



Chapter 20

Climate Change and Ozone Depletion



“It’s A Small World After All”

Outline

Past Climate Change and the Greenhouse Effect

- A. Temperature and climate have been changing throughout the earth’s history.
 - 1. Climate shifts have occurred due to volcanic emissions changes in solar input, continents moving on shifting plates, meteor strikes and other factors.
 - 2. Alternating cycles of freezing and thawing are known as glacial and interglacial periods.
- B. Geologic records and atmospheric measurements provide a wealth of information about past atmospheric temperatures and climate.
 - 1. Antarctic ice cores indicate the current interglacial period could last another 15,000 years.
 - 2. Sediment cores are also analyzed for pollen, fossils and other clues about the plant types that lived in the past.
 - 3. Direct temperature records go back to 1861.
 - 4. Air samples are collected at different locations and analyzed for changes in chemical composition in the troposphere.
- C. Certain gases in the atmosphere absorb heat and warm the lower atmosphere
 - 1. A natural process called the greenhouse effect warms the lower troposphere and surface.
 - 2. A large process also takes place at the earth’s surface due to heat absorbed by surface water.
 - 3. The earth’s average surface temperature is about 15 degrees Celsius.
- D. The four major greenhouse gases in the lower atmosphere are water vapor, carbon dioxide, methane, and nitrous oxide.
 - 1. Measurements of CO₂ concentrated in glacial ice correlate fairly closely with estimated variations in the average global surface temperature during the past 160,000 years.
 - 2. The United States releases more greenhouse gases per person than any other country.
 - 3. With about 4.6% of the world’s population, the U.S. produces about 22% of the total global the emission
 - 4. U.S. also emits large quantities of CH₄, with most coming from landfills, domestic livestock natural gas and oil and coal mining.

Climate Change and Human Activities

- A. Humans have increased levels of greenhouse gases in the troposphere by use of fossil fuels, farming, use of inorganic fertilizers, burning forests, etc.
 - 1. Greenhouse gases are at higher levels than in the past 160,000 years.
 - 2. Burning of fossil fuels has generated much of the CO₂ increase.
 - 3. Deforestation and clearing grasslands release CO₂ and N₂O.
 - 4. Increased cattle raising and other livestock has added methane release.
 - 5. Use of inorganic fertilizers in rice cultivation releases N₂O into the troposphere.
 - 6. There is evidence that the earth’s troposphere is warming, mostly because of human actions. The Intergovernmental Panel on Climate Change (IPCC) was formed in 1988 to evaluate possible future climate changes. Conclusions and projections use several levels of certainty: virtually certain (more than 99% probability), very likely (90-99% probability) and likely (66-90% probability).
 - 7. Seven findings of the IPCC that support the scientific consensus that the troposphere is very likely getting warmer are:
 - a. The 20th century was the hottest century in the past 1,000 years
 - b. Since 1861 the average global temperature has risen 0.6 degrees centigrade, with most increase occurring since 1980.
 - c. The 10 warmest years since 1861 have occurred since 1990.
 - d. Over the past 50 years, Arctic temperatures have risen almost twice as fast as those in the rest of the world.
 - e. Glaciers and floating sea ice in some parts of the world are melting and shrinking at increasing rates.
 - f. Warmer temperatures in Alaska and Russia are melting the permafrost, releasing more greenhouse gases into the troposphere.
 - g. The world’s average sea level rose by 10-20 centimeters (4-8 inches).

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- B. There is strong evidence that human activities will play an important role in changing the Earth’s climate during this century.
 - 1. Computer models are used to project future changes in the earth’s average temperature.
 - 2. Global warming refers to temperature increases in the troposphere, which can cause climate change.
 - 3. Global climate change is a broader term that refers to changes in any aspects of the earth’s climate.
- C. A rapid increase in the temperature of the troposphere during this century would give us little time to deal with its harmful effects.

Factors Affecting the Earth’s Temperature

- A. A number of natural and human-influenced factors might amplify or dampen projected changes in the average temperature of the troposphere.
- B. There is uncertainty about how much carbon dioxide and heat the oceans can remove from the troposphere and how long the heat and carbon dioxide might remain there.
- C. One of the largest unknowns in global warming is the change in distribution of clouds.
 - 1. Additional clouds may have a warming effect by absorbing and releasing more heat into the troposphere, or a cooling effect by reflecting more sunlight back into space.
 - 2. Several factors will affect the net result of more cloud cover such as the amount of water vapor in the troposphere, whether clouds are thin or thick, coverage, altitude of the cloud, size and number of water droplets or ice crystals formed in clouds.
- D. Aerosol pollutants and soot can warm or cool the troposphere, but these effects will decline with reduction in outdoor air pollution.
 - 1. Some clouds have a high albedo and reflect more sunlight back into space during the day.
 - 2. Warmer nights are due to clouds that prevent stored heat from dissipating into space. Some aerosols/particulates in the troposphere tend to cool the air, but black carbon aerosols may be responsible for 15-30% of global warming during the past 50 years.
 - 3. Scientists hypothesize that pollution can dim sunlight in two ways: soot particles in the atmosphere reflect some of the sunlight back into space; airborne particles cause more water droplets to condense out of the air, leading to thicker, darker clouds.
 - 4. Scientists don’t expect aerosol pollutants to have a major effect on global warming since they are only in the atmosphere for a short time and they are also being reduced.
- E. Increased CO₂ in the troposphere could increase photosynthesis and remove more CO₂, but several factors can limit or offset this effect.
 - 1. Old-growth Amazon rainforests are experiencing rapid changes in species composition apparently due to higher levels of CO₂ in the atmosphere.
 - 2. When these larger trees reach maturity and die out it could lead to a decrease in the amount of CO₂ absorbed.
- E. Acceleration of global warming can occur because of two major sources of methane gas release: bogs and wetlands and from methane hydrates trapped under arctic permafrost.

Effects of Global Warming

- A. A warmer troposphere could have both beneficial and harmful effects. Rich, temperate countries are likely to benefit from moderate global warming while the poorer tropical and subtropical countries will see more harmful effects.
- B. The melting of some of the world’s ice means that less sunlight is reflected back into space, and helps warm the troposphere further.
 - 1. Increasing temperature tend to be greater in the polar regions. Scientists consider these areas as early warning sentinels of changes in average temperature of earth’s troposphere.
 - 2. Floating ice is melting faster than it is being formed. Ice formations are important for helping to cool the earth by reflecting 80-90% of incoming light back into space.
 - 3. It is not known whether the shrinkage of ice is a result of natural polar climate fluctuation or caused by man-made increases in greenhouse gases or a combination of these.
 - 4. Researchers estimate that up to half of the Arctic sea ice could disappear by 2050. This would shift the storm-guiding jet stream northward and result in less spring and summer water for areas such as California.

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5. The big problem area may well be Greenland if the ice pack completely melts. It would raise sea levels by 7 meters (23 feet).
6. Warmer temperatures are melting glaciers and snow in parts of Alaska.
7. Permafrost is warming and melting in some parts of Alaska and buildings, roads, utility lines and the Alaska pipeline have suffered sinking, shifting and sometimes a break up.
8. There is an increase in infestation of the spruce bark beetle because of lack of cold spells that help to control them.
9. Mt Kilimanjaro, Africa may be ice free within 15 years.
10. Loss of frozen water means a loss of reservoirs of water for warmer months of the year.
- C. Global sea levels are very likely to rise during this century.
 1. The projected rise in sea level is about 88 centimeters (35 inches).
 2. Harmful effects of this rise in sea level include:
 - a. threatening half the world’s estuaries and wetlands and coral reefs
 - b. disruption of many of the world’s coastal fisheries
 - c. flood low-lying barrier islands and gently sloping coastlines will erode and retreat inland about 0.9 miles.
 - d. flood agricultural lowlands and deltas where much of the world’s rice is grown
 - e. contamination of freshwater coastal aquifers with salt water
 - f. submergence of some low-lying islands in the Pacific Ocean and Indian Ocean.
- D. Global warming could alter ocean currents and cause excessive warming in some parts of the world and severe cooling in others.
 1. Oceans help moderate the earth’s average surface temperature by absorbing both CO₂ and heat from the atmosphere.
 2. Ocean currents are also important for storage of CO₂ and transfer of heat.
 3. Movement and speed of the ocean currents may contribute to significant alterations in temperature patterns in the northern hemisphere.
 4. Physical oceanographers have found that the tropical oceans are saltier and the polar oceans are less salty than they were just 40 years ago. It suggests that global warming may be accelerating the global water cycle.
 5. Changes in the hydrologic cycle may affect global precipitation patterns. It may result in regional cooing because of changes in the distribution of water vapor and movement of ocean currents.
- E. A warmer troposphere can decrease the ability of the ocean to remove and store carbon dioxide by decreasing the nutrient supply for phytoplankton and increasing the acidity of ocean water.
- F. Global warming will lead to prolonged heat waves and droughts in some areas and prolonged heavy rains and increased flooding in other areas.
- G. A warmer troposphere will change the distribution and population sizes of wild species, shift locations of ecosystems and threaten some protected reserves and coral reefs.
 1. A warmer climate could expand the ranges and populations of plant and animal species that can adapt to warmer climates.
 2. Warming could also threaten plants and animal species that can’t migrate rapidly enough to new areas.
 3. Many wildlife reserves, wilderness areas, wetlands and coral reefs would be threatened with some loss of biodiversity.
 4. IPCC says it is very likely that tree deaths will increase from more disease and higher pest populations.
 5. Wildfires in forests and grasslands are very likely to increase and destroy wildlife habitats with a large release of CO₂ into the troposphere.
 6. Ecosystems most likely to be disrupted are coral reefs, polar seas, coastal wetlands, arctic and alpine tundra and high-elevation mountaintops.
- H. Food production in some areas may increase in some areas and decrease in others.
 1. Warmer temperatures could shift growing areas farther north, but less fertile soils in these areas may reduce food production.
 2. Less snow packs in high-elevation areas could result in increasing water shortages in areas that are irrigated.
 3. Crop and fish production could be reduced in some areas by rising sea levels that would flood

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river deltas.

- I. Global warming will increase deaths from heat and disruption of food supplies in some areas, spread some tropical diseases to temperate areas, and greatly increases the number of environmental refugees from drought and flooding.
 - 1. Premature deaths from the side effects of global warming and increased incidences of disease are estimated to double by 2030.

Dealing with Global Warming

- A. Climate change is hard to deal with because it has many causes, its effects are uneven and long-term, and there is disagreement over what should be done.
 - 1. The problem is global.
 - 2. The effects will last a long time.
 - 3. The problem is a long-term political issue.
 - 4. The harmful and beneficial impacts of climate change are not spread evenly.
 - 5. Many actions that might reduce the threat of climate change, such as phasing out fossil fuels, are controversial because they can disrupt economics and lifestyle.
 - 6. These characteristics confront us with difficult scientific, economic, political, and ethical questions.
- B. There is disagreement over what we should do about the threat of global warming.
 - 1. Scientists, economists, business leaders, and political leaders debate the causes, how rapidly the changes might occur, the effects on humans and ecosystems and the responses that should be taken.
 - 2. There are two basic ways to deal with global warming; one is mitigation, the other is adaptation.
 - 3. There are two schools of thought concerning what we should do now to reduce or mitigate the effects of global warming. One is to adopt a wait-and-see strategy; the other is to act now.
- C. The solutions offered for slowing the rate and degree of global warming come down to three major strategies: improve energy efficiency to reduce fossil fuel use, shift from carbon-based fossil fuels to a mix of carbon-free renewable energy resources, and sequester or store as much CO₂ as possible in soil, in vegetation, underground, and in the deep ocean.
- D. We can remove and store some CO₂ we produce as shown in figure 20-15.
 - 1. Plant trees that will store CO₂ in biomass.
 - 2. Soil sequestration is a possibility, but warmer temperatures can increase soil decomposition with CO₂ then being returned to the troposphere.
 - 3. Reduce release of CO₂ and nitrous oxide from soil by altering agriculture practices to include no-till cultivation and letting fields lie fallow.
 - 4. Remove CO₂ from smokestacks and pump it deep underground or inject it into the deep ocean. There are several problems with this approach at present.
 - 5. Some scientists suggest adding iron to the oceans to increase production of algae to remove CO₂ through photosynthesis. This is a very temporary solution and we do not know the effects of adding iron to the ocean’s ecosystems.
- E. Governments can tax emissions and energy use, increase subsidies and tax breaks for saving energy and using renewable energy, and decrease subsidies and tax breaks for fossil fuels.
 - 1. One possible solution is to phase in carbon taxes on fossil fuel use and at the same time decrease taxes on income, labor, and profits to offset the consumption taxes.
 - 2. Greatly increase government subsidies for energy-efficiency and carbon-free renewable-energy technologies.
 - 3. A third strategy is technology transfer; transfer knowledge from developed countries to developing countries.
- F. It will probably cost less to help slow and adapt to global warming now than to deal with its harmful effects later.
 - 1. Projected costs of global warming will cost the world \$300 billion annually by 2050.
 - 2. Some studies indicate that implementing conservation strategies would boost the global and U.S. economies.
 - 3. Some economic models indicate the costs exceed the benefits, but these do not include the huge cost savings of the strategies and they underestimate the ability of the marketplace to act

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rapidly when money is to be made.

What is Being Done to Reduce Greenhouse Gas Emissions?

- A. The Kyoto Protocol, developed in 1997 would require 38 developed countries to cut emissions of some gases by about 5.2% below 1990 levels by 2012.
 - 1. Developing countries would not have to make cuts until a later date.
 - 2. By mid-2004 it had been ratified by more than 120 countries.
 - 3. In 2001, President George W. Bush withdrew the U.S. from the Kyoto Protocol.
- B. Countries could work together to develop a new international approach to slowing global warming.
 - 1. Support and action is needed by the world’s largest greenhouse gas emitters the U.S., China, Russia and India.
 - 2. Establishment of a global emissions trading program that includes developing countries omitted from the trading plan under the first phase of the Kyoto Protocol.
- C. Many countries, states, cities, companies, schools, and individuals are reducing their greenhouse gas emissions, improving energy efficiency, and increasing their use of carbon-free renewable energy.
 - 1. The European Union plan to increase use of renewable energy to 12% by 2010 and cut energy use 20% by 2020.
 - 2. China is attempting to reduce its CO₂ emissions by phasing out coal subsidies, shutting down inefficient coal-fired electric plants, stepping up to a 20 year commitment to energy efficiency, and restructuring its economy toward use of renewable energy resources.
 - 3. Some major global companies have established targets to reduce their greenhouse gas emissions by 10-65% from 1990 levels by 2010.
 - 4. Some individuals (see Fig. 20-16) and schools are reducing greenhouse gas emissions and wasting less energy.
- D. Many countries and cities are looking for ways to cope with the harmful effects of climate change.
 - 1. Estimates are that current emissions of greenhouse gases must be cut by at least 60% by 2050 to stabilize concentrations at their present levels.
 - 2. For political and economic reasons, such a reduction is extremely unlikely.
 - 3. We should begin to prepare for possible effects of long-term atmospheric warming.

Ozone Depletion in the Stratosphere

- A. Less ozone in the stratosphere will allow more harmful UV radiation to reach earth’s surface. The overwhelming consensus of researchers is that ozone depletion is a serious threat to humans, other animals, and some of the primary producers that support earth’s food.
- B. Widespread use of a number of useful and long-lived chemicals has reduced ozone levels in the stratosphere.
 - 1. The first chlorofluorocarbon (CFC) was discovered in 1930 by Thomas Midgley. Chemists developed a family of useful CFCs. Freons are the most widely used of these.
 - 2. They had many uses and became very popular since they were inexpensive to manufacture and seemed to be dream chemicals.
 - 3. In 1974, chemists Rowland and Molina found that CFCs were lowering the average concentration of ozone in the stratosphere.
 - 4. Four major conclusions came from their research:
 - a. CFCs remain in the atmosphere because they are insoluble in water and chemically unreactive.
 - b. Over 11-20 years these chemicals are lifted into the stratosphere, mostly by convection currents and turbulent mixing of air.
 - c. CFC molecules break down under the influence of high-energy UV radiation. Chlorine is released and is highly reactive. Fluorine, bromine and iodine are also released. This causes ozone to be broken down faster than it is formed.
 - d. These CFC molecules can last in the stratosphere for 65-385 years.
 - 5. In 1988, after 14 years of delay tactics, the CFC industry acknowledged that CFCs were depleting the ozone and agreed to stop manufacture of them.

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6. Rowland and Molina received the Nobel Prize in chemistry for their work.
- C. During four months of each year up to half of the ozone in the stratosphere over Antarctica and a smaller amount over the Arctic is depleted.
 1. Ozone loss is often called the ozone hole, but it is actually ozone thinning.
 2. The total area of stratosphere that suffers from ozone thinning varies from year to year.
 3. The primary culprits are CFCs and other ODCs.
 4. The polar vortex is a swirling mass of very cold air that is isolated from the rest of the atmosphere for several months. Ice crystals in this mass collect CFCs and other chemicals and set up conditions for formation of ClO, the molecule most responsible for seasonal loss of ozone.
 5. As sunlight returns to Antarctica in October, the light stimulates ClO molecules and within a matter of weeks the ozone is reduced by 40-50% on average.
 6. In 1988 it was discovered that less severe ozone depletion occurs over the Arctic during the arctic spring and early summer with seasonal loss of 11-38%.
 7. It is unlikely that the Arctic thinning will be as severe as that over Antarctica, but it is predicted that the worst ozone thinning will be between 2010 and 2019.
- D. Increased UV radiation reaching the earth’s surface from ozone depletion in the stratosphere is harmful to human health, crops, forests, animals, and materials such as paints and plastics. Figure 20-21 lists the effects of ozone depletion.
- E. Exposure to UV radiation is a major cause of skin cancers.
 1. The primary cause of squamous cell and basal cell skin cancers is years of exposure to UV-B radiation. Fortunately, 90-95% of these cancers can be cured if detected early enough.
 2. Malignant melanoma is a third type of skin cancer that may occur anywhere on the body. It kills a fourth of its victims (most under the age of 40) within 5 years.
 3. Women who used tanning parlors at least once a month increased chances of developing melanoma by 55%.
 4. Evidence suggests that exposure to UV-A may also contribute to skin cancer.
 5. Caucasians are most susceptible to melanomas.

Protecting the Ozone Layer

- A. To reduce ozone depletion we must stop producing all ozone-depleting chemicals.
 1. If we immediately stop producing all ozone-depleting chemicals it will take 60 years for the ozone layer to return to 1980 levels and about 100 years to return to pre-1950 levels.
 2. The goal of the 1987 Montreal Protocol was to cut emissions of CFCs by about 35% between 1989 and 2000.
 3. Representatives met again in 1990 and 1992 and adopted the Copenhagen Protocol, an amendment that accelerated the phase out of key ozone-depleting chemicals.
 4. These agreements have now been signed by 180 countries.
 5. A study in 1998 by the World Meteorological Organization stated that ozone depletion has been cooling the troposphere and helped to disguise as much as 30% of the global warming from greenhouse gas emissions.

Summary

1. The earth’s average surface temperature and climate has changed in the past. The changes include prolonged periods of global cooling and global warming.
2. In the future there will be increased emissions of carbon dioxide, methane, and nitrogen oxide leading to increased natural greenhouse effects.
3. Factor’s influencing changes of earth’s average surface temperature include changes in the solar output, the earth’s reflectivity, the ability of oceans to store carbon dioxide, the ocean currents, the average sea level, cloud cover, and air pollution.
4. Possible effects from a warmer earth include shifts in plant-growing areas, crop yields, and pests, extinction of some species, loss of habitats, prolonged heat waves and droughts, increased flooding,

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changes in water supplies, decreased water quality, changes in forest composition, increased fires, rising sea levels, beach erosion, contamination of aquifers, spread of tropical diseases into temperate zones, increased respiratory diseases and allergies, increased deaths, and migration.

5. To prevent global warming we should limit fossil fuel use, shift from coal to natural gas use, place energy efficient technologies in developing countries, improve energy efficiency, shift to renewable resources, reduce deforestation, use sustainable agriculture, limit urban sprawl, reduce poverty, and slow population growth.
6. Human activities that cause ozone depletion include emissions of chlorofluorocarbons, methyl bromide, hydrogen chloride, carbon tetrachloride, methyl chloroform, and others. We should care about the ozone depletion because it causes sunburns, cataracts, skin cancers, immune suppression, reduced crop yields, reduced seafood supplies, decreased forest productivity, increased acid deposition, increased photochemical smog, and global warming.
7. To slow and eventually eliminate depletion of the ozone layer, we must ban use of all the chemicals that cause it.

Objectives

1. Describe the greenhouse effect and what the Earth would be like without a greenhouse effect. List the two predominant greenhouse gases. List four greenhouse gases which have risen in the last few decades. List four human activities which contribute greenhouse gases to the atmosphere. Distinguish between *greenhouse effect* and *global warming*.
2. Describe the pattern of the earth's average surface-temperature fluctuation throughout geologic time. Describe the period the earth has been experiencing for the last 10,000 years.
3. Describe the general trend of mean global temperature since 1860. List two factors other than the greenhouse effect that may have contributed to the general temperature change. State the consensus science view about the relationship between observed temperature changes and the likelihood of global climate change brought on by human activities.
4. Briefly describe projections of the major climate models regarding changes in mean surface temperature and average sea level. List eight important factors that lend considerable uncertainty to climate models and their projections.
5. State the range of temperature change which could cause real damage to ecosystems. Explain why a range so seemingly small can have such major consequences. Summarize the projections of possible effects of global warming on (a) food production, (b) water supplies, (c) forests, (d) biodiversity, (e) sea levels, (f) weather extremes, (g) human health, and (h) environmental refugees.
6. Describe three schools of thought about global warming and how we as a human society should act. List seven strategies which would slow potential global warming, including both prevention and cleanup approaches.
7. Describe the origin of stratospheric ozone and the role it plays in protecting life on Earth. Briefly describe changes which have been occurring in stratospheric ozone.
8. Describe the scientific work on CFCs and their relationship to ozone. Describe the political response to the scientific information. Summarize the consensus science view of CFCs and stratospheric ozone. Summarize alternative views that have received much attention. Explain the significance of a critically thinking citizenry to the democratic process.
9. Explain the potential consequences of ozone depletion. Propose three ways for slowing these changes.

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Key Terms (Terms are listed in the same font style as they appear in the text.)

<i>adaptation</i> (p. 480) <i>adaptation strategy</i> (p. 485) <i>amplify</i> (p. 471) <i>basal cell skin cancer</i> (p. 488) <i>black carbon aerosols</i> (p. 472) <i>burning fossil fuels</i> (p. 467) <i>cooling effect</i> (p. 472) <i>Copenhagen Protocol</i> (p. 490) <i>coupled global circulation models (CGCMs)</i> (p. 469) <i>dampen</i> (p. 471) <i>early warning sentinels</i> (p. 473) <i>energy taxes</i> (p. 482) <i>glacial and interglacial periods</i> (p. 466) global climate change (p. 470) <i>global cooling</i> (p. 465) <i>global warming</i> (p. 465) global warming (p. 470) <i>greenhouse effect</i> (p. 467) <i>greenhouse gases</i> (p. 467) <i>halons and hydrobromofluorocarbons (HBFCs)</i> (p. 487) <i>hexachlorobutadiene</i> (p. 487) <i>hydrogen chloride</i> (p. 487) Intergovernmental Panel on Climate Change (IPCC) (p. 468) <i>Kyoto Protocol</i> (p. 483) <i>malignant melanoma</i> (p. 489)	<i>carbon dioxide (CO₂)</i> (p. 467) <i>carbon taxes</i> (p. 482) <i>carbon tetrachloride</i> (p. 487) <i>chlorofluorocarbon (CFC)</i> (p. 486) <i>clearing and burning forests</i> (p. 467) <i>climate skeptics</i> (p. 470) <i>methane (CH₄)</i> (p. 467) <i>methane hydrates</i> (p. 473) <i>methyl bromide</i> (p. 487) <i>methyl chloroform</i> (p. 487) <i>mitigation</i> (p. 480) <i>Montreal Protocol</i> (p. 490) <i>natural cooling process</i> (p. 467) <i>nitrous oxide (N₂O)</i> (p. 467) <i>n-propyl bromide</i> (p. 487) <i>ozone hole</i> (p. 487) <i>ozone thinning</i> (p. 487) <i>ozone-depleting compounds (ODCs)</i> (p. 487) <i>planting rice and using inorganic fertilizers</i> (p. 467) <i>polar vortex</i> (p. 487) <i>soil sequestration</i> (p. 481) <i>soot</i> (p. 472) <i>squamous cell skin cancer</i> (p. 488) <i>technology transfer</i> (p. 482) <i>wait-and-see strategy</i> (p. 480) <i>warming effect</i> (p. 472) <i>water vapor</i> (p. 467)
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