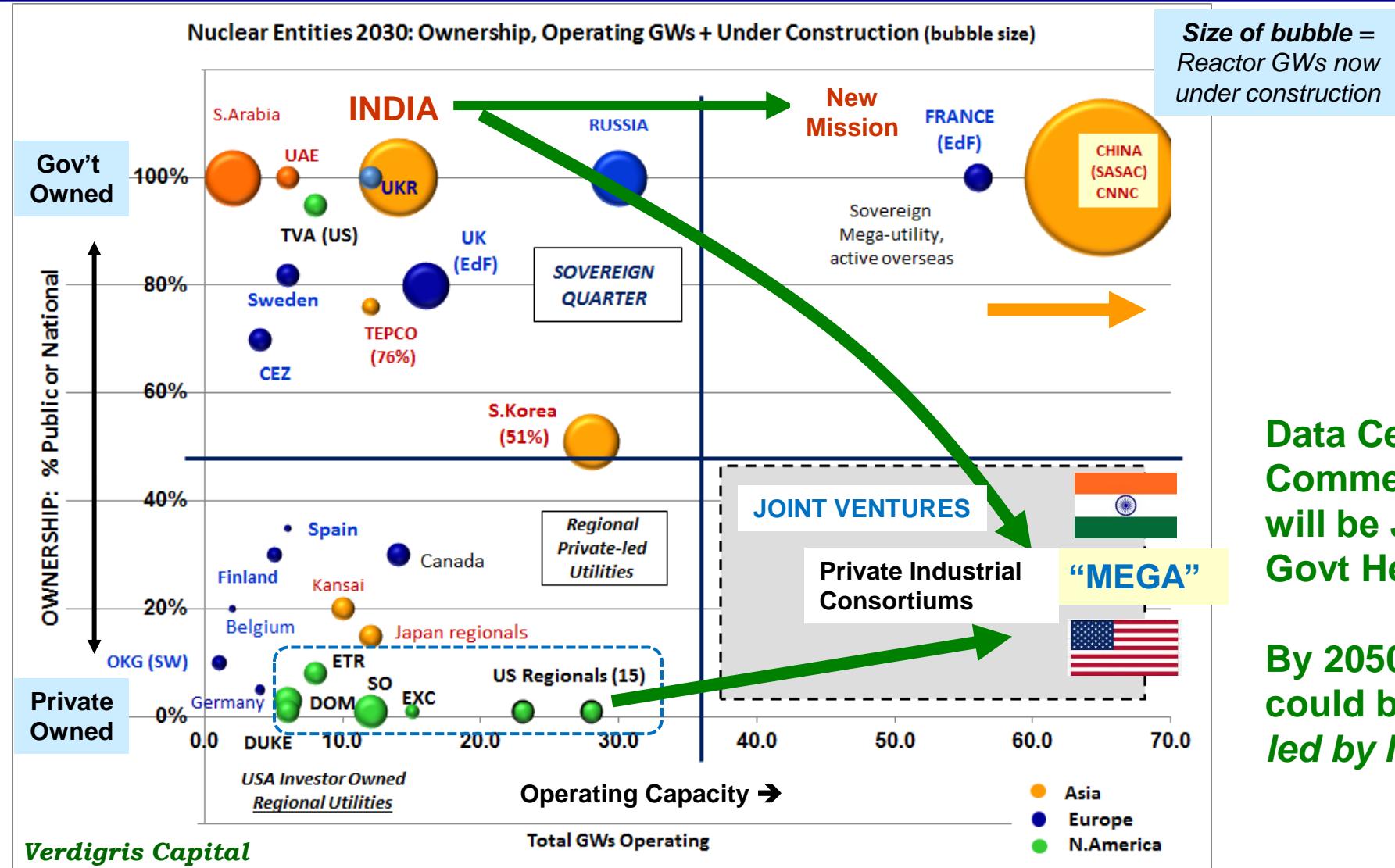
Recent shifts in  
Strategy favor  
more Nuclear

## How does Ownership affect Financing Structure ?

### Nuclear Plant Ownership, Construction 2020: Sovereign Owners vs Private Utilities



# Sovereign Nuclear Energy Landscape 2030



Data Centers and Commercial SMRs will be JVs... not Govt Heirarchies

By 2050, SMRs could be 400 GWs, led by Industrials

# Panel of Experts on Nuclear Energy at ISUW

## Panel on Nuclear Renaissance led by Dr. Ganapati, Myneni

1. Andrew Paterson, Senior Fellow, US Nuclear Industry Council; Board Member, Environmental Business International; and former Senior Analyst at Dept. of Energy Office of Policy & International Affairs, USA. Advisor to Allied Nuclear Partners, led by IP3.
2. Timothy L Head, Assistant Director, NEXT Lab at Abilene Christian Univ, USA
3. Everett Redmond, Senior Director, Federal Affairs, OKLO, Board Member USNIC; Former Senior Technical Advisor, NEI
4. Kailash Mittal, BSCE Bharat Ltd
5. Thierry Advocat, Nuclear Counsellor, Embassy of France in India
6. Rajnath Ram, Advisor-Energy, NITI Aayog\*
7. Chandra Tiwari, Head – BD, Services and Technology, Tata Power Company Limited
8. Akira Yamamoto, Senior Scientist and Professor, Acceleratory Laboratory, KEK, Japan (Virtual)

# PANEL DISCUSSION on NUCLEAR ENERGY AT ISUW



## ➤ Key Drivers for Financing New Nuclear are different overseas than in USA

1. Much of the world lacks cheap natural gas (of US + CAN, under \$4 / mBtu).
2. **No other country is extending 80 GWs+ of already built nuclear capacity.**
3. Carbon emission policy in USA is very fragmented; will not be resolved soon.
4. Most other countries regulate electricity rate policy nationally, not regionally or by state
5. Many other countries define new nuclear energy goals, “UK for 24 GWs by 2050” – **USA does not**

Why less new nuclear build in USA?

## ➤ Is URBAN Growth and Reliability now the #1 Driver for new nuclear capacity globally?



Major urban growth is now OUTSIDE OECD

- Does Energy Security surpass Carbon Policy as driver for new nuclear? [NATO Region, Asia]
  - EU Gas price roller coaster in 2022, plus cut off of Russian supply. Nations seek Energy Sovereignty.
- Intermittent Wind and Solar for URBAN energy is very ill-suited... OPTIONS?
  - Mass transit and large-scale shift to Electric vehicles in OECD cities demands 24/7 Nuclear
  - Wind and solar do not effectively charge millions of new EVs in cities, nor power for rail.
- Major shifts coming in Industrial sectors- from N.gas to Hydrogen, some by nuclear
- **Nuclear is the only “always-on, emission-free, small footprint” solution**

## OPENING

This is my first visit to India – so I come very optimistic about India's future!

On 3 Feb. of this year, India announced a bold mission toward 100 GWs by 2047+

<https://www.world-nuclear-news.org/articles/indian-budget-launches-nuclear-energy-mission>

1) Now – if you are skeptical and believe this Govt goal is not realistic, please feel free to stay in the room. I am definitely in India now. [In Beijing, that usually clears the room.]

On 12 Feb., PM Modi invited us when he visited the WH recently to embrace MAGA with MIGA for a MEGA opportunity.

So, what can we do together to reach our goals?

2) Getting here involved Karma around approval of my VISA, which I submitted late. But, this trip is now the start of a new chapter in my Dharma – it must be. [When the pupil is ready the teacher appears. By Buddha, 500 BC]

## Why Nuclear

△ Mass x 90 Quadrillion Square-meters per second squared (or 90 Billion KM-squared)

90,000,000,000,000 per square meter per second-squared

X mass = JOULES (KG x square meter per second-squared)