Science Teachers Colloquium

"Energy Supply and Demand"

29 July 2024

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Outline

- Fundamental concepts in energy supply and demand
- Global energy trends to 2050
- The unique characteristics of the U.S. energy system
- The Energy Transition and system challenges
- Class discussion

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Concept #1:
Energy systems are multi-dimensional

Science and Technology

+

Investment and Economics

+

Government and Regulation

+

Societal Expectations and Consumer Behavior

Energy systems vary widely by region and country

Fundamental Concept #2:

All energy systems are impacted by scale, time, and capital

Scale, Time, and Capital

- **Scale:**
  - $20 Billion worth of energy consumed every day
  - Global oil consumption is more than 0.5 gallon per day for every human on earth
  - Global growth in electricity demand requires constructing the equivalent of 2 major power plants per day
  - Globally there are more than 1 billion light-duty vehicles on the road (U.S. has about 275 million); expected to reach 2+ billion by 2050

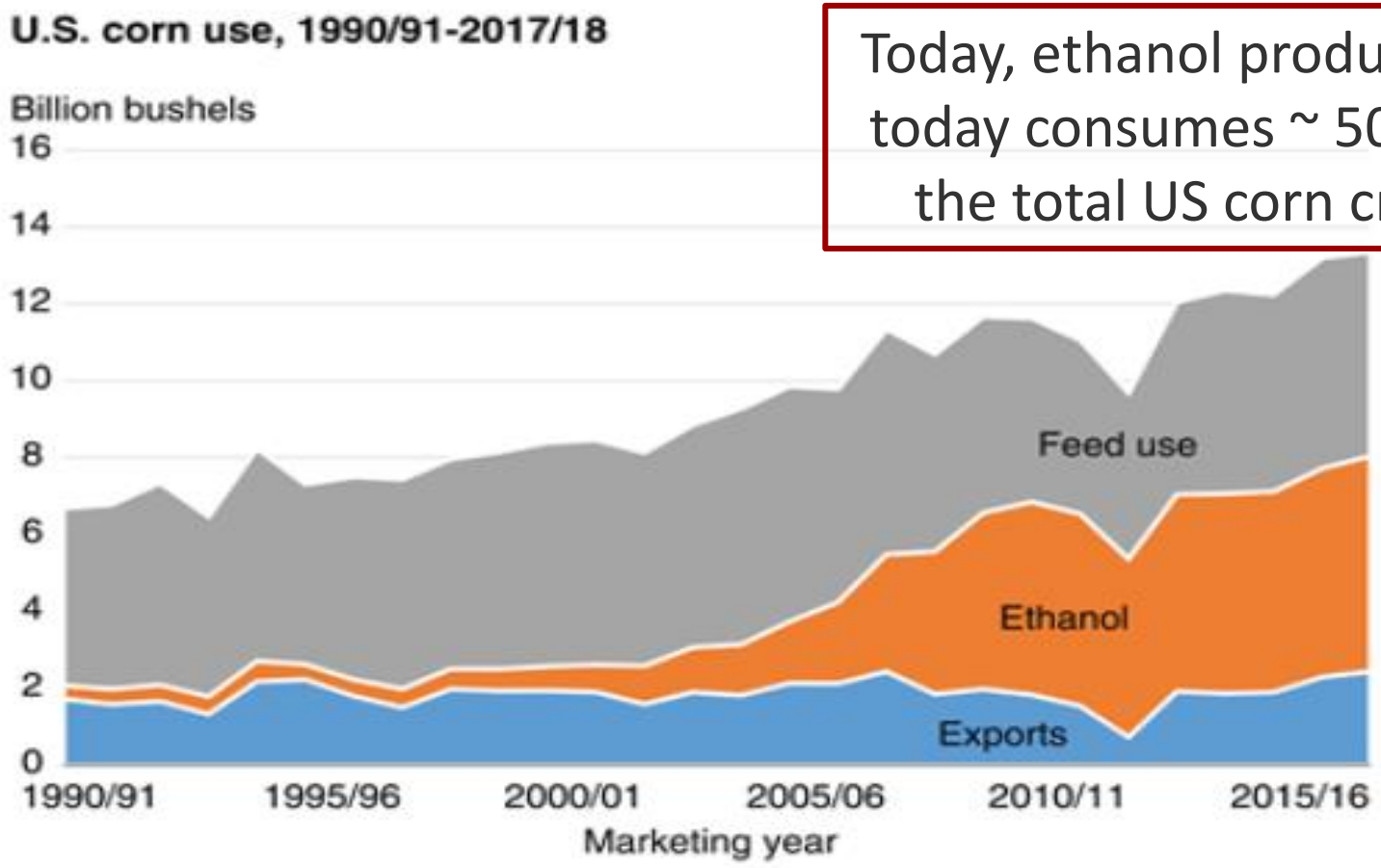
Scale, Time, and Capital

- **Scale:**
- **Time:**
  - Autos last about 17 years (U.S. average) and major appliances last 10+ years
  - Refineries and power plants last decades to 50+ years
  - Oil, gas, and mining resources last decades to 100+ years

Scale, time, and capital

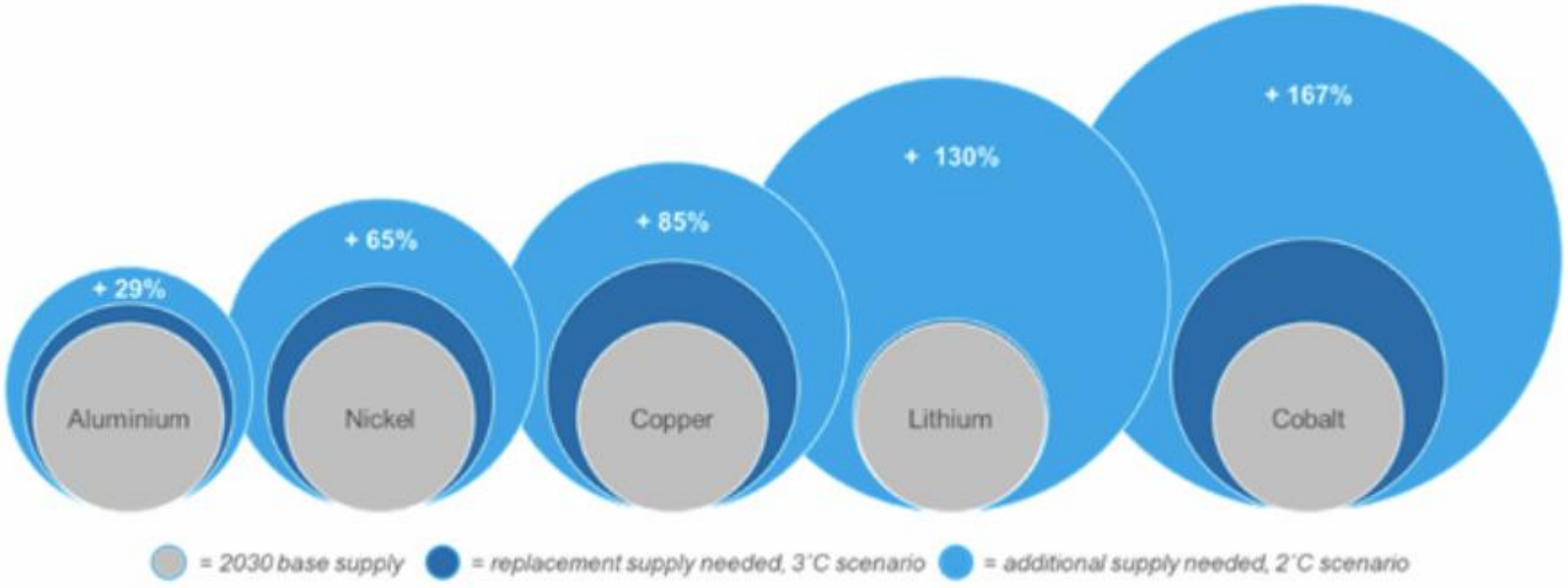
- **Scale:**
- **Time:**
- **Capital:**
  - Global energy investments are about $2 Trillion per year
  - Diversification of energy supply investments continues with the largest growth segments in non-hydro renewables and natural gas
  - Energy investment needed through 2030: ~ $25 Trillion to meet expected demand growth and planned fossil fuel and nuclear facilities retirements
  - Some estimates for meeting Energy Transition targets by 2050 will require an additional $ 75 Trillion

Scale, time, and capital impacts
Example: U.S. ethanol production



Today, ethanol production today consumes ~ 50% of the total US corn crop

Example: Growth in battery demands puts pressure on long-term natural resource development



Scale and Complexity Effects:

- One 1000-pound car battery requires 500,000-pounds of materials
- For EVs to fully replace new ICE vehicles will require global mining to expand by at least 5X

Concept #3:

Energy demand has three major drivers

Energy Demand =

Population

X

Per Capita GDP

X

Economic Energy Intensity

Estimating energy demand changes

△% Energy Demand =

△% Population

+

△% Per Capita GDP

+

△% Economic Energy Intensity

Concept #4:
ALL energy production begins with natural resource development

- Land
- Water
- Sun
- Wind
- Biomass
- Geological resources
  - Hydrocarbons
  - Minerals

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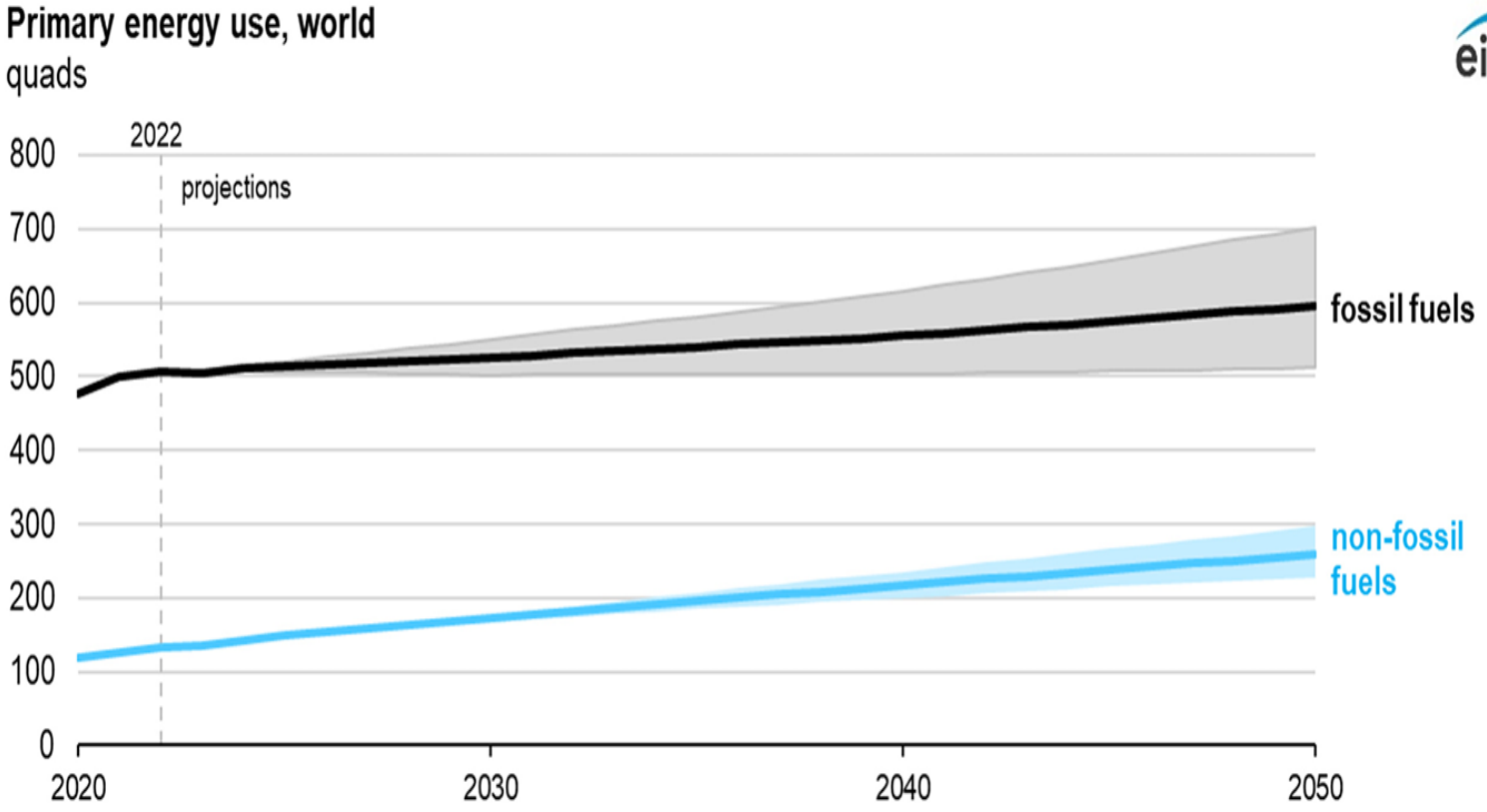
U.S. DOE Energy Information Administration(EIA) projections of global primary energy use to 2050



Data source: U.S. Energy Information Administration, *International Energy Outlook 2023* (IEO2023)
Note: Each line represents IEO2023 Reference case projections. Shaded regions represent maximum and minimum values for each projection year across the IEO2023 Reference case and side cases. Quads=quadrillion British thermal units.

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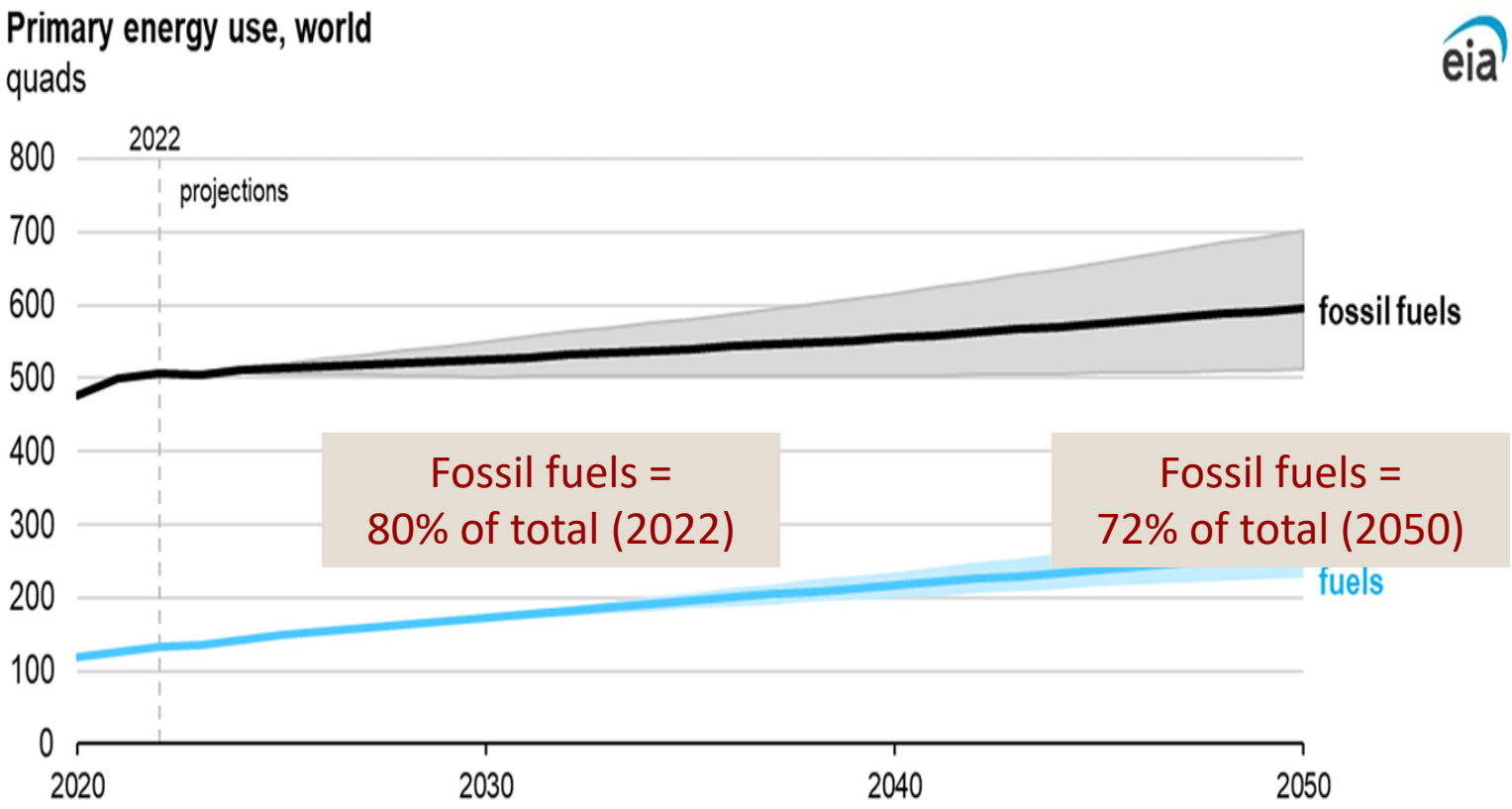

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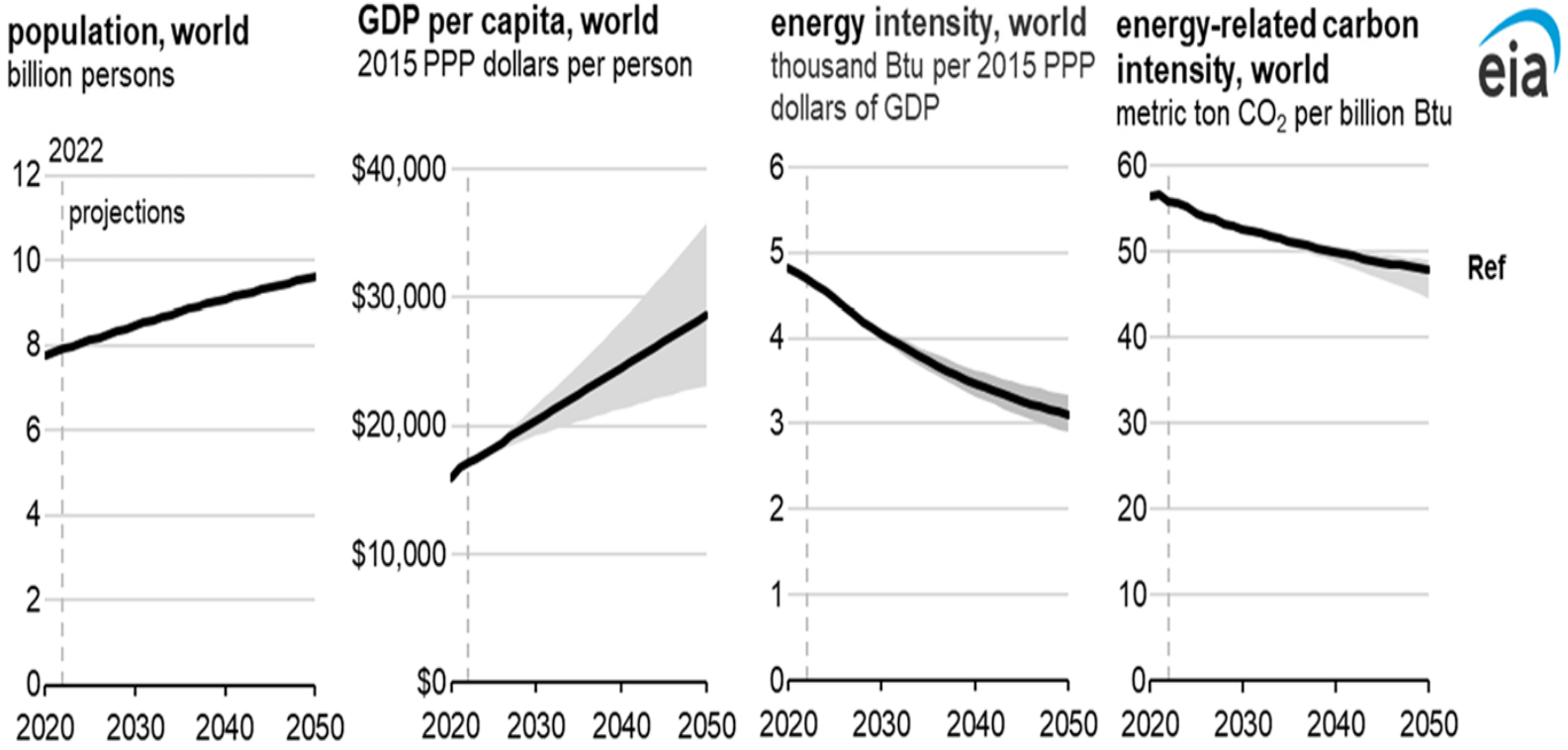
Projections on population, per capita GDP, and energy intensity to 2050



Data source: U.S. Energy Information Administration, *International Energy Outlook 2023* (IEO2023)
Note: Shaded regions represent maximum and minimum values for each projection year across the IEO2023 Reference case and side cases. Our global population assumptions do not vary across side cases. GDP=gross domestic product; PPP=purchasing power parity; Btu=British thermal units; Ref=Reference case.

Estimating global demand growth

Energy Demand Growth =

▲ Population (+1%)

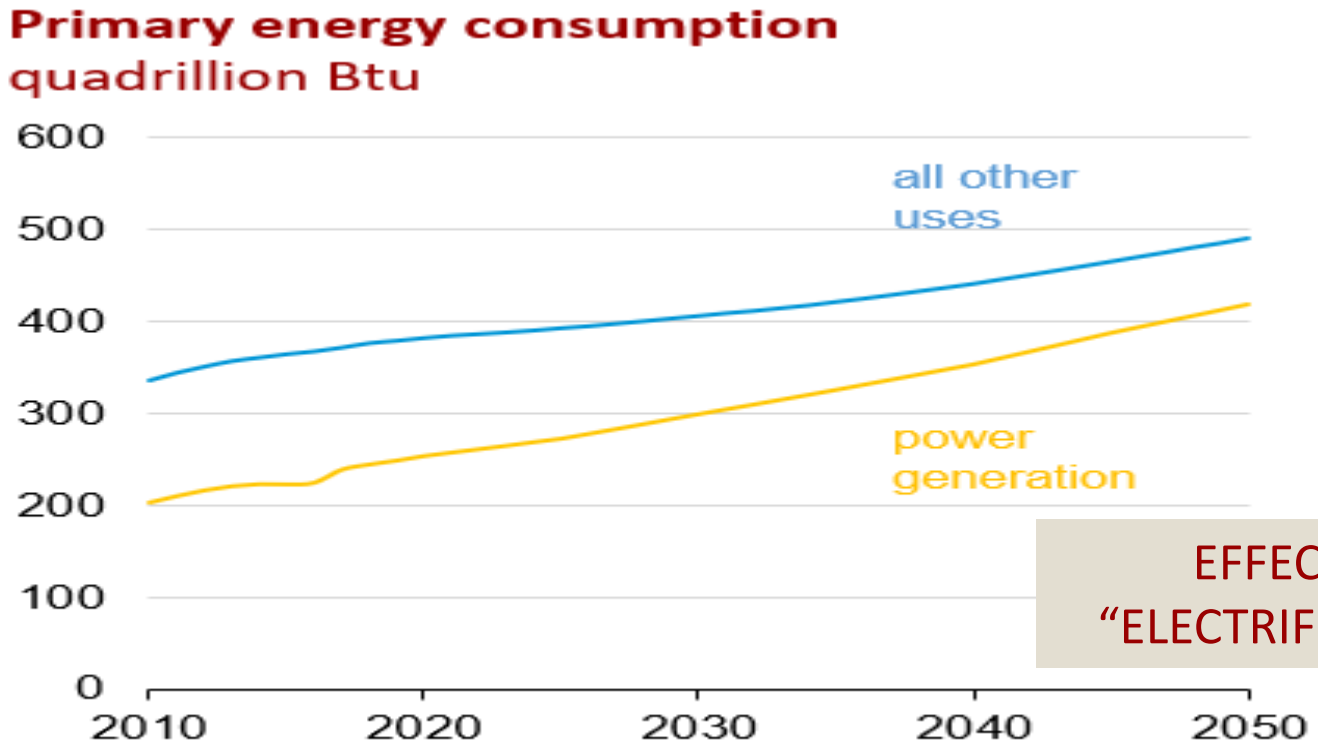
+

▲ Per Capita GDP (+2.5%)

+

▲ Economic Energy Intensity (-1.5%)

Power is the fastest growth segment in global energy

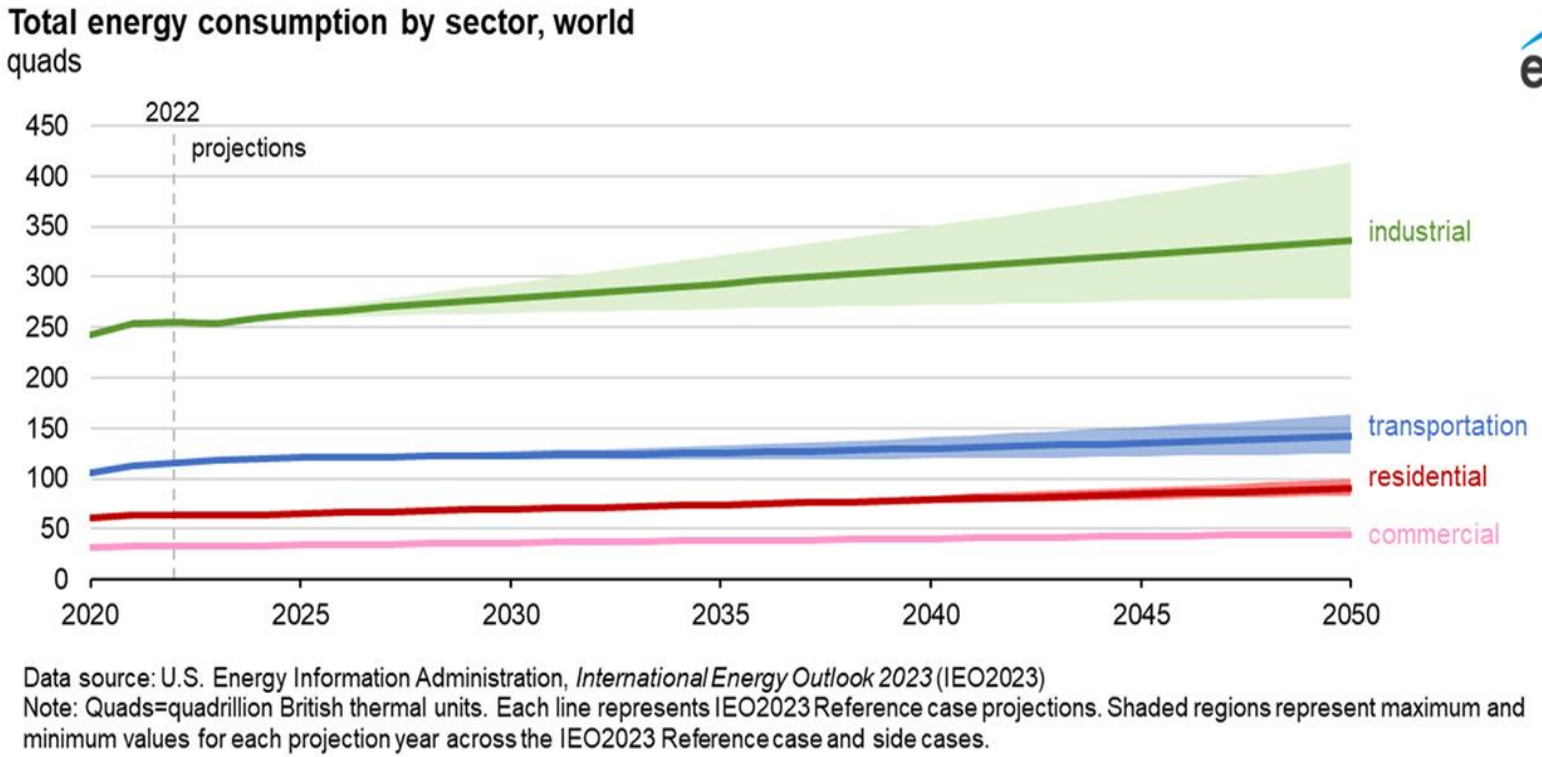


EFFECT OF "ELECTRIFICATION"

Source: U.S. Energy Information Administration, International Energy Outlook 2019

Dr. Linda Capuano, EIA
IEO2020, October 14, 2020

Projections of energy demand by sector



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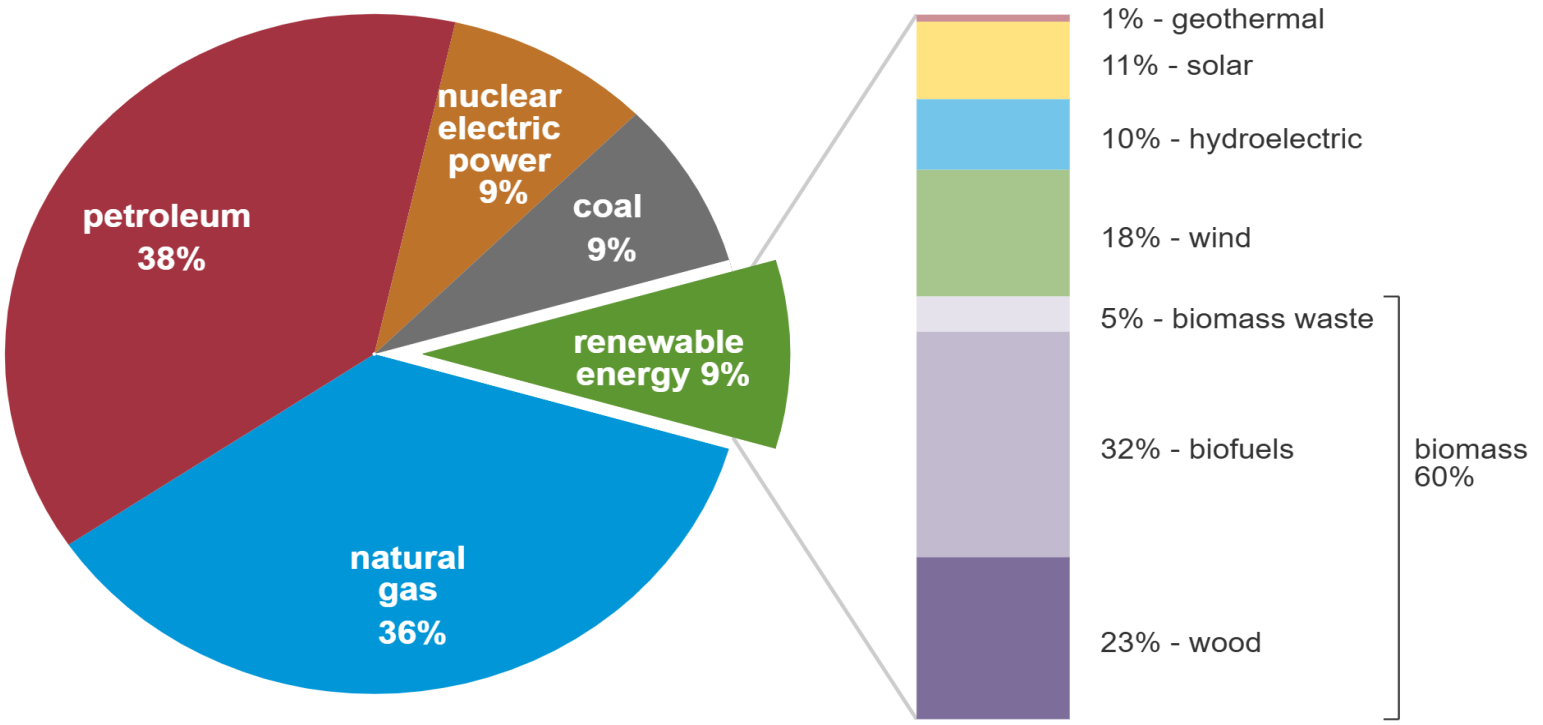
The U.S. has the largest and most diverse energy supply system

U.S. primary energy consumption by energy source, 2023

total = 93.59 quadrillion British thermal units

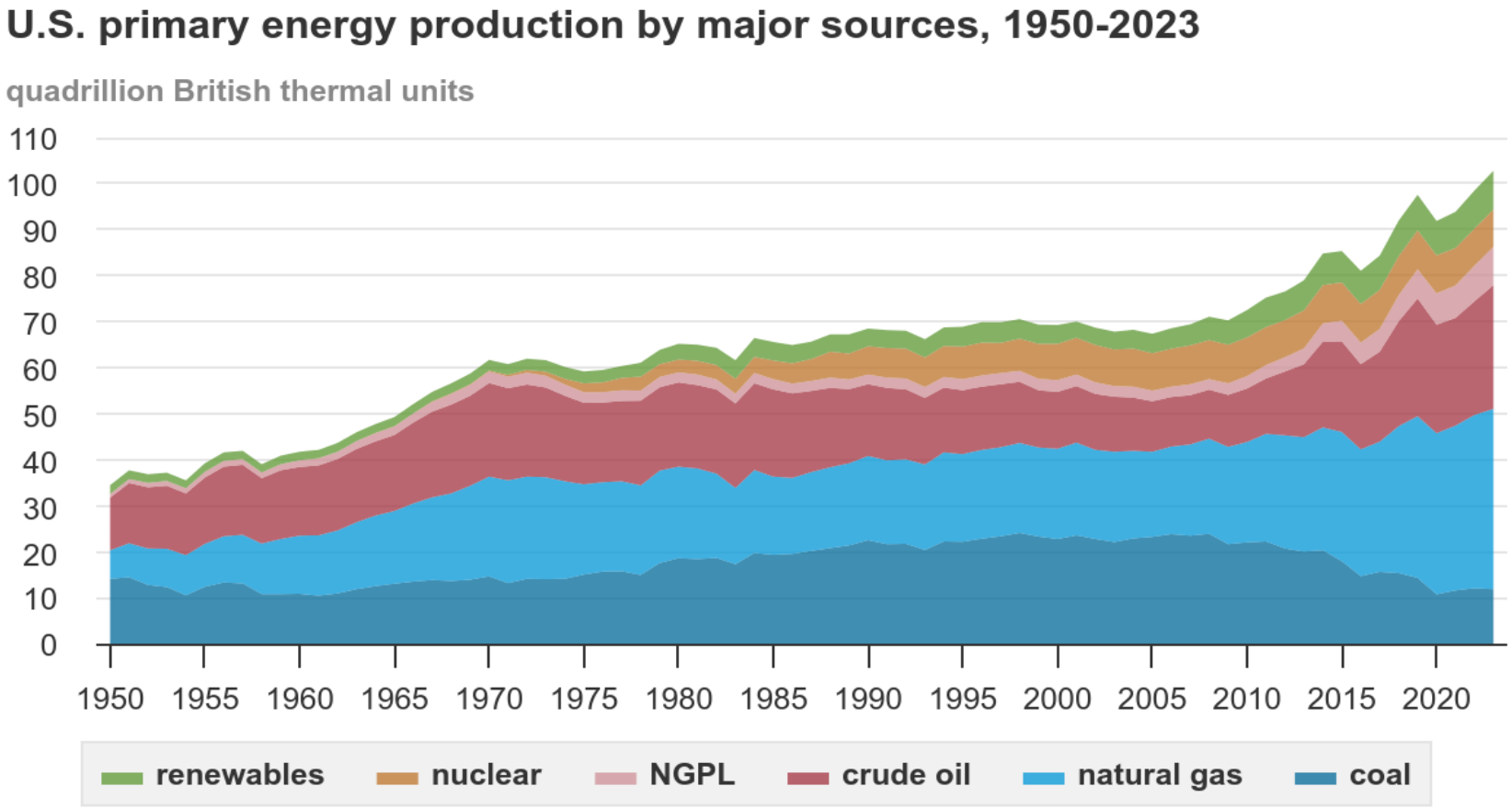
total = 8.24 quadrillion British thermal units



Data source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 1.3 and 10.1, April 2024, preliminary data

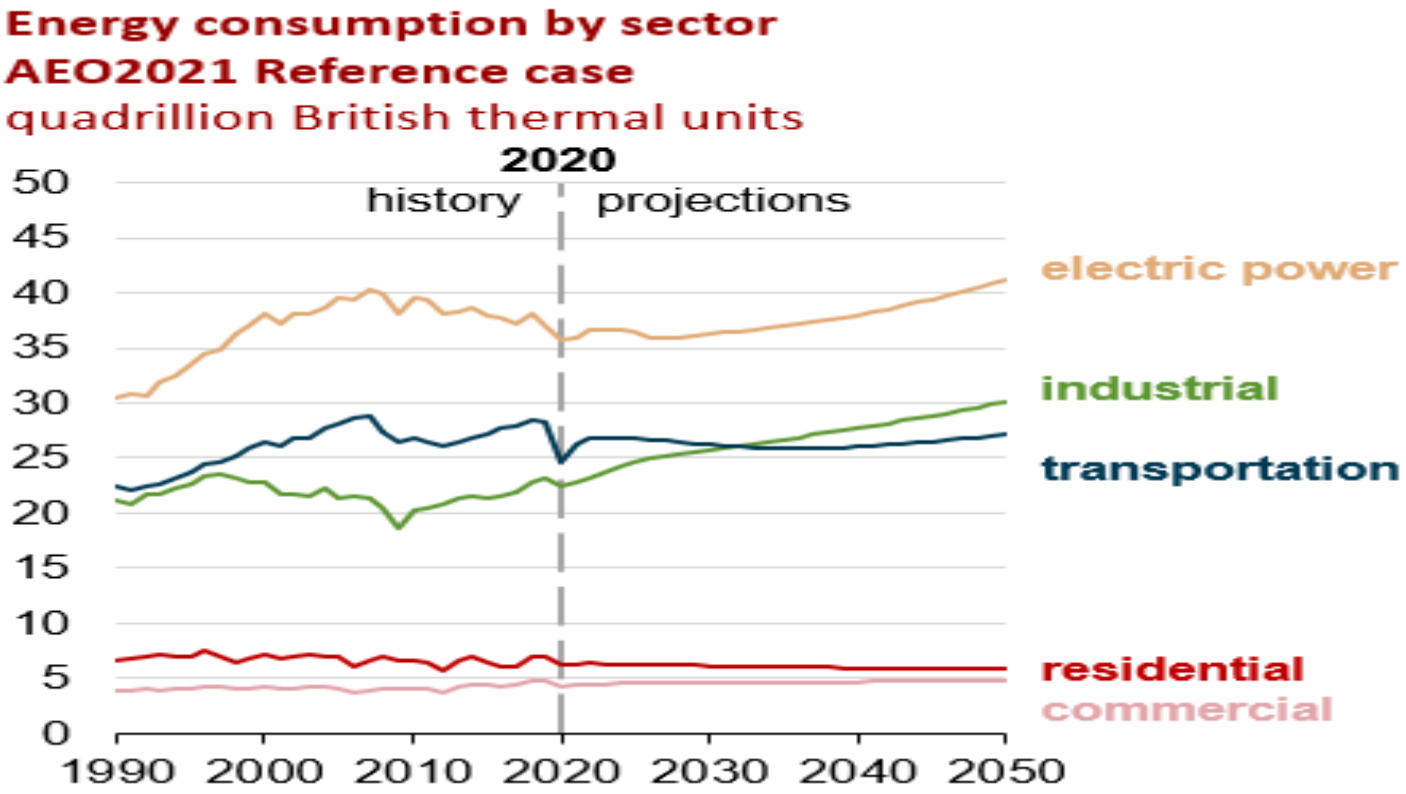
Note: Sum of components may not equal 100% because of independent rounding.

The U.S. energy supply system continues to grow and evolve



Data source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 1.2, April 2024, preliminary data for 2023
Note: NGPL=natural gas plant liquids

U.S. energy demand by sector



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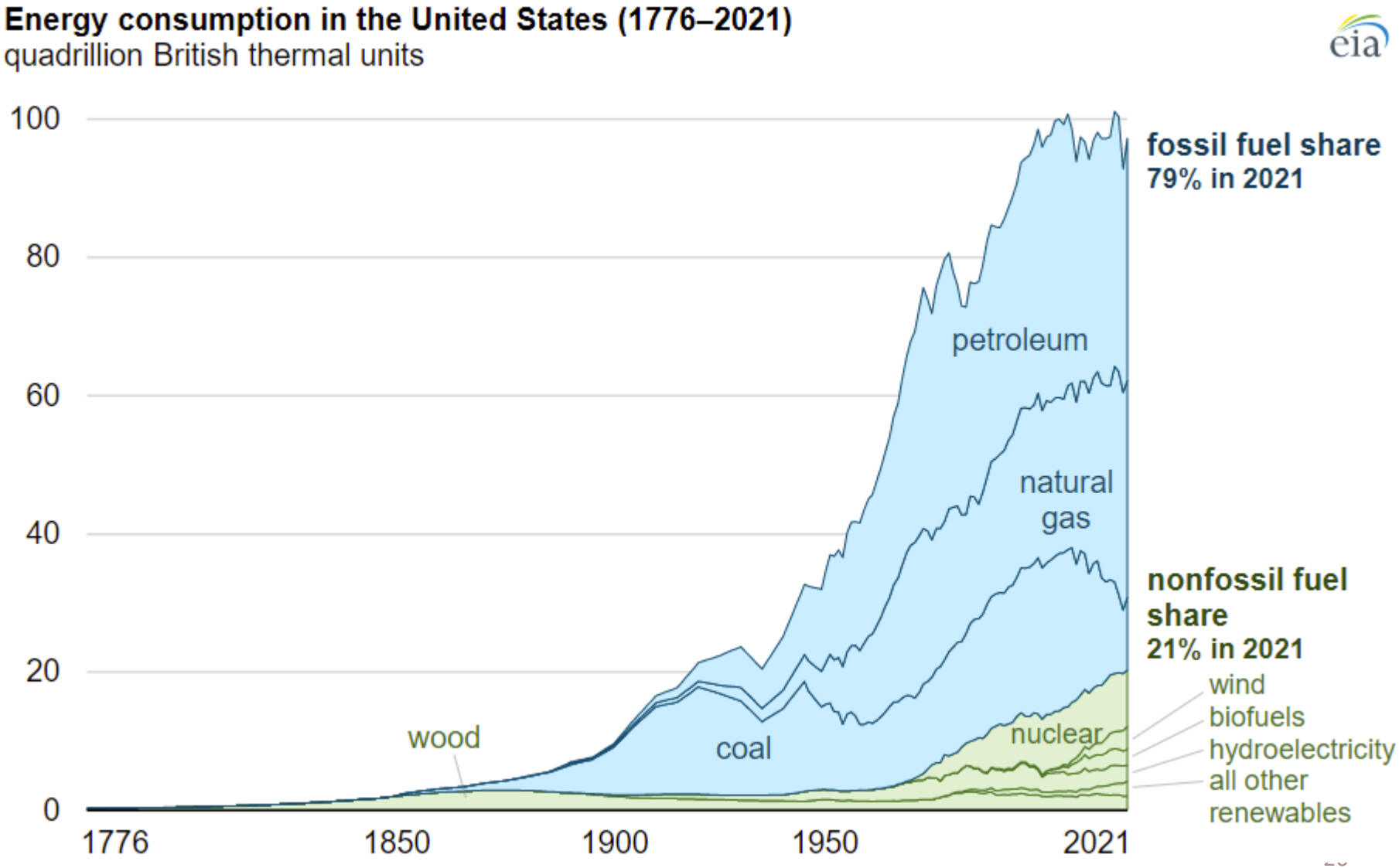
Energy Transitions in the U.S.



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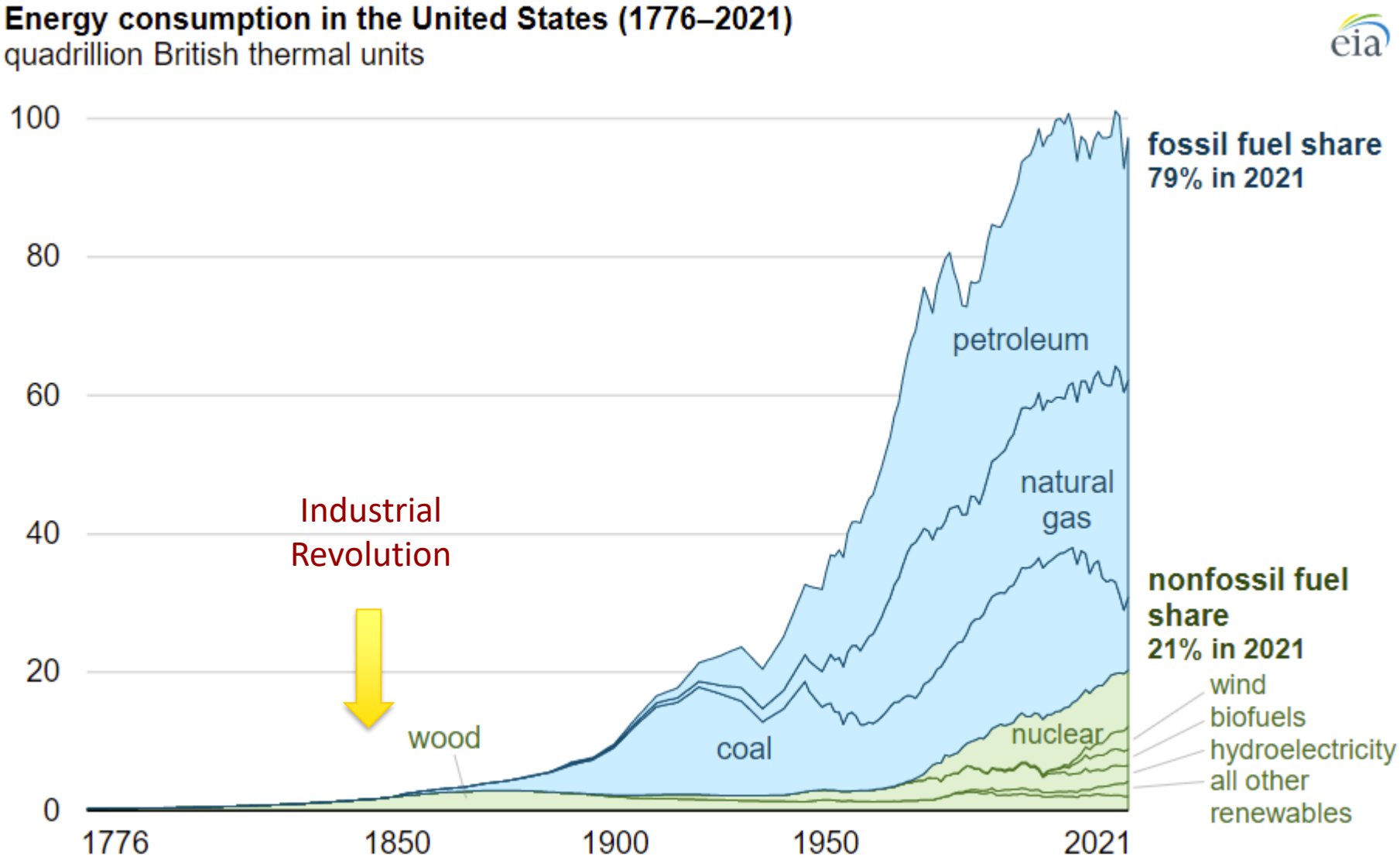

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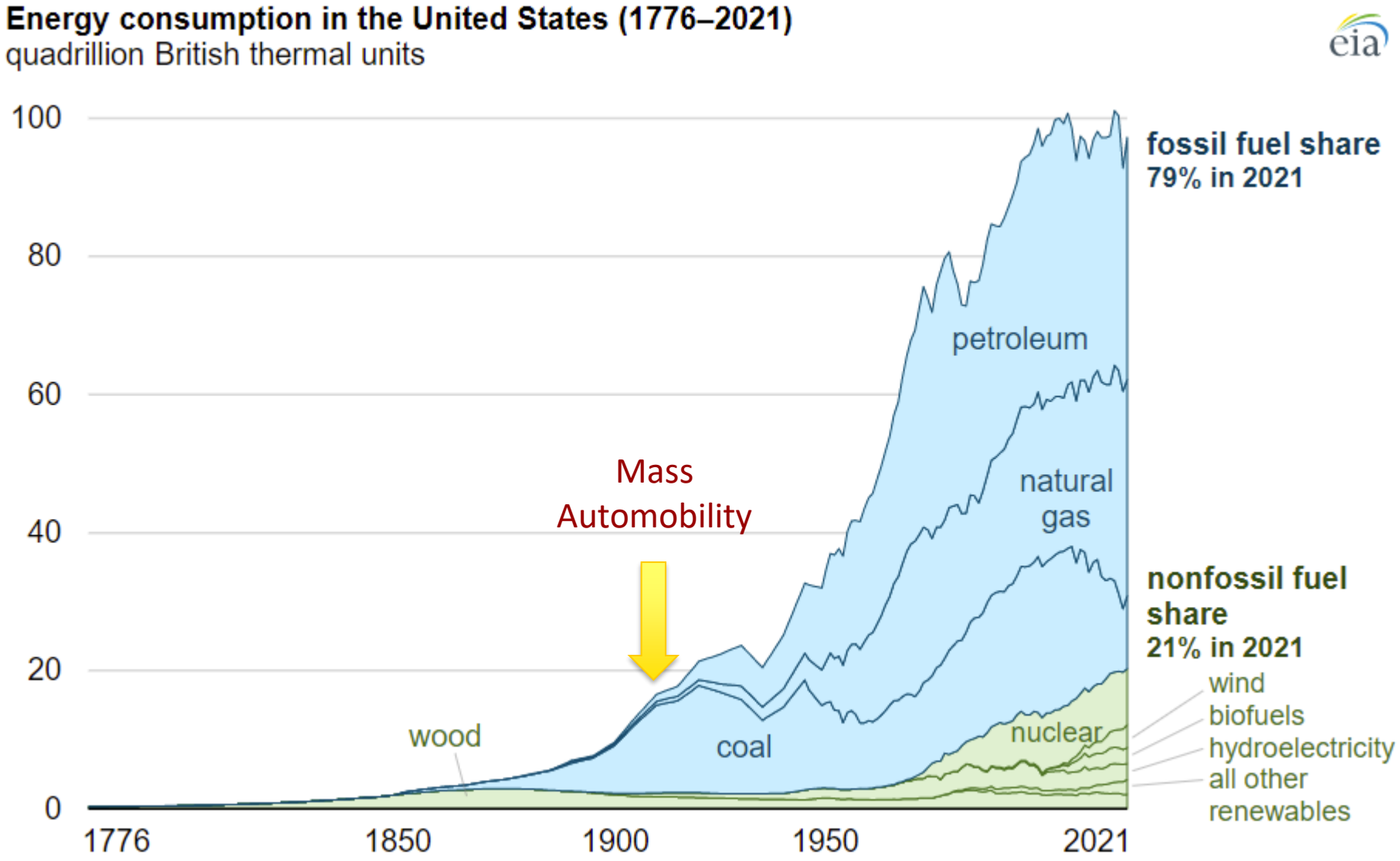

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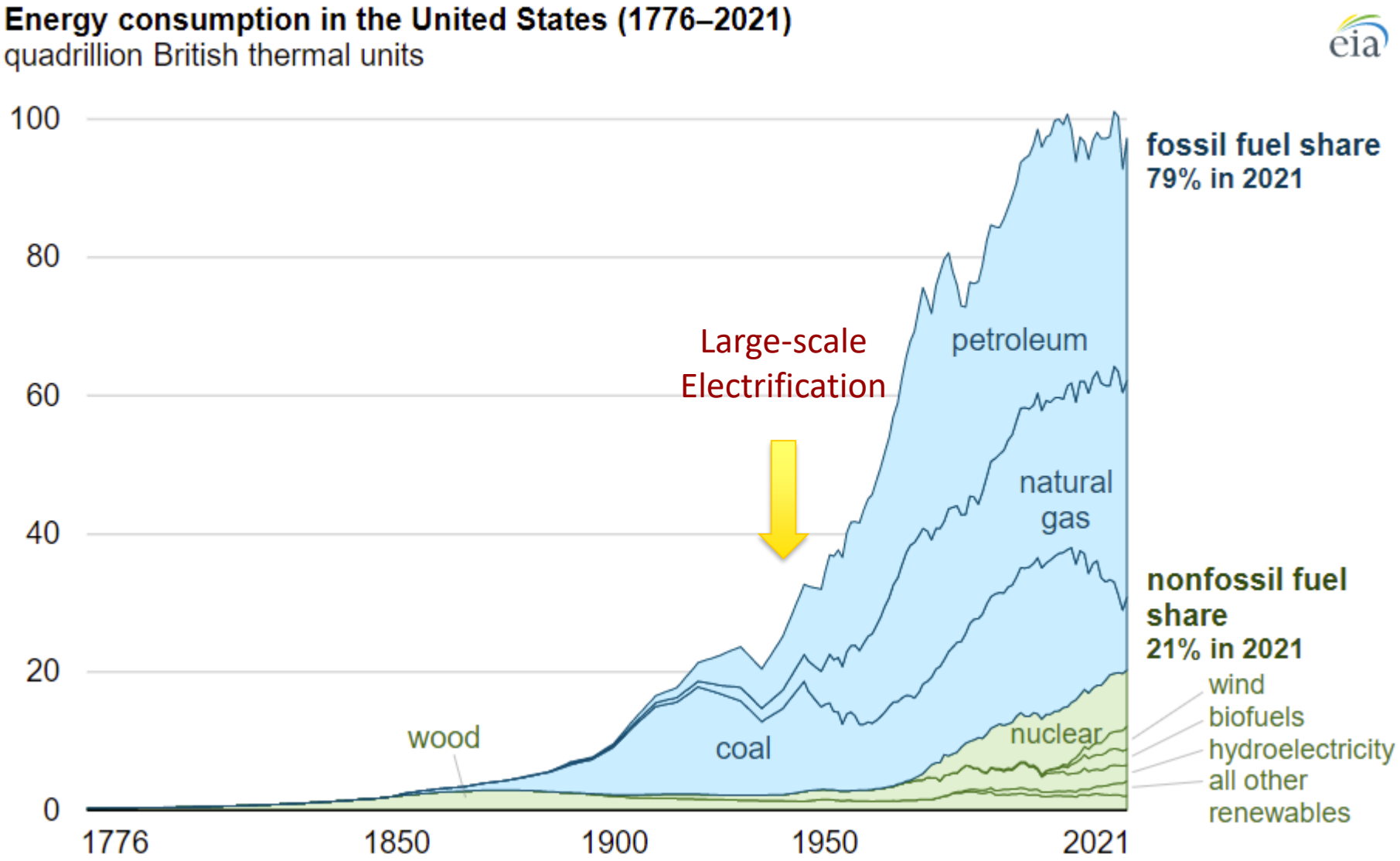

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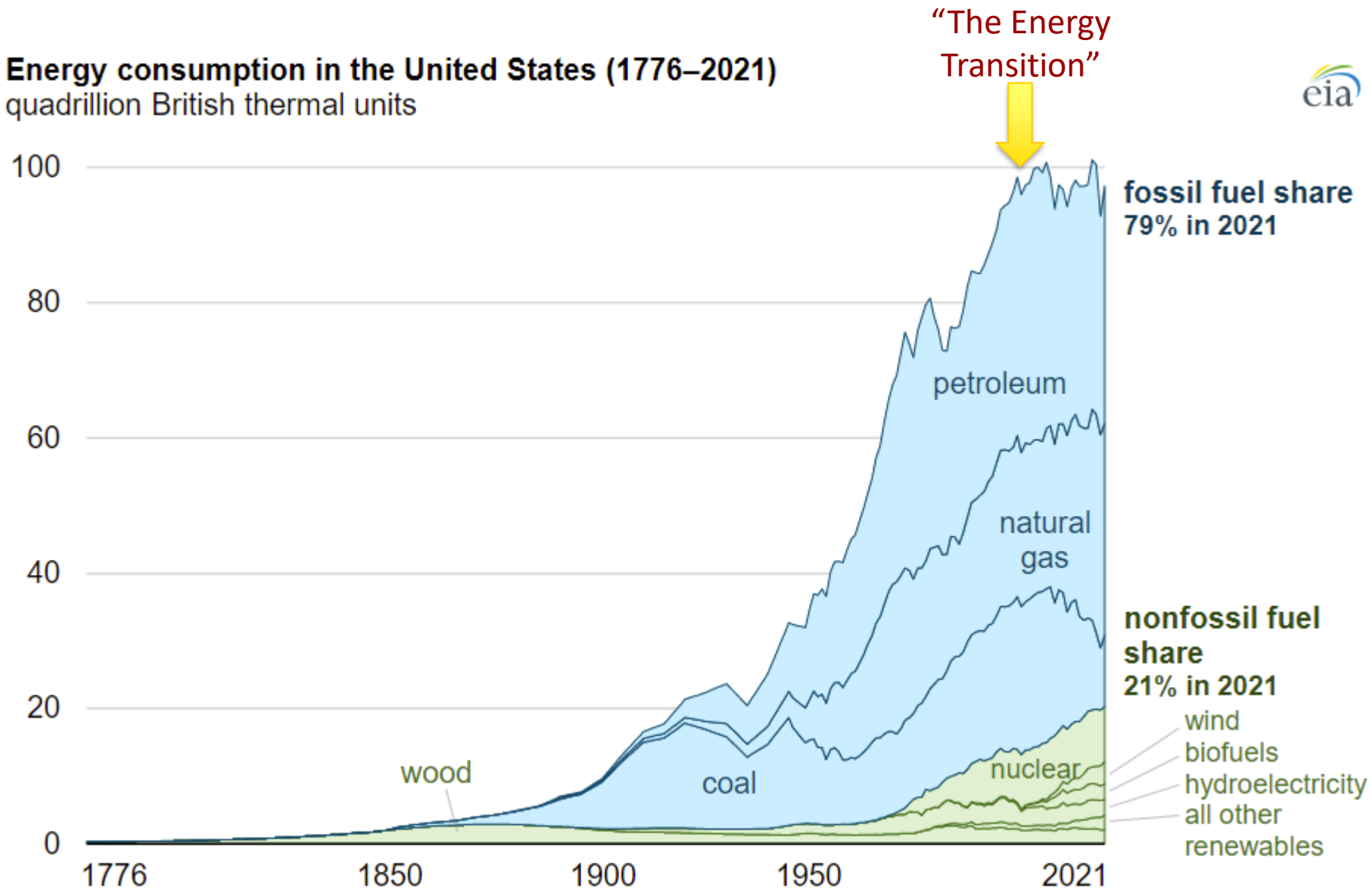

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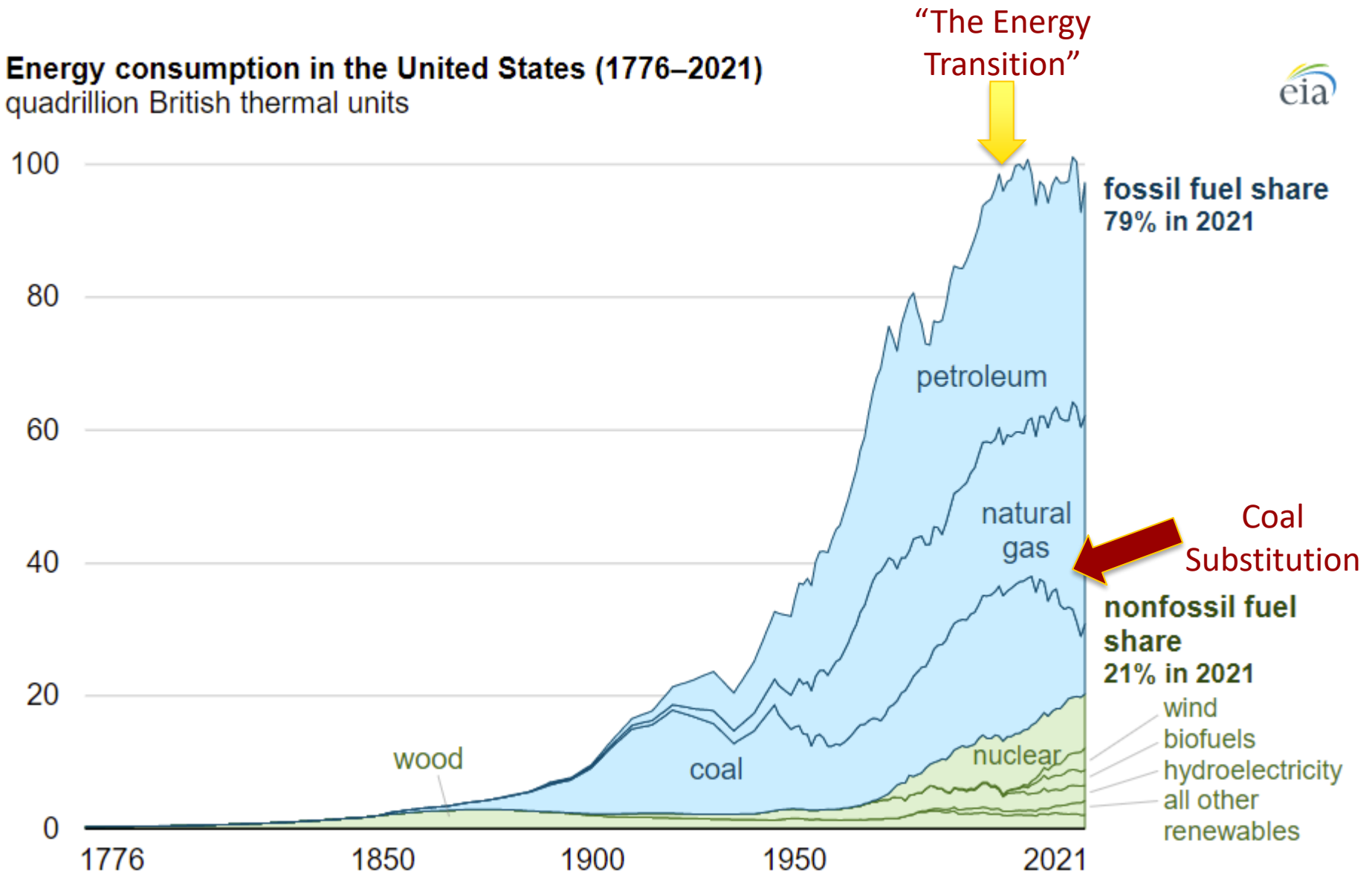


Historical drivers of energy transitions

- New energy resources and technology deployable at scale
- Increases in energy demand from new applications and markets of scale (automobiles, aircraft, computers, etc.)
- Growth in available investment capital

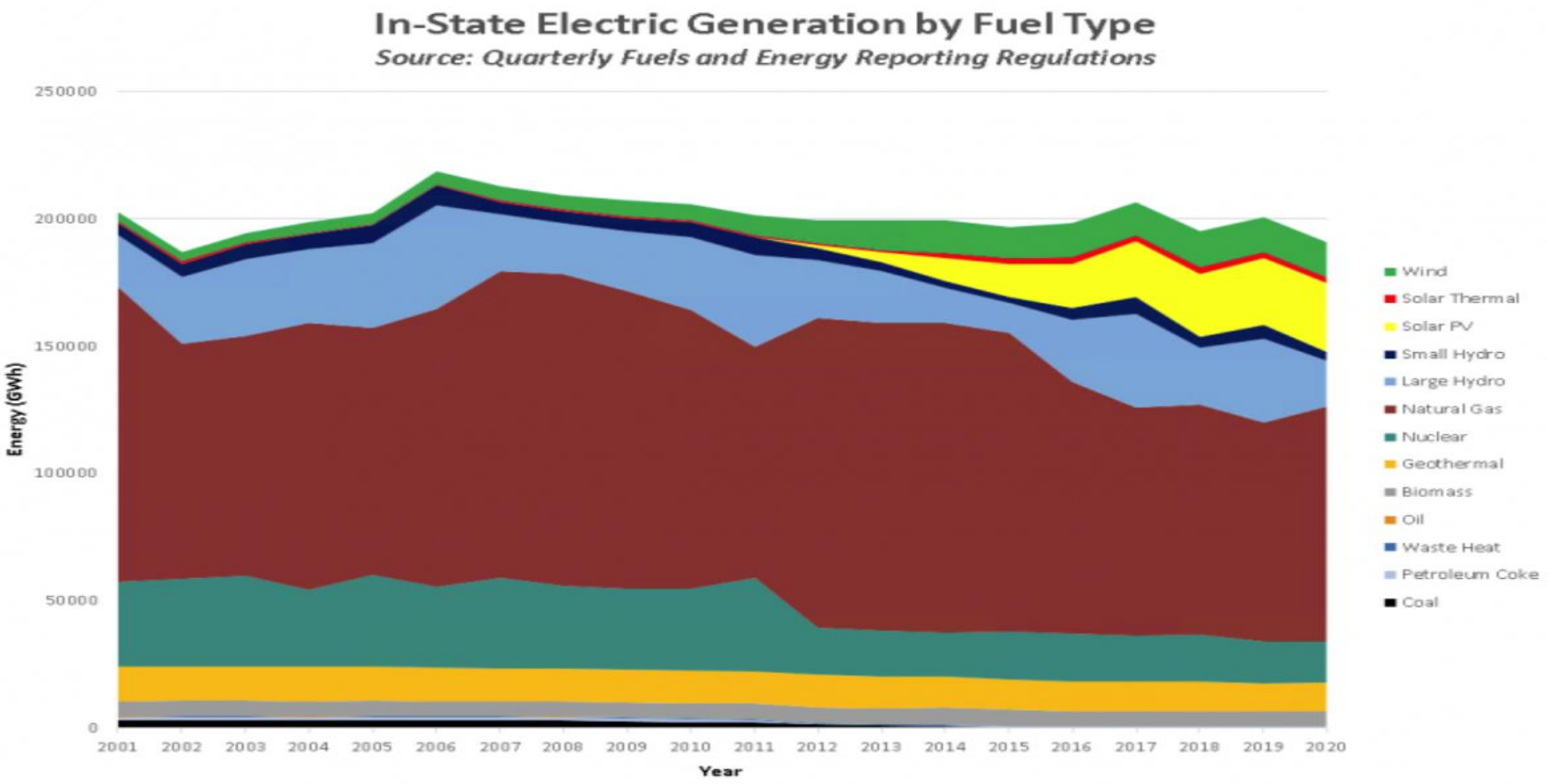
Past Energy Transitions have been **additive** to supply to meet new growth in energy demand

Drivers of the new Energy Transition

- Lower-carbon energy resources and technologies deployable at scale
- Growth in political and societal demands for lower-carbon energy sources
- Shifting investment capital flows

The new Energy Transition is **both additive and substitutive** to meet demand growth **and** displace higher-carbon supplies

Energy Transition example: California's power system



Ref. CA Energy Commission

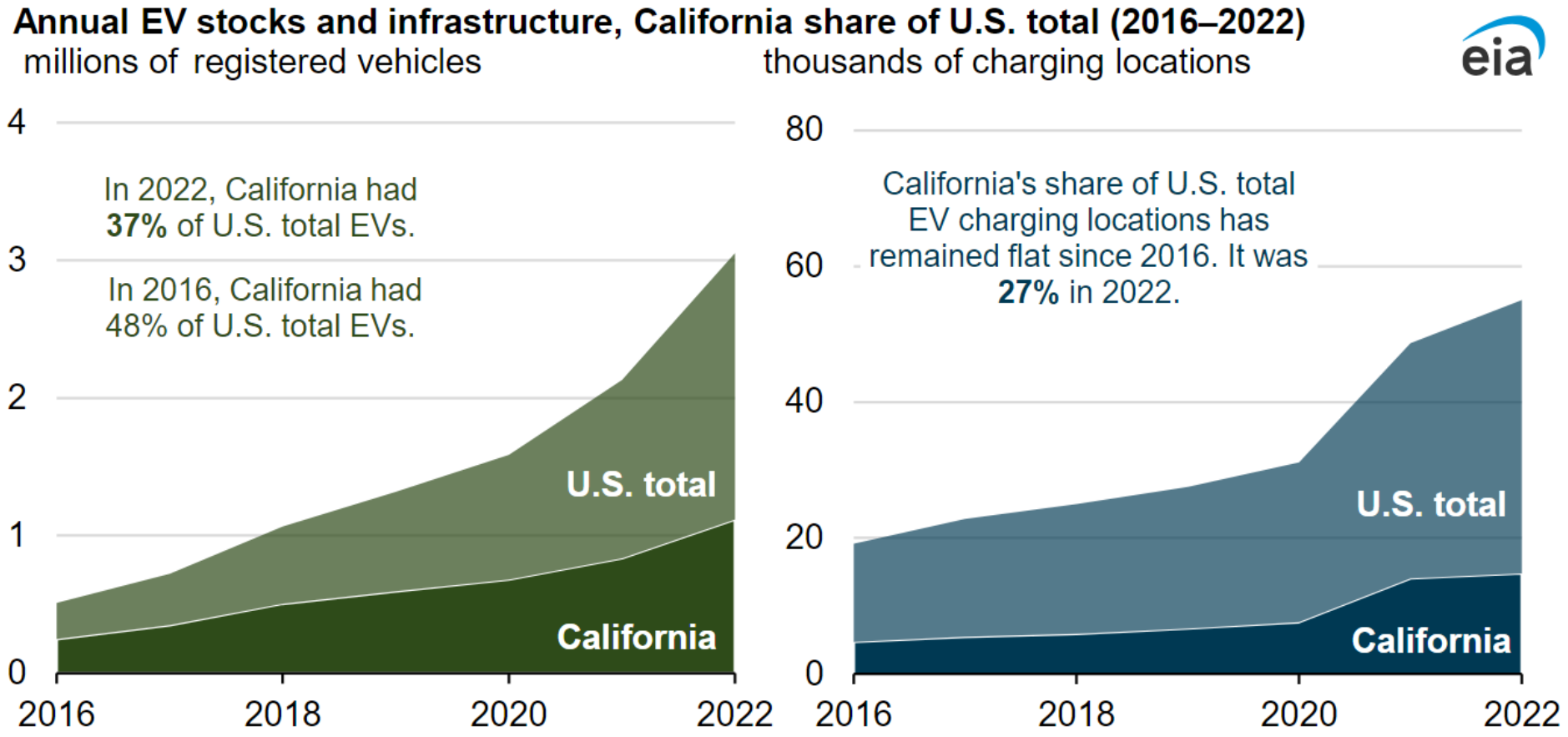
Some observations on the Energy Transition

- The Energy Transition will be “uneven”
- Unforeseen events will intervene (as they always have)
- The Transition will take longer and may take form in ways which challenge current political goals
- Capital investment level will need to greatly expand
- The Transition is not possible without the transition of the fossil energy system

Challenges to the Energy Transition for the U.S. (and the world)

- Meeting energy demand growth for electrical power
  - Electrification of ground transportation
  - Meeting rapid growth in data centers and demand for AI
  - Creating more resiliency to meet a changing climate

U.S. EV penetration



Data source: U.S. Energy Information Administration, State Energy Data System
Note: Data are for end of year. EV=electric vehicle.

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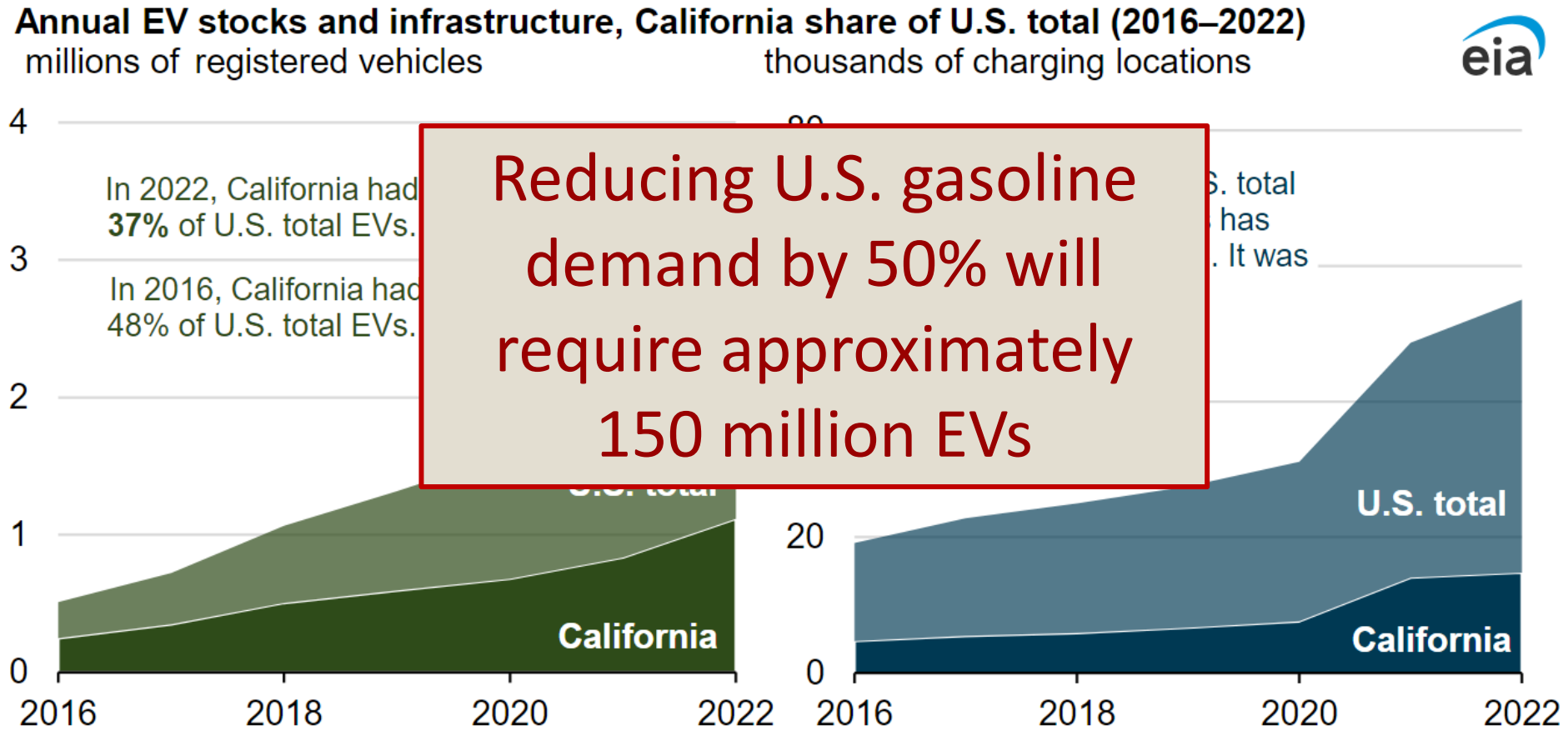

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Amazon buys nuclear-powered data center from Talen

Thu, Mar 7, 2024, 5:01AM | Nuclear News

Susquehanna nuclear plant in Salem Township, Penn., along with the data center in foreground. (Photo: Talen Energy)


International
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The Future of Cooling

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  - Electrification of ground transportation
  - Meeting rapid growth in data centers and demand for AI
  - Creating more resiliency to meet a changing climate
- Re-industrializing while de-carbonizing
- Finding the enormous investment capital needed
- Developing the next generation of energy workers

Summary thoughts

- All energy systems and technologies depend upon the development of natural resources.

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- The scale of the global energy system is enormous, which in turn, drives the time frame and level of capital investment needed for the Energy Transition.
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- The electricity generation component of energy is decarbonizing (with exceptions) by displacement of coal by renewables and natural gas.

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- The scale of the global energy system is enormous, which in turn, drives the time frame and level of capital investment needed for the Energy Transition.
- Global energy demand is going to increase as population gains and economic growth are likely to outpace improvements in energy system efficiency.
- The electricity generation component of energy is decarbonizing (with exceptions) by displacement of coal by renewables and natural gas.
- Decarbonizing the transportation, industrial, and agricultural sectors at scale remains a major economic, political, and technological challenge.

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Final thought:
Transition of the energy system will involve more than just changing technologies and policies

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