

01-Energy Flows

Text: Chapter 1

ECEGR 3500

Electrical Energy Systems

Professor Henry Louie

➤ Overview

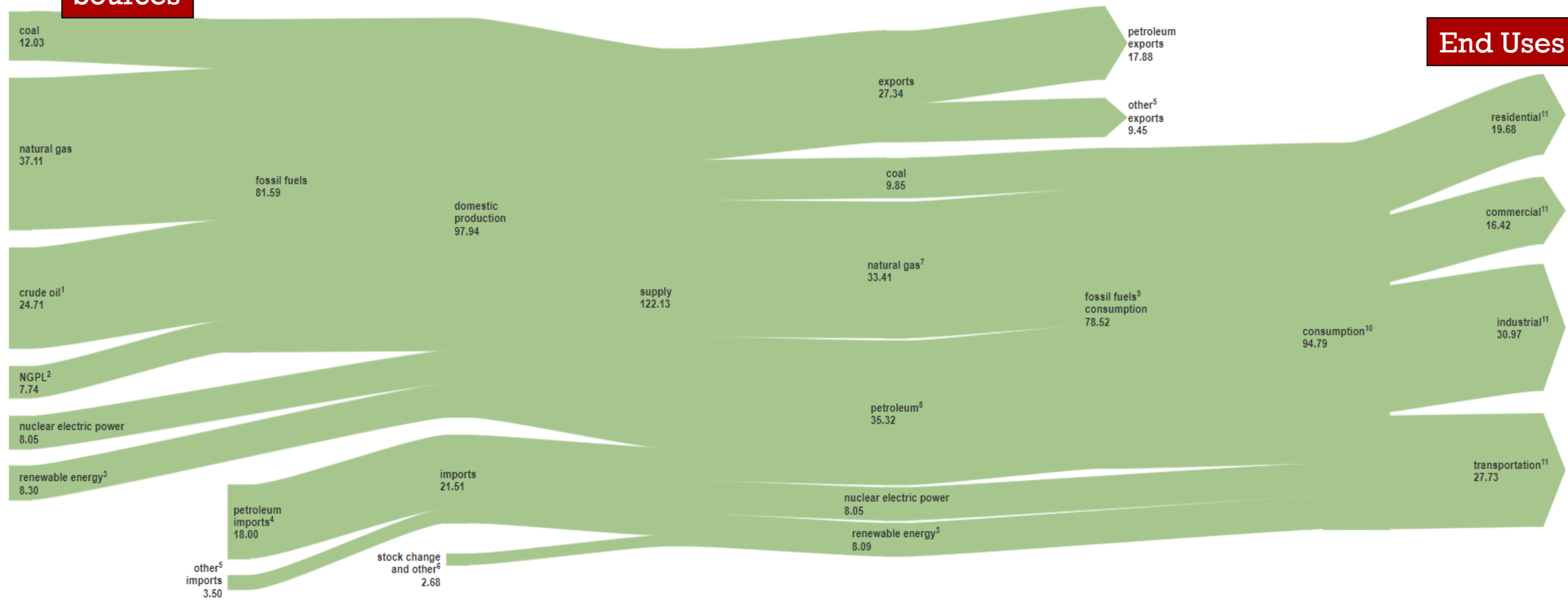
- Energy Flows
- Electrical Energy Flows
- Changes in Energy Flow

U.S. energy flow, 2022

quadrillion Btu

1 kWh = 3412 BTU

Sources

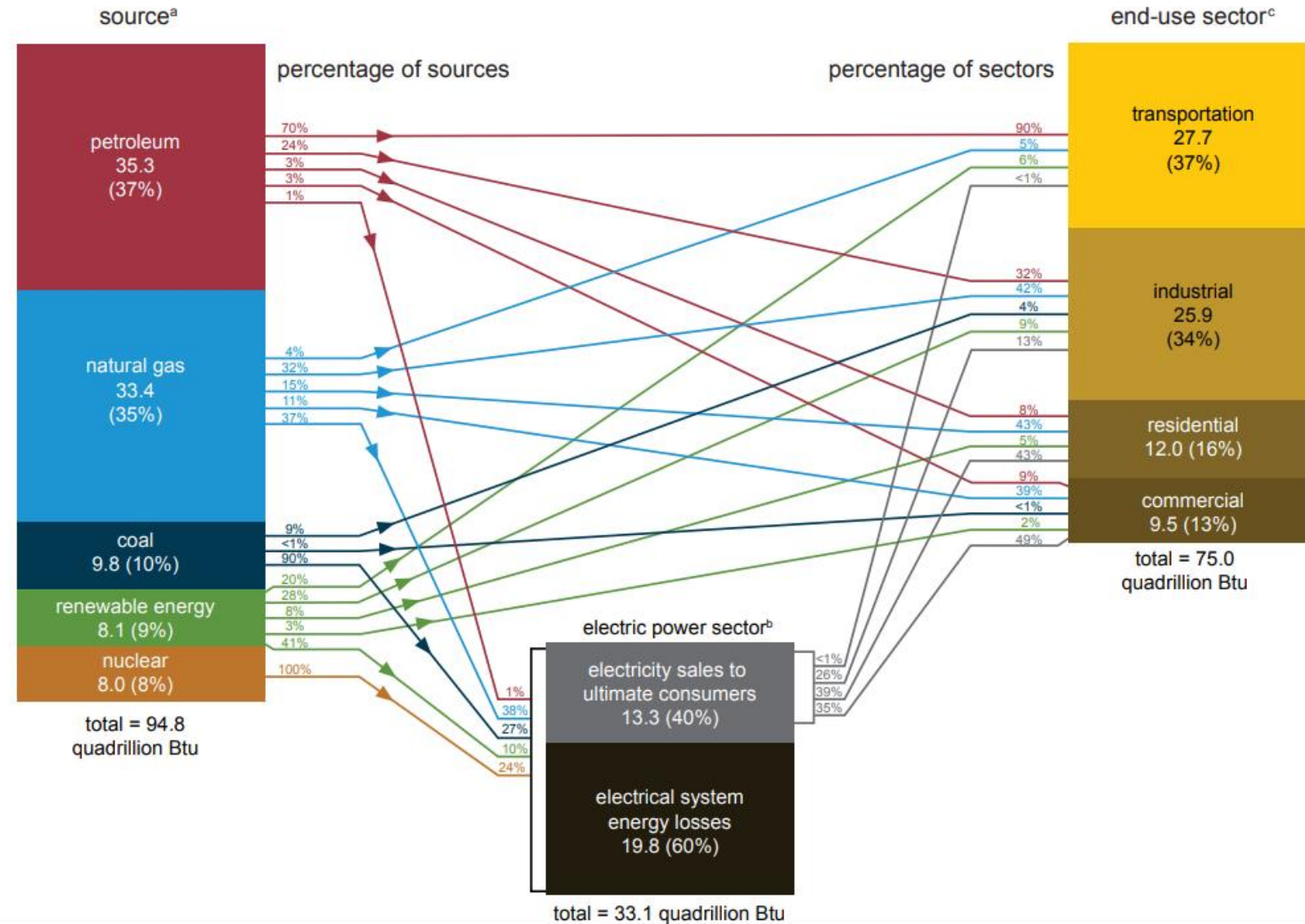


¹ Includes lease condensate. | ² Natural gas plant liquids. | ³ Conventional hydroelectric power, biomass, geothermal, solar, and wind. | ⁴ Crude oil and petroleum products. Includes imports into the Strategic Petroleum Reserve. | ⁵ Natural gas, coal, coal coke, biomass, and electricity. | ⁶ Adjustments, losses, and unaccounted for. | ⁷ Natural gas only; excludes supplemental gaseous fuels. | ⁸ Petroleum products supplied. | ⁹ Includes -0.06 quadrillion Btu of coal coke net imports. | ¹⁰ Includes 0.14 quadrillion Btu of electricity net imports. | ¹¹ Total energy consumption, which is the sum of primary energy consumption, electricity sales to ultimate customers, and electrical system energy losses. Losses are allocated to the end-use sectors in proportion to each sector's share of total electricity sales. See Note 1, "Electrical System Energy Losses," at the end of U.S. Energy Information Administration (EIA), *Monthly Energy Review* (September 2023), Section 2. See Note 2, "Other Energy Losses," at the end of U.S. Energy Information Administration (EIA), *Monthly Energy Review* (September 2023), Section 2 | Notes: • Data are preliminary • Values are derived from source data prior to rounding for publication • Totals may not equal sum of components due to independent rounding

Source: www.eia.gov

U.S. energy consumption by source and sector, 2022

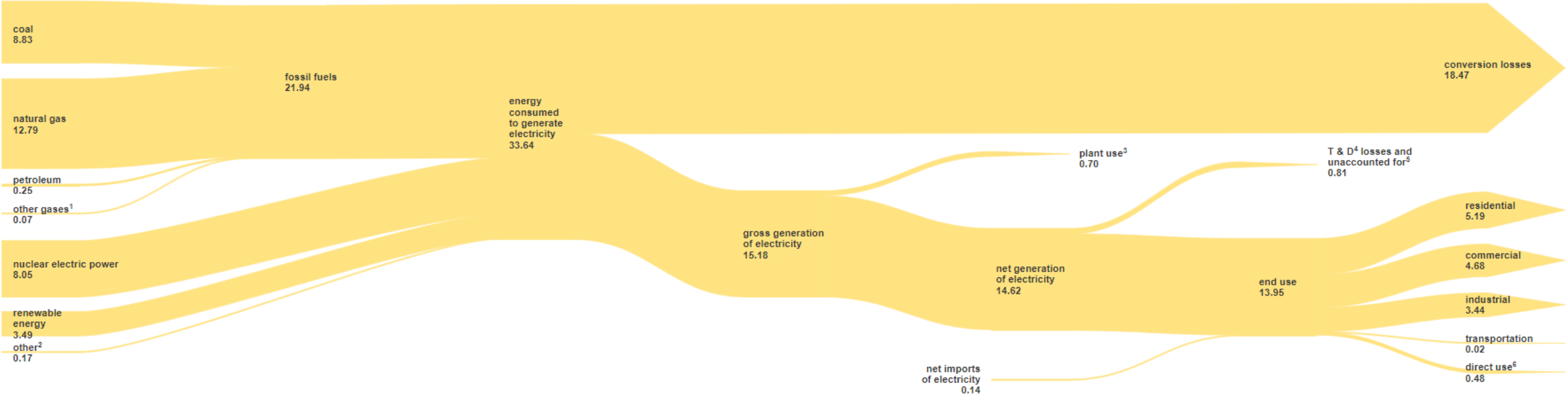
quadrillion British thermal units (Btu)



More energy is devoted to electricity generation than any other sector.

U.S. electricity flow, 2022

quadrillion Btu



¹ Blast furnace gas and other manufactured and waste gases derived from fossil fuels. | ² Batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, miscellaneous technologies, and non-renewable waste (municipal solid waste from nonbiogenic sources, and tire-derived fuels). | ³ Electric energy used in the operation of power plants. | ⁴ Transmission and distribution losses (electricity losses that occur between the point of generation and delivery to the customer). | ⁵ Data collection frame differences and nonsampling error. | ⁶ Use of electricity that is 1) self-generated, 2) produced by either the same entity that consumes the power or an affiliate, and 3) used in direct support of a service or industrial process located within the same facility or group of facilities that house the generating equipment. Direct use is exclusive of station use. | Notes: • Data are preliminary. • Data are for utility-scale facilities. • See Note 1, "Electrical System Energy Losses," at the end of U.S. Energy Information Administration (EIA), Monthly Energy Review (September 2023), Section 2. • Net generation of electricity includes pumped storage facility production minus energy used for pumping. • Values are derived from source data prior to rounding for publication. • Totals may not equal sum of components due to independent rounding.

eia Sources: U.S. Energy Information Administration (EIA), *Monthly Energy Review* (September 2023), Tables 7.1, 7.2a, 7.3a, 7.6, and A6; and EIA, Form EIA-923, "Power Plant Operations Report."

Source: www.eia.gov

» Exercise

In 2022, 33.1 Quads were used to generate electricity. Of this, 19.8 Quads were lost in the energy conversion process. What is the average efficiency of the energy conversion process?

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Answer: $100 \times (1 - 19.8/33.1) = 40.2$ percent

Conversion of thermal energy to electrical energy has a low efficiency (although not all electricity is generated from thermal energy, for example, in a wind turbine). Overall efficiency has been rising—why?

» Exercise

In 2022, 0.81 Quads were consumed by losses associated with transmission and distribution of electricity. How efficient is the transmission and distribution of electricity? (Gross electricity generation was 15.18 Quads).

» Exercise

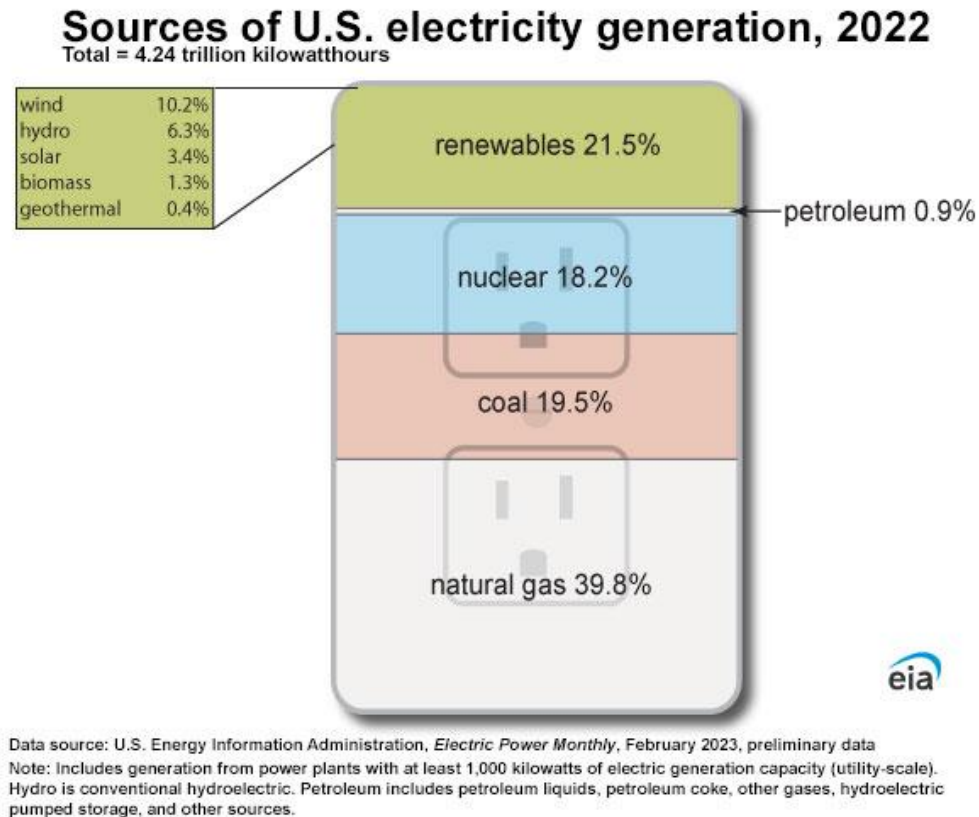
In 2022, 0.81 Quads were consumed by losses associated with transmission and distribution of electricity. How efficient is the transmission and distribution of electricity? (Gross electricity generation was 15.18 Quads).

Answer: $100 \times (1 - 0.81/15.18) = 94.7$ percent

The electrical system is highly efficient.

Energy Flows (U.S.)

2022: 4,240 TWh (terawatthours) of electrical energy consumed

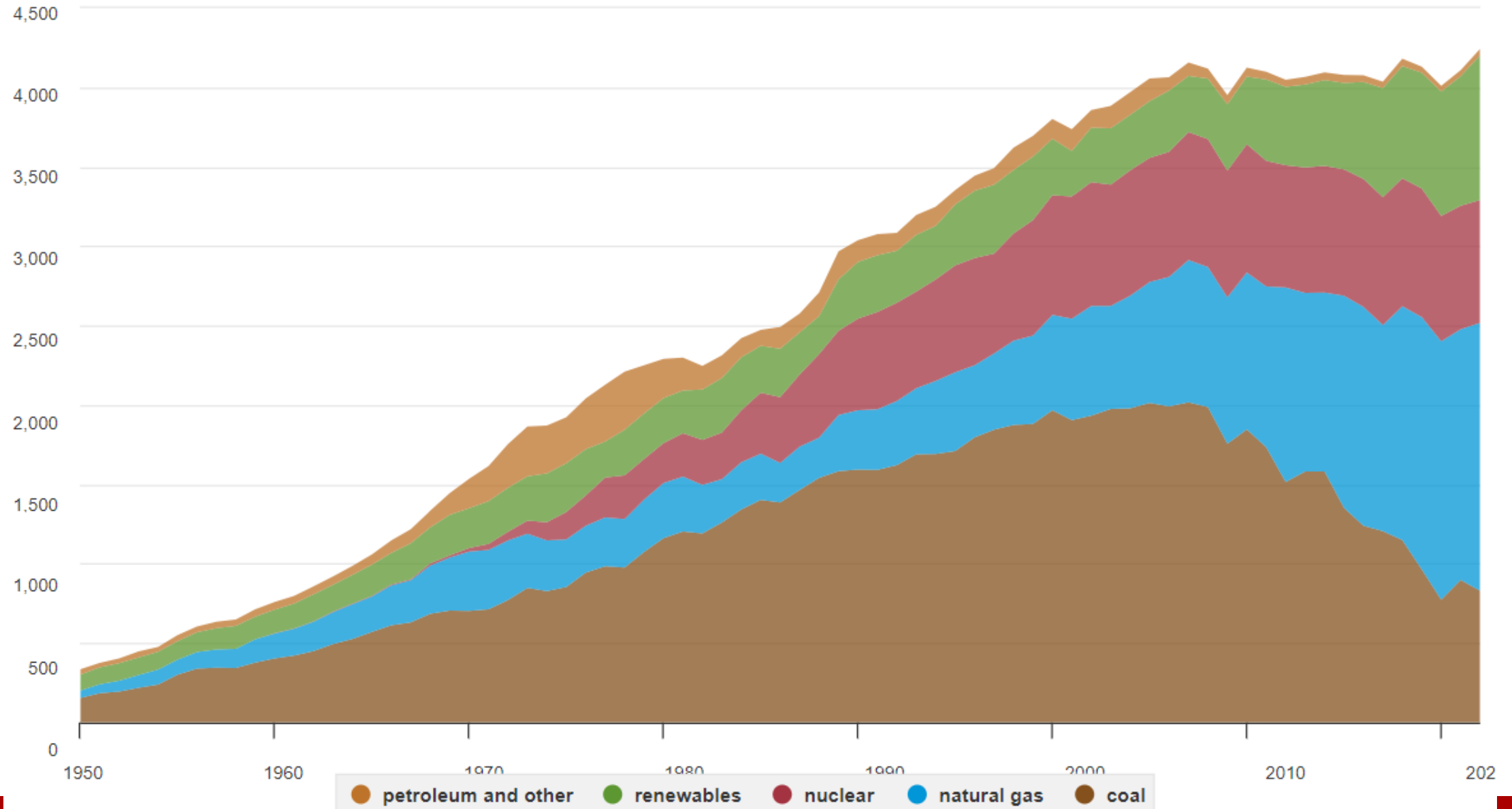


Snapshot statistic
What are the trends?

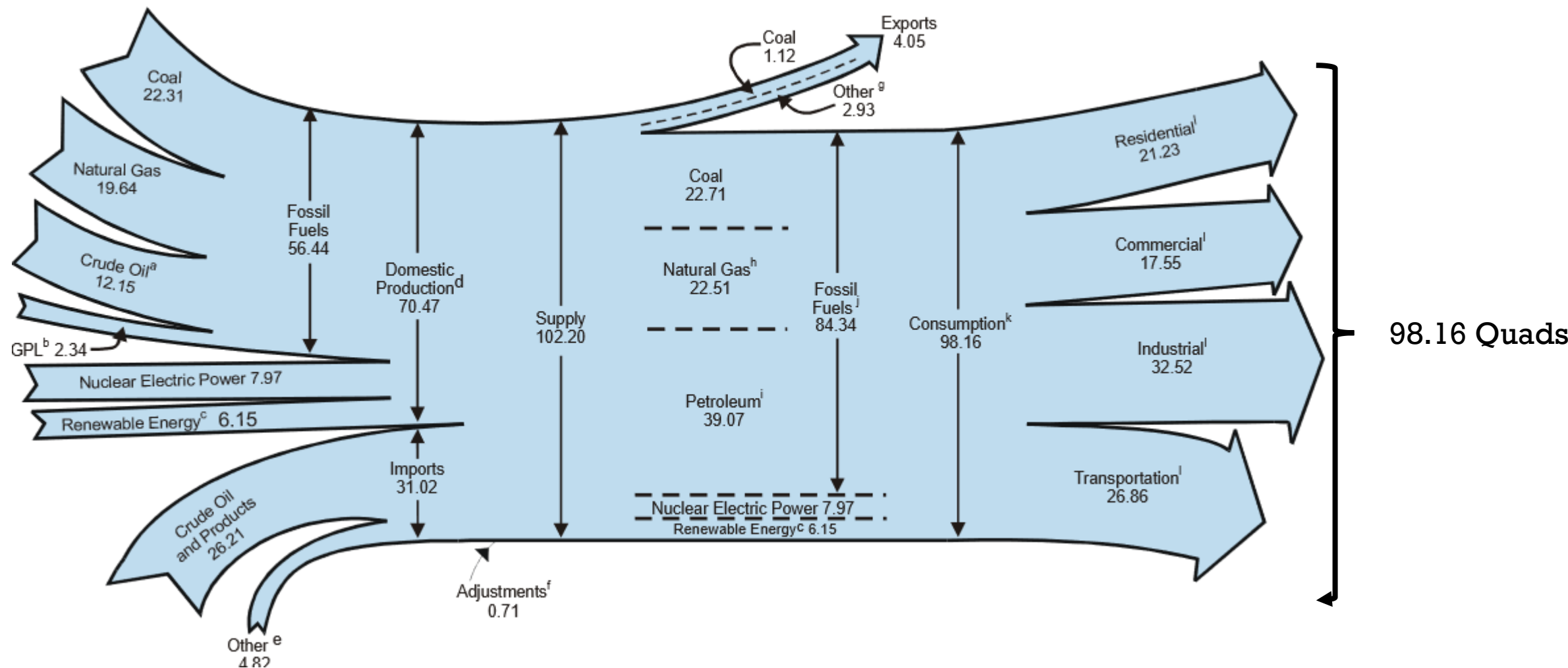
U.S. electricity generation by major energy source, 1950-2022



billion kilowatthours



U.S. Energy Flow, 2003 Quadrillion BTU

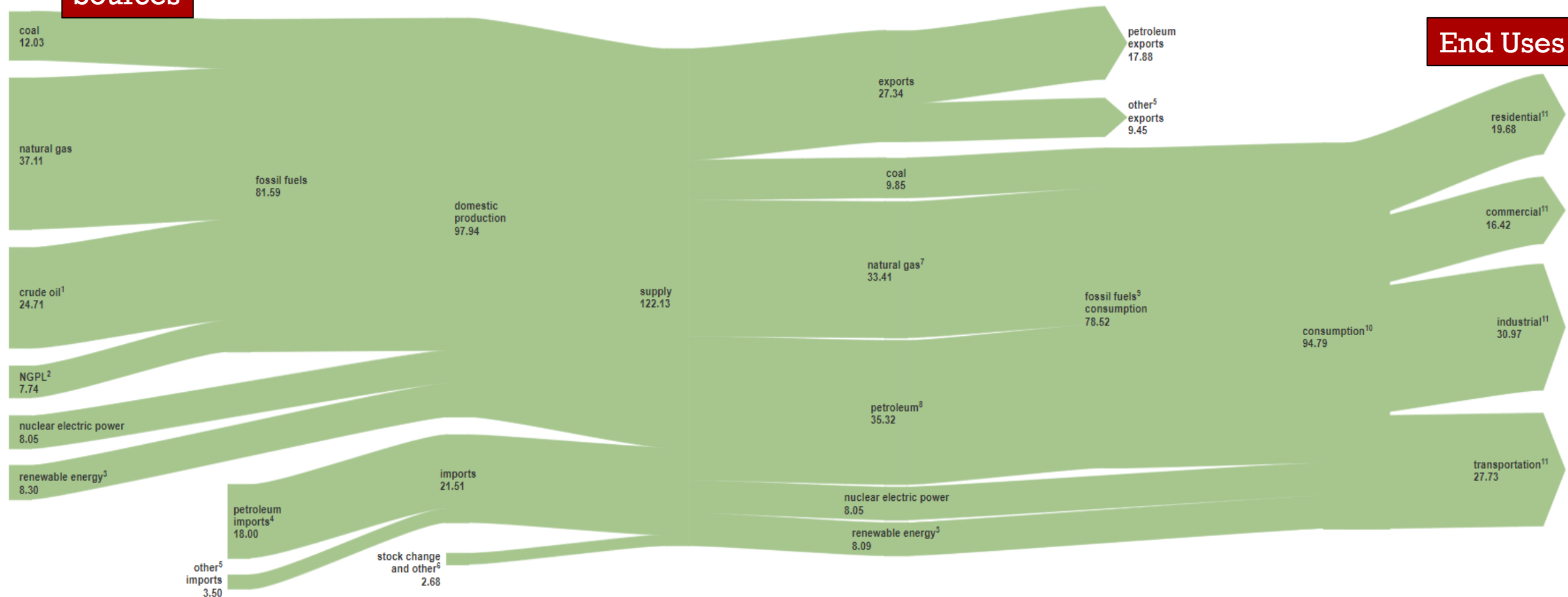


U.S. energy flow, 2022

quadrillion Btu

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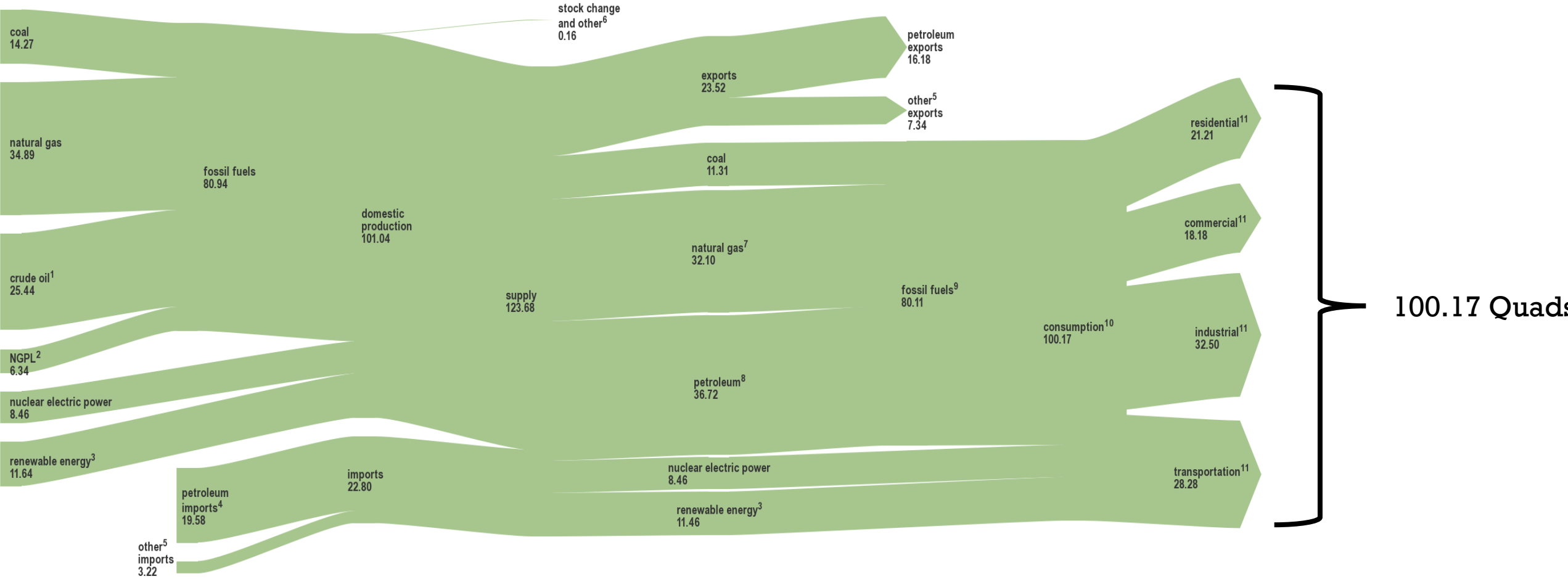


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U.S. energy flow, 2019

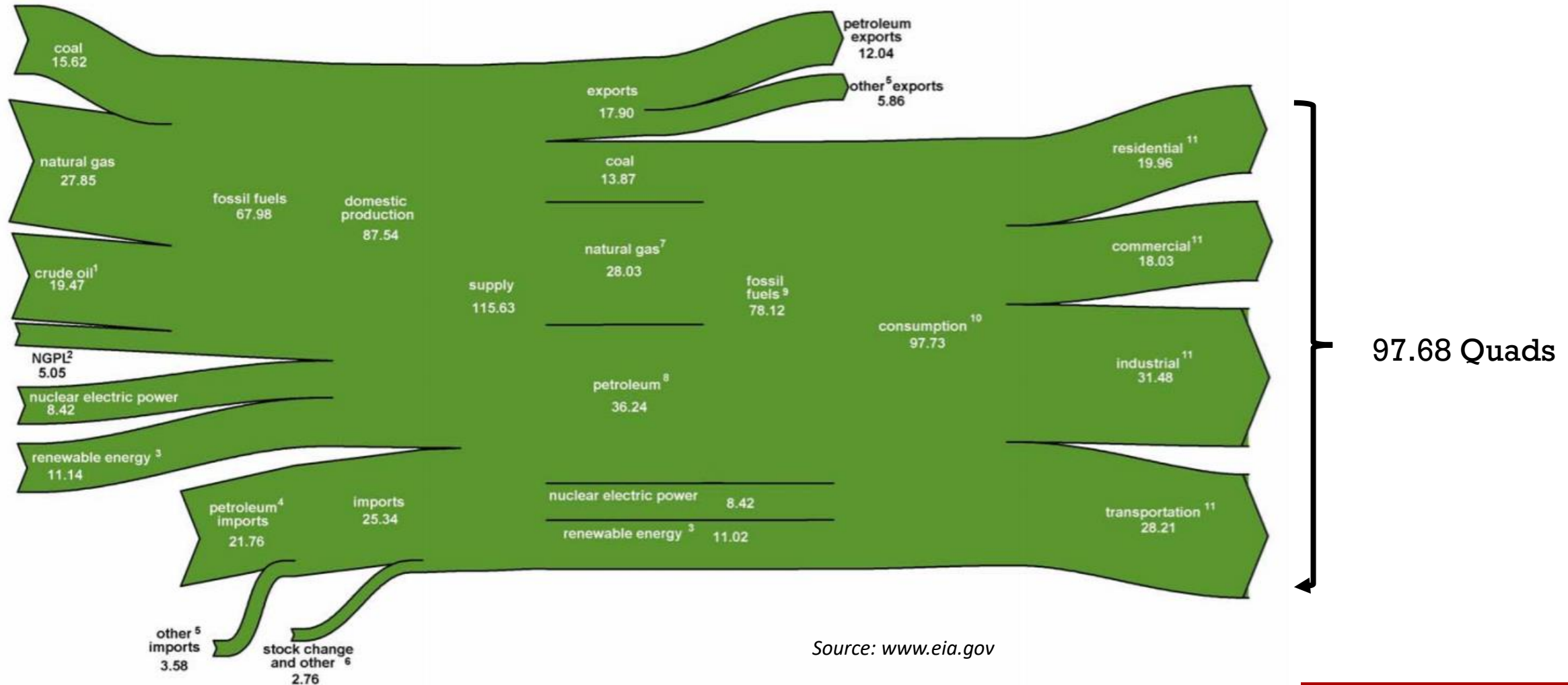
quadrillion Btu



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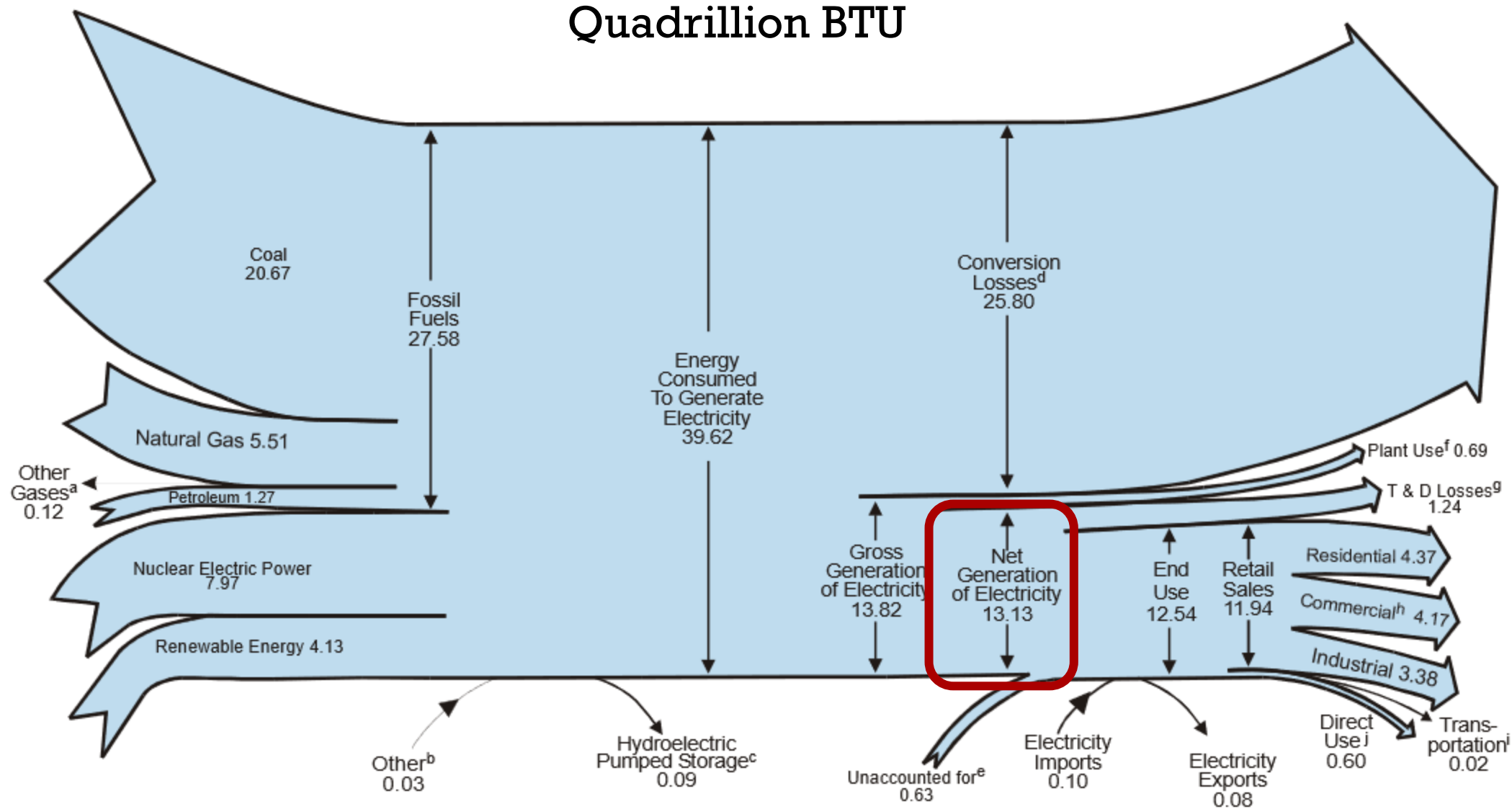
U.S. energy flow, 2017

quadrillion Btu



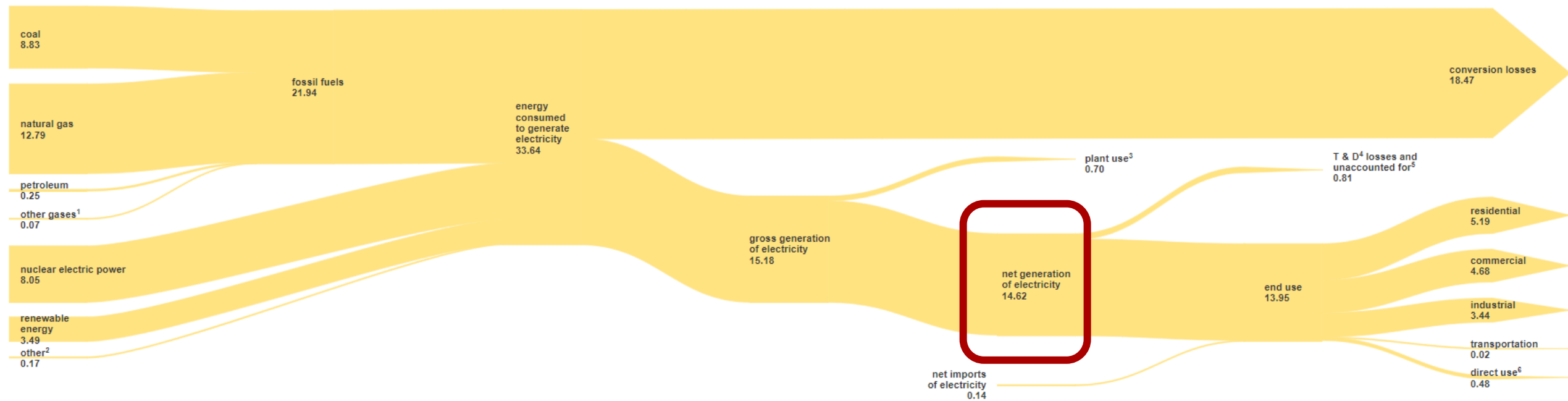
U.S. Electricity Flow, 2003

Quadrillion BTU



U.S. electricity flow, 2022

quadrillion Btu



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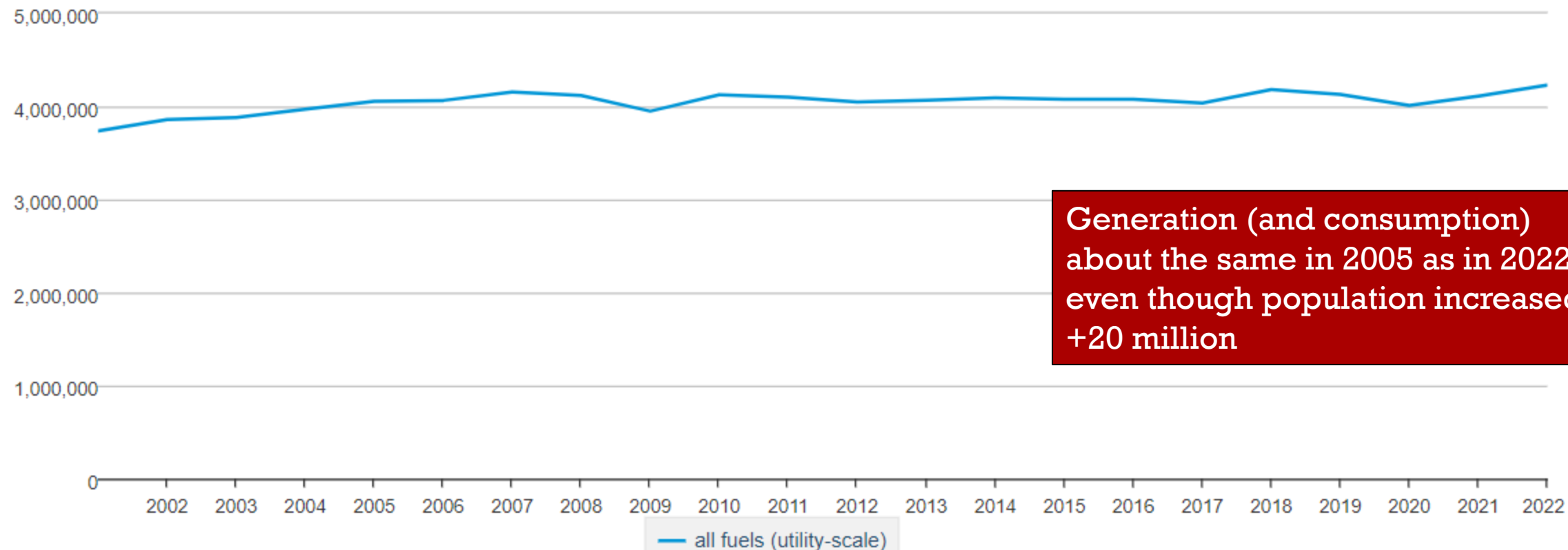
Sources: U.S. Energy Information Administration (EIA), *Monthly Energy Review* (September 2023), Tables 7.1, 7.2a, 7.3a, 7.6, and A6; and EIA, Form EIA-923, "Power Plant Operations Report."

Recent U.S. Electricity Trends

Net generation, United States, all sectors, annual

DOWNLOAD

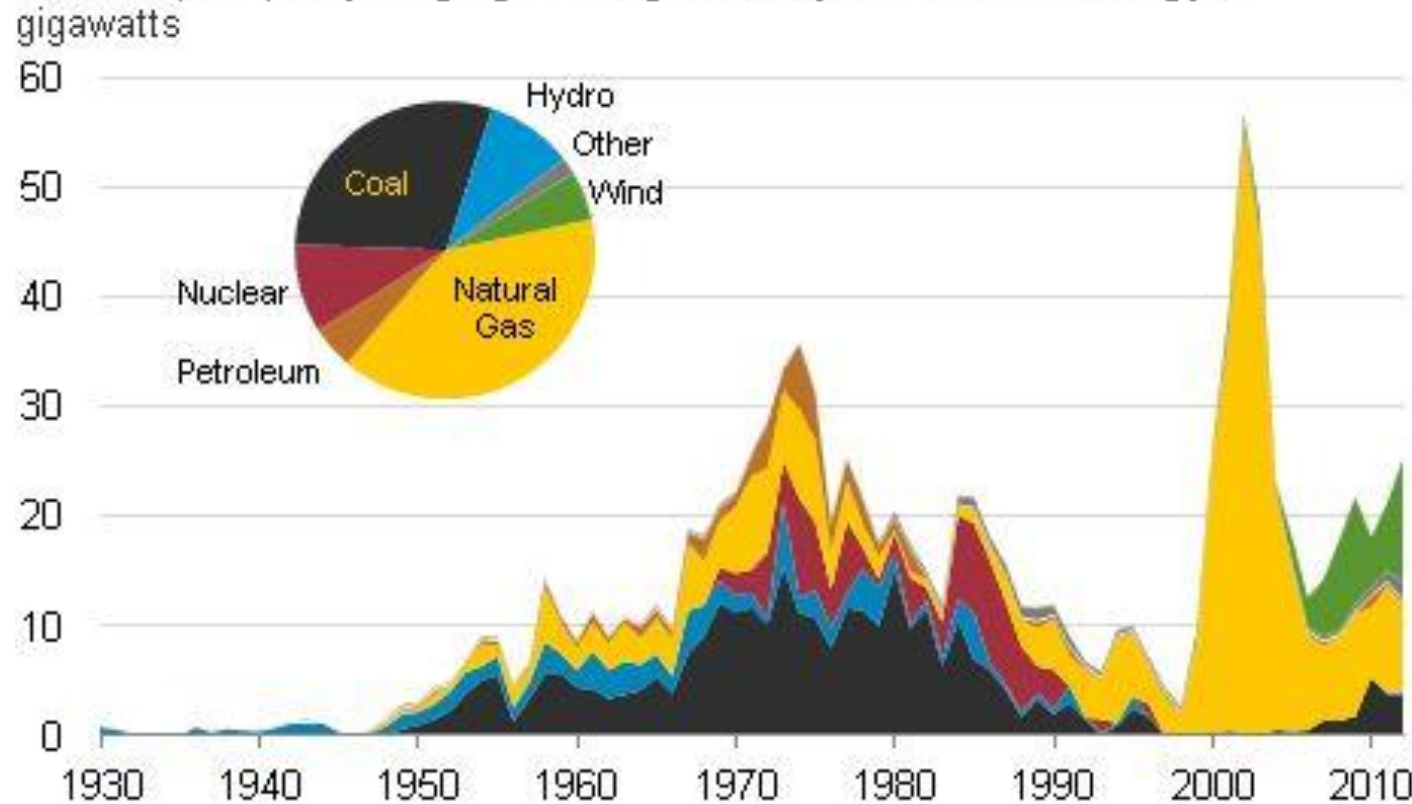
thousand megawatthours



Data source: U.S. Energy Information Administration

Power Plant Capacity Additions by Year

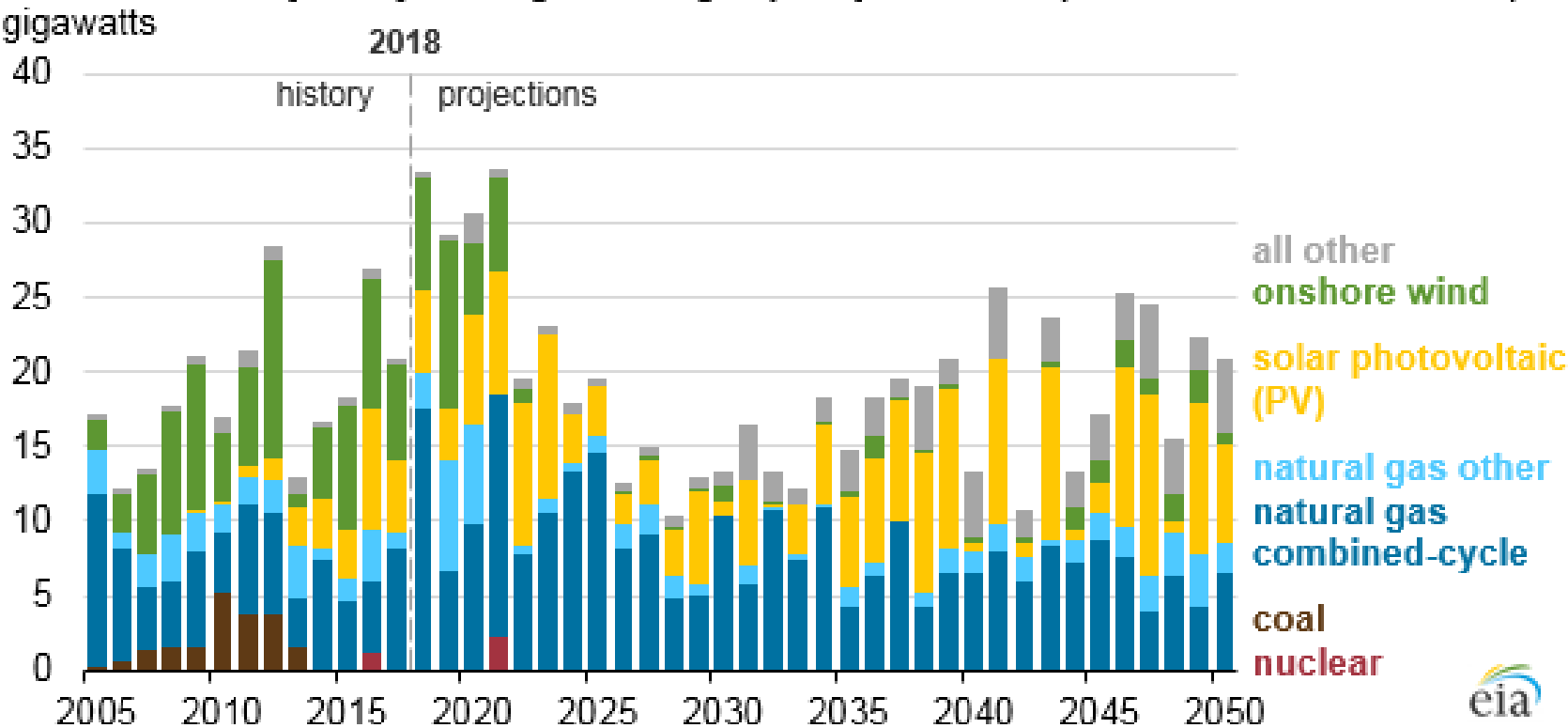
Current (2012) capacity by initial year of operation and fuel type



- Coal: most built before 1980
- Nuclear: built between 1960s-1990
- Wind: 2000-present
- Hydro: pre-1930 to mid 1980s
- Natural Gas: sporadic



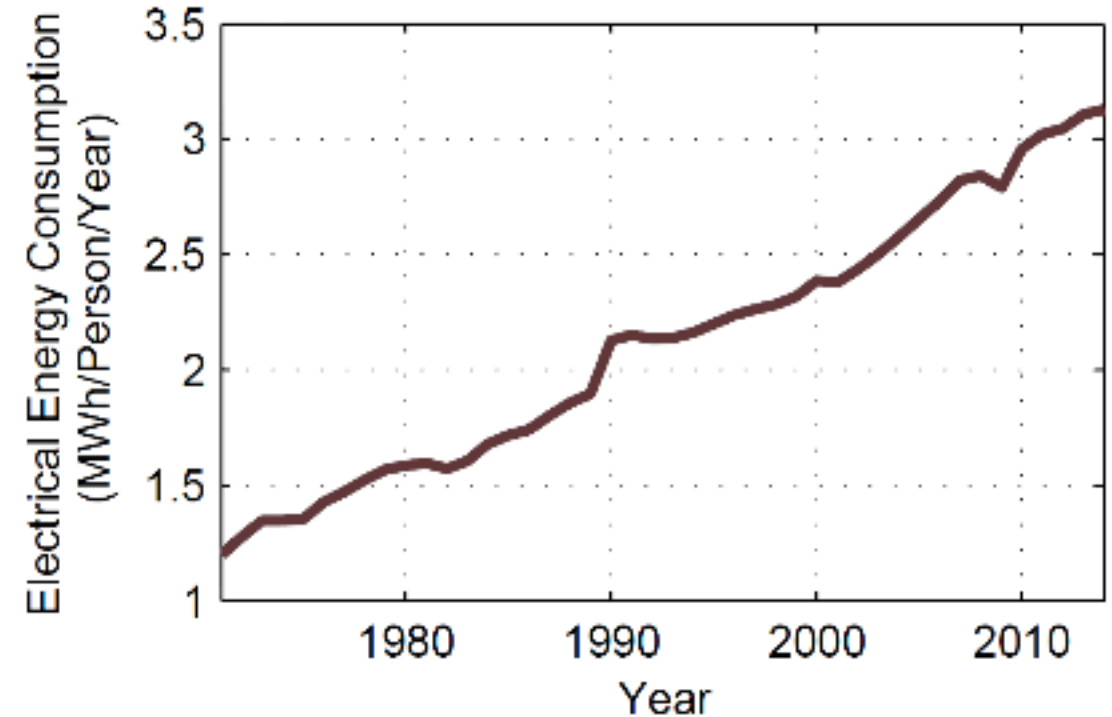
Annual electricity utility-scale generating capacity additions (AEO2019 Reference case)



Recent additions have been primarily solar, natural gas and wind

» Global Electricity Consumption

- Global per person electricity consumption has steadily increased 260% from 1972 to 2015 (2.3% per year)
- Total electricity consumption increased by 505%



» Energy Poverty

Energy Poverty is:
the lack of access to modern fuels



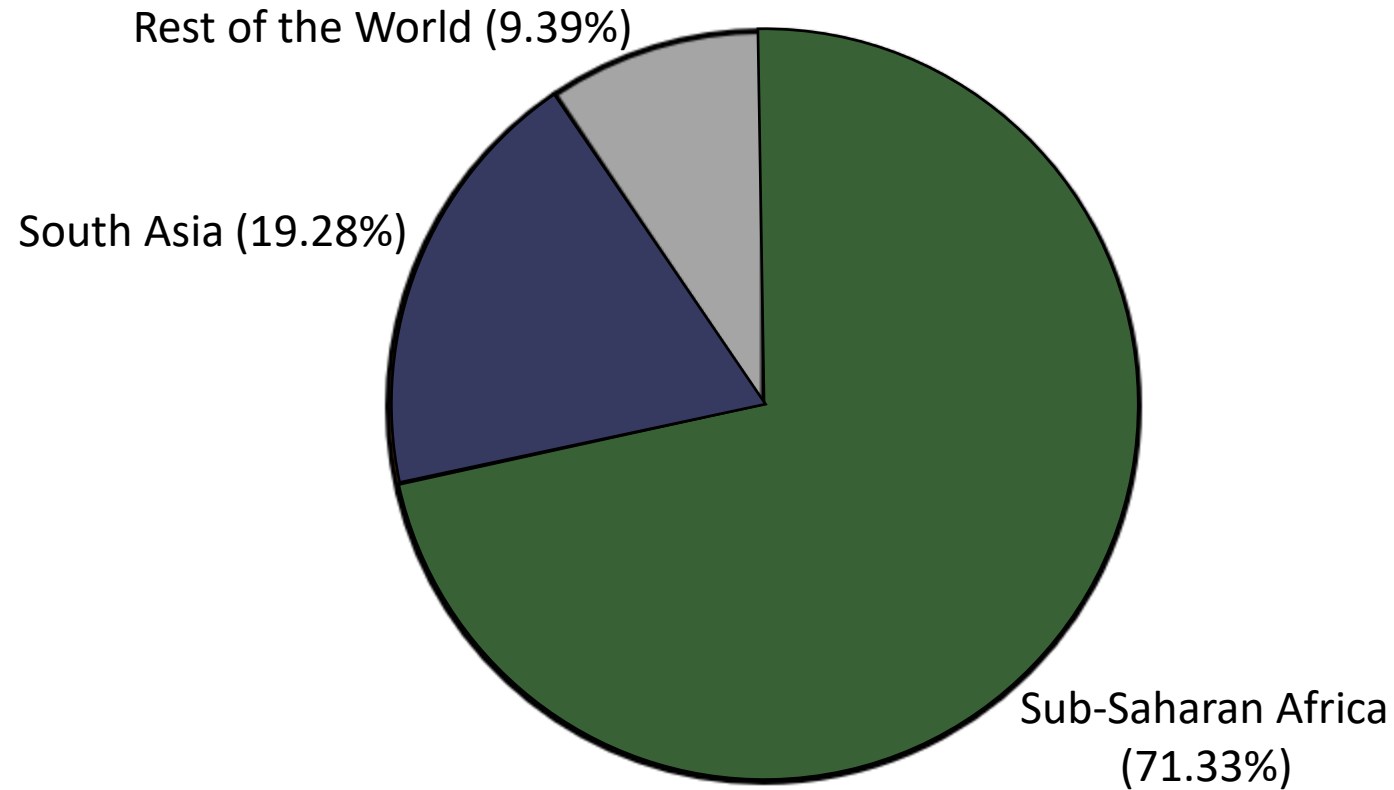
2.4 billion people rely on solid biomass for cooking/heating



733 million people do not have access to electricity



Distribution of Population without Electricity Access



» Key Points

- Electricity is an important component of the U.S. energy mix, consuming about 40% of the energy
- Generation resource mix in the U.S. is composed of mostly coal, natural gas and nuclear power plants
- Coal-fired power plants are in decline, while natural gas, wind and solar power plants are increasing
- Electric consumption has been relatively stable in the U.S. for the past 20 years
- Electric power system is highly efficient (but conversion of thermal energy to electric energy is not)
- Approximately 10% of world does not have access to electricity