Overview of Unit 4

Air Pollution: The Issue of Global Warming

Introduction:

In this unit students analyze the controversial topic of global warming. Your students will discover that there is much scientific uncertainty surrounding global warming. This makes it particularly difficult for public policy makers, who must decide whether or not to implement costly greenhouse gas reduction policies which will yield indeterminate results far into the future.

Learning Objectives:

After completing this unit students will:

1. Explain the greenhouse effect

2. Explain why the issue of greenhouse warming involves spillover costs.

3. Identify advantages and disadvantages of a carbon tax.

4. Understand that public policy decisions involve trade-offs among goals.

Unit Outline:

I. Facts About Global Warming

II. Global Warming Vocabulary

III. Teaching Activities

- A. Teacher Instructions
- B. Specific Activities
  1. Greenhouse Warming: What Is It?
  2. How Much Is Enough?
  3. Analyzing Greenhouse Data
- 4. Further Investigations
  5. Debating the Issues
  6. EEE Actions — You Can Make A Difference!
  7. Case Study

C. Answers to Selected Teaching Activities

Facts About Global Warming

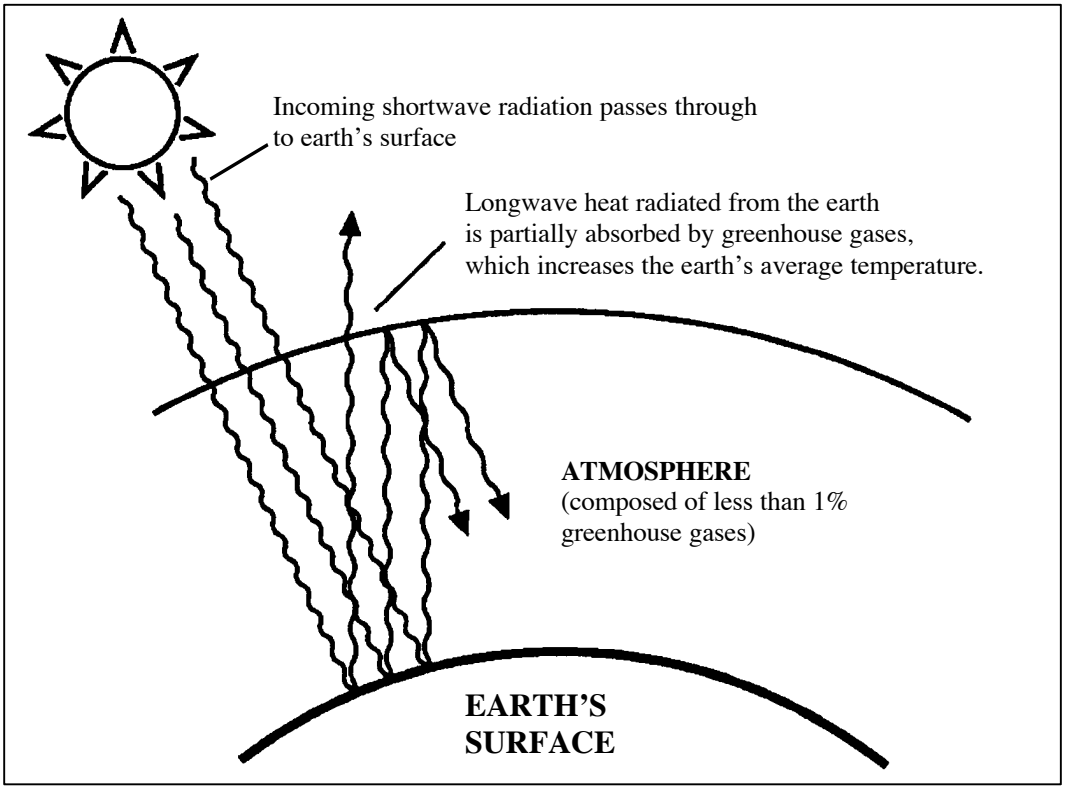
Introduction

The topic of global warming is currently receiving much attention. Despite the uncertainty surrounding this issue, global warming is a cause of concern for many people. The following information provides some basic facts about global warming and clarifies some of the policy options for dealing with this environmental concern.

The "Greenhouse Effect"

The concern about global warming centers on a common scientific phenomenon known as the "greenhouse effect." This concept is rather simple. Certain "greenhouse gases" in the Earth's atmosphere let sunlight through to the Earth's surface, and then trap (absorb) outgoing infrared (long-wave) radiation, much the same way that a greenhouse prevents heat from escaping through its glass panels. This greenhouse effect is beneficial to life on Earth since without this warming the Earth's average temperature would be about 63 degrees F *(35* degrees C) cooler, and would be much less suitable for human life.

Figure 4-1
The Greenhouse Effect



The primary greenhouse gases are carbon dioxide (CO_2) and methane (CH_4). Water vapor also exhibits greenhouse gas characteristics, and is often classified as a greenhouse gas. Chlorofluorocarbons (CFCs) and nitrous oxide (N_2O) are minor greenhouse gases, although some scientists believe that CFCs play a relatively significant role in greenhouse warming. Despite their importance to the greenhouse effect, all the greenhouse gases make up less than .04 percent of the world's atmosphere, with carbon dioxide comprising about .03 percent.

All the greenhouses except CFCs occur *naturally* in the atmosphere. The amount of carbon that is cycling from

naturally occurring processes in the biosphere as CO_2 is enormous – about 700 billion tons. Scientists believe that the general long term climate stability indicates that the amounts of CO_2 generated by natural processes have, until recently, been about equal to the amounts absorbed by these processes. Methane is the major constituent of natural gas, and is also produced by many biological decay processes. Naturally occurring nitrous oxide emissions come from biological processes in the soil.

Human activities affect the naturally occurring concentrations of the greenhouse gases. The burning of fossil fuels is the human activity that most affects the concentration of carbon dioxide. Methane comes from cattle-raising, rice paddies, and trash dumps, as well as from natural gas lost to the atmosphere during production. Human related increase in nitrous oxides comes mainly from combustion. CFCs are stable, nontoxic compounds that contain carbon, chlorine, fluorine, and sometimes hydrogen. They have increased as a result of their use in refrigerants, cleaning solvents, aerosol propellants, and in the manufacture of plastic foams. The production of CFCs is leveling off largely due to the provisions of the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer. Some current evidence indicates that the global warming effects of CFCs may be much less than scientists had previously thought.

The current controversy about global warming is due to fears about increasing concentrations of greenhouse gases, especially CO_2. Some scientists and environmentalists believe these increasing concentrations will intensify the greenhouse effect, causing average earth temperatures to rise. This would produce dire results, including crop failures, increased storm intensity, and coastal flooding resulting from rising sea levels. Other scientists, however, believe that these fears are greatly exaggerated, and that there is little danger of catastrophic climate change. According to this view, policies to drastically reduce greenhouse gas emissions would be a mistake, since these policies would have very harmful effects on the world's economies.

Does the Greenhouse Effect Cause Global Warming?

Many scientists are studying the greenhouse effect to determine if severe climate change is likely. There is general agreement that concentrations of greenhouse gases have increased and are increasing, due largely to human activity, especially the burning of fossil fuels. Scientists estimate that since the beginning of the Industrial Revolution (after 1750), concentrations of CO_2 have increased by 25 percent and CH_4 by 50 percent. Concentrations of CO_2 are rising by *0.5* percent per year and CH_4 by 0.9 percent per year. CFCs do not occur naturally and were not found in the atmosphere until a few decades ago.

While there is agreement that greenhouse gas concentrations have increased, it is *not* possible at this time to tell whether this increase is causing global warming. Temperature readings around the world have been recorded consistently only during the past 100 years. During this time the average global temperature has risen about *0.5* degrees C, with most of this increase occurring between 1890 and 1940. While some scientists believe this warming is due to increasing greenhouse emissions, other scientists point out that the temperature increase also could be attributed to natural climate variability. Given today's limited understanding of climate change, neither possibility can be ruled out completely.

General Circulation Models (GCMs)

Scientists who believe that greenhouse warming will be a serious problem base their predictions primarily on complex, theoretical computer models, known as general circulation models, or GCMs. A typical GCM involves hundreds of equations and dozens of variables. There are currently about six different model types, with others being developed. The global temperature change predictions of these models assume a doubling of preindustrial levels of carbon dioxide, an amount that should be reached sometime in the middle of the next century. Current GCM simulations based on this assumption show a range of average global temperature increases of 3.4 degrees to 9.4 degrees F. However, in its final report to Congress, the National Academy of Sciences concluded that because of the large degree of uncertainty associated with the GCMs, prudent public policy should be based on a possible global average temperature increase of between 1.8 degrees to 9.0 degrees F. The Academy concluded that "It is still

unreasonable to expect current GCMs to provide precise predictions, decades into the future, of global average temperature.... Substantial improvements in GCM capabilities are needed for GCM forecasts to increase their credibility."[6]

Other scientists have far less confidence in the predictive ability of the GCMs. They believe that more accurate predictions of the greenhouse effect can be made by analyzing actual temperature data from the last 100 years. According to these scientists, correlations of temperature and greenhouse gas concentrations indicate that the greenhouse effect has had little, if any, effect on global climate change. h the May 1992 report of the George C. Marshall Institute, these scientists stated that the greenhouse warming produced from a doubling of CO2 in the next century will be "less than 1 degree C, and may be as small as *0.5* degrees C." The report contends that differing levels of solar activity provide a much more likely explanation for increases in average global temperature.[7]

Consequences of Greenhouse Warming

The National Academy of Sciences report categorizes climate change predictions into three categories reflecting different levels of plausibility:

Highly plausible:	Global average surface warming Global average precipitation increase Reduction in sea ice Surface winter warming at high altitudes
Plausible:	Global sea level rise intensification of summer mid-altitude drying High-latitude precipitation increase
Highly uncertain:	Local details of climate change Regional distribution of precipitation Regional vegetation changes increase in tropical storm intensity or frequency

The report concludes that any of the changes above would vary significantly from region to region, and would be very difficult to predict. "The nature and magnitude of the weather conditions and events that might accompany greenhouse warming at any particular location in the future are extremely uncertain."[8]

Adapting To Climate Change

Even if some of the climate changes listed above occur, it is not clear how human and natural systems will adapt to them. Adaptation would depend on two basic factors: the *extent* and the *rate* of climate change, and would vary from region to region. Some regions might benefit from the hypothesized effects of global warming, while some might be harmed. It is generally acknowledged that it would not be difficult for industry and agriculture in industrial countries to adapt to gradual climate change. Poorer countries would have more difficulty, since they have less money, information, and expertise.

While many scientists currently believe that there could be some adverse regional effects from greenhouse warming, some scientists contend that the effects of greenhouse warming would be overwhelmingly positive. This view, based on natural experiments as opposed to theoretical climate models, believes that a more carbon-rich environment coupled with overall increased precipitation levels, would greatly enhance tree and plant growth. This would result in more organic matter being returned to the soil, which would set off a host of beneficial consequences.

Policy Implications of Greenhouse Warming

Because of the uncertainty surrounding greenhouse warming, policy implications are varied and complex. However, it

is possible to identify three broad categories of public policy responses to greenhouse warming.

1. *Do Nothing—Continue* to finance some additional research, but do not incur any major costs until more is known about the extent and implications of greenhouse warming. For example, in the early 1980s, a rise of more than several meters in the sea level due to global warming was considered a possibility. The estimated range by 1990 was much less, from 02 meters to 0.7 meters. Some recent scientific articles even predict that global warming will actually cause sea levels to fall, as warmer air at the poles allows the frigid air there to hold more moisture, resulting in more snowfall.[10] Costly $C0_2$ mitigation policies, based on some of the dire predictions in the early l[9]80s, would have been unwise given more recent research results.

2. *Take Limited Action to Reduce Greenhouse Emissions* —Adopt precautionary measures that make modest immediate reductions in greenhouse emissions, and make modest investments now that will reduce the costs of larger future reductions, should they become necessary. Such policies include elimination of subsidies for energy use and deforestation, significant funding of additional research, and broader dissemination of information about energy-saving technologies.

3. *Take Immediate and Significant Action to Stabilize or Reduce Greenhouse Emissions*. This view believes that the problem is serious enough to warrant immediate and significant action to reduce greenhouse emissions. This statement by environmentalist Jan Beyea of the National Audubon Society illustrates this view: "Although we cannot be sure that these projections (about increasing greenhouse warming) are correct, we must act as if they are correct. We cannot take the risk that the global climate models (GCMs) are wrong." Proponents want governments to enforce stringent policies for reducing greenhouse gases, including specific emission reduction targets and definite time tables.

In a very thorough analysis of world environmental issues, the *World Development Report 1992* stresses that the choice among policy options to address greenhouse warming must depend on the relative *marginal costs* and *marginal benefits* of the options. Policies must not severely hamper legitimate economic development, since development provides the financial capital necessary for meeting environmental challenges. "Without adequate economic development there will not be enough resources for needed investments and environmental protection will fail." I~2 For this reason the *World Development Report 1992* recommends only limited greenhouse reduction policies at this time.

> The balance of the evidence does not support a case for doing nothing, but neither does it support stringent measures to reduce emissions now — the costs are too high in relation to the prospective benefits.... Such an insurance policy, which would go further than economic efficiency alone would dictate, is justified by uncertainty about the physical and economic effects of climate change and by the lags between action and response.[13]

Summary

The critical conclusion that emerges from a current study of this controversial issue is the large measure of *uncertainty* that currently surrounds it. Despite the virtual acceptance of greenhouse warming in the popular media as a scientific fact, in fact, it is not. The George C. Marshall Institute report goes so far as to state that, "The predictions of the greenhouse theory are contradicted by the temperature records to such a degree as to indicate that the anthropogenic greenhouse effect has not had any significant impact on global climate in the last 100 years."[14]

Other groups of scientists, worried that science itself is being discredited, have issued statements recently clarifying how little science really knows about greenhouse warming, and reiterating the need to be careful in implementing public policies that could stifle global economic growth. For example, the Heidelberg Appeal, a statement published in April 1992 by a group of 218 scientists from around the world, including 27 Nobel Prize winners from the United States, expresses great concern about the "emergence of an irrational ideology which is opposed to scientific and industrial progress and impedes economic and social development."[15]

The uncertainty surrounding global warming makes it very difficult for policymakers, who must decide whether or

not to implement costly greenhouse gas reduction policies which will yield indeterminate results far into the future. Until there is more definite scientific evidence about the effects of greenhouse gases on the environment, public policies dealing with global warming will remain highly controversial.

Global Warming Vocabulary

Adaptation
the adjustment by both human and natural systems to new climatic conditions

Carbon Dioxide
CO_2 the most abundant greenhouse gas

Carbon Cycle
a process occurring in nature that maintains a balance between the release of carbon compounds from their sources and their absorption in sinks, such as oceans and forests

Carbon Sink
natural systems in the environment, such as forests and oceans, that absorb carbon compounds such as $C0_2$; oceans are the largest active carbon sink

CFCs
chloroflorocarbons, the only manmade greenhouse gas; released from refrigeration units, aerosol sprays, and insulating foams; present m the atmosphere in small, but increasing concentrations

Cost Benefit Analysis
a technique used in economic analysis to compare the costs and benefits of various policy options

Energy Efficiency
the amount of energy it takes to do a certain amount of work

Fossil Fuels
nonrenewable fuels, such as coal, oil, and natural gas (all contain carbon)

GCMs
general circulation models; complex mathematical computer models used to predict global climate change

Global Warming
the possible increase in average global temperature resulting from greater concentrations of greenhouse gases.

Greenhouse Effect
the warming influence produced by greenhouse gases as they absorb energy radiated from the earth; without this effect, the earth's temperatures would be much cooler

Greenhouse Gases

trace gases, such as carbon dioxide, methane, nitrous oxide, and CFCs

Mitigation
the reduction of offsetting greenhouse gas emissions

Photosynthesis
a process shared by all green plants by which solar energy is converted to chemical energy. Carbon dioxide taken in by the leaves is broken down into carbon, which is retained by the plant, and oxygen, which is released into the atmosphere. h this capacity, plants serve as a carbon sink.

Spillover Cost
when the harmful effects of pollution are imposed on individuals not directly involved in the buying and selling decisions that caused the pollution

Trade-off
giving up some of one thing in order to get some of another. For example, countries that implement significant greenhouse emission reduction policies are trading off economic growth for protection against possible climate change. Countries that do not reduce emissions are trading off protection against possible climate change for more economic growth.

[6] National Academy of Sciences, *Policy Implications of Greenhouse Warming*. (Washington, D.C.: National Academy Press, 1991), pgs. 18,93.
[7] George C. Marshall Institute, *Global Warming Update: Recent Scientific Findings* (Washington, D.C.: The George c. Marshall Institute, 1992), pgs. 25-26.
[8]*National Academy of Sciences,* p.76
[9]David D. Kemp, *Global Environmental Issues* (London and New York: Routledge, 1990), pgs. 160-161. The main proponent of the natural experiment view, Sherwood Idso, has published extensively on this issue.
[10]George C. Marshall Institute, *Global Warming Update,* pgs. 22-24.
[11]Jan Beyea, "Energy Policy and Global Warming," in Richard Wyman (ed.), *Global Climate Change and Life on Earth* (New York: Chapman and Hall, 1991), p. 224.
[12]World Bank, *World Development Report 1992* (New York: Oxford University Press, 1992), p.2.
[13]World Bank, *World Development Report 1992,* p. 161.
[14]George C. Marshall Institute, *Global Warming Update,* p.5. The Institute report notes that "nearly the entire observed rise of 0.5 degrees Centigrade (in average global temperature rise during the last 100 years) occurred before 1940. However, most of the manmade carbon dioxide entered the atmosphere after 1940. The greenhouse gases cannot explain a temperature rise that occurred before these gases existed." (p.3)
[15]Quoted in *"Beware of False Gods of Rio,* " Wall Street Journal, June 1,1992. The full text of the Heidelberg Appeal and the names of the signers appear in this article.

Teaching Instructions

Overview:

The specific teaching activities in this unit do not necessarily have to be done in order. However, the Case Study probably should be done toward the end of the unit, when students have mastered much of the basic information.

Some of the basic information to teach your students is in the Facts About Global Warming section. Other information is available from a variety of sources. Encourage your students to research this information on their own. The Further investigations section suggests a variety of research activities.

Some of the key economic concepts your students should learn are described below in the Important Concepts to Emphasize section. The Key Questions to Ask Students section should also be helpful.

Important Concepts To Emphasize:

1. Carbon Dioxide Emissions as a Spillover Cost. A carbon tax is a current public policy consideration because many believe that carbon dioxide emissions from fossil fuels contribute to the problem of global warming, with potentially great societal costs. To the extent that this is true, $C0_2$ emissions are a spillover cost (external cost) of production, since the costs of producing goods and services using fossil fuels do not reflect accurately the full social costs of production. The tax is an attempt to *internalize* the negative external affects of carbon dioxide emissions.

2. **Is a Carbon Tax a Good Idea?** *If it* is determined that global warming is indeed a danger, a carbon tax may be a good policy option for several reasons. First, because the tax would cover $C0_2$ *emissions,* firms would have an economic incentive to reduce their emissions. Second, a carbon tax can achieve overall $C0_2$ reductions at far less overall cost to society than "command and control" regulations. Not only are administrative costs lower, but a properly designed tax would encourage emission reductions by those firms that could accomplish the reductions at a low cost. Third, it is a "corrective tax," one that improves the functioning of the market by internalizing the presumed harmful spillover costs of $C0_2$ emissions. Fourth, a higher price for fossil fuels (to reflect their full social costs to the environment) would reduce the amount demanded and would encourage the development of alternative energy sources.

There would also be some disadvantages to a carbon tax. The tax would probably result in a greater burden on lower income groups. It would also have a very adverse effect on states that rely heavily on fossil fuel production, such as West Virginia. Also, a carbon tax would increase product prices in the United States and would have a negative impact on the United States balance of trade. This is because the United States uses more energy per unit of GDP than Japan and most European countries. This high energy/GDP ratio occurs for several reasons. First, the United States is a very large country that depends heavily on long distance freight and passenger travel. Also, the United States has extreme climate variability, resulting in high energy use for heating and cooling. This heating and cooling impact is significant because land in the United States is not as scarce as in these other countries, and houses tend to be much larger.

3. **Opportunity Cost and Trade-Offs**: Any policy choice will involve opportunity costs and trade-offs among policy goals. Tax monies are limited and choices must be made among competing alternatives. Monies used for climate research cannot be used for cancer research. Also, different policies will always reflect different social goals. For example, advocates of a "do nothing at this time" policy toward global warming probably favor economic growth over certain environmental goals. Public policy compromises involve trade-offs among policy goals.

4. **Marginal Benefit/Marginal Cost**: The real issue in this case study is not the advantages or disadvantages of the carbon tax, but the more fundamental issue of whether the United States should act to mitigate greenhouse emissions in the midst of major uncertainty about climate change. If scientists determined that there were some adverse effects from increasing greenhouse gases, would avoiding these effects be worth the enormous cost of not using cheap and abundant fossil fuel resources? The availability of these fuels has enabled many people throughout the world to raise their standard of living and can enable many more to do so. Is the marginal benefit that we would obtain from mitigating some global warming worth the significant marginal cost of what it would take to do so? That is the real economic question.

Teaching Suggestions:

Review information about global warming with your students.

Discuss the information provided in the Facts About Global Warming section. Also, discuss the data presented in Table 4-1: Carbon Dioxide Emissions.

ACTIVITY 1: GREENHOUSE WARMING: WHAT IS IT? Encourage students to do neat, careful work. Encourage them to research various sources to get information.

ACTIV1TY 2: HOW MUCH IS ENOUGH? Follow the directions given to you very carefully. It should take no more than 20-30 minutes, depending on the amount of discussion/debriefing.

ACTIVITY 3: ANALYZING GREENHOUSE DATA. The key point to emphasize in this activity is that some scientists believe experimental temperature data do not support the fact of global warming as predicted by computer models. The data reveal that most of the warming during the past century occurred *before* 1940. However, it was *after* 1940 that the greatest increases in greenhouse gases occurred. This teaching activity reveals why there is so much scientific uncertainty surrounding the greenhouse effect. See answers to Activity 3.

ACTIVITY 4: FURTHER INVESTIGATIONS. Encourage students to do research on their own. There have been many articles in the popular media on this controversial topic. Encourage students to share information they have learned with their classmates.

ACTIVITY *5:* DEBATING THE ISSUES. Students can debate orally, or can present the views in a written assignment.

ACTIVITY 6: EEE ACTIONS: YOU CAN MAKE A DIFFERENCE! Encourage students to implement some of the suggested activities.

ACTIVITY 7: CASE STUDY: THE CASE OF THE CARBON TAX You can do the case study as a large or small group activity. Students should use the Decision Worksheet and Decision Grid from Unit 1. Discuss different group decisions.

Key Questions to Ask Students:

1. *Why are greenhouse gases considered by some to be a spillover (external) cost?* (Some believe high concentrations of these gases will lead to harmful effects on society, such as climate disruption and flooding. Producers do not have to bear the costs of these adverse effects in production; they are imposed on society.)

2. *Assuming that the greenhouse effect is a real problem, what are the advantages and disadvantages of a carbon tax?* (Advantages: taxing emissions creates incentives to reduce emissions; higher fuel prices as a result of the tax reduce the quantity of fossil fuel purchased and stimulate research in new, less carbon-intensive fuel technologies; it corrects inefficiencies in the market by dealing with negative externalities; it is less costly to administer than "command and control" regulations. Disadvantages: would raise the prices of domestically produced goods and services; would make us less competitive in international markets; could have a disproportionate impact on individuals with low incomes; would harm the economies of certain regions of the United States which produce fossil fuels.)

3. *What are some of the goods and services that will become more expensive if a carbon tax* iv *imposed?* (Electricity, gasoline, all goods and services that require energy for production.) *If your income stayed constant, what might you have to give up? Is a reduction in carbon worth it to you? Why or why not?* (Answers will vary.)

4. *What are some major social goals that are involved in the issue of greenhouse warming?* (Environmental quality, economic growth, jobs and employment, regional equity, price stability, trade competitiveness.)

5. *What are some of the trade-offs among goals that arise in analyzing this issue*. (Example: stressing environmental quality through policies to reduce greenhouse gases means accepting less progress toward the goals of economic growth, income, and trade competitiveness, and vice versa.)

6. *What is the opportunity cost of "doing nothing" to alleviate increases in greenhouse gases?* (Giving up the benefits of having less greenhouse gases m the atmosphere.) What is the opportunity cost of implementing

rigorous policies to reduce greenhouse emissions? (Giving up whatever else could be done with the money and resources it would take to implement these policies.)

Table 4-1: Carbon Dioxide Emissions

(1988 Estimates)

Country	Total $C0_2$ Emissions (Million tons/yr.)	Per Capita $C0_2$ Emissions	$C0_2$ Emissions per unit of GDP (Million tons $C0_2$ /$1000 GDP)
China	2236.3	2.1	6.01
East Germany	327.4	19.8	2.05
France	320.1	5.9	.34
Japan	989.3	8.1	.35
Romania	220.7	9.5	2.77
United Kingdom	559.2	9.9	.80
United States	4804.1	19.4	.98
USSR	3982.0	13.9	1.50
West Germany	669.9	11.0	.56

Source: National Academy of Science, Policy Implications of Greenhouse Warming, National Academy Press, Washington, DC, pgs 7-8

Source: Indiana Department of Education, Energy Environment, & Economics