



Chapter 12

Nonrenewable Energy Resources

LAWS OF THERMODYNAMICS

1. **CONSERVATION OF ENERGY** WHICH STATES ENERGY IS NOT CREATED NOR DESTROYED, IT IS CONVERSED.....TRANSFERRED FORMS

2. WHEN **ENERGY IS TRANSFORMED**, ITS ABILITY TO DO *WORK* (FORCE APPLIED X DISTANCE IN THE DIRECTION OF FORCE) DIMINISHES, SOME ENERGY IS "LOST" DURING EACH CONVERSION
(ENTROPY)

- ENERGY IS DEGRADED (HEAT), AS IT MOVES UP THE TROPHIC LEVELS...CONVERTED INTO OTHER FORMS OF ENERGY

(TOTAL ENERGY BEFORE = TOTAL ENERGY AFTER)

ENERGY IS SPONTANEOUSLY REGENERATED BY THE SUN...WE HAVE MATTER ON EARTH THAT THE SUN GIVES ENERGY (PRODUCERS GROW 100%) WE EAT AND GET THAT ENERGY **(10% RULE)**...

Nonrenewable energy resources- SUBSTANCES THAT ONCE USED UP, CANNOT BE REPLENISHED (NEED TO BE REPLACED, FINITE)

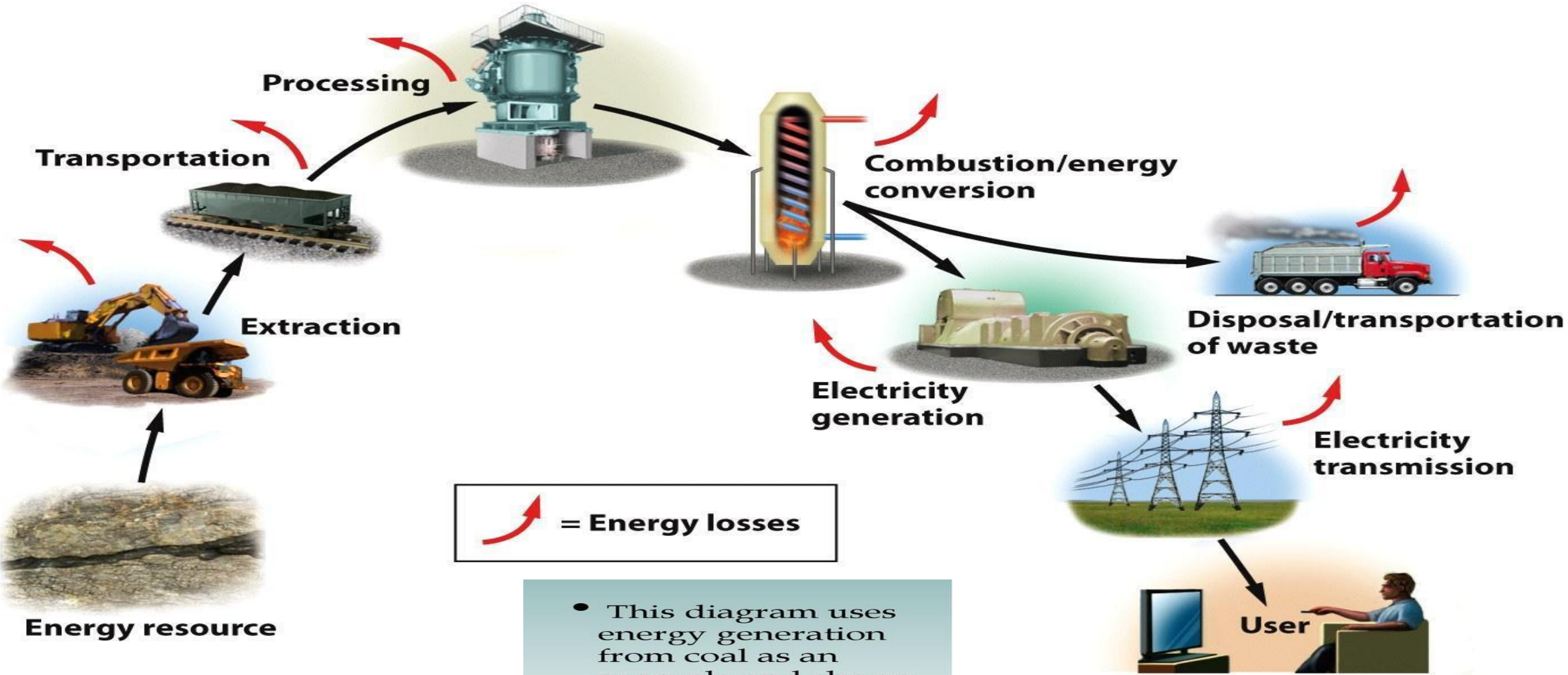
2 TYPES OF NONRENEWABLE RESOURCES:

1. **FOSSIL FUELS** – DERIVED FROM BIOLOGICAL MATERIAL THAT BECAME FOSSILIZED MILLIONS OF YEARS AGO.
 - COAL, OIL (PETROLEUM), NATURAL GAS – *BURNED TO HARNESS THE HEAT ENERGY FROM COMBUSTION.*
2. **NUCLEAR FUELS**- DERIVED FROM RADIOACTIVE MATERIAL THAT GIVES OFF ENERGY.
 - *HARNESS ENERGY BY TRANSFERRING HEAT.*

Fossil Fuels...1. Coal

- **Coal**- a solid fuel **formed** primarily from the **remains of trees, ferns, and other plant materials (ancient biomass)** that were preserved 280–360 million years ago.
 - **THE EFFICIENCY OF THE TRANSFER OF ENERGY FROM A FUEL TO ELECTRICITY FOR A COAL-FIRED POWER PLANT IS APPROXIMATELY 35%**
 - These **four types** are: *lignite, sub-bituminous, bituminous, and anthracite* **RANKED FROM LESSER TO GREATER AGE, EXPOSURE TO PRESSURE, AND ENERGY CONTENT.**
 - The **largest coal reserves** are in the *United States (24%), Russia (15%), Australia (14%), China (13%)* – *largest Disturber (consumes half global production) of coal production (over 50%)*
 - **IDEAL FUEL FOR STATIONARY COMBUSTION APPLICATIONS, SUCH AS POWER PLANTS, AND INDUSTRY**

Process of Energy Use - coal

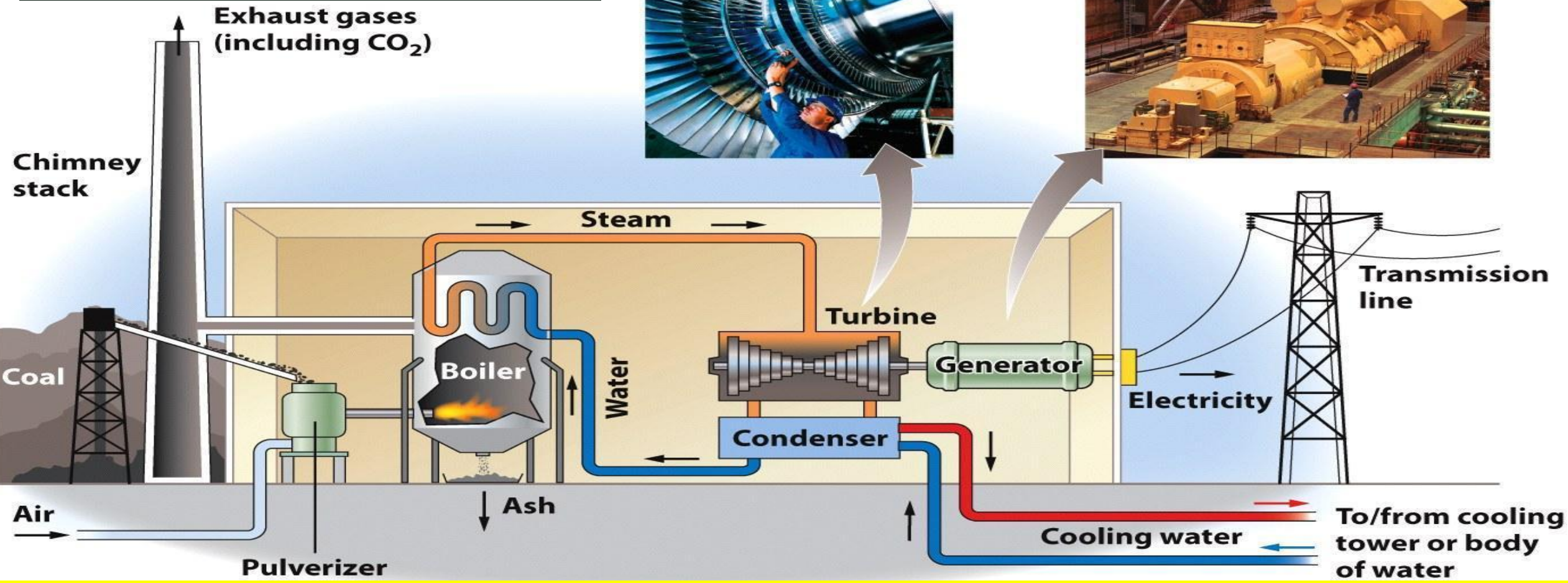


• This diagram uses energy generation from coal as an example and shows how energy is lost in each stage of the process.

Figure 12.5
Environmental Science
© 2012 W. H. Freeman and Company

Electricity Generation

Coal supplies over one-third of global electricity generation and plays a crucial role in industries such as iron and steel manufacturing. Despite concerns about air pollution and greenhouse gas emissions, coal use is likely to continue to be significant in the near future.



mechanical motion generates energy...
Potential to kinetic (generates electricity through the use of turbines)

Advantages coal

Disadvantages coal

Energy-dense (-35% efficiency)

Contains impurities

Plentiful (*abundant in U.S*)

Release **impurities into air when burned**

**** World has about 139 years of coal left at current consumption levels...excluding unproven reserves*

Easy to exploit by surface mining

Trace metals like mercury, lead, and arsenic are found in coal

Technological **demands are small**
(*capabilities to manufacture*)

Combustion leads to **increased levels of sulfur dioxide and other air pollutants** into the atmosphere.

Economic **costs are low**

Ash is left behind

Easy to handle and transport

Carbon is released into the atmosphere which **contributes to climate change**

Needs little refining

LIQUIFIED COAL (CTL)

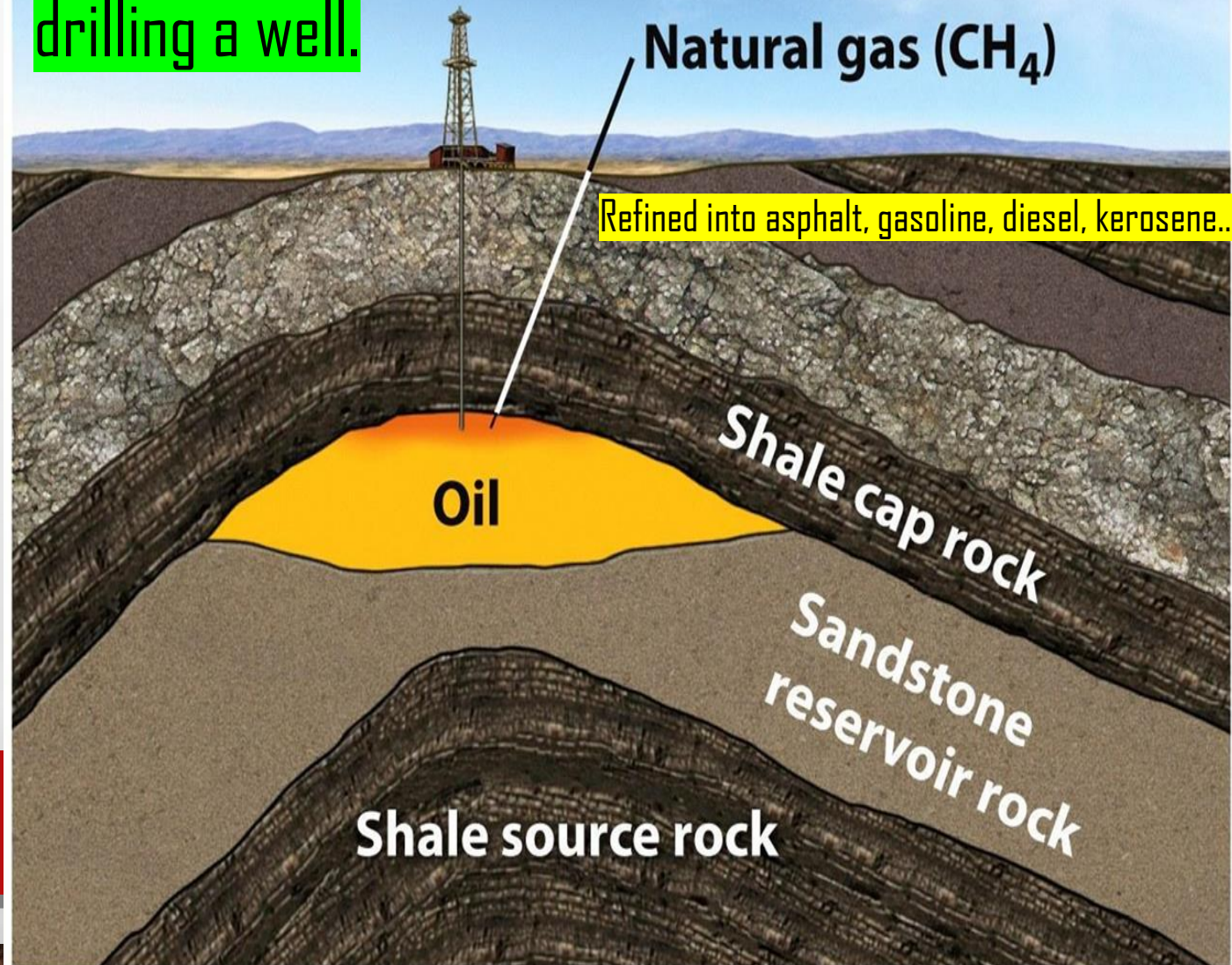
- COAL LIQUEFACTION IS A PROCESS OF CONVERTING COAL INTO LIQUID HYDROCARBONS: LIQUID FUELS AND PETROCHEMICALS
 - MOST COMMON PROCESS CHAIN IS "COAL TO LIQUID FUELS" (CTL). **CTL IS AN ALTERNATIVE FUEL TO DIESEL**
- **ADVANTAGE:**
 - LOWER GREENHOUSE EMISSIONS THAN REGULAR COAL, BUT *MORE THAN PETROLEUM*
- **DISADVANTAGE:**
 - LARGE DEMAND FOR WATER
 - LARGE DEMAND FOR ENERGY NEEDED TO PROCESS COAL
 - LAND DEGRADATION IN THE UNITED STATES

2. Petroleum- a mixture of hydrocarbons, water, and sulfur that occurs in underground deposits.

Oil and gasoline make this ideal for mobile combustion, such as vehicles.

Formed from the remains of ocean-dwelling phytoplankton that died 50-150 million years ago.

Petroleum migrates to the highest point in a formation of porous rock and accumulates there.
Liquid petroleum (*crude oil*) can be removed by drilling a well.



Oil Reserves

SHARE OF GLOBAL

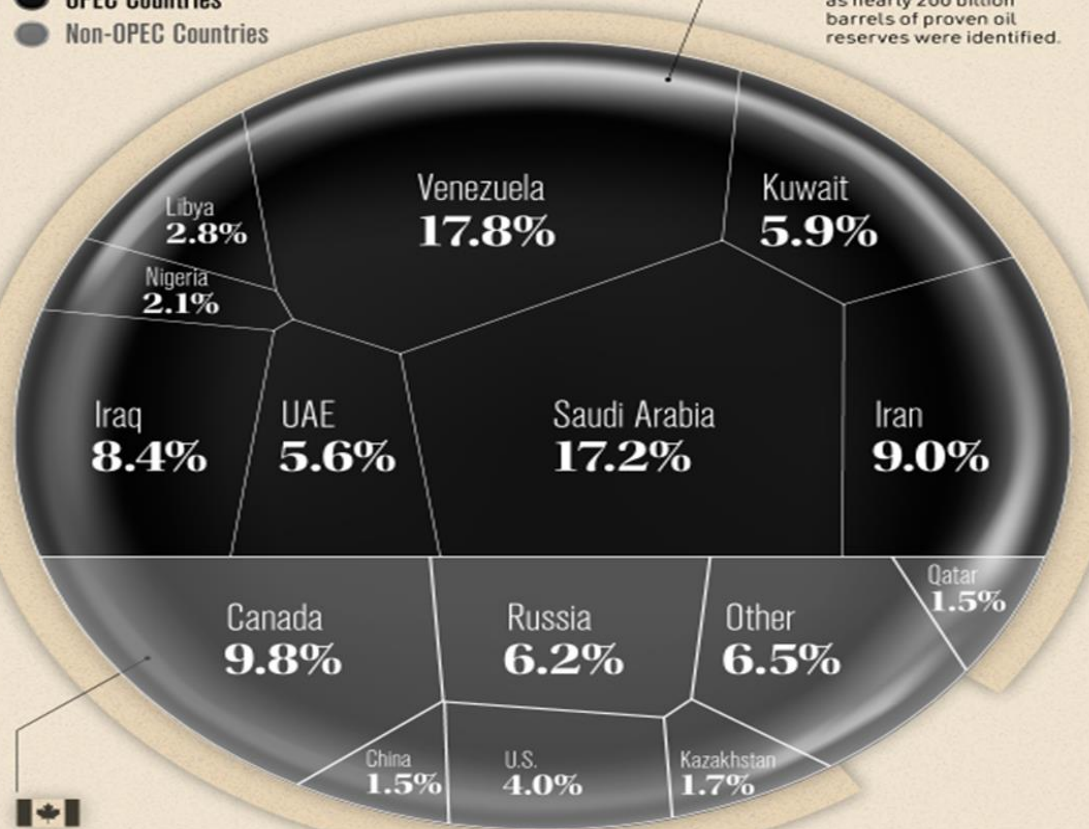
Across the globe, oil remains a key component of the energy mix. Of course, resources aren't distributed equally between countries, and oil is no exception.

Here's how oil reserves are spread between countries:

- OPEC Countries
- Non-OPEC Countries

BY COUNTRY

Between 2005 and 2015, Venezuela jumped from 5th in the world to number one as nearly 200 billion barrels of proven oil reserves were identified.



In 2002, Canada's proven oil reserves jumped from 5 billion to 180 billion barrels based on new estimates of Oil Sands reserves.

93.5% of known oil reserves are discovered in these top 14 countries.

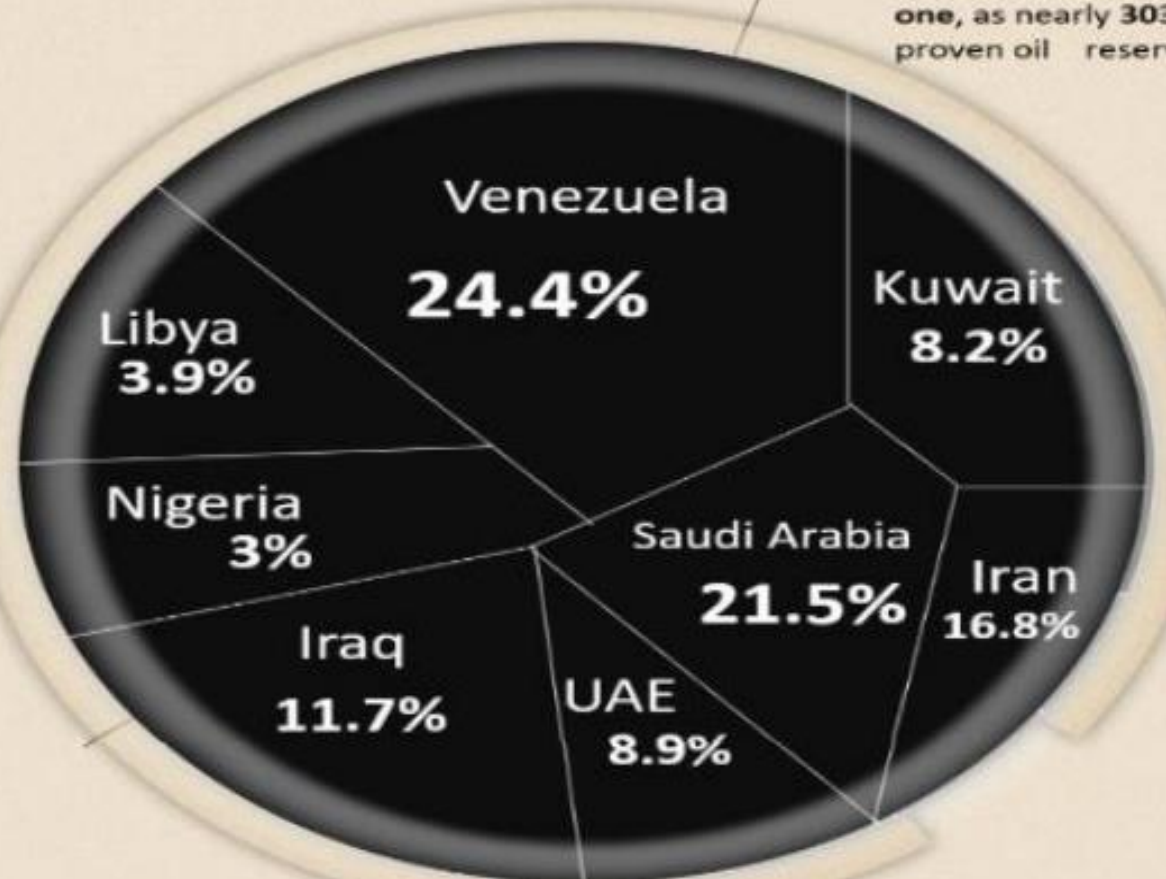
Source: BP Statistical Review of World Energy 2020

Oil Reserves

Biggest Share of OPEC Countries

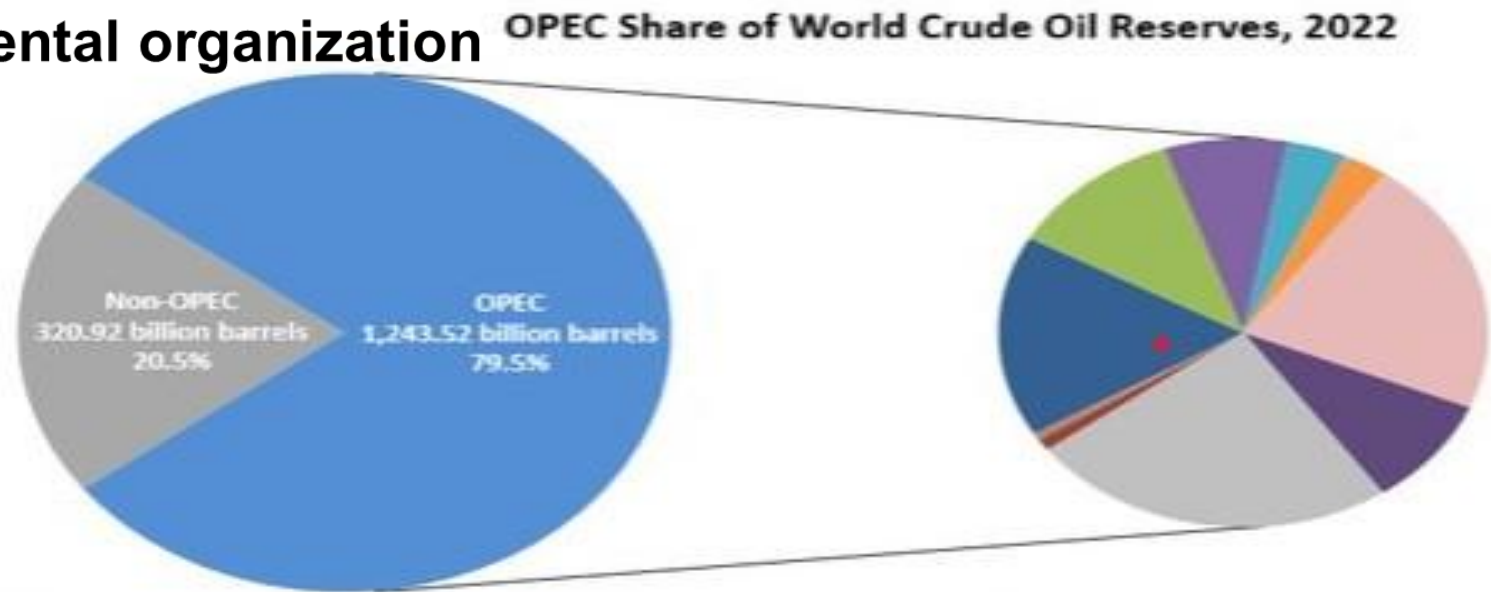
BY COUNTRY

Between 2005 and 2015, Venezuela jumped from 5th in the world to number one, as nearly 303 billion proven oil reserves were identified.



OPEC - Organization of the Petroleum Exporting Countries is an intergovernmental organization

Mission of OPEC: control the PRICE of the World oil by limiting the SUPPLY.



- Countries**
- Algeria
 - Angola
 - Congo
 - Equatorial Guinea
 - Gabon
 - IR Iran
 - Iraq
 - Kuwait
 - Libya
 - Nigeria
 - Saudi Arabia
 - United Arab Emirates
 - Venezuela

OPEC proven crude oil reserves, at end 2022 (billion barrels, OPEC share)

Venezuela	303.22	24.4%	United Arab Emirates	113.00	9.1%	Algeria	12.20	1.0%	Equatorial Guinea	1.10	0.1%
Saudi Arabia	267.19	21.5%	Kuwait	101.50	8.2%	Angola	2.55	0.2%			
IR Iran	208.60	16.8%	Libya	48.36	3.9%	Gabon	2.00	0.2%			
Iraq	145.02	11.7%	Nigeria	36.97	3.0%	Congo	1.81	0.1%			

Source: OPEC Annual Statistical Bulletin 2023

According to current estimates, 79.5% (1,243.52 billion barrels) of the world's proven oil reserves are located in OPEC Member Countries, with the bulk of OPEC oil reserves in the Middle East, amounting to 67.2% of the OPEC total.

According to 2022 estimates, 80.4% (1,241.82 billion barrels) of the world's proven oil reserves are located in OPEC Member Countries, with the bulk of OPEC oil reserves in the Middle East, amounting to 67.1% of the OPEC total.

Oil Production

BY COUNTRY IN 2021

Production in Thousand Barrels Per Day*

○ OPEC Countries ○ Non-OPEC Countries

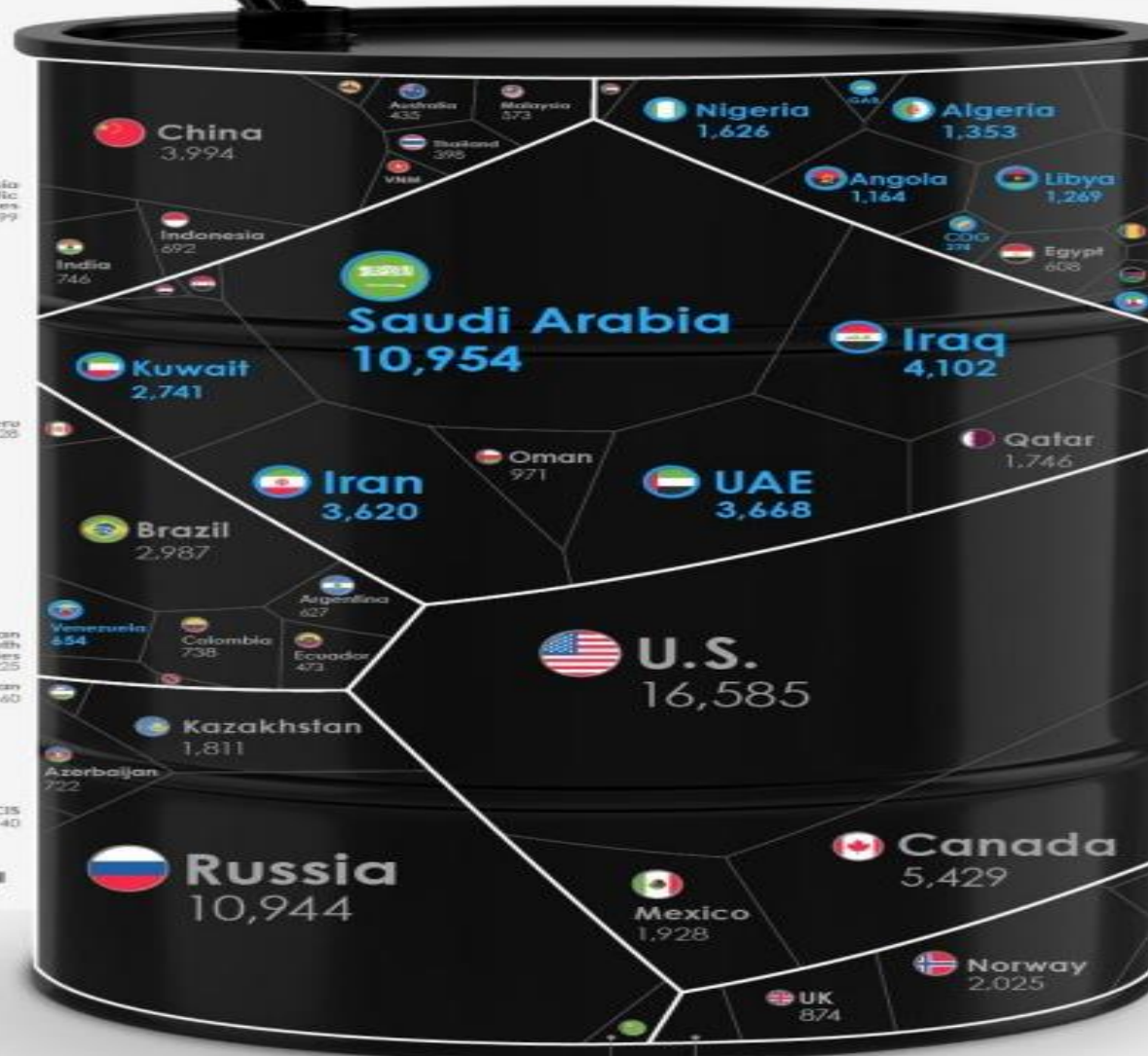
Total Production
89,876



Saudi Arabia, the largest exporter of crude oil, plans to raise its production capacity to a maximum of **13 million barrels per day** by 2027.



Russia accounted for **25%** of the EU's oil imports in 2021 and has exported over \$48B worth of oil since the invasion.



Other African Countries 293

Chad 116

Tunisia 45

South Sudan 153

Equatorial Guinea 140

Other Middle East Countries 191



The U.S. is both the world's largest producer and consumer of oil.

Denmark 45

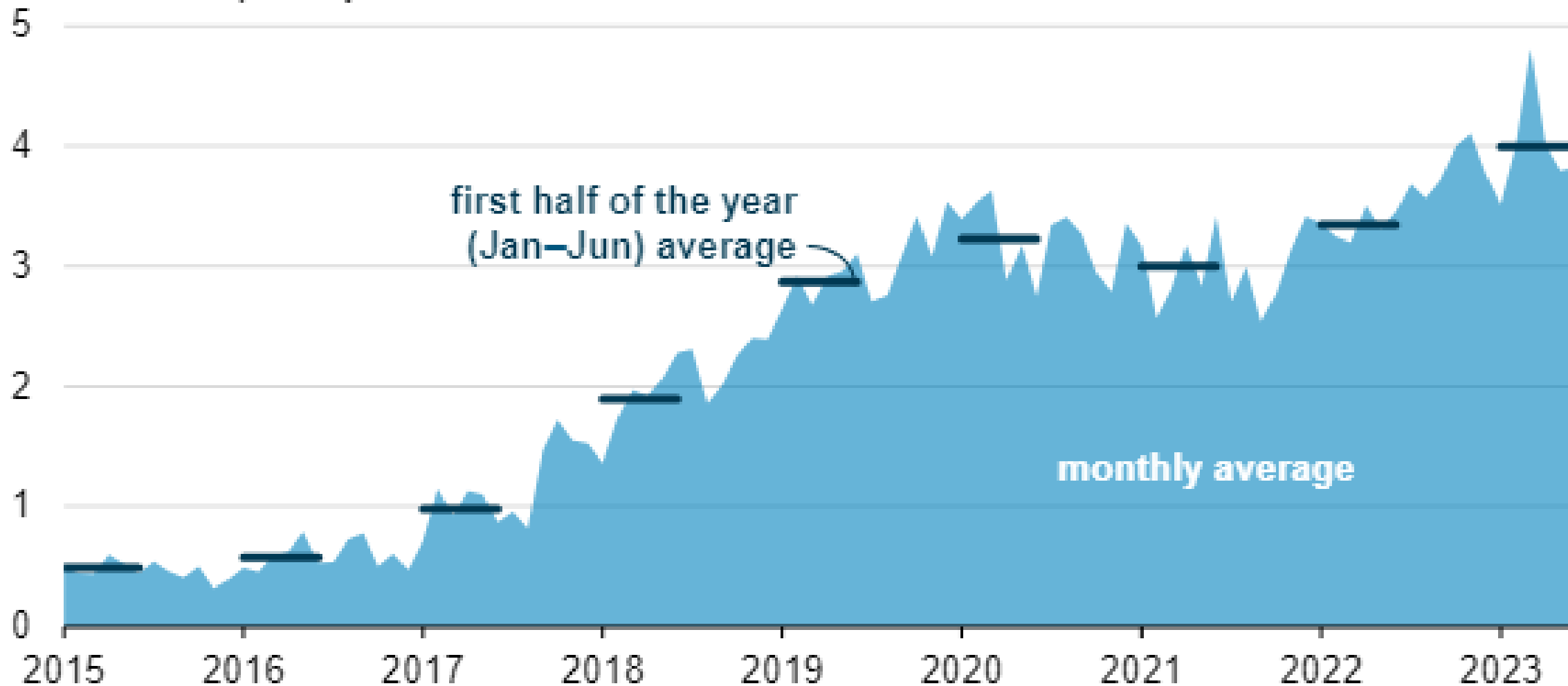
Italy 100

Romania 70

Turkmenistan 252 Other European Countries 286

U.S. crude oil exports (Jan 2015–Jun 2023)

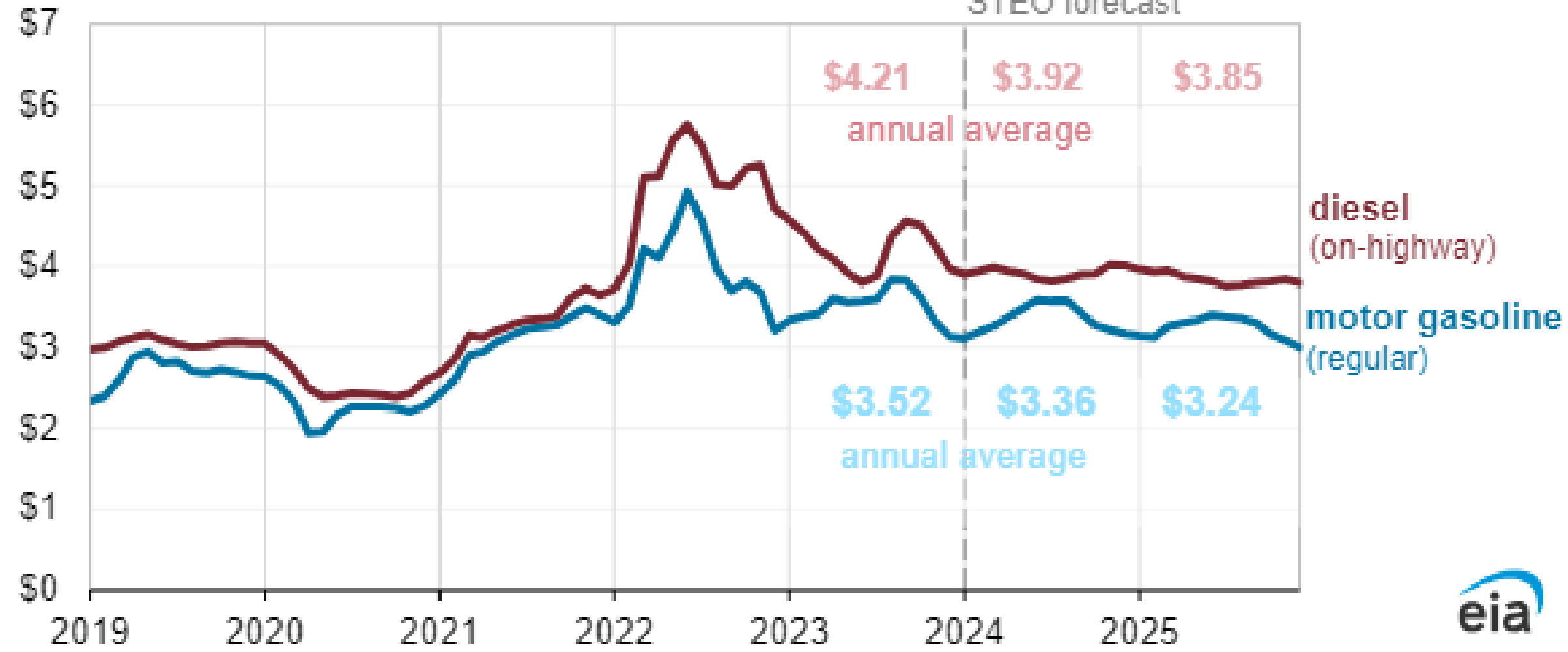
million barrels per day



U.S. crude oil exports in the first half of 2023 averaged 3.99 million barrels per day (b/d), which is a record high for the first half of a year since 2015, when the *U.S. ban on most crude oil exports from the United States was repealed (1975 – 2015 to boost US economy and lower gas prices)*. Although exports increased in the first half of 2023, the United States still imports more crude oil than it exports, meaning it remains a net crude oil importer.

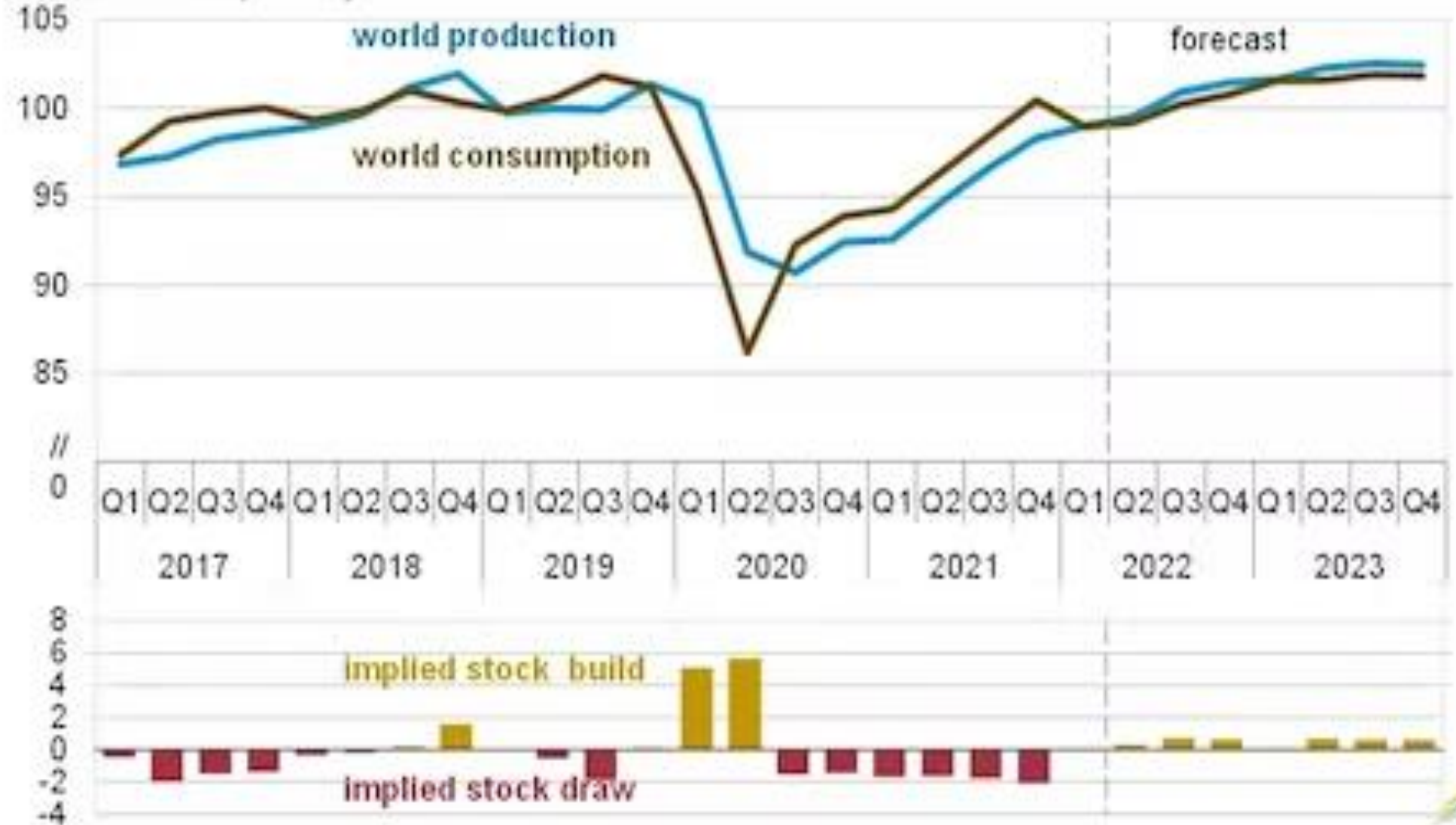
Monthly U.S. retail fuel prices (Jan 2019–Dec 2025)

dollars per gallon



World liquid fuels production and consumption balance

million barrels per day



Source: U.S. Energy Information Administration, Short-Term Energy Outlook, April 2022



Advantages oil

Disadvantages oil

Convenient to transport and use

Releases carbon dioxide into atmosphere (other pollutants, S, Hg, Pb, As... like coal)

Relatively energy-dense

Possibility of leaks when extracted and transported (oil spills)

Cleaner-burning than coal

Not abundant in the U.S. (*get from outside the states*)

85% of oil entering marine waterways come from **runoff** from land, rivers, airplanes, boats, and accidental spills (Killing birds and marine life)

3. Natural gas- exists as a **component of petroleum** in the ground as well as in gaseous deposits separate from petroleum (typically extracted with petroleum).

□ Contains **80 to 95 percent methane** and 5 to 20 percent ethane, propane, and butane.

□ **LARGEST USES OF NATURAL GAS IS ELECTRICITY GENERATION AND INDUSTRIAL PROCESSES (32% OF PRIMARY ENERGY USED IN U.S)**

□ **BE USED AS NITROGEN FERTILIZER, COOKING, RESIDENTIAL EFFICIENT FUEL (ONE-HALF U.S USES TO HEAT HOMES)**

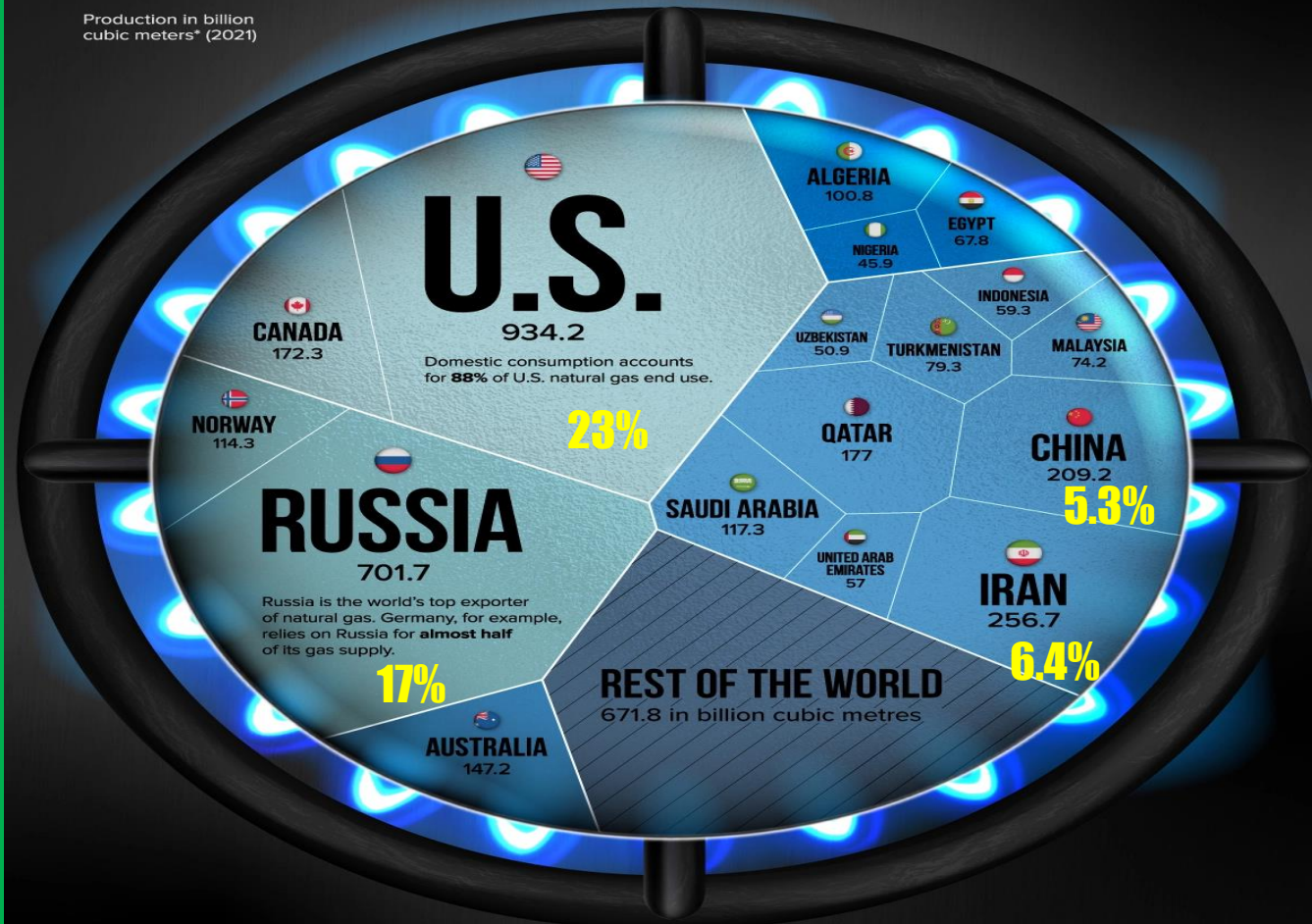


THE LARGEST PRODUCERS OF NATURAL GAS

Russia's invasion of Ukraine has exacerbated the tightening supply of natural gas underway since mid-2021, further pushing up prices. Besides having the largest natural gas reserves, Russia is the second biggest producer, only behind the United States.

i Natural gas is a naturally occurring hydrocarbon gas and non-renewable fossil fuel that forms below the Earth's surface. Liquefied natural gas (LNG) is a natural gas that has been cooled to -162°C, a process that is commonly done for gas export purposes as it reduces the volume of the transported gas.

Production in billion cubic meters* (2021)

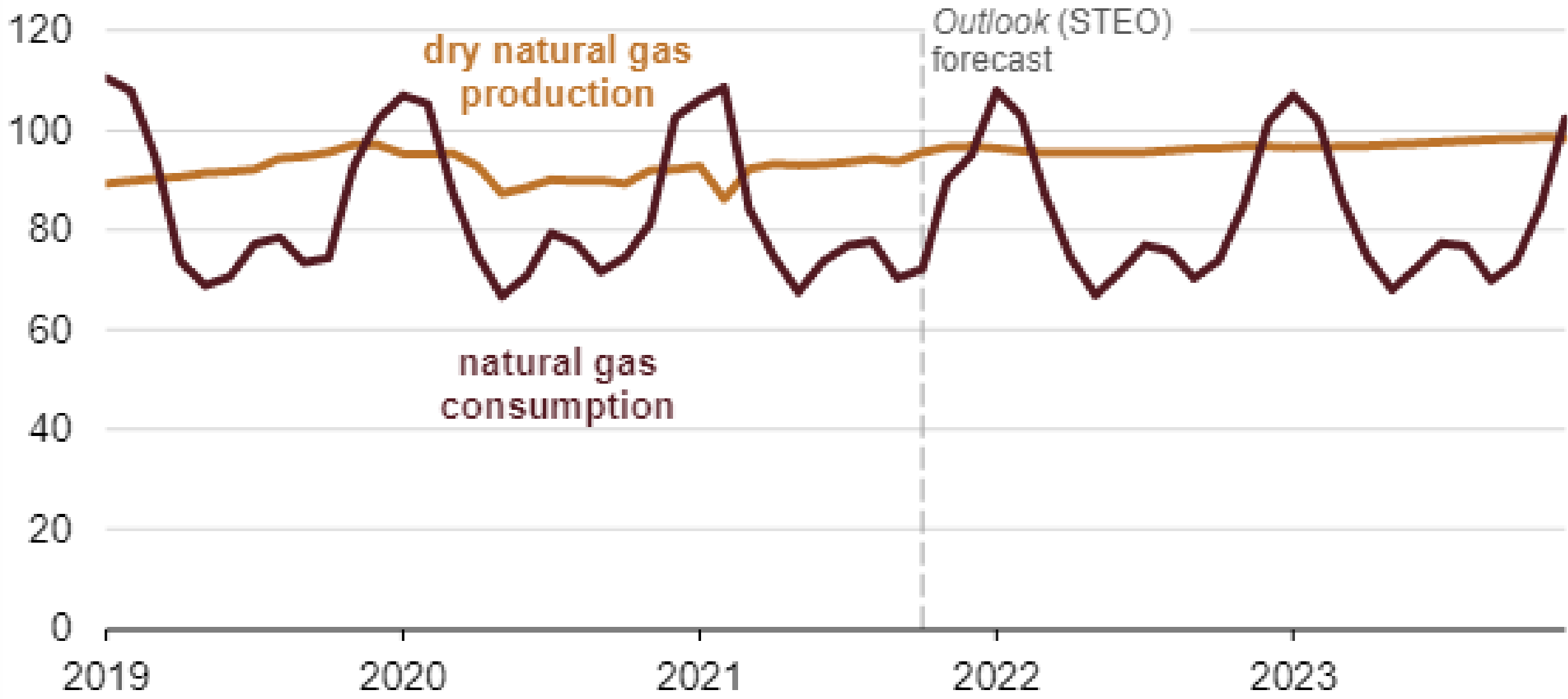


*Excludes gas flared or recycled. Includes natural gas produced for Gas-to-Liquids transformation. Source: bp Statistical Review of World Energy 2022

U.S. natural gas consumption and dry natural gas production (2019–2023)



billion cubic feet per day (Bcf/d)



Monthly average Henry Hub natural gas spot price (Jan 2019–Dec 2023)

dollars per million British thermal units (\$/MMBtu)



The U.S. natural gas price averaged \$2.57 per million British thermal units (MMBtu) in 2023, about a 62% drop from the 2022 average annual price. The monthly average price was below \$3.00/MMBtu in every month except January, with the lowest monthly average in May at \$2.19/MMBtu.

Advantages N.G

Considered to be the “clean” fossil fuel

Contains fewer impurities and therefore emits almost no sulfur dioxide or particulates (lower per unit energy obtained)

Emits only 60% as much carbon dioxide as coal

Disadvantages N.G

Unburned natural gas-**methane**- escapes into the atmosphere is a potent greenhouse gas that is **25x more** efficient at **absorbing Infrared energy than CO₂**

Exploration of natural gas has the potential of **contaminating groundwater** flow, causing areas to flood or wells to go dry

Disturb soil (“*thumper trucks*” generating seismic vibrations in order to identify natural gas deposits)

Process of drilling & opening up rock in order to **release natural gas** is called **Hydraulic Fracturing/Fracking** (pipelines in sensitive areas)...large quantities of water is used in this process; water becomes contaminated with chemicals...**groundwater contamination**.

2. NUCLEAR ENERGY

- **SAME BASIC PROCESS** AS ELECTRICITY GENERATION FROM FOSSIL FUELS... **STEAM** TURNS A TURBINE THAT TURNS A GENERATOR THAT GENERATES ENERGY.
- **DIFFERENCE** IS THAT A NUCLEAR POWER PLANT USES **RADIOACTIVE ISOTOPES** (EX. URANIUM-235) AS **ITS FUEL SOURCE**.
- **URANIUM-235 IS A GREAT FUEL SOURCE DUE TO ITS ABILITY TO CONDUCT FISSION EFFICIENCY**
- **FISSION** (splits neutrons into two or more parts) VS. **FUSION** LIGHTER NUCLEI ARE FORCED TOGETHER, HEAT IS RELEASE, MIMIC THE SUN)

FUSION - *ATOMS OF HYDROGEN TO FUSE TOGETHER (MIMICKING THE SUN)*

- U.S. DEPARTMENT OF ENERGY'S **LAWRENCE LIVERMORE NATIONAL LABORATORY** (AFTER 6 DECADES OF TRIAL AND ERROR OF UNCONTROLLED FUSION – CALIFORNIA) THE WORLD'S LARGEST LASERS *FORCED ATOMS OF HYDROGEN TO FUSE TOGETHER (HELIUM)* IN THE SAME KIND OF *ENERGY PRODUCING REACTION THAT FIRES THE SUN*.
- NATIONAL IGNITION FACILITY, OR NIF, WAS BUILT FOR \$3.5 BILLION TO IGNITE SELF-SUSTAINING FUSION
- IF FUSION CAN BE DEPLOYED ON A LARGE SCALE (STILL DECADES AWAY FROM THIS...), IT WOULD OFFER AN **ENERGY SOURCE DEVOID OF THE POLLUTION AND GREENHOUSE GASES CAUSED BY THE BURNING OF FOSSIL FUELS** AND THE **DANGEROUS LONG-LIVED RADIOACTIVE WASTE CREATED BY CURRENT NUCLEAR POWER PLANTS**, WHICH USE THE SPLITTING OF URANIUM TO PRODUCE ENERGY.
- **INSIDE THE NUCLEAR FUSION BREAKTHROUGH THAT COULD BE A STEP TO UNLIMITED CLEAN ENERGY IN THE DISTANT FUTURE**

Advantages and Disadvantages of Nuclear Energy

Advantages

No air pollution is produced

Countries can limit their need for imported oil

Disadvantages

Possibility of accidents (nuclear meltdowns – radiation released into environment... *Chernobyl*)

Disposal of the **radioactive waste** (based on half life will determine the disposal method). The longer the half-life, the longer it will take to decay. **(mostly stored at the plant that produced it)**

Cannot be incinerated, destroyed using chemicals, shot into space, dumped on the ocean floor, or buried...all can damage our atmosphere and bodies or water

Waste should be stored in a geological stable site away from human habitation.



Change in population and residential housing stocks

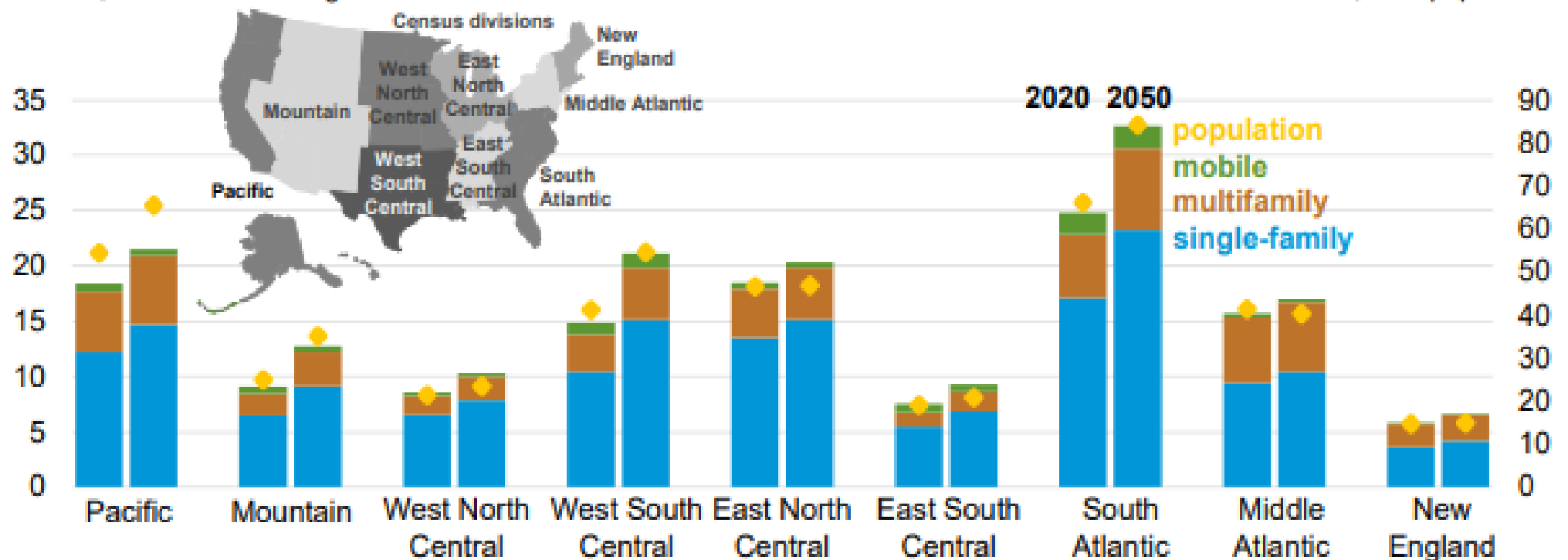
Residential housing unit and population changes by region and type in 2020 and 2050

◆ population

AEO2021 Reference case

millions, residential housing units

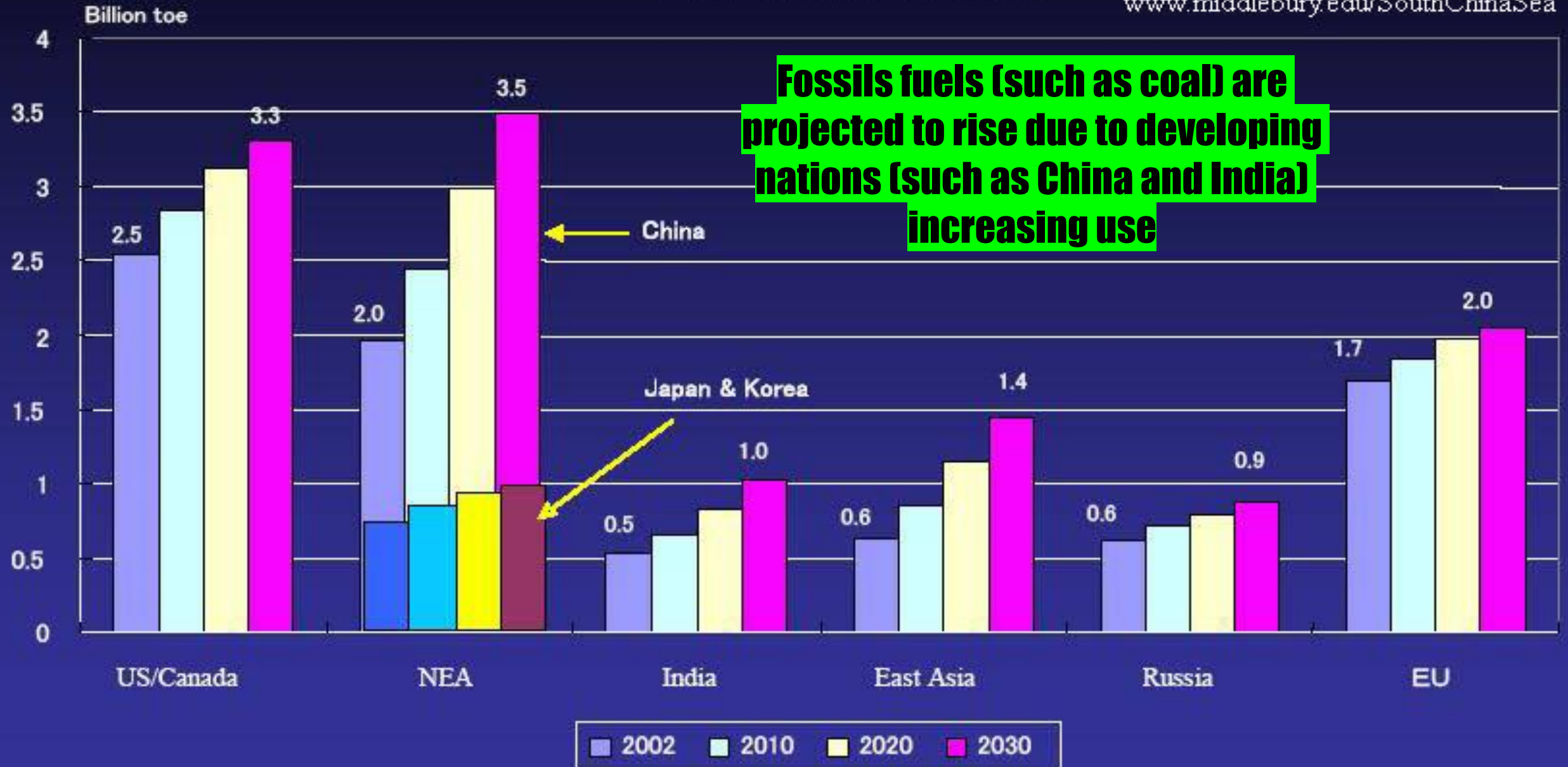
millions, U.S. population

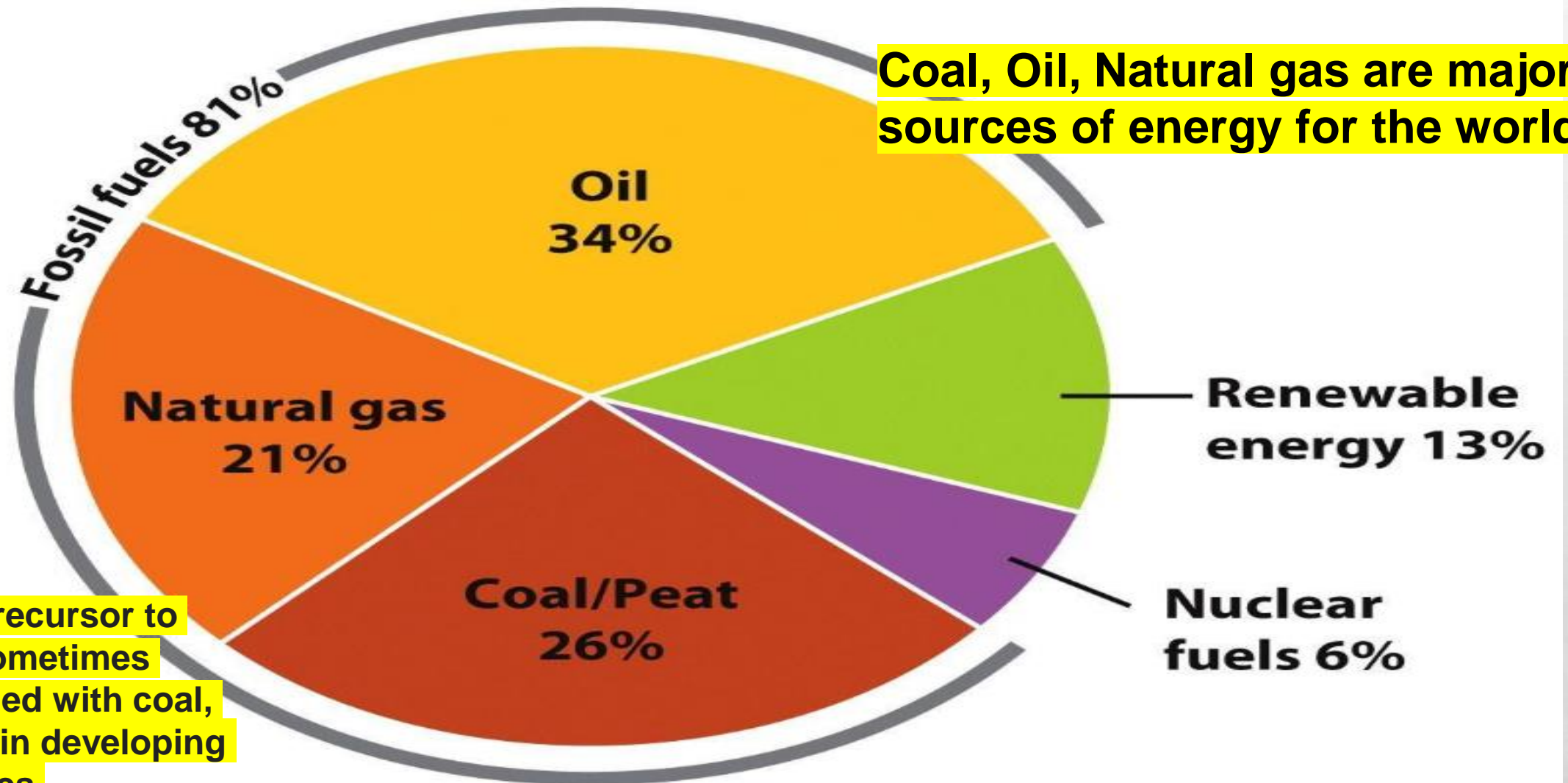


Energy Consumption Patterns

Drysdale, Asian Energy Forum, IEEJ, 2005

www.middlebury.edu/SouthChinaSea





Coal, Oil, Natural gas are major sources of energy for the world

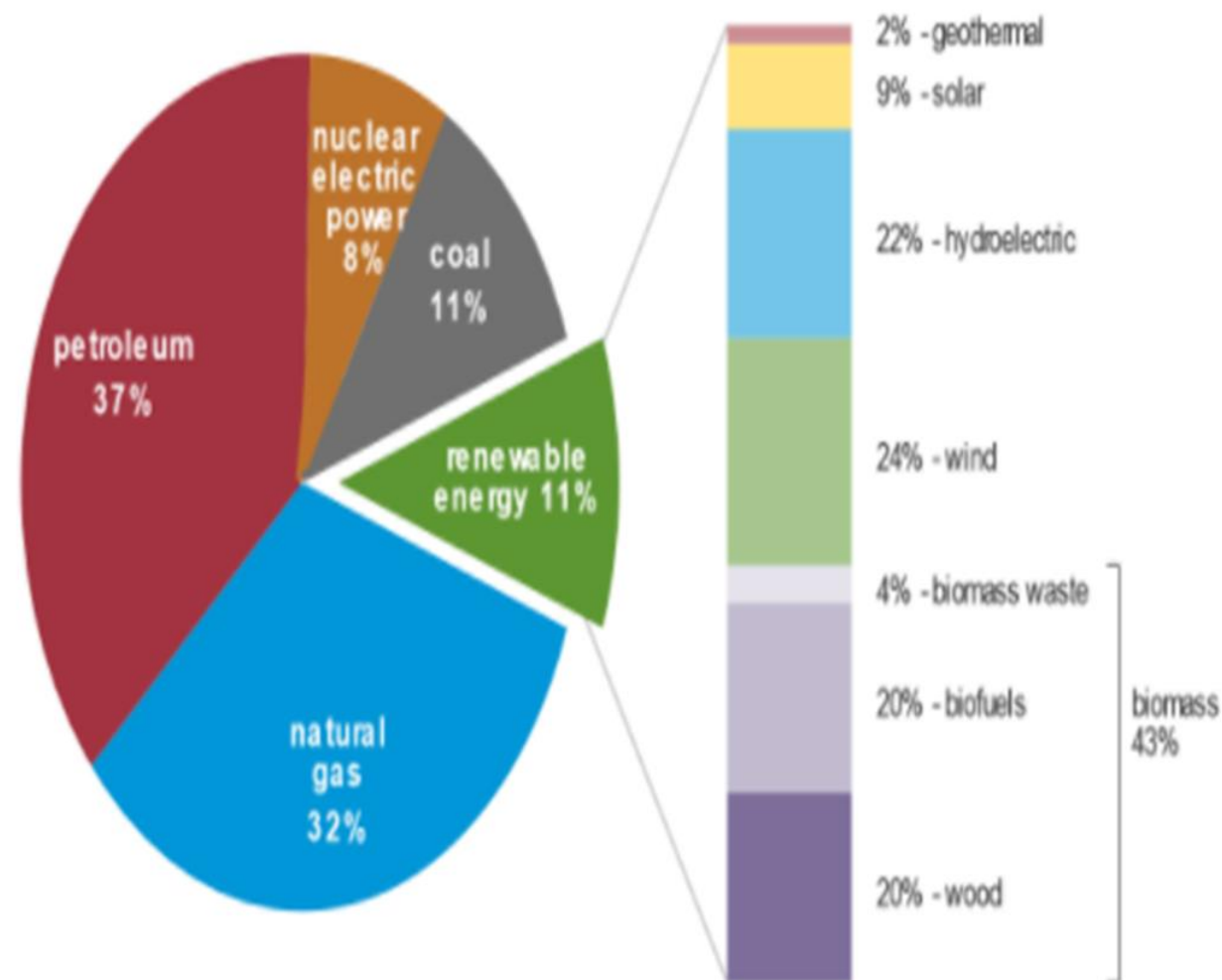
Peat, precursor to coal, sometimes combined with coal, mostly in developing countries.

Total = 495 exajoules (469 quadrillion Btu, or "quads") per year

U.S. primary energy consumption by energy source, 2019

total = 100.2 quadrillion
British thermal units (Btu)

total = 11.4 quadrillion Btu



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

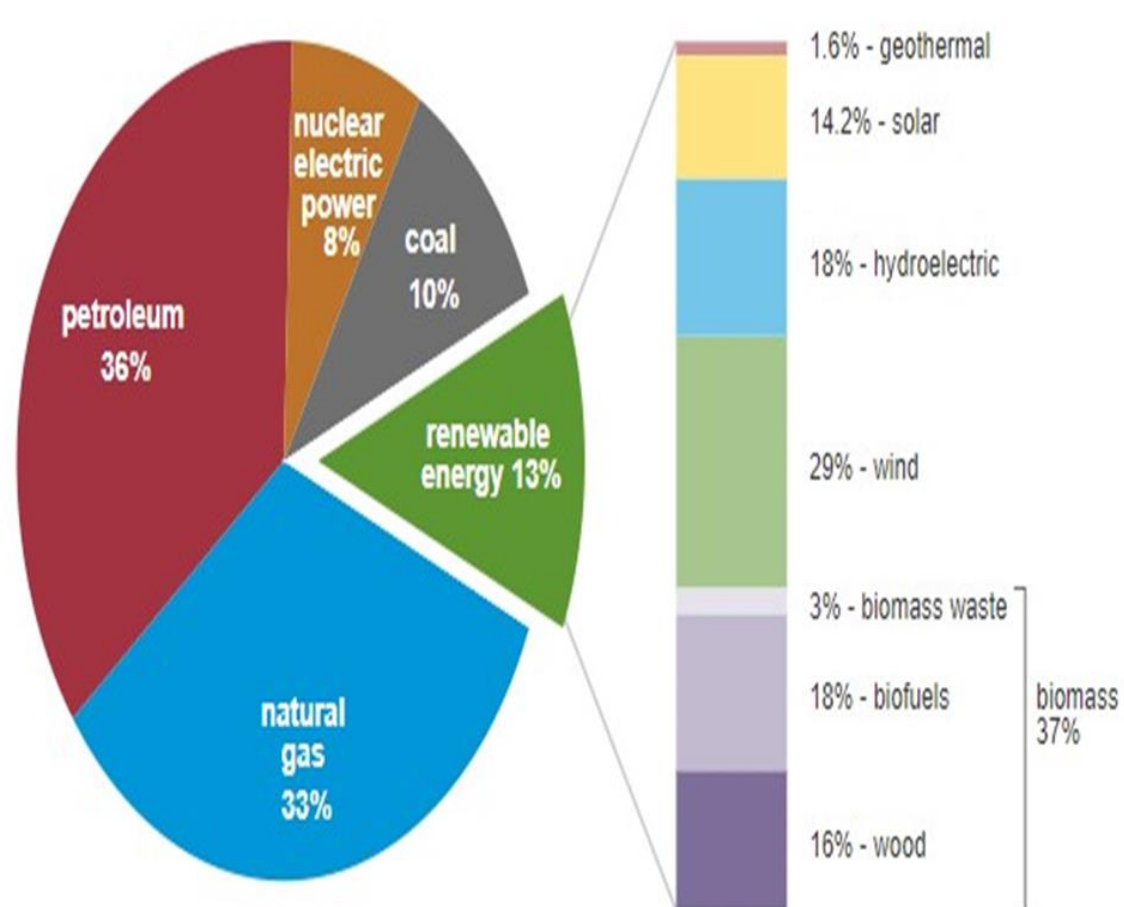
Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 1.3 and 10.1, April 2020, preliminary data



U.S. primary energy consumption by energy source, 2022

total = 100.41 quadrillion
British thermal units (Btu)

total = 13.18 quadrillion Btu

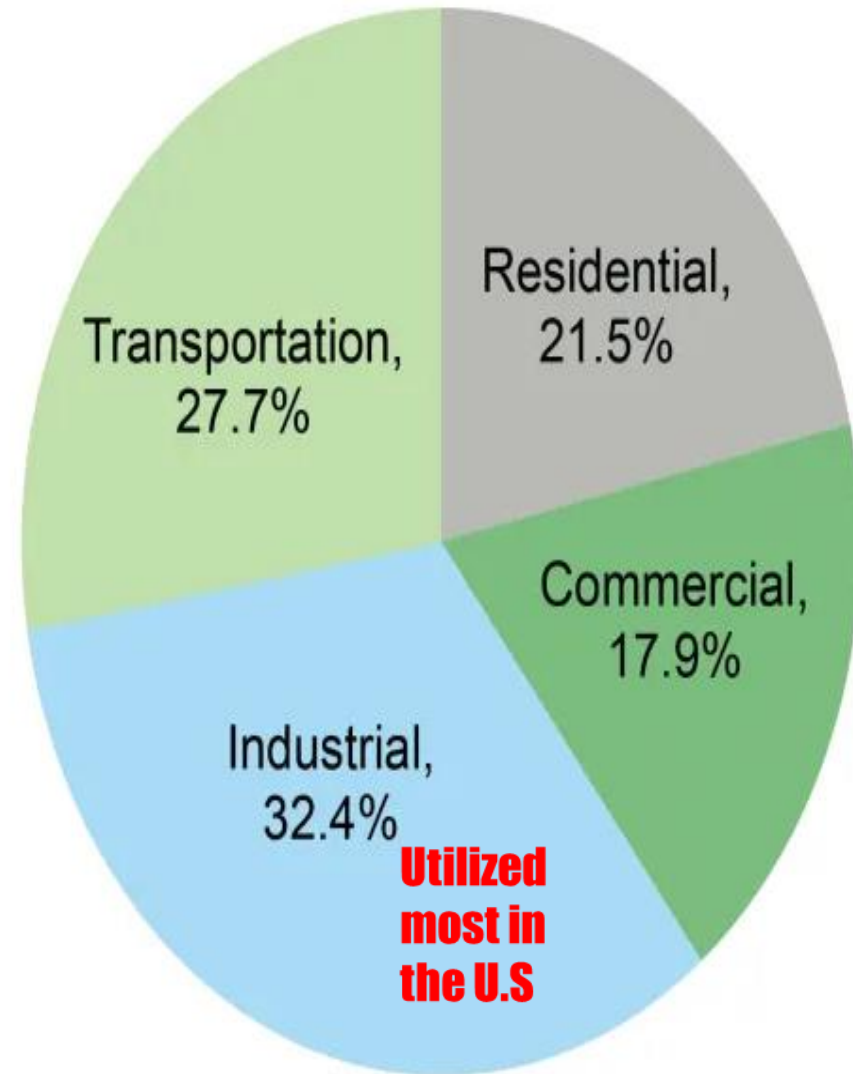
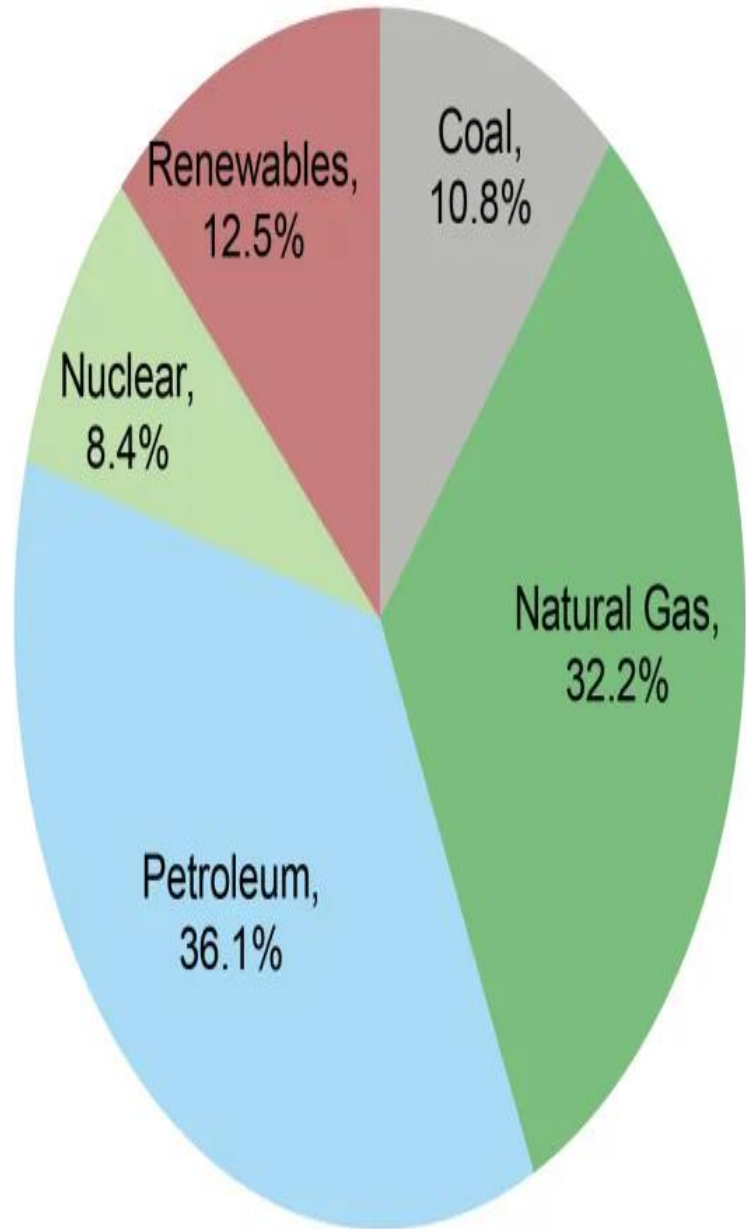


Data source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 1.3 and 10.1, April 2023, preliminary data

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

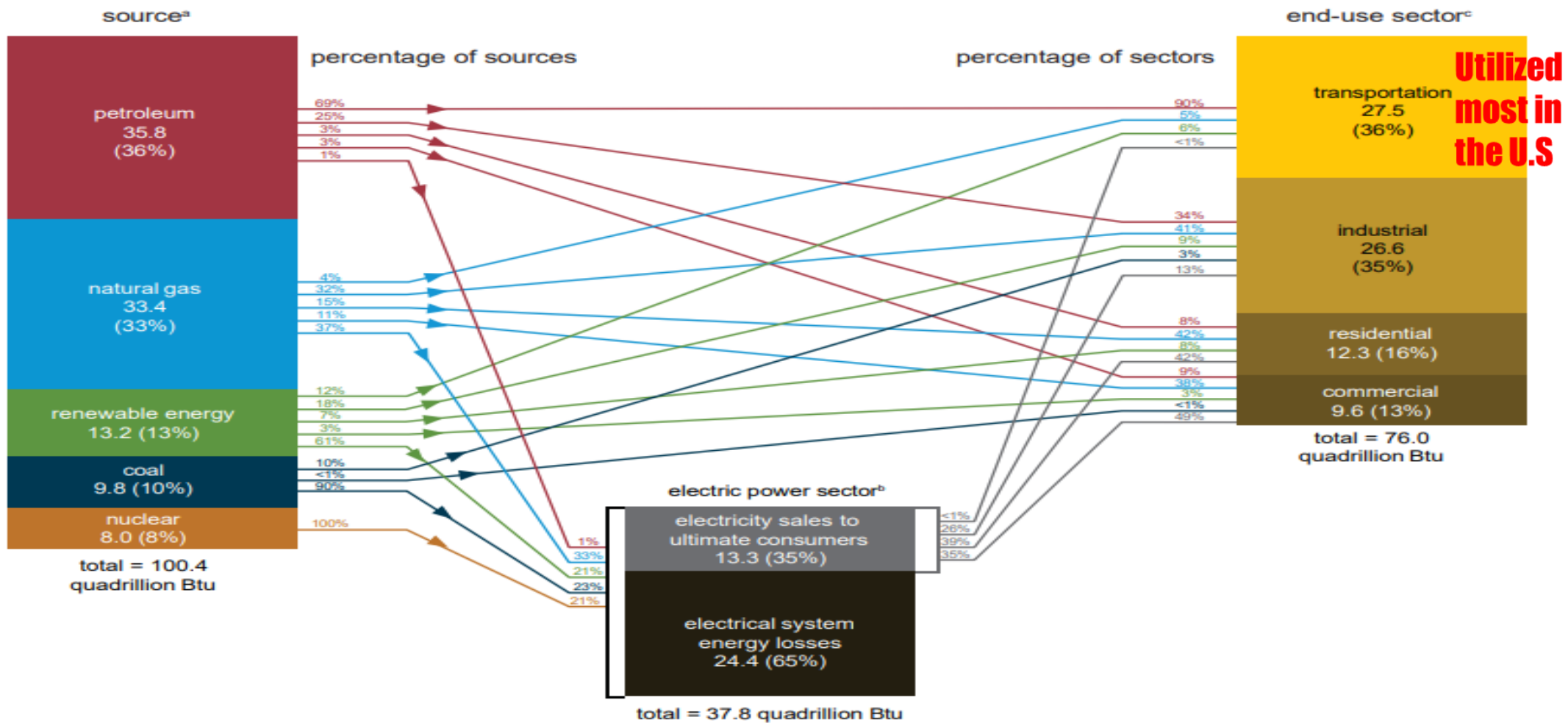


U.S. ENERGY CONSUMPTION BY SECTOR, 2021⁵



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

quadrillion British thermal units (Btu)



Sources: U.S. Energy Information Administration (EIA), *Monthly Energy Review* (April 2023), Tables 1.3, 1.4c, and 2.1a-2.6.

Note: Sum of components may not equal total due to independent rounding. All source and end-use sector consumption data include other energy losses from energy use, transformation, and distribution not separately identified. See "Extended Chart Notes" on next page.

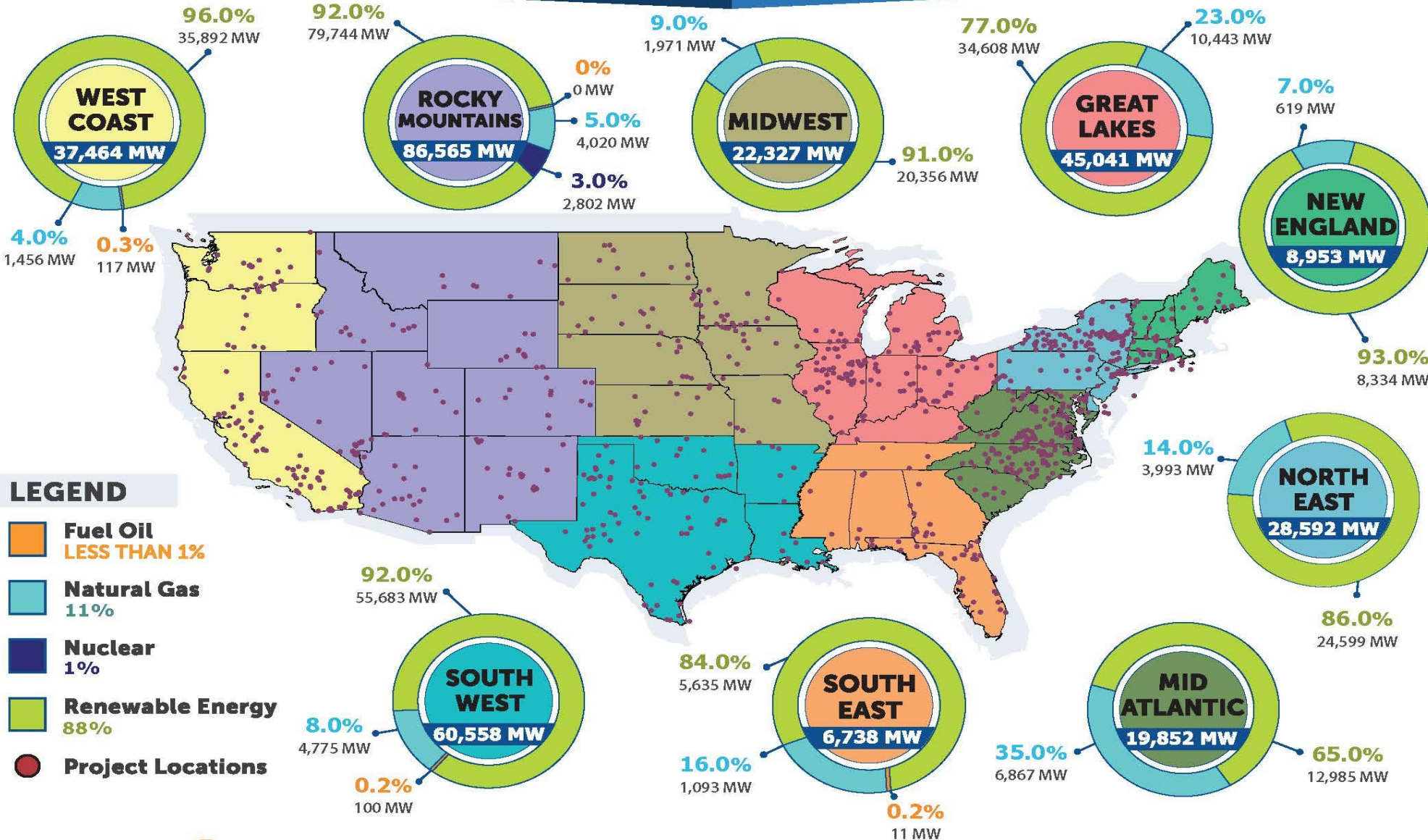
^a Primary energy consumption. Each energy source is measured in different physical units and converted to common British thermal units (Btu). See *EIA's Monthly Energy Review (MER), Appendix A*. Generation from noncombustible renewable energy sources are converted to Btu using the "Fossil Fuel Equivalency Approach." See *MER Appendix E*.

^b The electric power sector includes electricity-only and combined-heat-and-power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public. Energy consumed by these plants reflects the approximate heat rates for electricity in *MER Appendix A*. The total includes the heat content of are electricity net imports, not shown separately. Electrical system energy losses are calculated as primary energy consumed by the electric power sector minus the heat content of electricity sales to ultimate consumers. See Note 1, "Electrical System Energy Losses," at the end of *MER Section 2*.

^c End-use sector consumption of primary energy and electricity sales to ultimate consumers, excluding electrical system energy losses. Industrial and commercial sectors consumption includes primary energy consumption by CHP and electricity-only plants contained within the sector.

U.S. POWER GENERATION CAPACITY

UNDER DEVELOPMENT WITH CONSTRUCTION KICK-OFF SCHEDULED DURING 2022-2026

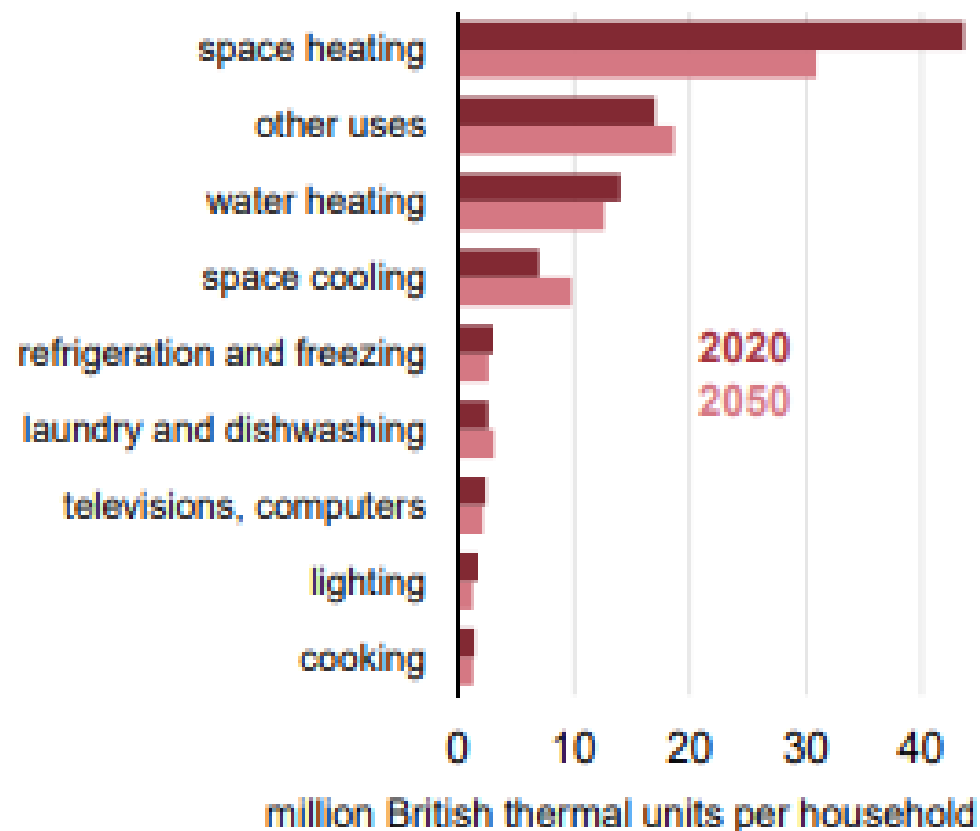


Renewables are now projected to account for about **88% of all U.S. new-build** generation capacity over the 2022- 2026

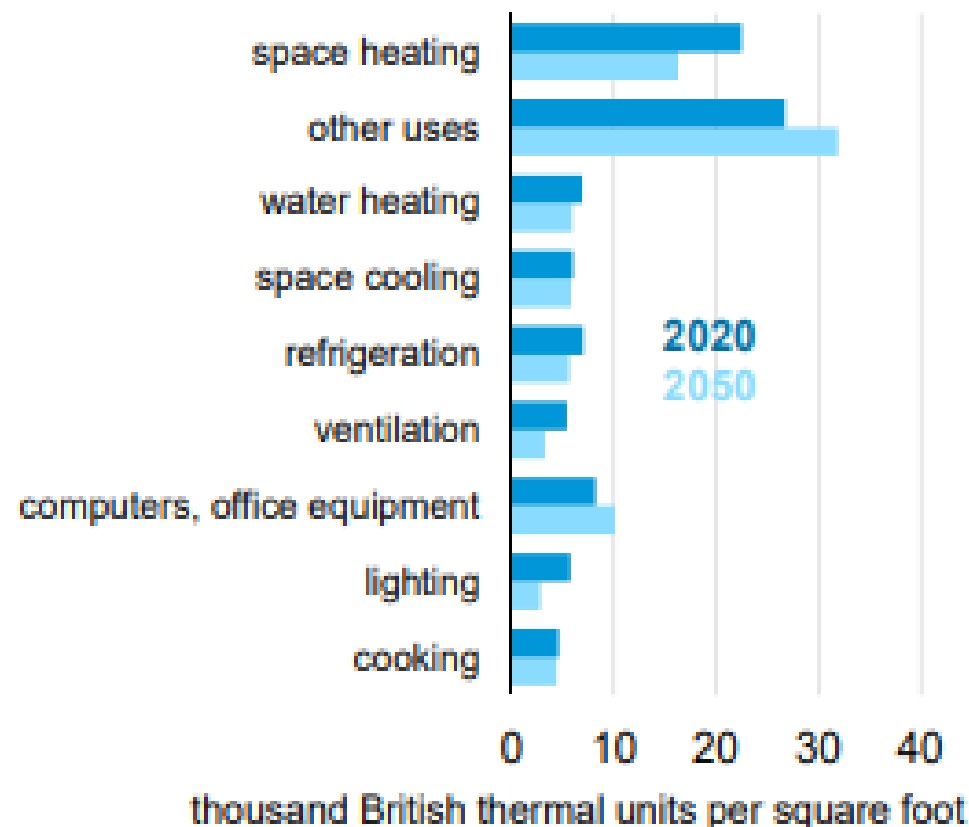


Residential and commercial overall energy intensity by end use

Residential energy intensity by end use
AEO2021 Reference case

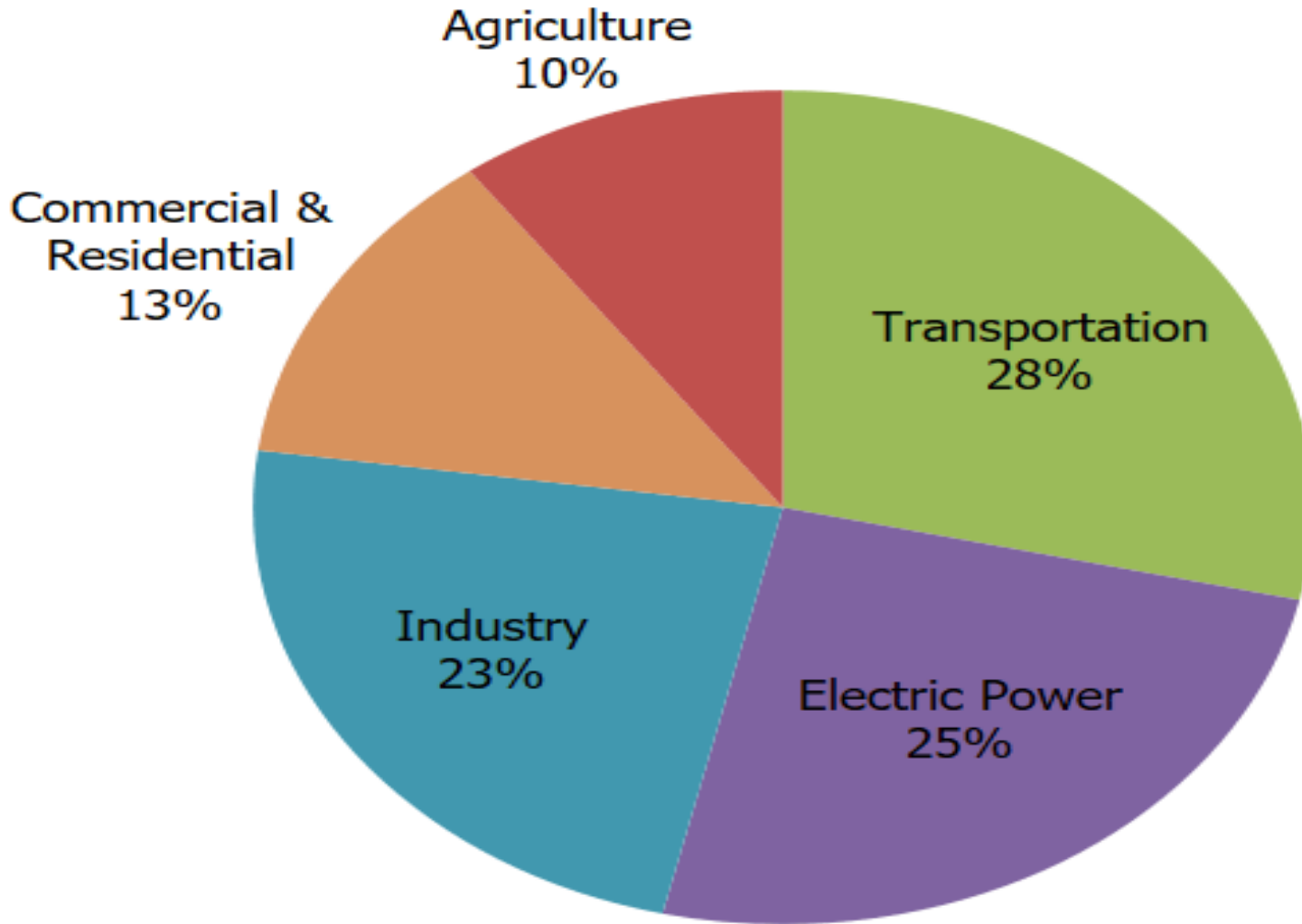


Commercial energy intensity by end use
AEO2021 Reference case



Note: Intensities reflect all energy sources consumed, including both purchased electricity and electricity produced onsite for own use.

Total U.S. Greenhouse Gas Emissions by Economic Sector in 2021



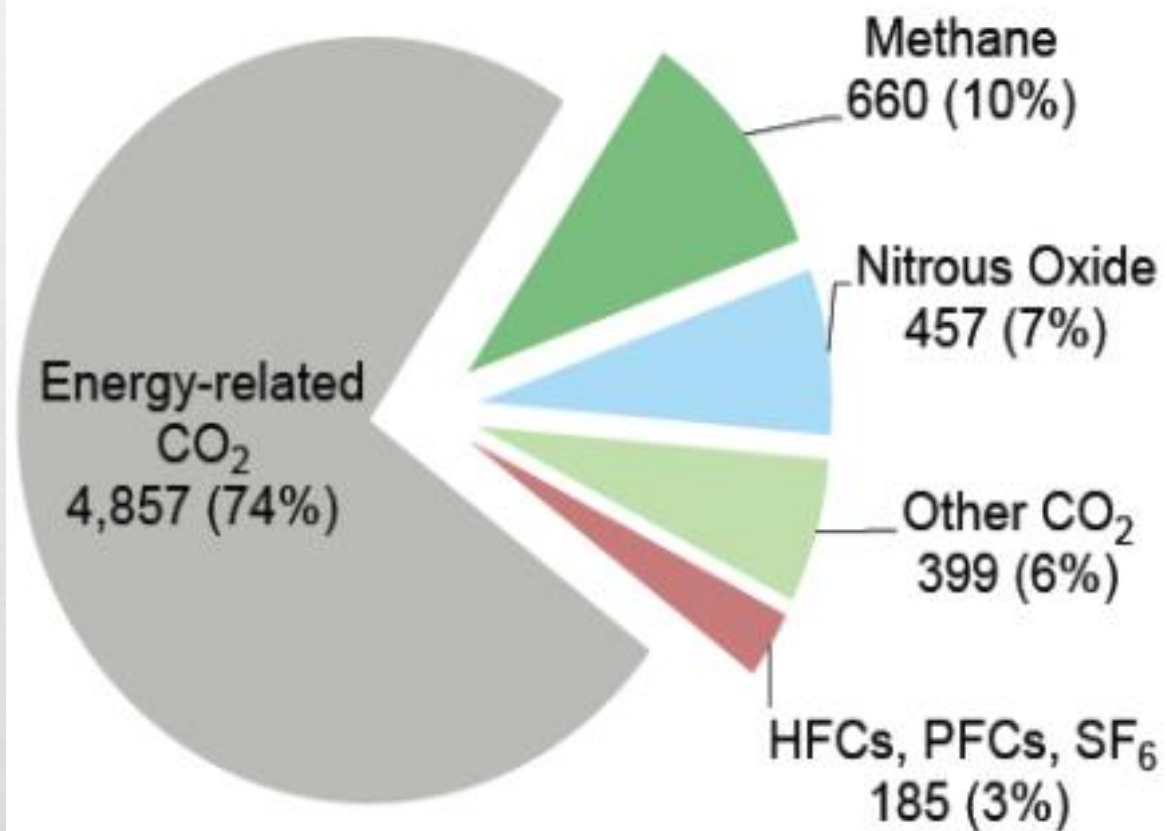
Total U.S. Greenhouse Gas Emissions by Economic Sector

Greenhouse gases trap heat and make the planet warmer.

Human activities are responsible for almost all of the increase in greenhouse gases in the atmosphere over the last 150 years.

The largest source of greenhouse gas emissions from human activities in the United States is from burning fossil fuels for electricity, heat, and transportation.

(MILLION METRIC TONS CO₂ EQUIVALENT)



Ex. California proposal to install panels on all roofs 2022...
No solar-tax, encourage vs. enforce installation of panels &
battery storage, reduce utilities payments (\$.5 kw-h vs.
\$.30kw-h), reduce overburden of energy when sun goes
down. State law has set a target of 90% zero-carbon
energy by 2035 and 100% by 2045.

SOLUTIONS AND SUSTAINABLE ALTERNATIVES

1. CONSUME LESS

Reducing energy consumption not only brings environmental benefits, but also can result in cost savings for individuals, businesses, and government agencies.

2. INCREASE EFFICIENCY

3. INCREASE RENEWABLES

4. ENCOURAGE SUPPORTIVE PUBLIC POLICY

The U.S. currently produces 15% of the world's energy-related CO₂ emissions.

U.S. emissions are projected to decrease by 0.2% by 2035 from current levels.

The **Climate Action Now Act**, passed by the House in May 2019, would require an annual plan to ensure the United States meets its stated goals under the Paris Agreement of **reducing greenhouse gas emissions by 26-28% by 2025.**

Example Reduction Opportunities for the Electric Power Sector

Type	How Emissions Are Reduced	Examples
Increased Efficiency of Fossil-fired Power Plants and Fuel Switching	Increasing the efficiency of existing fossil fuel-fired power plants by using advanced technologies, substituting less carbon-intensive fuels, and shifting generation from higher-emitting to lower-emitting power plants.	<ul style="list-style-type: none">•Converting a coal-fired boiler to use of natural gas, or co-firing natural gas.•Converting a single-cycle gas turbine into a combined-cycle turbine.•Shifting dispatch of electric generators to lower-emitting units or power plants.
Renewable Energy	Using renewable energy sources rather than fossil fuel to generate electricity.	Increasing the share of total electricity generated from wind, solar, hydro, and geothermal sources, as well as certain biofuel sources, through the addition of new renewable energy generating capacity.
Increased End-Use Energy Efficiency	Reducing electricity use and peak demand by increasing energy efficiency and conservation in homes, businesses, and industry.	EPA's ENERGY STAR® partners avoided over 400 million metric tons of greenhouse gases in 2020 alone, helped Americans save over \$42 billion in energy costs, and reduced electricity use by 520 billion kWh.
Nuclear Energy	Generating electricity from nuclear energy rather than the combustion of fossil fuels.	Extending the life of existing nuclear plants and building new nuclear generating capacity.
Carbon Capture and Sequestration (CCS)	Capturing CO ₂ as a byproduct of fossil fuel combustion before it enters the atmosphere, transporting the CO ₂ , injecting the CO ₂ deep underground at a carefully selected and suitable subsurface geologic formation where it is securely stored.	Capturing CO ₂ from the stack of a coal-fired power plant and then transferring the CO ₂ via pipeline, injecting the CO ₂ deep underground at a carefully selected and suitable nearby abandoned oil field where it is securely stored. Learn more about CCS.

Energy Efficiency Singapore

Waste to Energy Ethiopia

□ Most coal burning power plants are about only 35% efficient.

Net Zero Buildings

Clean Energy

- **Combined cycle** technology uses natural gas-fired power plant, which has two turbines and generators. Natural gas is combusted, and the combustion products turn a gas turbine. The waste heat is also collected and boils water to make steam.