The Energy Transition...
What Energy Transition?

Robert Bryce presentation to:

Tennessee Gas Association

Miramar Beach, FL

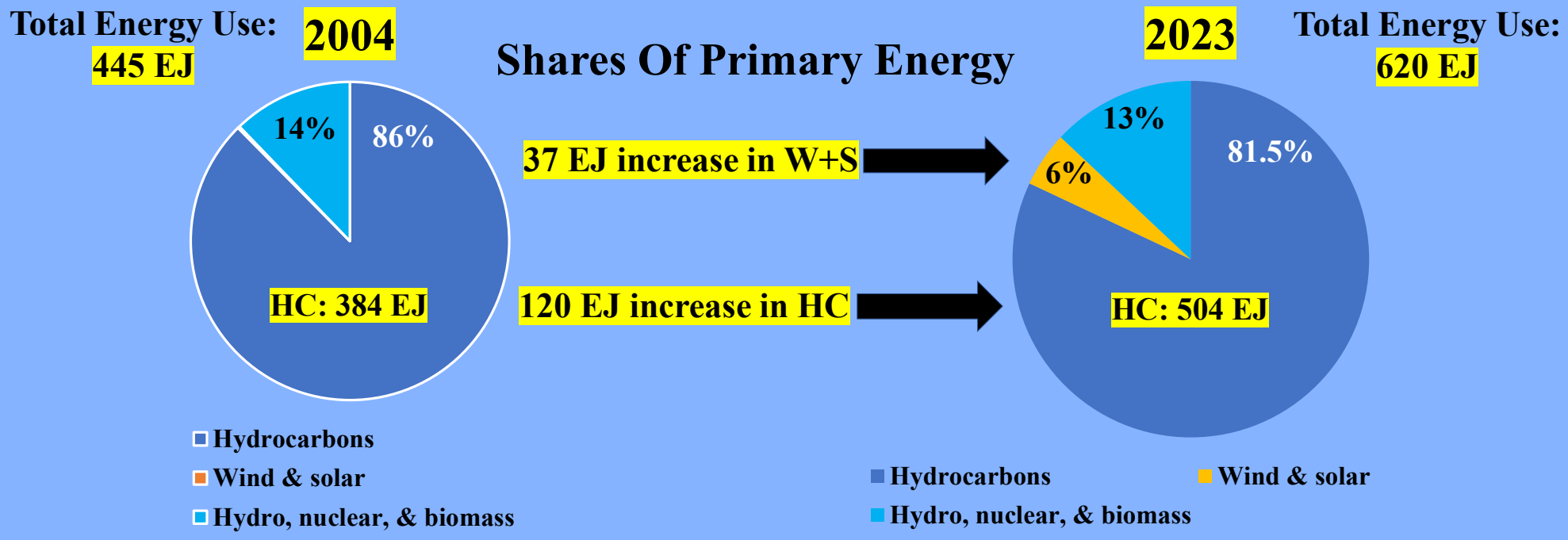
4 June 2025

Five Points:

- What energy transition?
- Land-use conflicts are raging
- Inflation + AI + surging electricity demand
- EU, Germany, & Britain are facing disaster
- N2N: Nat gas to nuclear

What Energy Transition? From 2004 to 2023, Global Spending On Wind + Solar Totaled $4.7 Trillion

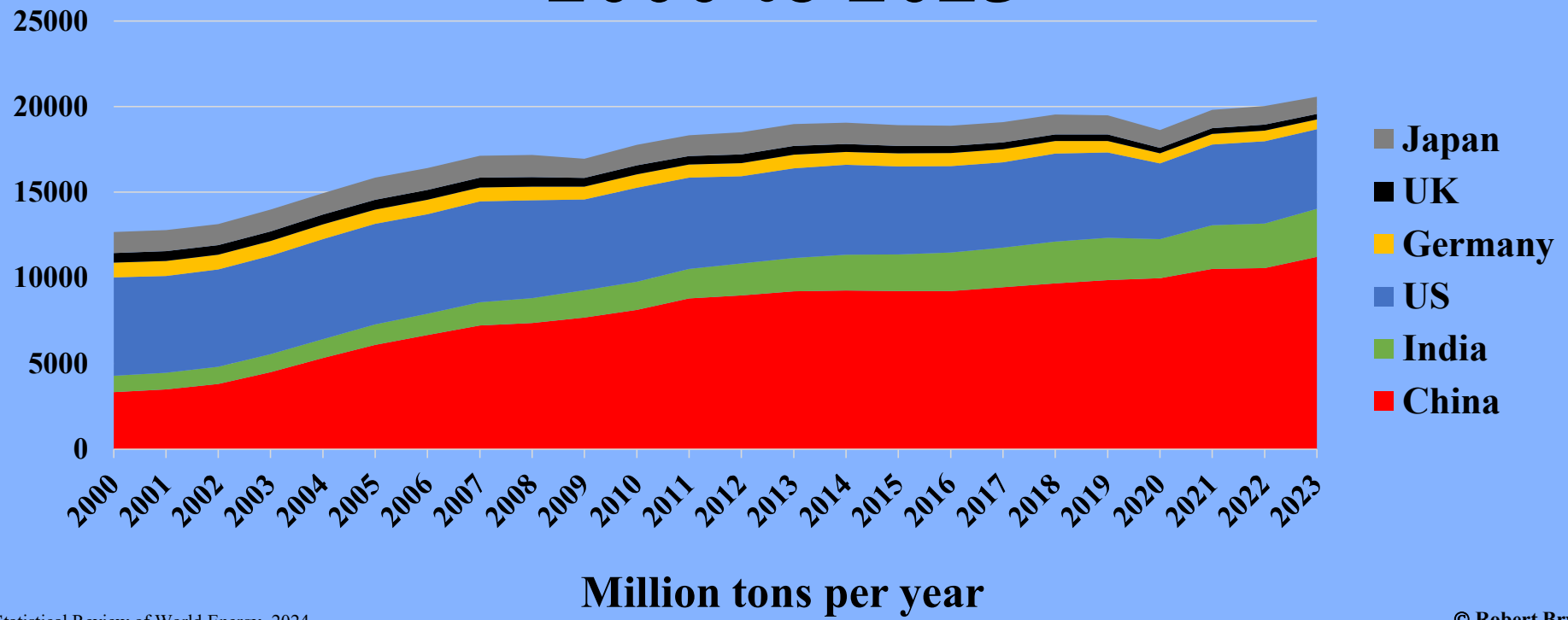
Yet Hydrocarbon Use Increased 3.2x Faster



Source: Statistical Review of World Energy 2024, BNEF

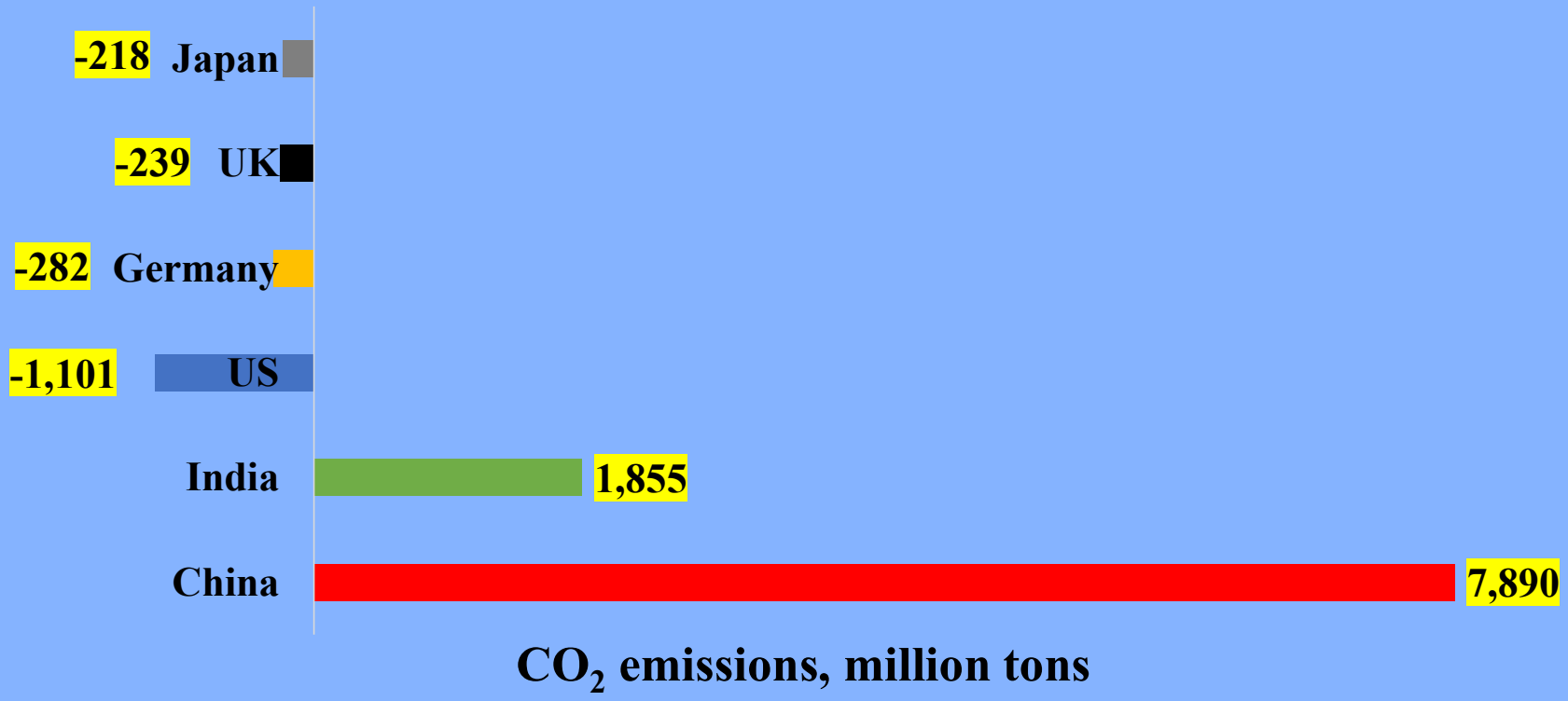
What Energy Transition?

CO_2 Emissions In Six Largest Economies, 2000 to 2023



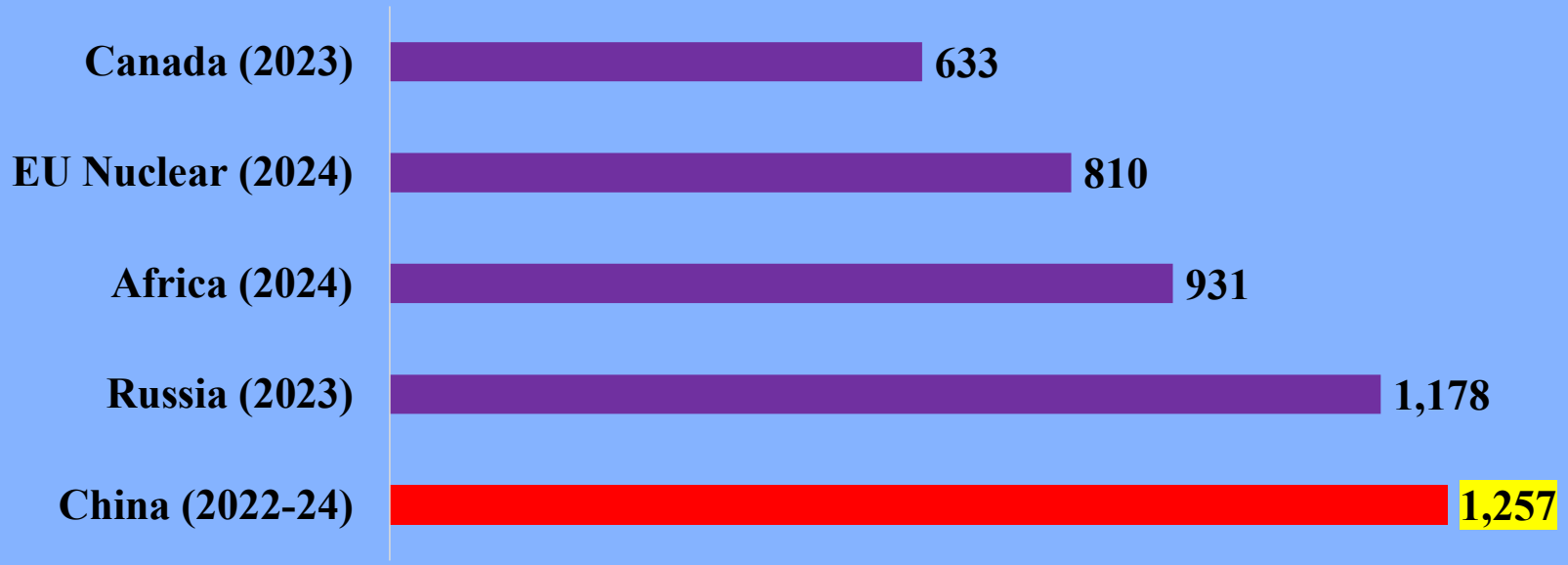
Source: Statistical Review of World Energy 2024

Change In CO_2 Emissions In The Six Largest Economies, 2000 to 2023



Source: Statistical Review of World Energy 2024

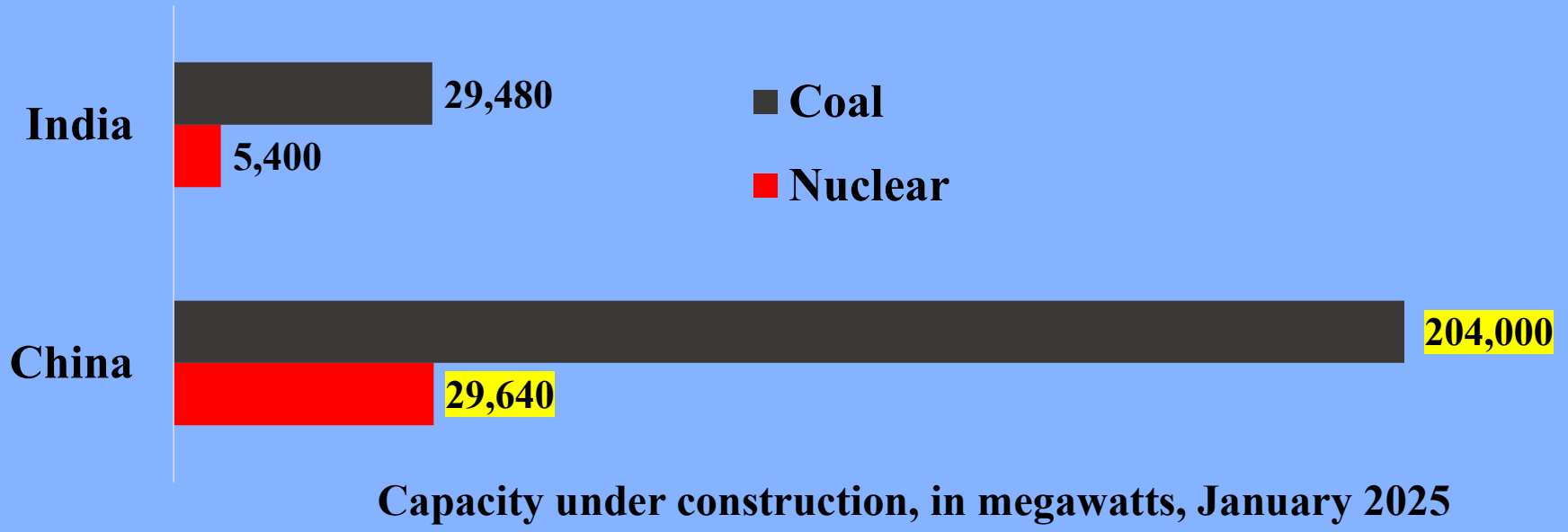
China's Electricity Demand Growth Is Gobsmacking



Growth in China's electricity generation from 2022 to 2024, compared to other countries/regions, in TWh

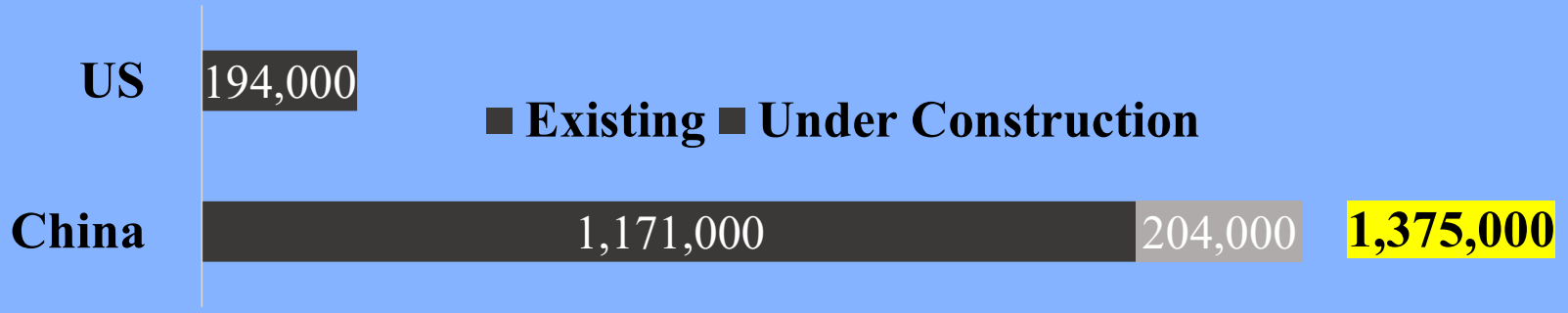
Source: IEA Electricity 2025, https://www.iea.org/reports/electricity-2025

>50% Of New Nuclear Capacity Is Being Built In China & India, But Their Coal-Fired Capacity Is Growing >5x Faster



Sources: IAEA, https://pris.iaea.org/pris/worldstatistics/underconstructionreactorsbycountry.aspx
Global Energy Monitor, https://docs.google.com/spreadsheets/d/1_6AkrRZOn3ZXhSV9O6tZnX-m7aJsfG9HiQ_iEqBkbW8/edit?gid=1228809590#gid=1228809590
https://docs.google.com/spreadsheets/d/1sHBsK_Ez7C9XA4HKRQSvopO4IvGSLz65jxdG0GQXeVk/edit?gid=1236850196#gid=1236850196

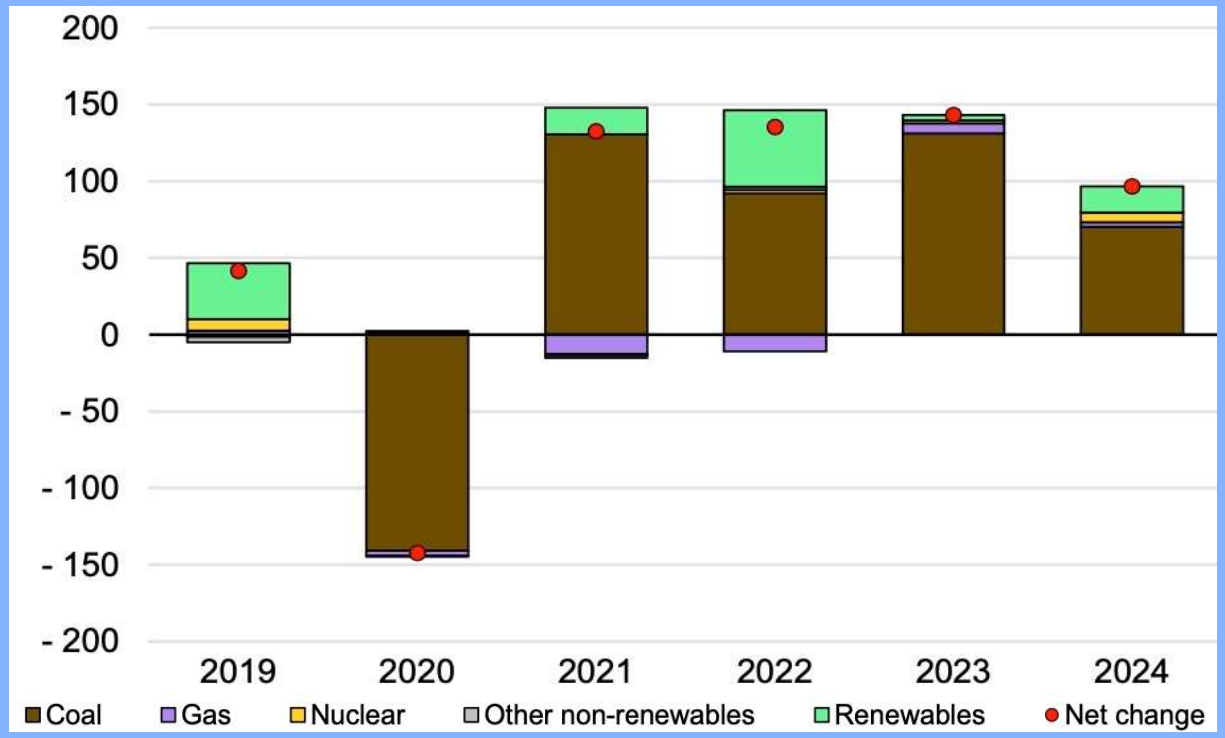
Coal-Fired Capacity Under Construction In China Is Greater Than *All Existing US Coal Capacity*



Coal-fired capacity, existing, under construction, & total, MW, January 2025

Source: Global Energy Monitor, https://docs.google.com/spreadsheets/d/1_6AkrRZOn3ZXhSV9O6tZnX-m7aJsfG9HiQ_iEqBkbW8/edit?gid=1228809590#gid=1228809590
https://docs.google.com/spreadsheets/d/1sHBsK_Ez7C9XA4HKRQSvopO4IvGSLz65jxdG0GQXeVk/edit?gid=1236850196#gid=1236850196

India's Coal-Fired Generation Is Surging



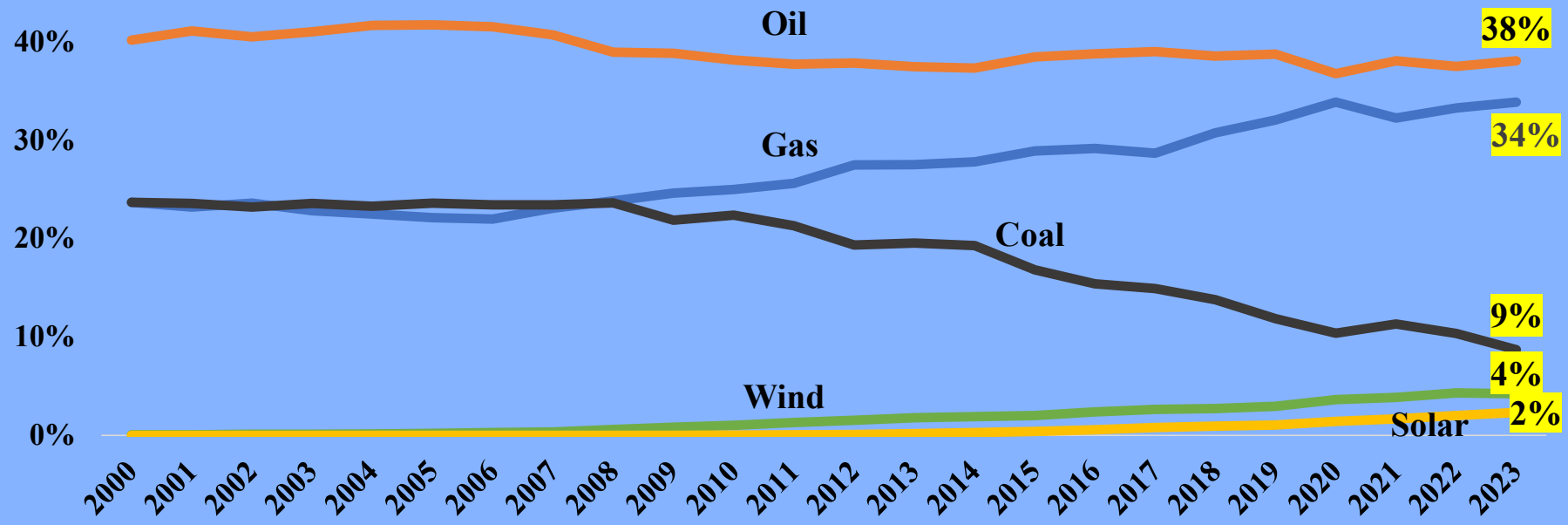
Change in electricity generation by source, TWh, 2019 to 2024

Source: IEA, Electricity 2025, https://www.iea.org/reports/electricity-2025

Electricity demand in India increased by 5.8% in 2024... Coal-based generation remains the backbone of India's electricity mix, accounting for 74% of the total share in 2024...The government plans for a minimum of 80 GW of new capacity to come from coal-based power plants by 2030.
— IEA, Electricity 2025, Feb. 14, 2025

Hydrocarbons Are Here To Stay

81% Of US Primary Energy Comes From Oil, Gas, & Coal

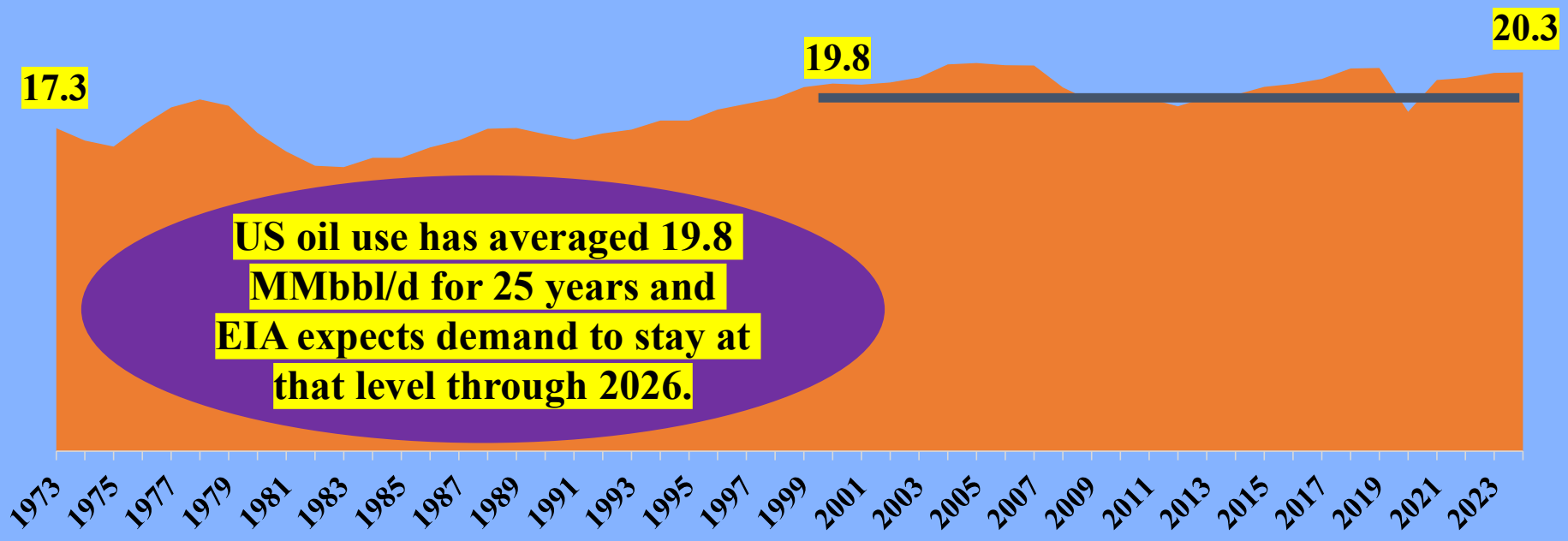


Share of primary energy use, 2000 to 2023

Source: Statistical Review of World Energy

“Let’s be the generation that finally frees America from the tyranny of oil.”

— President Barack Obama, 2007



US oil use, million bbl/day, 1973 to 2024

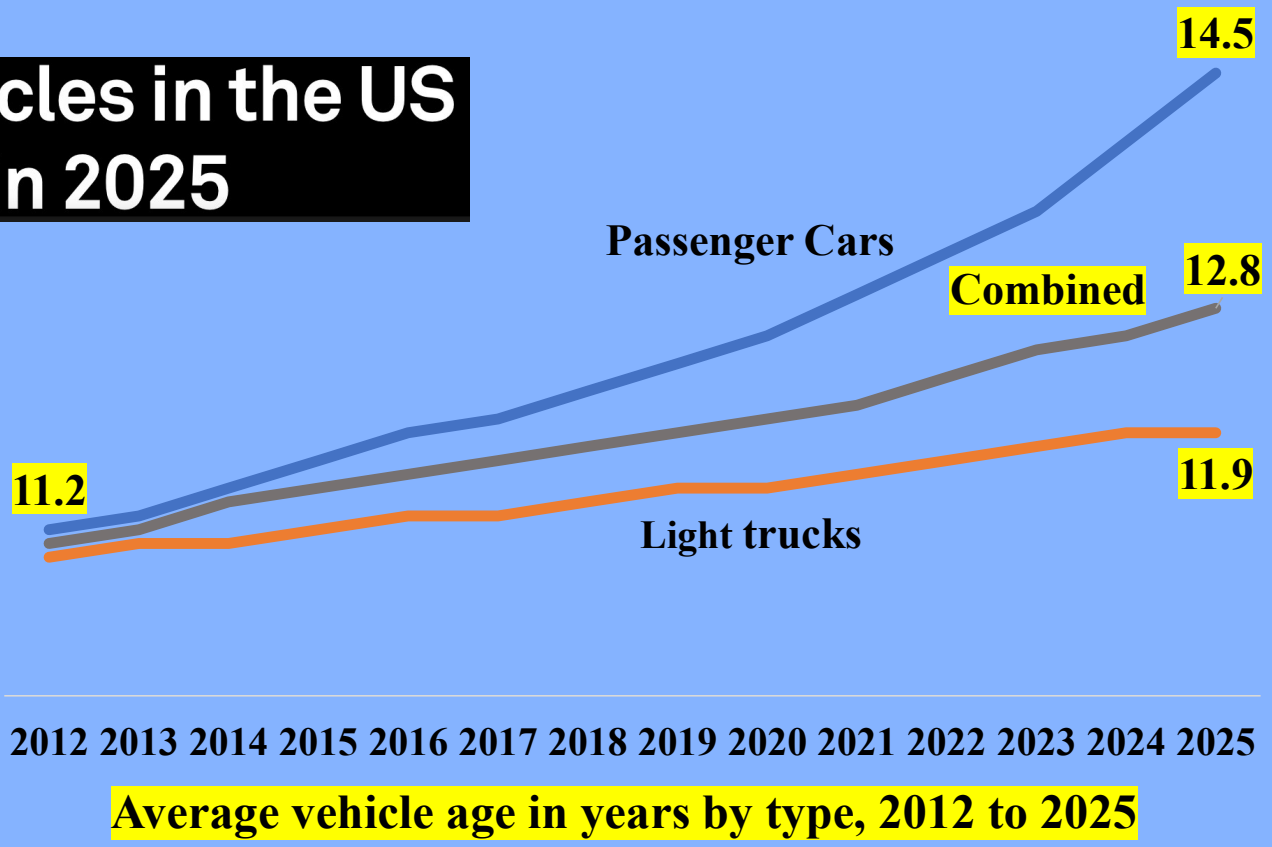
Source: EIA, https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MTTUPUS2&f=A, https://tinyurl.com/mryvxb42 , https://www.eia.gov/outlooks/steo/pdf/steo_full.pdf

289M Vehicles In US, "Graying" Of Fleet Is "More Than A Statistic"

Average Age of Vehicles in the US Rises to 12.8 Years in 2025

The average age of vehicles in the US continues to climb, reaching 12.8 years in 2025...older vehicles are staying on the road longer, steadily increasing the average age of the fleet.

— S&P Global Mobility, May 21, 2025

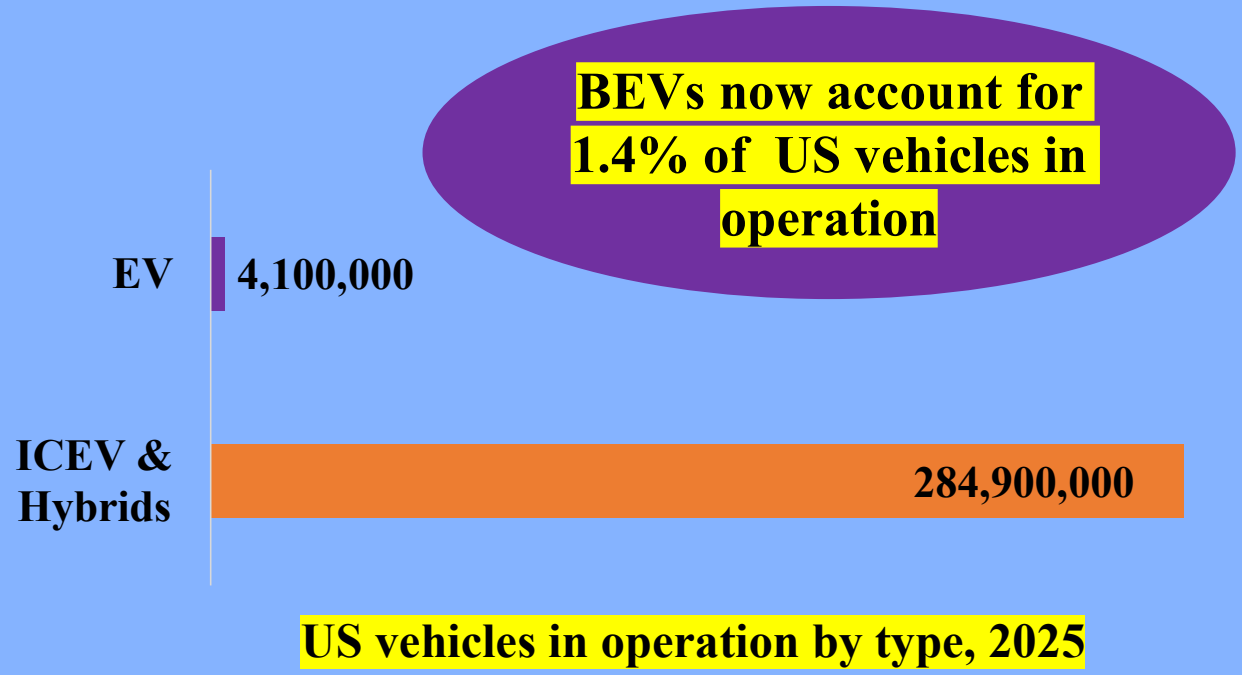


Average vehicle age in years by type, 2012 to 2025

Source: https://www.spglobal.com/automotive-insights/en/blogs/2025/05/average-age-of-vehicle-in-us#link1

Sales Are Growing, But BEVs Remain A Tiny Fraction Of US Fleet

The transition to full EVs has slowed, as hybrids currently appear to be the more comfortable choice for the majority of Americans seeking electrified options.
— Edmunds, April 3, 2025



Sources: https://www.edmunds.com/electric-car/articles/how-many-electric-cars-in-us.html ,

Big Wind: Friction From Nebraska To Norway

MidAmerican Energy Abandons Plan To Add 30 Wind Turbines, Madison County Residents Celebrate: 'How Awesome'

Cherokee County panel adopts 1-year wind farm moratorium

Reno Commission approves moratorium on wind, to consider development ban in zoned areas

Moonlight Range Wind Farm project axed by Queensland government

San Bernardino County bans large-scale solar, wind in some areas

4 Druze seriously injured, 12 cops hurt in massive riots against Golan wind farm

Gage County extends ban on new wind or solar permits, through mid-July

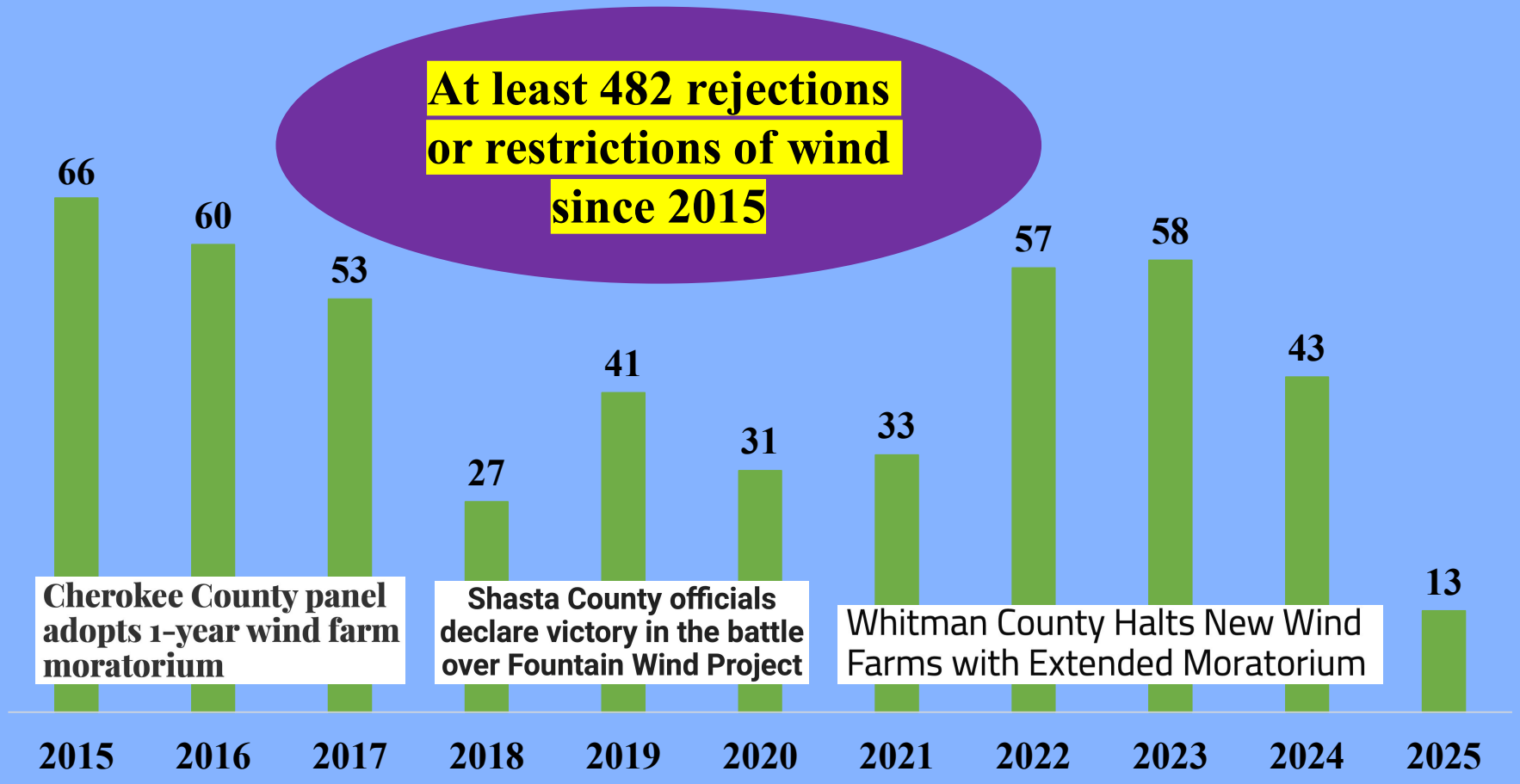
County planning and zoning commission to consider potential wind energy regulation changes

Wednesday, January 13th 2021, 12:50 PM CST

Norwegian wind farms violate rights of Sámi reindeer herders, says court

Source: Media outlets

US Wind Energy Rejections, 2015 To 2025



Source: Renewable Rejection Database

Enel Must Remove 84 Wind Turbines In Osage County At Cost Of $300 Million

The Osage Nation won permanent injunctive relief and "ejectment of the wind turbine farm for continuing trespass."

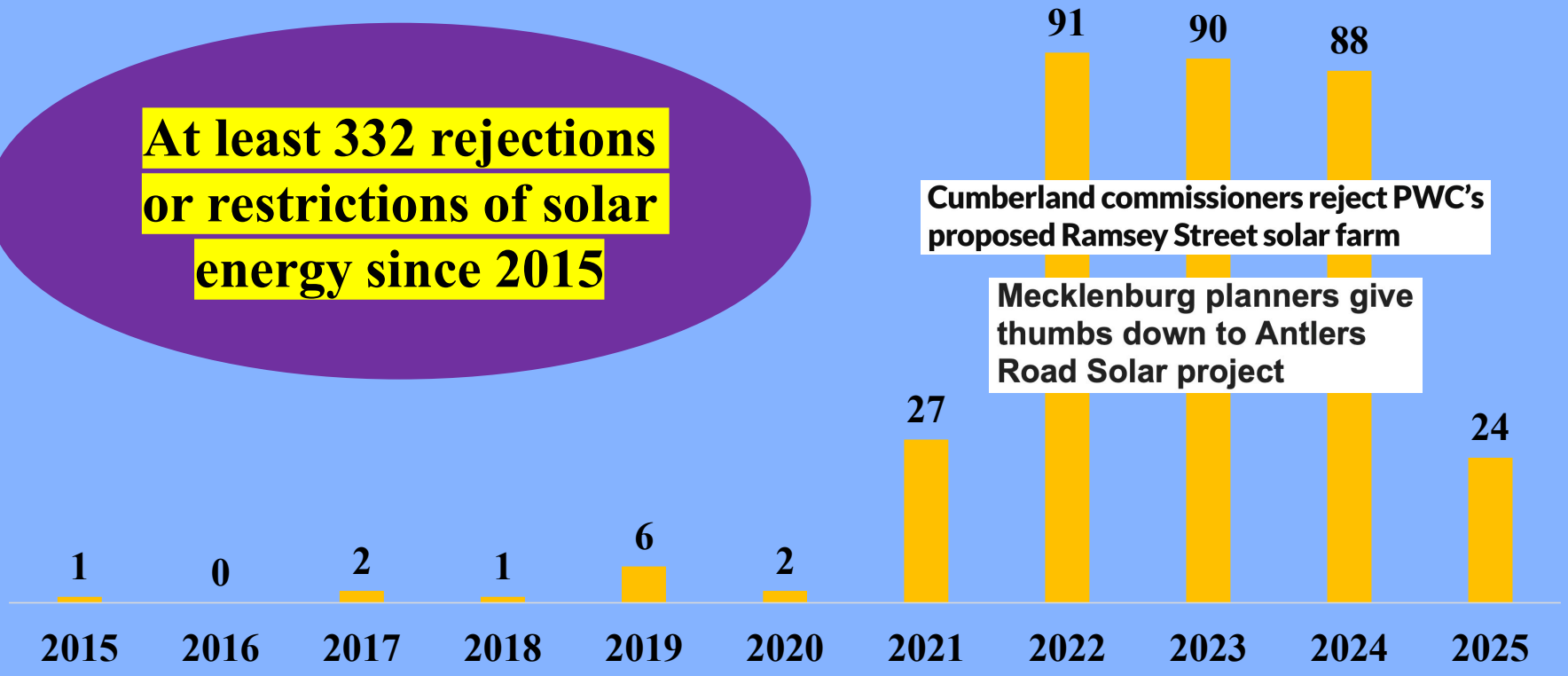
Enel's "refusal to obtain a lease constitutes interference with the sovereignty of the Osage Nation and is sufficient to constitute irreparable injury."

— Federal Judge Jennifer Choe-Graves, December 20, 2023

Source: Robertbryce.substack.com

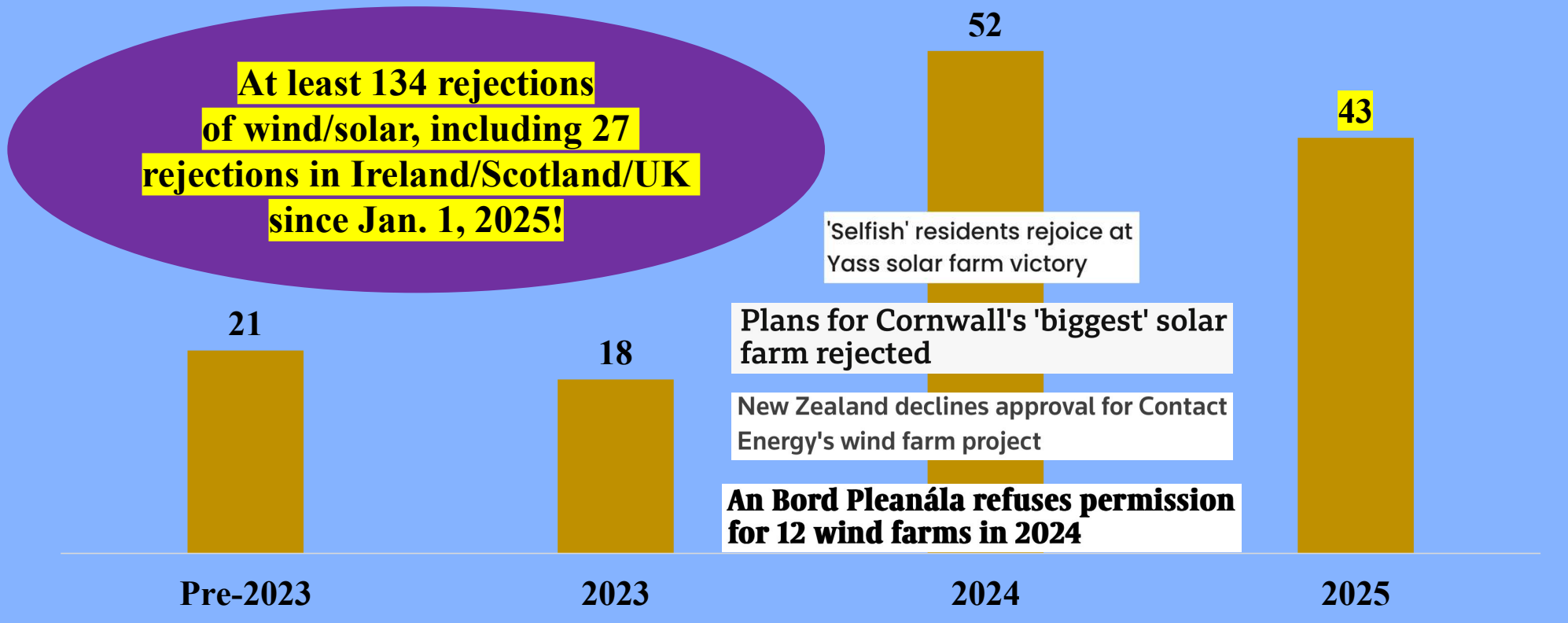
US Solar Energy Rejections, 2015 To 2025

At least 332 rejections or restrictions of solar energy since 2015



Source: Renewable Rejection Database

Global Wind & Solar Rejections, Pre-2023 to 2025



Source: Global Renewable Rejection Database

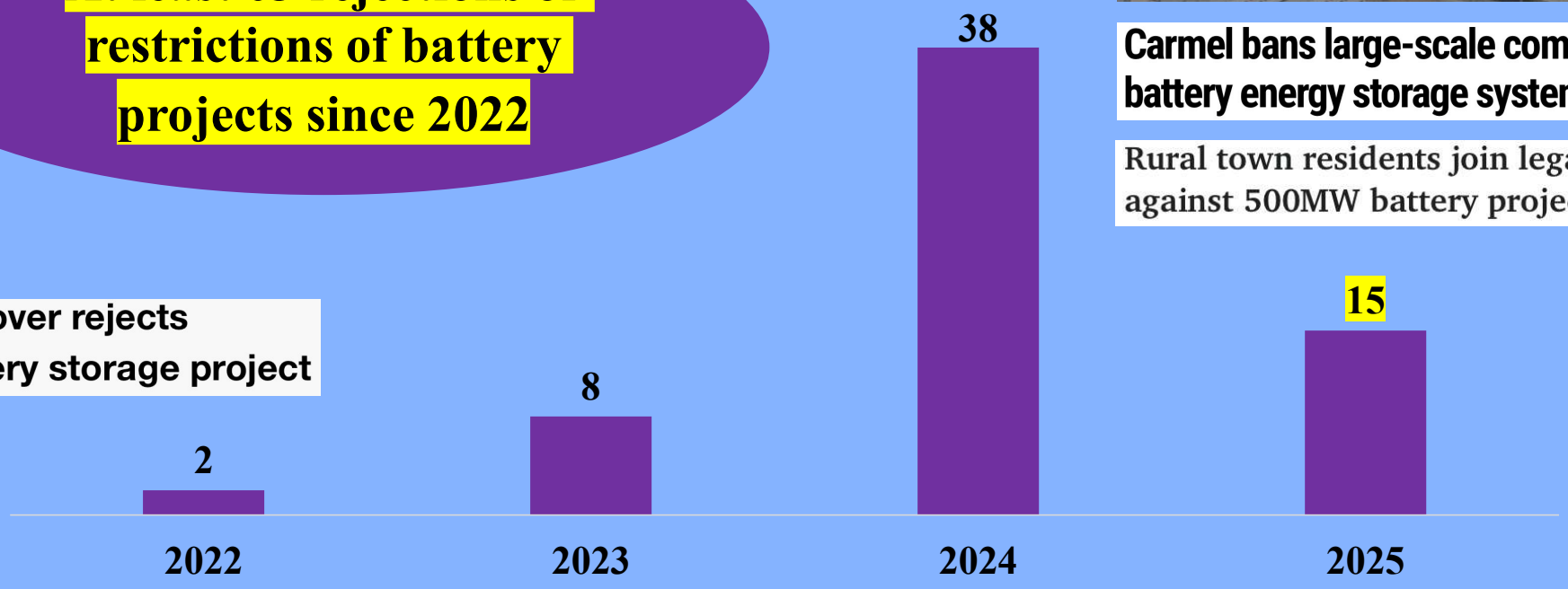
Global Battery Rejections, 2022 To 2025

At least 63 rejections or restrictions of battery projects since 2022

Carmel bans large-scale commercial battery energy storage systems

Rural town residents join legal battle against 500MW battery project

Hanover rejects battery storage project



Rejections or restrictions per year

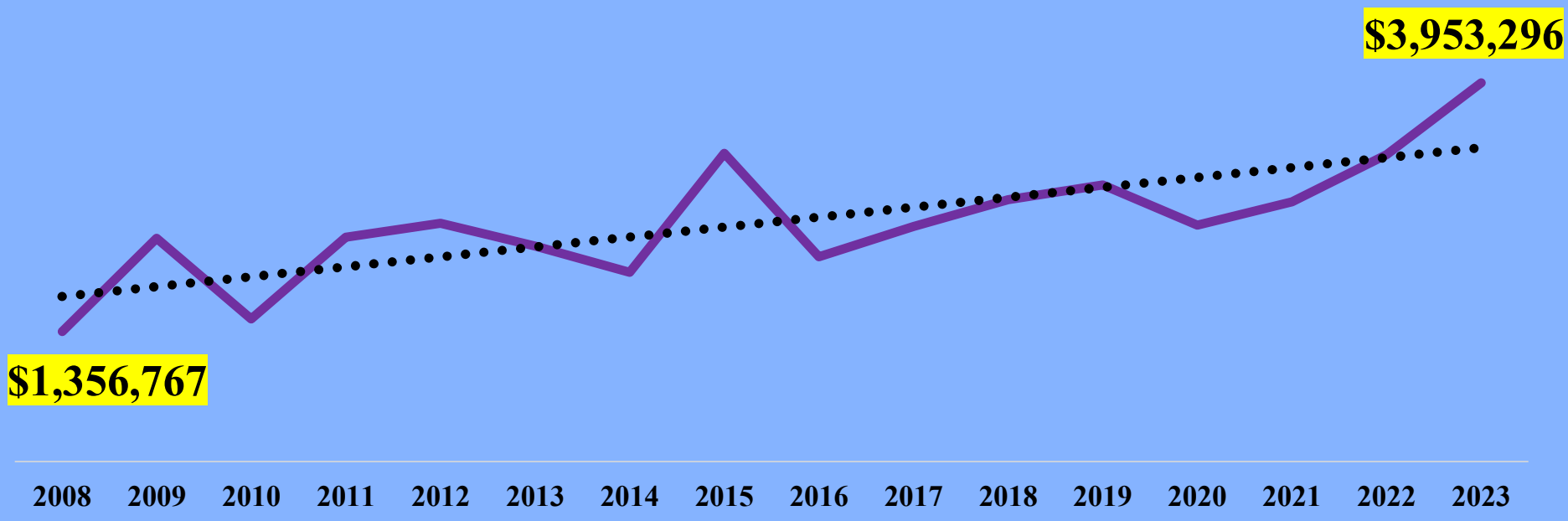
Source: Global Battery Rejection Database

Inflation Is Surging Across Energy & Power Supply Chains. Long Wait Times For Key Components Are Common

- **Wait times for large gas turbines: 4 years**
- **Price increases over past 2 years: 50 to 75%**
- **Wait for high-power transformers: 4 to 5 years**
- **Lead times for equipment increase with voltage**
- **"If we had the parts, we don't have the people. And if we had the people, we don't have the parts."**

Source: EIA https://www.eia.gov/todayinenergy/detail.php?id=61483#:~:text=Last%20year%20marks%20the%20third,Bcf%2Fd)%20in%202023.

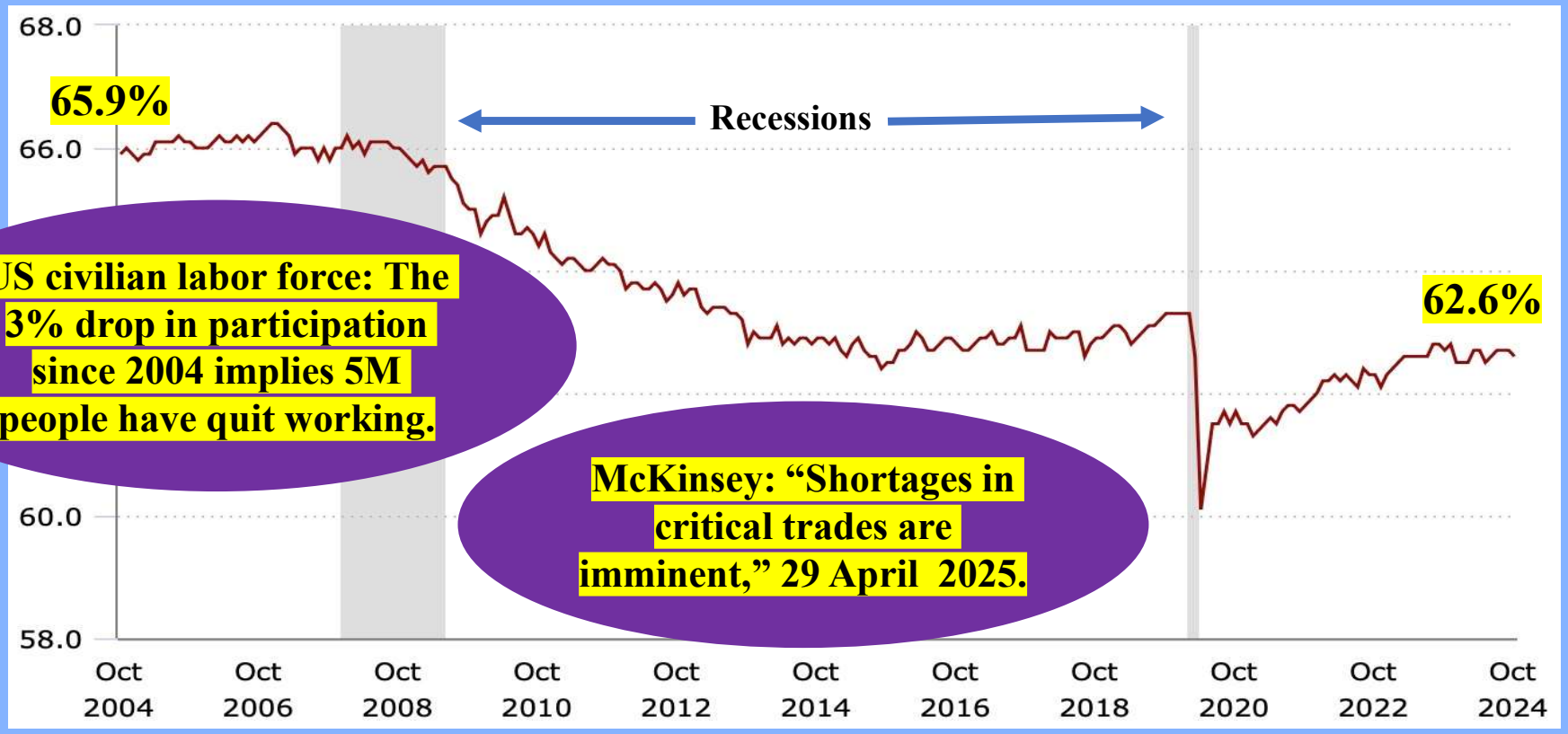
Between 2008 & 2023, Per-Mile Cost Of New HV Transmission Tripled



Source: C Three Group

Cost per mile, 230 kV and above, per year

If We Had The People...(The Great Resignation)



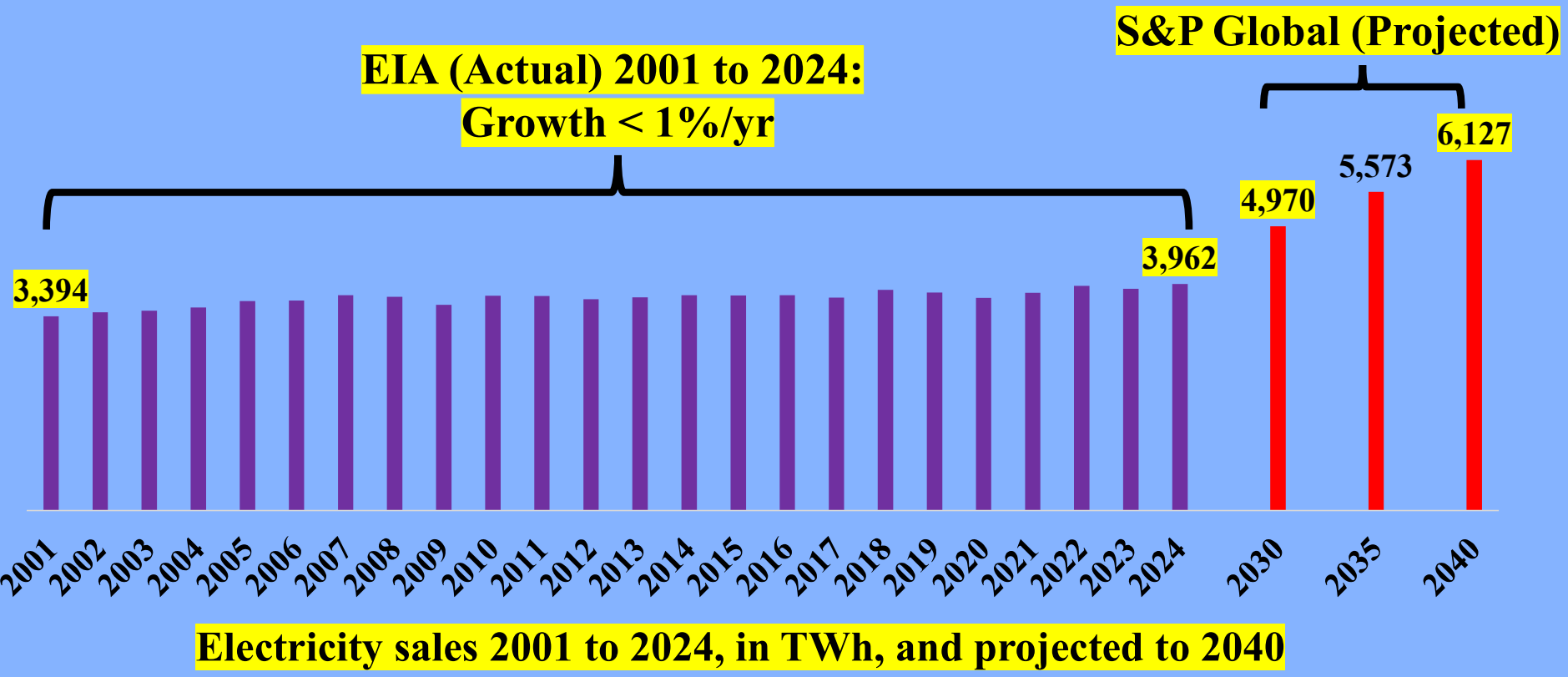
Labor force participation rate, %, 2004 to 2024

Source: BLS, https://www.bls.gov/charts/employment-situation/civilian-labor-force-participation-rate.htm, https://www.mckinsey.com/industries/public-sector/our-insights/powering-a-new-era-of-us-energy-demand, https://tinyurl.com/4avud7wa

What About AI? How Much Power? How Much Gas?

- **S&P Global: By 2040, "electricity demand in the US is expected to grow by 35-50% driven by a combination of underlying economic growth, large industrial loads like datacenters and manufacturing."**
  - **"The next five years pose a major risk of supply and demand imbalance."**
- **"Natural gas-fired capacity and other firm resources like batteries will be critical to provide capacity and balancing support."**
- **"The ability of renewables and batteries to respond to new demand growth is constrained by siting and permitting barriers."**

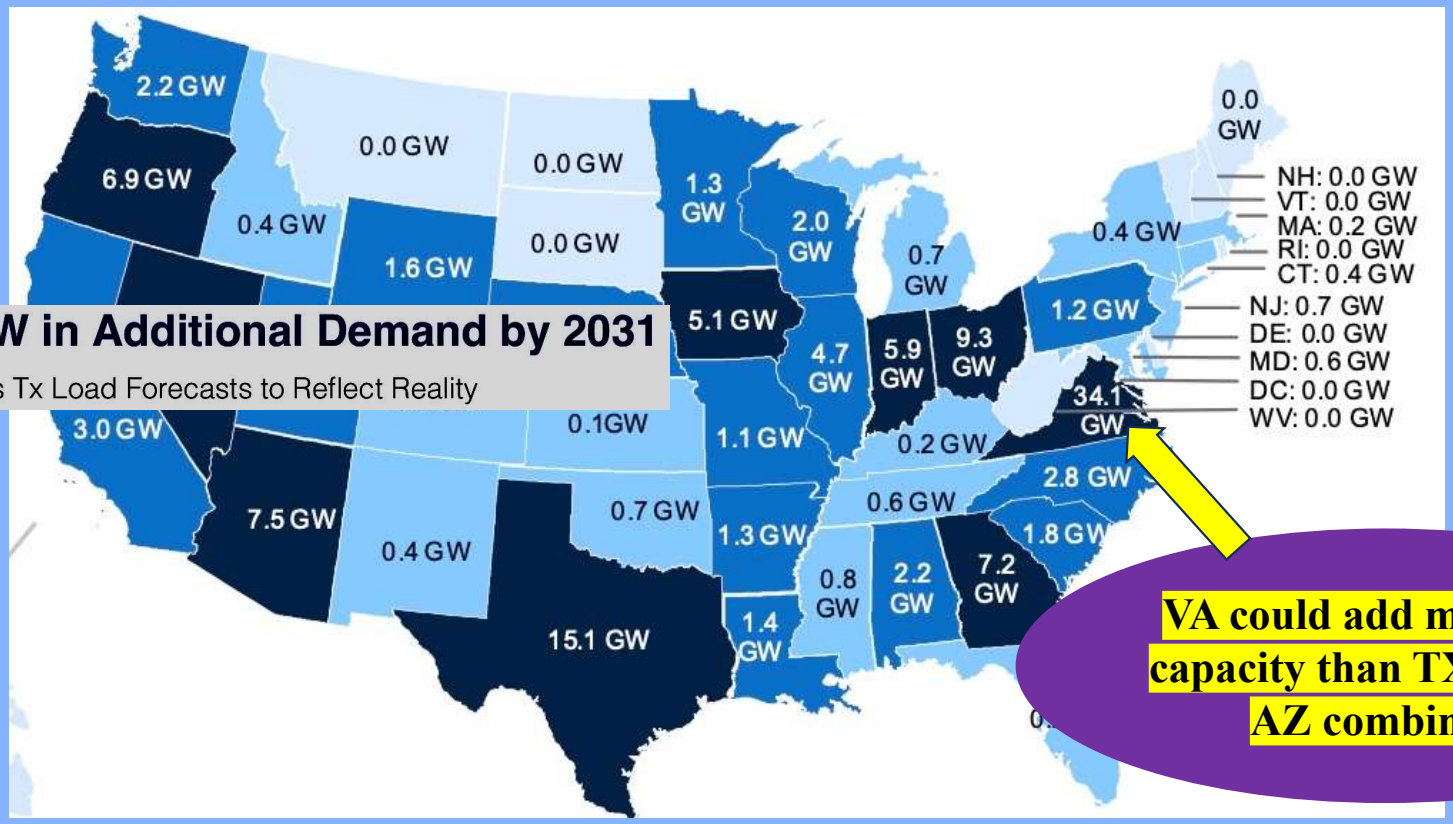
S&P Global: US Electricity Use Will Jump 25% By 2030 & 55% By 2040!



Electricity sales 2001 to 2024, in TWh, and projected to 2040

Source: EIA , https://cleanpower.org/wp-content/uploads/gateway/2025/03/US_National_Power_Demand_Study_2025_ExecSummary.pdf and S&P Global, https://cleanpower.org/wp-content/uploads/gateway/2025/03/US_National_Power_Demand_Study_2025_ExecSummary.pdf

Data Center Growth Will Be Concentrated In VA, TX, OH, AZ, GA, OR, & IN



ERCOT: 60 GW in Additional Demand by 2031

Grid Operator Adjusts Tx Load Forecasts to Reflect Reality

VA could add more new capacity than TX, OH, & AZ combined!

New data center capacity expected by 2030

Source: Boston Consulting Group, Datacenter Hawk

AI Will Be Fueled By Natural Gas

Williams Inks $1.6B Deal to Provide Natural Gas & Power Infrastructure

Why Gas Pipelines Are the Unsung Heroes of AI Data Center Expansion

Requests to connect to ~70 data centers in 12 states

Requests to connect to ~200 data centers in 14 states across our footprint

Entergy Louisiana Eyes 2.2 GW of New Gas-Fired Generation to Support Data Center Demand

Kinder Morgan foresees big boost to natural gas demand from AI operations

HYPERSCALE

Crusoe Adds 4.5 GW Natural Gas to Fuel AI, Expands Abilene Data Center to 1.2 GW

Germany Is Dunkelf**ked

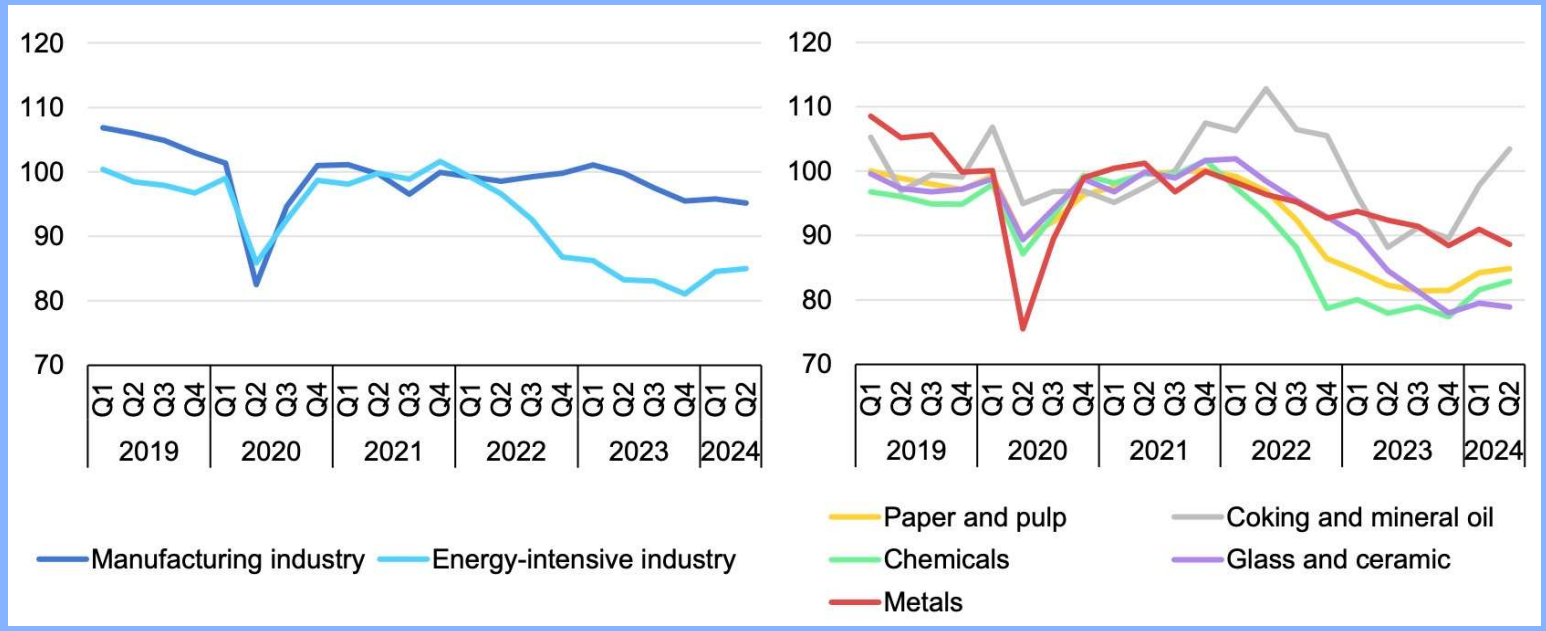
The *energiewende* in action: power prices hit €820/MWh during a dunkelflaute

German hourly renewable generation, Oct. 28 to Nov. 7, 2024

German power prices jumped to over two-year highs this week as dark and calm 'dunkelflaute' weather exposed the grid reliability risks of anti-nuclear/anti-fossil 'energiewende' transition policies.
— Mobius Risk Group, Nov. 7, 2024

Source: Mobius Risk Group, https://research.mobiusriskgroup.com/p/german-power-prices-hit-energy-crisis-levels-on-dunkelflaute?_bhlid=e7dc76562d339e7c419a8a33addff57746d4d5d1&utm_campaign=german-power-prices-hit-energy-crisis-levels-on-dunkelflaute&utm_medium=newsletter&utm_source=research.mobiusriskgroup.com

Germany Is Deindustrializing

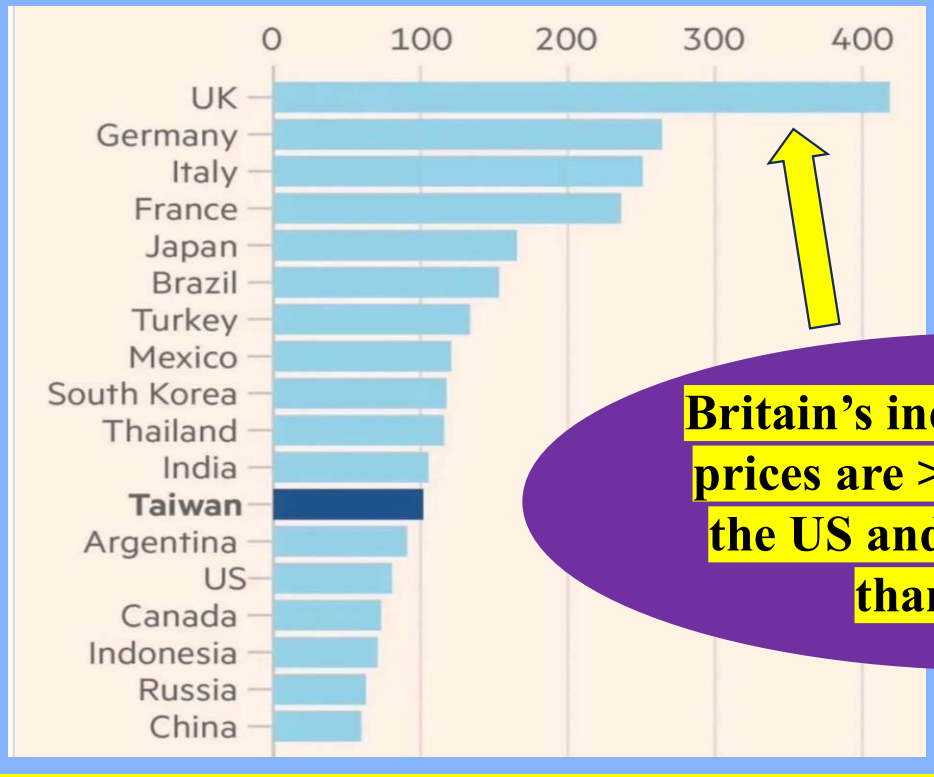


Production indices of selected industries in Germany, 2019-2024

The decline in industrial energy consumption was directly related to reduced production in 2023. Energy-intensive sectors were particularly affected, with production falling by 11.2%.
— Federal Statistical Office
Nov. 4, 2024

Sources: IEA, https://iea.blob.core.windows.net/assets/234d0d22-6f5b-4dc4-9f08-2485f0c5ec24/ElectricityMid-YearUpdate_July2024.pdf, 15
Destatis, quoted in Xinhua, https://english.news.cn/europe/20241105/0c9f10cacf9b4fecbbb353ac977627b6/c.html

High-Cost Electricity Is Destroying Europe's Manufacturing

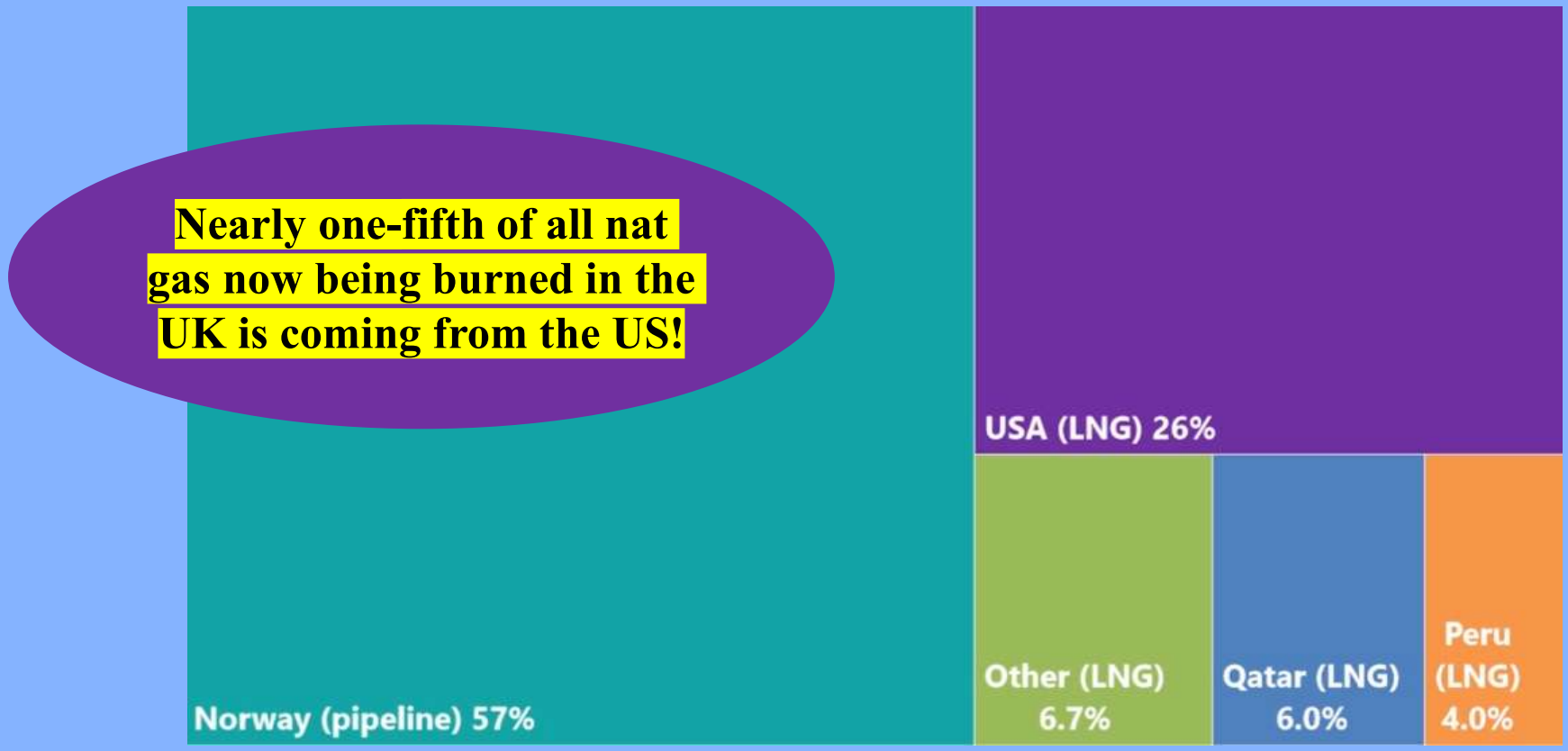


Britain's industrial electricity prices are >4x higher than in the US and about 5x higher than in China

Average electricity prices for industrial users, $ per MWh, 2023

Source: FT, BNEF, https://x.com/SimonMagus/status/1909532128691224663

Britain's Natural Gas Imports, By Country, 2023



Source: https://assets.publishing.service.gov.uk/media/66a7e14da3c2a28abb50d922/DUKES_2024_Chapters_1-7.pdf

Best No-Regrets Strategy Is N2N: Natural Gas to Nuclear

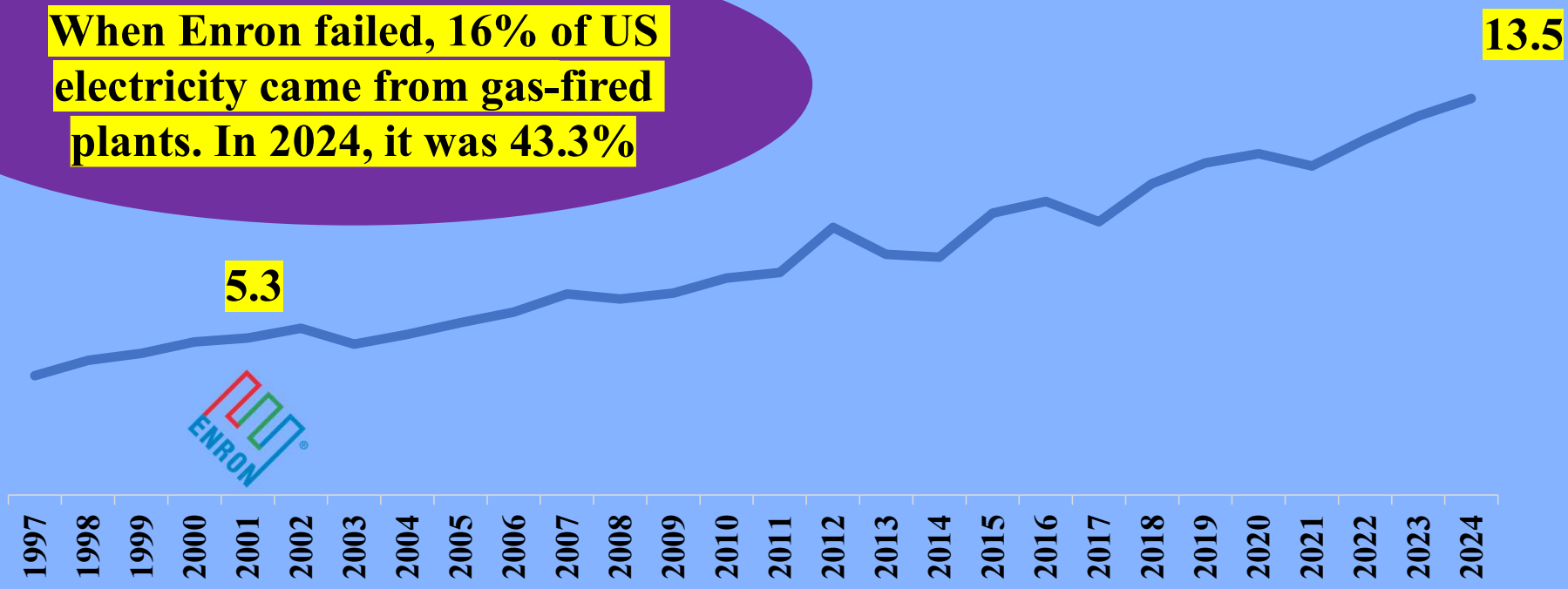
- 3B+ people need a LOT more juice
- Lower resource intensity, high power density & EROEI
- Wind/solar can't scale, not dispatchable, land-use conflicts
- Technologies are mature & scalable

Why Natural Gas?

- It's relatively cheap
- Global CH_4 resources are super abundant
- Low political risk, can be burned in turbines & ICEs
- Gas-fired generation in developing world is ***miniscule***

Since 2001, Gas-Fired Power Production Has Nearly Tripled

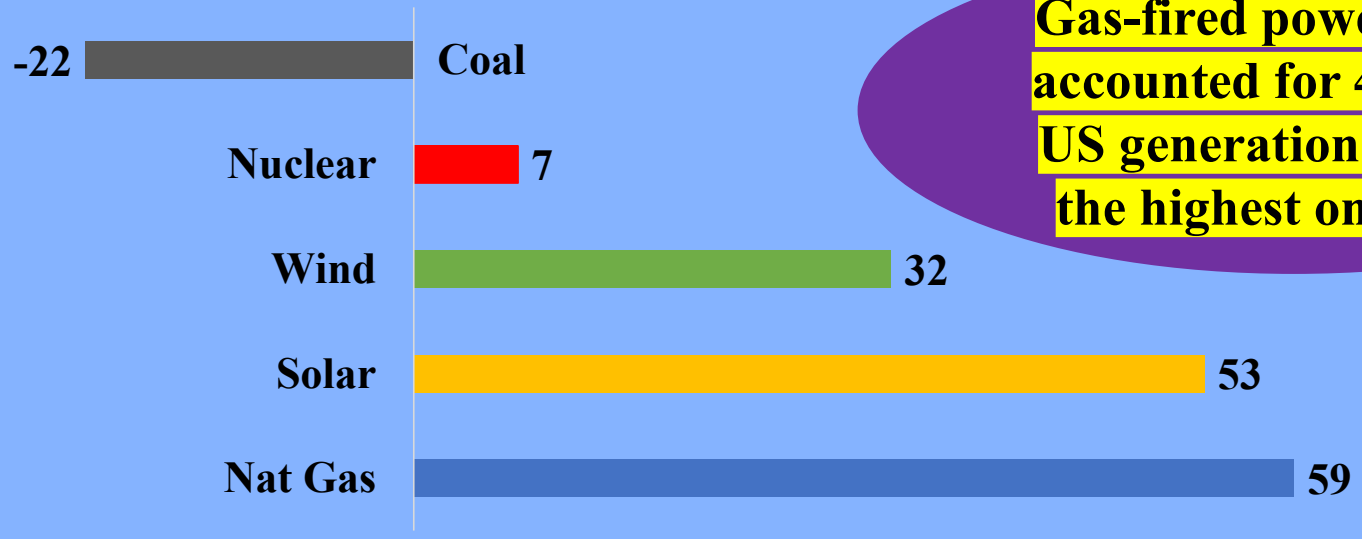
When Enron failed, 16% of US electricity came from gas-fired plants. In 2024, it was 43.3%



US power burn, 1997 to 2024, Tcf/year

Source: EIA, https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm https://www.eia.gov/tools/faqs/faq.php?id=427&t=3 Statistical Review of World Energy

In 2024, US Gas-Fired Generation Grew Almost 2x Faster Than Wind & Slightly Faster Than Solar

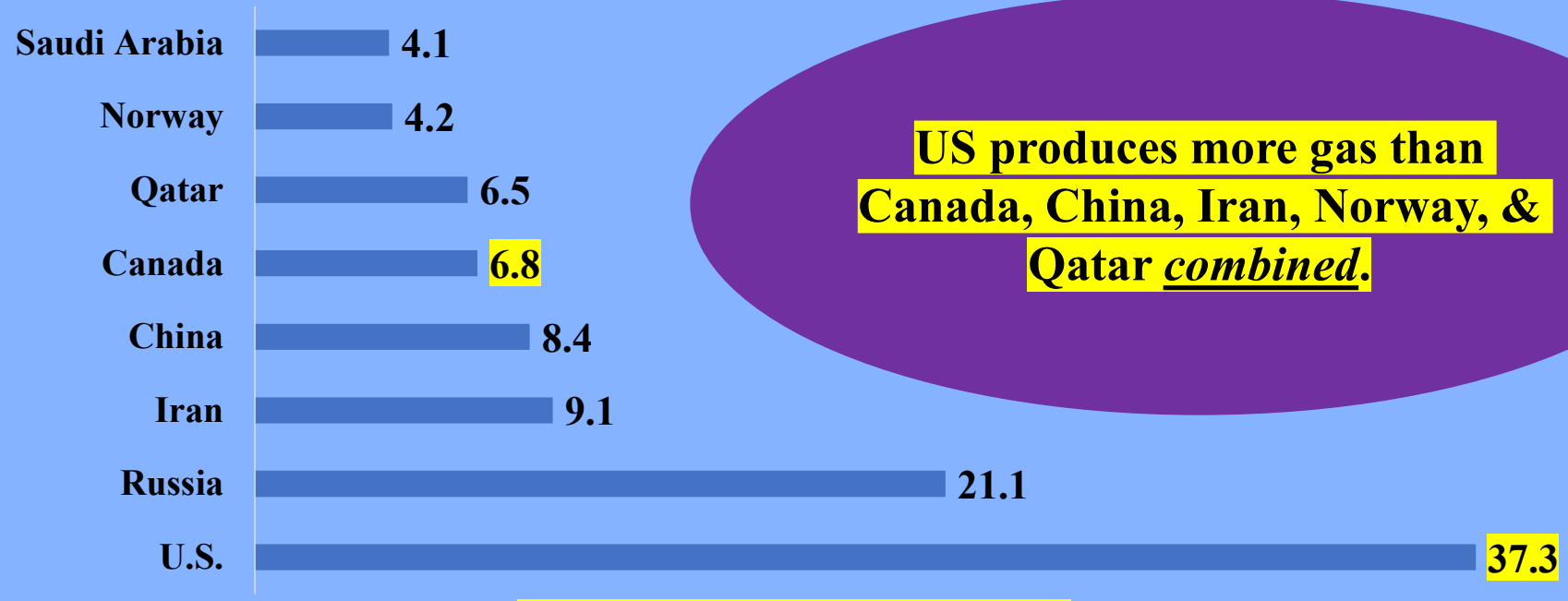


Gas-fired power plants accounted for 43.3% of US generation in 2024, the highest on record

Change in generation, 2023 to 2024, in TWh

Sources:: EIA, https://www.eia.gov/electricity/monthly/current_month/february2025.pdf

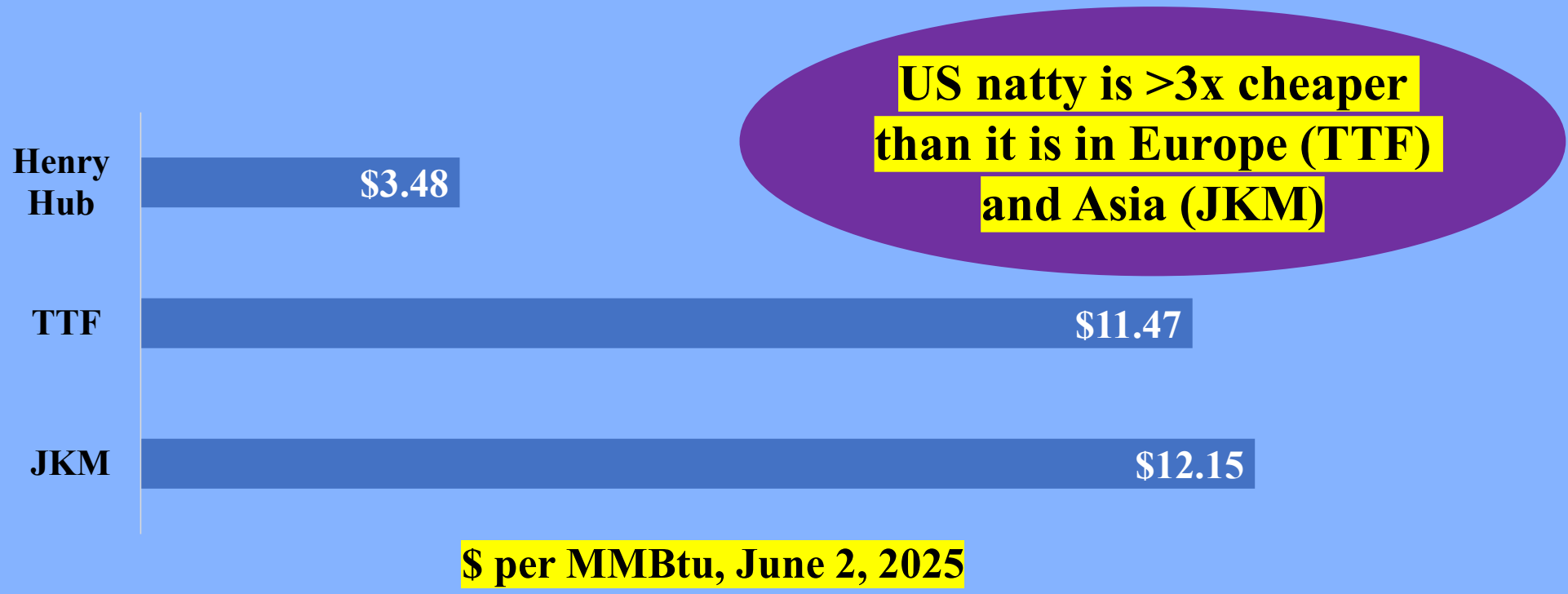
The US Is A Natural Gas Superpower



Source: Statistical Review of World Energy, https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/natural-gas/043024-permian-basin-producers-undeterred-by-negative-natural-gas-prices-enterprise

US Has A Price Advantage Over ROW

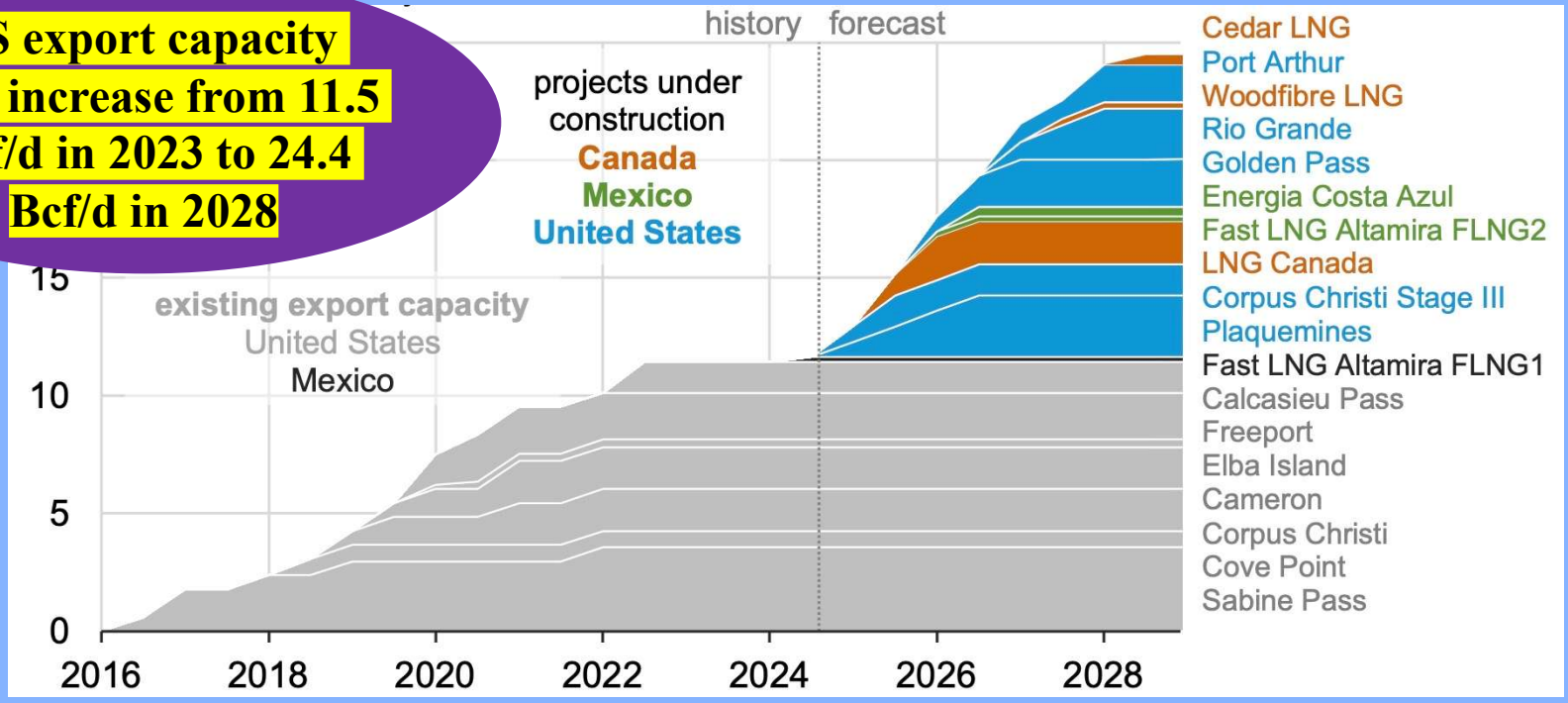
Nat Gas Prices: Henry Hub vs. JKM & TTF



Source: CME Group

US LNG Export Capacity Could Double By 2028

US export capacity may increase from 11.5 Bcf/d in 2023 to 24.4 Bcf/d in 2028



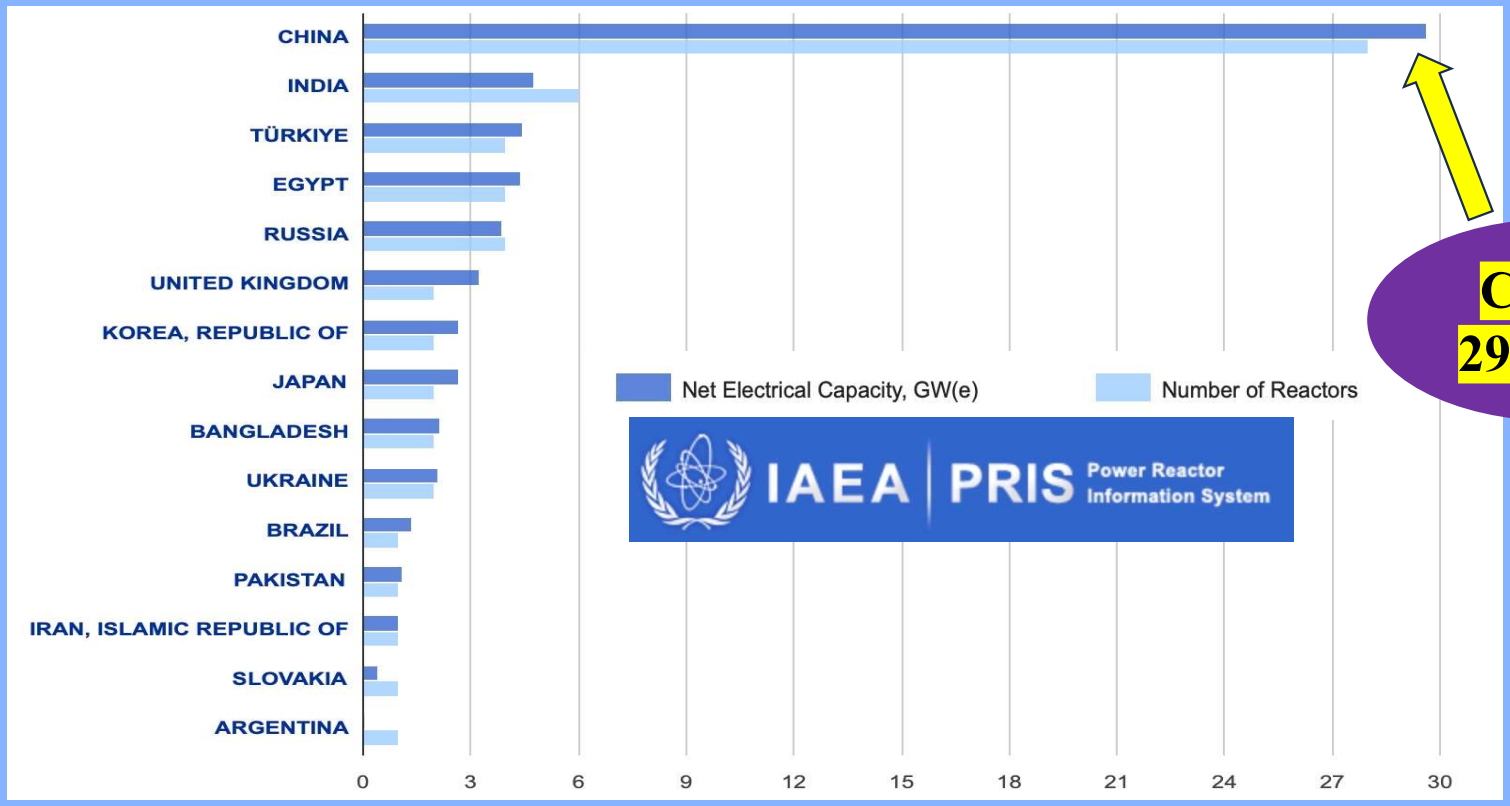
N. American LNG export capacity, by project, in Bcf/d, 2016-2028

Source: EIA, https://www.eia.gov/todayinenergy/detail.php?id=62984

Why Nuclear?

- Needs 2,000x less land than wind, 200x less than solar
- Can be built near load centers
- Energy security, fuel diversity, grid stability
- Price hedge against natural gas
- Zero emissions

Here's The IAEA's List Of Reactors Under Construction. Where's The US?



Sources: IAEA, https://pris.iaea.org/pris/worldstatistics/underconstructionreactorsbycountry.aspx

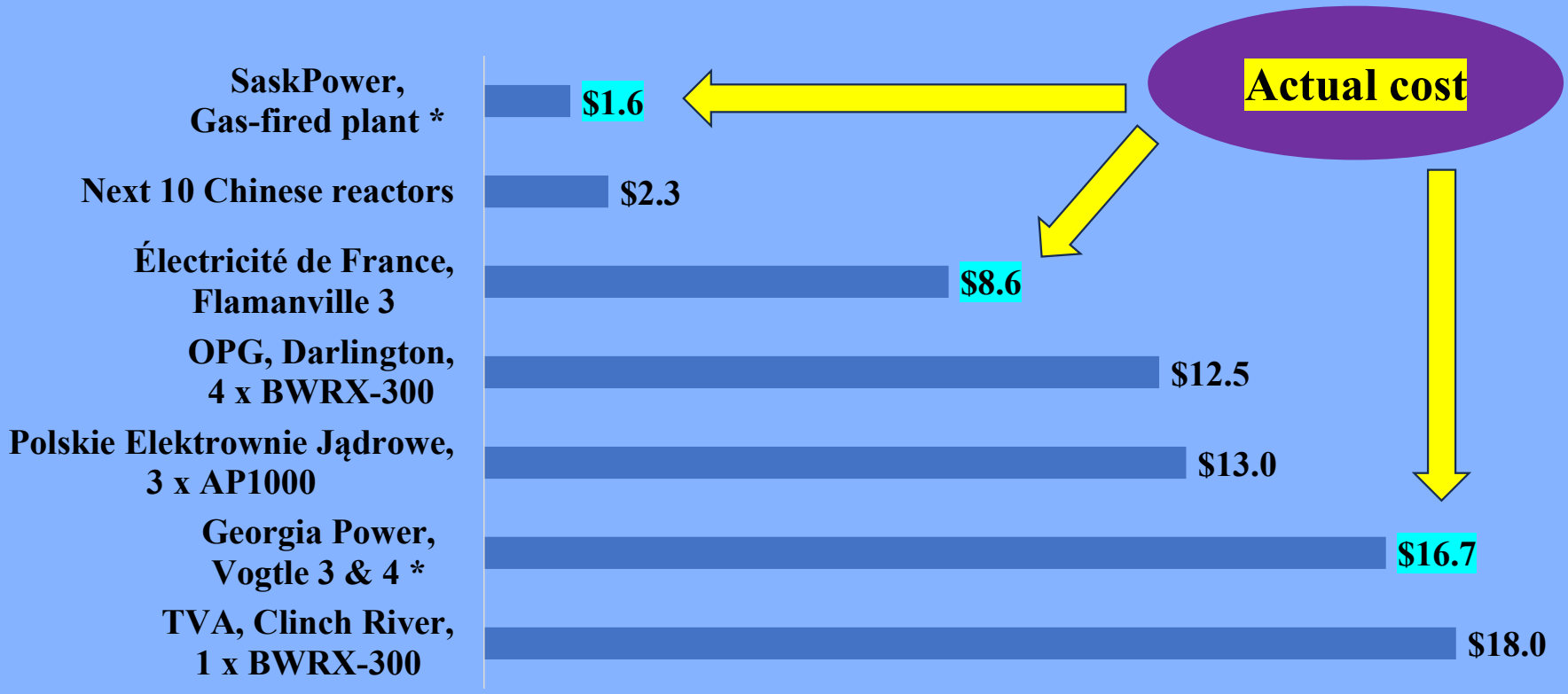
50 Companies Want To Sell SMRs

Which Ones Will Survive?
What Chemistry? What Size (MW)? Cost? When?

1. Steady Energy
2. Oklo
3. NuScale Power
4. Kairos Power
5. Rolls-Royce
6. GE Hitachi
7. Westinghouse
8. TerraPower
9. Terrestrial Energy
10. ARC Clean Technology
11. X-energy
12. General Atomics
13. Holtec International
14. Aalo
15. Rosatom
16. China Nat'l Nuclear Corp
17. Last Energy
18. Blue Energy
19. Radiant Nuclear
20. Thorcon
21. Flibe Energy
22. Moltex Energy
23. Ultra Safe Nuclear
24. Natura Resources
25. NuWard (EDF)
26. Newcleo
27. Core Power
28. Exodys Energy
29. Shine Technologies
30. Nano Nuclear
31. Curio Energy
32. Copenhagen Atomics
33. Seaborg Technologies
34. Blykalla (LeadCold)
35. Dual Fluid
36. BWX Technologies
37. Smart Power
38. NuCube Energy
39. Thorizon
40. Calogena
41. Deep Atomic
42. MicroNuclear
43. Huaneng
44. HolosGen
45. U-Battery
46. NPCIL (India)
47. Mitsubishi Heavy Ind.
48. KEPCO
49. Gen4 Energy
50. StarCore

Sources: Company websites, Perplexity

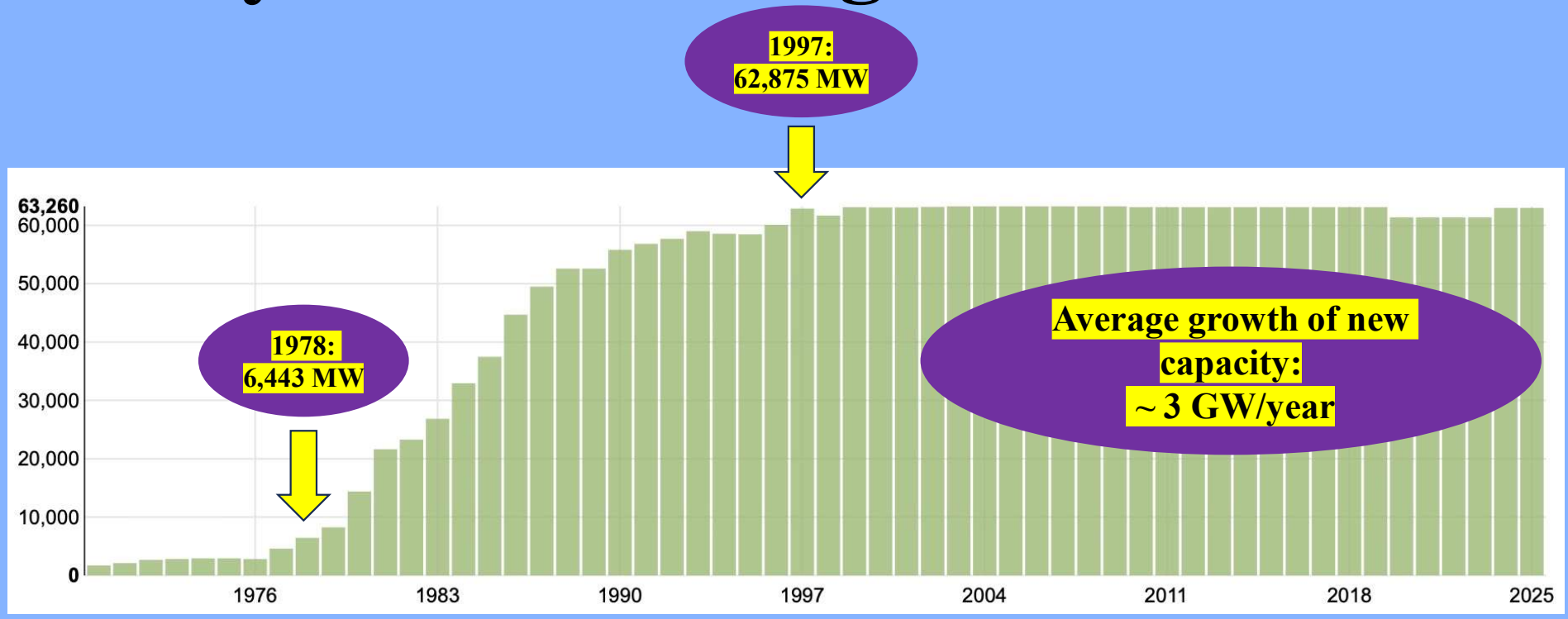
Reactors Are Still Too Expensive



Estimated cost per megawatt of new capacity, $US million

Sources: Media reports

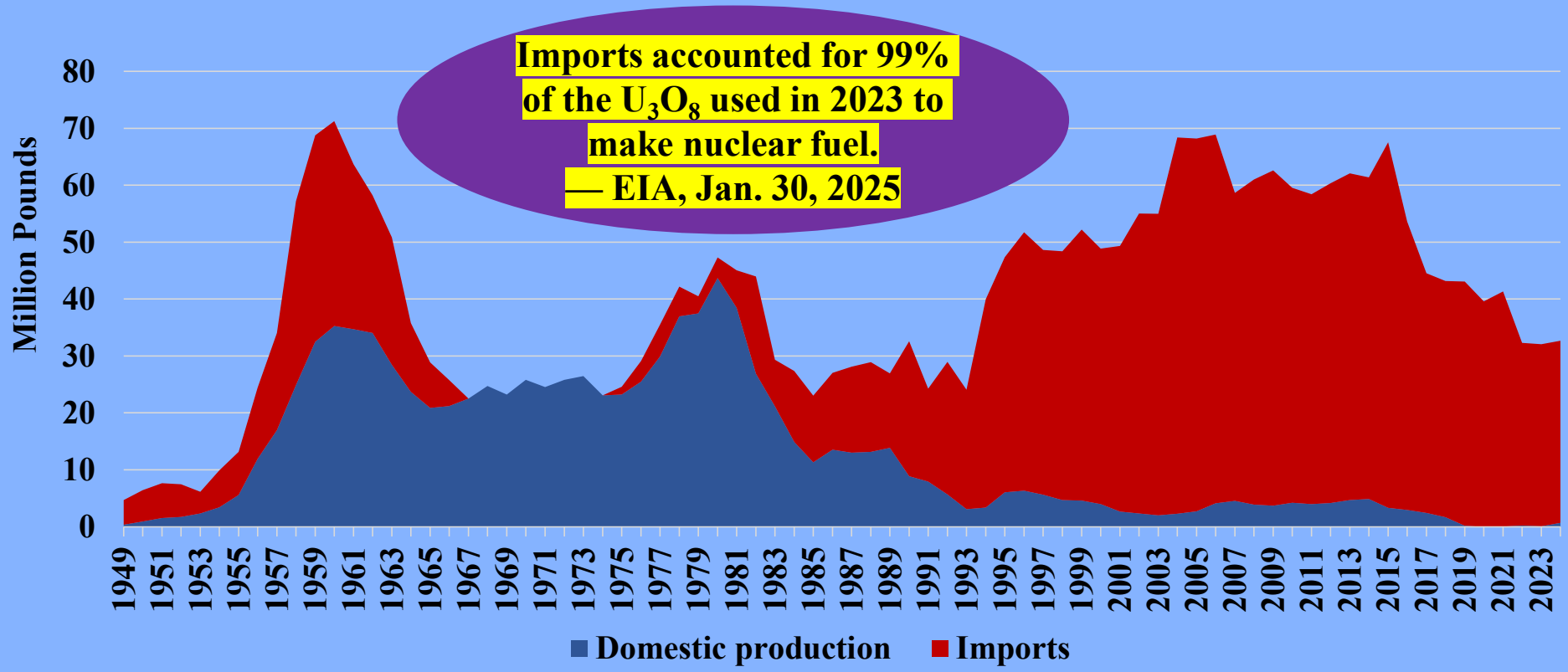
France Rapidly Expanded Its Fleet By Standardizing Its Reactors



Operable nuclear capacity, MWe, 1970 to 2025

Sources: World Nuclear Association, https://tinyurl.com/2e5bmyv6

US Production Of Uranium Oxide Vs. Imports, 1949 to 2024



Source: EIA, EPM , https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf Table 8.2, https://www.eia.gov/todayinenergy/detail.php?id=64444

Energy security is national security

Energy realism is energy humanism

Key Issues For US Gas & Electric Grids

- Keep all coal plants open!
- Fuel diversity = energy security
- Reshoring/AI/electricity demand are driving gas demand
- Land-use conflicts will continue
- Power grid becoming too dependent on nat gas
- New nuclear? When? Where? How much?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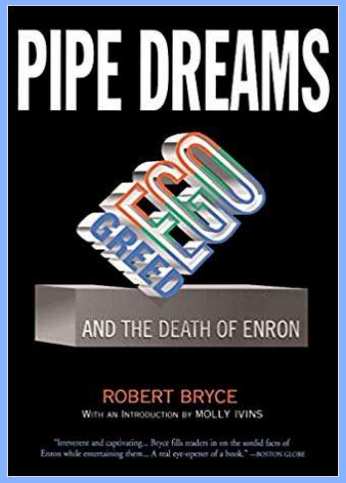

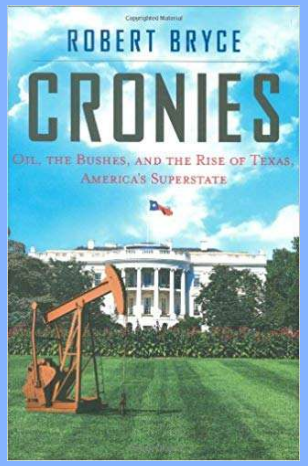

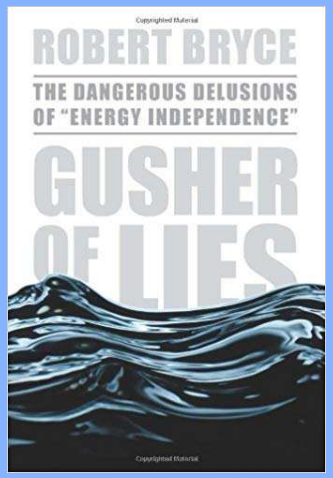

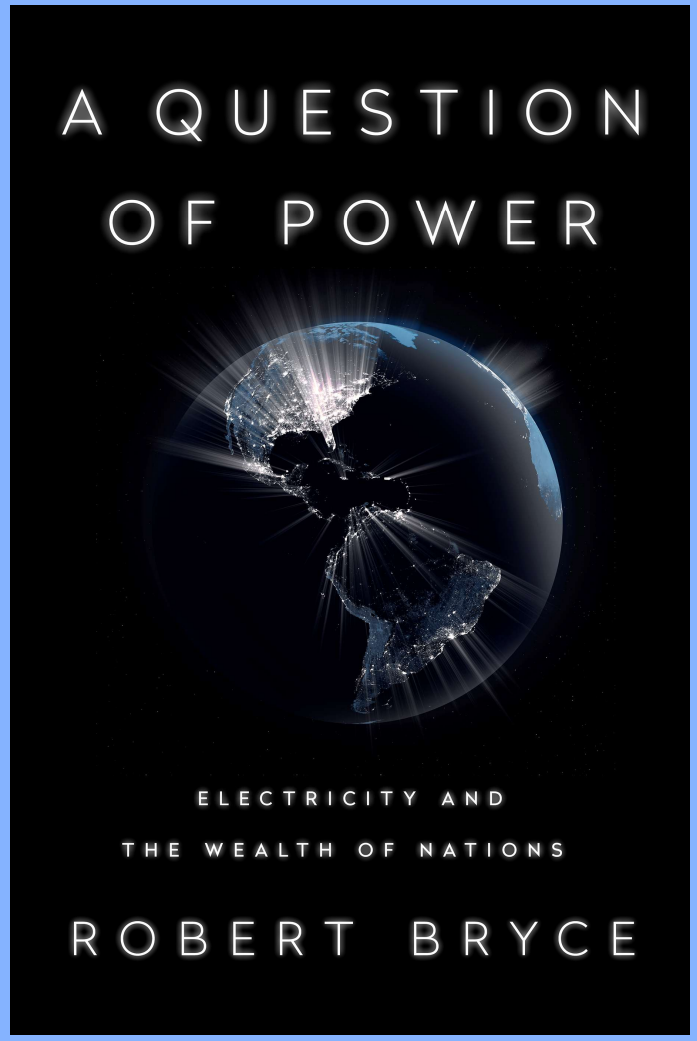

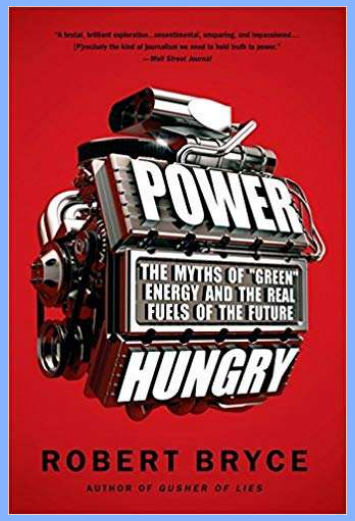

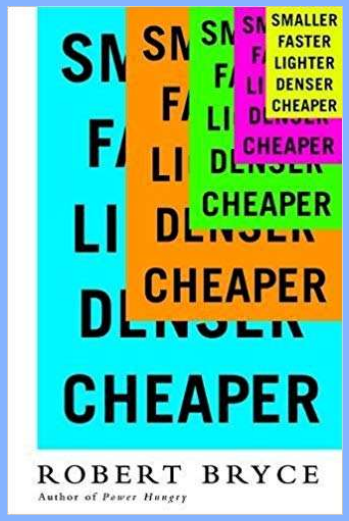

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Thank you