

Climate Change

An Introduction

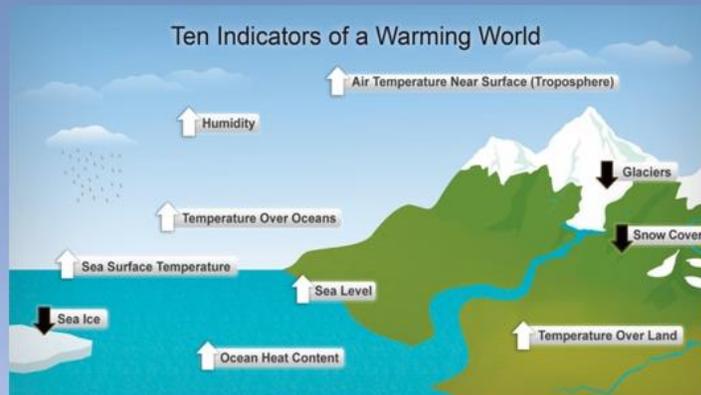
AAAS STEM Volunteers



This presentation is designed to provide key information about:

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

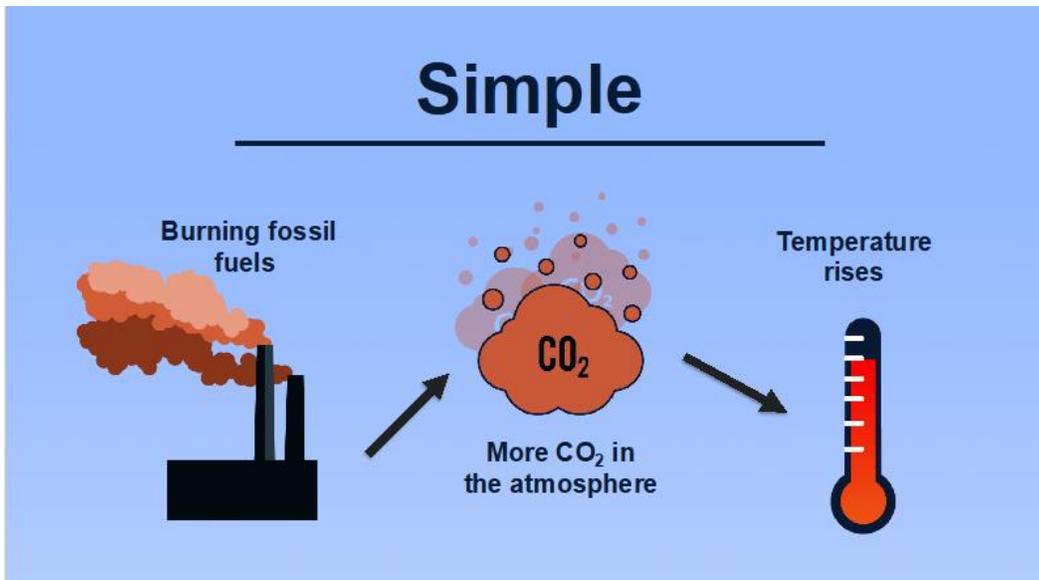
How Do Scientists Know There is a Problem?



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 in the world.

Image Source: National Oceanic and Atmospheric Administration (NOAA)



Climate Change can seem to be a complex problem, but it doesn't have to be.

You can start by breaking it down to these three things:

- Humans burn fossil fuels.
- Burning fossil fuels puts carbon dioxide (CO₂) into the atmosphere.
- CO₂ is a greenhouse gas, and it makes the planet warmer.

Hopefully this presentation will help you understand that it is a **SERIOUS** but **SOLVABLE** problem.

Infographic Source: Climate Central

What Are “Fossil Fuels?”

Natural Gas



Composition

- Carbon
- Hydrogen
- Nitrogen
- Sulfur
- Oxygen

Petroleum



Composition

- Carbon
- Hydrogen
- Nitrogen
- Sulfur
- Oxygen
- Minerals

Coal



Composition

- Carbon
- Hydrogen
- Nitrogen
- Sulfur
- Oxygen
- Minerals

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, liquid, or solid.
- Natural gas consists mainly of Methane – a potent Greenhouse Gas in its natural state. When burned, it produces CO₂.
- 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>

What Happens When Fossil Fuels are “Burned?”



They can produce multiple types of air pollutants:

- Carbon Dioxide
- Carbon Monoxide
- Sulfur Dioxide
- Nitrogen Oxides
- Lead
- Particulate Matter

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.

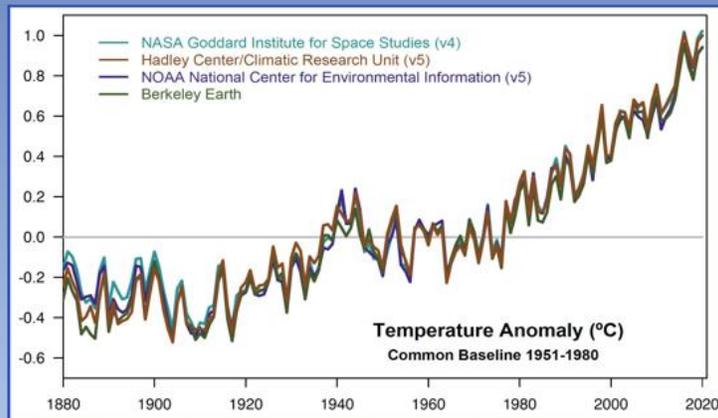
Excess carbon dioxide is also the single largest contributor to our changing climate over a long period of time.

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

Source: <https://www.e-education.psu.edu/egge102/node/2207>

Image Source: National Park Service via Wikimedia Commons

As a Result - The Earth's Temperature Rises



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.

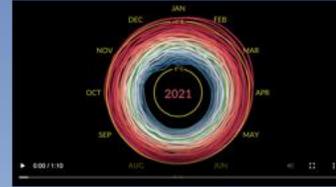
For an interactive view of this trend, see the next page.

Source:

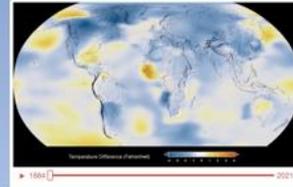
<https://climate.nasa.gov/faq/21/why-does-the-temperature-record-shown-on-your-vital-signs-page-begin-at-1880/>

See These NASA Visualizations Of Global Temperature Rise

<https://svs.gsfc.nasa.gov/4975>



<https://climate.nasa.gov/interactives/climate-time-machine>



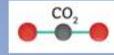
The first visualization presents monthly global temperature anomalies between the years 1880-2021.

The second visualization shows a progression of changing global surface temperatures since 1884 with a color-coded map.

What are “Greenhouse Gases?”

- Gases that Absorb and Emit Energy in the Infrared portion of the Electromagnetic Spectrum
- Here are the the gases of concern

Carbon Dioxide



Methane



Nitrous Oxide



Hydrofluorocarbons



Let’s get a better understanding of what is meant by a greenhouse gas. The first 3 gases listed above are **naturally occurring**, but humans are significantly contributing to their presence. These gases, plus the man-made hydrofluorocarbons, will trap heat in the atmosphere and warm the planet.

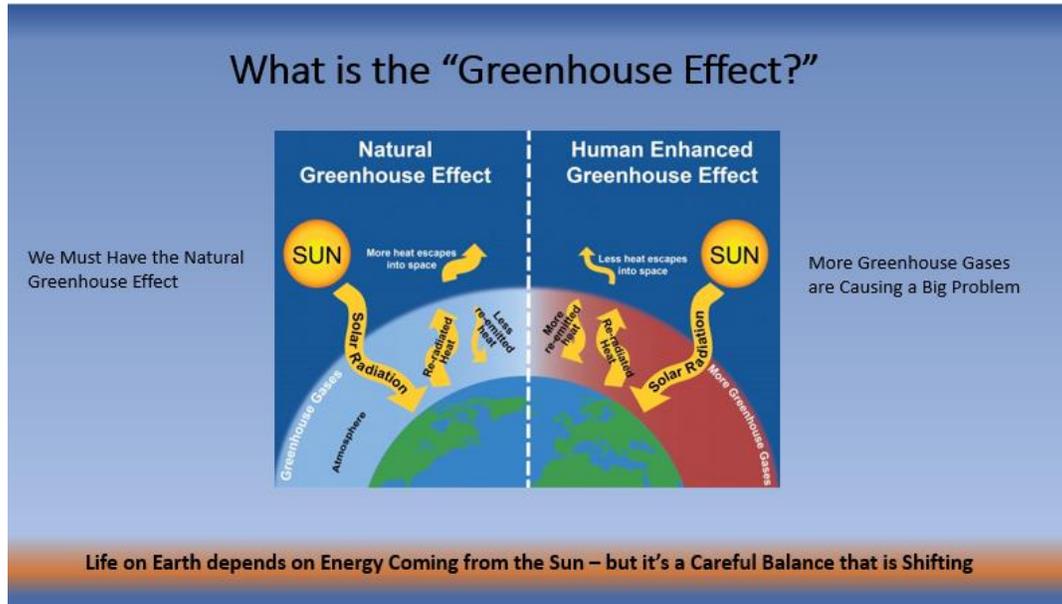
Water vapor is another naturally occurring greenhouse gas and plays a key role in climate change because of its heat-trapping ability. Warmer air holds more moisture than cooler air. Therefore, as greenhouse gas concentrations increase and global temperatures rise, the total amount of water vapor in the atmosphere also increases, further amplifying the warming effect.

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 CO₂ 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/>

What is the “Greenhouse Effect?”



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 degrees Celsius (or 0 degrees Fahrenheit). Those naturally occurring greenhouse gases, plus water vapor, keep us at about 15 degrees Celsius (or 59 degrees Fahrenheit) today. This temperature is steadily rising.

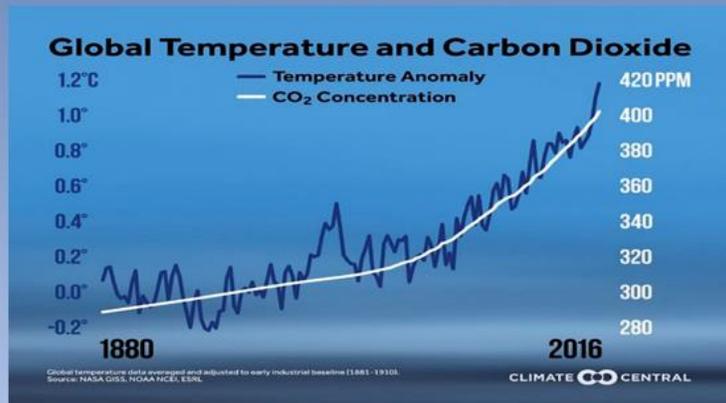
Here are some useful video links:

<https://climatekids.nasa.gov/greenhouse-effect/>

<https://climate.nasa.gov/causes/>

Image Source: National Park Service

What Effect has Increasing CO₂ Levels Had on Global Temperatures?



You can see from this chart that CO₂ (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 CO₂ levels during this entire period.

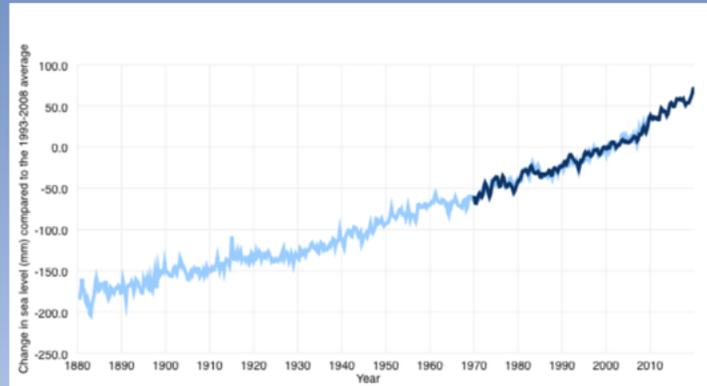
The chart shows a correlation between CO₂ content and global mean temperature. But this correlation does not prove causality. What makes the correlation interpretable as a causal relationship is that climate models that are run without anthropogenic (human induced) CO₂, do not predict a significant global mean temperature rise, whereas the same models run with anthropogenic CO₂ produce similar warming trends to what is actually observed.

You can also see that in 1960 the CO₂ 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

Impacts - What We Know Sea level is Rising Around the World



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. Per a recent NOAA study, this rate of change is expected to increase dramatically over the next few decades. See <https://oceanservice.noaa.gov/hazards/sealevelrise/sealevelrise-tech-report.html>.

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:

- Arctic Ocean
- Greenland
- Antarctic Continent

For more information on Sea Level Rise, see:

<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>

Impacts - What We Know

Climate Change Is Making Hurricanes More Dangerous

Warmer Water Means

- More Fuel
- Heavier Rain
- Higher Storm Surge
- More Potential Destruction



Hurricanes are WEATHER Phenomena.

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.

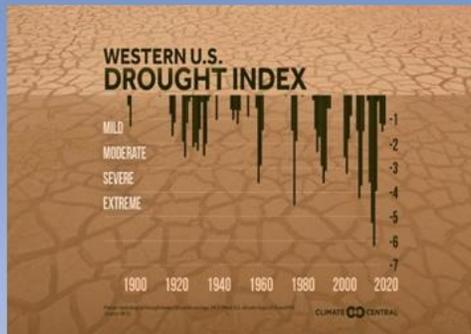
Source:

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

Image Source: NASA

Impacts - What We Know

Forest Fires are more Numerous, Frequent and Destructive



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:

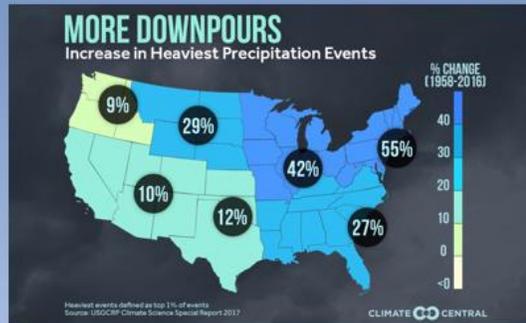
Climate Central

National Park Service

Impacts - What We Know Heavy Rain Events and Flooding are Increasing

A warming atmosphere will hold more water which will ultimately result in heavier downpours.

The Northeast and Upper Midwest are seeing significantly more rain events and flooding.



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

What We Know Greenhouse Gas Impacts on our Oceans

The oceans cover about 70% of the earth's surface

- But are absorbing about 90% of the excess heat

Excess heat is driving some fish species to migrate towards the North or South Pole

Ocean "acidification" is also increasing

- Carbon pollution is changing the ocean's chemistry
- This harms marine life we depend on



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.

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.

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.

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>

<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>

Projections for the Year 2100 at the Current Growth of Greenhouse Gases

Temperature will likely increase between 2.3°C – 4.5°C



As the world overheats, suffering from heat stress will become widespread

Sea level may increase up to 2.4 meters or 7.9 feet



This projection is highly dependent on the contribution of the Antarctic ice sheet

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°C (95°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).

See the latest report on Impacts, Adaptation, and Vulnerability from the IPCC.

<https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/>

Sources:

<https://www.wcrp-climate.org/news/science-highlights/1604-climate-sensitivity-2020>

<https://www.washingtonpost.com/weather/2020/05/08/hot-humid-extremes-un survivable-global-warming/>

<https://nca2018.globalchange.gov/chapter/2/>

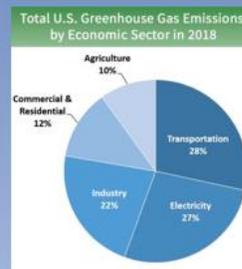
Image Sources:

<https://www.drought.gov/events/fy22-nidis-coping-drought-ecological-drought-informational-webinar>

<https://medialibrary.climatecentral.org/>

How Does the US Economy Contribute to Greenhouse Gas Production?

- Transportation 28%
- Electricity 27%
- Industry 22%
- Commercial & residential 12%
- Agriculture 10%



ALL ECONOMIC SECTORS NEED TO START CHANGING NOW TO SOLVE THE PROBLEM

How do we start to solve this problem?

In the US, the economy drives many things – including the production of Greenhouse Gases. The graphic shows 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>

What Changes Need to be Made?

Accelerate the Development and Deployment of New “Utility Scale” Energy Infrastructure

- Solar Facilities
- Wind Turbine Farms – both Onshore and Offshore
- Battery facilities to offset Wind and Solar variability
- Safer Technology Nuclear Plants, including Nuclear Fusion
- Hydrogen and Fuel Cell Technologies
- Smart Grid Technology



**WE MUST ELIMINATE OUR RELIANCE ON FOSSIL
FUEL BASED ENERGY SOURCES**

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 Other Changes Need to be Made to Protect the Earth and Its Inhabitants?

- Convert To Electric Propulsion For Cars And Trucks
- Reduce the CO₂ emissions from building construction and operations
 - Use climate friendly building materials
- Modify Farming And Forestry Practices
- Deploy Rooftop Solar Panels
- Capture and Store Carbon
- Reduce, Reuse, and Recycle the Earths Finite Resources – Move to a "Circular Economy"



What Else Should We Do?

Transportation is the economic sector in the US that contributes the most greenhouse gases, so conversion to electric cars and trucks is essential. Shifting transportation from high emission trucking to lower emission rail should be implemented.

How we construct buildings and manage their energy needs must change. The production of concrete alone accounts for about 8% of the world's CO₂ emissions.

Our forests are huge "carbon sinks" – they draw carbon out of the atmosphere. But forests are being cleared worldwide, so we need massive reforestation 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 CO₂. If we stopped adding CO₂ today, most of the excess CO₂ would remain in the atmosphere for many decades.

The circular economy means moving away from the world's current – and enormously wasteful – economic model of "take, make, throw away", in which resources are extracted, turned into products, used, and discarded.

It entails redesigning products to be more durable, reusable, repairable, and recyclable

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/>

How Can Individuals Contribute to the Solution? Reduce your Carbon Footprint

- A carbon footprint is **the amount of greenhouse gases** generated by our actions
- Here's how the US compares with some other nations for emissions per person:



Country	CO2 Emissions per capita (tons)	CO2 Emissions (tons, 2016)
China	7.38	10,432,751,400
United States	15.52	5,011,686,600
India	1.91	2,533,638,100
Russia	11.44	1,661,899,300
Japan	9.70	1,239,592,060



A Carbon Footprint Calculator Can Tell You What Your Contribution Is

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.

Use 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/>

Climate Change is a Very Serious Problem But Solvable

- We need to act NOW.
- It Cannot Be Solved By A Single Group Or Country, Or Technology - Everyone Must Do Their Part
- As Educators, We Have A Responsibility To Help The Younger Generations Understand what is at Stake



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.

Additional Information

- For more information on Climate Change, including mitigation strategy, go to Climate Change Overviews, http://www.scientificsolutions1.com/Some%20Overviews%20of%20Climate%20Change_new_1_3_22.pdf
- For classroom responses, including experiments, lessons and PBL projects, go to Climate Change Classroom Applications, http://www.scientificsolutions1.com/Some%20Climate%20Change%20Classroom%20Applications_new_1-3-22.pdf