

Feedback

- I want to know why I got the score of my essay. The feedback of essay.
Hope to improve my skills
- Please give feedbacks on essays.
- 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 :(

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

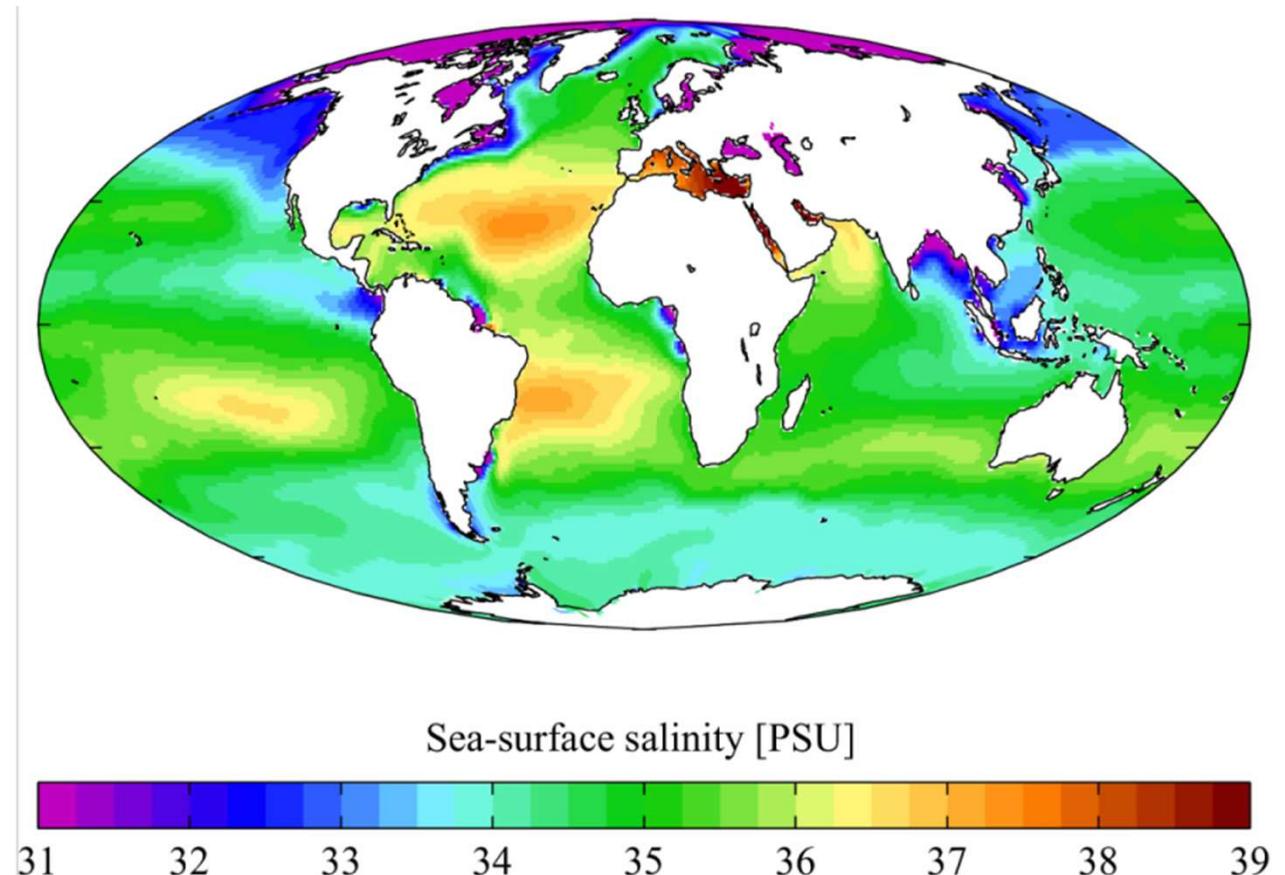


<https://www.technologynetworks.com/applied-sciences/news/richest-marine-biodiversity-threatened-by-ocean-warming-363859>

<https://oceanoliteracy.unesco.org/ocean-biodiversity/>

Review: Ocean and Climate

- Salinity tends to be lower in the high latitude region



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

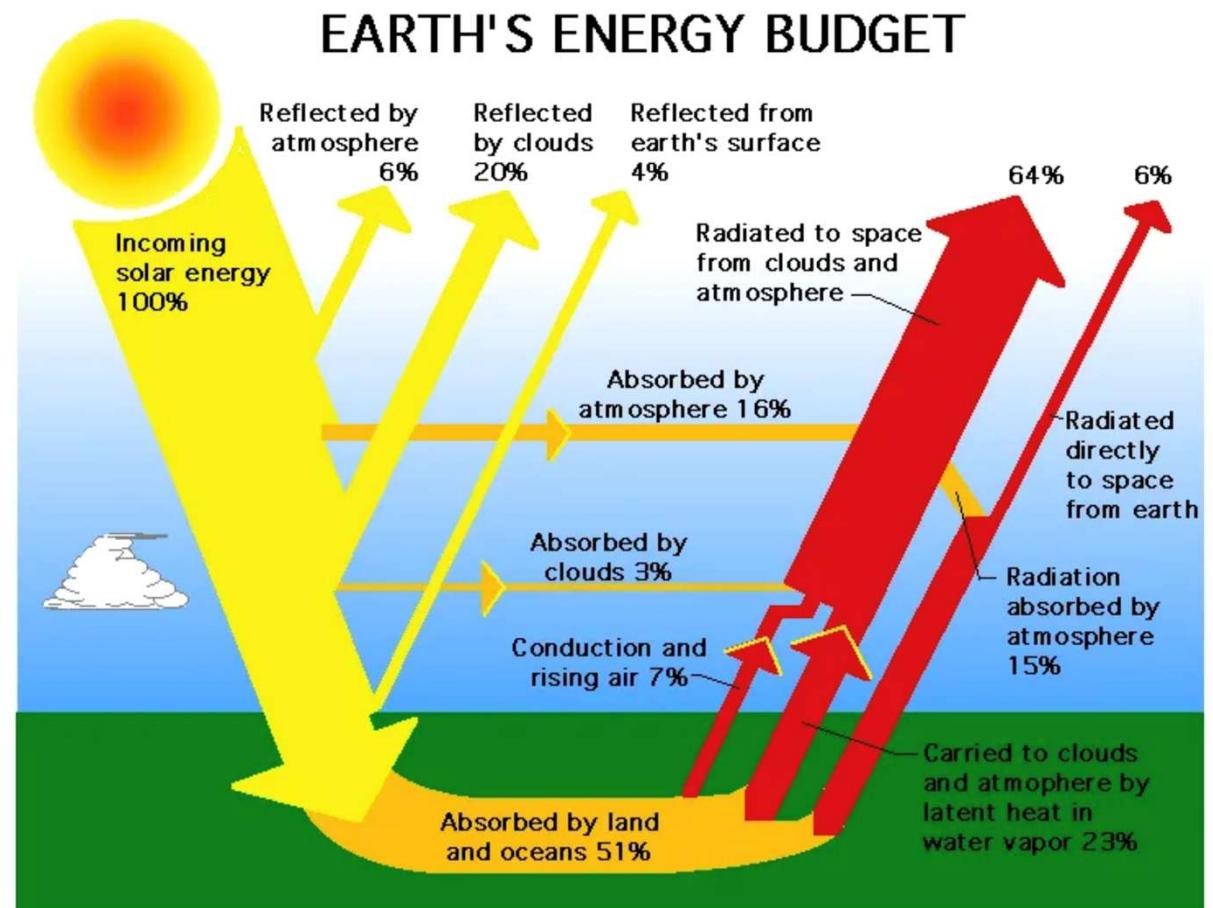
- Only 5% of the ocean and have been explored and documented
- Over 150 new species of marine fish are found every year
- One research priority in many countries



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

Review: Ocean and Climate

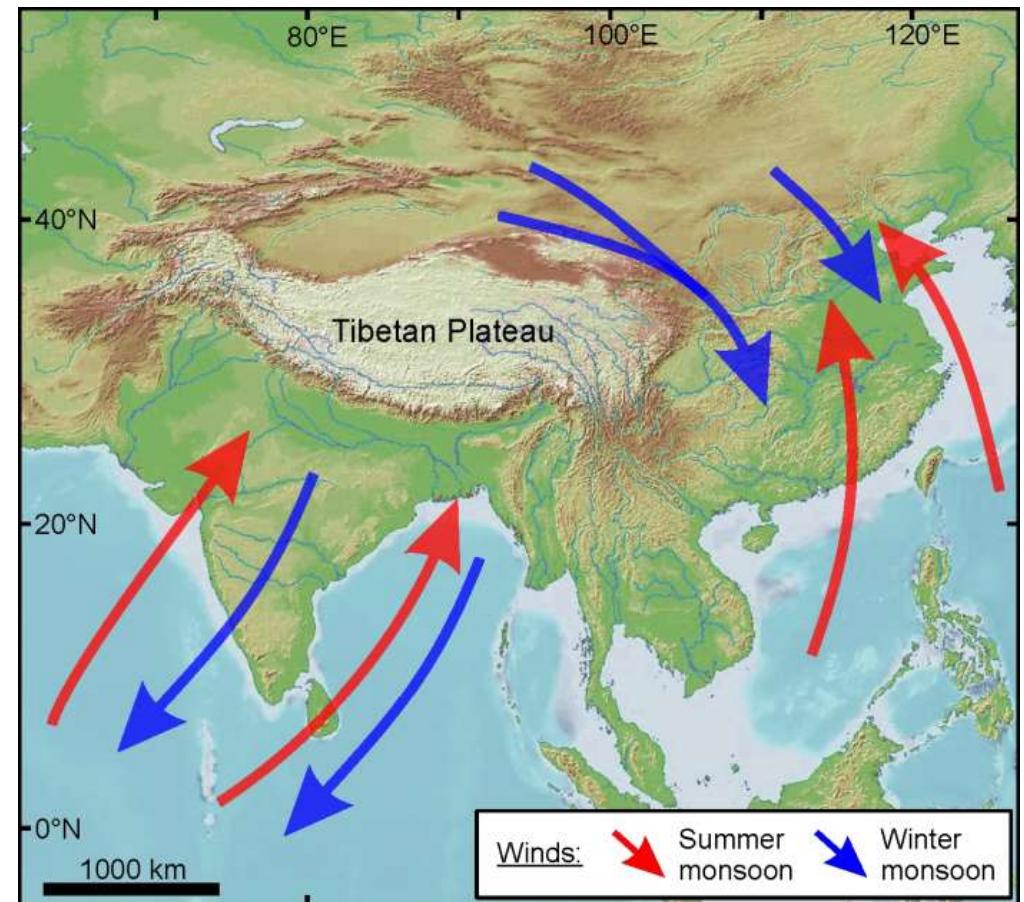
- Large areas
- Dark color
- High specific heat
- Ocean reflects only 6% of the sun's energy and absorbs the rest.



[The Energy Budget | Center for Science Education \(ucar.edu\)](http://www.ucar.edu)

Oceans regulate global water cycle

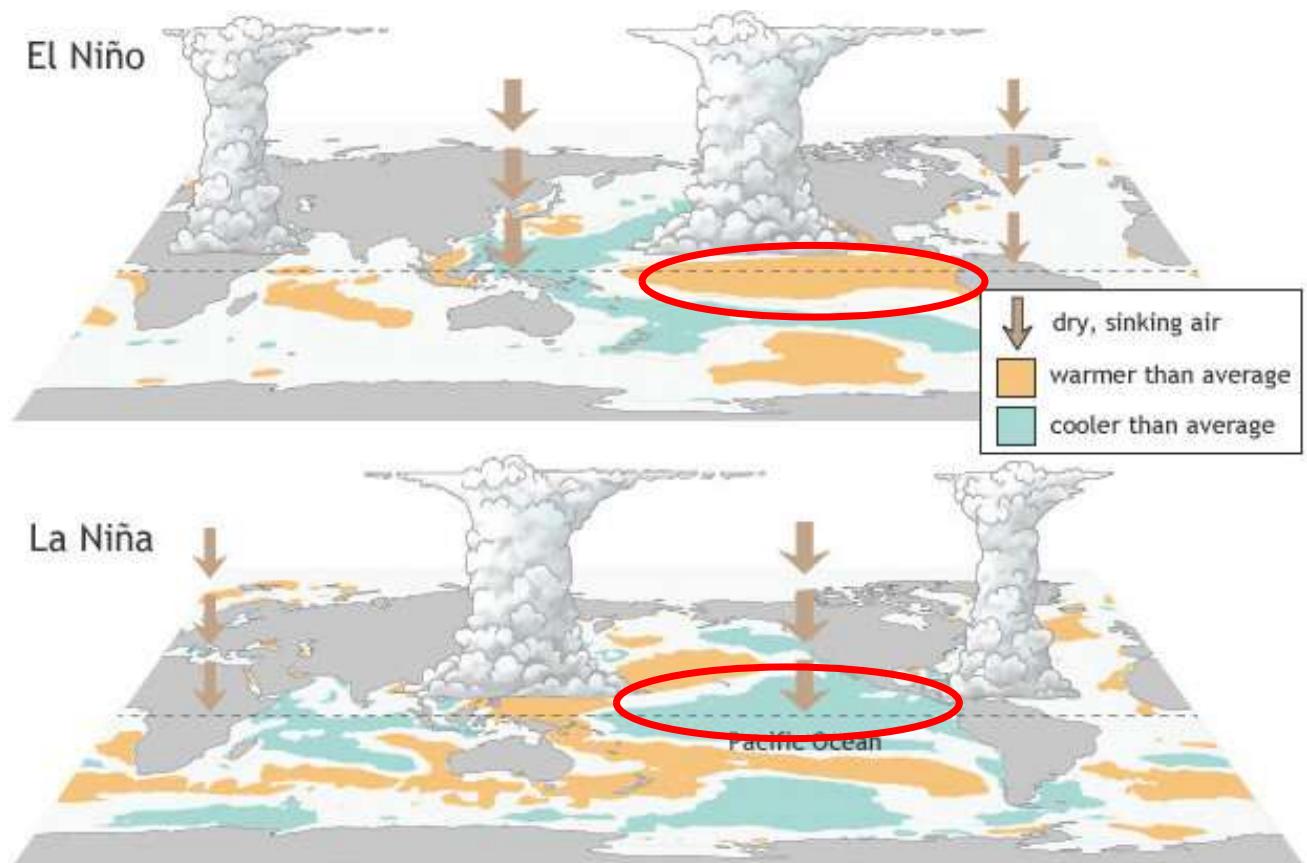
- Warm and humid summer
- Cold and dry winter



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

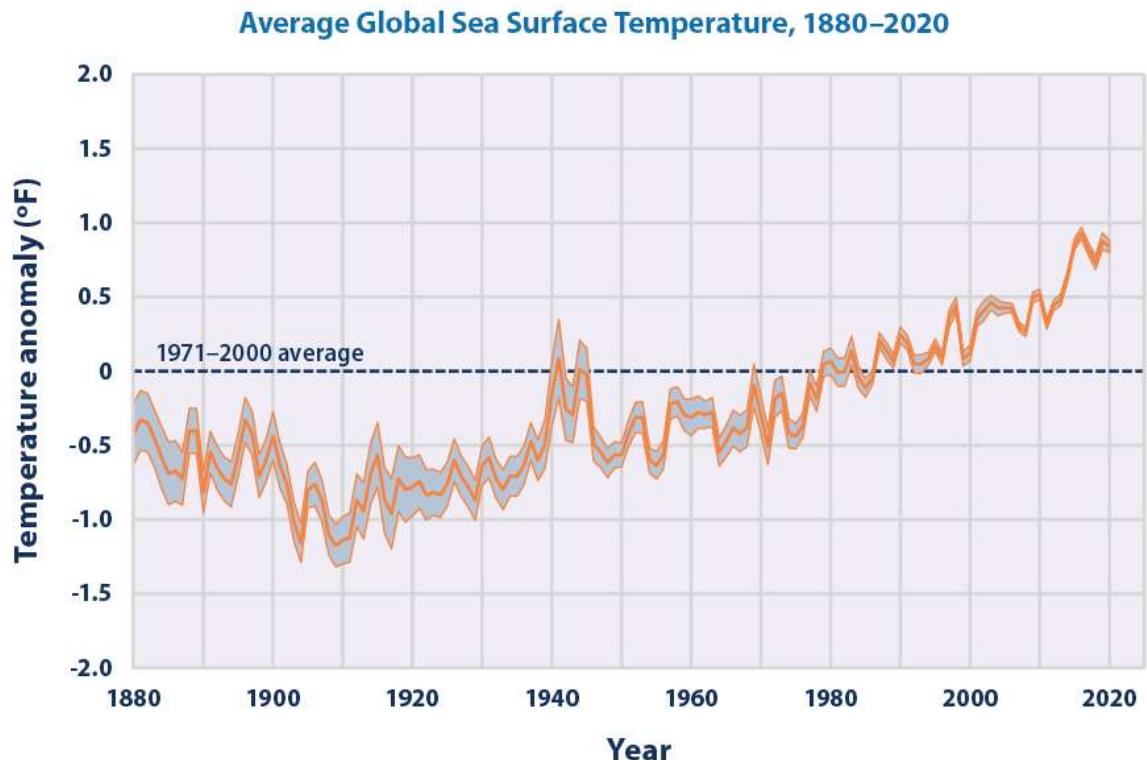
El Niño–Southern Oscillation (ENSO)

- 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



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



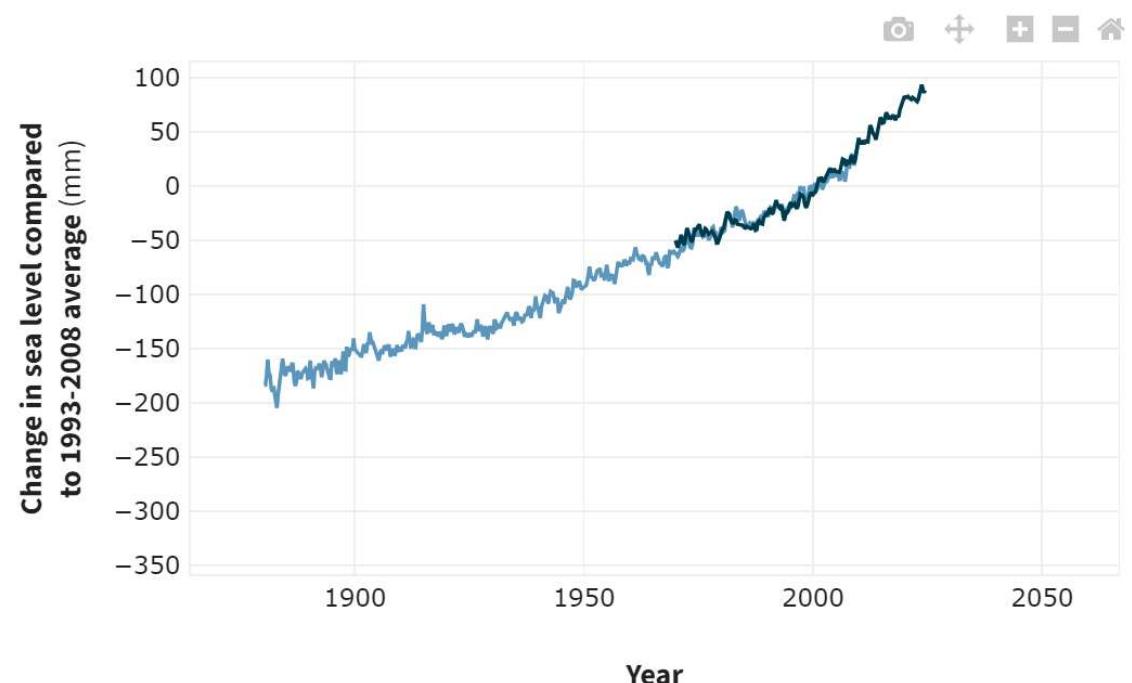
Data source: NOAA (National Oceanic and Atmospheric Administration). 2021. Extended reconstructed sea surface temperature (ERSST.v5). Accessed February 2021.
www.ncdc.noaa.gov/data-access/marineocean-data/extended-reconstructed-sea-surface-temperature-ersst.

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

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.**

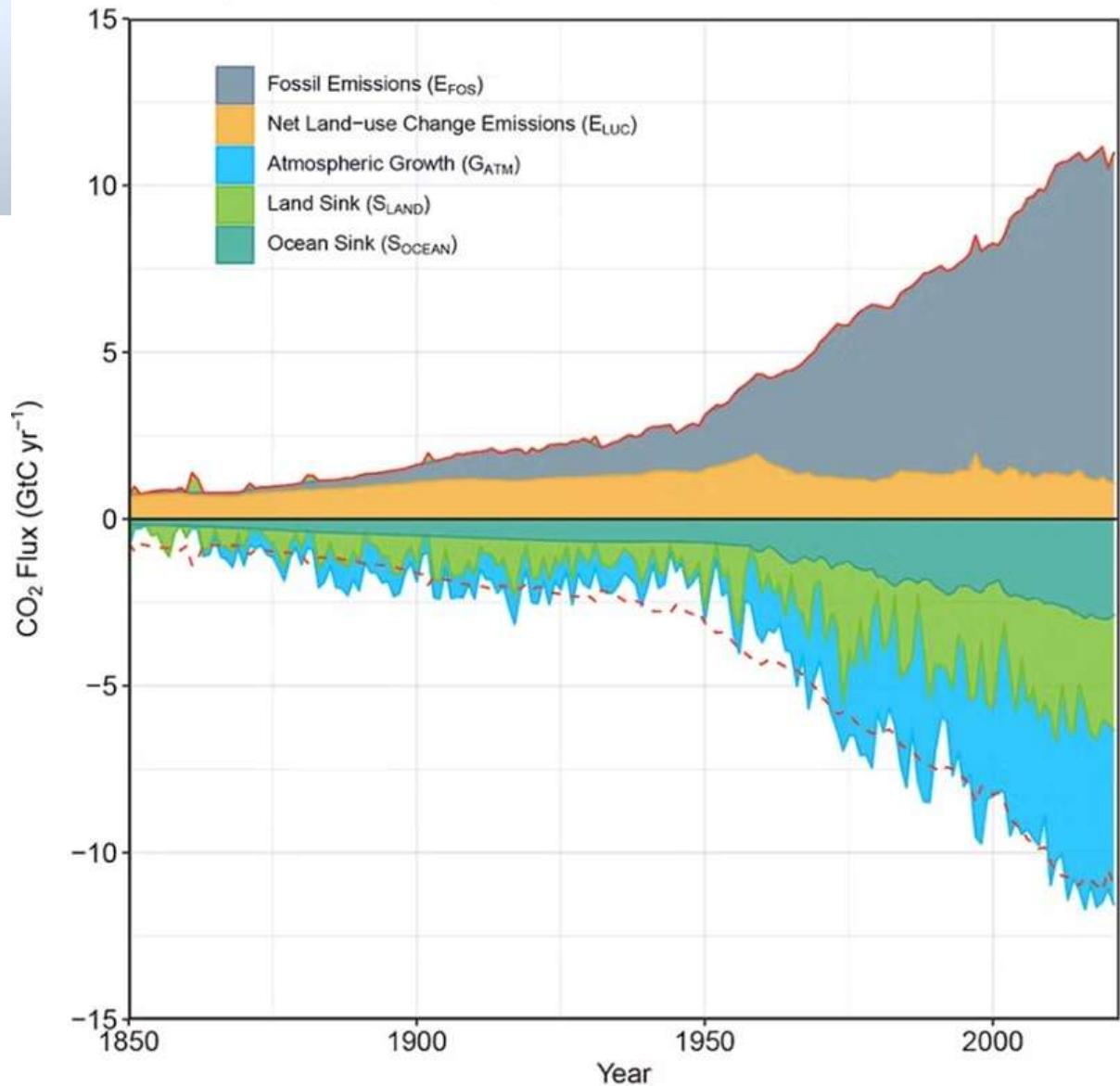
GLOBAL SEA LEVEL



NOAA

Oceans regulate global carbon cycle

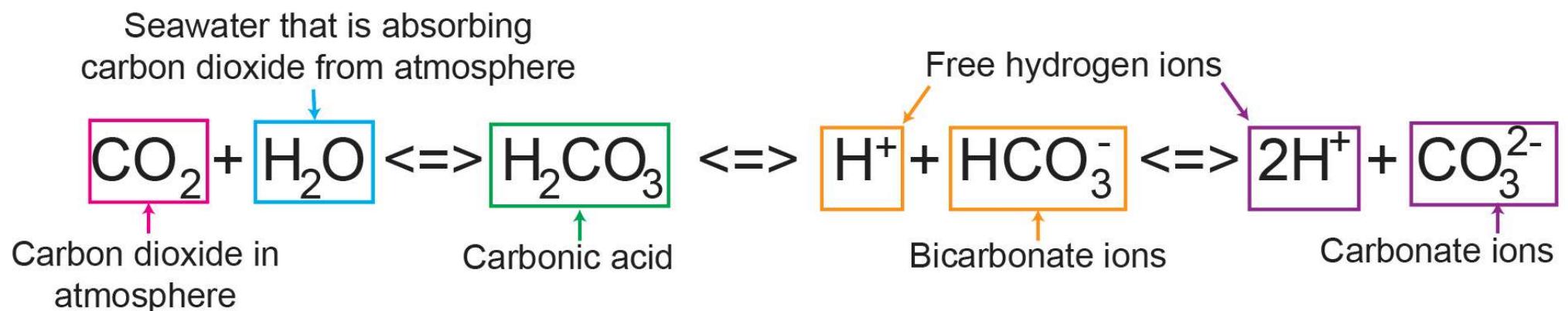
- ~30% of CO₂ emissions are absorbed by oceans



<https://theconversation.com/>

Ocean as a buffer of CO₂ change

- High CO₂ concentrations leading to more dissolution of CO₂ in sea water



Acidification of the Ocean

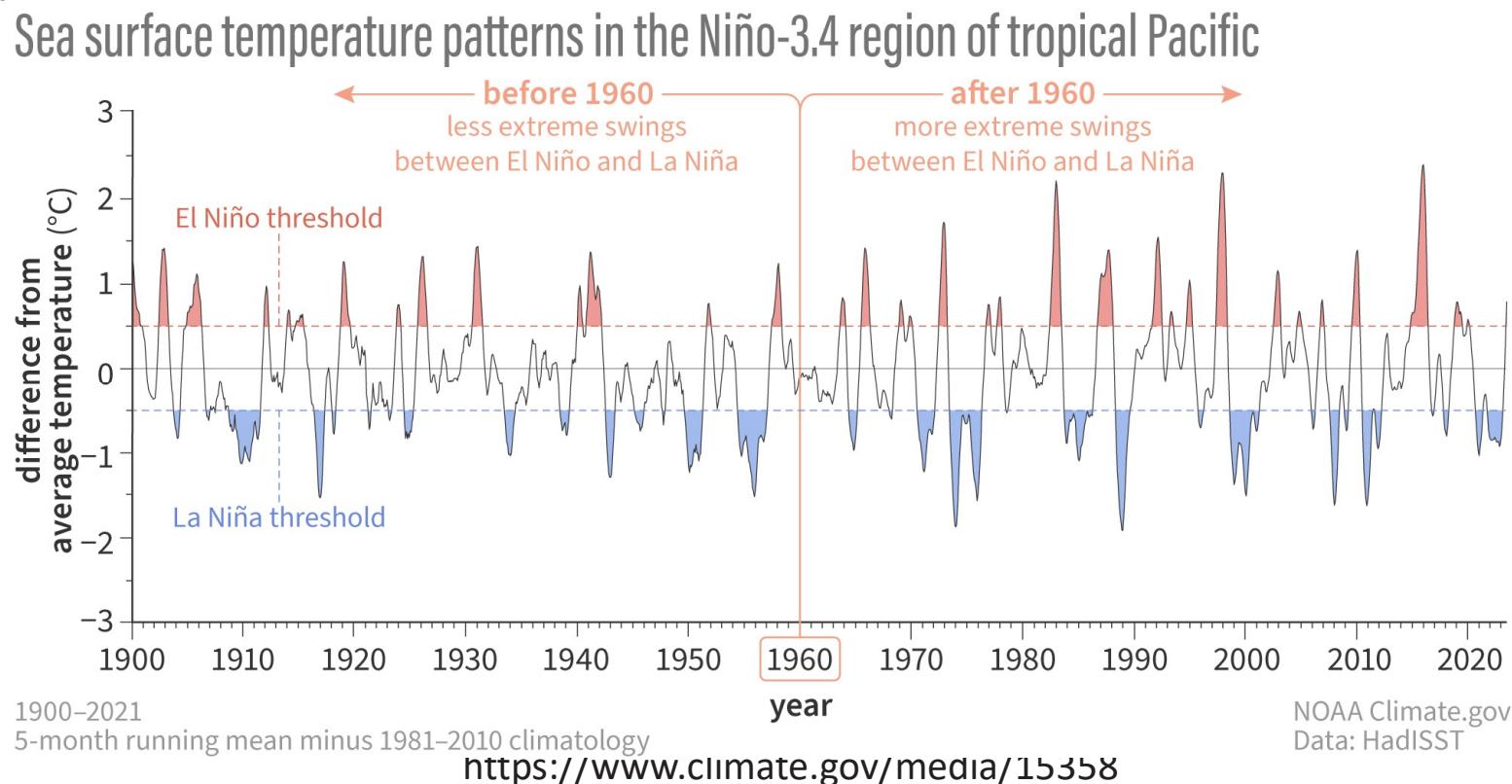
- Shells become thinner
- Death rates increase



<https://nwtreatytribes.org/>

Global warming and ENSO

- More frequent
- Intensify overtime



Global warming and ENSO

NATURAL SWINGS



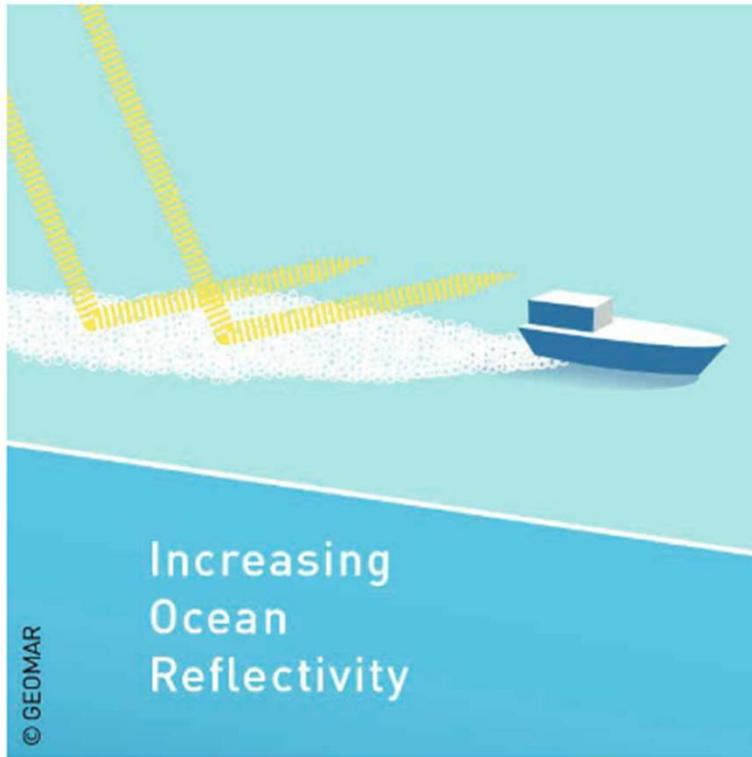
NATURAL SWINGS PLUS CLIMATE CHANGE



Outline

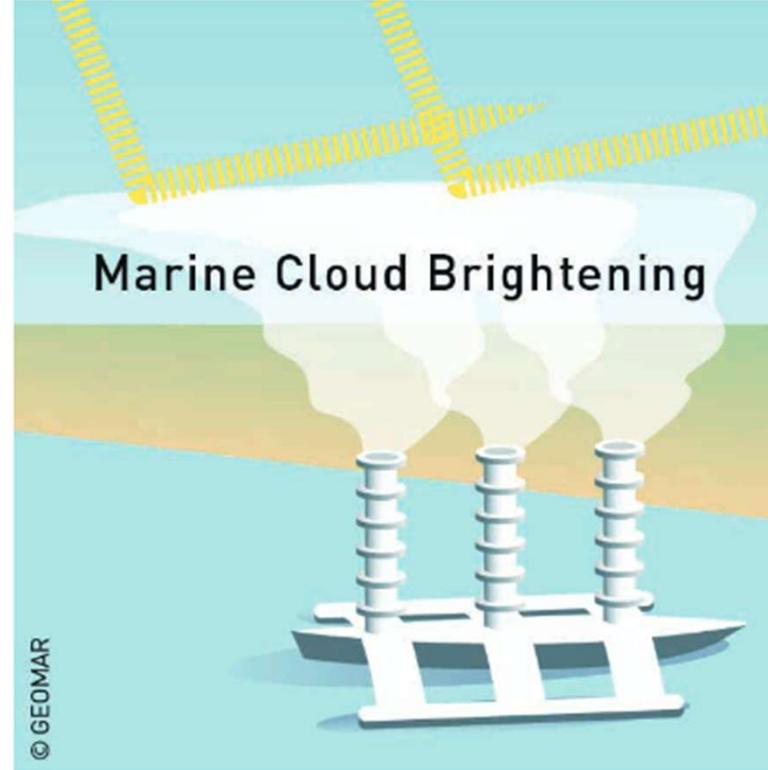
- **Introduction of Ocean**
- **Importance of Oceans to functioning of the earth**
- **Impacts of climate change on the Ocean**
- **Managing oceans to mitigate climate change**

Increasing ocean albedo



© GEOMAR

Adding reflective particles, microbubbles, foams, ice & reflective algal blooms

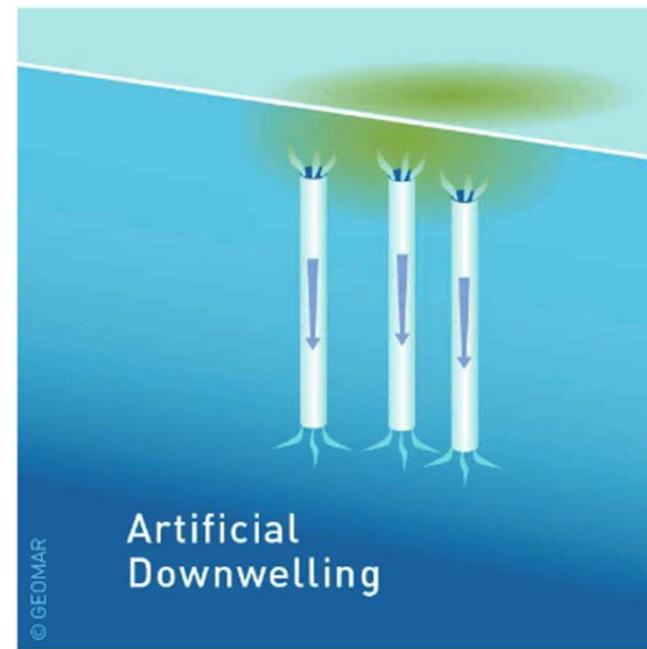
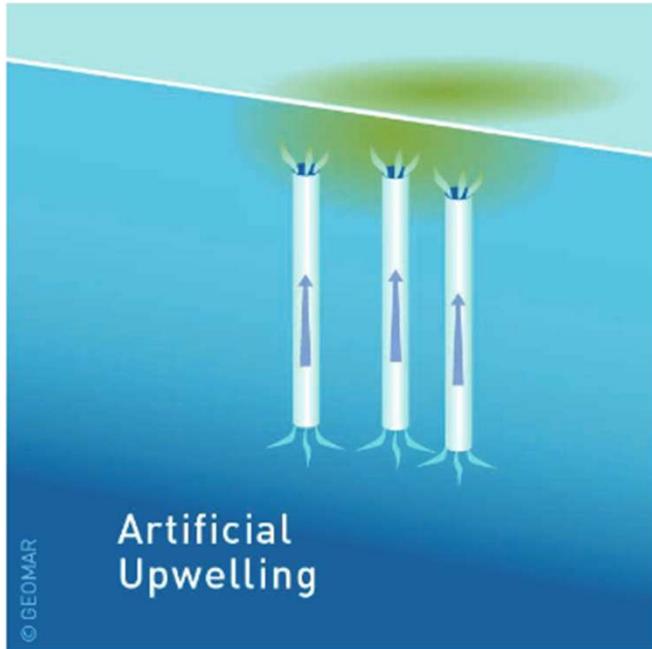


Seeding marine stratocumulus clouds with sub-micrometre sea water particles
→ making the clouds denser and thus more reflective

Credit to Liuqian Yu

GESAMP (2019)

Ocean pumping



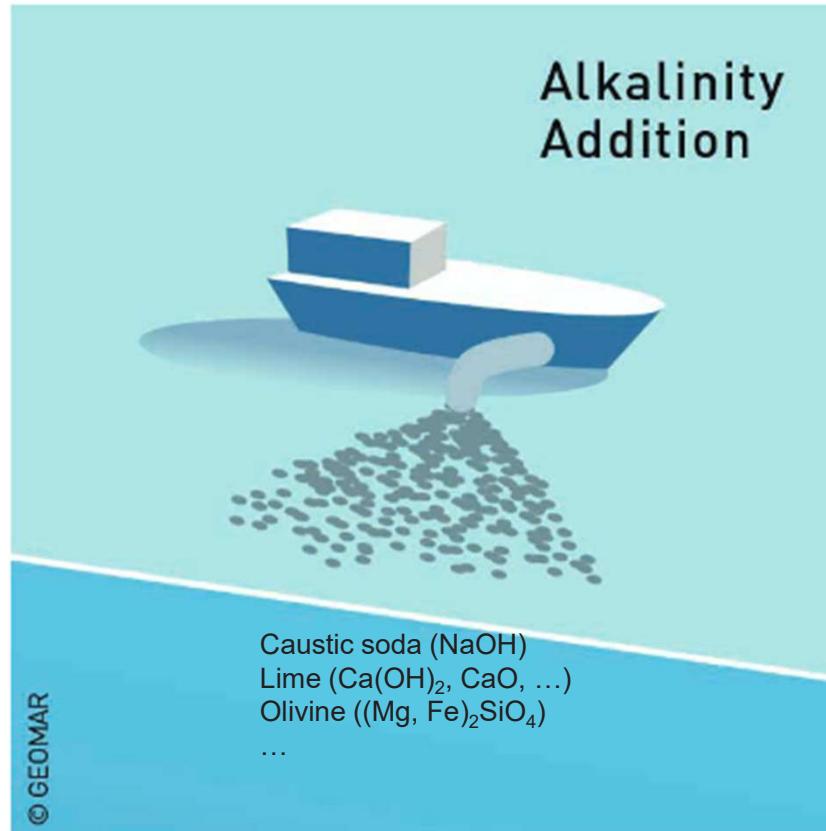
- Fertilize the surface ocean with nutrient-rich deep water
- Cool the surface atmosphere with cold deep water
- Transport the DIC to deep water for long term storage

Credit to Liuqian Yu

GESAMP (2019)

Enhancing ocean alkalinity

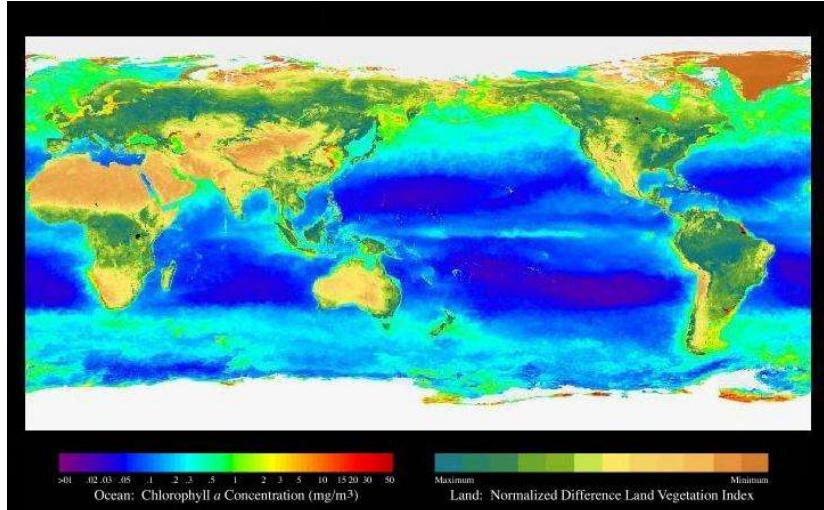
- Increase alkalinity of sear water
- Increase the absorption of CO₂



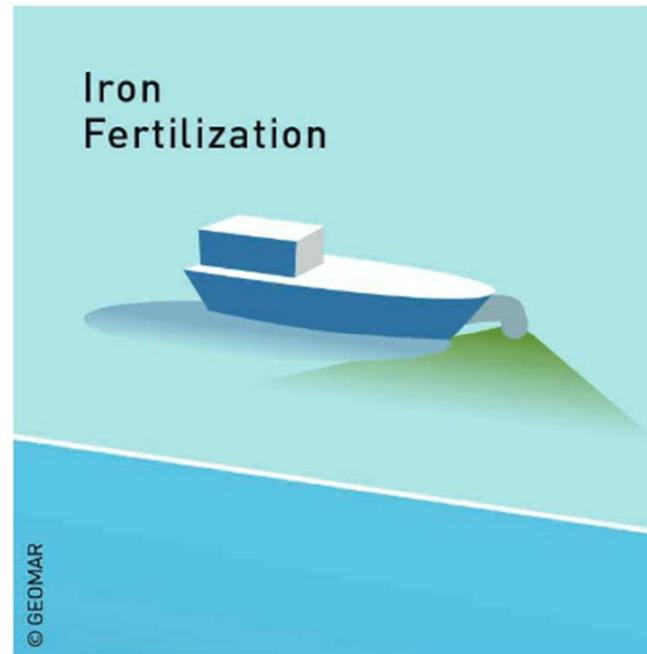
Credit to Liuqian Yu

Cai & Jiao 2022 The Innovation GESAMP (2019)

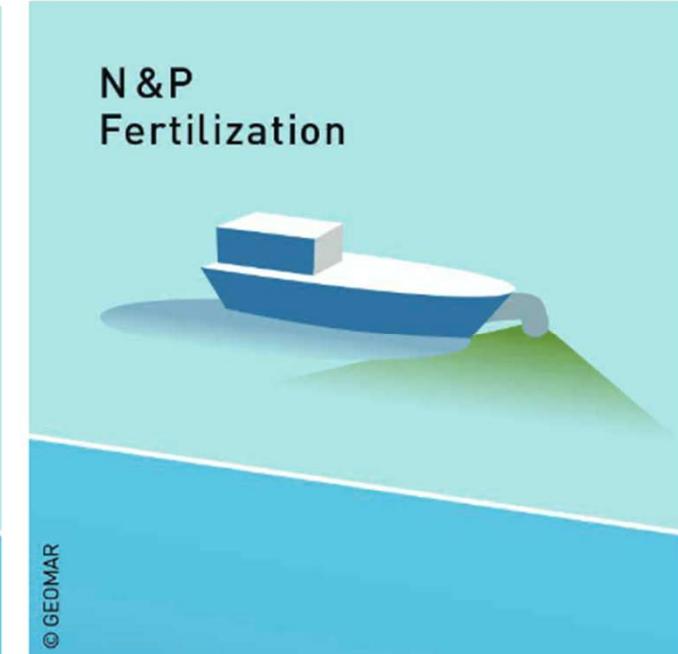
Ocean fertilization



Distribution of Chlorophyll concentrations



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



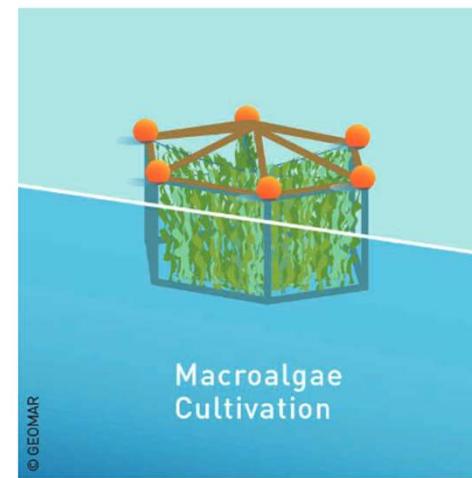
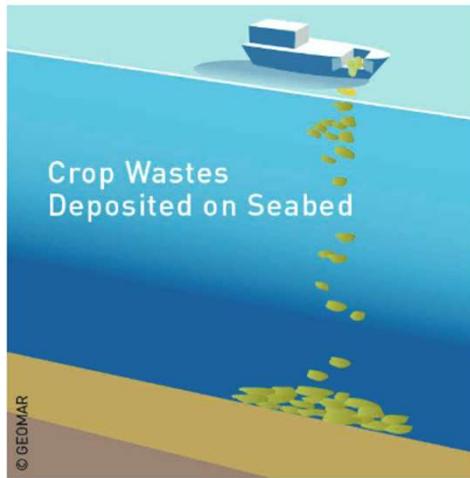
High-nutrient, low-chlorophyll
region (nutrients from dusts could
not reach those regions)

Credit to Liuqian Yu

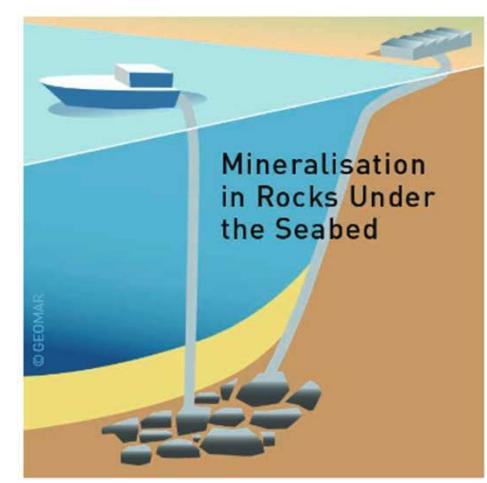
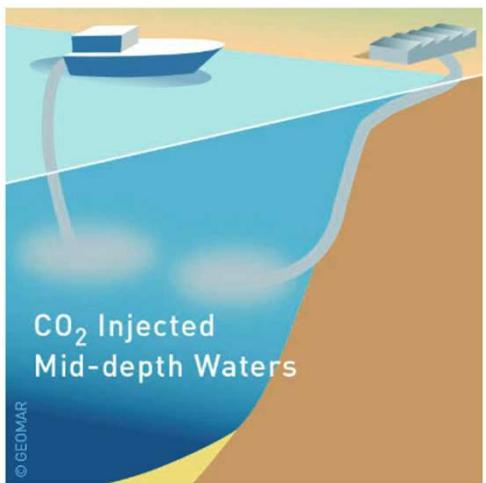
GESAMP (2019)

Carbon storage in the ocean

Biotic



Abiotic



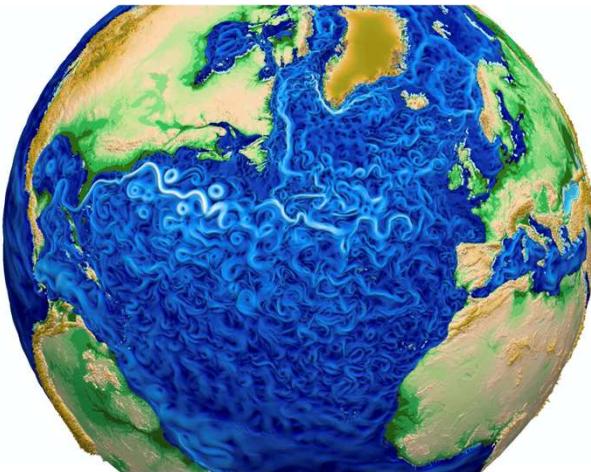
Credit to Liuqian Yu

GESAMP (2019)

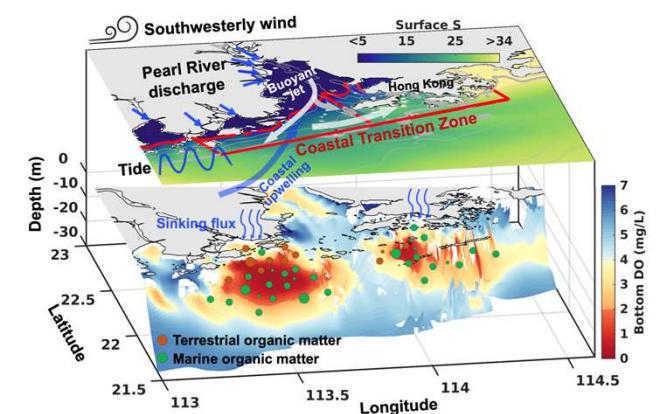
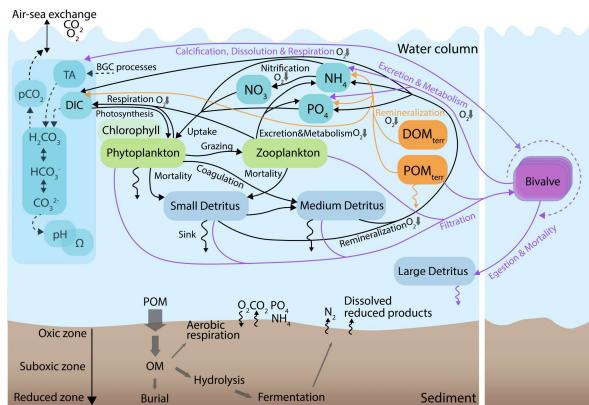
Ocean study in the EOAS Thrust

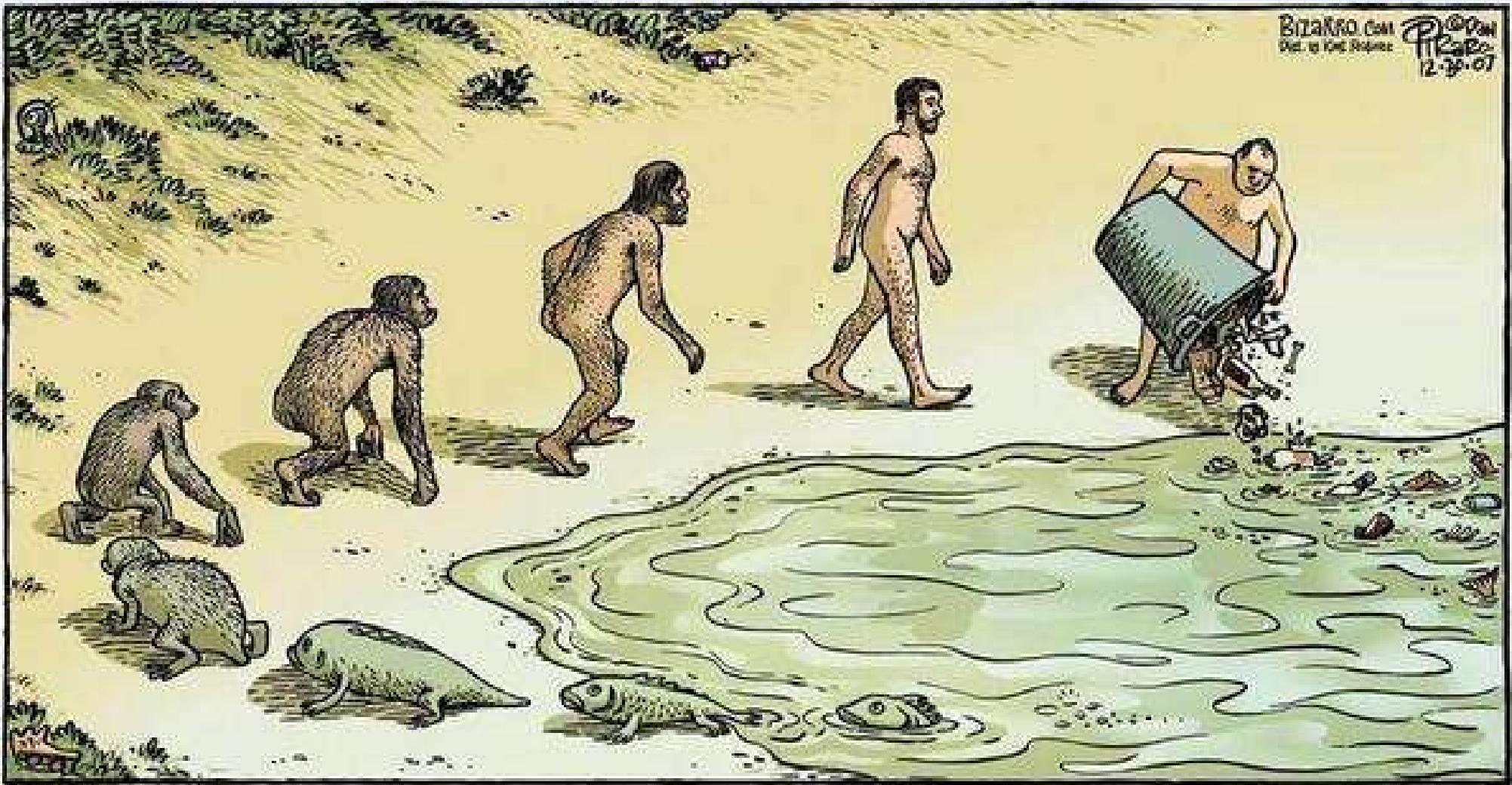


Qing LI 李庆



Liuqian Yu
余柳倩





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**)

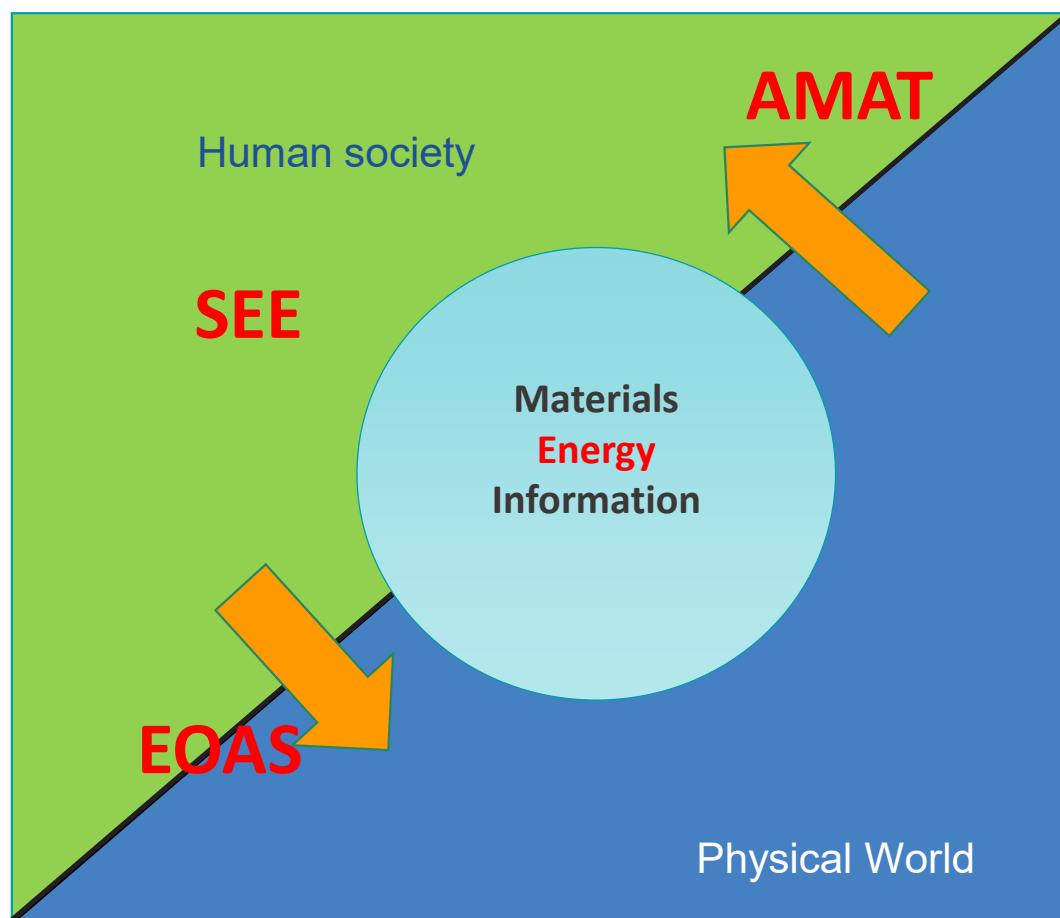
Solutions for sustainable development

- 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**)

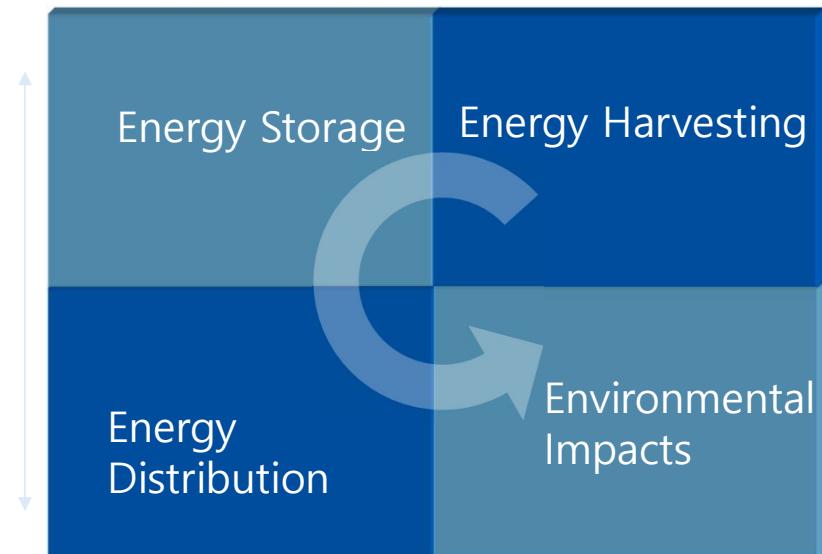
12 lectures in total

Thrusters of Function Hub

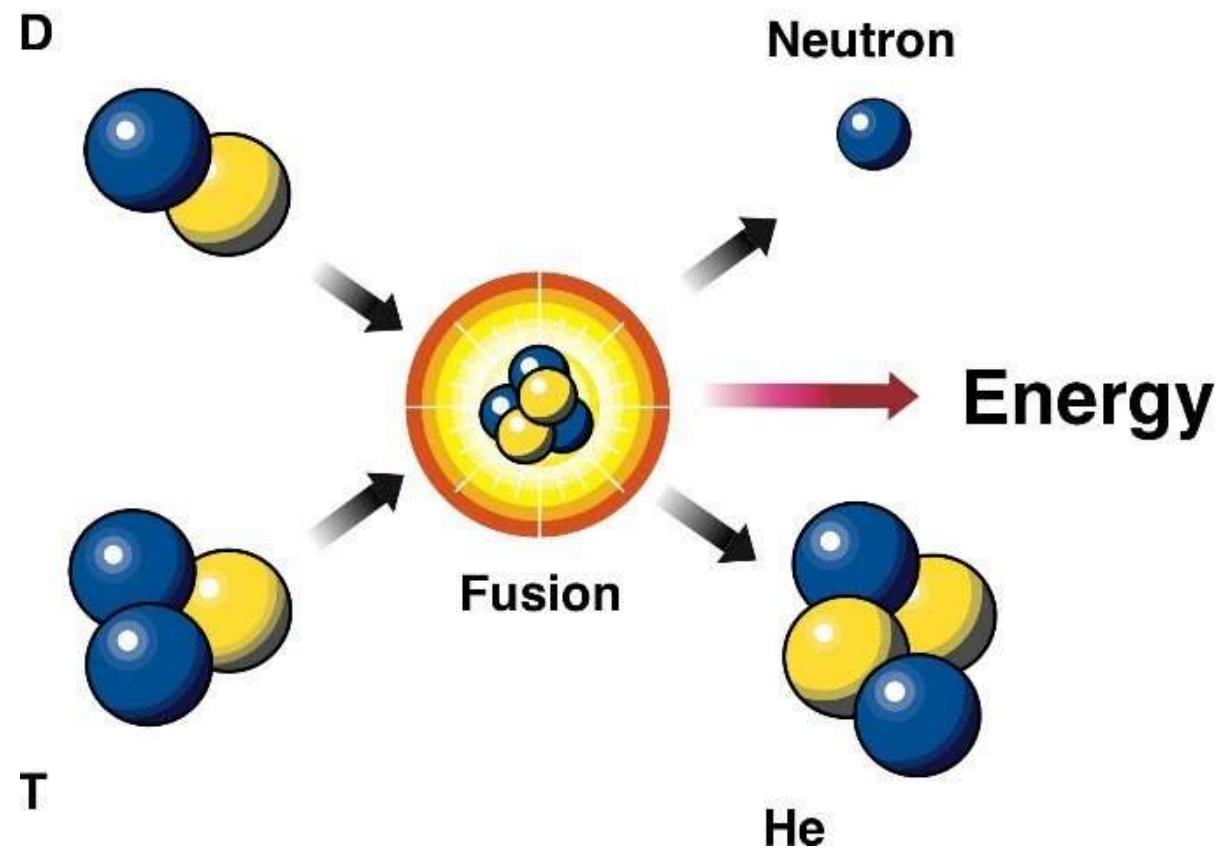


Research of the SEE Thrust

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

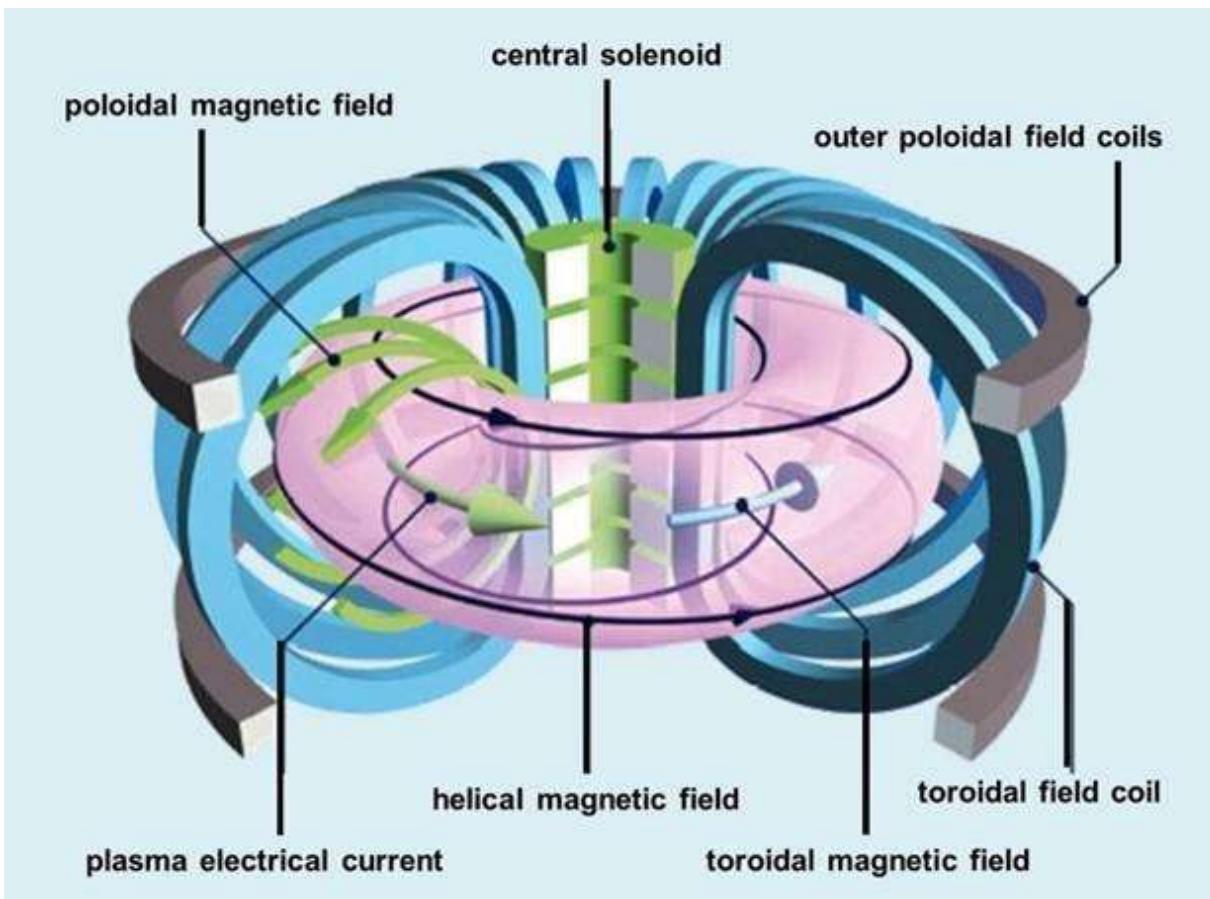


Nuclear fusion

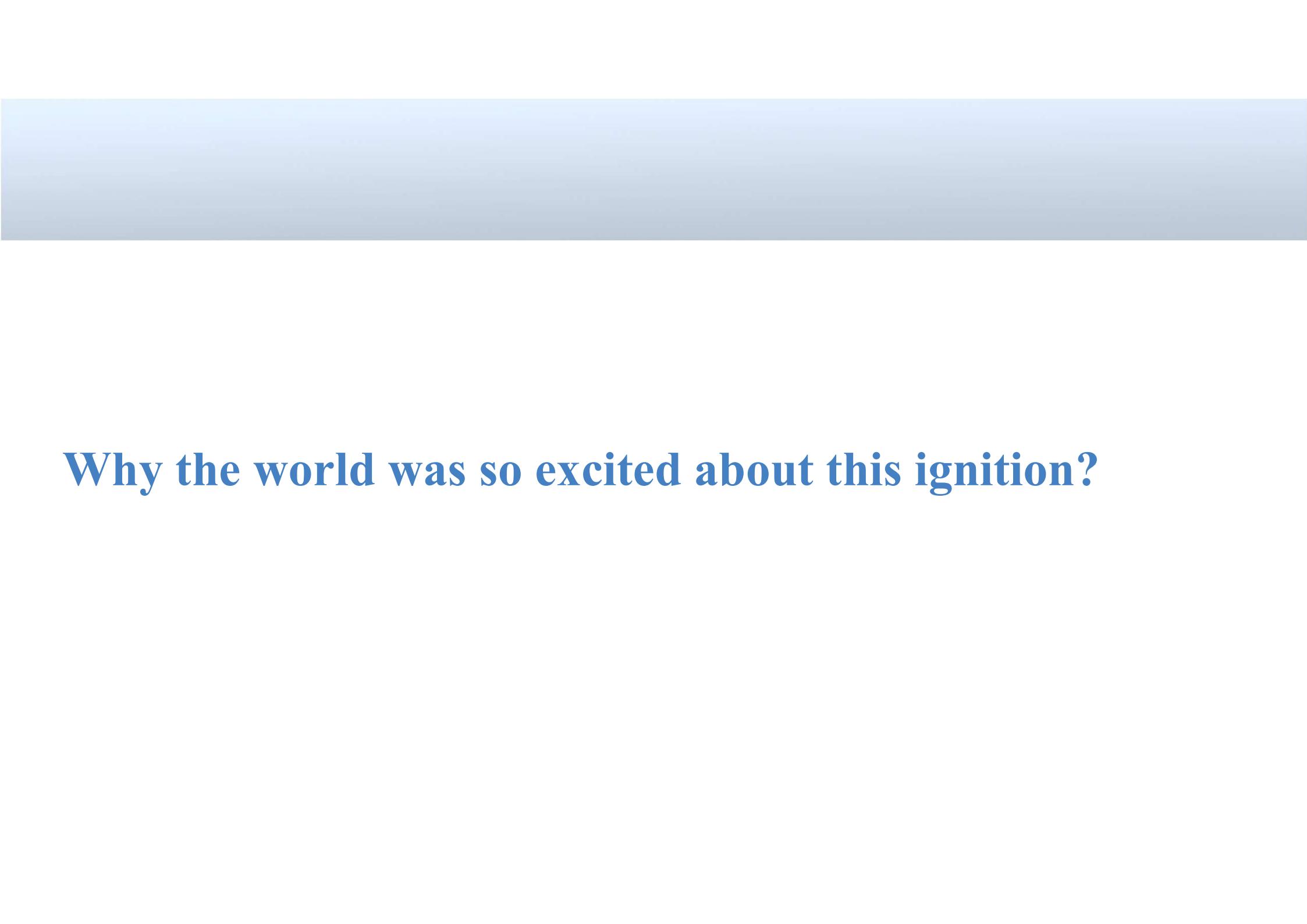


DOE of the U.S.

Controlled nuclear fusion in a Tokamak

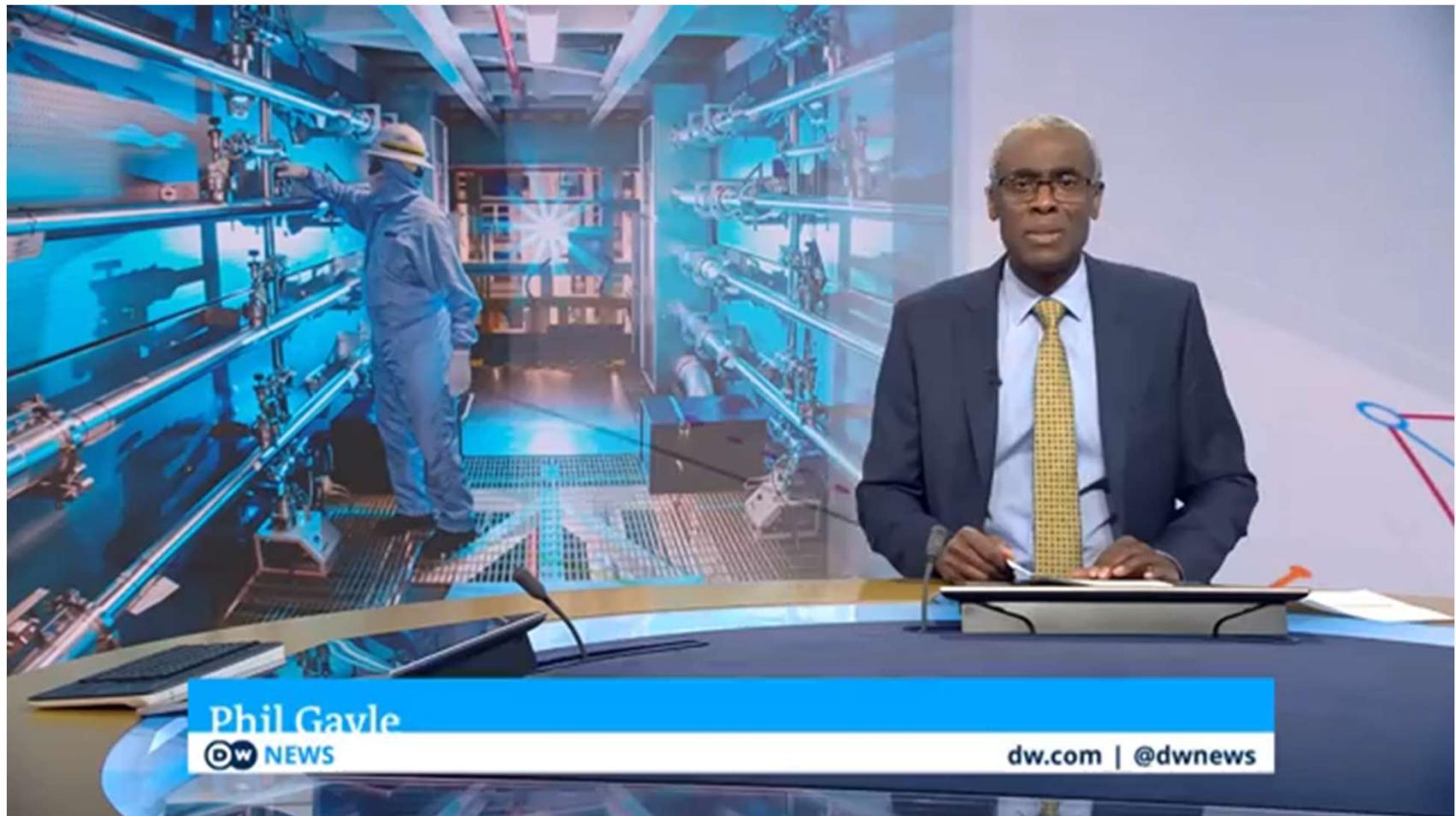


<https://www.energy.gov/science/doe-explainstokamaks>



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

2024-10-28

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**

Outline

- History of Energy Use
- Traditional Energy Production
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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

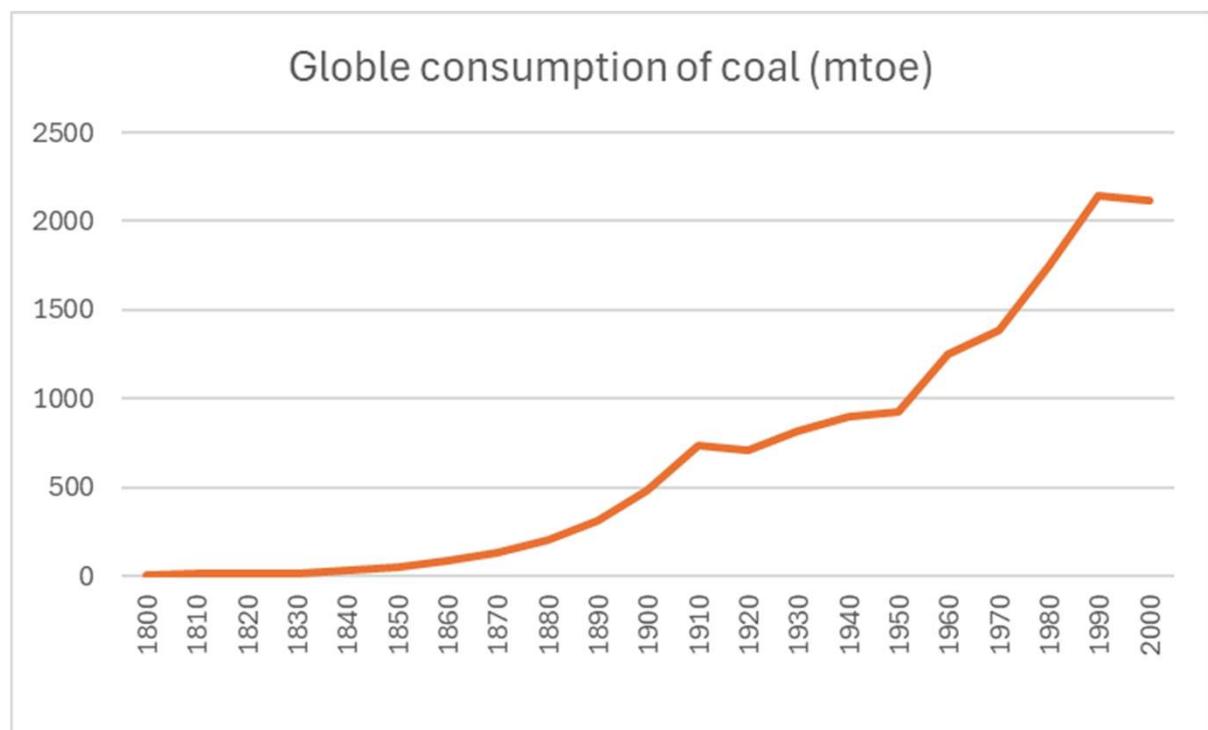
- Started from the 1760s, sophisticated machines replaced human and animal labor in the manufacture and transportation of goods.
- Steam engines converting heat energy into forward motion was central to this transformation



<https://science.howstuffworks.com/>

Global use of coal

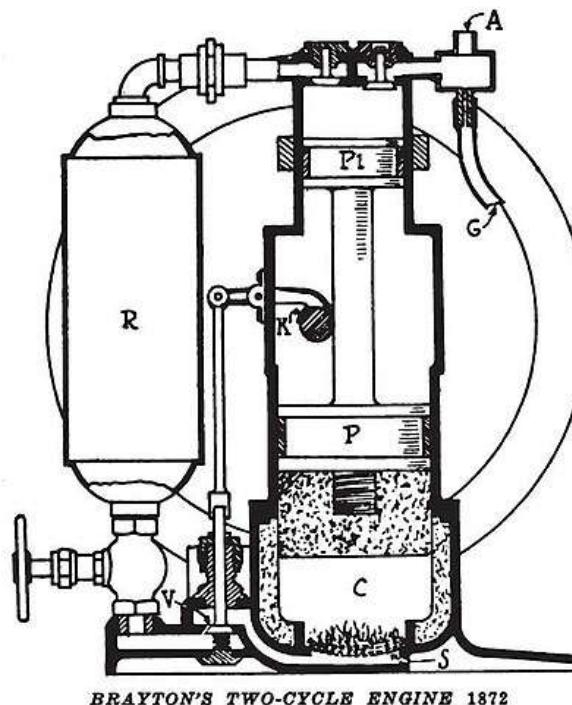
- Steam engine: first practical device converting thermal energy to mechanical energy



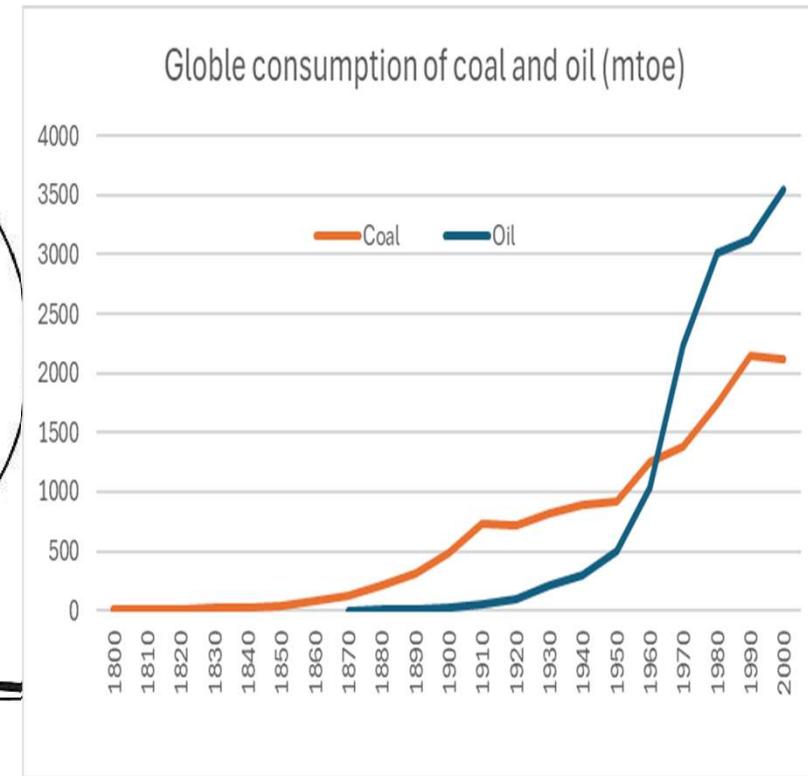
Mtoe: Millions of tones of oil equivalent
<https://www.encyclopedie-energie.org/>

Internal Combustion Engine

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



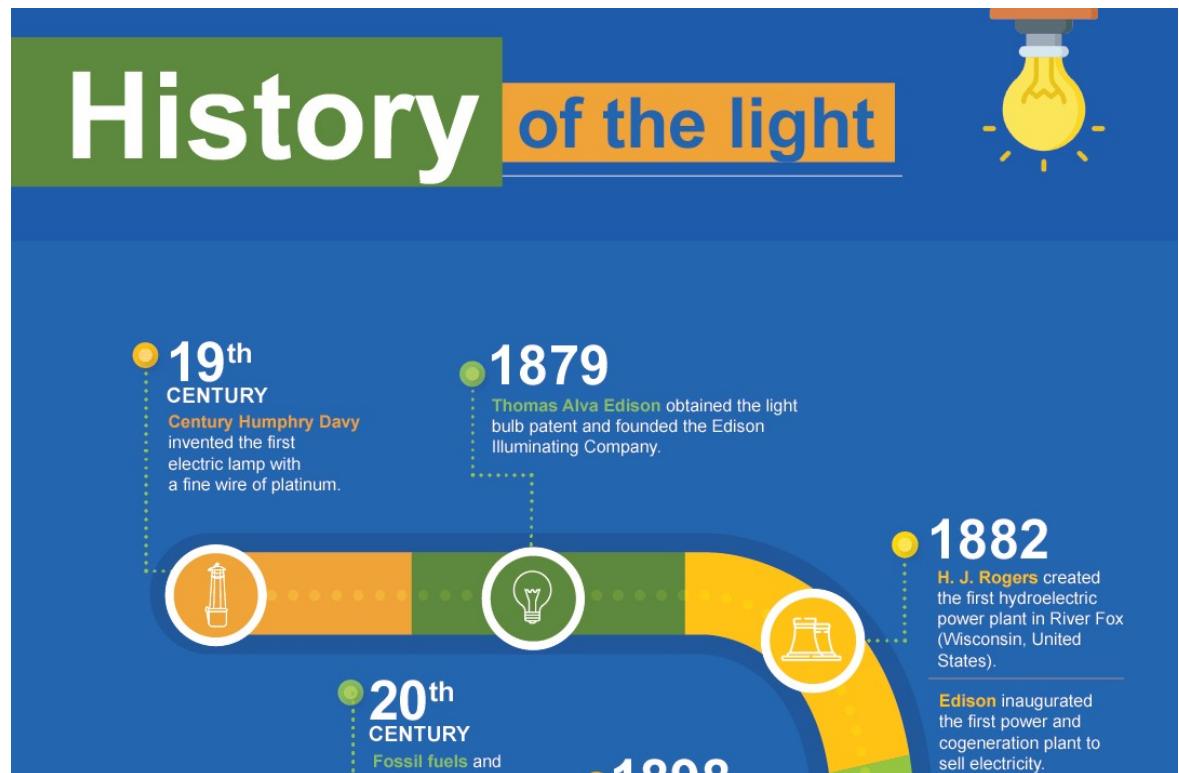
Brayton Gas engine 1872



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 \(iberdrolamexico.com\)](http://iberdrolamexico.com)

Electricity use

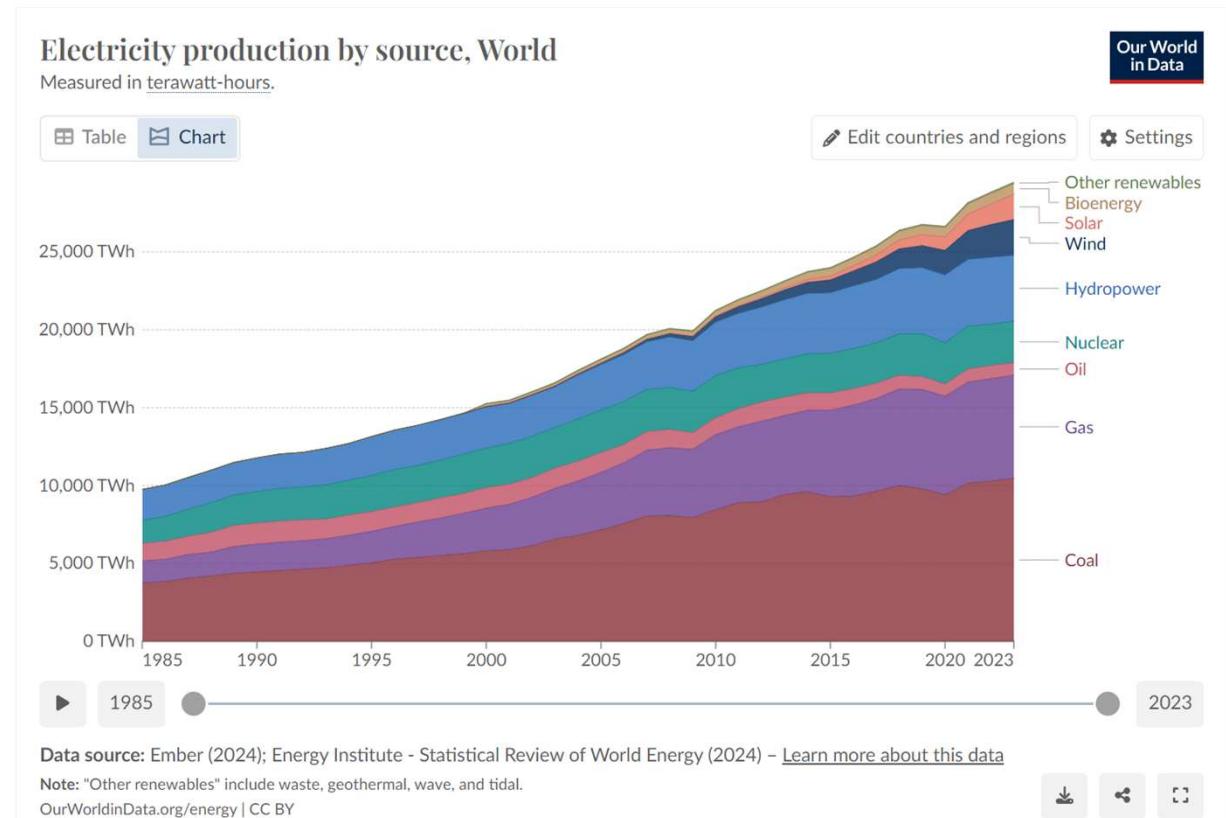
- Electric motors revolutionized industry, change power transmission
- Converting electrical energy into mechanical power
- Electric motors consume ≈50% of the world's electricity
- Residential use also increased quickly



<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



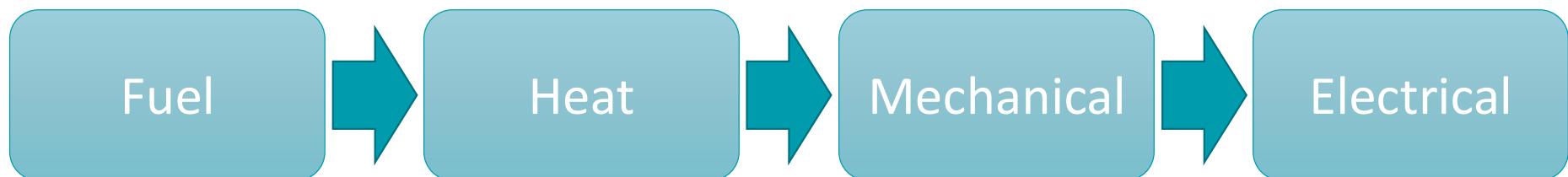


Outline

- 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

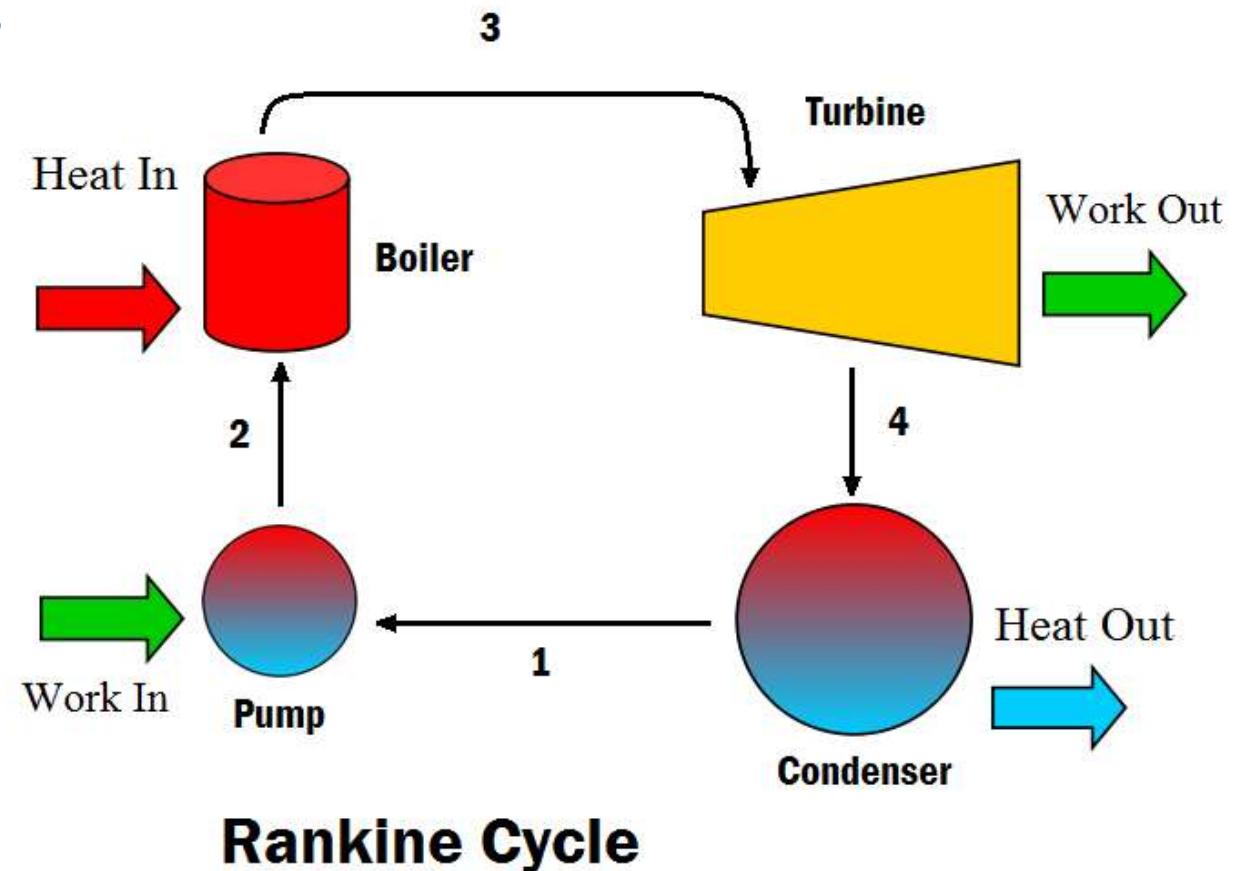


Credit to Prof. Yunlong Zi

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

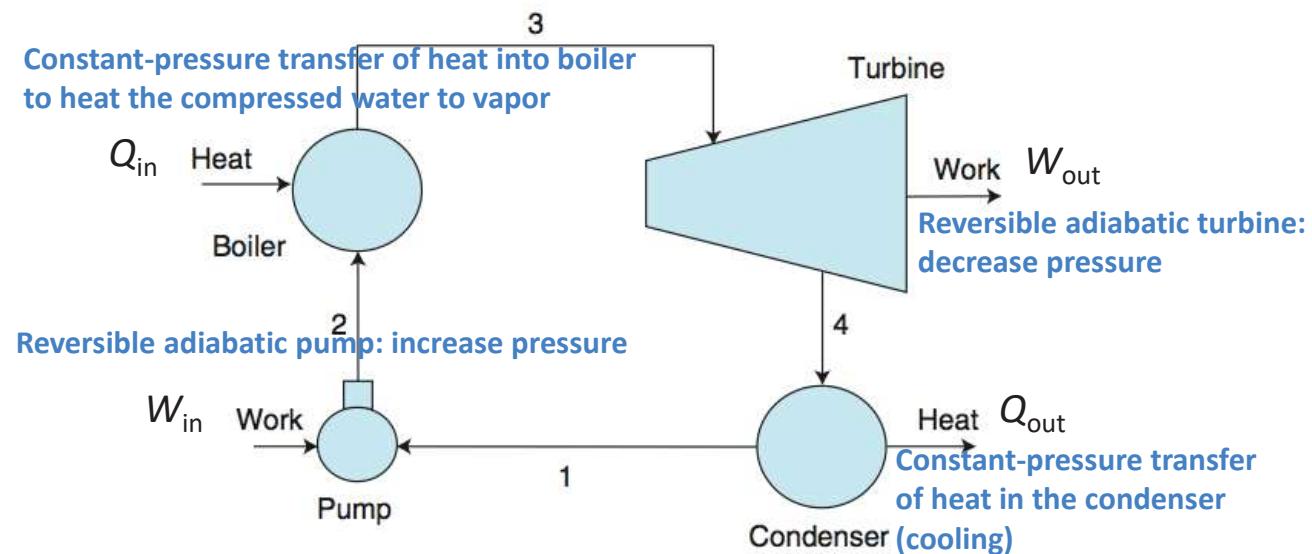


Rankine Cycle

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

► With efficiencies around 30%

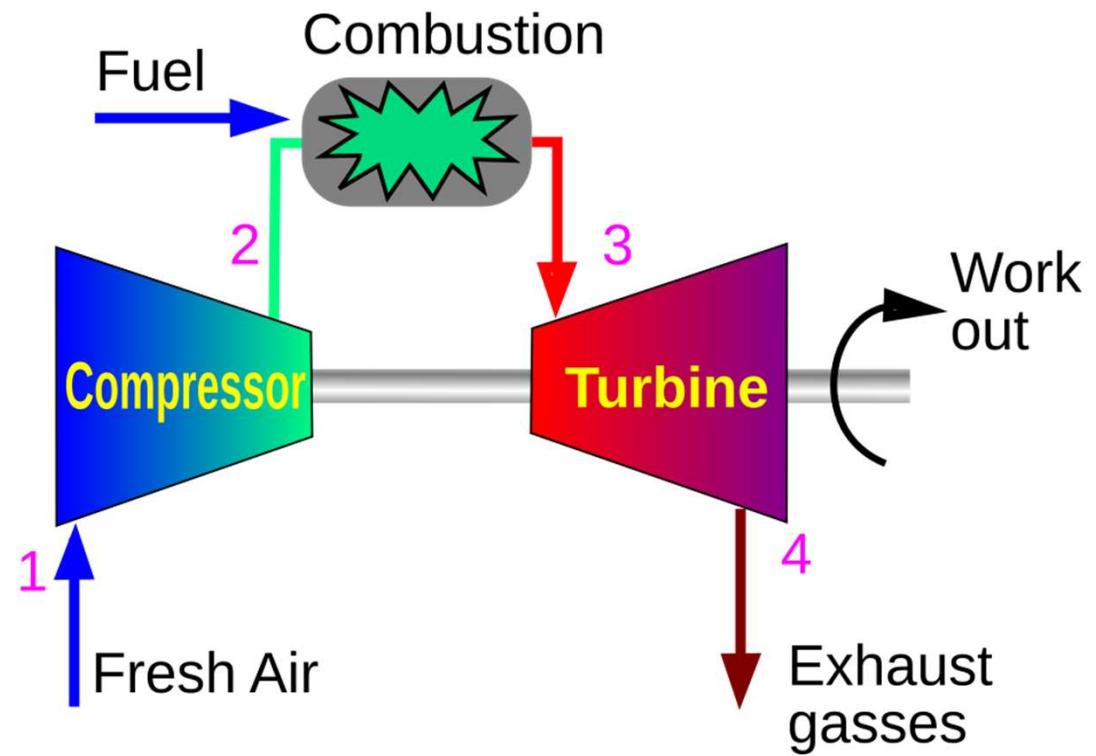
Schematic of components in an ideal Rankine device



Credit to Prof. Yunlong Zi

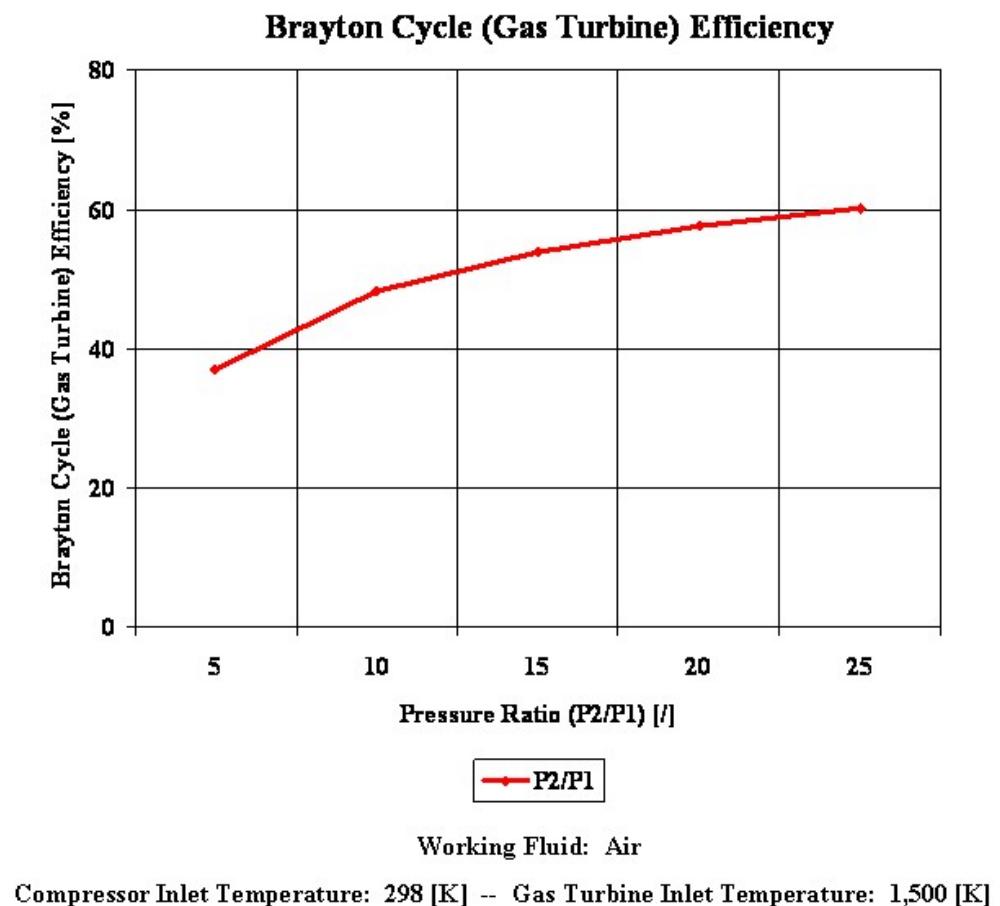
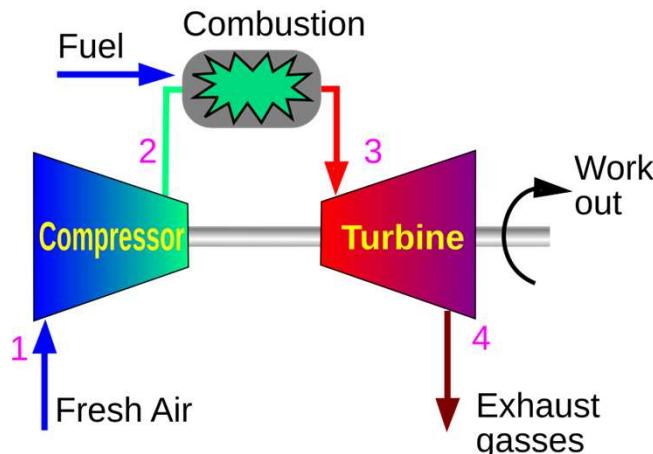
Electricity production through gas burning: Brayton Cycle

- ▶ 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



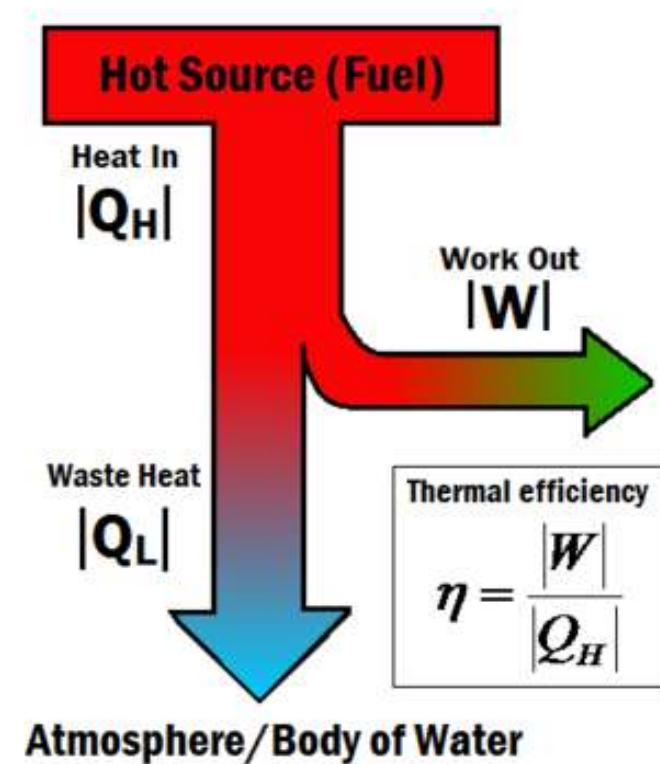
Brayton Cycle: Gaseous Fuel and Gas Turbine

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



Advanced Combustion Cycles for improving efficiencies

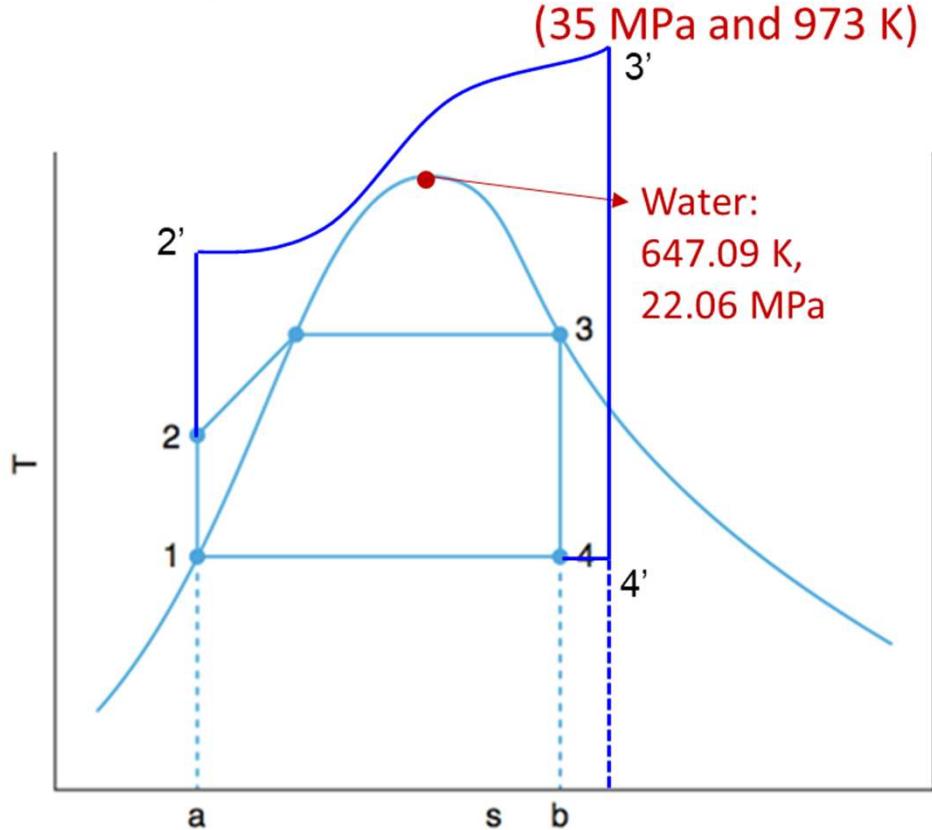
- Three major ways to improve efficiencies:
 - ✓ Supercritical cycle
 - ✓ Combined cycle
 - ✓ Cogeneration



Supercritical cycle

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

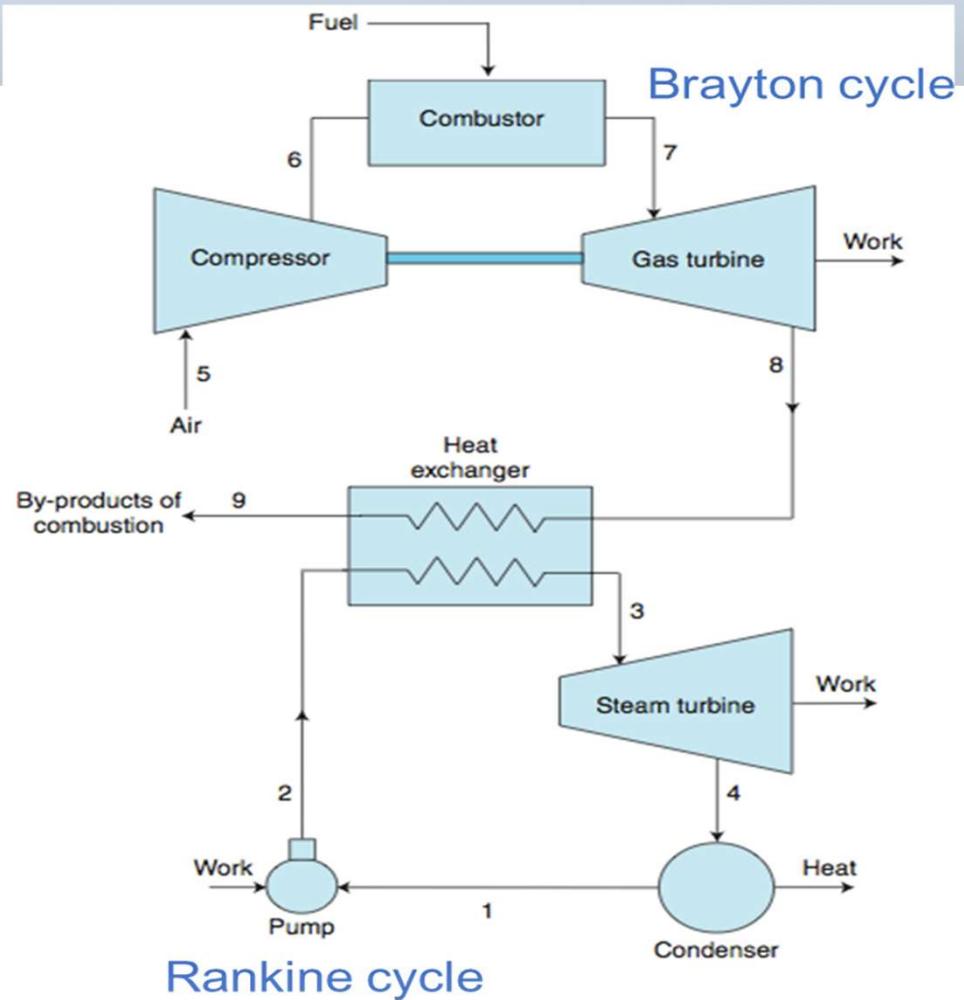
T-s diagram for the ideal Rankine cycle
(35 MPa and 973 K)



Combined Cycle

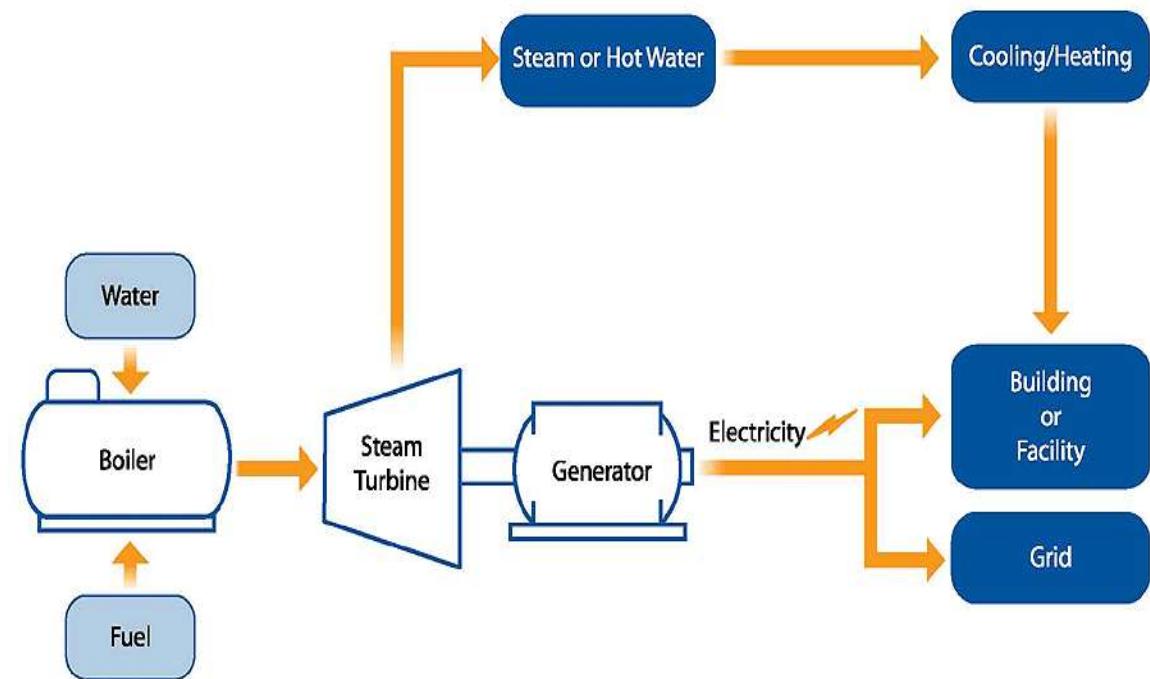
- The remaining energy in the exhaust from the gas turbine can be put to reuse to increase overall system output

Schematic of combined cycle system



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.



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

Environmental problems of fossil fuel combustion

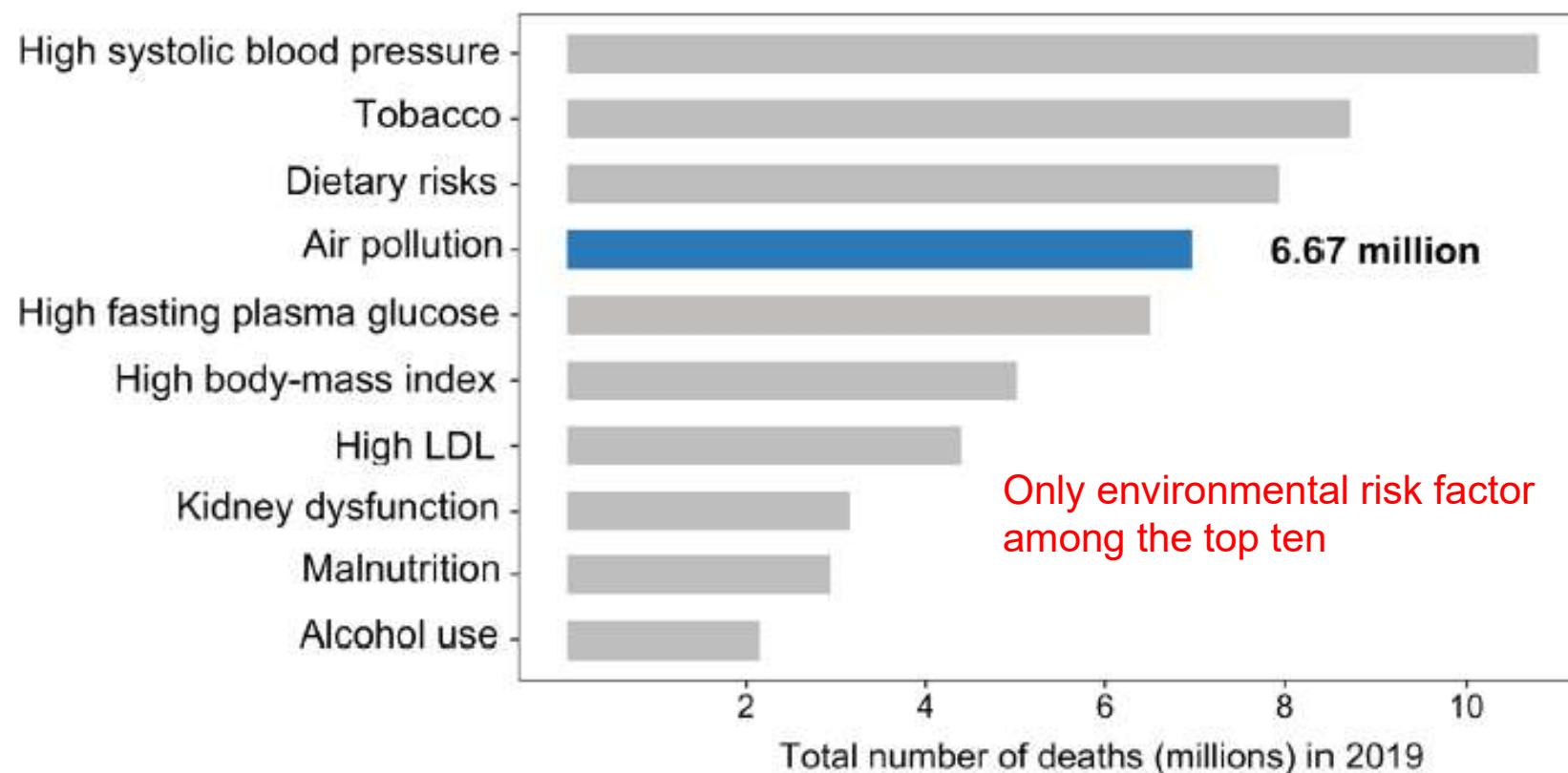
- ▶ NO_x
- ▶ SO₂
- ▶ Particulate
- ▶ Mercury and other heavy metals
- ▶ Ash
- ▶ Smog and acid rain



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

Health effect - Air Pollution causes death!

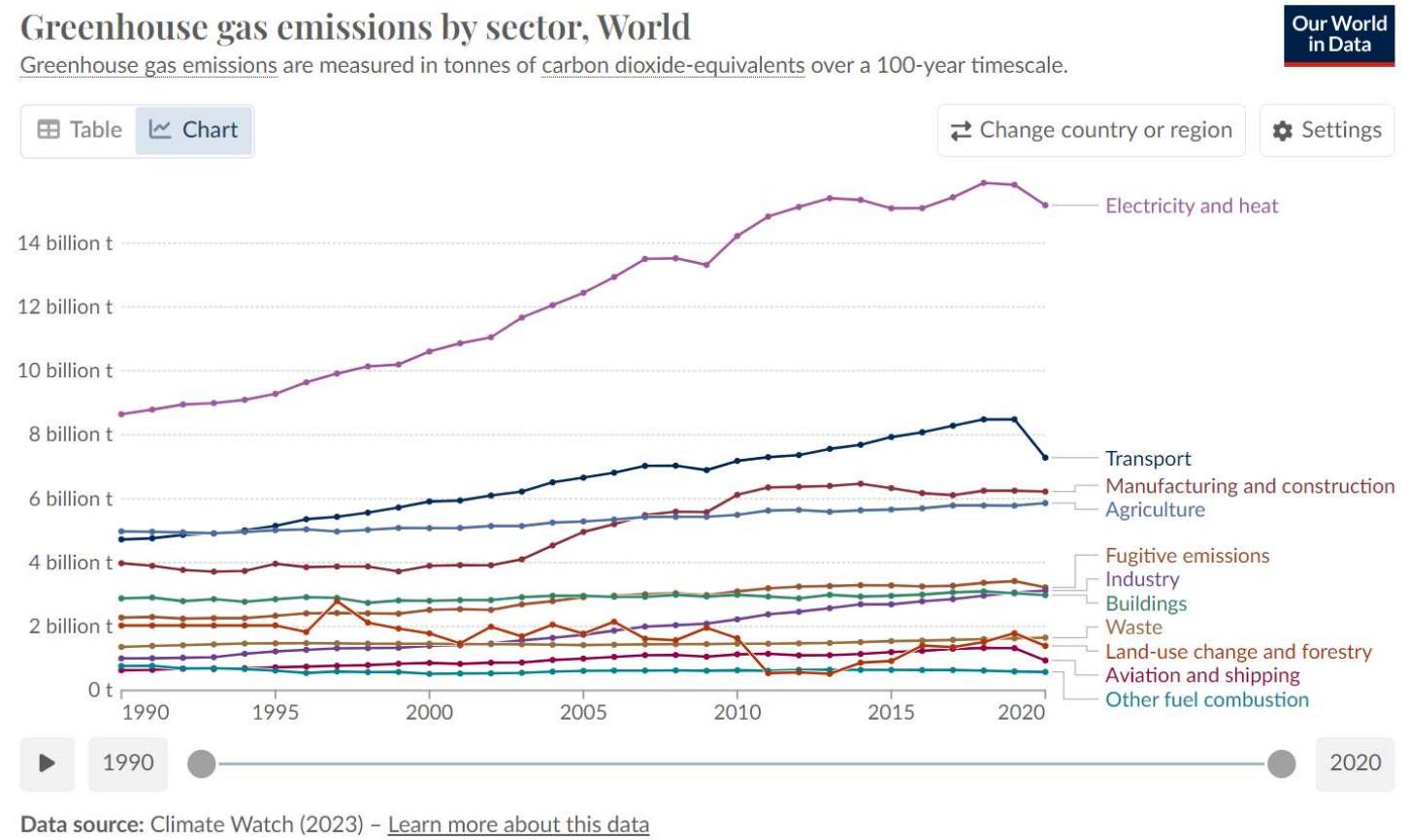
FIGURE 1 Global ranking of risk factors by total number of deaths from all causes in 2019.



Credit to Prof. Ting Fang

Carbon emission

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



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Renewable energy: opportunities and challenges

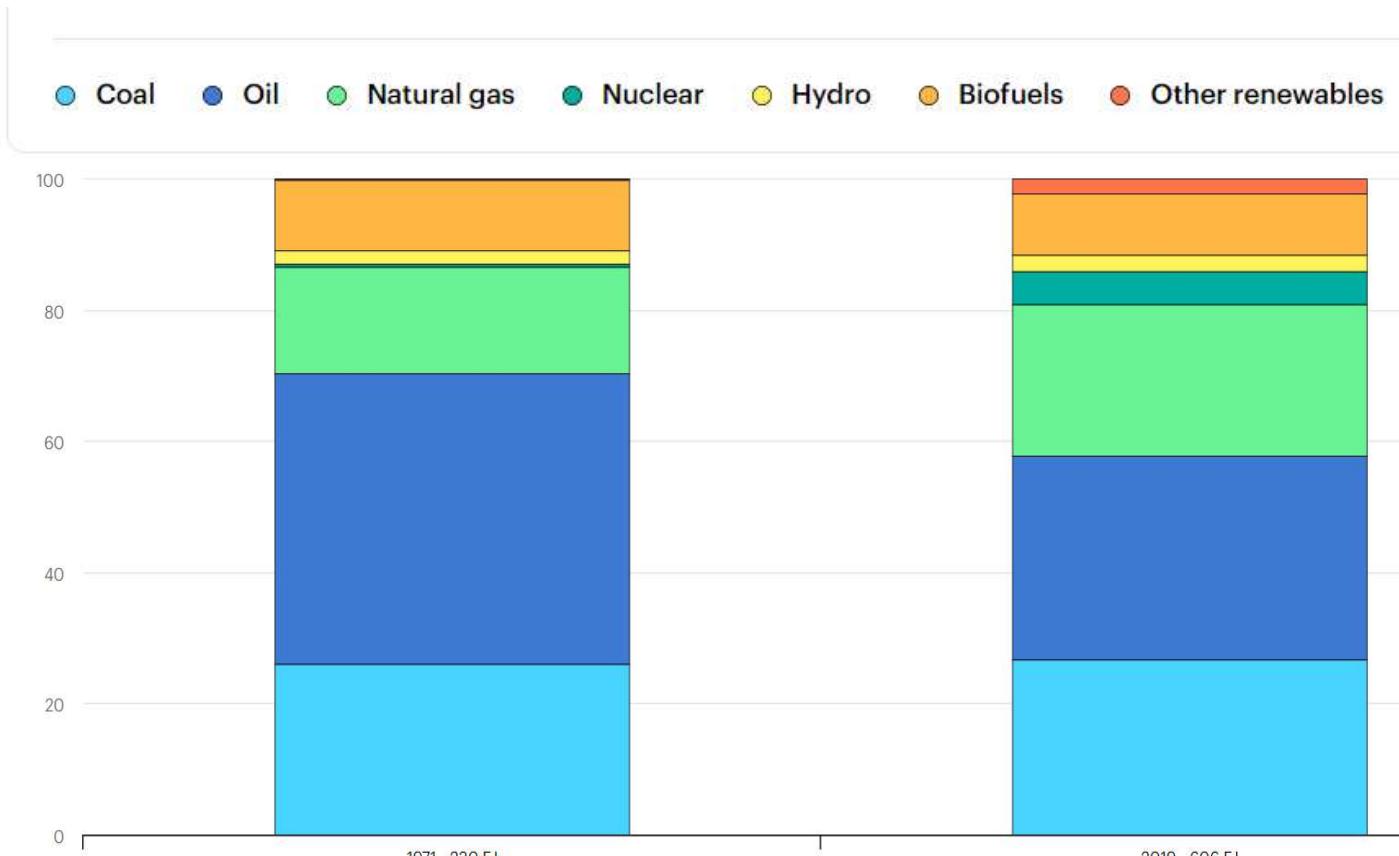
- Wind
- Solar power
- Biofuel



<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

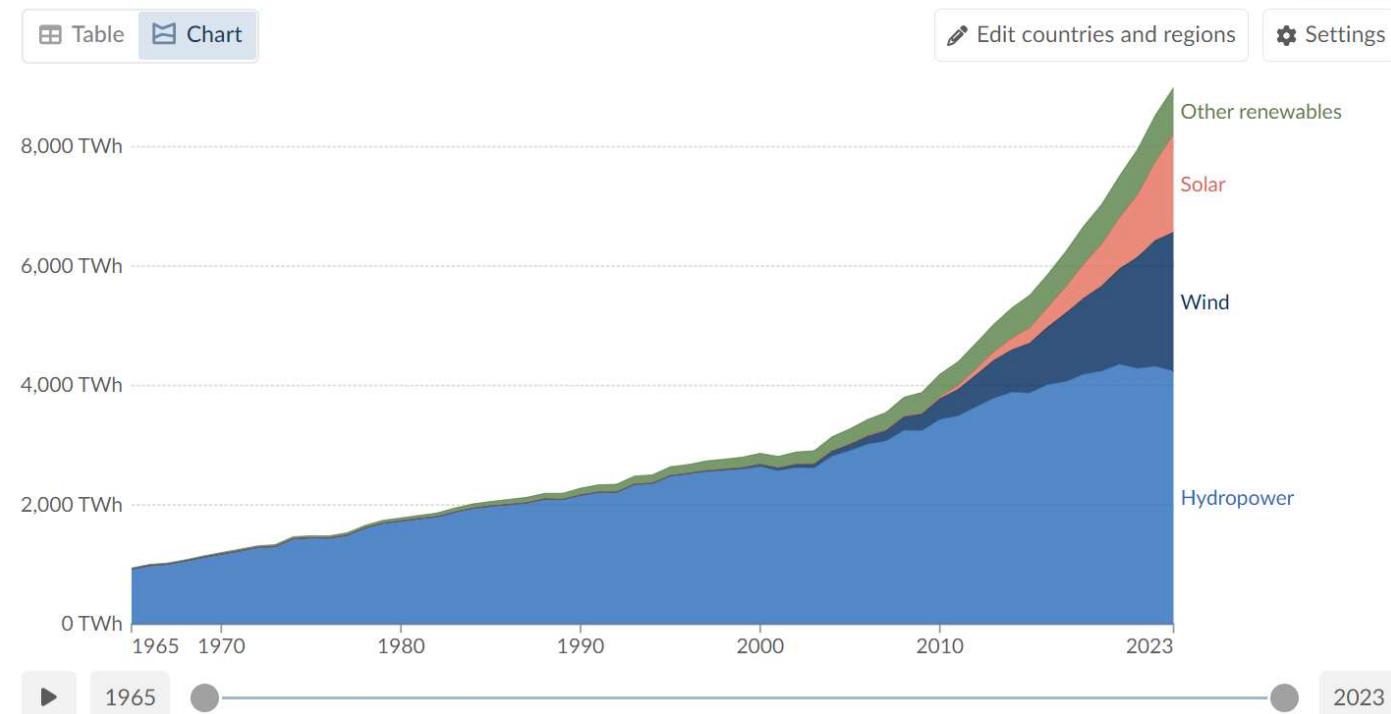


<https://www.iea.org/reports/world-energy-balances-overview/world>

Renewable energy

- Wind and solar are becoming critical sources of renewable energy.
- Increased quickly since the 2000

Renewable electricity generation, World



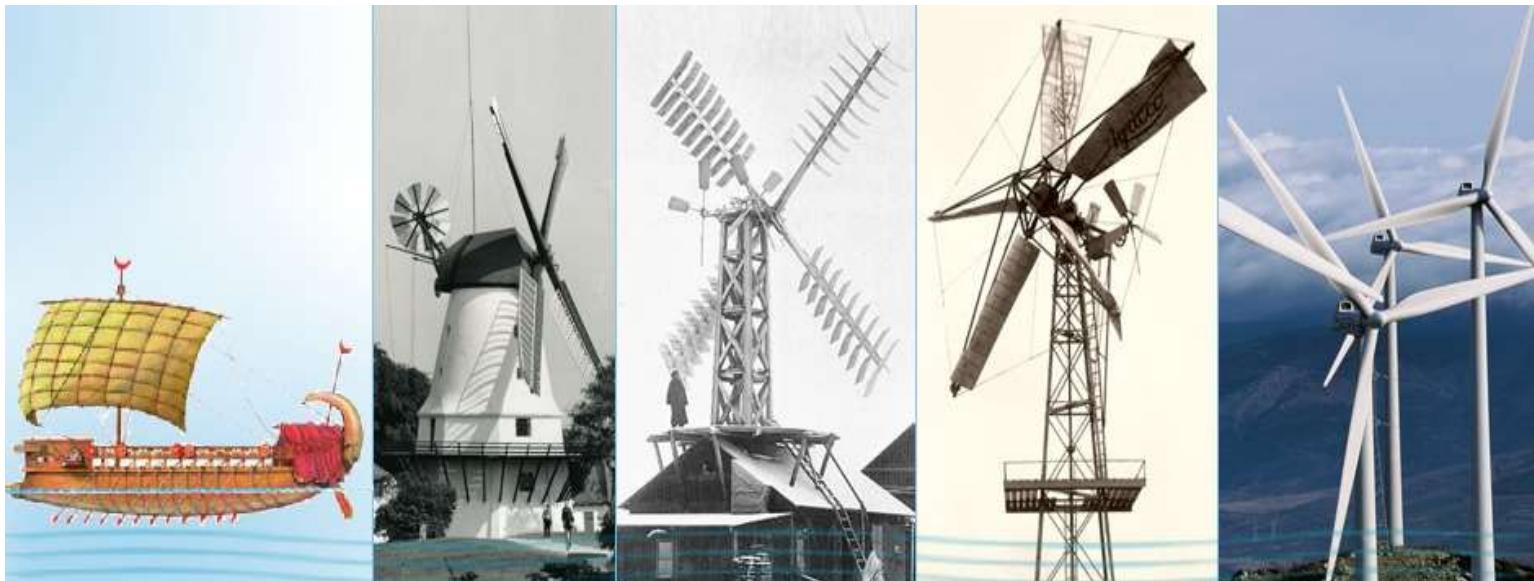
<https://ourworldindata.org/renewable-energy>

Large wind farms across the world



Wind energy

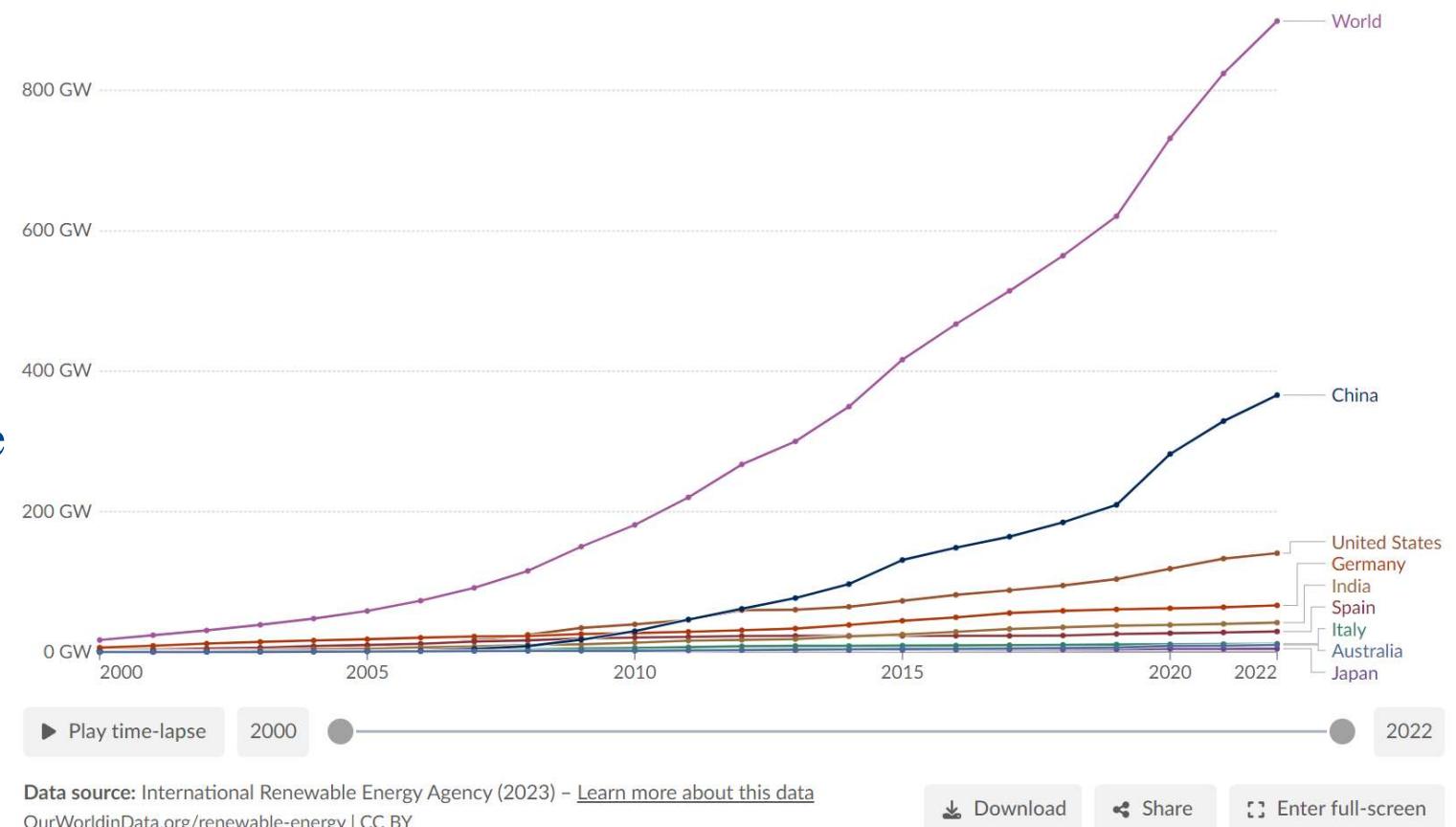
- Historical developments of wind power
 - ✓ Sailing Ships, Grinding Grain, Pumping water, Power Source of Factories



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



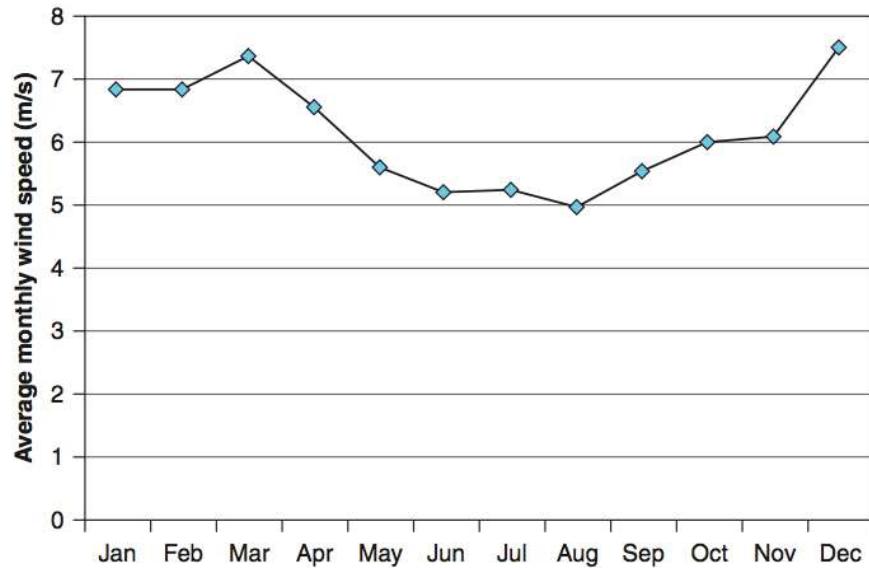
Wind power

- 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

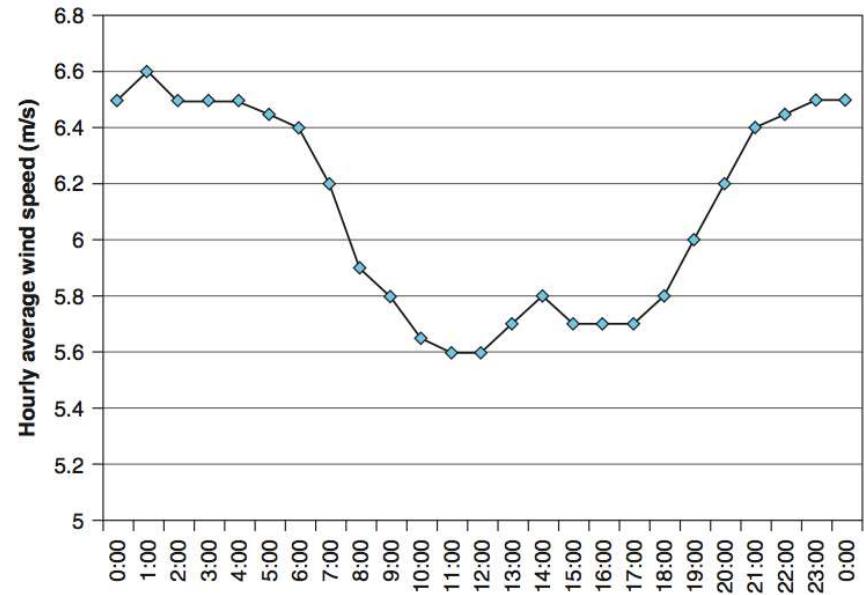
Temporal variability of wind speed

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

Seasonal distribution of wind speed in m/s



Hourly distribution of wind speed

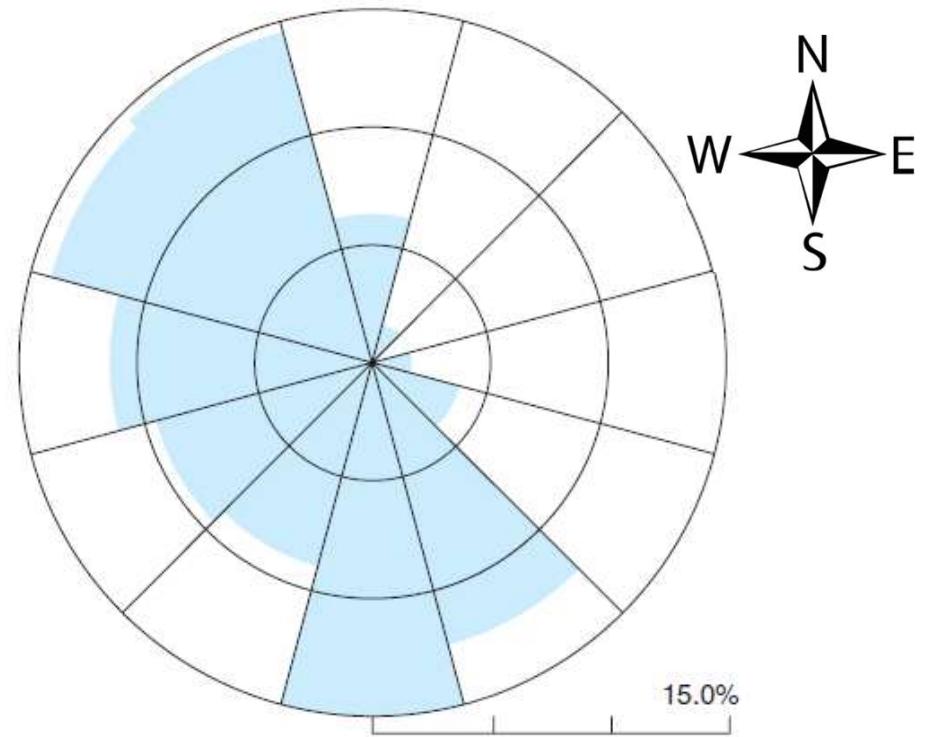


Credit to Prof. Yunlong Zi

Effect of wind direction

- Varied wind direction
- Design wind turbine like a “sunflower”

Percentage time distribution of wind direction



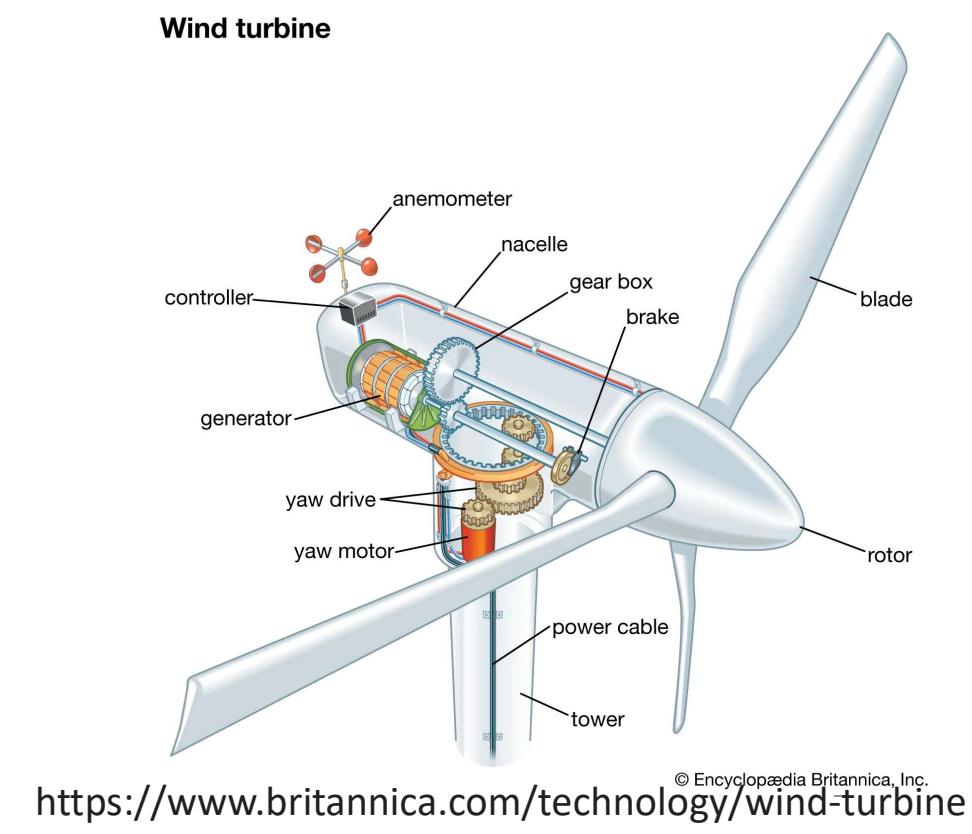
Credit to Prof. Yunlong Zi

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/>

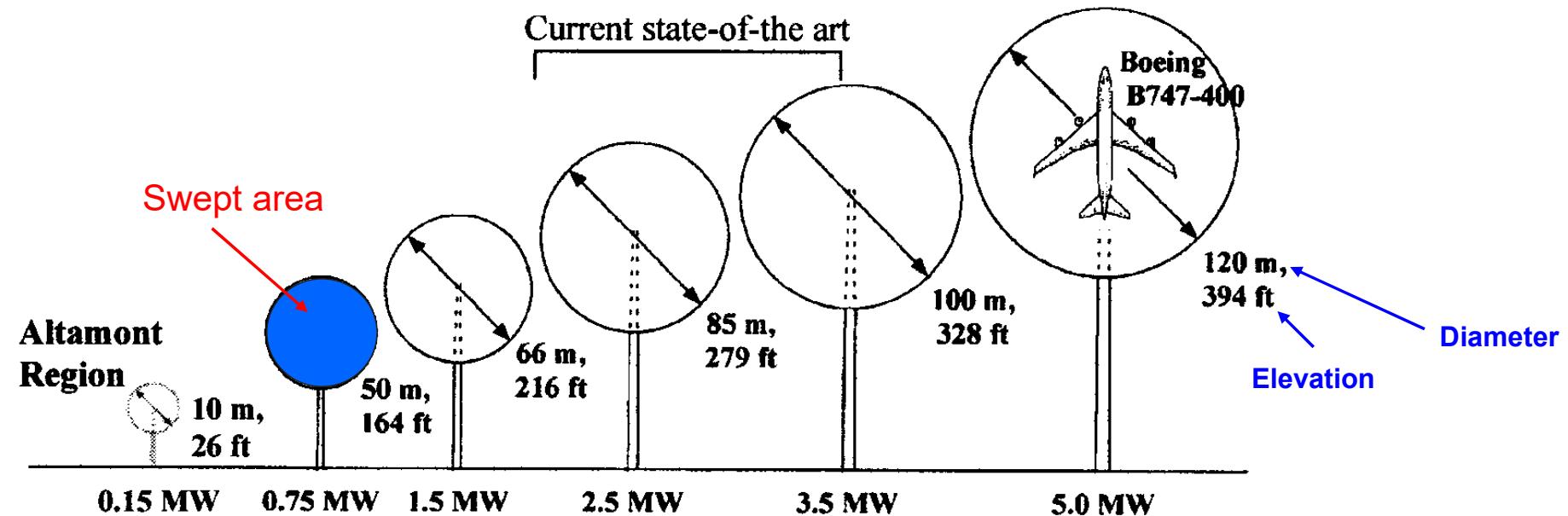


<https://www.britannica.com/technology/wind-turbine>

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Blade size

- Larger area, higher power; but requires better technology

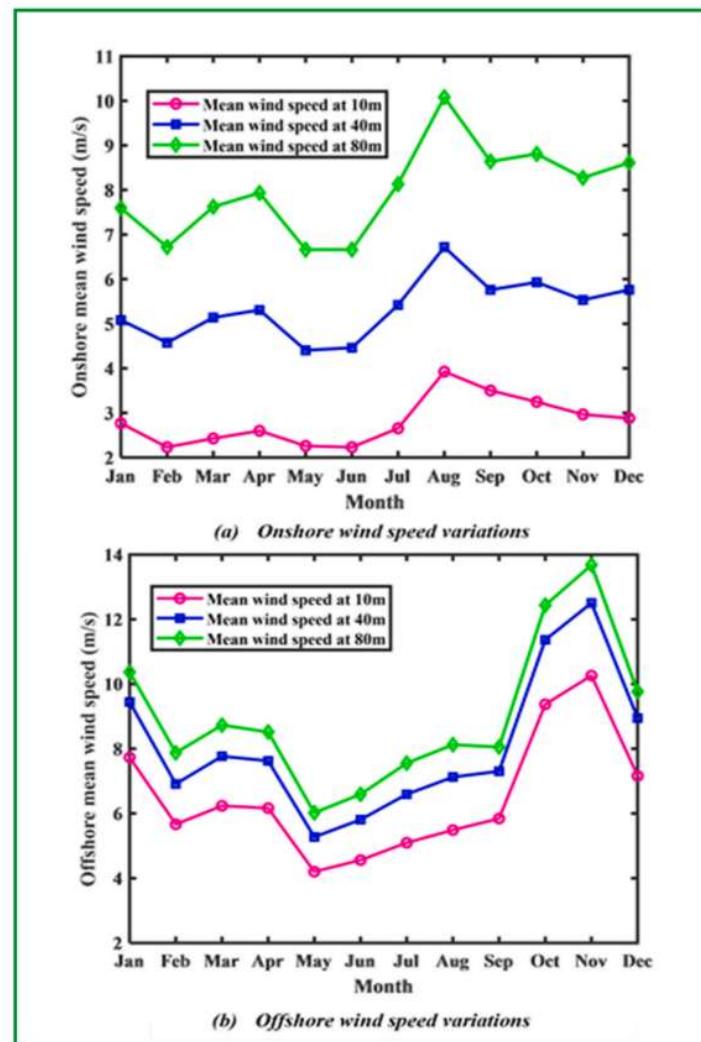


Credit to Prof. Yunlong Zi

Onshore vs. Offshore wind

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

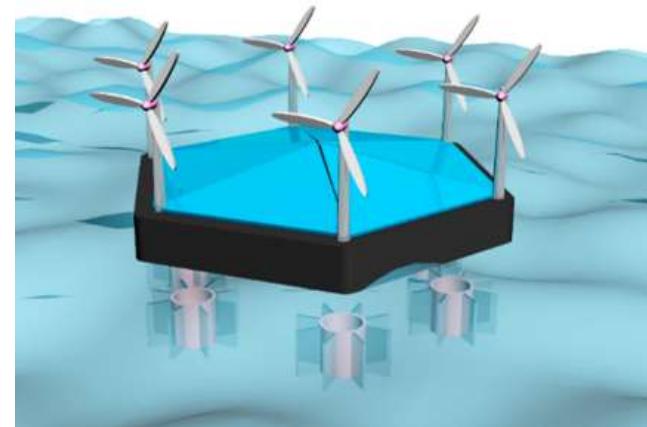
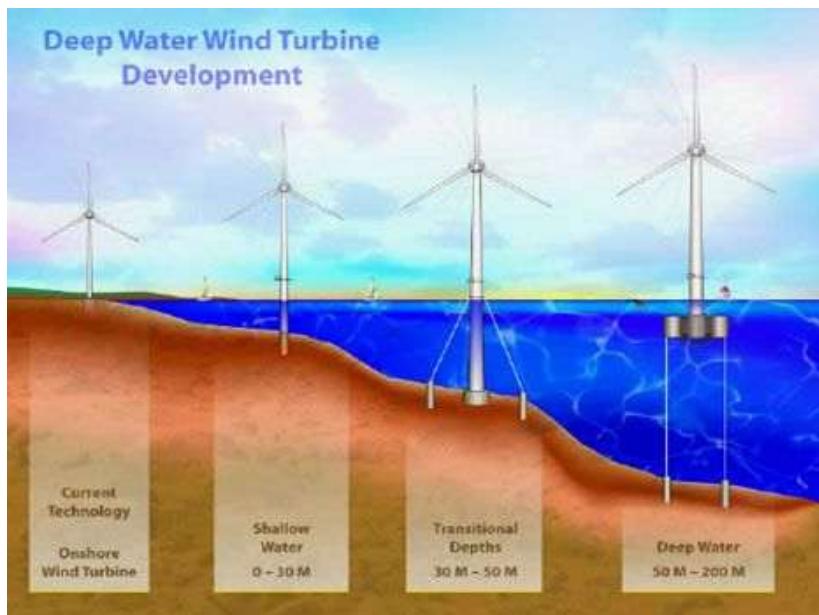
Desalegn, 2023



Year	I. Historical Data (GW)	
	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

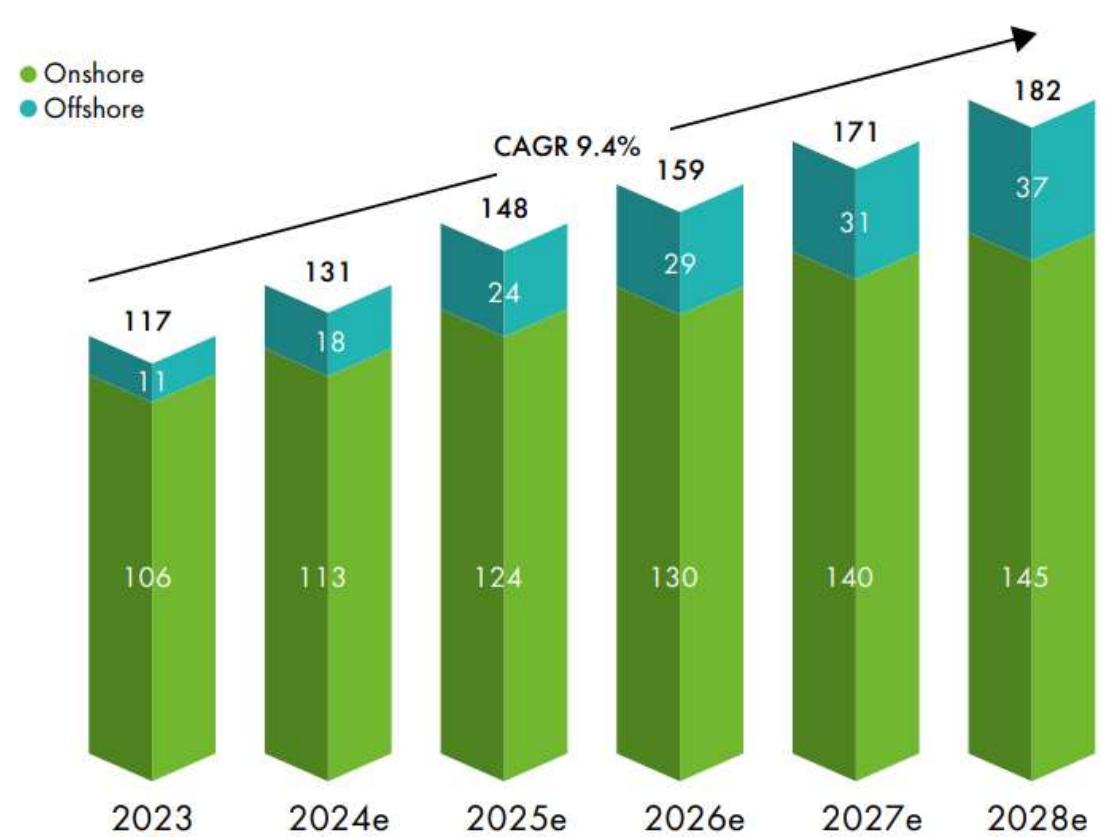


proposed comprehensive
energy harvesting panel

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.



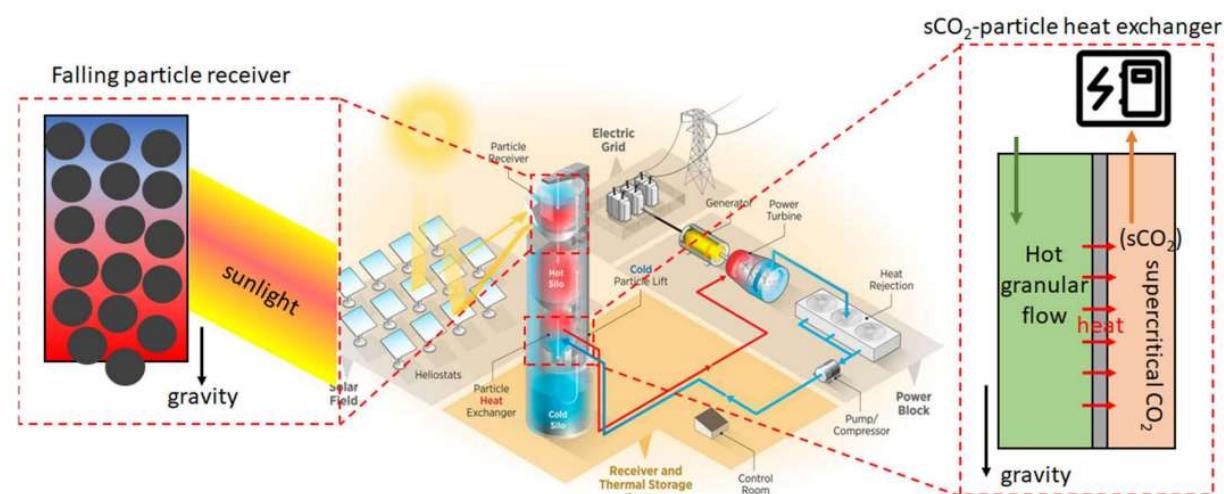
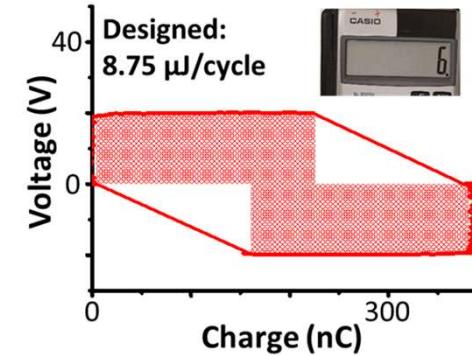
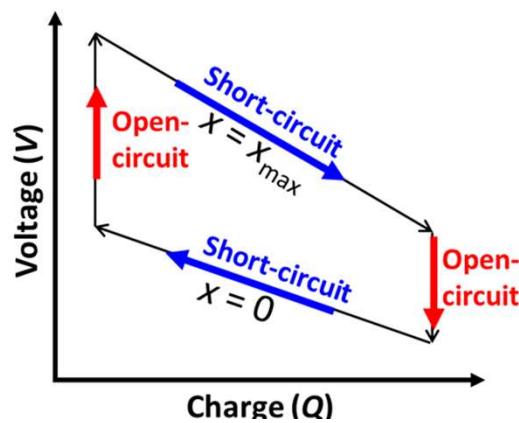
Energy production related Research in the SEE Thrust



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



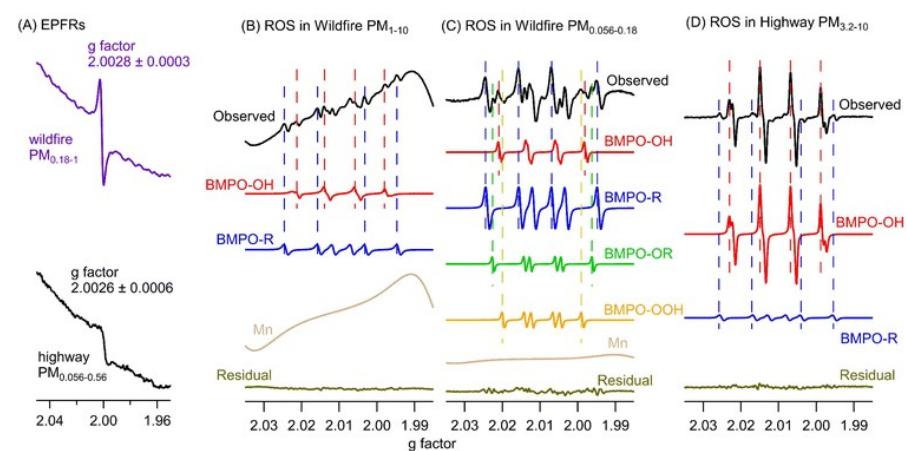
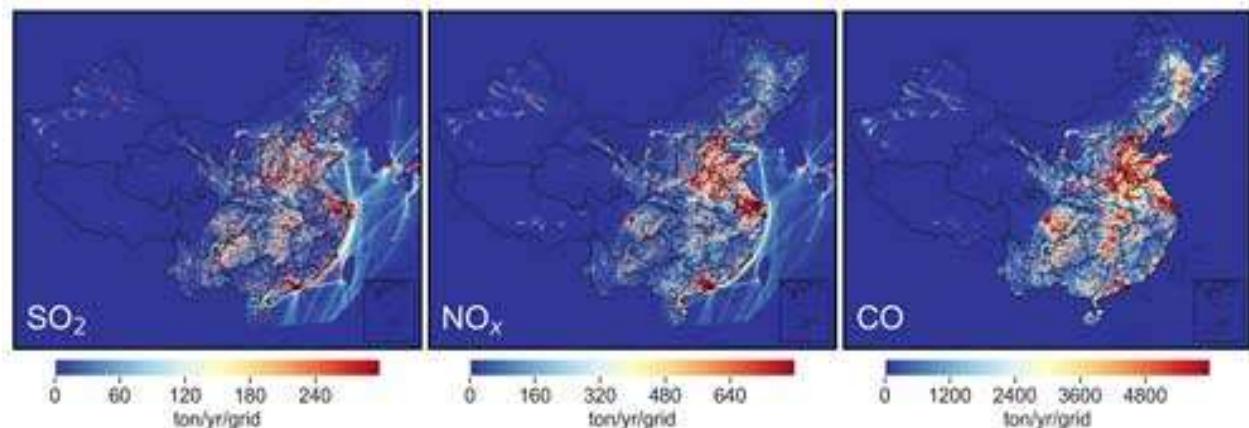
Shuncheng LEE 李顺诚



Ting Fang 方婷



Yutong LIANG 梁雨桐



**Your
feedback is
highly
appreciated!**

