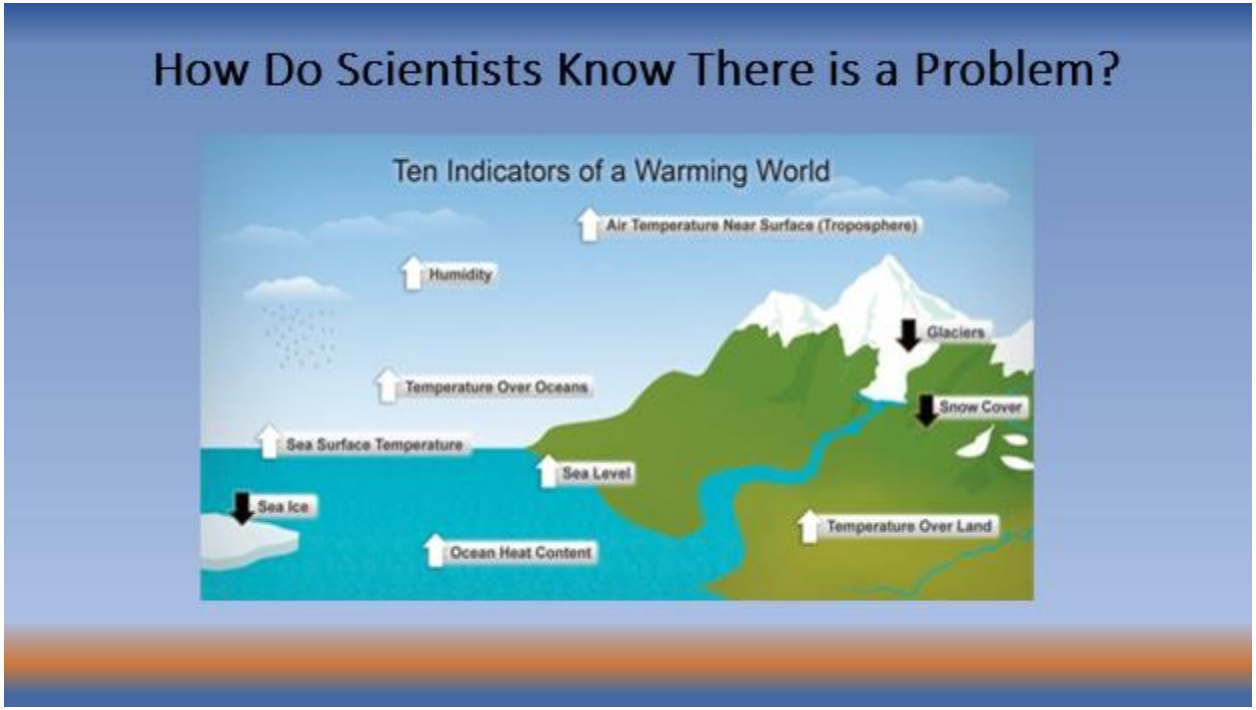
This presentation is designed to provide answers to these questions about Climate Change.

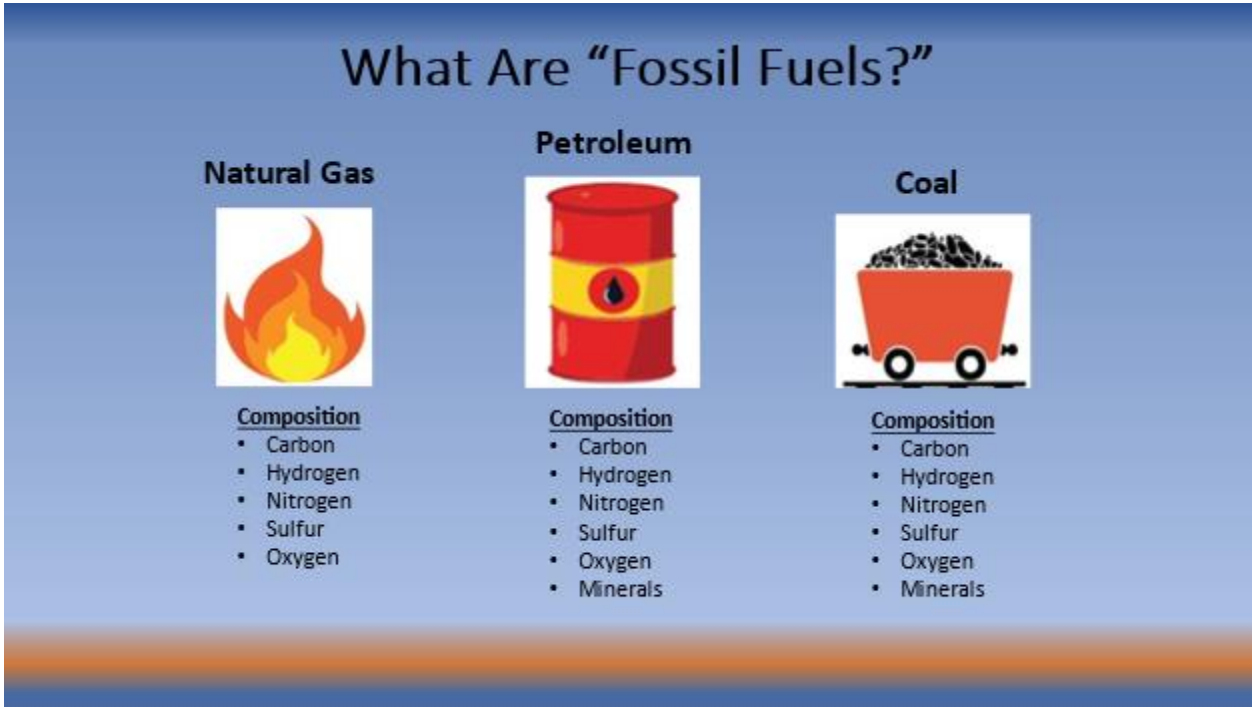
- What is causing the earth's climate to change?
- What are the impacts of those changes?
- What can we do to reduce those impacts on the earth and human society?



Let's start with what scientists have been observing for decades.

All of the above are critical indicators that have been measured or observed by thousands of scientists from every major developed country around the world.

Image Source:
National Oceanic and Atmospheric Administration (NOAA)



Fossil fuels, which we primarily depend on for our energy needs, were formed over millions of years by compression of plant and animal material.

They include Natural Gas, Petroleum and Coal and are known as "hydrocarbons" because of their high content of Carbon and Hydrogen.

- While they are composed of mostly the same elements, they are all in different "states" – gas or liquid or solid.
- Natural gas consists mainly of Methane – a potent Greenhouse Gas in its natural state, and when burned, it produces CO_2.
- Petroleum is also known as "crude oil" or just "oil".

Fossil fuels are buried in the earth and must be extracted which can cause significant environmental damage.

Source: https://www.e-education.psu.edu/egee102/node/1950

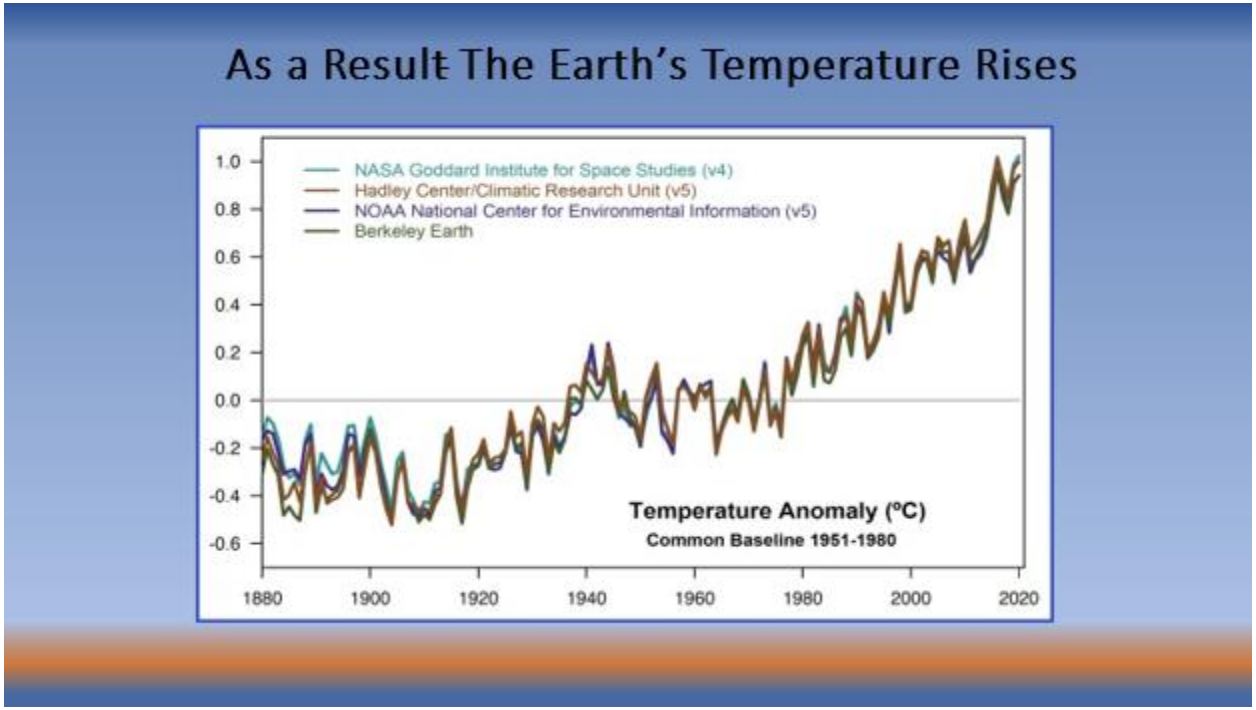
When fossil fuels are burned, carbon dioxide and other types of pollutants are produced. Note that the element carbon accounts for 60–90 percent of the mass of fuels that we burn.

Excess carbon dioxide is also the single largest contributor to our changing climate over a long period of time.

All of the other products of combustion have negative health and/or environmental impacts.

Source:
https://www.e-education.psu.edu/egee102/node/2207

Image Source:
National Park Service via Wikimedia Commons

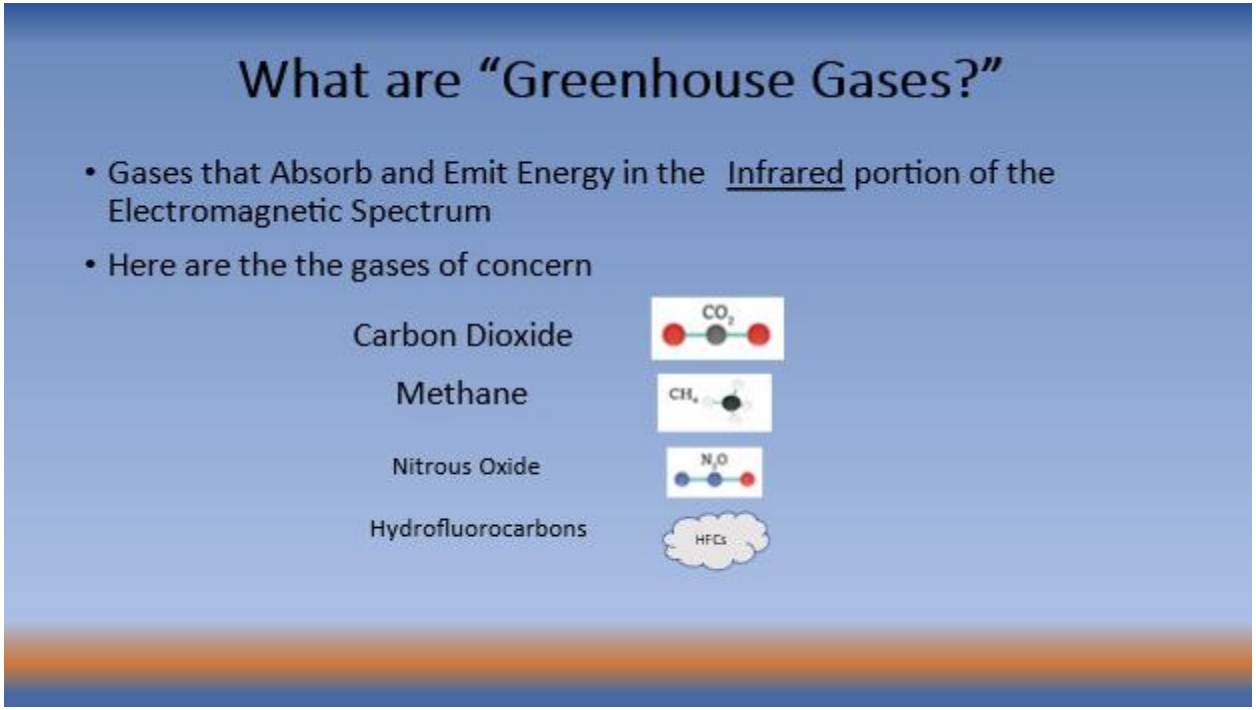


This chart shows how the Earth's temperature has risen since accurate measurements of global temperature began in 1880.

These data points are averages across the planet. The Earth is not "heating up" uniformly. A few areas of our planet will have stable temperatures over this period, but many more will have extreme variations with temperatures rising substantially.

For an interactive view of this trend, see
https://climate.nasa.gov/interactives/climate-time-machine

Source:
https://climate.nasa.gov/faq/21/why-does-the-temperature-record-shown-on-your-vital-signs-page-begin-at-1880/



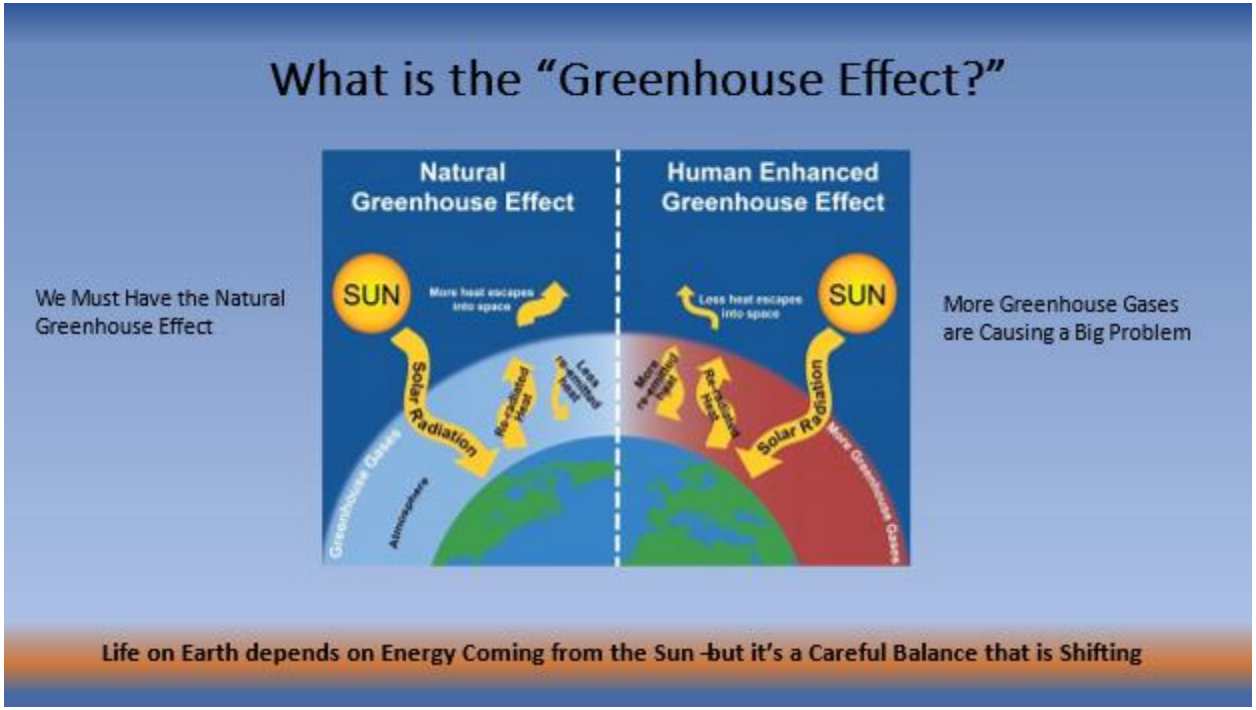
Let's get a better understanding of what is meant by a greenhouse gas. The first 3 gases listed are **naturally occurring**, but humans are significantly contributing to their presence. Water vapor is also a greenhouse gas, but humans are not increasing the presence of water vapor in the atmosphere.

These gases will trap heat in the atmosphere and warm the planet.

Carbon dioxide receives the most attention because it is by far the most prevalent and can last hundreds if not thousands of years in the atmosphere.

According to the Environmental Defense Fund, methane has more than 80 times the warming power of carbon dioxide over the first 20 years after it reaches the atmosphere. Even though CO_2 has a longer-lasting effect, methane sets the pace for warming in the near term.

For more information on methane, visit: https://www.scientificamerican.com/article/how-bad-of-a-greenhouse-gas-is-methane/



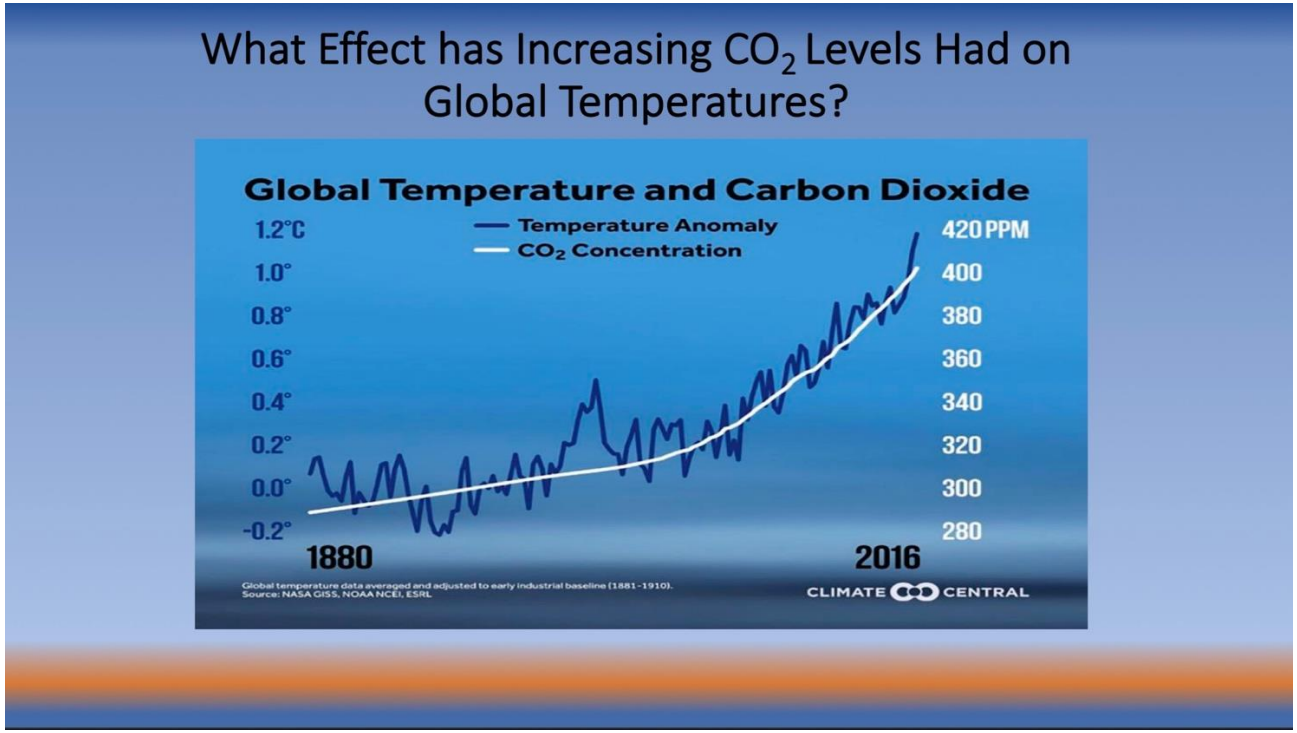
How do greenhouse gases affect the earth's climate? Here is some key information on the Earth's energy budget.

- The incoming solar radiation from the Sun arrives as visible light.
- Only about 50% of that reaches the surface, most of the rest of that light energy is reflected back to space.
- The energy that reaches the surface will be re-radiated back to the atmosphere – but it experiences what is known as a "frequency shift", meaning it is no longer visible light. It has been transformed into infrared energy.
- Unlike visible light, infrared energy is absorbed by greenhouse gases which warm the atmosphere.

The "Natural Greenhouse Effect" is essential for life on earth. If we didn't have it, the average temperature on the earth would be about -18^{0}C (0^{0}F). Those naturally occurring greenhouse gases, plus water vapor, keep us at about 15^{0}C (59^{0}F) today. This temperature is steadily rising.

Here are some useful video links:
https://climatekids.nasa.gov/greenhouse-effect/
https://climate.nasa.gov/causes/

Image Source: National Park Service



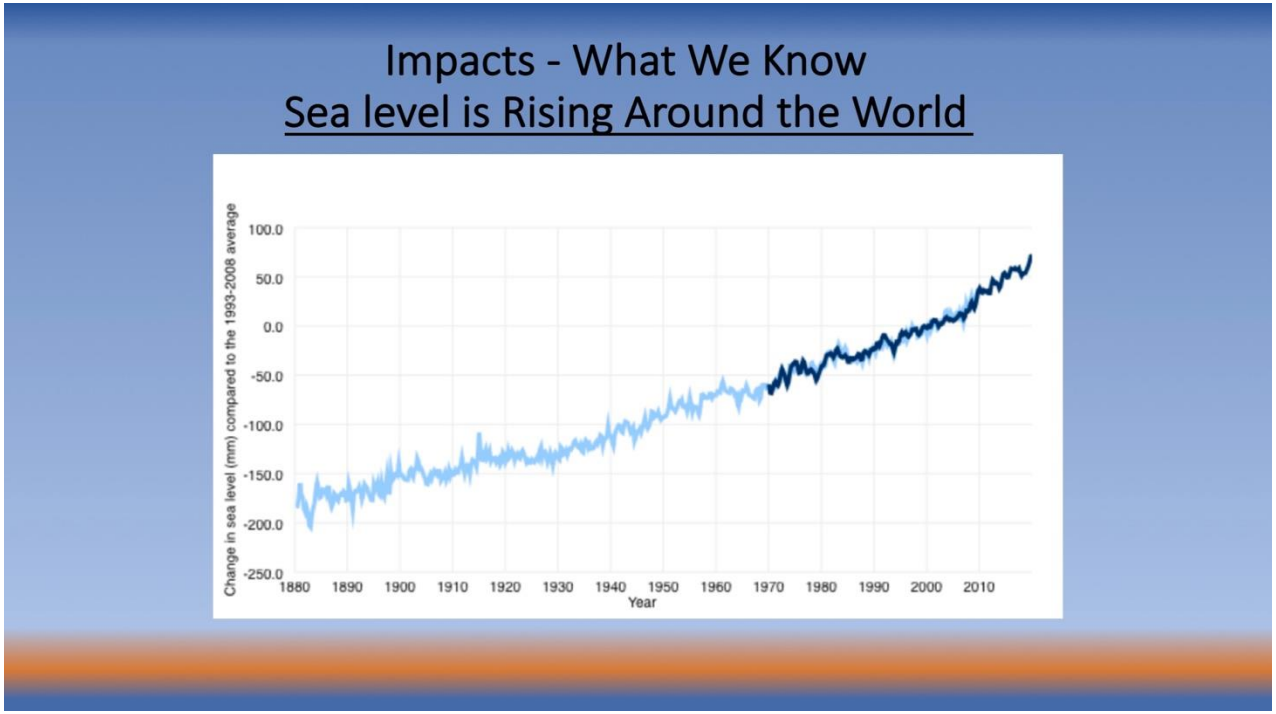
You can see from this chart that CO_2 (white Line) began increasing with the Industrial Revolution and accelerated in the 20th Century - and that the Global Temperature changes (blue line) **track** those rising CO_2 levels during this entire period.

It is very clear what the relationship is between the two.

You can also see that in 1960 the CO_2 levels in part per million (ppm) was about 320, in March 2021 it was 417 ppm, or an increase of 30%.

This is a very disturbing “rate of change.”

Infographic Source: Climate Central



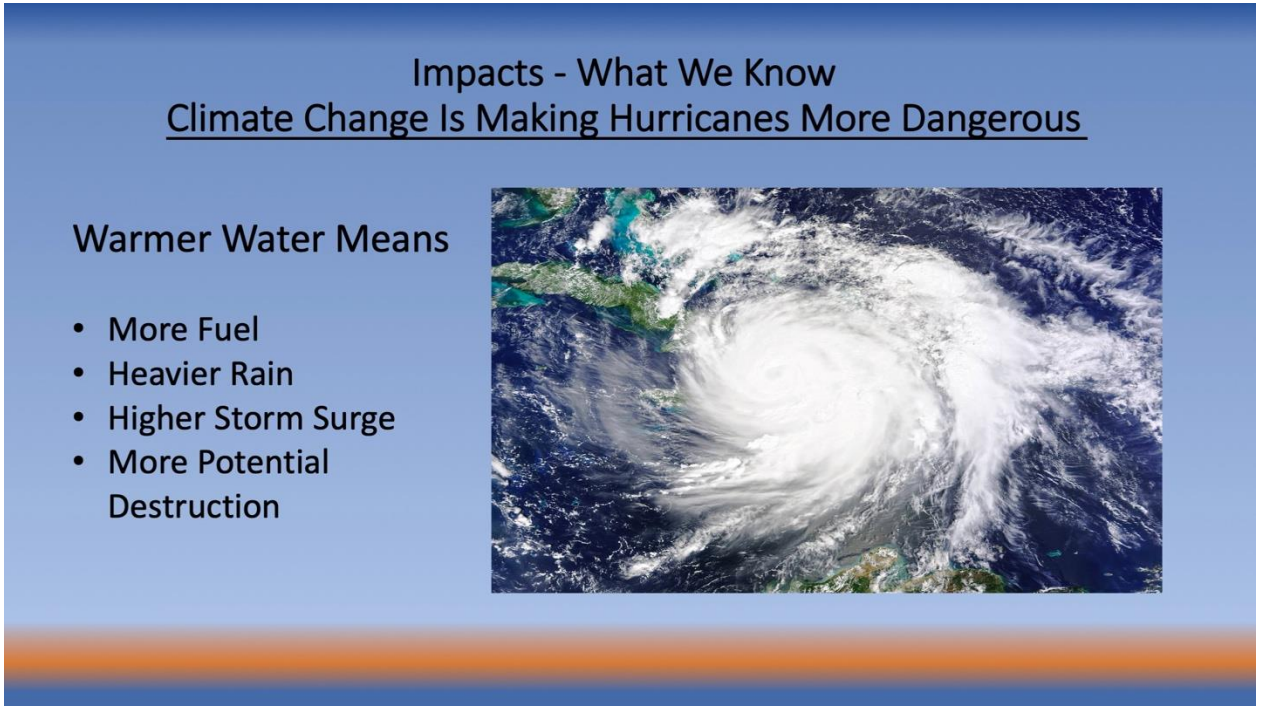
Global mean sea level has risen about 8–9 inches since 1880, with about a third of that coming in just the last two and a half decades.

Sea level rise is caused primarily by two factors: Ice melt and heat-driven expansion of ocean water. Most of the change in sea level so far is due to THERMAL EXPANSION – as the oceans expand, they have nowhere to go but "up".

Of MAJOR CONCERN for future sea level rise is the melting ice in these areas: (1) Arctic Ocean, (2) Greenland, and (3) Antarctic Continent.

For more information on Sea Level Rise:
https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level
https://www.nasa.gov/goddard/risingseas

Sources:
https://nca2018.globalchange.gov/chapter/2/
https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level



Hurricanes are a WEATHER Phenomenon. Weather is a specific event—like a rainstorm or hot day—that happens over a few hours, days, or weeks.

Climate is the average weather conditions in a place over 30 years or more. *Climate is what you expect, weather is what you get!*

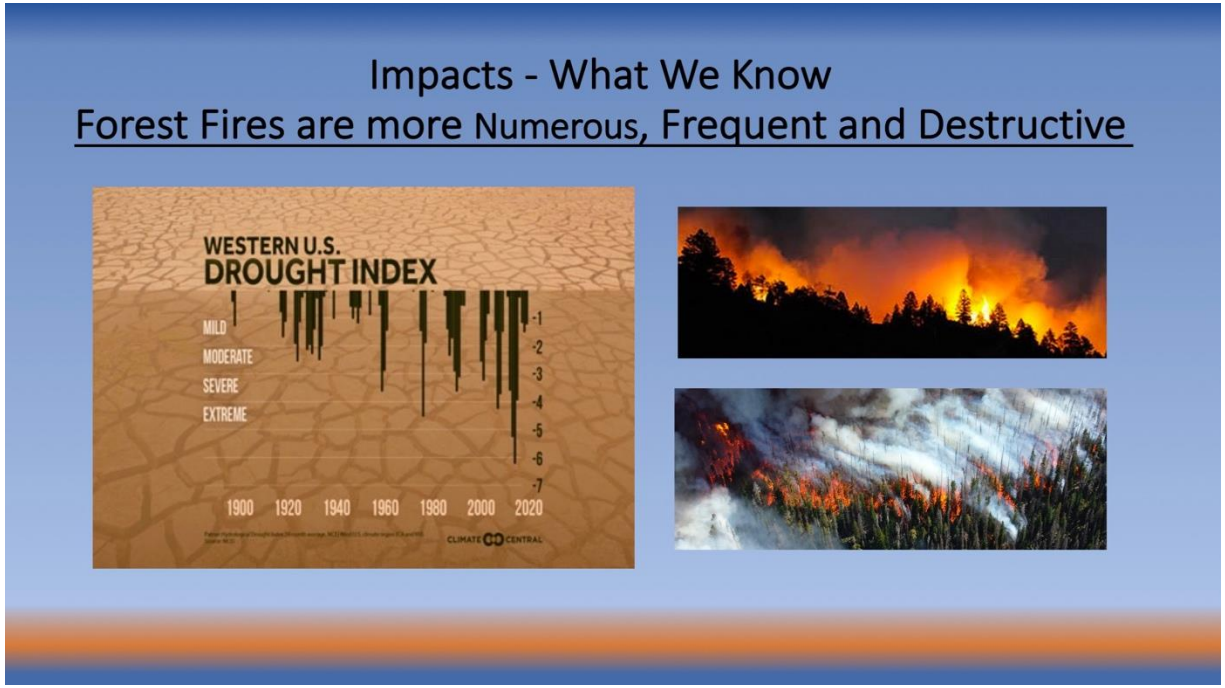
Climate Change influences severe weather by causing longer droughts and higher temperatures in some regions and more intense deluges in others.

Warming oceans, a warmer, wetter atmosphere, and rising seas come together to make hurricanes more destructive. Hurricanes are fueled by warm oceans, so there is now more fuel for these storms. This doesn't necessarily mean there are more, but there is greater potential for bigger, more powerful storms that last longer.

Storms that do form are also intensifying more rapidly. When hurricanes and tropical storms do make landfall, increasing sea levels mean that storm surge pushes further ashore, increasing the damage.

Source:
https://yaleclimateconnections.org/2019/07/how-climate-change-is-making-hurricanes-more-dangerous

Image Source: NASA



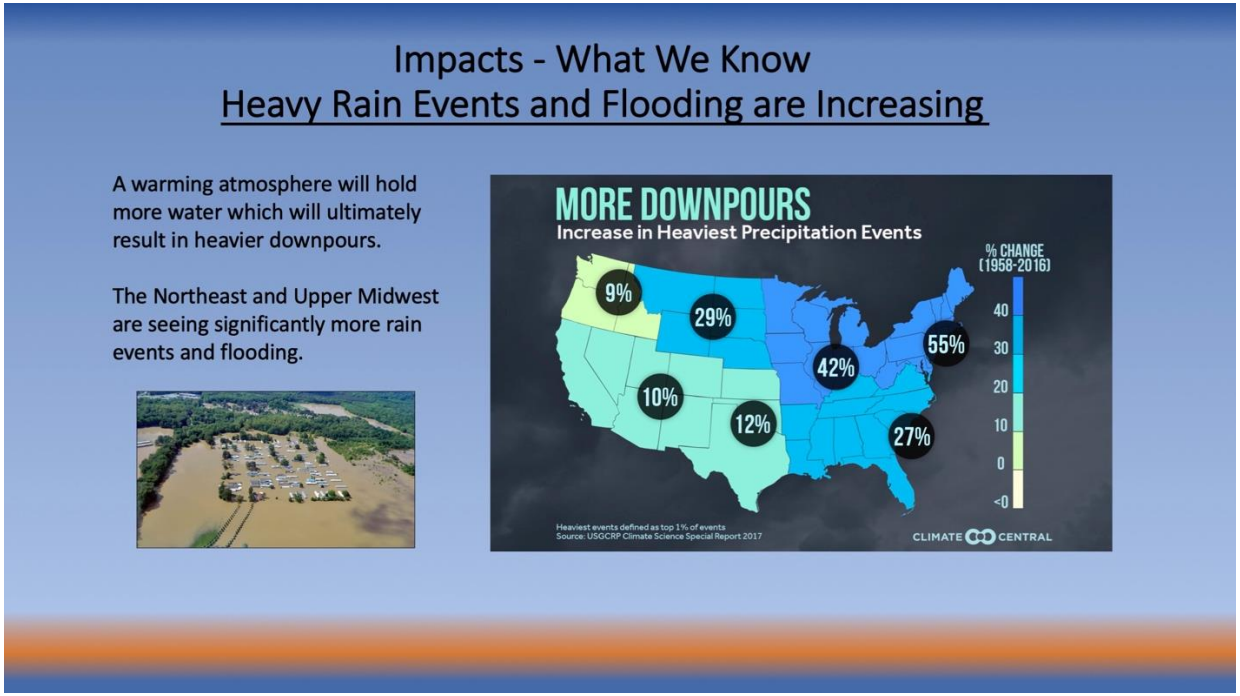
In the Western US, drought is increasing resulting in dryer conditions.

- Higher temperatures and drought increase the potential for wildfire.
- Lower precipitation and warmer air temperatures dry the forests and other vegetation.

Climate change has increased fire risk in both direct and indirect ways. When an ignition happens, even if it's natural (e.g., lightning), the chances of it spawning a big fire are much higher than they would be, absent climate change. Overall, over the past few decades in the State of California, the annual average area burned has increased fivefold.

Source:
https://www.nationalgeographic.com/science/article/climate-change-increases-risk-fires-western-us

Image Sources:
Climate Central and the National Park Service



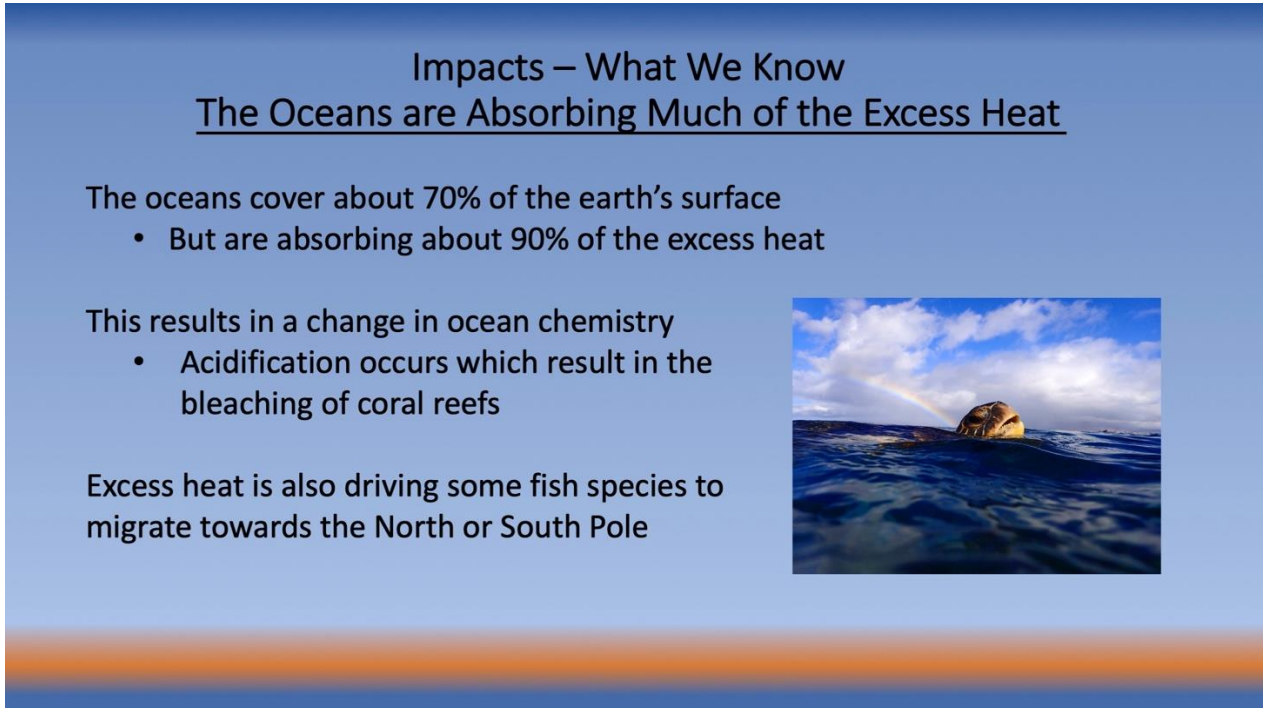
Since 1958, the number of heavy precipitation events has increased dramatically in the US. Heavy precipitation events are happening with greater frequency not only in the US but also in many other parts of the world with record floods and loss of life occurring in Europe and China in 2021.

For each 1°C (1.8°F) of warming, saturated air contains 7% more water vapor on average. Just as a bigger bucket can hold and dump more water, a warmer atmosphere can hold more water vapor and therefore dump more water when it rains.

"Heavy precipitation" refers to instances during which the amount of rain or snow experienced in a location substantially exceeds what is normal. What constitutes a period of heavy precipitation varies according to location and season.

Sources:
https://www.epa.gov/climate-indicators/climate-change-indicators-heavy-precipitation
https://medialibrary.climatecentral.org/extreme-weather-toolkits/heavy-rain-flooding
https://www.climatesignals.org/climate-signals/atmospheric-moisture-increase#more

Image and Infographic Sources:
National Weather Service
Climate Central



Sea surface temperatures have been consistently higher during the past three decades than at any other time since reliable observations began in the late 1800s.

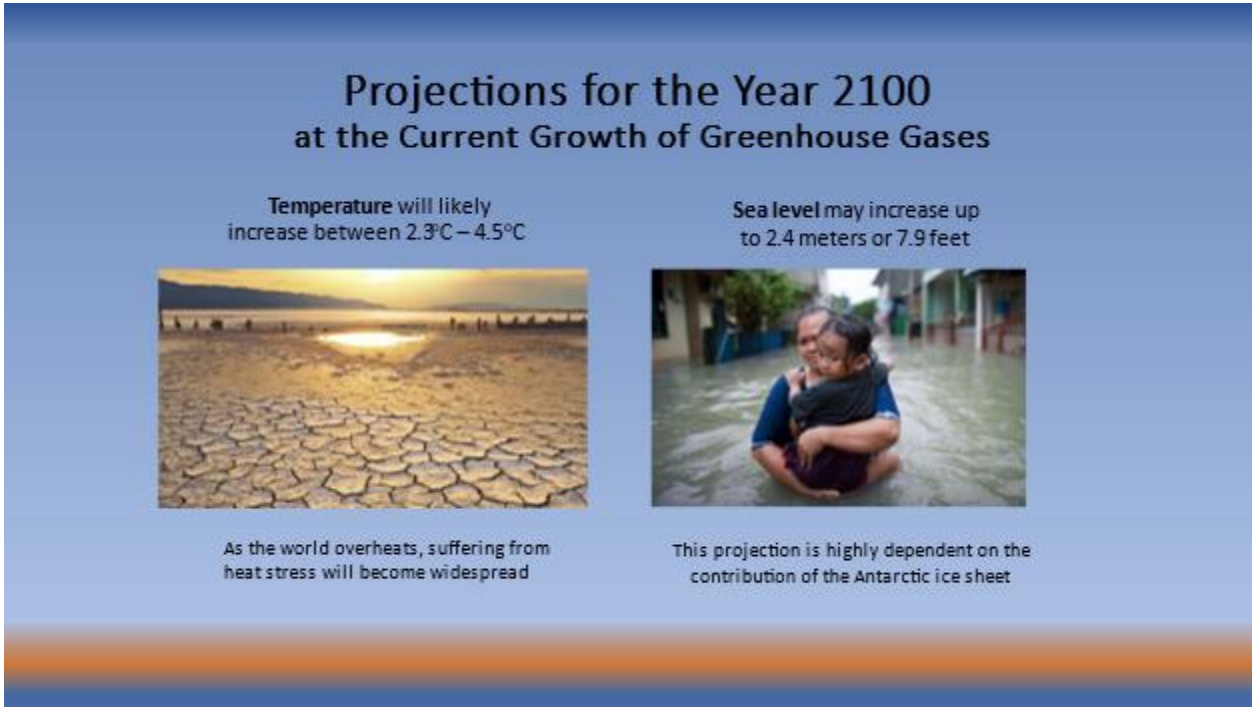
The ocean has become more acidic over the past few decades because of increased levels of atmospheric carbon dioxide, which dissolves in the water. Increased acidity makes it difficult for corals and shellfish to build their skeletons and shells. This results in the starvation, shrinkage and death of the corals that support the thousands of species that live on coral reefs.

Researchers have estimated that the oceans are home to up to 1 million different species. Increased ocean temperatures risk causing the mass migration of species. This kind of change will have a very serious impact on global fisheries and aquaculture.

So far, the oceans have protected us from the worst effects of climate change, but there is great uncertainty regarding the ability of the ocean to absorb carbon dioxide in future.

Sources: https://www.epa.gov/climate-indicators/oceans; https://www.edf.org/blog/2013/10/08/5-ways-climate-change-affecting-our-oceans; and https://www.un.org/en/chronicle/article/climate-change-poses-threat-our-oceans

Image Source: https://www.nist.gov/news-events/news/2018/09/how-reliable-are-turtles-measuring-ocean-trash-and-marine-health



Here are projections for temperature increases and sea level rises.

Extreme Heat will continue to spread.

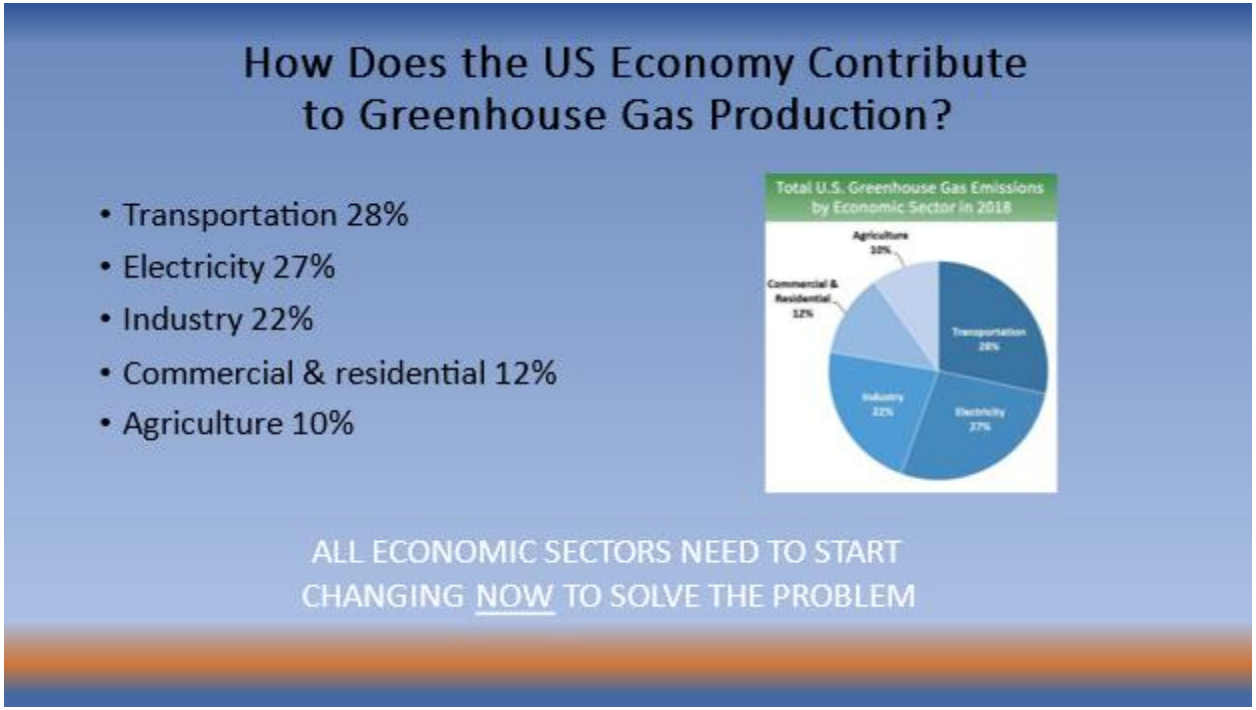
- Extremely humid heat will continue to increase and approach a crucial human survivability limit in many parts of the world. Recent studies have shown that wet-bulb temperatures of 35^{0}C (95^{0}F) — which render ineffective the human heat response of sweating to shed heat through evaporation are already occurring for short periods of time at a few weather stations. To understand the term "wet bulb" refer to https://www.weather.gov/tsa/wbgt.

Sea Level Rise will continue, but the impacts can vary regionally.

- Sea level matters in the United States, since almost 40 percent of the population lives in relatively high population-density coastal areas, where sea level plays a role in flooding, shoreline erosion, and hazards from storms.
- Globally, 8 of the world's 10 largest cities are near a coast (from the U.N. Atlas of the Oceans).

Sources: https://www.wcrp-climate.org/news/science-highlights/1604-climate-sensitivity-2020; https://www.washingtonpost.com/weather/2020/05/08/hot-humid-extremes-unsurvivable-global-warming/; and https://nca2018.globalchange.gov/chapter/2/

Image Sources: https://www.drought.gov/events/fy22-nidis-coping-drought-ecological-drought-informational-webinar; https://medialibrary.climatecentral.org/



How do we start to solve this problem?

In the US, the economy drives many, many things – including the production of Greenhouse Gases. Here is the breakout of the contribution of Greenhouse Gases by Economic Sectors.

This is the "starting point" for understanding what changes we'll have to make to solve the Climate Change problem.

You can see that virtually every aspect of our society will be impacted by what needs to be done.

Source:
https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

We must rapidly reduce the use of fossil fuels as our energy source.

- The highest priority is to move to "Utility Scale" alternatives. Utility Scale generally mean large scale grid connected energy sources (not rooftop solar panels).

- Solar and Wind are proven energy sources, but battery technologies and their costs need to be addressed to ensure constant availability during nighttime and/or low wind conditions.

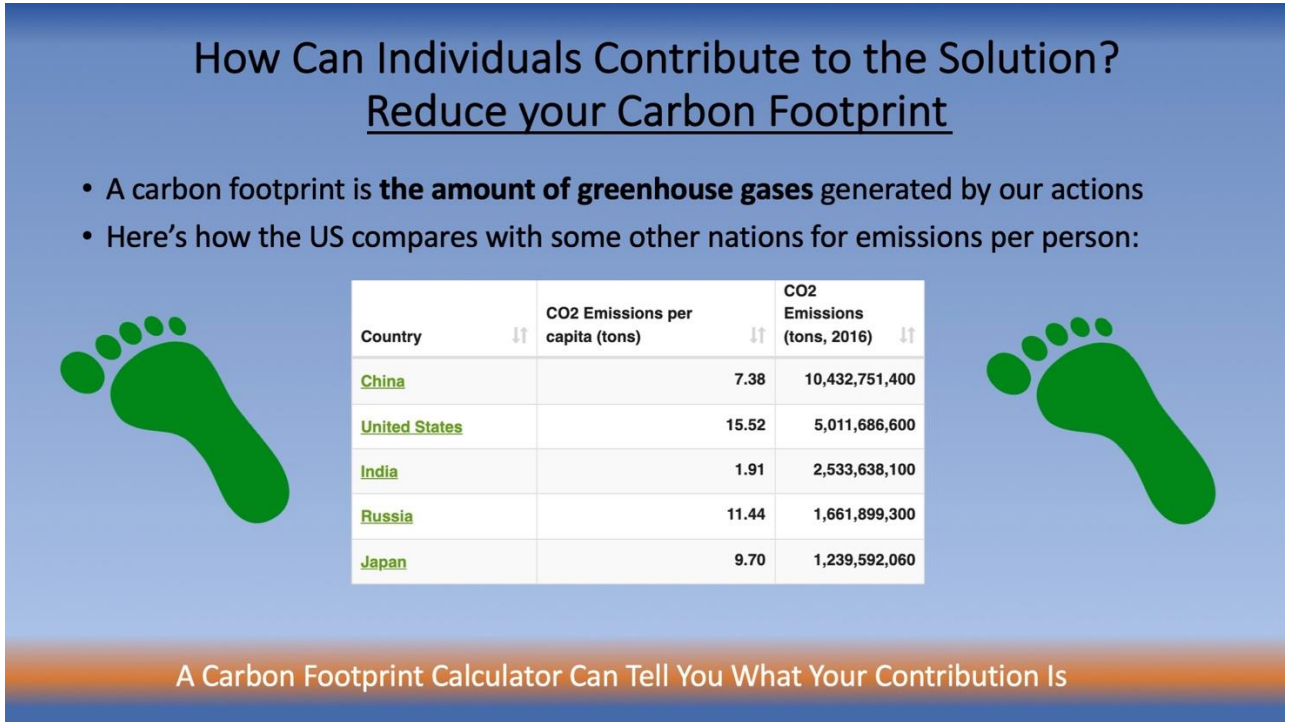
- There is a place for both safer Nuclear and Hydrogen as energy sources. These are newer technologies and (unlike Solar and Wind) are years away from commercialization.

Smart Grid is a concept for transforming the electric power grid by using advanced automatic control and communications techniques and other forms of information technology. It integrates innovative tools and technologies from generation, transmission, and distribution all the way to consumer appliances and equipment.

What Else Should We Do?

- The economic sector in the US that contributes the most greenhouse gases is transportation, so conversion to electric cars and trucks is essential.
- How we construct buildings and manage their energy needs must change. The production of concrete alone accounts for about 8% of the world's CO_2 emissions.
- Our forests are huge "carbon sinks" – they draw carbon out of the atmosphere. But forests are being cleared worldwide, so we need massive reforesting programs.
- Farm operators can change production practices or land use to increase the carbon stored in soil or vegetation. Other changes they can make will result in reduced emissions of methane and nitrous oxide.
- We need to advance our ability to capture and store CO_2. If we stopped adding CO_2 today, most of the excess CO_2 would remain in the atmosphere for many decades.

Sources:
https://www.bbc.com/news/science-environment-46455844
https://www.iucn.org/resources/issues-briefs/forests-and-climate-change
https://www.ers.usda.gov/topics/natural-resources-environment/climate-change/



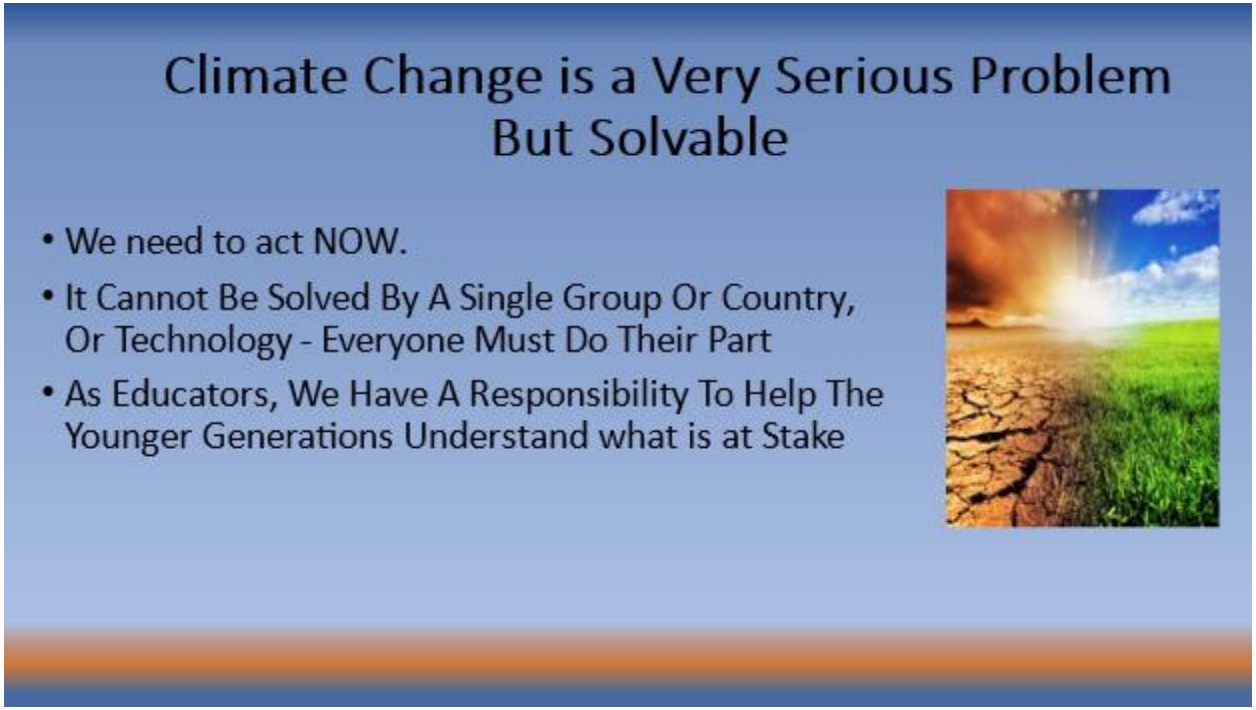
What is a "Carbon Footprint?"

A carbon footprint is **the total amount of greenhouse gases (including carbon dioxide and methane)** that are generated by our actions.

See the following Carbon Footprint calculators that will show you what yours is and how you might reduce it.

https://www3.epa.gov/carbon-footprint-calculator/
https://www.carbonfootprint.com/calculator.aspx
https://www.nature.org/en-us/get-involved/how-to-help/carbon-footprint-calculator/

Image Source:
https://www.worldometers.info/co2-emissions/co2-emissions-per-capita/



We have seen that there is solid scientific evidence about what is causing this global problem.

We have also seen that the impacts are far ranging and significant.

We know how to solve this problem – but we need to act now to avoid much more serious consequences.

And everyone has a role to play.