ISE STUDENT CHAPTER

October Newsletter: A renewable energy crash course

A simple guide to help you understand the science of energy and the keywords behind the sustainable energy transition.

Upcoming ISE student chapter events

Friday November 14th

9:00 am -10:30 am

ERC 125

Offshore wind and its effects on marine fisheries

Julia Livermore, RI DEM

Thursday December 4th

11:00 am - 12:00 pm

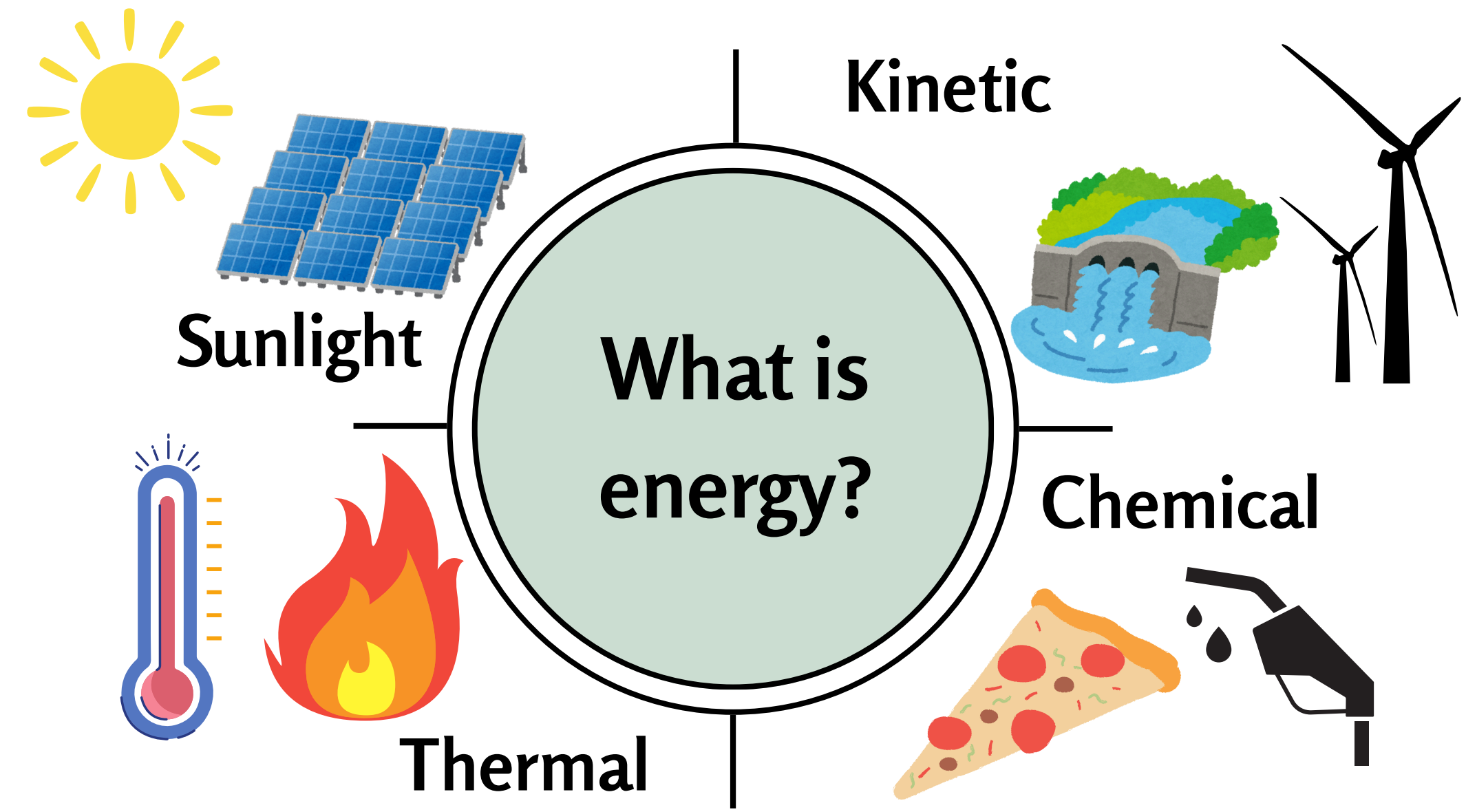
The current state of solar energy

Round table discussion

Energy is the ability to cause change or do work

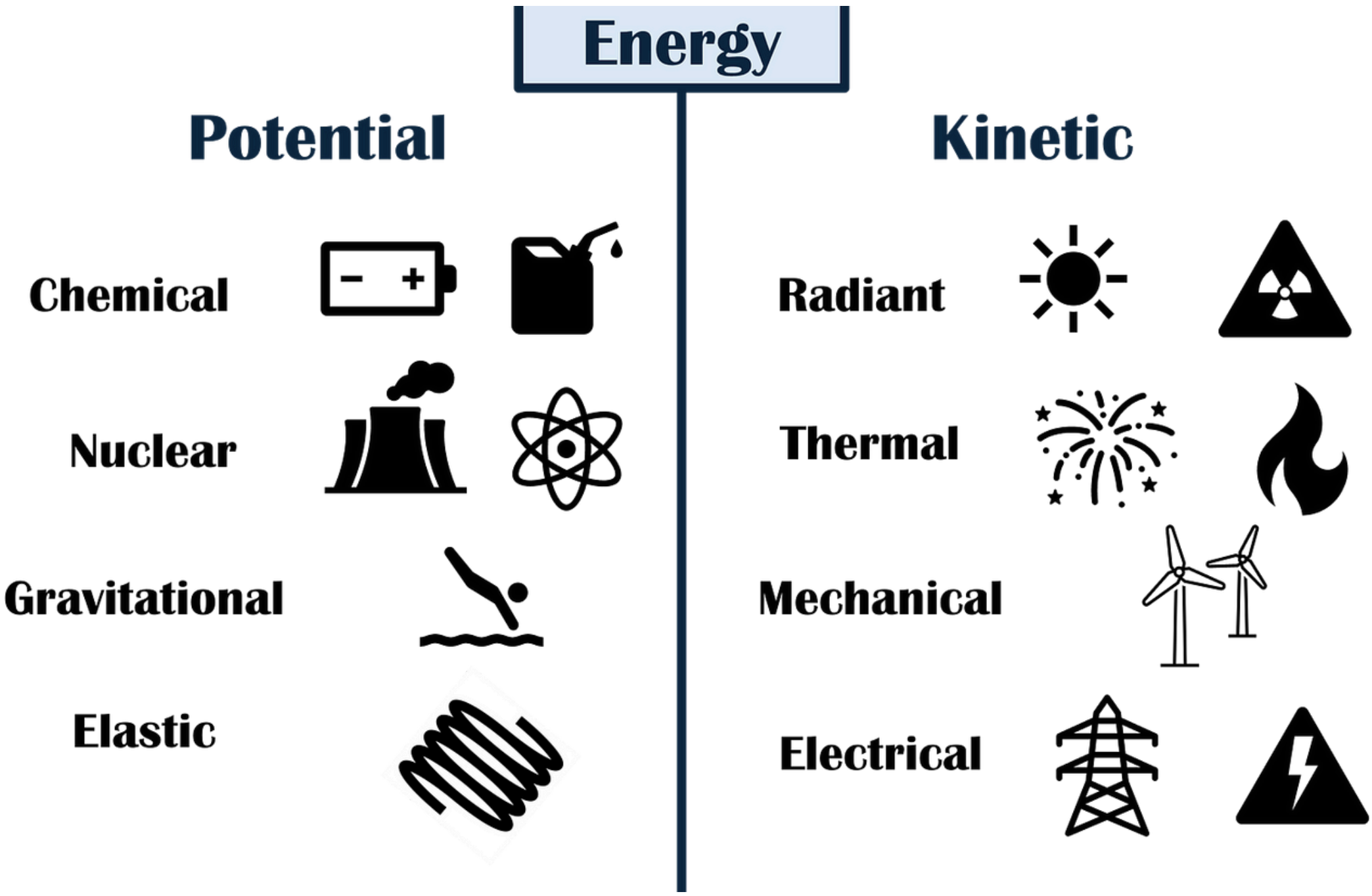
That definition is intentionally broad, as some kind of **energy is necessary** for everything we do and see around us.

Energy is not a tangible “thing” that exists by itself; rather, it is observed and measured indirectly through its effects on matter.



Types of energy

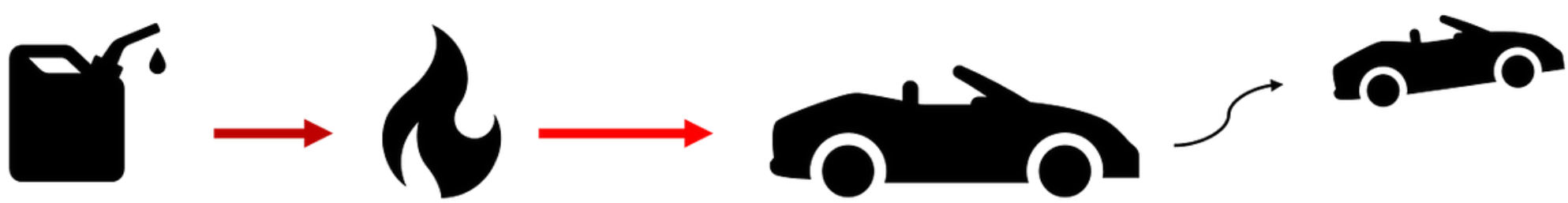
Kinetic energy is the energy of motion, and potential energy is a stored energy or an energy of position. Specific types of potential and kinetic energy that we often encounter are detailed in the image below.



Thermodynamics: The science of energy

First Law of Thermodynamics : Energy Is Conserved

This fact is so integral that in the 1850s, it became the first law of thermodynamics.



Potential energy: Stored in chemical bonds of gasoline

Kinetic energy: Internal combustion engine creates thermal energy

Kinetic energy: The thermal energy is converted to mechanical energy that drives the car

Thermodynamics is concerned with how energy is converted from heat and work, and the device that transforms thermal energy (heat) into organized kinetic energy (work) is known as a **heat engine**. The engine and motor of a car do exactly this.

Thermodynamics: The science of energy

Second Law of Thermodynamics: Converting Heat to Work Cannot be Done Perfectly

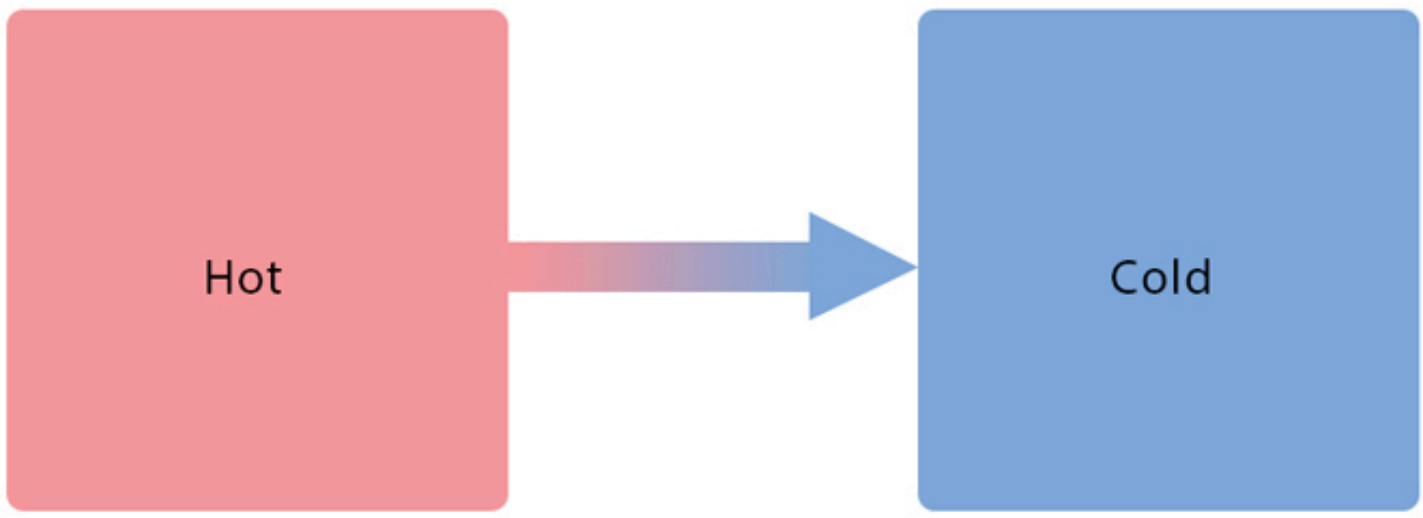
The energetic losses are attributed to a thermodynamic property called **entropy**.

According to the second law, not all of the heat created in the combustion engine of a car can be converted into useful work — some must flow to a cooler place (the exhaust to the environment).

Second Law of Thermodynamics

The entropy (S) of any natural and spontaneous process either increases or remains constant

Example: Heat flow from a hot body to a cold body



$\Delta S = 0$ For reversible process

$\Delta S > 0$ For irreversible process

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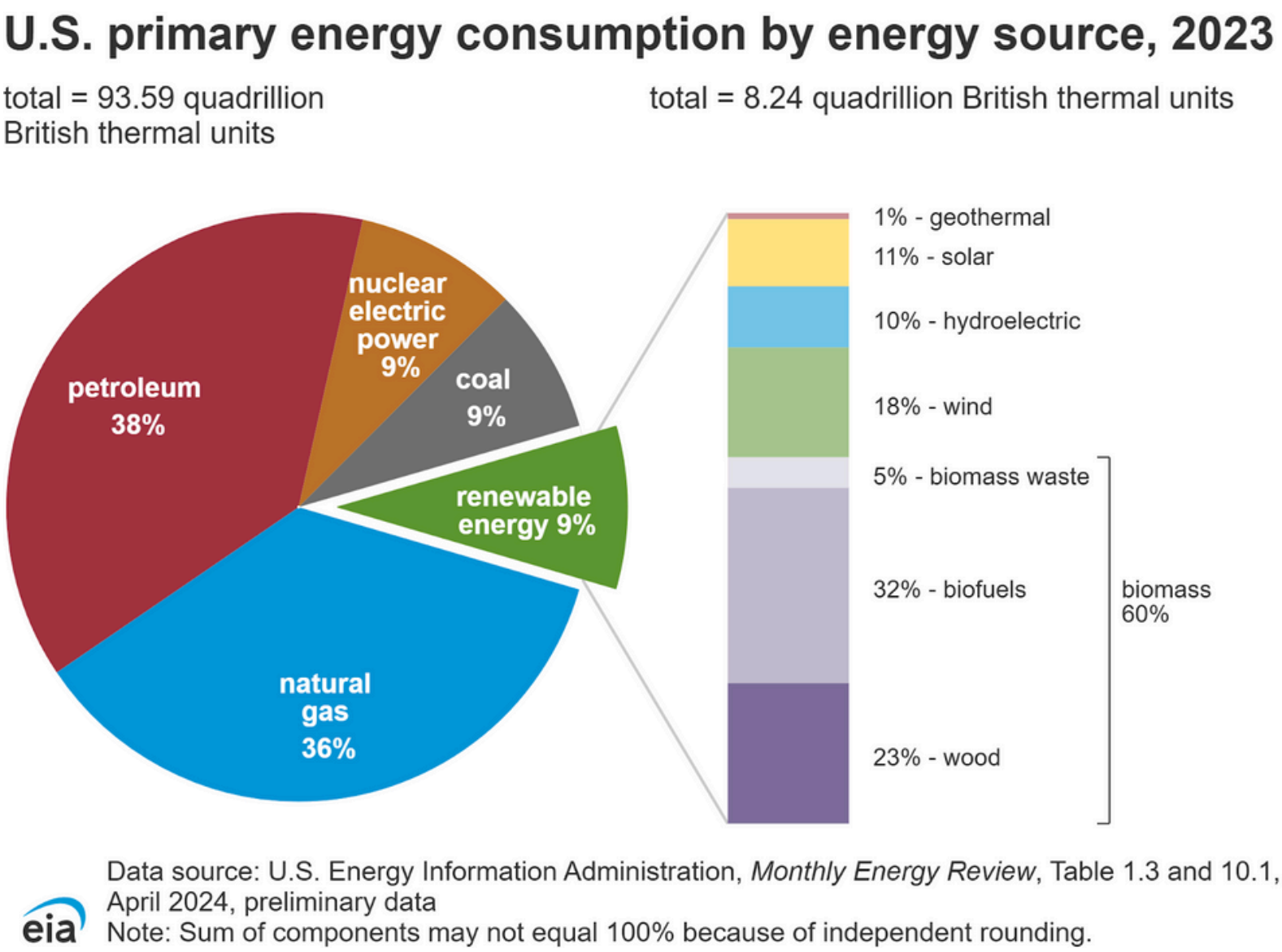
Where do we get our energy from?

The U.S. grid remains largely fossil-fuel based, relying mainly on **natural gas**, along with **coal** and **petroleum** (oil and diesel).



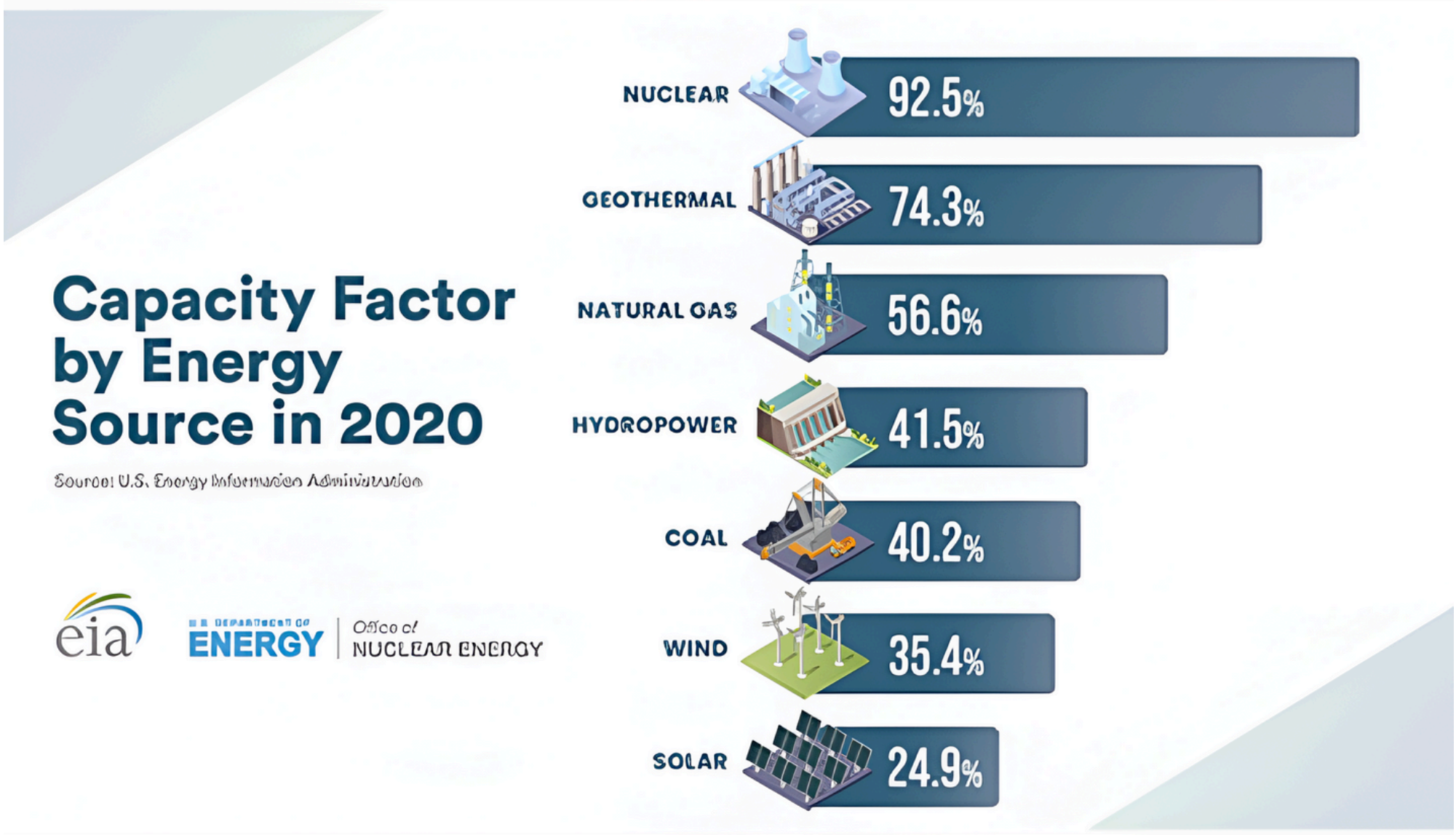
To meet the rising demand for low-cost energy, renewable and alternative sources are critical. Currently, **less than 20% of our energy consumed in the U.S. is from renewables or nuclear**. These energy sources are not only CO_2 emission-free, they are also not constrained in the same way as fossil fuels, by quantity or geographical location in the Earth's crust.

What is renewable energy?

Renewable energy is a form of energy with a source that must **replenish equally or faster than its consumption** within the span of a human lifetime. Additionally, renewable energy usage **does not typically have a direct CO_2 impact,** with biomass being the sole outlier.

What is renewable energy?

The most impactful and widely used renewable energies are shown below, along with their capacity factors.

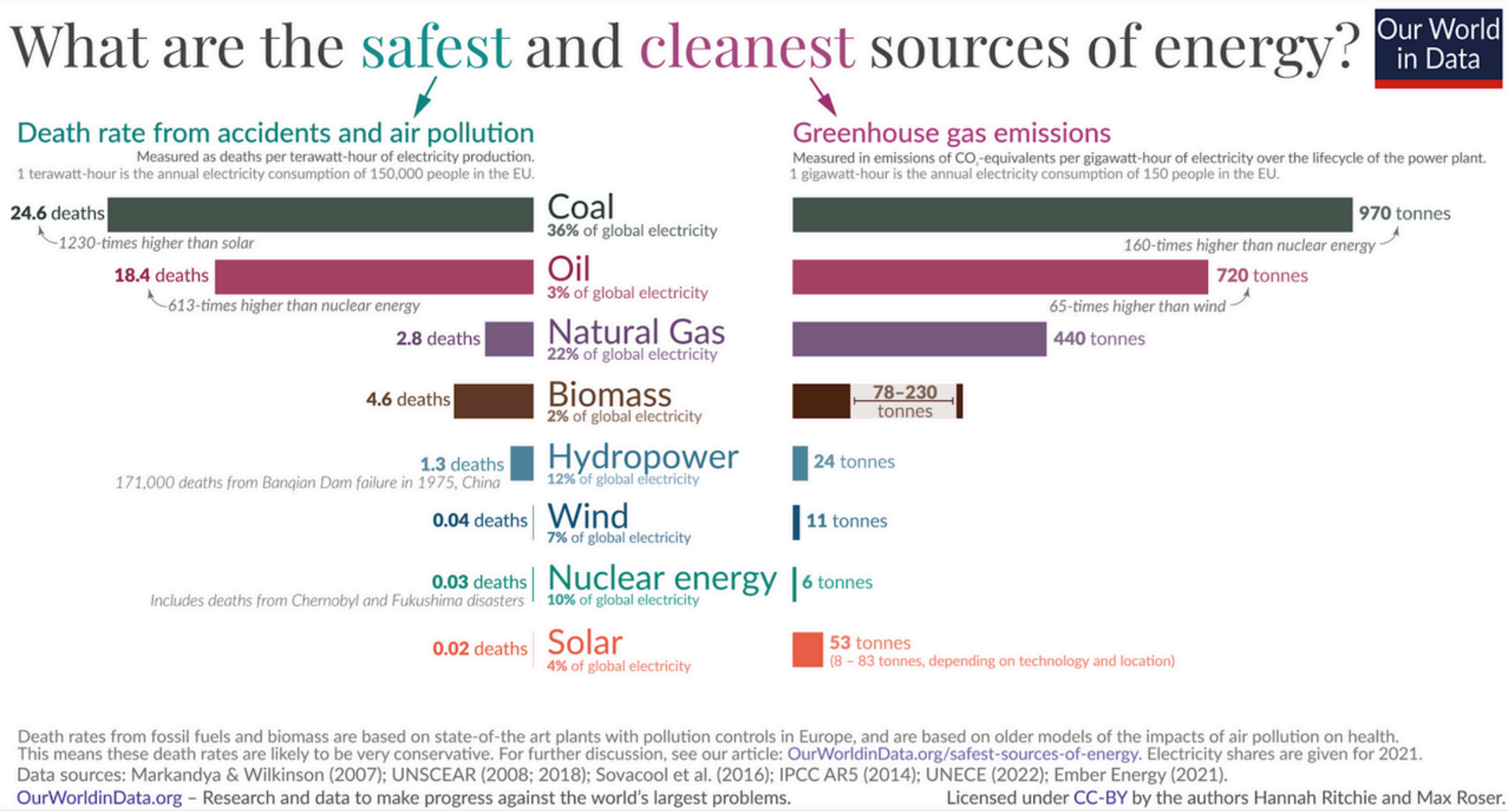


Capacity Factor

The average ratio of actual energy production over their maximum energy output. This discrepancy between actual vs optimal output can be attributed to variables such as weather patterns, unit efficiencies, or other environmental factors.

What is alternative energy?

Alternative energy, such as nuclear fusion or fission, has **no direct carbon footprint.** However, unlike renewable energy, the sources for alternative energy (such as uranium) are **not able to be replenished faster than we consume them.** Despite this, Nuclear is the most efficient form of energy which is utilized today.

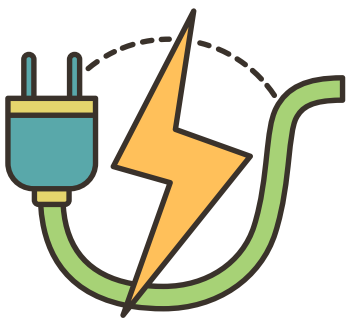


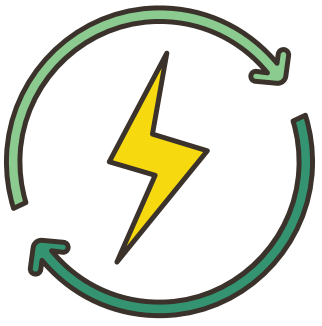
Contrary to common belief, nuclear power is one of the safest forms of energy known to humans. The safety index of the energy sources used in the United States, from Our World in Data, is shown above.

How do we measure energy?

We measure energy using several units across physics, engineering, and everyday life. The most frequently encountered standard unit in physics and engineering is the **Joule (J)**.

1 Joule is the amount of energy used to apply a force of 1 Newton (N) over 1 meter (m).
1 Joule is also equivalent to one watt (W) of power exerted for one second





1 Wh (Watt-Hour)
= 3,600 J

1 eV(electron volt)
= 1.602×10^{-19} J

1 kJ (kilojoule)
= 1000 J

1 BTU
(British Thermal Unit)
= 1,055 J

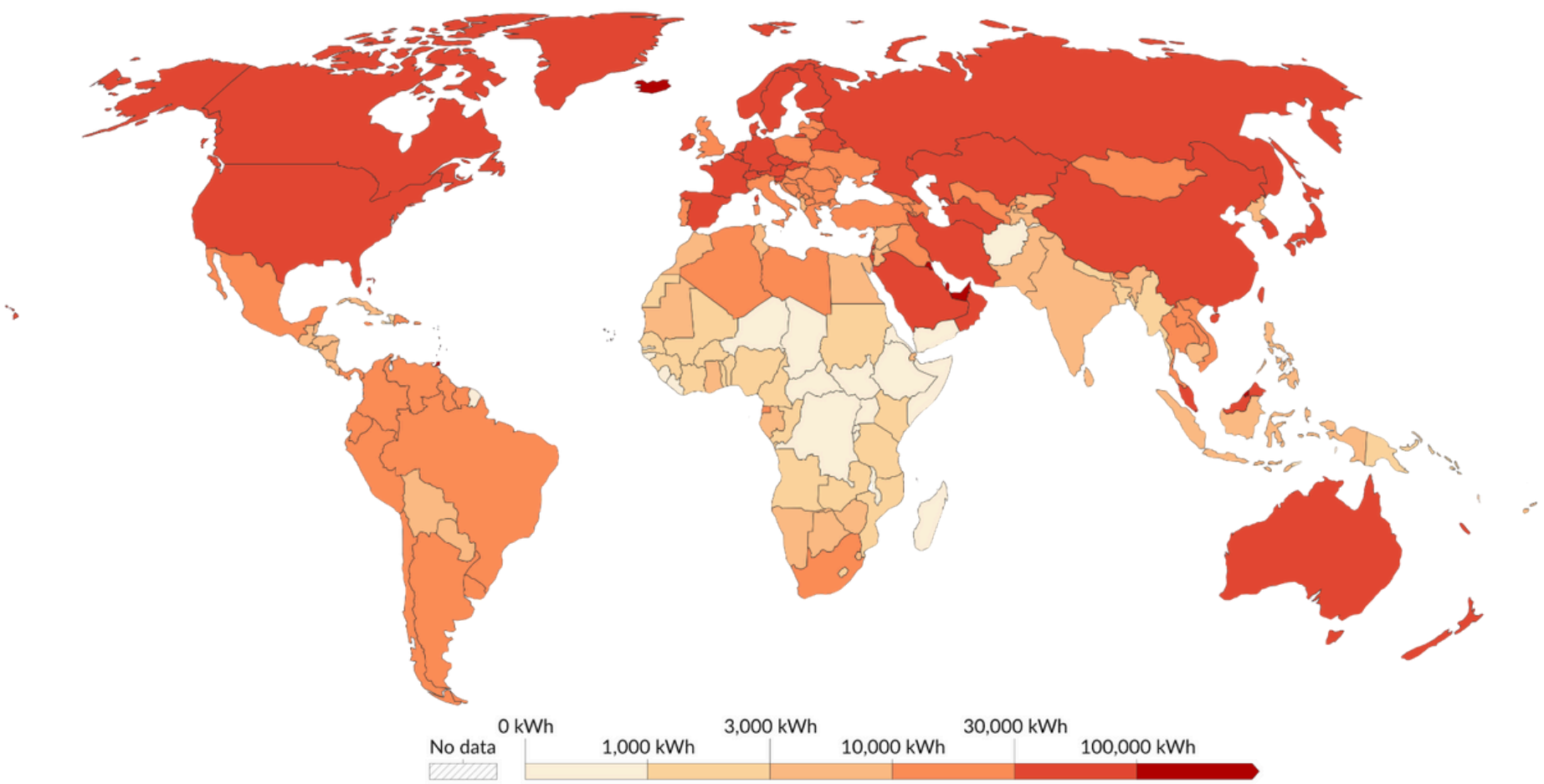
1 Joule (J)

1 GJ (GigaJoule)
= 10^9 J

1 kWh (kilo-Watt-Hour)
= 3,600,000 J

1 cal (calorie)
= 4.184 J

1 kcal (kilocalorie)
= 4,184 J



How much energy do we use?

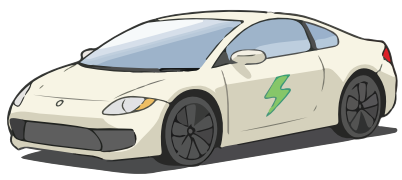
2023 US energy consumption: 27,000 TWh = $9.72*10^{10}$ GJ

Global energy consumption in 2023: 170,000 TWh = $6.12*10^{11}$ GJ

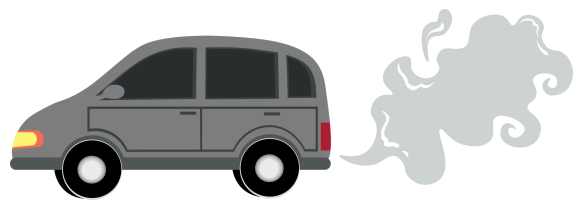
How much energy do our everyday activities require?

Charge a Smartphone, EV
0.01 - 0.02 kWh/charge

Brew Coffee
0.08 kWh/pot brewed



Drive 1 Mile, EV
0.3 - 0.4 kWh/mi



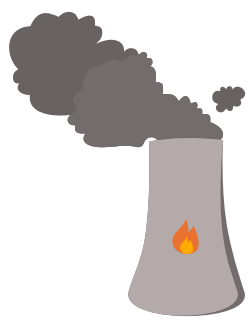
Drive 1 Mile, Gas Car
1.35 kWh/mi

How much energy do we produce?

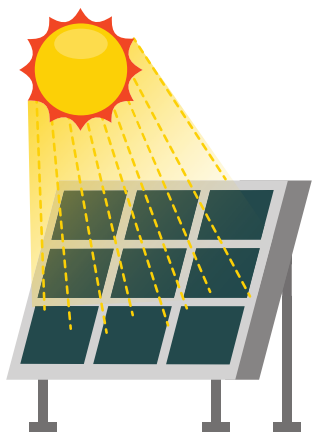
In 2023, U.S. energy Production was 30,160 TWh = $1.09*10^{11}$ GJ. Since 2019, the U.S. total annual energy production has exceeded its total annual energy consumption.

Annual energy production of common U.S. power sources, differences in plant size and capacity factor (CF) affect total output:

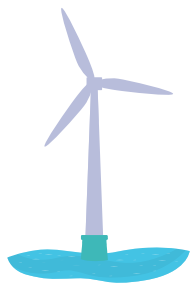
Onshore Wind Turbine,
(3MW @ 35% CF)
9 GWh/yr



Natural Gas Plant,
(500MW @ 60% CF))
2,600 GWh/yr



Solar Panel Farm (100MW @ 25% CF)
219 GWh/yr



Offshore Wind Turbine,
(12MW @ 45% CF)
47 GWh/yr

Hydroelectric Plant (500 MW @ 50% CF)
2,190 GWh/yr

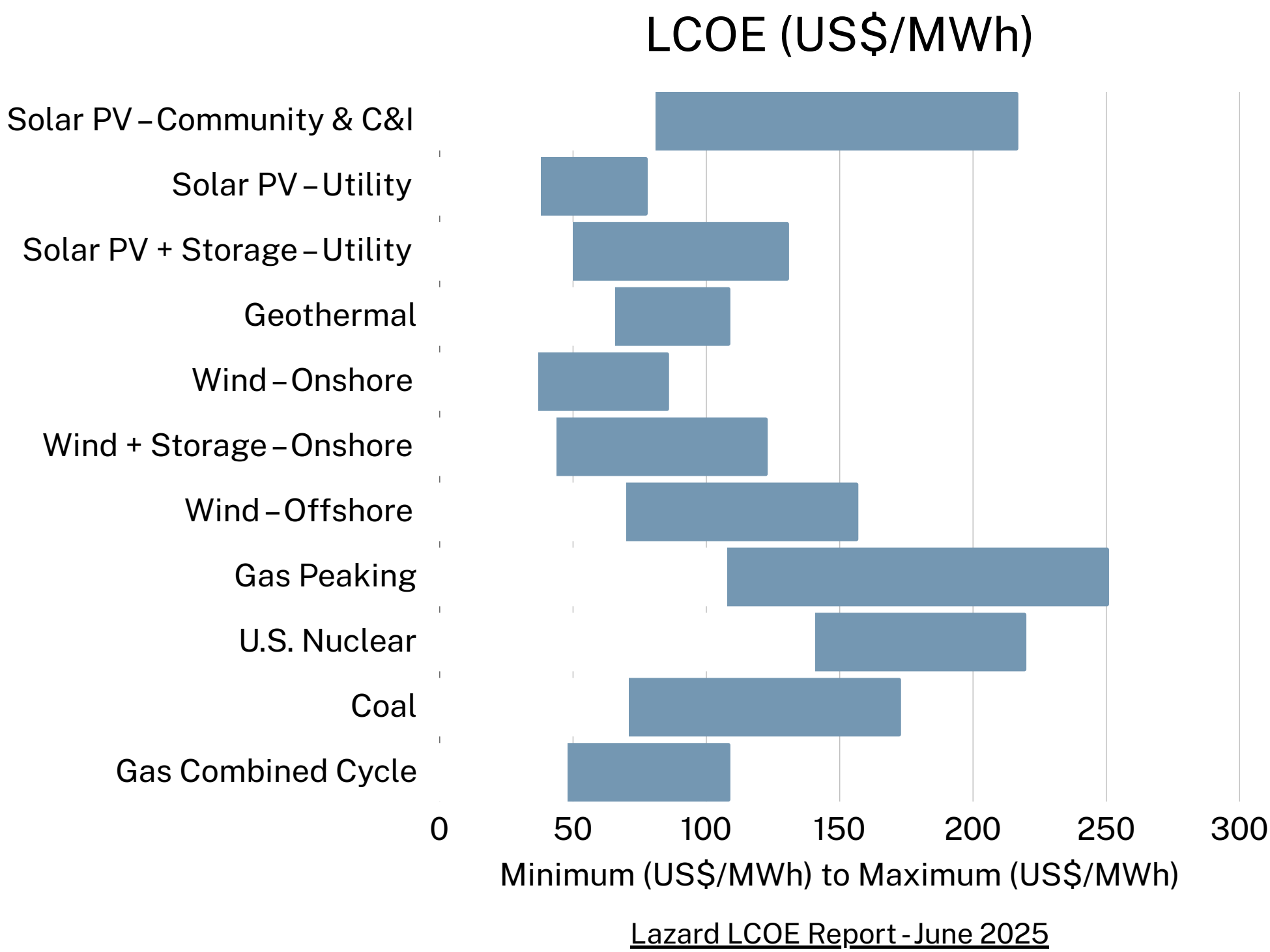
The average U.S. household uses about 11 MWh annually. This means a single onshore turbine could power more than 800 homes!

How much does it cost?

Electricity generation costs vary significantly by source, but renewable cost per MWH continues to trend down.

Levelized Cost of Electricity (LCOE)

The average total cost to build and operate over an energy sources lifetime, divided by the total energy it produces



Lazard LCOE Report - June 2025

Pricing electricity in the market

This stack auction process is fundamental to the operation of wholesale electricity markets, helping to balance supply and demand efficiently and set the wholesale price of electricity.

1

Bidding

In a stack auction, generators bid the lowest price they'll accept to sell electricity.

2

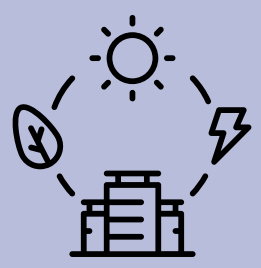
Stack Development

Bids are ranked from cheapest to most expensive, forming a supply "stack."

3

Market Decisions

The market operator accepts bids until demand is met, starting with the lowest-cost sources.

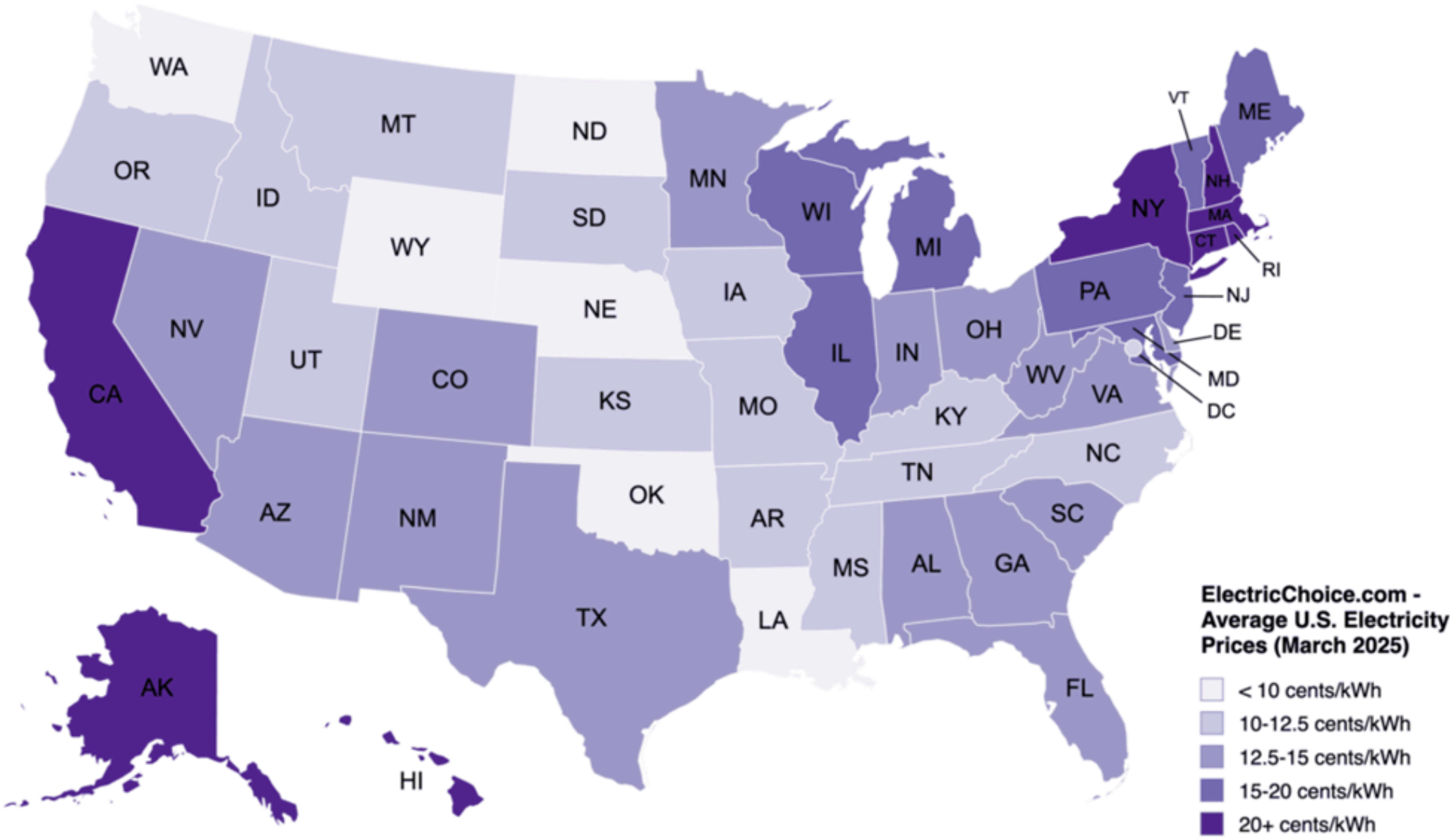


Renewable Input

Renewables usually bid lowest since extra output costs little, but natural gas often sets the marginal price, making consumer rates reflect higher costs even when most power is renewable.

Regional cost of electricity

Energy costs in the United States vary widely by region due to differences in resource availability, infrastructure, regulation, and market design.



Why Are Prices High In New England?

Reliance on natural gas, significant temperature variation, and aging infrastructure drive up our energy costs.

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