Balancing Energy Security, Affordability and Decarbonization

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***Ettore Marjorana Foundation and Centre for Scientific Culture**, August 20-24, 2023* (Erice, Italy)

Institute for Economic Affairs, August 30, 2023 (London)

Parliamentary Intelligence-Security Forum

31st August - 1st September 2023 (Westminster, London)

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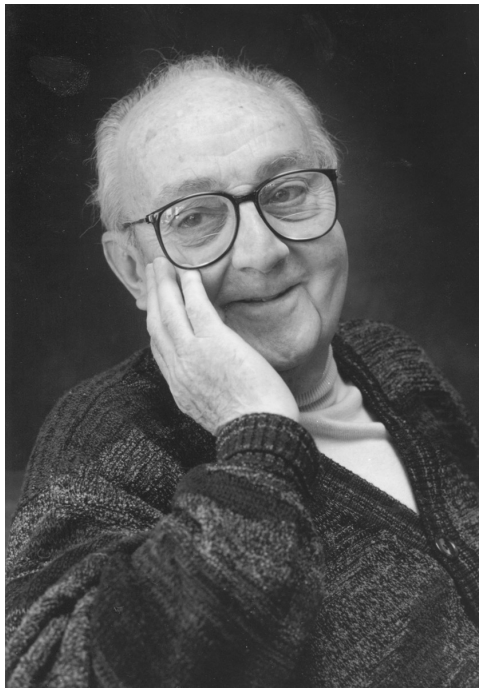
"All Models are Wrong, but Some are Useful"

George G.P. Box
British Statistician, 1919-2013



….Or Exactly How Hard is Net Zero When Balancing Energy Security, Affordability and Decarbonization?

Large Uncertainties Even in Business-as-Usual Forecasts

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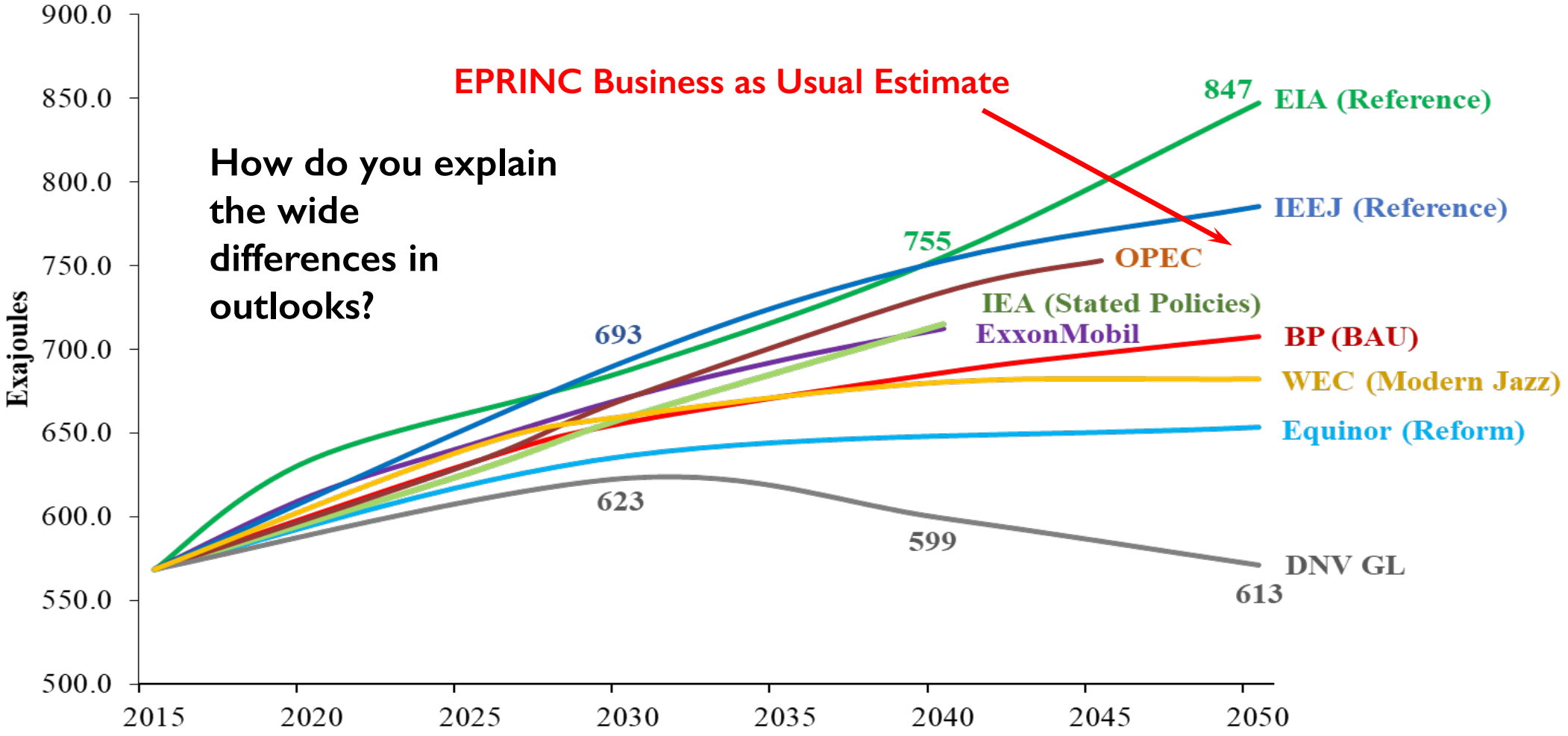

Note: Exajoule (EJ) is a comprehensive unit of energy, roughly equivalent to 1.05 quadrillion British thermal units (quads). One EJ equals 10^{18} (one quintillion) joules, and one joule equals the amount of work done on a body by a 1 Newton force that moves the body over 1 meter. One exajoule per year = 447,000 barrels of oil equivalent per day.

It's Hard to Predict Non-OECD Demand: China Case

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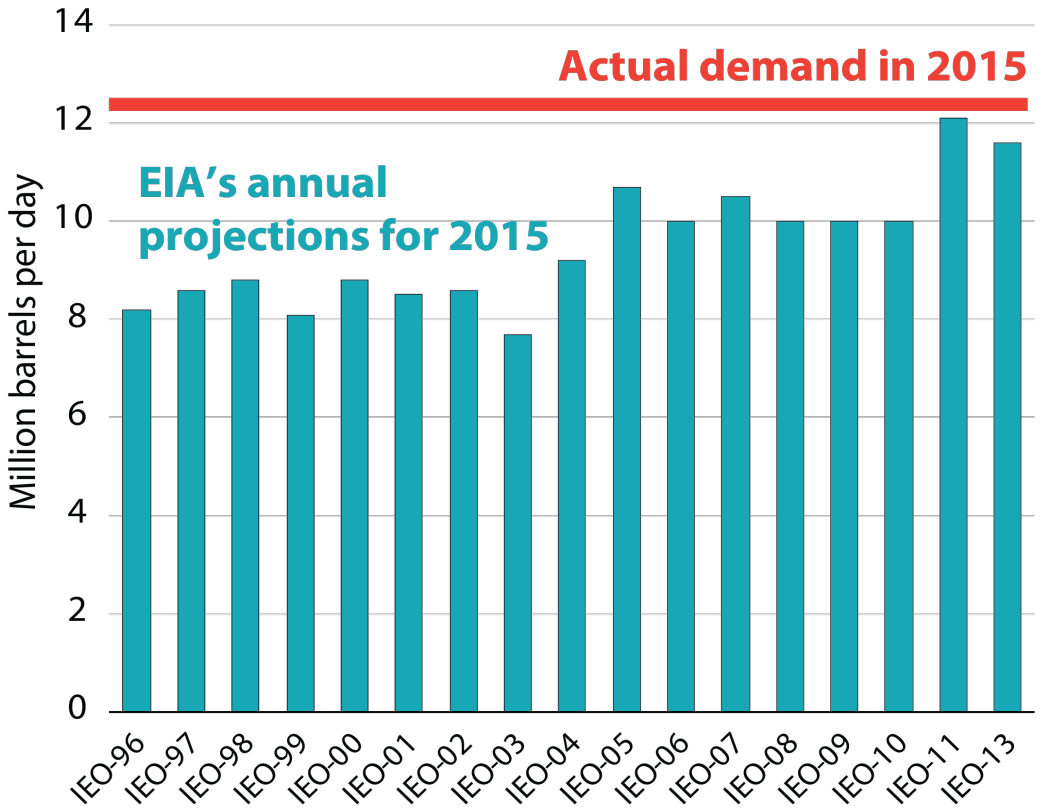
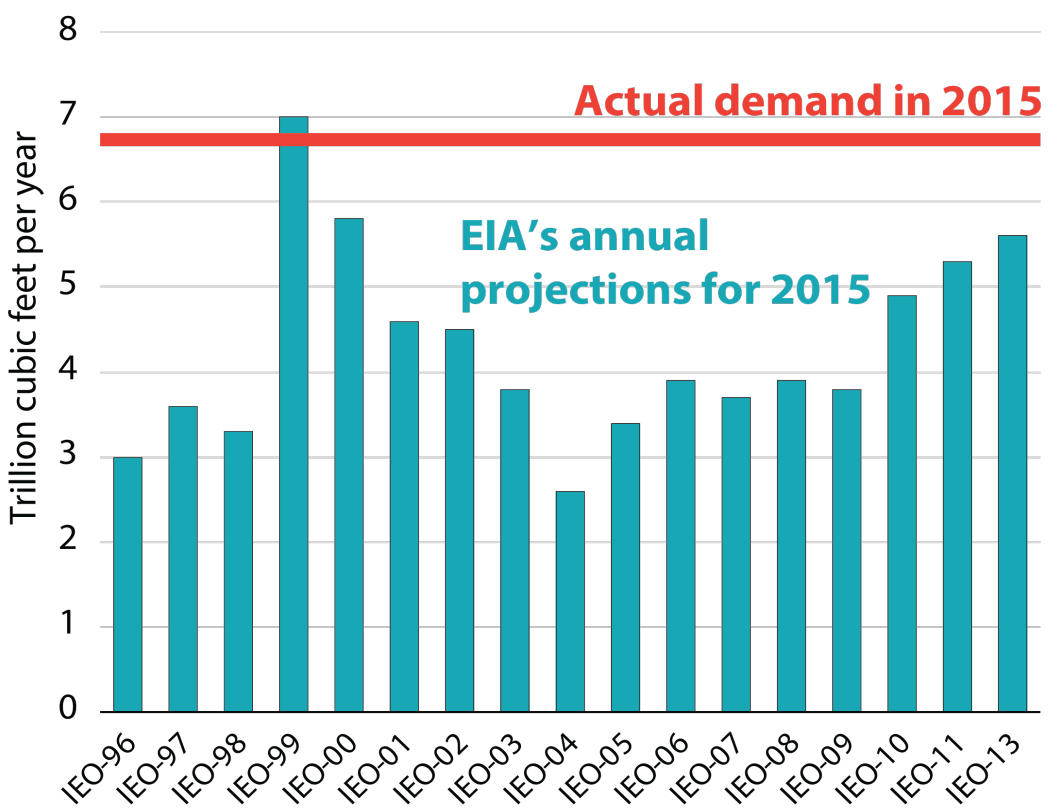
China's Liquids Demand in 2015: Projected vs. Actual



China's Gas Demand in 2015: Projected vs. Actual



Source: U.S. EIA's International Energy Outlooks (IEO) 1996-2013, 2016, EPRINC.

Note: On March 27, 2023, CNPC announced that 2023 petroleum demand would be 756 milion metric tons (mt) . Earlier forecasts for 2023 were 690mt (2018), 705mt (2019) and 740mt (2020). Bloomberg

Ambition vs. Reality

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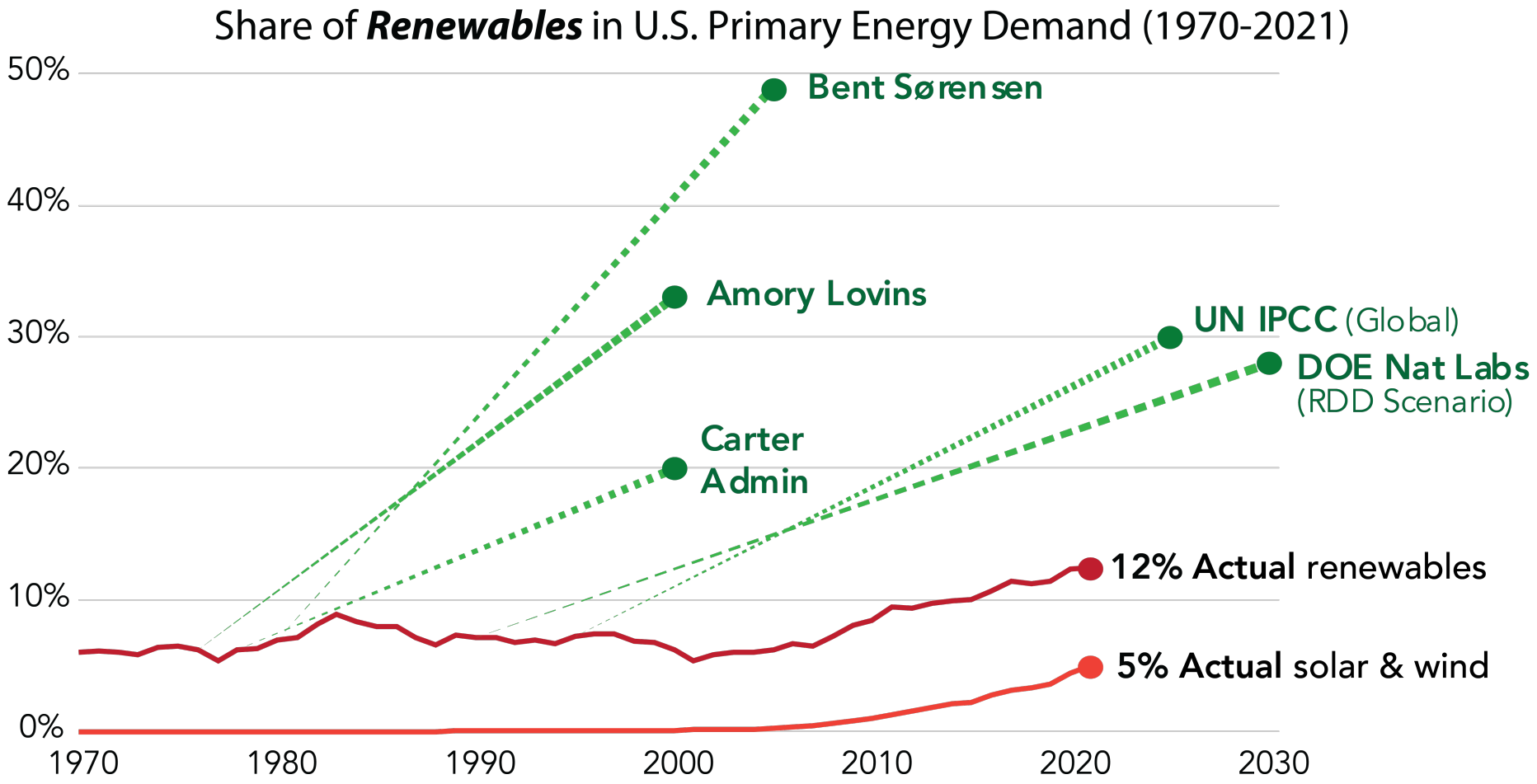

Worldwide experience is similar:

According to Bloomberg NEF, direct government subsidies and payments for wind, solar and other modern renewable fuels amounted to $5 trillion over the last 20 years. It has yielded a total contribution to worldwide primary energy demand of approximately 5%.

Sources: Vaclav Smil (original chart from *JPMorgan 2021 Annual Energy Paper)*; Amory Lovins, "Energy Strategy: The Road Not Taken?" (1976); "President Jimmy Carter's Remarks at White House Solar Panel Dedication Ceremony, 1979"; DOE, *The Potential of Renewable Energy: An Interlaboratory White Paper* (1990); *IPCC Second Assessment: Climate Change 1995.*
Note: Renewables include wind, solar, hydropower, geothermal, biomass.

How Difficult is Net Zero?

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1. Efficiency & Electrification

Consumer energy investment and use behaviors change

- 300 million personal EVs
- 130 million residences with heat pump heating

Industrial efficiency gains

- Rapid productivity gain
- EAF/DRI steel making

2. Clean Electricity

Wind and solar

- Rapidly site 10s-100s of GW per year, sustain for decades
- 3x to 5x today's transmission

Nuclear

- In RE- scenario site up to 250 new 1-GW reactors (or 3,800 SMRs).
- Spent fuel disposal.

NGCC-CCS

- In RE-, 300+ plants (@750 MW)

Flexible resources

- Combustion turbines w/high H_2
- Large flexible loads: electrolysis, electric boilers, direct air capture
- 50 - 180 GW of 6-hour batteries

3. Zero-Carbon Fuels

Major bioenergy industry

- 100s of new conversion facilities
- 620 million t/y biomass feedstock production (1.2 Bt/y in E- B+)

H_2 and synfuels industries

- 8-19 EJ H_2 from biomass with CCS (BECCS), electrolysis, and/or methane reforming
- Largest H_2 use is for fuels synthesis in most scenarios

4. CO_2 capture & storage

Geologic storage of 0.9 – 1.7 $GtCO_2/y$

- Capture at ~1,000+ facilities
- 21,000 to 25,000 km interstate CO_2 trunk pipeline network
- 85,000 km of spur pipelines delivering CO_2 to trunk lines
- Thousands of injection wells

5. Non-CO_2 Emissions

Methane, N_2O, Fluorocarbons

- 20% below 2020 emissions (CO_{2e}) by 2050 (30% below 2050 REF).

6. Enhanced land sinks

Forest management

- Potential sink of 0.5 to 1 $GtCO_{2e}/y$, impacting ½ or more of all US forest area (≥ 130 Mha).

Agricultural practices

- Potential sink ~0.20 $GtCO_{2e}/y$ if conservation measures adopted across 1 – 2 million farms.

Larson, et al, Net-Zero America: Potential Pathways, Infrastructure, and Impacts. See https://environmenthalfcentury.princeton.edu/sites/g/files/toruqf331/files/2020-12/Princeton_NZA_Interim_Report_15_Dec_2020_FINAL.pdf

EV PRODUCTION COMES WITH A LARGE CARBON FOOTPRINT

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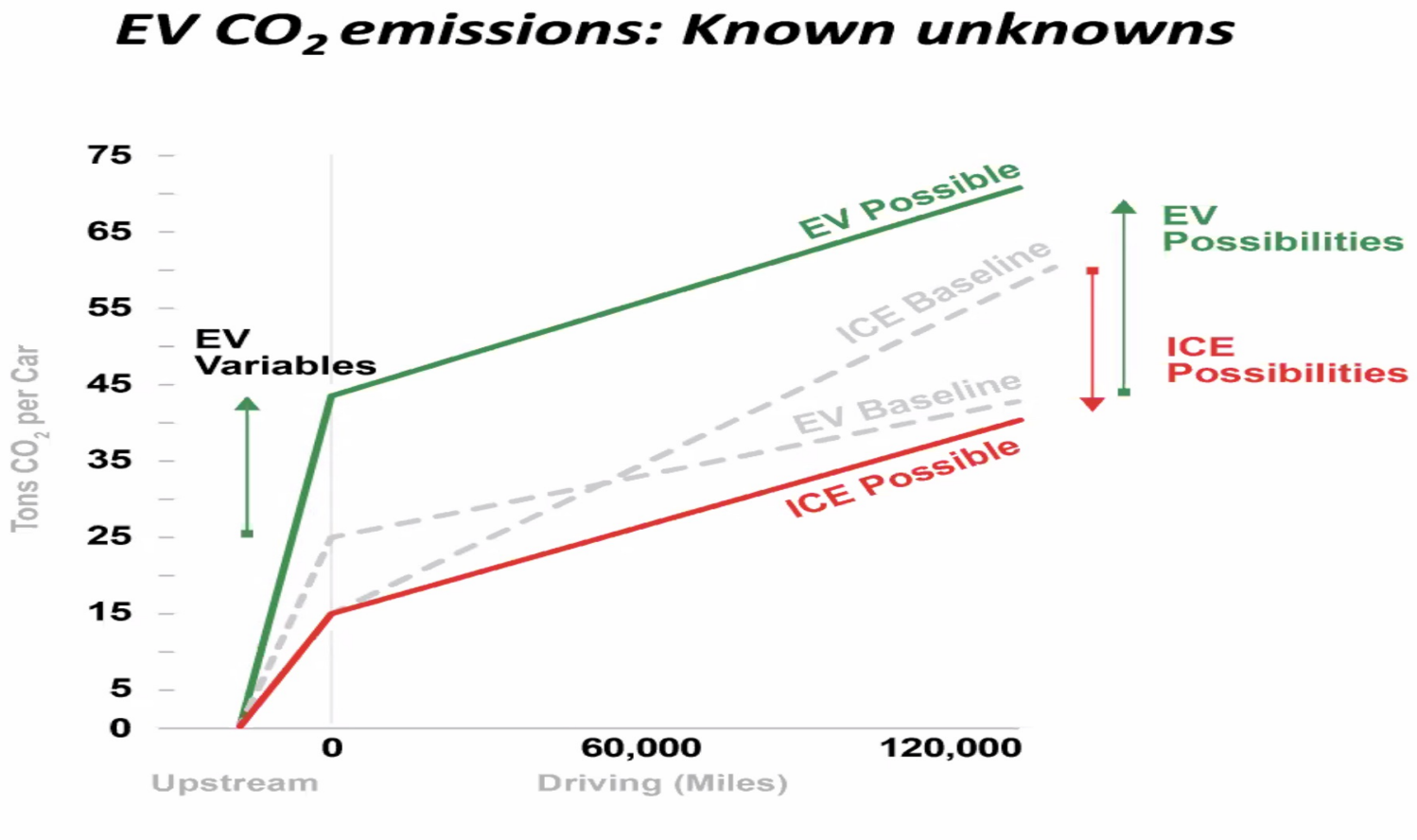

Mills, Mark. Evs the Impossible Dream. *see* [*https://manhattan.institute/article/electric-vehicles-for-everyone-the-impossible-dream*](https://manhattan.institute/article/electric-vehicles-for-everyone-the-impossible-dream)

Net Zero Requires Wide Range of Measures

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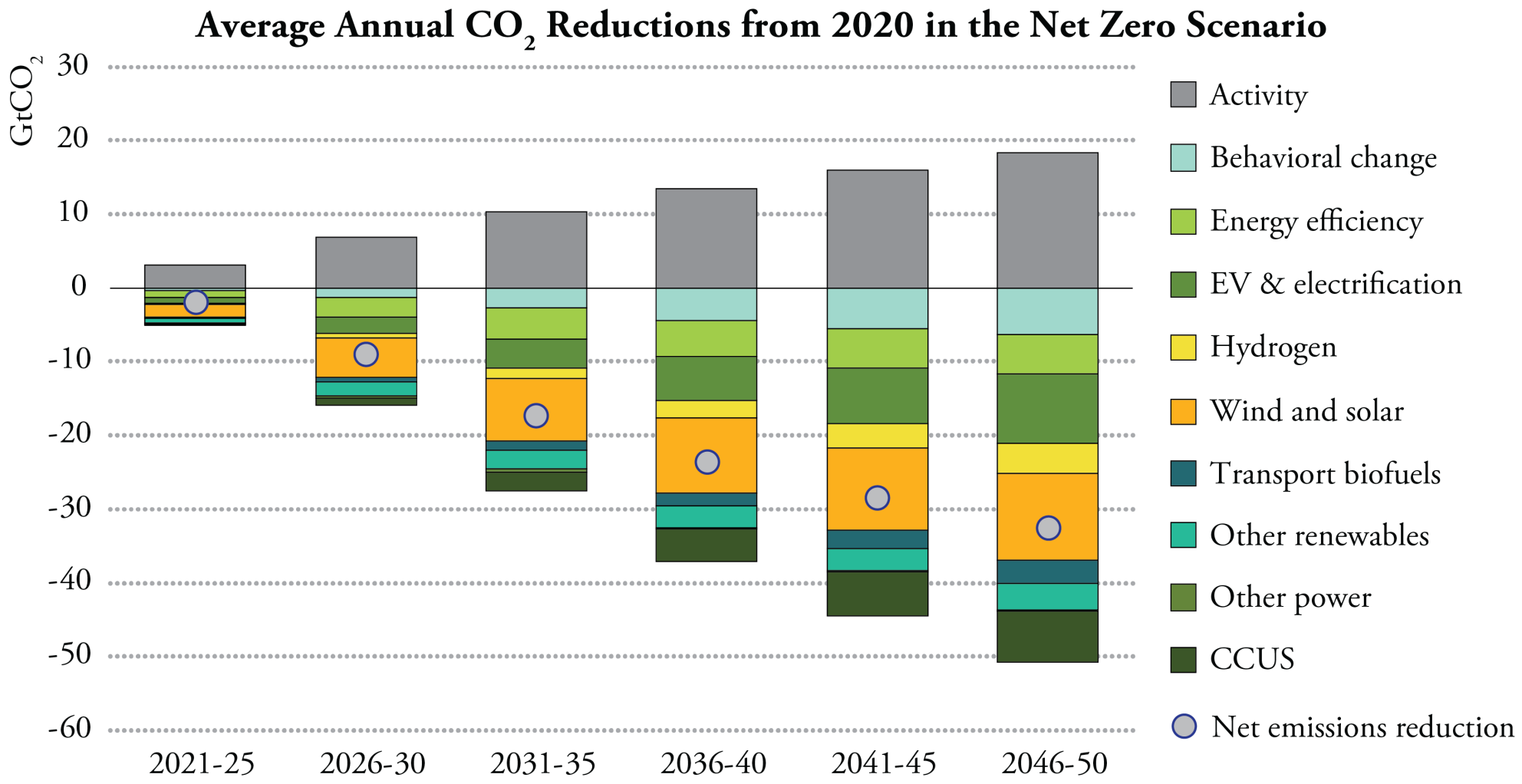

Source: IEA, *Net Zero by 2050 (2021)*.

Energy Transition is Hard & Rare

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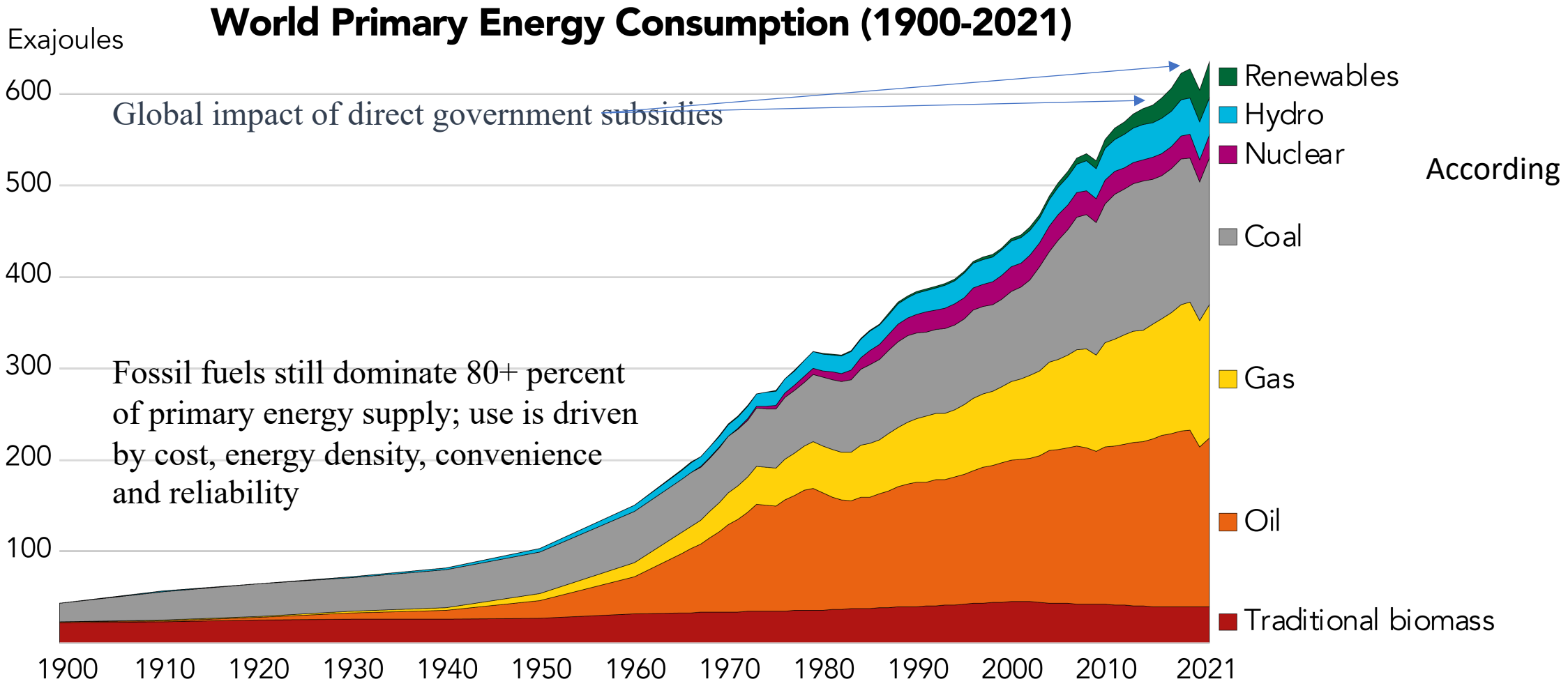

According

Source: Energy Policy Research, Vaclav Smil, BP

MAIN PILLARS OF MODERN CIVILIZATION RELY ON FOSSIL FUELS

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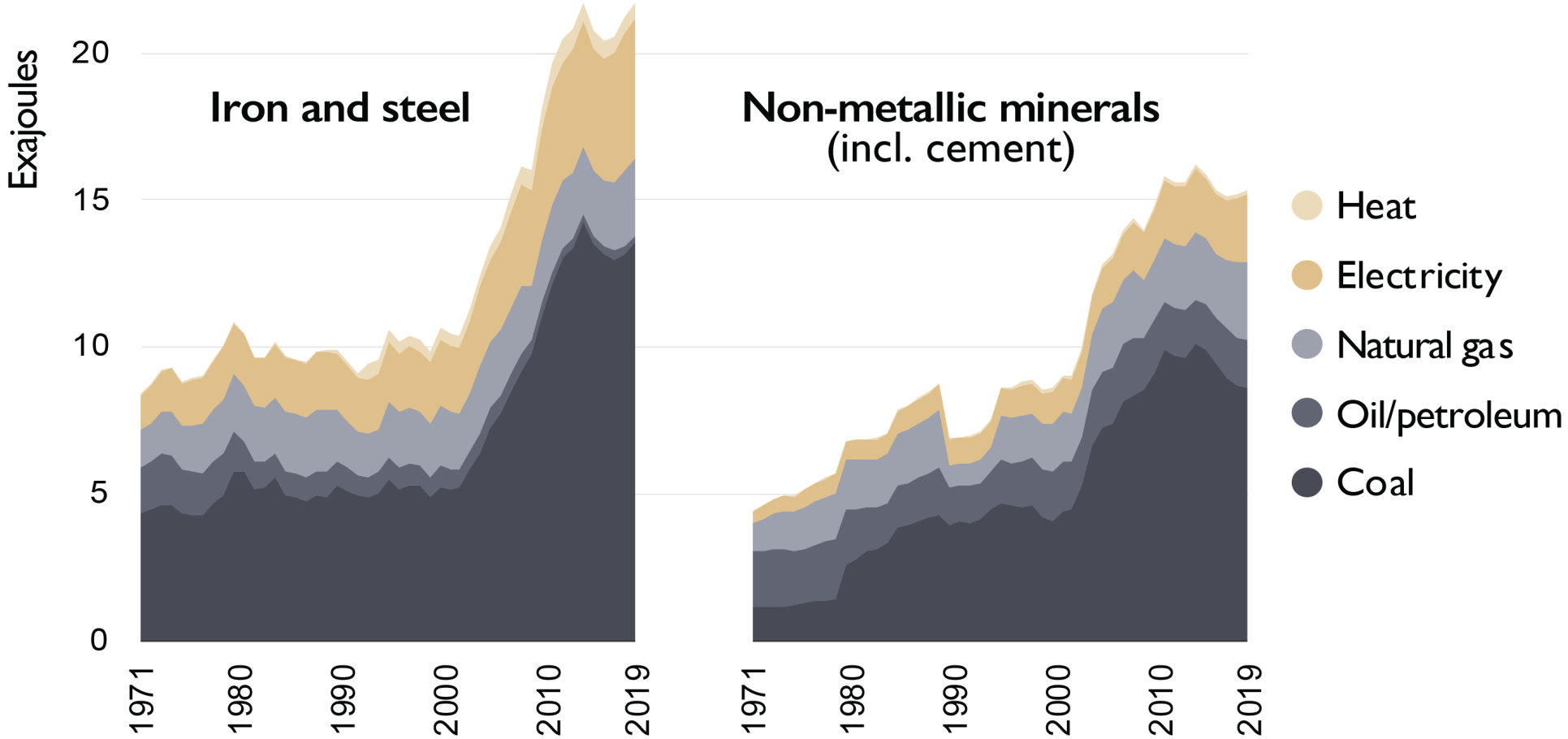
It's extremely hard to displace the direct use of coal (and other fossil sources) in the global production of steel and cement, which the modern society depends on.



An Exajoule/year equals 447,000 bbl of oil/day.

Source: EPRINC analysis, IEA data

System Power Cost Rise with Intermittent Energy Sources

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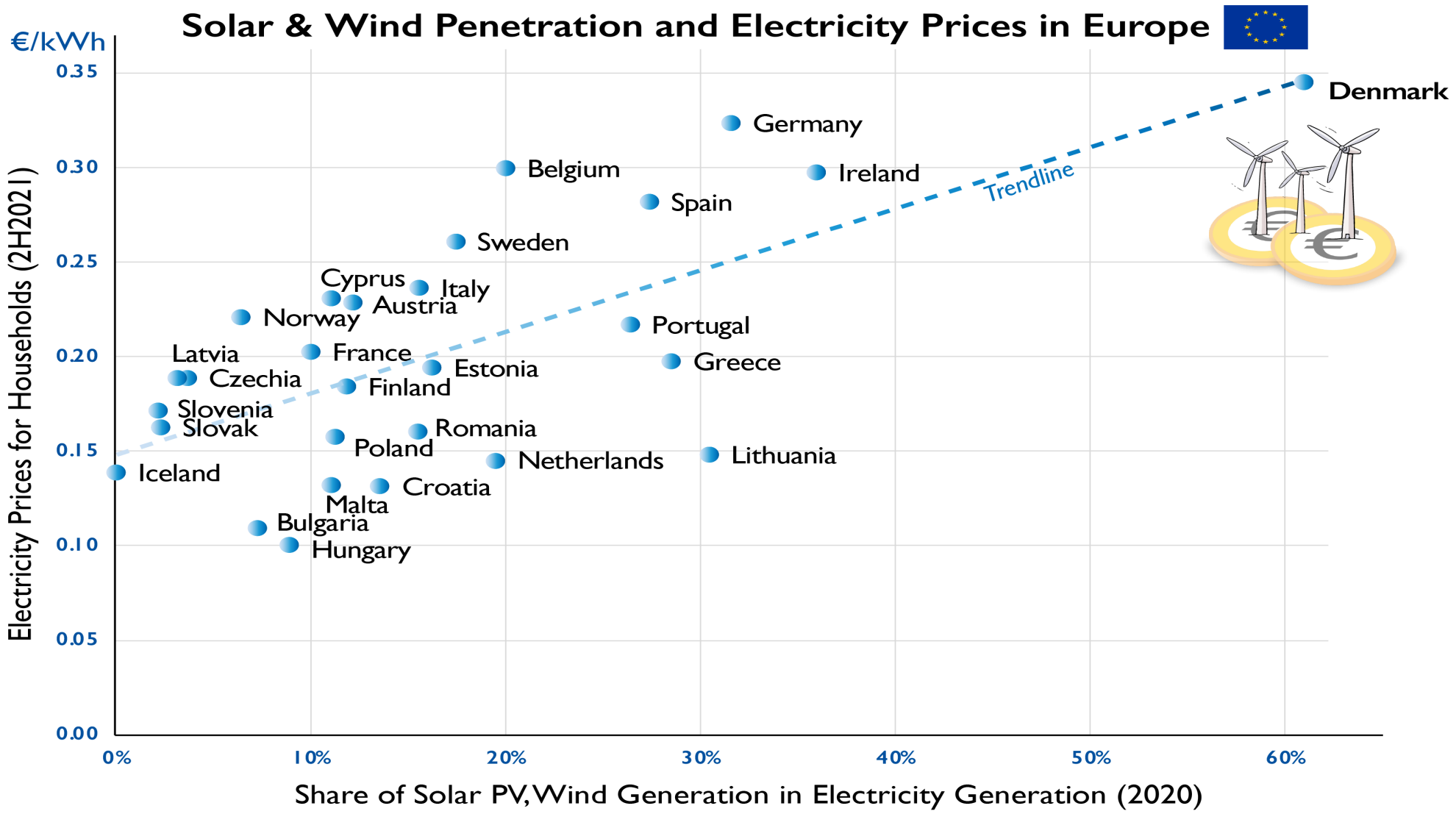

Data sources: Eurostat, IEA World Energy Statistics

Energy Supply and Human Development Index

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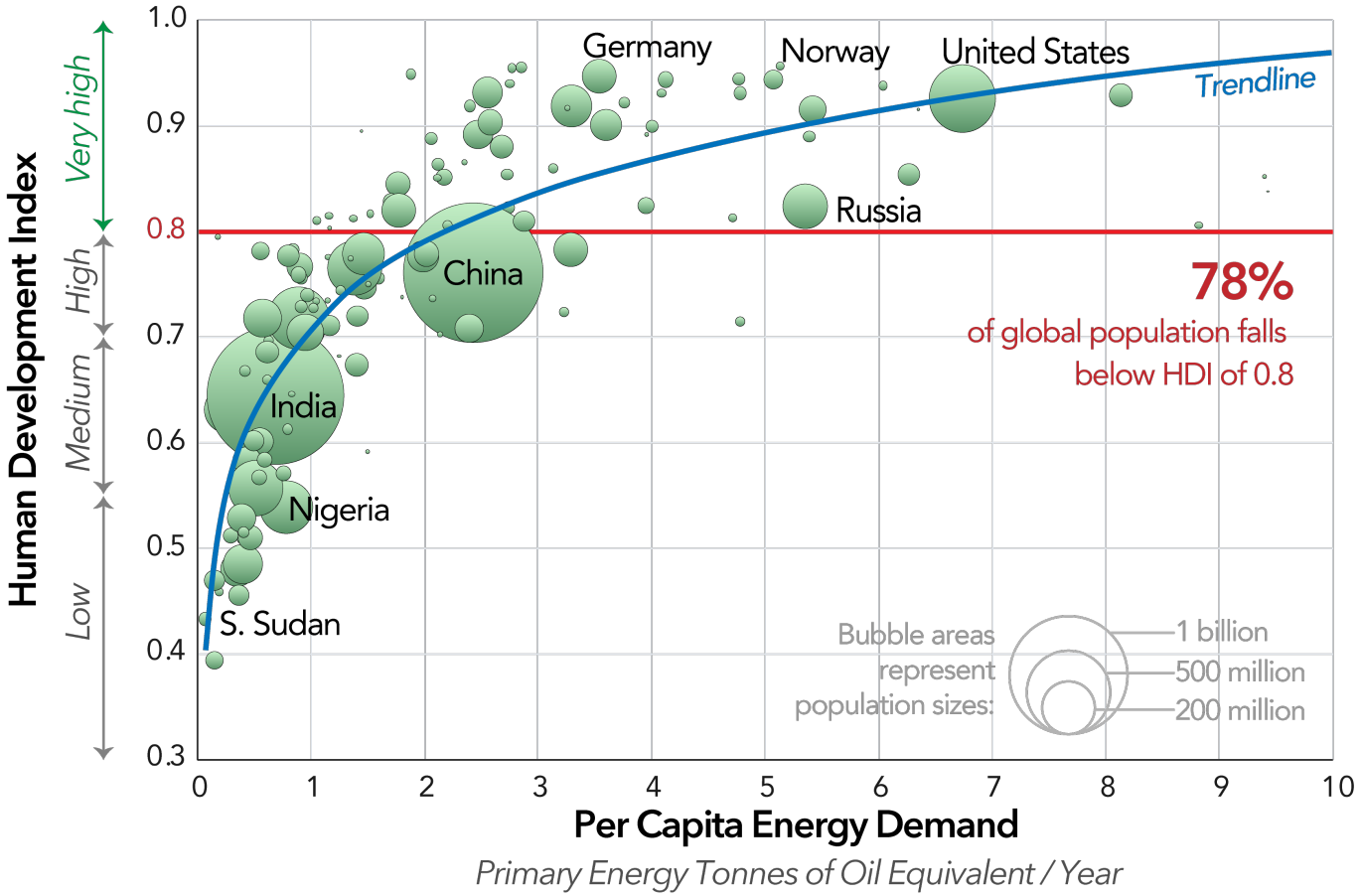
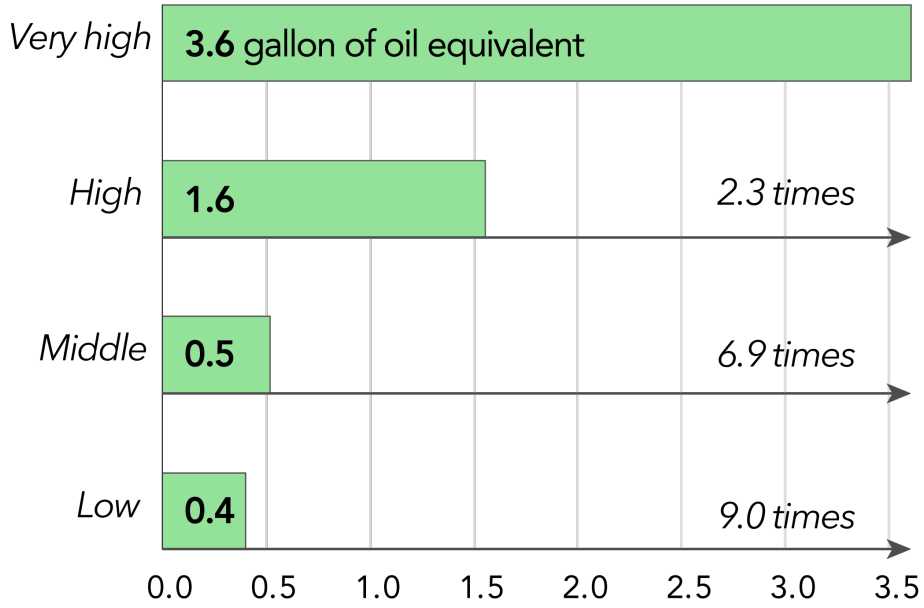
Per Capita Energy Demand and Human Development Index (2019)



Daily per Capita Energy Demand by Human Development Index (2019)

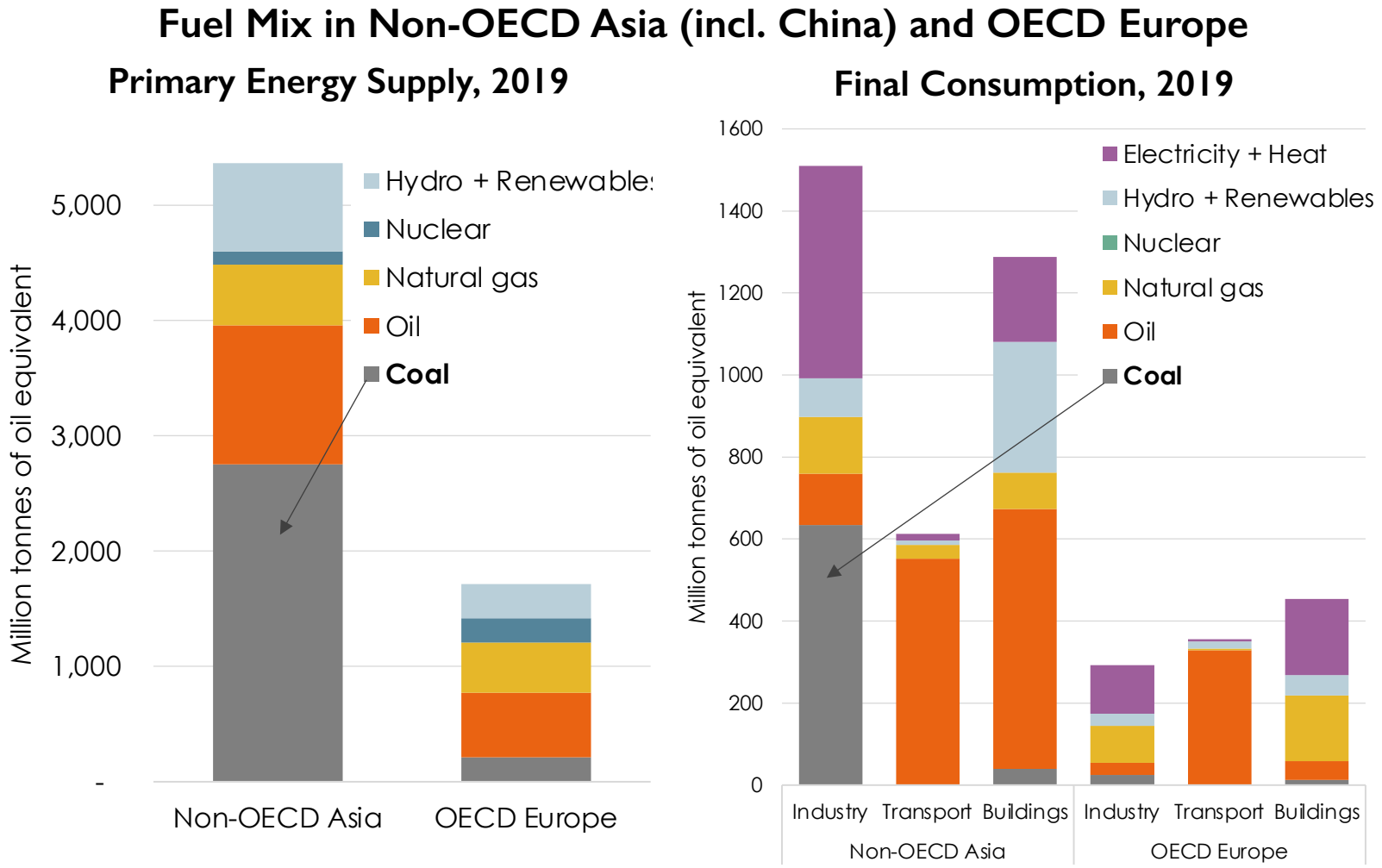


Source: Energy Policy Research

Different Pictures in Europe and Asia

Primary coal supply in non-OECD Asia (incl. China and India) was 2,751 Mtoe, 60% higher than the entire primary energy supply of OECD Europe.

In final consumption, 94% of non-OECD Asia coal use is consumed in industry, incl. “harder-to-abate” sectors like cement and steel.



Source: EPRINC figures based on IEA data

Electrification Trends: Non-OECD Long Way to Go

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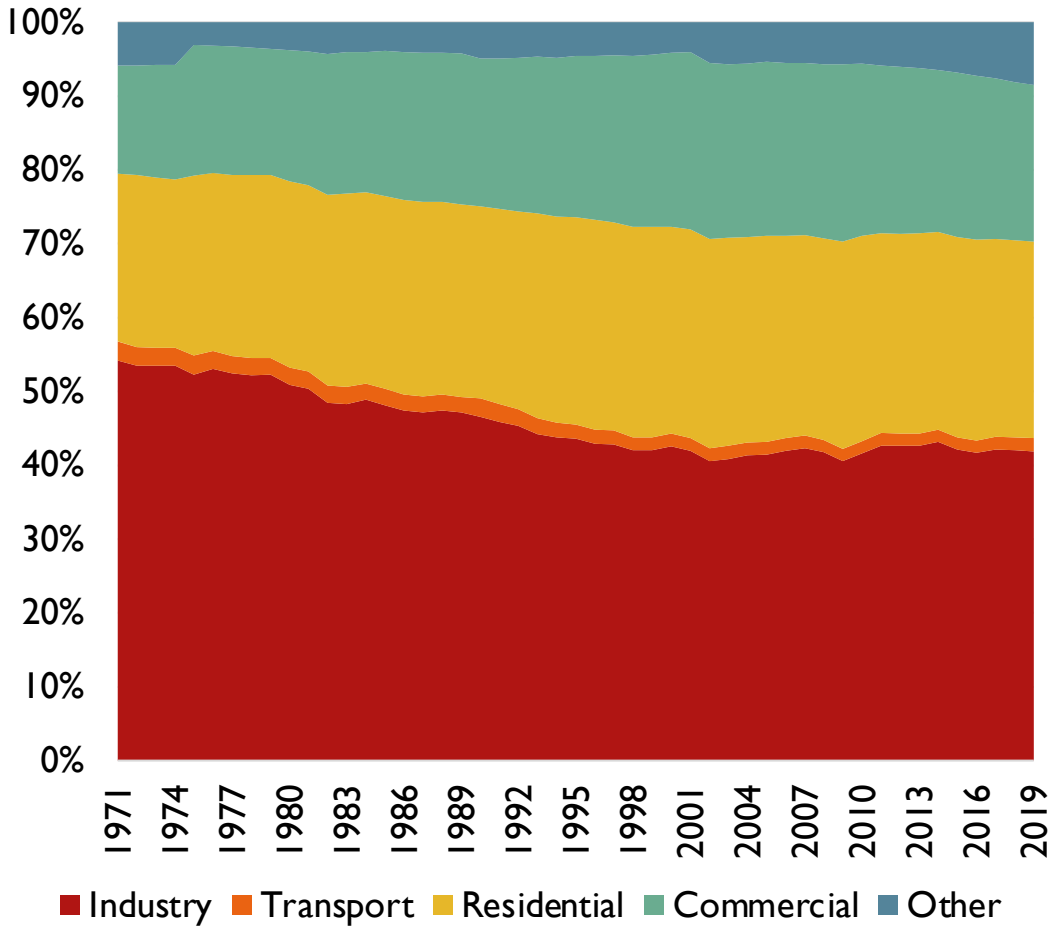
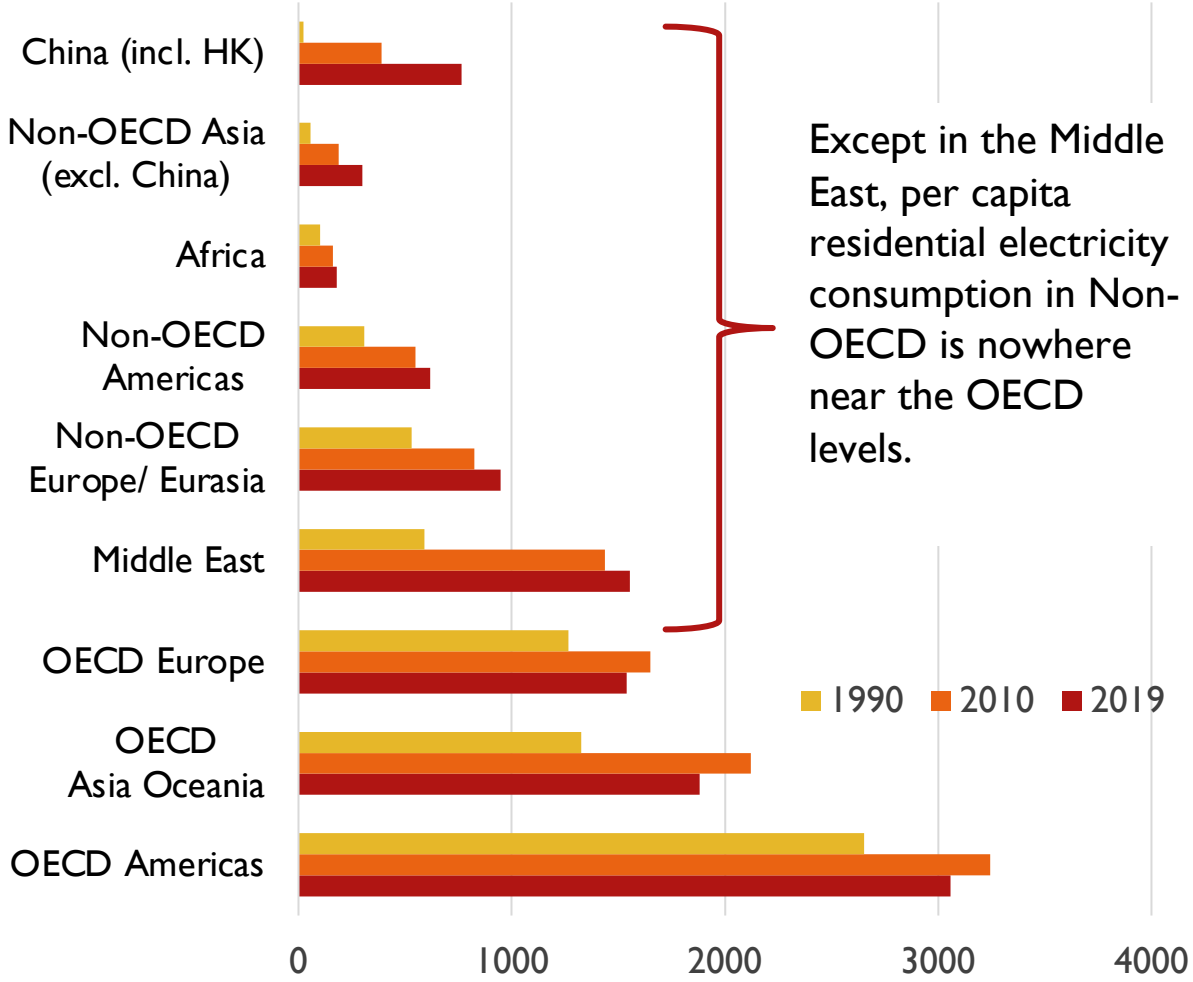
Global electricity consumption by end-use sector, 1971-2019



Source: Energy Policy Research, IEA WEB

Residential generation, kWh per capita



Non-OECD: Energy Must Grow to Meet Economic Progress

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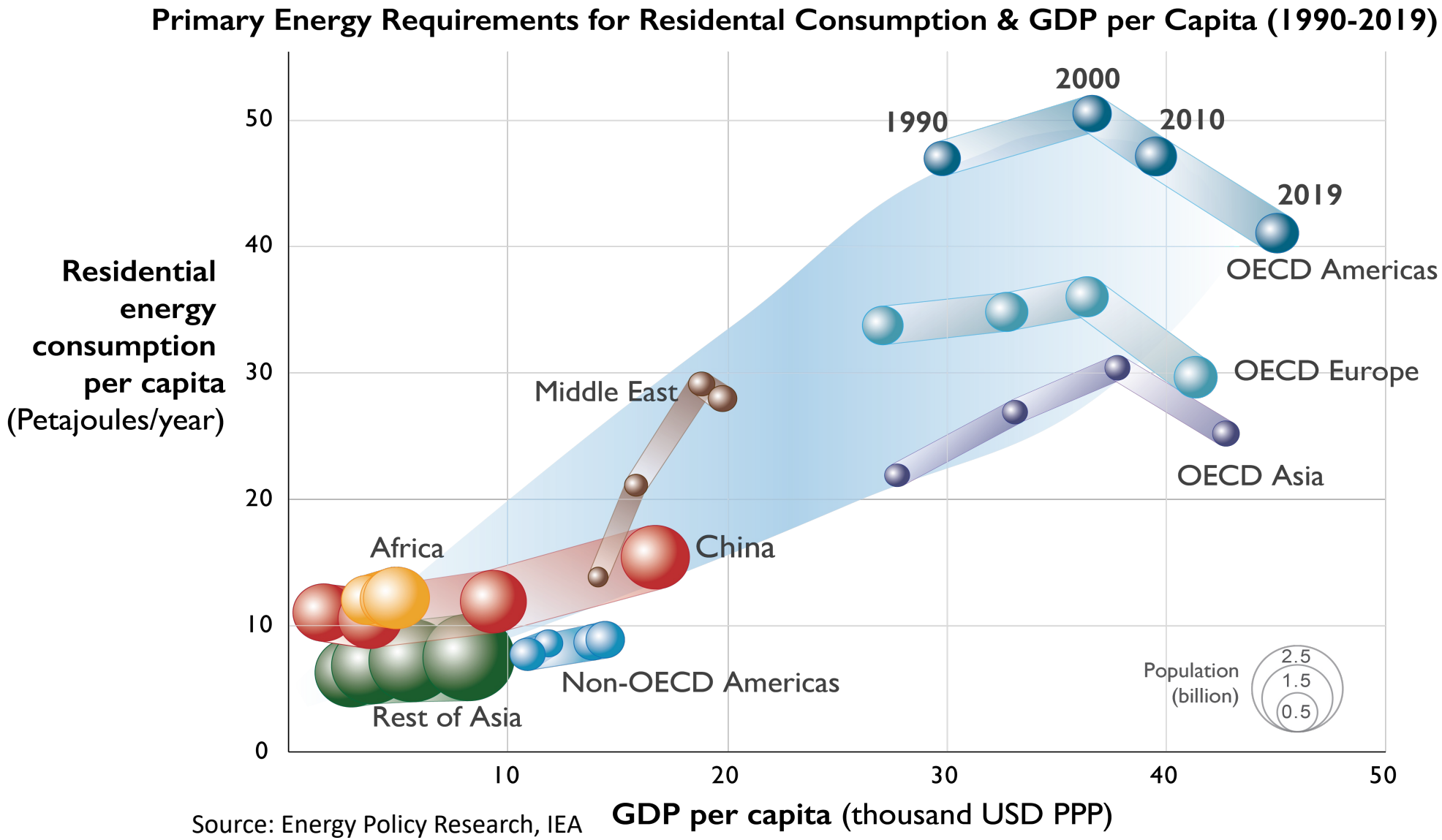
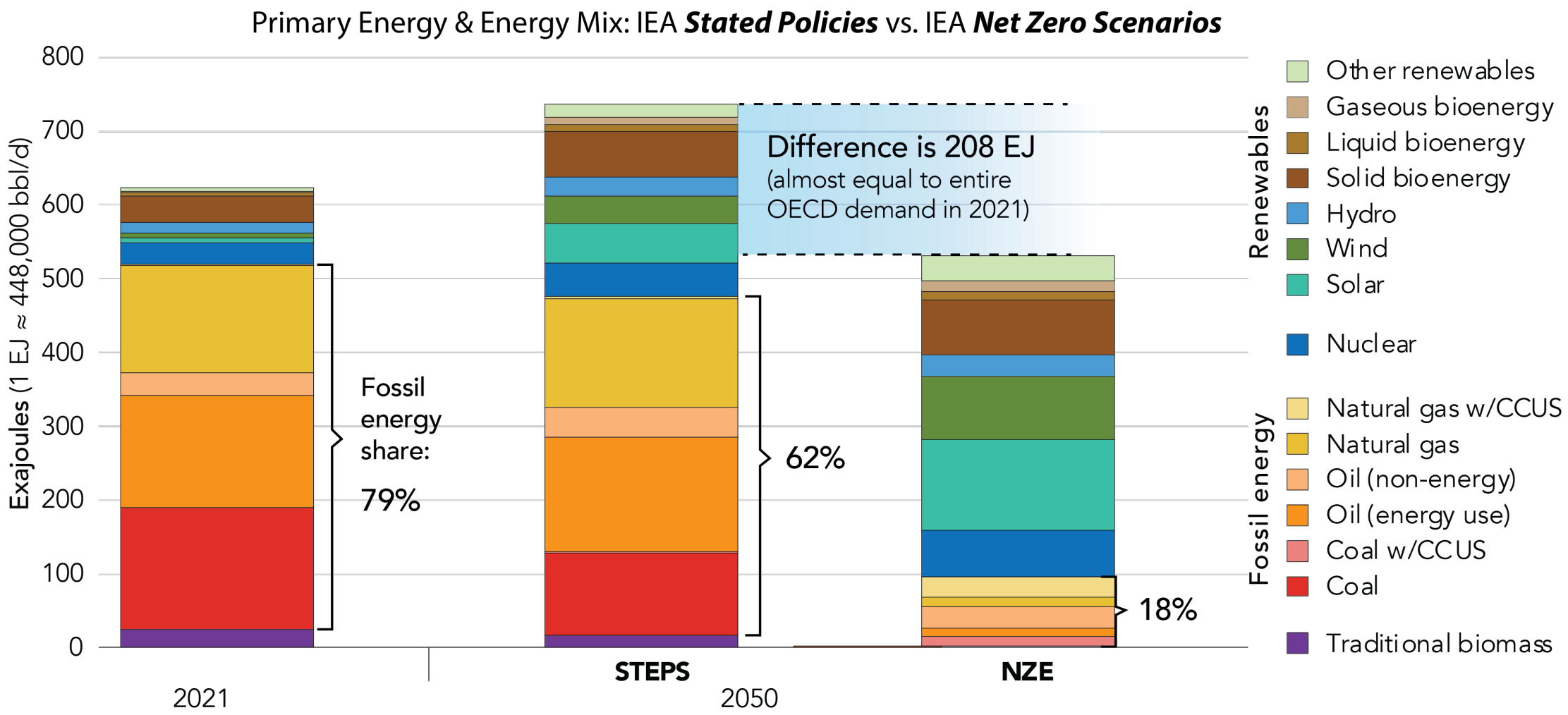


Source: Energy Policy Research, IEA

Net Zero Goals: Ambition or Delusion?



Source: EPRINC figures & calculations based on IEA World Energy Outlook 2022

WORLD FOOD PRODUCTION IS DEPENDENT ON FOSSIL BASED FERTILIZERS

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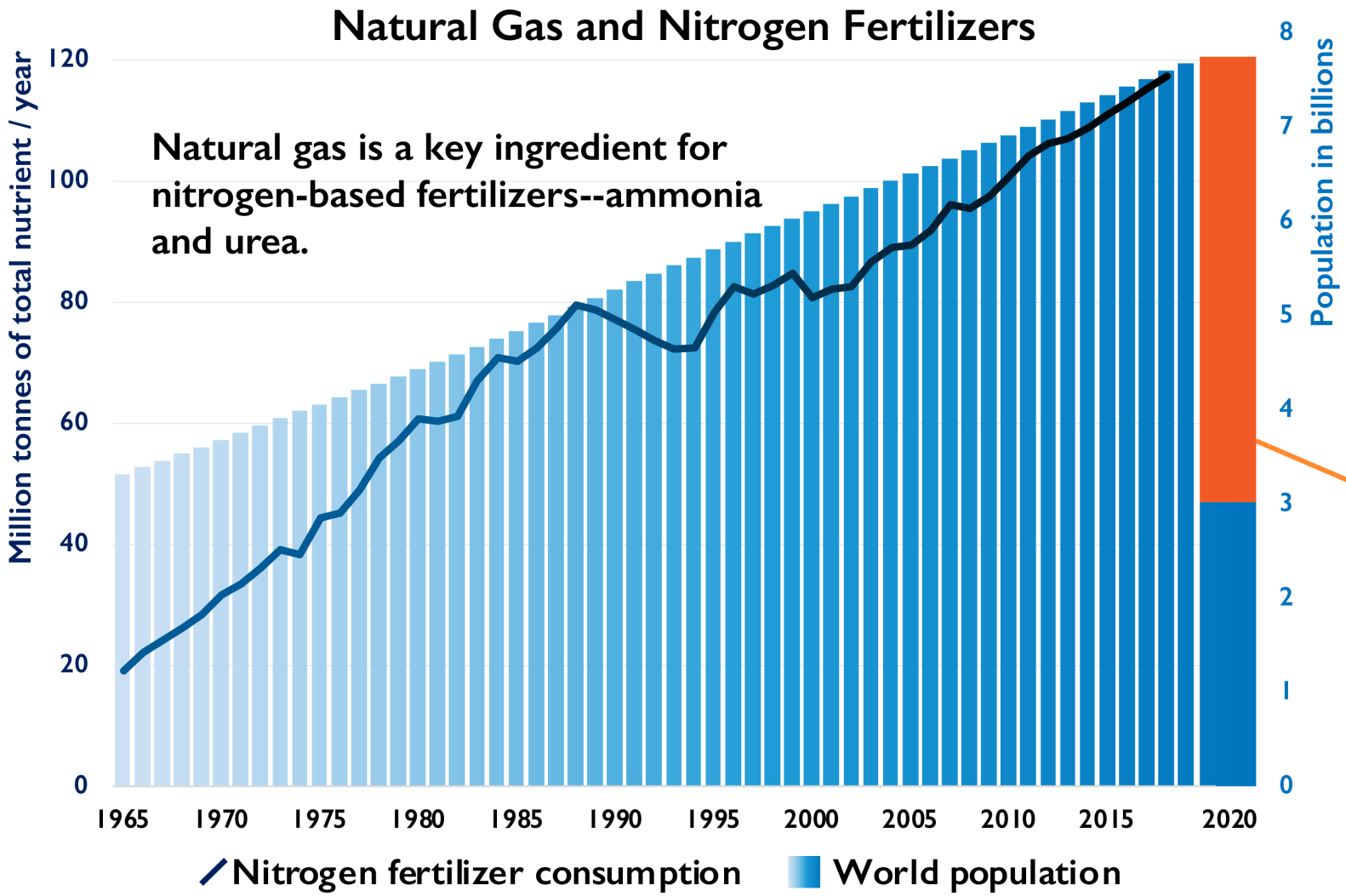

"[Nitrogen fertilizer] has been called one of the greatest inventions of the 20th Century, and without it almost half the world's population would not be alive today." - BBC

Without fossil fuel-based fertilizers, agriculture can support, at most, 3 billion people on plant-based diets, vs. today's 8 billion on mixed diets.

Sources: Vaclav Smil, FAO, World Bank, Statista,

Problem with OECD-Centered Worldview

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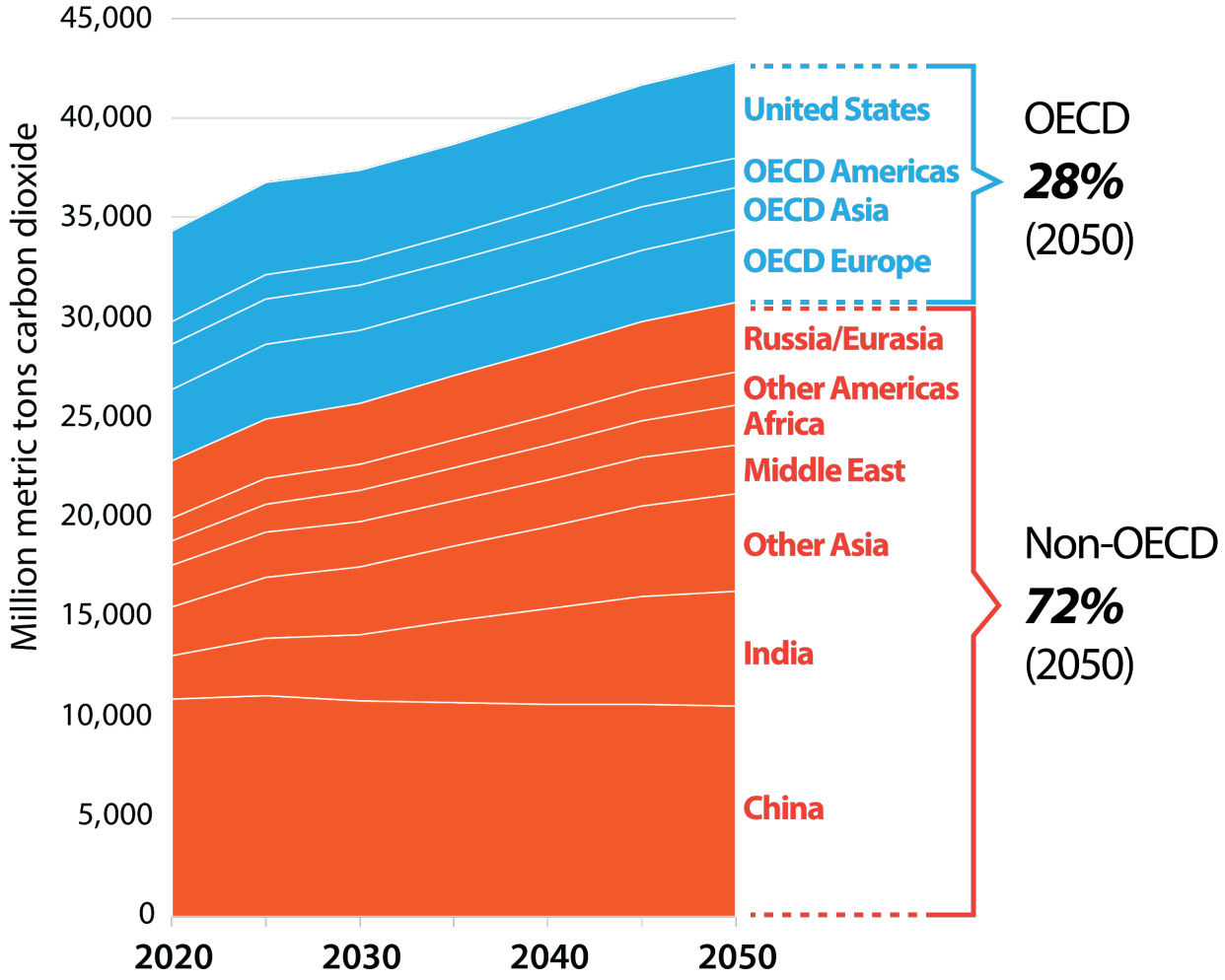
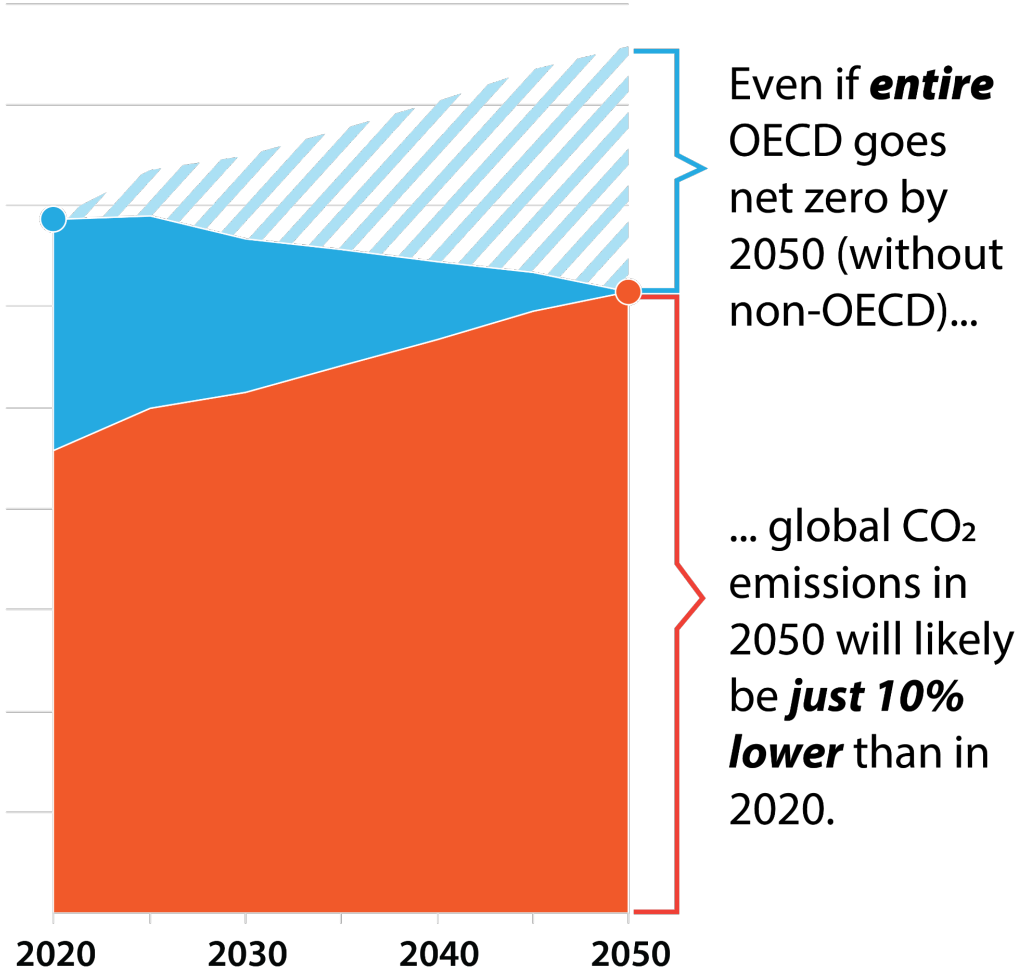
EIA Reference Case: ***Projected CO_2 Emissions***

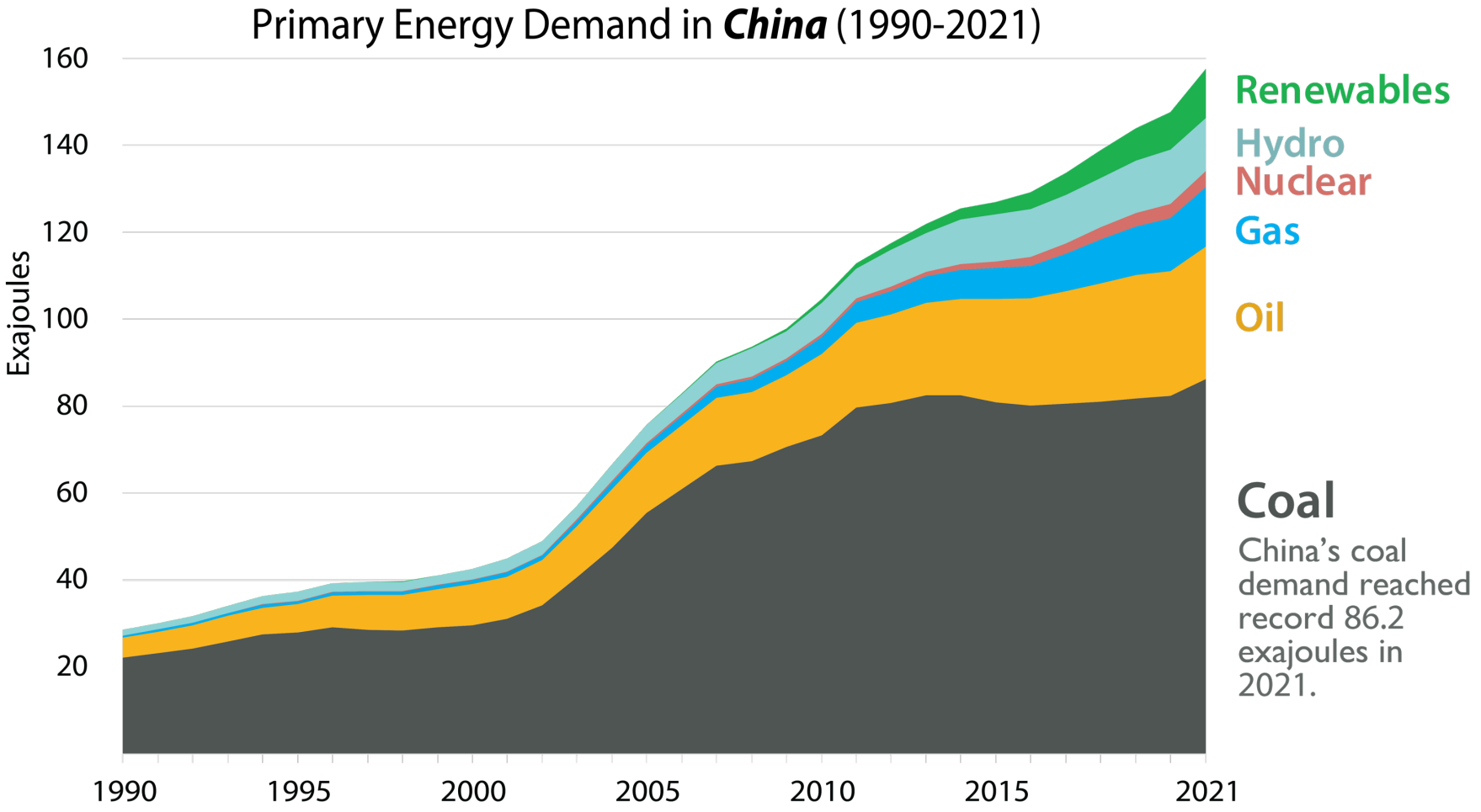


Will ***OECD Net Zero*** Matter?



EPRINC analysis based on EIA's International Energy Outlook 2021 (most recent)

China Runs on Coal and Keeps Consuming Record Volumes

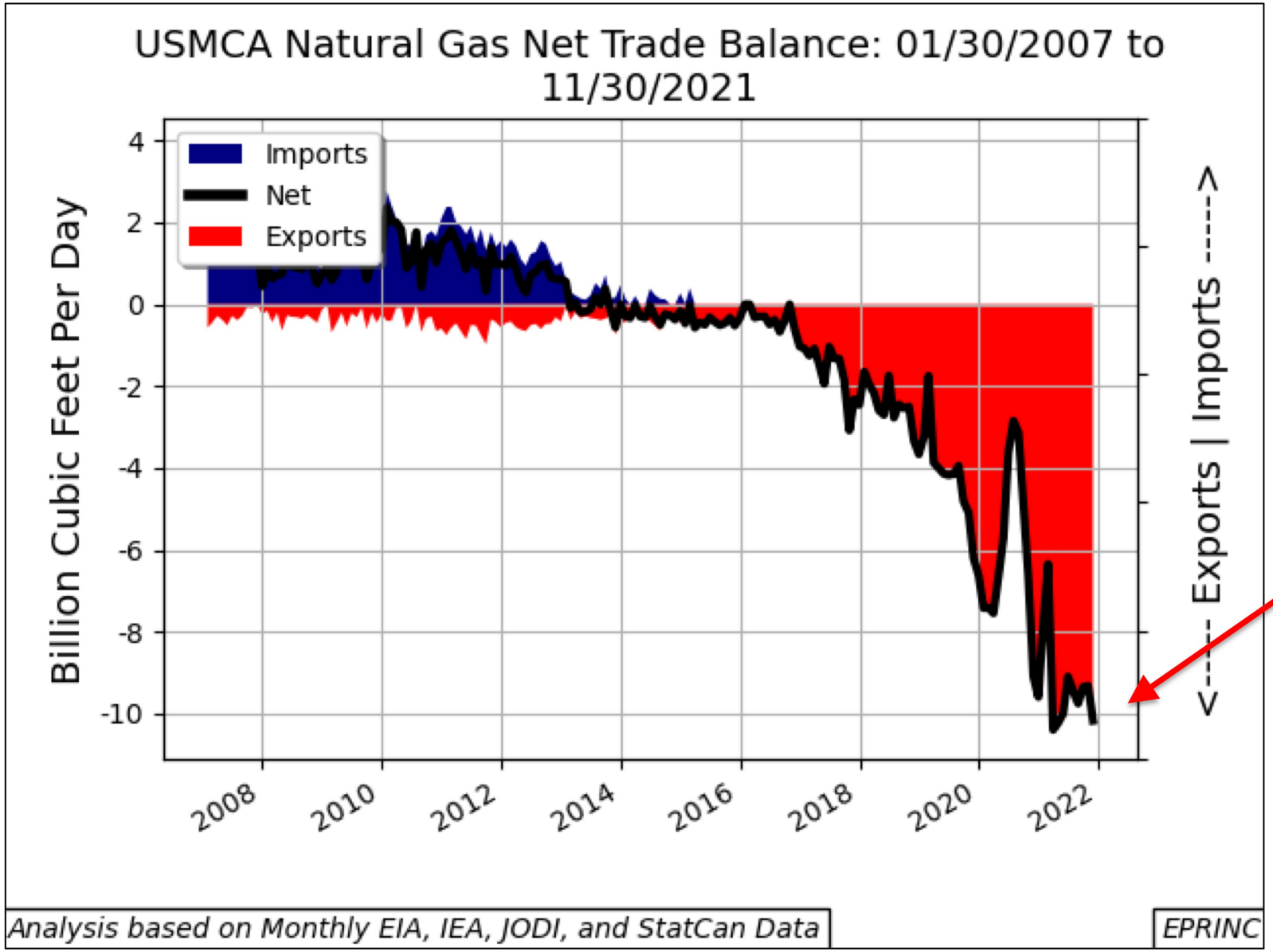


EPRINC chart based on BP Statistical Review of World Energy

Managing natural gas demand is not easy. Many think the primary risk is the energy transition, but the real risk is coal.

Despite its carbon neutrality goals, China's coal consumption is estimated to reach 136 exajoules (EJ) in 2023. It was 82.5 EJ in 2014.

USMCA Natural Gas Trade Balance



As with crude oil and products, the North American Petroleum Renaissance, USMCA countries' combined increase in natural gas production, coupled with relatively level demand, has created large extra-regional export opportunities.

In the last six months, regional natural gas net exports have reached 10 BCF/d.

Expansion of US Production Kept Gasoline Prices Low

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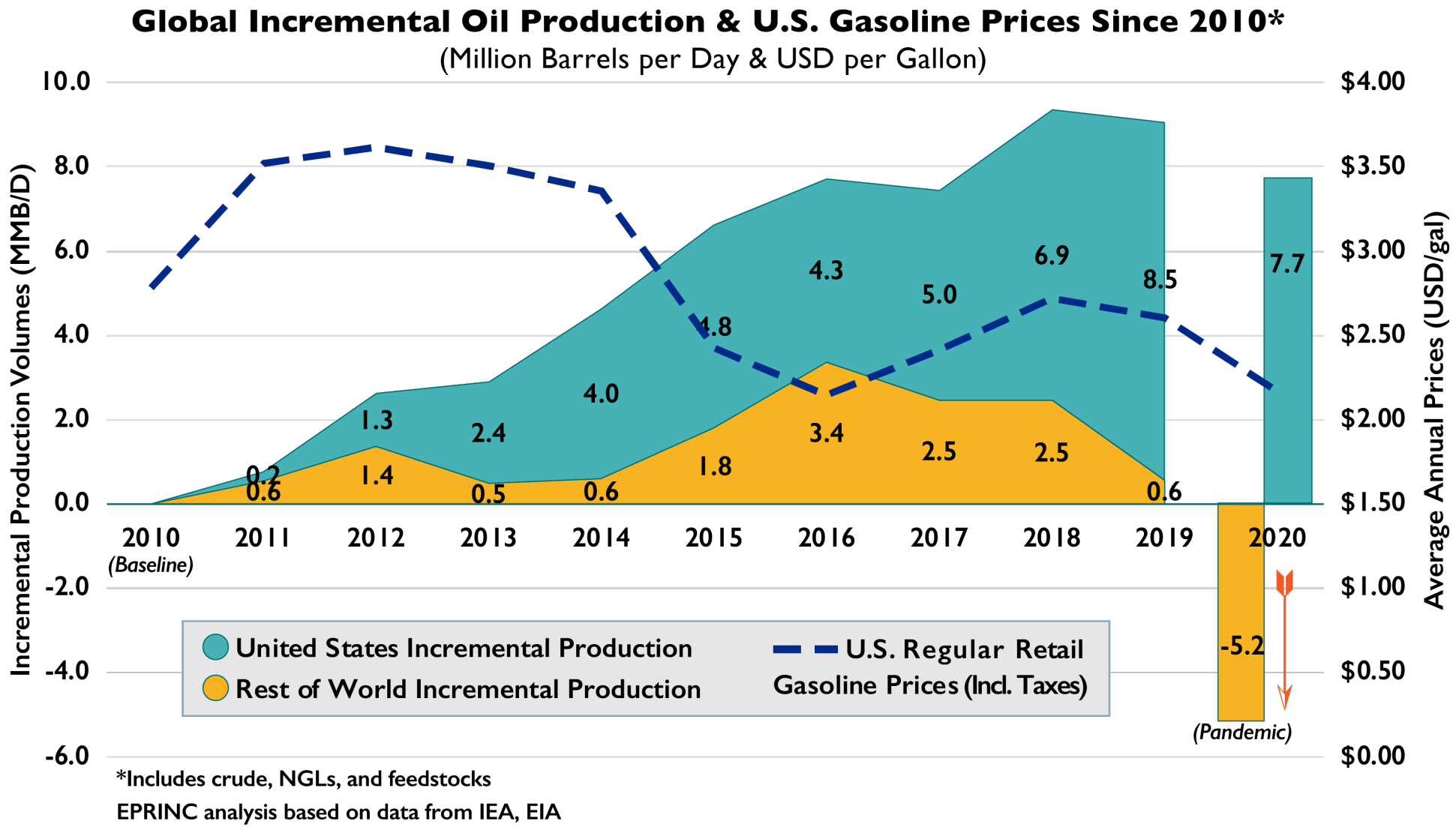

*Includes crude, NGLs, and feedstocks

EPRINC analysis based on data from IEA, EIA

U.S. supplied **84%** of incremental global liquids demand between 2010 and 2020.

Change in Annual CO2 Emissions from Energy in 1999-2019, Mt CO2

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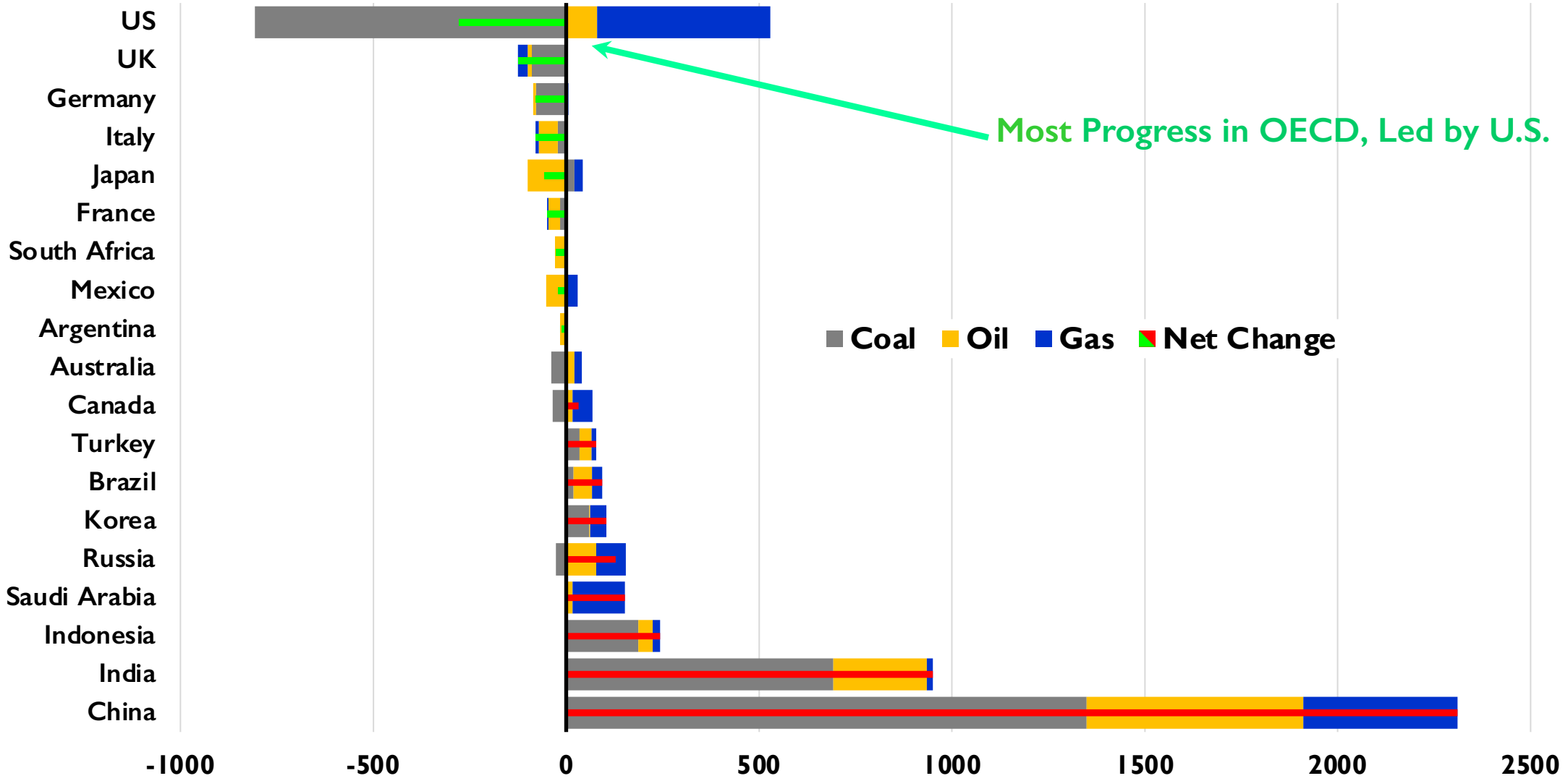
G20 Countries



Source: Batt Odgerel, EPRINC based on data from Global Carbon Project

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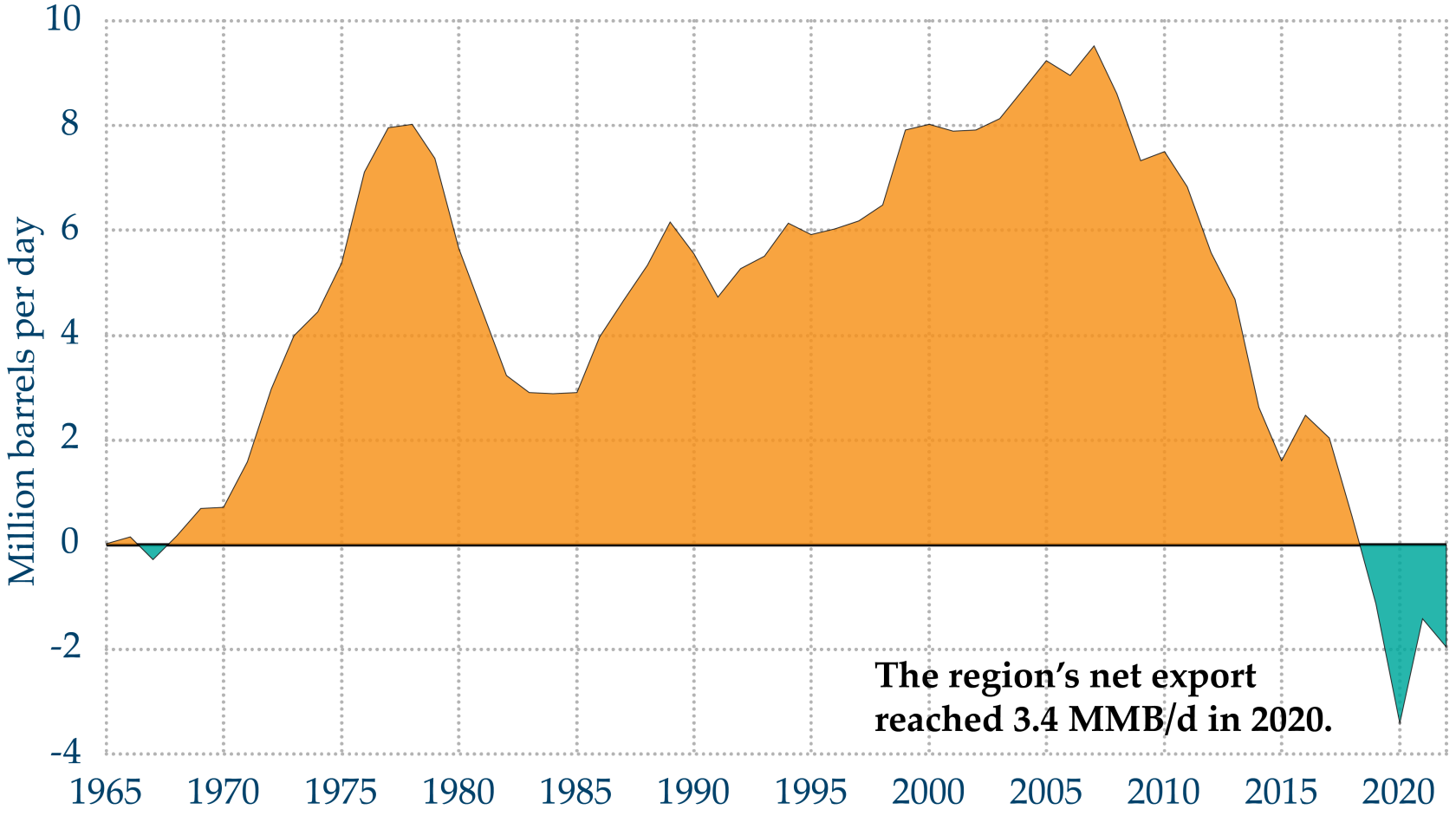
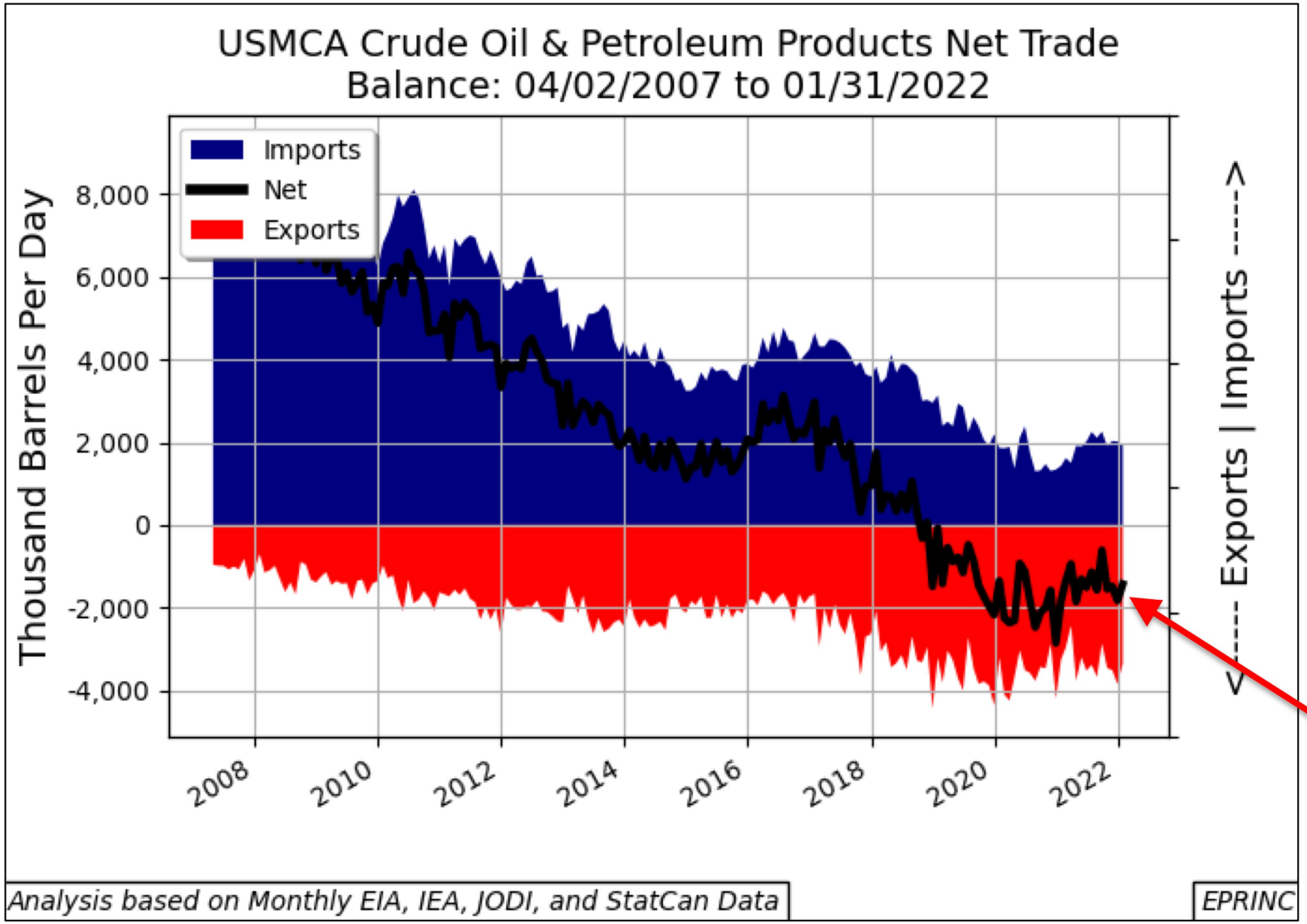
Net Oil Imports of Western Hemisphere (North, Central, & South Americas)



Data: EI's Statistical Review of World Energy

USMCA Combined Crude Oil & Petroleum Products Trade Balance



Thanks to the North American Petroleum Renaissance, USMCA countries' combined increases in crude oil and products production, along with relatively level demand, have created large extra-regional export opportunities.

All combined this improves the region's national security, economic prosperity, and trade balance.

2 MBD of net exports over the last two years!

EIA Expects US Crude Oil Production to Hit All Time High in 2024

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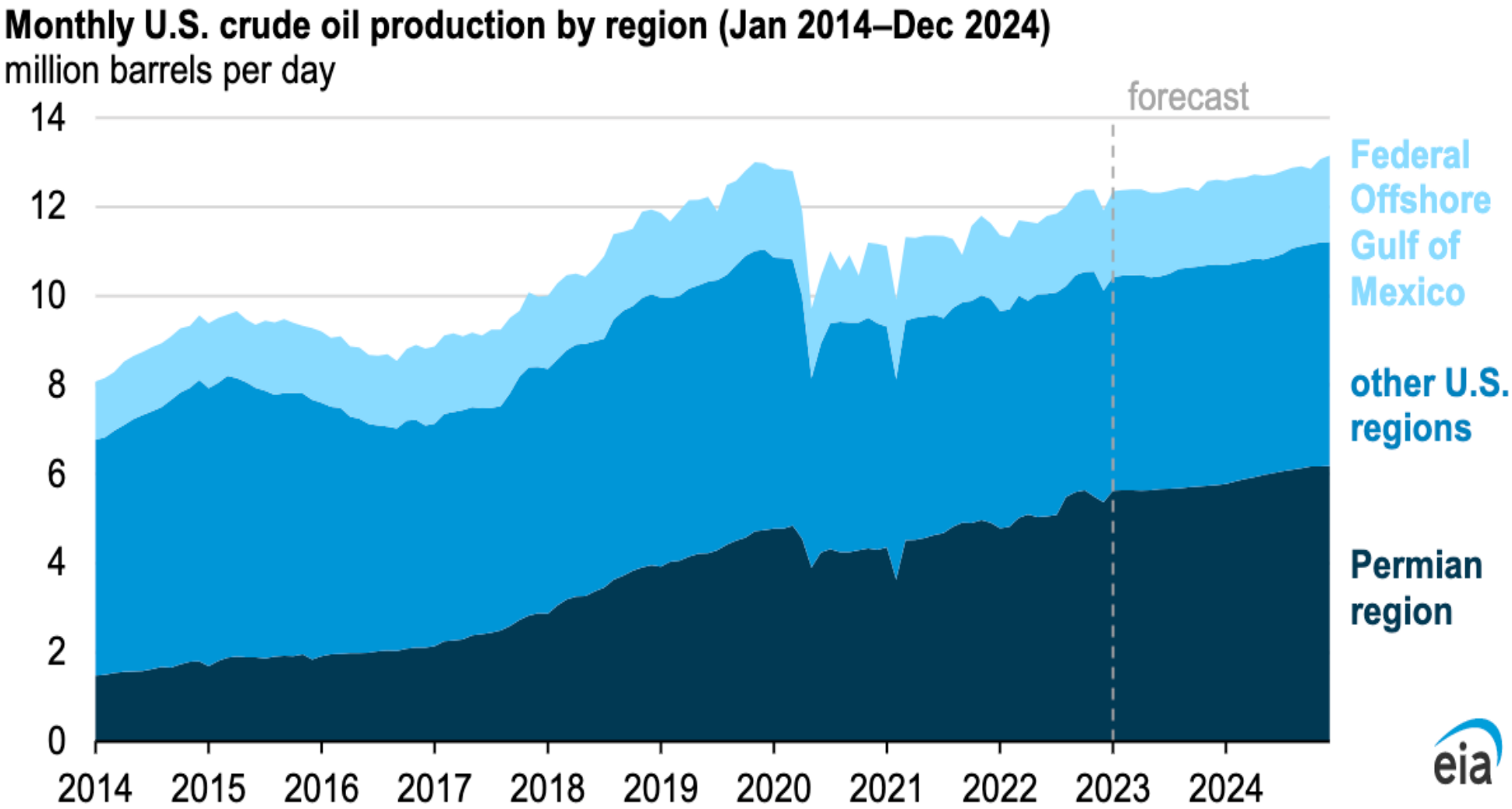

What Happens if Investment is Halted Worldwide for New Oil and Gas Development?

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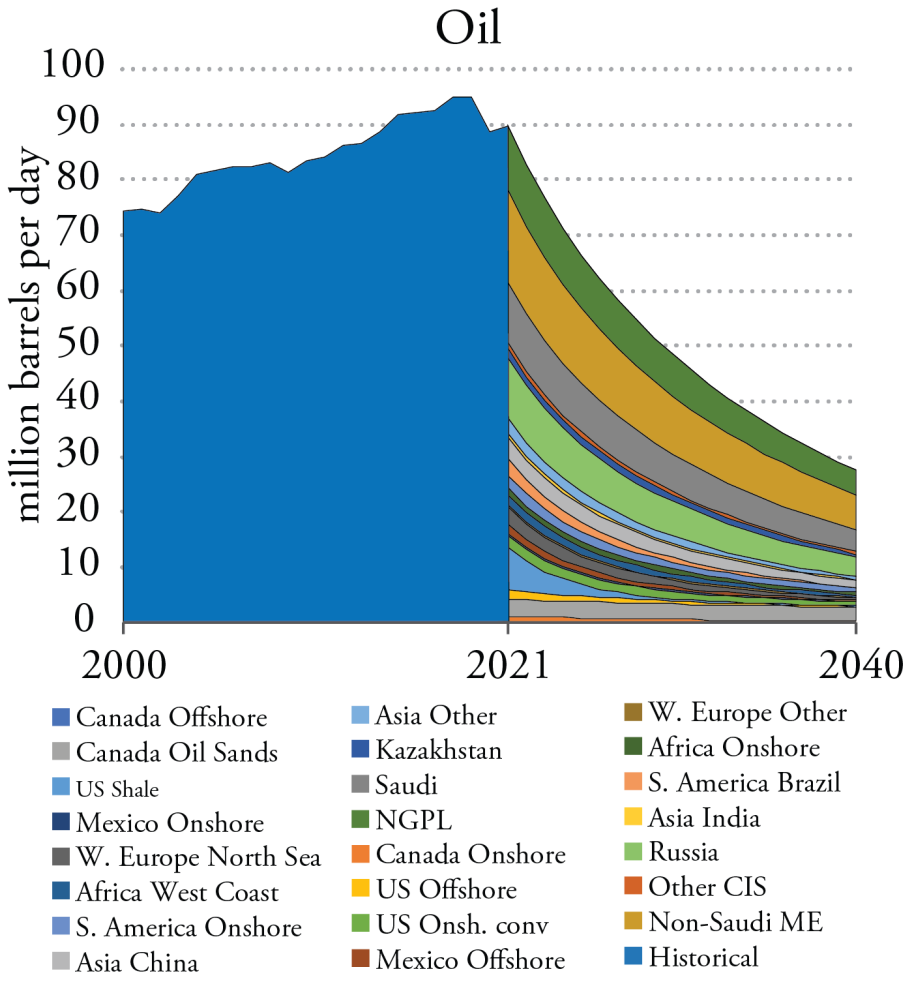
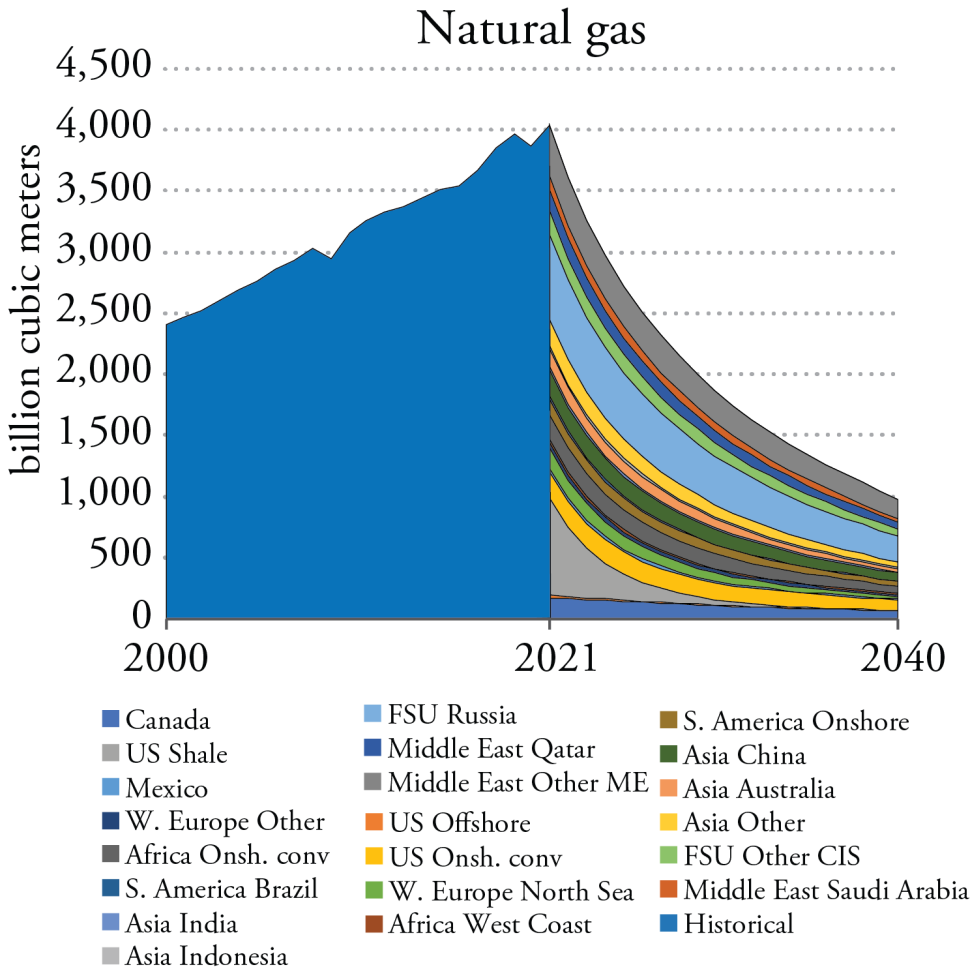
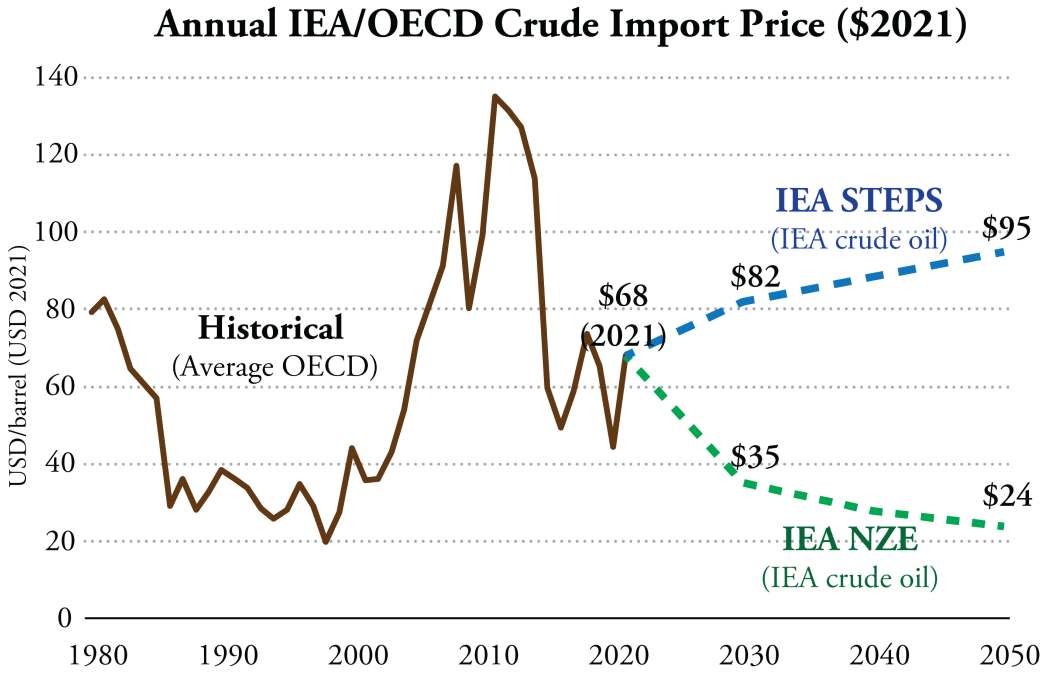
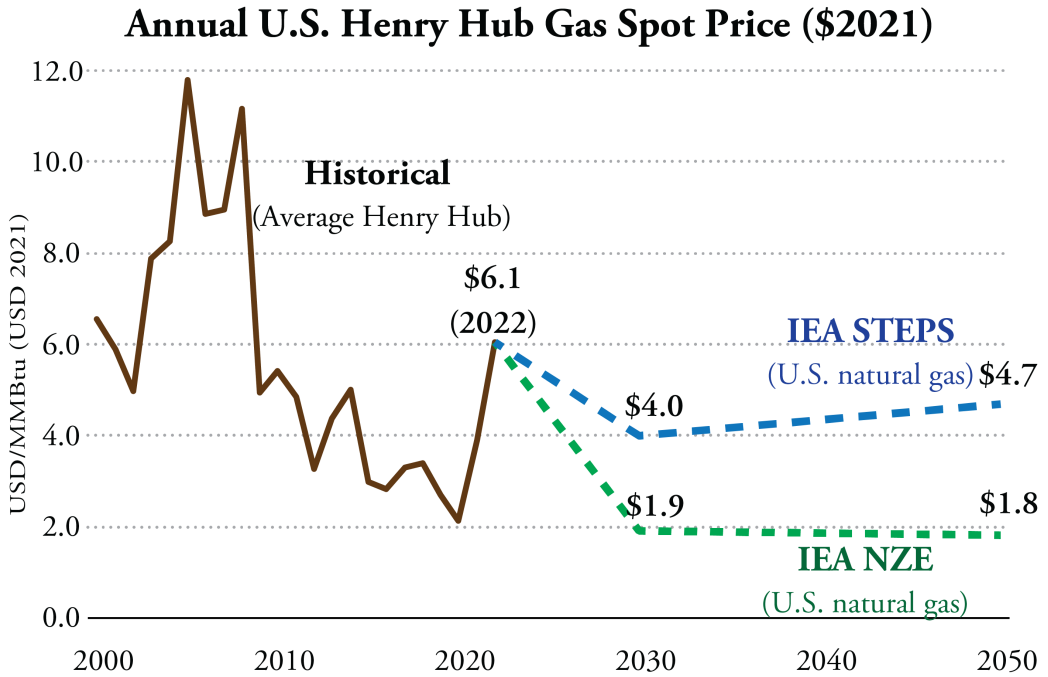




Source: Energy Policy Research, Michael Lynch

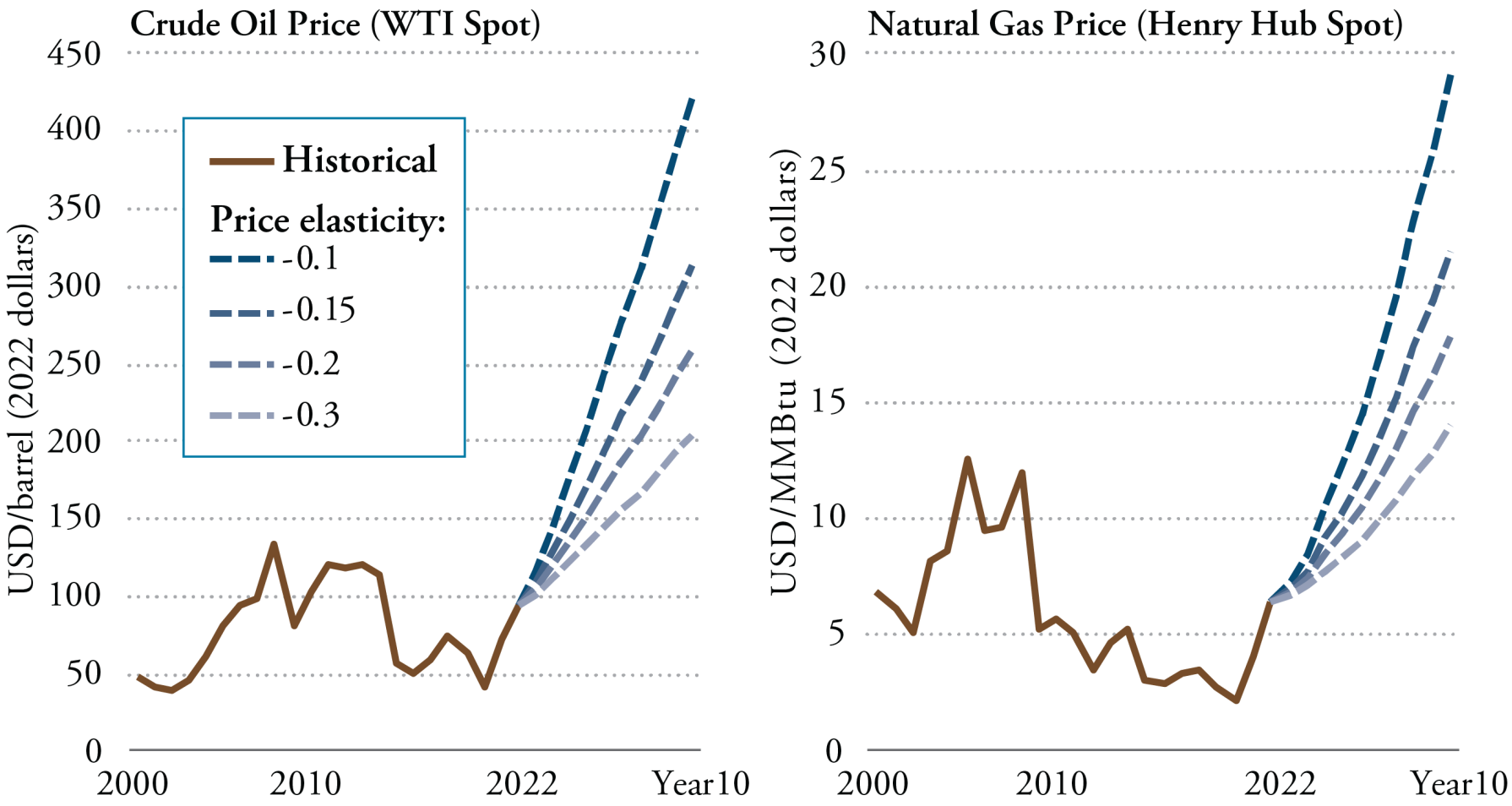
Oil and Gas Prices According to IEA





"If supply were to transition faster than demand, with a drop in fossil fuel investment preceding a surge in clean energy technologies, this would lead to much higher prices—possibly for a prolonged period—even if the world moves towards net zero emissions." (IEA, WEO–2022, p. 134)

Oil and Gas Prices Under No New Investment Scenario (IEA-NZE) Based on Historic Price Elasticities of Demand



Source: Energy Policy Research

Implications of High Oil and Gas Prices Under No Investment Scenario

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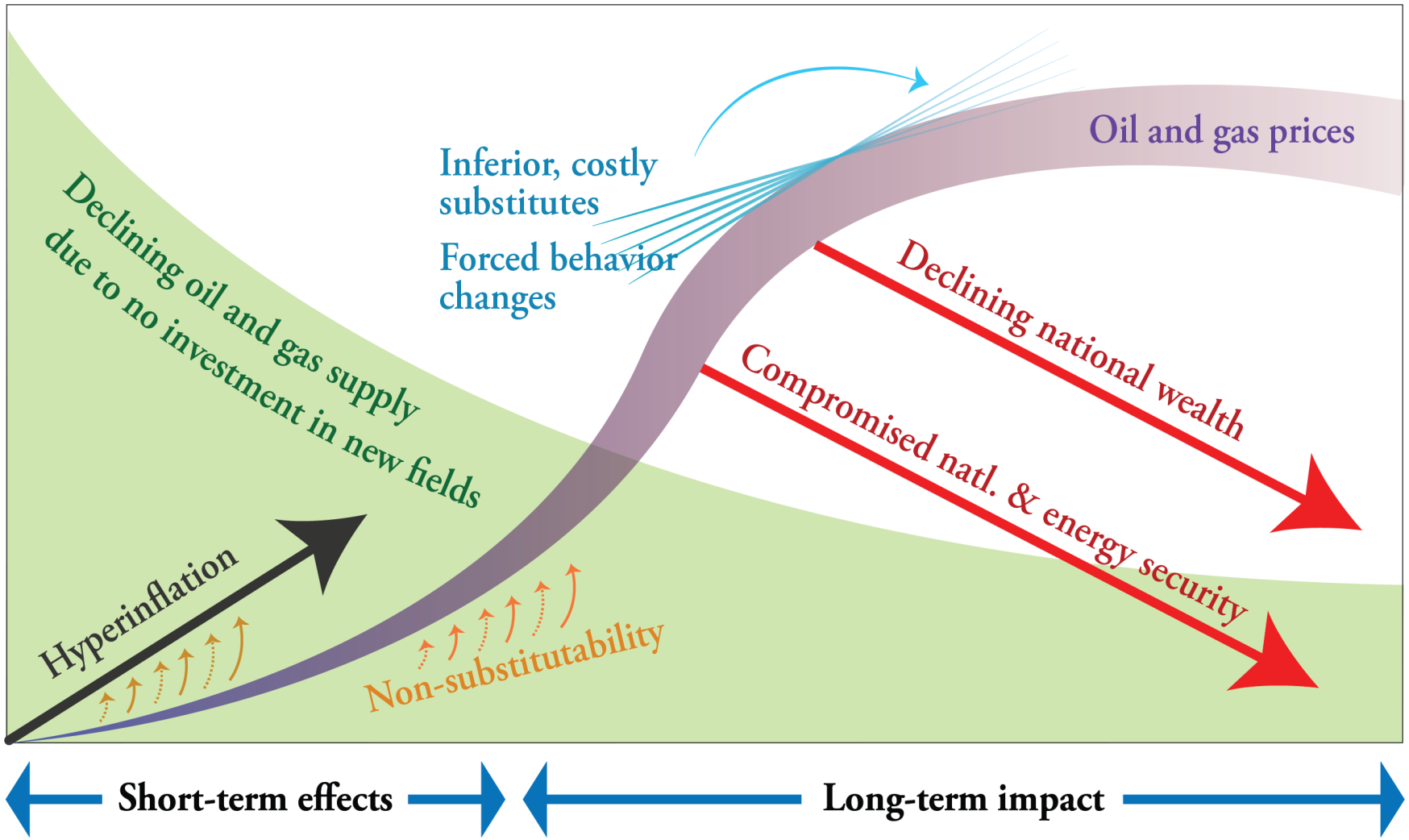
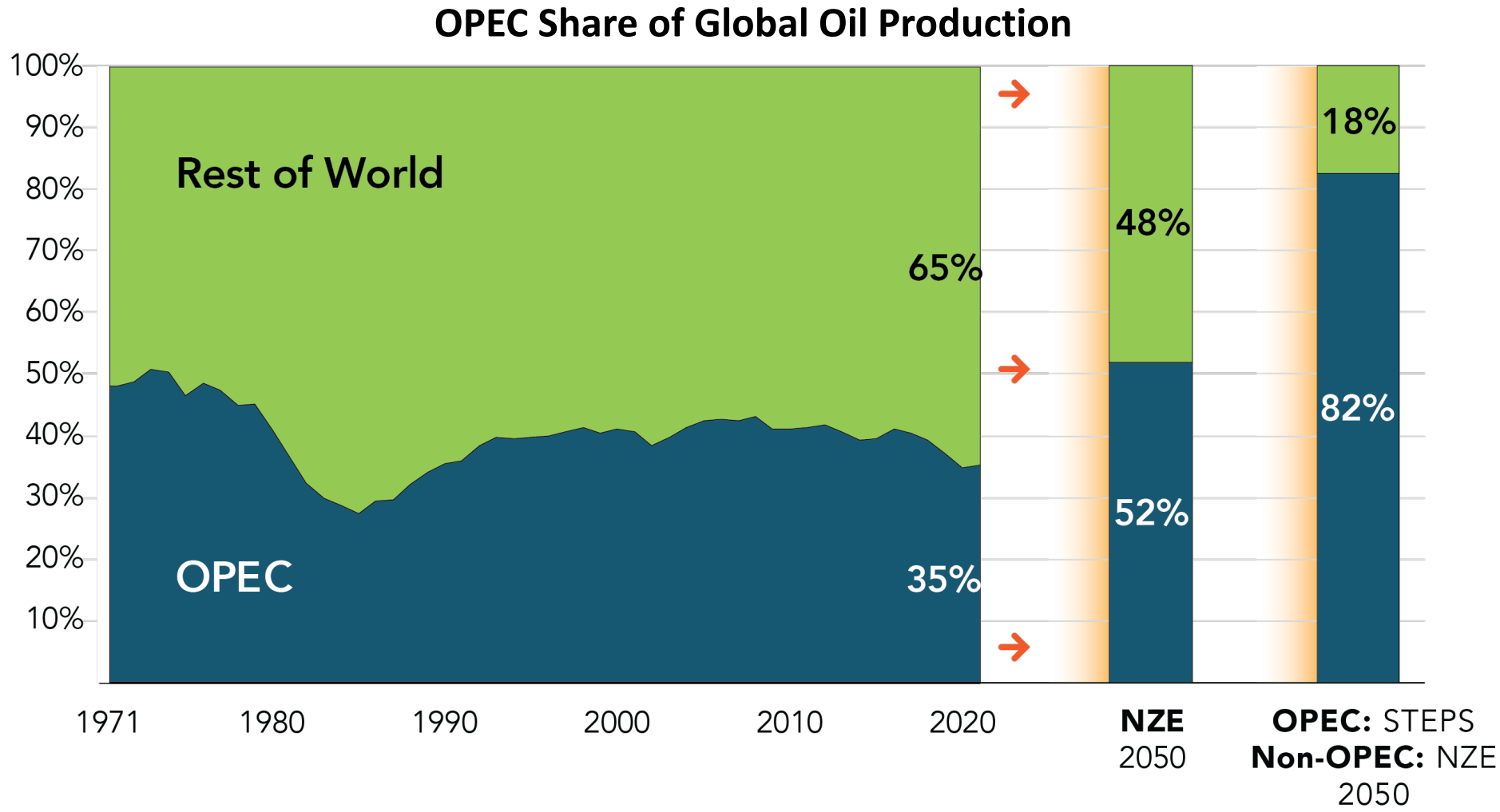


Oil Supply Concentration under Net Zero



Source: EPRINC figure based on IEA World Energy Outlook 2022, WEB data

Level of Commitment: Divide Between OECD and Non-OECD

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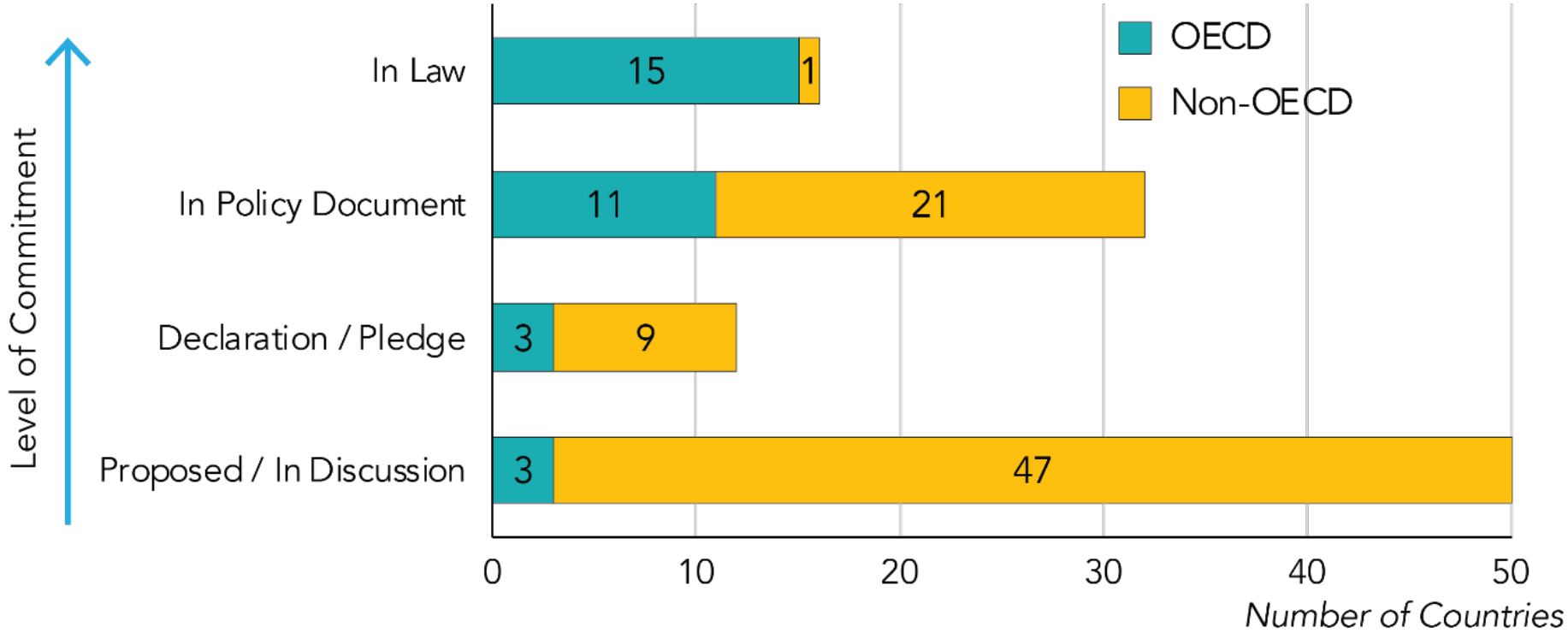
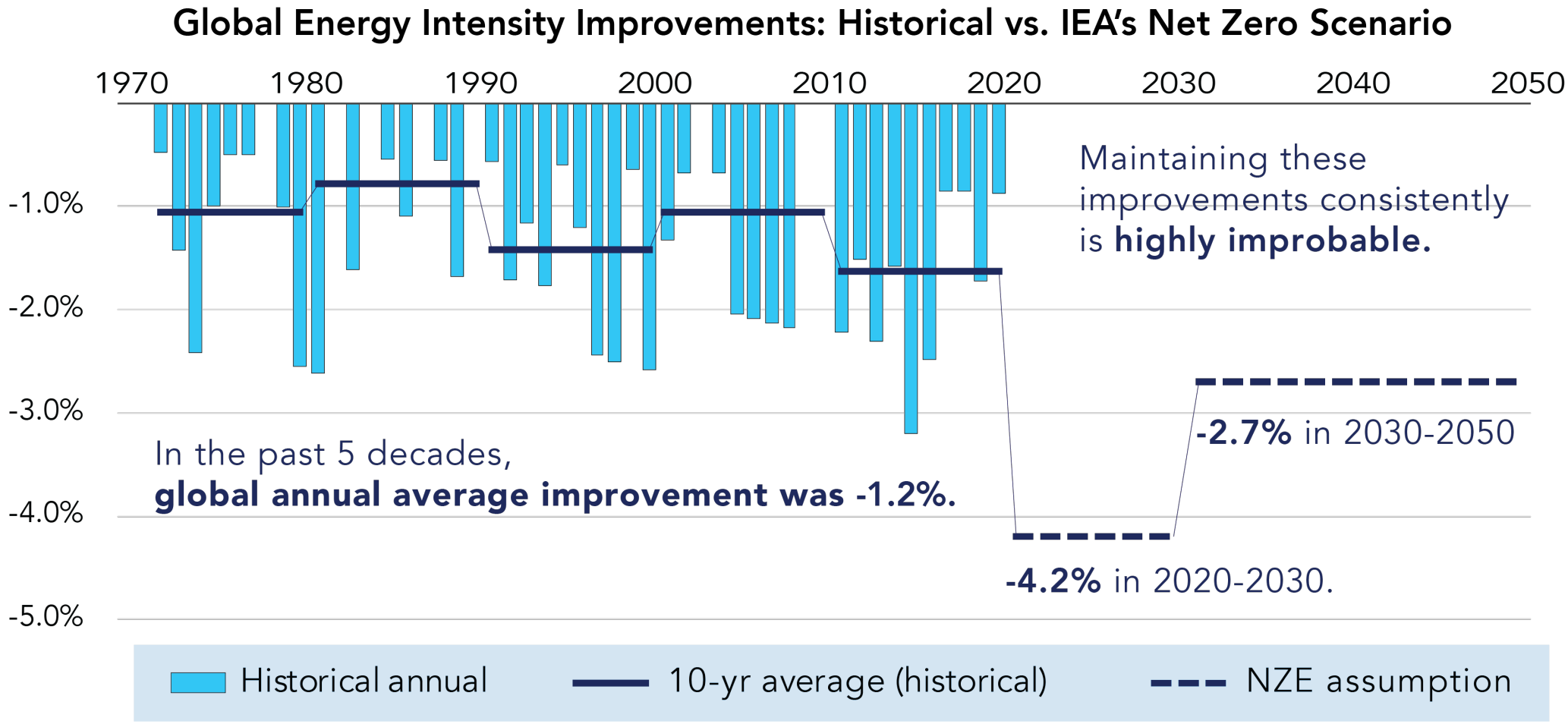
Two-Speed Transition: Net Zero by 2050 Level of Commitment



Sources: EPRINC figure based on data from Net Zero Tracker.

Energy Intensity Improvements under Net Zero



Source: EPRINC figures & calculations based on IEA WEB
Note: Primary energy / GDP (2019 USD PPP) is used for the calculation.

Many Technologies Still in Early Stages of Readiness

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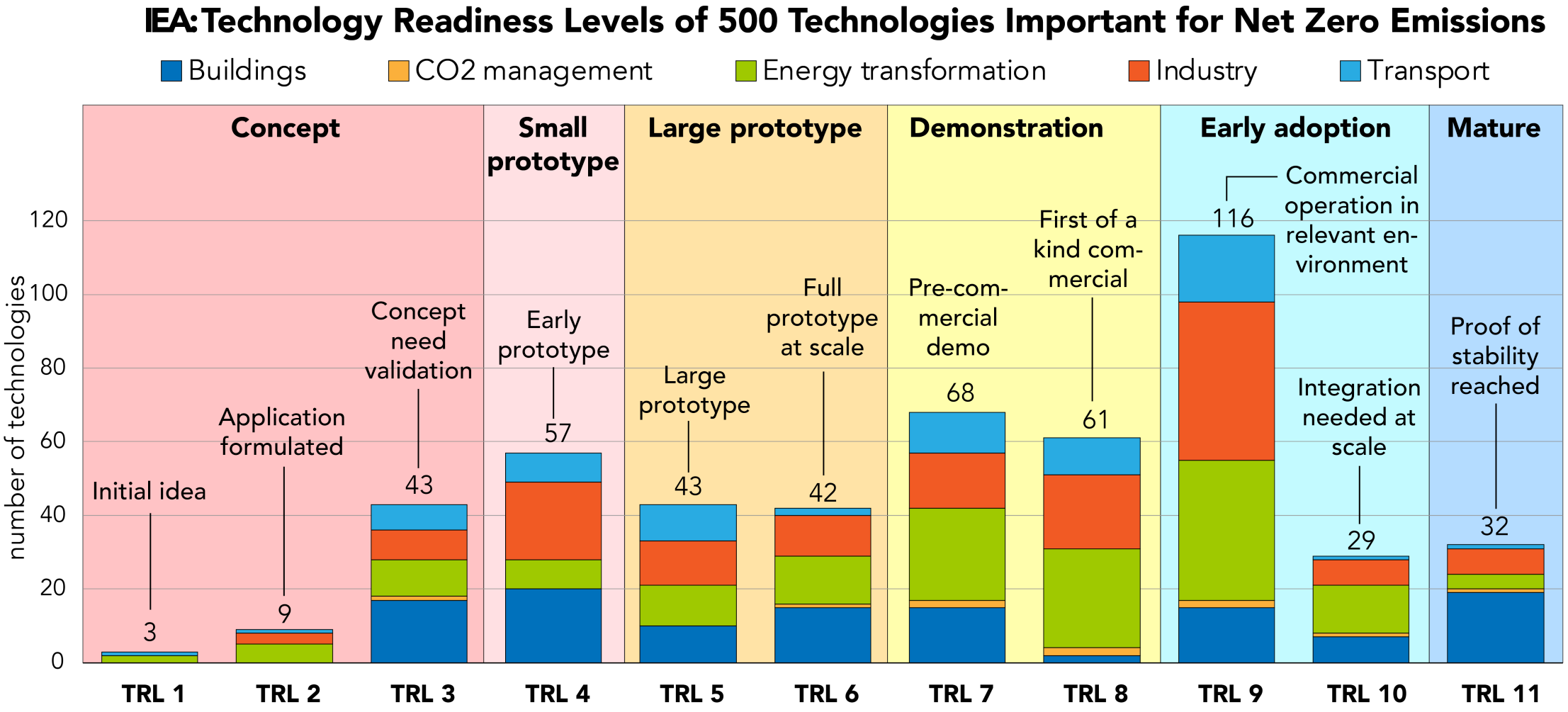

Source: EPRINC analysis based on IEA ETP

Massive Critical Minerals Required in a Low-Carbon Future

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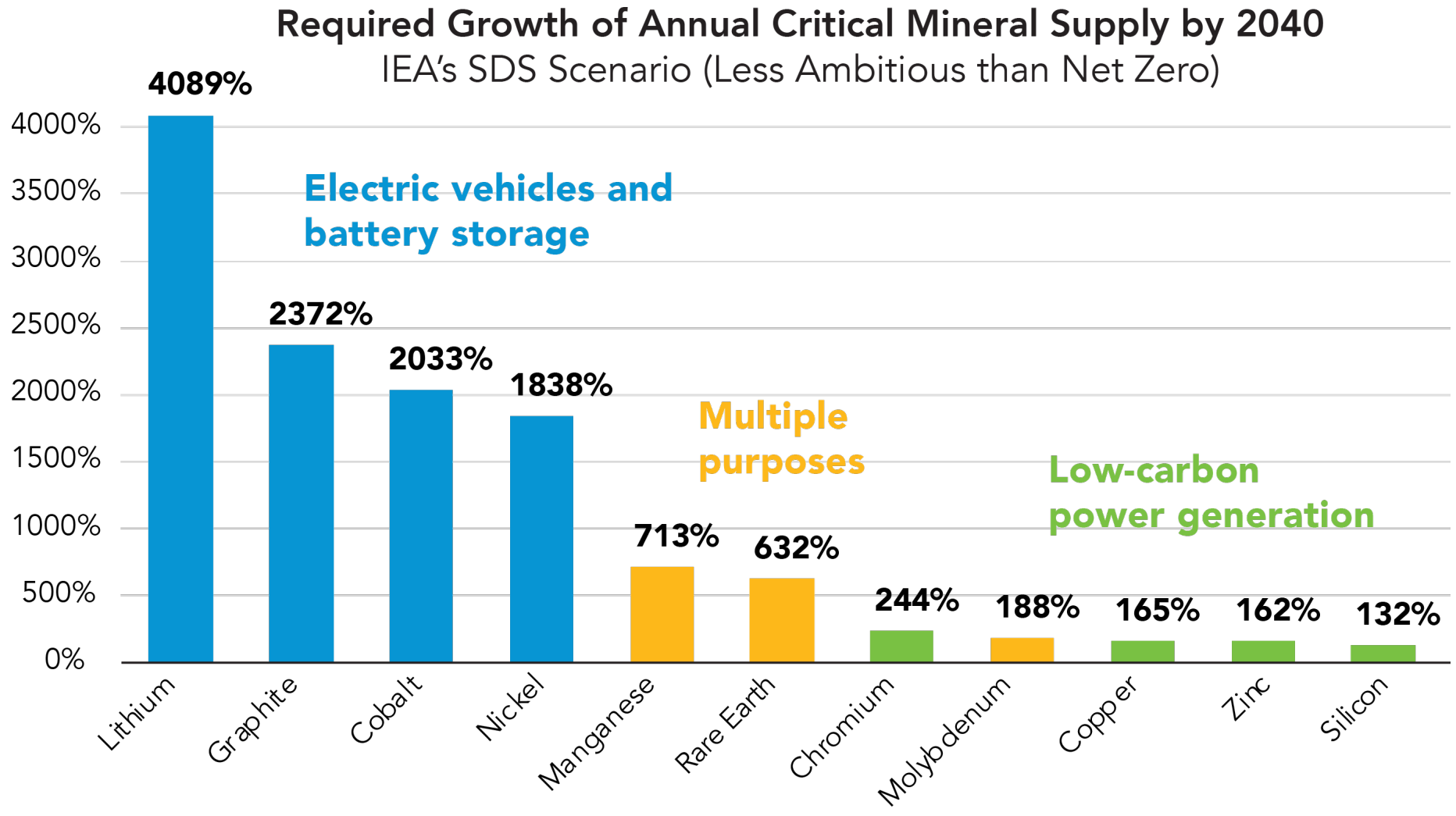
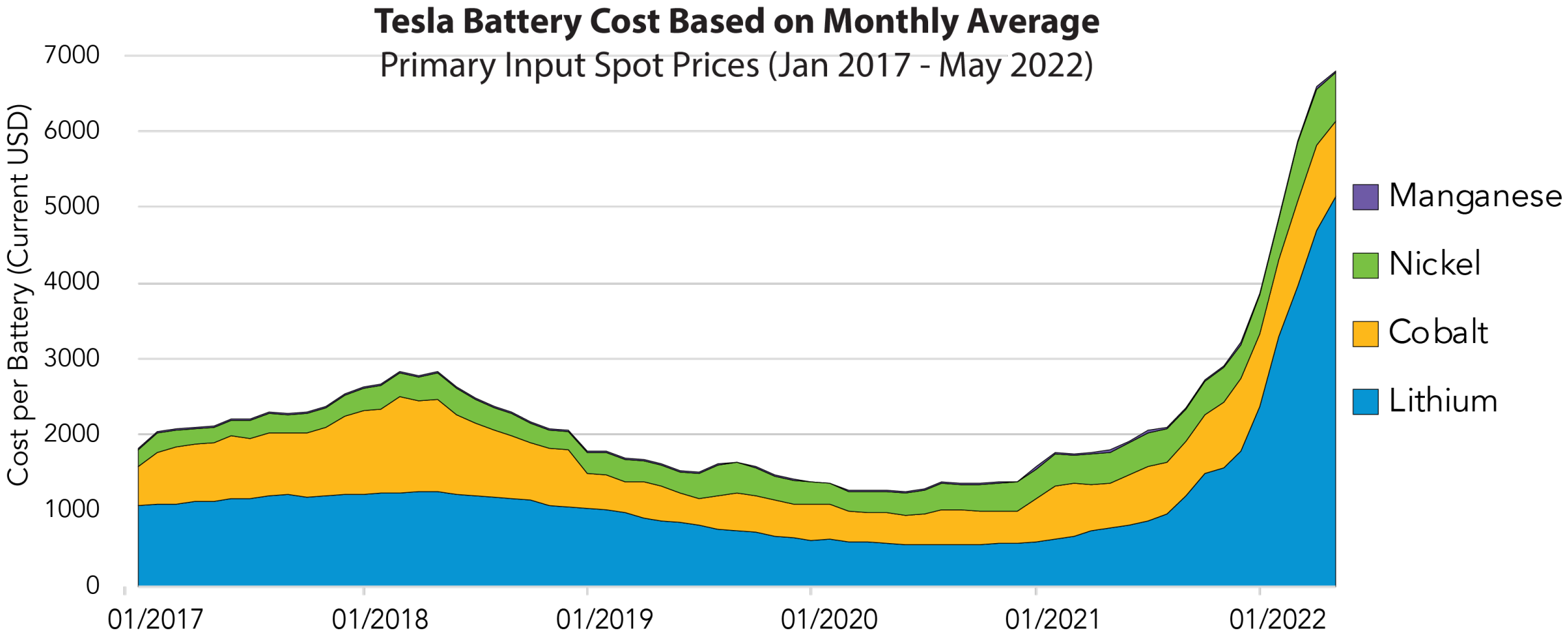


Source: EPRINC analysis based on IEA Critical Mineral Report 2021

Increased Vulnerability to Mineral and Metal Prices



Source: EPRINC analysis based on LME Monthly Data

Dependence on China to Increase with Energy Transition

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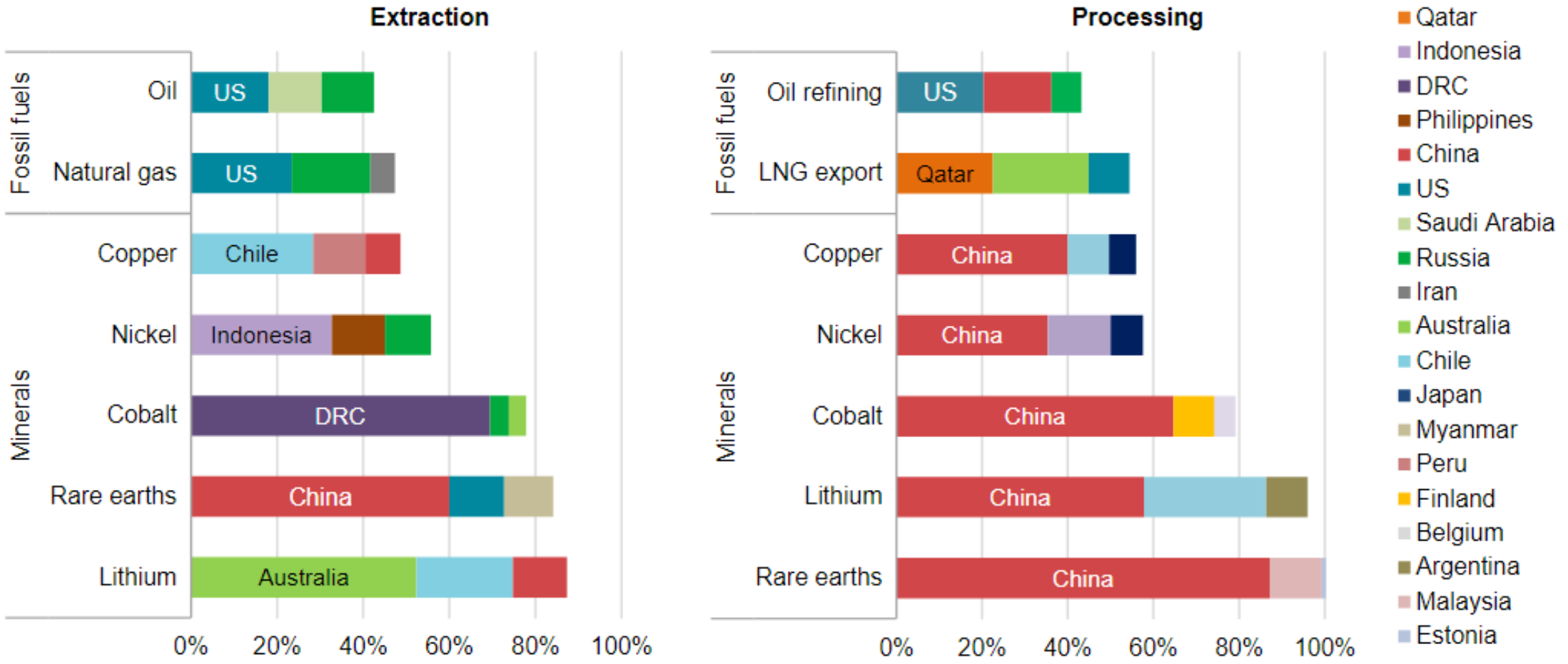
Share of top three producing/processing countries in ***selected minerals and fossil fuels***, 2019



Sources: IEA Report *The Role of Critical Minerals in Clean Energy Transition*; USGS (2021), World Bureau of Metal Statistics (2020); Adamas Intelligence (2020)

The Myth of Stranded Oil & Gas Assets

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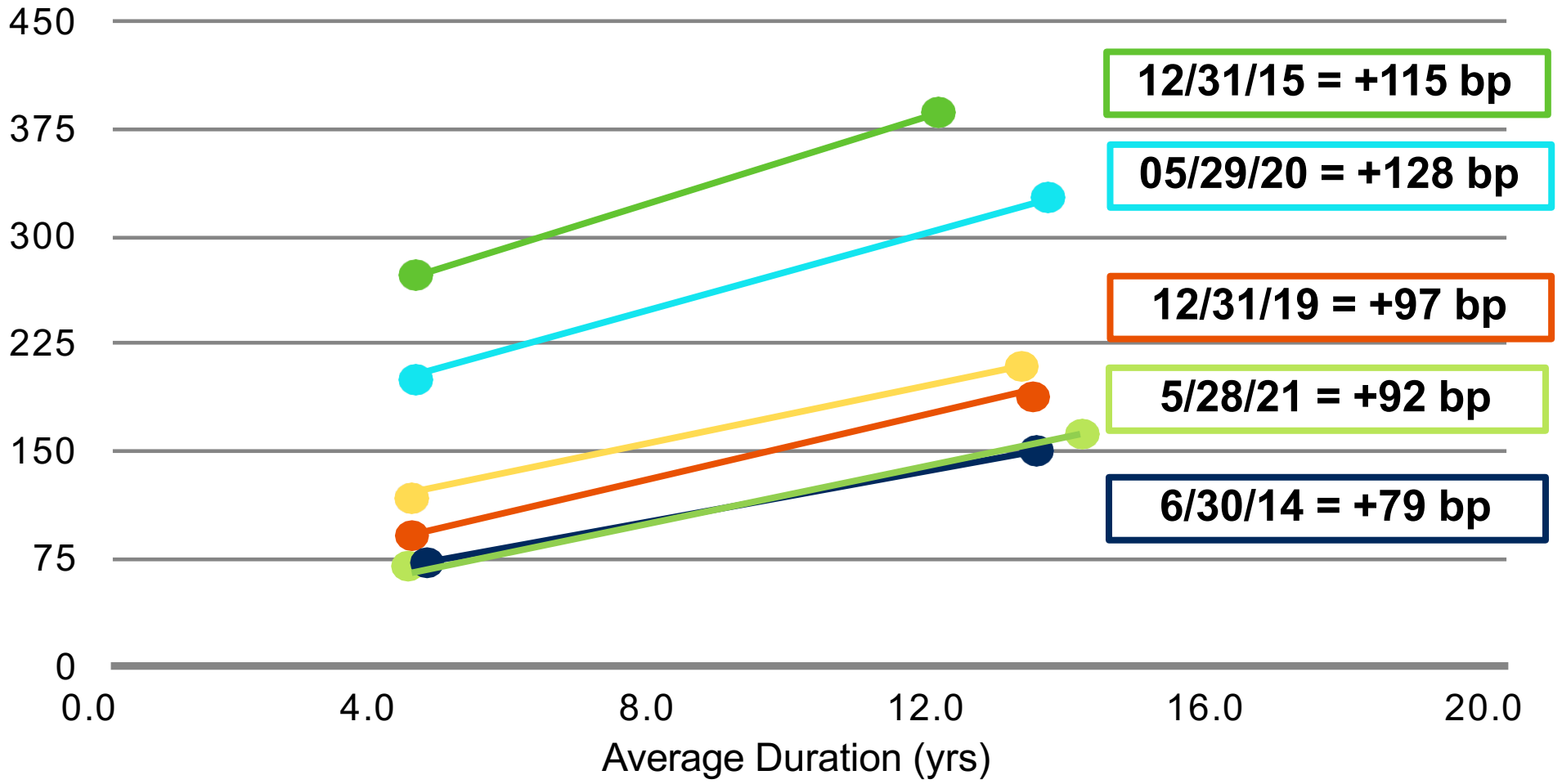
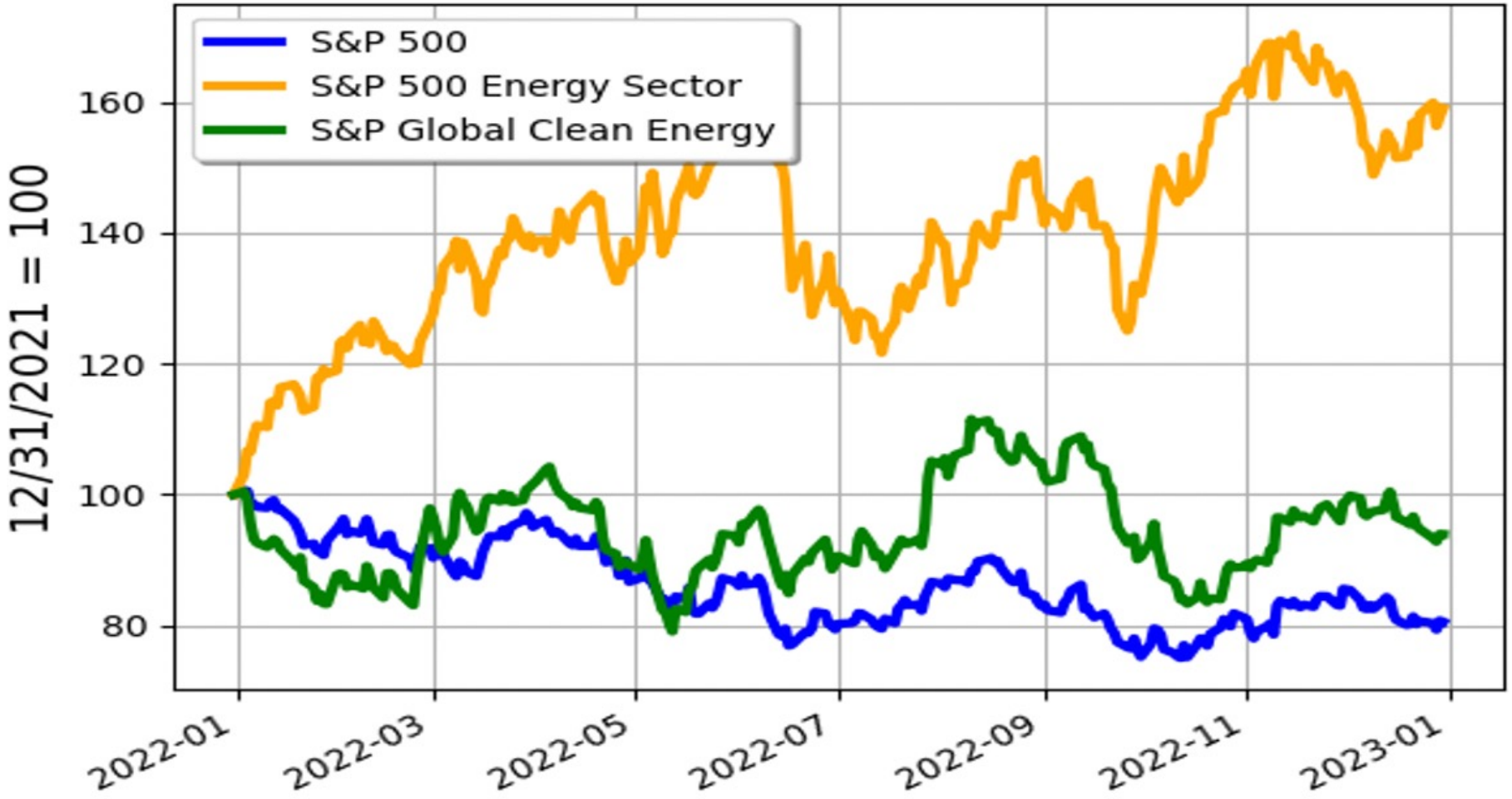
U.S. Investment Grade Energy Bond Credit Spread Curves



Source: Bloomberg Barclays

Performance of Index Funds: S&P 500, S&P 500 Energy Sector and S&P Global Clean Energy



Source: Energy Policy Research

Do Policy Makers Understand the Consequences of the Net Zero Energy Transition?

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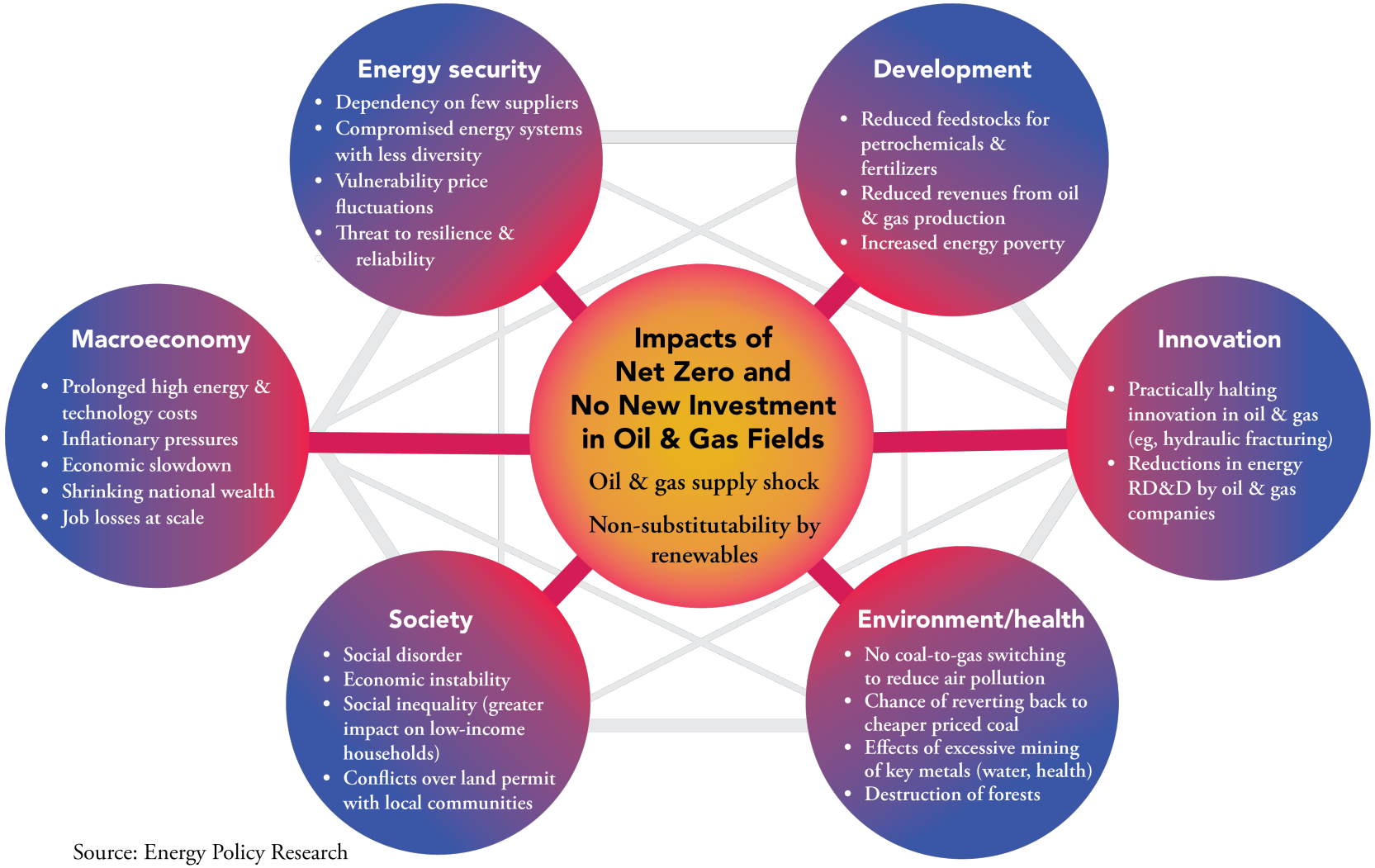

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About Energy Energy Policy Research

Energy Policy Research Foundation

- Founded 1944
- Not-for-profit organization
- Studies intersection of petroleum/energy economics and public policy. Routinely testifies before Congress
- Provides independent and technical analyses for distribution to the public
- Supports USG projects, e.g., Quadrennial Energy Review, DoD strategic outlook
- EPRINC Embassy Series
- IEEJ-EPRINC Project on "Future of ASIAN LNG " upcoming program on "Sustaining Resilience & Security in the Energy Transition"
- Launch of Gaskins Center for Energy Security Studies
- www.eprinc.org