New Nuclear is Hot!

Session 1

Work, Heat, Power, Conversion, Watt, Carbon, CO2

Literally red hot!
Cheaper than coal.
Lets developing nations prosper.
Cuts rapacious minerals mining.
Zeros electric power CO2.

Public support

Five supporters per opponent.
Relieves energy security concerns.

Seafuel

Net-zero gasoline for your car.
Climate-neutral diesel for industry.
Guilt-free jet flights.
Uses existing combustion engines.
Zeros transportation CO2.

Humans harnessed fire 1.8 million years ago.

The final confrontation with the Environmental Anti Fire Party

Distinguish HEAT energy and USEFUL energy.

Heat energy is the composite, kinetic energy of many molecules in disorganized motion.

Useful energy includes electricity, kinetic energy, gravitational potential energy, chemical potential energy, mechanical stress, etc that can be efficiently transformed to **work** (force x distance).

Distinguish ENERGY and POWER.

Power is the rate of energy transfer.

Power = Energy / Time

Energy = Power x Time

Outfits like IEA confusingly use “power” to describe electric energy.

Try to be strict. Avoid “My power bill was $122 last month.”

US Department of Energy
Energy Informatiion Agency

uses arcane units.

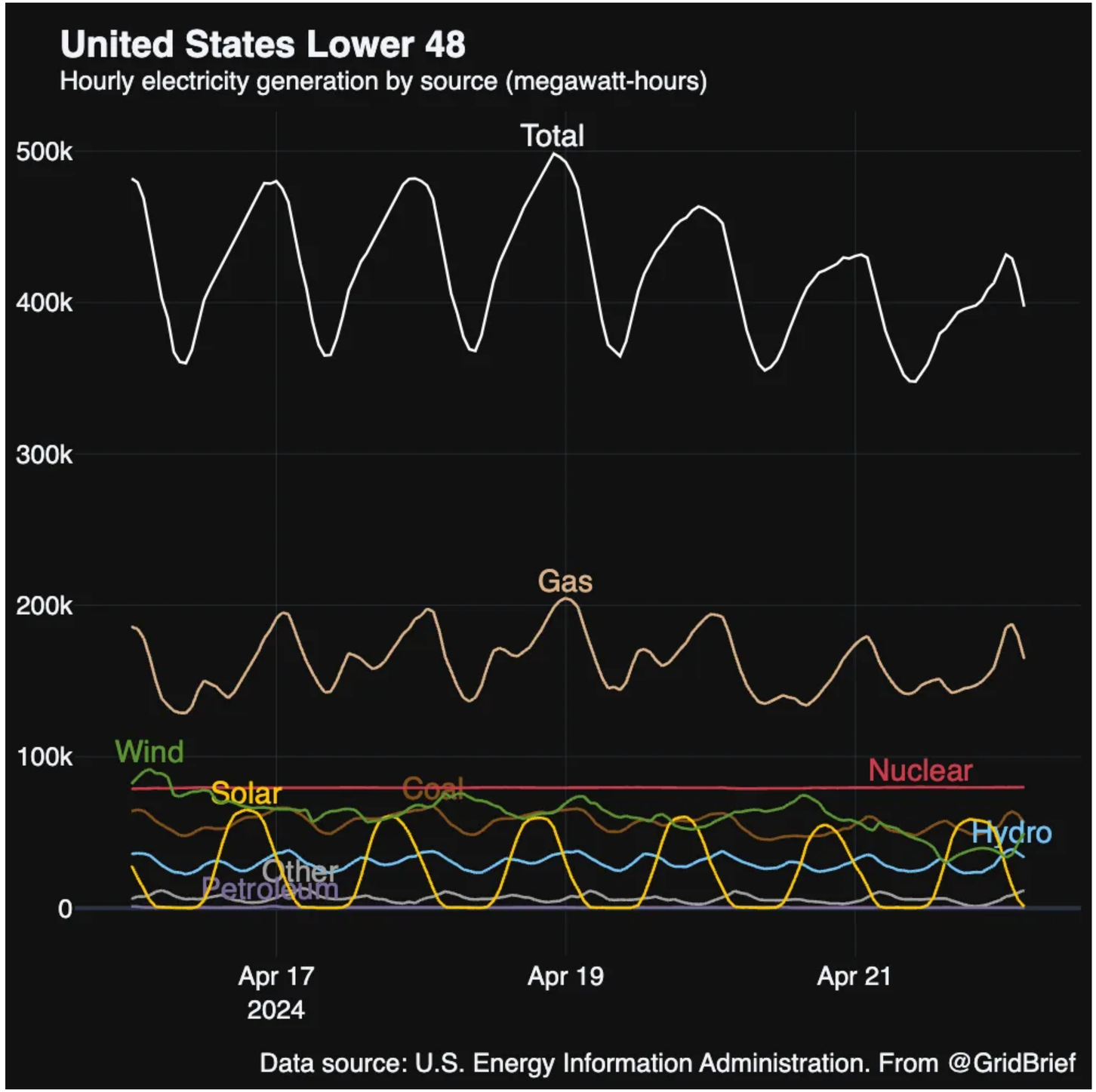
On the vertical axis

“500k” means

500,000 megawatt hours per hour

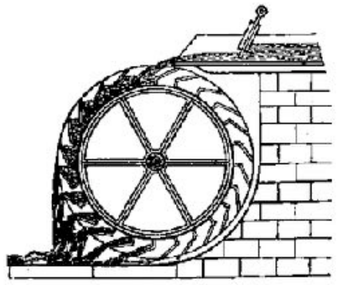
or more straightforwardly

500 GW



Kinetic energy is one form of ***useful energy***.

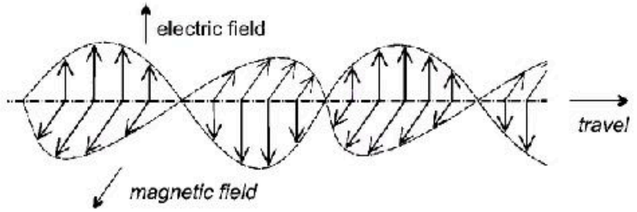
Kinetic energy: mass x velocity squared / 2



Gravitational energy: height x mass x g

Work: force (newtons) x distance (meters)

Electric energy is a form of ***useful energy***.



Electric energy: amps x volts x time

1 watt-sec = 1 amp x 1 volt x 1 sec

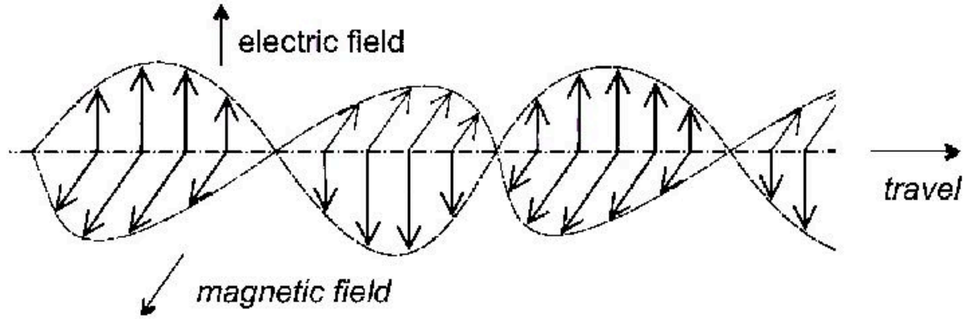
1 Joule = 1 watt-sec = 1 newton-meter

60 x 60 watt-sec = 1 watt-hour = 1 Wh

1 kWh = 3,600,000 J

1 J/sec = 1 watt (a **power** measure)

Electric energy and work are exchangeable energy forms.



Force (newtons) = Mass (kilograms) x 9.8 (Earth gravity accel.)

Work energy (joules) = Force (newtons) x Distance (meters)

Power (watts) = Work (joules) / Time (seconds)

Energy (joules) = Power (watts) x Time (seconds)

Power (watts) = Current (amperes) x Potential (volts)

Energy (kilowatt-hours) = 1000 x 3600 x Energy (joules)

Cooking with heat energy.

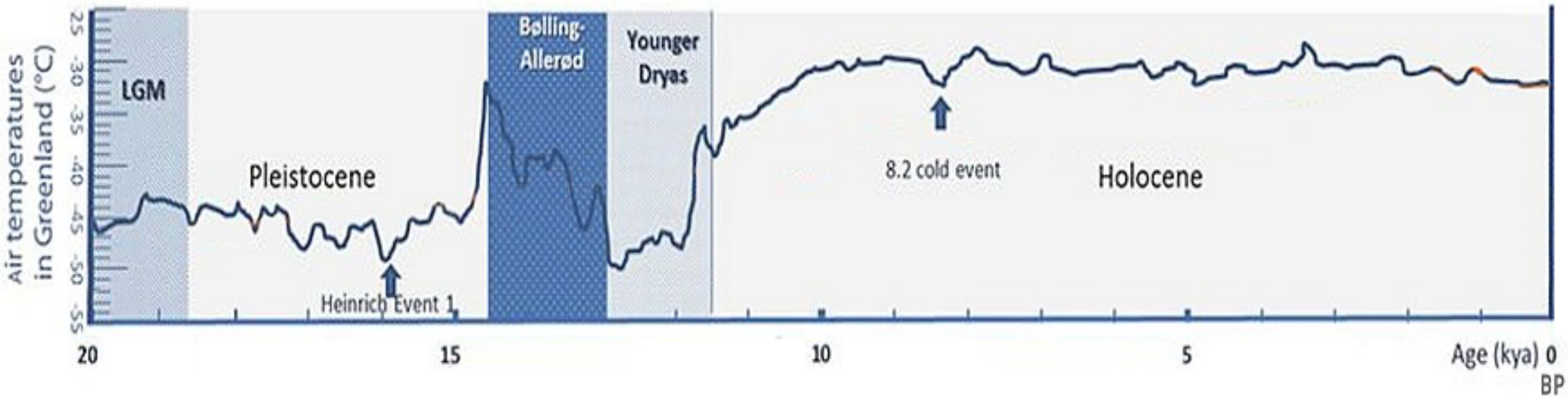
Cooking food saved time and energy. Primates still spend half their day chewing raw food.

By switching to cooked, softer, more energetically rich food homo erectus was able to **devote time to more productive activities**, making tools, farming, and interacting socially

Reduced kinetic energy demands for metabolism permitted **evolution of the human's large brain**, which consumes a quarter of the body's energy.

Fossil records show evolution to larger brains and smaller guts, jaws, and teeth.

Climate warming in 10,000 BC enabled agriculture.



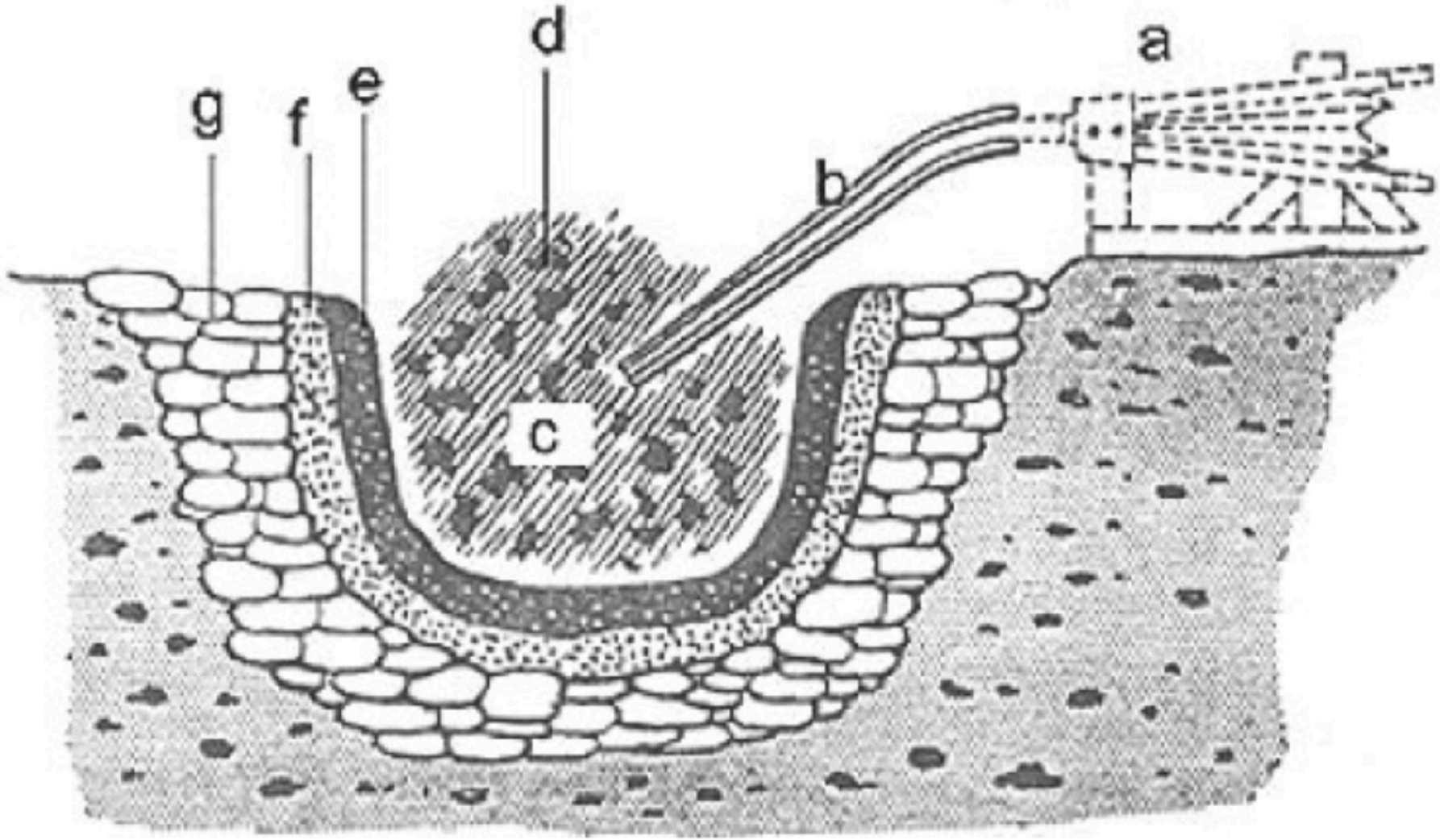
Earlier stone age roving bands subsisted on hunting animals and gathering food.

Productive agriculture of cereals enabled storage of food and free time to make tools, build shelters, develop writing, and advance civilization.

Stored food was **wealth**.

https://en.wikipedia.org/wiki/Neolithic_Revolution#Social_change

Bronze Age 3000 BC
1100°C furnace for melting copper and tin



a-Smile (bellows?)

b-nozzle

c-charcoal (wood?)

d-fine "grind" of copper and tin ore

e-lining of clay

f-priming with pen

g-stone lining

https://www.researchgate.net/publication/233731071_The_investigation_of_microstructure_and_hardness_of_archaeological_alloys/figures?lo=1

Iron Age 1200 BC; 1250-1535°C heat needed.

Killick A well-preserved tall (2.2 m) natural draft iron smelting furnace in the Kasungu National Park, Malawi

https://www.researchgate.net/publication/298801110_A_global_perspective_on_the_pyrotechnologies_of_Sub-Saharan_Africa/figures?lo=1

Iron ore is plentiful, inexpensive.

1250°C to reduce iron ore to iron bits that could be pounded together, **forged**, to form “wrought iron”.

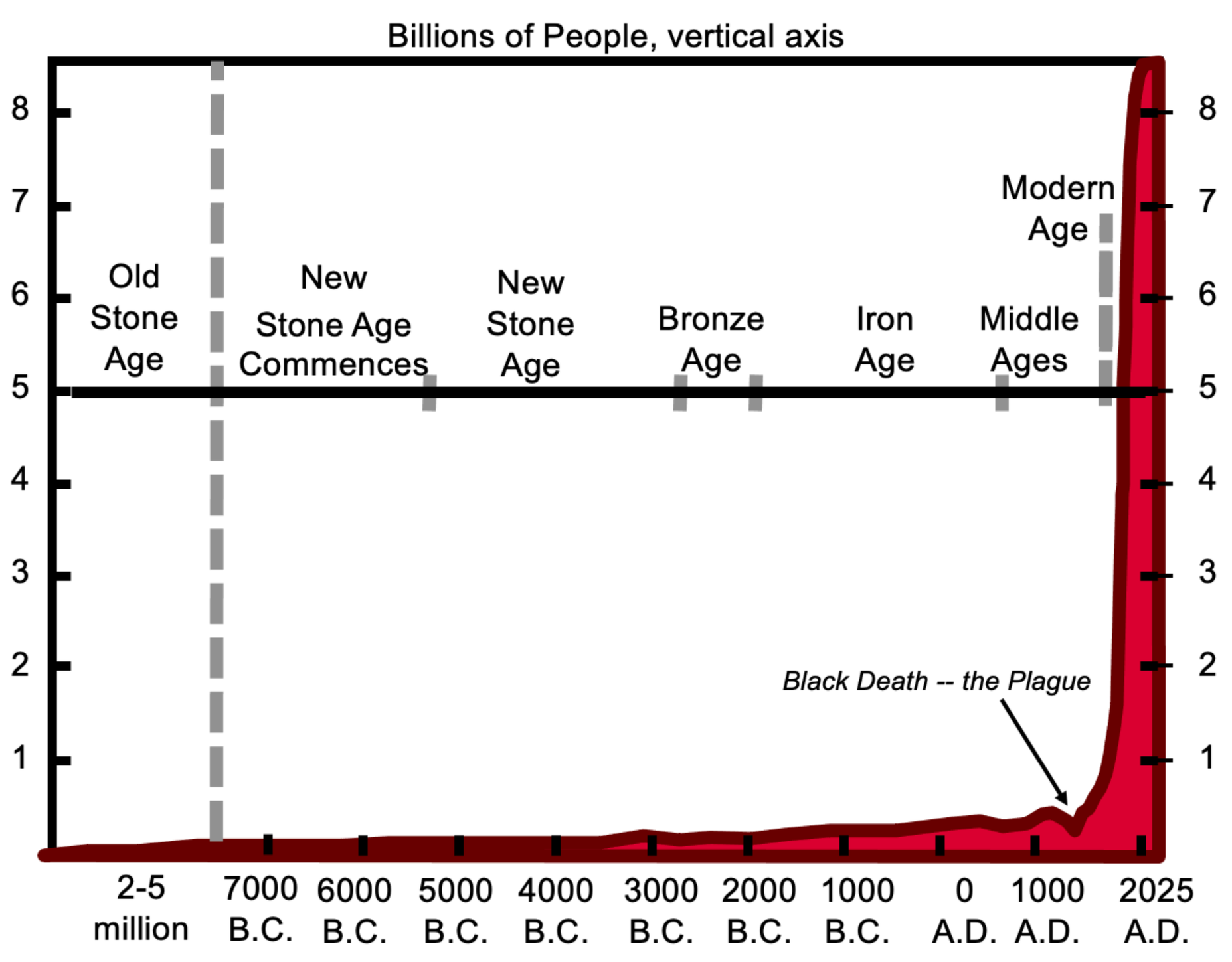
African hardwood fuel burns hotter, as does charcoal.

1535°C to melt iron to form “cast iron”.

Adding carbon lowers iron melting point to 1150°C, but iron is brittle.

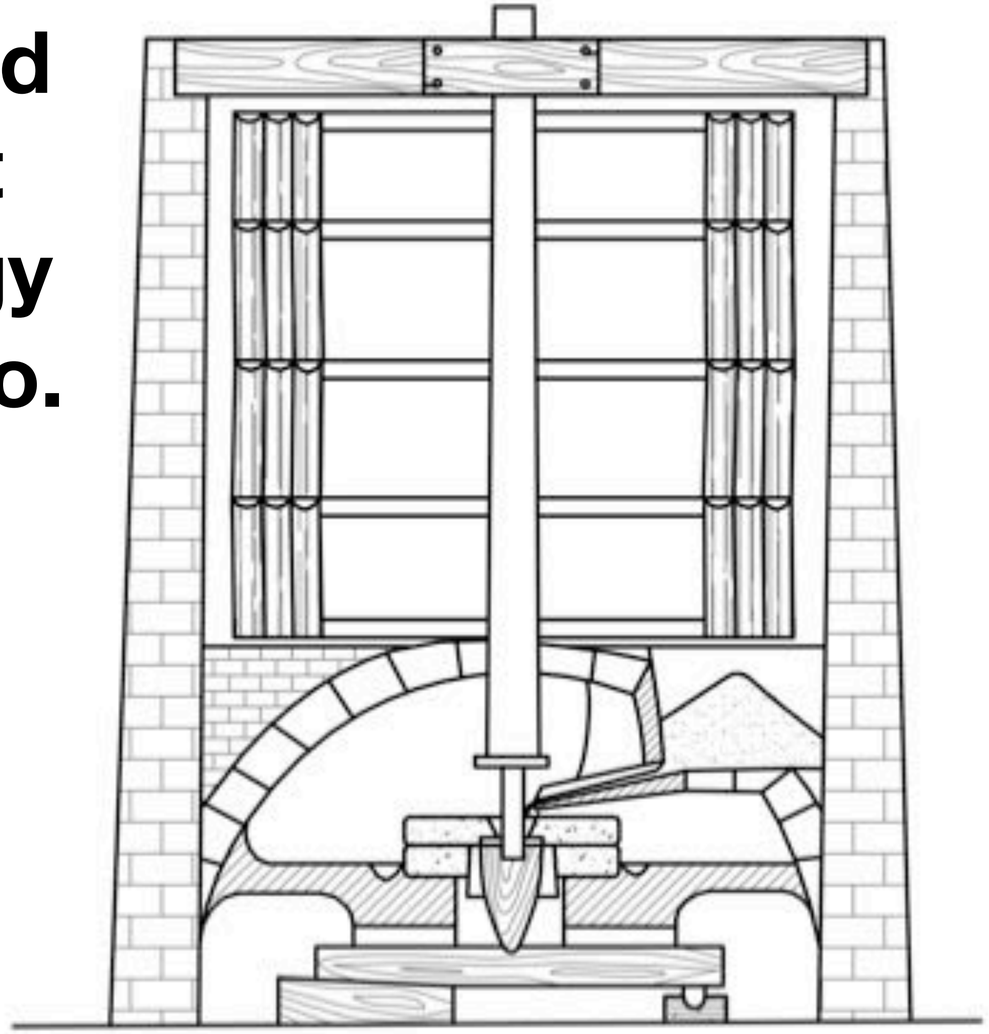
Civilization's slow growth made use of HEAT energy.

WORK energy rapidly enabled the modern era.

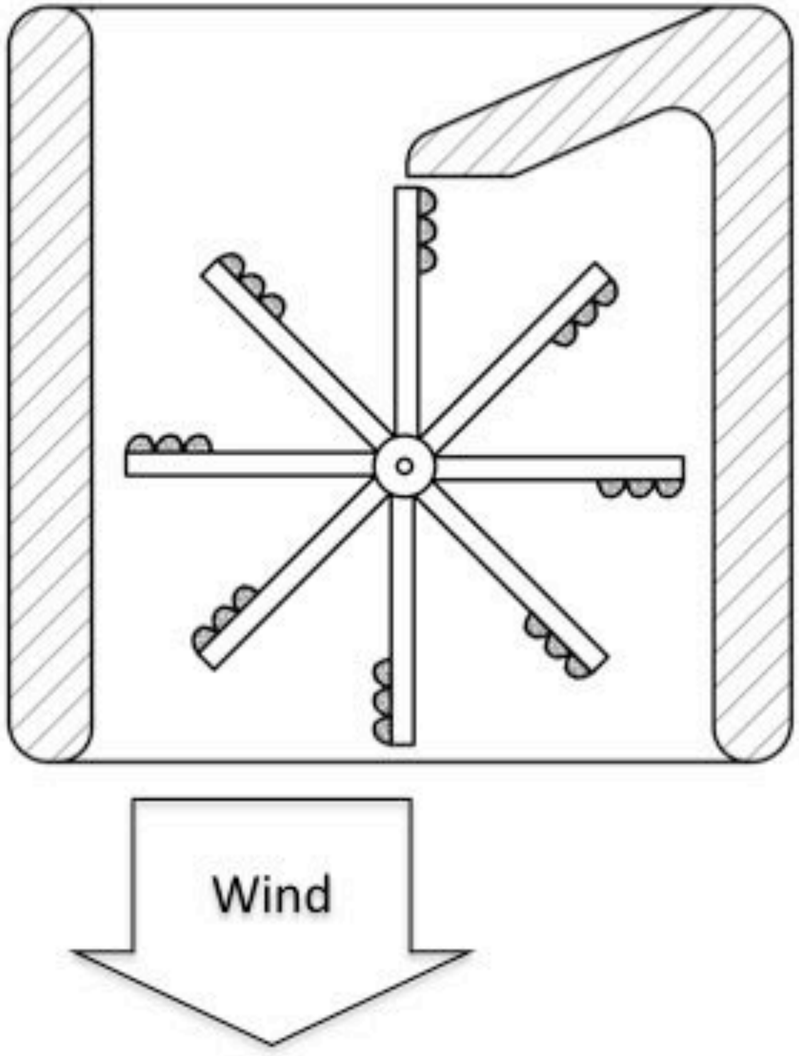


People used wind to get work energy millenia ago.

Side view

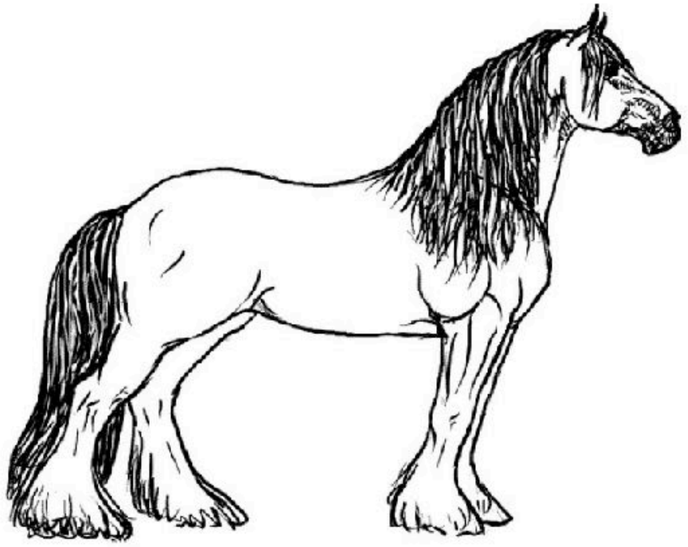


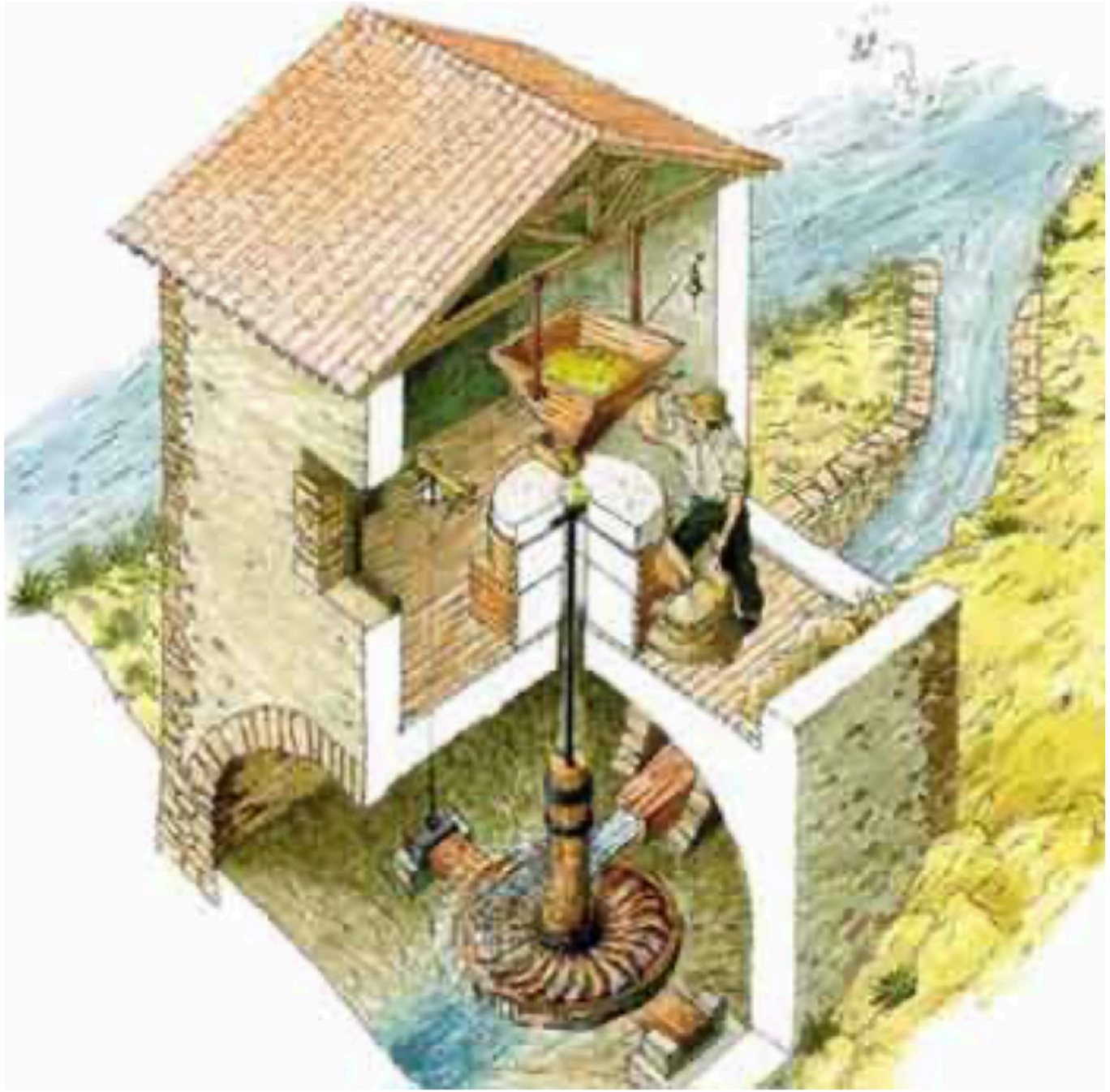
Top view



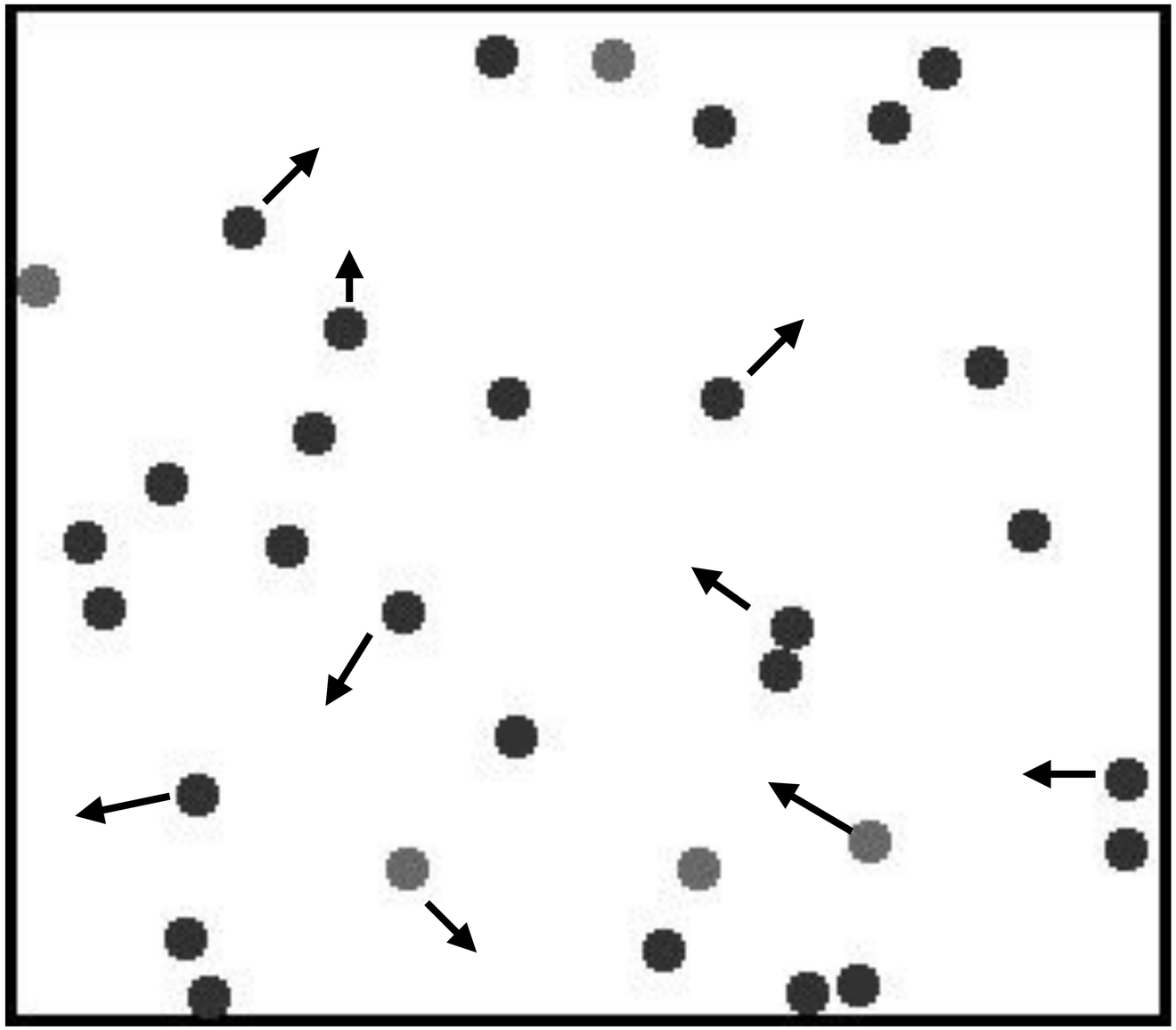
People used water flow for work energy a milleneum ago

and harnessed animals for work.

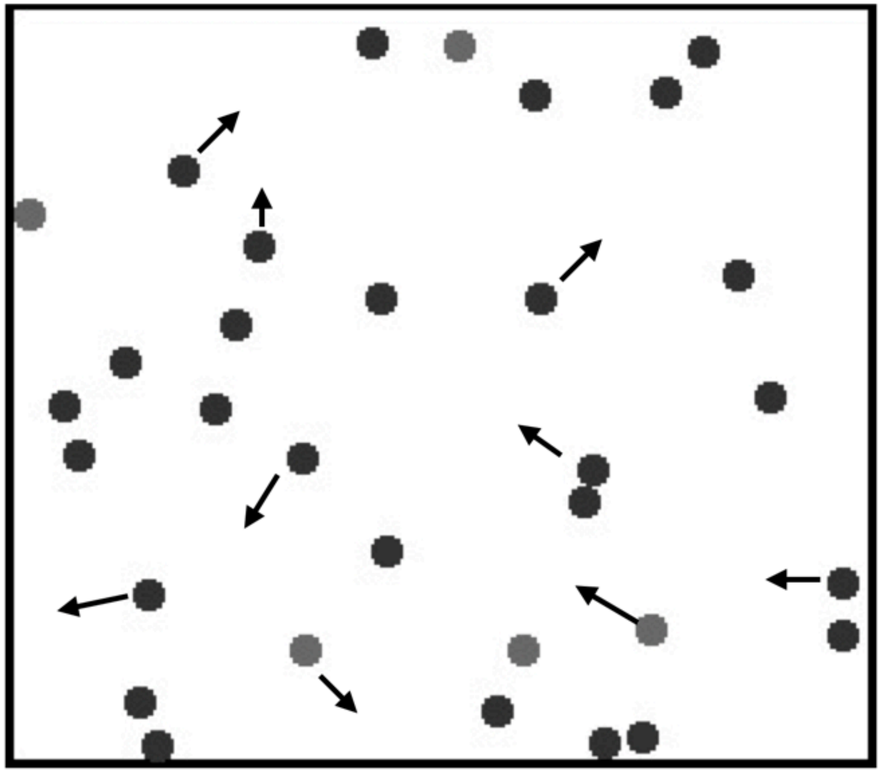




Heat **energy is the kinetic energy of many molecules.**

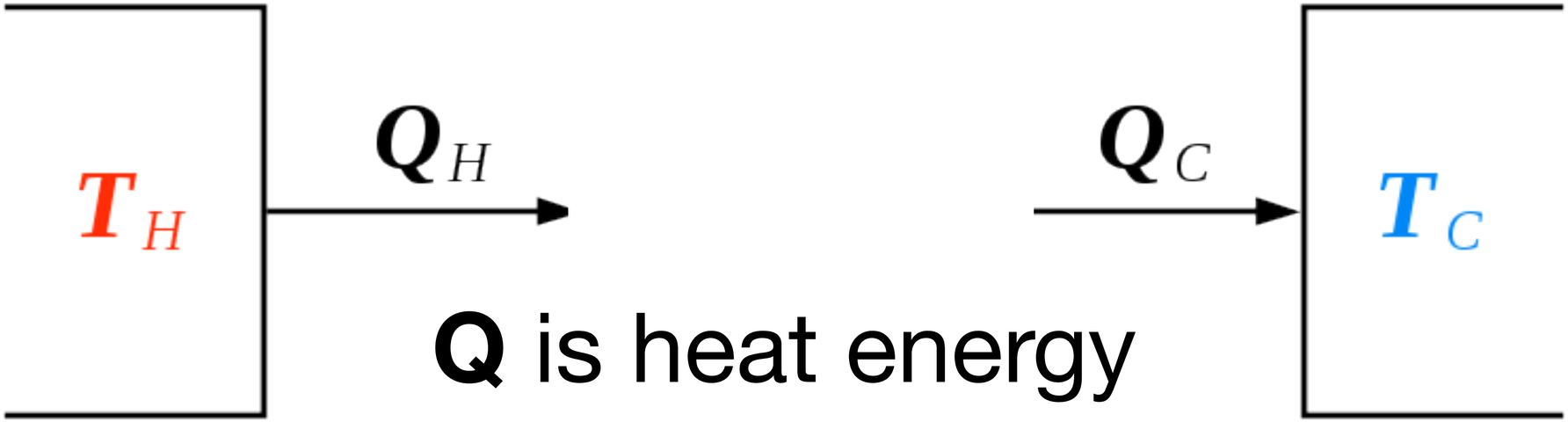


Temperature is proportional to the kinetic energy of the molecules.



Motionless molecules' temperature is 0°Kelvin = -273°Celsius.

Heat flows from ***hot*** to cold.

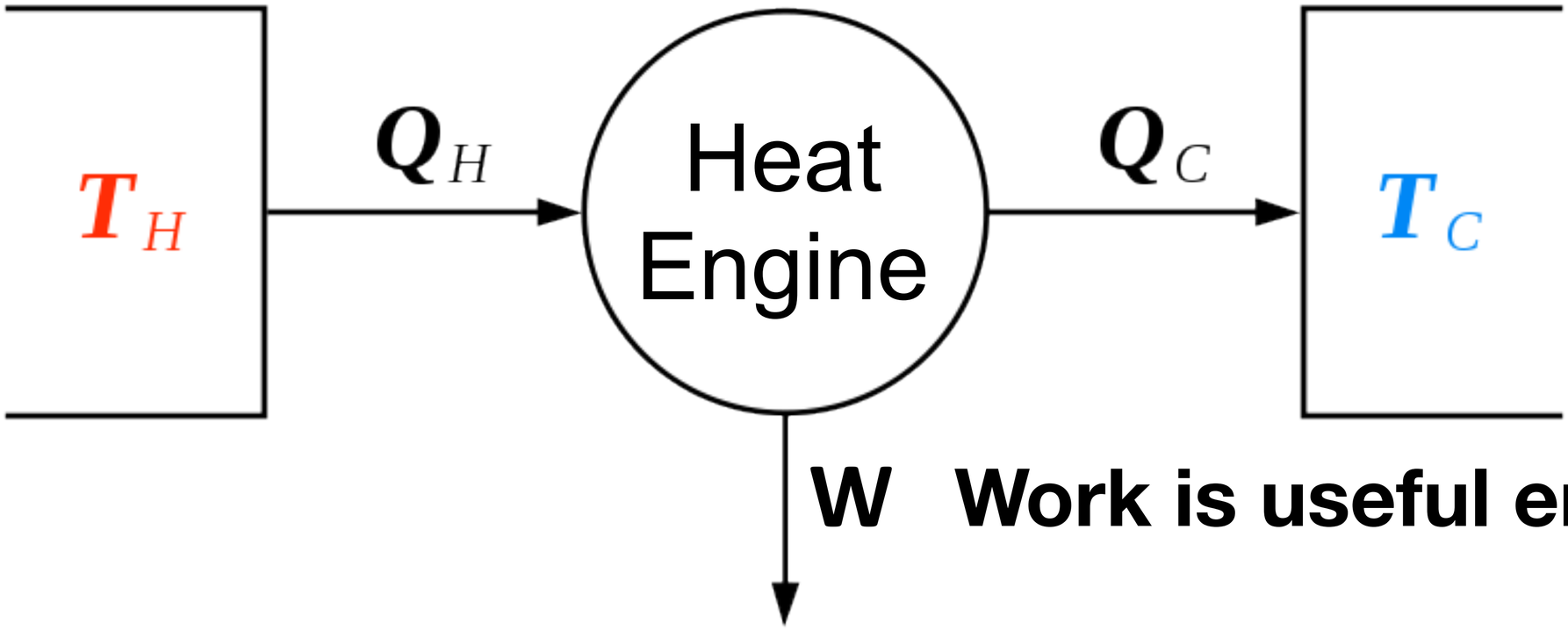


Q is heat energy

Hot heat source

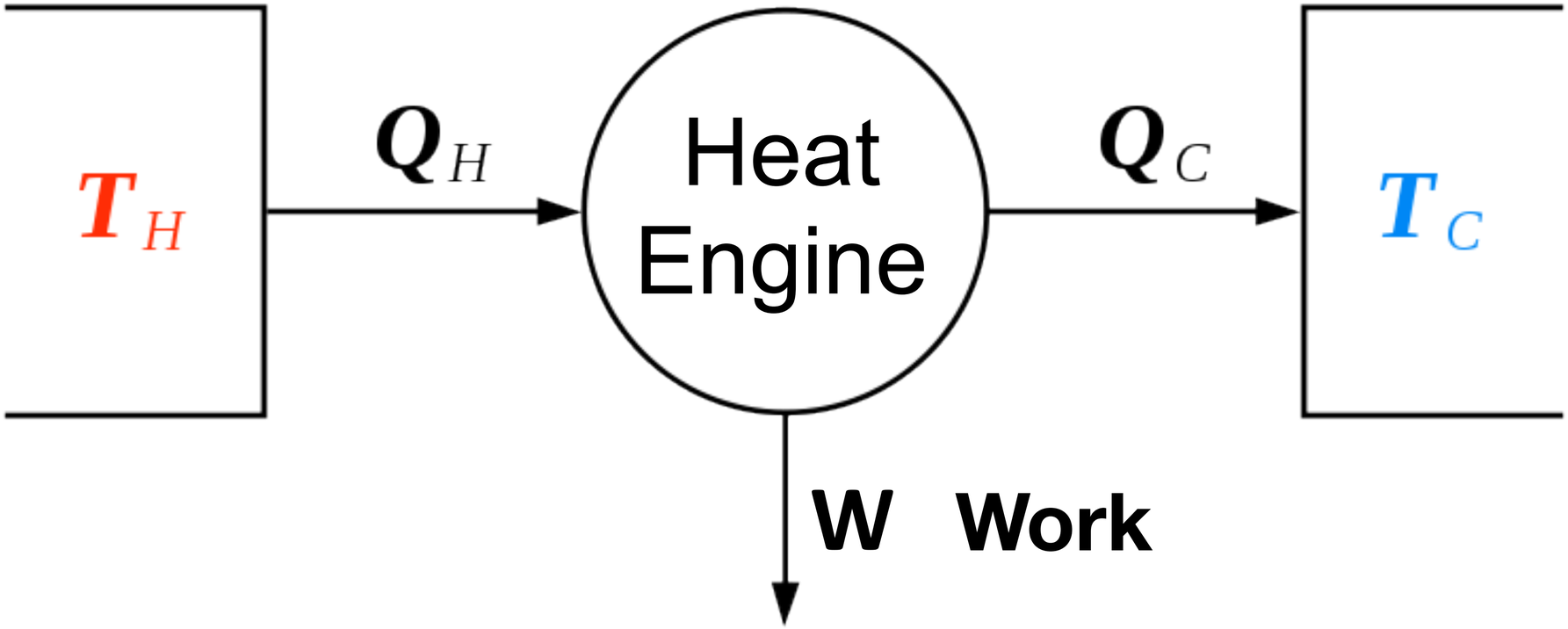
Cold heat sink

Work, **useful energy, can be extracted from the *flow* of *heat* from *hot* to cold.**



Work is useful energy

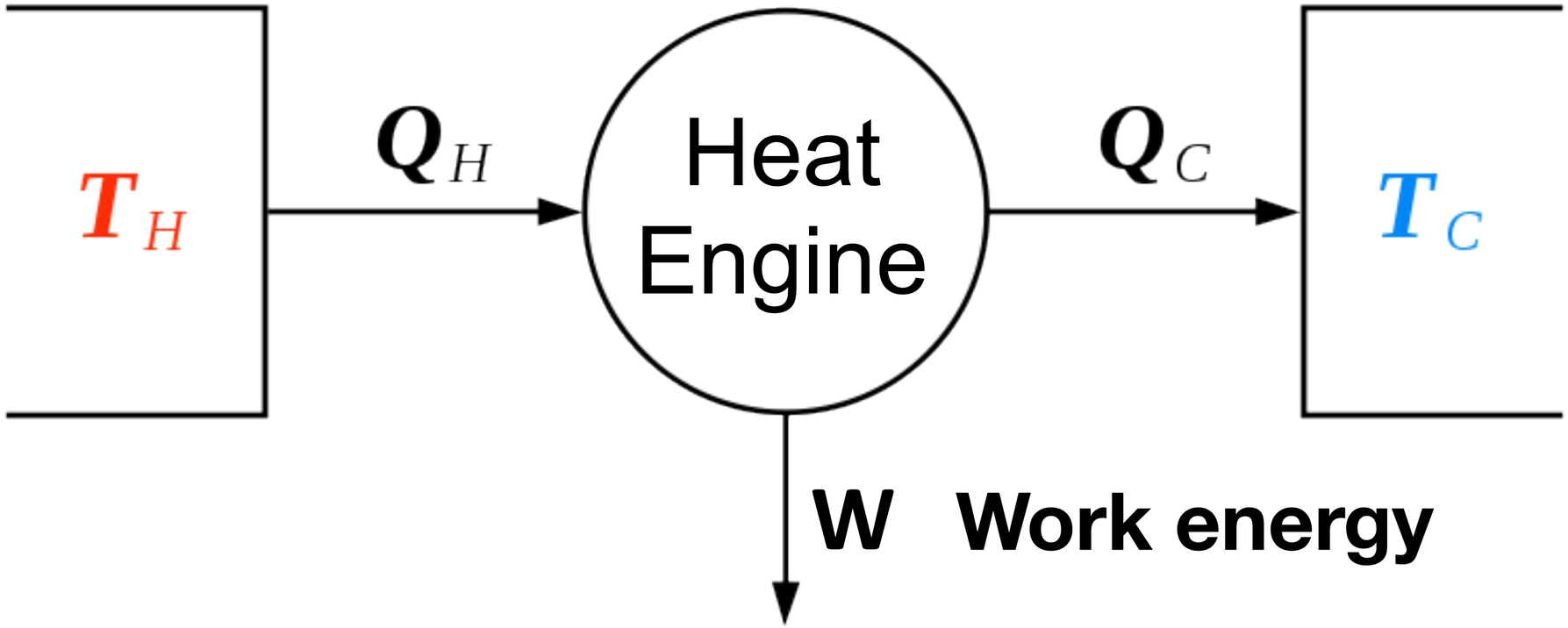
Work, **useful energy, can be extracted from the *flow* of *heat* from *hot* to cold.**



Efficiency = W / Q_H

Efficiency **max** = (T_H - T_C) / T_H

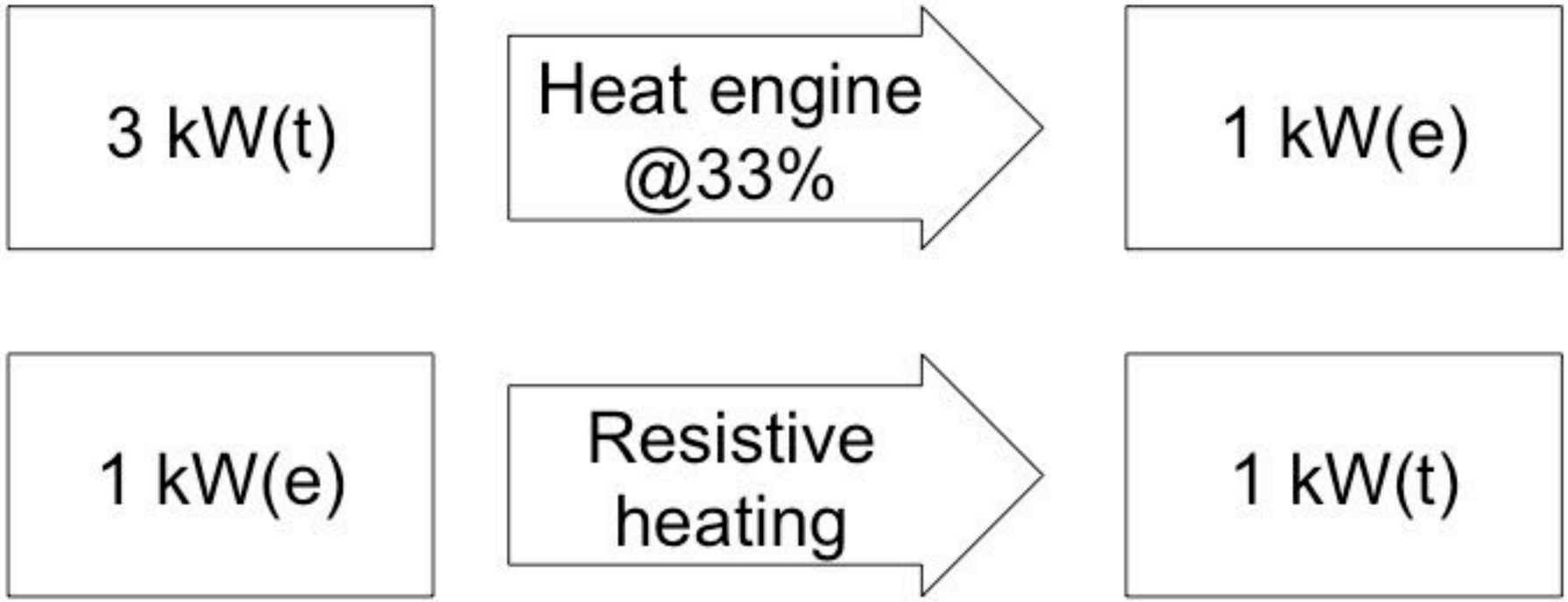
Converted work energy depends on BOTH heat energy (joules) and temperature (kelvins).



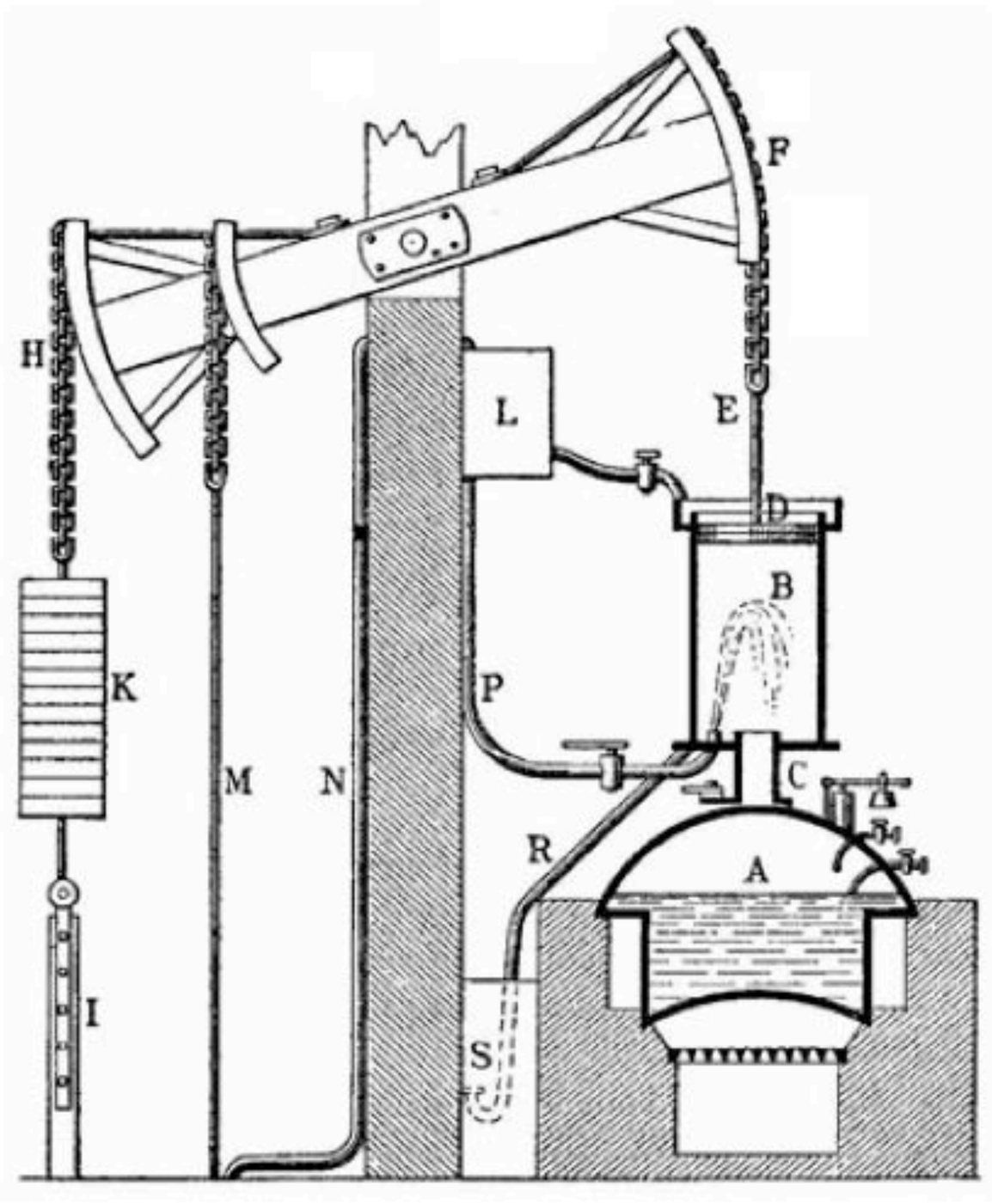
Hence the utility of **HOT** heat is a theme of

New Nuclear is HOT!

Typical efficiencies.

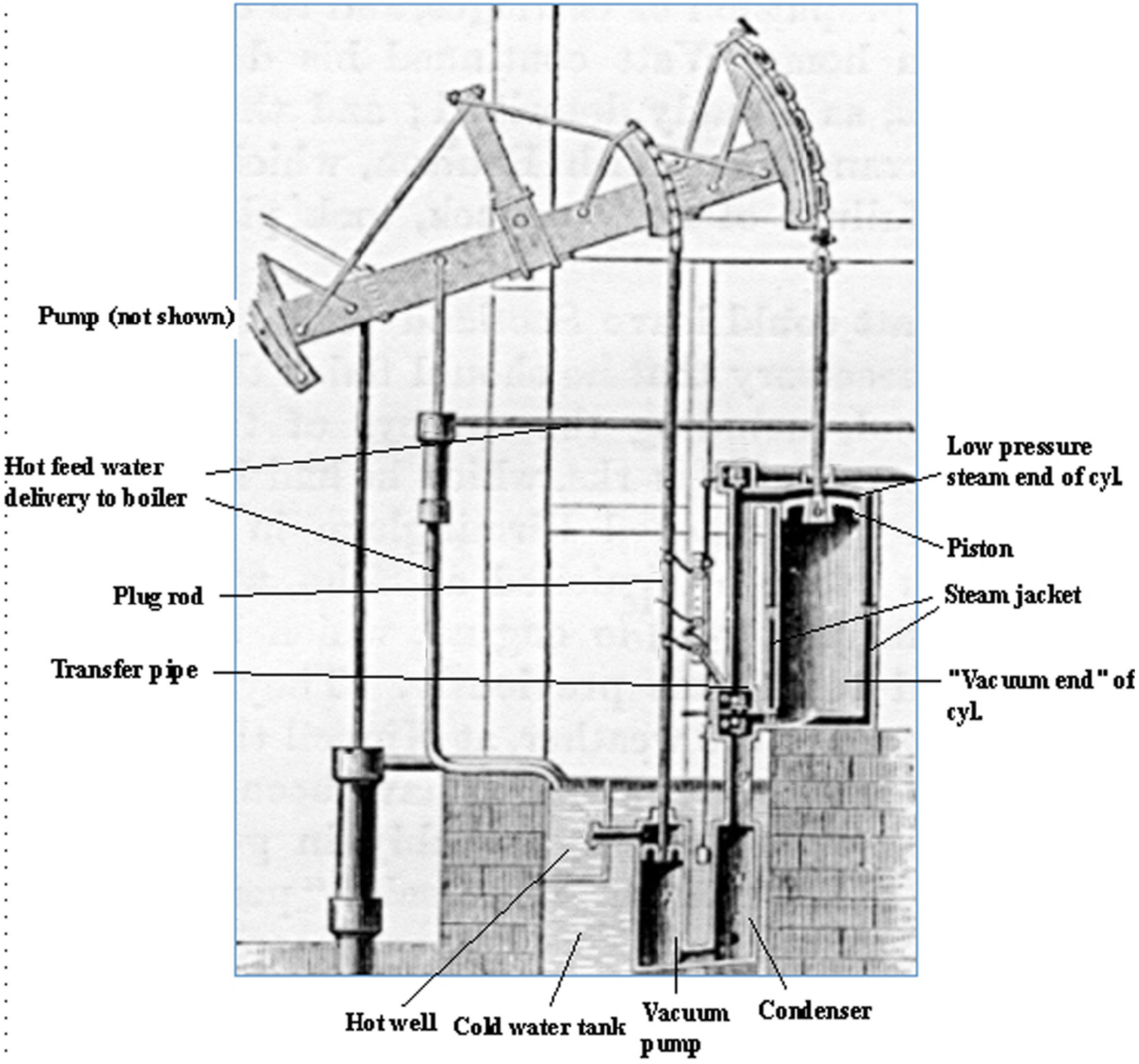


Early inventions by Savery and Nucomen put hot steam in a cylinder which was then cooled to create a vacuum pulling a piston.



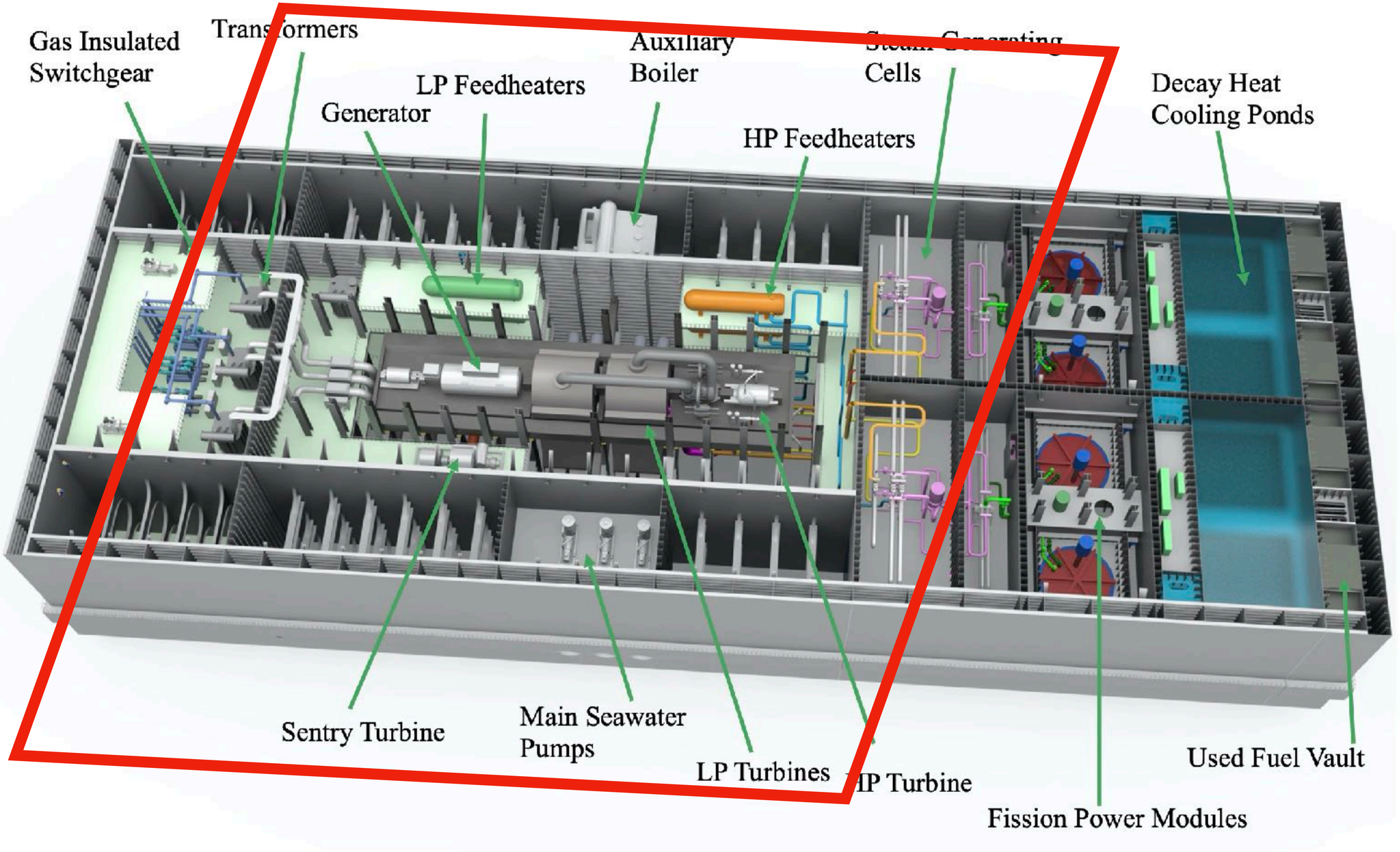
1763-1775 James Watt developed the steam engine.

- Pumped water from coal mines.
- Powered industrial revolution.
- Patented.
- Efficiency ~ 1%

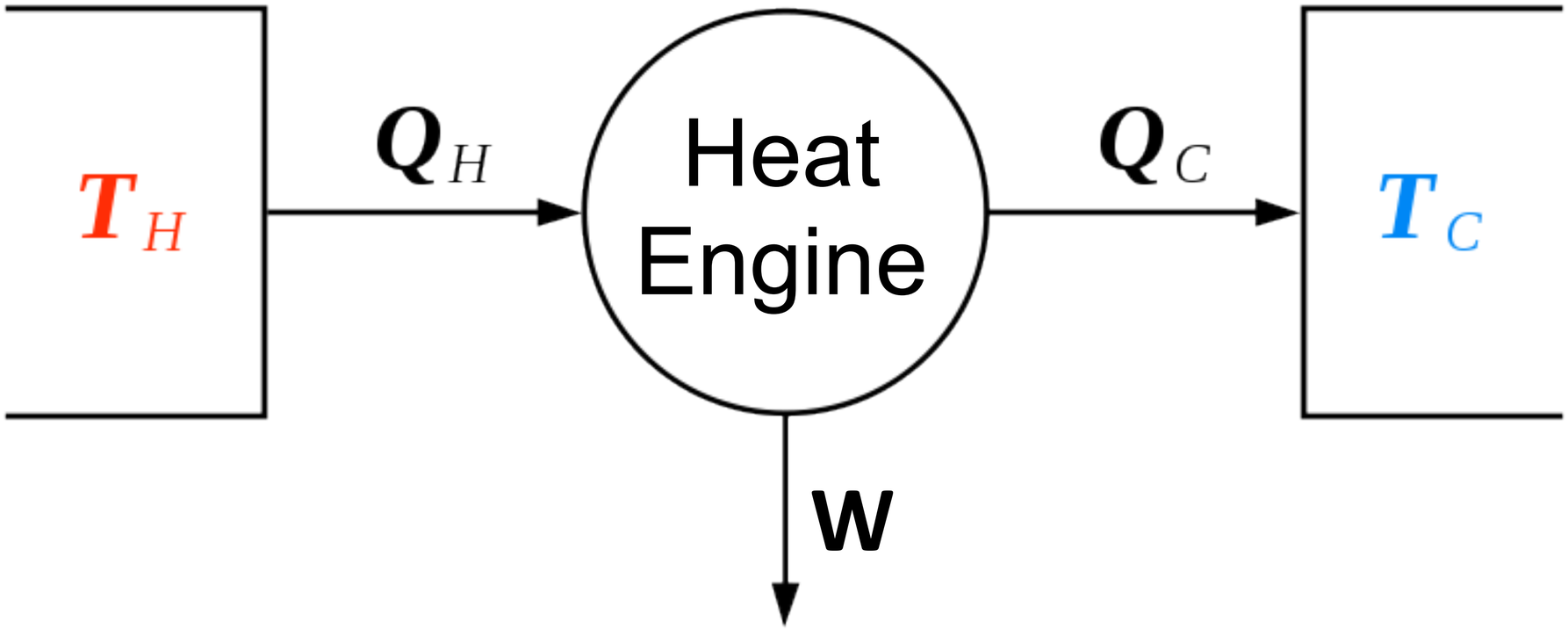


https://en.wikipedia.org/wiki/James_Watt

The *heat engine* is the biggest part of a power plant.

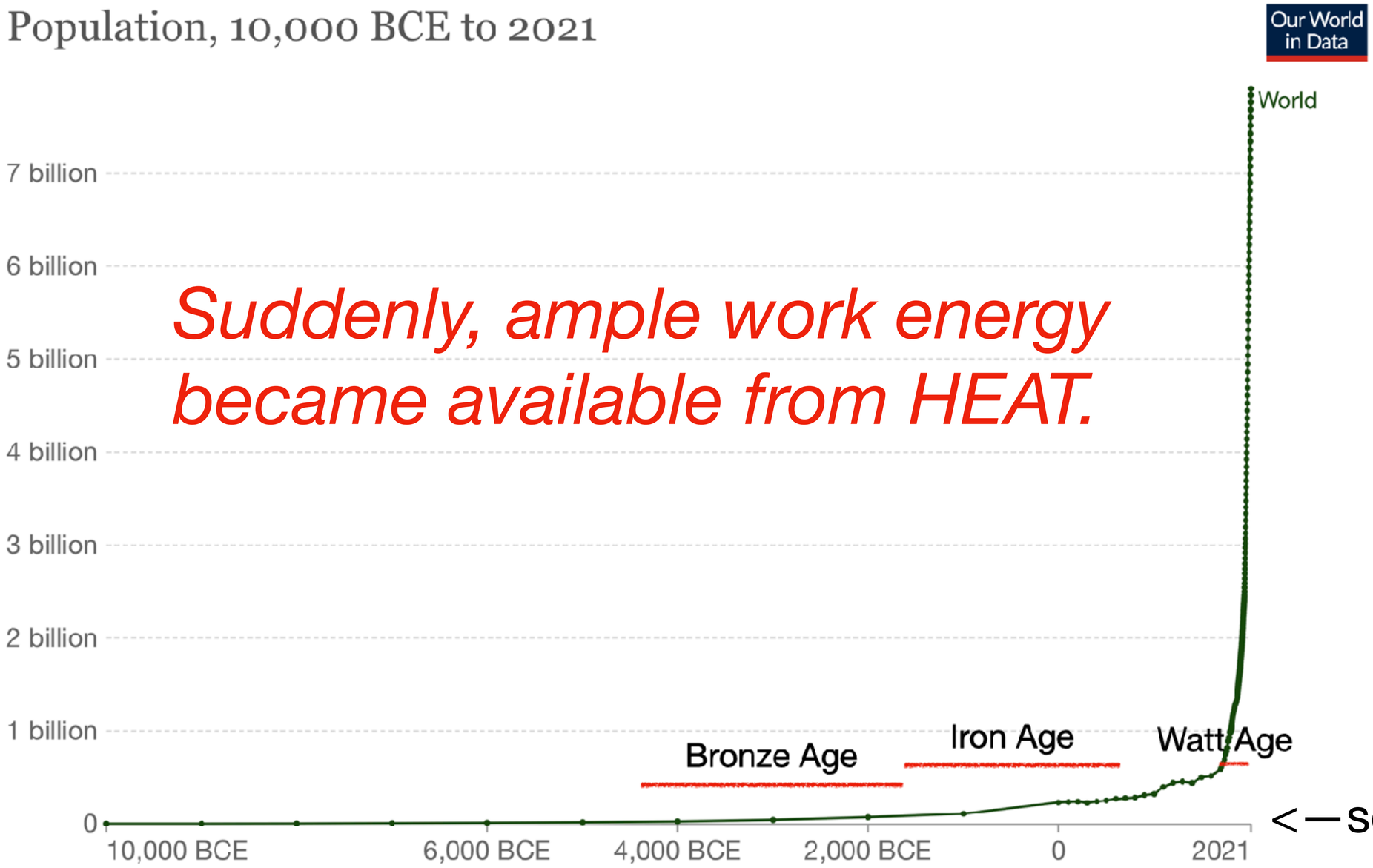


In a power plant, Qc is termed rejected heat, but denigrated as waste heat.



Cogeneration
Rejected heat can be transferred in hot water to heat buildings.

Watt Age started only 250 years ago.



<—scale change at 0

ENERGY notation: heat: kWh(t) useful: kWh(e)

"thermal" "electric"

Heat and useful energy are both measured in joules (J) (watt-seconds) so we distinguish them as:

1 **kWh(t**) = kilowatt-hour thermal = (3600 x 1000 J)

1 **kWh(e)** = kilowatt-hour electric = (3600 x 1000 J)

I rarely see J(t) clearly distinguished from J(e)

POWER notation: heat kW(t) useful kW(e)

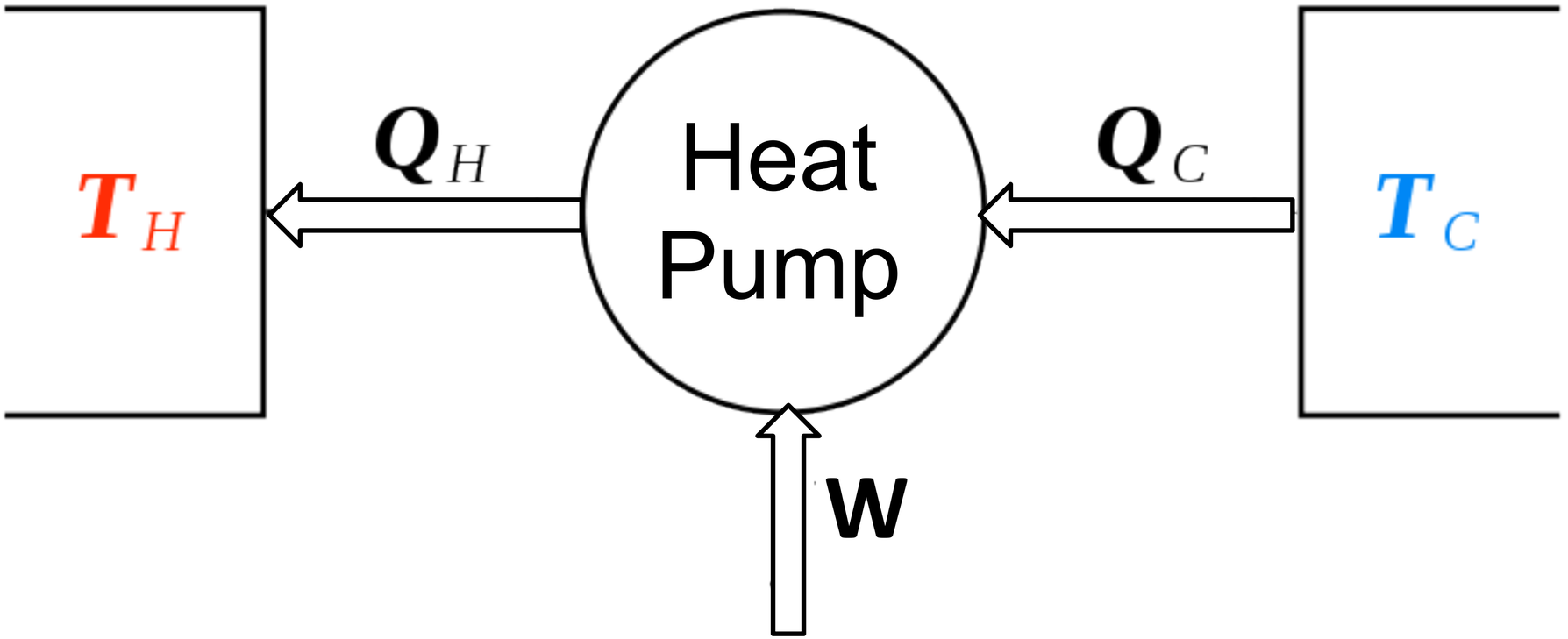
"thermal" "electric"

Heat flow and electric power both measured in watt units (joules/sec), so distinguish them as:

1 **kW(t)** = kilowatt thermal = (3600 x 1000 J/sec)

1 **kW(e)** = kilowatt electrical = (3600 x 1000 J/sec)

Using *work* energy, *heat* can flow in reverse from cold to *hot*.

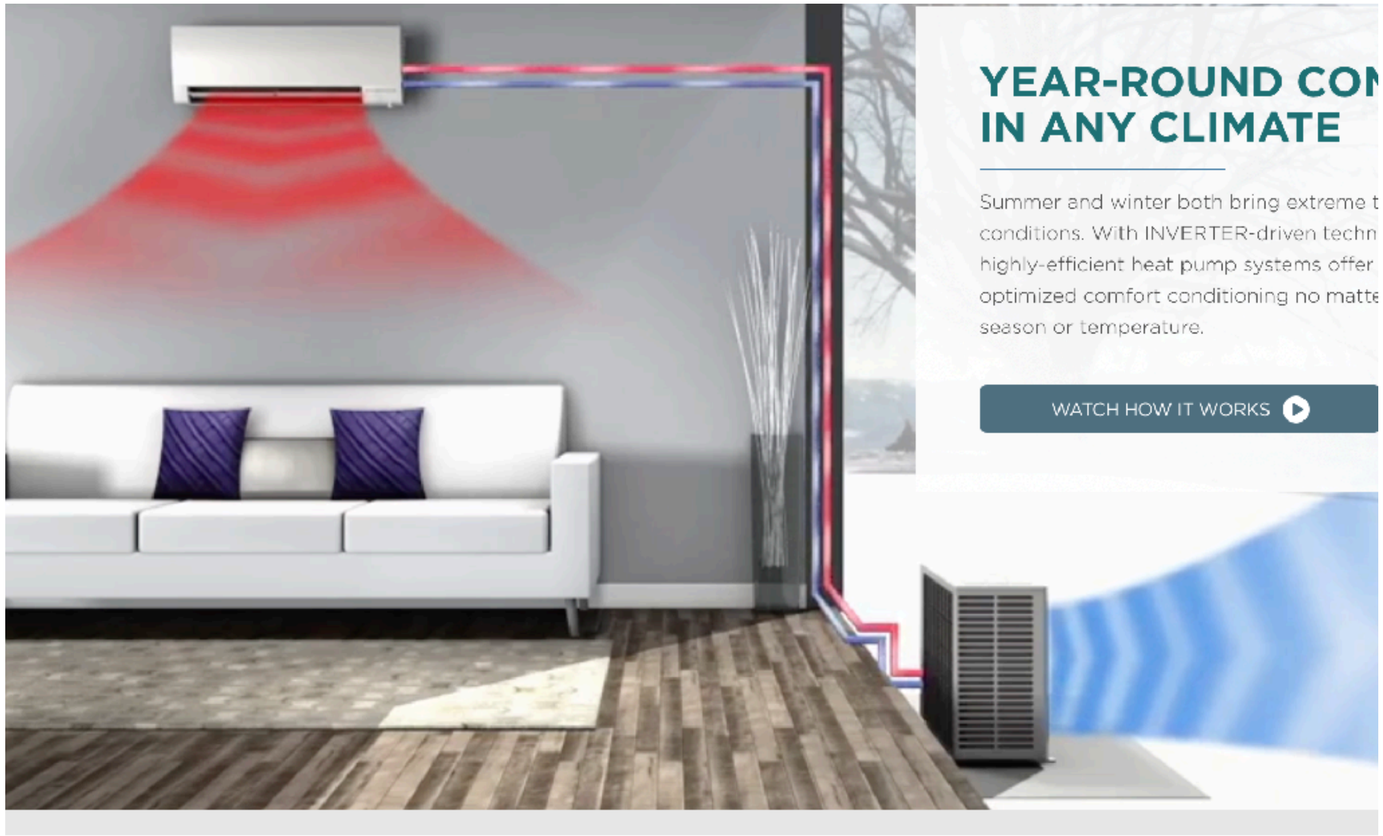


Heat pump examples:

LG air conditioner

For cooling

Mitsubishi air source heat pump



For heating and cooling

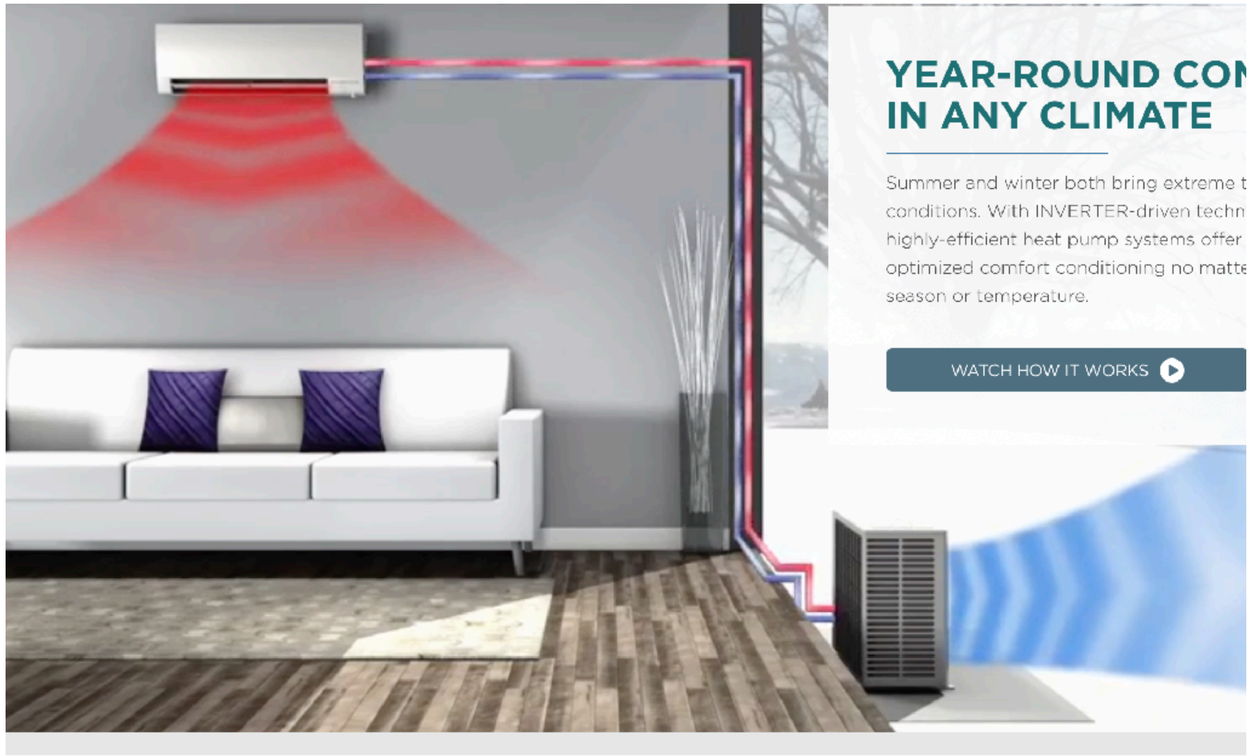
Heat pump

Coefficient of Performance
= kW(t) / kW(e)
= heat output / electicity input

COP
~ 3.8 to 2.9

As air temperature drops
from 55°F to 5°F
heat output may drop
from 7 kW(t) to 3 kW(t).

Mitsubishi air source heat pump



Power = energy *flow,* measured in watts

Really dumb answers to real questions:

Q: How far away is Burlington, VT?
A: 65 miles per hour

Q: How much energy is stored in world batteries?
A: 52 gigawatts [Statista 2022]

Next: California's grid operator and its largest newspaper print similar nonsense.

California ISO

Renewables Grid Initiative

"As of September 2019, global tracked energy storage totalled nearly 188 GW"

https://www.caiso.com/Documents/EnergyStorage-PerspectivesFromCalifornia-Europe.pdf

Giant batteries, key to solar and wind power plans, start to get bank backing

"The U.S. has about 1,400 megawatts of battery storage — equivalent to the output of two natural-gas-fired power plants"

https://www.latimes.com/business/story/2020-03-04/solar-batteries-banks

You now know more about energy and power than policy makers, politicians and reporters. You can

Distinguish **heat energy** from **useful energy.**

Distinguish **power** from **energy.**

Vaclav Smil: Energy from burning carbon is the basis of civilization.

We need to put in place a different source of reliable, economic energy before removing the old.

How the World Really Works by Vaclav Smil — what powers our economies

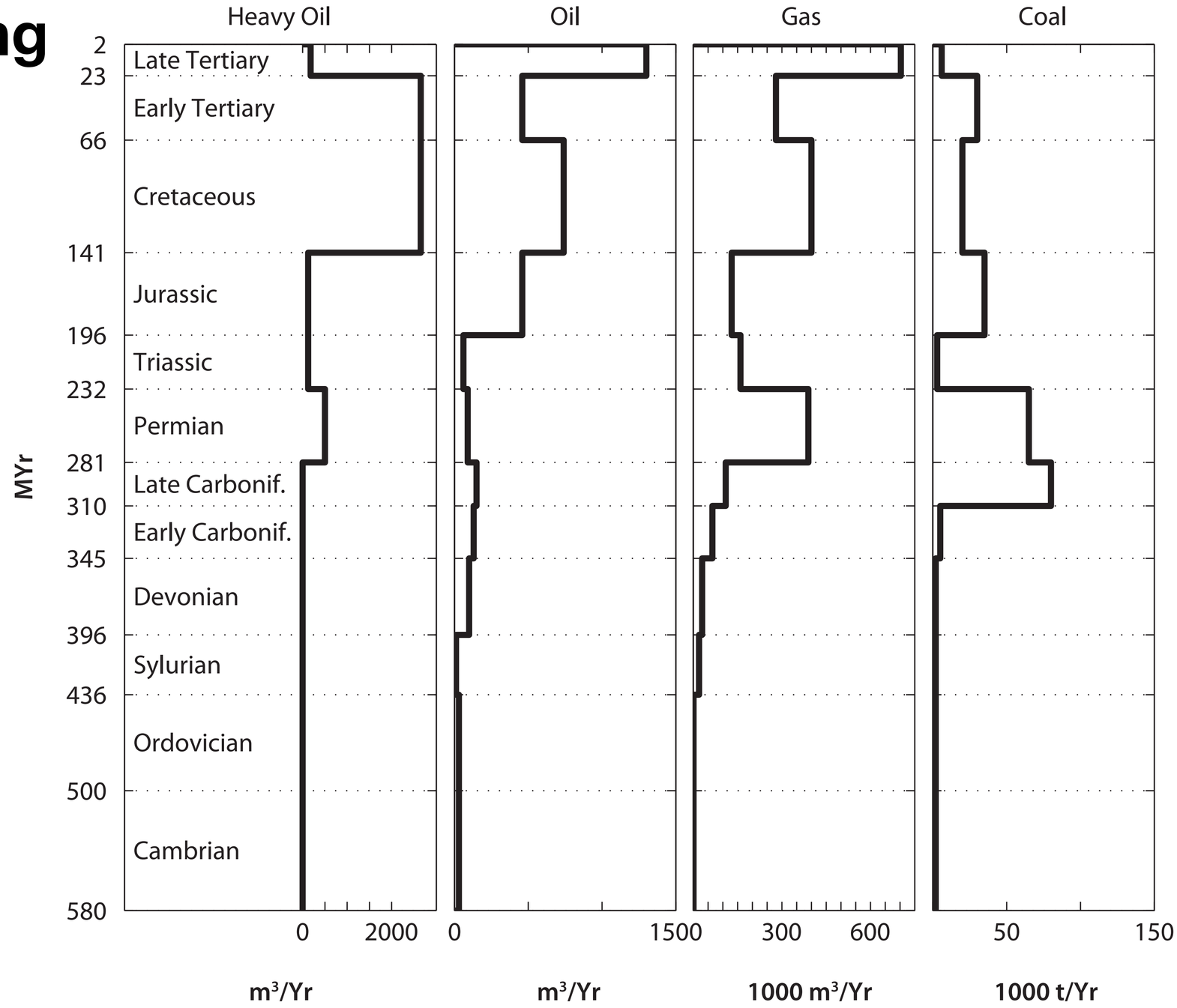
https://www.ft.com/content/71072c77-53b3-4efd-92ae-c92dc02f09ad?desktop=true&segmentId=7c8f09b9-9b61-4fbb-9430-9208a9e233c8#myft:notification:daily-email:content

Carbon battery charging

Coal
300,000,000 BC
50,000 tons/year

Gas
200,000,000 BC
300 tons/year

Oil
100,000,000 BC
500 tons/year



https://12dadd6d-9c4d-e9cc-5e32-ec7b4524c1a4.filesusr.com/ugd/eca6d5_75b738f056fb44a5ae1f2b7ead8f8fcb.ppt?dn=SPU-14%20Glacial%20Cycles%202016.ppt

Annual energy discharge of world carbon battery

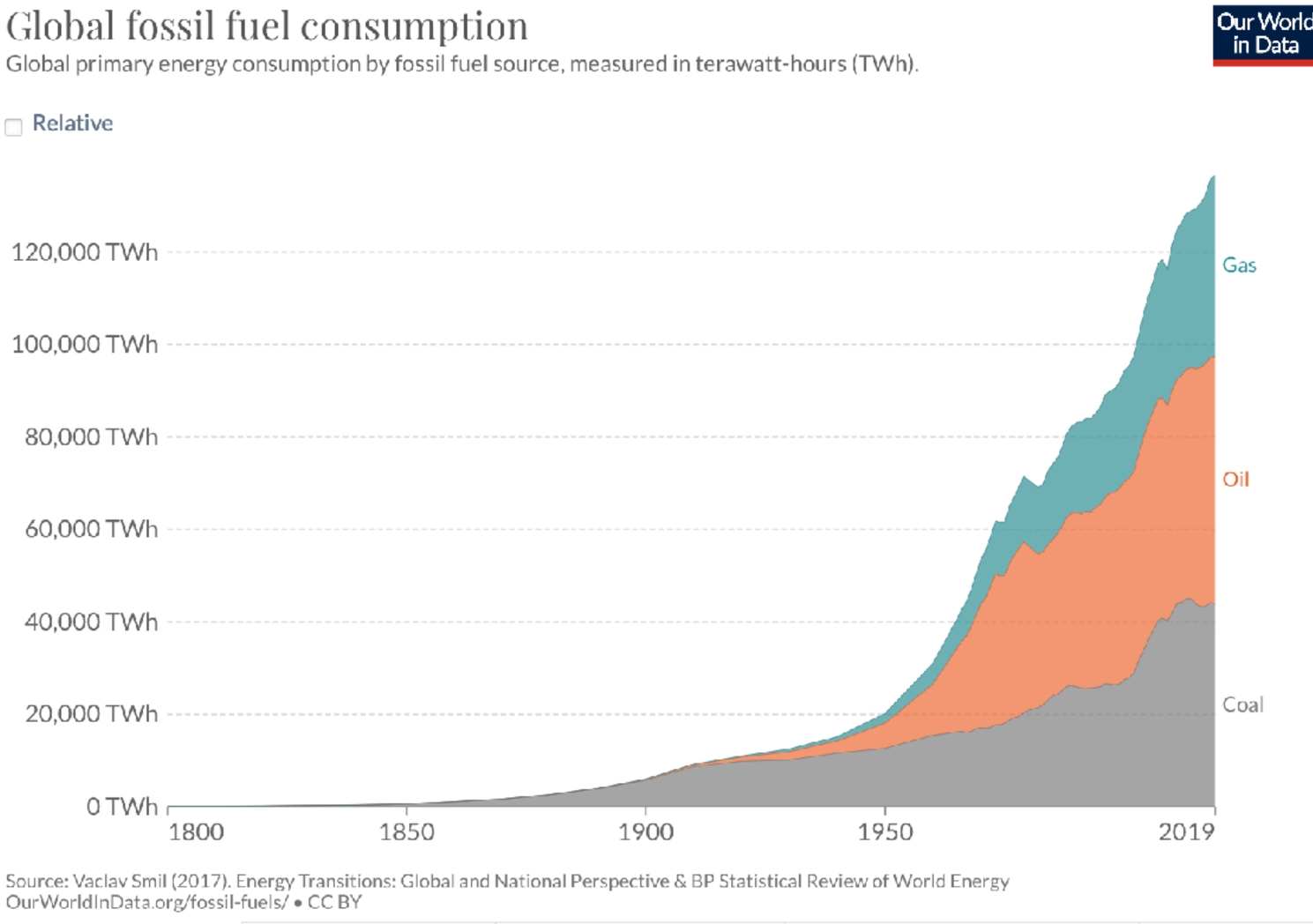
130,000 TWh (heat)

= 468 EJ = 15,000 GW-yr

~ 40 billion tons of oil or coal

~ 4 cubic miles of oil

Discharge rate: 15,000 GW
= 3 million x charge rate



1 TWh is the energy of 123,000 t-coal.

https://ourworldindata.org/explorers/energy?tab=chart&facet=none&country=USA~GBR~CHN~OWID_WRL~IND~BRA~ZAF&Total+or+Breakdown=Total&Energy+or+Electricity=Primary+energy&Metric=Annual+consumption

King Hubbert, for Shell, 1956

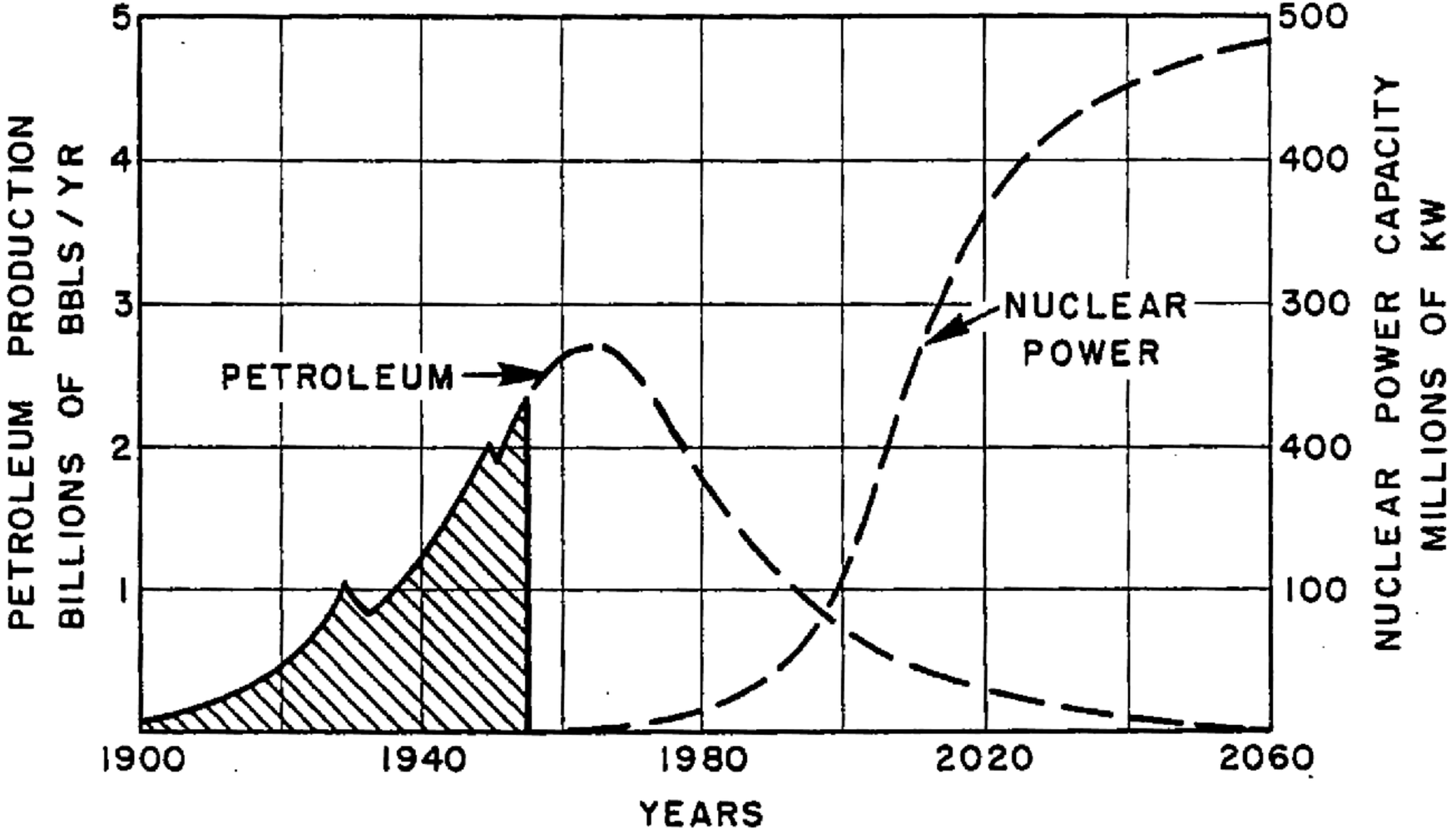


Figure 29 – Concurrent decline of petroleum production and rise of production of nuclear power in the United States. Growth rate of 10 percent per year for nuclear power is assumed; actual rate may be twice this amount.

http://www.energycrisis.com/Hubbert/1956/1956.pdf

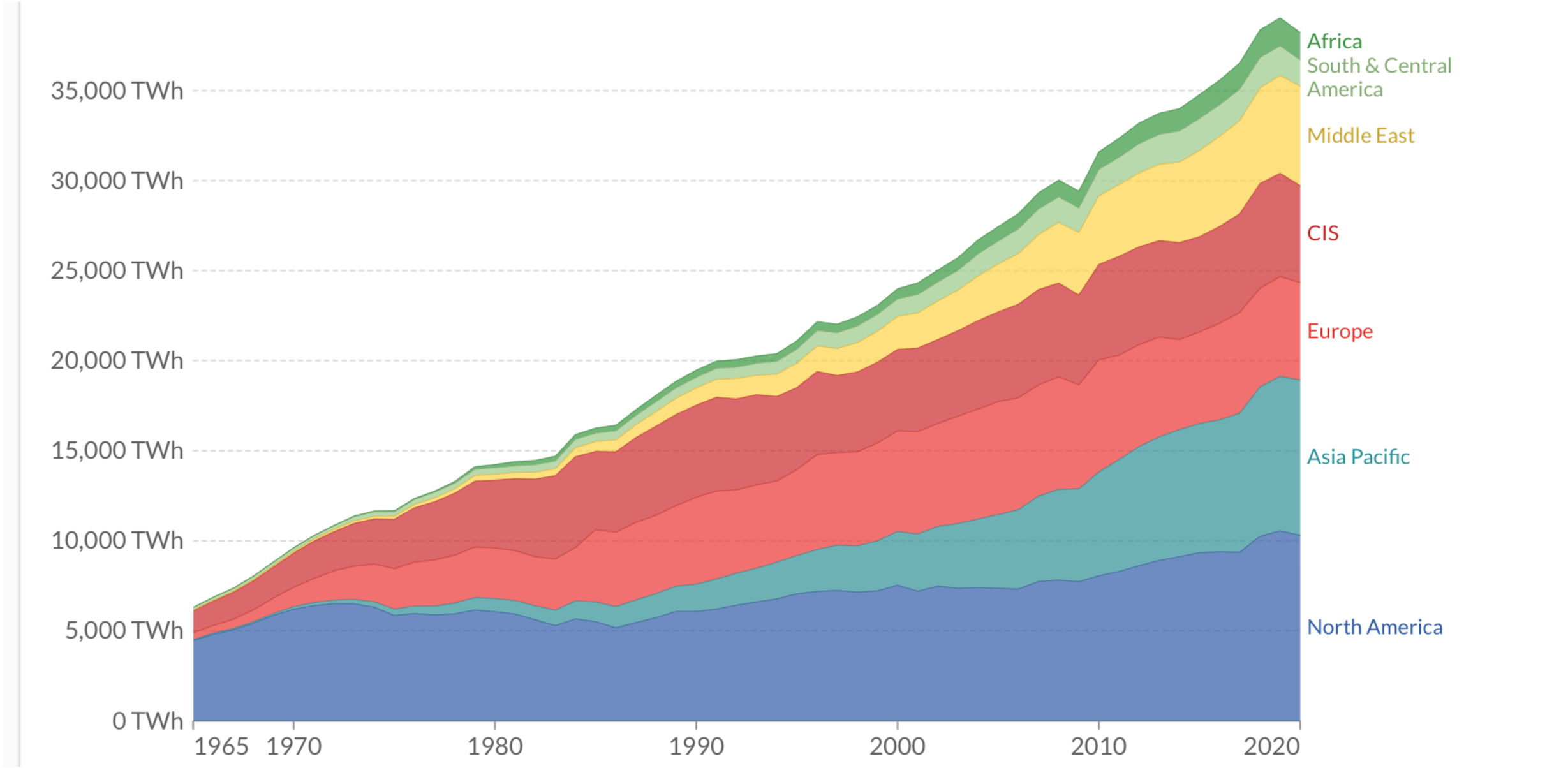
Useful energy decays to heat. [2nd Law]

kWh(e)

kWh(t) heat

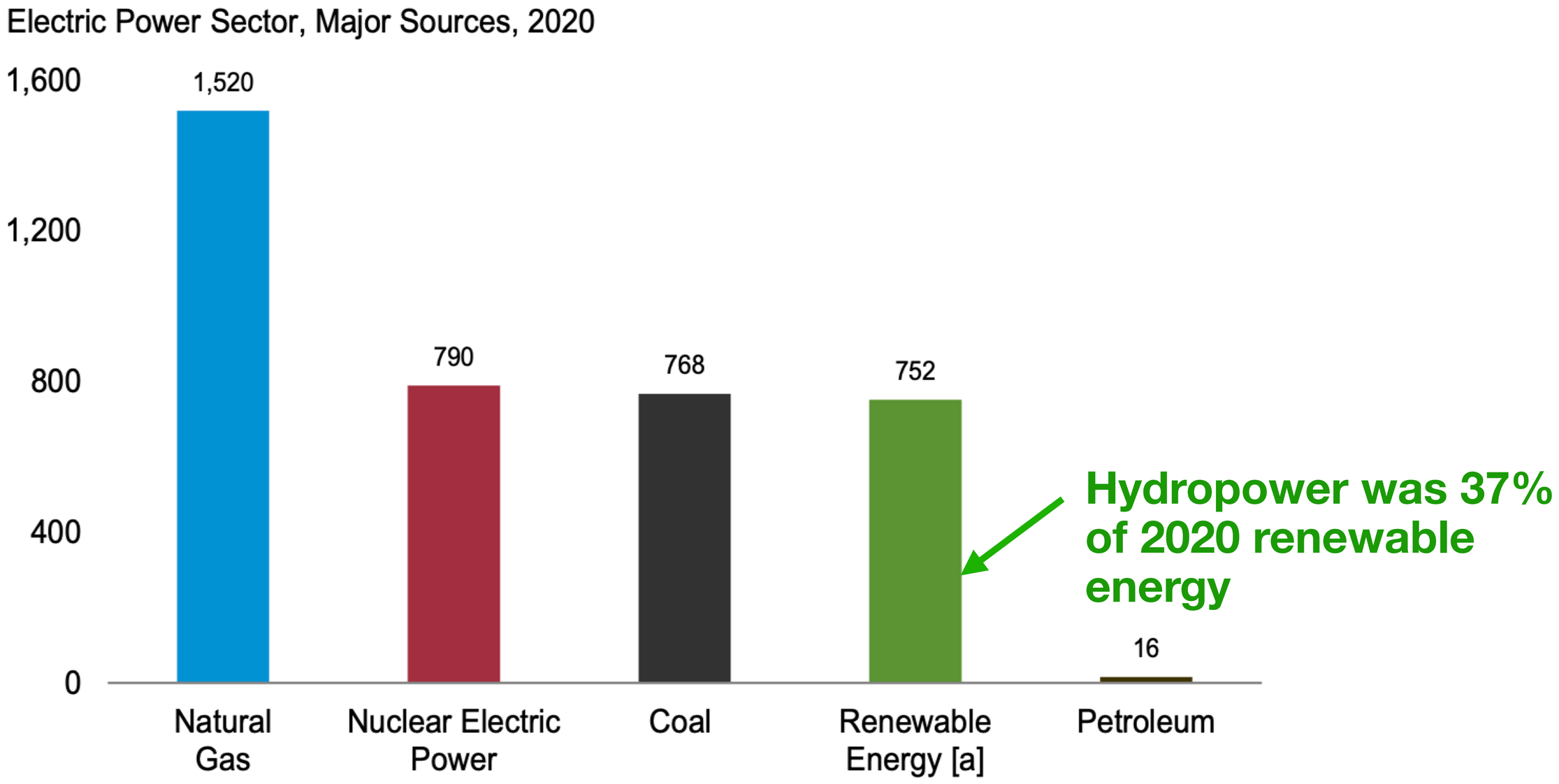
Gas consumption by region (2020)

4,400 GW total



https://ourworldindata.org/grapher/natural-gas-consumption-by-region

Natural gas is the largest source of energy for US electricity.



https://www.eia.gov/totalenergy/data/monthly/pdf/sec7.pdf https://www.eia.gov/energyexplained/hydropower/

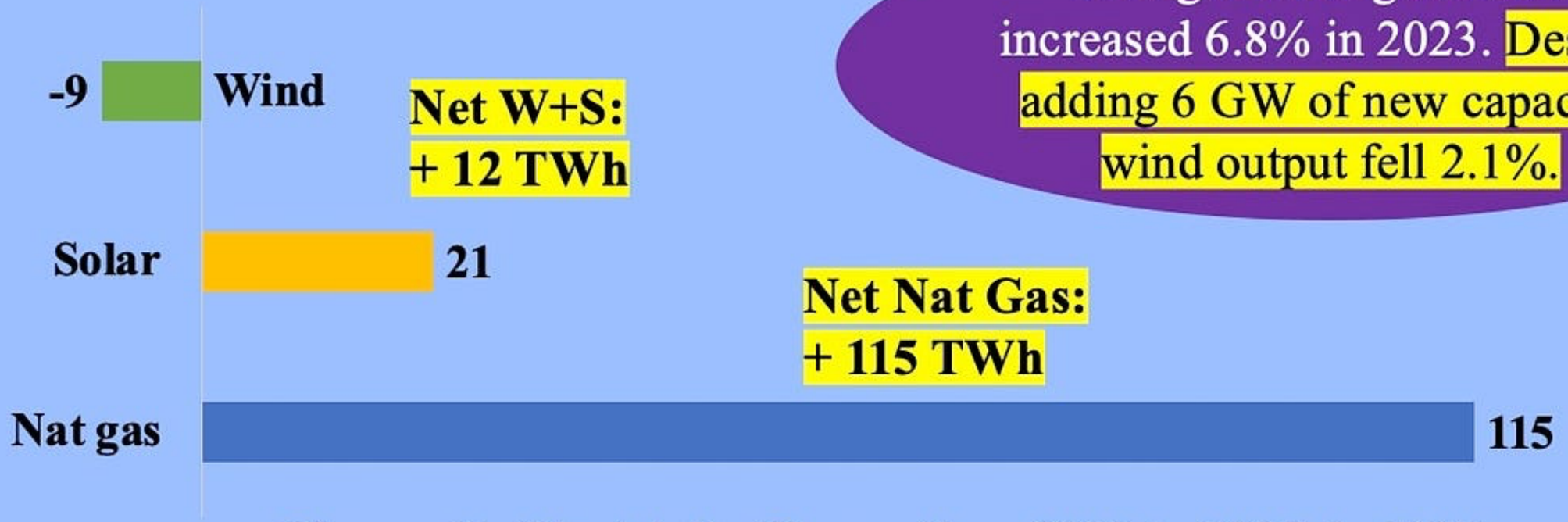
Robert Bryce

What Energy Transition?

In 2023, U.S. Gas-Fired Generation Grew

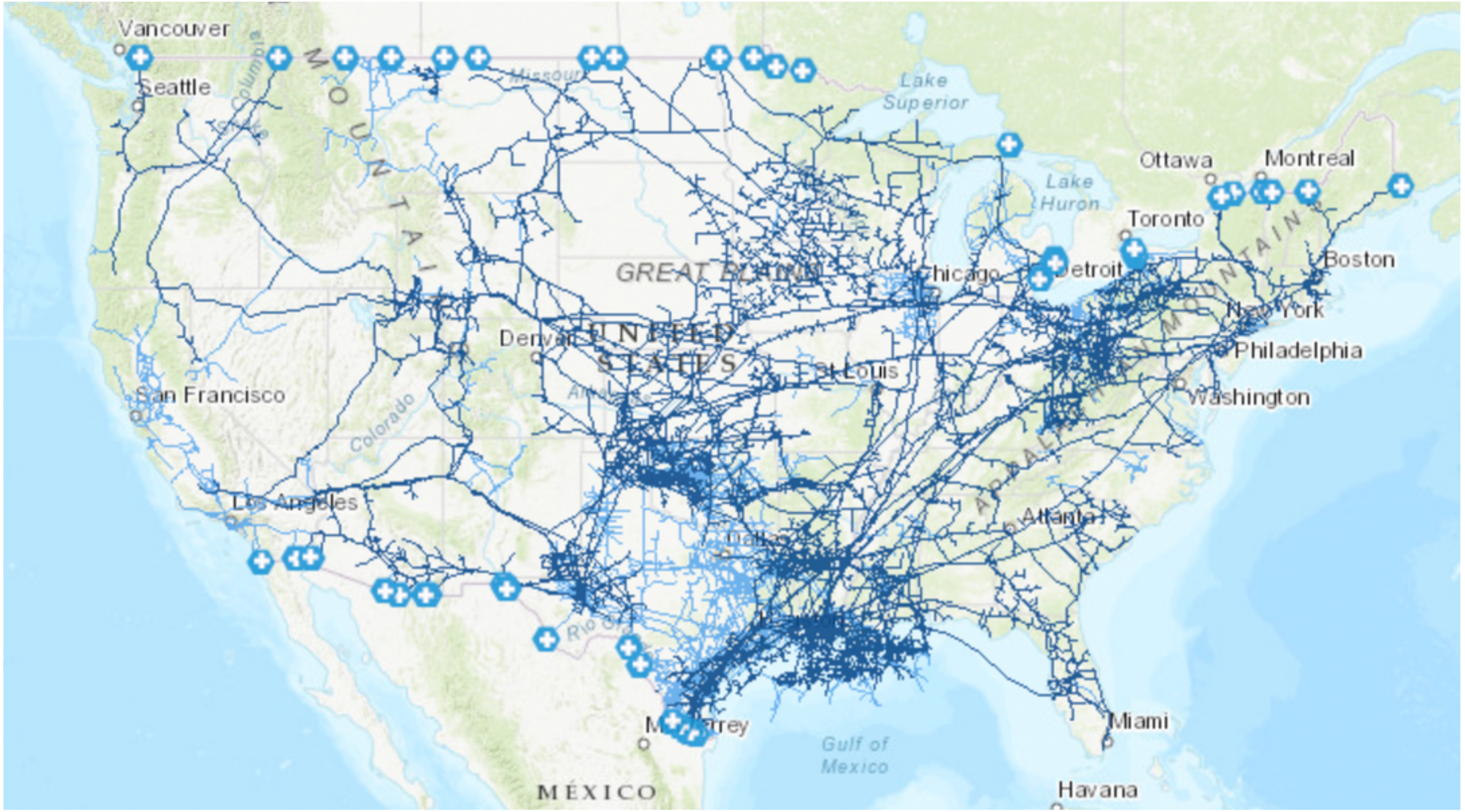
9.5x Faster Than W + S Combined

U.S. gas-fired generation increased 6.8% in 2023. Despite adding 6 GW of new capacity, wind output fell 2.1%.



Sources:: EIA, Electric Power Monthly, February 2024, https://www.eia.gov/electricity/monthly/current_month/february2024.pdf, tables 1.7.B, 1.14.B, 1.17.B, 6.2.B,

US pipelines supply natural gas for electricity and heating.



https://doomberg.substack.com/p/have-fun-staying-cold?s=w

Liquified Natural Gas liquefaction and transport

Sabine Pass, liquefaction train #4
$2 to 4 billion each

https://pgjonline.com/news/2017/10/sabine-pass-train-4-placed-in-service

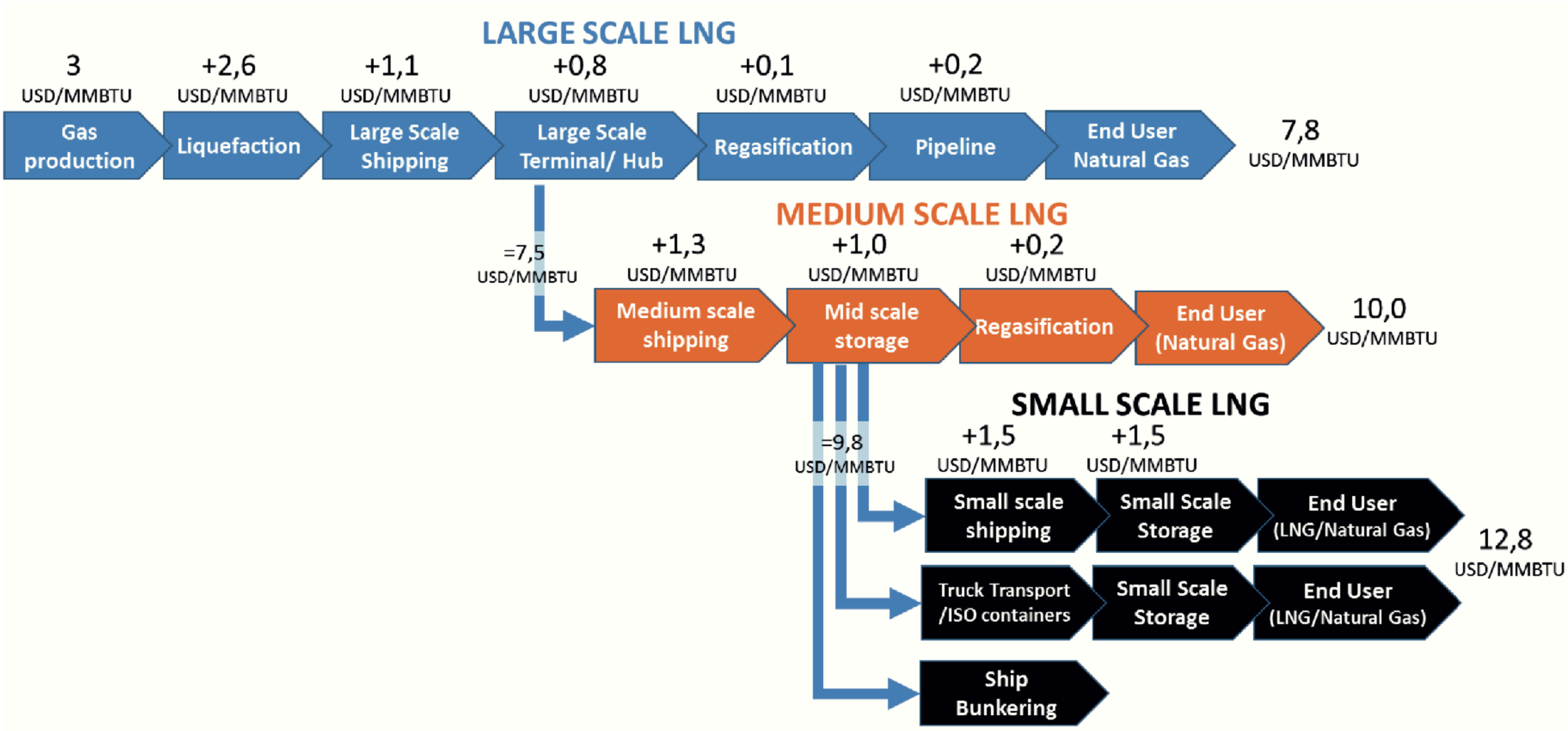
Typical $200 million LNG tankship
LNG liquid at -160°C

https://pgjonline.com/news/2017/10/sabine-pass-train-4-placed-in-service

LNG from tankship may be stored, regassified, transferred to pipelines by $500 million floating storage and regasification unit (FSRU).

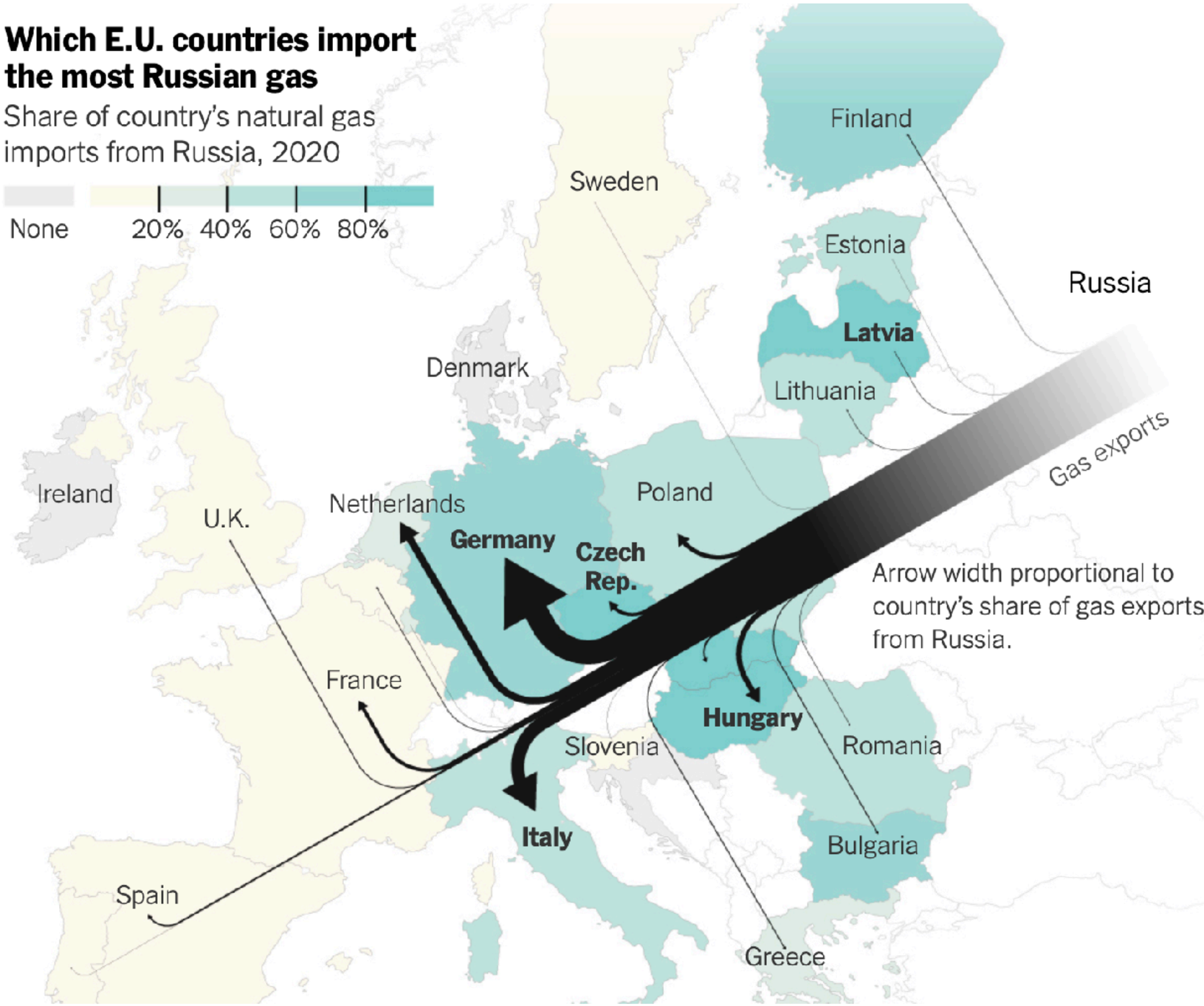
https://www.econnectenergy.com/articles/how-does-regasification-of-lng-work

LNG liquefaction, transport, regasification *adds* 5 cents/kWh(e)



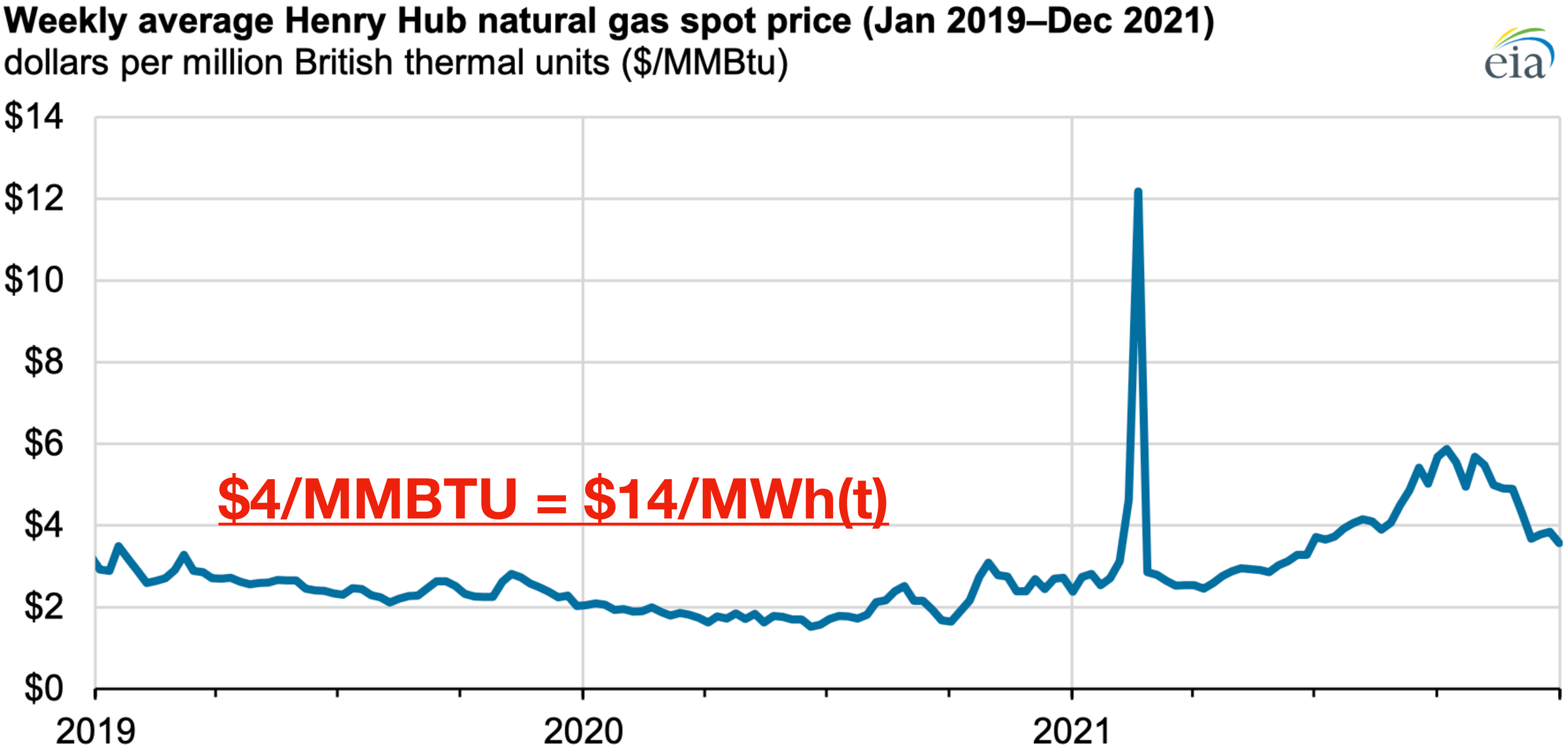
https://cdn.wartsila.com/docs/default-source/oil-gas-documents/white-paper-o-lng-logistics-chain.pdf?sfvrsn=4

(2020) Russia dominated natural gas supplies to Europe.



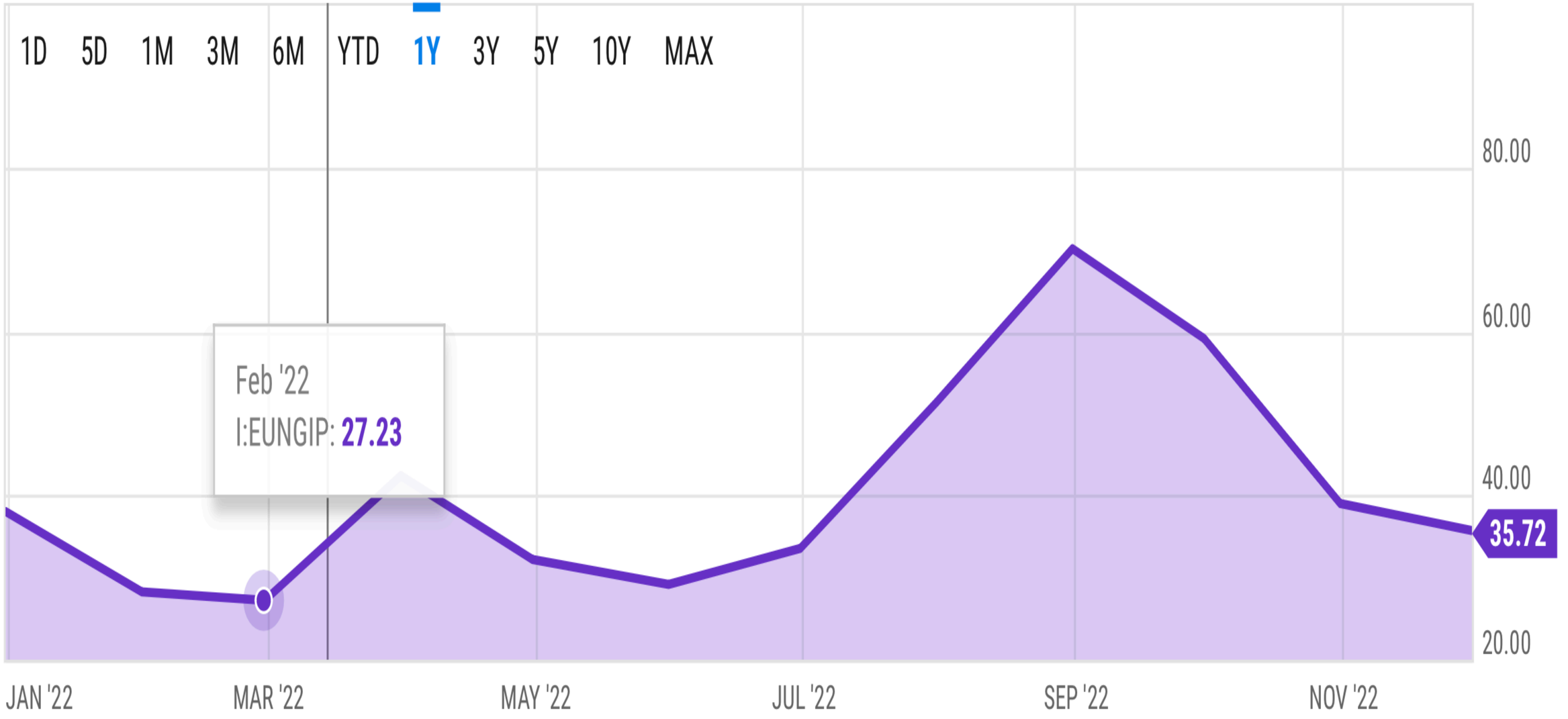
https://www.nytimes.com/interactive/2022/02/15/business/energy-environment/russia-gas-europe-ukraine.html https://www.eia.gov/energyexplained/hydropower/

US natural gas prices doubled to $4/MMBTU at end 2021.



https://www.eia.gov/todayinenergy/detail.php?id=50778

2022 European Union Natural Gas Import Price $36/MMBtu



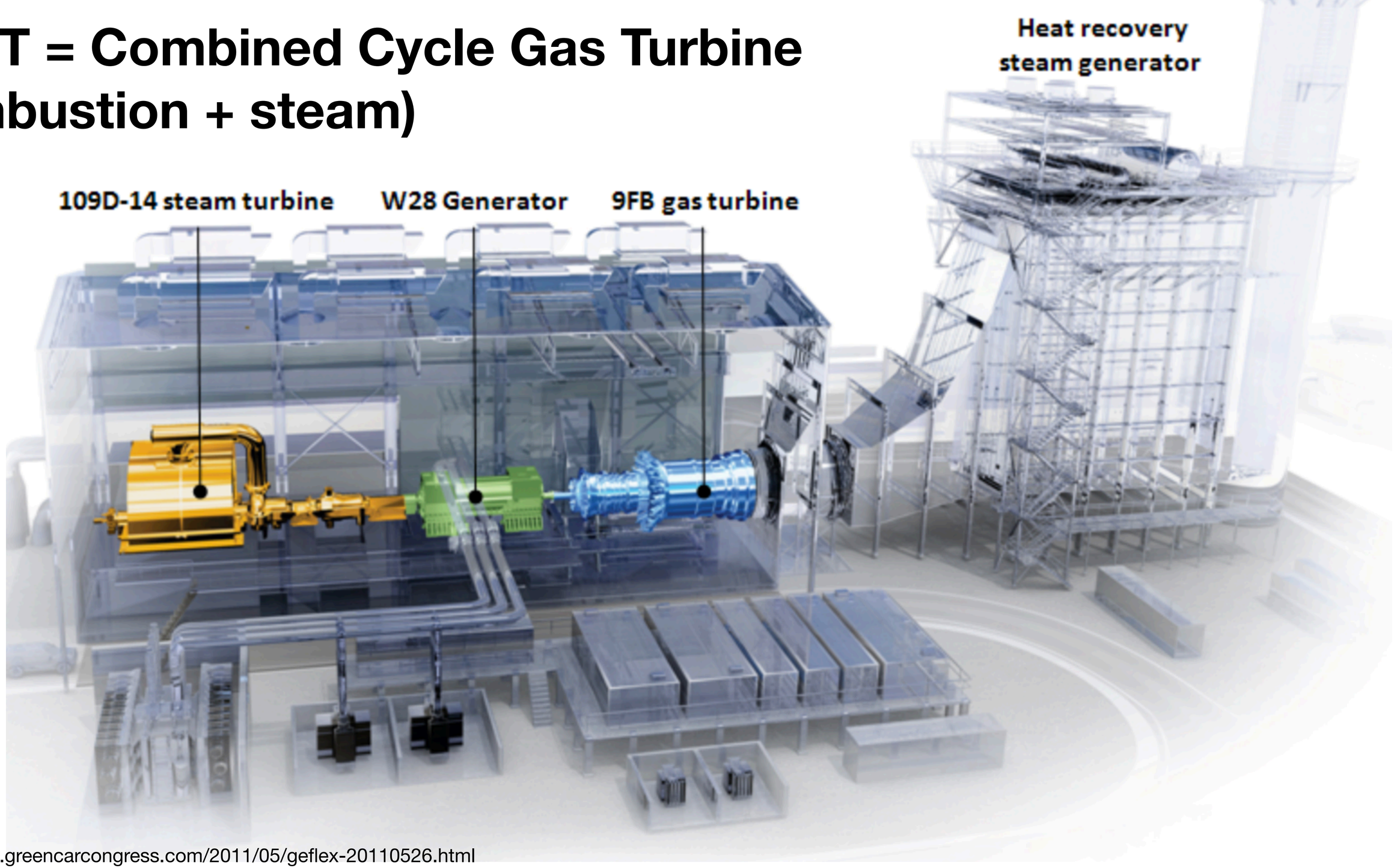
https://ycharts.com/indicators/europe_natural_gas_price

Gas turbine, 34% work/heat efficiency: $700/kW capital cost

photo https://www.ge.com/news/reports/ges-new-repair-tech-center-in-singapore-helps-asia-flip-the-switch-to-gas-power

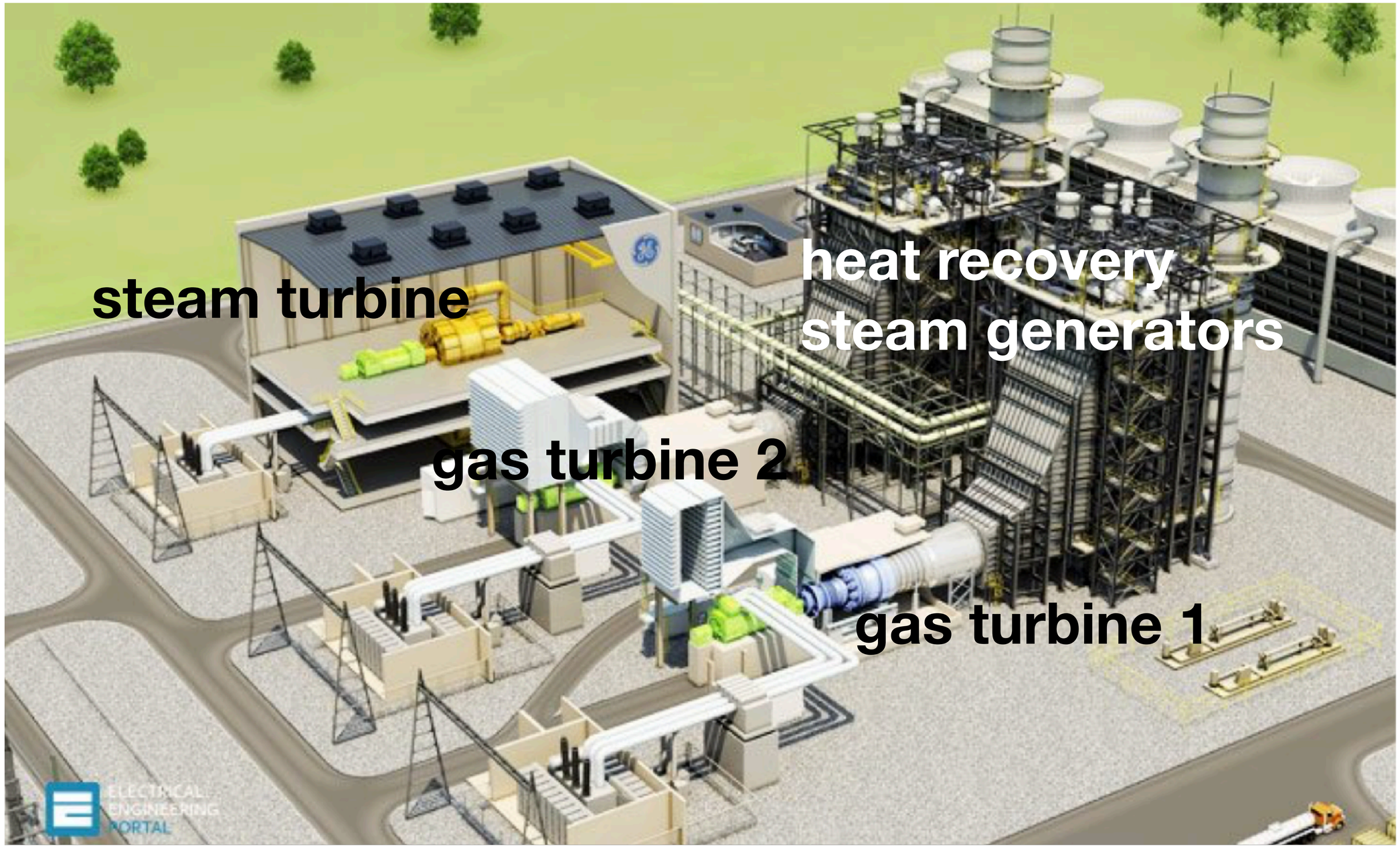
US DOE EIA data

CCGT = Combined Cycle Gas Turbine (combustion + steam)



https://www.greencarcongress.com/2011/05/geflex-20110526.html

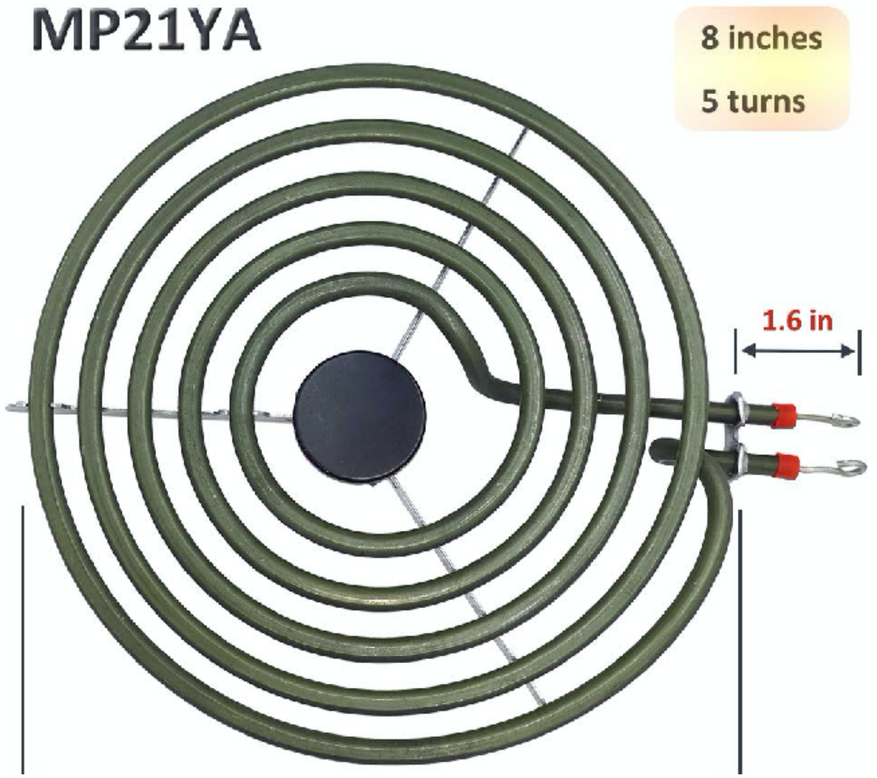
CCGT plant, 53% efficiency: $1100/kW



https://electrical-engineering-portal.com/an-overview-of-combined-cycle-power-plant

Banning home gas stoves burns more gas.

Power company distributes
2 kW(t) natural gas
to make 2 kW(t) of heat



Power company burns
~ 4.5 kW(t) natural gas
to generate 2 kW(e) of electricity
to make 2 kW(t) of heat

Banning home gas stoves burns more gas.

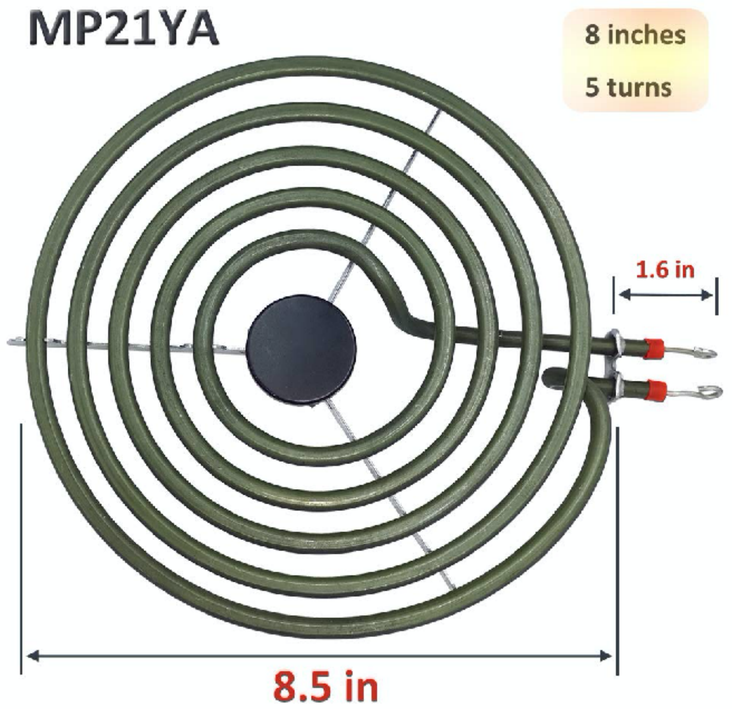
BUT, fission, wind, or solar power would cause no CO2 emissions.

STILL, natural gas is the largest, *increasing* energy source for the US grid.

Solar power not available for evening meal cooking.

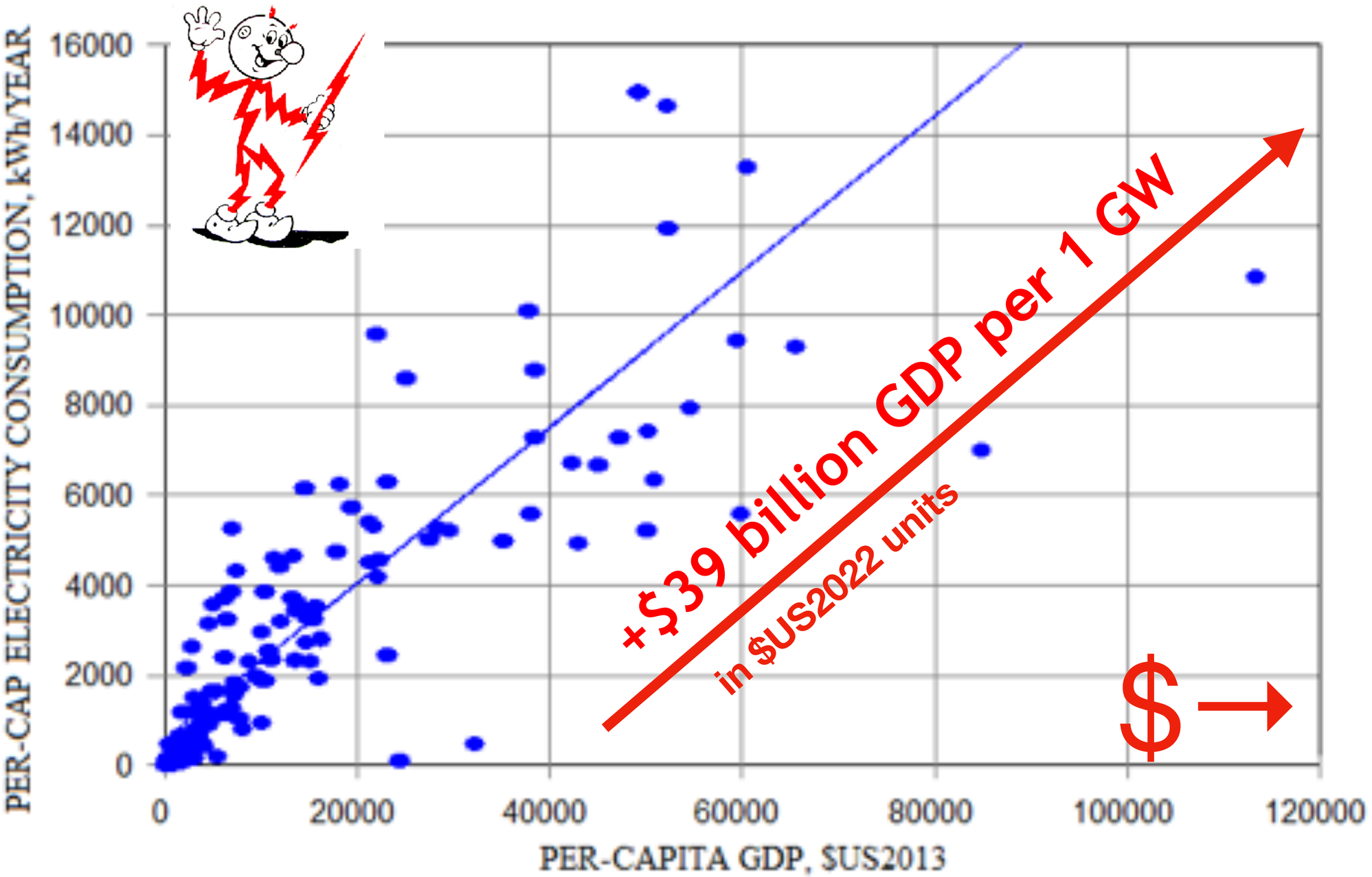
Wind does not speed up when you turn the stove on.

Dispatchable power on demand is needed.

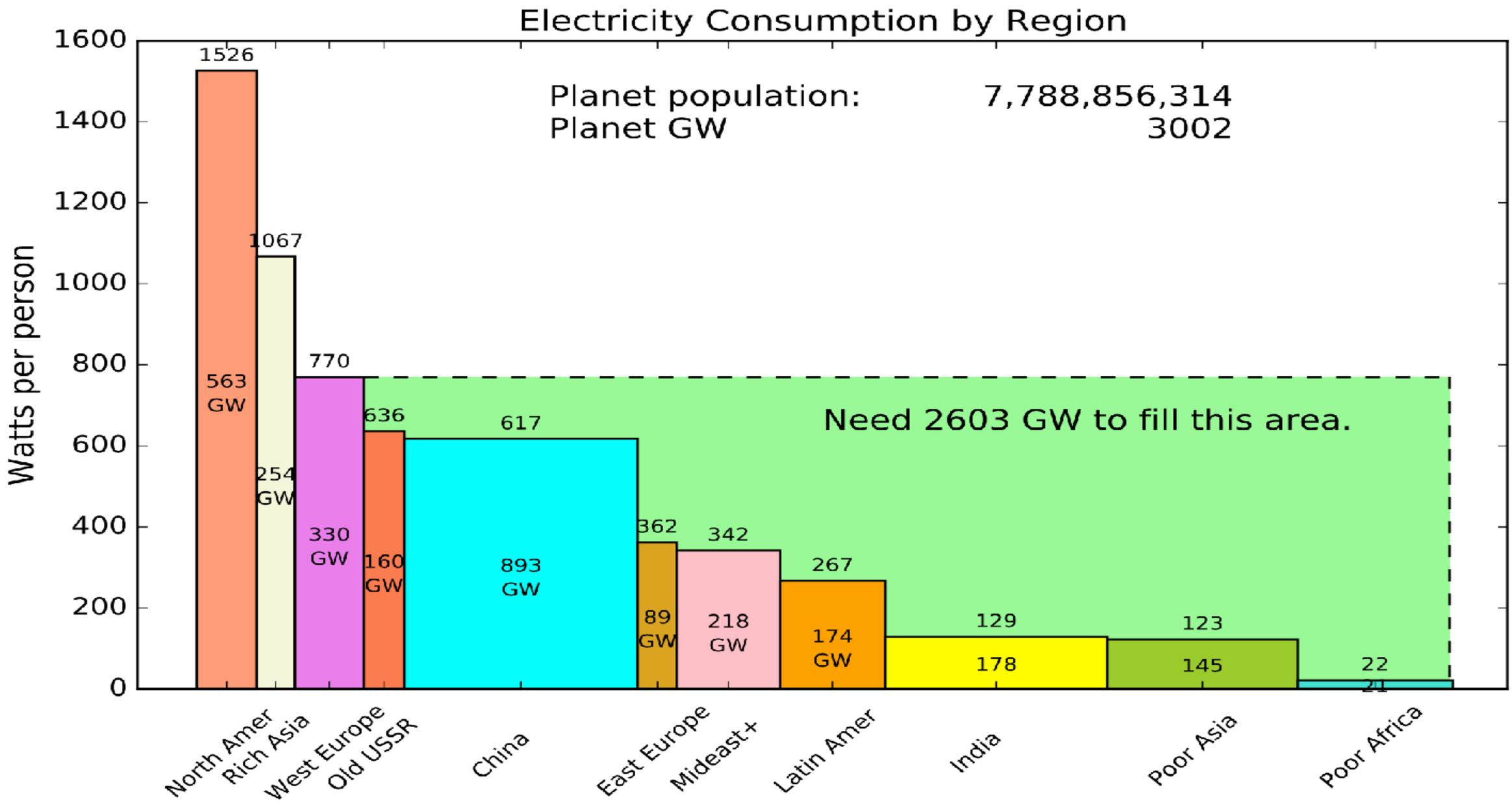


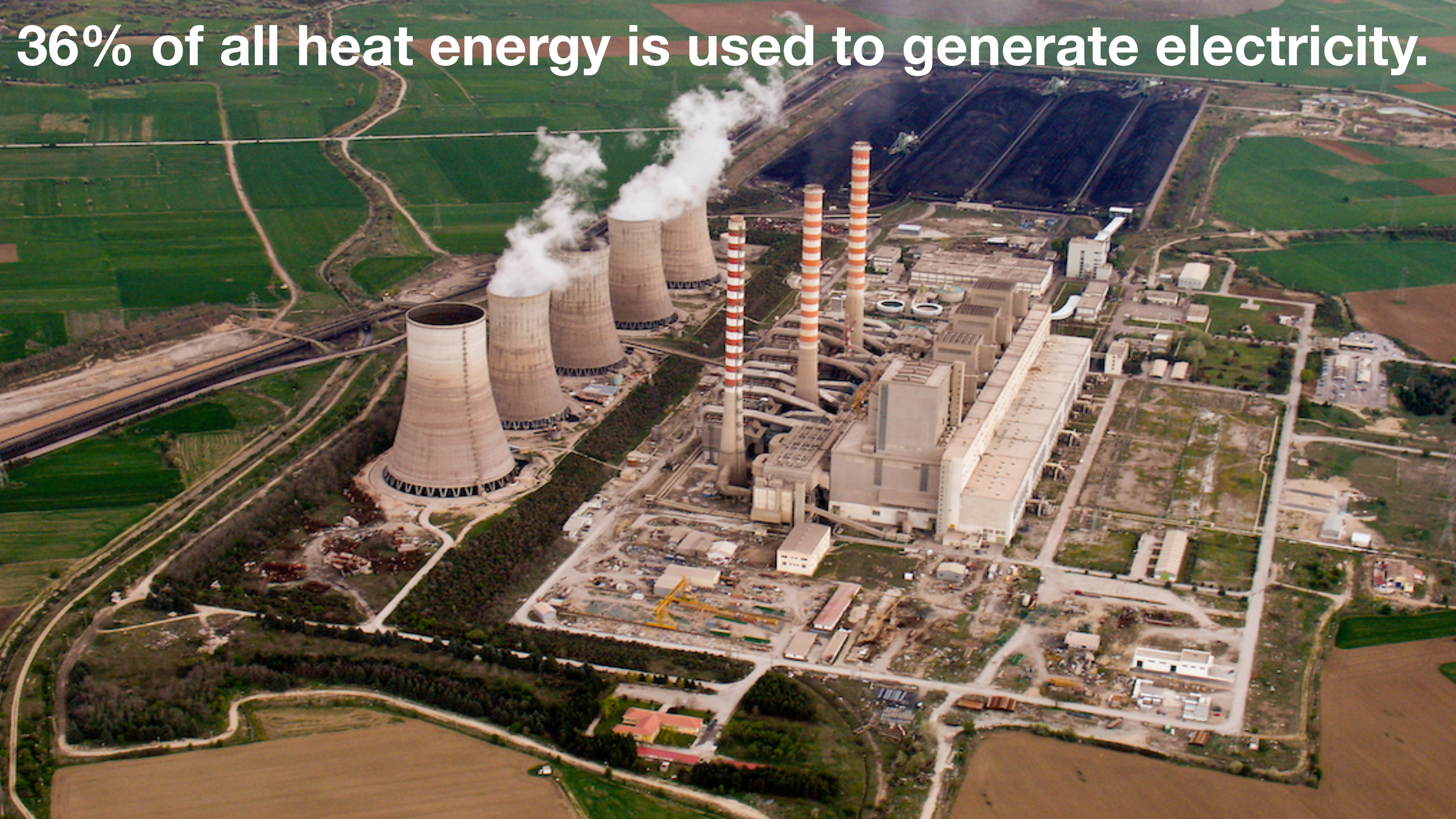
Power company burns
~ 4.5 kW(t) natural gas
to generate 2 kW(e) of electricity
to make 2 kW(t) of heat

Nations' GDPs are proportionate to electric power.



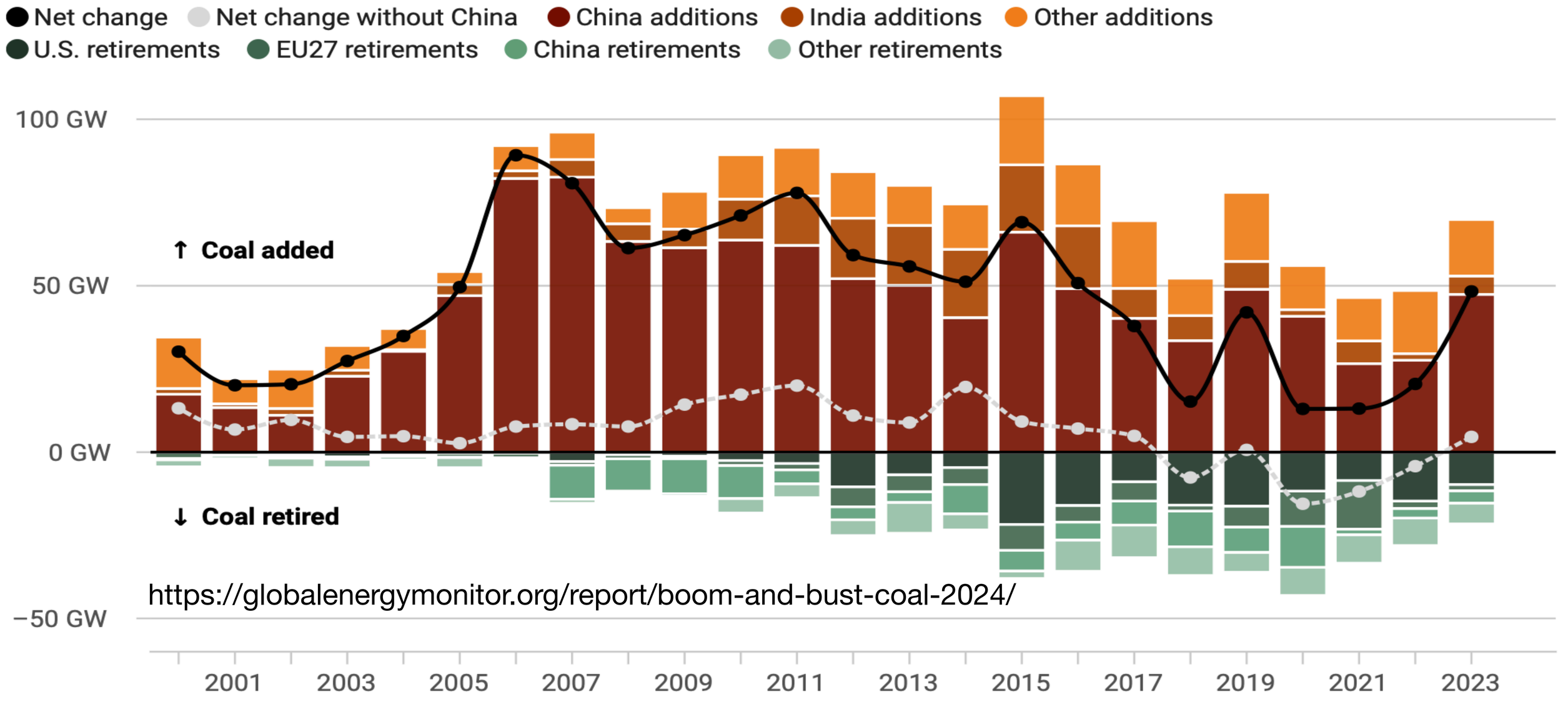
3,000 GW global electricity use may grow by 2,600 GW.




36% of all heat energy is used to generate electricity.

2023 netted 48 GW more coal-fired power plants.

Annual change in coal-fired power capacity, in gigawatts (GW)

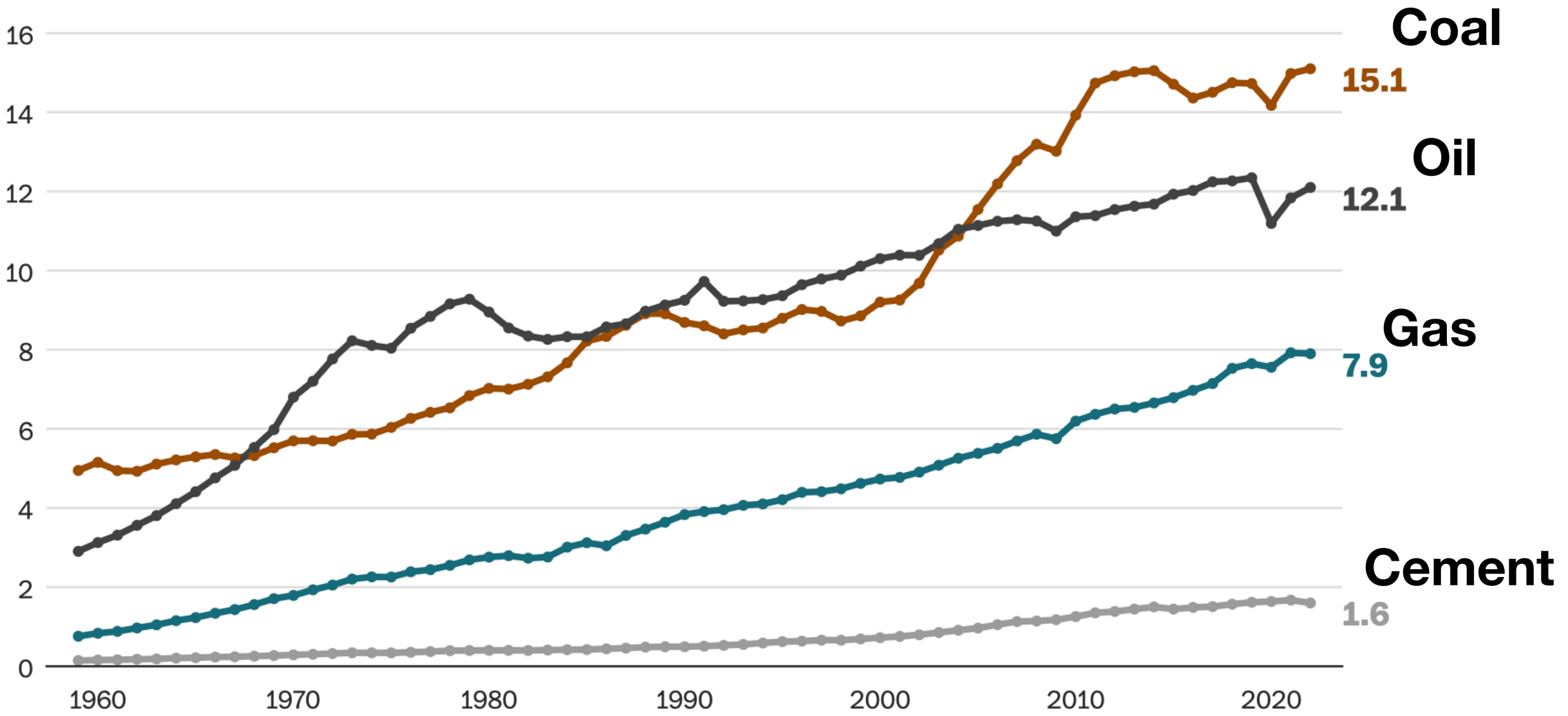


Source: Global Coal Plant Tracker, January 2024 https://globalenergymonitor.org/report/boom-and-bust-coal-2024/

Global Energy Monitor

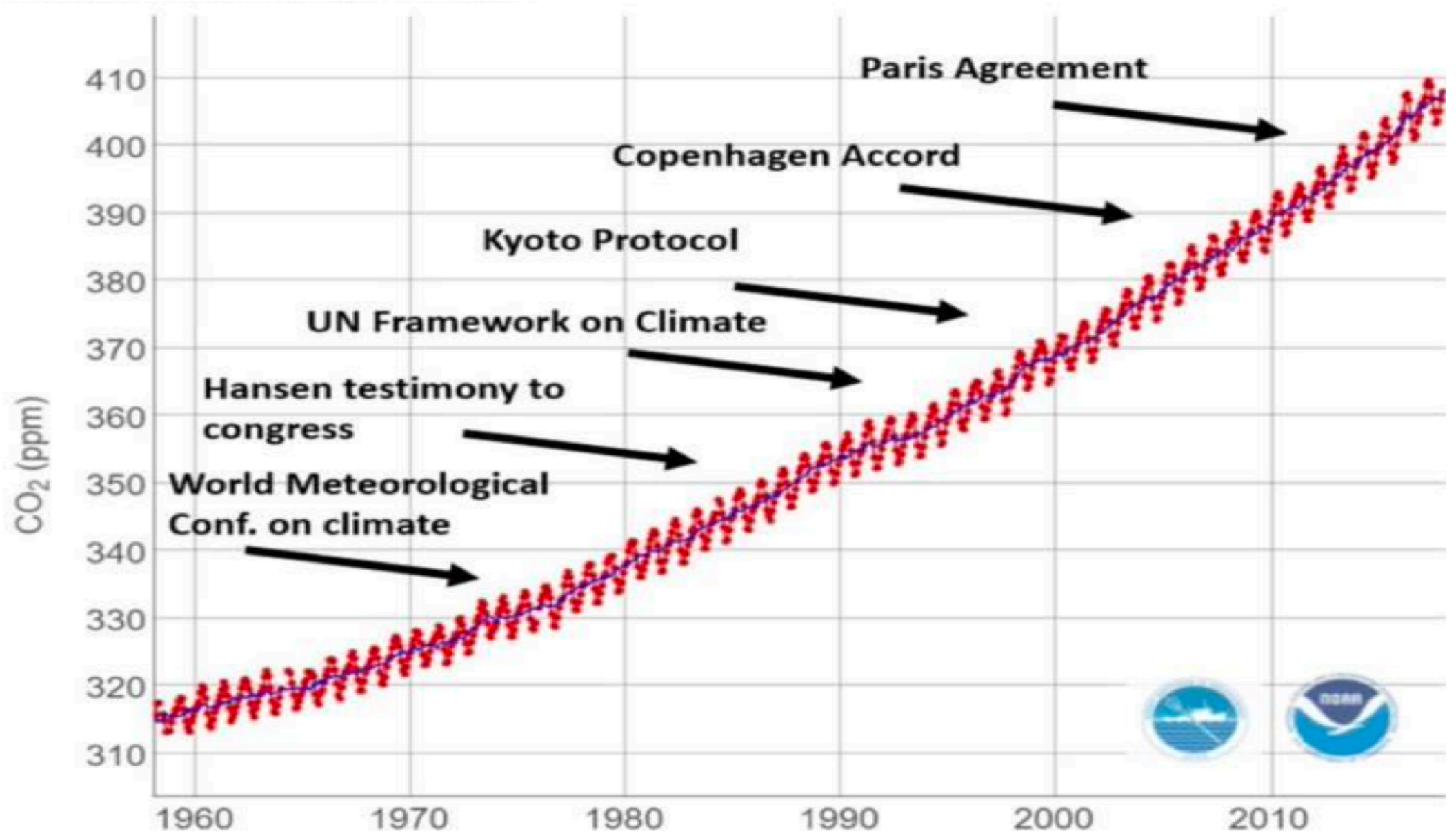
Each new 1-GW coal plant emits 6 Mt CO2/year.

Global CO2 emissions by source, in gigatons CO2 per year



https://www.washingtonpost.com/climate-environment/2022/12/05/carbon-emissions-peak-record-2022/?mc_cid=31685cb856&mc_eid=0c0eac7096

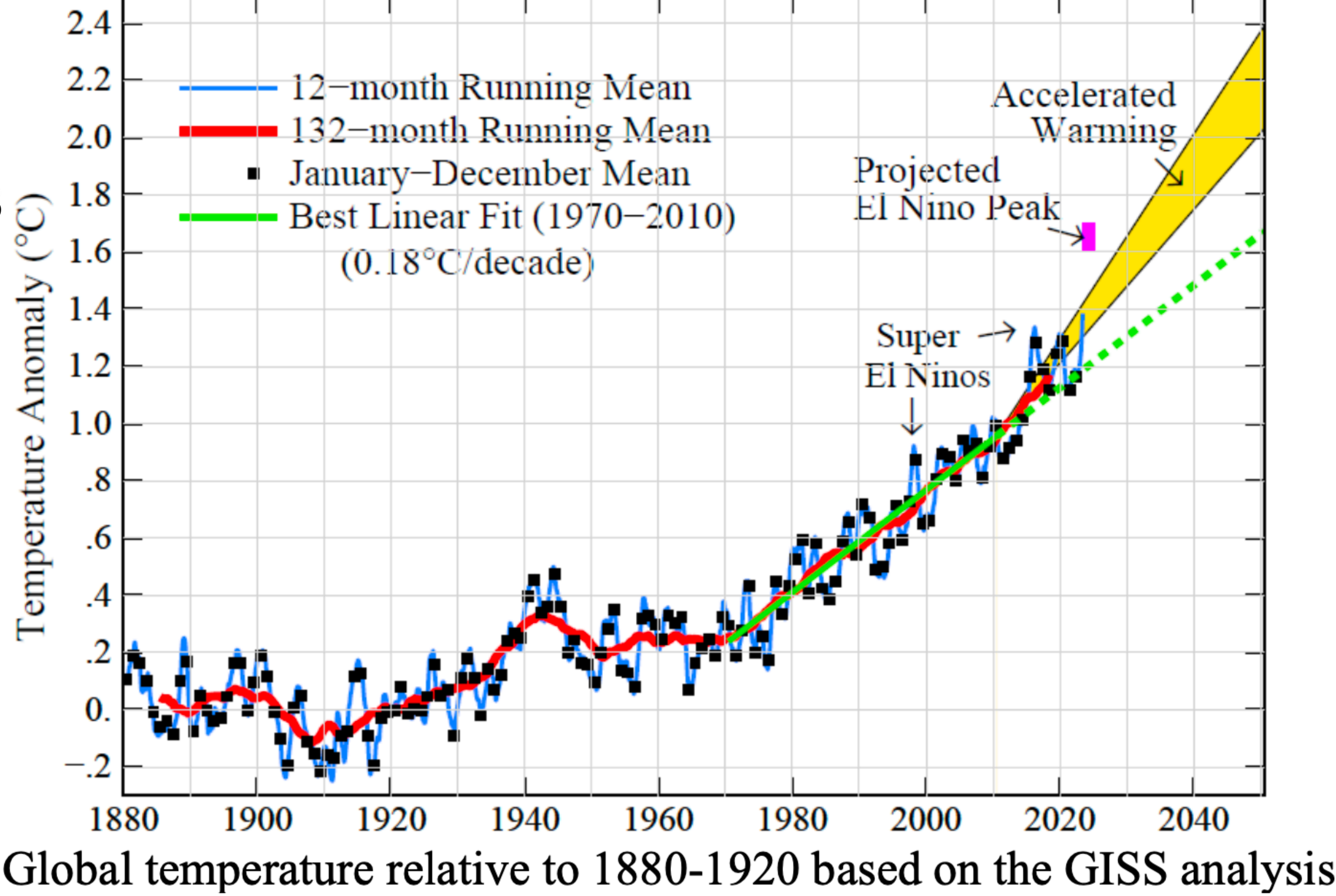
Politicians have zero effect on CO2, as measured.



https://www.esrl.noaa.gov/gmd/ccgg/trends/

Hansen et al, Dec 2023

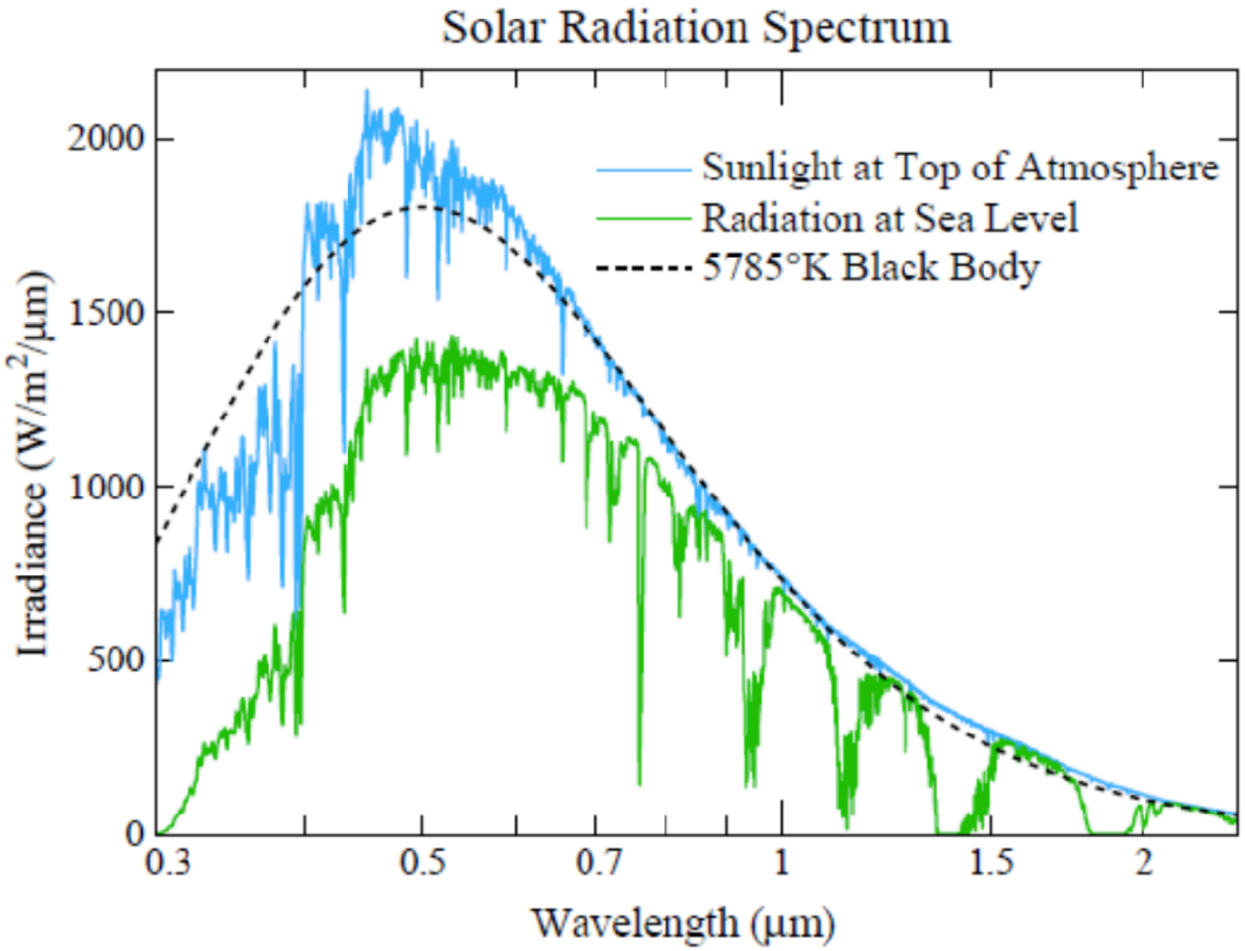
"A miracle will occur" is not sensible climate policy.



Global temperature relative to 1880-1920 based on the GISS analysis

Incoming visible radiation

Outgoing infrared radiation



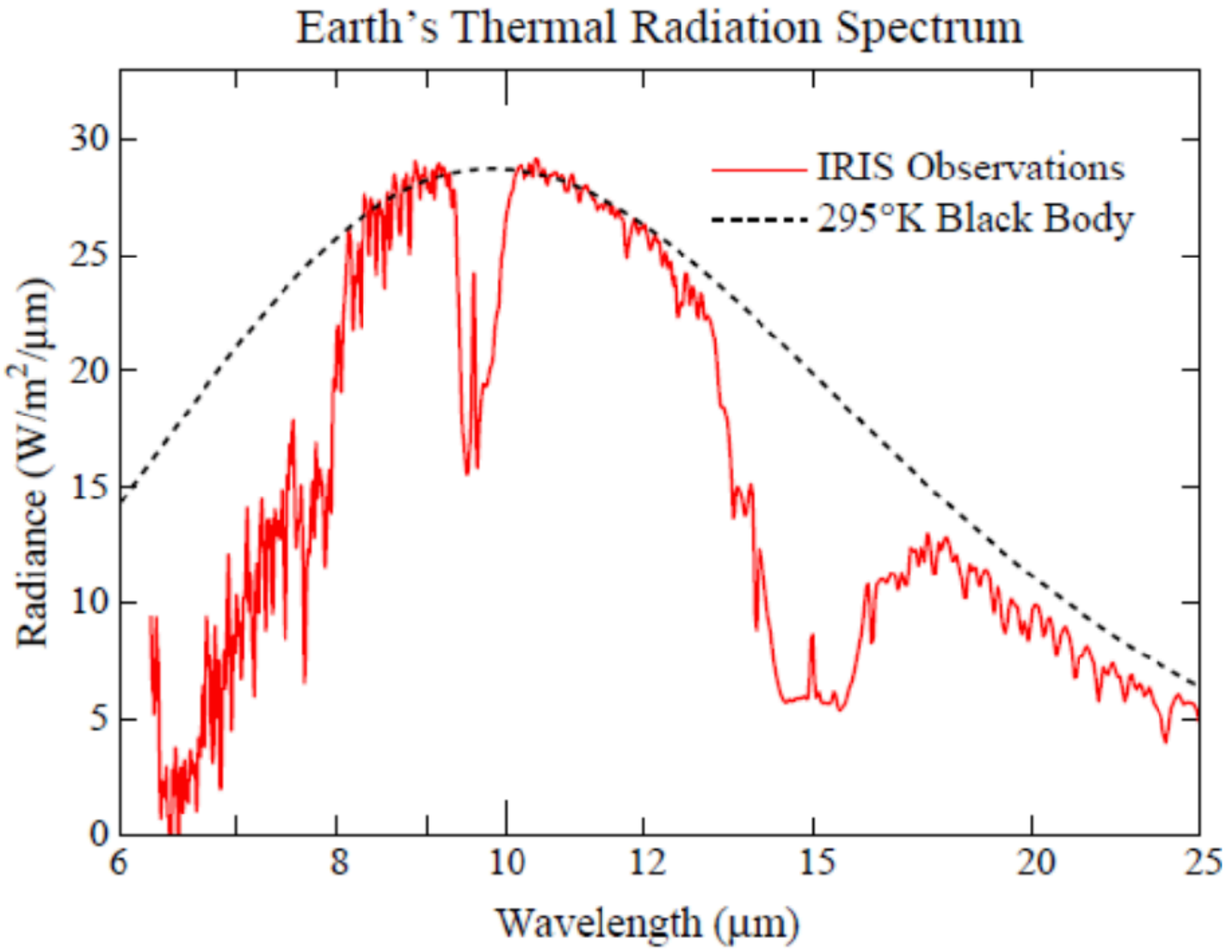
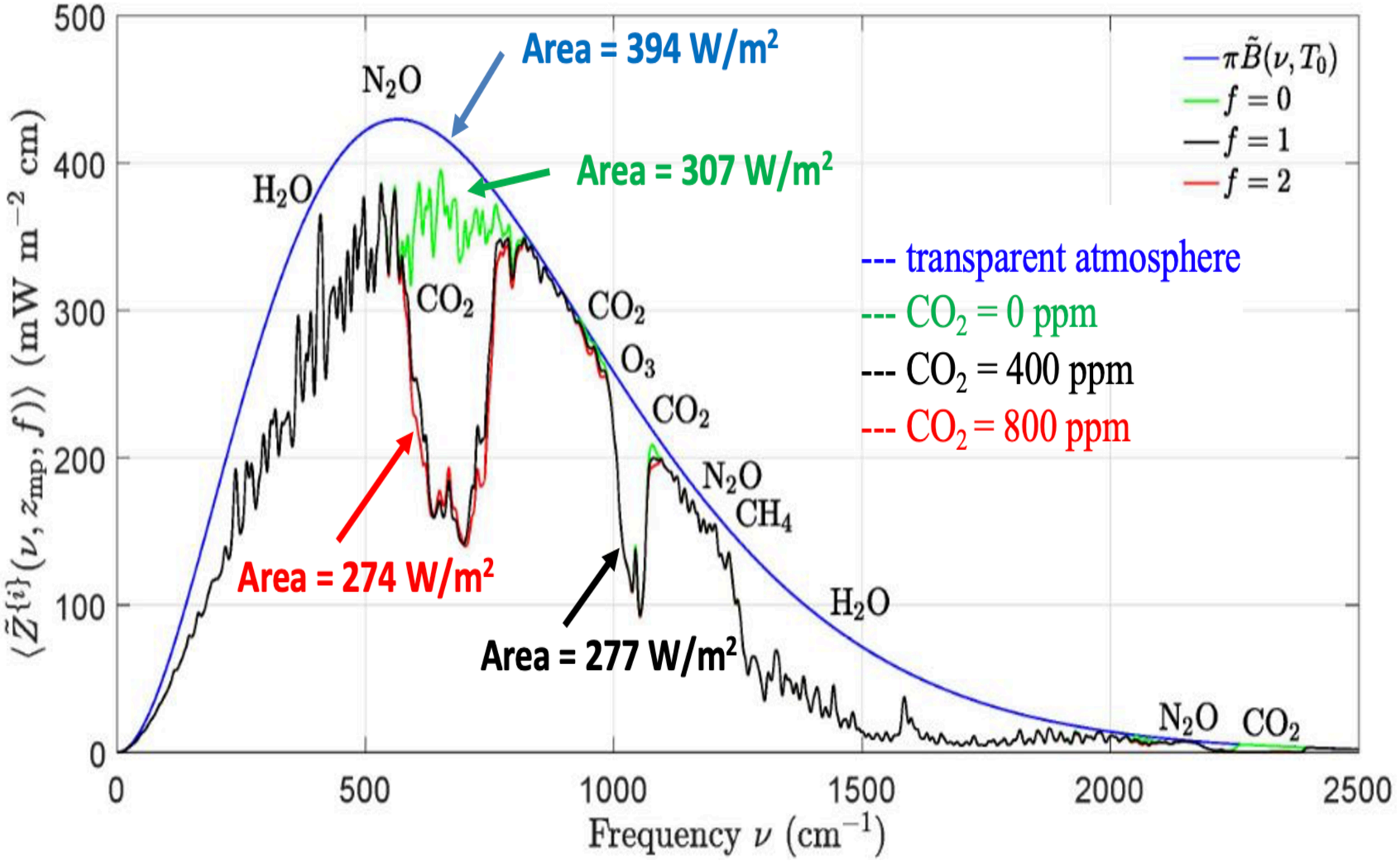


Fig. 31.1. Sunlight reaching Earth and reaching the ground for clear sky conditions (left). Thermal (heat) radiation to space measured from a satellite over the Sahara desert (right).

Source: Jim Hansen book draft http://www.columbia.edu/~jeh1/SophiePlanet/Planet.Chapter31.pdf

Princeton Prof William Happer: more CO2 is ineffectual.



Green zero CO2

Black 400 ppm CO2

Red 800 ppm CO2

Happer: Doubling the concentration of CO2 (from 400 to 800 ppm) would cause a forcing increase (the area between the black and red lines) of 2.97 W per m2.

Surface temp 60°F; 16°F w/o greenhouse gases

https://arxiv.org/abs/2006.03098

Happer and Lindzen 2022 Congressional testimony shows IPCC reports are political consensus, not science.

IPCC SPM Rule No.1: All Summaries for Policymakers (SPMs) Are Approved Line by Line by Member Governments

"IPCC Fact Sheet: How does the IPCC approve reports? 'Approval' is the process used for **IPCC Summaries for Policymakers (SPMs). Approval signifies that the material has been subject to detailed, line-by-line discussion, leading to agreement among the participating IPCC member countries**, in consultation with the scientists responsible for drafting the report."[9]

IPCC Reports Rule No. 2: Government SPMs Override Any Inconsistent Conclusions Scientists Write for IPCC Reports

Jim Hansen:
It's a shame that the UN created the IPCC to obfuscate climate science.

https://www.sec.gov/comments/s7-10-22/s71022-20132171-302668.pdf

CCS, carbon capture and storage, is not feasible.

Petra Nova CO2 capture at NRG coal plant, Texas, killed in 2020. DOE, $195M grantor, still optimistic.

$1 billion total

Goal: 33% capture from 240 MW boiler

81 mile pipeline to oil field to sell CO2 for injection to push up more oil

Uses 45 MW natural gas power, halving CO2 savings

https://www.reuters.com/article/us-usa-energy-carbon-capture-idUSKCN2523K8

Lake Nyos CO_2 suffocated 1,746 people overnight.

Its deep waters became a high-pressure CO_2 storage unit. It overturned, releasing hundreds of thousands of tons of CO_2, suffocating people.

Offsets? Planting trees can't absorb enough CO2.

Global forests cover
4 billion hectares.

Add a billion ha more?

- **Mature** forests emit as much CO2 as they absorb, as trees die and rot or burn.
- **New** forest growth absorbs 8 tons/hectare per year, until maturity @ ~ 100 years.
- Increasing forests by planting 1 billion more hectares of trees (2X the Amazon basin) would absorb only 8 Gt/year, for ~ 100 years.
- Manmade world CO2 emissions are ~ 50 Gt per year.

https://www.1t.org Davos World Economic Forum

Economic suicide?

Don’t end reliable, cheap power before getting a substitute!

Vaclav Smil:

Energy from burning carbon is the basis of civilization.

https://www.wyodaily.com/photos/big/11242/12

Bob’s plan

1 New Nuclear power, $ < coal

2 Seafuel

3 District heating

4 Work to lower industry CO2

NY Times: 18 Apr 2023
The Fantasy of Reviving Nuclear Energy

Solar alone added more than 400 gigawatts of capacity worldwide last year, two-thirds more than the previous year. That's more than the roughly 375 gigawatts of combined capacity of the world's 415 nuclear reactors…

At the same time, investment in energy storage technology is rapidly accelerating.

NY Times: 18 Apr 2023
The Fantasy of Reviving Nuclear Energy

500 GW, US average electric power use

100 hours, storage period for dim sunlight

50,000 GW-hours to run US on stored electricity

$1,000/kWh cost of utility batteries (2x Tesla $)

= $1 billion/GWh

50,000 x 1G$ = $50 trillion for batteries

NY Times: 18 Apr 2023
The Fantasy of Reviving Nuclear Energy

For much less money and in less time, the world can reduce greenhouse gas emissions through the use of renewables like solar, wind, hydropower and geothermal power, and by transmitting, storing and using electricity more efficiently. A recent analysis by the German Environment Agency… found that renewable energy “is the crucial and primary driver.”

The End Session 1