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"The stakes, for all life on the planet, surpass those of any previous crisis. The greatest danger is continued ignorance and denial, which could make tragic consequences unavoidable."

James Hansen et al., April 7, 2008,
http://www.columbia.edu/~jeh1/

# Global Warming

## History of Earth's Atmosphere

About 3.5 billion years ago volcanos spewed out carbon dioxide, water vapor, ammonia, nitrogen gas and hydrogen gas over our young Earth. This early atmosphere was more dense that now. As now, the $CO_2$ acted as a greenhouse gas. Over years this first greenhouse warming elevated the Earth's temperature from a chilly $0^o$ to $59^o$ F. The warmer prevailing temperatures allowed life to flourish.

The water vapor condensed producing rainfall. Water accumulated to form oceans. Fifty percent of the carbon dioxide dissolved in the early oceans. This halted the warming.

Cyanobacteria, earlier termed blue-green algae, arose about 3 billion years ago. Their chlorophyll captures energy from sunlight to carry out photosynthesis. This multi-step process splits water and ultimately makes sugars as their food. From the split water, the hydrogens are incorporated in the sugar molecules, and the oxygen is released into the air. That final point has enormous importance. Cyanobacteria by releasing oxygen into the atmosphere over thousands of years changed the atmosphere into an oxygen-rich one, one in which aerobic processes can occur. A fraction of the oxygen forms ozone, $O_3$.

Another milestone occurred about 400 million years ago when ozone reached 10 ppb [parts per billion]. That concentration in the stratosphere [upper atmosphere] screens out harmful UV [ultraviolet] light. With this protection, life moved from water onto land and flourished there.

Our current atmosphere contains 78% nitrogen, 21% oxygen, 1% argon and traces of twelve other gases.

## Early Alert on Global Warming

Svante Arrhenius, Swedish chemist and winner of the Nobel Prize in chemistry for 1903, recognized that "We are evaporating our coal mines into the air." After many calculations, he was among the first to predict that Earth's temperature would rise substantially.

## Carbon Dioxide

Constantly, carbon dioxide is being added to air and simultaneously removed from it. Additions result primarily from the combustion of fuels and to a much lesser degree from the respiration of organisms. Removals result from photosynthesis by algae and plants. When additions exceed removals, carbon dioxide concentration increases. Currently, the quantity climbs at about three ppm per year, due to enormous additions from combustion of fuels. The US releases more $CO_2$

than any other country per capita [per person] and our emissions continue to increase. China's total now exceeds ours, (but their per capita production remains much lower).

Several cycles influence carbon dioxide release into the troposphere [lower atmosphere]. Rush hour traffic increases $CO_2$ output. Burning fossil fuels to heat homes and businesses in winter increases output. Operating air conditioners in summer has the same effect. But the intake of $CO_2$ for photosynthesis during daylight in spring and summer in vegetated areas reduces $CO_2$ output.

Measurements of $CO_2$ from air trapped in ancient ice cores in Antarctica reveals the historic trend for the last 800,000 years. From 900 AD to about 1850 air contained 280 ppm. In the ice core the fastest increase was of the order of 30 ppm by volume over a period of about 1000 years. Combustion associated with industrialization began adding to the $CO_2$ load. Alarmingly, the last 30 ppm increase has taken place in just 17 years (since 1990). It increased until in 2007 it measured 385 ppm.

## Mechanisms of Warming

As the glass in greenhouses traps and holds heat to protect sensitive plants during cool weather, greenhouse gases in the troposphere trap and hold heat in our atmosphere. All act like a thin blanket absorbing infrared radiation from the earth. The most abundant greenhouse gases shown in the table below differ in strength, concentration, sources and sinks [processes that remove them]. Note that water vapor is measured in parts per hundred; carbon dioxide in parts per million; most others in parts per billion; and finally CFC's [chloroflorocarbons] in parts per trillion.

Note also that most of these gases contain three atoms. Such molecules due to their flexible bonding absorb heat rays especially well.

As greenhouse gases continue to accumulate, more heat is retained producing additional warming. The average temperature climbed $1^oF$ in the $20^{th}$ century. Predictions suggest increases of 1 to $10^oF$ in the $21^{st}$ century. Global warming threatens the survival of our civilization.

As temperatures climb, ice melts and sea level rises. Over the last 20 years the northern polar ice cap has thinned 46%. Early explorers searching for the North pole trudged over ice in bitter cold and blizzards. In August 2000, an ice-breaker cruise ship discovered that the North Pole is now open water! The North polar ice cap present for millions of years, may disappear by 2013. Polar ice loss appears to be accelerating. Antarctica over the South pole lost 75% more ice in 2006 than 1996.

| Gas | Multiple of $CO_2$ strength | Duration | Concentration in 1800 | Now | Sources: Natural | Sources: Human generated | Sinks |
|---|---|---|---|---|---|---|---|
| Carbon dioxide ($CO_2$) | 1 | hundreds of years | 280 ppm | 385 ppm | Respiration; aerobic decay | Fossil fuel burning primarily from coal-fired power plants, vehicle exhausts & industries; land clearing & burning. | Photosynthesis |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Methane ($CH_4$) | 23x | about 12 years. | 750 ppb | 1780 ppb | Anaerobic bacteria in wetlands.. | Anaerobic bacteria in rice paddies & cows; released from mouth & anus; leaks in natural gas pipelines; leaks from coal mining. | Soil bacteria |
| Nitrous oxide ($N_2O$) | 296x | 114 years | 275 ppb | 315 ppb | Soil bacteria; lightning. | Combustion of fossil fuels; nylon production; breakdown of N fertilizer in soil. | Soil bacteria |
| Water vapor | | | 1-5 pph | 1-5 pph | Evaporation from oceans. | Combustion. | Condensation |
| Tropospheric Ozone ($O_3$) | | hours to days | 25 ppb | 34 ppb | Lightning | Reactions of air pollutants from exhausts, etc. | |
| CFC's (include "freon") | 1,700x to 10,600x | 12 years to 100 yrs. | 0 | 155-545 ppt | None | Leaking air-conditioners & refrigerators; production of styrofoam; & spray can propellants. | |
| Nitrogen trifloride ($NF_3$) | 17,000x | 500 years | | | None | Used in making flat-screens for computers & TV's. | |

Due to melted ice, adjacent waters have become warmer and less salty. White ice reflects more than half the sunlight that strikes it during the summer. Dark water absorbs 90% of the energy in sunlight. By reflecting heat, polar ice contributes to cooling. More dark polar water will slowly accelerate global warming.

Melting polar ice includes permafrost [soil that was previously permanently frozen]. Plant & animal remains long frozen in permafrost in Alaska, northern Canada, Siberia, etc. are starting to melt, decompose and release methane. Methane ($CH_4$), twenty three times more potent as a greenhouse gas than $CO_2$, threatens to accelerate global warming.

## Cement Making

Portland cement, the strong, water resistant form of cement, is made from three ingredients. Limestone supplies lime. Clay contributes silica and alumina. The limestone and clay are crushed separately, ground into a fine powder, mixed in a specific ratio, and burned in large rotating kilns. Most cement kilns utilize coal as fuel. Burning at 1450$^{o}$C produces fused lumps known as clinkers. After the clinkers are ground, the powder is mixed with gypsum to form portland cement. When water is added to this cement, the water combines with calcium silicates to form a gel. If sand, gravel or crushed stone has been added to the mixture, this gel will harden to form concrete. Concrete is the Earth's most widely used building material.

The crushing, grinding, mixing & burning in this process consume quantities of fossil fuel. Consequently, cement making generates quantities of carbon dioxide gas. For each ton of cement produced, one ton of carbon dioxide gas is released. About half comes from the fuel and half from changes to limestone.

In 2008 China is using more cement than the rest of the Earth combined. The Three Gorges

Dam alone will require 34 million cubic yards of concrete. China is rapidly building infrastructure. In 2007 it produced and used itself 1.3 gigatons of cement. The second largest producer, India, made .15 gigatons.

A new environmentally friendly alternative, Eco-cement, substitutes magnesium for calcium in the cement. It reacts in the kiln at 650$^{o}$C. And the concrete actually absorbs some carbon dioxide from the air. Builders are wary of it because it has somewhat different properties.

Impacts of Global Warming

1. In December 2007, meteorologists announced that 2007 was the hottest year on record in the Northern Hemisphere. US weather stations broke or tied 263 high temperature records.

2. Climate zones will shift. In the northern hemisphere, this will typically be northwards. Living organisms that can will shift their ranges to areas with their preferred temperatures, ones favorable for their growth & development. Where habitats disappear, the occupants must locate similar new habitats or die.

3. Global warming will increase weather extremes. It strengthens hurricanes; prolongs droughts; triggers more flooding; generates more tornados and intensifies snow storms.

4. Weather changes will change agriculture. Food growing areas in the northern hemisphere will shrink and move north.

5. Global warming will elevate sea level. Floating ice displaces its weight in water. When icebergs melt, this will not change sea level. When ice on land in glaciers melts and runs into the ocean, or when glaciers calve icebergs, this will raise sea level. If all Antarctica ice (at the south pole) melts from land, sea level will climb 70 meters! Even less will submerge south Florida and parts of major cities: Amsterdam, London, Miami, New York City, New Orleans. Moving large groups of people will challenge the resources and stability of other areas.

6. Additional carbon dioxide dissolved in the oceans will lower the pH of the oceans making sea water more acidic. Acid conditions dissolve calcium carbonate, the primary skeletal material of many species of phytoplankton, many corals, snails, clams, barnacles, etc. This would affect 46% of human seafoods. Many species will probably become extinct severely impacting ocean food chains.

Tipping Point

Some simple changes follow a linear pattern. As one variable increases it triggers an increase in another. For example, as we apply heat to a pot of water, the more heat, the higher the temperature of the water climbs. Then a dramatic, nonlinear event occurs, the water begins to bubble with tumultuous rolling and the temperature remains constant. It's boiling. Similarly, climate is expected to reach a nonlinear change termed a tipping point

Jim Hansen, the leading NASA climate scientist quoted at the opening of this exercise, warns that we are only 10 years at most, from a "tipping point", an irreversible catastrophic change. Others suggest it may be only 2 years. Prior to the tipping point we must halt the yearly increase in $CO_2$ output and begin to decrease it. The first step is to reduce it to 350ppm. Our output must be reduced 80% by 2050. Peter deMenocal, an expert on ancient climates at Columbia University, warns that global warming will destroy our modern civilization, as abrupt climate changes in the past caused earlier civilizations to collapse.

The Intergovernmental Panel on Climate Change [IPCC, a UN network of 400 scientists and governmental officials], recommends that $CO_2$ emissions be reduced by 25 % to 40% below 1990 levels by 2020, a rigorous standard. While the US in 2008 continues to increase its output, Germany, the leader, may achieve 30% reduction by 2020. The Nobel Peace prize for 2007 was shared by the IPCC and former Vice President Al Gore for their work to educate people and highlight this crisis.

## Global Dimming

Particles in the air such as soot from the combustion of fuels intercept incoming sunshine. Consequently, less solar energy reaches the earth. In the US particulate pollution has reduced incoming sunshine by 10%. This global dimming occurs over the Earth.

## Carbon in Plant Material

Green plants by photosynthesis incorporate carbon from carbon dioxide into living plant cells. When that plant sheds leaves, they will decay converting their stored carbon into carbon dioxide that escapes into the air. Carbon stored in living plants remains as a plant part until the plant is cut down or dies. Old growth forests store lots of carbon as long as they live. We cannot alter an old growth forest to increase its storage. If the tree is sawn into lumber, that plank stores the carbon in cellulose and lignin for as long as it persists. When it decays, its carbon returns to the atmosphere as carbon dioxide. Fire breaks down living and dead plant material into carbon dioxide and water vapor. Continuing deforestation in Brazil makes it the fourth largest emitter of carbon dioxide gas.

## Data on Carbon Dioxide Concentrations & Temperatures

The table below presents average global temperatures over land and ocean ($^oF$) (data from NOAA) and atmospheric carbon dioxide in ppm (data from the Mauna Loa Observatory).

| | 1960 | 1965 | 1970 | 1975 | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2007 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp. | 57.0 | 56.9 | 57.1 | 56.8 | 57.3 | 57.2 | 57.7 | 57.7 | 57.7 | 58.0 | 58.0 |
| $CO_2$ | 316 | 319 | 325 | 330 | 337 | 345 | 354 | 359 | 368 | 378 | 385 |

On a single sheet of graph paper draw two graphs. Place years on the horizontal axis; a range of temperatures on one vertical axis, and a range of carbon dioxide concentrations on the opposite vertical axis. Plot this data and label your lines.

## Predictions for the future

| Atmospheric $CO_2$ | Prevailing conditions on Earth |
|---|---|
| 350ppm | Recommended by James Hansen as the upper limit that is safe ; Existed in 1988; Earth remains almost as now. To reduce to this level Hansen would 1) ban new coal fired power plants that don't capture carbon, 2) phase out old coal powered generators, 3) tax carbon enough to prevent the mining of tar sands & oil shale. |

| | |
|---|---|
| 450ppm | Temperature increase of 2-3 $^{o}$C; Sea level rises tens of meters; A sea level increase of 10meters will flood 25% of the US population. |
| 560ppm | Expected in 2050; Human population predicted at 9 billion; Warming of 11$^{o}$F; Nearly ice-free planet: Sea level rises 65 meters. |
| 1000ppm | Expected about 2090; Massive greenhouse extinction event; Ocean shoreline encrusted with rotting organic matter; Flat, oily purple ocean due to tons of bacteria; No fish; No birds; Pale green sky; Probably no flowering plants. |

Recently scientists have described conditions they expect to prevail in the future with different $CO_2$ levels in our atmosphere. Those scenarios appear in the table above.

Ways to Counteract Global Warming

Daily we make many choices that affect greenhouse gas emissions. The table below gives the most effective individual actions to reduce gas production.

Tree planting combats global warming. Each mature tree over its life removes 1 ton of carbon (in carbon dioxide) from the atmosphere. Environmental groups promote tree planting.

Even better than tree planting is saving existing forests. A typical mature forest stores 20 times as much carbon as a cultivated field of, for example, soybeans. The rapid burning of Amazonian forests in Brazil defies this wisdom.

| Action | Notes |
|---|---|
| Hang clean wet clothes on a clothes line to dry. | Clothes dryers gobble energy. |
| Reduce home cooling in summer & heating in winter by adding insulation and adjusting thermostats.. | This also reduces the gas & electric bills. |
| When feasible, walk, bike, take mass transit or carpool & drive slower. | A car that gets 26 miles per gallon of fuel, releases one pound of $CO_2$ per mile. Car efficiency decreases above 55 mph. Exercise is a secondary benefit. |
| Eat less beef. | Over Earth livestock production generates 18% of greenhouse gases. Generally cows must eat 10 kilocalories of corn to produce 1 kc of beef. Americans consume 110 grams of protein a day; we need 30 g a day. |
| Reduce, reuse & recycle cans, paper & glass. | To make new costs up to 20 times more energy than to remake. It also reduces greenhouse gas production from decay & preserves landfills. |
| Grow & consume local foods. | The average food travels 1500 miles to reach your plate. Eating locally saves that energy & provides fresher foods. |

| | |
|---|---|
| Use energy star compact florescent bulbs. Turn off appliances & lights not in use. | CFL's use about 1/4 the energy of incandescent bulbs. Small actions by many people can reduce $CO_2$ emissions significantly. |
| Substitute reusables (cloth goods) for paper or plastic disposables (shopping bags, napkins, table cloths, kitchen towels, handkerchiefs, baby diapers, etc.) | Plastic & paper items cost resources & energy to make, to dispose of and they clutter land fills. |

Carbon Pools

Like all mineral elements, carbon is not created nor destroyed, it cycles. Carbon from atmospheric carbon dioxide by the processes of photosynthesis and polymerization might become carbon in cellulose in an oak leaf. That same atom from the oak leaf as it decomposes might be incorporated in humus in soil. Carbon circulates between five global pools. (In the example here the carbon moves from the atmospheric pool to the biota pool to the soil pool.)

Over the Earth the rocks hold an impressive 83 million petagrams [one Pg = $10^{15}$ grams or one billion metric tons] (That includes about 4,000 Pg of fossil fuels.) The oceans contain 38,000 Pg of carbon. Soils to a depth of one meter contain 2300 Pg. The atmosphere in 2008 holds 820 Pg. The final pool, the biota on Earth, contains an estimated 550 Pg.

Each pool constantly gains and loses carbon. The difference between gain and loss determines if that pool expands or shrinks. To reduce global warming, the atmospheric pool of $CO_2$ must give up more than it gains and one or more of the remaining pools must gain more than they release. Because the rock pool is very stable, turning over every 100 million years, it will not remove substantial carbon dioxide over the short term.

Soils lose carbon when humus breaks down, when $CO_2$ is released (by aerobic respiration), when $CH_4$ is given off (from anaerobic decay by bacteria), and when erosion removes soil. Because several of these processes occur when natural ecosystems are converted to agricultural ecosystems, this triggers the loss of 1/3 to ½ of their organic carbon.

Soils gain carbon by the addition of organic matter (leaves, twigs, manure, etc.). Enriching soil by adding organic matter, in addition to reducing greenhouse gases, also improves soil quality and crop yield.

Carbon Sequestration

Carbon sequestration, or storing carbon, refers to any process that captures and holds carbon for a long time. Two processes, an ancient one and a recent one, are described here.

A. Brazilian native people of the Amazon River basin smoldered [burned with little oxygen] organic materials such as crop wastes to produce **bio char** (biological charcoal). They dug this into soil to enrich it making **terra preta** [literally, "more earth"] or black soil. In contrast to plain soil from that region with only .5% carbon, terra preta contains 9% carbon and more N, P, Ca & S. Fine-grained charcoal holds these mineral elements in its pores. This enriched soil increased the yield of beans 46%. Because carbon in charcoal does not oxidize to become carbon dioxide, bio char has persisted in Amazonian soils for 1500 years! Impressively, it retains its fertility. Producing bio char from agricultural wastes is currently of interest as a method to sequester carbon. It has exciting potential. Prof. Johannes Lehmann at Cornell University spearheads a project to better understand bio char.

B. Can we divert $CO_2$ from power plants and industries where it is produced directly to storage underground in geological formations? The answer remains unknown. What impact will it have underground? Will it leak out?

For years oil companies have forced carbon dioxide underground into depleted oil fields, not to sequester carbon, but to force out any remaining oil. One recent study evaluates leaks. When compressed liquid $CO_2$ was forced 1.5 km deep into sandstone in a depleted oil field east of Houston, TX, no leaks were observed within the first year. However within that year, the carbon dioxide acidified ground water. This dissolved the minerals that held the sandstone together. This will create fissures that will allow the gas to escape. Such sandstone is unreliable for long term storage.

In spite of unknown risks, two oil companies now pump carbon dioxide underground: a Norwegian one pumps it under the North Sea, a British one pumps it underground in Algeria (North Africa).

Enriching Oceans with Iron

The late John Martin of Moss Landing Marine Lab in California first proposed the "iron hypothesis". Having survived polio, John Martin was confined to a wheelchair. Impressively, he conducted lab research and led his research team on cramped oceanographic vessels from his wheelchair. Phytoplankton growth and reproduction in nutrient-rich but iron-poor Pacific ocean water is very slow. Adding iron accelerated phytoplankton growth, especially that of diatoms, to 30 times that of adjacent untreated areas. This bloom removed carbon dioxide from the water and air, but the fate of the carbon following the death of the plankton continues to be debated. Was it ultimately deposited on the ocean floor? Many unanswered questions remain. After further study, the use of iron might provide a tool to counteract global warming.

All the above ideas either remove $CO_2$ or prevent its formation. Consequently, **any efforts that reduce combustion or utilize emission-free renewable energy counteract global warming**. Lester Brown, ecological economist, argues that the US must take the lead in replacing fossil fuels with renewables, if global climate is to be stabilized.

Incentives for Entrepreneurs

With fossil fuels increasing in price, declining in abundance and adding to global warming, there is a push to accelerate the development of renewable energy. The urge to make money drives engineers & inventors to develop new processes and solutions. Financial incentives encourage these folks to work diligently. Two systems stimulate innovation.

A. The **cap and trade system** places a limit, a maximum or cap, on, for example, carbon emissions allowed in the US. Each industry is allowed a specific part of this total. If a clever industry reduces its carbon emissions below its portion, it can sell its deficit to another business and make money. The cap declines over successive years leading to environmental improvements.

B. **Green taxes** have begun to replace other taxes in some European countries. These tax environmental problems: carbon emissions, pollution, fossil fuel use, waste generation, etc. The smart business person will develop methods to minimize this activity and save money.

## Economics of Fighting Global Warming

Nicholas Stern, a leading British economist, conducted a thorough study published in 2006 of the costs of global warming. It's startling conclusion is that tackling climate change would cost 20 times **less** than doing nothing. Acting now will cost far less than acting later.

## Calculate Your Carbon Footprint

Our lifestyles contribute carbon dioxide to this problem. When you drive your car or fly to Florida for Spring break you increase your carbon footprint. Please calculate your personal footprint. The web site http://www.climatecrisis.net/takeaction/carboncalculator/ is easy to use on a single page. However, it requires that you know your average miles driven per year and average energy bills.

Enter your value on the lab report. Answer the questions there.

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LAB REPORT 29

Name_____
Lab day/time_____

1. Match the following.

___cyanobacteria altered its composition.
___Hydrogen gas abundant
___allows aerobic processes.
___contains ozone.

A. Early atmosphere
B. Present atmosphere

2. Which are true and which false?

___Cyanobacteria released most of the oxygen that first made Earth's atmosphere aerobic.
___The decay of wood releases oxygen gas.
___Combustion releases water vapor.
___Carbon dioxide is the strongest greenhouse gas.
___Carbon dioxide is the most abundant greenhouse gas.
___Our current global warming is the first in Earth's history.

3. Define the following.

Carbon Sequestration_____
Terra preta_____
Petagram_____
Tipping point_____
Green taxes _____

4. What process contributes most $CO_2$ to the increasing quantity in the air?_____

5.A detailed graph shows that air $CO_2$ climbs most in winter. Explain this.
_____

6. Name the greenhouse gas described by each:
_____strongest. _____one in highest concentration.
_____most persistent _____one made by anaerobic decay

7. From each pair circle the one that you expect to store the most carbon.
Oak sapling - Old oak tree Field of corn - Mature pine plantation Field of corn - Lawn

Rank the following from shortest carbon storage to longest. Use the numbers: 1, 2, 3 & 4.
_____2 x 4 _____small pile of sawdust _____ living magnolia tree _____ terra preta

8. Match the following.
___massive tree planting programs would __ atmospheric $CO_2$ levels. a. increase
___destruction of large tracts of tropical rain forest will __ $CO_2$ levels. b. decrease
___converting forest to cotton field __ $CO_2$ levels in air. c. no change
___burning fossil fuels __ atmospheric $CO_2$.

9. Check those activities that will decrease $CO_2$ output and slow global warming.
___substituting a push broom for a gasoline leaf blower to clean a driveway.
___carpooling.
___replacing incandescent bulbs with compact fluorescents.
___riding mass transit.
___burning paper trash instead of recycling it.
___eating fresh strawberries in December.

10. What does each abbreviate or represent?
UV_____ ppb_____
IPCC_____
$CH_4$ _____ $CO_2$_____
Pg_____
CFC's_____ $O_3$_____

11. Which process in cement making requires most energy?_____ How could that energy demand be reduced? _____

12.Which carbon pool does each represent?
Limestone _____ Methane in air _____
Earthworm _____ Coal _____
Humus _____ Seaweed _____

13. Which carbon pools are most likely in future to absorb more carbon due to human manipulation? _____, _____

14. Name two fears associated with pumping of $CO_2$ into rocks underground.
_____, _____

15.Answer each with a number and unit.
_____carbon dioxide concentration in air in 2007.
_____multiples of carbon dioxide warming of methane.
_____estimate of $CO_2$ in 2020 if output accelerates as your graph projects.
_____desirable value according to Hansen for atmospheric carbon dioxide on Earth.

16. Rank the following from smallest (1) to largest (4). ____ppt ____pph ____ppm ____ppb

17. From your graph the annual increase in $CO_2$ is less in1960-61 than from 2006-07. T or F

18. Mountain top removal coal mining includes: clear cutting the timber, pushing the soil & rocks into valleys with giant bulldozers, blasting the tops off the mountains with explosives & filling the valleys & stripping out seams of coal. Give 3 ways this increases green house gas emissions. _____, _____, _____

19. What is the cap in a cap & trade process? _____Give one advantage of a cap and trade system for reducing carbon emissions. _____

20. What is your estimated carbon footprint? _____tons/year The US average is 7.5 tons/yr/person. List 2 actions to reduce yours. _____, _____