QUANTUM

RFK Compass Investors 2023 Summer Conference

Updates on Energy Security and the Energy Transition

Bill Montgomery

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QUANTUM CAPITAL GROUP 25th ANNIVERSARY

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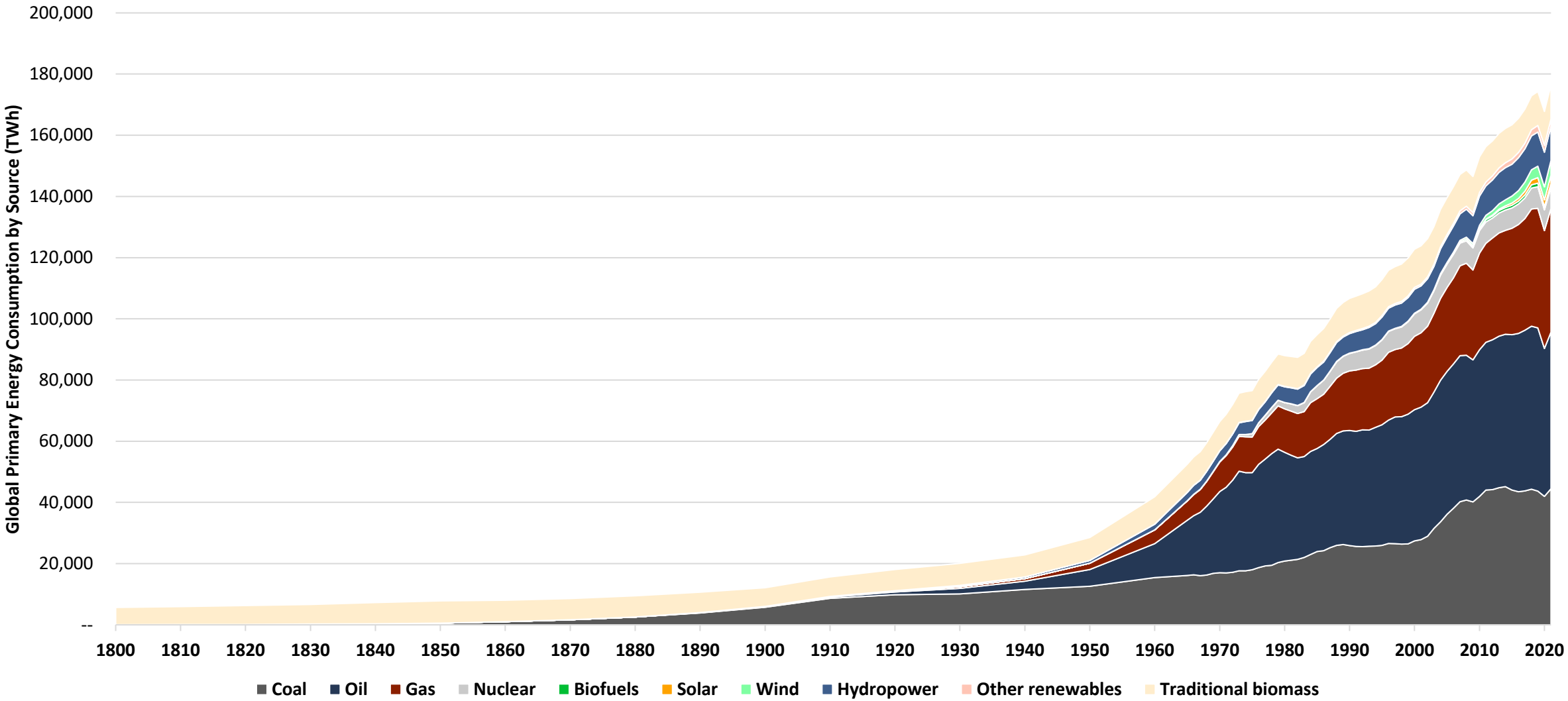
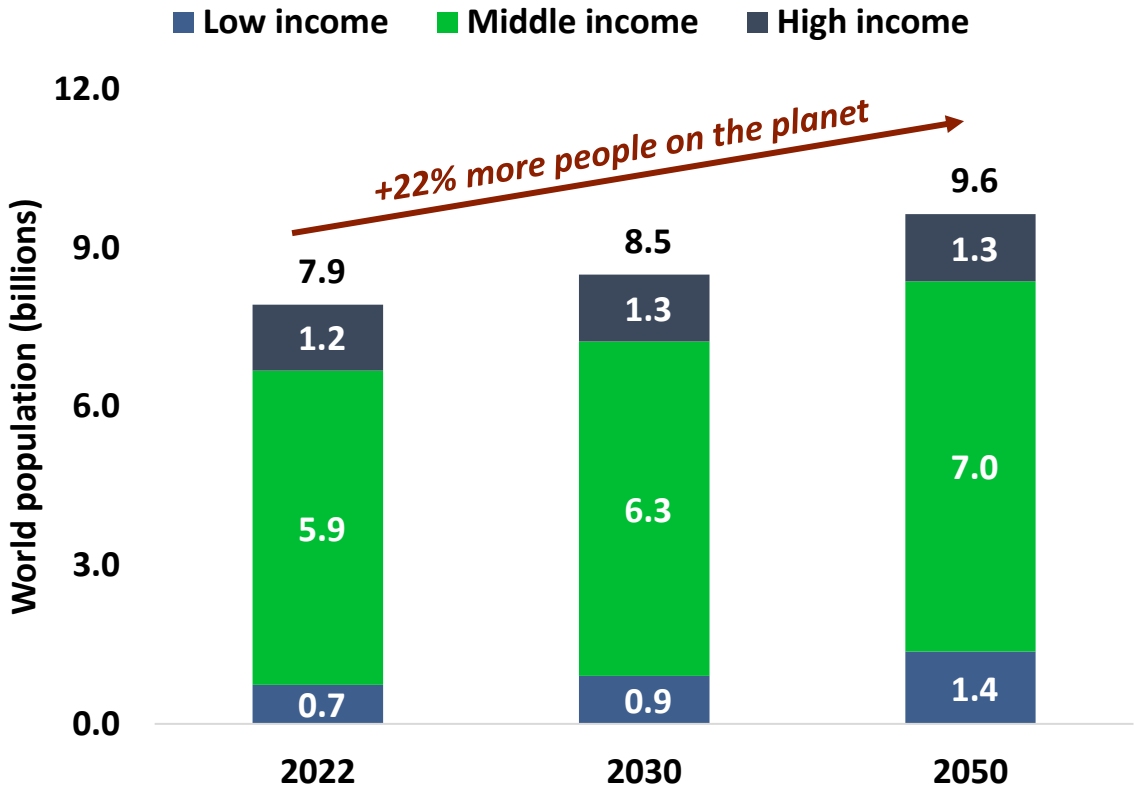
“Energy Transitions” are actually more like “Energy Additions” since prior fuel sources rarely decrease in absolute usage



Source: Vaclav Smil, Our World in Data.

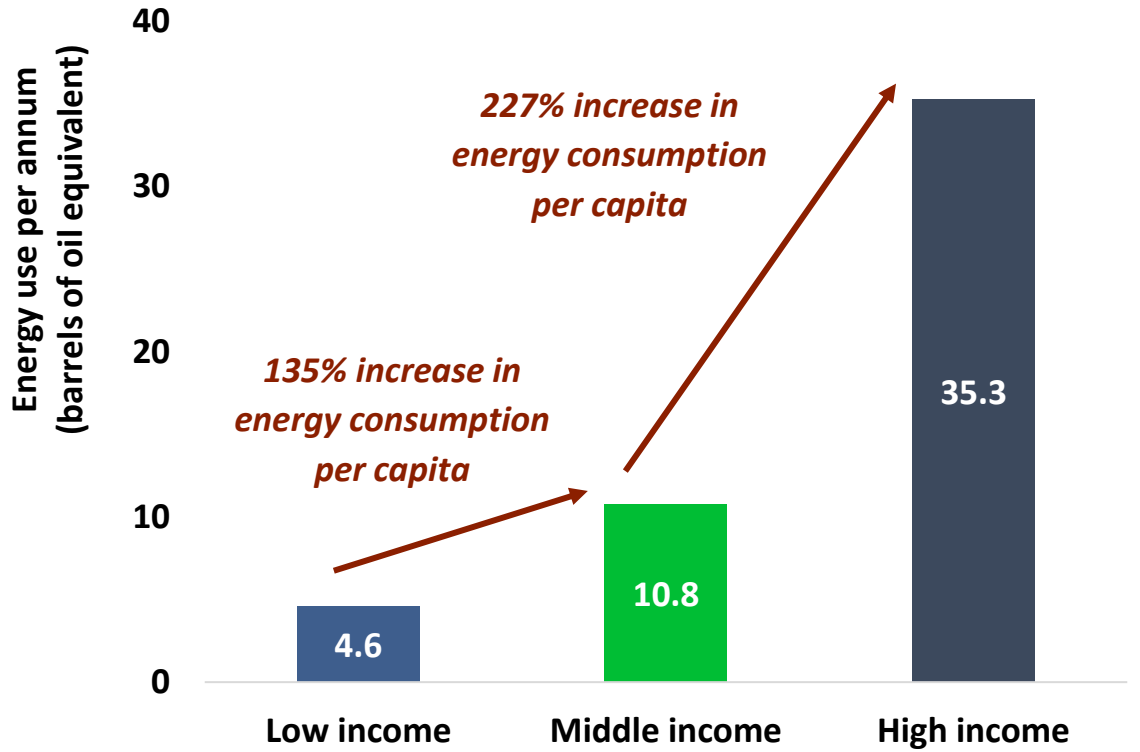
Though energy efficiency will continue to increase, energy demand will grow in tandem …

The world's population is continuing to grow …



Through 2050, the world's population will grow by ~2 billion, with ~98% of the growth occurring in developing regions (e.g., Asia, Africa)

… and billions seek to use more energy to improve their quality of life

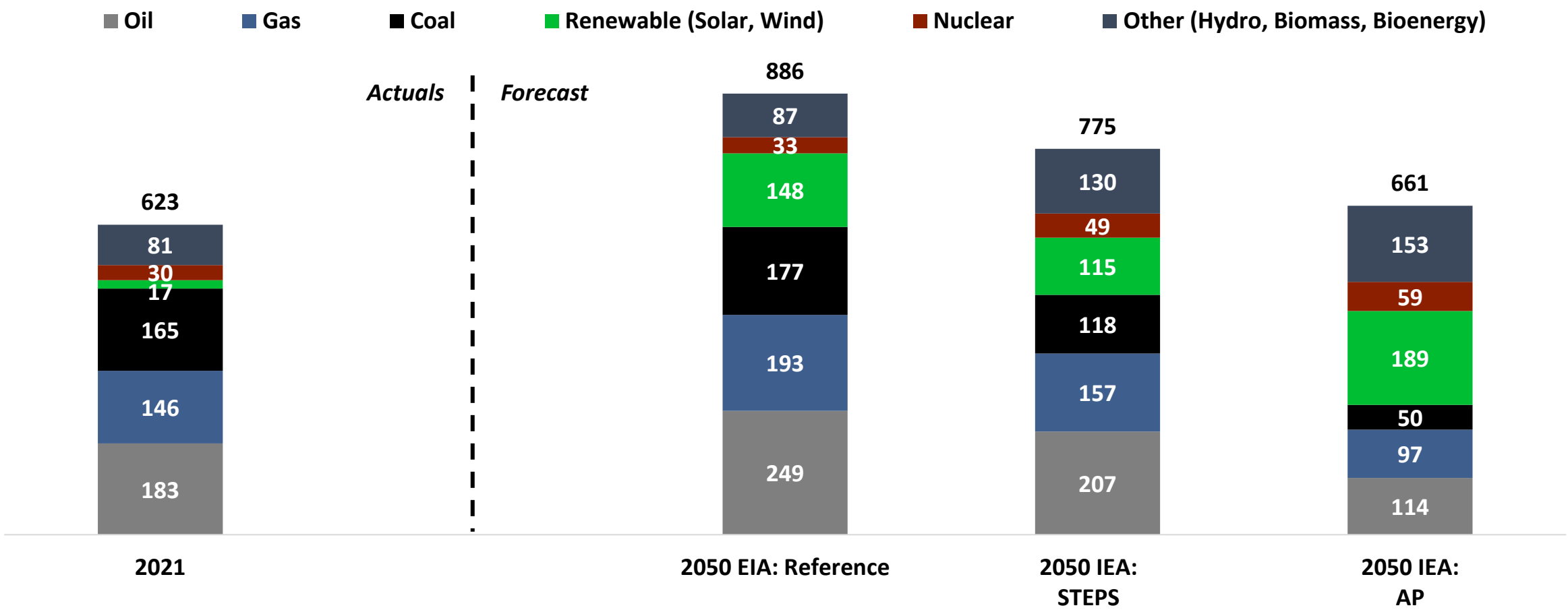


~87% of the world's population in 2050 will live in countries categorized as low/middle income; these populations want, and have a right to, the modern luxuries afforded by energy consumption

Source: The World Bank DataBank.
Note: Low income, Middle income and High income designations based on World Bank country classifications as of December 2022.

Forecasts for global energy demand vary widely – one of the few constants is that the world is going to need a lot more energy with meaningful contribution from all sources

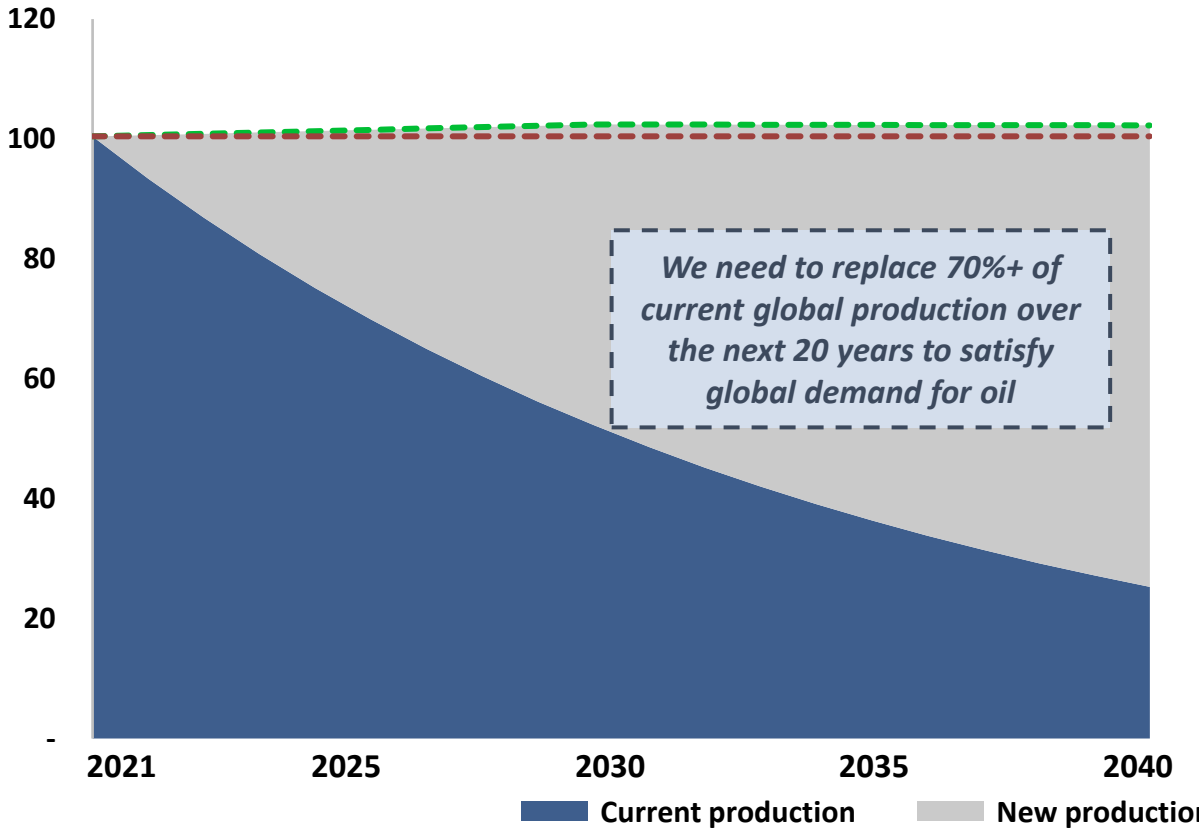
Global energy consumption mix forecast (QBtu)



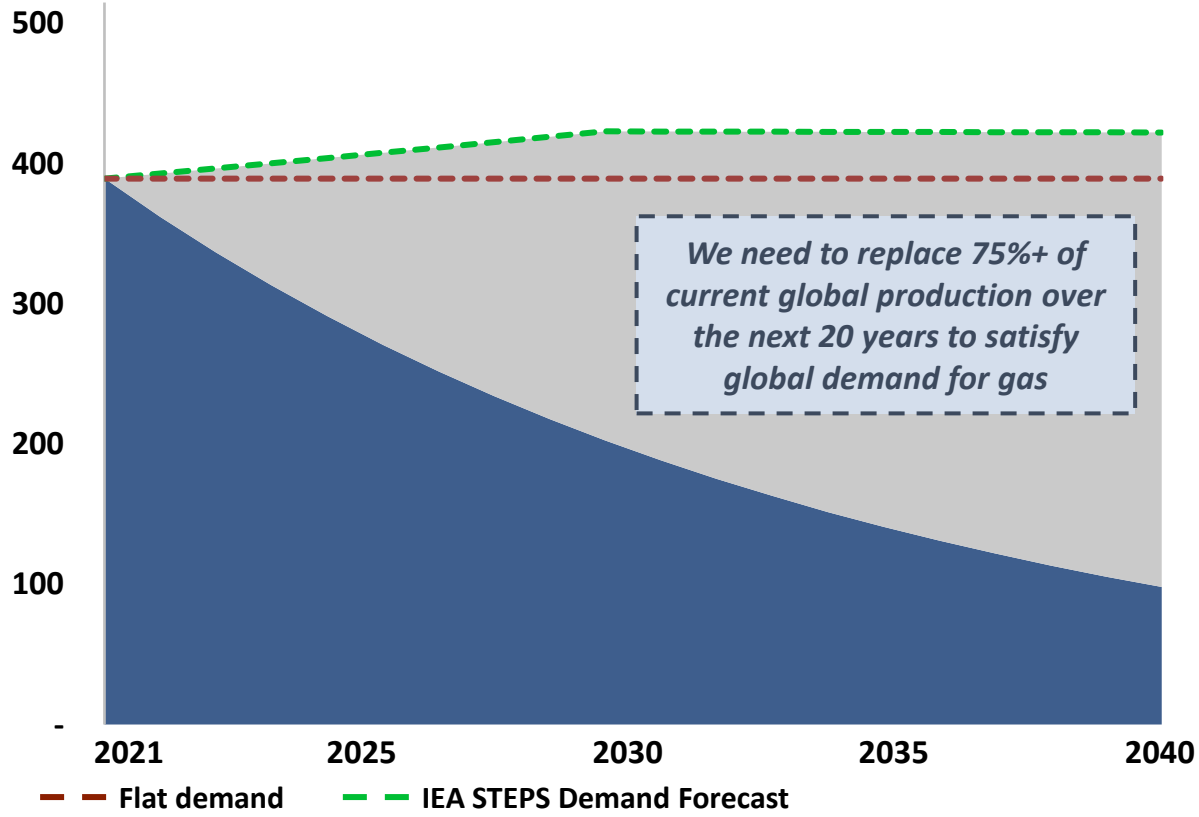
Source: EIA International Energy Outlook 2021, IEA 2022 Stated Policies Scenario (STEPS), IEA 2022 Announced Pledges Scenario (AP), Resources For the Future.

Given the depleting nature of oil and gas, even with flat to modest demand growth, the world will need to replace 60-70% of current production over the next 20 years …

Global liquids supply and demand (MMBbl/d)



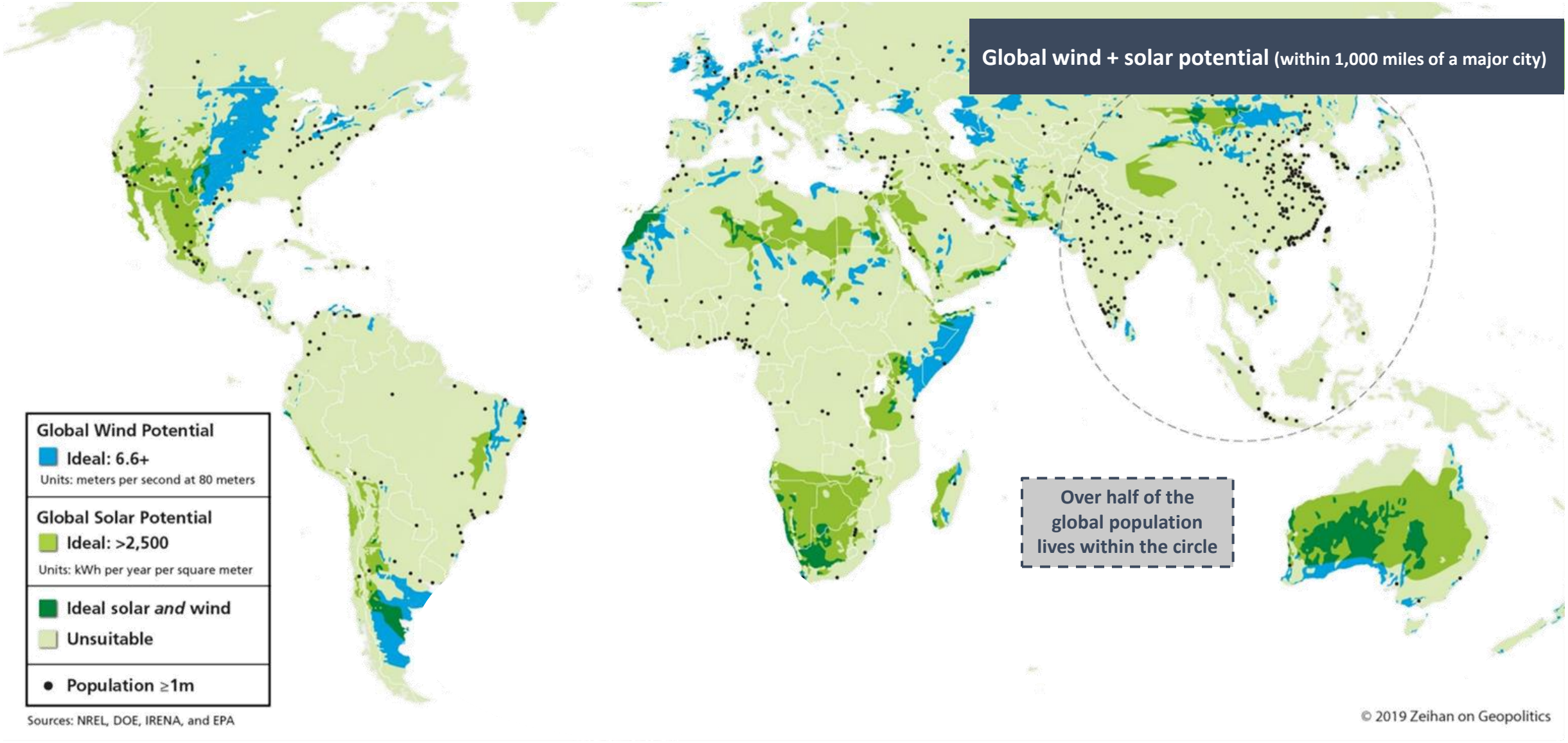
Global natural gas supply and demand (Bcf/d)



In order to meet forecasted demand between now and 2040, the world will need to invest ~$12 trillion to find ~350 billion barrels of oil and ~3,000 trillion cubic feet of natural gas – this will necessitate an annual spend of ~$600bn per year, which is an ~50% uptick over the ~$400bn per year spent over the past 8 years

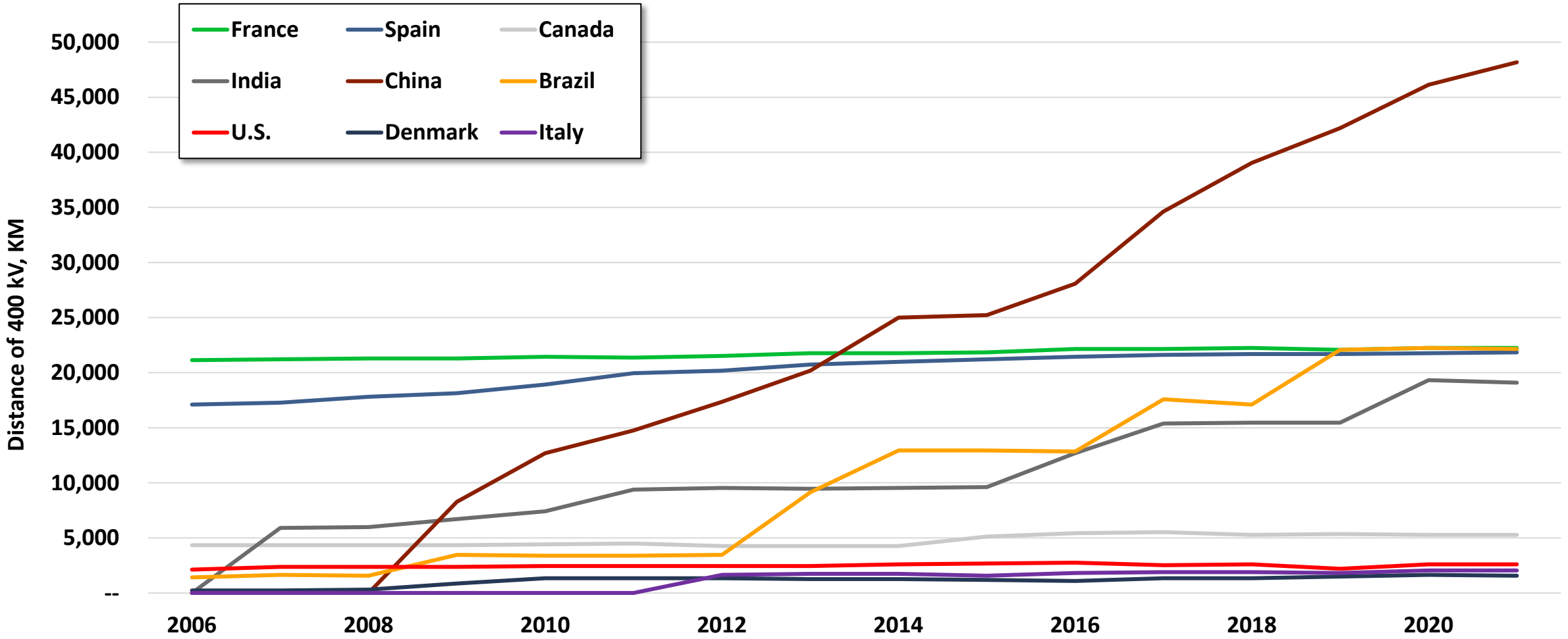
Source: Source: IEA World Energy Outlook 2022 – STEPS scenario., BMO Capital Markets, Jefferies, ExxonMobil, Quantum estimates.

The challenge with renewables on a global basis becomes very evident when considering where ideal wind and solar potential are located within 1,000 miles of a major city – think transmission



What is different about the current Energy Transition, and what are the greatest impediments to scaling solar, wind and batteries?

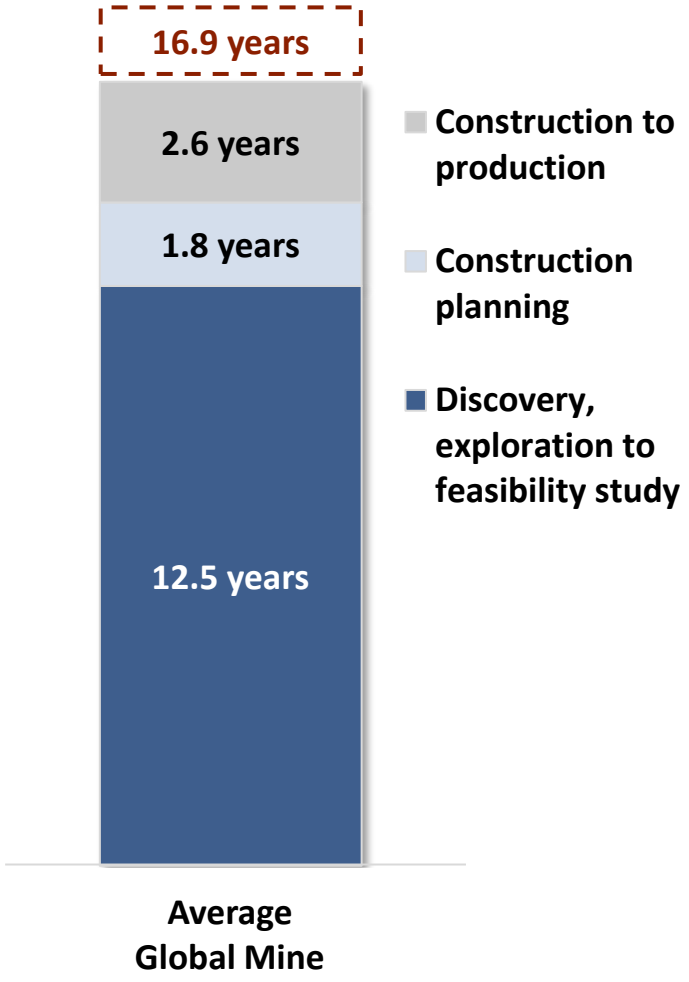
High voltage direct current lines by country



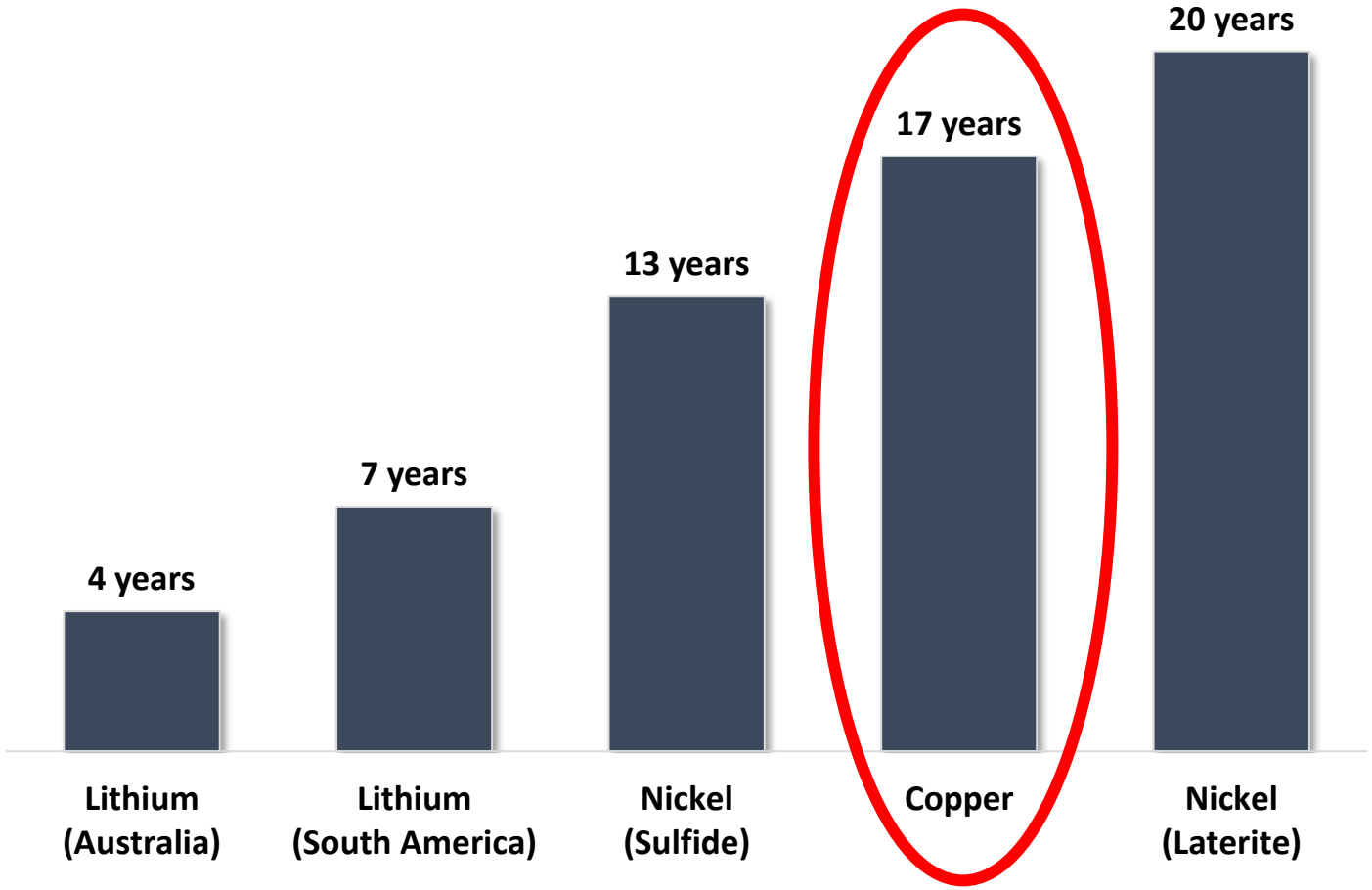
Source: Vaclav Smil, Energy Transitions, Praeger (2018); V. Smil, Power Density MIT Press (2015). Global Transportation, JPMAM (2022).

On average, large-scale mines take 17 years to come online – so how will the mining industry be able to meet the increasing demand for the key minerals and metals for the Energy Transition?

Global average lead times from discovery to production



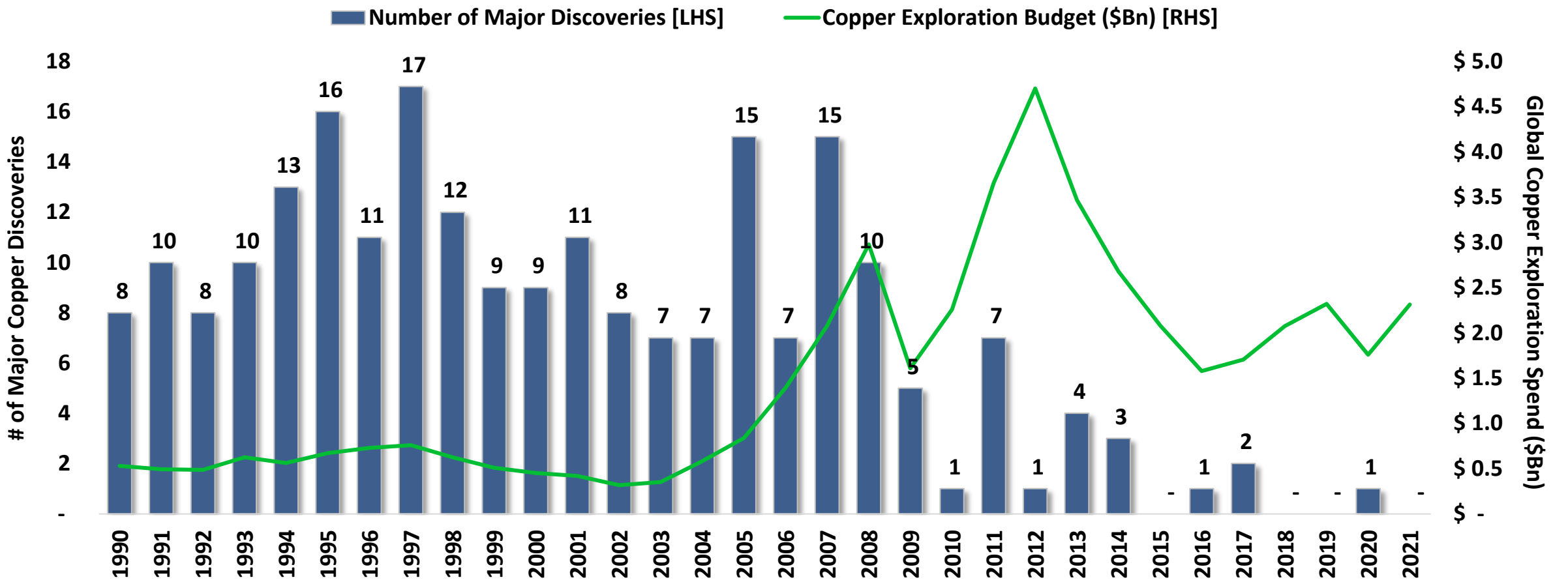
Average observed lead times from discovery to production for selected minerals



Source: IEA.

Even when exploration spending for key minerals, such as copper, is significantly increased, major reserve discoveries have been scarce over the past decade

Number of major global copper discoveries vs. global copper exploration spending

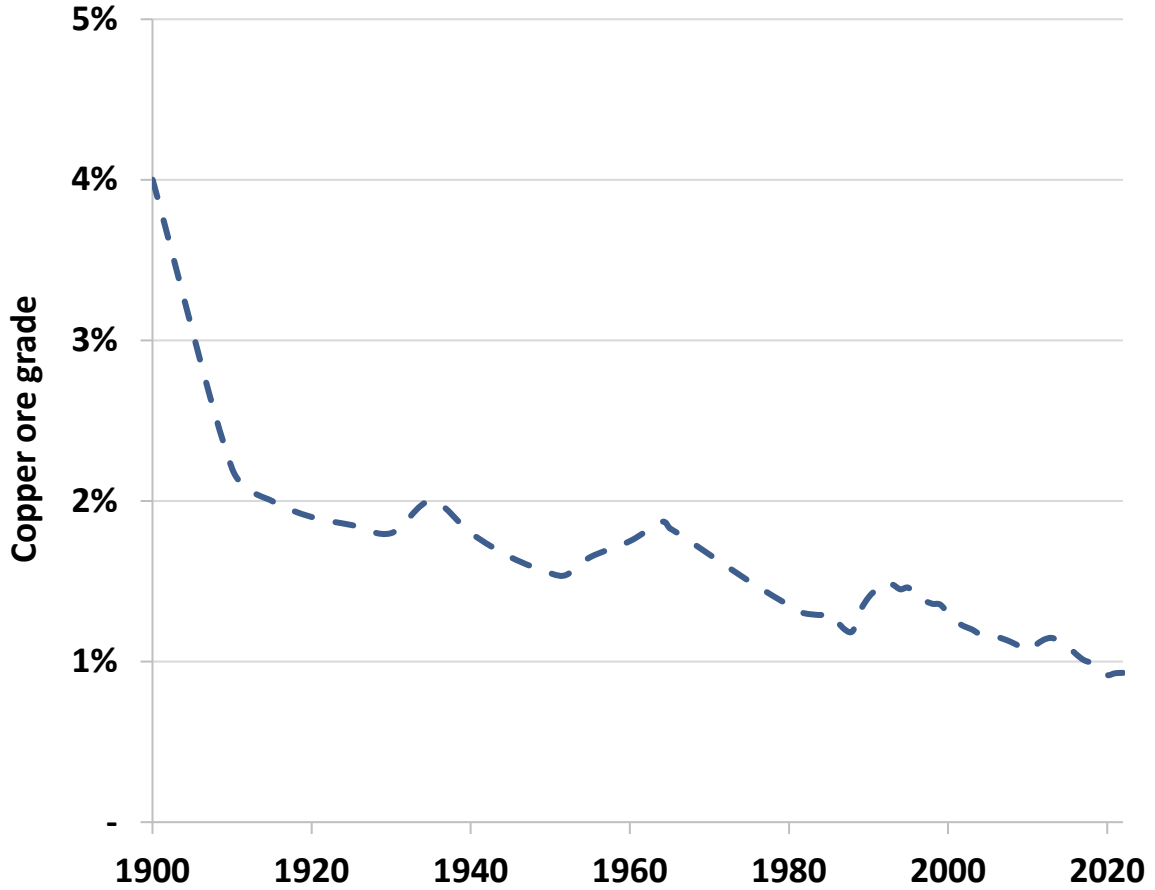


Discovering new critical mineral reserves to meet the demand for the Energy Transition over the coming decades will be challenging, as evidenced by an ~85% decrease in major global copper discoveries over the past decade despite an ~5x increase in exploration spending

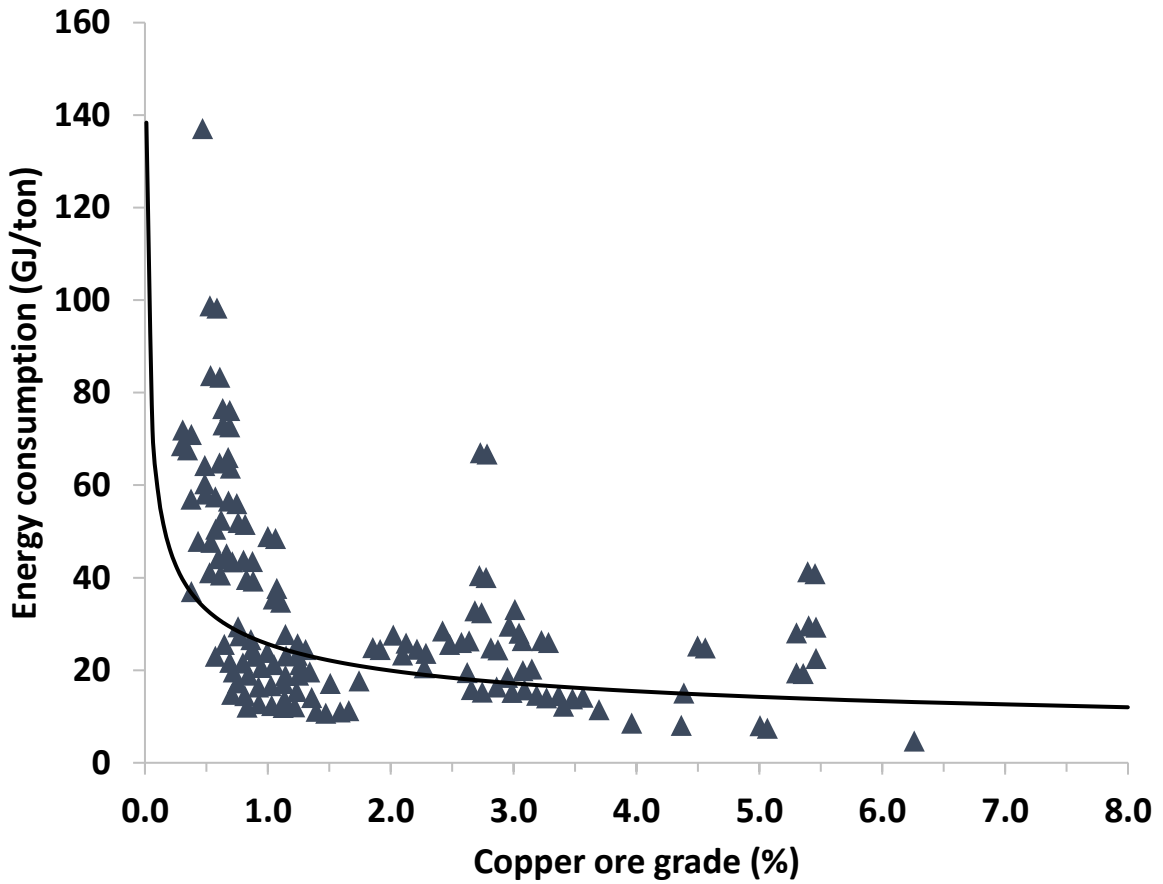
Source: S&P Global Market Intelligence.

Ore grades of most key minerals will continue to decline over time, requiring the mining and processing of ever-increasing amounts of earth to extract the same amounts of minerals

Grades of copper mined over time



Energy use per ton of copper vs ore grade

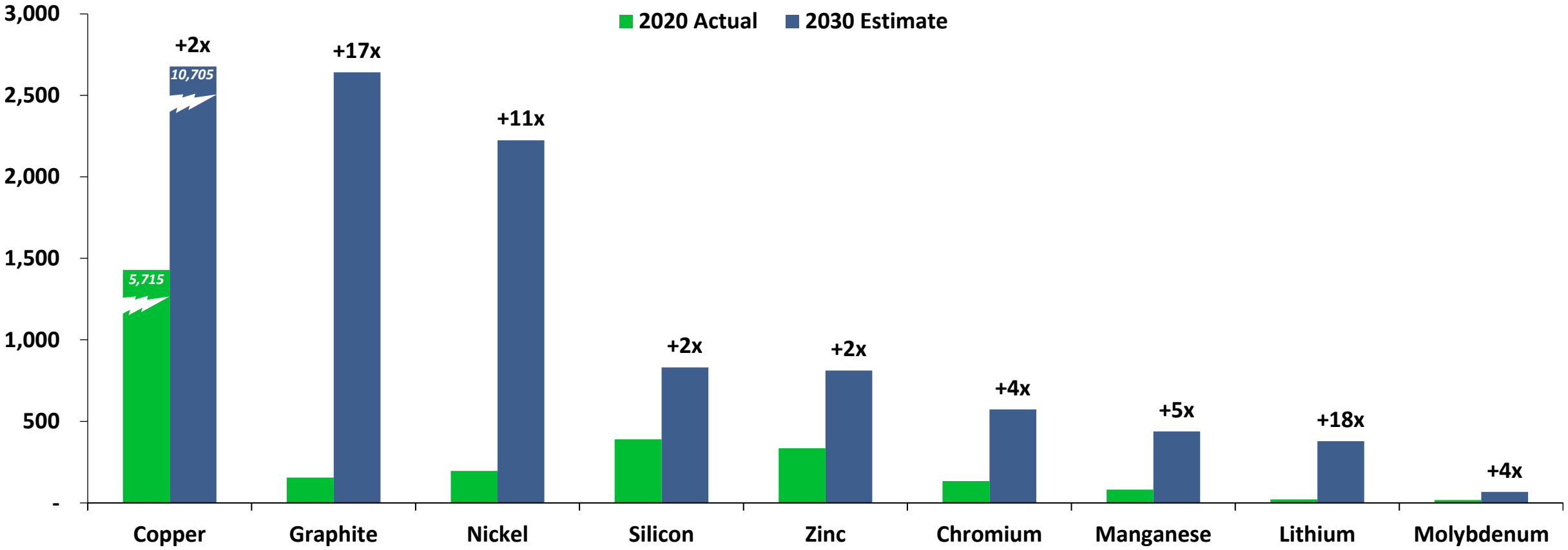


More earth being mined and processed means more energy being consumed, and thus higher emissions as the energy used is mainly fossil fuels, and higher costs per unit of mineral, as more tons of earth and more energy will be used to extract and process the same amount of minerals

Source: Wood Mackenzie.

So just how much will these technologies increase demand for the essential minerals and metals to make them possible? A LOT!!

Actual vs. future demand from clean energy uses (thousands of tons)[1]



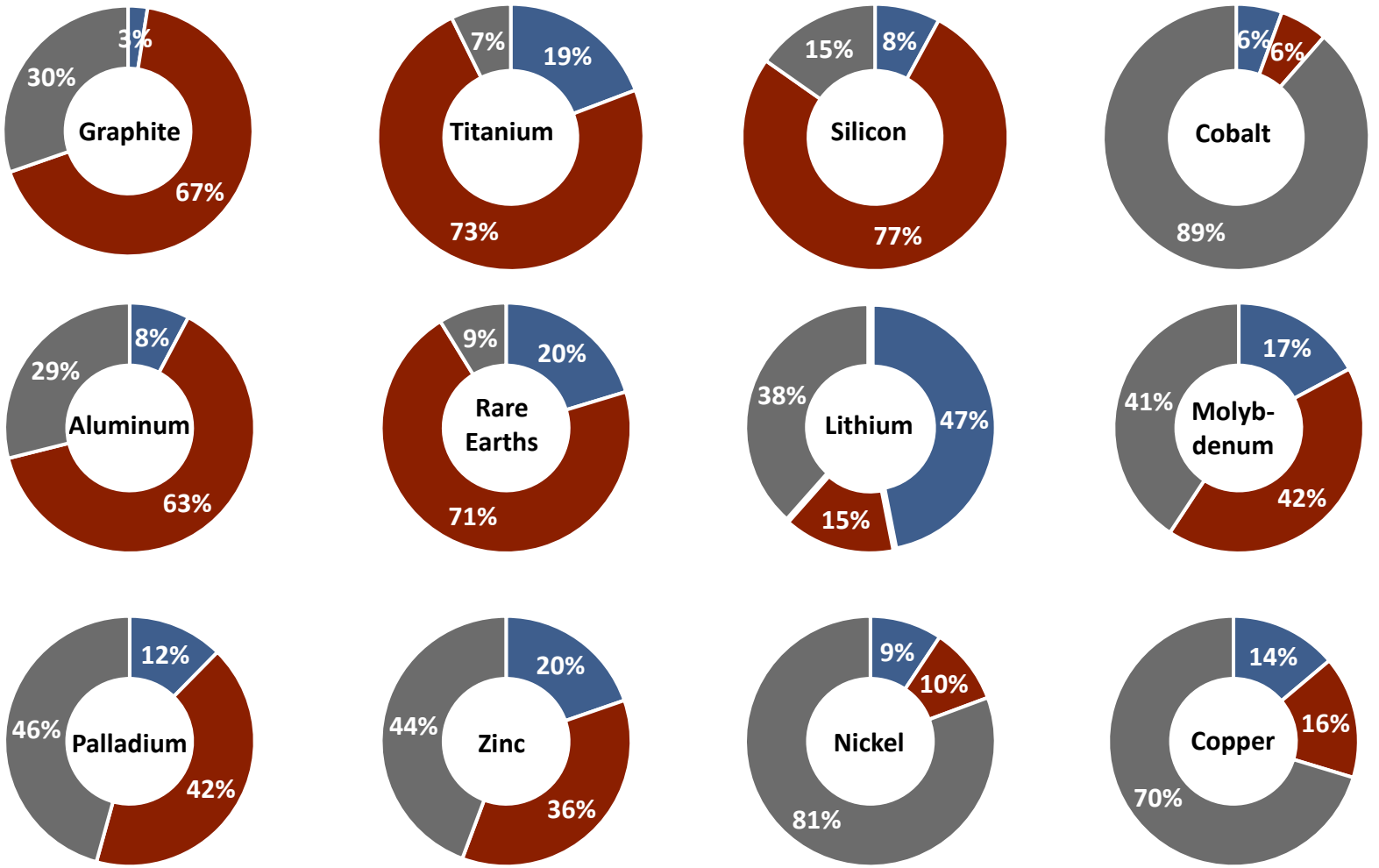
No extractive industry has ever been able to increase global supply by 100% in a decade, much less the 300% to 1,700% suggested for these various key inputs needed to achieve Net Zero – remember, a 2-3% change in supply/demand balance of a typical commodity moves prices materially

Source: IEA Critical Minerals Outlook.
(1) Based on IEA World Energy Outlook estimates for the Sustainable Development Scenario.

Unfortunately, mining of many of these key minerals and metals are controlled by the China-Russia bloc which doesn't bode well for energy security for Western democracies

% of 2022 Production By Region

- ***China, Russia, Kazakhstan, Venezuela, Iran, and North Korea***
- ***U.S., Western Europe, Japan, Canada, Australia, and South Korea***
- ***All Other Countries***

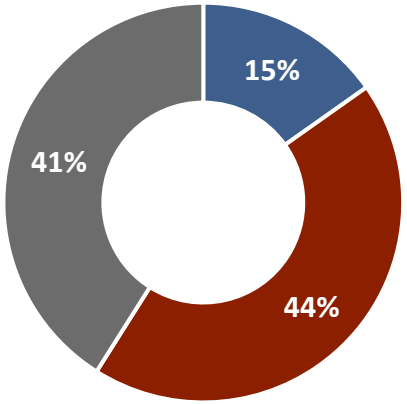


We believe the energy security issues highlighted by Russia's war on Ukraine have begun to reverse more than 40 years of globalization as the world moves towards two isolated trading blocs, thus straining global supply chains and potentially slowing down the energy transition to renewables and EVs

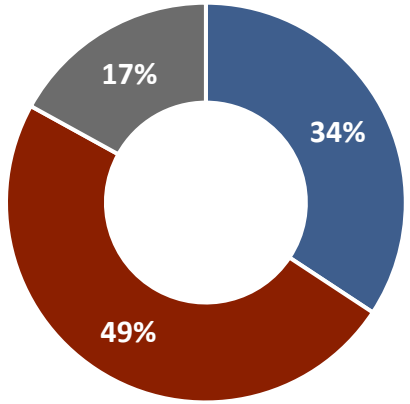
The China-Russia bloc also has by far the largest market share in refining capacity for key minerals and metals

Refining capacity[1]

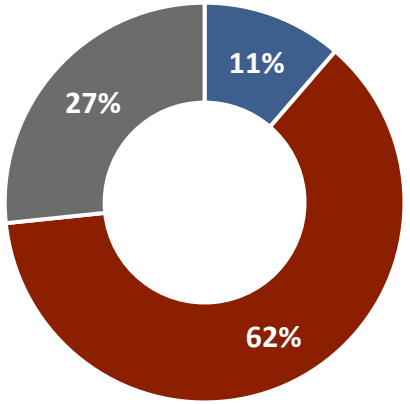
Copper



Nickel



Lithium



China, Russia, Kazakhstan, Venezuela, Iran, and North Korea

U.S., Western Europe, Japan, Canada, Australia, and South Korea

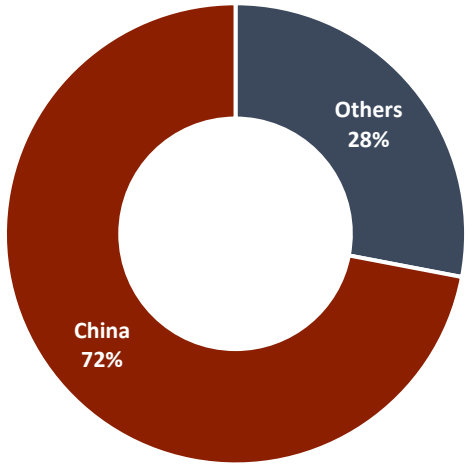
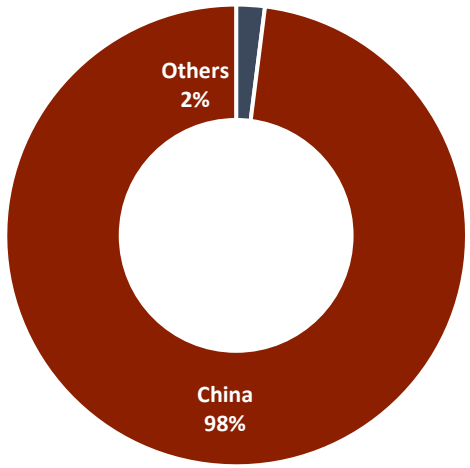
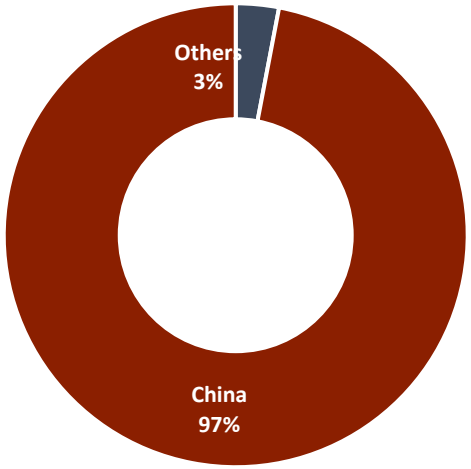
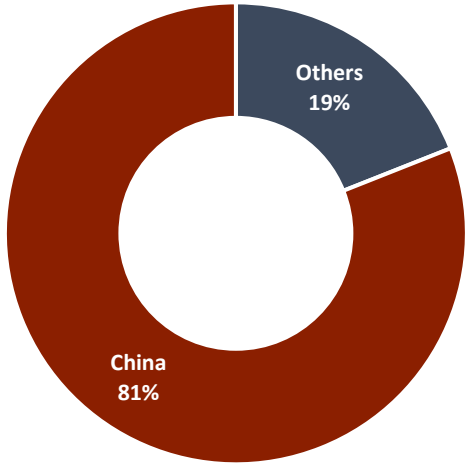
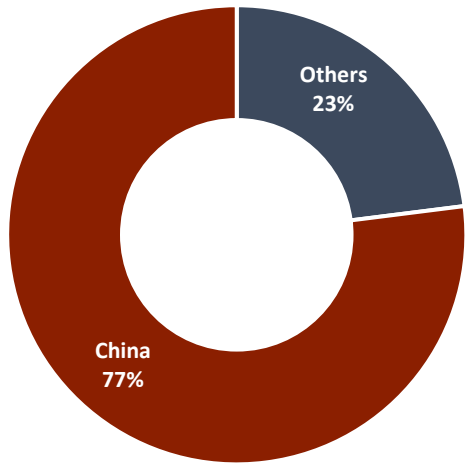
All Other Countries

Source: Bloomberg New Energy Finance and USGS.

(1) Lithium and Nickel includes currently in production or under construction refineries. Copper includes currently in production refineries only.

The U.S. has historically relied on China for manufacturing of solar panels

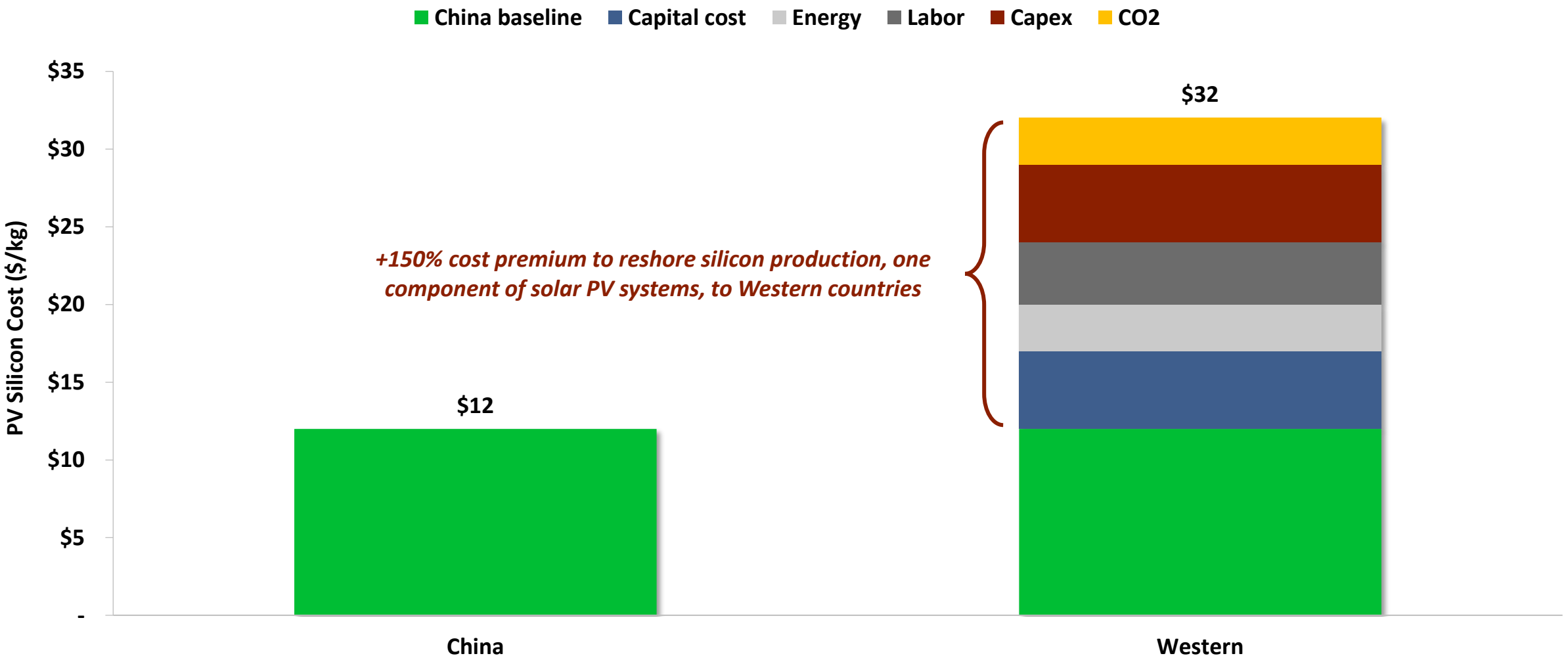
China dominates production of all the major inputs into solar panels, but tensions between the U.S. and China have created supply chain bottlenecks

Polysilicon	Ingot	Wafer	Cell	Module
				

Source: U.S. Department of Energy, Thunder Said Energy.

Reshoring materials and manufacturing domestically from China will take years and drive the cost of solar higher

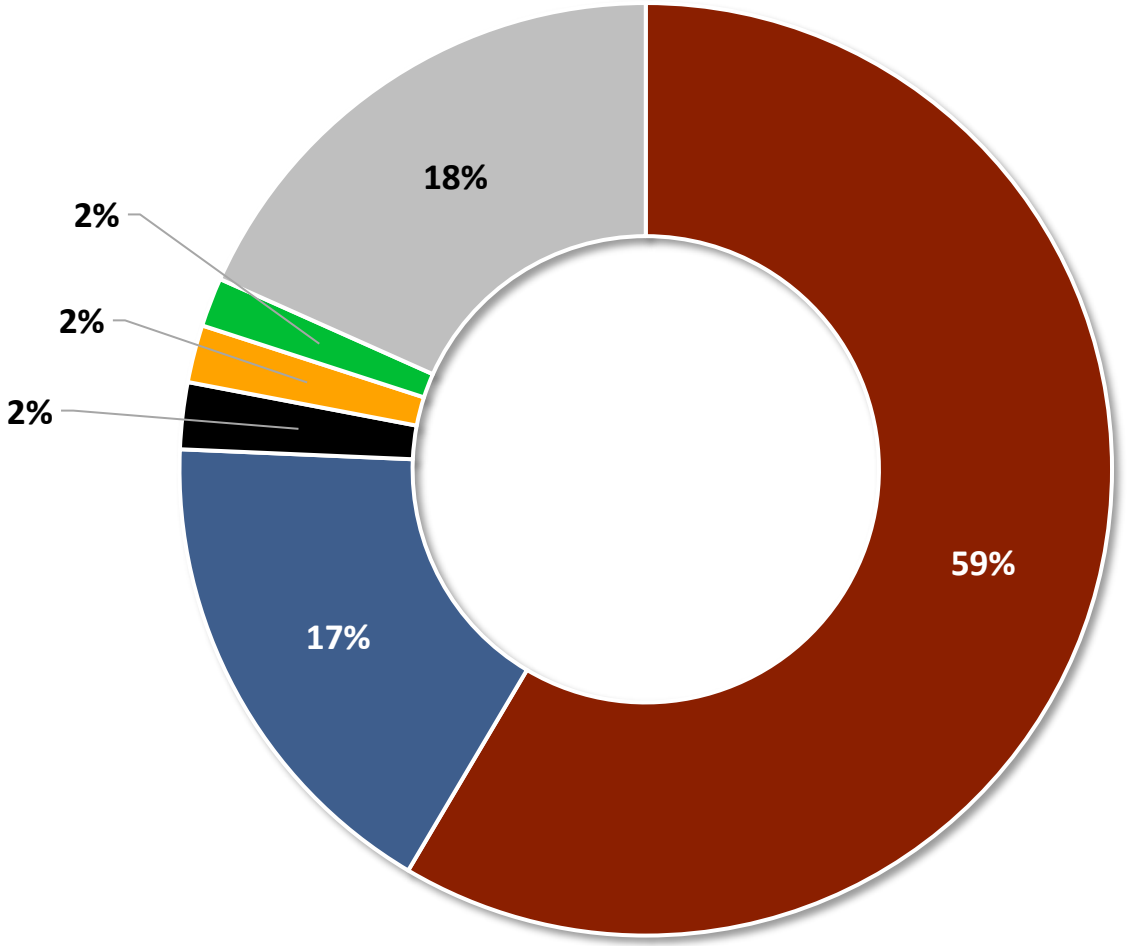
The U.S. will likely begin to reshore manufacturing, but would face substantially higher costs and long plant build-out times



Source: U.S. Department of Energy, Thunder Said Energy.

Unlike the solar supply chain, the wind supply chain has both local and global characteristics, with China and the U.S. serving as major manufacturing hubs

Wind turbine manufacturing capacity by country (% total capacity)



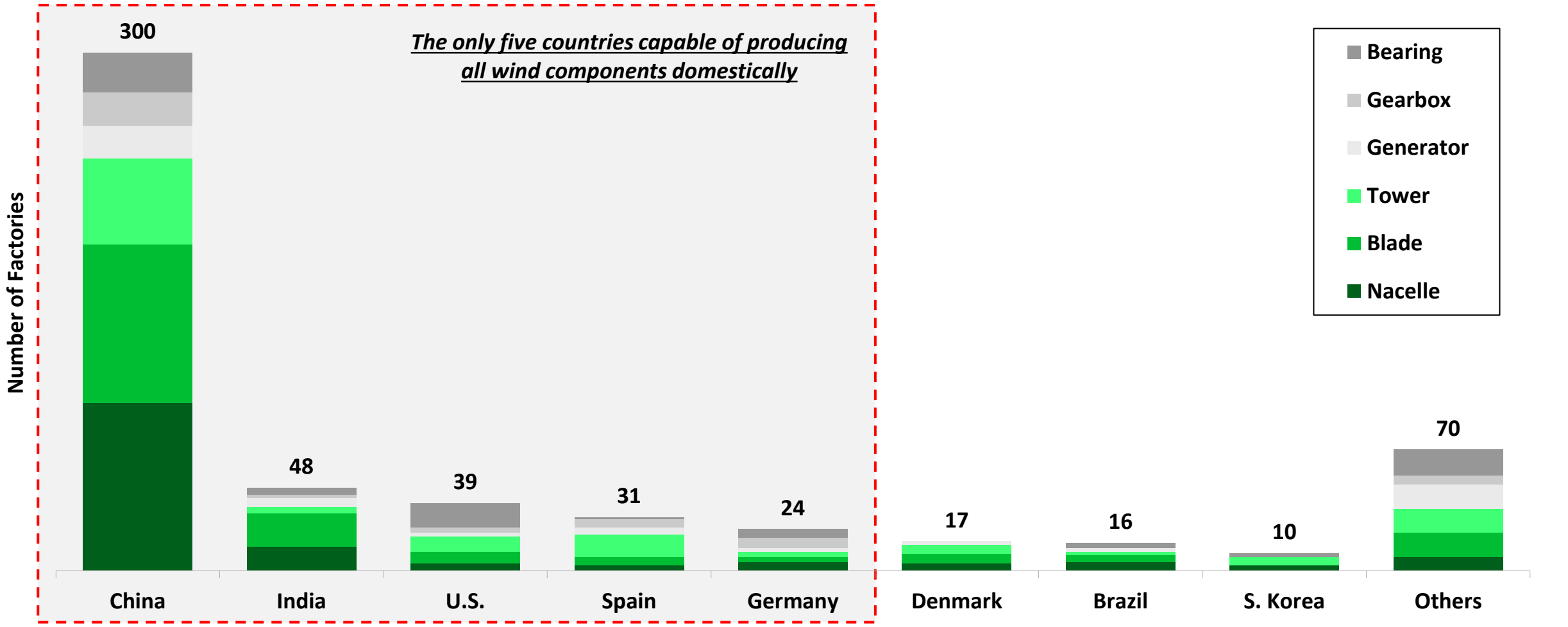
~60% of global wind turbine manufacturing capacity is in China

- China
- United States
- Germany
- Sweden
- Spain
- Others

As the wind industry deploys larger turbines to capture more resource and reduce unit costs, countries are pushing to localize supply chains

Source: Bloomberg New Energy Finance.

Very few countries can produce all the required wind turbine components domestically

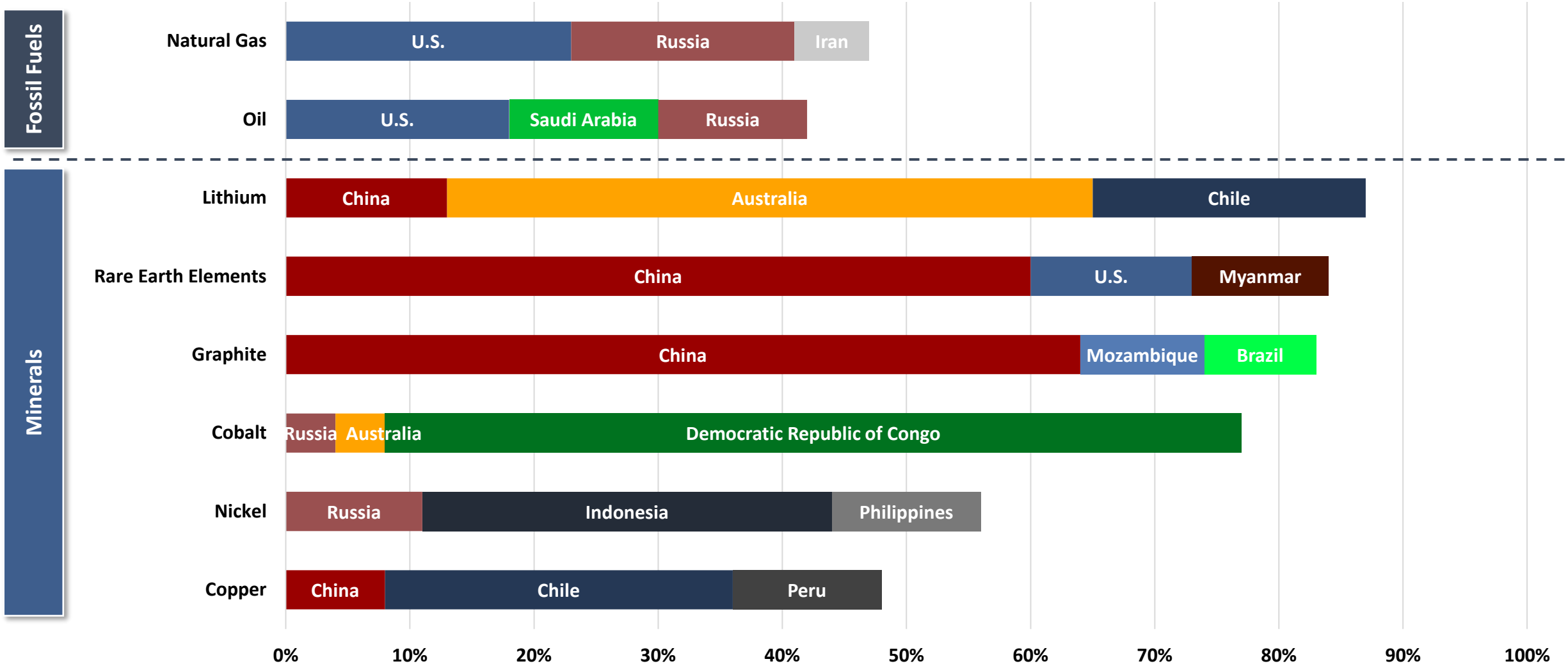


As the wind industry deploys larger turbines to capture more resource and reduce unit costs, countries are pushing to localize supply chains

Source: Bloomberg New Energy Finance.

Does wind and solar solve the world's reliance on OPEC …

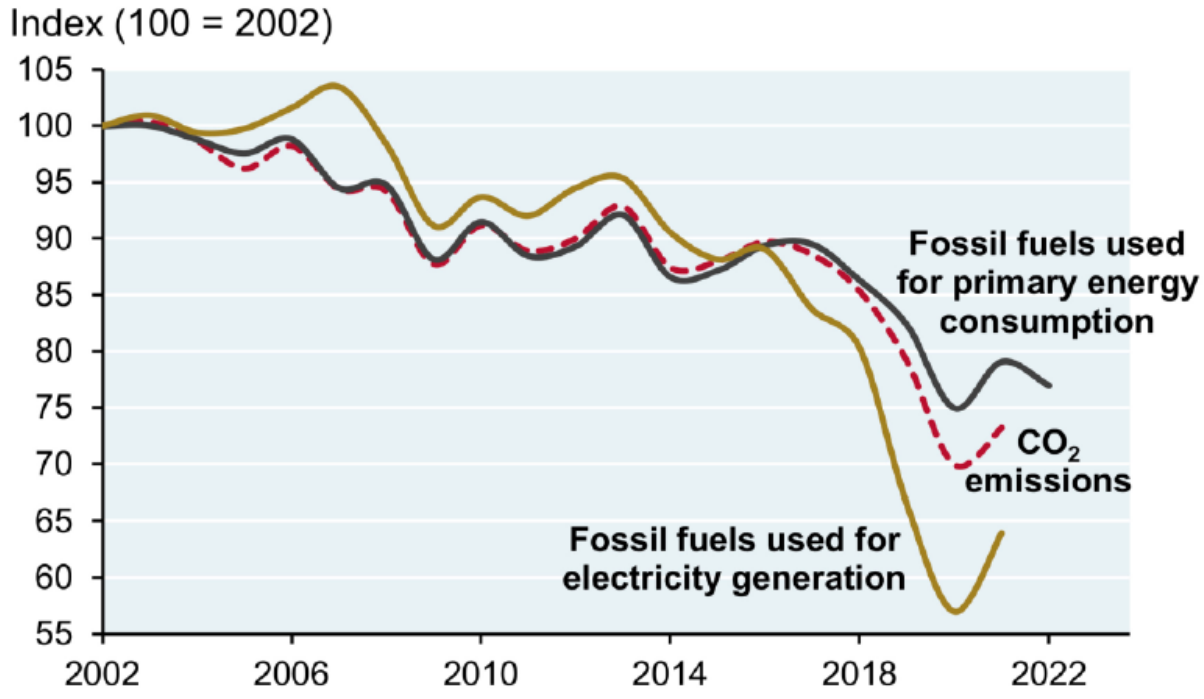
Share of top 3 producing countries in total production for selected fossil fuels and minerals (2019)



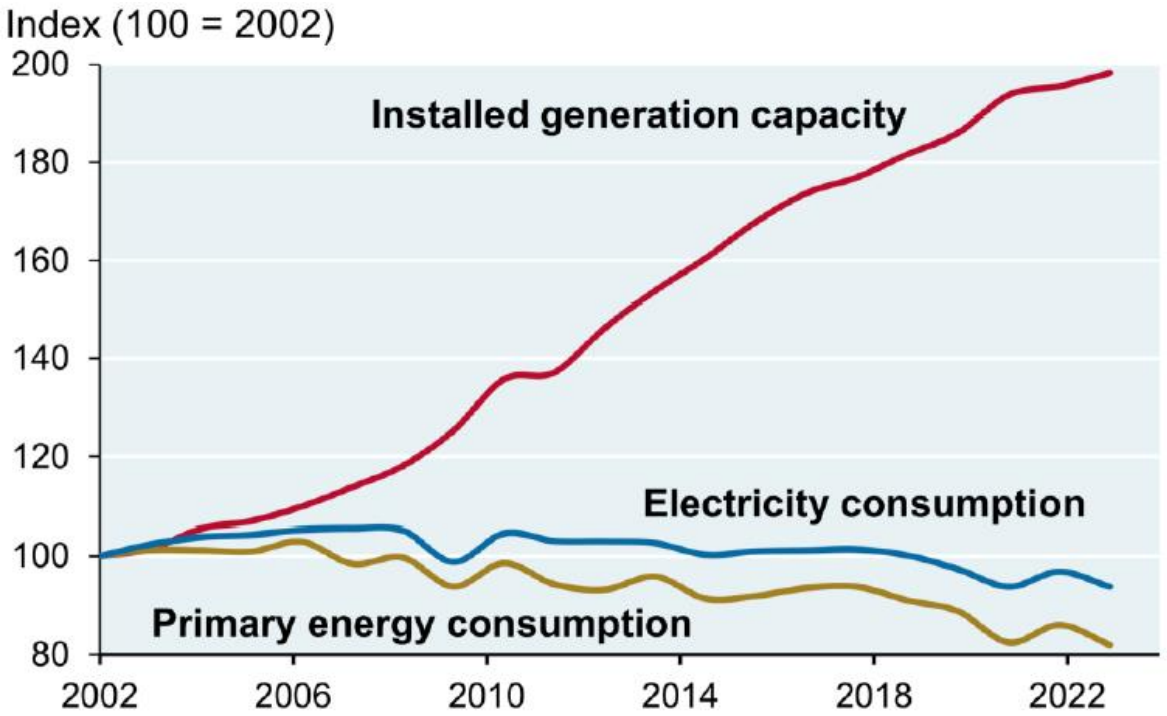
Source: IEA.

What can we learn from Germany's quest to build renewables?

Germany CO2 Emissions and Fossil Fuel Use



Germany Generation Capacity and Energy Use

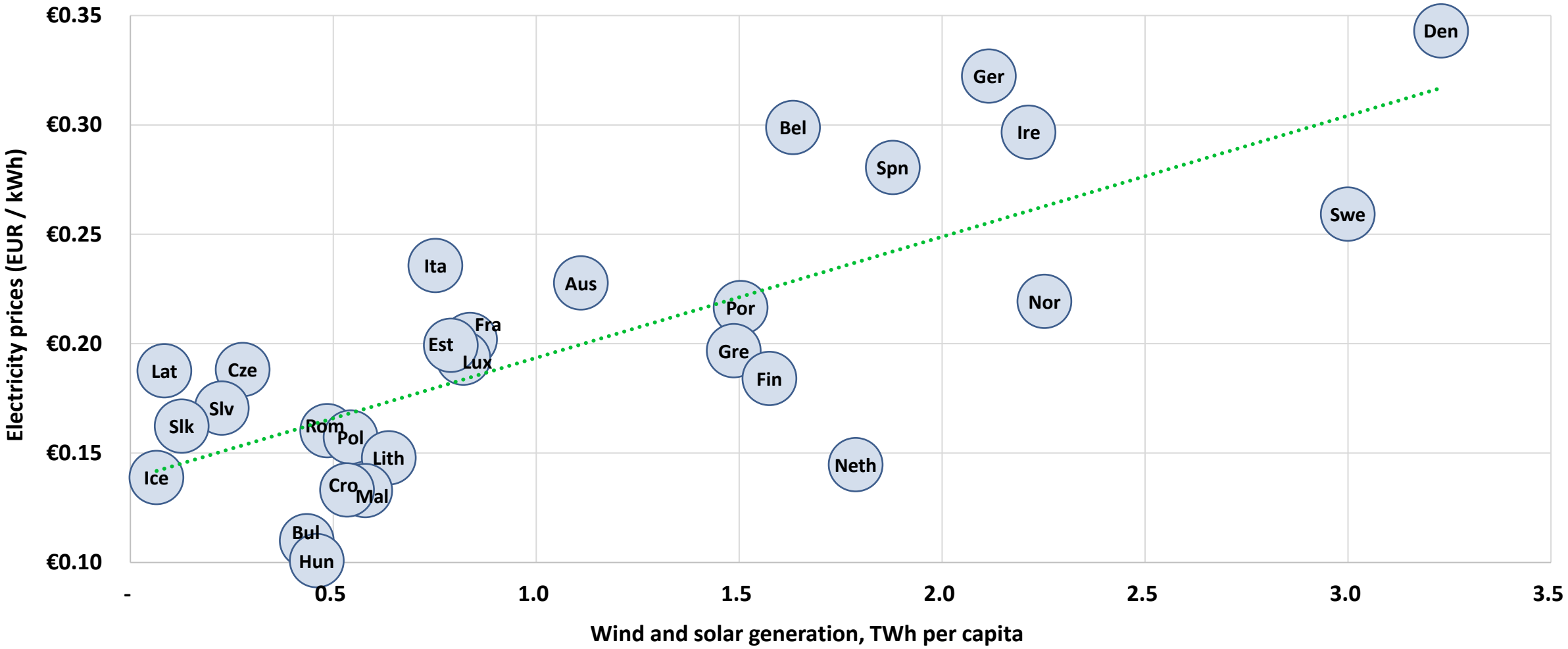


In 2023, Germany will generate ~50% of electricity from renewable energy, though, over the last two decades, fossil fuels as a percent of total energy consumption has only fallen from 84% to 78%

Source: AG Energiebilanzen, BP, Bundesverband BDEW, Fraunhofer Institute, JPMAM (2023).

What can we learn from Germany's quest to build renewables?

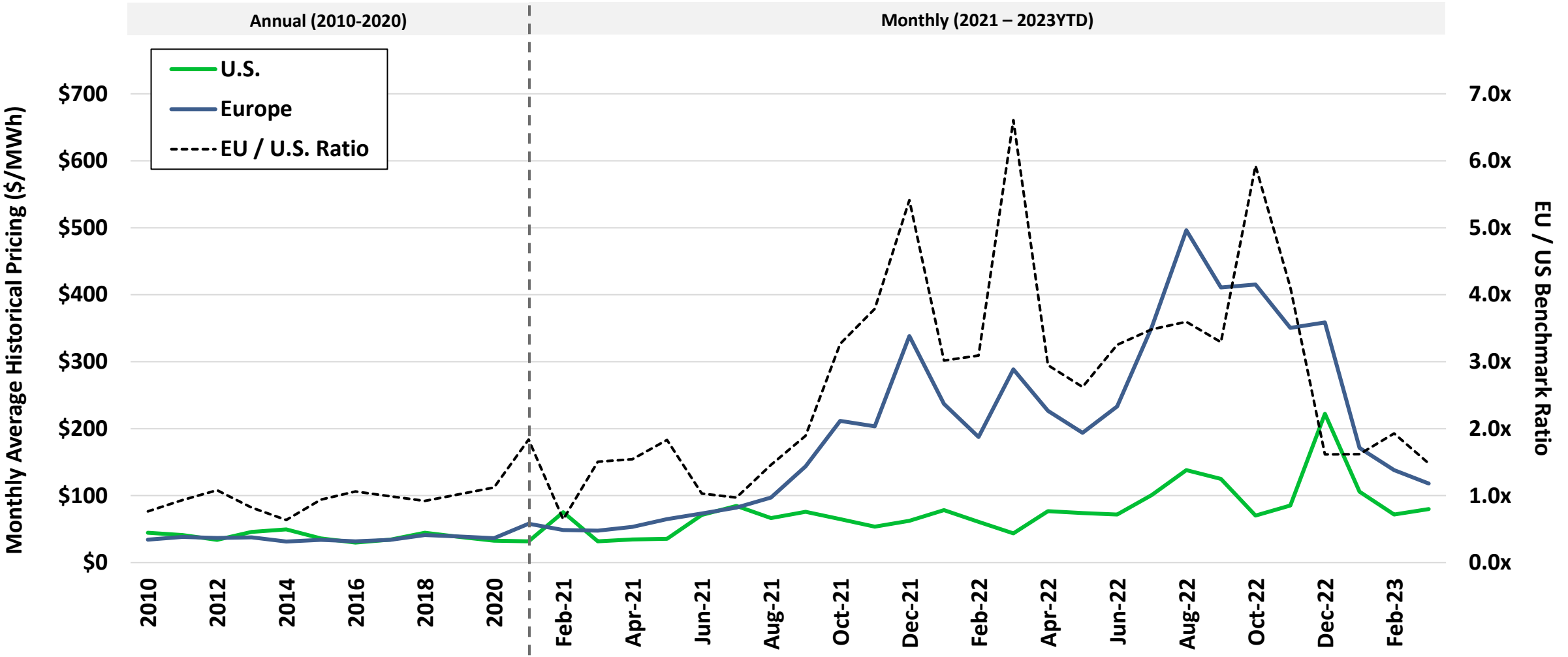
Household Electricity Prices versus Wind and Solar Penetration in Europe by Country (2H 2021)



Source: Eurostat, JPMAM (2022)

The consequences of a singular focus on renewables without simultaneously continuing to invest at appropriate levels in domestic hydrocarbon supplies, creates a financial tax on society

Average monthly European electricity prices relative to U.S. electricity [1]

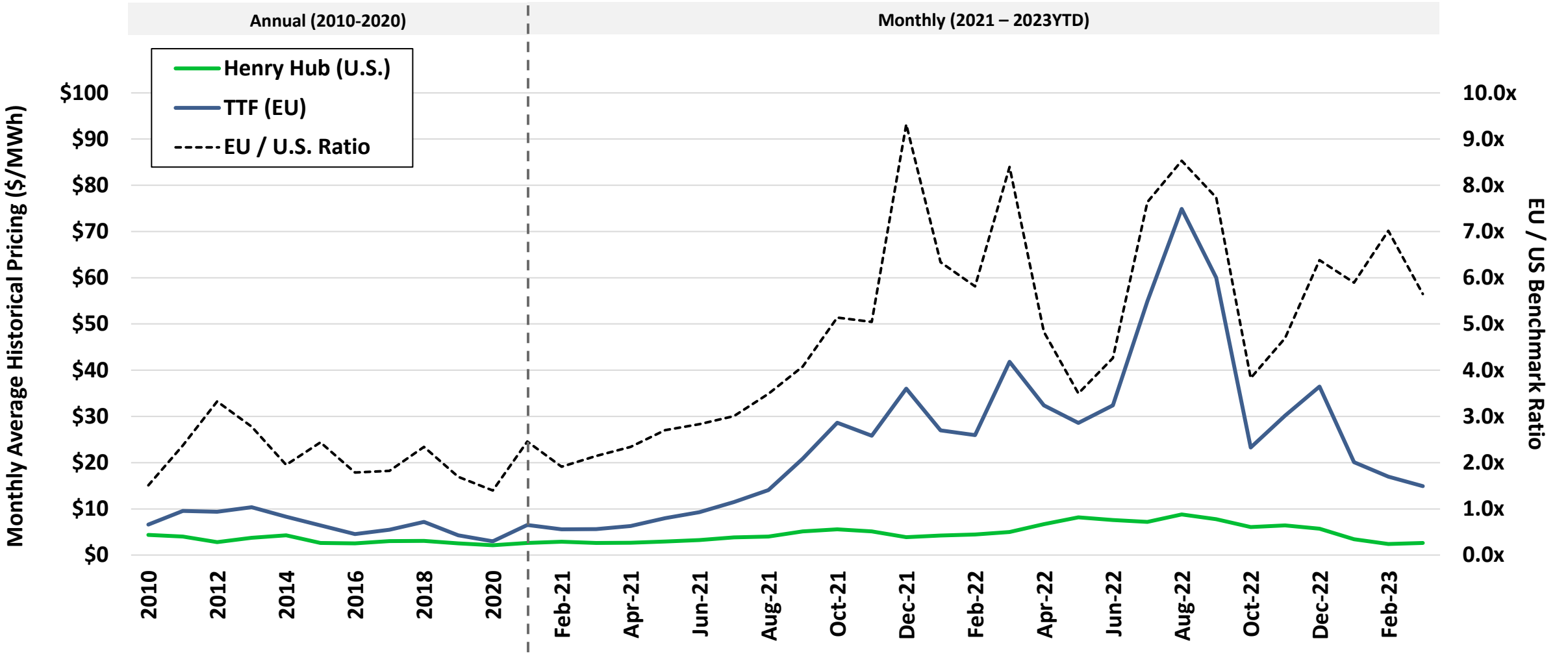


Source: EIA, Bloomberg.

(1) Europe benchmark reflects average of France, Germany, UK and Netherlands baseload power sales. U.S. reflects average of main wholesale electricity hubs.

The consequences of a singular focus on renewables without simultaneously continuing to invest at appropriate levels in domestic hydrocarbon supplies, creates a financial tax on society

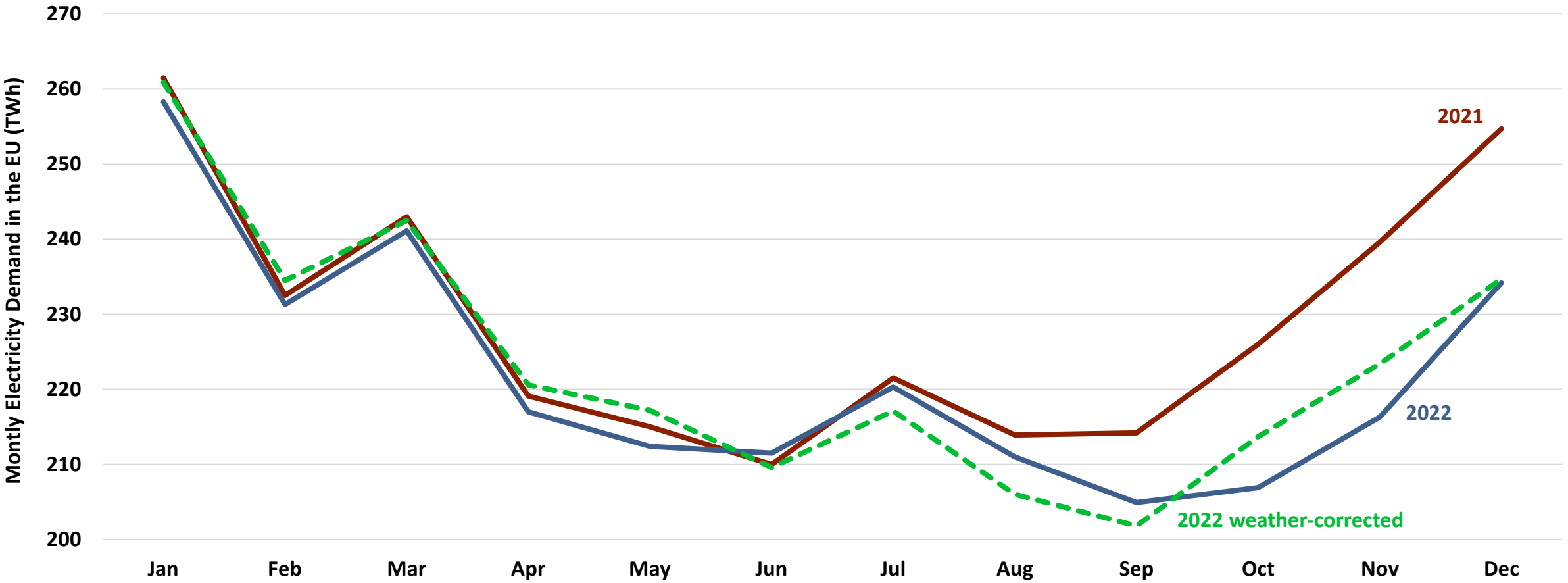
European natural gas prices relative to U.S. natural gas prices



Source: EIA, Bloomberg.

Russia's invasion of Ukraine yielded substantially different results than many had predicted

Monthly electricity demand in the European Union (2021-2022)

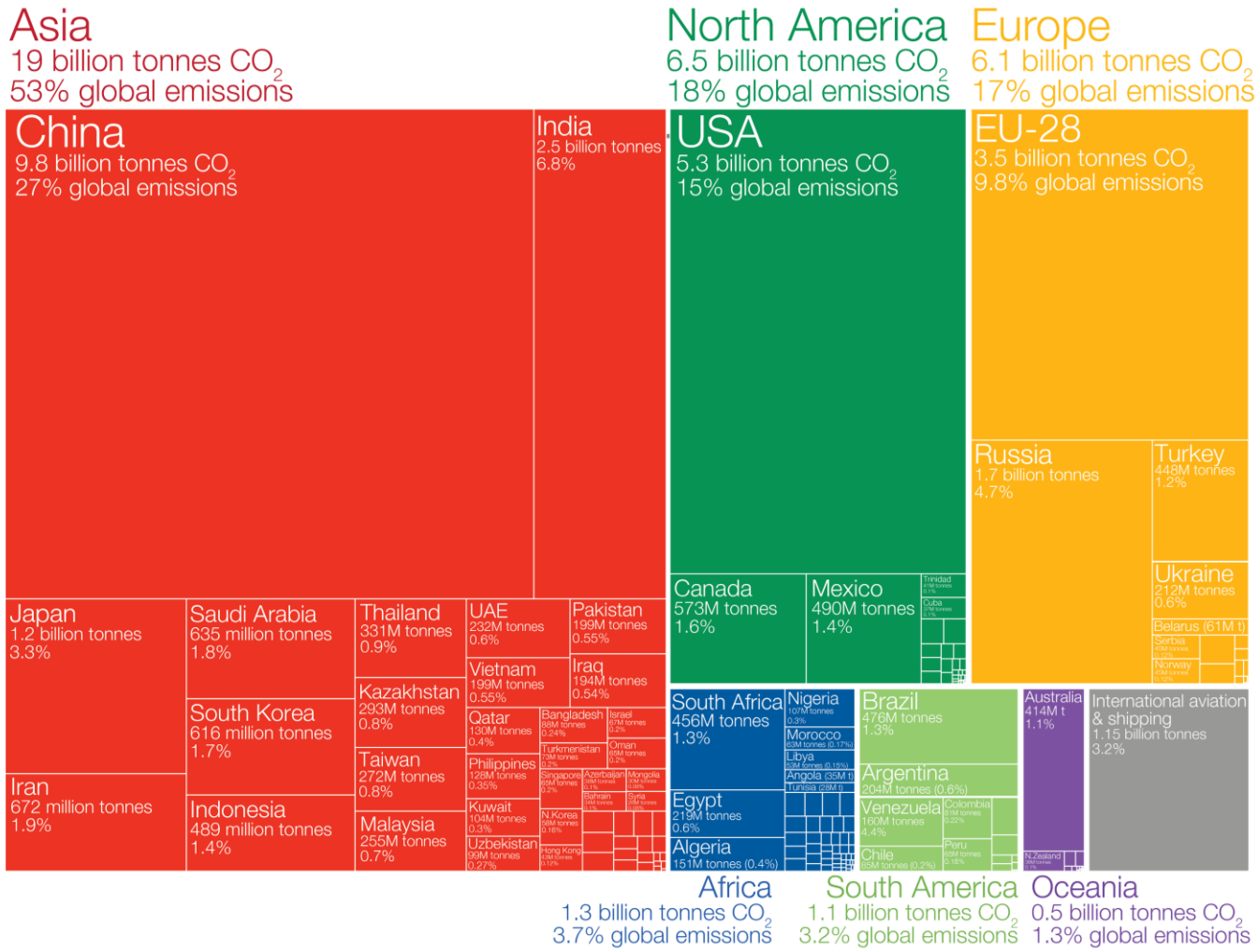


IEA: ***"Our analysis shows that electricity demand in the European Union in 2022 was in fact shaped predominantly by a combination of a milder winter, a hotter summer and price effects"***

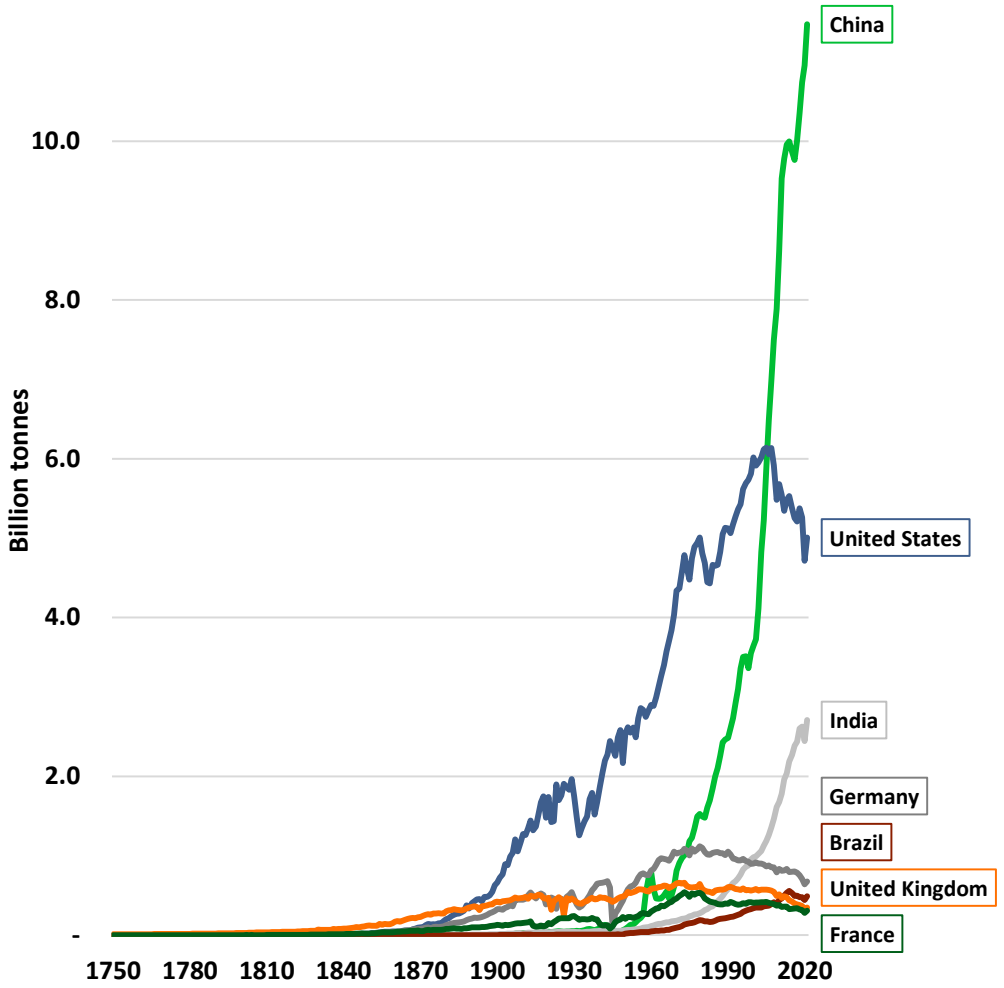
Source: IEA.

Western countries are spending considerable time and money to transition to a lower carbon economy – given increasing emissions in Asia, will it make a material difference?

Who emits the most CO_2?



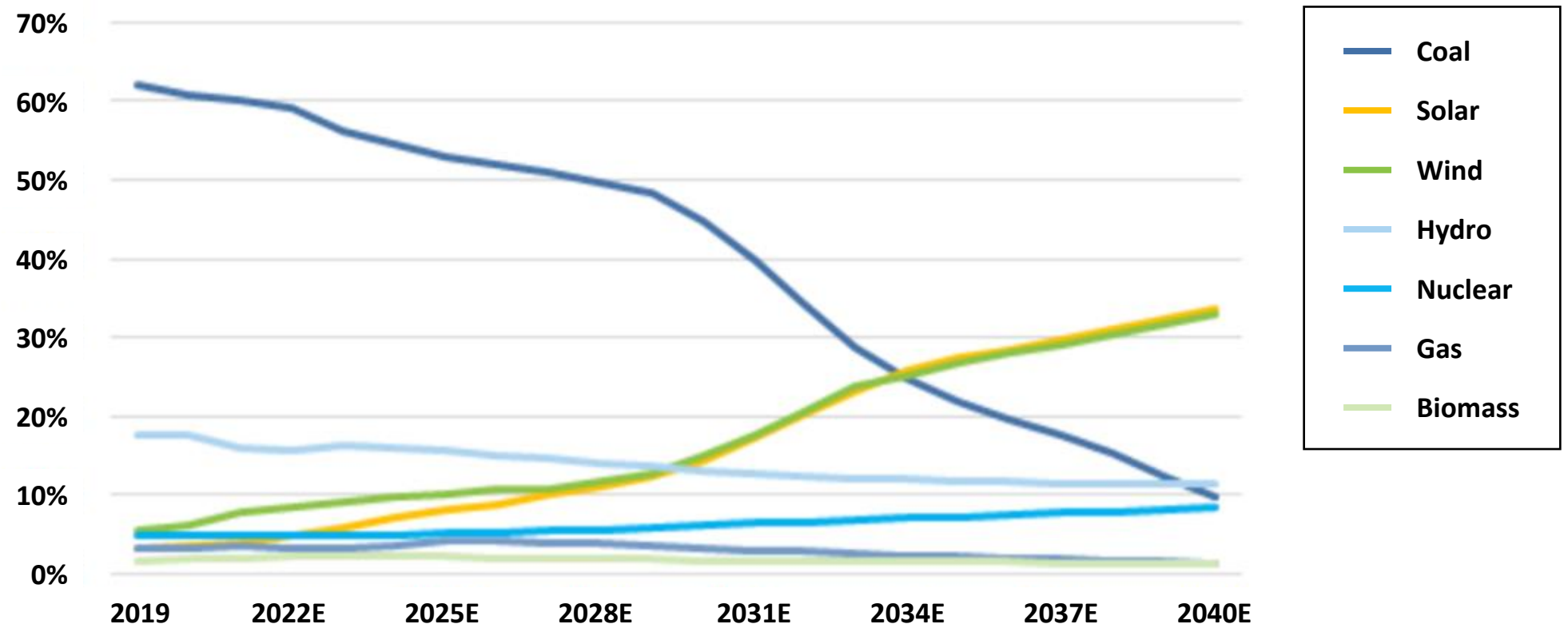
Annual CO_2 emissions by country



Source: Our World in Data, Global Carbon Project (GCP).

China has been and will continue to lead the world in construction of renewable power generation

China's power generation mix forecast

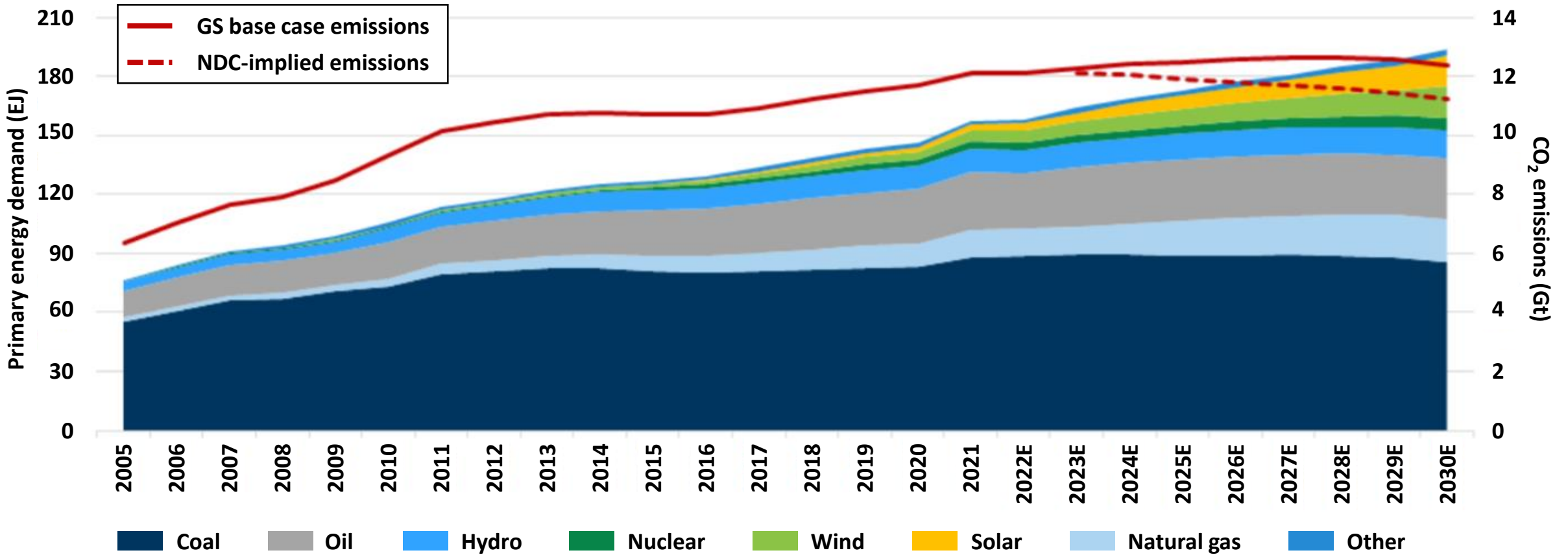


China's expansion of clean technologies is expected to exceed its government target and could help accelerate its path towards energy independence

Source: Wind, CEC, Goldman Sachs Global Investment Research.

…which should provide optimism around their emissions in the coming years

China's energy demand and emissions forecast

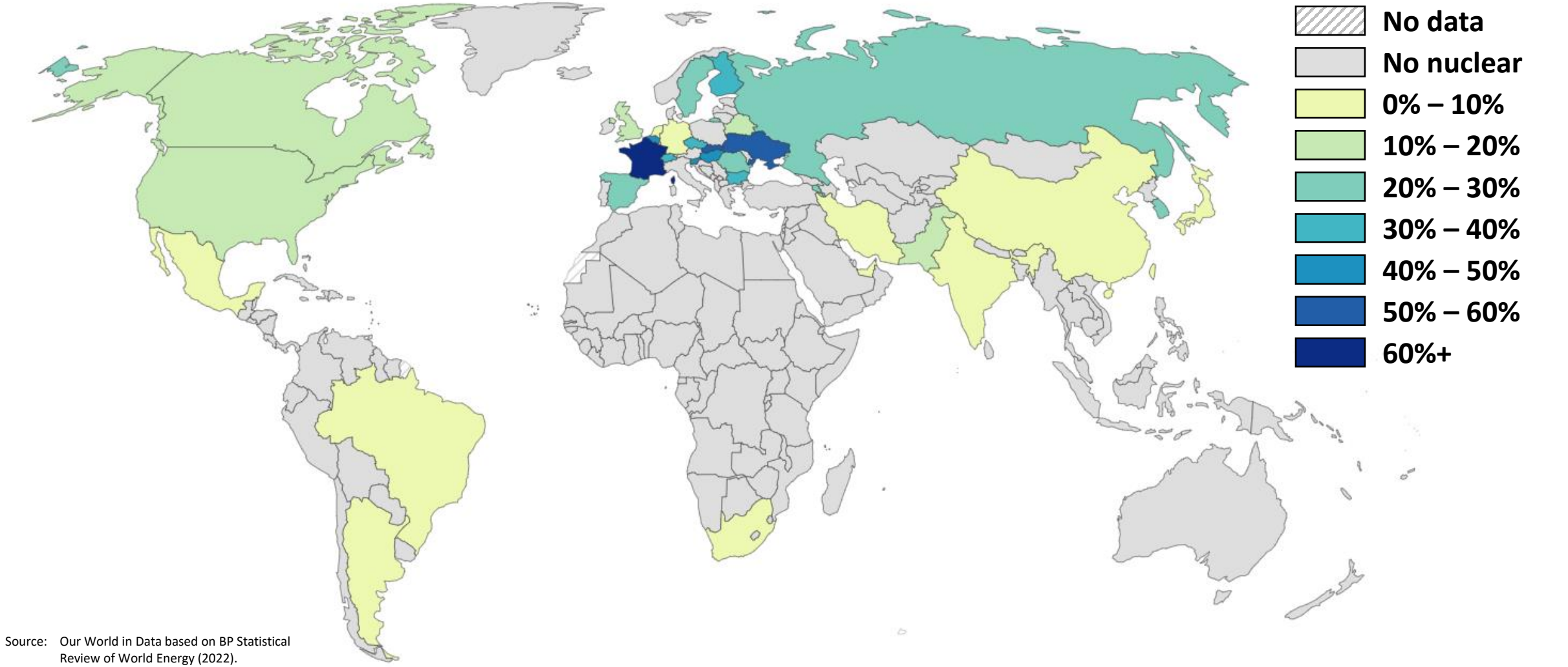


Forecasts for China's emissions pathway through 2030 indicate that emissions will peak by 2028 and emissions per GDP will decline by ~60% vs. 2005

Source: NBS, UNFCCC, IEA, European Commission Joint Research Centre, bp Statistical Review of World Energy, Goldman Sachs Global Investment Research.

From an environmental, energy density and performance perspective, nuclear seems to be a near ideal energy source – why has it stalled out in the US at about 10% of energy production?

Share of electricity production from nuclear in 2022



Source: Our World in Data based on BP Statistical Review of World Energy (2022).

Many believe that Small Modular Reactors (SMRs) can play a key role goal in providing safe, clean, and affordable nuclear power options.

NuScale Power Reactor Building using SMRs

Nuclear power plants in the US produced 809 billion kWh of electricity; the highest generation ever recorded

1 uranium pellet

produces as much energy as…

120 gallons of oil,

1 ton of coal, or

17,000 cubic feet of natural gas

Source: Nuclear Energy Institute and NuScale