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Environmental Awareness: Introduction to Green House Gas Sources, Impacts, and Control

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Environmental Awareness: Introduction to Green House Gas Sources, Impacts, and Control

Course Content

Green House Gases and Global Warming are issues regularly discussed in the news and important factors in the US economy. This course presents basic information on the chemicals considered to be Green House Gases, the sources of these emissions, relative emission quantities from all sectors, and how these estimates are developed. At the completion of this course, the student should have a basic understanding of the activities that contribute Green House Gases and ideas on steps that can be taken to control them.

1. Climate, Weather, and Green House Gases (Reference 1)

Climate is the average weather, including seasonal extremes and variations, either locally, regionally, or across the globe. In any one location, weather can change very rapidly from day to day and from year to year, even within an unchanging climate. These changes involve shifts in, for example, temperatures, precipitation, winds, and clouds. In contrast to weather, climate is generally influenced by slow changes in features like the ocean, the land, the orbit of the Earth about the sun, and the energy output of the sun.

Climate is controlled by the long-term balance of energy between the Earth and its atmosphere. Incoming radiation from the sun, mainly in the form of visible light, is absorbed at the Earth's surface and in the atmosphere above. On average, absorbed radiation is balanced by the amount of energy returned to space in the form of infrared "heat" radiation.

Green House Gases such as water vapor and carbon dioxide, as well as clouds and small particles (called aerosols), trap some heat in the lower part of the Earth's atmosphere. This is called the greenhouse effect. If there were no natural greenhouse effect and heat was not trapped in the lower part of the atmosphere, the average surface temperature would be about 34°C (61°F) colder than it is today.

Winds and ocean currents redistribute heat over the surface of the Earth. The evaporation of surface water and its subsequent condensation and precipitation in the atmosphere redistribute heat between the Earth's surface and the atmosphere, and between different parts of the atmosphere. The natural redistribution process and results strongly influence weather but do not by themselves change climate.

Natural events can cause changes in climate. For example, large volcanic eruptions put tiny particles in the atmosphere that block sunlight, resulting in a surface cooling of a few years' duration. Variations in ocean currents change the distribution of heat and precipitation. El Niño events (periodic warming of the central and eastern tropical Pacific Ocean) typically last one to two years and change weather patterns around the world, causing heavy rains in some places and droughts in others. Over longer time spans, tens or hundreds of thousands of years, natural changes in the geographical distribution of energy received from the sun and the amounts of Green House Gases and dust in the atmosphere have caused the climate to shift from ice ages to relatively warmer periods, such as the one we are currently experiencing.

2. Green House Gases and Global Warming

Although the Earth's atmosphere consists mainly of oxygen and nitrogen, neither plays a significant role in enhancing the greenhouse effect because both are essentially transparent to terrestrial radiation. The greenhouse effect is primarily a function of the concentration of water vapor, carbon dioxide (CO_2), and other trace gases in the atmosphere that reduce by absorption the terrestrial radiation leaving the surface of the Earth. Changes in the atmospheric concentrations of these greenhouse gases can alter the balance of energy transfers between the atmosphere, space, land, and the oceans.

Human activities can intensify the greenhouse effect by increasing Green House Gas emissions, leading to the phenomenon of Global Warming. In particular, there is substantial world-wide concern at this time that the industrial revolution and consequent changes to the environment have caused a significant increase in average earth temperature. Evidence of Global Warming includes the reduction in size of glaciers and increases in sea levels.

As noted above, there are natural causes for climate change. The concern today is that human activities are influencing Global Warming via increased anthropogenic sources of Green House Gases. (Anthropogenic is a change in nature influenced or caused by human activity.) For example, the atmospheric amounts of many Green House Gases are increasing, especially carbon dioxide, which has increased by 30% over the last 200 years. The cause for this increase is believed to primarily result from changes in land use (e.g., deforestation) and burning of fossil fuels (e.g., coal, oil, and natural gas) by automobiles, industry, and electricity generation.

Green House Gas emissions have been estimated and a world-wide inventory has been developed since 1992 (Reference 2). Based on the inventories and current trends, it is estimated that the amount of carbon dioxide in the atmosphere would double during the twenty-first century, with further increases thereafter. The amounts of several other greenhouse gases would increase substantially as well. The consequences of these increases are predicted to be a continued increase in temperature, a continued reduction in glacier size, and a continued rise in sea levels.

3. Green House Gases and Chemicals (Reference 2)

Green House Gases include naturally occurring and anthropogenic sources from industrial activities. The categories of Green House Gases of major interest because they contribute to changes in the atmosphere include:

Naturally occurring Green House Gases

- Water vapor (H20)
- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Ozone (O_3)

Industrial Sources of halogenated substances

- Contain fluorine, chlorine, or bromine
- Chlorofluorocarbons (CFCs)
- Hydrochlorofluorocarbons (HCFCs)
- Bromofluorocarbons (i.e., Halons).

Stratospheric ozone depleting substances

- CFCs
- HCFCs
- Halons

Fluorine-containing halogenated substances that do not deplete stratospheric ozone but are a potent Green House Gas include:

- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulfur hexafluoride (SF_6)

There are also several gases that do not have a direct global warming effect but influence the formation or destruction of other Green House Gases, including tropospheric (close to the Earth surface) and stratospheric (upper atmosphere) ozone. These gases include:

- Carbon monoxide (CO)
- Oxides of nitrogen (NOx)
- Non-methane volatile organic compounds (NMVOCs)

Aerosols, which are extremely small particles or liquid droplets, such as those produced by sulfur dioxide (SO_2) or elemental carbon emissions, can also affect the absorptive characteristics of the atmosphere and therefore the net energy balance for the Earth.

4. Measuring and Reporting Green House Gas Emissions (Reference 2)

In 1992, under the United Nations Framework Convention on Climate Change (UNFCCC), the United States, along with 185 other countries, agreed to develop and submit a national inventory of anthropogenic Green House Gas emissions and sinks. (A sink represents the reduction of a Green House Gas; e.g., carbon in biomass derived from atmospheric carbon dioxide.) To fulfill this obligation, each year the US Environmental Protection Agency (EPA) prepares the official *Inventory of US Greenhouse Gas Emissions and Sinks* (**Reference 2**) in cooperation with the US Department of State and other US government agencies. Under the direction of the Intergovernmental Panel on Climate Change (IPCC), hundreds of scientists and national experts collaborated in developing a set of methodologies and guidelines to help countries create inventories that are comparable across international borders.

Gases included in the inventory can contribute to the greenhouse effect both directly and indirectly.

Direct effects occur when the gas itself absorbs radiation.

Indirect effects are termed "radiative forcing" and occur when:

- Chemical transformations of the substance produce other Green House Gases,
- A gas influences the atmospheric lifetimes of other gases, and/or
- A gas affects atmospheric processes that alter the radiative balance of the earth (e.g., affect cloud formation).

The Intergovernmental Panel (IPCC) developed the Global Warming Potential concept to compare the ability of each Green House Gas to trap heat in the atmosphere relative to another gas. A gauge of these changes is called "radiative forcing", which is a simple measure of changes in the energy available to the Earth-atmosphere system. Holding everything else constant, increases in Green House Gas concentrations in the atmosphere will produce positive radiative forcing (i.e., a net increase in the absorption of energy by the Earth).

The Global Warming Potential for a Green House Gas is defined as a dimensionless ratio:

> Global Warming Potential is the ratio of the time-integrated radiative forcing from the instantaneous release of 1 kg of a trace substance relative to that of 1 kg of a reference gas.

The reference gas selected for developing the Global Warming Potential is Carbon Dioxide (CO_2). The Global Warming Potential for other Green House Gases is determined by estimating the long-term effect on energy absorption, considering factors such as persistence in the atmosphere and relative absorption over a long period of time. The Global Warming Potential is calculated as a dimensionless conversion factor to report the Green House Gas emissions as the CO2 equivalent emissions. The relationship between a gas and its CO_2 equivalent can be expressed as follows:

$$CO_2 \text{ Equivalent, grams} = (\text{Gas, grams}) \times (\text{Global Warming Potential})$$

The Global Warming Potential for each Green House Gas has been estimated by the IPCC as shown in Table A.

Table A: Global Warming Potentials (100 Year Time Horizon)

GAS	Chemical	Global Warming Potential Factors (Relative to CO_2)
Carbon Dioxide	CO_2	1
Methane	CH_4	21
Nitrous Oxide	N_20	310
Hydrofluorocarbons	HFC-23	11,700
"	HFC-32	650
"	HFC-125	2,800
"	HFC-134a	1,300
"	HFC143a	3,800
"	HFC-152a	140
"	HFC-227ea	2,900
"	HFC-236fa	6,300
"	HFC-4310mee	1,300
Chlorofluorcarbons	CF_4	6,500
"	C_2F_6	9,200
"	C_4F_{10}	7,000
"	C_6F_{14}	7,400
Sulfur Hexafluoride	SF_6	23,900

Source: **Reference 2**

The methane Global Warming Potential includes the direct effect of absorption and indirect effects due to the production of tropospheric ozone and stratospheric water vapor. The indirect effect due to the production of CO_2 is not included.

A Global Warming Potential factor is not defined for CO, NOx, NMVOCs, SO_2, and aerosols because these are short-lived in the atmosphere, spatially variable, or have only indirect effects on radiative forcing (**Reference 2**).

Estimates of Green House Gases from all world-wide sources have been developed since the 1990s and inventories for the US have been prepared since 1990. (Section 7 discusses the results of the US inventories.) The method used includes estimating the emission of each Green House Gas and converting this to the Carbon Dioxide equivalent. A defined protocol is followed by all international agencies preparing the individual inventories. The emissions are then summed and reported as CO_2 equivalents in Teragrams:

- 1 Teragram = 10^{12} grams
- 1 Teragram = one billion kilograms
- 1 Teragram = 2.2 billion pounds
- 1 Teragram = 1.1 million tons (2000 pounds/ton)
- 1,000 Teragram = 1.1 billion tons

In 2003, total US Green House Gas emissions were 6,900.2 Teragrams CO_2 Equivalent, which is equivalent to 7.6 billion tons of carbon dioxide emissions.

5. Measuring and Reporting Green House Gas Emissions (Reference 1)

Energy Sector

Historically, energy-related activities have accounted for more than three-quarters of Global Warming Potential-weighted Green House Gas emissions. Most of these are carbon dioxide emissions; however, some emissions of methane and nitrous oxide also result from stationary and mobile combustion. Almost all emissions from the energy sector result from fossil fuel combustion, which includes the burning of coal, natural gas, and petroleum. Fossil fuel combustion from stationary sources, such as electricity generation, represents more than half of energy-related emissions, while combustion of fossil fuels by mobile sources, such as automobiles, represents approximately one-third. In addition to fossil fuel combustion-related activities, carbon dioxide is also emitted as a result of natural gas flaring and biomass burning. Methane is emitted through coal mining as well as the production, processing, transmission, and distribution of natural gas and petroleum.

Industrial Processes

Industrial processes emit Green House Gases as a by-product of various non-energy related industrial activities. Manufacture of cement, lime, soda ash, iron, steel, aluminum, ammonia, titanium dioxide, and ferroalloys produces carbon dioxide as a by-product. The consumption of limestone, dolomite, and carbon dioxide as raw materials in industrial applications also releases carbon dioxide emissions. The production of petrochemicals and silicon carbide result in small amounts of methane emissions, while producing nitric and adipic acid generates nitrous oxide emissions. Emissions of HFCs, PFCs, and SF_6 are particularly important as substitutes for ozone-depleting substances such as chlorofluorocarbons (CFCs). These gases may also be emitted as a result of aluminum and hydrochlorofluorocarbon (HCFC-22) production, semiconductor manufacturing, electrical transmission and distribution, and magnesium production and processing.

Agriculture

Agricultural activities contribute directly to emissions of methane and nitrous oxide. The majority of nitrous oxide emissions occur because cropping and fertilizer practices increase the quantity of reactive nitrogen in the soils. This occurs through application of commercial fertilizers, livestock manure, and sewage sludge; production of nitrogen-fixing crops and forages; retention of crop residues on the field; and the cultivation of soils high in organic matter. These activities make more nitrogen available for the generation of nitrous oxide through microbial activity. The normal digestive processes in ruminant livestock (known as enteric fermentation) account for the largest portion of methane emissions. The agriculture sector also emits methane and nitrous oxide from managed and unmanaged manure, rice cultivation, and the burning of agricultural residues.

Land Use Change and Forestry

The natural carbon fluxes between biomass, soils, and the atmosphere result in a net removal of carbon dioxide from the atmosphere. This natural flux can change when humans alter the terrestrial biosphere through land-use, changes in land-use, and forest management practices. Various forest, agricultural soil, and land management practices can result in the uptake (i.e., sequestration) or emission of carbon dioxide. Forestlands contribute the most to the net uptake of carbon dioxide, followed by agricultural soils.

Waste Management

Waste management and treatment activities are another source of Green House Gas emissions in the United States. Landfills are the nation's largest source of anthropogenic methane emissions. Wastewater treatment systems, including human sewage treatment, are also sources of methane and nitrous oxide emissions.

6. Overall Trends for Green House Gases (Reference 2)

It is estimated that human activities have changed the atmospheric concentration of direct Green House Gases since the pre-industrial era (i.e., since about 1750) (**Reference 2**):

- Carbon dioxide (CO_2) increased by 31 %
- Methane (CH_4) increased by 150 %
- Nitrous oxide (N20) increased by 16 %

Beginning in the 1950s, the use of Chlorofluorocarbons (CFCs) and other stratospheric Ozone Depleting Substances increased by nearly 10 percent per year until the mid-1980s. At that time, international concern about ozone depletion led to restrictions on manufacture and use (referred to as the *Montreal Protocol)*. Since then, the production of Ozone Depleting Substances is being phased out. In recent years, use of Ozone Depleting Substance substitutes such as Hydrofluorocarbons (HFCs) and Perfluorocarbons (PFCs) has grown as they begin to be phased in as replacements for CFCs and HCFCs. Accordingly, atmospheric concentrations of these substitutes have been growing (**Reference 2**).

Total US Green House Gas emissions have risen by 13 percent from 1990 to 2003, while the US gross domestic product has increased by 46 percent over the same period (**Reference 2**). Important factors in emissions from year to year include:

- Economic growth leading to increased demand for electricity and fossil fuels
- Energy prices (e.g., rising natural gas prices cause some electric power producers to switch to burning coal)
- Weather and comfort heating and cooling

7. Contributions of Green House Gases by Sector

Listed below are estimates for Green House Gas emissions in the US for several years since 1990. The individual sectors are discussed below.

Table B: Recent Trends in US Green House Gas Emissions and Sinks by Sector (Reported as Teragram CO_2 Equivalent) (Reference 1)

SECTOR	1990 Teragrams CO_2 Eq. % of Total	2000 Teragrams CO_2 Eq. % of Total	2003 Teragrams CO_2 Eq. % of Total
Energy	5,141.7 84.5 %	5,985.3 86.1 %	5,964.4 86.4 %
Industrial Processes	299.9 4.9 %	332.1 4.8 %	308.6 4.5 %
Solvent and Other Product Use	4.3 < 0.1 %	4.8 < 0.1 %	4.8 < 0.1 %
Agriculture	426.5 7.0 %	444.1 6.4 %	433.3 6.3 %
Land-Use Change and Forestry (Emissions)	5.6 < 0.1 %	6.3 < 0.1 %	6.4 < 0.1 %
Waste	210.1 3.5 %	180.6 2.6 %	183.8 2.7 %
Total Green House Gas Emissions (All Sources)	**6,088.1** **100 %**	**6,953.2** **100 %**	**6,900.2** **100 %**
Agriculture and Forestry Net Flux (Sinks)	(1,042.0) 17.1 %	(822.4) 11.8 %	(828.0) 12.0 %
Net Emissions (Sources and Sinks)	**5,046.1** **82.9 %**	**6,130.8** **88.2 %**	**6,072.2** **88.0 %**

Some important observations from these inventory estimates:

- Total Emissions increased from 1990 to 2000 (14%) and 2000 to 2003 (< 1 %)
- The Energy Sector increase represents most of the increase (98.7 %)
- Sinks (Agriculture and Forestry) decreased from 1990 to 2003 (- 20.5 %)

Data from the 2003 US inventory are included in Table C for the major Green House Gases in order of magnitude. Carbon dioxide emissions from fossil fuel combustion — particularly from mobile combustion in road vehicles and stationary combustion of coal, gas, and oil — are the most substantial US sources. Some observations from the data in Tables B and C for each sector include:

Energy Sector

- Emissions result from stationary sources and activities including fuel combustion and fugitive fuel emissions.
- Energy-related activities, primarily combustion, account for the vast majority of US CO_2 emissions.
- Approximately 86 percent of the energy consumed in the United States was produced through fossil fuels indicating a strong link between energy use and Green House Gas emissions.
- The remaining 14 percent of energy consumed in the United States came from other energy sources such as hydropower, wind, and solar energy which do not directly generate Green House Gas emissions.
- Support activities for energy generation also generate some Green House Gases, so that the overall energy sector accounts for a combined 87 percent of total US Green House Gas emissions in 2003.

Industrial Processes Sector

- Emissions include by-product or fugitive emissions of Green House Gases from industrial processes (but do not include emissions directly related to energy activities, e.g., energy from fossil fuel combustion)
- Emissions from industrial processes release HFCs, PFCs and SF_6.
- Overall, emission sources in the Industrial Process chapter account for 4.5 percent of US Green House Gas emissions in 2003.

Agriculture Sector

- Emissions are from a variety of processes (except fuel combustion, which is included with the Energy Sector) including:
    - Enteric fermentation in domestic livestock
    - Livestock manure management
    - Rice cultivation
    - Agricultural soil management
    - Field burning of agricultural residues
- Methane emissions from enteric fermentation and manure management represented about 21 percent and 7 percent of total CH_4 emissions from anthropogenic activities, respectively in 2003.
- Agricultural soil management activities were the largest source of US N_2O emissions in 2003, accounting for 67 percent of N_2O emissions; mobile transportation (39.9 %) is next largest source of N_2O emissions

Table C: Key Source Categories for the United States (Reference 2)

Source Categories	Gas	2003 Emissions (Teragram CO_2 Equivalent)
Energy		
Emissions from Stationary Combustion – Coal	CO_2	2,013.8
Mobile Combustion: Road & Other	CO_2	1,538.5
Emissions from Stationary Combustion - Gas	CO_2	1,134.9
Emissions from Stationary Combustion - Oil	CO_2	635.3
Mobile Combustion: Aviation	CO_2	171.3
Fugitive Emissions from Natural Gas Operations	CH_4	125.9
Emissions from Non-Energy Use of Fuels	CO_2	118.0
International Bunker Fuels	Several	85.1
Mobile Combustion: Marine	CO_2	57.5
Fugitive Emissions from Coal Mining and Handling	CH_4	53.8
Mobile Combustion: Road & Other	N_2O	39.9
Fugitive Emissions from Oil Operations	CH_4	17.1
Industrial Processes		
Emissions from Substitutes for Ozone Depleting Substances	Several	99.5
Emissions from Iron and Steel Production	CO_2	53.8
Emissions from Cement Production	CO_2	43.0
Emissions from Ammonia Production and Urea Application	CO_2	15.6
Emissions from Electrical Equipment	SF_6	14.1
Emissions from HCFC-22 Manufacture	HFCs	12.3
Emissions from Adipic Acid Production	N_2O	6.0
Emissions from Aluminum Production	PFCs	3.8
Agriculture		
Direct Emissions from Agricultural Soils	N_2O	155.3
Emissions from Enteric Fermentation in Domestic Livestock	CH_4	115.0
Indirect Emissions from Nitrogen Used in Agriculture	N_2O	98.2
Emissions from Manure Management	CH_4	39.1
Waste		
Emissions from Solid Waste Disposal Sites	CH_4	131.2
Emissions from Wastewater Handling	CH_4	36.8
Emissions from Waste Incineration	CO_2	18.8
Subtotal of Key Source Emissions		**6,833.6**
Total Emissions		**6,900.2**

- In 2003, emission sources in the Agricultural sector were responsible for 6.3 percent of total US Green House Gas emissions.

Land-Use Change and Forestry Sector

- Table D summarizes the change in sinks (reductions) and sources
- Sequestration (Uptake) Activities (i.e., carbon sinks)
    - Forests (including vegetation, soils, and harvested wood) accounted for approximately 91 percent of total 2003 sequestration
    - Urban trees accounted for 7 percent of total 2003 sequestration
    - Agricultural soils (including mineral and organic soils and the application of lime) accounted for 1 percent of total 2003 sequestration
    - Landfilled yard trimmings and food scraps accounted for 1 percent of the total sequestration in 2003
    - Carbon sink (sequestration) of 828.0 Teragram CO_2 Equivalent represents an offset of approximately 14 percent of total US CO_2 emissions, or 12 percent of total gross Green House Gas emissions in 2003
    - Total land use, land-use change, and forestry net carbon sequestration declined by approximately 21 percent between 1990 and 2003 (from 1,042.0 to 828.0 Teragram CO_2 Equivalent)

- Emissions
    - Land use, land-use change, and forestry activities in 2003 also resulted in Green House Gas emissions (6.4 Teragram CO_2 Equivalent)

Table D: Net CO_2 Flux from Land-Use Change and Forestry (Teragrams CO_2 Equivalent) (Reference 1)

ACTIVITY (SINKS)	1990	2000	2003
Forest Carbon Stocks	(949.3)	(747.9)	(752.7)
Agricultural Soil Carbon	(8.1)	(5.7)	(6.6)
Urban Trees	(58.7)	(58.7)	(58.7)
Landfilled Yard Trimmings & Food	(26.0)	(10.2)	(10.1)
Total Sink (reductions)	(1,042.0)	(822.4)	(828.0)

Waste Sector

- Landfills were the largest source of anthropogenic methane emissions, accounting for 24 percent of total US CH_4 emissions
- Overall Waste Sector emission sources accounted for 2.7 percent of total US Green House Gas emissions in 2003

8. Controlling Green House Gas Emissions

Measure Baselines

One immediate action to control Green House Gas emissions has included measurements for the US annual inventory and for the world-wide inventory. Much progress has been made in improving the techniques for these estimates. Approaches for developing and evaluating Green House Gas emissions data include:

- Year over year comparisons (overall measurement)
- Unit emissions (normalize to production)
- Benchmark (normalize to best practices)

Typically, targets for reduction of Green House Gas emissions are based on measurements with annual and long-term goals established.

Energy Impact and Controls

The biggest opportunity for control of Green House Gas emissions lies with the energy sector, including both fixed and mobile sources. Opportunities and approaches include:

- Reduce energy use
- Improve energy use efficiency
- Change type of energy use to "non" Green House Gas sources (e.g., solar)
- Replacing "fossil" fuels with renewable resources (e.g., replacing oil with ethanol). Although replacing oil with ethanol still results in Green House Gas emissions of CO_2 this approach does reduce carbon release from fossil sinks.

Managing Sinks

One strategy to increase the sequestration of carbon is by introducing new sinks:

- Planting trees
- Land use practices (don't burn)
- Increasing and/or managing forest area, as well as a net accumulation of carbon stocks in harvested wood pools
- Developing urban forests
- Converting cropland to permanent pasture and hay production
- Increasing adoption of conservation tillage practices
- Increasing use of organic fertilizers (e.g., manure and sewage sludge applied to agriculture lands)
- Landfilling of yard trimmings and food scraps for the long-term accumulation of carbon in landfills.

Industrial Chemical Use and Substitution

Industrial practices present opportunities for reducing certain chemical use. Institutional controls are used to reduce Green House Gas emissions from chemicals with the highest Global Warming Potential (Table A). Current control focus includes:

- Classes of halogenated substances that contain fluorine, chlorine, or bromine
  - Chlorofluorocarbons (CFCs) and Hydrochlorofluorocarbons (HCFCs) (contain chlorine)
  - Halons are bromine containing chemicals (bromofluorocarbons)
- Stratospheric ozone depleting substances (i.e., CFCs, HCFCs, and Halons)
- Non-ozone depleting substances with high Global Warming Potential
  - Hydrofluorocarbons (HFCs)
  - Perfluorocarbons (PFCs)
  - Sulfur hexafluoride (SF6)

Personal Choices

There also are common sense steps that people can make at home or at work to control and reduce Green House Gas emissions:

- Reduce, reuse, and recycle materials
- Use fuel-smart vehicles
- Use alternatives to personal vehicles (e.g., public transportation, car pools)
- Implement building and home energy savings
- Use non-Green House Gas energy sources (e.g., solar)
- Plant and maintain actively growing trees (carbon sinks)

9 References and Information Sources

Reference 1 Common Questions about Climate Change, United Nations Environment Programme - World Meteorological Organization www.gcrio.org.

Reference 2 US Inventory of Greenhouse Gas Emissions and Sinks 1990-2003 (EPA 2005) EPA 430-R-05-003 yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2005.html

Additional References and Web Sites

Global Warming – Resource Center yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterToolsGHGCalculator.html