Day 1:

Climate Change and Renewable Energy

S15060: Saving the World with the Science of Sustainability!

Instructor: Simo

Saturday, July 9th, 2022

2:30-4:00 PM

Special thanks to Chad Wilson, who taught this class and made the original slides in 2020!

Our goals for today

1. Define light, energy, and the greenhouse effect.

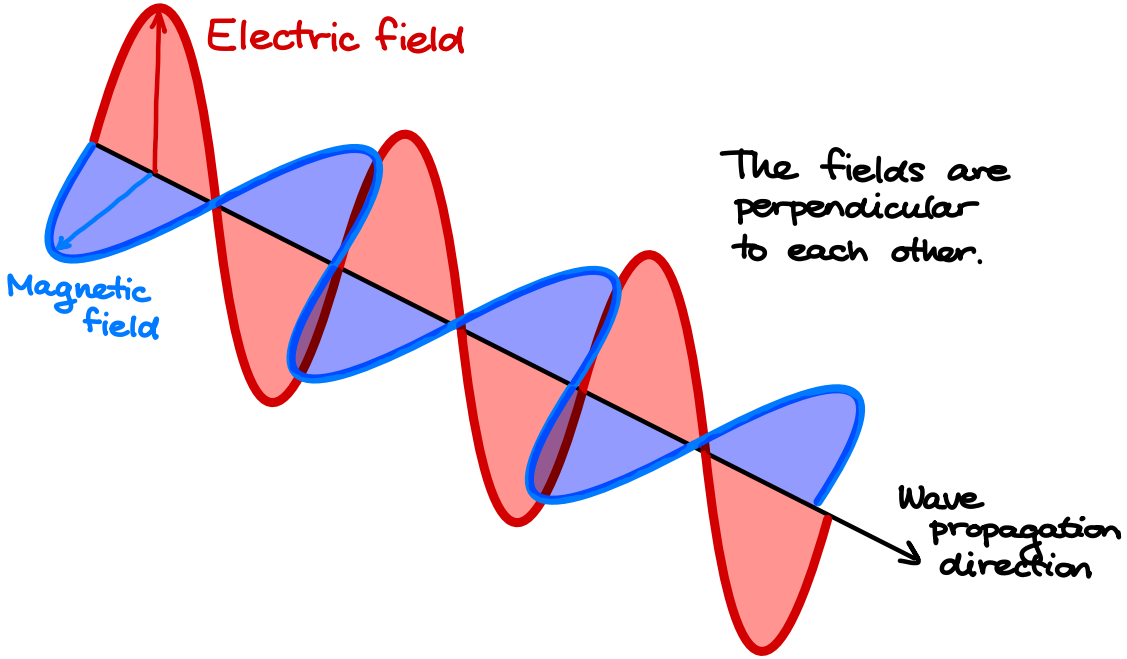
2. Understand what gases are responsible for global warming and how they work.

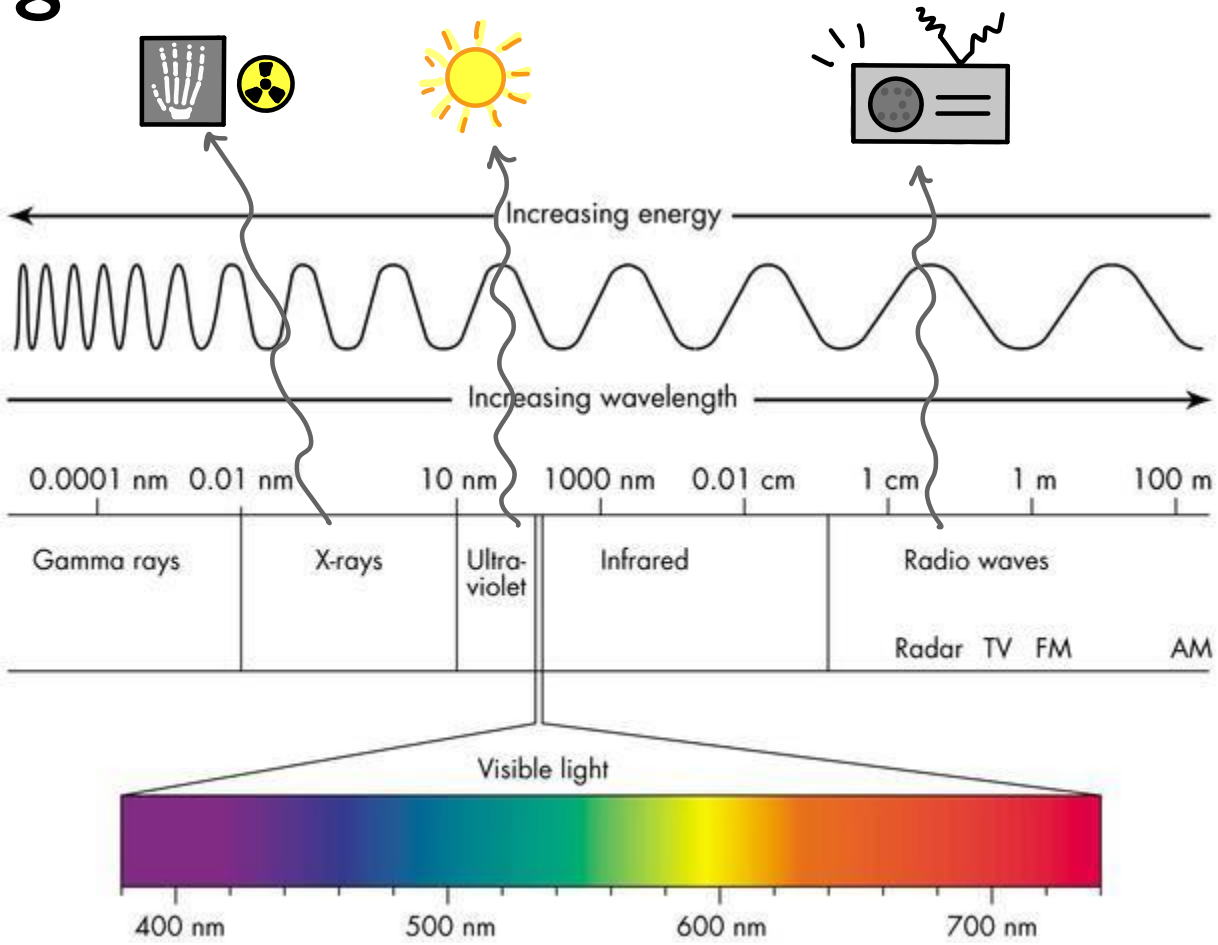
3. Understand *why* global warming is such a serious problem.

4. Understand how **greenhouse gases** are produced.

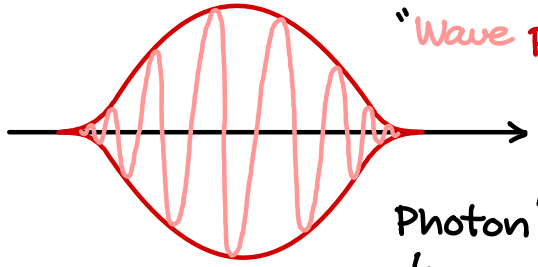
5. Learn about how we can avoid producing greenhouse gases and the role thermal science plays in doing so.

LIGHT is an *electromagnetic wave*





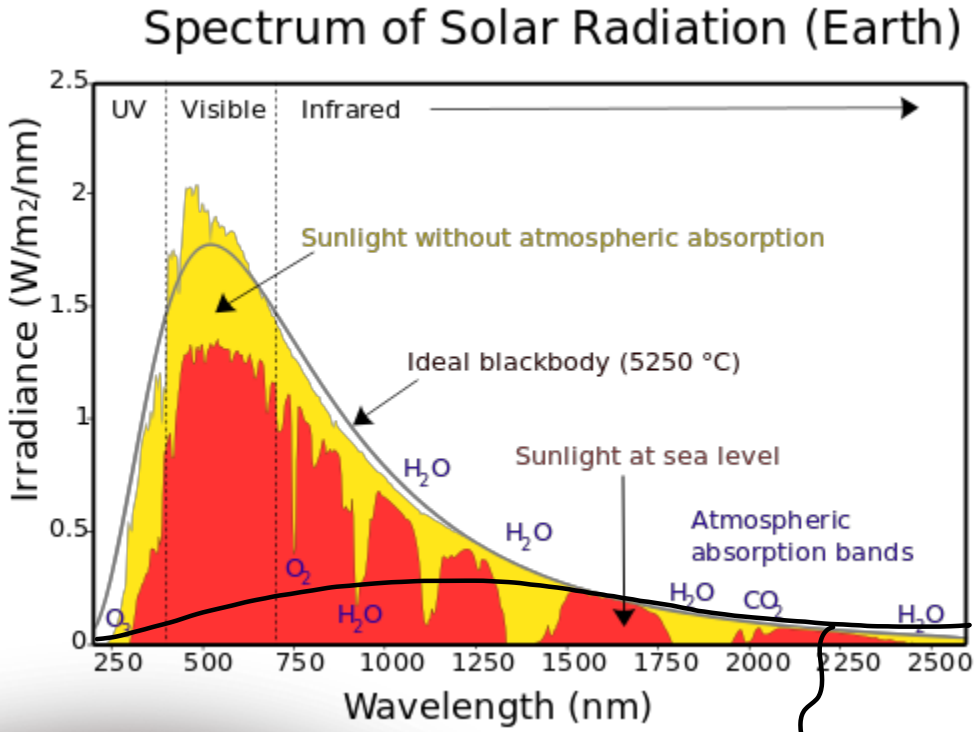
Strictly speaking, light more like a "wavepacket" and has some particle-like characteristics…



Photon → Planck → "quanta"

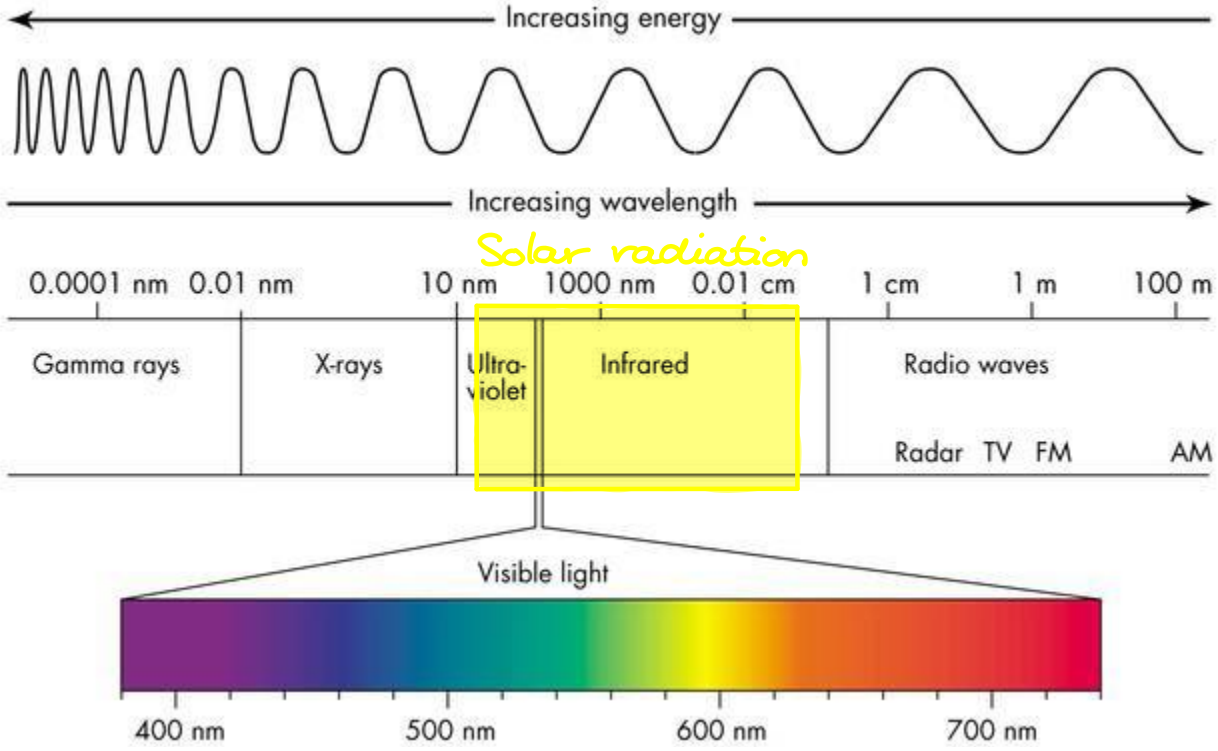
↳ Einstein → Photoelectric effect

The primary source of all light on Earth is the sun

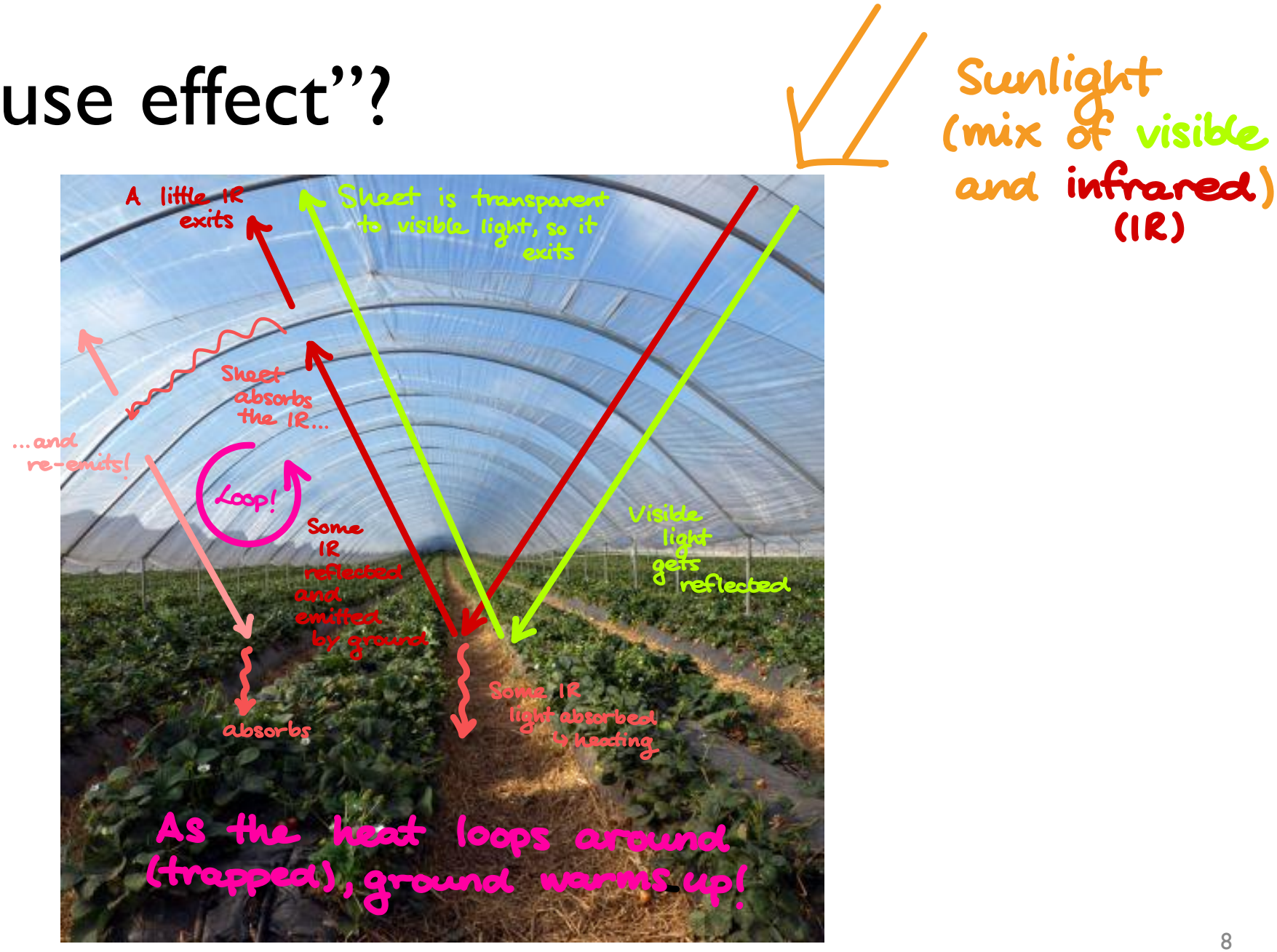


Spectrum of a room temp. object

Where is solar radiation in this picture?



"Greenhouse effect"?



Pause for questions!

1. ~~Define light, energy, and the greenhouse effect.~~

Next…

2. Understand <u>what</u> gases are responsible for global warming and <u>how</u> they work.
3. Understand *why* global warming is such a serious problem.
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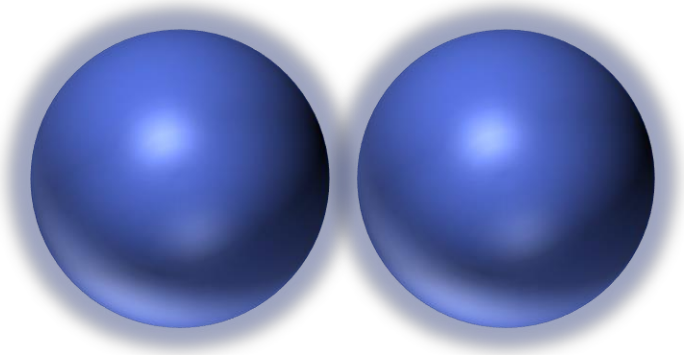
Let's get gassy—a molecular view on the greenhouse effect

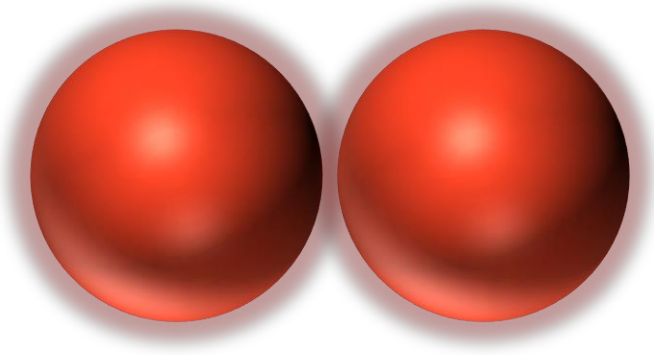
In the case of our planet, it's not plastic trapping heat—it's GAS

78%



Nitrogen (N_2)

21%



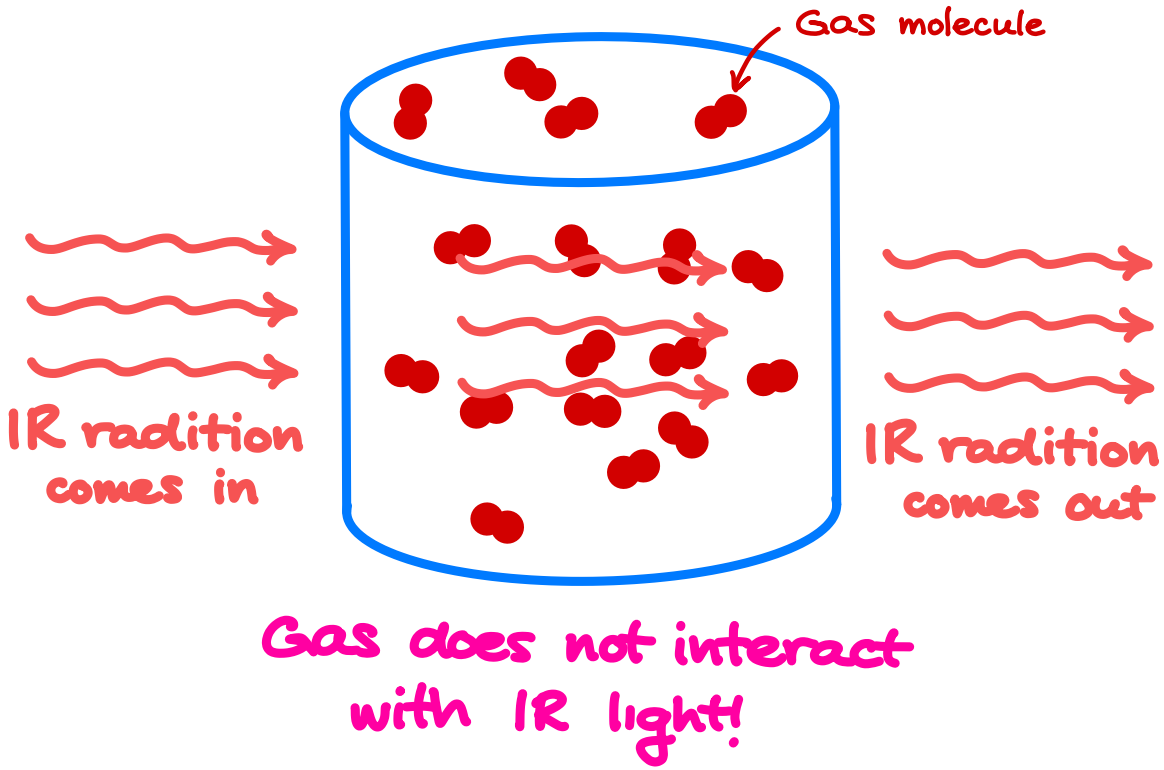
Oxygen (O_2)

The rest of it includes…

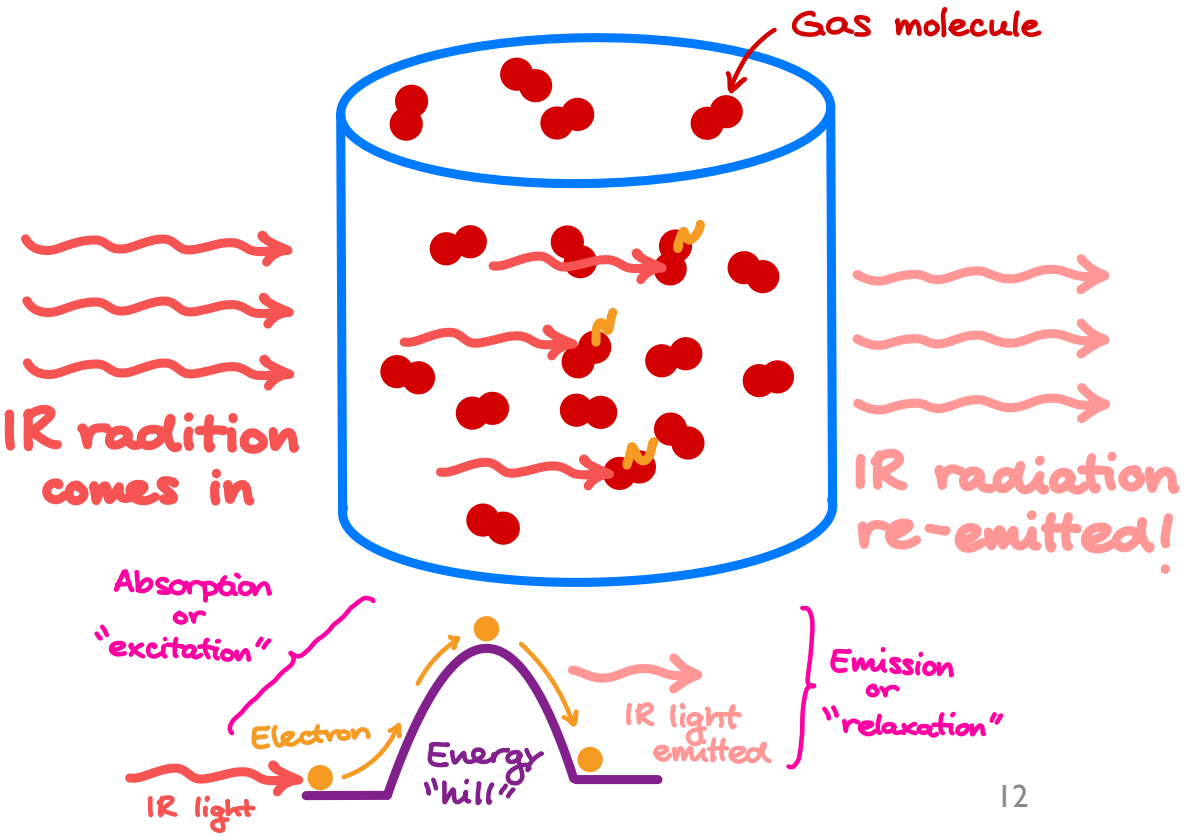
- Water vapor (H_2O)
- Carbon dioxide (CO_2)
- Argon (Ar)
- Neon (Ne)
- Helium (He)
- Methane (CH_4)
- Krypton (Kr)
- Hydrogen (H_2)

Gases in the atmosphere can be transparent or absorbing

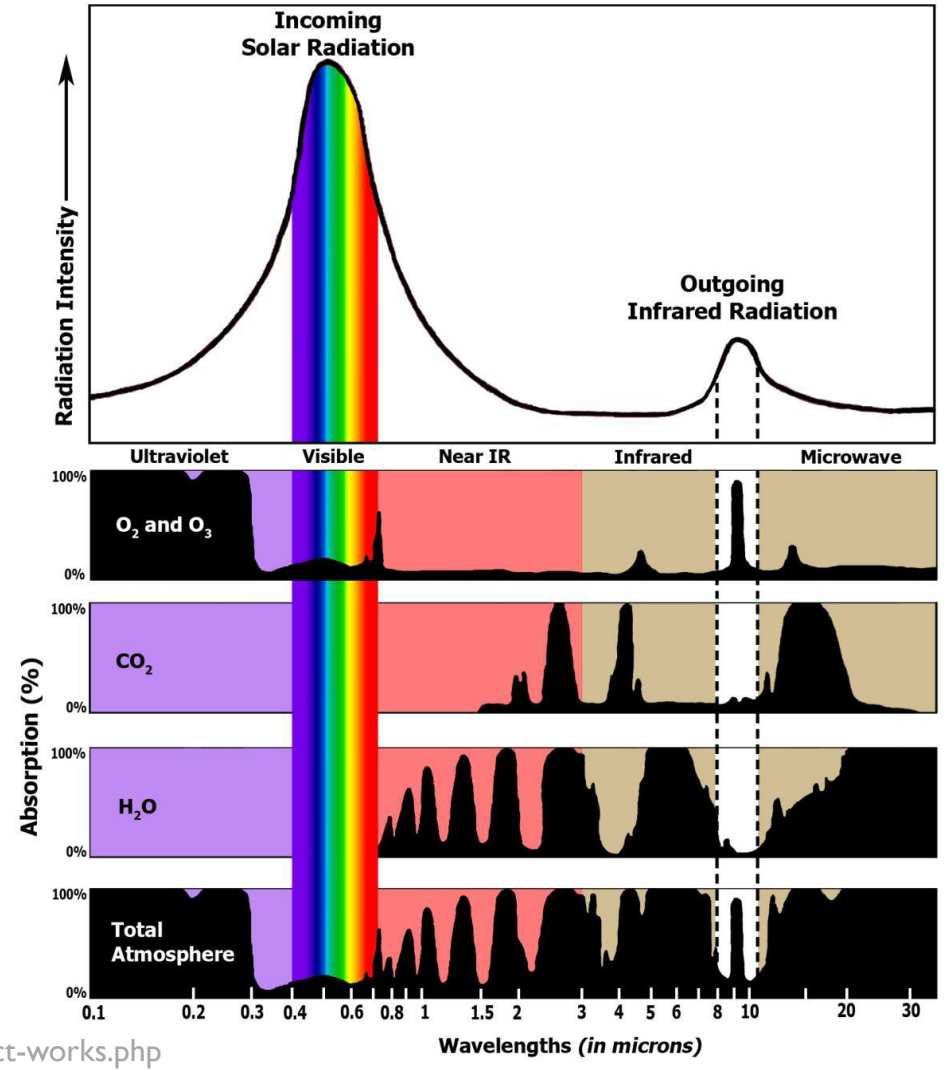
Transparent



Absorbing

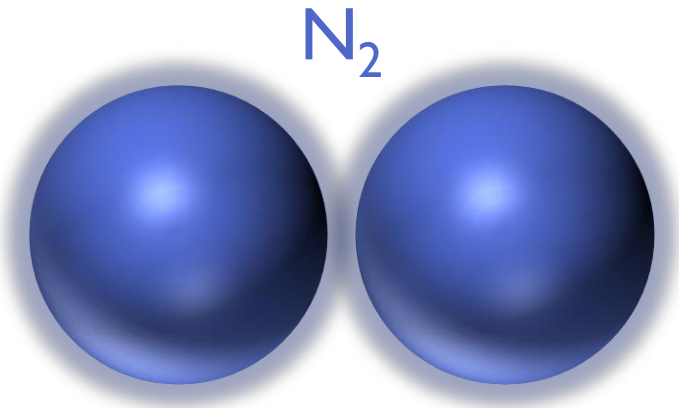


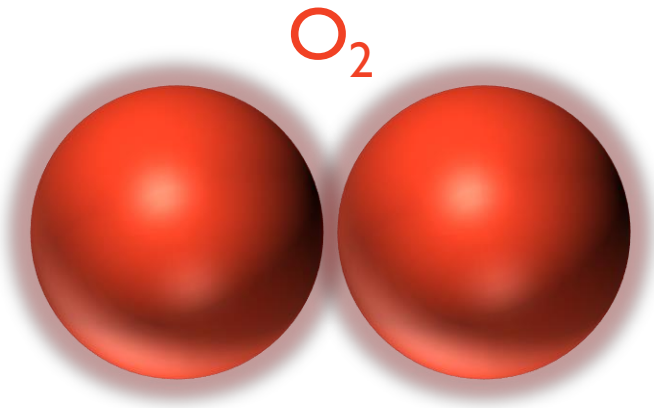
Gases in the atmosphere can be transparent or absorbing *at different wavelengths of light*



http://www.ces.fau.edu/nasa/module-2/how-greenhouse-effect-works.php

Each gas has its own problems

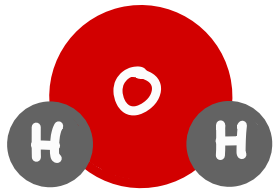




Except for these two—transparent in the visible and infrared!

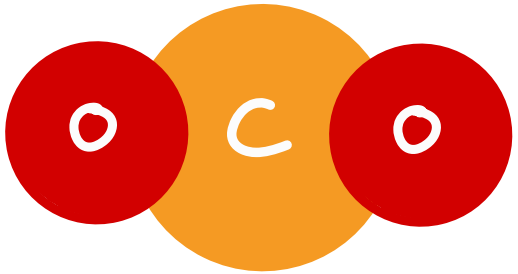
GHGs:

H_2O (Water!)



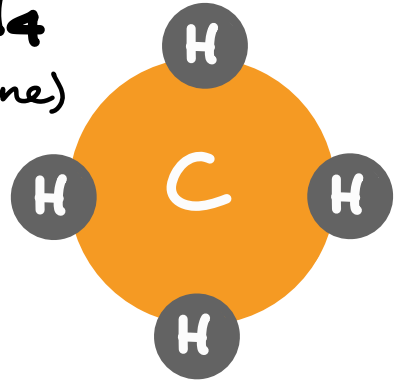
- Very absorbing
- Strong temp. dependence

CO_2



- Great IR absorber
- Long atmospheric lifetime !!

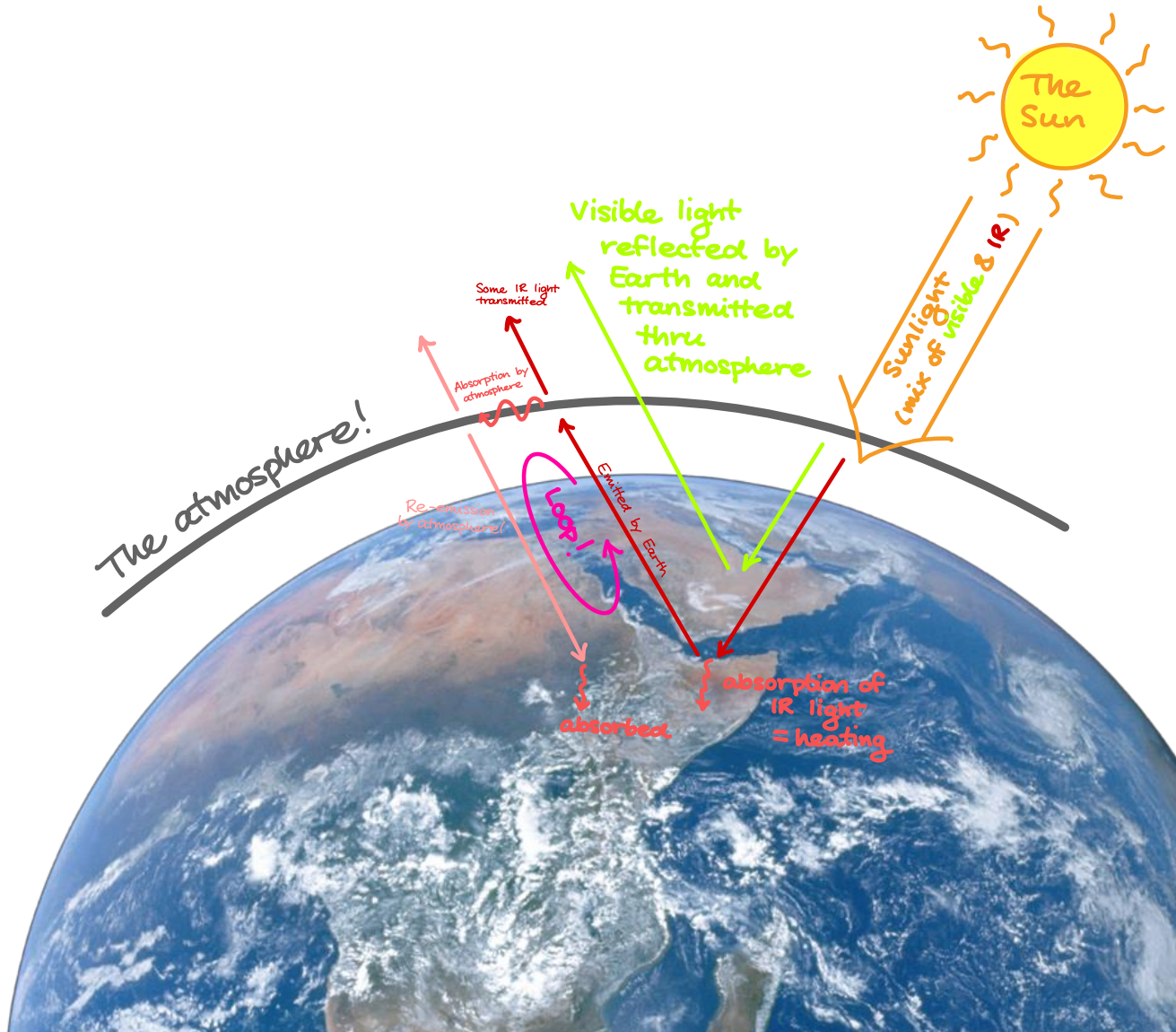
CH_4 (Methane)



- 30x stronger IR absorber than CO_2
- Short atmospheric lifetime

Others: SO_x NO_x CFCs HCFCs (from aerosols and fridges)

Using what we know, let's scale up to Earth



As the heat loops around, planet heats up!

Pause for questions!

1. ~~Define light, energy, and the greenhouse effect.~~

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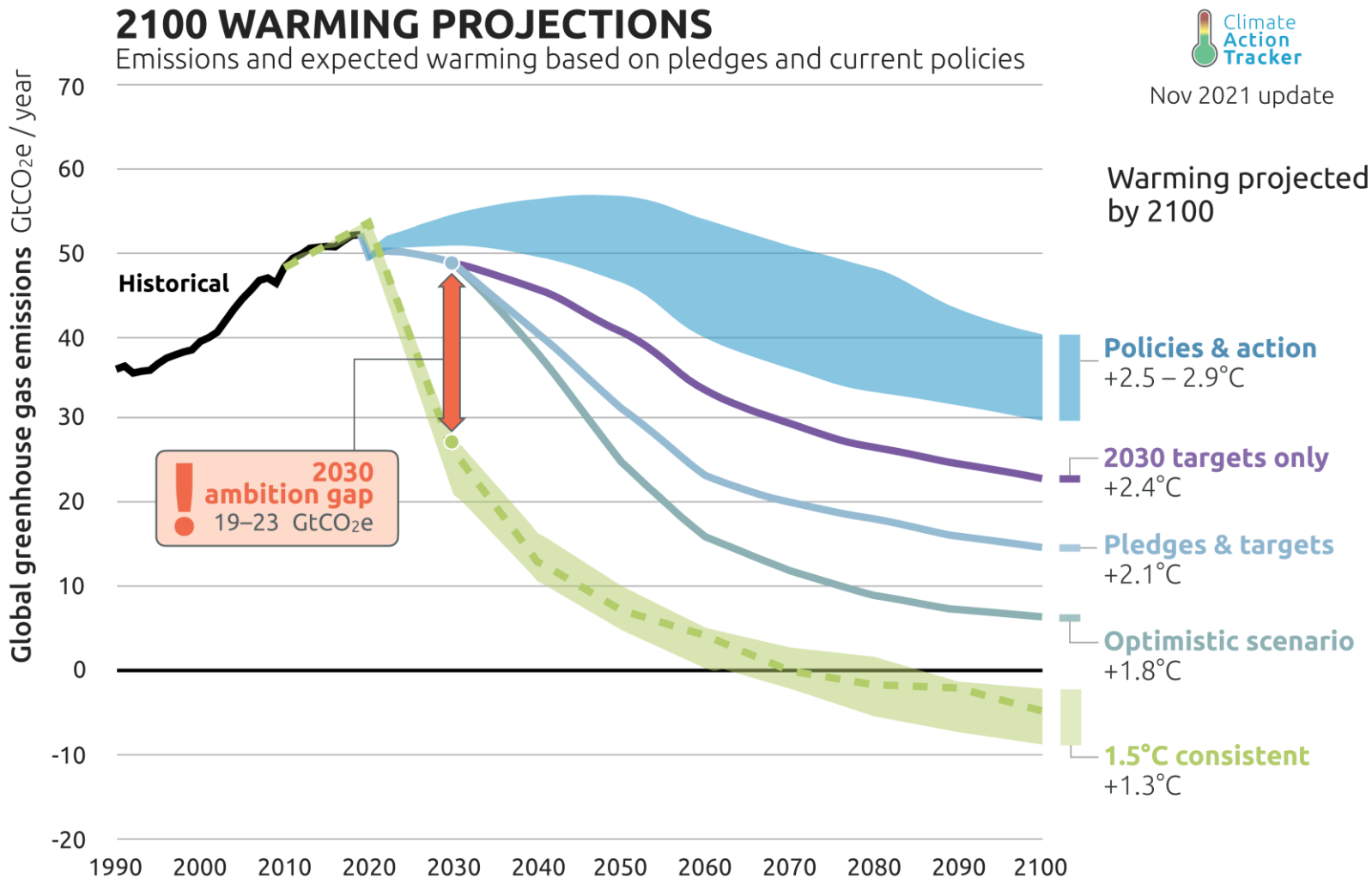
So we've got a bit of a problem…

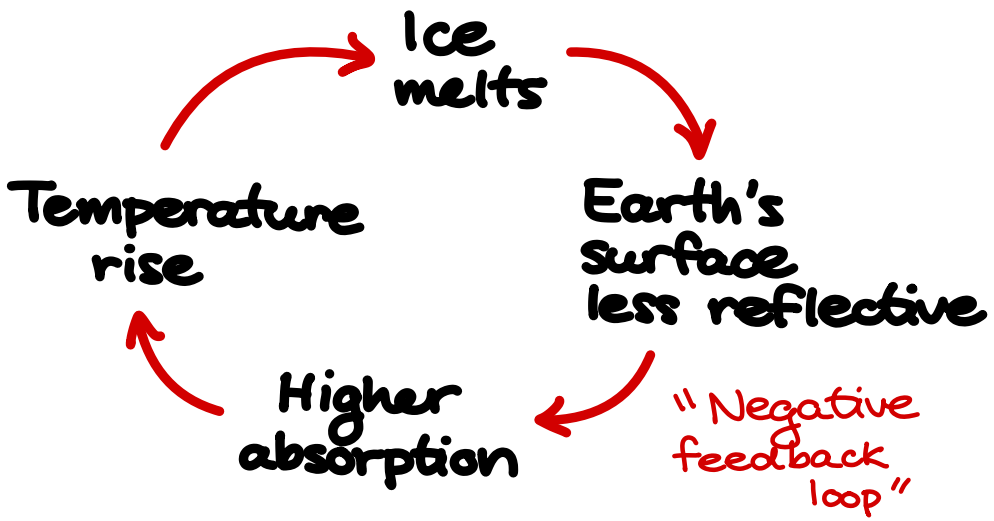


Okay, uh, quite a few problems…

Another one I forgot to mention… Melting of permafrost
- ↳ release of CO_2 & methane that was frozen in ground in form of biomass
- ↳ destruction of homes & ecosystems in the tundra

Rising sea levels

Ice is highly reflective…



Sea levels projected to rise 1-8 ft by 2100, which could lead to 1 billion climate refugees by 2050

Wildfires

Warmer → Drier → Better kindling!

Australia 2020:

- > $100 billion in damages
- 25 people and 0.5 billion animals dead
- 20 million acres burned down

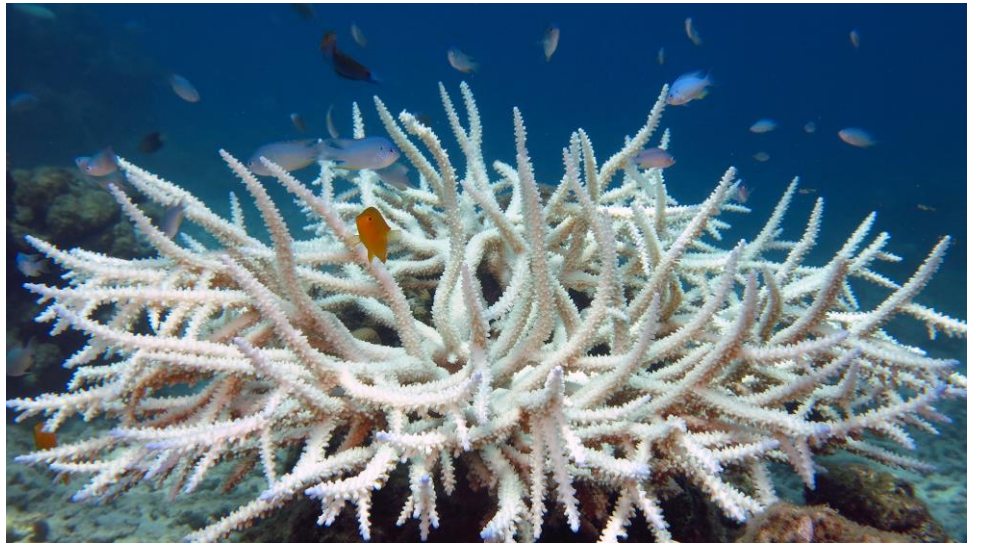
Okay, uh, quite a few problems… Part 2!!

Increased frequency
and intensity of storms

Hurricane Florence (NASA)

Extinction due to
ocean acidification

Animals like crabs will have their calciferous shells softened



Bleached coral

Pause for questions and discussion

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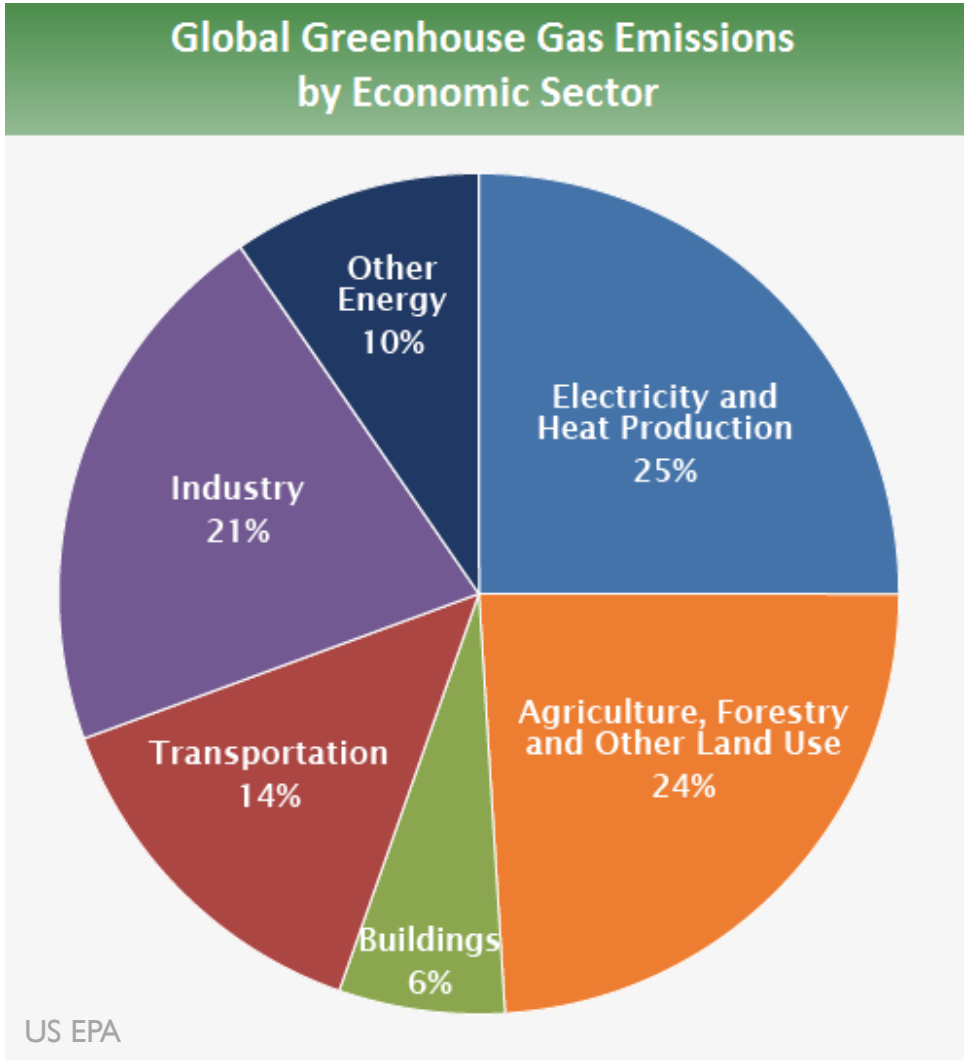
Where are greenhouse gases coming from?



When we combust fossil fuels to extract their energy, GHGs are a byproduct

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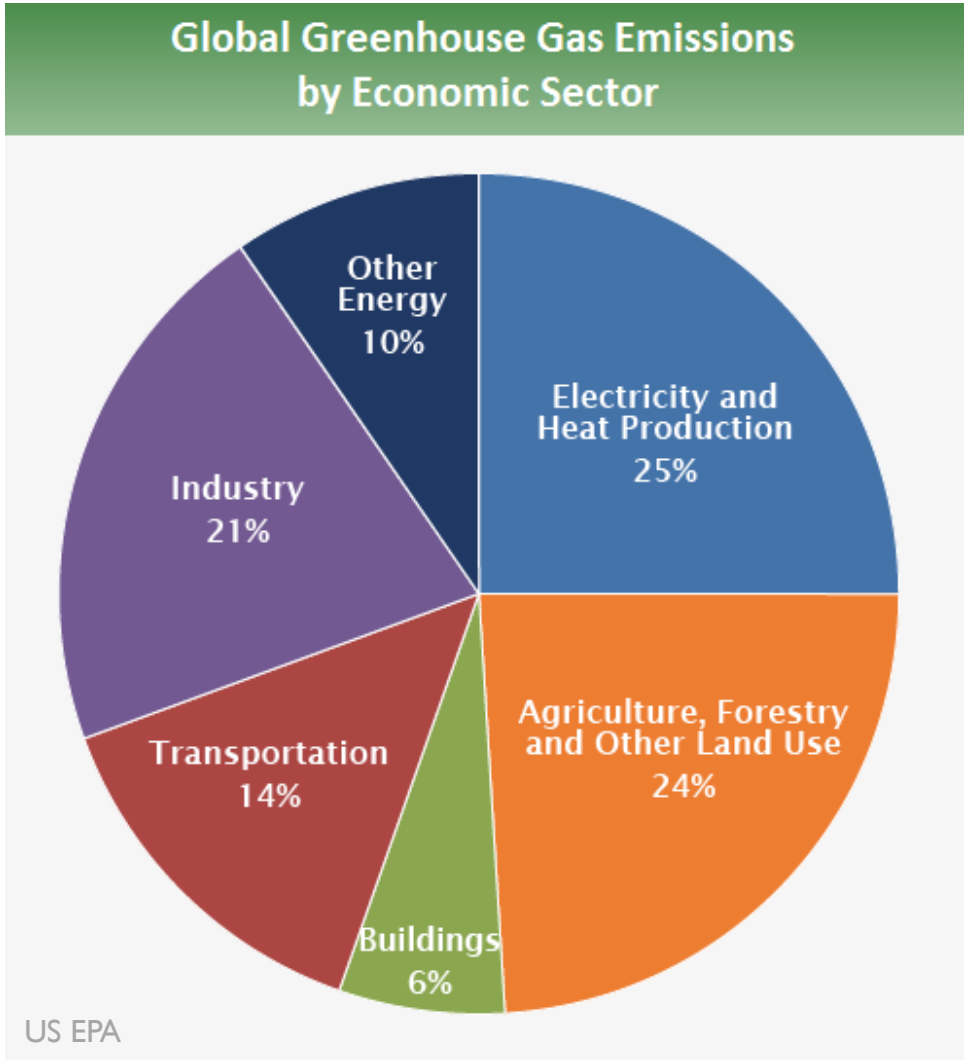

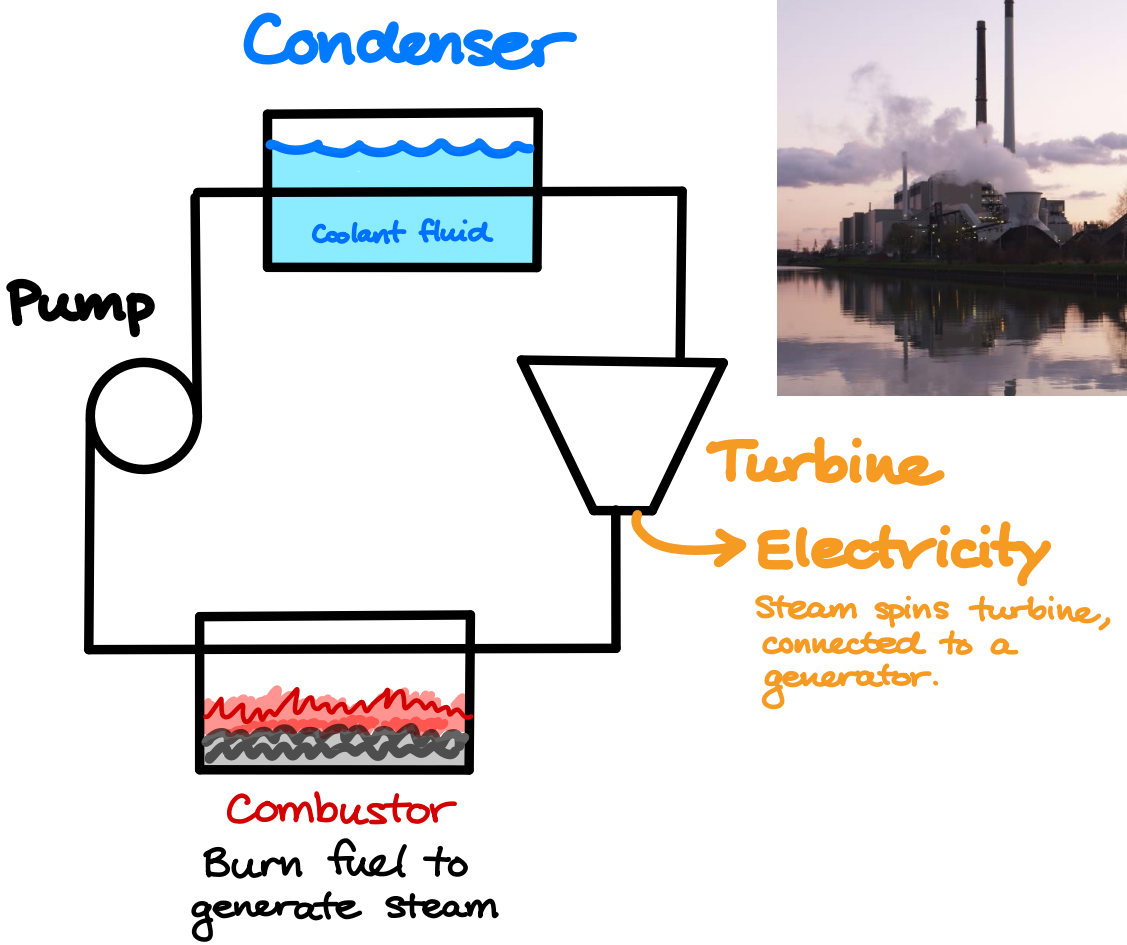

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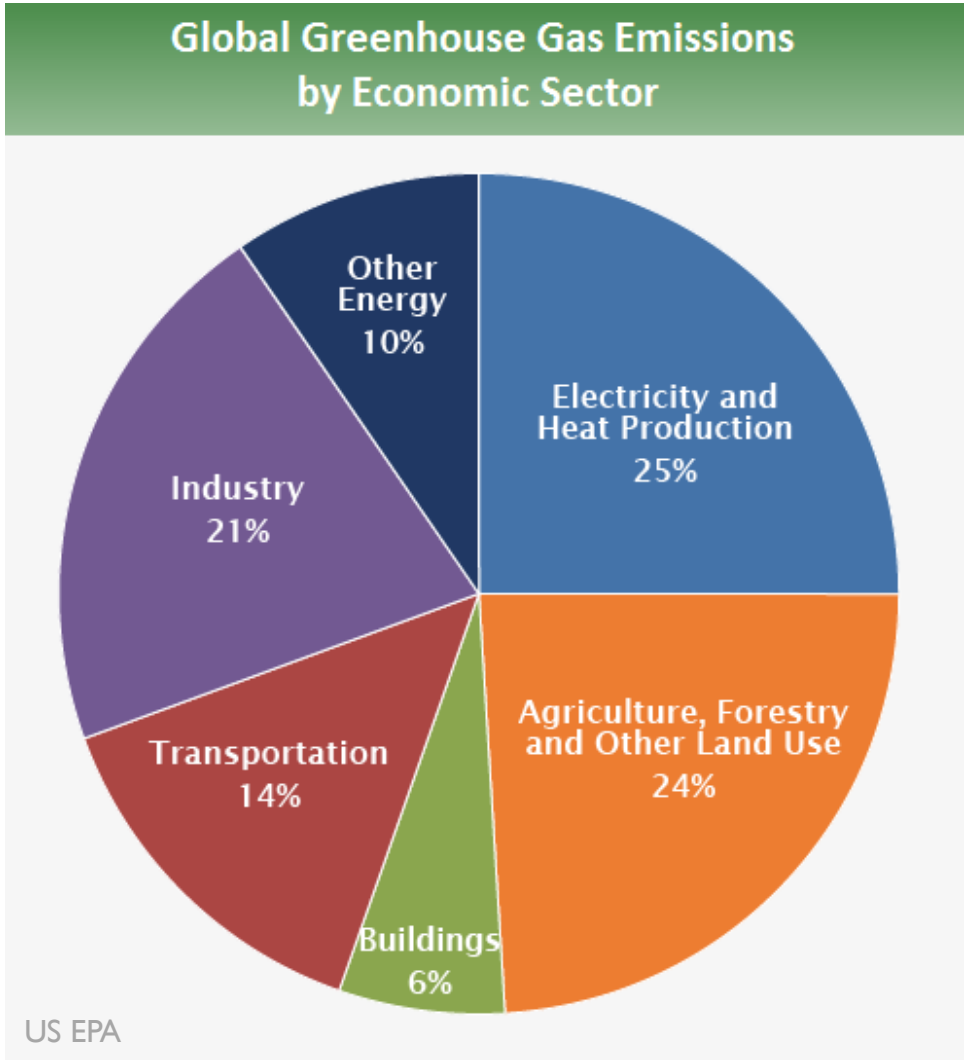
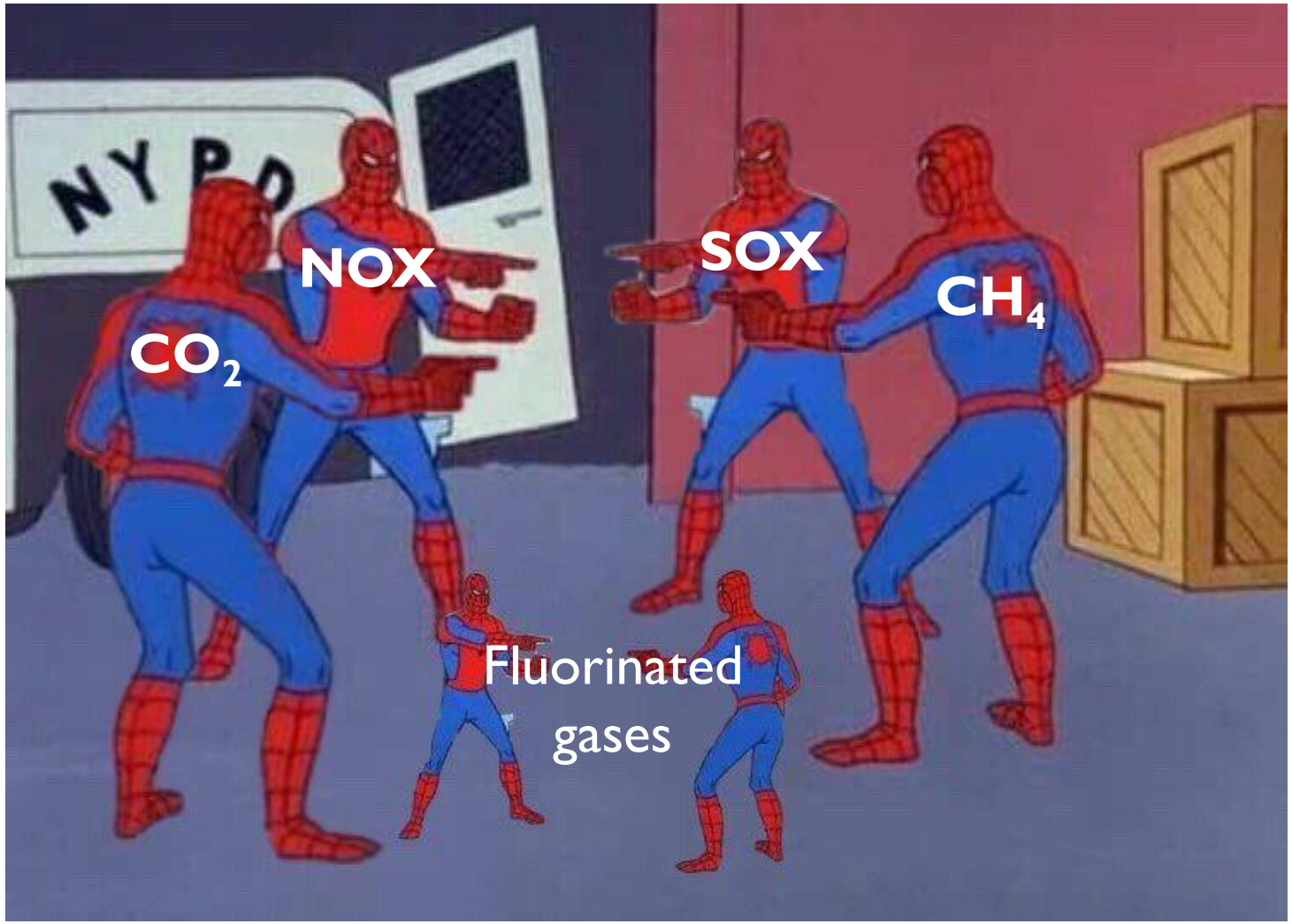


How much methane produced by cow farts/burps in a day?

1.5 billion cows x 100-200 L of CH_4 = A whole lot!!

Which gases are to blame?



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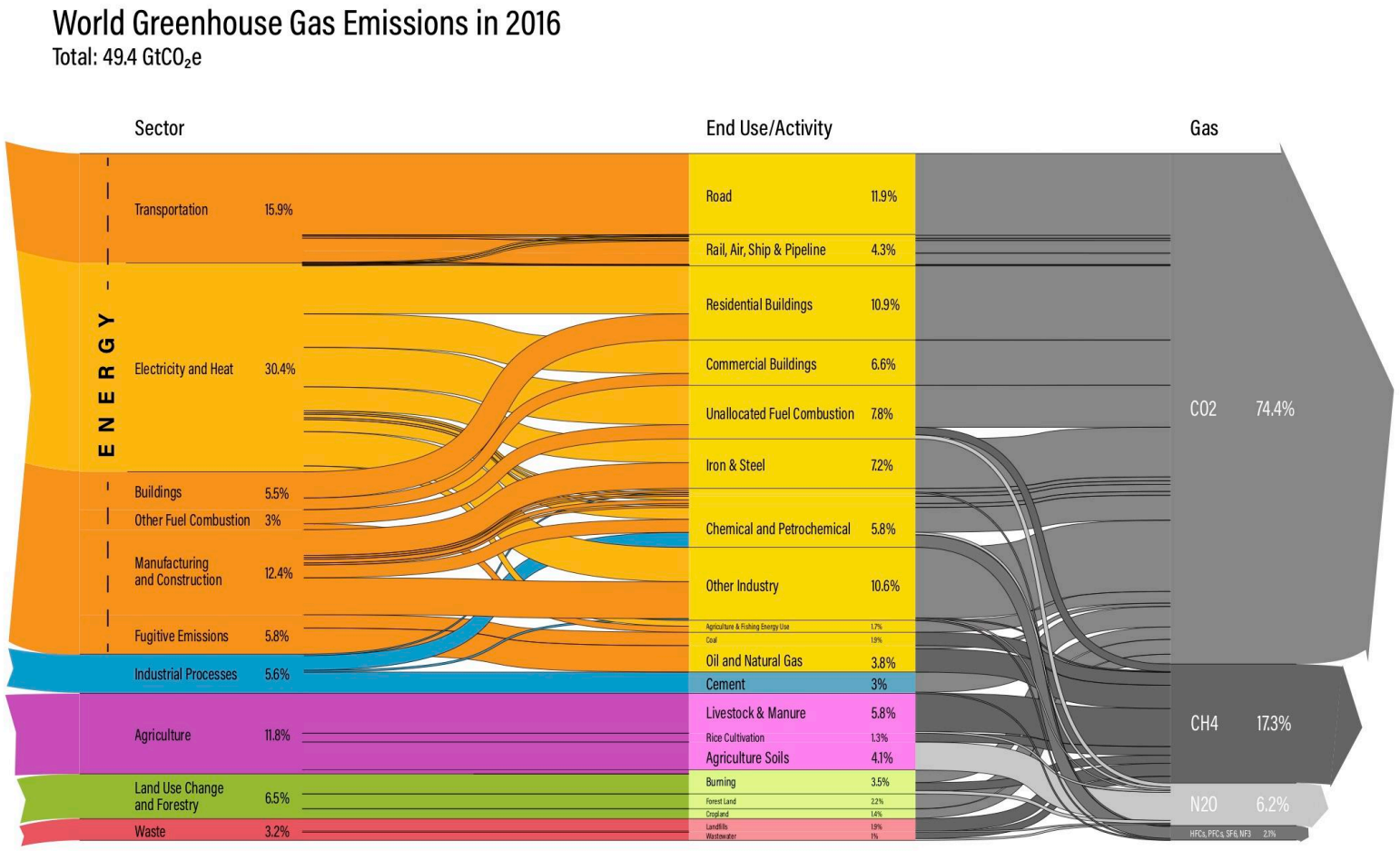


Source: Greenhouse gas emissions on Climate Watch. Available at: https://www.climatewatchdata.org

WORLD RESOURCES INSTITUTE

Global Warming Potential (GWP)

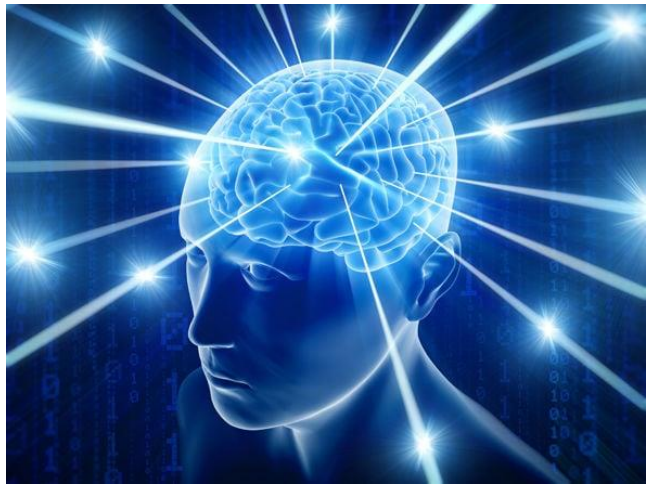
Greenhouse Gas	Atmospheric Concentration		Atmospheric Lifetime (Years)	100-Year Global Warming Potential
	Pre-Industrial (1000-1750)	Recent (2019)		
CO_2	280 ppm	410 ppm	50-200	1
CH_4	0.7 ppm	2 ppm	12	23
N_2O	0.270 ppm	0.330 ppm	114	296
CF_4	40 ppt	80 ppt	> 50,000	5700
SF_6	0	10 ppt	3200	22,200

1.5×

>2×

US EPA

Pause for questions!



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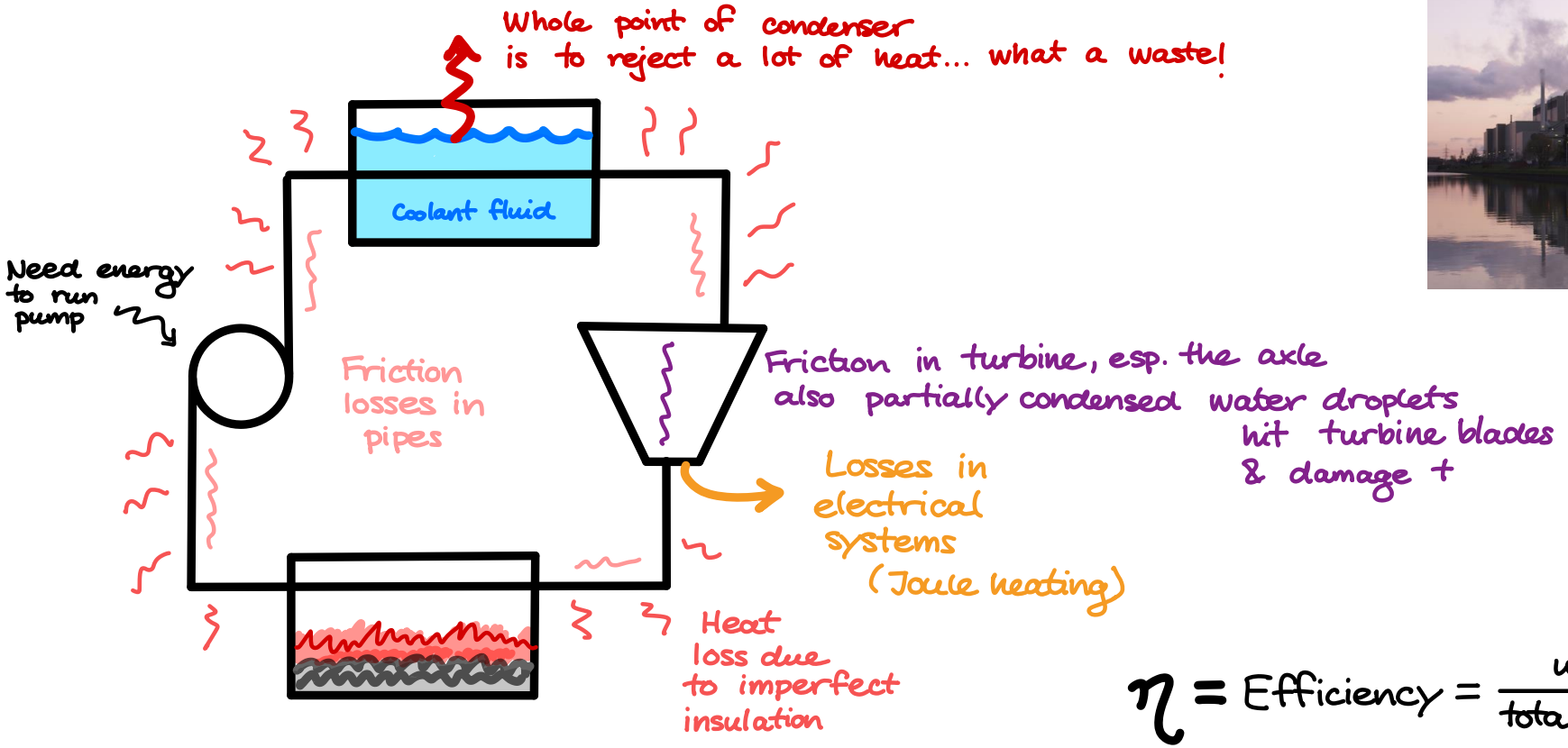
Thermal science can help by reducing waste heat

Back to the coal power plant example…

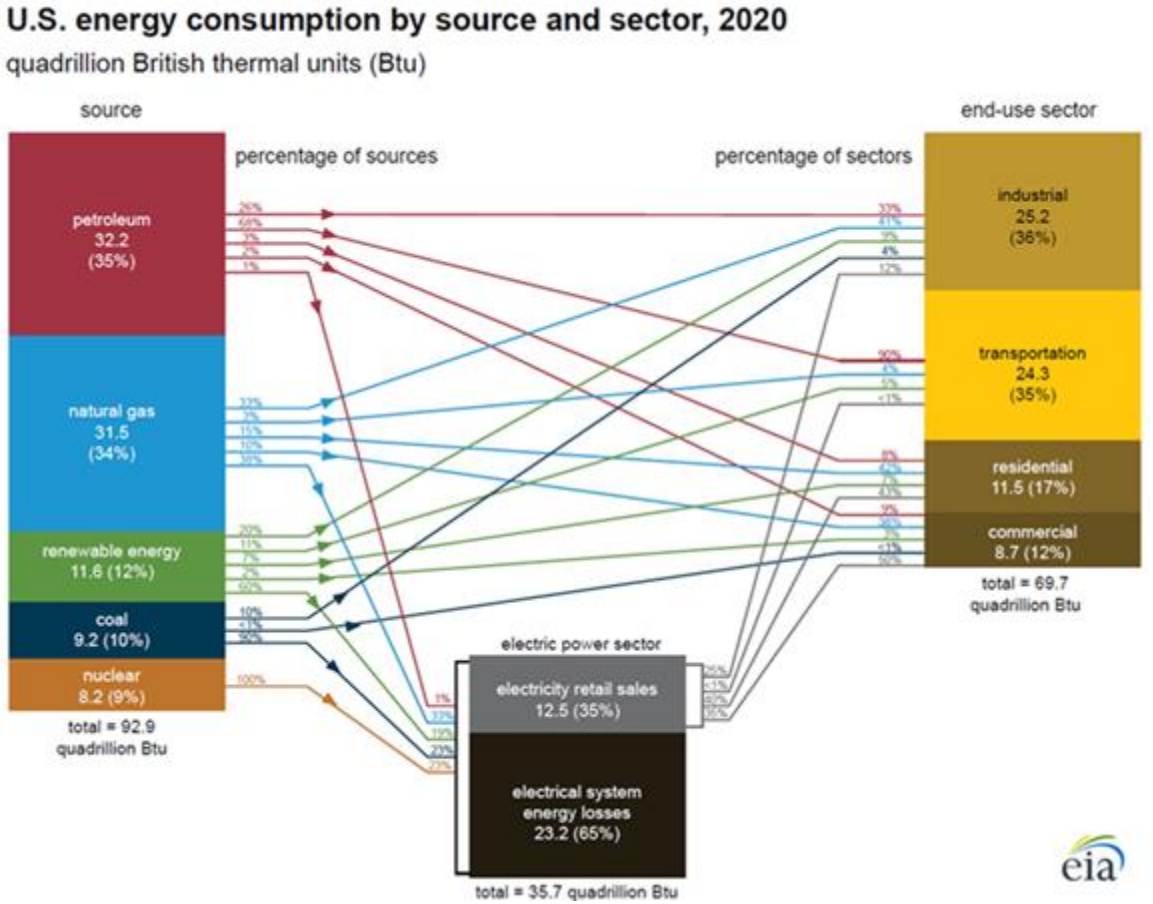


$$\eta = \text{Efficiency} = \frac{\text{useful work}}{\text{total energy input}}$$

We waste heaps of energy!

"It is estimated that between **20 to 50%** of industrial energy input is lost as waste heat in the form of hot exhaust gases, cooling water, and heat lost from hot equipment surfaces and heated products."

—US Office of Energy Efficiency and Renewable Energy

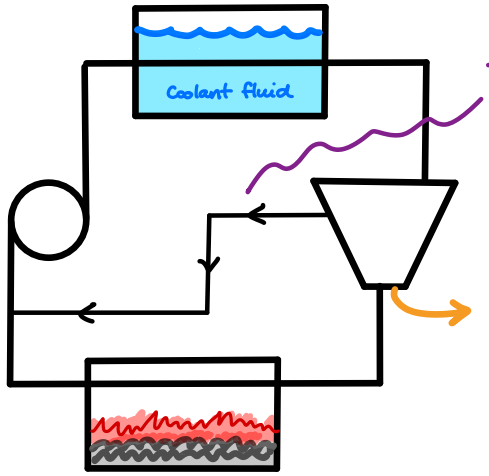


US Energy Information Administration (EIA)

All of these strategies can be combined!

Ways we can minimize waste heat

Regeneration



Take some steam out of the turbine to pre-heat the water before entering combustor

↓

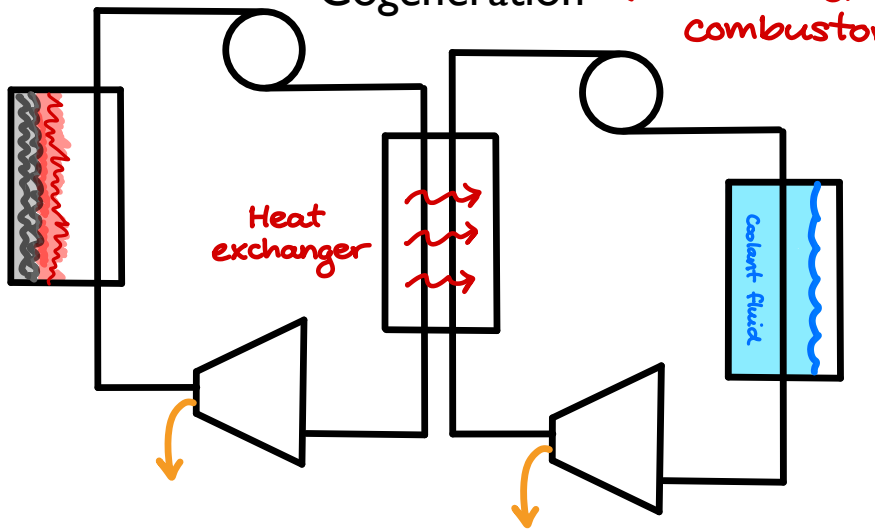
Less energy needed to boil the water!

0.5% rise in η

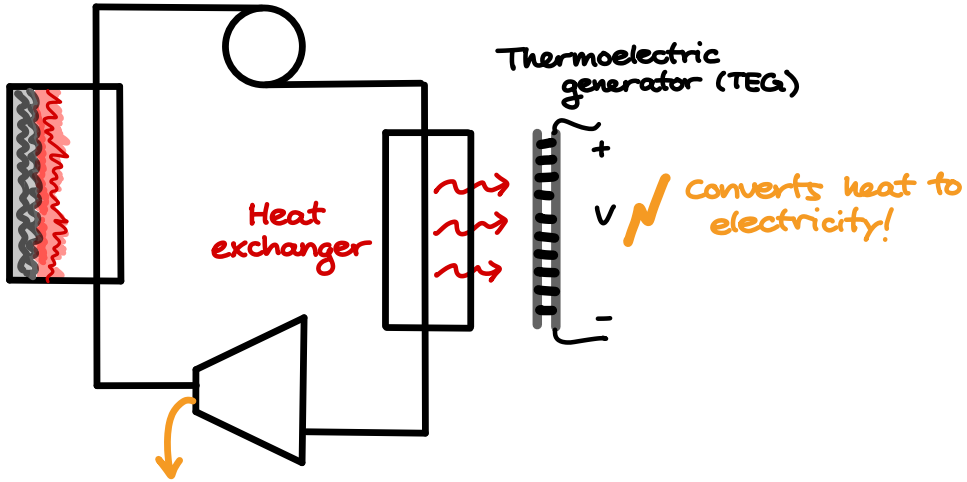
(That's very good!)

Cogeneration

Heat rejected by one power plant goes to run another (instead of another combustor)

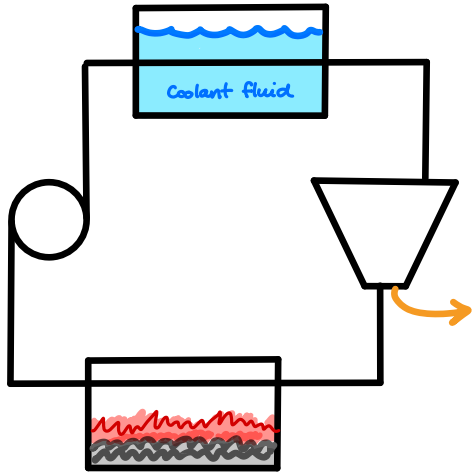


Using low-grade waste heat



Converts heat to electricity!

Energy storage



Can literally use a giant battery. OR

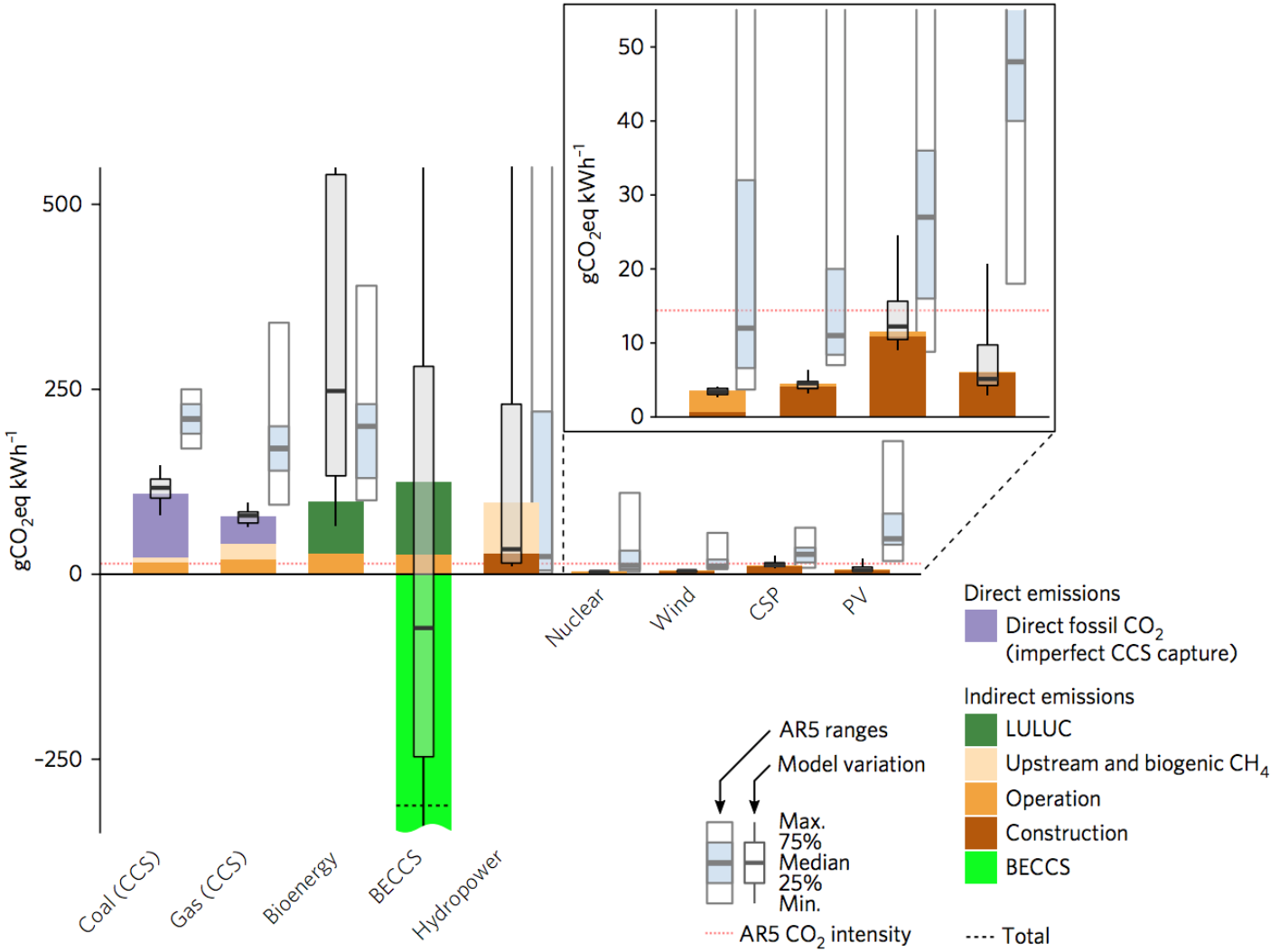
Store it!

Thermal energy storage in liquid metal

↑

We produce excess energy sometimes, but it is very inefficient to stop the power plant when supply > demand...

Options *that aren't burning fossil fuels!*

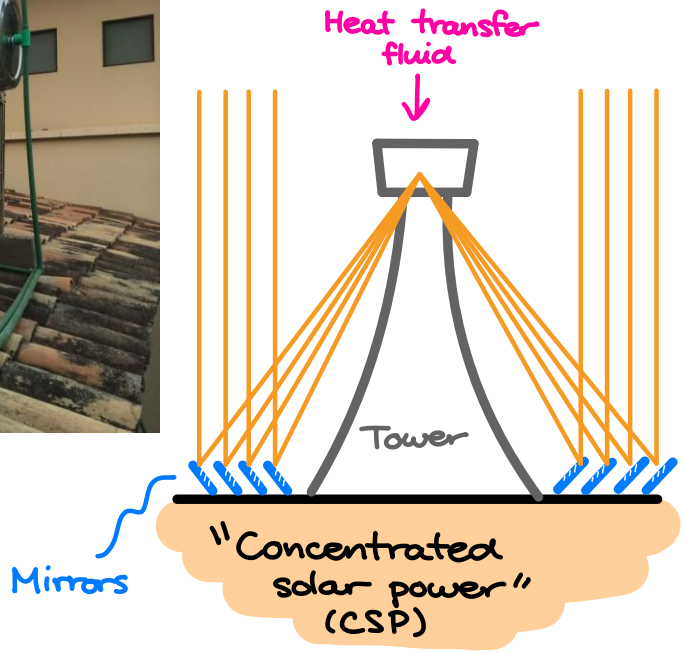


M. Pehl *et al.* Nat. Energy **2**, 939 (2017). https://doi.org/10.1038/s41560

Two kinds of solar energy: solar photovoltaic and solar thermal

Solar photovoltaic

Solar thermal



We can also extract energy from fluids already flowing in nature!

Hydropower

Wind power

All done!

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