Global Warming

An Interactive Qualifying Project Report
Submitted to the Faculty
Of the
Worcester Polytechnic Institute
By:

Luke Costesso

Sean Nelligan

Ryan Neyland

Approved by:

Arthur Gerstenfeld

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I. Introduction

The objective of this project is to determine the importance and the real reasons for global warming. This includes analyzing the greenhouse effect, climate and greenhouse gas concentration trends, and how they influence the world around us. There is a strong debate concerning the responsibility that man has for the causes of climate change. This study is an attempt to sort out the issues and to gain a better understanding of global warming and to propose once again some possible solutions to the problem.

In order to understand global warming and the problems that are related to it, one must have a good understanding of the greenhouse effect. There are two parts of the greenhouse effect: the natural greenhouse effect and the enhanced greenhouse effect. The natural greenhouse effect is a completely natural process that acts to maintain enough heat on the earth to sustain life. It involves the existence of certain gases in the atmosphere to trap heat from the sun. These gases are called greenhouse gases. On the other hand, the enhanced greenhouse effect is an unnatural process that is caused by unnatural human emissions of many of the same heat trapping gases. These unnatural emissions cause increases in the gas concentrations, hence causing the atmosphere to trap more heat.

There is abundant evidence that the earth's surface and ocean temperatures have changed recently, especially over the last century. The concentration of greenhouse gases has also changed noticeably over this time period. This evidence comes from various weather and gas studies done globally over the last several decades. These studies have recovered data that dates back over 400,000 years by analyzing ice core patterns, tree rings, and even weather stations more recently. Results are consistent in determining that both global temperature and greenhouse gas concentrations have increased at an unnaturally high rate since the Industrial Revolution began in 1790.

While it is certain that the earth's temperature has increased, it remains unclear whether or not the increase is solely due to the increase of greenhouse gases in the atmosphere. Some scientists argue that humans and industry are mostly responsible for the temperature rises based on the increased greenhouse gases that are emitted. These same scientists note that this is a serious issue that will result in drastic changes to human life and the environment if action is not taken. Some of these changes could include drastic weather patterns, rising ocean levels, and increased disease and health problems.

Other scientists are convinced that the temperature changes are part of a natural cycle of the earth. Although there are visible changes in the environment including rising temperatures and sea levels, these scientists argue that there is no need to regulate greenhouse gas emissions and hurt the economy when it is not certain that man is the cause of the problems.

Our project is aimed at evaluating different aspects of global warming in order to develop an opinion based on numerous forms of evidence and data. We intend to show the importance of the greenhouse effect and examine the validity of previous publications and studies. After obtaining a good background of the topic, we continue by exploring the possible implementation of solutions in countries with emission problems. Various methods of reducing emissions have already been developed, but their efficiencies must be increased to make them economically feasible. Since many countries are not willing to make great cost sacrifices for the environment when it is uncertain that the greenhouse gases will have a serious effect on the planet, it is important that any solution be reasonable in price.

This is where the debate of global warming begins. Are emission reductions really worth the cost? When there is such great uncertainty in the effects of greenhouse gas emissions, it seems unreasonable to make both economic and personal sacrifices. There is a tendency in human nature not to act too soon. We intend to show that global warming is a dangerous threat, and that the world must act now before it's too late.

II. Literature Review - Background on Global Warming

This section of the paper examines the literature pertaining to the issues of global warming. We intend to show both sides of the issue argued and then show the significance of human activity on climate change.

A. *Global Warming: A Problem*

"In only 60 years or less, all life on earth will be dramatically touched from a planetary heat–rise such as the world has not undergone for 10,000 years," said the head of NASA Goddard Institute for Space Studies James Hansen, in 1988 (Wildavsky, 1995, p. 342). Many other prominent scientists agree that immediate action must be taken to prevent further climate changes as described by Dr. Hansen.

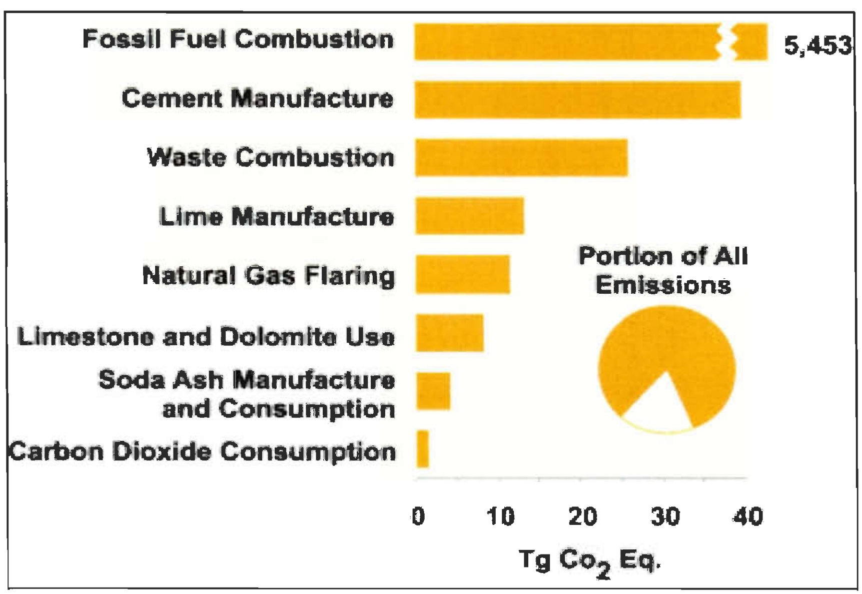
The evidence for this opinion is based on the global warming trend that has been observed especially over the last one hundred years. During this time period, global measurements show that temperatures at the Earth's surface rose about 0.6 degrees Celsius (IPCC, 2001, p. 26). There is a correlation between this rise in temperature and the increase of greenhouse gases in the atmosphere over this same time period. The most drastic change in all of the greenhouse gases has been in the increase of carbon dioxide, thus making it the cause for most concern. In fact, there has been about a twenty five percent increase in carbon dioxide in the atmosphere from 280 parts per million before the industrial revolution began in 1790 to over 370 parts per million now (Rowland, 2001, March, p. 29). In the last two decades there has been an average increase of 1.5 parts per million per year, making carbon dioxide more abundant in the atmosphere now than ever recorded before (Committee on the Science of Climate Change, 2001).

There are various other greenhouse gases, preeminently water vapor but also methane, chlorofluorocarbons, nitrous oxide, and ozone, that let light through the atmosphere to heat the earth but then trap that heat, keeping the earth warmer than it otherwise would be. There have also been noticeable increases in the concentrations of these gases. Increases in methane from about seven hundred parts per billion before the Industrial Revolution to more than 1700 parts per billion today have been recorded along with the changes in the other gases (Shively, 2001, p. 302). The concentrations of these other gases in the atmosphere may be low relative to carbon dioxide, but just their presence can be significant. For example, the ability of methane to retain heat is twenty one times greater than that of carbon dioxide (p. 302).

However, it is also important to realize the increase of greenhouse gases that has occurred in the oceans. The oceans and the atmosphere work together in determining the climate. This means that changes in greenhouse gas concentrations in the oceans should also cause climate changes.

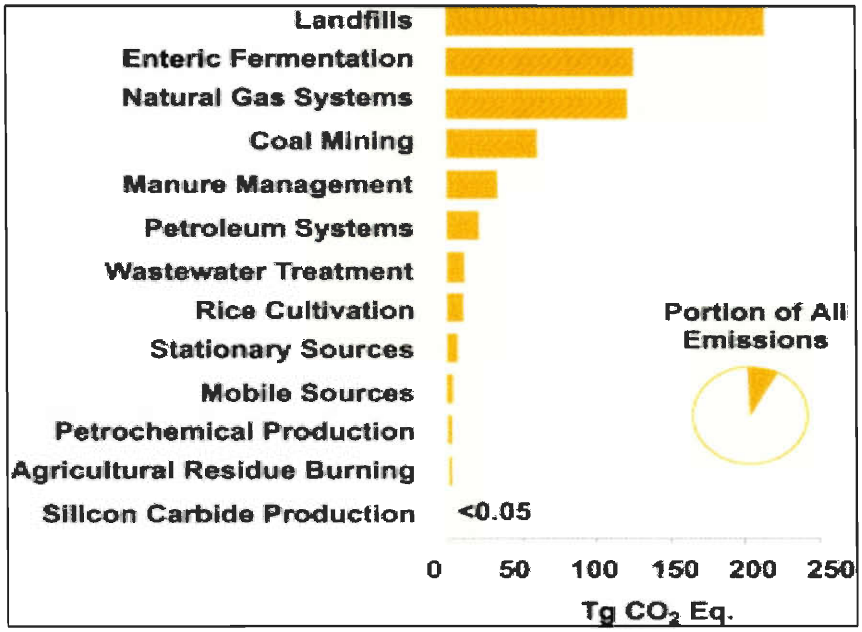
Carbon dioxide is the major greenhouse gas absorbed into the oceans. It is

Figure 2-1: 1999 Sources of CO2



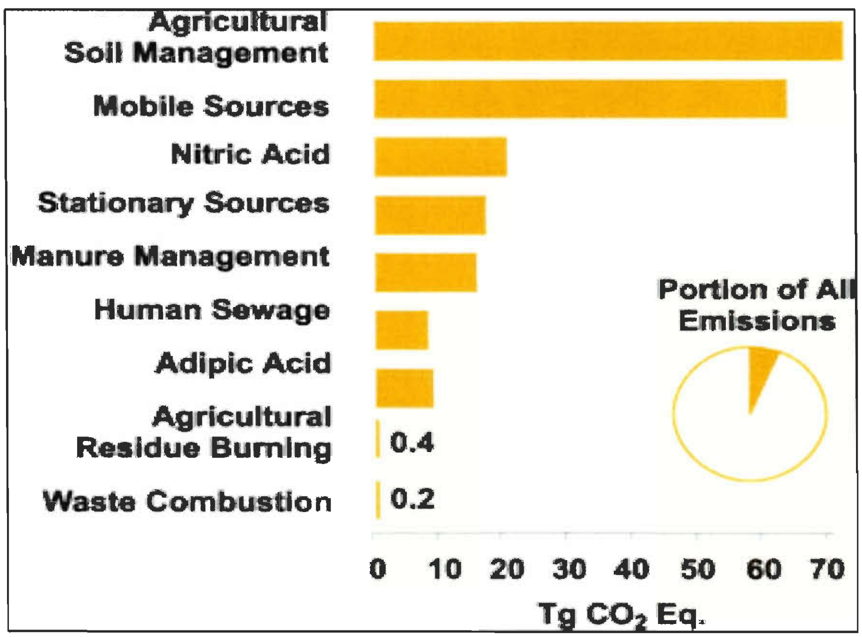
Source: EPA, 2001

Figure 2-2: 1999 Sources of CH_4



Source: EPA, 2001

Figure 2-3: 1999 Sources of N_2O

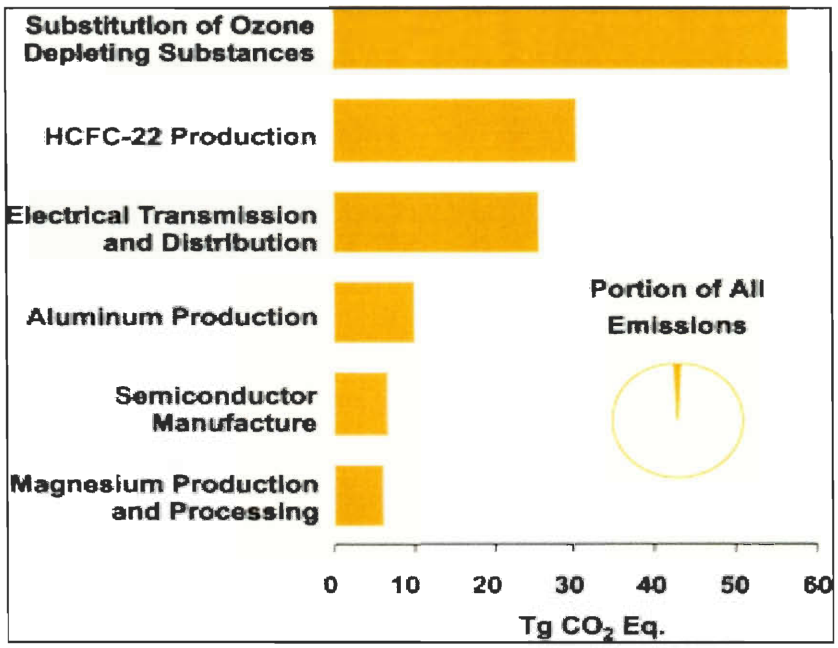


Source: EPA, 2001

absorbed by plankton through photosynthesis and is stored there. Thus as carbon dioxide emissions increase, more of the gas comes in contact with the oceans and force it to be absorbed. This type of carbon storage is called a "carbon sink" as the oceans are one of the Earth's major sinks.

Now knowing these increases in greenhouse gases, the next problem that arises is to determine where they have come from. Since the United States is the world's largest emitter of greenhouse gases in the world, it is a good country to observe emissions data in. Figures 2-1, 2-2, 2-3, and 2-4 show the distributions of greenhouse gas emissions throughout the U.S. in 1999. The total overall emissions that year were approximately 7,000 teragrams (1 Tg = 10^9 kilograms) (EPA, 2001, p.1-15).

Figure 2-4: 1999 Sources of HFCs, PFCs, and SF6



Source: EPA, 2001

As shown in Figure 2-1, the reason that carbon dioxide has the highest concentration of all greenhouse gases in the atmosphere by far is that its emissions are greatly attributed to fossil fuel combustion. This includes the combustion of coal, natural gases, and petroleum. These emissions due to human activity can all be directly attributed to the overall greenhouse gas concentration increases that have been observed.

Now that the reason for these increases has been largely accounted for, what effects are they having on the world? Some of the major concerns are changes in sea level and effects on agriculture due to climate changes. Other possible problems for the future involve health risks for humans and drastic changes in the environment. These consequences of global warming that have been observed and are predicted for the future maintain a serious concern for the problem.

Over the past century, global sea levels have risen between four and eight inches (National Assessment Synthesis Team, 2000, p. 13). This has caused a decrease in shorelines and land area in many countries. For example, in 1870 the Cape Hatteral lighthouse in North Carolina was built 1500 feet inland from the shoreline. By the late 1980's the ocean had crept to within 160 feet and the lighthouse had to be moved to avoid collapse. Also, Japanese fortifications that were built on Korea Island in the southwest Pacific Ocean during World War II to guard against U.S. Marines' invading the beach are now underwater at high tide (Lemonick, 2001, April 9, p. 29). Changes like these are just the beginning of what will be seen if these sea level changes continue.

The reason that global warming is responsible for the rise in sea levels is partly due to the melting of large ice sheets in the polar regions of the earth. The raise in global temperatures lengthens melting seasons and ice sheets and glaciers on land slowly deteriorate and fill the oceans. The melting rate increases as global temperatures increase. Mount Kilimanjaro in Africa has lost seventy five percent of its ice caps since 1912. It is predicted that Montana will lose all glaciers in Glacier National Park by 2070 if the current rate of melting continues (p. 25).

Another concern related to rises in sea level is in the effects on agriculture. As ocean water rises, it runs upstream in rivers and contaminates freshwater and farmland with saltwater. In Florida, farmland up to one thousand feet away from shore has been flooded by saltwater, leaving it too toxic to grow plants (p. 29). If this continues the Earth's farmland could be reduced drastically, especially in low elevation coastal regions.

However, saltwater is not the only threat to farmland. If weather patterns change due to increased greenhouse gases then droughts, hurricanes, and flash flooding could occur to destroy millions of acres of farmland. A drought near Dallas, Texas destroyed a crop season when temperatures topped one hundred degrees Fahrenheit for twenty-nine days straight during the summer of 1998 (p. 26). Record-breaking climate changes like this have occurred more in recent years and act as strong evidence that global warming is taking place.

While natural disasters caused by global warming remain a threat, there are also many health problems that are changing life on Earth. Heat rises could lead to more heat related deaths. Higher temperatures will lead to respiratory problems and heat strokes. The most affected by this will be the elderly and those exposed to outdoor conditions without proper cooling systems. Warmer temperatures will also reduce the winter freezes of disease carrying insect eggs, thus creating a larger summer insect population. Diseases like malaria, dengue fever, encephalitis, and Lyme disease will become more common (p. 26). If action to slow the rate of global warming is not taken, these problems will continue to appear and the results could be even worse than predicted.

B. *Global Warming: Not A Problem*

According to Richard Lindzen of MIT:

> Most of the literate world today regards 'global warming' as both real and dangerous. Indeed, the diplomatic activity concerning warming might lead one to believe that it is a major crisis confronting mankind. However, I can find no substantive basis for the warming scenarios being popularly described in the world today (Wildavsky, 1995, p. 349).

It is true that there is great uncertainty in the global warming hypothesis. At present, many correlations have linked rises in temperature and greenhouse gas concentrations to global warming, but none of the correlations have proven that global warming causes these rises. Besides that, it is difficult to believe that the global temperatures recorded over the last several hundred years can possibly be completely accurate.

The scientific evidence explaining how greenhouse gases trap heat has been shown to be true through the chemical properties of the gases. However, this trapping of heat has not proven to warm the Earth's surface. Besides that, most of the recent temperature increase occurred before 1940 when the majority of human greenhouse gas emissions were after that year. Even over 440 million years ago the carbon dioxide concentrations were ten times the present measurements while global temperatures were similar to those of today (IUCC, 1993).

Throughout history there are instances in which carbon dioxide concentrations have increased and temperature has not and vise versa. An example is during the time period near 4,000 B.C. when temperatures were one to two degrees Celsius above today's levels but the carbon dioxide concentrations were actually twenty five percent lower than today's (Marshall Institute, 1996). Based on this historical evidence, it is difficult to prove that human emissions can have any significant effect on warming.

There is evidence that explains these temperature changes that shows they are not related to greenhouse gas emissions. First of all, the warming that has occurred has been mostly during the night. Also, most of the warming has taken place at the Earth's surface and not in the upper atmosphere where greenhouse gases are. This is inconsistent with the theory that warming is due to greenhouse gases. It does suggest that that warming may be due to an urban heat island, where cities retain heat from the day to warm the night (Hoyt, 2001, March 24).

Another major cause for argument against temperature rise is that measurements are inaccurate. There was certainly not sufficient technology before the twentieth century to record global temperature changes accurate to within a tenth of a degree. Measurements made by pulling up water in leather buckets and using uncalibrated thermometers do not inspire confidence. Neither do those made after running water through engines before its temperature is taken (Wildavsky, 1995, p. 345). Temperature recording may simply be inaccurate. Recording devices may be affected by changes in urban surroundings like tree growth and building development. This is the evidence that is the basis for the "Changing Skyline Hypothesis" (Hoyt, 2001, March 24).

It is agreed by the scientific community that there has indeed been a temperature increase over the last century. It is also agreed that there has been an increase of greenhouse gas concentrations in the atmosphere. However, the causes and the quantities of these changes are still controversial. The significance of human activity in these changes is also uncertain.

III. Methodology

The methodology we have adopted in this report is based largely upon the strategy used in Aaron Wildavsky's guide to understanding science and technology But Is It True? (Wildavsky, 1995, pgs. 1-10). Wildavsky, who was a UC Berkeley professor and president of the California Association of Scholars, wrote this book to help the public learn to make informed decisions about technological issues. The method he described was not to make the public into scientists or experts in a particular field, but rather have them educate themselves enough to make well-informed conclusions. The approach modified from Wildavsky and illustrated in this report includes three main steps to gaining a knowledgeable background in a scientific topic. These steps are gaining a better understanding of both sides of the scientific debate, participating in informed group discussions, and making defendable claims.

This report implements these three steps to give a detailed account of the global warming issue. To gain a better understanding of the global warming debate, we researched and analyzed reputable articles and literature. This research included not only the study of factual evidence, but also theoretical arguments of scientists from both sides of the issue.

After being educated on the topic and understanding the details of the controversy, group discussions were established. These discussions began with inter-group communication based on the analyzed data from each side of the issue. The main theme of concern was that whether global warming is a problem or whether it's not a problem. Important parts to this included whether or not human activity plays a significant role in the cause of global warming.

Following these initial discussions, experts on the global warming topic were sought out to defend their own theories against the groups' questions. Meetings were scheduled individually with each scientist to discuss the data they use to support their claims and to disprove the evidence of opposing sides. At the conclusion of these interviews, inter-group discussions were conducted again to assess the findings and resulting opinions. Each scientist's interview was discussed and analyzed based on research of the facts and a comparison to the opposing scientist interviewed.

After initially struggling greatly with which side of the issue to stand on, we were finally able to take a side on the issue. The direction of the report emerged because of the overwhelming and logical evidence from the side defending that global warming is indeed a problem. Although at first glance it may seem difficult to fully support one side of the issue, after thorough research there is certainly enough evidence to prove the problem. However, not only is there enough evidence to prove that global warming is a problem, there is enough to disprove the theories that state it may not be a problem. This report will discuss in detail the significance of human activity and prove that global warming is a problem.

IV. Findings

IV-I. The Scientific Process

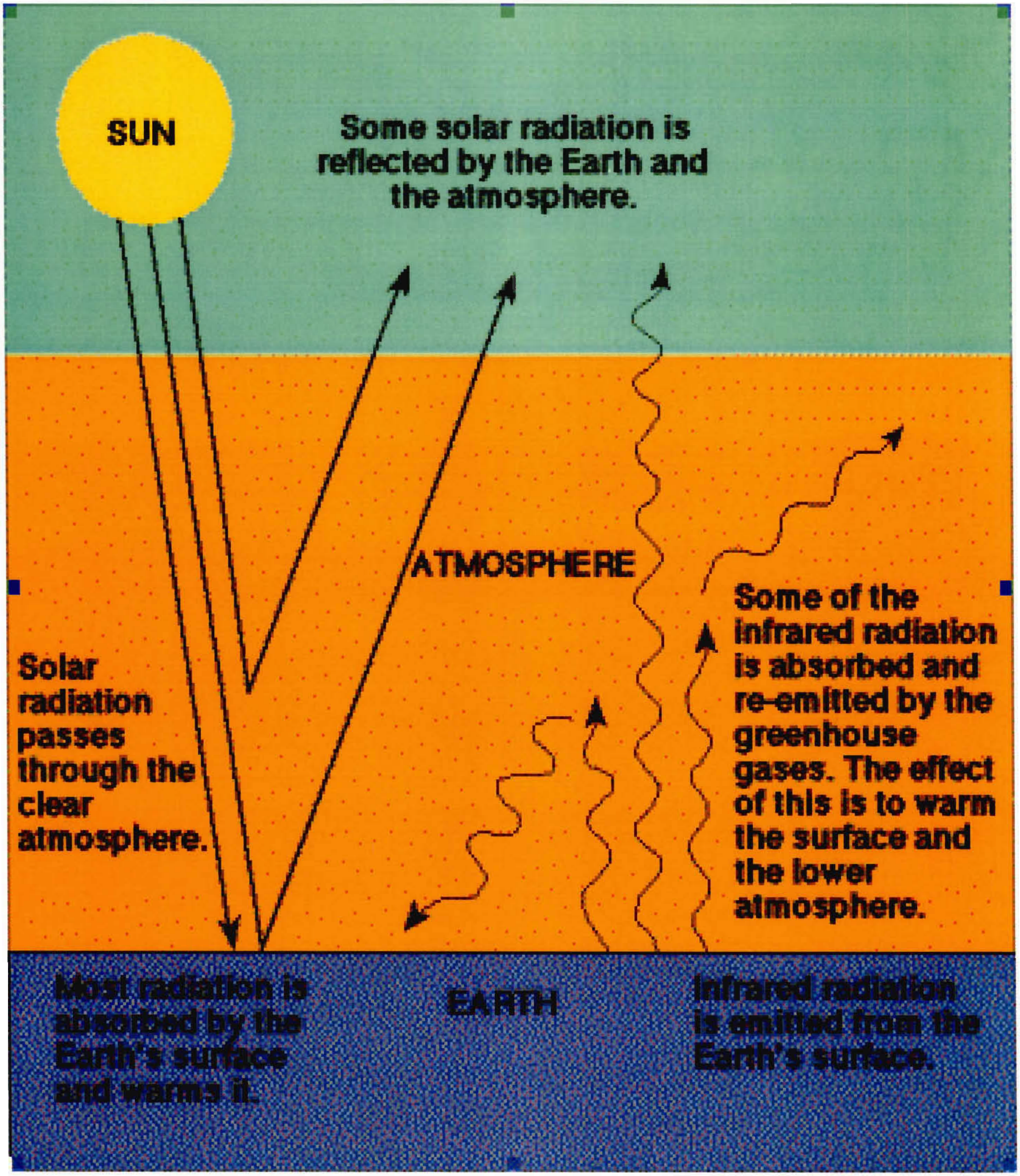
A. *The Natural Greenhouse Effect*

Regardless of your opinion on the global warming issue, the cycle by which the world is heated is a scientific fact. The natural greenhouse effect is a process by which radiant heat from the sun is trapped in the Earth's lower atmosphere by greenhouse gases. The term "greenhouse" is used to describe this phenomenon since these gases act like the glass of a greenhouse to trap heat and maintain higher interior temperatures than would normally occur (NASA, 1999). This process lets the sun's energy through to the Earth's surface, but prevents the energy from escaping back into space and maintains the surface temperature of the Earth, allowing for life to exist. The greenhouse gases that help trap heat include water vapor, carbon dioxide, methane, and nitrous oxide.

The process of the natural greenhouse effect begins as energy emitted from the sun passes down through the Earth's atmosphere to the surface freely. Some of the sun's energy is reflected straight back into space by clouds and by the earth's surface. However, most of the sun's energy is absorbed at the earth's surface and trapped there by greenhouse gases, which causes warming at the Earth's surface and the lower parts of the atmosphere. The natural greenhouse effect is illustrated in Figure 4-1 (Renwick, 1998)

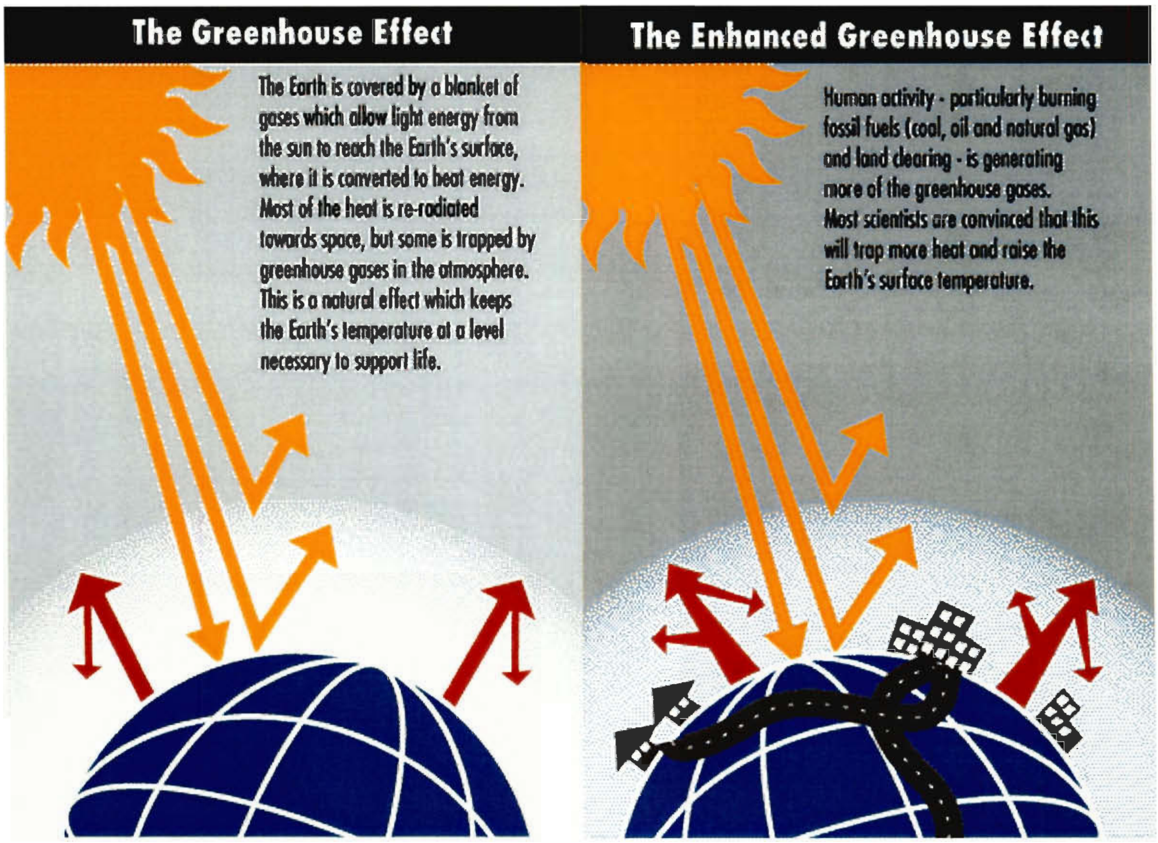
Without the natural greenhouse effect the Earth's surface temperature would be much colder. According to F. Sherwood Rowland, who was awarded the Nobel Prize in Chemistry in 1995, the surface temperature would be -18°C, which is 33°C colder than the current mean surface temperature. This theoretical temperature is calculated using three known constants. These are the surface temperature of the sun, the distance of the

Figure 4-1 : The Natural Greenhouse Effect, Source: Renwick, 1998



earth from the sun, and the fraction of sunlight reflected from the earth back into space (Rowland, 2001, March, p. 29). The presence of greenhouse gases in the atmosphere accounts for the temperature difference. Without this naturally occurring phenomenon, the temperature would be too cold for life to exist on earth.

Figure 4-2 : Natural vs. Enhanced Greenhouse Effect, Source: EPA, 2001

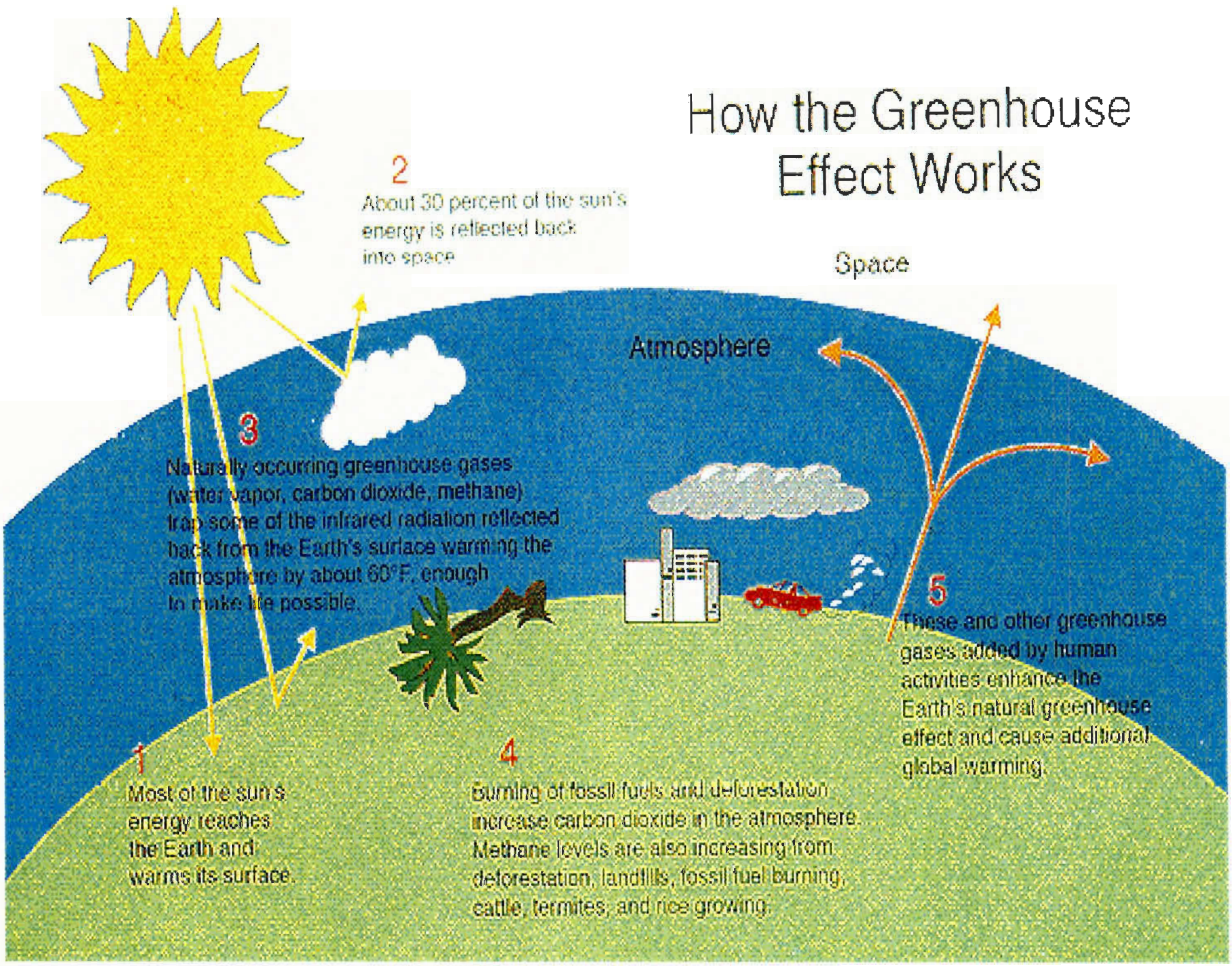


B. *The Enhanced Greenhouse Effect*

The additional amount of greenhouse gases added to the atmosphere due to human activity is called the enhanced greenhouse effect. Its level of intensity is directly proportional to human greenhouse gas emissions because they increase the gas concentrations in the atmosphere, thus causing a stronger effect. Since the beginning of the industrial revolution all greenhouse gas concentrations have increased. Since this time it has been found that these excess greenhouse gases have come primarily from the burning of fossil fuels, the burning of vegetation to clear land, and various agricultural practices that force the atmosphere to become warmer.

The cycle of the enhanced greenhouse effect is displayed in Figure 4-3, where it is shown that greenhouse gases are emitted through different forms of human activity. The transportation, industrial, and deforestation factors of the enhanced greenhouse effects are shown.

Figure 4-3: The Enhanced Greenhouse Effect, Source: EPA, 2001



The significance of each greenhouse gas is based on its global warming potential. Each gas has its own specific potential to warm the earth's surface. The importance of each gas is in its ability to absorb heat, which is its global warming potential, its lifespan when released to the atmosphere, and its concentration in the atmosphere. The global warming potentials (GWP) and atmospheric lifetimes of several greenhouse gases are given in Table 4-4, where carbon dioxide is used as the reference gas since it is the most abundant (EPA, 2001). For example, methane has a GWP that is twenty one times that of carbon dioxide. However, the higher atmospheric concentration of carbon dioxide and its atmospheric lifetime makes it a more important greenhouse gas.

Table 4-4 Global Warming Potentials and Atmospheric Lifetimes (Years), Source: EPA, 2001

Gas	Atmospheric Lifetime	GWP[a]
Carbon dioxide (CO_2)	50-200	1
Methane (CH_4)[b]	12±3	21
Nitrous oxide (N_2O)	120	310
HFC-23	264	11,700
HFC-125	32.6	2,800
HFC-134a	14.6	1,300
HFC-143a	48.3	3,800
HFC-152a	1.5	140
HFC-227ea	36.5	2,900
HFC-236fa	209	6,300
HFC-4310mee	17.1	1,300
CF_4	50,000	6,500
C_2F_6	10,000	9,200
C_4F_{10}	2,600	7,000
C_6F_{14}	3,200	7,400
SF_6	3,200	23,900

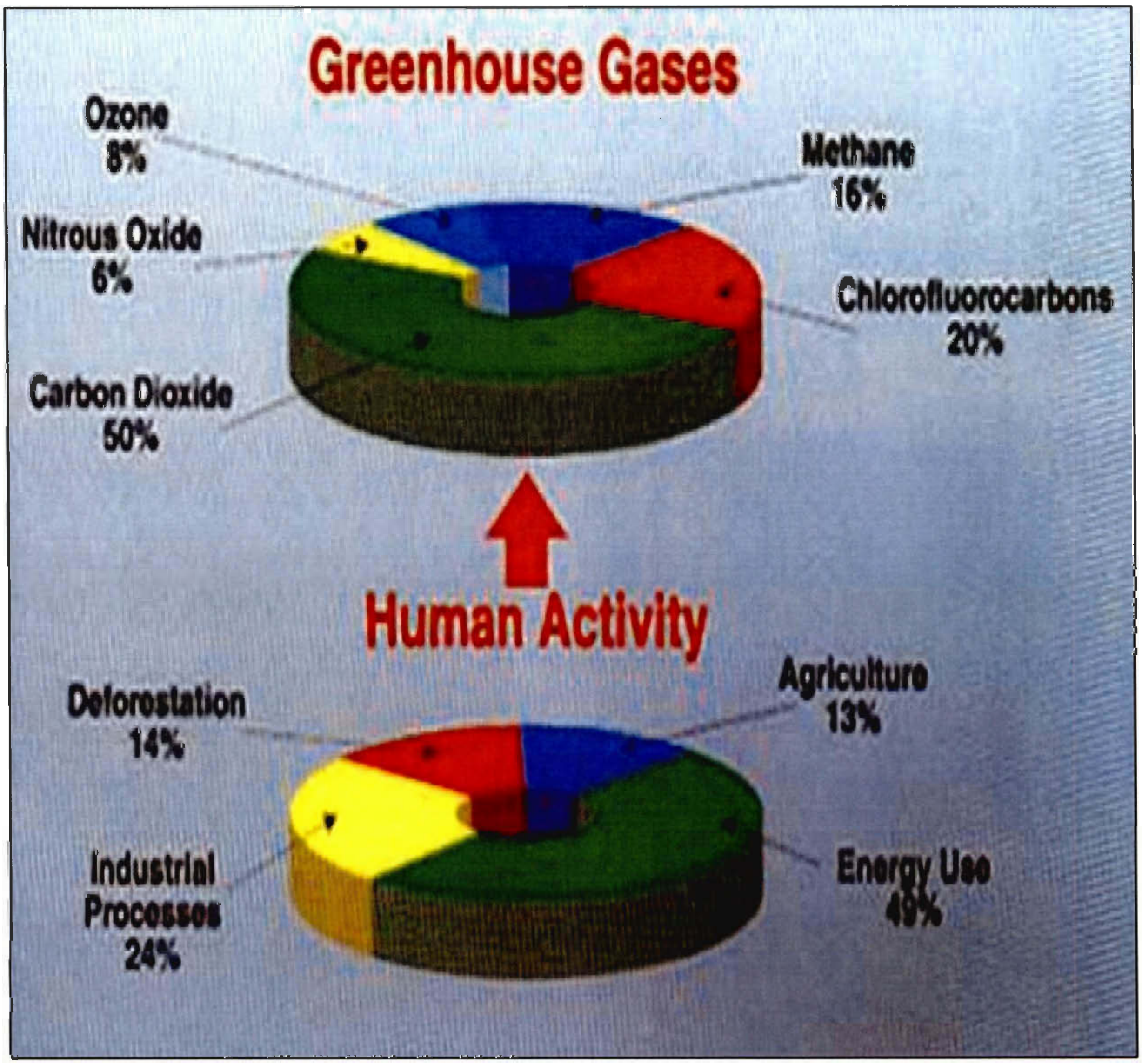
Source: (IPCC 1996)

[a] 100 year time horizon

[b] The methane GWP includes the direct effects and those indirect effects due to the production of tropospheric ozone

The distribution of greenhouse gas concentration and emissions due to human activity is depicted in Figure 4-5 (UMAC, 2001). The distribution of human activity shown below, accounts for the cause of the enhanced greenhouse effect. This figure separates the relative concentrations of gases produced from human activity. Even though water vapor is a major greenhouse gas, it is not included in the figure because humans have little direct effect on its abundance in the atmosphere.

Figure 4-5 : Human Contributions to Greenhouse Effect, Source: UMAC, 2001



C. *Natural Sinks*

After showing how greenhouse gases are being emitted to cause a greenhouse effect, we must identify exactly where these gases are stored. The earth's carbon emitted naturally and unnaturally is stored in places called sinks. A sink is a reservoir that absorbs a pollutant or greenhouse gas as a part of its cycle. An example is the absorption of carbon dioxide into sinks because of its abundance and importance in greenhouse emissions.

There are three different types of sinks including terrestrial, oceanic, and atmospheric, all of which have the ability to take in carbon dioxide. These sinks work together to store and cycle the gases. When carbon dioxide is emitted into the atmosphere it is eventually absorbed and stored by the terrestrial and oceanic sinks. The atmosphere also absorbs carbon from the other sinks as part of the cycle.

Globally over the past two decades, fossil fuel emissions were about 5.4 billion tons per year, and emissions from net deforestation were about 1.6 billion tons per year. Of that, approximately 3.4 billion tons per year accumulated in the atmosphere, approximately 2.0 billion tons annually accumulated in the oceans, and 1.6 billion tons is presumed to have gone into land sinks (Keeler, 2001).

Although the atmospheric sink receives a majority of concern in the global warming issue, the ocean and land sinks are also important sinks. In the oceans, the rate of accumulation depends on how much carbon dioxide humans emit and how much of this excess carbon dioxide is absorbed by plants and soil or is transported down into the ocean depths by plankton. The oceans currently absorb thirty to fifty percent of the carbon dioxide produced by the burning of fossil fuels. If they did not absorb any carbon dioxide, the atmospheric levels of carbon dioxide would be approximately two hundred ppmv more than they are now (IUCC, 1993).

The oceans absorb carbon dioxide through microscopic plants and animals living in the ocean called plankton. Plankton allow for the absorption of gases between the atmosphere and the oceans. In any given region of the earth, the relative amounts of carbon dioxide contained in the atmosphere and dissolved in the ocean's surface layer determine whether the ocean emits or absorbs gas. The amount of carbon dioxide dissolved in the water depends on the amount of plankton in the water. The plankton consume carbon dioxide through the process of photosynthesis. This process occurs mostly within the first fifty meters of the ocean's surface but changes depending on the season and location of the plankton.

The four components of carbon storage in the terrestrial sink include trees, plants growing on the forest floor, fallen leaves and other decaying matter on the forest floor, and soil. It is estimated that about a third of all the world's carbon is stored in forests. Although the world's forest cover is declining due to deforestation activities, commercial tree plantations are expanding. The problem is that these plantations are not the same as forests and do little to fix the problems caused by forest loss. As forests are destroyed carbon dioxide is released, contributing to twenty percent of global greenhouse gas emissions (Barr, 2001, March, p. 70).

Carbon dioxide is also released from soils, which absorb carbon dioxide from the atmosphere and then later release it. Although forests and other land uses are accepted as carbon sinks, they must store carbon for a very long period of time, perhaps 100 to 150 years in order to prevent excessive buildup of carbon dioxide in the atmosphere.

However, only about twelve percent of carbon stored in commercial tree plantations remains there for more than five years (p. 70). Therefore each natural sink plays an imperative role in the storage of carbon on earth and cannot be replaced. These sinks and their ability to store carbon directly influence the greenhouse effect and thus climate change.

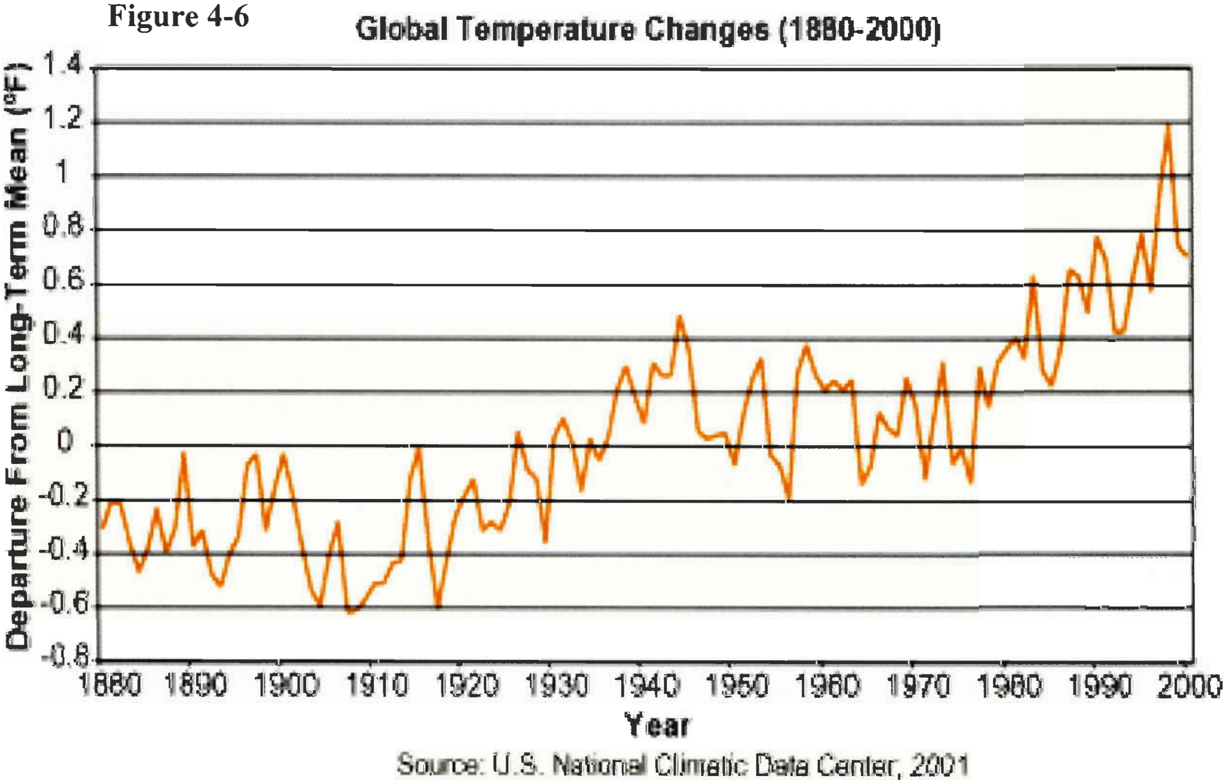
IV-II. Overview of the Facts:

A. *Observed Temperature Increase*

Since there are so many uncertainties on the global warming issue, it is necessary to understand the facts. Some of the occurrences that have been observed are increases in temperature, greenhouse gas concentrations, and weather changes. There is no debate that these changes have taken place based on scientific measurements and historical records. The exact magnitude of these changes may be argued, but the evidence proves that there is a definite problem.

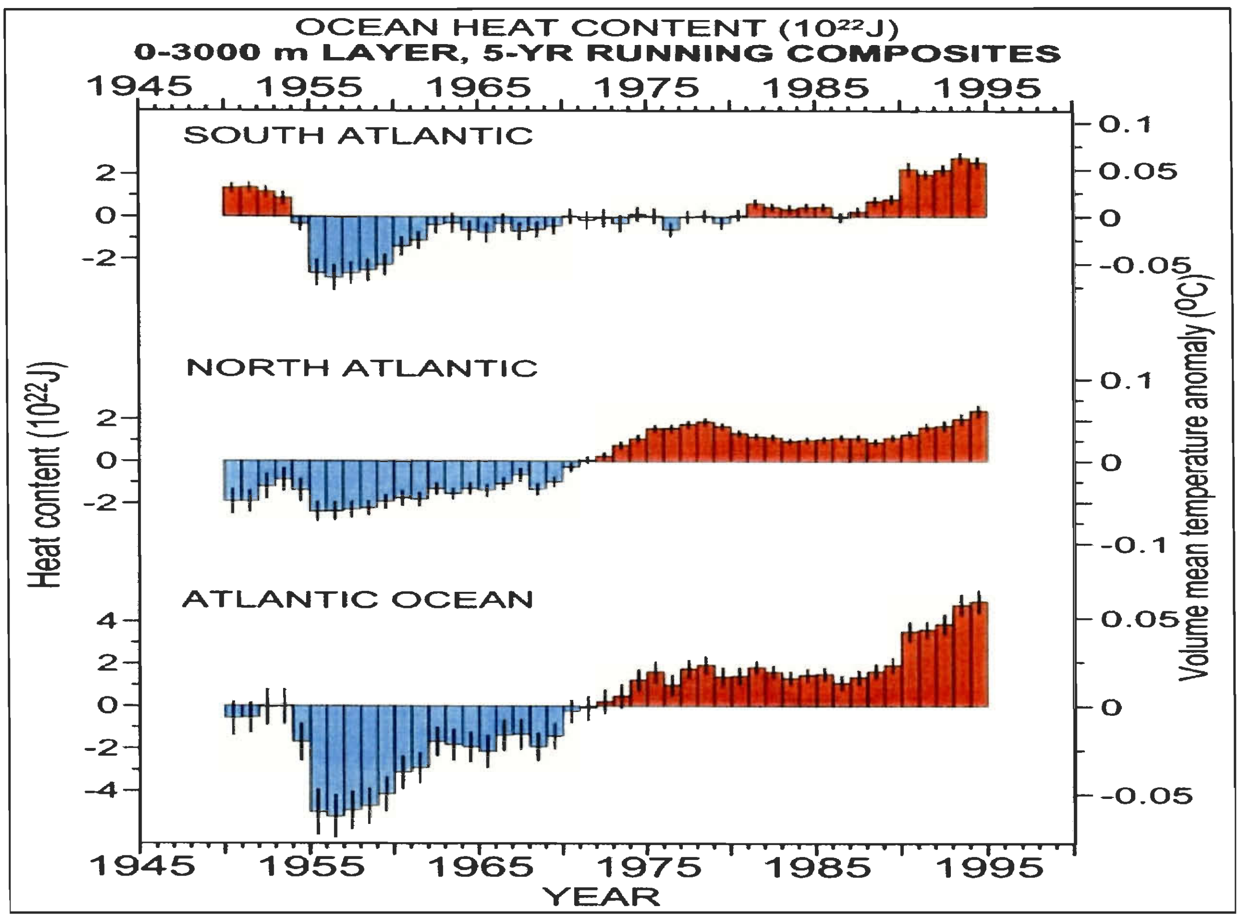
The IPCC has concluded that there has been about a 0.6 ± 0.2 degrees Celsius increase during the twentieth century (IPCC, 2001, p. 26). This is shown in Figure 4-6, which displays the temperature change over the past century (U.S. National Climatic Data Center, 2001). Besides the global surface temperature, the ocean temperatures have also increased. Recent warming has been greater over land compared to oceans. The

Figure 4-6



increase in sea surface temperature over the period from 1950 to 1993 is about half that of the mean land-surface air temperature (IPCC, 2001, p. 26). According to the National Oceanic and Atmospheric Administration (NOAA), "Scientists reported that an extensive study of ocean data shows that temperatures deep in the ocean have increased by one-tenth to one-half a degree Celsius since the 1950s" (Williams, 2000, pg. 1). For example, the temperature change in the Atlantic Ocean since 1950 can be seen in Figure 4-7 (NOAA, 2001). Based on the evidence shown, there has clearly been an increase in temperature on land and in the ocean.

Figure 4-7, Source: NOAA, 2001



B. *Observed Greenhouse Gas Concentrations Increase*

As a correlation to this temperature increase, there has also been an increase in greenhouse gas concentrations. These greenhouse gases include carbon dioxide, methane, water vapor, nitrous oxide, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6). Atmospheric concentrations over the past century for carbon dioxide, methane, and nitrous oxide are shown in Figure 4-8 (Encyclopedia of the Atmospheric Environment, 2000).

C. *Observed Human Emissions in the United States*

Another recent changed is the increase in greenhouse gas emissions due to human activity. Emissions by humans are primarily caused by fossil fuel combustion. This mainly includes the transportation and industrial industries as shown in Table 4-9 (EPA, 2001).

Table 4-9: CO2 Emissions from Fossil Fuel Combustion by End-Use Sector (Tg CO2 Eq.)
Source: EPA, 2001

End-Use Sector	1990		1995	1996	1997	1998	1999
Industrial	1,636.0		1,709.5	1,766.0	1,783.6	1,758.8	1,783.9
Transportation	1,474.4		1,581.8	1,621.2	1,631.4	1,659.0	1,716.4
Residential	930.7		988.7	1,047.5	1,044.2	1,040.9	1,035.8
Commercial	760.8		797.2	828.2	872.9	880.2	864.0
U.S. Territories	33.7		44.0	40.1	42.8	47.9	53.0
Total	4,835.7		5,121.3	5,303.0	5,374.9	5,386.8	5,453.1

Figure 4-8 : Concentration Trends Since 1750, Source: Encyclopedia of the Atmospheric Environment, 2000, Greenhouse Gases

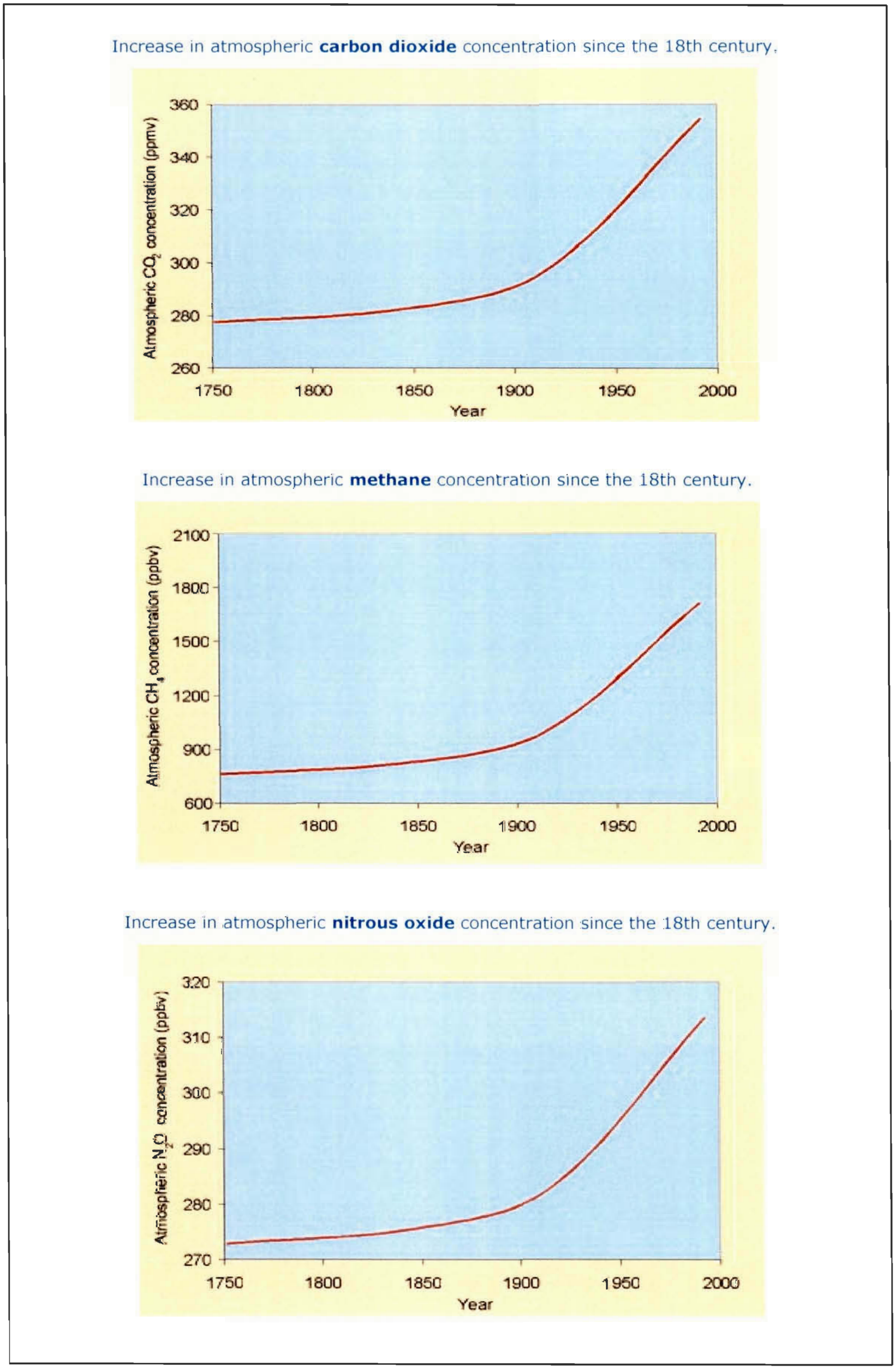
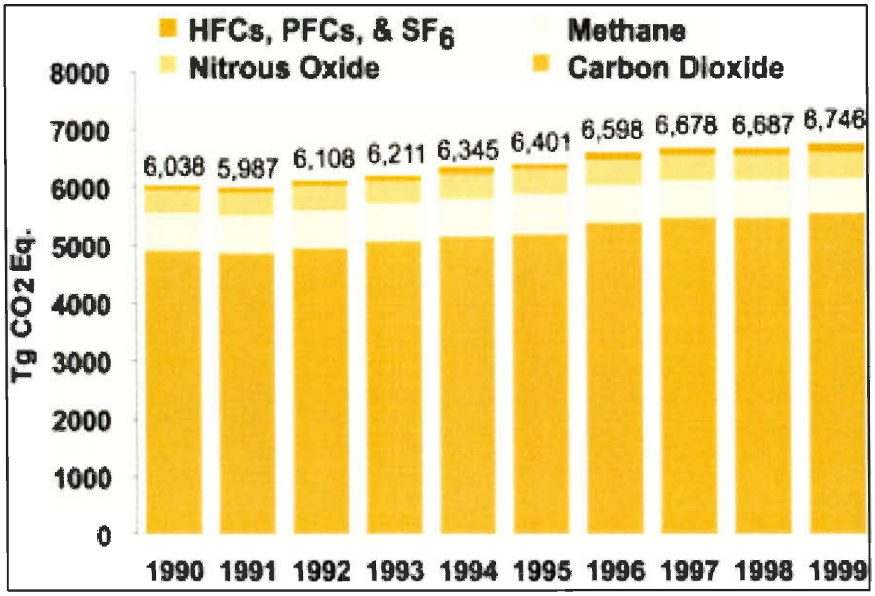


Figure 4-10 : U.S. GHG Emissions by Gas, Source: EPA, 2001



Carbon dioxide emissions have clearly been the most drastic increase, but there have also been changes in the other greenhouse gases as shown in Figure 4-10 and Table 4-11 (EPA, 2001). Although methane emissions have slightly decreased over the past decade, the total greenhouse gas emissions have drastically increased.

D. *Observed Physical Changes*

1.) *Precipitation*

One of the most visible changes observed recently has been in precipitation and atmospheric moisture. Land precipitation in the middle and high latitudes of the northern hemisphere has increased by ten percent over the past century (National Assessment Synthesis Team, 2000, p. 13). Tropical land-surface precipitation has also increased over the past century by about two to three percent. However, not all land-surface precipitation has increased. Over the sub-tropics, rainfall has decreased by

Table 4-11: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks (Tg CO_2 Eq.)

Gas / Source	1990	1995	1996	1997	1998	1999
CO2	**4,913.0**	**5,219.8**	**5,403.2**	**5,478.7**	**5,489.7**	**5,558.1**
Fossil Fuel Combustion	4,835.7	5,121.3	5,303.0	5,374.9	5,386.8	5,456.1
Cement Manufacture	33.3	36.8	37.1	38.3	39.2	39.9
Waste Combustion	17.6	23.1	24.0	25.7	25.1	26.0
Lime Manufacture	11.2	12.8	13.5	13.7	13.9	13.4
Natural Gas Flaring	5.1	13.6	13.0	12.0	10.8	11.7
Limestone and Dolomite Use	5.1	7.0	7.3	8.3	8.1	8.3
Soda Ash Manufacture and Consumption	4.1	4.3	4.3	4.4	4.3	4.2
Carbon Dioxide Consumption	0.8	1.0	1.1	1.3	1.4	1.6
Land-Use Change and Forestry (Sink)[a]	(1,059.9)	(1,019.1)	(1,021.6)	(981.9)	(983.3)	(990.4)
International Bunker Fuels[b]	114.0	101.0	102.2	109.8	112.8	107.3
CH4	**644.5**	**650.5**	**638.0**	**632.0**	**624.8**	**619.6**
Landfills	217.3	222.9	219.1	217.8	213.6	214.6
Enteric Fermentation	129.5	136.3	132.2	129.6	127.5	127.2
Natural Gas Systems	121.2	124.2	125.8	122.7	122.1	121.8
Coal Mining	87.9	74.6	69.3	68.8	66.5	61.8
Manure Management	26.4	31.0	30.7	32.6	35.2	34.4
Petroleum Systems	27.2	24.5	24.0	24.0	23.3	21.9
Wastewater Treatment	11.2	11.8	11.9	12.0	12.1	12.2
Rice Cultivation	8.7	9.5	8.8	9.6	10.1	10.7
Stationary Combustion	8.5	8.9	9.0	8.1	7.6	8.1
Mobile Combustion	5.0	4.9	4.8	4.7	4.6	4.5
Petrochemical Production	1.2	1.5	1.6	1.6	1.6	1.7
Agricultural Residue Burning	0.5	0.5	0.6	0.6	0.6	0.6
Silicon Carbide Production	+	+	+	+	+	+
International Bunker Fuels[b]	+	+	+	+	+	+
N2O	**396.9**	**431.9**	**441.6**	**444.1**	**433.7**	**432.6**
Agricultural Soil Management	269.0	285.4	294.6	299.8	300.3	298.3
Mobile Combustion	54.3	66.8	65.3	65.2	64.2	63.4
Nitric Acid	17.8	19.9	20.7	21.2	20.9	20.2
Manure Management	16.0	16.4	16.8	17.1	17.2	17.2
Stationary Combustion	13.6	14.3	14.9	15.0	15.1	15.7
Adipic Acid	18.3	20.3	20.8	17.1	17.2	17.2
Human Sewage	7.1	8.2	7.8	7.9	8.1	8.2
Agricultural Residue Burning	0.4	0.4	0.4	0.4	0.5	0.4
Waste Combustion	0.3	0.3	0.3	0.3	0.2	0.2
International Bunker Fuels[b]	1.0	0.9	0.9	1.0	1.0	1.0
HFCs, PFCs, and SF6	**83.9**	**99.0**	**115.1**	**123.3.**	**138.6**	**135.7**
Substitution of Ozone Depleting Substances	0.9	24.0	34.0	42.1	49.6	56.7
HCFC-22 Production	34.8	27.1	31.2	30.1	40.0	30.4
Electrical Transmission and Distribution	20.5	25.7	25.7	25.7	25.7	25.7
Aluminum Production	19.3	11.2	11.6	10.8	10.1	10.0
Semiconductor Manufacture	2.9	5.5	7.0	7.0	6.8	6.8
Magnesium Production and Processing	5.5	5.5	5.6	7.5	6.3	6.1
Total Emissions	**6,038.2**	**6,401.3**	**6,597.8**	**6,678.0**	**6,686.8**	**6,746.0**
Net Emission (Sources and Sinks)	**4,978.3**	**5,382.3**	**5,576.2**	**5,696.2**	**5,703.5**	**5,755.7**

+ Does not exceed 0.05 Tg CO2 Eq.
[a] Sinks are only included in net emissions total, and are based partially on projected activity data.

about three percent over the same time period. Some extreme precipitation has caused floods and droughts. The precipitation is related to changes in atmospheric water vapor and cloud amounts.

2.) *Snow Cover and Sea-Ice*

Decreasing snow cover and land-ice extent has been another significant observation since the middle of the twentieth century. Records show that there have been decreases of about ten percent in the range of snow cover over this time period (IPCC, 2001, p. 30). Sea-ice levels have also decreased by fourteen percent with the rate of loss increasing greatly in the 1990s. Sea-ice over the Arctic Basin has lost about forty percent of its total thickness, thinning by three to six feet, since the 1960s (National Assessment Synthesis Team, 2000, p. 76).

Along with the changes in sea-ice, changes in sea levels have also occurred. Global sea level rose four to eight inches during the twentieth century (p. 13). Different rates of sea-level rise occur at different locations due to local rates of land settling or uplift. In fact, about thirty-three acres of land are lost on Massachusetts's Cape Cod each year- seventy three percent due to advancing seawater and twenty seven percent to erosion (New England Regional Assessment Group, 2001, p. 50).

There are countless other changes that have been noticed throughout the world over the past century. Some of these include migration and population changes of animals and plant life native to certain areas. With all of these changes making impacts on the world, the next important step is to find an explanation for their causes. These observations must be correlated to their causes and proven by scientific facts and data.

IV-III. Evidence of the Global Warming Problem:

A. *Human Activity and Greenhouse Gas Concentrations*

It is certain that human activity plays a significant role in climate change. This is due to the increase of greenhouse gas emissions by humans over the past century. The largest contributions to these increased emissions come from the burning of fossil fuels during the Industrial Revolution when it became the primary source of energy. Fossil fuels include coal, natural gas, petroleum, and energy related geothermal resources. The changes in greenhouse gas concentrations by human activities since the pre-industrial revolution are shown in Table 4-12 (IPCC, 2001, p. 38).

Table 4-12: Examples of Greenhouse Gases that are Affected by Human Activities, Source: IPCC, 2001, p. 38

	CO_2 (Carbon Dioxide)	CH_4 (Methane)	N_2O (Nitrous Oxide)	CFC-11 (Chlorofluoro-carbon-11)	HFC-23 (Hydrofluoro-carbon-23)	CF_4 (Perfluoro-methane)
Pre-industrial concentration	about 280 ppm	about 700 ppb	about 270 ppb	zero	zero	40 ppt
Concentration in 1998	365 ppm	1745 ppb	314 ppb	268 ppt	14 ppt	80 ppt
Rate of concentration change[b]	1.5 ppm/yr [a]	7.0 ppb/yr [a]	0.8 ppb/yr	−1.4 ppt/yr	0.55 ppt/yr	1 ppt/yr
Atmospheric lifetime	5 to 200 yr [c]	12 yr [d]	114 yr [d]	45 yr	260 yr	>50,000 yr

[a] Rate has fluctuated between 0.9 ppm/yr and 2.8 ppm/yr for CO_2 and between 0 and 13 ppb/yr for CH_4 over the period 1990 to 1999.

[b] Rate is calculated over the period 1990 to 1999.

[c] No single lifetime can be defined for CO_2 because of the different rates of uptake by different removal processes.

[d] This lifetime has been defined as an "adjustment time" that takes into account the indirect effect of the gas on its own residence time.

1.) *Carbon Dioxide*

As fossil fuels are combusted, the carbon stored in them is almost entirely emitted as carbon dioxide. The observed increase in carbon dioxide is predominantly due to the oxidation of organic carbon by fossil-fuel combustion and deforestation (p. 39).

However, the amount of carbon in fossil fuels varies by type. For example, coal contains the highest amount of carbon per unit of energy, while petroleum has about twenty five percent less carbon than coal, and natural gas about forty five percent less (EPA, 2001). In the 1990s, petroleum supplied the greatest share of U.S. energy demands, accounting for an average of thirty nine percent of total energy consumption. Natural gas and coal accounted for an average of twenty four percent and twenty three percent of total energy consumption respectively over this same time period (EPA, 2001). The complete breakdown for sources of carbon dioxide emissions is illustrated in Table 4-13.

Table 4-13: U.S. Sources of CO_2 Emissions and Sinks (Tg CO_2 Eq.), Source: EPA, 2001

Source or Sink	1990		1995	1996	1997	1998	1999
Fossil Fuel Combustion	4,835.7		5,121.3	5,303.0	5,374.9	5,386.8	5,453.1
Cement Manufacture	33.3		36.8	37.1	38.3	39.2	39.9
Natural Gas Flaring	17.6		23.1	24.0	25.7	25.1	26.0
Lime Manufacture	11.2		12.8	13.5	13.7	13.9	13.4
Waste Combustion	5.1		13.6	13.0	12.0	10.8	11.7
Limestone and Dolomite Use	5.1		7.0	7.3	8.3	8.1	8.3
Soda Ash Manufacture and Consumption	4.1		4.3	4.3	4.4	4.3	4.2
Carbon Dioxide Consumption	0.8		1.0	1.1	1.3	1.4	1.6
Land-Use Change and Forestry (Sink)[a]	(1,059.9)		(1,019.1)	(1,021.6)	(981.9)	(983.3)	(990.4)
International Bunker Fuels[b]	114.0		101.0	102.2	109.8	112.8	107.3
Total Emissions	4,913.0		5,219.8	5,403.2	5,478.7	5,489.7	5,558.1
Net Emissions (Sources and Sinks)	3,853.0		4,200.8	4,381.6	4,496.8	4,506.4	4,567.8

As shown in previously in Table 4-9, carbon dioxide emissions from fossil fuel combustion can be separated into four main sectors: transportation, industrial, residential, and commercial. These four main sectors are the main ways through which humans emit carbon dioxide through the burning of fossil fuels. With the excessive use of these natural resources, humans are directly responsible for the increases in carbon dioxide concentrations.

a. *Industrial sector*

In 1999, the industrial sector accounted for approximately a third of carbon dioxide emissions from fossil fuel combustion. On average, sixty five percent of these emissions resulted from the direct consumption of fossil fuels in order to meet industrial energy demands such as for steam and process heat. The remaining thirty five percent was associated with their consumption of electricity for uses such as motors, electric furnaces, ovens, and lighting (EPA, 2001). The largest section of energy consumption in the industrial sector is manufacturing, but construction, mining, and agriculture also play significant roles. Manufacturing activity accounted for eighty four percent of total consumption in the industrial sector in 1994. These included the industries of petroleum products, chemical products, primary metals, paper and products, foods, and stone, clay, and glass products. In 1999, industry was also the largest consumer of fossil fuels for non-energy uses. This includes production of products such as fertilizers, plastics, asphalt, and carbon storing lubricants. In theory emissions from the industrial sector should increase proportionally to the growth in overall U.S. economy. Actually, from 1990 to 1999, emissions from the industrial sector increased only nine percent, while the industrial output in the U.S. increased forty nine percent. This increase is less than that of all other carbon dioxide emitting sectors, and is related to improvements in energy efficiency.

b. *Transportation Sector*

The transportation sector was second next to the industrial sector in amount of U.S. carbon dioxide emissions from fossil fuel combustion in 1999. It has since overtaken the Industrial sector due to a more rapid growth in the sector. In fact since 1990, travel activity in the United States has grown more rapidly than population, with a fourteen percent increase in vehicle miles traveled per capita and a nine percent increase in per capita jet fuel consumption by U.S. commercial air carriers (EPA, 2001). Almost all of the energy consumed in the transportation sector comes from petroleum-based products. These products include mostly gasoline consumption but also diesel fuel and jet fuel. The specific uses of fossil fuels giving off carbon dioxide emissions in the transportation sector are shown in Table 4-14 (EPA, 2001).

c. *Residential and Commercial Sectors*

The residential and commercial sectors account for a smaller percentage of carbon dioxide human emissions as shown in Table 4-9, but they still have significant effects on the carbon dioxide concentrations. In 1999, they combined for about thirty five percent of carbon dioxide emissions from fossil fuel combustion. The major use of fossil fuels in these two sectors is for electrical purposes. Electric consumption of fossil fuels for lighting, heating, air conditioning, and operation appliances contributed to about seventy four percent and sixty six percent of emissions from the commercial and residential sectors, respectively (EPA, 2001).

These emissions fluctuate seasonally depending on severity of weather conditions, population growth, and changes in building structures. For example in 1999, winter conditions in the United States were warmer than normal, although not nearly as warm as

Table 4-14: C02 Emissions from Fossil Fuel Combustion in Transportation End-Use Sector (Tg CO2 Eq.), Source: EPA, 2001

Fuel/Vehicle Type	1990	1995	1996	1997	1998	1999
Motor Gasoline	**955.5**	**1,023.00**	**1,041.40**	**1,050.60**	**1,074.00**	**1,096.60**
Passenger Cars	612.8	634.3	646.6	652.3	66.8	680.9
Light-Duty Trucks	274.1	314.2	320.4	323.1	342.4	349.6
Other Trucks	41.4	40	40.7	40.5	32.1	32.8
Motorcycles	1.6	1.7	1.7	1.7	1.7	1.8
Buses	2	3	2.1	2.2	0.8	0.9
Construction Equipment	2.2	2.4	2.4	2.5	2	2
Agricultural Machinery	4.4	7.9	7.8	8.2	7.6	7.8
Boats (Recreational)	16.9	19.5	19.7	20.1	20.5	21
Distillate Fuel Oil (Diesel)	**277.4**	**312.2**	**329**	**342.8**	**353.5**	**367.1**
Passenger Cars	7.1	7.6	7.6	7.9	7.6	8
Light-Duty Trucks	9	11.2	13.1	14.2	14.4	15.1
Other Trucks	164.1	195.4	207	216.1	225.5	236.5
Buses	7.9	9.9	8.6	9.2	10.7	11.2
Construction Equipment	10.5	10.5	10.9	11.2	10.8	11.3
Agricultural Machinery	23.1	23	23.8	24.5	23.7	24.9
Boats (Freight)	18	16.1	18.4	18.3	17.8	18.7
Locomotives	26.3	29.5	31.5	32.4	31.6	33.2
Marines Bunkers	11.4	9.1	8.2	9	11.4	8.2
Jet Fuel	**220.4**	**219.9**	**229.8**	**232.1**	**235.6**	**242.9**
General Aviation	6.3	5.3	5.8	6.1	7.7	8.4
Commercial Air Carriers	118.2	121.4	124.9	129.9	131.4	137.3
Military Vehicles	36.1	21.6	20.1	17.8	18.4	17.1
Aviation Bunkers	46.7	51.1	52.1	55.9	55	61
Other	13.1	20.5	26.8	23	23	19.2
Aviation Gasoline	**3.1**	**2.7**	**2.6**	**2.7**	**2.4**	**2.7**
General Aviation	3.1	2.7	2.6	2.7	2.4	2.7
Residual Fuel Oil	**80.4**	**72.1**	**67.5**	**56.7**	**55.9**	**64.1**
Boats (Freights)	24.5	31.3	25.7	11.8	9.5	25.9
Marines Bunkers	55.8	40.8	41.8	44.9	46.4	38.2
Natural Gas	**36**	**38.3**	**38.9**	**41.5**	**34.9**	**34.8**
Passenger Cars	+	0.1	+	+	+	+
Light-Duty Trucks	+	+	+	+	+	+
Buses	+	0.1	0.1	0.2	0.2	0.2
Pipeline	36	38.2	38.8	41.3	34.7	34.6
LPG	**1.3**	**1.0**	**0.9**	**0.8**	**0.9**	**1.0**
Light-Duty Trucks	+	+	+	+	+	+
Other Trucks	0.5	0.5	0.4	0.4	0.3	0.4
Buses	0.8	0.5	0.5	0.4	0.5	0.6
Electricity	2.6	2.4	2.4	2.5	2.5	2.4
Buses	+	+	+	+	+	+
Locomotives	2.1	1.9	1.9	1.9	2	1.9
Pipeline	0.5	0.5	0.5	0.6	0.5	0.5
Lubricants	11.7	11.2	10.9	11.5	12	12.1
Total (Including Bunkers)	**1,588.40**	**1,682.80**	**1,723.40**	**1,741.20**	**1,771.70**	**1,823.70**
Total (Excluding Bunkers)	**1,474.40**	**1,581.80**	**1,621.40**	**1,631.40**	**1,659.00**	**1,716.40**

\+ Does not exceed 0.05 Tg of CO2 Eq.

in 1998. Partly due to this slight cooling relative to the previous year, emissions from natural gas consumption in residences and commercial establishments increased by three percent and two percent, respectively (EPA, 2001).

2.) *Methane*

Methane is an important component of the greenhouse effect, second only to carbon dioxide as a contributor to human greenhouse gas emissions. Atmospheric methane concentrations have increased by about 150 percent (1060ppb) since 1750. The present methane concentration has not been exceeded during the past 420,000 years (IPCC, 2001, p. 41). According to the IPCC, over fifty percent of current methane

Table 4-15: U.S. Sources of Methane Emissions (Tg CO2 Eq.), Source: EPA, 2001

Source	1990		1995	1996	1997	1998	1999
Landfills	217.3		222.9	219.1	217.8	213.6	214.6
Enteric Fermentation	129.5		136.3	132.2	129.6	127.5	127.2
Natural Gas Systems	121.2		124.2	125.8	122.7	122.1	121.8
Coal Mining	87.9		74.6	69.3	68.8	66.5	61.8
Manure Management	26.4		31.0	30.7	32.6	35.2	34.4
Petroleum Systems	27.2		24.5	24.0	24.0	23.3	21.9
Wastewater Treatment	11.2		11.8	11.9	12.0	12.1	12.2
Rice Cultivation	8.7		9.5	8.8	9.6	10.1	10.7
Stationary Combustion	8.5		8.9	9.0	8.1	7.6	8.1
Mobile Combustion	5.0		4.9	4.8	4.7	4.6	4.5
Petrochemical Production	1.2		1.5	1.6	1.6	1.6	1.7
Agricultural Residue Burning	0.5		0.5	0.6	0.6	0.6	0.6
Silicon Carbide Production	+		+	+	+	+	+
International Bunker Fuels*	+		+	+	+	+	+
Total	644.5		650.5	638.0	632.0	624.8	619.6

+ Does not exceed 0.05 MMTCE.
* Emissions from International Bunker Fuels are not included in totals.

emissions are from human sources, such as landfills, natural gas and petroleum systems, agricultural activities, and other industrial processed as shown in Table 4-15 (EPA, 2001).

a. *Landfills*

Landfills are the largest source of human methane emissions in the U.S. Landfills are an environment where oxygen levels are very low. This allows for organic materials, such as yard waste, household waste, food waste, and paper to be decomposed by bacteria, which results mostly in the generation of methane. Methane emissions from U.S. landfills have been slightly reduced since 1990 due to better management of municipal solid waste and landfill gases.

b. *Natural Gas Systems*

Methane is also a major component of natural gas. Large amounts of methane emissions occur during production, processing, transmission, and distribution of natural gas. This accounts for approximately twenty percent of U.S. methane emissions (EPA, 2001). Over the last decade methane emissions from natural gas systems have decreased slightly, but this decrease is insignificant compared to the great increase over the past one thousand years.

c. *Agriculture*

Another major contributor to methane emissions in the U.S. is agriculture. It accounted for twenty eight percent of methane emissions in the U.S. in 1999, with enteric fermentation in livestock, manure management, and rice cultivation accounting for the majority. Enteric fermentation is a process, which occurs during animal digestion. The animals that cause the majority of these emissions include cattle, buffalo, sheep, and goats. In 1999, enteric fermentation accounted for about twenty one percent of total U.S. methane emissions (EPA, 2001).

Another leading cause for methane emissions is manure management. The decomposition of organic animal waste in an oxygen free environment promotes methane emissions due to manure management. This accounted for six percent of U.S. methane emissions in 1999, and it is a direct effect from the method of manure management used by livestock owners (EPA, 2001).

Rice cultivation is the third major agricultural contributor to methane emissions in the U.S. Rice is grown on flooded fields where oxygen free conditions develop a decomposition to release methane into the atmosphere. The methane is released primarily through the rice plants themselves, and this was the cause for 2 percent of methane emissions in the U.S. in 1999 (EPA, 2001). This amount varies due to changes in the rice industry.

3.) *Nitrous Oxide*

Nitrous oxide is a greenhouse gas that is produced both naturally and by human activity. It is produced naturally from a large variety of biologically sources in soil and water. Humans produce it by agricultural, energy-related, industrial, and waste management activities as shown in Table 4-16 (EPA, 2001). The atmospheric concentration of nitrous oxide has steadily increased during the Industrial Era and is now sixteen percent (446ppb) larger than in 1750 (IPCC, 2001, p. 42). As shown, the major human activities producing nitrous oxide in the U.S. are soil management, fuel combustion in motor vehicles, and nitric and adipic acid production.

Table 4-16: U.S. Sources of Nitrous Oxide Emissions (Tg C02 Eq.), Source: EPA, 2001

Source	1990		1995	1996	1997	1998	1999
Agricultural Soil Management	269.0		285.4	294.6	299.8	300.3	298.3
Mobile Sources	54.3		66.8	65.3	65.2	64.2	63.4
Nitric Acid Production	17.8		19.9	20.7	21.2	20.9	20.2
Stationary Sources	16.0		16.4	16.8	17.1	7.3	9.0
Manure Management	13.6		14.3	14.9	15.0	15.1	15.7
Human Sewage	18.3		20.3	20.8	17.1	7.3	9.0
Adipic Acid Production	7.1		8.2	7.8	7.9	8.1	8.2
International Bunker Fuels*	0.4		0.4	0.4	0.4	0.5	0.4
Agricultural Residue Burning	0.3		0.3	0.3	0.3	0.2	0.2
Waste Combustion	1.0		0.9	0.9	1.0	1.0	1.0
Total Emissions	**396.9**		**431.9**	**441.6**	**444.1**	**433.7**	**432.6**

* Emissions from International Bunker Fuels are not included in totals.
Note: Totals may not sum due to independent rounding.

Nitrous oxide is produced naturally in soils through processes of adding and removing nitrogen from it. Human activity causes emissions of nitrous oxide through unnatural addition of nitrogen to soil. These additions occur through applications of synthetic and organic fertilizers, production of nitrogen-fixing crops, and livestock manure. Over the last decade, emissions of nitrous oxide increased eleven percent as the agricultural industry rose (EPA, 2001).

Although fossil fuel combustion primarily emits carbon dioxide, nitrous oxide is a secondary product. Nitrous oxide comes from the reaction that occurs between nitrogen and oxygen during combustion. The quantity of nitrous oxide emitted by combustion varies according to fuel type, technology, and pollution control devices used. Over the last decade, nitrous oxide emissions from fuel combustion increased by sixteen percent, mostly due to fuel from motor vehicles (EPA, 2001).

The third largest method of emissions for nitrous oxide is in the production of nitric and adipic acid. Nitrous oxide is emitted as a by-product of the chemical synthesis of the acids. The majority of adipic acid is produced to manufacture nylon. Nitric acid is used to make synthetic commercial fertilizer, which is also a major component in explosives. The nitric acid production in the U.S. is by the oxidation of ammonia, during which nitrous oxide is formed and emitted in the atmosphere. Over the past decade emissions from acid production increased thirteen percent (EPA, 2001).

4.) *Hydrofluorocarbons, Perfluorocarbons, Sulfur Hexafluoride*

Chlorofluorocarbons (CFCs) have been proven to have severe negative impacts on ozone depletion, and thus have been banned from human use in recent decades. Since then, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6) have been used as alternatives to these harmful CFCs as shown in Table 4-17 (EPA, 2001). However, these substitutes are powerful greenhouse gases with a high potential to cause global warming. They are mainly emitted as by-products of industrial processes. PFCs and SF6 have many human sources, are strong absorbers of infrared radiation, and have extremely long atmospheric lifetimes. Thus even with relatively small emissions, these compounds have the potential to influence climate many years into the future. Over the last decade, there has been an increase of sixty two percent in total emissions of HFCs, PFCs, and SF6 (EPA, 2001).

Table 4-17: Emissions of HFCs, PFCs, and SF6 (Tg CO2 Eq.), Source: EPA, 2001

Source	1990		1995	1996	1997	1998	1999
Substitution of Ozone Depleting Substances	0.9		24.0	34.0	42.1	49.6	56.7
HCFC-22 Production	34.8		27.1	31.2	30.1	40.0	30.4
Electrical Transmission and Distribution	20.5		25.7	25.7	25.7	25.7	25.7
Aluminum Production	19.3		11.2	11.6	10.8	10.1	10.0
Semiconductor Manufacture	2.9		5.5	7.0	7.0	6.8	6.8
Magnesium Production and Processing	5.5		5.5	5.6	7.5	6.3	6.1
Total	**83.9**		**99.0**	**115.1**	**123.3**	**138.6**	**135.7**

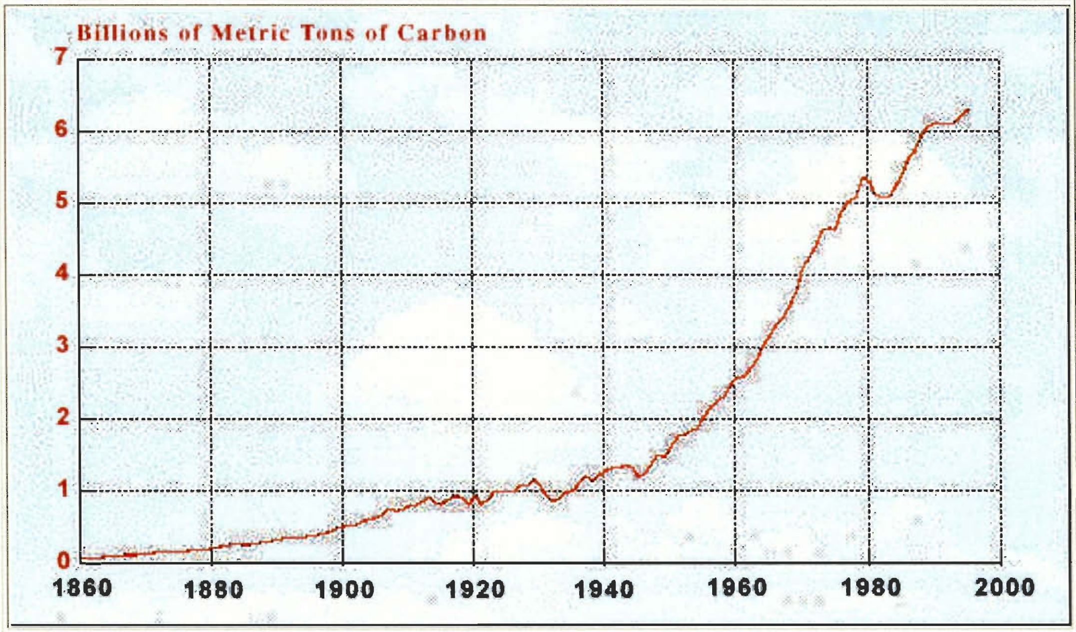
Note: Totals may not sum due to independent rounding

5.) *Overview of Emissions*

Human activity has caused greenhouse gas emissions to increase. Based on the results of all human emissions, it is certain that human activity is directly responsible for the increased greenhouse gas concentrations. The greenhouse gas concentrations over the last century are directly proportional to the increase in human emissions. As shown in Figures 4-18(A) and Figure 4-18(B), the carbon dioxide concentrations have risen at a similar rate to the increased human emissions.

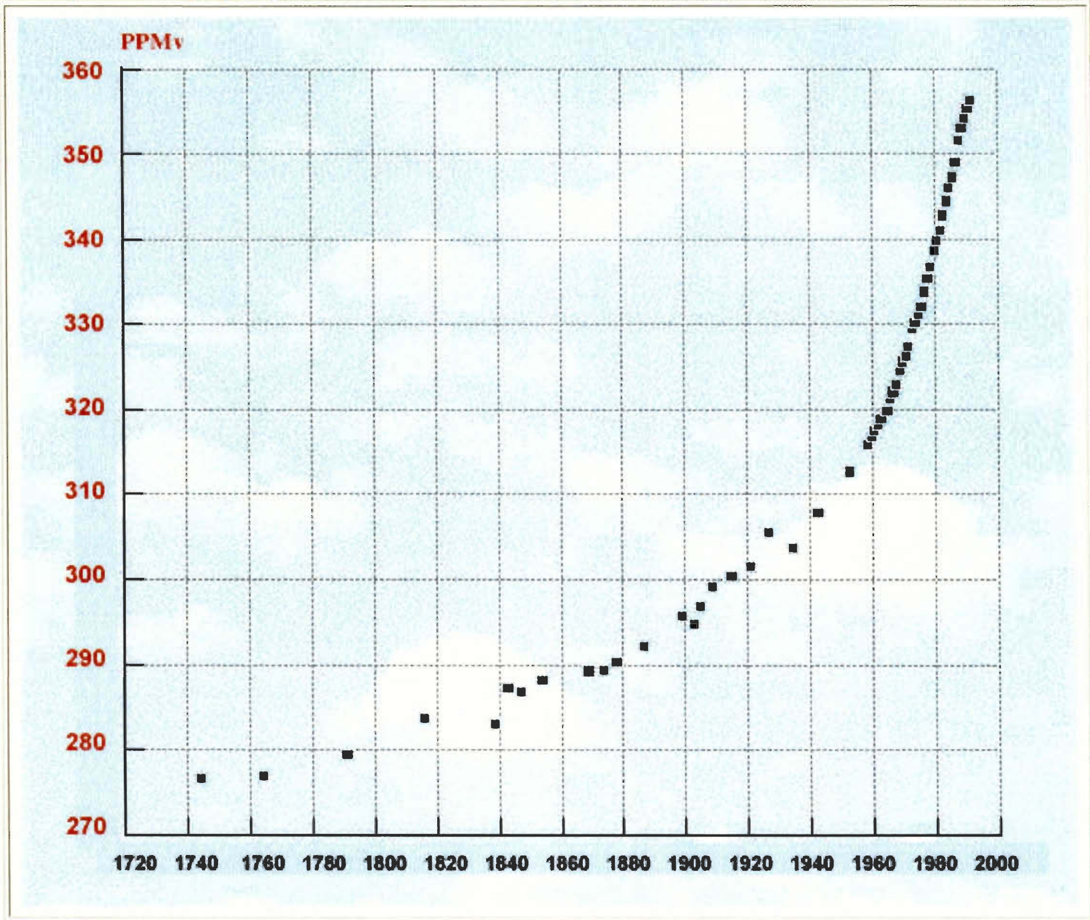
Now that the correlation between greenhouse gas emissions and concentrations in the atmosphere has been proven, they must be linked to the cause for temperature increase. As explained through the enhanced greenhouse effect, by increasing the concentration of greenhouse gases there is a warming of the earth's surface and a decrease in the loss of energy to space. Therefore, since greenhouse gases cause more heat to be trapped, this heat itself causes the temperature of the earth to increase. Since humans are responsible for the increased concentrations of greenhouse gases, they are also responsible for the temperature increases on earth.

Figure 4-18(A) **Global carbon dioxide emissions from fossil fuels**



Source: Marland, et al. 1994 "Trends '93: A Compendium of Data on Global Change," Oak Ridge National Laboratory.

Figure 4-18(B) **Global CO2 concentration**



Source: Neftel et al, 1994 "Trends '93: A Compendium of Data on Global Change," Oak RIdge National Laboratory, p. 13 and p. 19.

B. *Temperature Increase*

It is recognized by both sides of the global warming debate that there has indeed been an increase in temperature on earth over the past century, but there has been an argument over the actual amount. This argument is highly based upon a theory that temperature readings in the past may have been inaccurate. However, this is a hard case to argue since different methods for recording temperature lead to the same conclusion and thus reinforce their accuracy. These temperature readings are taken from basic thermometers, satellites, weather balloons, ice cores, and tree rings.

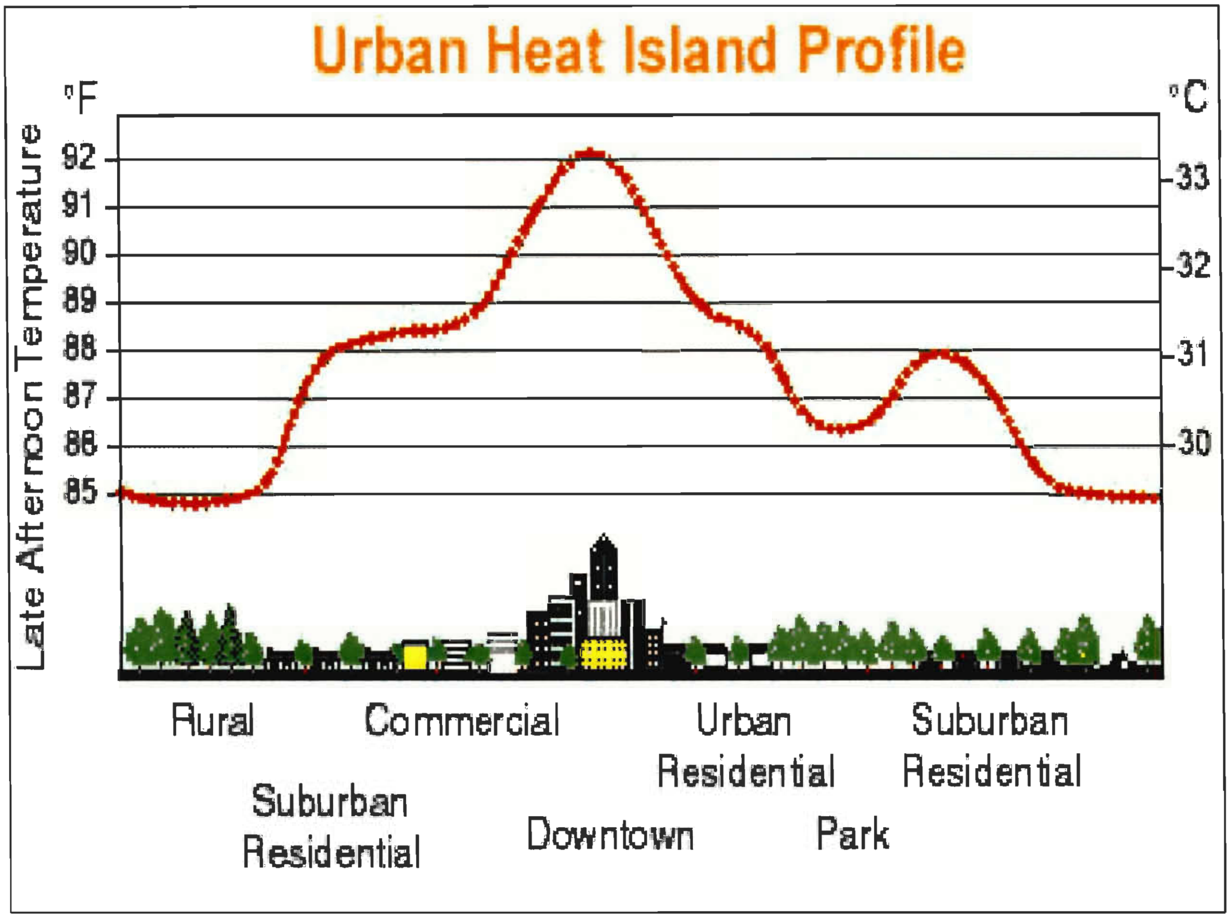
1.) *Recorded Temperatures for Land and Oceans*

Thermometer readings show that the global average surface temperature has increased by 0.6°C ± 0.2°C over the past century (IPCC, 2001, p. 26). This data is shown in Figure 4-6. This method of recording temperature may be argued to be inaccurate, but the other ways of measuring temperature prove that thermometers are reliable. Recent studies of temperature change have given us methods of accurately measuring global temperatures before the existence of thermometers.

a. *Urban Heat-Island Effect*

One of the concerns with the accuracy of thermometer readings is the "urban heat-island effect." On hot summer days, urban air can be one to six degrees Celsius hotter than the surrounding countryside. Heat islands form as vegetation is replaced by asphalt and concrete for roads, buildings, and other structures necessary to accommodate growing populations. Urban areas contain many buildings with vertical walls that act like traps to store heat during the day and then re-emit it at night. These surfaces absorb rather than reflect the sun's heat, causing surface temperatures and overall ambient temperatures to rise. The displacement of trees and shrubs eliminates the natural cooling effects of shading and evapotranspiration. This "heat island effect" specifically influences urban areas and is not a factor of temperature-reading accuracy in rural areas. As shown in Figure 4-19, temperature increases are not affected when they are taken further away from cities (EPA, 2001).

Figure 4-19: Urban Heat Island Effect, Source: EPA, 2001



It is important to understand that the heat-island effect is not the same as global climate change. Global warming must not be confused with this effect because although temperature rises in urban areas may be occurring, they are not directly related to increased greenhouse gas concentrations. The "heat-island effect" cannot be used to disprove global warming. This argument is inaccurate because new studies have taken this effect into account when taking temperature readings in urban areas and have still found rising global temperatures for results. Not only that, but temperature readings taken in rural areas show similar upward trends without the "heat-island effect" occurring.

Although the urban "heat-island effect" raises temperature without greenhouse gas emissions as in global warming, it can indirectly cause increased emissions. Hotter local temperatures can contribute to global climate change by increasing energy demand. As temperatures increase due to the "heat-island effect", humans require more electricity for cooling purposes such as indoor air conditioning. As fossil fuels are burned to produce cooling energy, power plant pollution and greenhouse gas emissions also increase. Thus, local temperature increases resulting from the heat island effect can have an impact on the global climate.

b. *Changing Skyline Hypothesis*

Another main concern with the accuracy of thermometer readings is the changing skyline hypothesis. Thermometers are setup around the world at stations where they can keep records of daily surface temperatures. Thermometer stations are located such that the thermometer screen is in view of both the earth's surface and the sky. The sky is cold compared to the surface so the station measures the net change in radiant energy emitted to the sky. However, over the years a portion of the sky seen by the average weather station may decrease because of growing trees or new nearby buildings. If these trees grow such that an additional one percent of the sky is blocked, then the temperature immediately around the radiation screen will rise by about 0.2° C. This temperature increase occurs because the thermometer is now embedded in a deeper and warmer cavity than before. The growing trees will also decrease wind velocities at the station, leading to further warming. For example, if the station is located in a field with a line of trees about the station that are twenty feet high and 150 feet away in 1979, and are thirty feet high and 150 feet away in 1996, the temperature of that site will warm by 0.2° C (Hoyt, 2001, March 24).

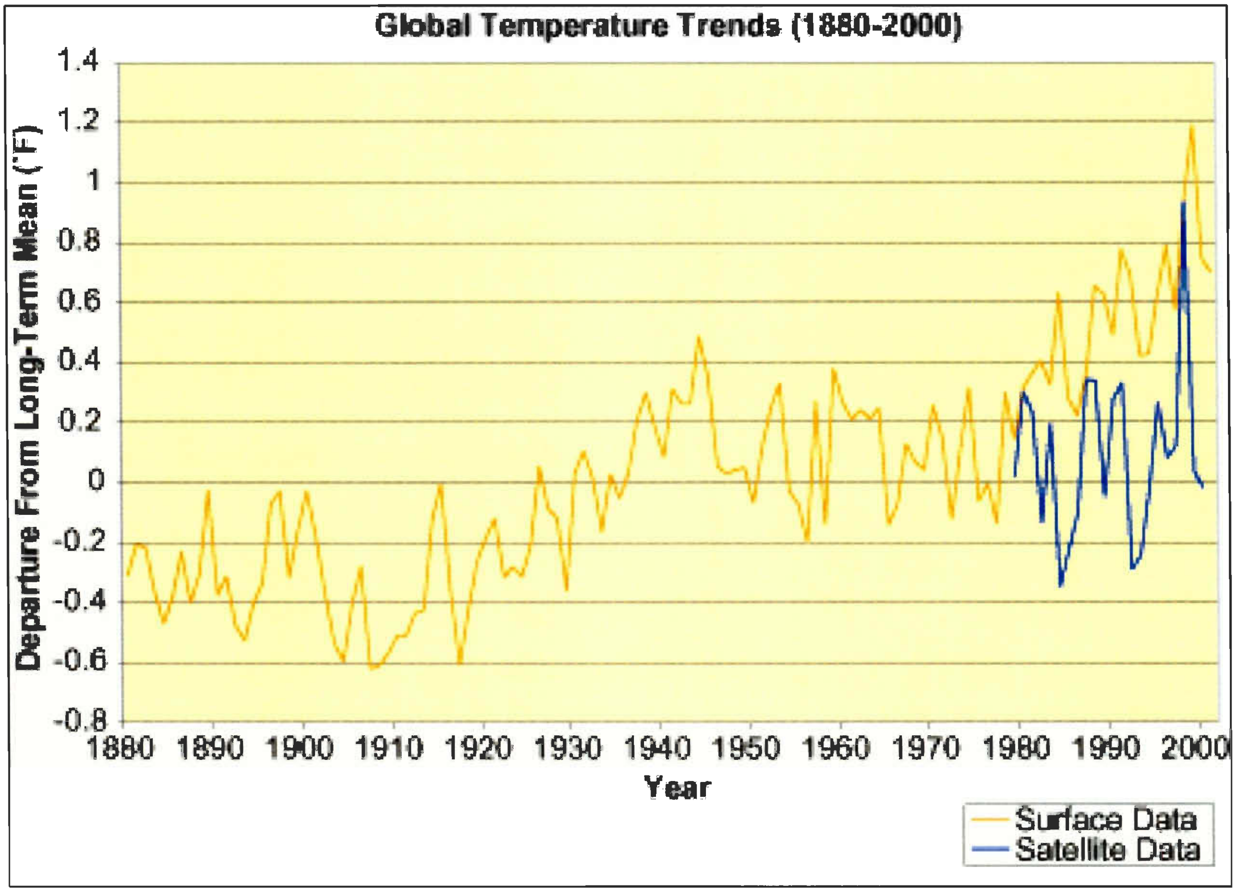
This hypothesis assumes that less radiation will be reemitted to the sky by the thermometer during the day due to more tree cover. However, with this higher amount of tree cover there will also be less radiation received by the station throughout the day, and there should be a negligible net change. The other methods for temperature measurement also act as supporting evidence that the changing skyline hypothesis is not valid.

c. *Satellites and Weather Balloons*

Satellites and weather balloons are reliable ways of measuring temperature to help prove the accuracy of thermometer readings. Satellite and balloon temperature measurements are much more recent than thermometer records, but their readings have shown similar trends. This is important because satellites and weather balloons use better technology to take measurements, and thus support the accuracy of historical data from thermometers.

There is irrefutable evidence that the surface-land and ocean temperatures have been rising. However, some scientists are not yet convinced that the atmospheric temperatures are also rising. Since 1979, satellite data on temperatures in the lower 4.8 miles of the atmosphere show very small warming trends when compared to the surface-based records over the same period. As shown in Figure 4-20, the 1979-2000 satellite data series may be too short to show a trend in atmospheric temperature (EPA, 2001). The records do not exactly match since temperatures are different on the surface of the earth than in the atmosphere. In fact, readings in the upper atmosphere show a

Figure 4-20: Surface vs. Satellite Temperature Readings, Source: EPA, 2001



downward trend which do not exactly match temperature changes on the surface since there are different physical properties in the upper atmosphere.

Another measurement method is using weather balloons, which have been used to measure temperatures in the lower 4.8 miles of the atmosphere since 1958, and show an overall warming trend from 1958-2000 similar to that of the surface record as shown in

Figure 4-21 (EPA, 2001). However, when the period 1979-2000 is considered, the balloon data also resemble the satellite data as in Figure 4-22 (EPA, 2001). This shows that although atmospheric and surface temperature trends may not match in the short term, they will show similarity in long term. Therefore balloon, satellite, and surface thermometer trends will be consistent in long-term records. This proves that they are all accurate ways for recoding temperature.

Figure 4-21: Balloon vs. Surface Temperature Readings, Source: EPA, 2001

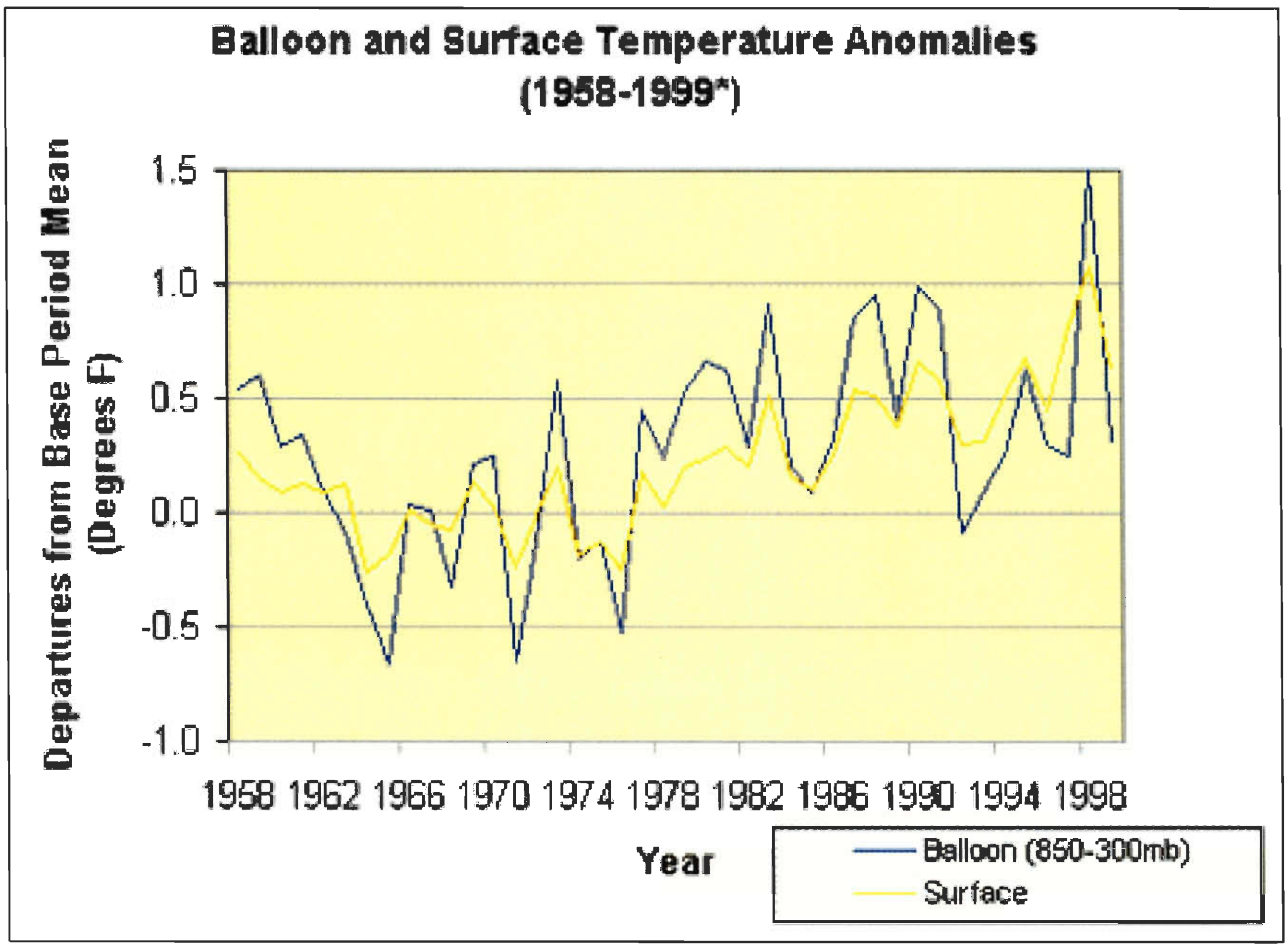
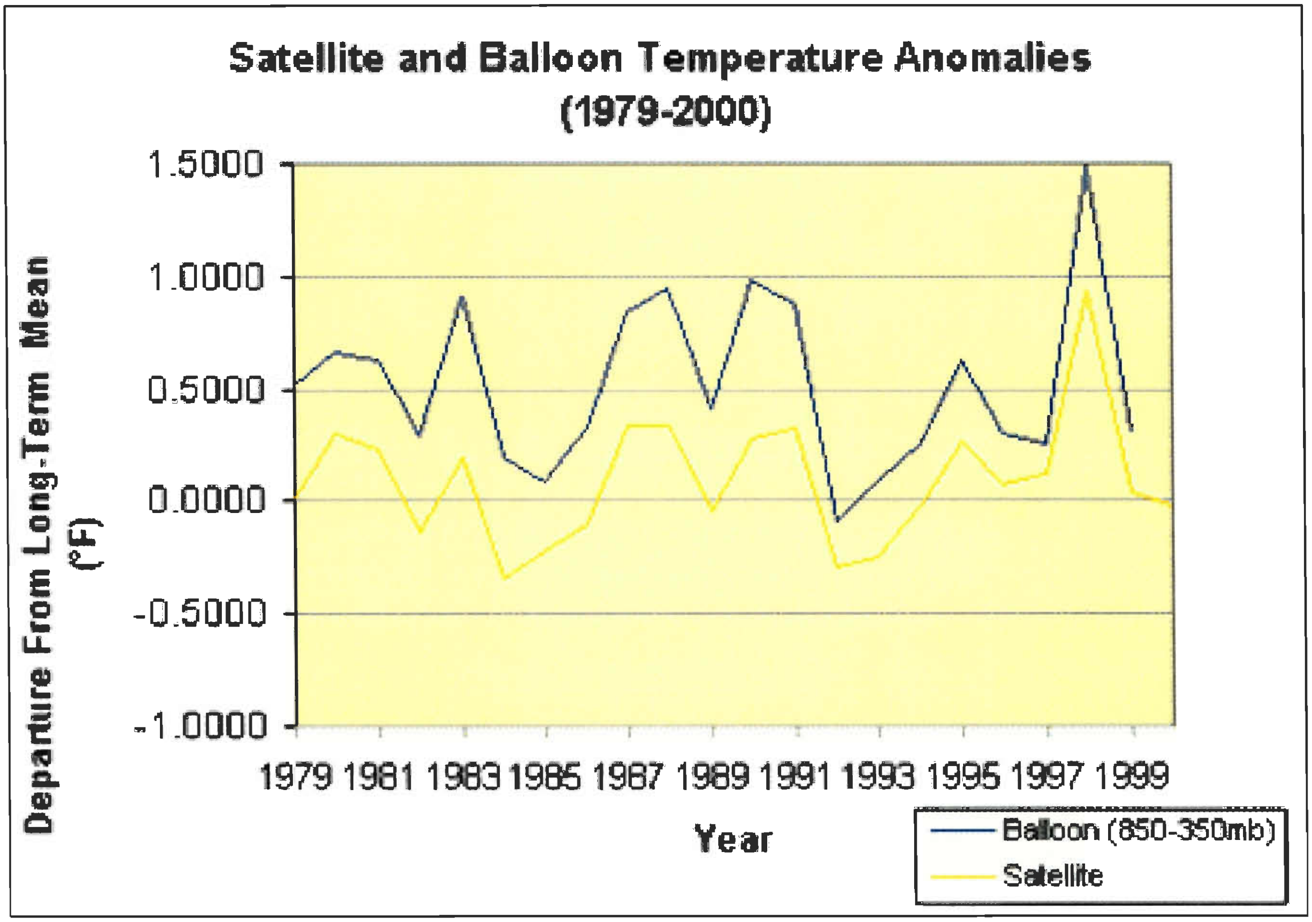


Figure 4-22: Balloon vs. Satellite Temperature Readings, Source: EPA, 2001



d. *Ice Cores and Tree Rings*

Another more recent method for studying the history of the earth's temperature is ice core analysis. This method provides data on temperatures and atmospheric compositions over different time periods. An ice sheet records its own history as it builds up layer by layer. Scientists drill into huge ice sheets and then remove samples that have trapped air bubbles from the past to give data. Some layers have the last 250,000 years preserved in them. The ice layers show a record of precipitation patterns, oxygen isotopic variations in the precipitation, atmospheric temperatures, and atmospheric content of ash, dust, carbon dioxide, and other gases (Solcomhouse, 2001).

For example, ice core data from glaciers in Wyoming and Peru show that there was an increase in global temperature during the Medieval Warm Period between the years 600 and 1150 and a global cooling period during the Little Ice Age between the years 1560 and 1850 (Mandia, 2001).

Besides ice core studies, dendrochronology is another good way of recording historical temperature data. Dendrochronology is the study of the width of tree rings to determine the tree's growth history. Each ring represents an individual year while the width of each ring shows the growth rate during that year's growing season. The width of rings from trees found at higher altitudes and higher latitudes are related to temperature where wide rings indicate warm years and narrow rings indicate cool years. Figure 4-23 shows results from a tree ring study done in California (Mandia, 2001). The data shows that the ring width of the bristle cone pine trees has indeed increased over time. This indicates that that the tree growing seasons have also increased and that there has been a pattern of warmer temperatures, especially over the past century.

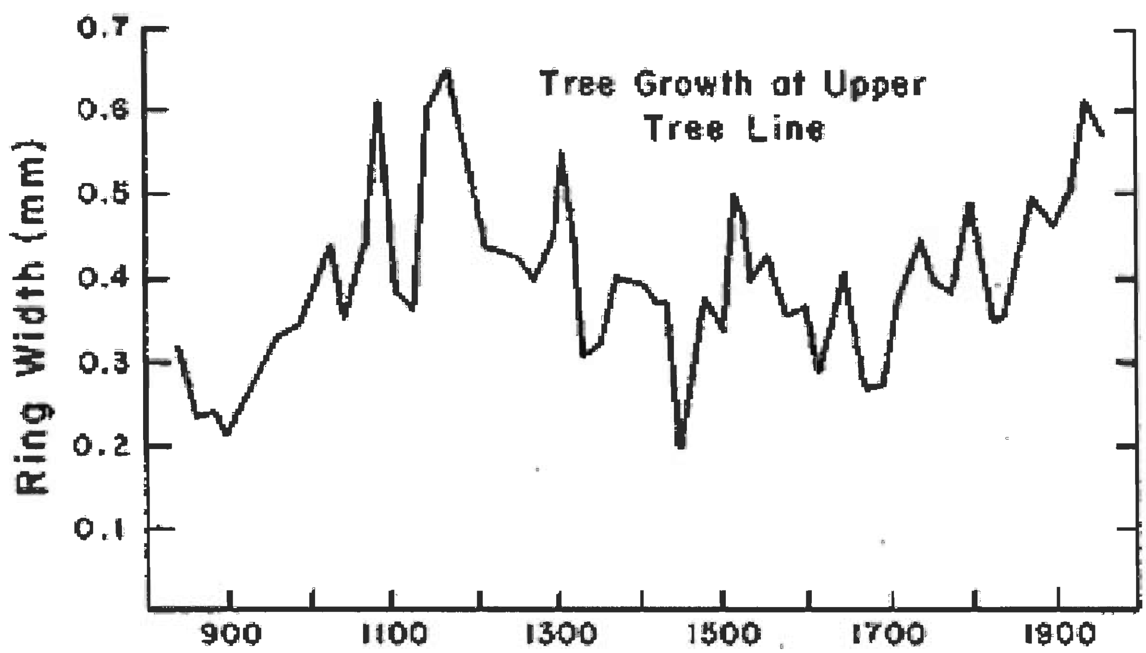


Figure 4-23: Tree-ring widths vs. time from California Bristle Cone Pine trees, Source: Mandia, 2001

C. *Future effects of climate change*

We have shown that temperature increases over the past century are caused by increases in greenhouse gases due to human emissions. These temperature increases have resulted in serious physical changes on earth's surface. These changes will continue to magnify as temperatures increase. These physical changes include human health risks, changes in mountain and forest habitats, sea ice and sea level changes, and agricultural and wildlife changes. The effects of climate changes have already been noticed and it is certain that they will become more drastic as global warming continues.

1.) *Human health*

The most important of these changes to humans are certainly the risks to their own health. Extreme temperatures can be directly blamed for loss of human life. This occurs most commonly among very old and very young people. For example, in July 1995 a heat wave killed more than seven hundred people in the Chicago area (EPA, 2001). The number of deaths will increase as temperatures continue to rise.

The number of people who die on any given day increases with higher temperatures. There are several reasons due directly to the temperature for the increased number of deaths. People with heart problems are more likely to be affected because their bodies must work harder to cool during hot weather. Heat exhaustion and some respiratory problems increase.

These are just some of the short-term health risks caused by high temperatures but there are also several long-term risks. Higher air temperatures increase the concentration of ozone at the earth's surface. The natural layer of ozone in the upper atmosphere blocks harmful radiation from reaching the earth surface. However, in the lower atmosphere, ozone becomes a harmful pollutant called smog. This smog damages lung tissue, and causes problems like asthma and lung diseases for people. Even a slight exposure to smog can cause healthy individuals to experience chest pains, nausea, and congestion. A warming of two degrees Celsius could increase ozone concentrations by about five percent (EPA, 2001).

On the other hand, warmer temperatures may someday decrease the number of people who die each year from cold weather. However, the overall deaths in the United States will steadily grow as temperatures increase. Only one thousand people die from the cold each year, while twice as many die from the heat (EPA, 2001).

Higher temperatures increase the risk of infectious diseases. Diseases that are spread by mosquitoes and other insects will become more common as warmer temperatures allow those insects to multiply in different areas. Some of these diseases include malaria, dengue fever, yellow fever, and encephalitis. In spite of these risks, increased mortality is not a definite consequence of global warming, but spreading of these diseases will certainly have an indirect effect on human health.

2.) *Mountain and Forest Habitats*

The earth's temperature increase will cause physical changes in mountain and forest areas. Mountainous regions throughout the world provide essential resources such as timber, minerals, and a large storage of the freshwater consumed by humans. As the climate changes, these resources will be diminished and the overall ecosystem will be changed. Some of the problems that will occur are increasing amounts of forest fires, changes in snow melting seasons, shifts in plant growth, and migration of wildlife.

Figure 4-24: Global Warming Future. Source: EPA, 2001

Impacts at a Glance

- Continued warming could melt all the glaciers in Glacier National Park by 2030.
- Mountain glaciers in many other parts of the world, including the Pacific Northwest, also may disappear.
- Snow cover may be reduced, leading to drier conditions downstream.
- Warmer mountain streams may harm trout and other cold-water species, adding to existing stresses such as whirling disease.
- Yellowstone National Park may experience more frequent fires if the climate becomes drier.
- Plant species distributions may change as the climate changes.
- Rare alpine plants may become increasingly rare under warmer conditions.
- Some plants and animals in alpine lakes above treeline may disappear locally as treelines move higher and lakes warm.
- Global warming could reduce populations of ducks and other waterfowl that breed in the prairie pothole region of the north-central United States and south-central Canada.

When temperatures change even slightly the snow melting season changes. Rising temperatures will cause snow to melt earlier and faster in the spring. This also affects the timing and distribution of runoff, thus influencing freshwater storage in reservoirs and river levels. When snow melts earlier in the year, the land dries out earlier in the year leading to higher risks of drought and wildfires. With less snow cover during the winters, more of the sun's radiation will be absorbed by the earth's surface where it is usually reflected by snow, thus causing even more of an increase in temperature.

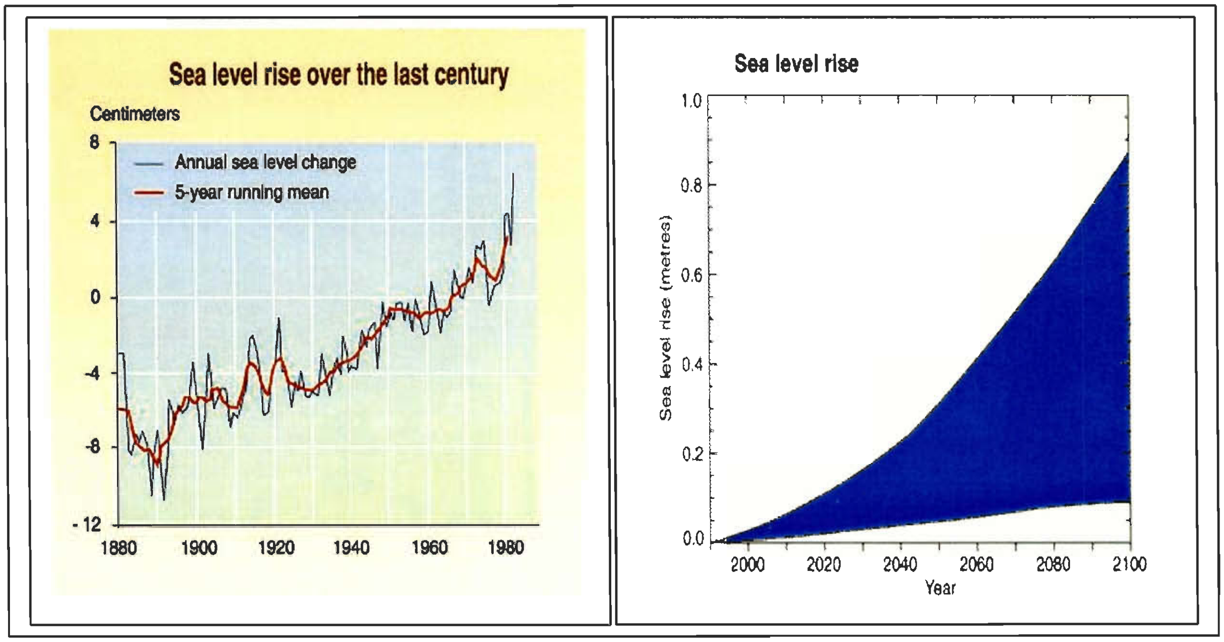
As warming continues there will be a shift in the growing region of many North American forest species by about three hundred kilometers to the north. If the climate changes slowly enough, warmer temperatures will cause trees to move north into areas that are colder, as southern areas became too hot and dry for them to survive. For example, these types of tree movements will affect the maple syrup and logging industries.

Changes in climate already are affecting many mountain glaciers around the world. In Montana, Glacier National Park's largest remaining glaciers are now only a third as large as they were in 1850, and it is estimated that all glaciers in the park will disappear completely within the next thirty years (EPA, 2001).

3.) *Sea ice and Sea level*

Warming temperatures will raise sea levels by expanding ocean water, melting mountain glaciers, and melting parts of the Greenland Ice Sheet. Rainfall and snowfall will also increase by about five percent over Greenland and Antarctica for every 0.6°C that temperatures increase. The IPCC report estimates that sea levels will rise nine to

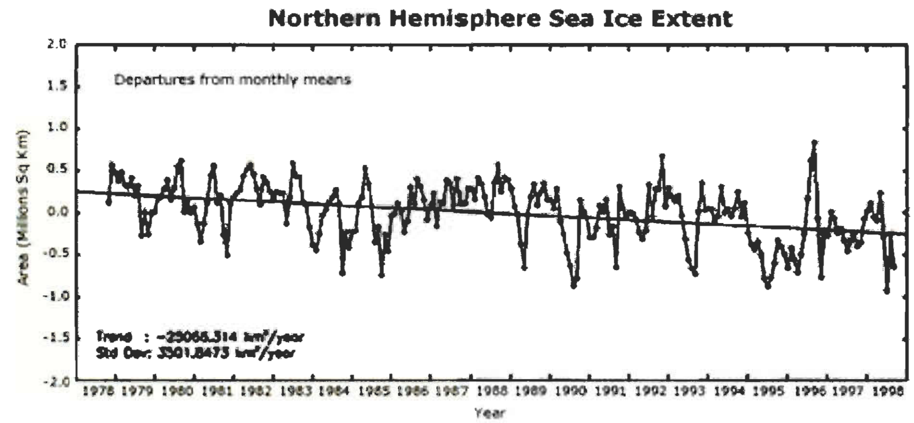
Figure 4-25: Sea Level Rise – Past and Future, Source: IPCC, 2001



eighty eight centimeters by the year 2100. An EPA estimate shows that global sea levels have a fifty percent chance of rising forty five centimeters by the year 2100. Figure 4-25 shows how the sea levels have risen over the past century and also the predictions made by the IPCC for this century's rises.

In the future more drastic changes in sea level are possible. As temperatures continue to increase, the West Antarctic Ice Sheet and other land ice sheets could break and slide into the oceans. According to the EPA, the West Antarctic Ice Sheet contains enough ice to raise sea levels twenty feet (EPA, 2001). If ocean temperatures increase by even a few degrees over the next couple of centuries, there will be a serious risk of an ice sheet collapse. As shown in Figure 4-26, there has already been a decrease in the extent of sea ice in polar regions. As temperatures increase this trend will continue, thus causing sea levels to rise. Mountain glaciers have also been affected in the same way. EPA scientists have recorded mountain glacier loss in Greenland, the European Alps, the

Figure 4-26: Sea Ice Changes over Past Decades



Satellite-derived departures from monthly means in sea ice extent for the Northern Hemisphere, 1978-1998.
Source: National Snow and Ice Data Center

Himalayas, Ecuador, Peru, Venezuela, New Guinea, and East Africa, among other places (EPA, 2001).

4.) *Agriculture and Wildlife*

Temperature changes results in both positive and negative impacts on agriculture and wildlife. This includes effects on farming of crops and livestock along with changes in migration patterns and populations of wildlife. These changes influence human food supplies and the economy through the agricultural industry.

High levels of carbon dioxide in the atmosphere and increased temperatures will actually increase crop production, because many plants will grow larger and will produce more crops in an environment with a higher concentration of carbon dioxide. The warmer temperatures will increase growing seasons, again resulting in more and better crops. However, gains in crop yield might be offset by more common and devastating droughts in certain areas, and by more weed, insect, and disease problems. For example, in the United States it is predicted that under the effects of climate change, southern

Wisconsin farms will begin to resemble those in present Kansas. Wheat would do well there, but the ideal region for corn and soybeans would shift northward, and these crops would not grow as well in northern Wisconsin (Mecozzi, 2000). This would affect the state agricultural industries individually and change farming methods in each area.

Dairy and livestock farmers will also see negative impacts as their herds suffer from heat stress, changing crop yields reduce the feed supply, and the water supply is reduced. Warmer, longer summers will support the growth of pest populations that could further hurt livestock and spread disease. This will lead to losses in the agricultural industry and decrease the quantity and quality of livestock products.

Wildlife will also suffer from the climate changes. This includes changes in migration patterns and population of land mammals, aquatic life, and birds. Global warming especially threatens the Arctic region where wildlife and nature have a delicate relationship. Animals like the polar bear are put into danger because the temperature change has caused a decline in the population of the ringed seal, the polar bear's main source of food. Warmer temperatures cause the snow dens of the seals to collapse, leaving them vulnerable to predators. As previously discussed, the warm temperatures also melt sea ice that is the bear's hunting ground. This makes it harder for the bears to find the seals during the short winter hunting season. This is just one example of how land mammals are being affected by global warming.

Migratory birds are also being influenced by the changing climate. Scientists studying the dates on which red-winged blackbirds arrive in northern Michigan found that warming temperatures have dramatically altered the birds' migration. They now arrive twenty one days earlier than they did in 1960 (Sierra Club, 2001). The migration season of birds is critical to the survival of many species. When migration begins too early or too late, survival becomes difficult as food sources are reduced.

As the earth continues to warm over the next one hundred years, the temperatures of streams, rivers, lakes and even oceans will continue to rise. This could completely wipe out many fish species. Trout and salmon need cool waters to survive. With even a three degrees Celsius rise in water average temperature, Connecticut, Indiana, Maine, Massachusetts, Ohio and Rhode Island could lose their entire rainbow trout populations. In addition, warming waters could force the salmon to abandon the British Columbia coast as well as the Gulf of Alaska. Threatened salmon populations in the West and Northwest will also be hurt. Not only will warming rivers and streams reduce their ability to reproduce, but rising ocean temperatures will shift currents. This will reduce salmon the food supply and leave them defenseless against predators during the period of their life at sea. These examples show the harmful consequences of global warming on wildlife. It is certain that if temperatures continue to increase the negative impacts on wildlife will be irreversible as species become extinct.

V. Conclusions & Recommendations:

We have shown with sufficient evidence that global warming is a problem that is due largely to human activity. This is shown through the correlations between human greenhouse gas emissions, gas concentration increases, and temperature increases. It is true that correlations do not necessarily equal causes for any problem. However, in this case there is scientific evidence that has shown exactly how human emissions have indirectly caused the world's average temperature increase. There is too much evidence supporting the problem to argue against it.

Figure 5-1: Global Warming Facts:

- **Greenhouse gases trap heat**
- **Humans greenhouse gases have increased**
- **Greenhouse gas concentrations have increased**
- **Temperatures have increased**
- **Sea levels have increased**
- **Sea ice and snow cover has decreased**
- **Growing seasons have increased**
- **Disease and insect populations have increased**
- **Migration seasons have changed**

With all these correlations you cannot deny the global warming problem

Science shows us how greenhouse gases trap heat and warm the earth through the natural greenhouse effect. Data from sources like the EPA shows that human greenhouse gas emissions have increased, thus causing the enhanced greenhouse effect. These emissions increases are proportional to the concentration increases. Through the evidence that shows how greenhouse gases warm the earth, it is reasonable that these concentration increases would increase temperature. Since temperatures have indeed increased, this global warming theory is further supported.

The changes that are taking place throughout the world are now explainable knowing that temperatures are increasing due to human activity. It makes sense that rising temperatures would expand ocean water, melt ice and snow, and increase growing seasons. This also explains how insect populations would increase due to milder winters and warmer climates and why animal habits change with temperature. If any of these pieces of evidence were conflicting with the temperature increase, then there would be reason to doubt the global warming problem. For example, if the sea levels weren't rising then this theory would be inconvincible since we know that water expands as it warms. Knowing that global warming is a serious problem, the next step is determining methods to solve it and learn from it.

A. *Solutions for the Future*

Now that we have identified the global warming problem and discussed the problems that will occur without action in the future, we must look for possible solutions for the future. Several solutions have already been discovered to reduce greenhouse gas emissions and concentrations. Some of the most effective possibilities include more efficient electrical energy sources, alternative energy sources to fossil fuels, more efficient fuel-burning automobiles and machinery, and better ways of disposing of greenhouse gases and wastes. These alternative methods all serve as good solutions to the problem but cost efficiency of their implementation is an important thing to consider in making them realistic.

As we mentioned earlier in this report the urban heat island effect, which is an event occurring when city temperatures are increased due to the absorption of the sun's heat by buildings and pavements, is not directly related to global warming. However, it is indirectly increasing greenhouse gas emissions. Therefore, the implementation of heat island reduction methods is needed.

As temperatures increase, people begin to use more air conditioning to withstand the heat. This increases energy use, which results in increased greenhouse gases emissions. These higher temperatures also help in the formation of ground level ozone known as smog. Some steps can be taken to help lessen the heat island effect and its dangers. One simple step is to plant trees in these urban areas. Planting trees will create more shade for people, seize solar radiation, and cool the air through the process of evapotranspiration. Traditional roofing and pavement materials that absorb heat can be replaced with reflective surfaces to cool the heat islands. If roofing materials were made to be a lighter color, this would reduce the heat absorbed by buildings and indirectly lower greenhouse gas emissions by lowering temperatures.

According to an estimate by the U.S. Department of Energy's Lawrence Berkeley National Laboratory (LBNL), reducing the average temperature in Los Angeles by five degrees Fahrenheit through the use of mitigation measures could be accomplished in fifteen years. The LBNL estimate takes into account the time required for trees to grow large enough to provide adequate shade, plus the average life span of existing pavement and roofing (EPA, 2001). If the average temperature in Los Angeles were decreased by five degrees Fahrenheit, it would decrease electricity, smog concentrations, and greenhouse gas emissions.

One practical way to reduce greenhouse gas emissions is by using better electrical energy sources in commercial and residential products. One plan that is already working toward this is the EPA's Energy Star Campaign. This campaign works to develop more energy efficient equipment to be used in households and businesses. Some examples of Energy Star labeled equipment include home appliances, heating and cooling equipment, and computers. Replacing the older appliances in one house with new energy efficient products will prevent the release of over 70,000 pounds of carbon dioxide over the lifetime of the products. That amount of pollution is the same as taking a car off the road for eight years (U.S. Department of Energy, 1997). The other advantage to these products is that they use less energy, thus saving money on energy bills for consumers. Energy Star labeled appliances and heating and cooling equipment can reduce an energy bill by up to forty percent, a potential savings of hundreds of dollars each year.

Another method of reducing greenhouse gas emissions is by cutting back on their major source, the burning of fossil fuels for energy. Some alternative energy sources include wind energy, solar energy, hydropower, and more efficient transportation energy sources. These sources are not fully effective yet due to high costs and the unwillingness to use them by many countries, but as technology improves, they will significantly reduce the amount of fossil fuels consumed.

Wind power is one of the fastest growing and most environmentally safe energy sources in the world. Windmills produce electricity by converting energy from moving air into mechanical power through rotating shafts that spin turbines. Windmills have been in use for several decades, but advancements in technology have made them more efficient and practical. They can now produce the same amount of energy for about the same cost as coal.

Solar energy is another energy source that is being implemented to reduce fossil fuel burning. There are two types of systems used to produce electrical energy from the sun. Photovoltaic solar systems are built like semiconductors to convert sunlight directly into an electrical energy. The solar thermal electric systems are the other type. They use heat from the sun to make electricity by using mirrors and lenses to magnify sunlight onto a receiver. From there it is moved through a steam generator or engine and converted to electricity. The benefits of these solar energy methods are that they are completely safe for the environment and are cost efficient.

The largest source of carbon dioxide emissions from burning fossil fuels is transportation. A large step in reducing them would be to find substitutes for fuels in automobiles. Some methods being developed to solve this problem include fuel cell technology, hybrid vehicles, and hydrogen and natural gas powered cars.

Fuel cells are now being used with great success to allow the production and use of clean efficient power for automobiles. This fuel in newly developed automobiles averages as much as sixty five miles to the gallon. It works by mixing hydrogen with oxygen from the air to produce electricity without combustion into carbon dioxide or pollution. This could reduce traffic smog and pollution greatly in the future.

Hybrid vehicles such as the Toyota Prius and the Honda Insight combine the best parts of electric and gasoline motors to make efficient, but low fuel burning automobiles. They are currently being sold for use and are becoming increasingly popular. By operating on both an electrical and a fuel combustion engine, these vehicles offer the same power as traditional cars and trucks do with a small fraction of the emissions. As their efficiency continues to improve, consumers will continue to save by spending less on fuel.

An older idea for saving on emissions is that of hydrogen and natural gas sources being used to power cars. The idea has been around for over a century, but it has recently become more popular in buses, trucks, and some cars. Both hydrogen and natural gas is used in a standard fuel combustion engine and produce similar mileage and power. Hydrogen emits only water vapor and natural gas is slightly less polluting than gasoline but the idea is a step in the right direction for reducing emissions (National Environmental Trust, 2001).

A way to reduce energy waste in industry is to implement more efficient production methods. In today's economy, companies have to become more competitive. Being competitive means improving in both quality and undoubtedly price. One way for companies to do this is to become leaner. Becoming leaner means that companies will reduces their wastes in all areas. Lean manufacturing techniques don't just entail great cost savings for a company, but they also result in reductions of greenhouse gas emissions. In the past, a machining plant measured its efficiency by the amount of material that a machine could remove from a piece of metal over time. These types of high-powered machines require large amounts of fuel and electricity. These industrial machines produce large amounts of wastes in both the process time needed and scrap metal. These processes are inefficient in cost and are large contributors to the global warming problem.

With the implementation of lean manufacturing methods, much waste can be eliminated. Efficiency will no longer be measured by material removed but rather by products produced. If raw materials are bought in more efficient sizes and shapes, then only the bare minimum amount of material will be removed producing less scrap. These new processes will require less powerful machinery that will use less fuel and less electricity. By using less fuel, companies will save money and contribute less to the global warming problem.

Humans can help reduce greenhouse gas concentrations by practicing better methods of waste management. There are also several new ideas for disposing of greenhouse gases to keep them out of the atmosphere. By taking these precautions to keep these gases out of the atmosphere, the effects of global warming can be reduced.

A step that will have a positive effect on the problem is better management of waste in landfills. By increasing recycling in cities, landfills will reduce the amount of waste that they combust or bury. Landfills can recycle organic matter especially by turning it into many types of commercial products including roadbeds, plastics, cement, insulation, and even polymer composites that might replace steel in cars.

Methods for disposing of gases already in the atmosphere and those being currently emitted are being put into use. There are plans being developed that involve capturing carbon dioxide from power plants and factories and pumping them into underground formations like dried-up oil wells. This is already being done to a small extent when oil producers inject carbon dioxide into oil wells in order to force petroleum through formations and out of other wells. This solution will be practical as the method becomes better developed because formations can be made near most power plants.

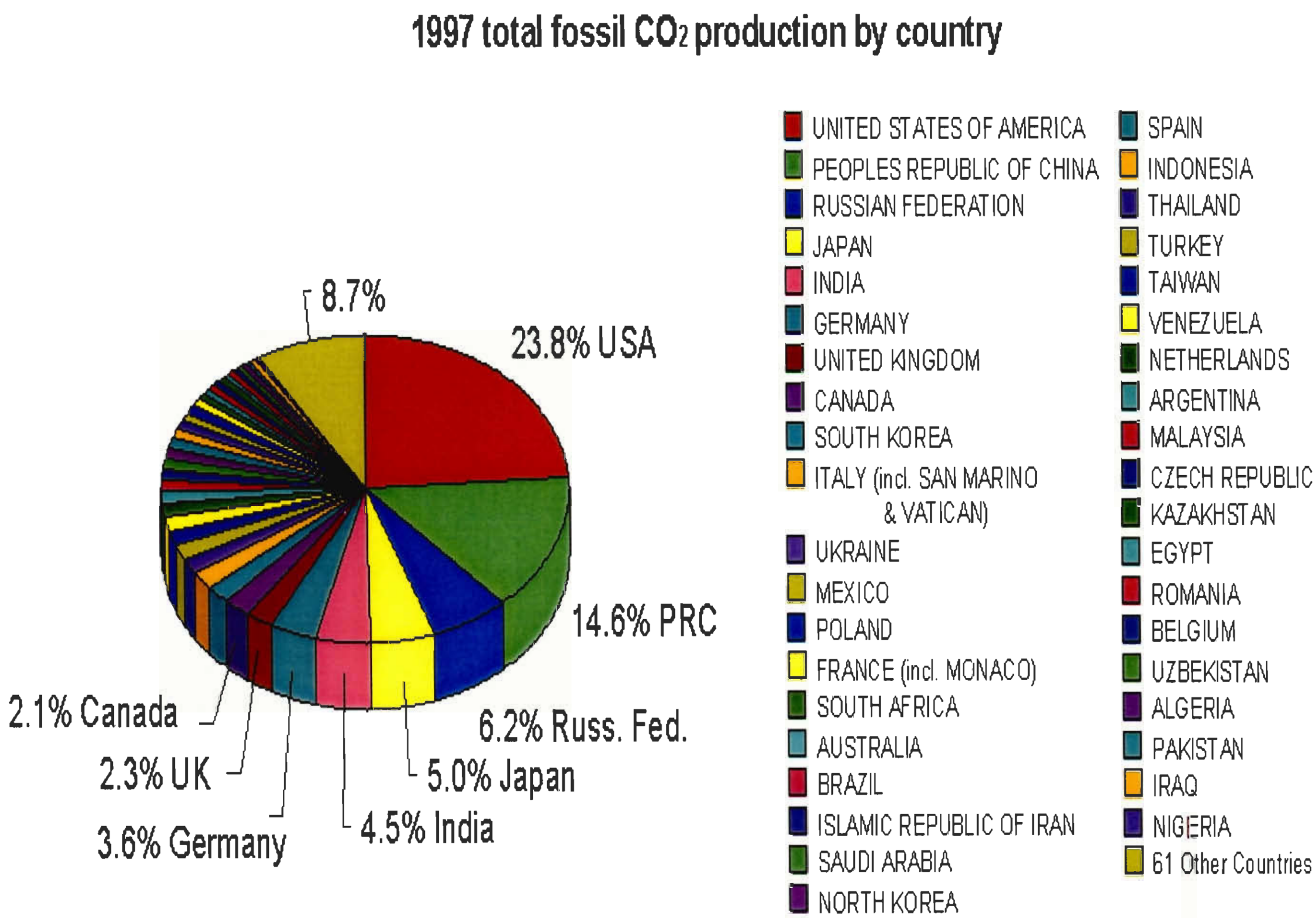
Other plans include storing carbon dioxide in the oceans since they are capable of holding large amounts of it. Carbon dioxide could be moved through a pipeline from a gas collector at shore to the deepest parts of the ocean where the water remains still and can hold it. A cheaper idea would be to add iron sulfate to the oceans to force algae to consume more carbon dioxide than normal. If artificial reefs made of cement were built underwater, more algae would grow on them also. On agricultural land, there have been thoughts of growing more plants to increase the ability of soil to store carbon (Solomon, 1999, p. 2828). All of these methods will work together to store carbon that humans and nature emits.

B. *The International Problem*

After discussing ways that humans can work to prevent further global warming, it is imperative that we stress that this problem is affecting the entire world. Throughout this report we have used the United States as a reference to view the problem since it is in fact the single largest contributor to greenhouse gas emissions. However, the United States is responsible for only about twenty four percent of the world's human carbon dioxide emissions as shown in Figure 5-2 (EPA, 2001). This means that even if the United Stated completely halted the production of all greenhouse gases, there would still be a serious global warming problem because of the other seventy six percent of the world's emissions.

Figure: 5-2

Source: EPA, 2001



Many countries have begun to impose emission regulations upon themselves in an attempt to help control climate change. However, individual countries working alone will not be enough to stop climate change unless they all commit to ending the problem together. This means that without the cooperation of all nations, the problem can never be solved since this is a global problem and must be dealt with by the world as a whole.

Imagining a bathtub full of water makes a good analogy to the global warming problem facing the world. The bathtub itself is the world and the water in the bathtub represents the greenhouse gases currently in the earth's atmosphere. There is also a drain in the bottom of tub that is open and draining water. This represents the natural disposal of greenhouse gases after their lifetimes in the atmosphere are over. Now imagine that the faucet is turned on and water is pouring out and filling the bathtub further. This represents the combined emissions of greenhouse gases by all nations into the atmosphere. The water level in the tub is rising because the drain cannot keep up with the amount of water pouring into the bathtub. As some countries work to reduce the emissions, the output of water from the faucet is decreased, slowing the rise of the water level in the bathtub. However, the water level in the bathtub is still rising. If the rate of input into the bathtub is not lowered below the rate of output by the drain, then the tub will overflow. This would represent the sinks of the earth being completely full with no room for further gases, resulting in a major disaster. Now imagine that the faucet is somehow turned completely off. The drain is still emptying water at the same rate as before, but it will still take time to empty the tub. This means that even if the world completely stopped emissions of greenhouse gases, the concentrations would remain the same until the atmospheric lifetimes of the gases are over. This extreme measure of cutting emissions may not be feasible, but drastic reductions are needed to maintain the quality of life on earth (Hurtt, 2001).

Humans cannot continue to wait for a global warming disaster to occur before they are willing to take action. Humans have been using a "business as usual" strategy to deal with global warming. This strategy involves setting the problem aside until it becomes severe enough where immediate action must be taken. However, this strategy will not work with the global warming problem because preventative measures must be taken far in advance to avoid disasters in the future.

Actions that must be taken for the future are based on the atmospheric lifetimes of greenhouse gases. For example, when humans emit carbon dioxide into the atmosphere it remains there for up to two hundred years. This means that even if the world stopped the emission of all carbon dioxide today, it could take up to two hundred years before it is completely removed from the atmosphere. Global warming would still affect the earth for many years after the emissions of all greenhouse gases were ended but there would eventually be positive results. More realistically as humans continue to slowly cut emissions, future generations will begin to see better living conditions as greenhouse gas concentrations decrease and the global warming problem is lessened.

In this report, we have identified the importance of the global warming problem and the consequences the earth will face because of it. We have shown that human activity is the major contributor to this problem, and the future conditions of human life on earth depend on how we respond to it. There is no longer time to wait and see the effects of what we are currently doing. If the world as a whole does not take steps now to improve the problem, then it may not be able to withstand global warming consequences in the future. The time is now to deal with global warming, and we must avoid human nature's ignorance of not taking action before the problem becomes threatening.

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