Feedback

- I want to know why I got the score of my essay. The feedback of essay. Hope to improve my skills

- Can I get a more detailed feedback from assignment grading? I don’t know what score I got from each criteria of the rubric, and have no clue how to improve my writing for the next assignment :(

- Please give feedbacks on essays.

Review: Ocean and Climate

- A blue planet
- Ocean covers 71% of the earth surface
- Average depth is 3.68 km
- Most of our ocean is unexplored

NASA, NOAA

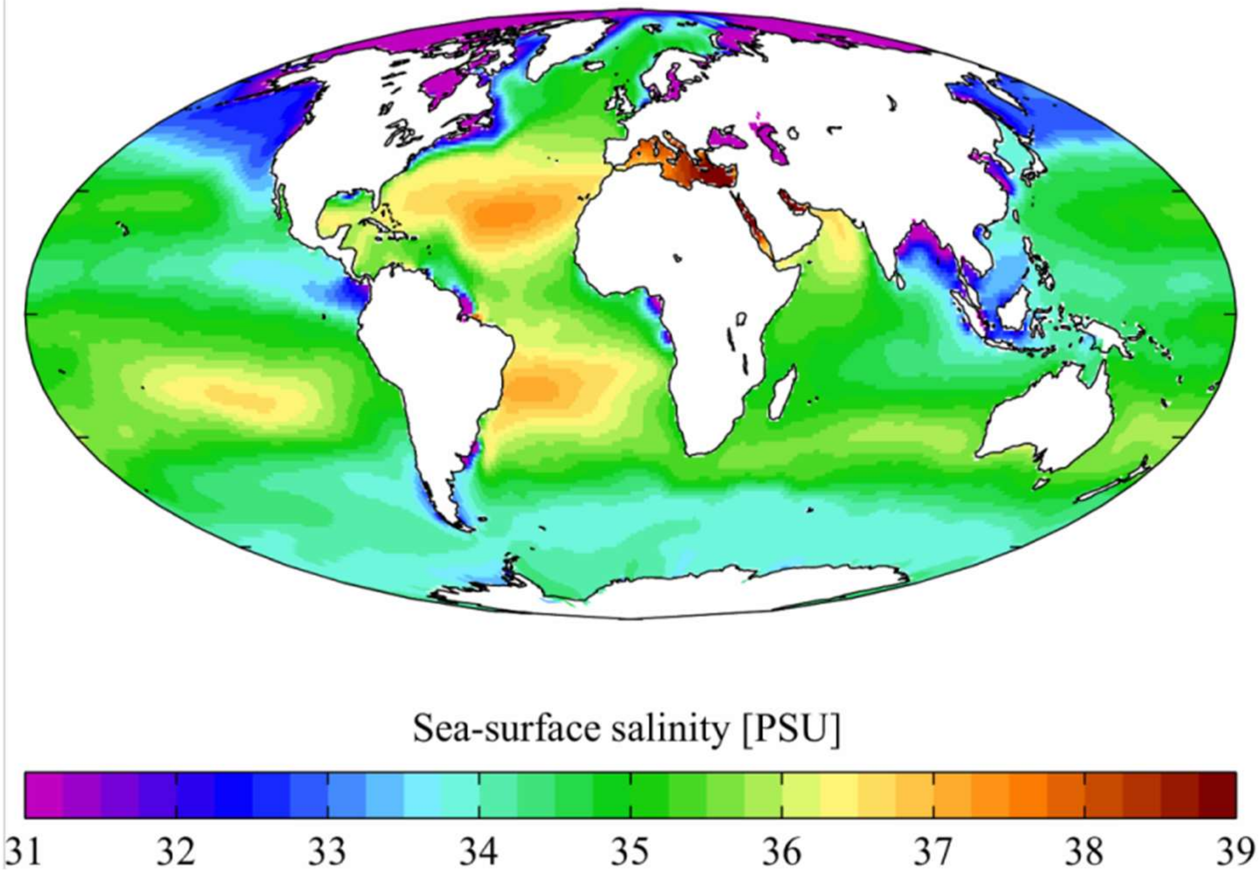
Review: Ocean and Climate

- May be home to **700,000** marine species
- **226,000** marine species have been identified and recorded

https://www.technologynetworks.com/applied-sciences/news/richest-marine-biodiversity-threatened-by-ocean-warming-363859
https://oceanliteracy.unesco.org/ocean-biodiversity/

Review: Ocean and Climate

- Salinity tends to be lower in the high latitude region



https://www.ck12.org/

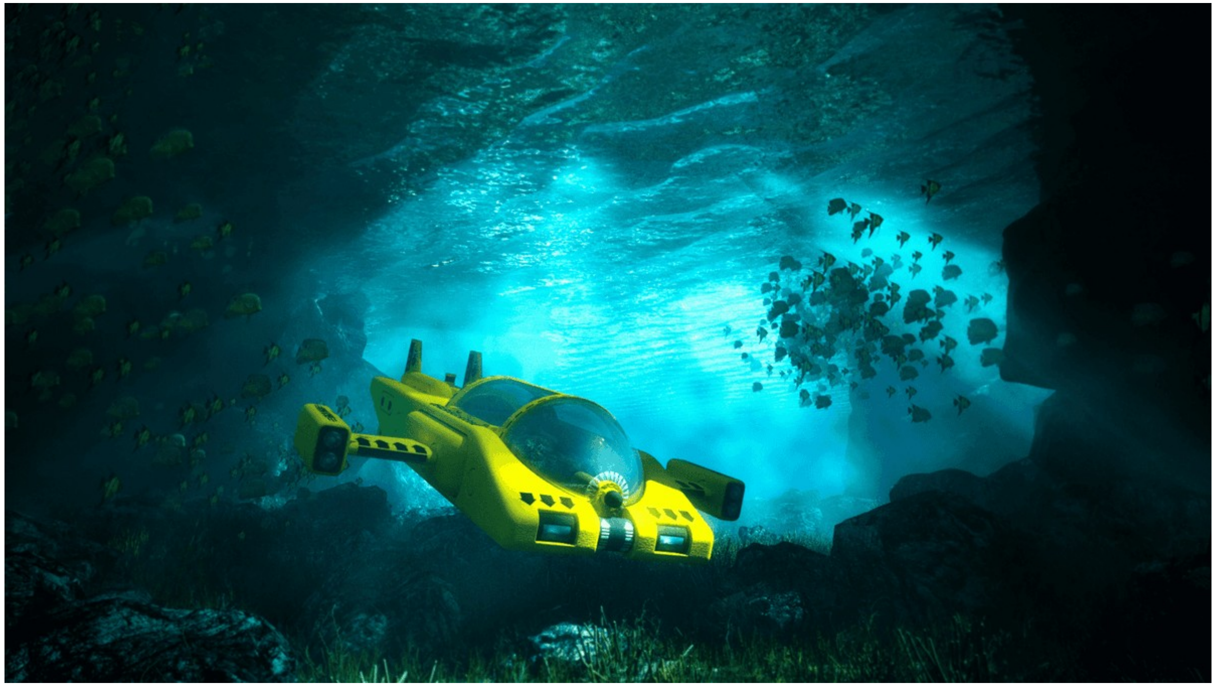
Review: Ocean and Climate

- Methane hydrates (gas hydrate/flammable ice)
- One cubic meter of methane clathrate releases about 160 cubic meters of gas
- Global storage ranges from 500 to 2500 Gt C, comparable with the C in the air

https://www.sohu.com/a/497417969_794222

Review: Ocean and Climate

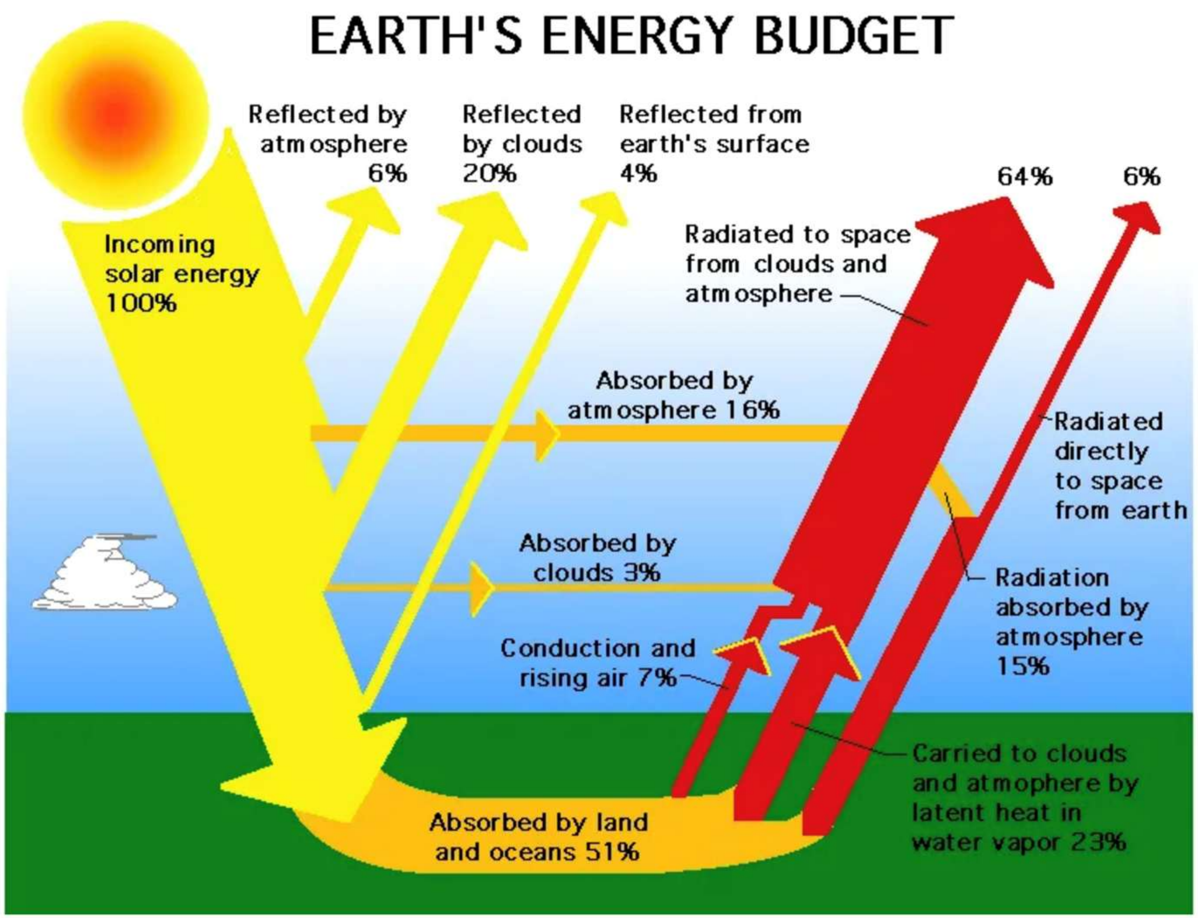
- Only 5% of the ocean and have been explored and documented
- Over 150 new species of marine fish are found every year
- One research priority in many countries



https://interestingengineering.com/science/we-know-little-about-the-ocean

Review: Ocean and Climate

- Large areas
- Dark color
- High specific heat
- Ocean reflects only 6% of the sun's energy and absorbs the rest.

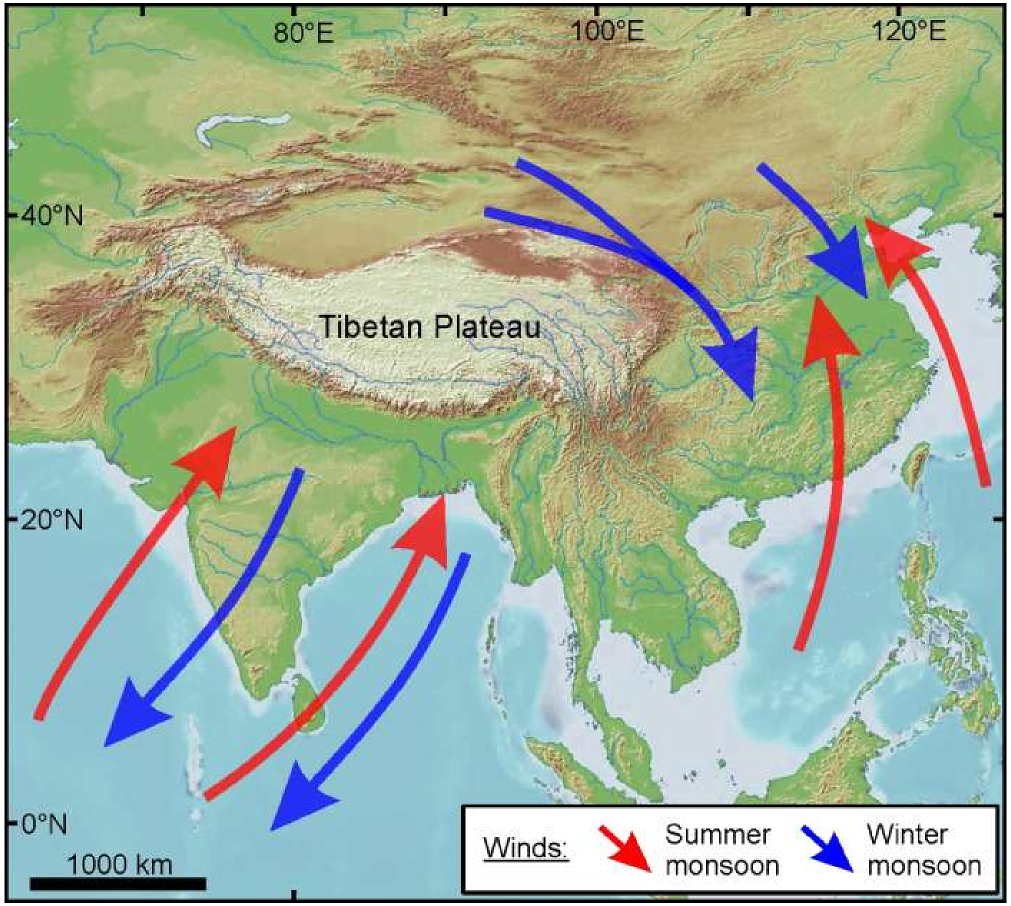


[The Energy Budget | Center for Science Education (ucar.edu)]

Oceans regulate global water cycle

- Warm and humid summer

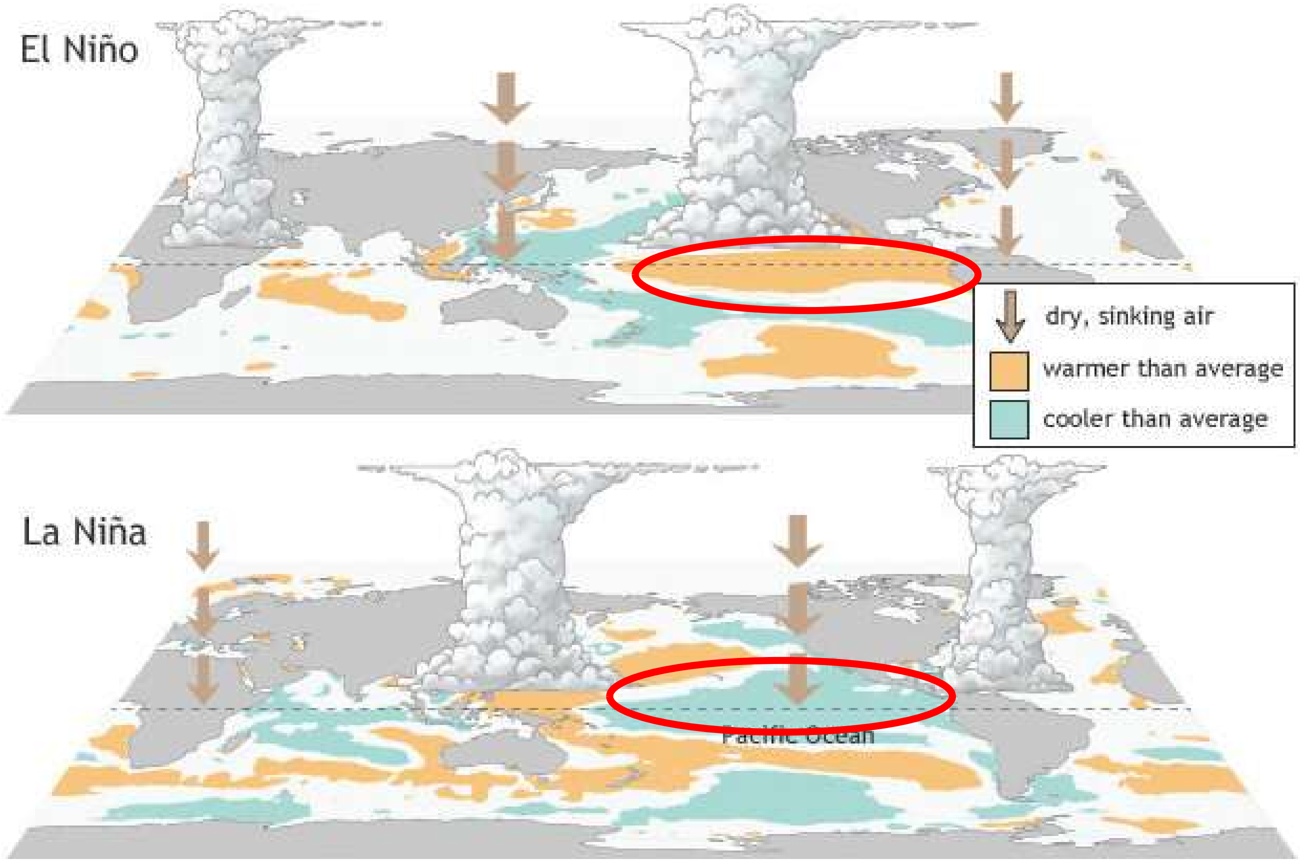
- Cold and dry winter



https://alexislicht.com/past-monsoons/

El Niño–Southern Oscillation (ENSO)

- Pacific Ocean warm or cool by anywhere from 1° C to 3° C, compared to normal
- El Niño: Warming
- La Niña: Cooling
- La Niña tends to happen in coming months

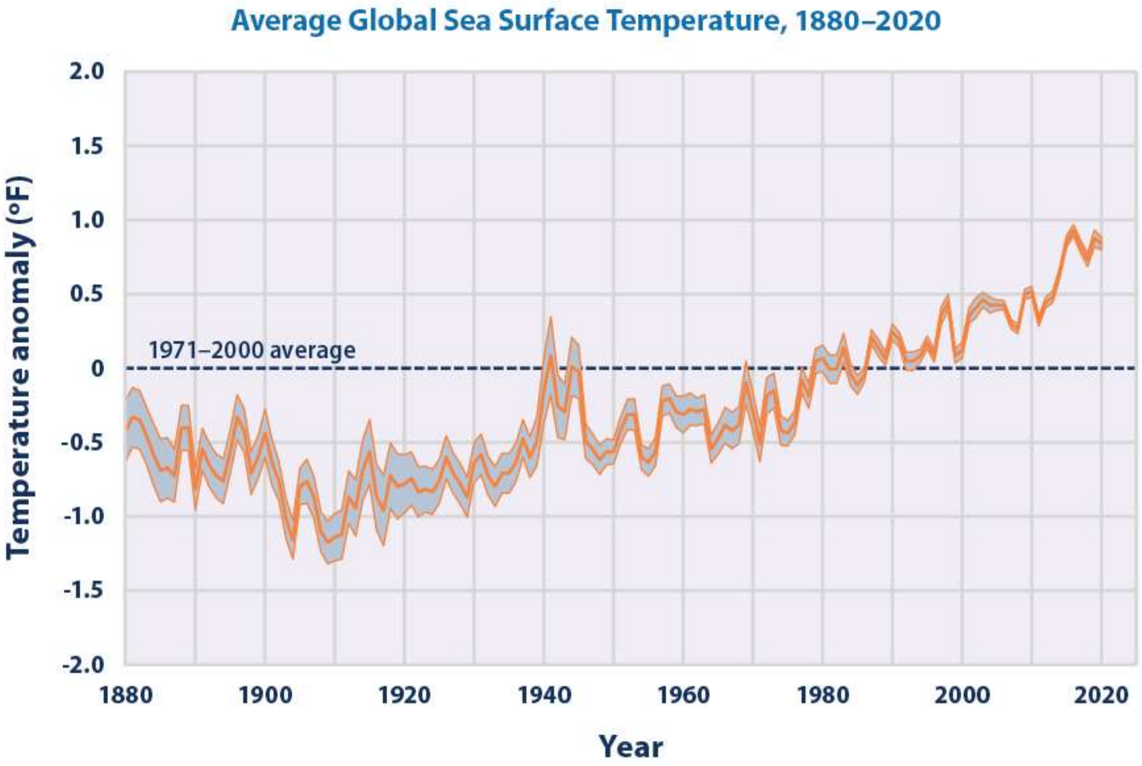


https://www.myesg.com.my/

Warming

- ➢ **90% of additional heat trapped by our emissions is absorbed by the ocean.**

- ➢ **Surface water of global ocean has warmed by more than 1.5° C since 1901**



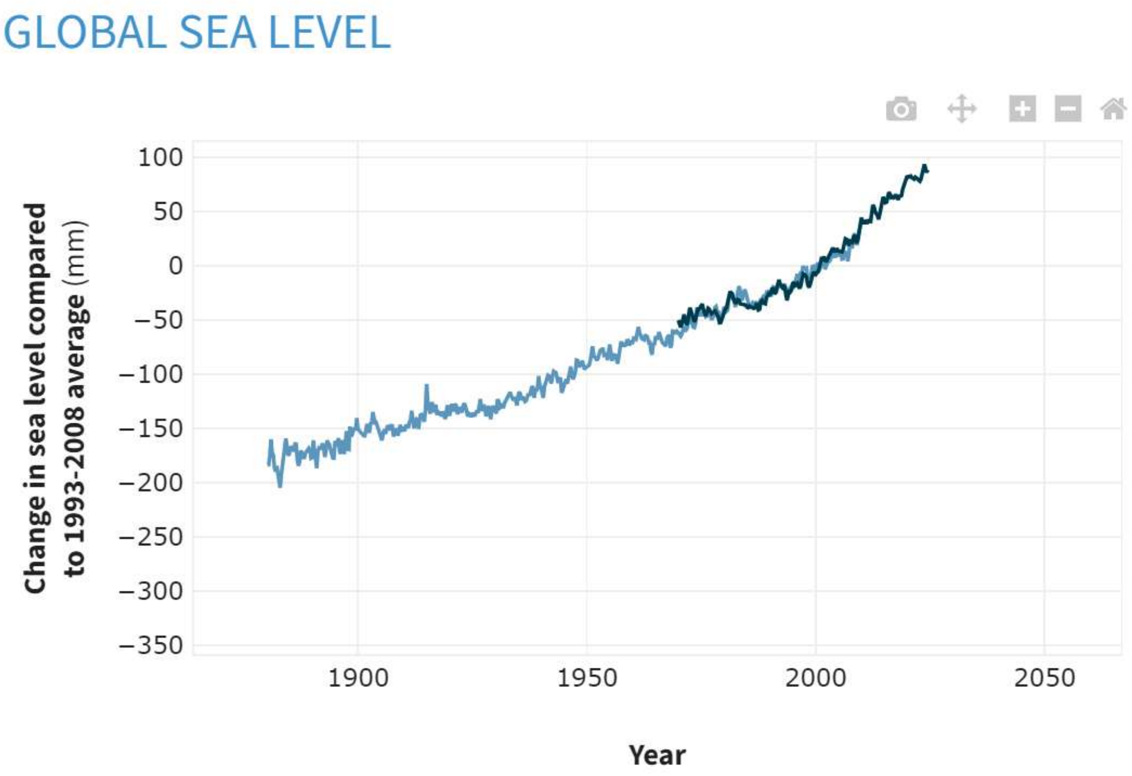
Data source: NOAA (National Oceanic and Atmospheric Administration). 2021. Extended reconstructed sea surface temperature (ERSST.v5). Accessed February 2021. www.ncdc.noaa.gov/data-access/marineocean-data/extended-reconstructed-sea-surface-temperature-ersst.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.

https://www.neefusa.org/story/water/warming-ocean

Sea level rise

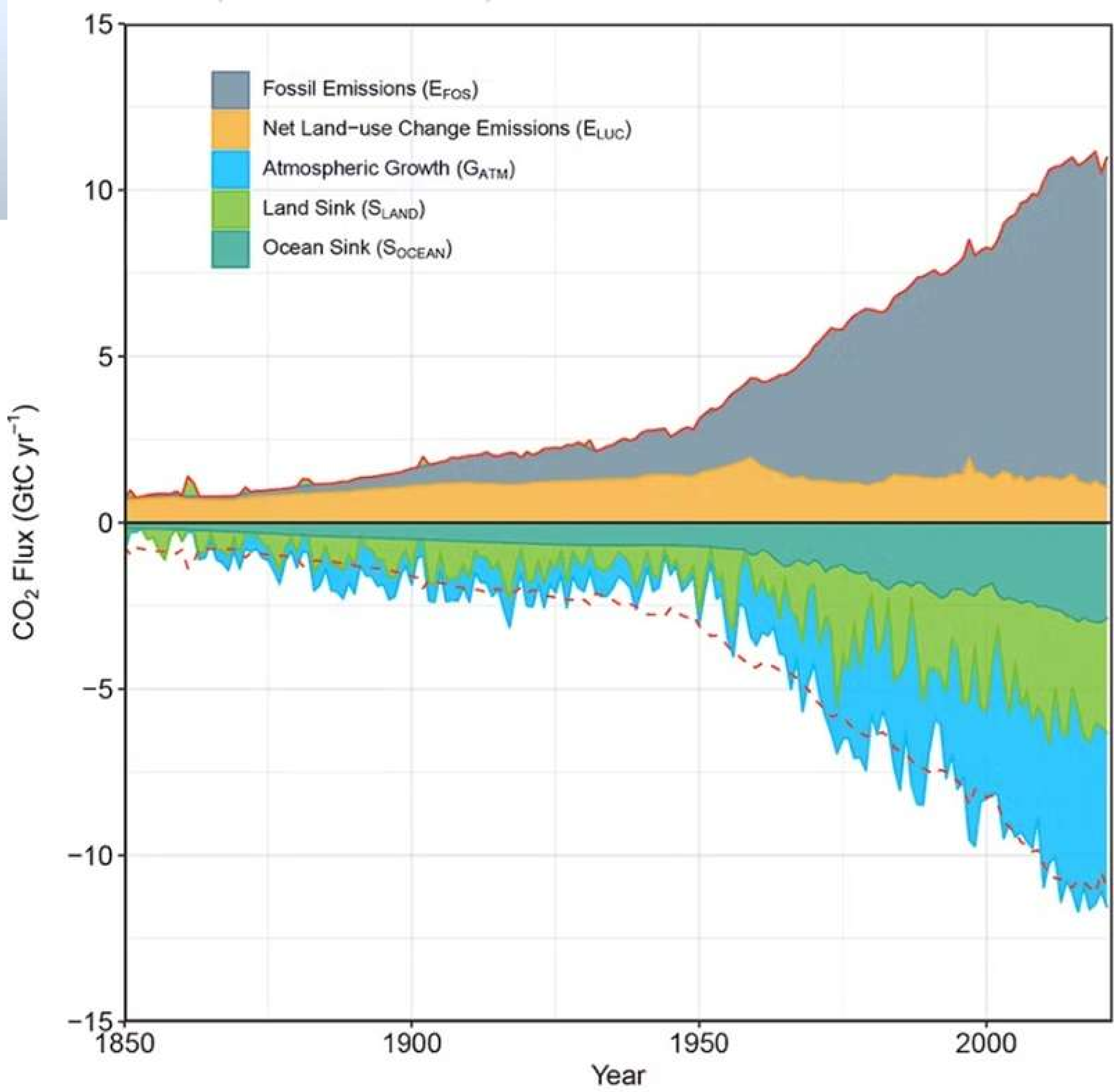
- Global average sea level has risen 21–24 centimeters since 1880.
- In 2023, global average sea level set a new record high—101.4 mm above 1993 levels.
- The rate of global sea level rise is accelerating: it has more than doubled from 1.4 millimeters per year throughout most of the twentieth century to 3.6 millimeters per year from 2006–2015.



NOAA

Oceans regulate global carbon cycle

- **~30%** of CO_2 emissions are absorbed by oceans



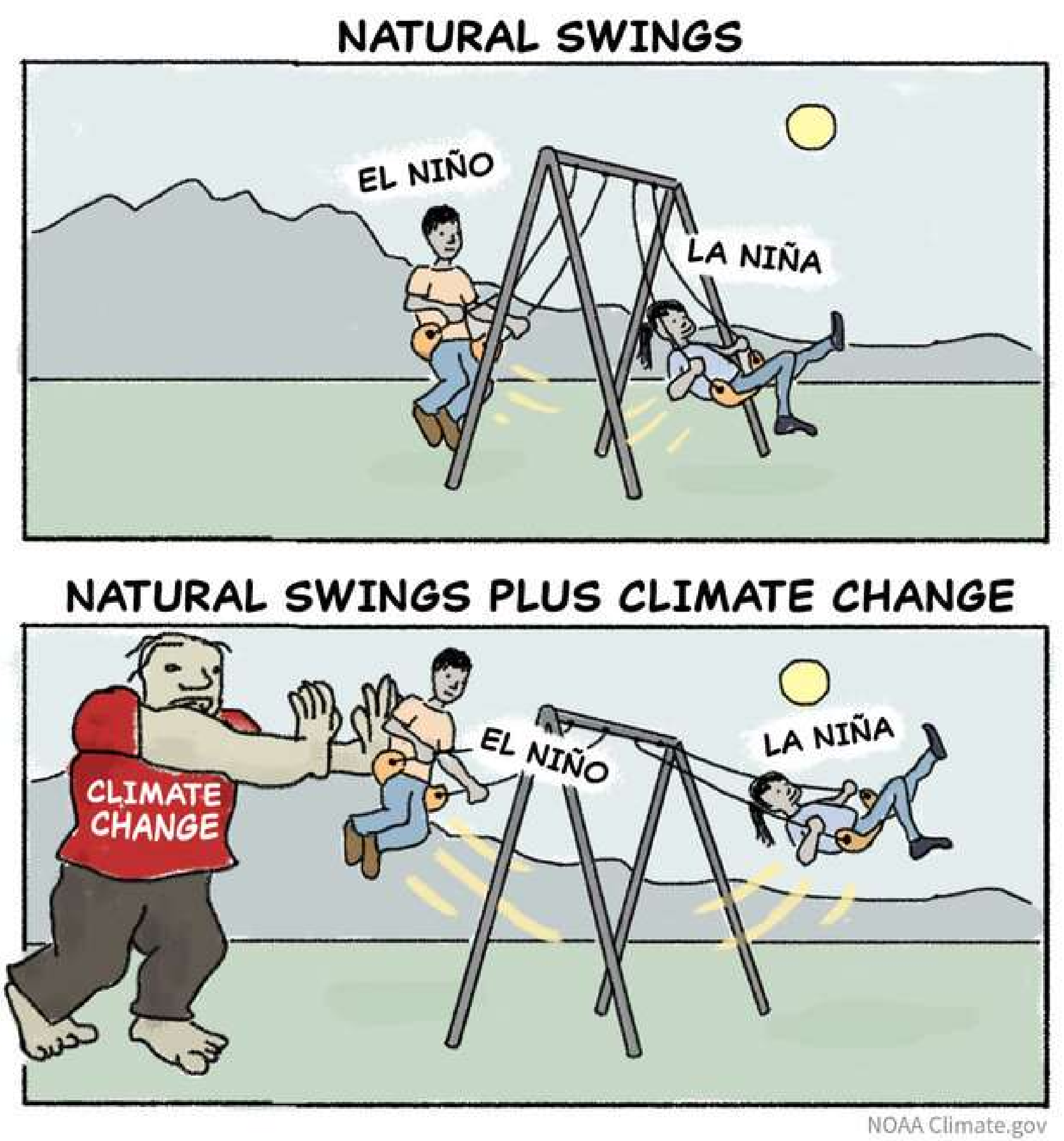
https://theconversation.com/

Acidification of the Ocean

- Shells become thinner
- Death rates increase

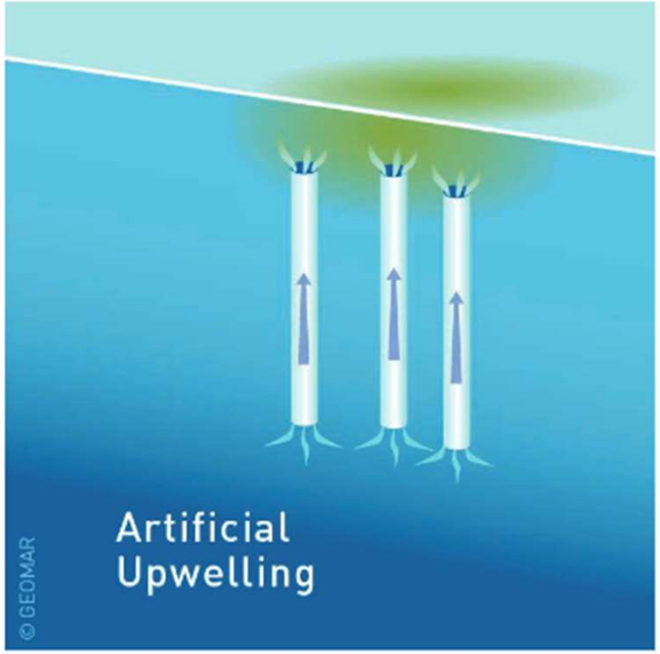
https://nwtreatytribes.org/

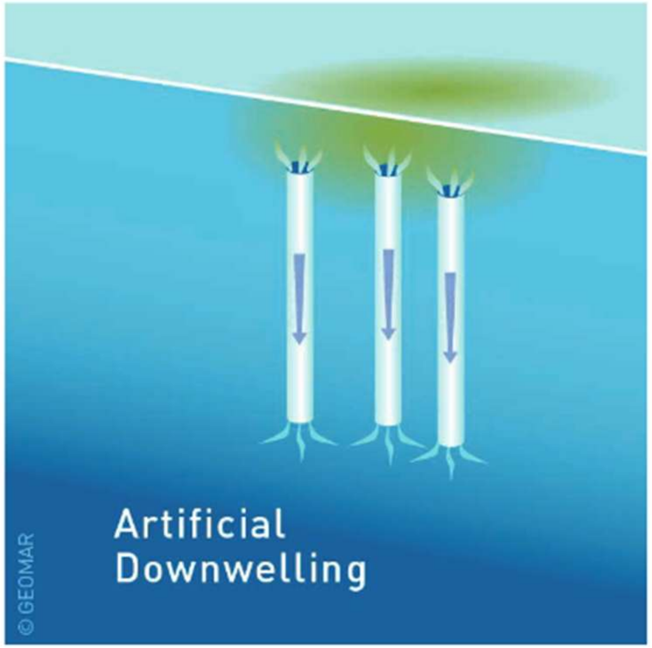
Global warming and ENSO



https://www.climate.gov/

Ocean pumping





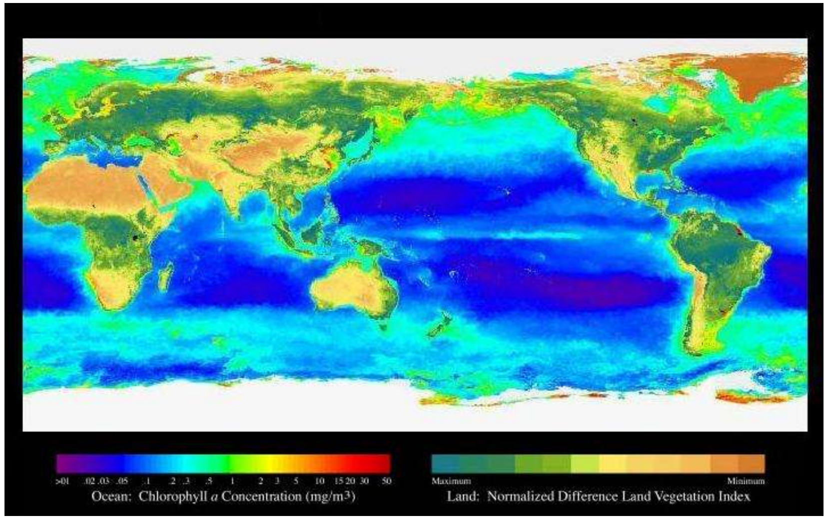
- Fertilize the surface ocean with nutrient-rich deep water
- Cool the surface atmosphere with cold deep water

- Transport the DIC to deep water for long term storage

Credit to Liuqian Yu

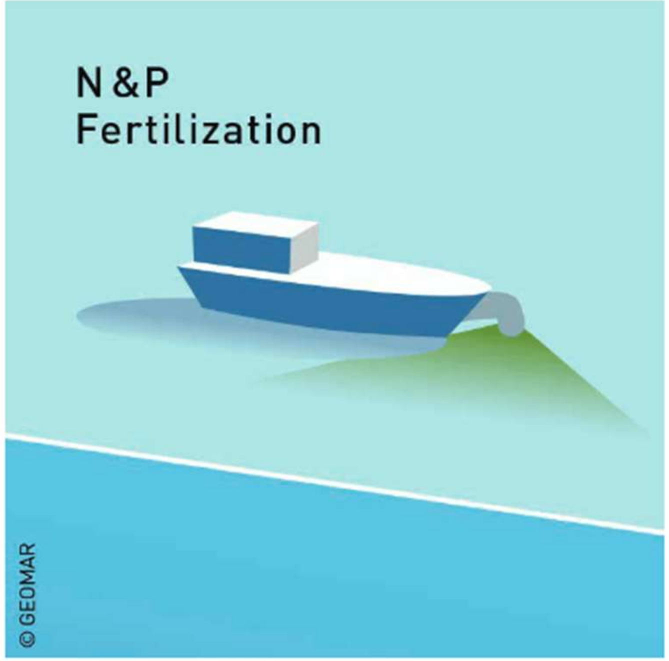
GESAMP (2019)

Ocean fertilization



Distribution of Chlorophyll concentrations

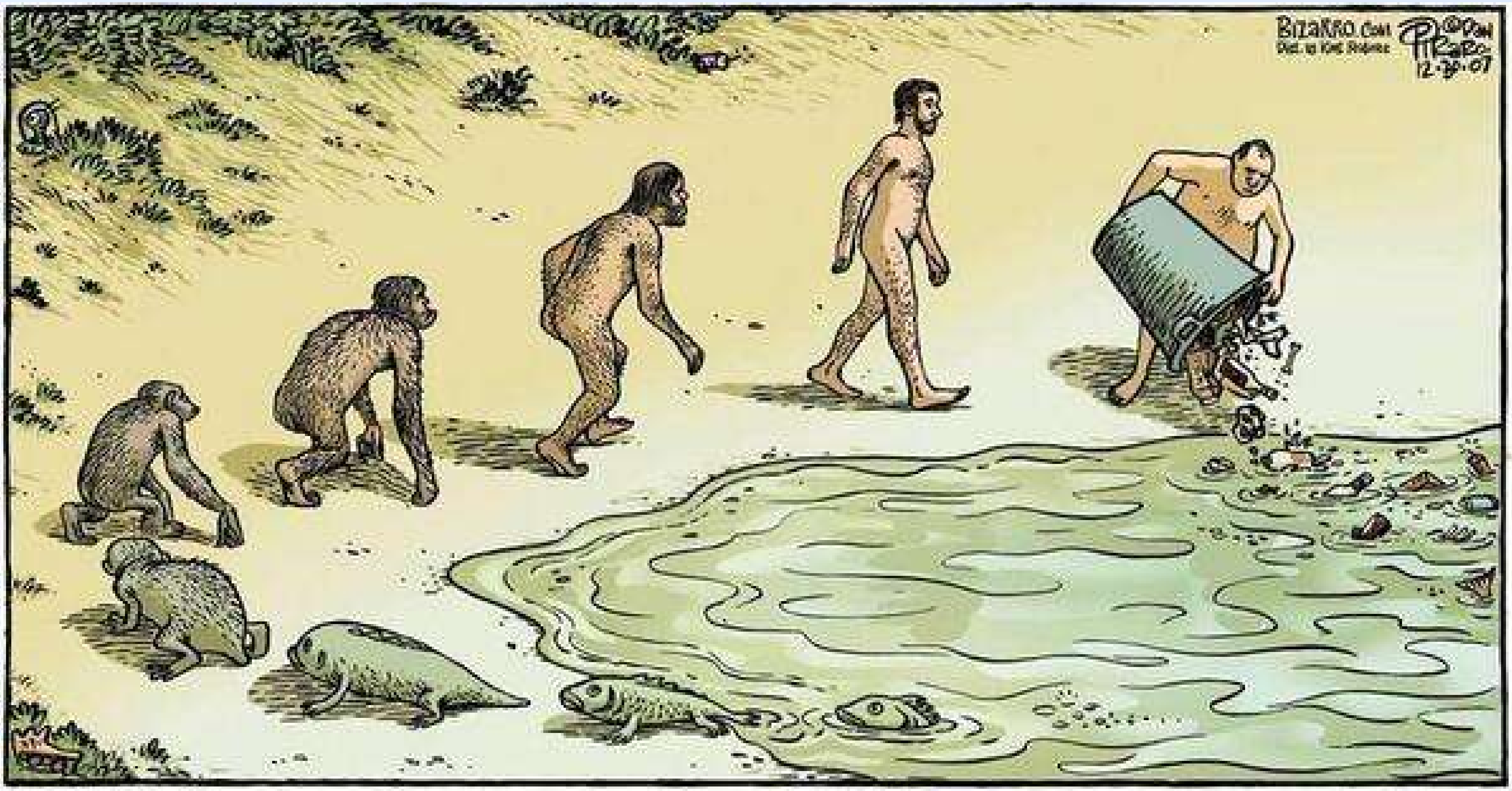
High-nutrient, low-chlorophyll (Iron is the most limiting nutrient)



High-nutrient, low-chlorophyll region (nutrients from dusts could not reach those regions)

Credit to Liuqian Yu

GESAMP (2019)



[Erik Olsen](#)
, post on X 2014

Lecture Topics

Fundamentals of the Human-nature system

- The history of material science and human civilization (**AMAT**)
- Polymers (**AMAT**)
- Graphene/AI Matter in Advanced Materials (**AMAT/SEE**)

Environmental challenges

- Climate change (**EOAS**)
- Hydrology and climate change (**EOAS**)
- Responses of Oceans to climate change **(EOAS)**

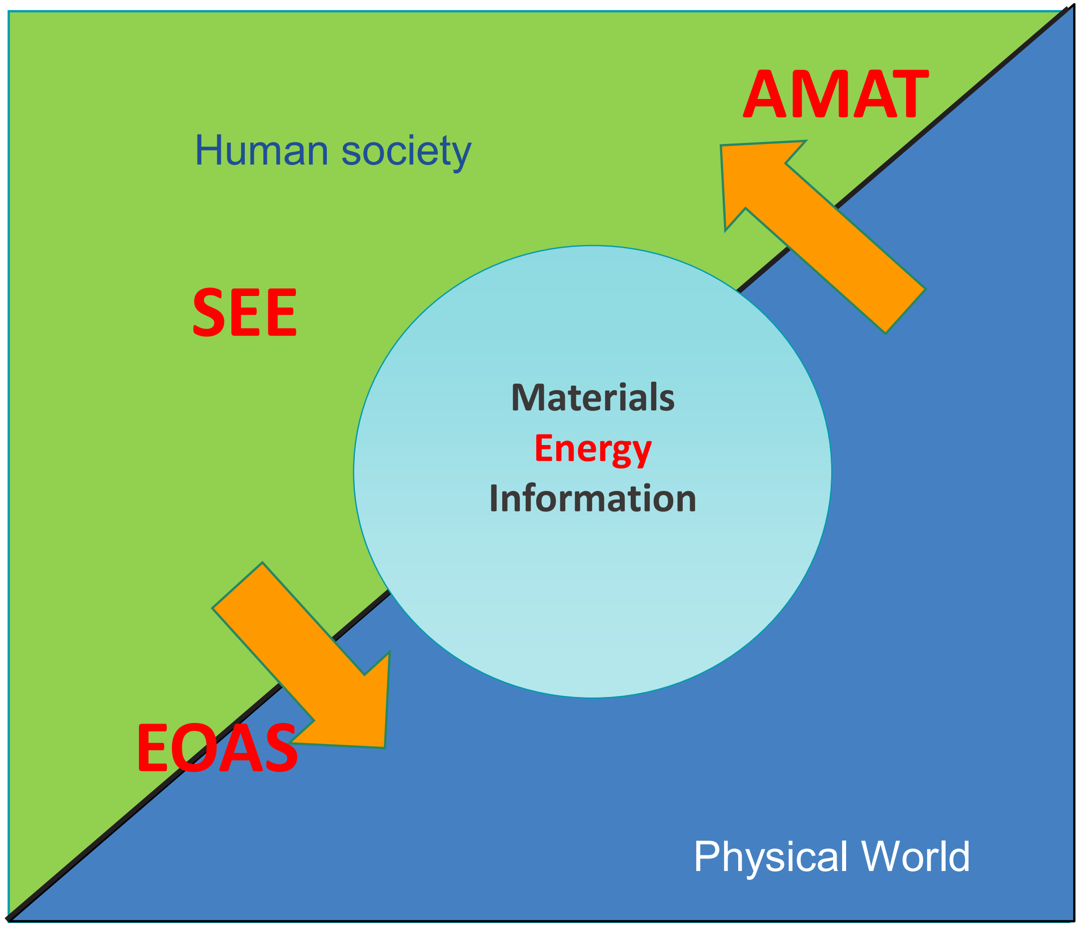
Solutions for sustainable development

- Renewable energy production (**SEE**)
- Energy storage and Electric Vehicles (**SEE/ AMAT**)
- Green Building (**SEE**)

- Development of computers (**MICS**)
- Chip production from sand (**MICS**)
- Supercomputing (**MICS/EOAS**)

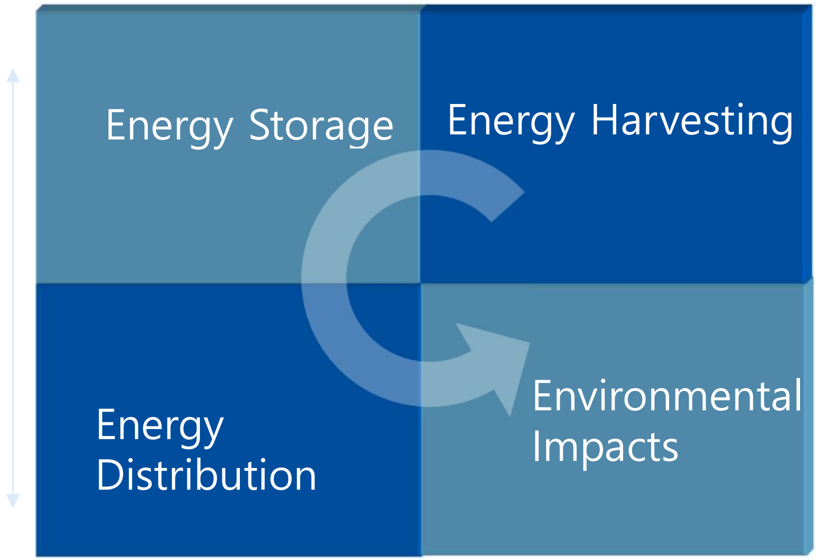
12 lectures in total

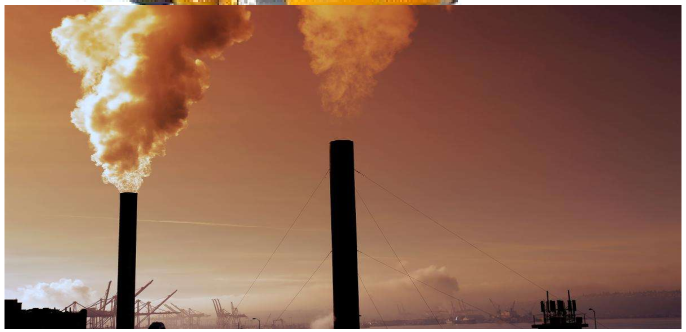
Thrusts of Function Hub



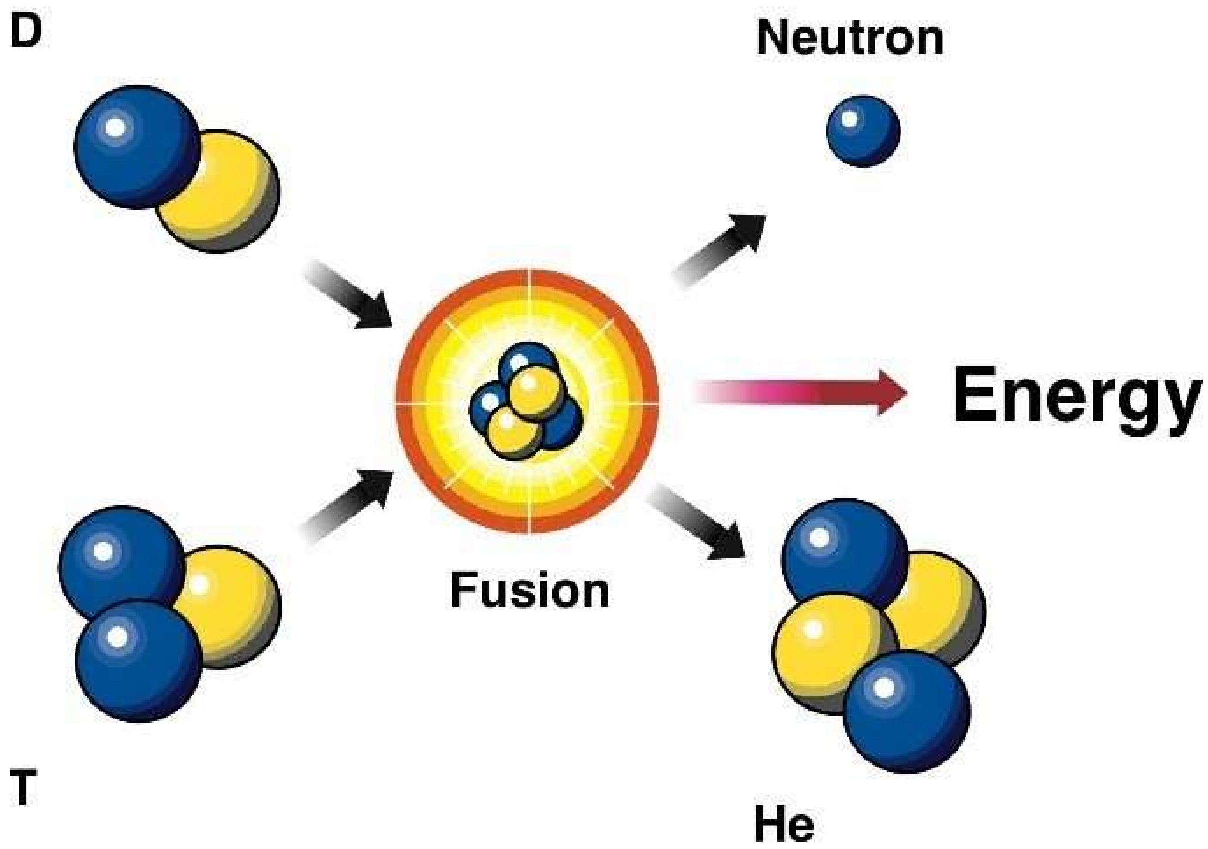
Research of the SEE Thrust

SEE: “To be a leading program in interdisciplinary education and research in sustainable energy and environment area”



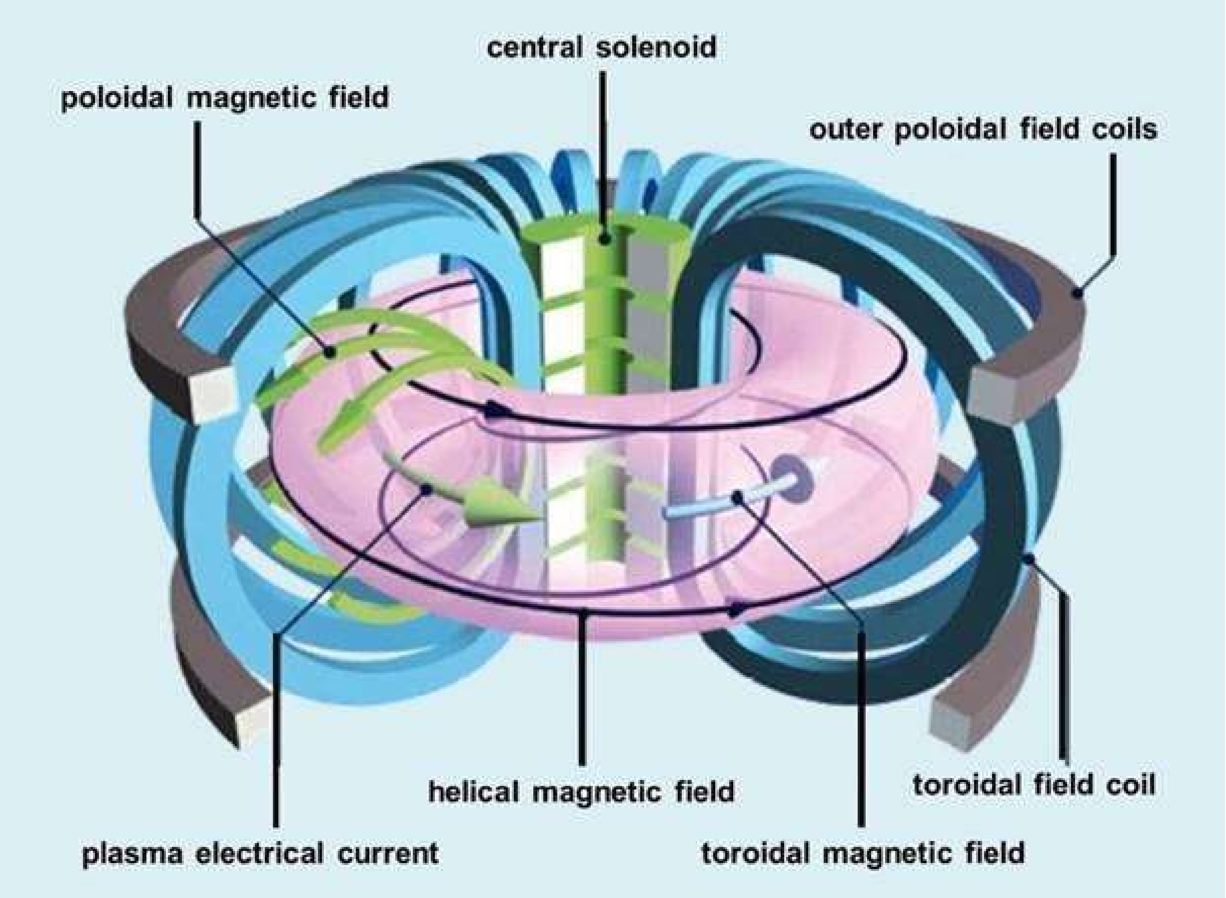


Nuclear fusion



DOE of the U.S.

Controlled nuclear fusion in a Tokamak



https://www.energy.gov/science/doe-explainstokamaks

Why the world was so excited about this ignition?

‘One of the most impressive scientific feats of the 21st century

Introduction to Function Hub For Sustainable Future

Lecture 7： Energy Production and Renewable Energy

Qichun Yang

2024-10-29

香港科技大学（广州）
THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY (GUANGZHOU)

Vocabulary of this lecture

- **Photosynthesis:** 光合作用
- **Ignition:** 点火
- **Fusion:** 聚变
- **Controlled nuclear fusion:** 可控核聚变
- **Plasma:** 等离子体
- **Metallurgy:** 冶金
- **Boiler:** 锅炉
- **Turbine:** 涡轮机
- **Supercritical:** 超临界
- **Onshore:** 陆上的
- **Offshore:** 离岸的
- **Photovoltaic:** 光伏
- **Triboelectric:** 摩擦起电

Outline

- History of Energy Use
- Traditional Energy Production
- Environmental Challenges Associated with Traditional Energy Production
- Renewable Energy: Opportunities and Challenges

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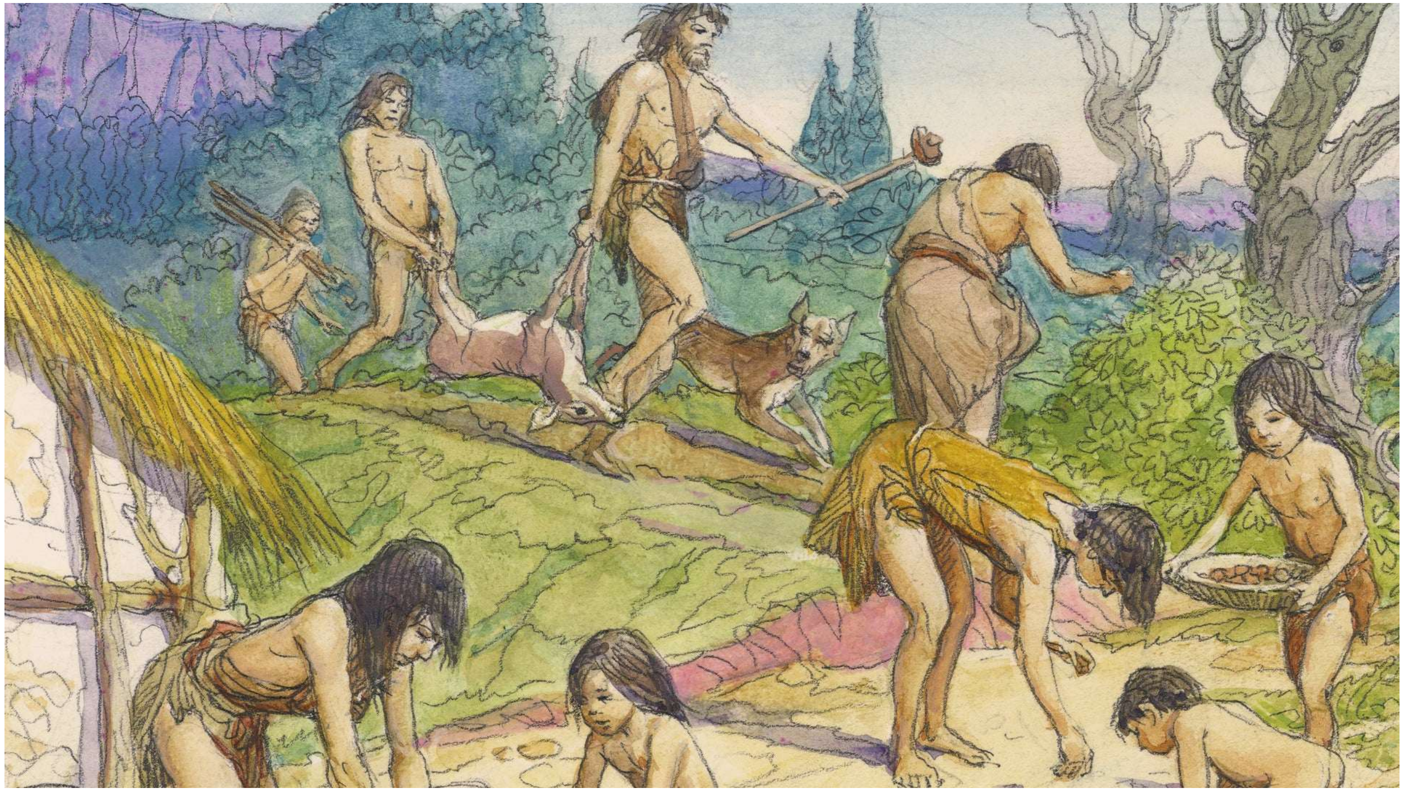
Energy use in early history

- Hunting and gathering for food
- Biological sources, originally from photosynthesis



https://www.history.com/

Energy use in middle ages

- **Animal labor**

https://www.history.com/

Energy use in middle ages

- ➢ **Wind**
- ➢ **Flowing water**

https://www.historyhttps://sailtraininginternational.org/vessel/eye-of-the-wind/.com/
Watermill of Braine-le-Château, Belgium (12th century)

Energy use in middle ages

- Increased use of wood for heating, cooking, and metallurgy.

- Replaced by coal in late 19th century

https://www.cozilogs.co.uk/

Energy use since the Industrial Revolution

- Started from the 1760s, sophisticated machines replaced human and animal labor in the manufacture and transportation of goods.

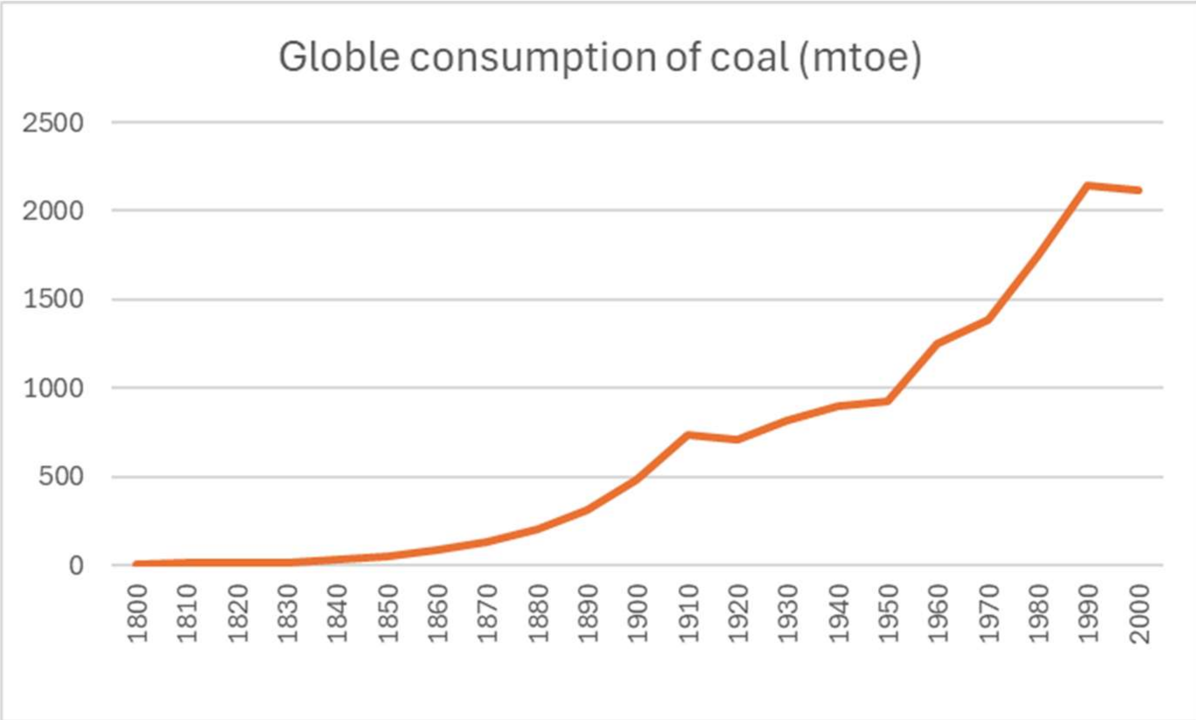
- Steam engines converting heat energy into forward motion was central to this transformation

https://science.howstuffworks.com/

Global use of coal

- Steam engine: first practical device converting thermal energy to mechanical energy

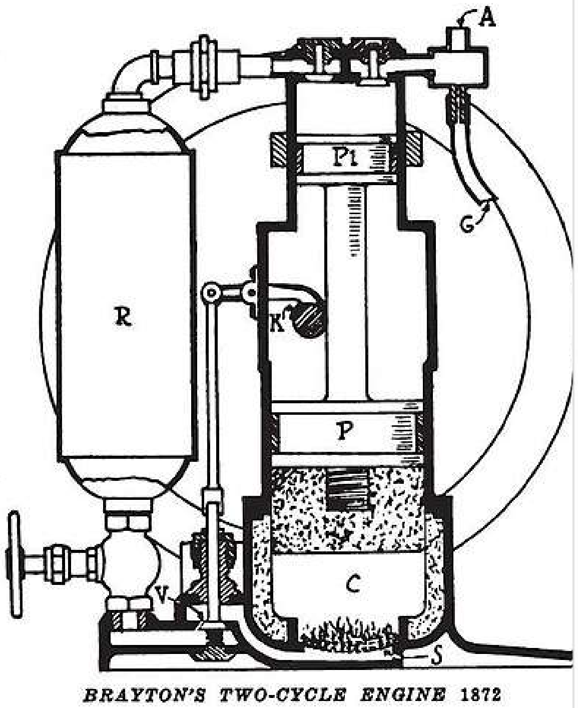
- Expanding factories



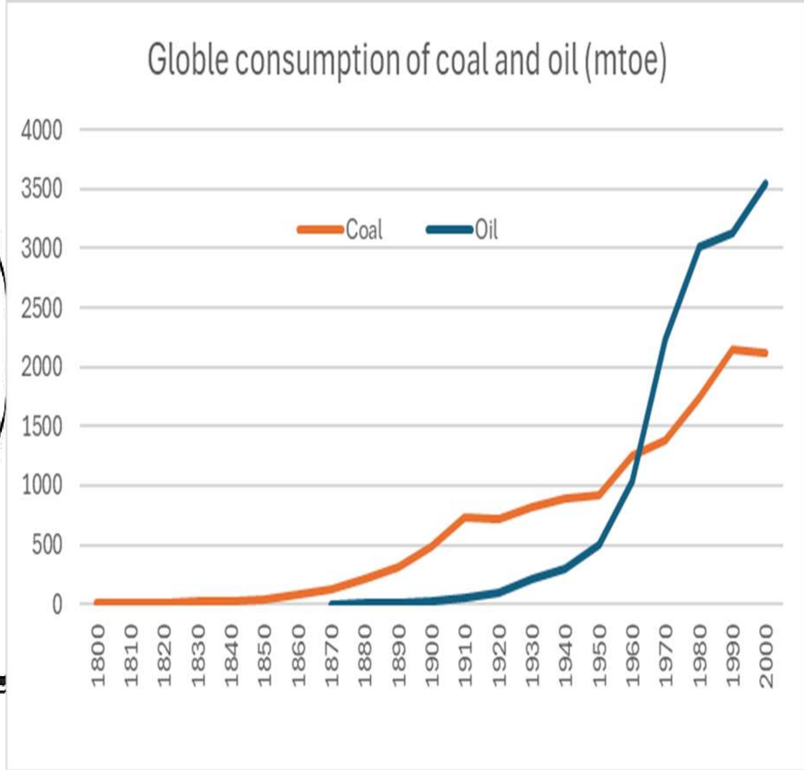
Mtoe: Millions of tones of oil equivalent
https://www.encyclopedie-energie.org/

Internal Combustion Engine

- 1872, commercial liquid-fueled internal combustion engine was invented
- Replaced stream engines in the 1900s because of the higher thermal efficiency, lower weight, and more compact structure.
- Increased the production of Oil



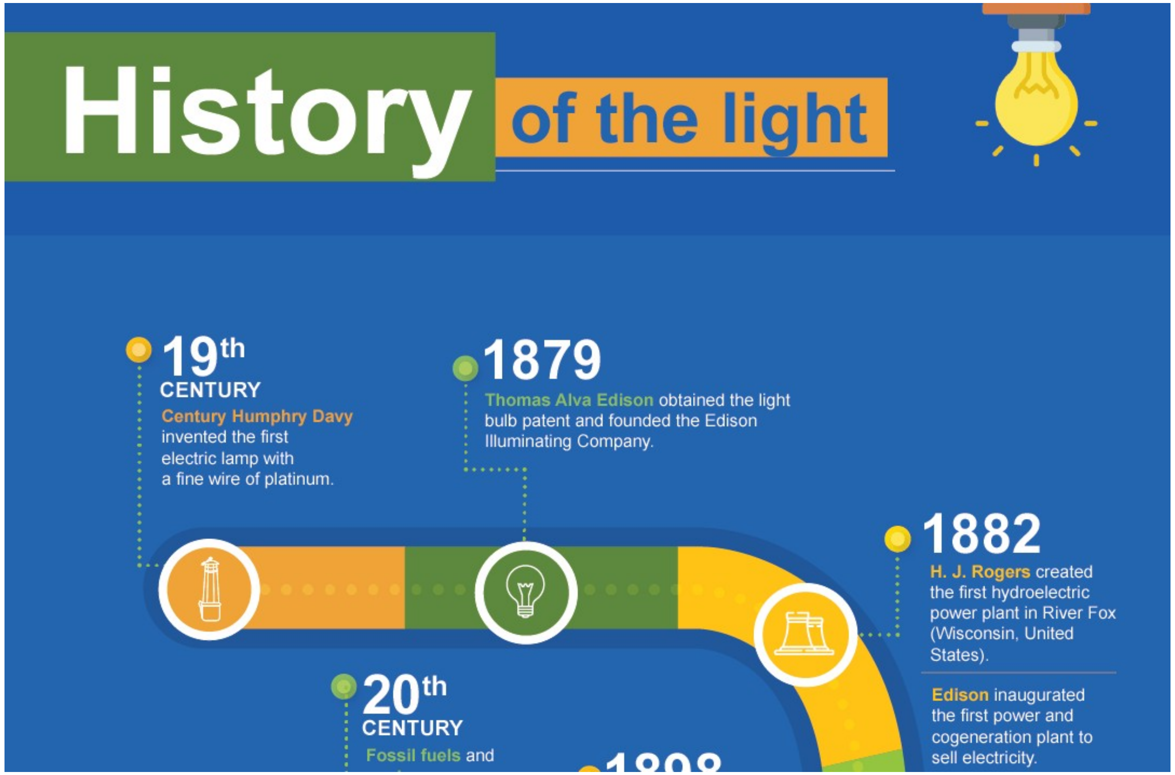
Brayton Gas engine 1872



Mtoe: Millions of tones of oil equivalent
https://www.encyclopedie-energie.org/

Electricity use

- Electricity was first commercially used for electric lightning in 1879.



[And then there was light: a brief history of electricity | Iberdrola México (iberdrolamexico.com)]

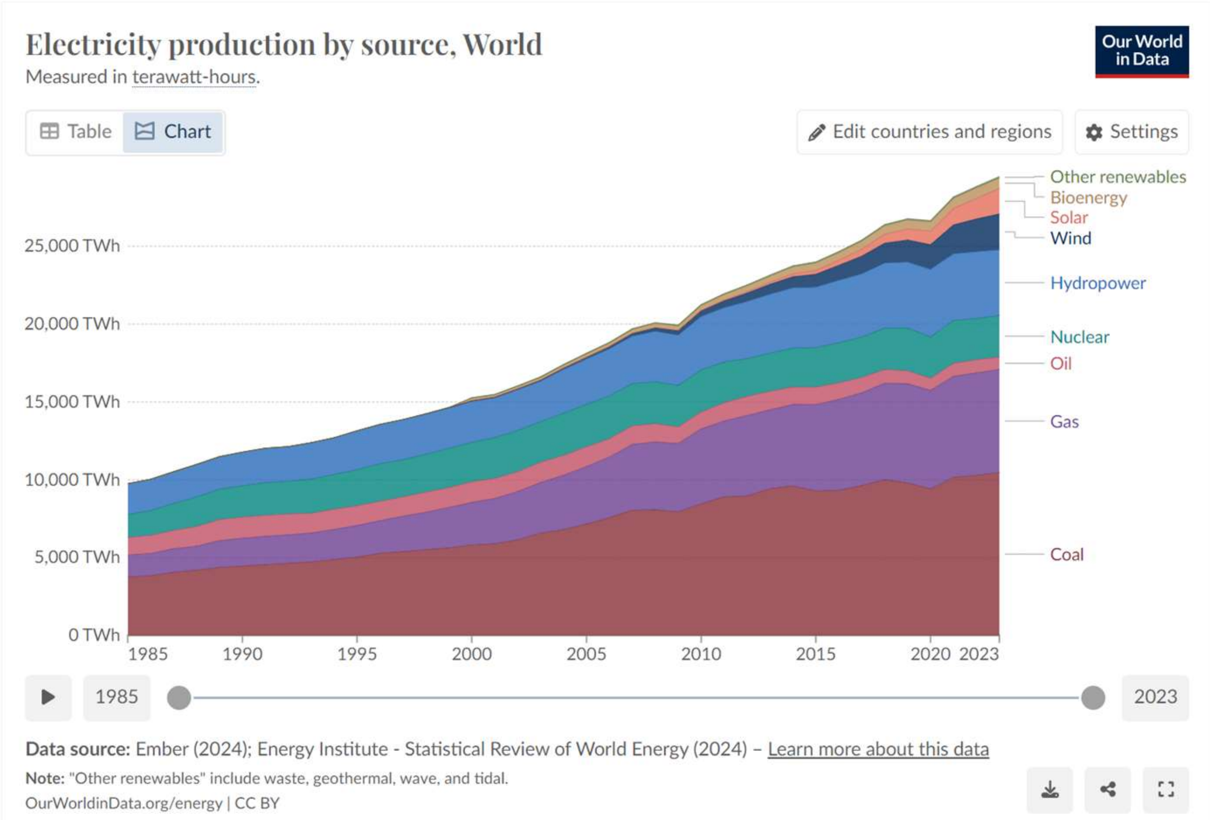
Electricity use

- Electric motors revolutionized industry, change power transmission
- Converting electrical energy into mechanical power
- Electric motors consume ≈50% of the world's electricity
- Residential use also increased quickly

http://www.vem-group.cn/products/low-voltage-motor.html

Electricity Production

- Production tripled since the 1980s
- Combustion of Coal and gases has been the primary source
- Other sources also increased quickly in recent years

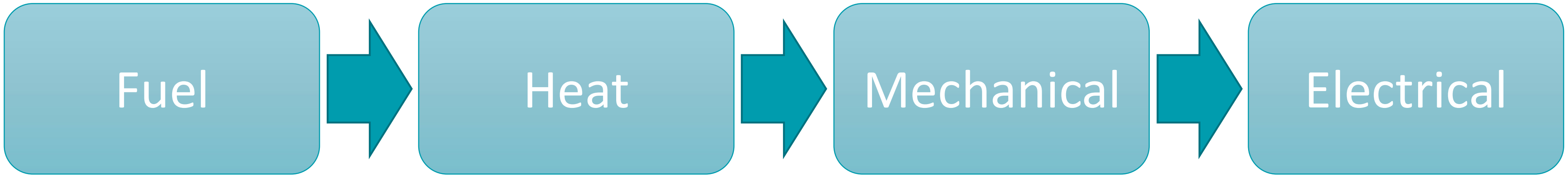


Outline

- History of Energy Use
- **Traditional Energy Production**
- Environmental Challenges Associated with Traditional Energy Production
- Renewable Energy: Opportunities and Challenges

Fossil Fuel Combustion for Electricity Production

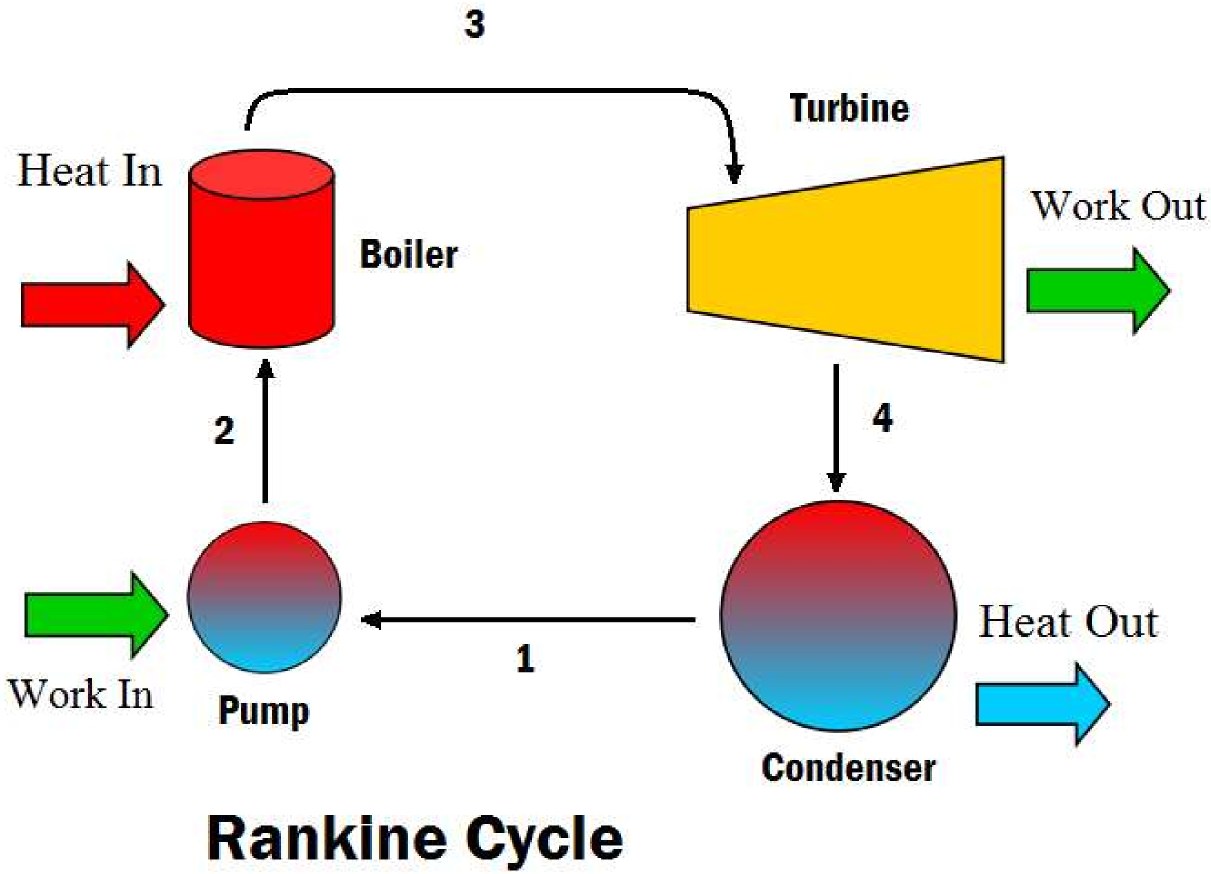
- **Converting fuel to heat, either through a boiler for systems that use water as the working fluid or a combustion chamber for gas-fired systems**
- **A turbine is used for converting heat energy to mechanical energy**
- **A generator for converting mechanical energy to electrical energy**



Credit to Prof. Yunlong Zi

Electricity production through coal burning: Rankine Cycle

- Combustion cycle that uses fuels to produce electricity
- Including 4 major steps: compress/heat water to vapor → expand the vapor through a turbine → generate mechanical energy

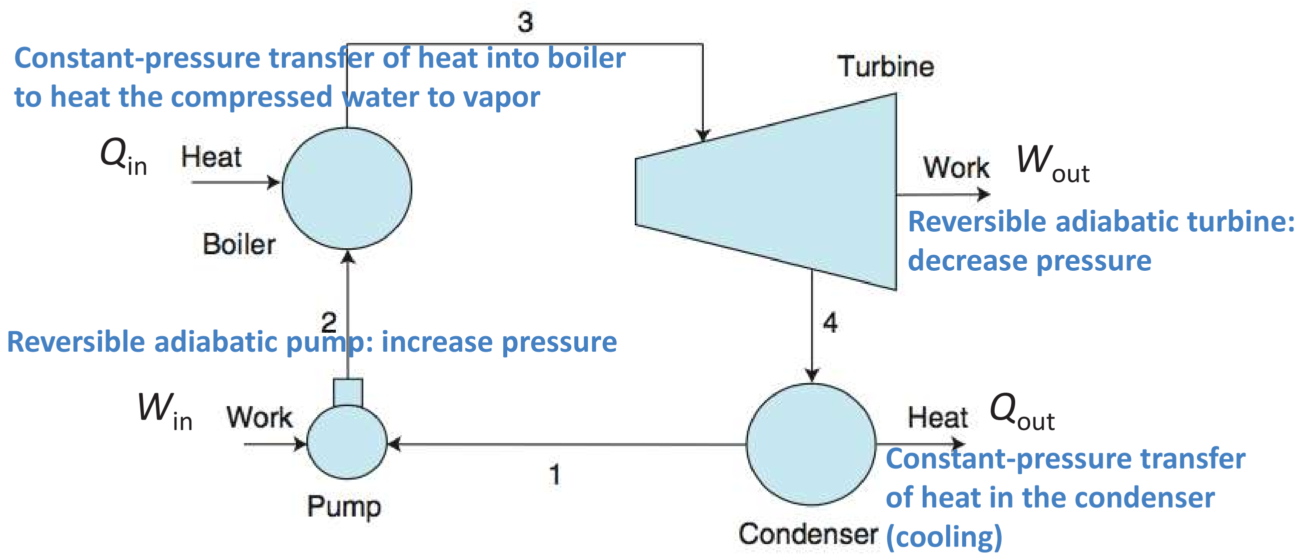


Rankine Cycle

$$\eta = \frac{W_{out} - W_{in}}{Q_{in}}$$

- With efficiencies around 30%

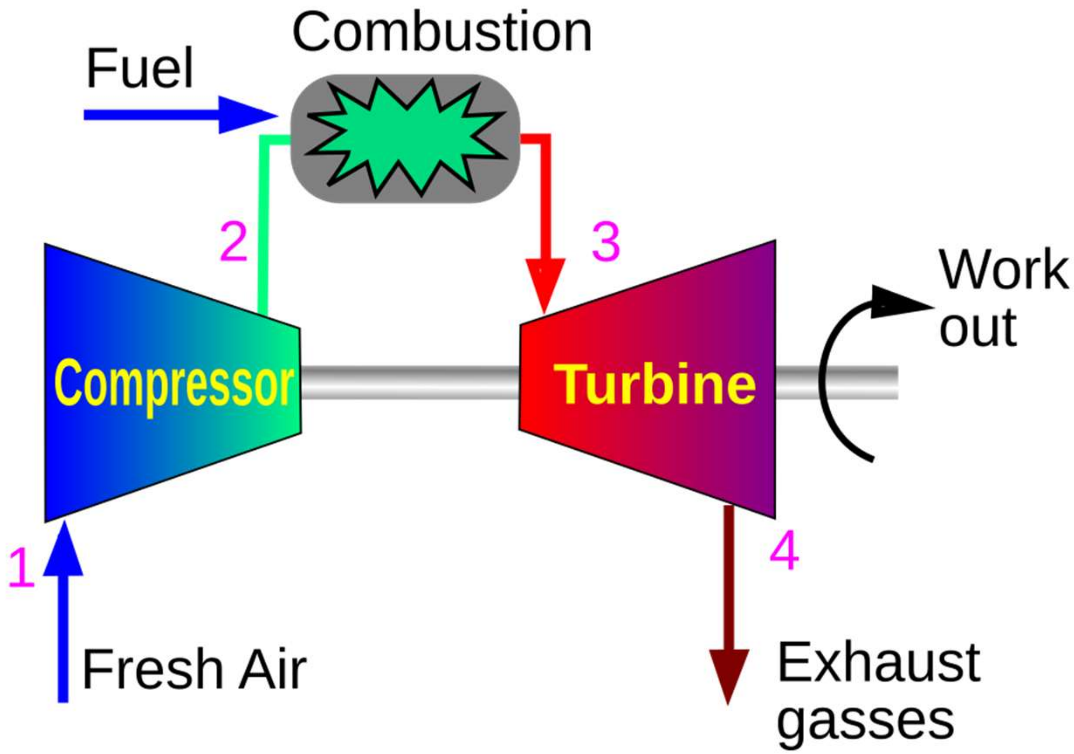
Schematic of components in an ideal Rankine device



Credit to Prof. Yunlong Zi

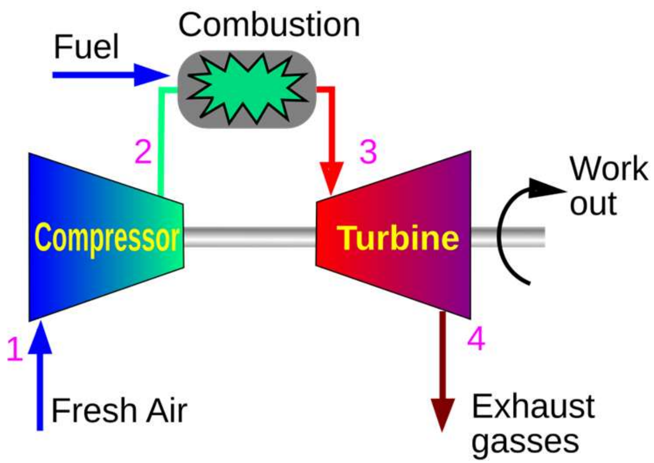
Electricity production through gas burning: Brayton Cycle

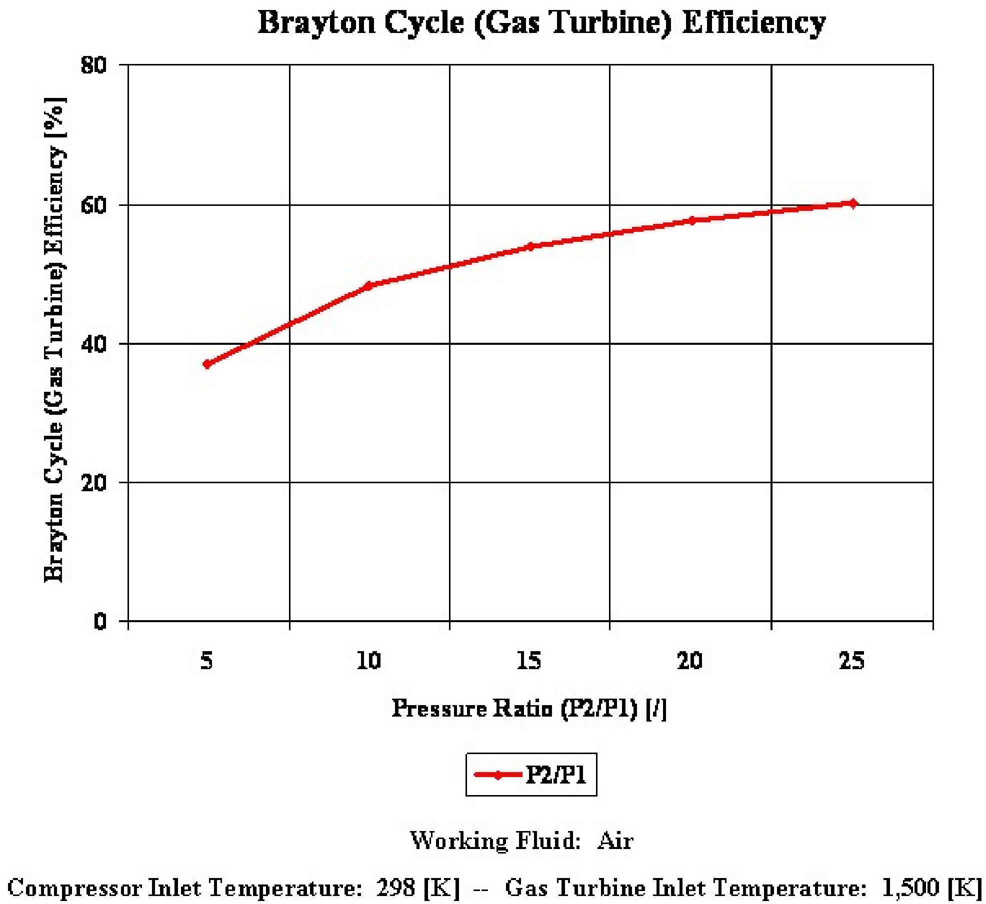
- A gaseous working fluid is used in Brayton cycle
- Atmospheric air encounters isentropic compression to the max. system pressure
- Fuel is injected to the combustor and combusted at constant pressure to heat the gases to the highest temperature
- Isentropic expansion to create the output work



Brayton Cycle: Gaseous Fuel and Gas Turbine

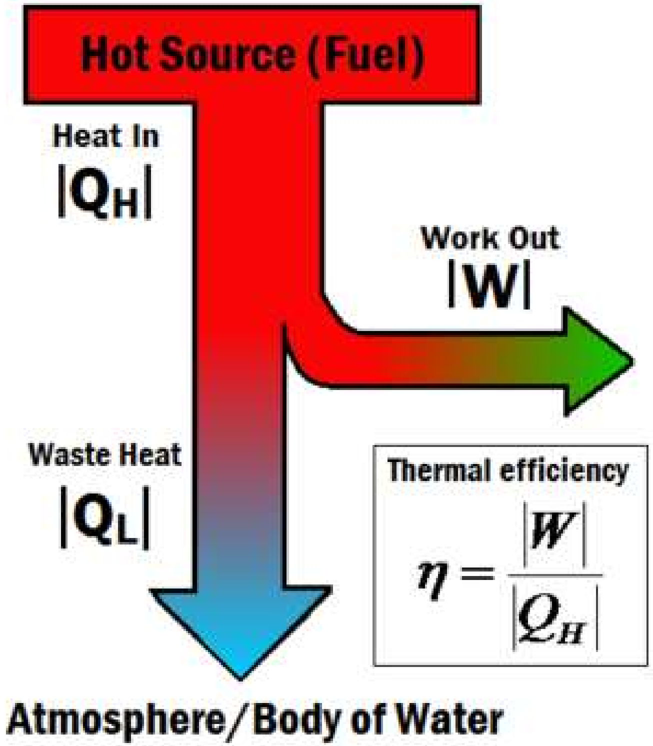
- With efficiency ranging from ~40 to 60%。
- Efficiency increases with pressure ratio





Advanced Combustion Cycles for improving efficiencies

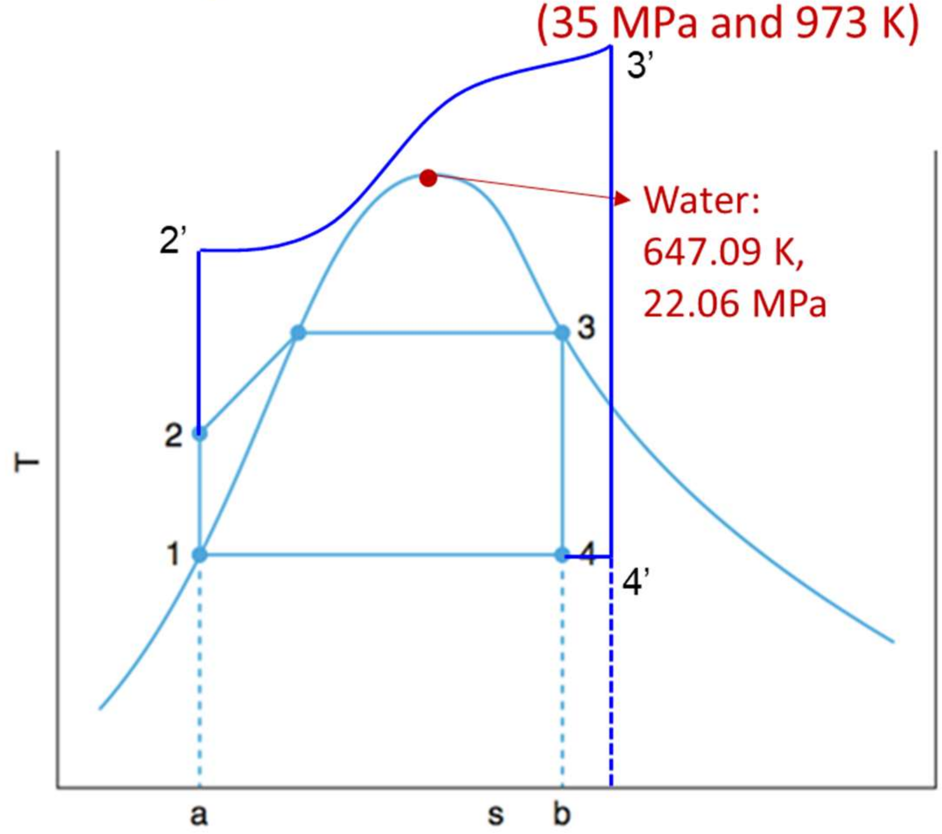
- Three major ways to improve efficiencies:
  - ✓Supercritical cycle
  - ✓Combined cycle
  - ✓Cogeneration



Supercritical cycle

- The sufficient compressed liquid in the boiler could be heated exceeding the critical pressure

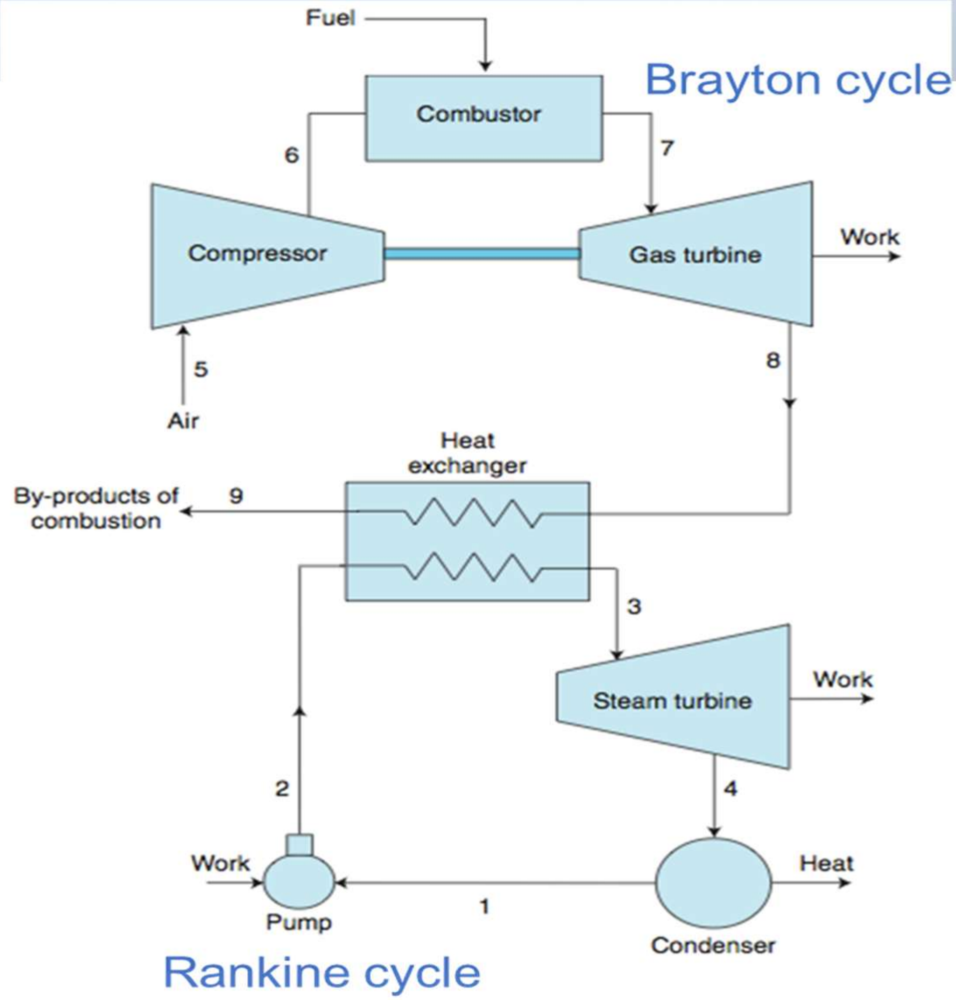
T-s diagram for the ideal Rankine cycle



Combined Cycle

- The remaining energy in the exhaust from the gas turbine can be put to reuse to increase overall system output

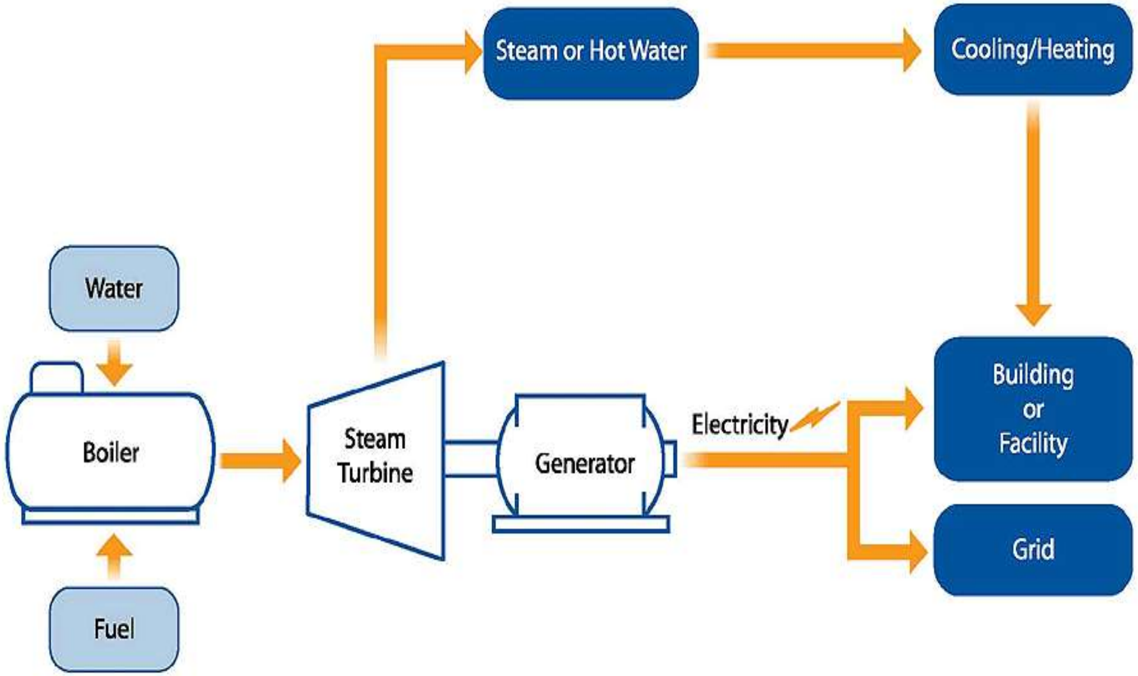
Schematic of combined cycle system



https://www.knick-international.com/zh/process-analytics

Combined Heat and Power (CHP)

- A single source of energy, such as a fossil fuel, is used for more than one application
- Combustion turbine or reciprocating engine CHP systems burn fuel to turn generators to produce electricity and use heat recovery devices to capture the heat from the turbine or engine.
- This heat is converted into useful thermal energy, usually in the form of steam or hot water.



https://www.epa.gov/chp/what-chp

Outline

- History of Energy Use
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- **Environmental Challenges Associated with Traditional Energy Production**
- Renewable Energy: Opportunities and Challenges

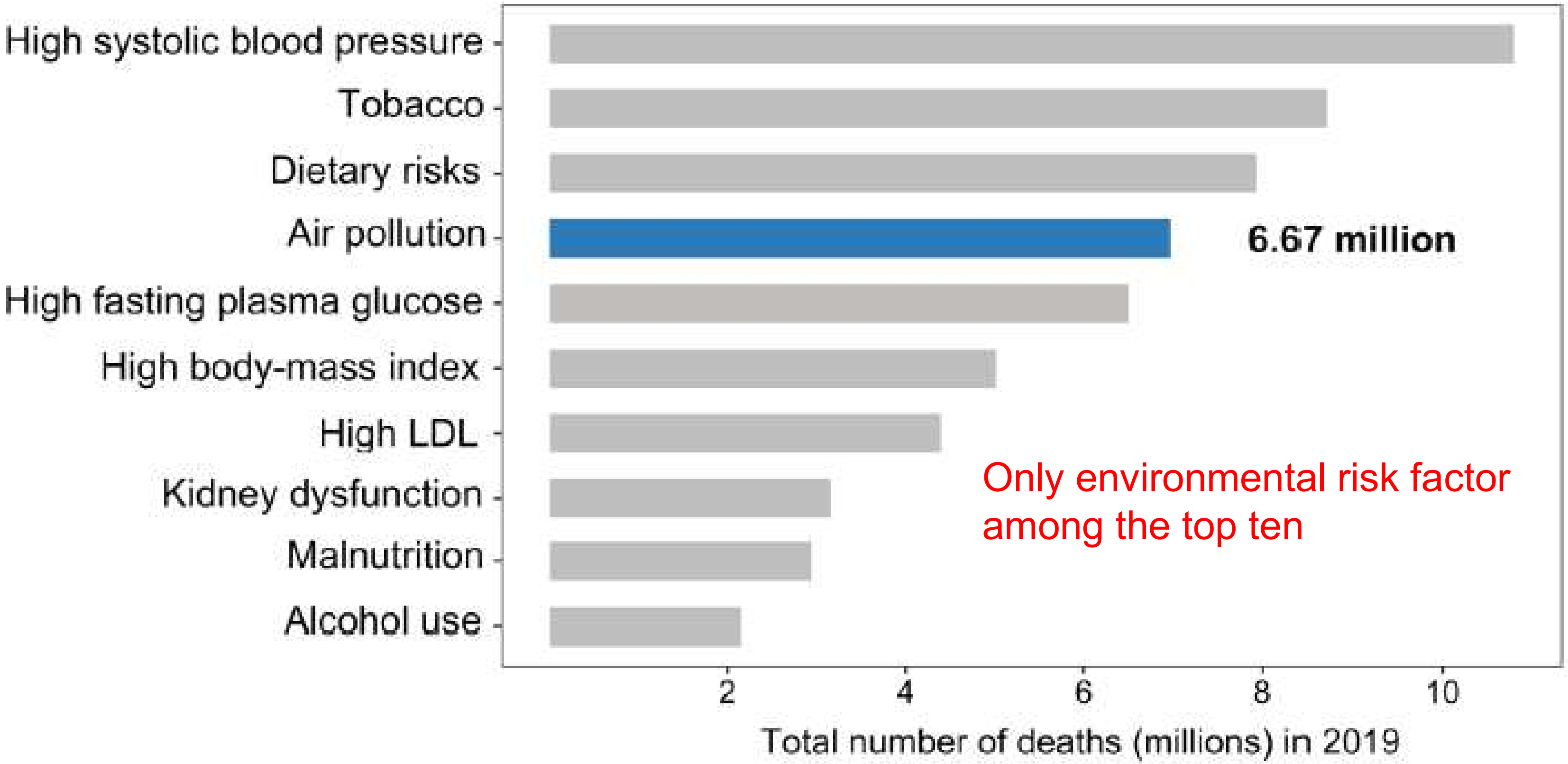
Environmental problems of fossil fuel combustion

- NO_X
- SO2
- Particulate
- Mercury and other heavy metals
- Ash
- Smog and acid rain

https://grist.org/climate-energy/coal-plant-pollution-can-be-deadly-even-hundreds-of-miles-downwind/

Health effect - Air Pollution causes death!

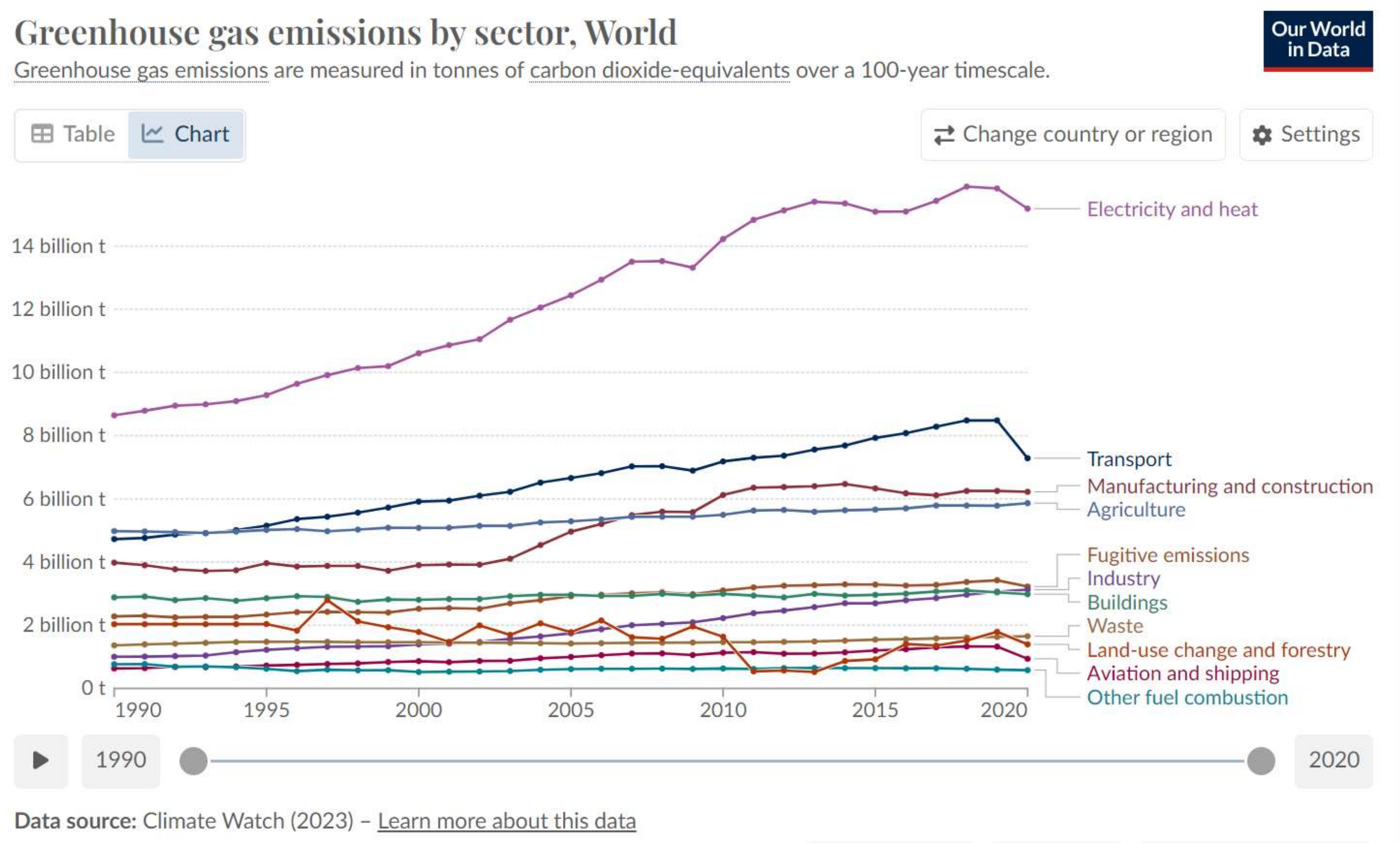
FIGURE 1 Global ranking of risk factors by total number of deaths from all causes in 2019.



Credit to Prof. Ting Fang

Carbon emission

- Electricity and heat production is the primary contributor of the global greenhouse gas emission



Outline

- History of Energy Use
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- **Renewable Energy: Opportunities and Challenges**

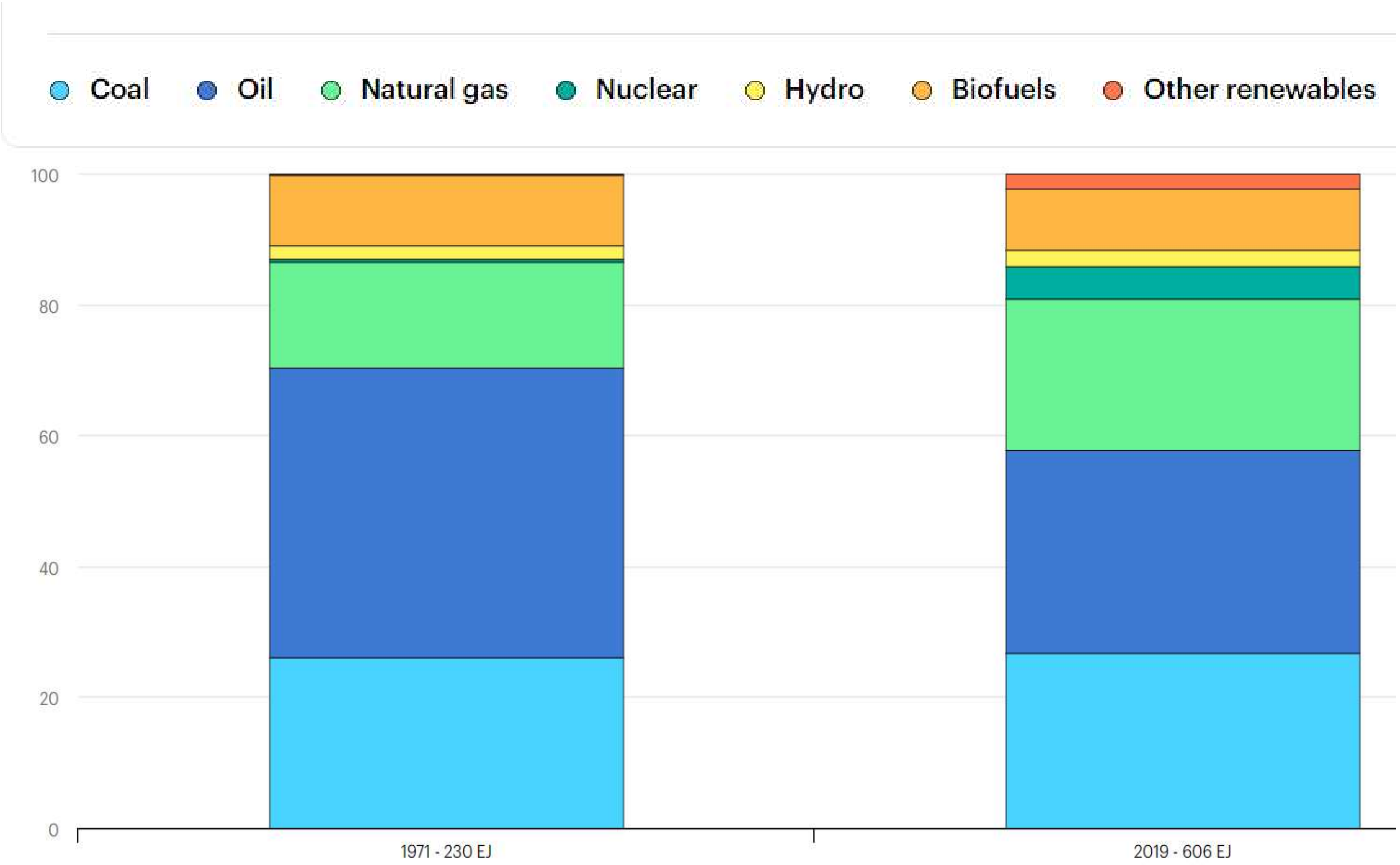
Renewable energy: opportunities and challenges

- **Wind**
- **Solar power**
- **Biofuel**

https://www.jasc.ch/the-top-5-renewable-energy-sources-for-homes

Renewable energy

- Total energy production increased by 160% since 1971
- Renewable energy account for 14.1% of total energy production in 2019

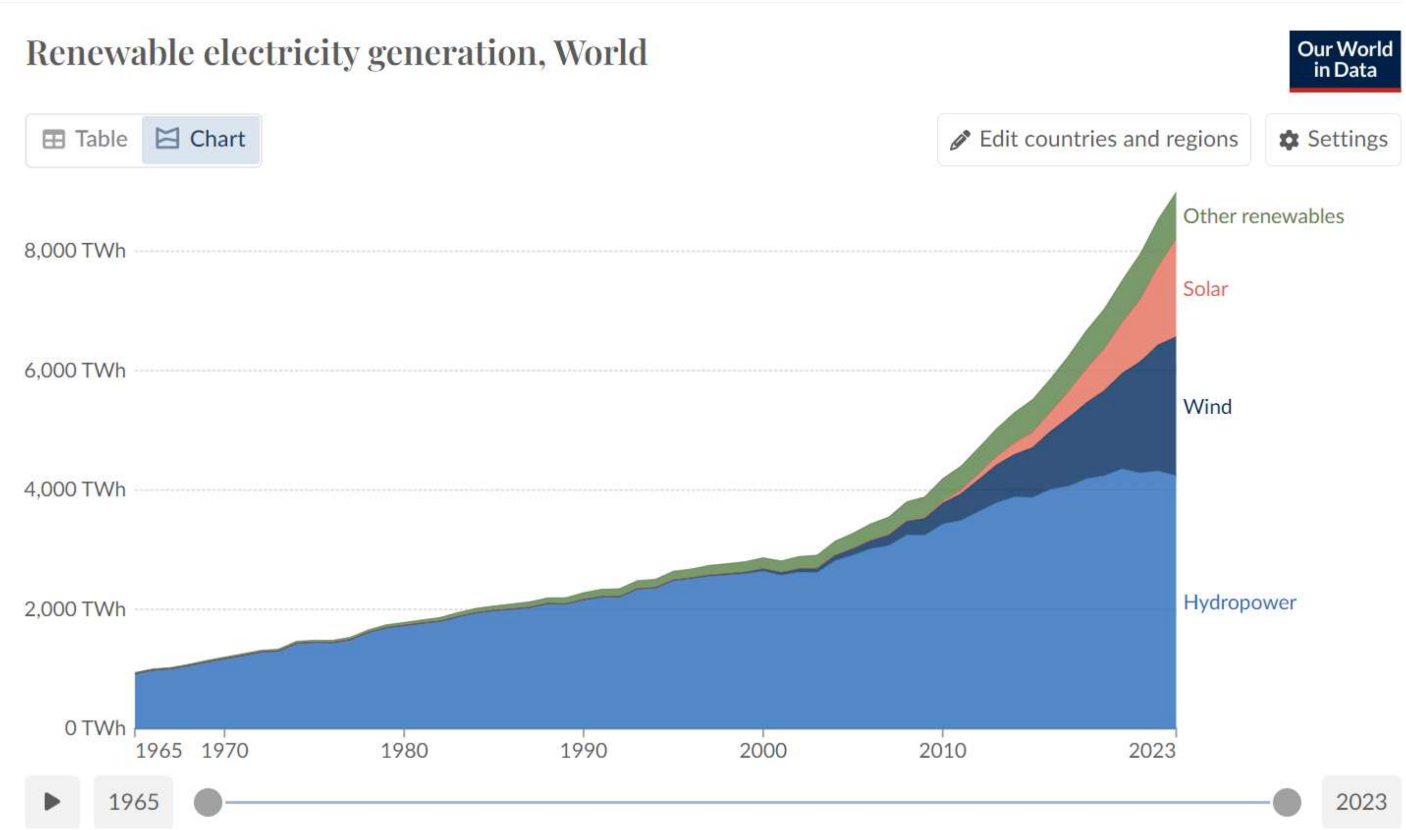


https://www.iea.org/reports/world-energy-balances-overview/world

Renewable energy

- Wind and solar are the becoming critical sources of renewable energy.

- Increased quickly since the 2000

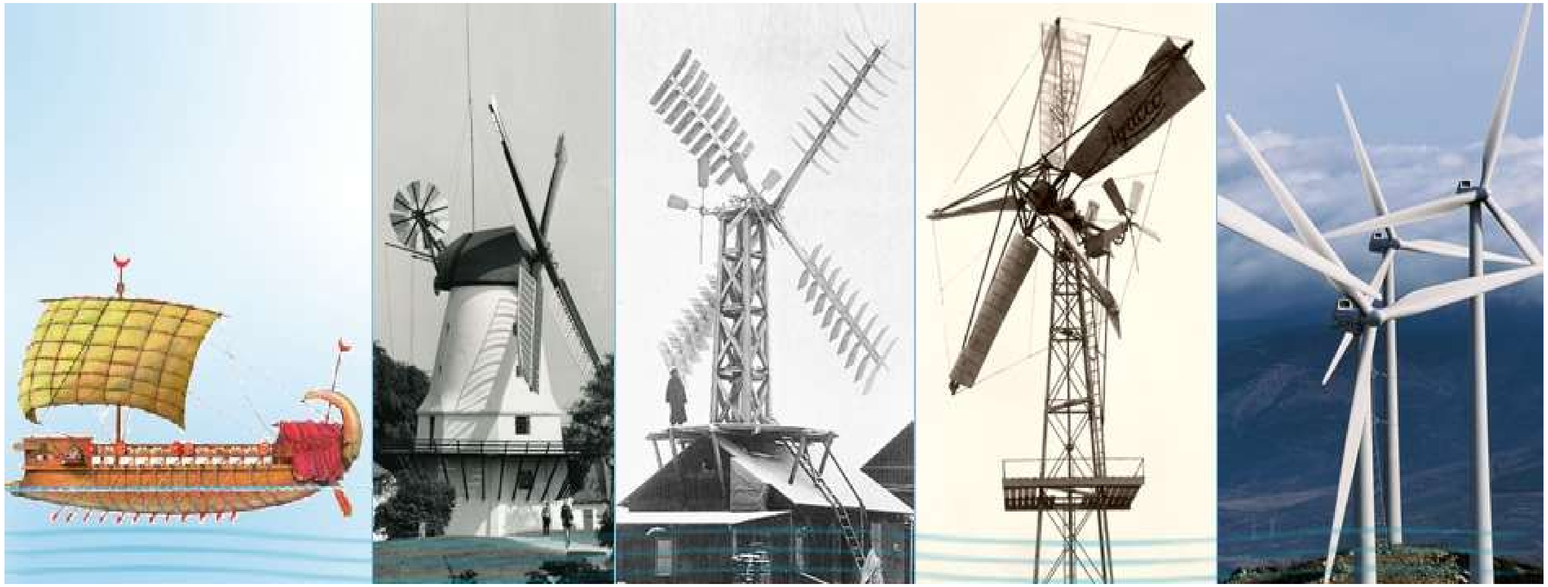


https://ourworldindata.org/renewable-energy

Large wind farms across the world

Wind energy

- Historical developments of wind power
  - ✓Sailing Ships, Grinding Grain, Pumping water, Power Source of Factories

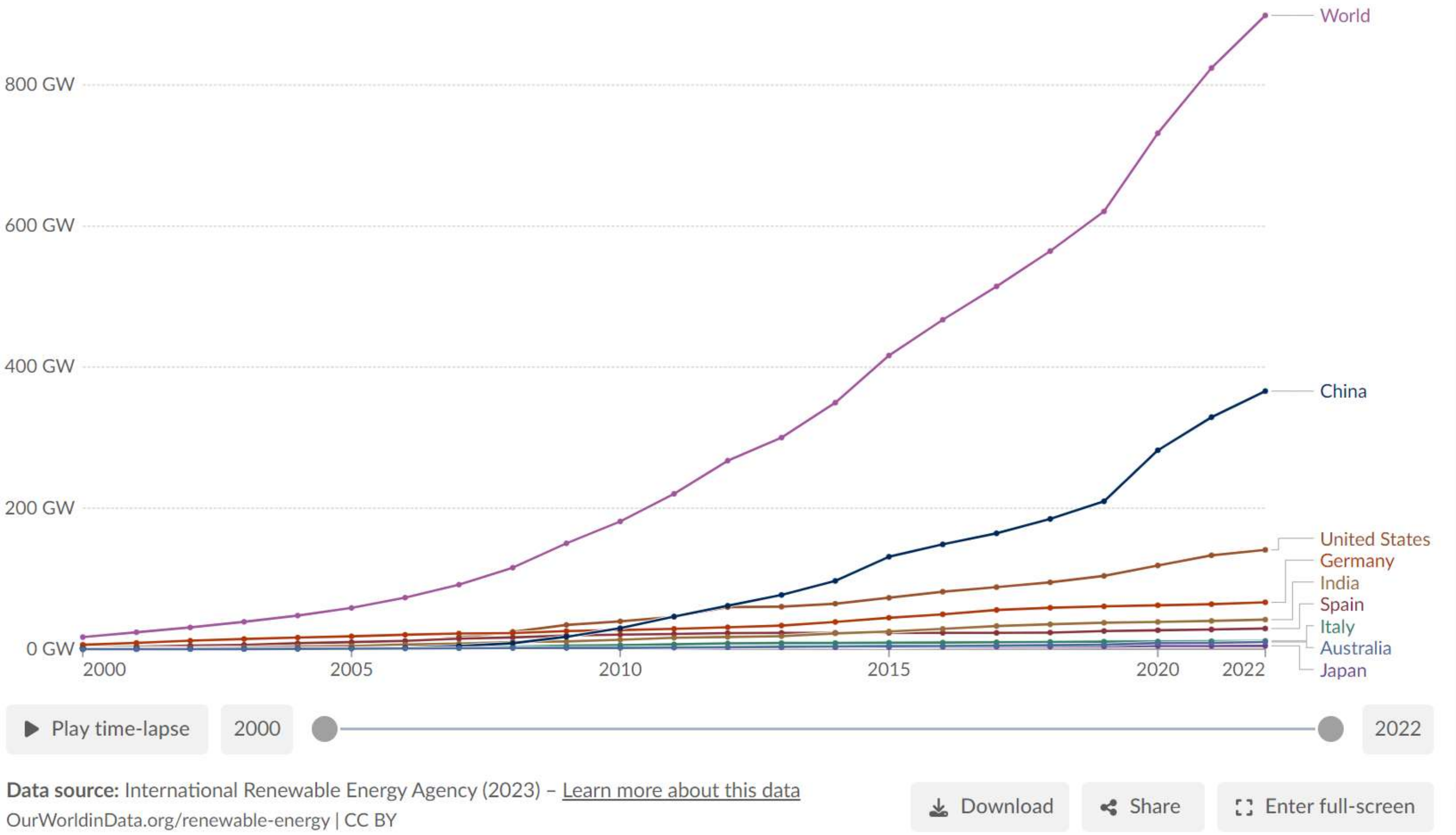


Credit to Prof. Yunlong Zi

Worldwide Installed Wind Power Capacity

- Installed capacity increased quickly since 2000

- China and the U.S. are the top two countries of the installed capacity



Wind power

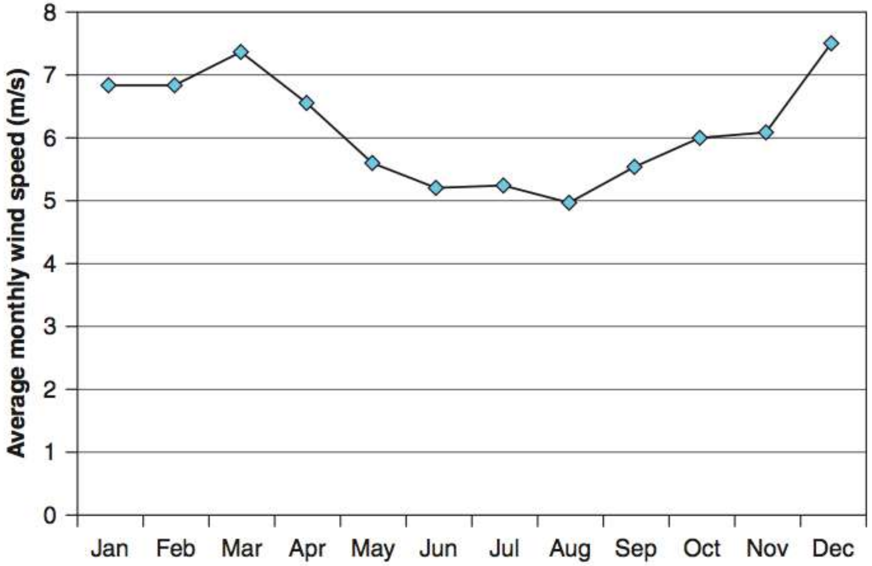
- Global onshore and offshore wind generation potential at 90m turbine hub heights could provide 872,000 TWh of electricity annually. Total global electricity use in 2022 was 26,573 TWh.
- However, vast wind energy available is too far from the earth surface, and in remote areas
- The wind power is highly variable
  - ✓During time of little wind: Require alternative energy supplies
  - ✓During time of extremely high wind: protect wind energy harvesting device from damage

https://css.umich.edu/publications/factsheets/energy/wind-energy-factsheet

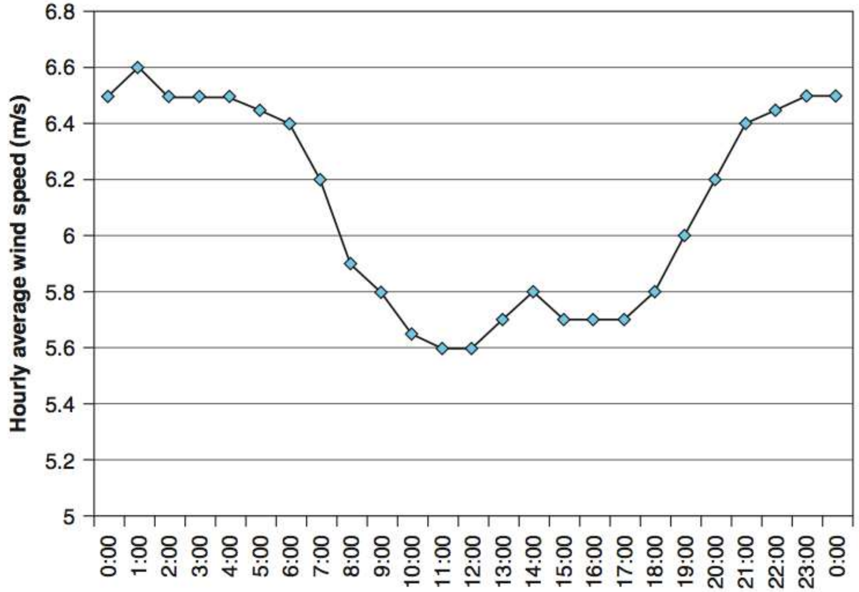
Temporal variability of wind speed

Enfield, New York, wind farm site (height =58m)

Seasonal distribution of wind speed in m/s



Hourly distribution of wind speed

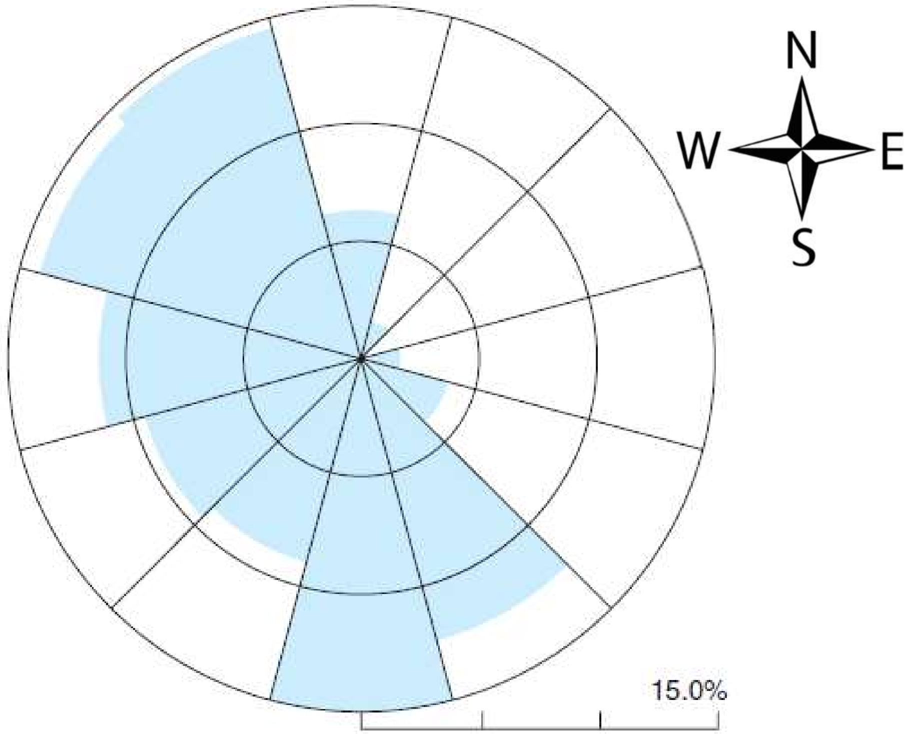


Credit to Prof. Yunlong Zi

Effect of wind direction

- Varied wind direction
- Design wind turbine like a "sunflower"

Percentage time distribution of wind direction

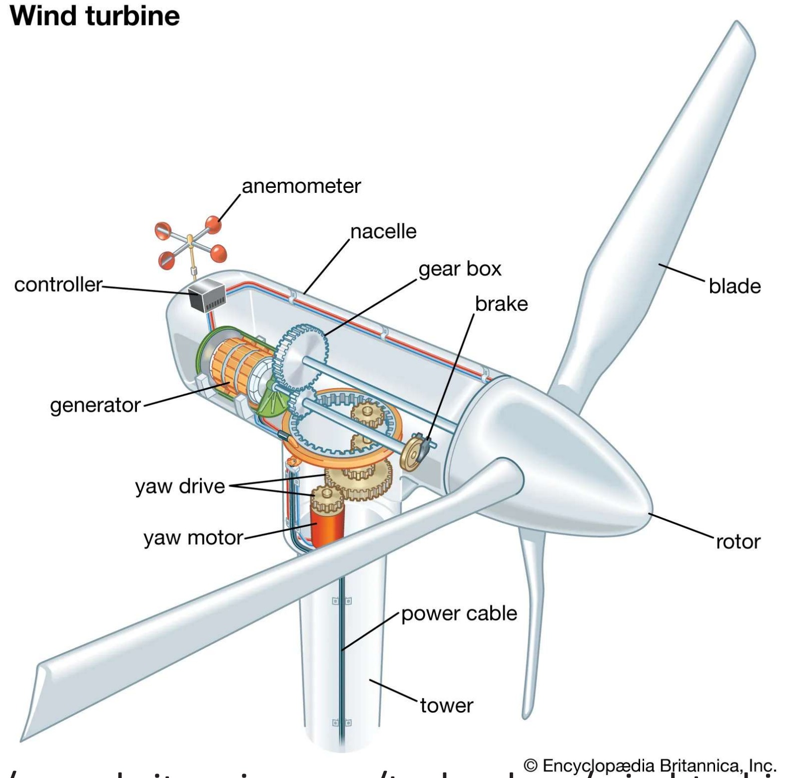


Credit to Prof. Yunlong Zi

Wind Turbine

- The rotor blades convert wind energy into mechanical energy
- The blades turn the main shaft that turns the electric generator

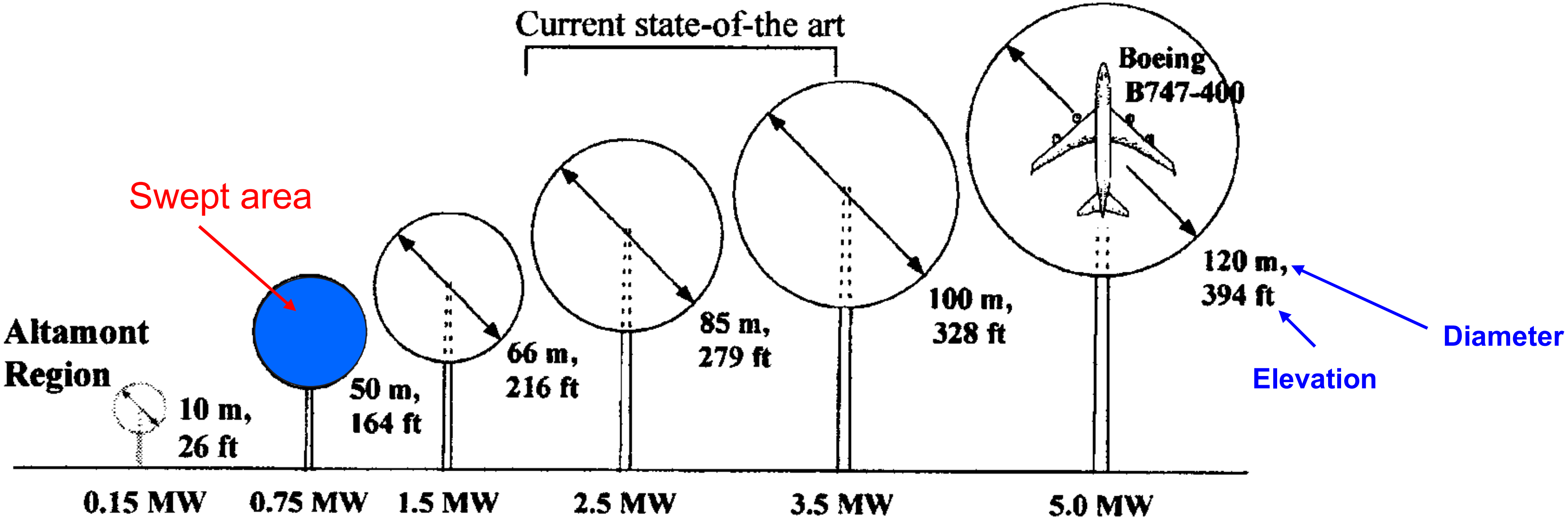
https://nsci.ca/2019/07/17/wind-power/



https://www.britannica.com/technology/wind-turbine

Blade size

- Larger area, higher power; but requires better technology

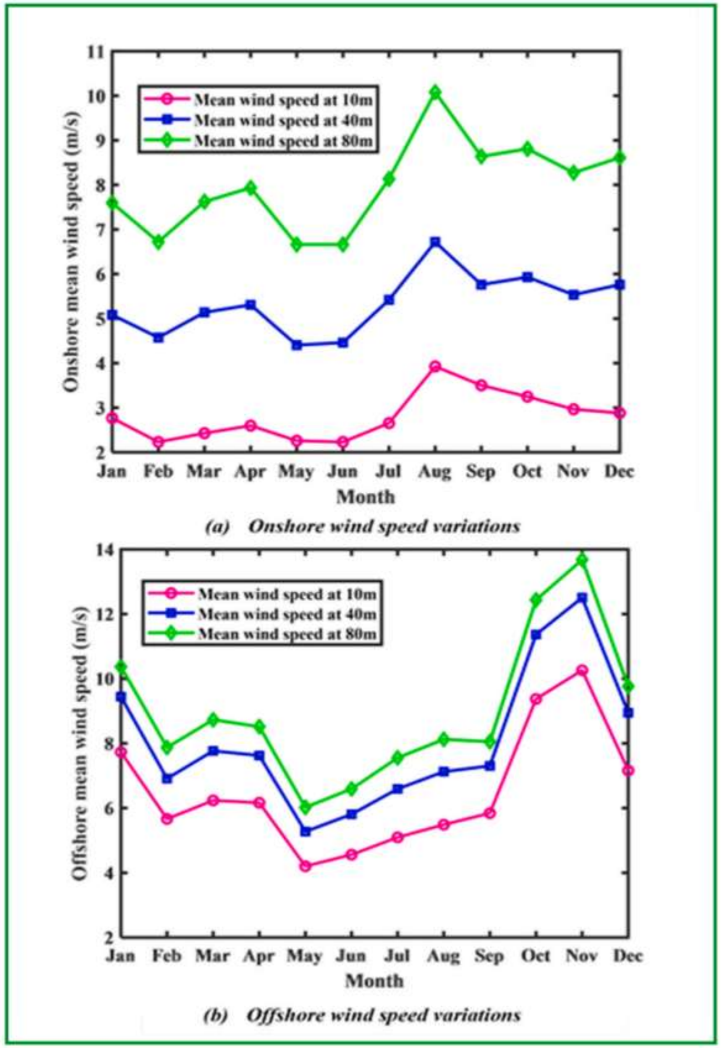


Credit to Prof. Yunlong Zi

Onshore vs. Offshore wind

- Offshore sites have higher wind energy potential
- Most existing wind farms are onshore
- More offshore wind farms are being built

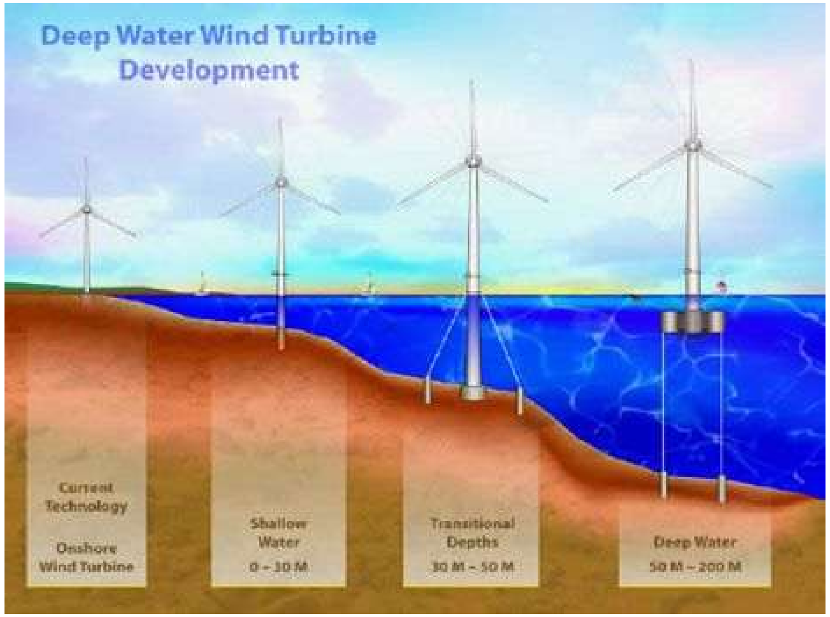
Desalegn, 2023

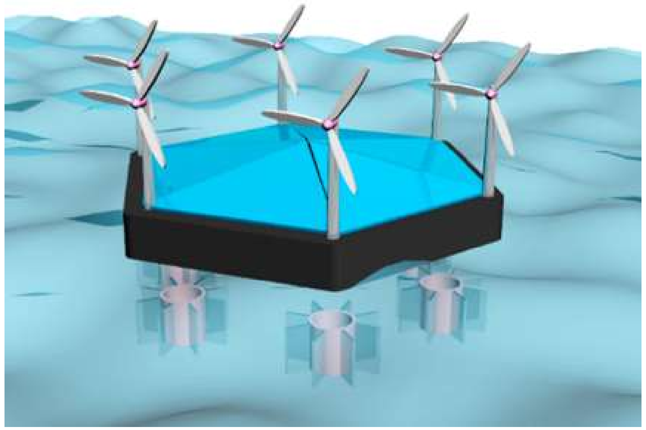


Year	I. Historical Data (GW)	
	(IRENA (2021), *Renewable Energy Statistics, 2021 The International Renewable Energy Agency, Abu Dhabi.*, n.d.; IRENA-International Renewable Energy Agency, 2023; Renewable Energy AgencyI, 2022)	
	Onshore	Offshore
2011	216.344	3.776
2012	261.579	5.334
2013	292.705	7.171
2014	340.816	8.492
2015	404.458	11.717
2016	452.515	14.342
2017	495.381	18.837
2018	539.888	23.626
2019	593.291	28.355
2020	698.043	34.367
2021	769.196	55.678
2022	836	63

Onshore wind technology (in water)

- Cons: more expensive considering the complexity of underwater foundations.
- Pros: higher average wind speed; possible to build larger blade
- “Floating” turbine design in development



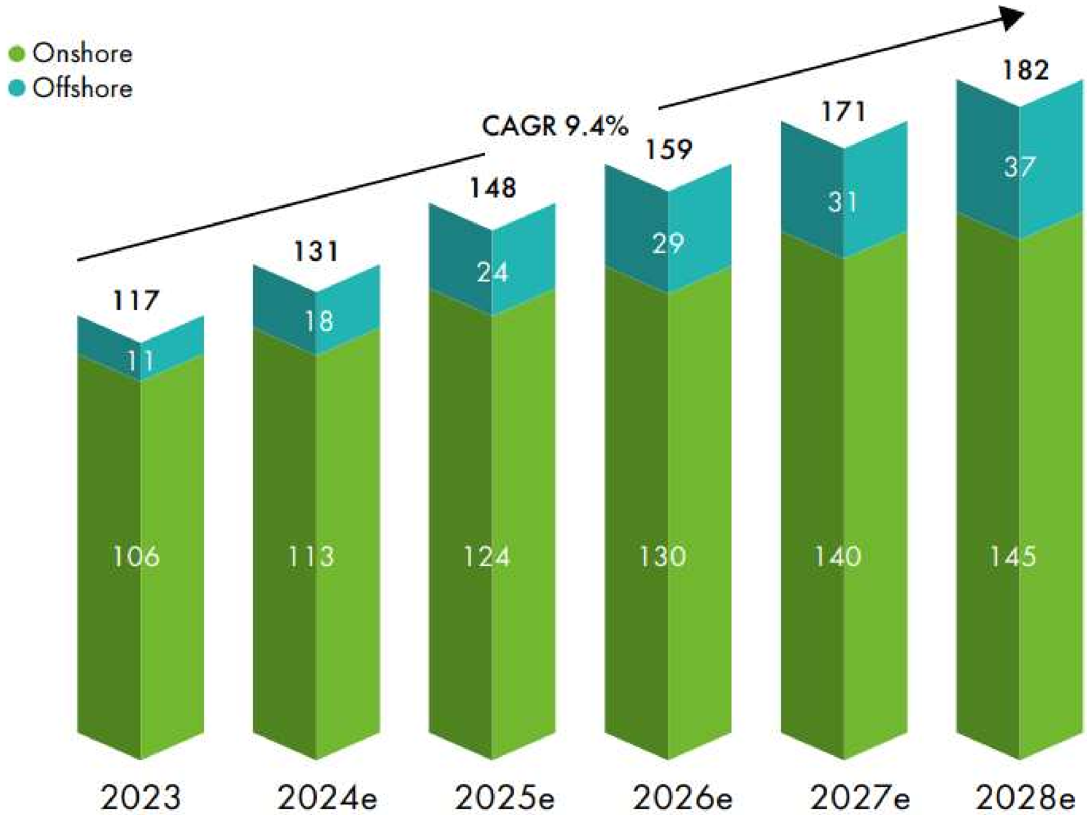


proposed comprehensive energy harvesting panel

Credit to Prof. Yunlong Zi

Future directions of Wind Power

- The projected growth rate for the next five years is close to 10%
- Growth in China, Europe and the US will remain the backbone of global onshore wind development in the next five years.
- China will continue to be the growth engine in the near term, making up more than 60% of total installations in 2024.



Future directions of Wind Power

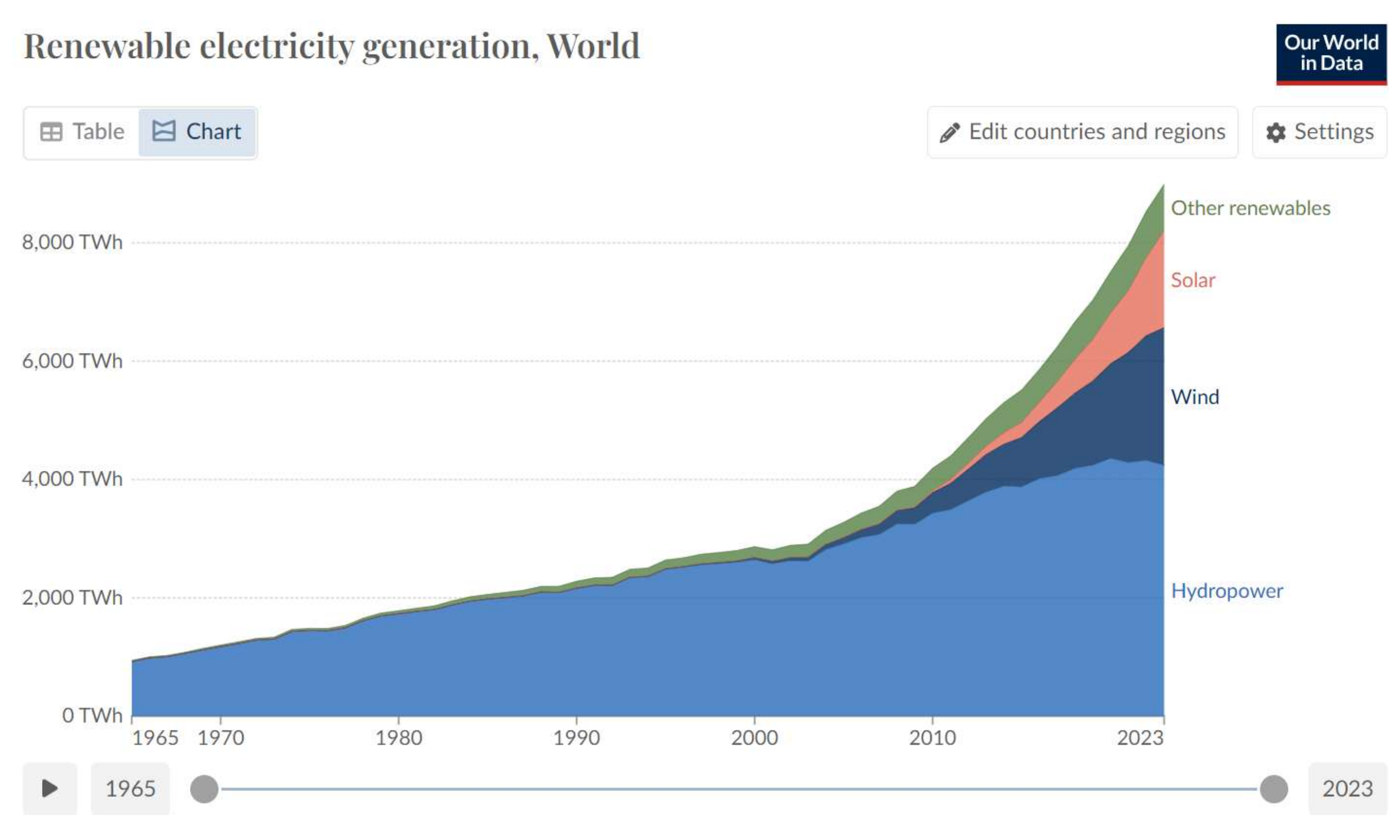
- Maximize turbine blade size (150 – 200 m diameter)
- Offshore turbines on floating platforms, moored to bottom
- Dynamic tuning of blades in real time to respond to changes in wind, maximize output

Solar energy

- Solar energy: enormous, nonpolluting, and inexhaustible
- Solar energy systems: direct convert solar energy
- Rapid growth from a small scale

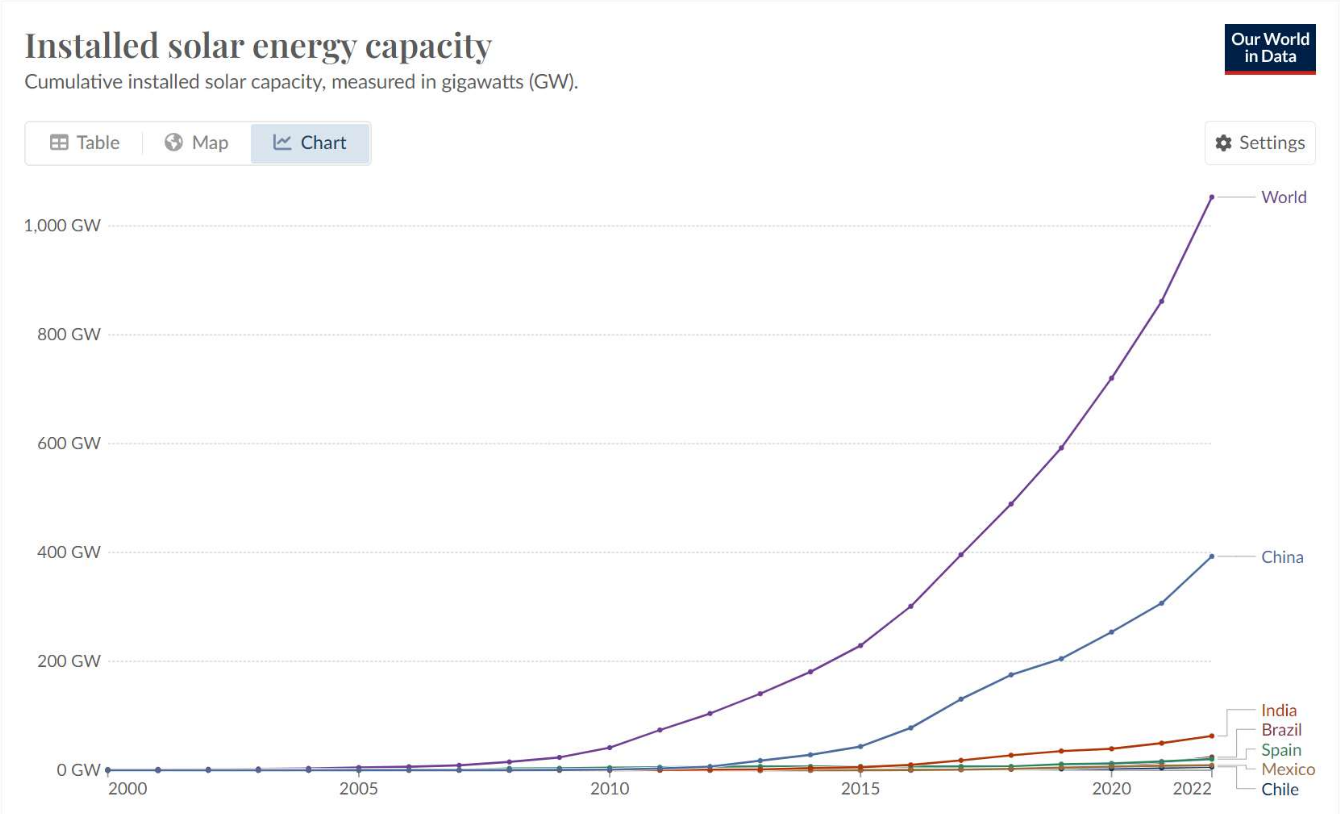
https://sempower.com/fun-facts-about-solar-energy/

Solar Energy



https://www.iea.org/energy-system/renewables

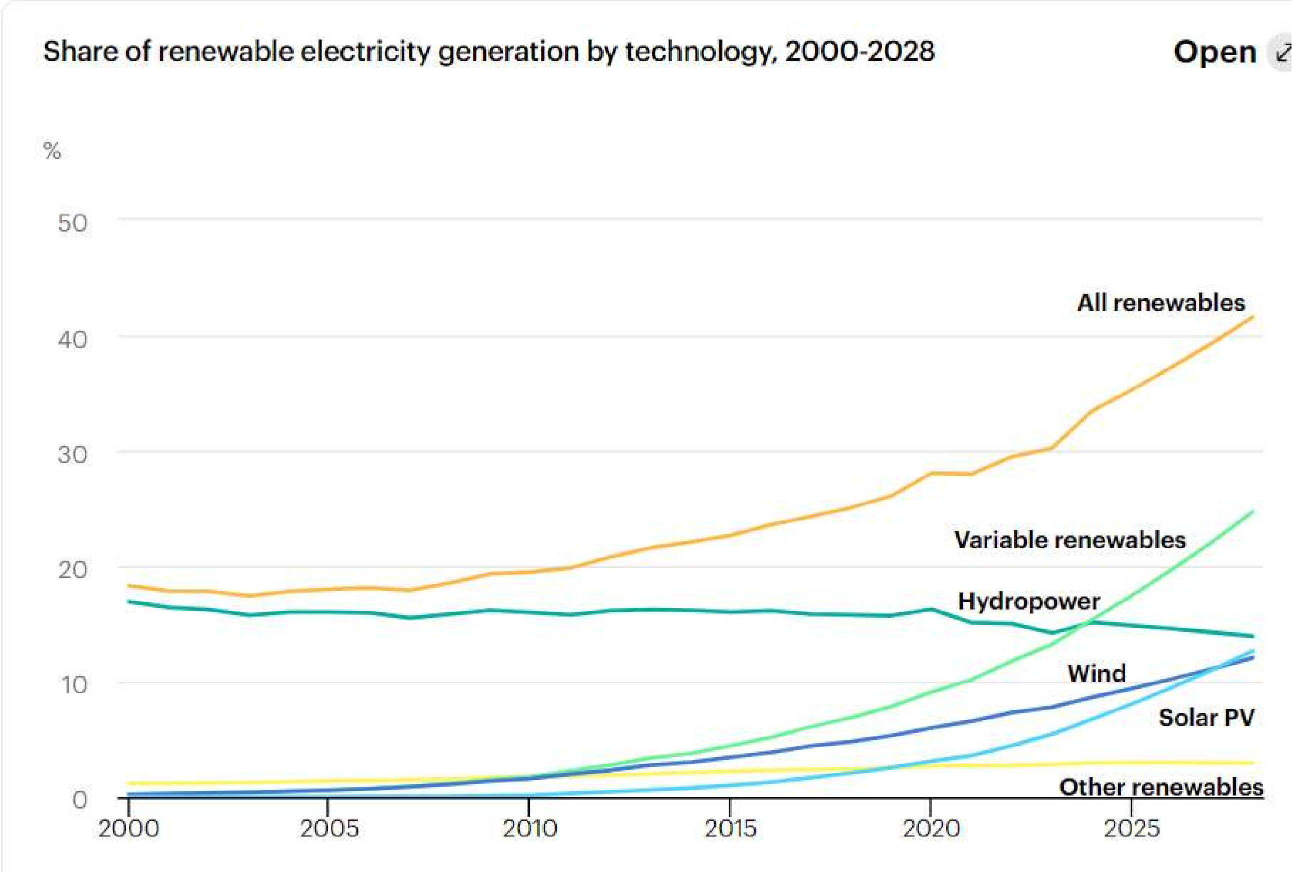
Solar Energy



[Installed solar energy capacity (ourworldindata.org)](https://ourworldindata.org)

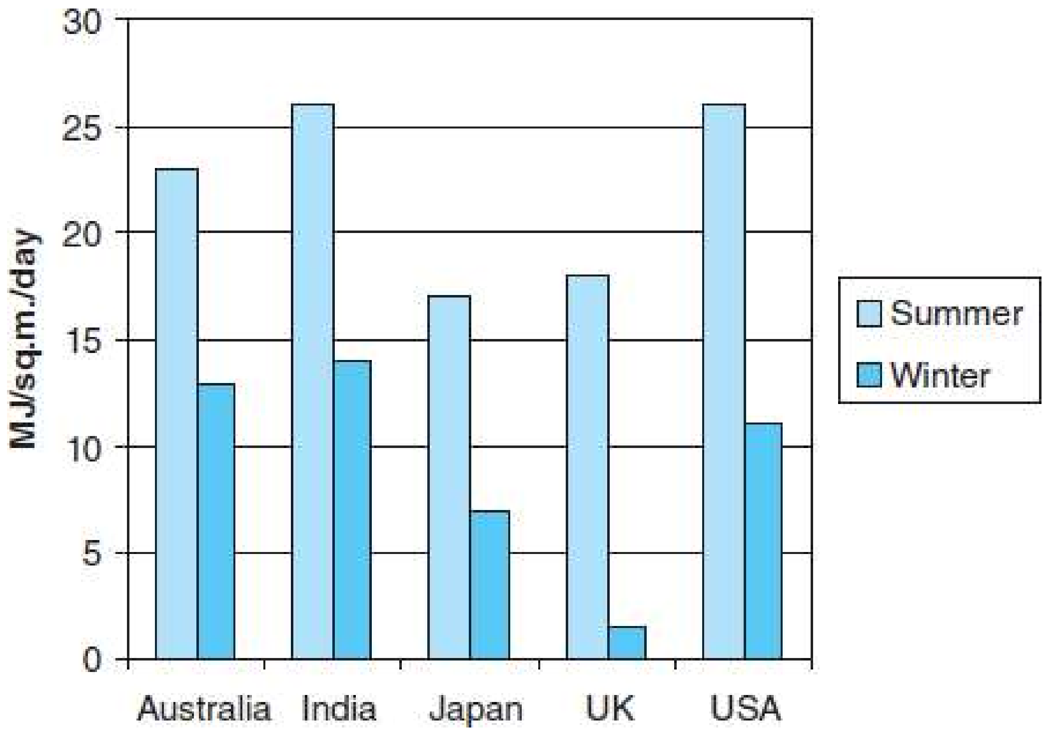
Solar Energy

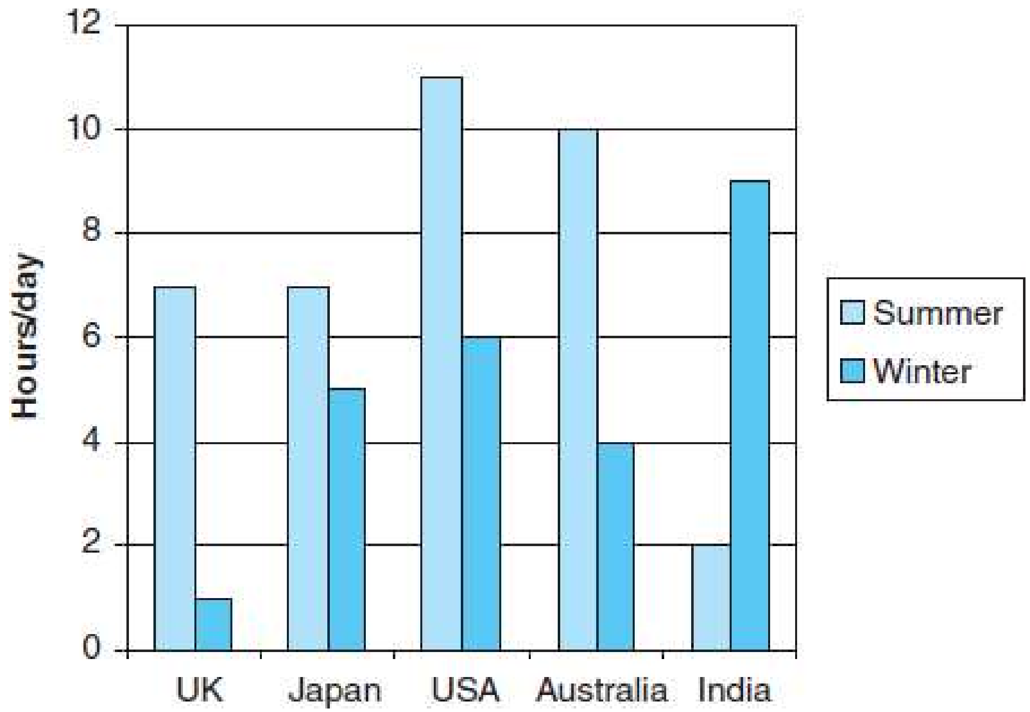
- In 2024, wind and solar PV together generate more electricity than hydropower.
- In 2025, renewables surpass coal to become the largest source of electricity generation.
- Wind and solar PV each surpass nuclear electricity generation in 2025 and 2026 respectively.
- In 2028, renewable energy sources account for over 42% of global electricity generation, with the share of wind and solar PV doubling to 25%.



Installed solar energy capacity (ourworldindata.org)

Availability of solar radiation





Credit to Prof. Yunlong Zi

Solar photovoltaic technology

- Convert sunlight into electrical energy
- n individual PV cell is usually small, typically producing about 1 or 2 watts of power
- they are connected together in chains to form larger units

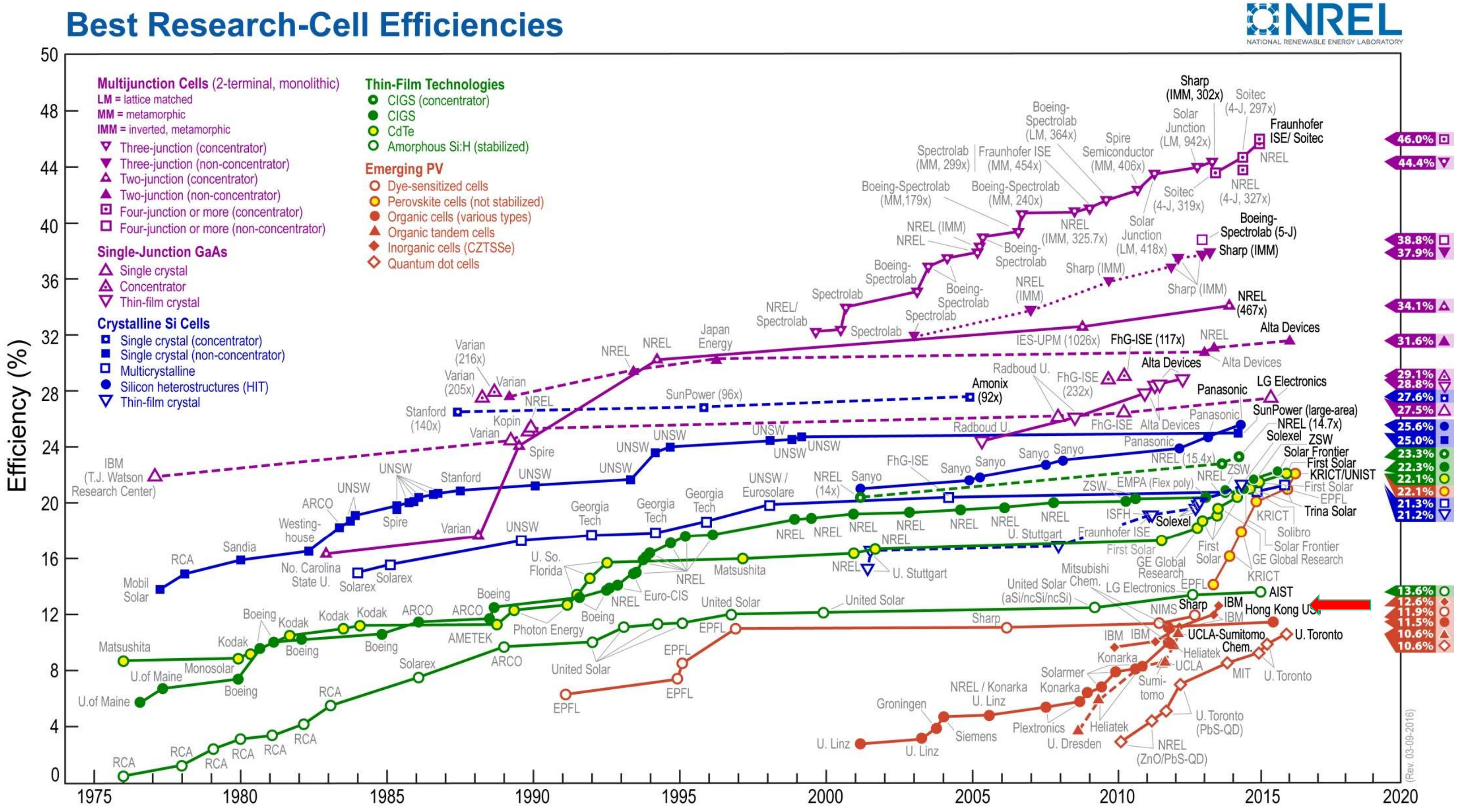
Credit to Prof. Yunlong Zi

History of Photovoltaic System

- History:
  - ✓1836 A.E. Becquerel observe photovoltaic effect
  - ✓1883 Charles Fritts made the first solar cell based on selenium
  - ✓1900 Planck postulates the quantum nature of light
  - ✓1946 Russel Ohl applied the first patent for modern solar cell
  - ✓1954 Chapin, Fuller and Pearson announce 6% efficient silicon solar cell
  - ✓1958 First use of solar cells on an orbiting satellite Vanguard I
  - ✓1970s start to use solar cells in civic applications
  - ✓2023 1247 GW capacity installed worldwide

Credit to Prof. Yunlong Zi

Overview of Solar Cell Research

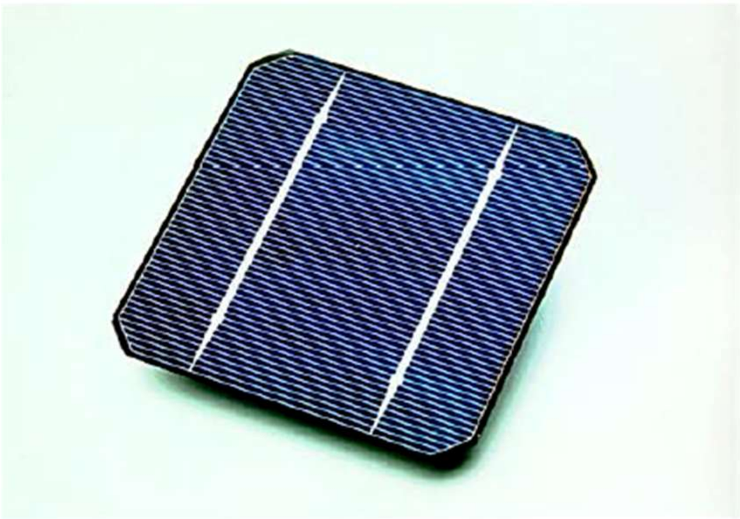


Credit to Prof. Yunlong Zi

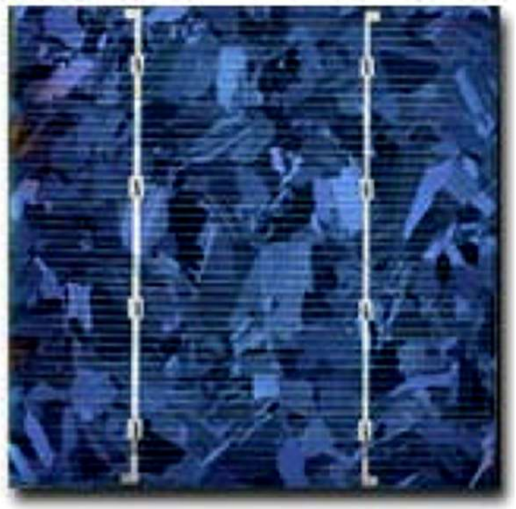
Silicon PV Cells

- silicon solar cells has a market share of 95%

Single crystal Si solar cell



Multi-crystalline Si solar cell



Credit to Prof. Yunlong Zi

Installation: Mounting

Solar farms

A solar farm is a large collection of photovoltaic (PV) solar panels that absorb energy from the sun, convert it into electricity and send that electricity to the power grid for distribution and consumption by customers like you.

https://chariotenergy.com/chariot-university/solar-farms/

Large solar farms

- The Xinjiang solar farm in China has just become the world's largest solar farm, with an installed solar capacity of 5GW， covering~800km2

- The Golmud Solar Park in China is now the world's second largest solar farm, with an installed solar capacity of 2.8 GW, putting it just above the second entry in our list.

https://www.theecoexperts.co.uk/solar-panels/biggest-solar-farms

ESG news

Challenges of solar energy

1. Economic and Financial Barriers
2. Technological Advancements and Efficiency
3. mismatch between energy production and consumption patterns
4. Grid Integration
5. Environmental and Social Impact

https://tamesol.com/solar-2024-challenges/

Future Directions

1. Increasing adoption: The use of solar energy is expected to continue to grow rapidly.

2. Innovations in technology: The solar industry is constantly innovating, with new technologies being developed all the time, including the use of nanomaterials to increase the efficiency of solar cells, the development of transparent solar panels that can be integrated into windows and other building materials, and the use of artificial intelligence to optimize the performance of solar systems.

3. Increased storage capacity: One of the main challenges of solar energy is the fact that it is an intermittent source of electricity

4. Policy and regulatory support: Governments and policymakers around the world are increasingly recognizing the importance of solar energy and are taking steps to support its adoption.

https://arka360.com/ros/future-of-solar-energy-predictions/

Biofuel

- ❑ Resources and uses
- ❑ Producing biofuels
- ❑ Environmental and economic impact

Image from Environment Society of Australia

Biofuel

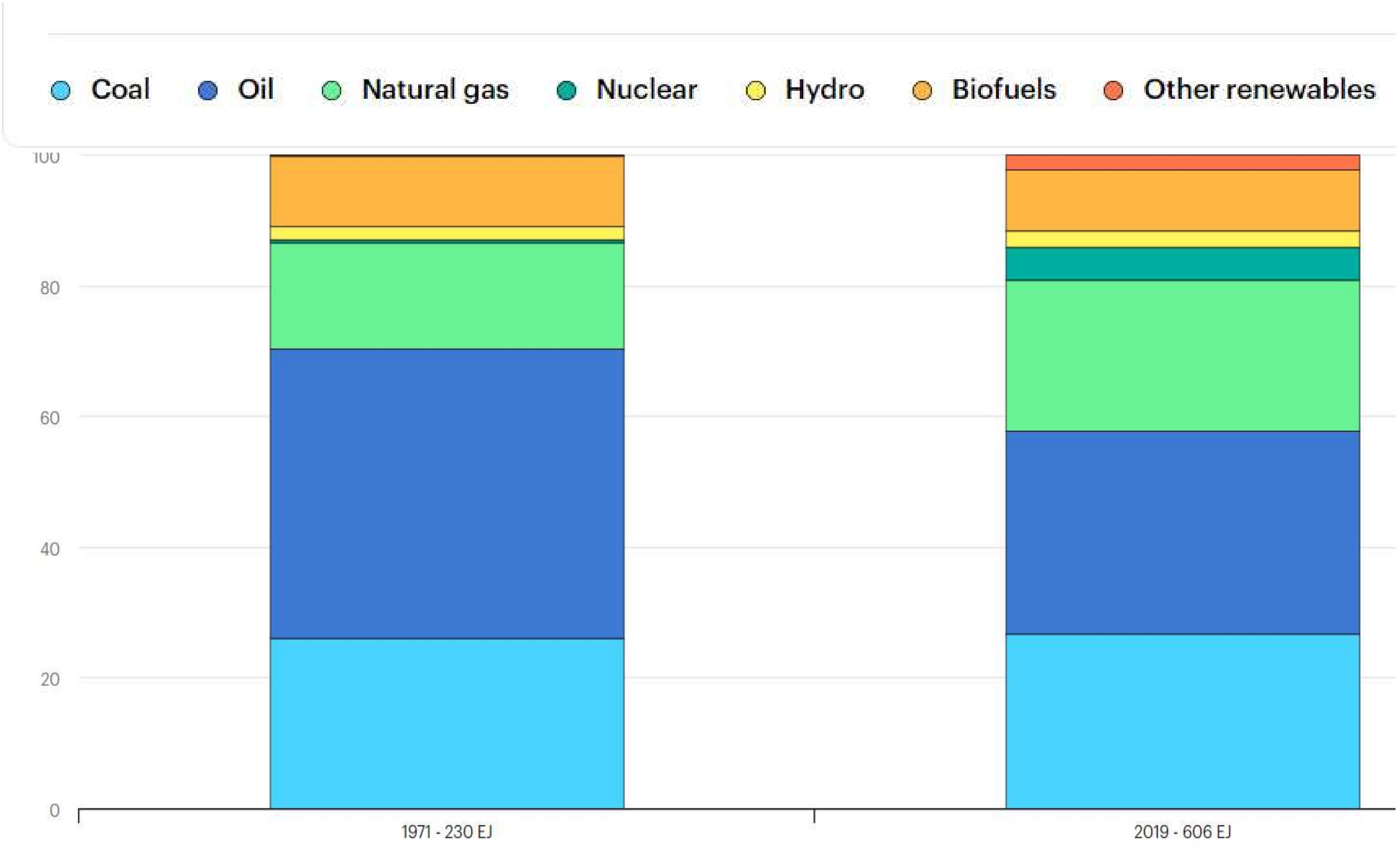
- Bioenergy is renewable energy made available from materials derived from biological sources.
- In narrow sense: bioenergy = biofuel: fuel derived from biological sources.
- In broad sense: bioenergy include biomass: the biological material used as a biofuel
  - ✓ **Wood, straw, sugarcane, corn…**
- Objectives:
  - ✓ **Reduce emissions of CO_2 and other pollutants compared to fossil fuel**
  - ✓ **Sufficient to displace a measurable fraction of fossil fuel, while safeguard the food supplies**

The Source of bioenergy

- Photosynthesis converts solar → chemical energy
  - ✓ $nCO_2 + mH_2O + hv \rightarrow C_n(H_2O)_m + nO_2$
  - ✓ **Average fixation ~0.42 W/m^2 (0.2% of solar insolation)**
  - ✓ **Photosynthesis stores ~300 EJ/yr, vs. human energy use ~400 EJ/yr**
- For large scale bioenergy NEED LOTS OF LAND (even much more than solar) and WATER

- If you have spare land and fresh water, relatively inexpensive to grow and harvest (e.g. much less capital than solar!)

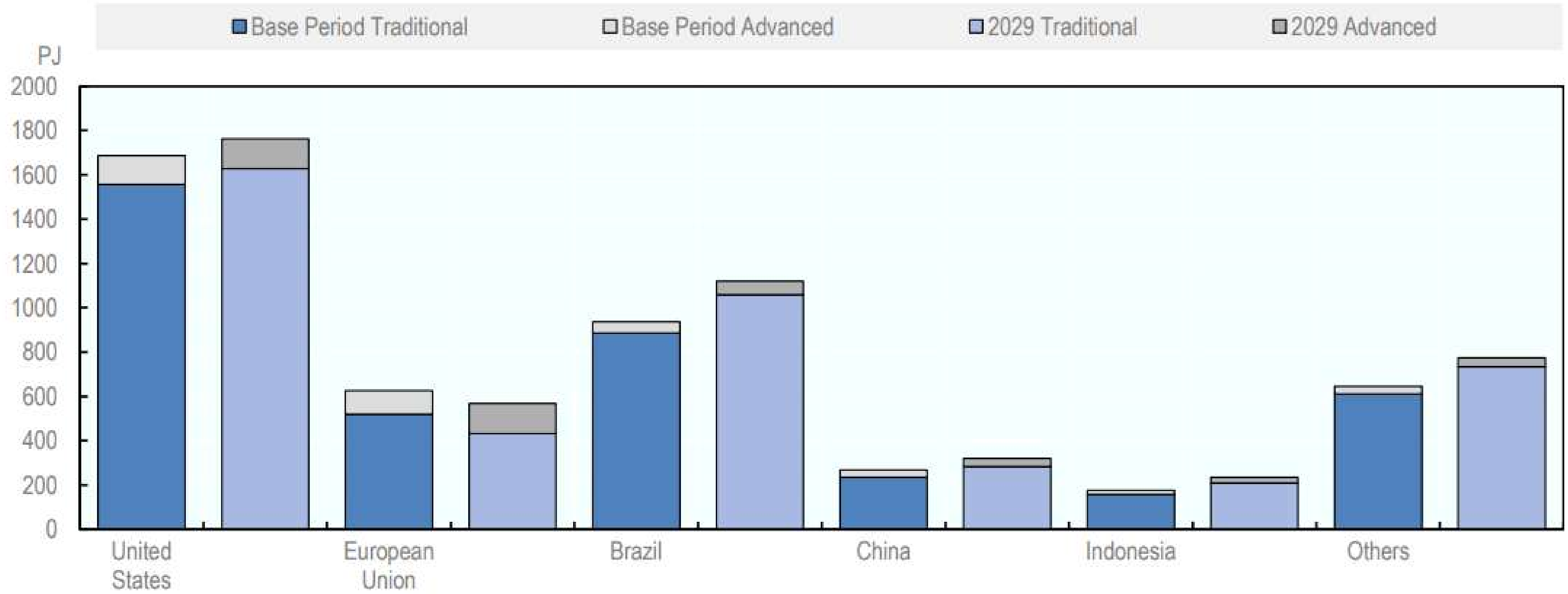
Bioenergy



https://www.iea.org/reports/world-energy-balances-overview/world

Bioenergy

Figure 9.3. World biofuel production from traditional and advanced feedstocks

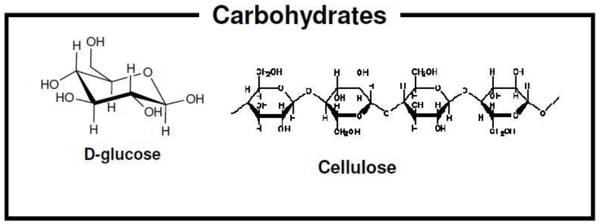


OECD-FAO AGRICULTURAL OUTLOOK 2020-2029, Chapter 9

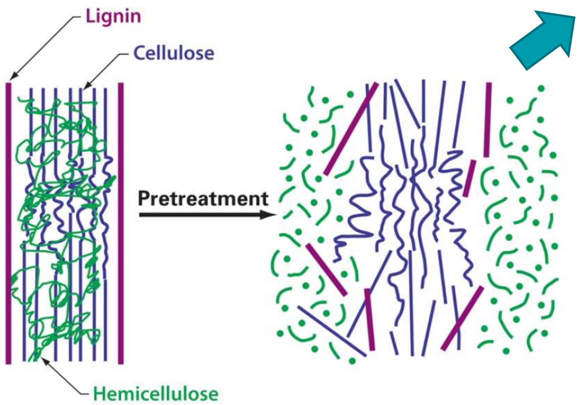
Bioenergy in the U.S.

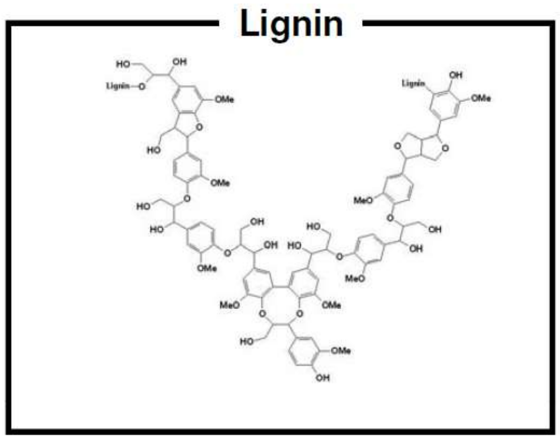
Main Components of Biomass

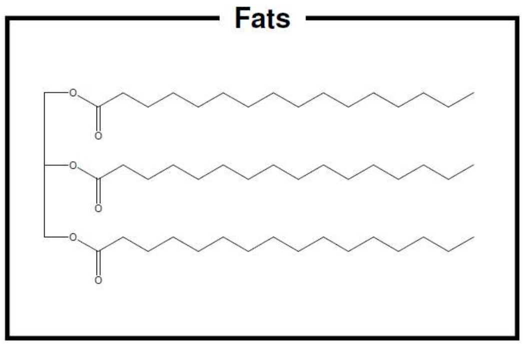
- Carbohydrates (cellulose) & lignin (+proteins, lipids)

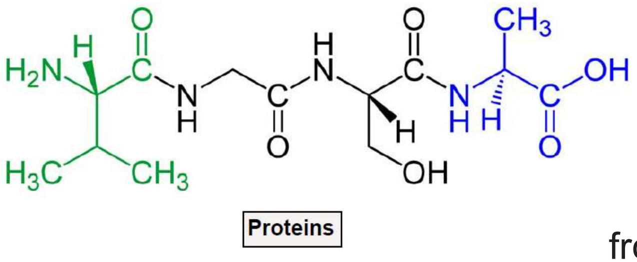


Mostly cellulose & hemicellulose









from Wikimedia Commons

Biomass for Energy: Options

- Burn it for electricity or heat
  - ✓ **However, Coal is usually cheaper for large-scale**
  - ✓ **Good option consider Carbon emission: mix biomass with coal**
- Convert to gas (CH_4 or CO/H_2)
  - ✓ **Practiced on small-scale using waste**
  - ✓ **However, coal-to-syngas and natural gas are cheaper**
- Convert to liquid fuels
  - ✓ **Ethanol, bio-oil, carboxylate (acetic acid)**

Conversion to Syngas

- Syngas is a mixture of CO/H_2 used for many purposes. Usually made from natural gas, but can also be made from biomass.

Biomass →
Steam or oxygen →
Gasifier 800 °C → Syngas: CO, H_2 → Electricity, CH_4, H_2, Gasoline/diesel, Ethanol

$$\underbrace{CH_{1.5}O_{0.67}}_{\text{wood}} + 0.33\ \underbrace{H_2O}_{\text{steam}} \rightarrow \underbrace{CO + 1.08\ H_2}_{\text{syngas}}$$

Depending on biomass composition, desired stoichiometry, mix in some $\mathbf{O_2}$ (partial combustion) to provide the heat of reaction

Source: National Renewable Energy Lab; F. Vogel, Paul Scherrer Institut, Switzerland.

Image by Gerfriedc on Wikimedia Commons.

Ethanol-Gasoline Blends

- Ethanol production
  - ✓ **Highest conc. of 15% during fermentation (yeast cannot survive)**
  - ✓ **Distillation is required to remove water (energy-intensive)**
- E85 (85% ethanol, 15% gasoline) + E30
  - ✓ **Can be used only in "flex fuel" vehicles**
- E10 (10% ethanol, 90% gasoline) + E15
  - ✓ **Ethanol acts as oxygenate to reduce CO emissions**

- Challenges with ethanol use
  - ✓ **2/3 the heat content per gallon as gasoline (21.3 MJ/L vs. 32.5 MJ/L)**
  - ✓ **Absorbs water during distribution (highly miscible)**

Biodiesel Challenges

- Problem is the land use:
  - ✓ **Oil Palm: 600 gallons/acre/yr**

» Replacing Asian rainforest with oil palm plantations to meet EU biodiesel demand

  - ✓ **Canola: 127 gallons/acre/yr**
  - ✓ **Soybean: 48 gallons/acre/yr**

- Future direction:
  - ✓ **Bacteria, yeast can convert sugars to lipids: make biodiesel from cellulose?**
  - ✓ **(Micro-) Algae to produce biodiesel**

Biofuels and the Energy Challenges

- U.S. could feasibly replace >1/3 of gasoline with domestic biofuels by 2030

- Sufficiency:
  - ✓ **limitations of land, infrastructure**
  - ✓ **Usually less energy density (Ethanol v.s. gasoline, biodiesel v.s. diesel)**

- Safety: can be used safely with adjustments

- Security: Can be made domestically

Environmental Impacts

- Land use for electricity generation

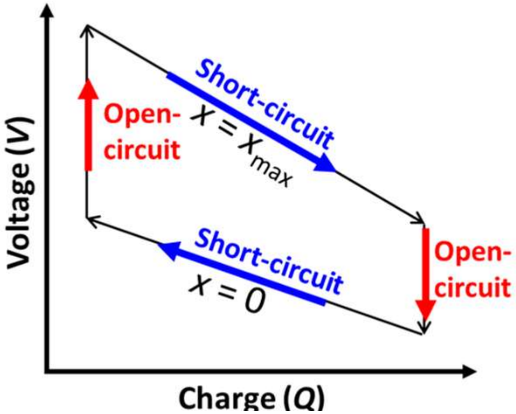
Technology	Land Required (km^2/exajoule-year)
Biomass	125,000 - 250,000
Large Hydro	8,300 - 250,000
Small Hydro	170 - 17,000
Wind	300 (turbines, roads); 17,000 (fetch area)
Photovoltaic	1,700 - 3,300
Coal	670 – 6,700
Natural gas	200 - 670

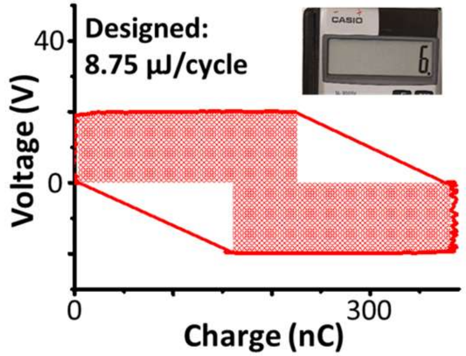
Tester et al. (data from Flavin & Lenssen, 1994)

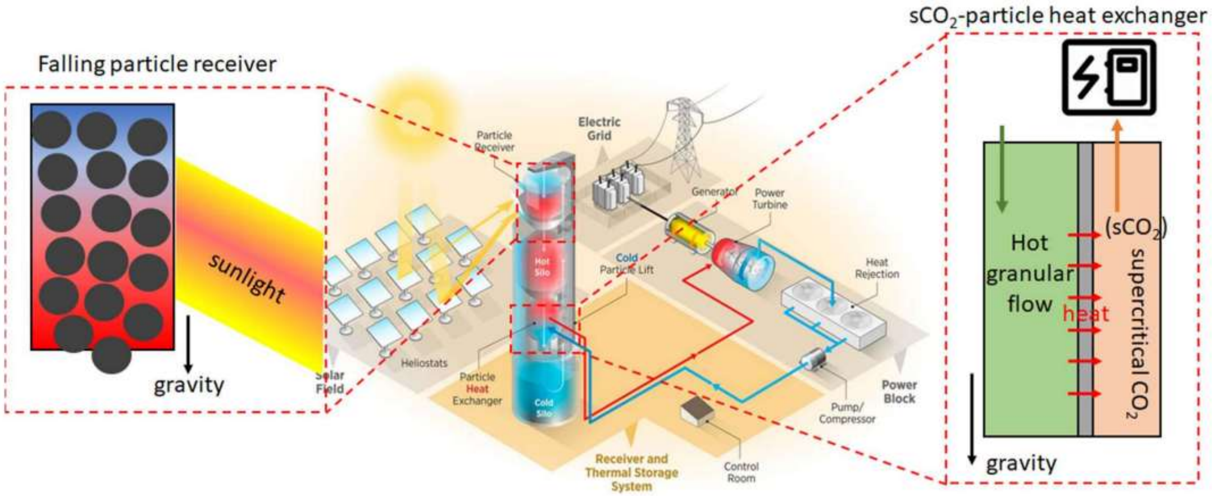
Energy production related Research in the SEE Thrust

Yunlong ZI 訾云龙

Jian ZENG 曾健







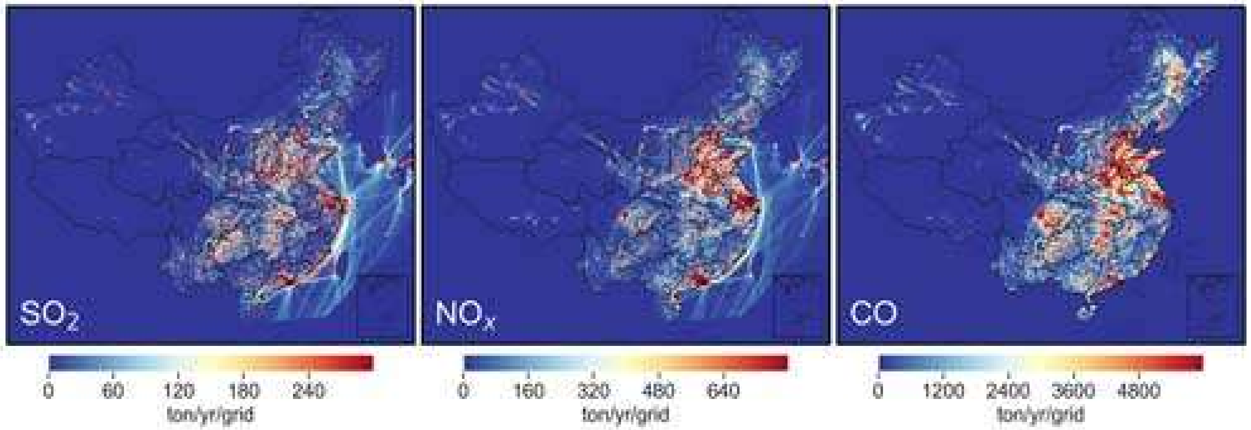
Research related to environmental impacts of energy production in the SEE Thrust

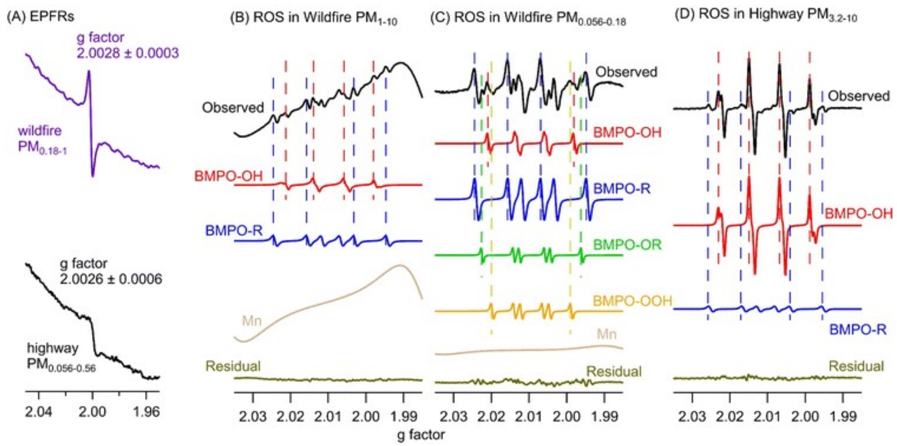
Junyu Zheng 郑君瑜

Shuncheng LEE 李顺诚

Ting Fang 方婷

Yutong LIANG 梁雨桐





Your feedback is highly appreciated!