Environmental Science, 15e

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15

Air Pollution, Climate Change, and Ozone Depletion

Core Case Study: Melting Ice in Greenland

- Atmospheric warming
  - The gradual rise in the average temperature of the surface atmosphere (over both land and sea)
  - A key factor contributing to the melting of Greenland's glaciers, as well as in long term climate change – a process caused primarily by human activity, and which if left unchecked, will have a harmful effect on global ecosystems and the services they provide

Greenland's Glaciers

- Greenland (the world's largest Island) is mostly covered by glaciers – some as much as 3.2km (2 miles) thick
- If climate change melted all of Greenland's ice, how much might sea level rise?
- Can you see effects of atmospheric warming where you live?

15.1 What Is the Nature Of the Atmosphere?

- The atmosphere is composed of several spherical layers
  - The layer of air directly above the surface is the troposphere, which supports life
  - The layer above this is the stratosphere, which contains the earth's protective ozone layer

The Troposphere and Stratosphere

- The troposphere contains the air we breathe and is composed mainly of nitrogen and oxygen – but also contains greenhouse gasses (H_20, CO_2, CH_4, N_2O)
- The stratosphere is similar in composition to the troposphere, but has much less water vapor and contains the ozone layer

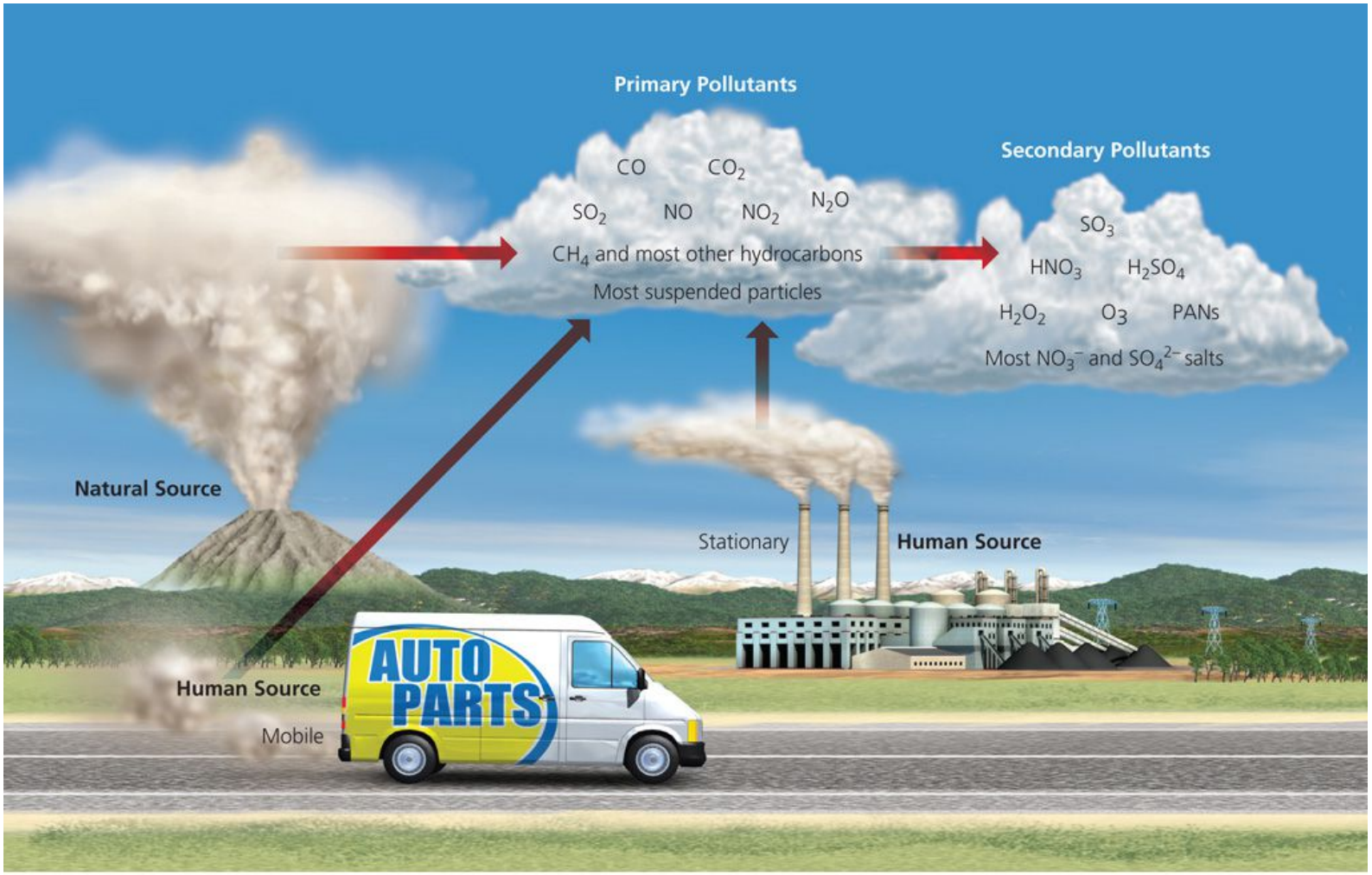
15.2 What Are the Major Air Pollution Problems?

- Outdoor pollution includes industrial smog (burning coal), photochemical smog (industrial emissions and cars), and acid deposition (coal-burning power/industrial plant and cars)
- Indoor pollution includes smoke/soot from wood/coal fires, cigarette smoke, and chemicals in building materials and cleaning products

Sources of Air Pollution

- Air pollution: atmospheric chemicals in high enough concentrations to harm organisms, ecosystems, and alter climate
  - Natural: dust, wildfires, volcanoes, and plants
  - Human activities: burning fossil fuels; car use
- Outdoor air pollutants:
  - Primary: emitted directly into air
  - Secondary: chemicals formed from primary pollutants

Natural and Human Inputs To Air Pollutants



Major Outdoor Air Pollutants

- Carbon oxides
- Nitrogen oxides and nitric acid
- Sulfur dioxide and sulfuric acid
- Particulates: suspended particulate matter
- Ozone
- Volatile organic compounds (VOCs)
  - Hydrocarbons, methane, benzene, and liquid solvents

Smog

- Industrial smog: a mix of sulfur dioxide, sulfuric acid, and particulates
  - China, India, Ukarine, Czech Republic, Bulgaria and Poland
- Photochemical smog: a mix of primary/secondary pollutants/chemicals formed in light activated reactions
  - Los Angeles, Salt Lake City, Sydney, Sao Palo, Bangkok and Mexico City

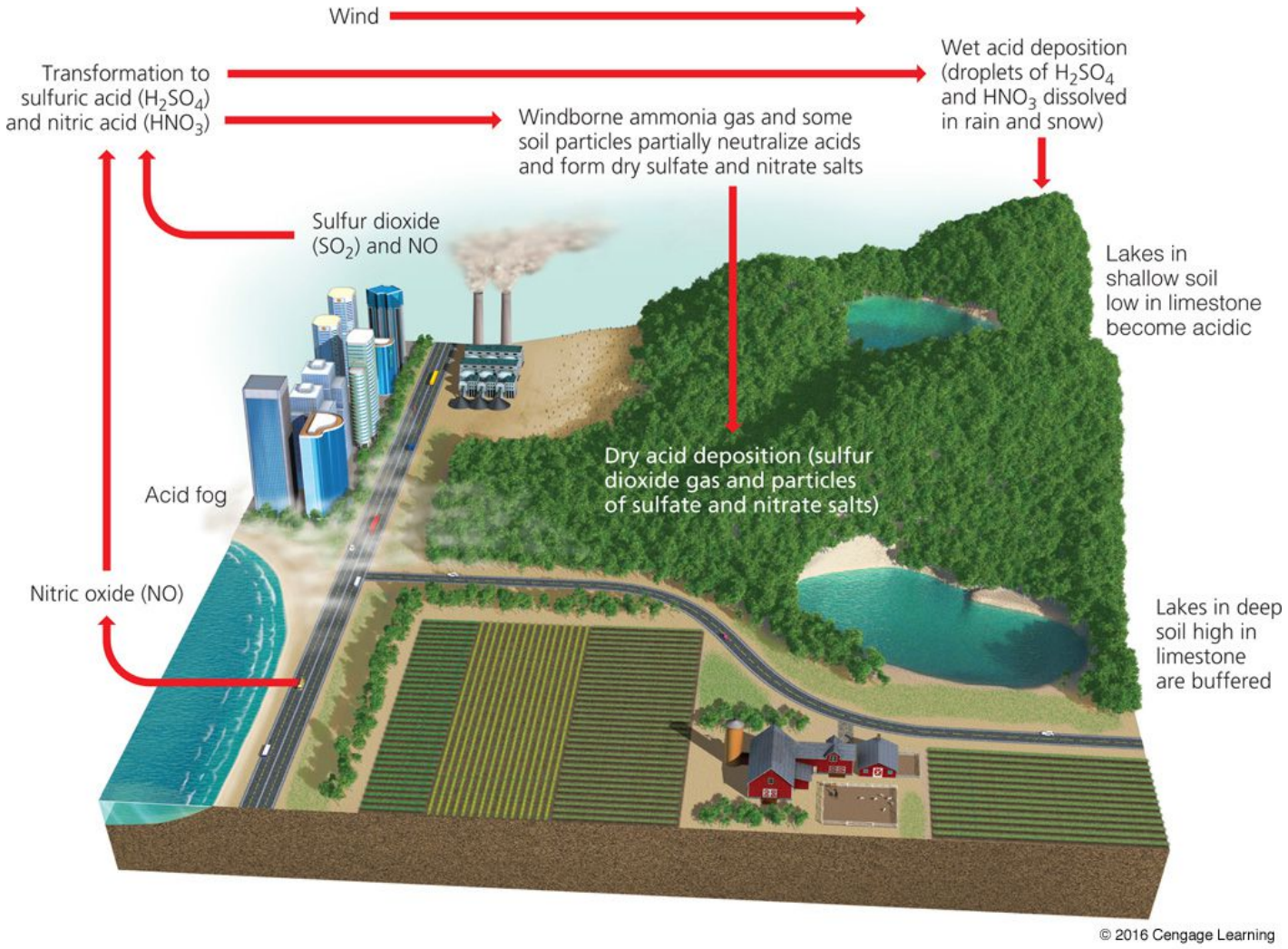
Factors Influencing Outdoor Air Pollution

- Reduced by:
  - Settling of particles heavier than air, cleansing by rain/snow, salty sea spray from the oceans, wind dilution and removal, chemical reactions in the atmosphere
- Increased by:
  - Urban structures that block winds, hills and mountains that block valley ventilation, high temperatures, emission of VOCs, grasshopper effect, temperature inversions

Acid Deposition

- Acidic compounds (H_2SO_4, HNO_3, SO_2^{-4} and NO^{-3}) formed during wind dispersal of outdoor pollutants can on descent result in far flung acid deposition (a mix of wet/dry deposition)
  - Wet deposition: acid rain/snow/cloud vapor; happens slowly in distant downwind areas
  - Dry deposition: acidic particles; happens quickly close to industrial sources

Natural Capital Degradation: Acid Deposition



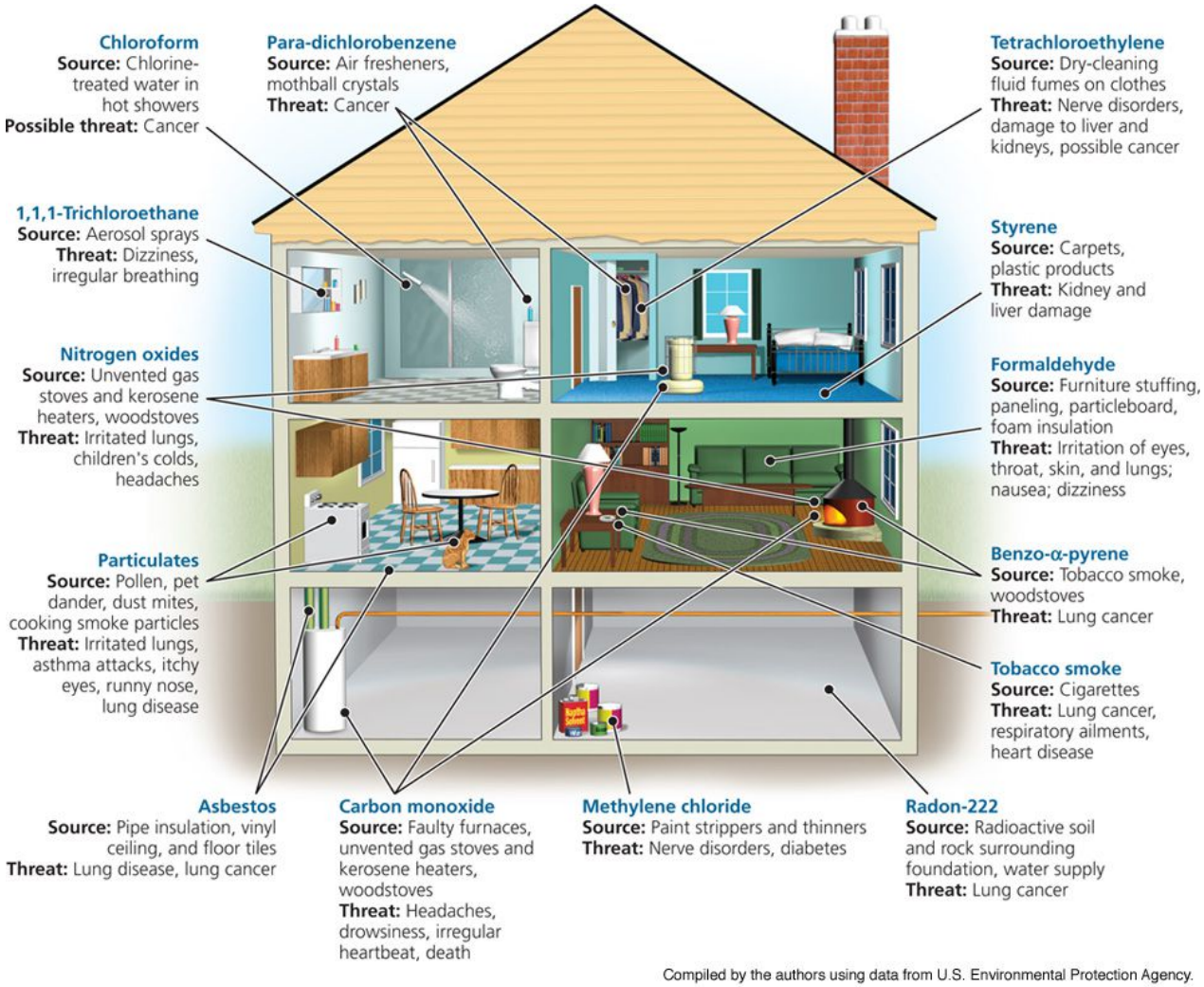
Acid Deposition: Problems and Solutions

- Harms crops, reduces plant productivity, leaches essential nutrients from soil, damages buildings, contributes to human respiratory disease, and leaches toxic metals into the environment that get biomagnified into food webs
- Prevention is the best solution – reduce or eliminate these pollutants from coal-fired power and industrial plants

Indoor Air Pollution

- In less-developed countries, mainly from indoor burning of wood, charcoal, dung, and coal in open fires/poorly vented stoves
- In more-developed countries, from fumes given off by building materials/furniture
  - 11 common air pollutants are higher inside U.S. buildings than outside
  - Air pollution inside cars in congested traffic can be almost 20 times higher than outside

Indoor Pollutants In Modern Houses



Compiled by the authors using data from U.S. Environmental Protection Agency.

Air Pollution Is a Big Killer

- Respiratory system pollution protection:
  - Hairs in your nose filter out large particles
  - Mucus in upper respiratory tract traps smaller particles/dissolves some gaseous pollutants
  - Sneezing/coughing expel contaminated air
  - Hair-like cilia in the upper respiratory tract oscillate and transport mucus/pollutants to your throat (swallowed or expelled)
  - Prolonged or acute exposure to air pollutants can break down these natural defenses

15.3 How Should We Deal with Air Pollution?

- While there are many legal, economic, and technological tools that can help us fight air pollution, the best solution is prevention

Reducing Outdoor Air Pollution

- Enact/regulate/enforce laws/standards
- Strengthen laws by:
  - Prevention, further reducing and controlling emissions (especially for cars and motorcycles), setting stricter regulations for airports and reducing indoor air pollution
- Authorizing/using emissions trading
  - Dependent on how low initial cap is set/how often this level is lowered to improve control

Reducing Indoor Air Pollution

- Transition from using open fires/poorly vented stoves in less-developed countries to more efficient clay/well vented metal stoves and solar cookers
- Ban indoor smoking and increase air circulation in commercial buildings/homes
- Set stricter standards for emissions from products designed/made for indoor use
- Use naturally based cleaning products

15.4 How Might the Earth's Climate Change In the Future?

- Scientific evidence indicates that atmospheric warming is happening at a rate that will likely lead to significant climate change

Weather, Climate and Change

- Weather: short-term changes in atmospheric variables over hours or days
- Climate: average weather conditions and patterns over the earth, or a specific region, for a minimum of three decades
- As the earth's average atmospheric temperature rises, some areas get warmer, others get cooler

Climate Change

- Over the earth's 3.5 billion year history climate has changed many times
- For the last 100 thousand years, humans have lived/developed in a reasonably steady, inter-glacial (thawing) climate
- Over the last 200 years, atmospheric temperatures have risen with urban growth
- The rate of climate change has been accelerating since 1978

More on Climate Change

- How do we know it is happening now?
  - Earth's average global surface temperature 1.4 degrees F. than 1906
  - Nine of the warmest years since 2000
  - Glaciers/summer arctic sea ice are shrinking
  - Melting permafrost; rising sea levels
  - More atmospheric greenhouse gasses
  - Migration of terrestrial/freshwater/marine species towards the poles

The Greenhouse Effect, Oceans,and Clouds

- Greenhouse effect: lower atmospheric warming caused by the reflection and interaction of some of the earth's incoming solar radiation with molecules in the air
  - Life on earth is dependent of this effect
- CO_2/heat uptake by oceans helps to moderate the earth's average surface temperature and slows climate change
- Cloud cover leads to atmospheric warming

15.5 What Are Some Possible Effects of a Warmer Atmosphere?

- The projected increases in atmospheric temperatures can have long-lasting effects:
  - Flooding
  - Rising sea levels
  - Shifts in the locations of croplands
  - Wildlife habitats
  - More extreme weather

Projected Consequences of Rapid Atmospheric Warming

- Worst case scenario: rising atmospheric temperatures will likely lead to rising sea levels, increased flooding, heat waves, forest fires, grasslands will turn to dust bowls, rivers will dry up, ecosystems will collapse, and ¼ of the world's species will go extinct
  - Result: increased poverty and loss of food security

Ice and Snow Likely To Melt

- Light-colored ice and snow in polar regions helps to cool the earth by reflecting incoming solar energy back into space (albedo effect)
  - Melting ice and snow will expose darker land and sea surfaces which reflect less sunlight and absorb more solar energy – this warms the atmosphere
  - Freshwater will be added to the ocean – changing chemistry?

Sea Levels

- Worst case scenario: a three foot rise could have the following effects
  - Degradation/destruction of coastal estuaries, wetlands, coral reefs, and deltas
  - Destruction of coastal fisheries
  - Flooding of low-lying countries and cities, erosion of low-lying barrier islands (especially in U.S.) and submersion of island nations
  - Saltwater invasion of coastal aquifers

Extreme Weather Could Become More Common

- Some regions will experience increased chance of extreme drought, more intense heat waves, and expansion of deserts
- Other regions will experience increased flooding, precipitation (snow, rain), stronger hurricanes and typhoons, and colder winters

Climate Change Is Likely To Alter Ecosystems

- Up to 85% of the Amazon Rain Forest (a major center of biodiversity) could be lost and converted to tropical savannah
- 25-50% of the world's species could face extinction (especially polar bears, penguins, and corals)
- Insect and fungi populations could explode
- As crop production falls, the diversity of crops will also decrease

Climate Change May Threaten Human Health

- More frequent and prolonged heat waves could increase illnesses/the death rate
- Fewer people will die from cold weather
- With a warmer, more CO_2 rich atmosphere, disease transmitting insects, microbes/mold populations will multiply
- Heavy photochemical smog will cause pollution related respiratory problems and often death

15.6 What Can We Do To Slow Projected Climate Change?

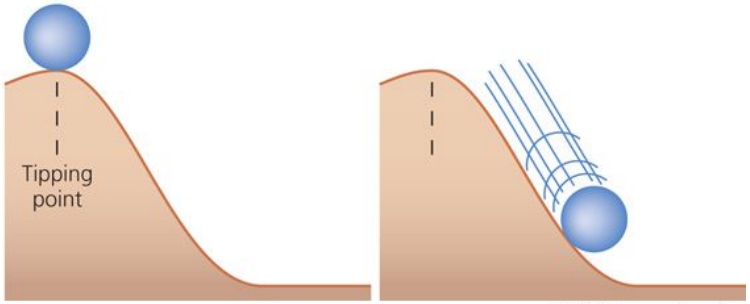
- If we cut waste and rely on new and renewable energy resources, we can:
  - Reduce greenhouse gas emissions
  - Save money
  - Improve human health
  - Reduce the threat of climate change

Dealing With Projected Climate Change Is Difficult

- The problem is complex, and both a global and a long-term political issue
  - Involves the uneven distribution of both beneficial and harmful impacts of climate change
  - Requires the reduction/phasing out of fossil fuel use (which is controversial)
- Projected effects of climate change are still uncertain

Climate Change Tipping Points

- Atmospheric carbon level of 450 ppm
- Melting of all arctic summer sea ice
- Collapse and melting of the Greenland ice sheet
- Collapse and melting of most of the western Antarctic ice sheet
- Massive release of methane from thawing arctic permafrost and from the arctic seafloor
- Collapse of part of the Gulf Stream
- Severe ocean acidification, collapse of phytoplankton populations, and a sharp drop in the ability of the oceans to absorb CO_2
- Massive loss of coral reefs
- Severe shrinkage or collapse of Amazon rain forest



What Can Governments Do?

- Strategies:
  - Strictly regulate CO_2 and CH_4
  - Phase out coal-burning power plants
  - Tax CO_2 or CH_4 emissions/start energy taxes
  - Use a cap-and-trade system
  - Phase out subsidies/tax breaks for fossil fuel industries and industrialized food production
    - Offer subsidies for energy efficient technologies
  - Increase development of alternatives

What Else Can Be Done?

- Some countries, states, cities and private companies are working to reduce their carbon footprints
  - Colleges and universities also reducing carbon footprints
- We can prepare for climate change
  - Focus the attention of relief organizations on expanding mangrove forests, building shelters on higher ground, and planting trees on slopes – build structures higher off the ground

15.7 How Have We Depleted Ozone In the Stratosphere?

- Reduced ozone levels in the stratosphere coming from the widespread use of certain chemicals is allowing more harmful ultraviolet (UV) radiation to reach the earth
- By not producing and using ozone depleting chemicals and adhering to international treaties that ban these chemicals, we can reverse ozone depletion

Ozone Depletion

- Ozone thinning stems from the overuse of harmful chlorofluorocarbons (CFCs) known as freons – used for coolants/air conditioning
- Ozone thinning allows:
  - More biologically damaging UV-A/UV-B radiation to reach earth's surface, contributing to cataracts and skin cancer
  - Impairs/destroys phytoplankton

Additional Case Study: Solar Cooking – One Solution to Indoor Air Pollution

- India invests in teaching solar cooking in schools
  - Part of a governmental five-year-plan to reduce indoor air pollution by providing both the technology (solar cookers) and training (classes for assembling/cooking)
  - Although solar cookers have been available in India since 1982 – families try solar cooking and then revert to traditional methods
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More On Solar Cooking in India

- By embedding classes in school curricula, the government hopes to increase acceptance and use of solar cooking
- How does a solar cooker work?
- What are three advantages and three disadvantages of solar cookers?
- In India, what issues with solar cookers need to be addressed to make usage more practical?

Solar Cooking and the Three Big Ideas

- Solar cooking prevents a significant amount of indoor air pollution
- Solar cookers rely on the sun and use an unlimited, free, renewable energy resource -- which helps slow climate change.
- Projects for converting populations to solar cooking are successfully underway in Africa, South America and India – in preparation for impacts of climate change