Chemistry, Energy, and Climate

How will our dependence on energy affect the global climate?

Intended for 11th, 12th grade science student's.

The Science of Weather
MST 589
Kyle Bridgewater

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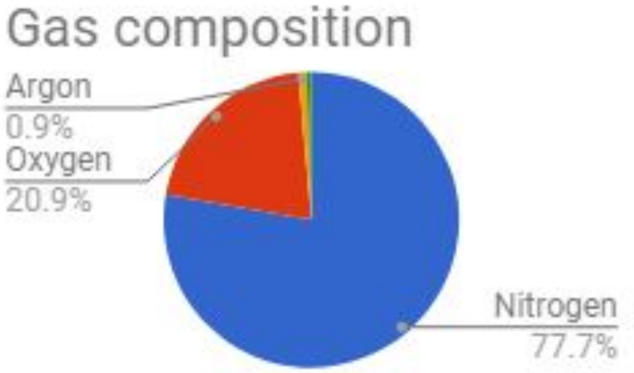
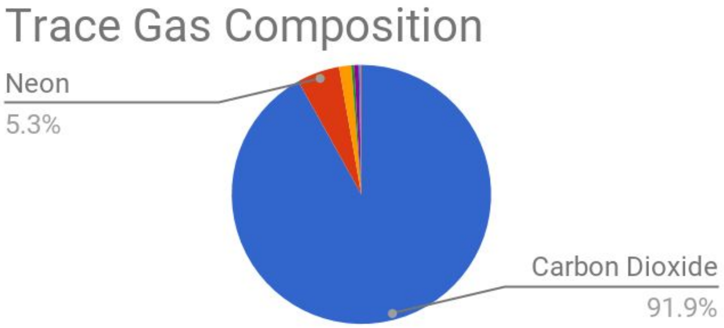
What is the our atmosphere made of?

(dry measurements, water vapor varies from 0.1%-7%)





Gas Composition	Volume (%)
Nitrogen	78.084
Oxygen	20.948
Argon	0.934
Trace Gases	0.0342

Trace Gas Composition	Volume (%)
Carbon Dioxide	0.0314
Neon	0.00182
Helium	0.000524
Krypton	0.000114
Methane	0.0002
Hydrogen	0.00005
Nitrous oxide	0.00005
Xenon	0.0000087

Chemical Reactions in the Atmosphere

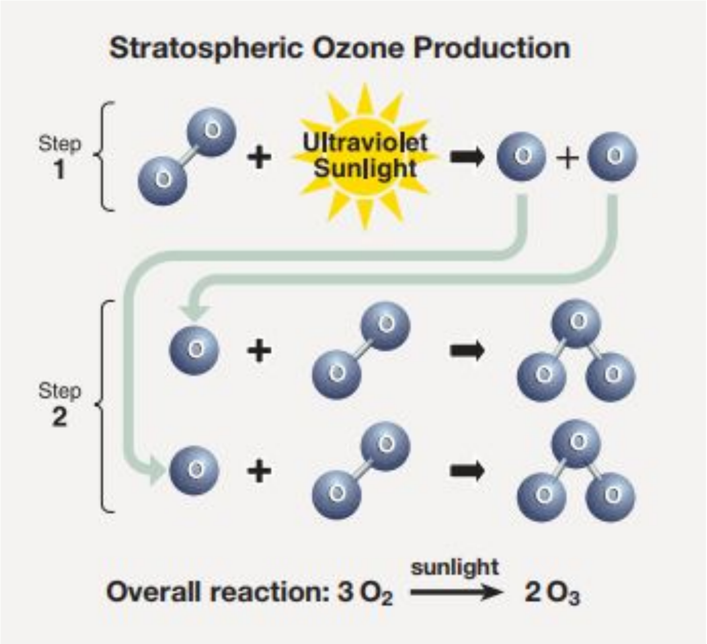
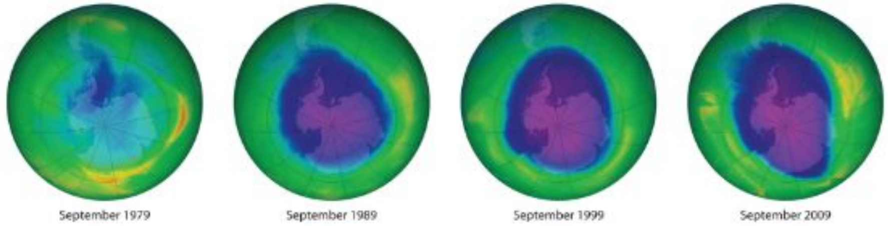


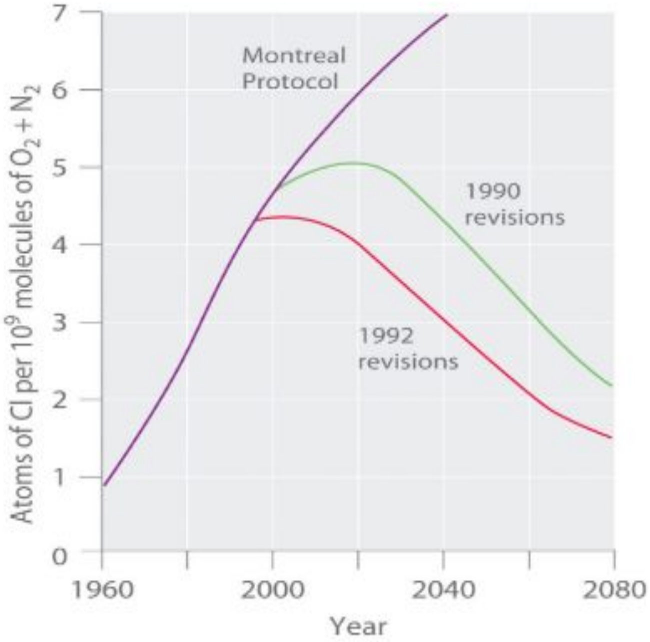
Figure 3.15 Satellite Photos of Earth Reveal the Sizes of the Antarctic Ozone Hole over Time



Chemical Reactions in the Atmosphere

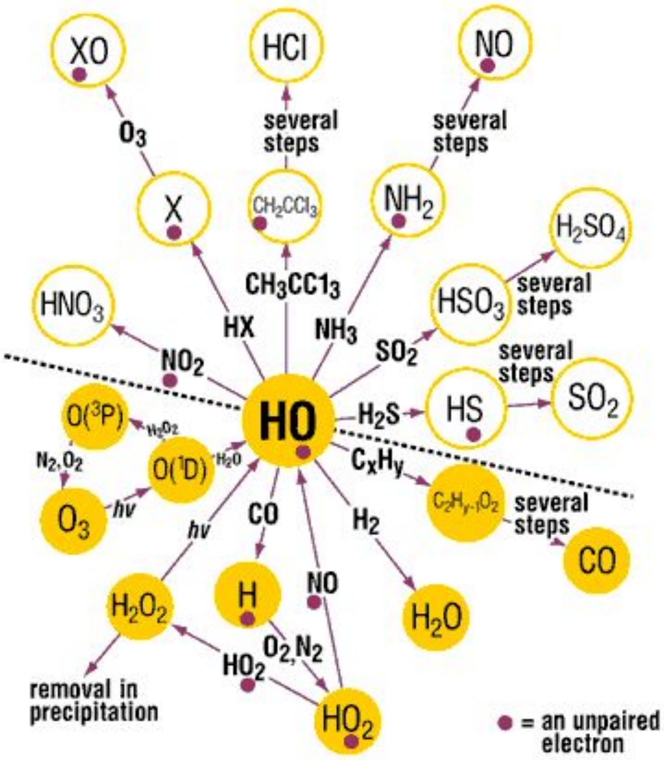
Ozone Formation

Figure 3.17 Projected Effects of International Agreements on Atmospheric Chlorine Levels

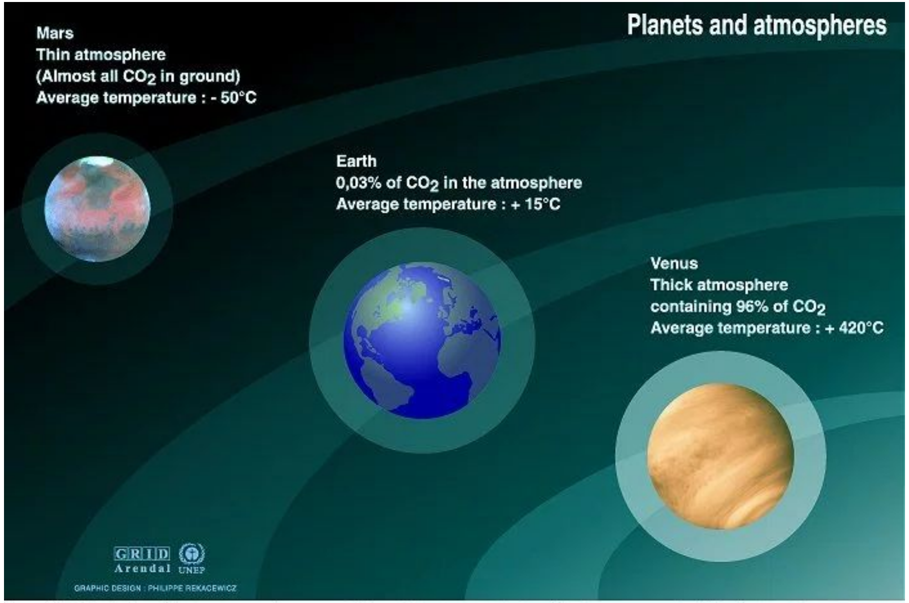


Chemical Reactions in the Atmosphere

Hydroxyl Radical Reactions in the Atmosphere



Three Planetary Examples



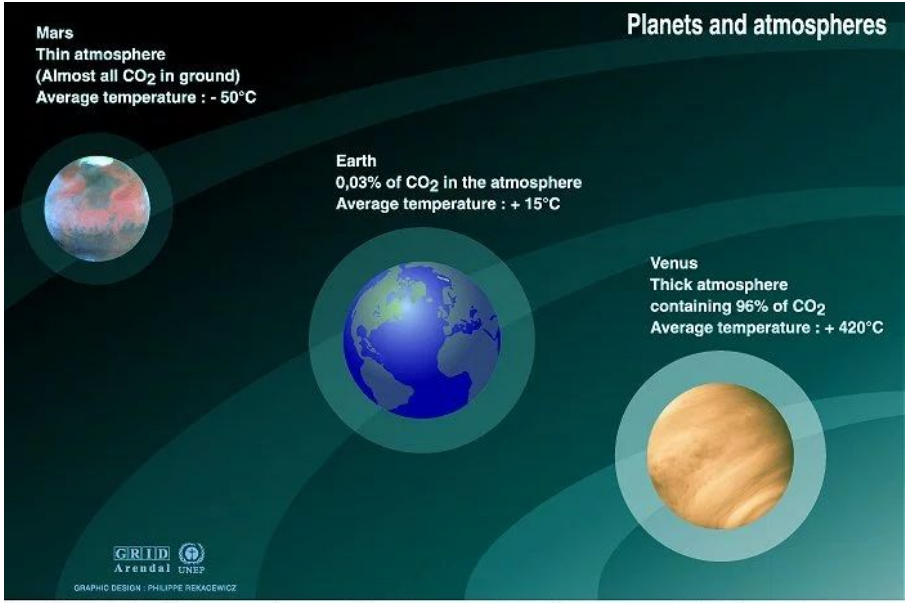
Sources: Calvin J. Hamilton, Views of the solar system, www.planetscapes.com; Bill Arnett , The nine planets, a multimedia tour of the solar system, www.seds.org/billa/tnp/nineplanets.html

Mars's atmosphere is so thin that it has almost no greenhouse effect.

Venus's dense atmosphere results in a runaway greenhouse effect that increases the planet's temperature by hundreds of degrees.

Earth lies in between, with its greenhouse effect.

Three Planetary Examples



Sources: Calvin J. Hamilton, Views of the solar system, www.planetscapes.com; Bill Arnett , The nine planets, a multimedia tour of the solar system, www.seds.org/billa/tnp/nineplanets.html

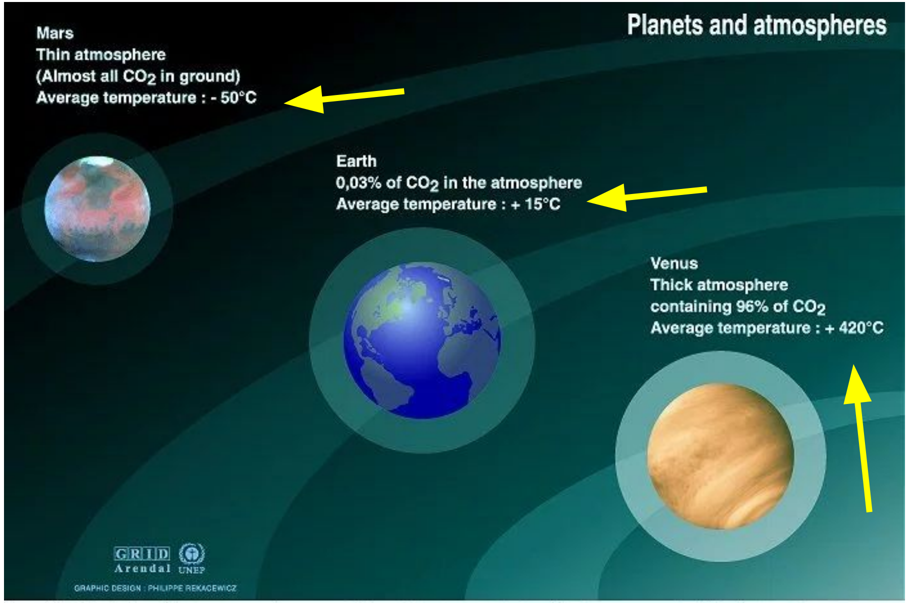
Average Temperature can be misleading, due to the distance from the Sun. Therefore we can correct for this variance.

In summary:

Sun provides on average 240 watts/m^2. Radiation is governed by the inverse square law. The energy loss by radiation is proportional to distance from the sun.

Therefore, if these planets did not have an atmosphere the surface temperatures would be -50C, -18C, +55C for Mars, Earth, and Venus respectively.

Three Planetary Examples



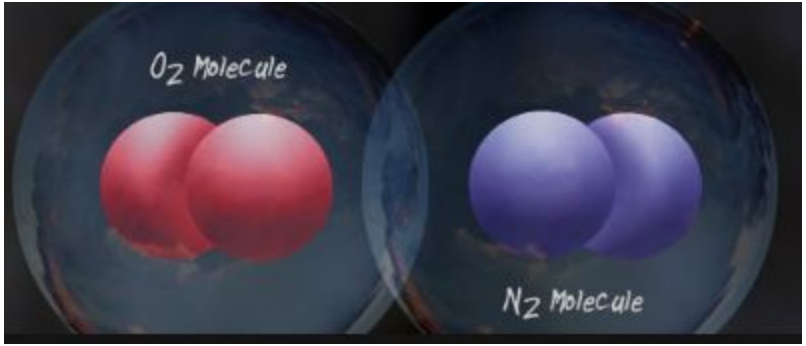
Sources: Calvin J. Hamilton, Views of the solar system, www.planetscapes.com; Bill Arnett , The nine planets, a multimedia tour of the solar system, www.seds.org/billa/tnp/nineplanets.html

The surface temperatures are different, because of the greenhouse effect of the atmosphere.

Mars atmosphere is about 1% the density of earth, much more energy is released into space.

Venus atmosphere is about 100X density of earth, and 96% CO2. Even if Venus was located in a different orbit, the greenhouse effect of the atmosphere would still make it a very hot planet.

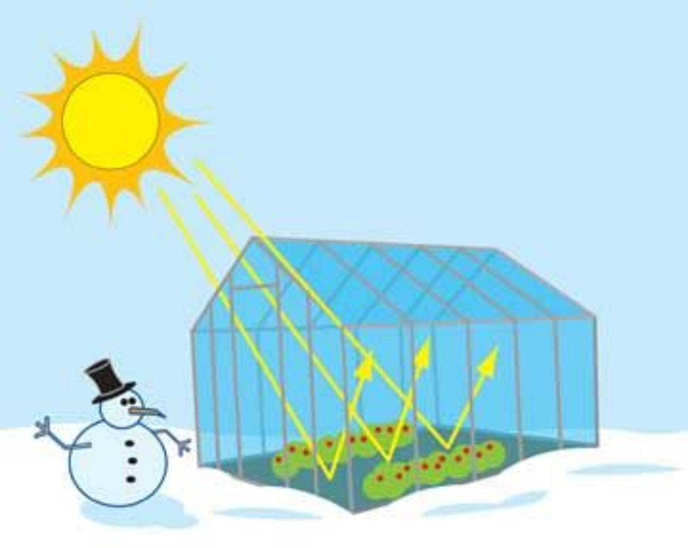
3 Ways to explain the Greenhouse effect



N2 and O2 molecules are stable diatomic molecules with zero enthalpy of formation, largely transparent to both incoming sunlight and outgoing infrared radiation. Earth's atmosphere is 90% of these. Do not cause a greenhouse effect.

Water vapor and carbon dioxide are the most influential Greenhouse gases in our atmosphere even at trace amounts.

3 Ways to explain the Greenhouse effect



This is a correlation between the energy from the sun and surface temperature of the planet due to the composition of the atmosphere.

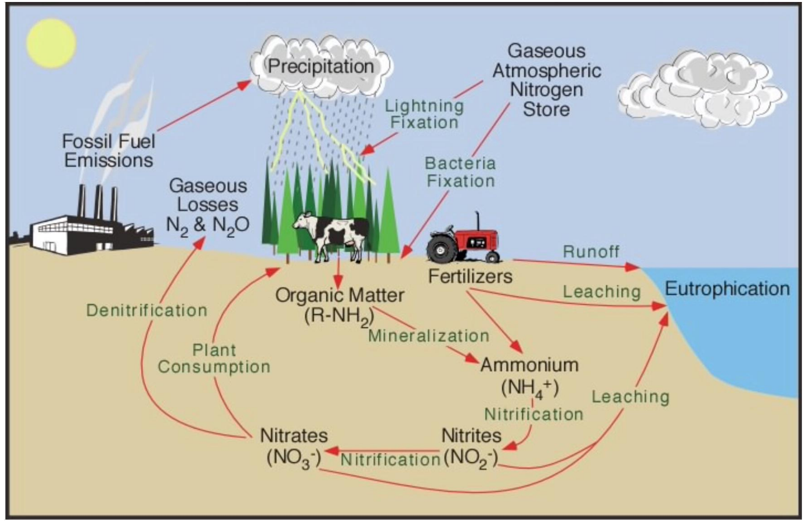
Simple: A big blanket covering the earth, increasing the surface temperature.

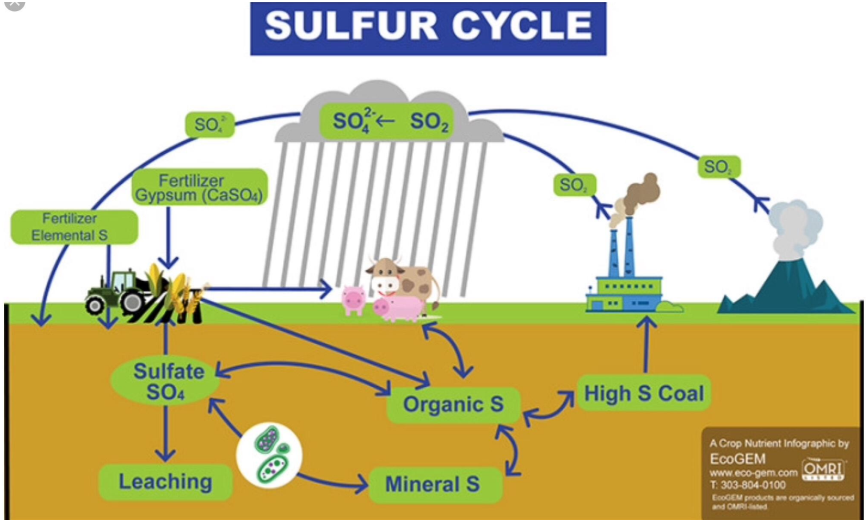
Intermediate: Greenhouse gases absorb outgoing radiation from the earth. Re-radiate back towards the earth, heating the surface.

Advanced: Upper atmosphere is colder than the lower atmosphere. Therefore, the greenhouse effect depends on the temperature difference between surface and upper atmosphere. Increasing greenhouse warming actually cools the upper atmosphere.

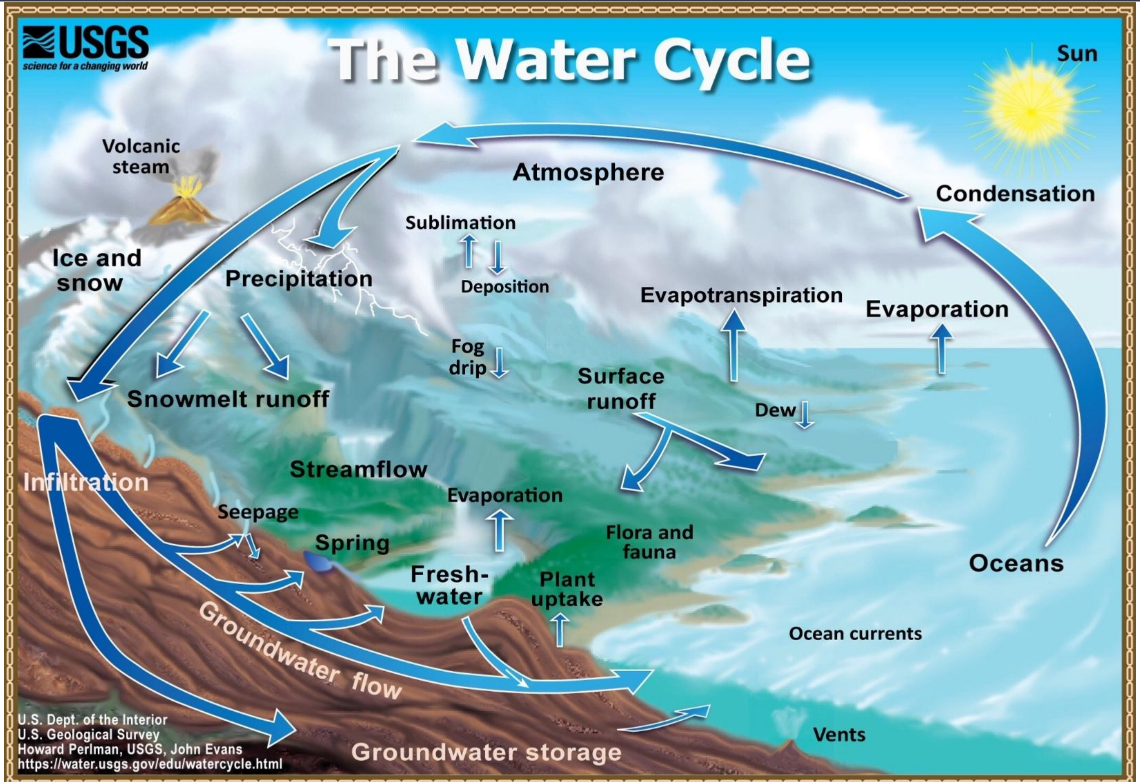
Dynamic Chemical Cycling

Nitrates, Sulfates, and Phosphates are compositional components that can impact cloud formation. There are also natural cycles for these molecules, industrial pollution can increase the amounts of these molecules. Not necessarily a significant greenhouse gas, but have documented effects on public health (respiratory diseases, carcinogens, etc.)



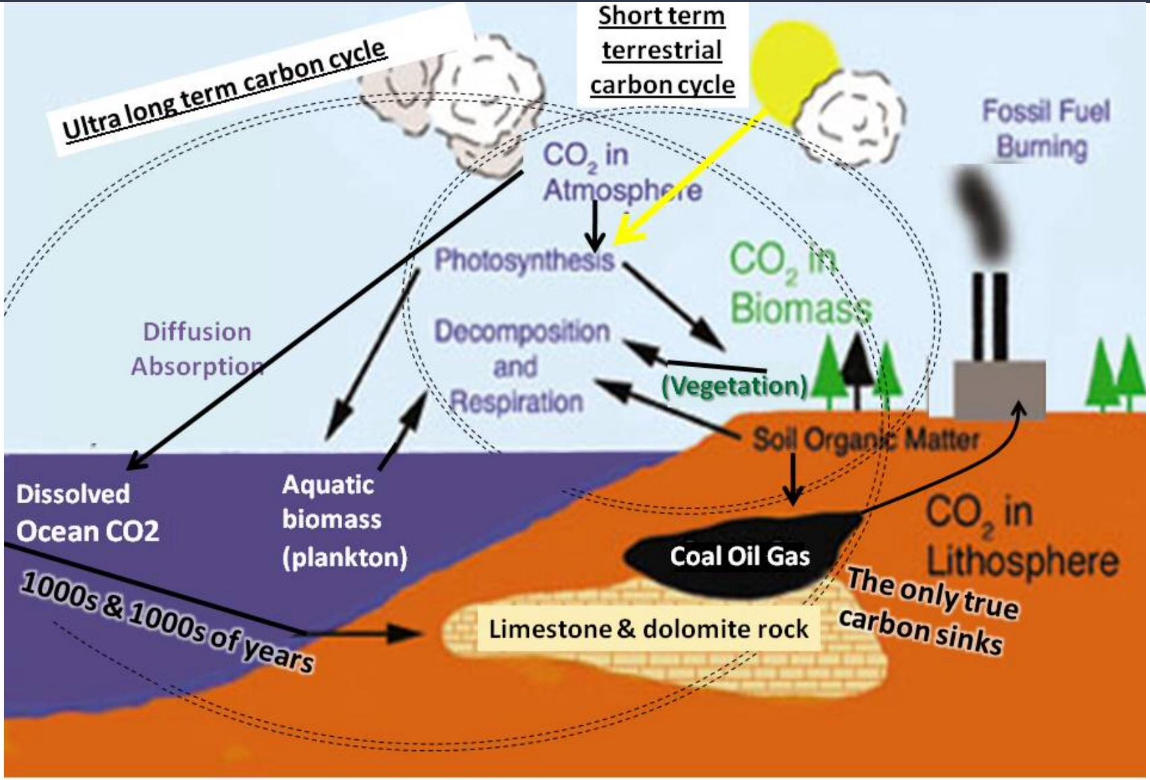


Dynamic Chemical Cycling



The time for 1 complete cycle can vary based on the location. On average the cycle can complete in about a week.

Dynamic Chemical Cycling

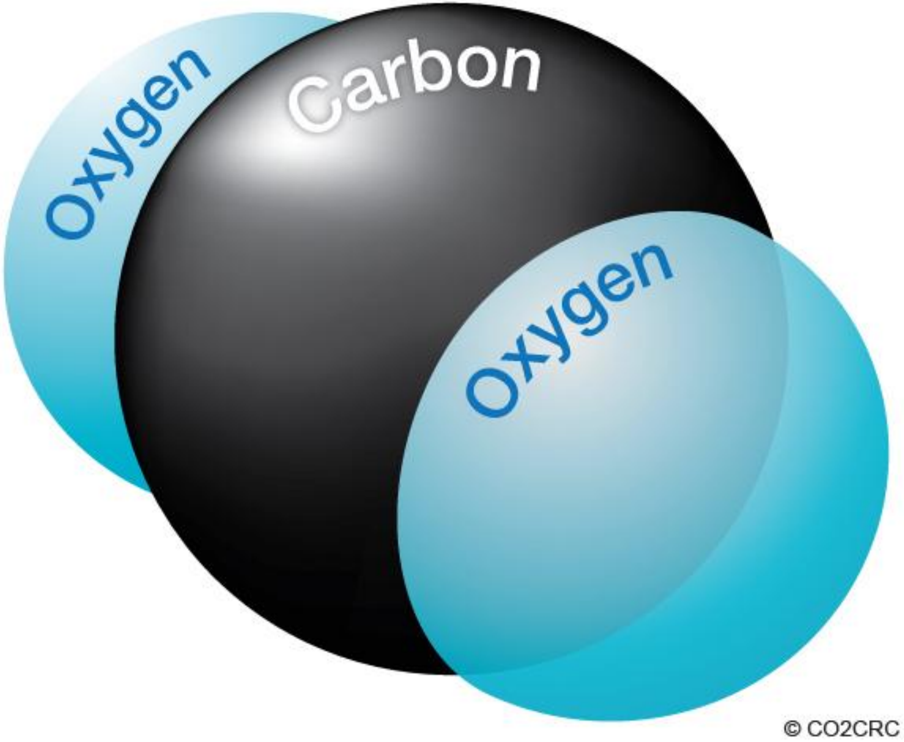


The time for complete short term cycle can vary based on the amount of vegetation (terrestrial or aquatic) present. The average for the short term cycle is about 5 years.

Significantly different than the 1 week from the water cycle.

The big question is: If this cycle is hacked and out of balance, would it be enough the change the climate?

Human Impacts



1) When predicting the future climate, we need to consider the human impacts.

2) Fossil fuel combustion removes stored carbon from the ground into the atmosphere.

3) Atmospheric carbon dioxide has risen 40% in the industrial era.

Human Impacts

4) Rampant deforestation across the globe, has a significant effect on carbon sequestration.

5) Agriculture and urbanization has decreased the amount of reflected sunlight, absorbing more energy in the biosphere.

6) Computer models that do not include a human impact display different data than what we see today.

7) Computer models that INCLUDE the human impact on CO_2 concentrations display data similar to what we see today.

Human Impacts

8) Not to mention ocean acidification and coral bleaching. Some predictions indicate that over 75% of all coral reefs will be gone with 50 years.

9) Overpopulation and urbanization, food insecurity, famine, poverty, pollution, distribution of freshwater, etc.

10) Big question: What are the energy needs of the future, given the level of dependence and the projected population growth?

Part 1 Summary

1) The composition of our atmosphere is made up Nitrogen (N_2), Oxygen (O_2), and water (H_2O), with trace amounts of other gases CO_2, Ar, etc.

2) Water and CO_2 are the most significant greenhouse gases in our atmosphere, gases that can re-radiate heat. Each have their own chemical cycles, the CO_2 is a longer cycle, so atmospheric carbon will stay in the atmosphere longer than water vapor.

3) Mars has a very thin atmosphere and doesn't have a greenhouse effect, while Venus has a very dense atmosphere with a significant greenhouse effect.

4) Chemicals in the atmosphere are not static, they can continuous react with one another. Hydroxyl radicals are highly reactive, along with halogens in aerosol form. Compounds can also react with large bodies of water, ie ocean acidification.

5) One form of carbon sequestering is photosynthesis, activities like deforestation coupled with fossil fuel combustion can Increase the concentration of CO_2.

Quiz Discussion #1

#1

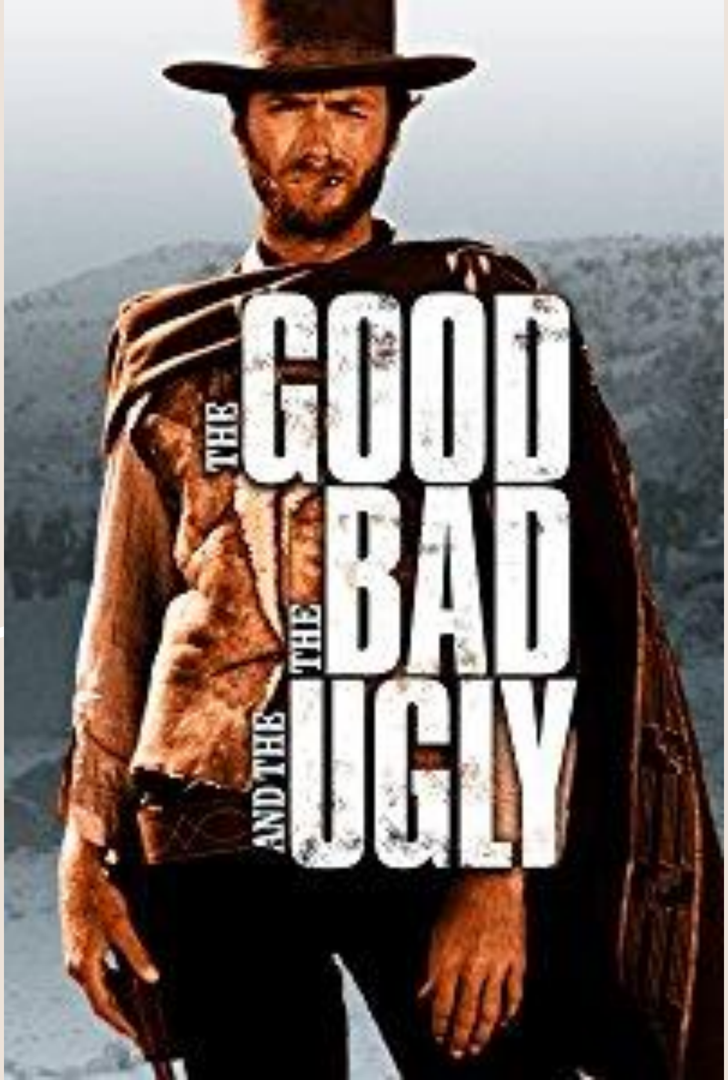
Carbon Dioxide makes up 0.03% of the composition of the atmosphere. Do you think a variance of 0.02% is a significant change? How would you measure the composition of the atmosphere? How would you predict the effects of this variance? Design an experiment.

#2

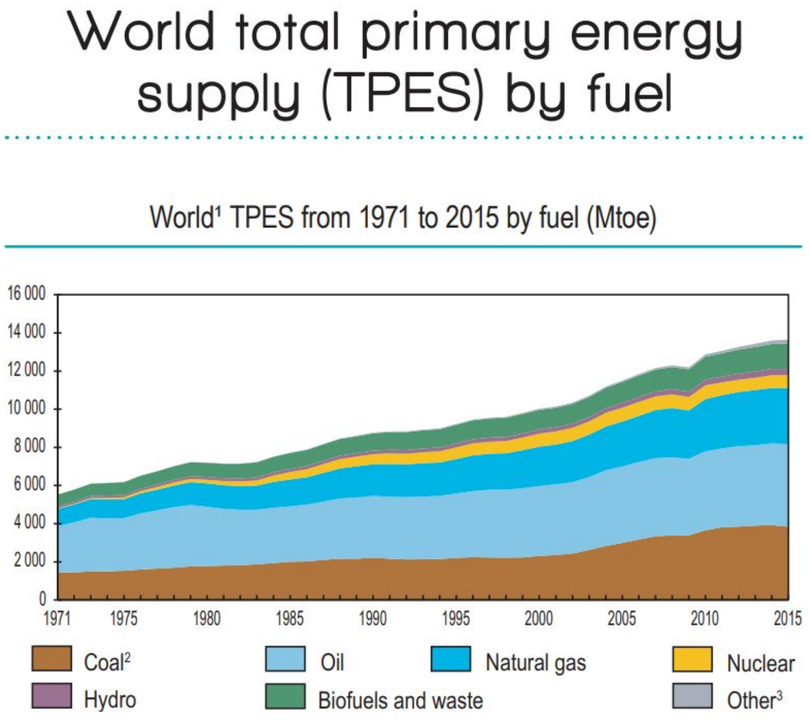
Ocean acidification is a natural carbon sequestration method intended to keep the homeostasis constant. It is likely that the coral reefs will not last through this century. If we are not willing to save the reef, will we be willing to save the next ecosystem that is in danger? What is considered “worth” saving?

Energy:

The Good
The Bad
and The Ugly

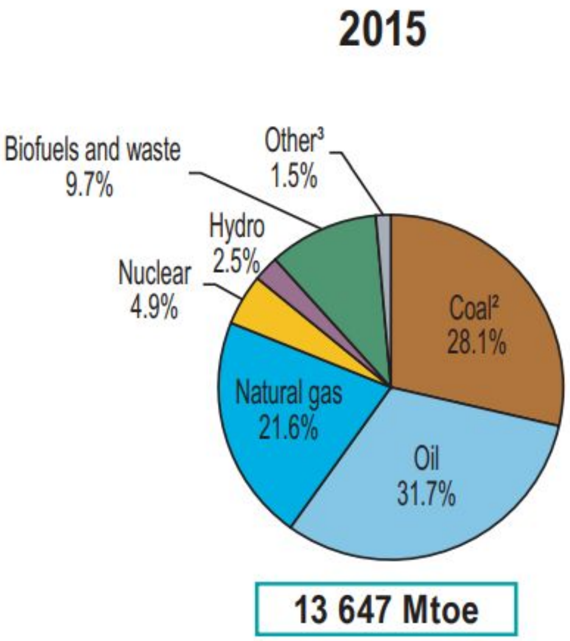


How much energy do we have on Earth?



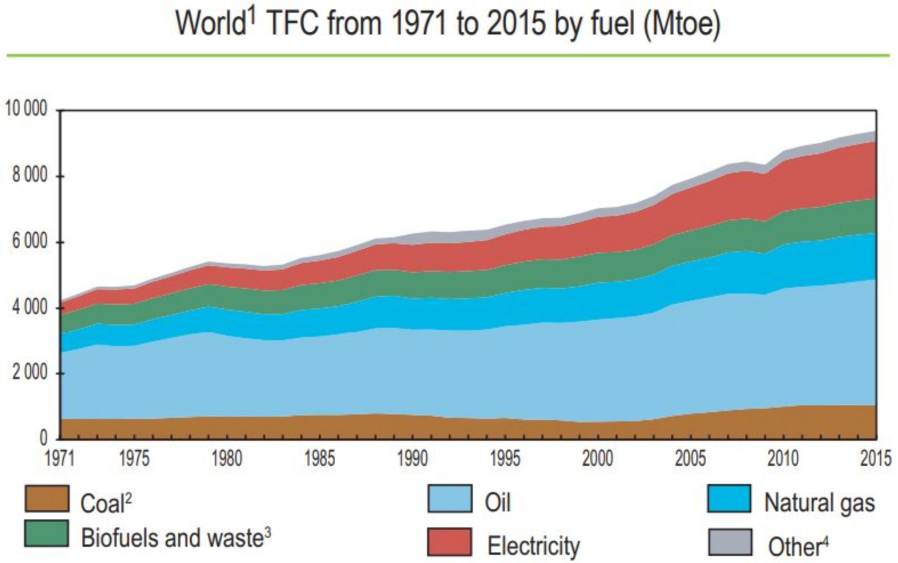
The world energy supply of 13,647 Mtoe, estimated about **1.59 x 10^11 KWh**

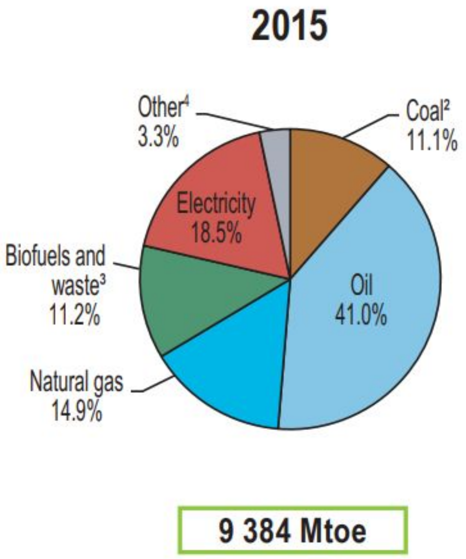
Coal, oil, and natural gas (all fossil fuels) combine to make up **81.4%** of our energy supply



How much energy do we use on Earth?

World total final consumption (TFC) by fuel

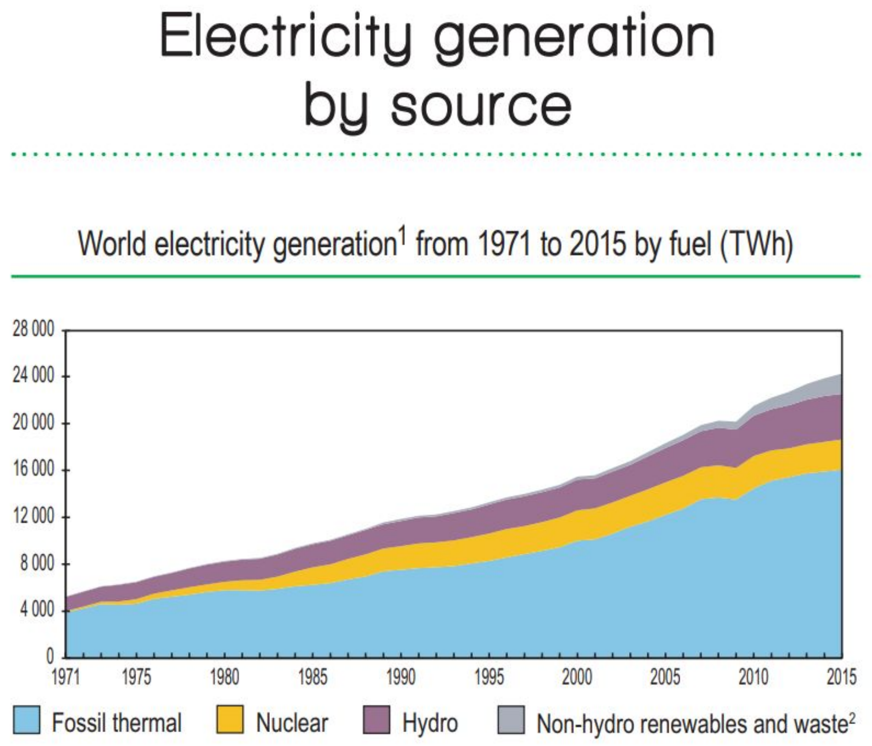


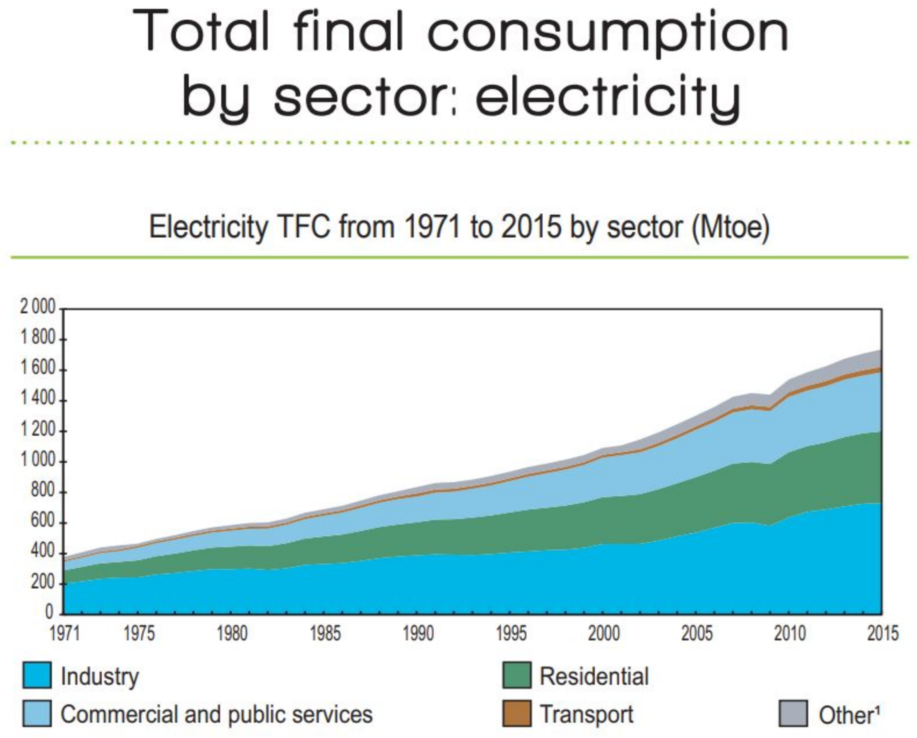


Estimated 68.7% of energy supply was consumed (2015)

Consumption

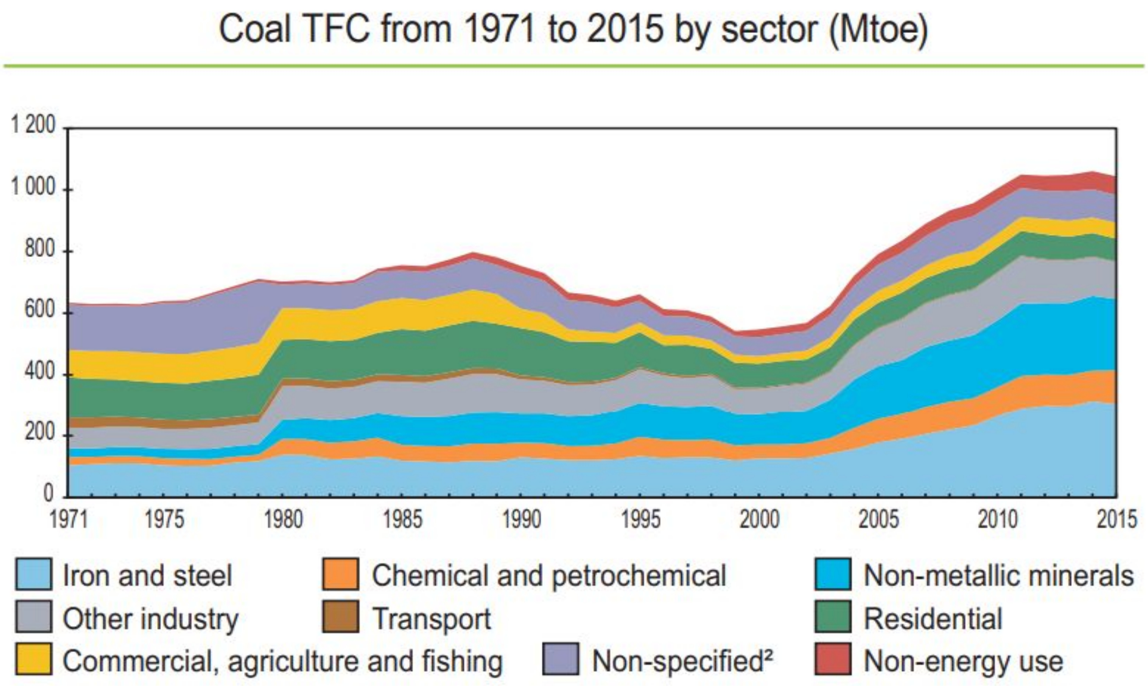
Electricity Generation and usage





Total final consumption by sector: coal[1]

#1

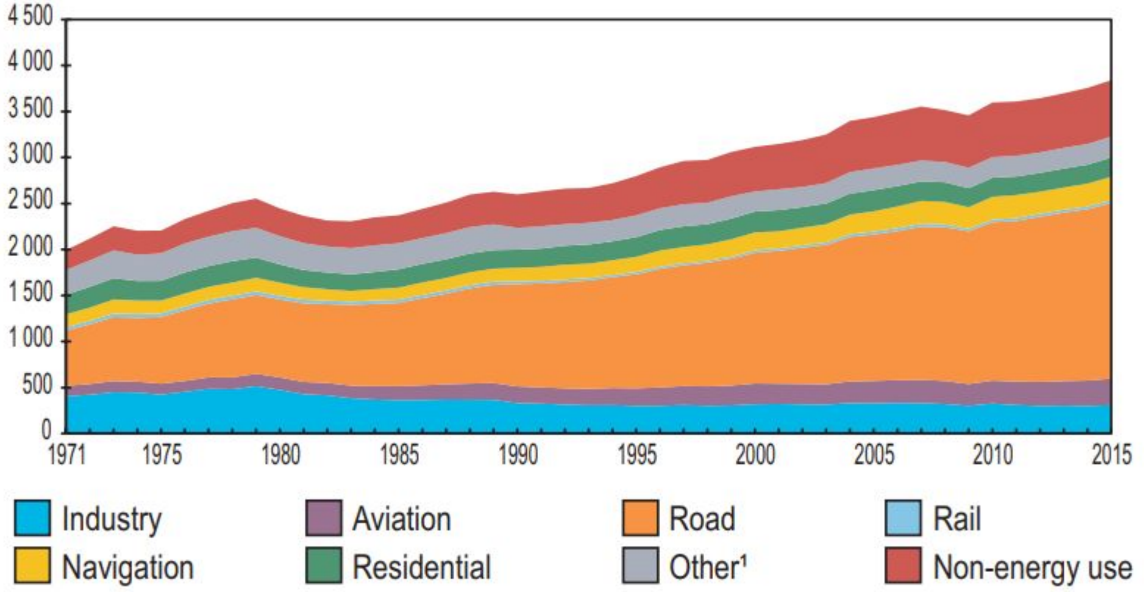


What observations can you make from this figure?

Total final consumption by sector: oil

#2

Oil TFC from 1971 to 2015 by sector (Mtoe)

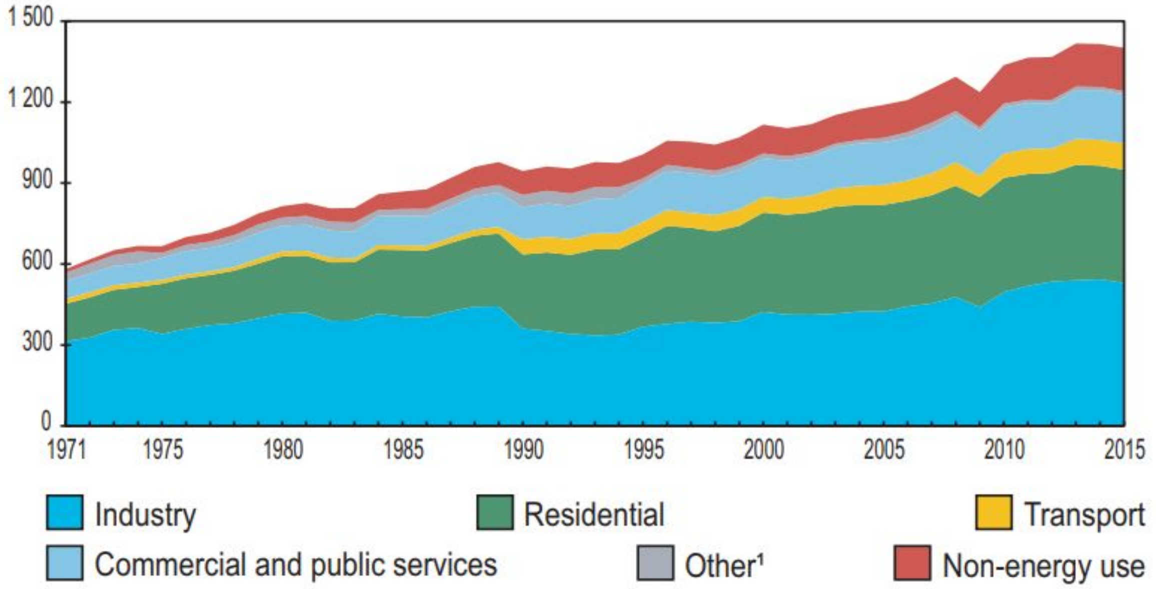


What observations can you make from this figure?

Total final consumption by sector: natural gas

#3

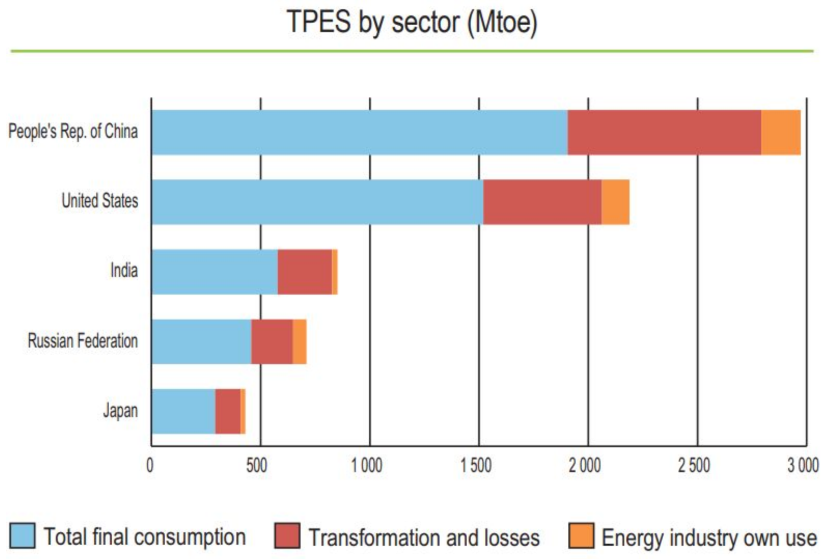
Natural gas TFC from 1971 to 2015 by sector (Mtoe)



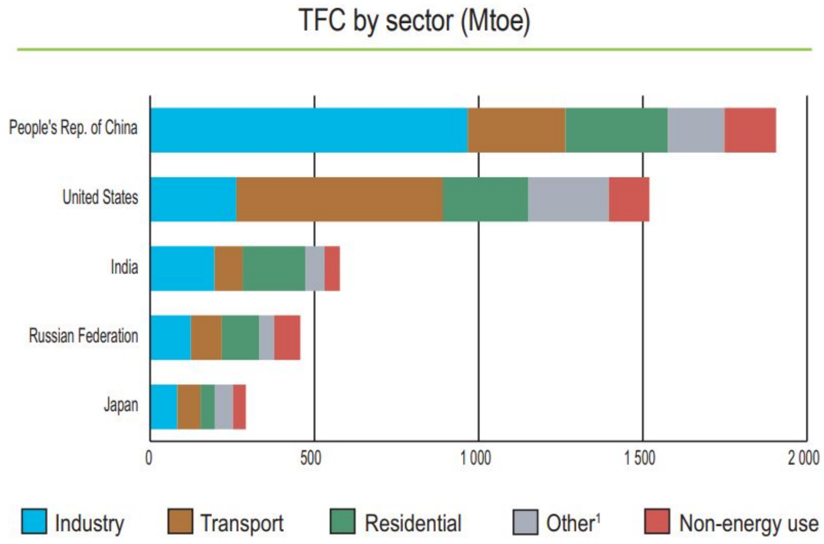
What observations can you make from this figure?

Compare Top 5 Supply and Consumption Countries

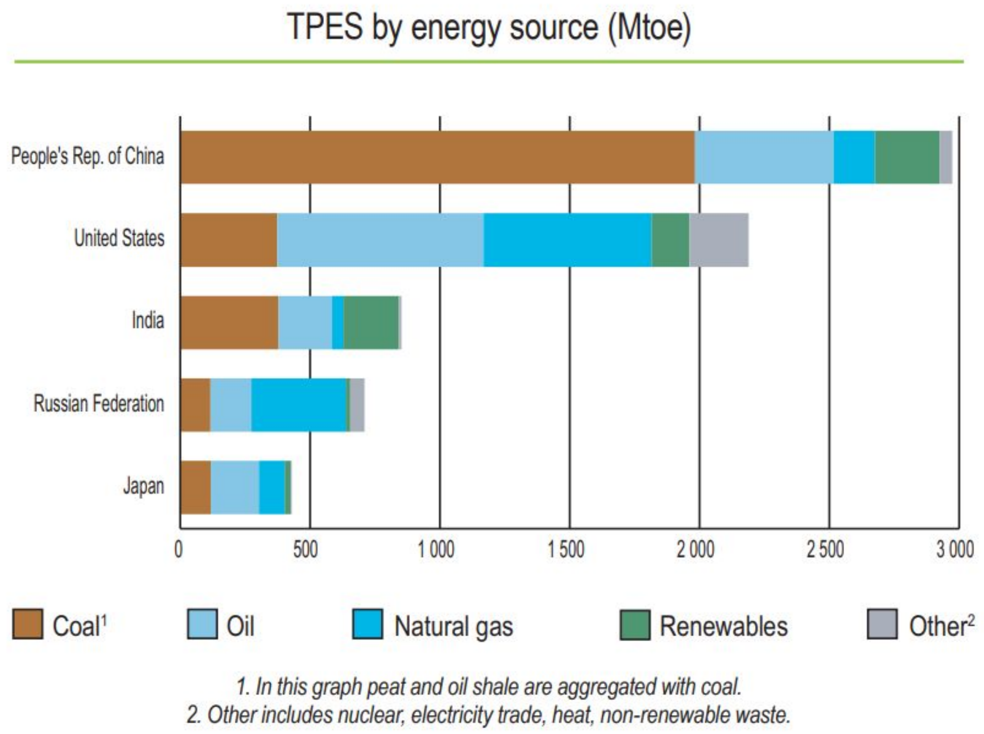
Top five countries by total primary energy supply (TPES)



Top five countries by total final consumption



Coal as the Primary Energy Supply in China

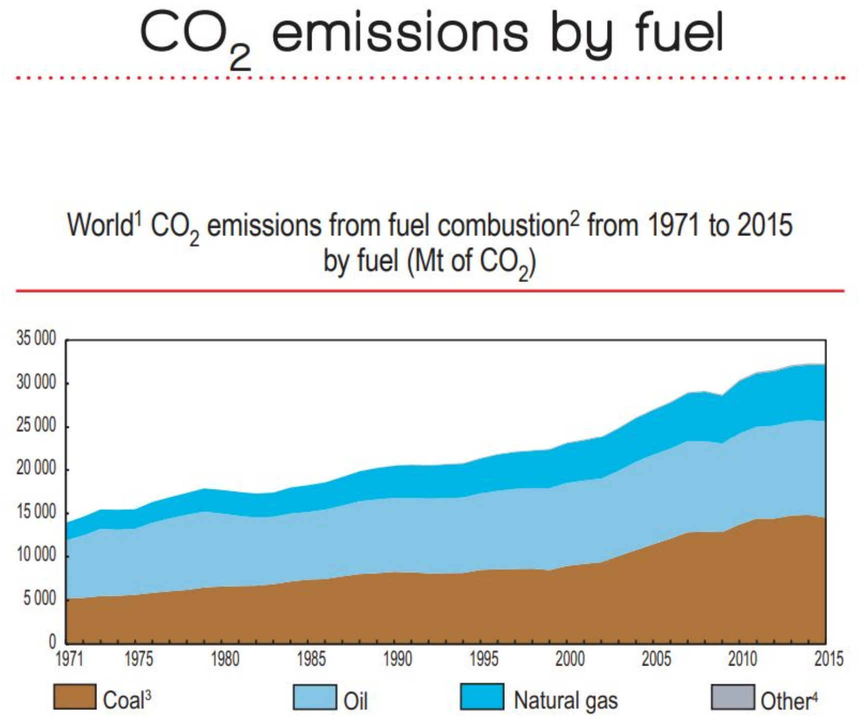


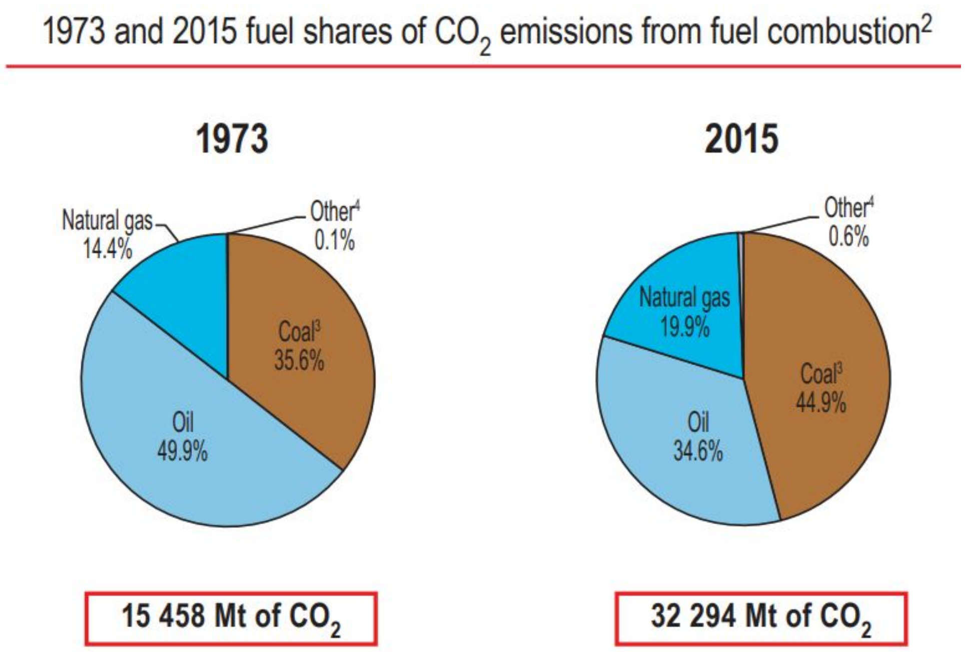
The political, social, and economical decisions that China makes, will determine the energy market of the future.

The People's Republic of China is the #1 supplier and consumer of coal energy in the world. The majority of the energy used is powering the industrialization and modernization of the country.

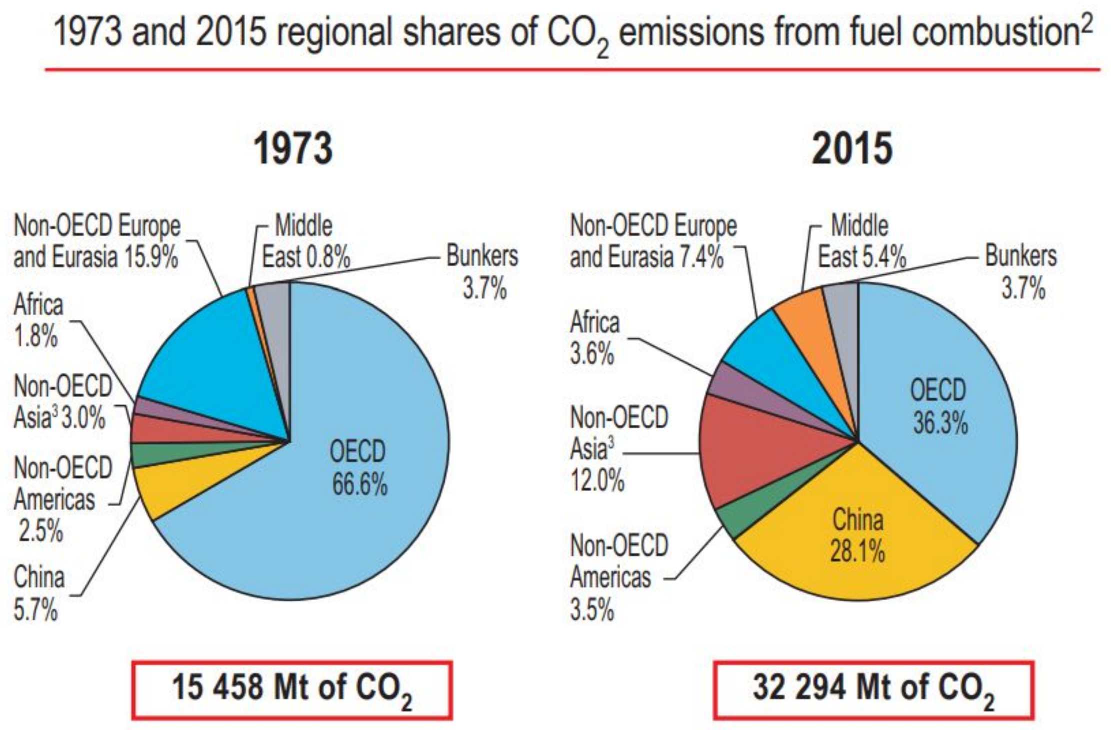
What does this energy consumption buy us?

CO2 Emissions from combustion of fossil fuels





CO2 Emissions from combustion of fossil fuels



<u>109%</u> increase in CO2 emissions 42 years!

EVERYTHING POINTS TO THIS QUESTION

Can a 109% increase in CO_2 emissions into the atmosphere, over a short period of time, have a measurable effect on the global climate?

Known Effects of increase atmospheric CO_2

1) Density of the atmosphere can affect the surface temperature, due to the Greenhouse Gas Theory.

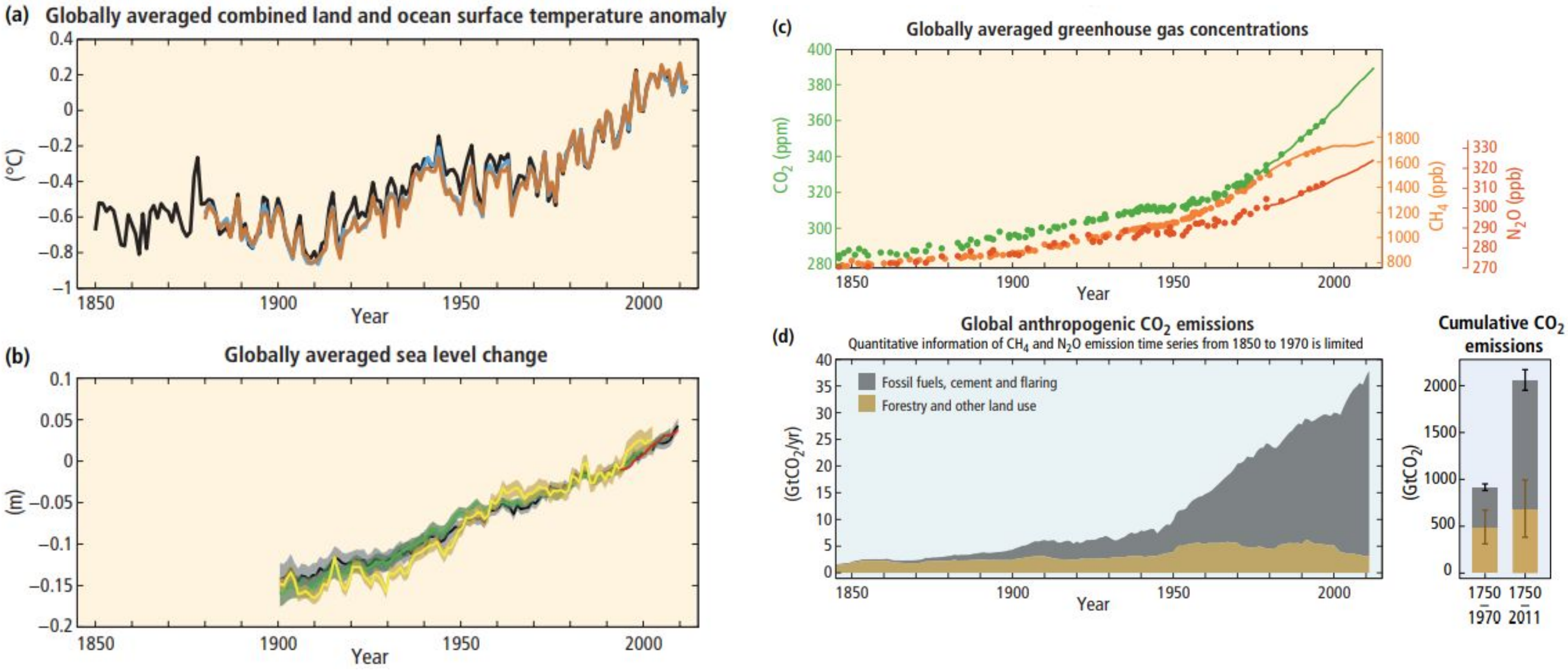
2) CO_2 is makes up a small percentage of the entire atmospheric composition (0.03%), but CO_2 is 92% of all trace gases.

3) The CO_2 chemical cycle can be short term (5 year cycle) or long term (1000's of years).

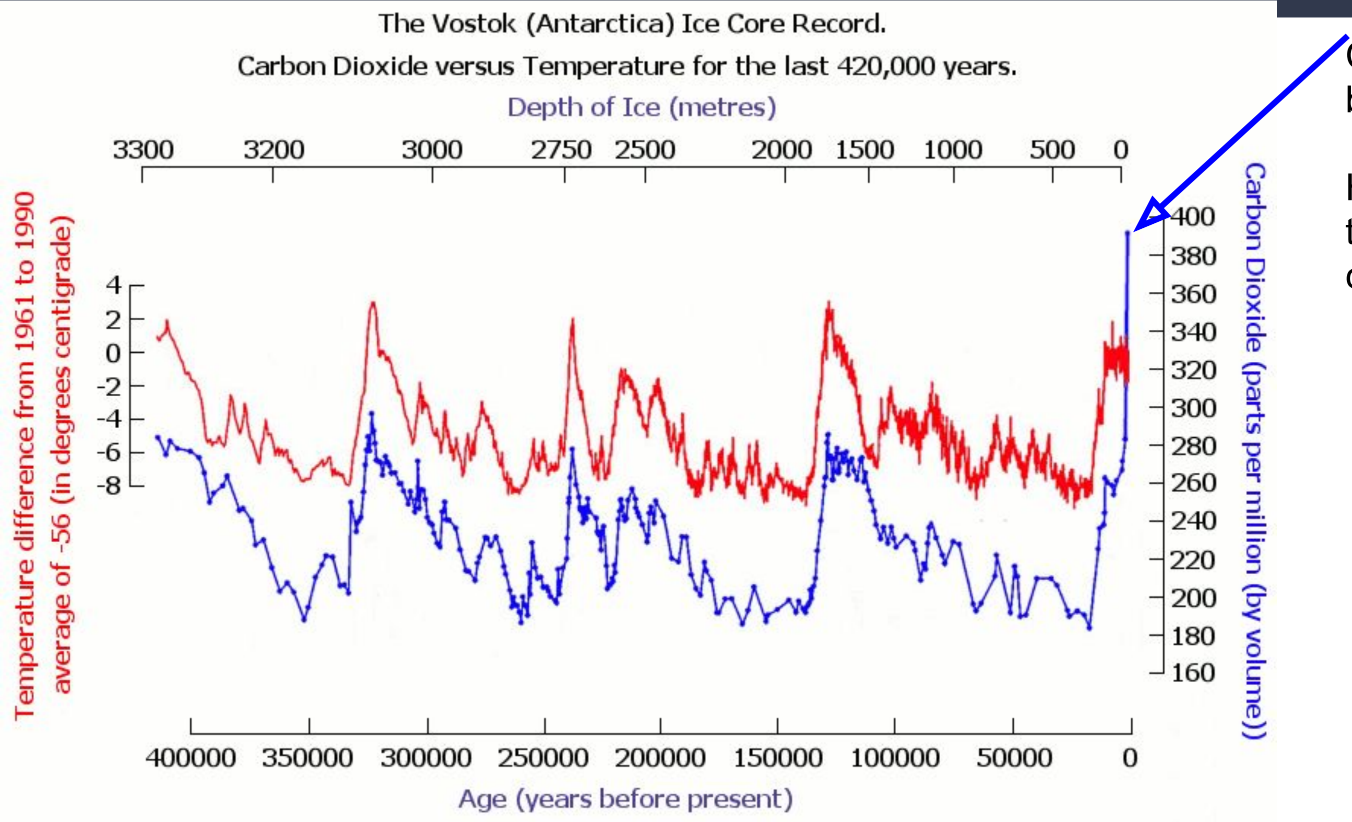
4) Water vapor in the atmosphere has a much greater percent composition (up to 7%). The water cycle is about 1 week.

HAS THE AVERAGE TEMPERATURE OF THE EARTH INCREASED OVER THE SAME PERIOD OF TIME?

CO2 and Temperature over a short period of time



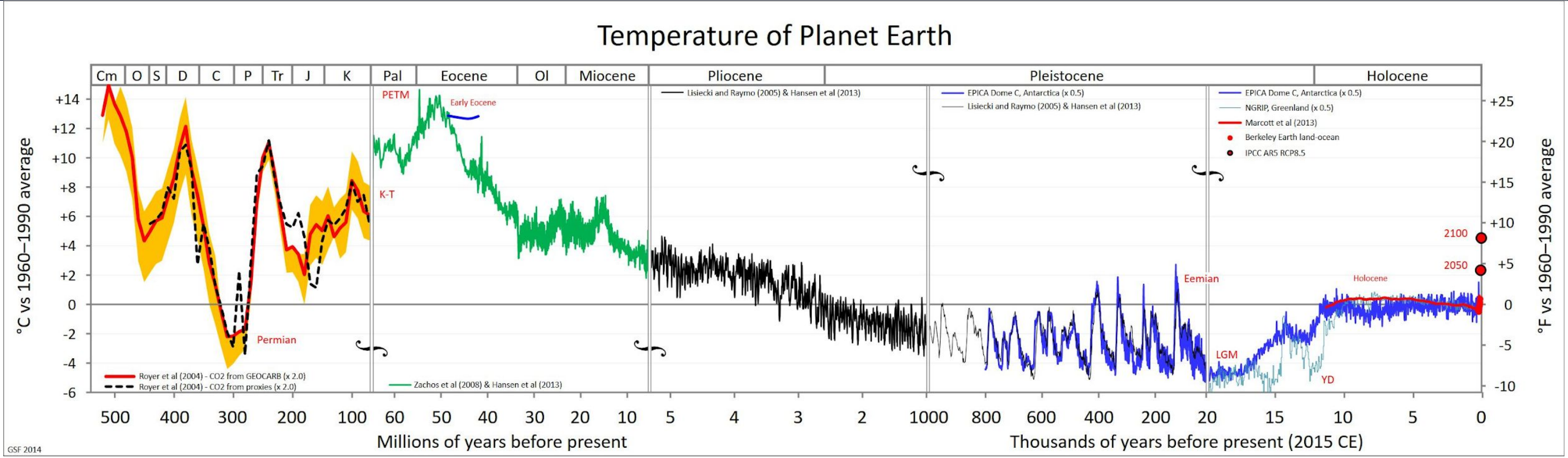
CO2 and temperature of a long period of time

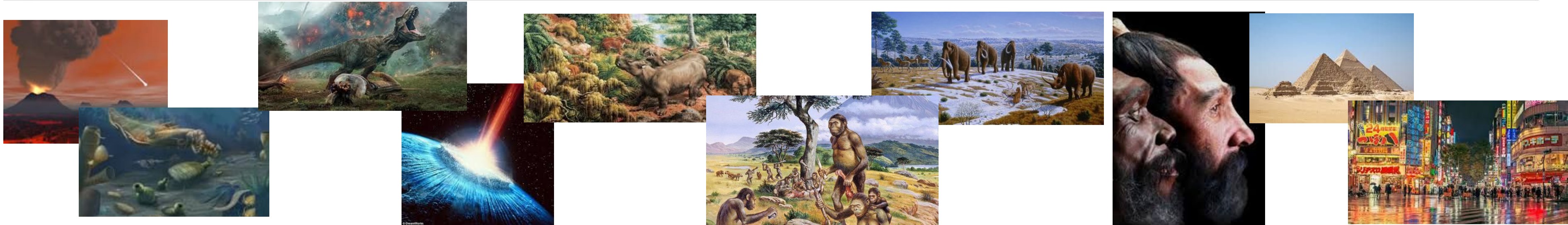


Current CO2 by volume

How will the temperature change?

Temperature over a LONG LONG time (reconstructed)





Potential Consequences of Warm Climate

Taken as a whole, the range of published evidence indicates that the net damage costs of climate change are likely to be significant and to increase over time.

- Intergovernmental Panel on Climate Change

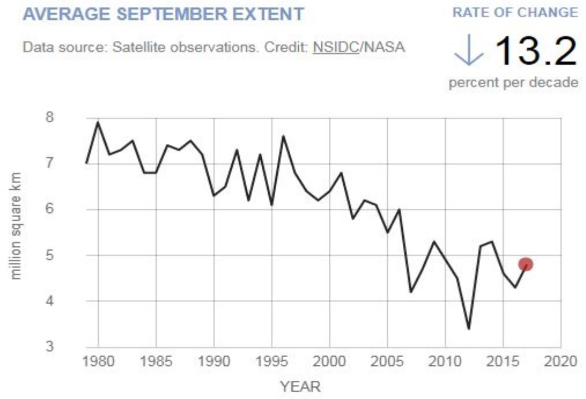
Potential Consequences of Warm Climate

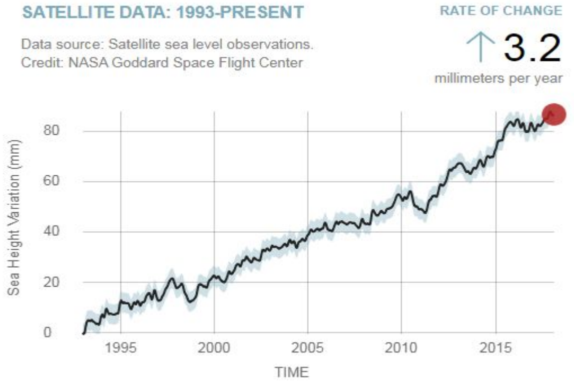
1) Unless global energy consumption pivots to resources that produce less atmospheric CO_2, carbon dioxide levels will rise.

2) Global temperature increase will be beneficial for some areas while destructive to other areas, based on geography and weather patterns.

3) Polar caps can buffer the effect of a temperature increase by melting into liquid water. Do we observe a decrease in Arctic sea ice? In turn the sea level could rise.

4) Prevalence of extreme weather will increase, due to the large differential between warmer and cooler climates. **Does extreme weather have economic impacts? What sections of the economy and societal demographics are impacted the most?**





Economic Cost to Climate Change: Case Study

3 Categories for Case Studies

- Droughts/Water scarcity
- Thunderstorms/Floods
- Hurricanes/Coastal Property Damage

Table ES - 1: Summary of agricultural impacts of the 2016 California drought

Description	Impact	Base year levels	Percent change
Surface water shortage (million acre-ft)	2.6	18.0	-14%
Groundwater replacement (m acre-ft)	1.9	8.4	23%
Net water shortage (million acre-ft)	0.7	26.4	-2.6%
Drought-related idle land (acres)	78,780	1.2 million*	6.6%
Crop revenue losses ($)	$247 million	$37 billion	0.6%
Dairy and livestock revenue losses ($)	Minor	$12.4 billion	NA
Costs of additional pumping ($)	$303 million	$780 million	38.8%
Direct costs of drought ($)	$550 million	NA	NA
Total economic impact ($)	**$603 million**	NA	NA
Direct drought job losses (farm seasonal)	1,815	200,000#	0.9%
Total job losses from drought	**4,700**	NA	NA

* NASA-ARC 2015 estimate of normal Central Valley idle land.

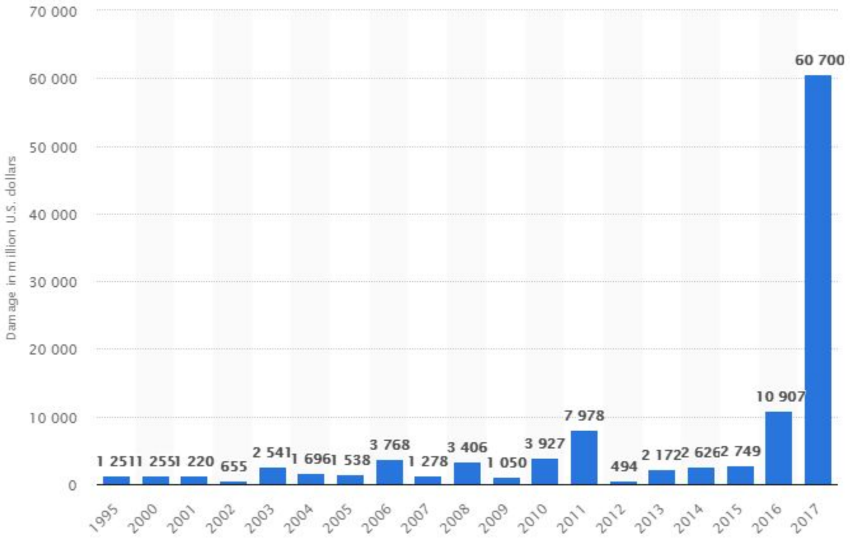
Total agricultural employment is about 412,000, of which 200,000 is farm production.

Economic Cost to Climate Change: Case Study

3 Categories for Case Studies

- Droughts/Water scarcity
- Thunderstorms/Floods
- Hurricanes/Coastal Property Damage

Economic damage caused by floods and flash floods in the U.S. from 1995 to 2017 (in million U.S. dollars)



Economic Cost to Climate Change:Case Study

3 Categories for Case Studies

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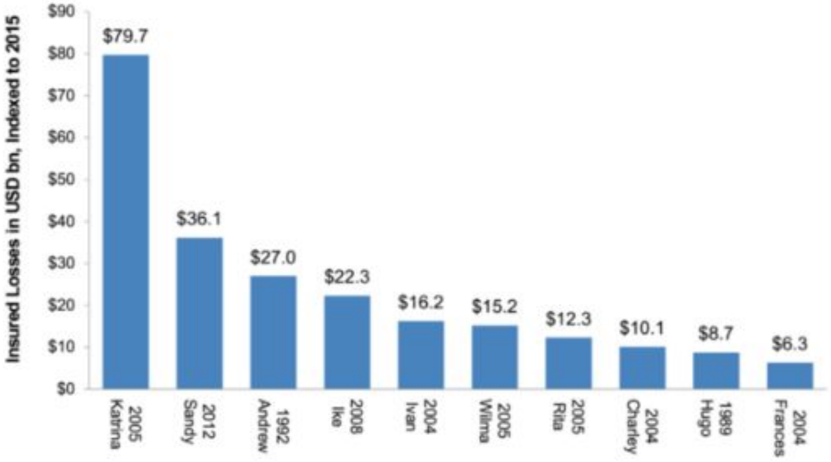
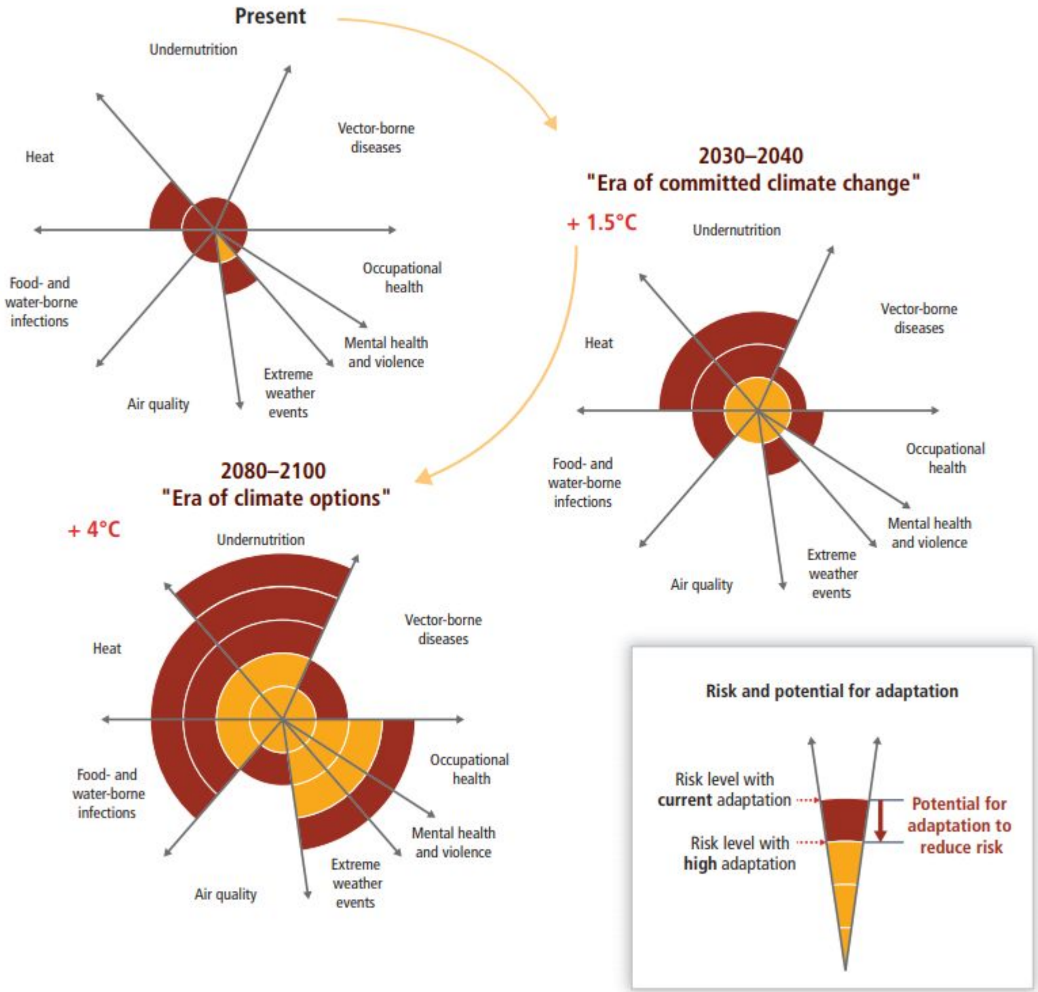
The cost of Harvey

Exhibit 5: Most Costly US Hurricanes



Source: Swiss Re Sigma, Morgan Stanley Research

Morgan Stanley



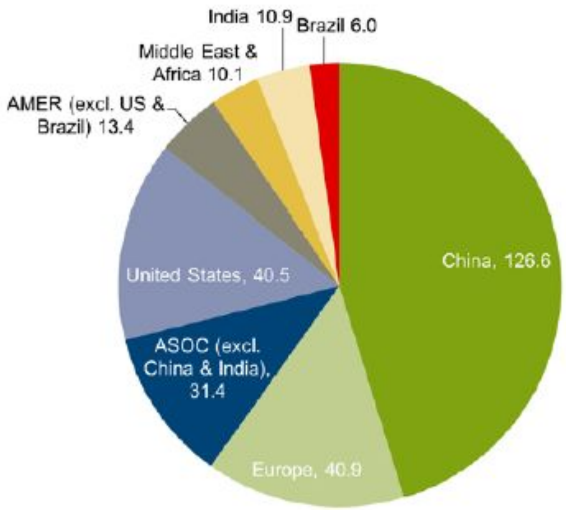
We know people in poverty will be affected the most, first. Privilege can buy a second chance.

FAQ 11.3 | Who is most affected by climate change?

While the direct health effects of extreme weather events receive great attention, climate change mainly harms human health by exacerbating existing disease burdens and negative impacts on daily life among those with the weakest health protection systems, and with the least capacity to adapt. Thus, most assessments indicate that poor and disenfranchised groups will bear the most risk and, globally, the greatest burden will fall on poor countries, particularly on poor children, who are most affected today by such climate-related diseases as malaria, undernutrition, and diarrhea. However, the diverse and global effects of climate change mean that higher income populations may also be affected by extreme events, emerging risks, and the spread of impacts from more vulnerable populations.

China Leads in Global Shift to Renewable Energy

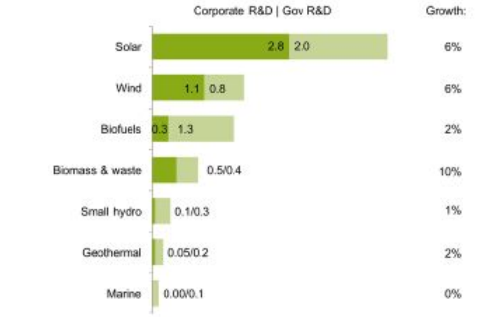
FIGURE 13. GLOBAL NEW INVESTMENT IN RENEWABLE ENERGY BY REGION, 2017, $BN



New investment volume adjusts for re-invested equity. Total values include estimates for undisclosed deals

Source: UN Environment, Bloomberg New Energy Finance

FIGURE 49. CORPORATE AND GOVERNMENT RENEWABLE ENERGY R&D BY TECHNOLOGY, 2017, AND GROWTH ON 2016, $BN



Source: Bloomberg, Bloomberg New Energy Finance, IEA, IMF, various government agencies

FIGURE 50. CORPORATE AND GOVERNMENT RENEWABLE ENERGY R&D BY REGION, 2017, AND GROWTH ON 2016, $BN

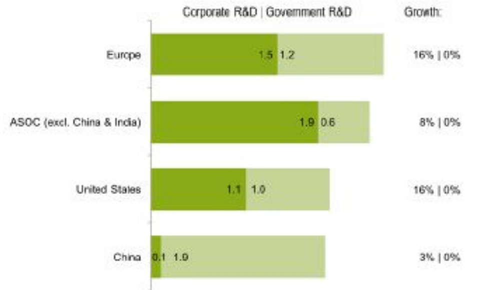
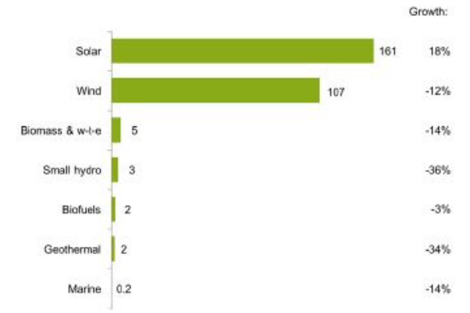


FIGURE 5. GLOBAL NEW INVESTMENT IN RENEWABLE ENERGY BY SECTOR, 2017, AND GROWTH ON 2016, $BN



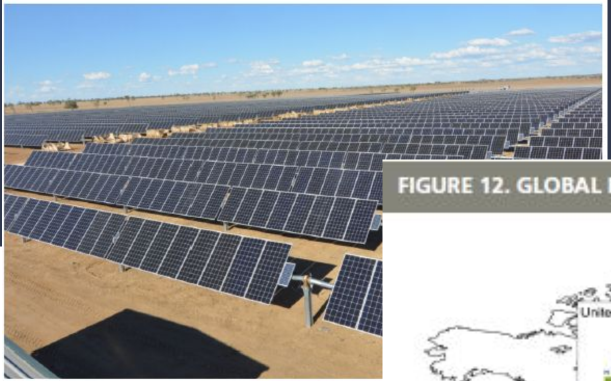
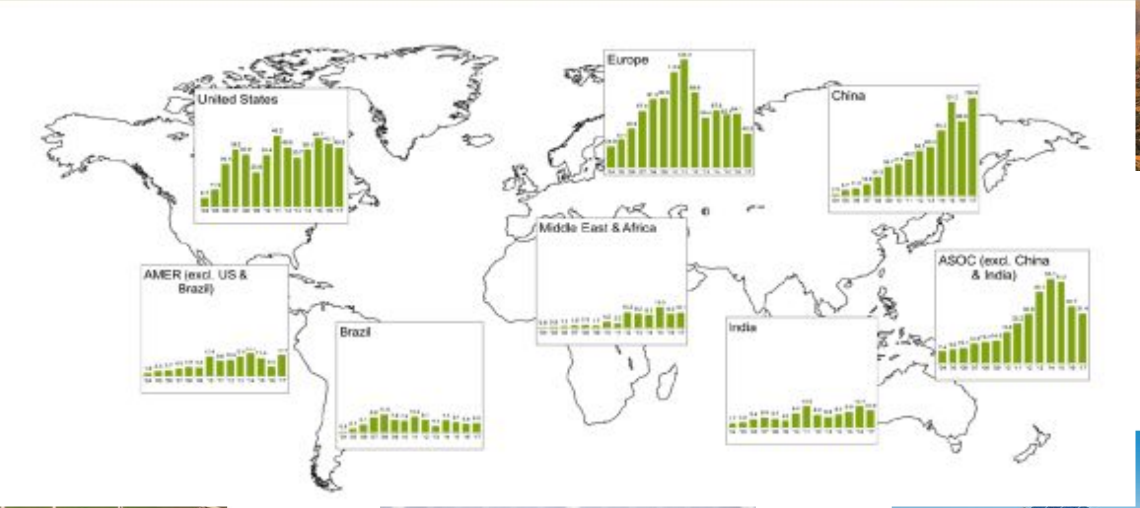
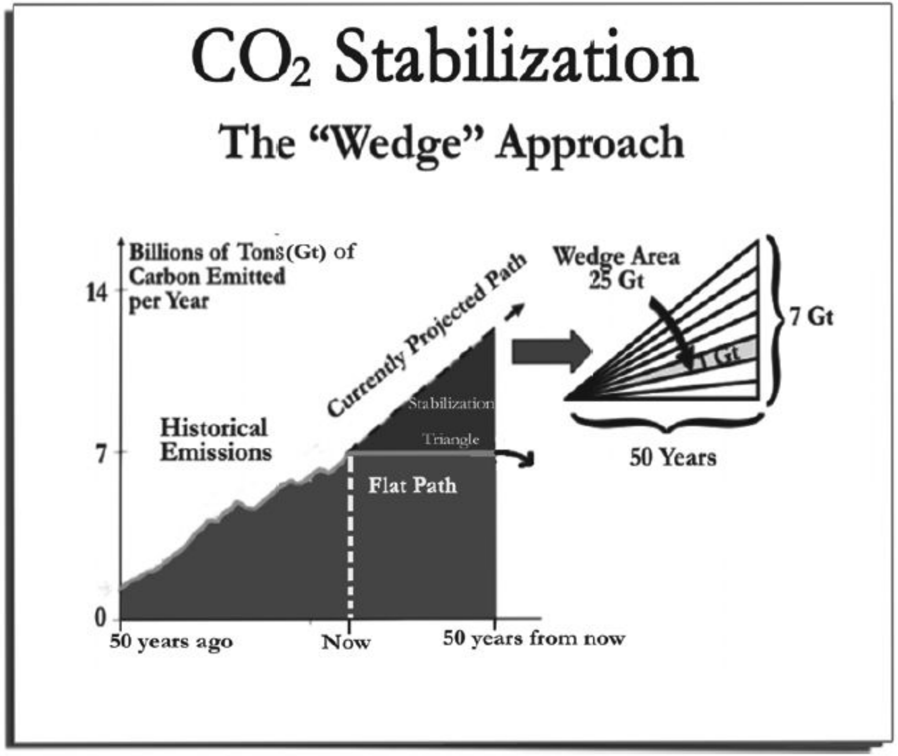
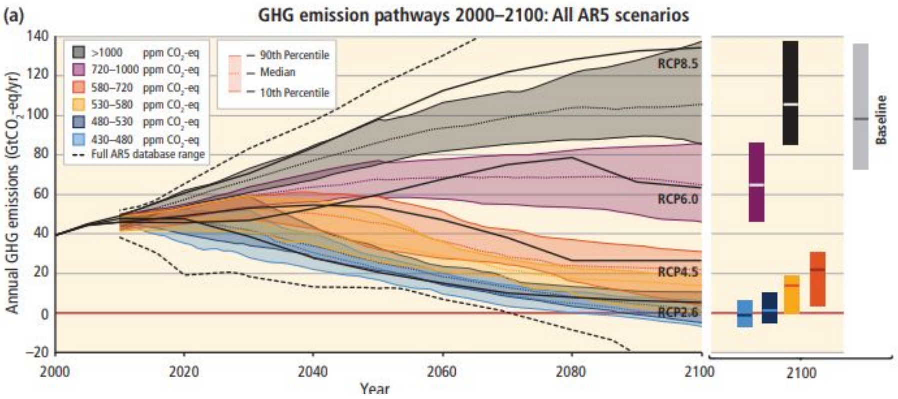


FIGURE 12. GLOBAL NEW INVESTMENT IN RENEWABLE ENERGY BY REGION, 2004-2016, $BN



4 Possible Scenarios





Four different GHG emissions scenarios are modeled by the IPCC, forecasting the potential to follow the "Wedge" approach to mitigating climate change. There is no one solution to anthropogenic climate change.

Part 2 Summary

1) The global energy supply is mostly made of fossil fuels, as is the majority of the global energy consumption. Fossil fuel combustion has waste, this waste is CO_2.

2) Different energy sources are used primarily in different sectors of the economy. This can help develop energy use plans for the future.

3) China's energy use can change the world. This is why they are leading the production or renewable energy technologies. (Cost limiting)

4) High levels of atmospheric CO_2 has expensive consequences. Consequences that will mostly affect people in poverty.

5) CO_2 stabilization is possible, 4 main scenarios exist based on different criteria. Still the only hope we have of intervention is to try and craft global policy that caps the amount of CO_2 emissions. The earth is repairable, as documented with the Ozone hole, but we as a people have to agree that this ecosystem is worth saving.

Research Quiz #2

#1

List the renewable energy resources or technologies. Find or calculate the amount of electricity (kWh) each produces. (hint: on an equal scale)

#2

Another problem that is tangential is plastic pollution. Find evidence for consequences of the amount of plastic pollution in the ocean. Brainstorm ways to reduce plastic pollution with the class. Is biodegradable plastic a viable solution?

To learn more, watch the movie and read the IPCC report…. The End

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