



Ecological Footprints of Products

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Environmental Studies 152



Department of
Environmental Studies

Impacts of a Product



- Global Warming**
 - Production of electricity to manufacture materials
 - Production of energy to run the unit
 - CO2 from transport
- Resource Depletion**
 - Iron ore
 - Oil
 - Coal
- Solid Waste**
 - Manufacturing waste
 - Waste from energy production
 - Disposal of packaging
 - Disposal of unit @ end of life
- Water Pollution**
 - Waste from electricity production (cooling tower)
- Ozone Depletion**
 - HCFCs used as refrigerant
 - Blowing agents for foam insulation
- Biodiversity**
 - Forest clearing to harvest timber for packaging
- Land Degradation**
 - Mining of iron ore for steel
- Air Pollution**
 - Steel and plastics manufacturing emissions
 - Electricity production
 - Particulate diesel transportation


Energy

Energy is at the root of all eco-impacts. Needed to gather resources, manufacture products, transport, sell, use, and even recycle

How we use energy is the difference between a sustainable and non-sustainable world


Fossil Fuels

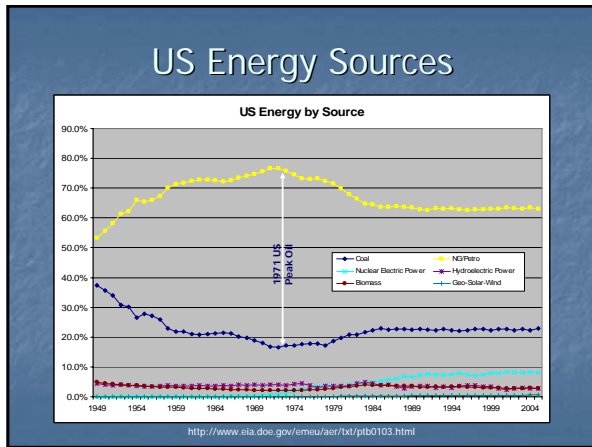
- Current consumption rates for fossil fuels (including oil, natural gas and various types of coal) convert the fuels into carbon dioxide (CO2) at a rate millions of times faster than nature can replenish the fuel reservoirs.



State of the World: Energy

- UNITED STATES
 - 16% of all commercially produced energy performs useful work; 84% is lost to inefficiencies (2nd law of thermodynamics)
 - US uses 30% of world supply (63% for transportation)
 - Declining domestic extraction
 - 50% of domestic wells >80% depleted
 - 91% of energy from nonrenewable sources
 - 60% oil imports
 - Continued subsidies of nonrenewable energy
- WORLD
 - 70% increase in energy use expected by 2025 (cause: pop. growth, China/India econ. growth)

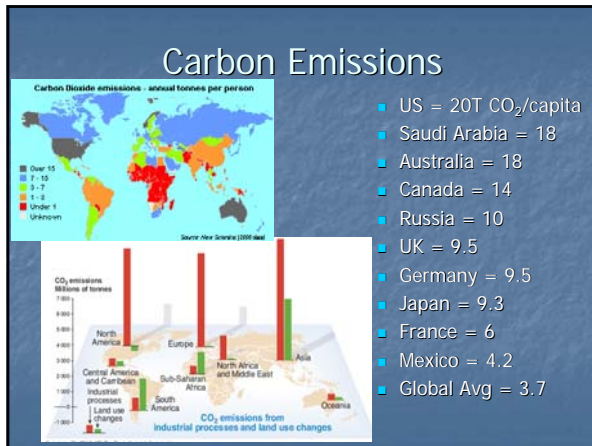


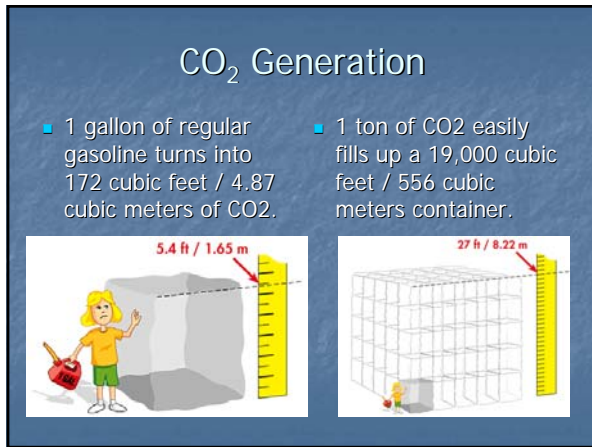


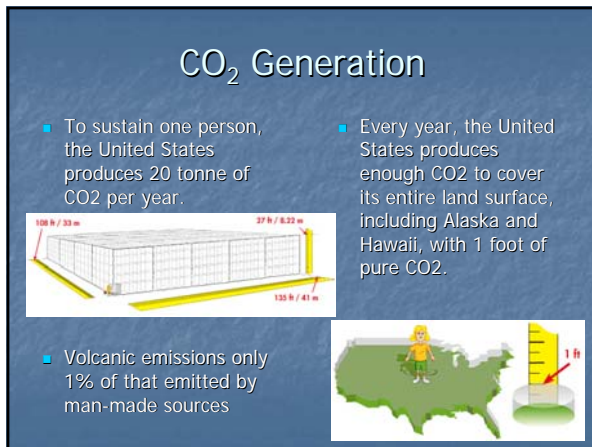
Oil

- Cheap energy for 100 years
- Biggest contributor to good and bad
 - Good: transportation, materials, chemicals, pharmaceuticals, technology, economic growth, life expectancy, decreased infant mortality, etc.
 - Bad: pollution, global warming gases, geopolitical turmoil, war (Pacific, Mid-East, Iran-Iraq, Gulf I & II), over-population?
- The party may soon be over



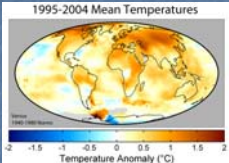
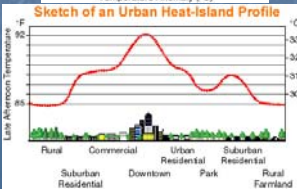






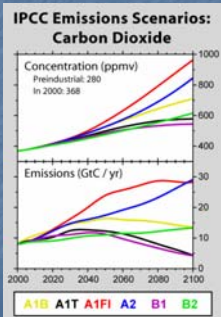
Evidence

- Uneven heat distribution
 - More significant in the Northern Hemisphere
- Urban Heat Islands
 - Urban areas can be 2-10° F warmer than surrounding areas

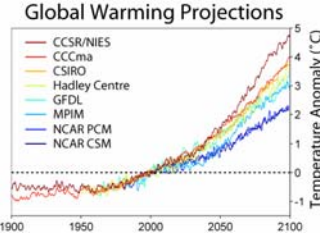



Consequences

IPCC Emissions Scenarios: Carbon Dioxide



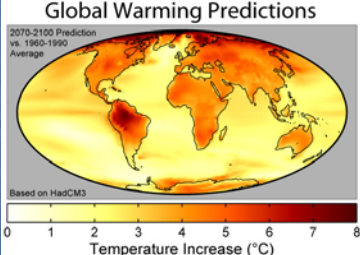
Global Warming Projections

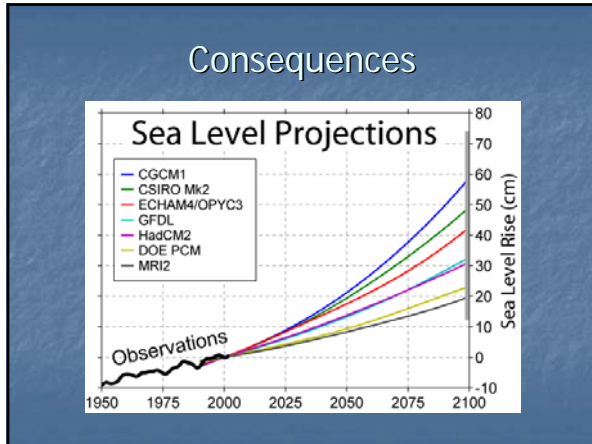


Consequences

Annual surface air temperature rise (in deg.) simulated by doubling the CO2 concentration.

Global Warming Predictions





Consequences

- Antarctica
 - 14 M km² contains 30 M km³ of ice (70 m)
 - ~90% of Earth's fresh water
 - WAIS may be starting to disintegrate
 - Would raise global sea level at least 16 feet
 - Larsen B Ice Shelf, 2002, melted in 3 weeks
- Greenland
 - 2.85 M km³ of ice
 - global sea level rise of 7.2 m (23.6 ft.)
 - Melting at 239 km³ (57.3 mi³)/yr; 3x faster than previously thought
 - Threshold: ~3°C temp incr. melt>snowfall; 8°C incr. melts entire ice sheet
 - J. M. Gregory, et al. *Nature* 2004
- Linkage
 - if Greenland melts, could trigger failure of WAIS
 - happened between 116,000 and 129,000 yrs ago. Greenland raised sea level by 11 ft... triggered melting of part of WAIS, adding an additional 9-10 feet

Consequences: Abrupt Climate Change?

- Rapid melt could interrupt "thermohaline conveyor"
 - Warm water is less dense, and more saline and runs along surface.
 - Reaches cold latitudes, it becomes denser/less saline and descends
 - Consequences:
 - Gulf Stream keeps Europe at moderate temps; cooling of Europe
 - Crop failures
 - Plankton stock collapse
 - Increased storms in tropics
- Thawing of Arctic Permafrost (20% of land mass)
 - Increases of 1-3°C in 20 yrs in Alaska, Canada, Siberia
 - Frozen since last ice age... thaw can release 70,000 MT of methane... equal to 1,470 GT CO₂. current global CO₂ generation from fuel is 25 GT/yr

from Rodman, *Earth's Climate Past and Future*
<http://earth.tsc.edu/~ipm150/visibility/geopocum.html>

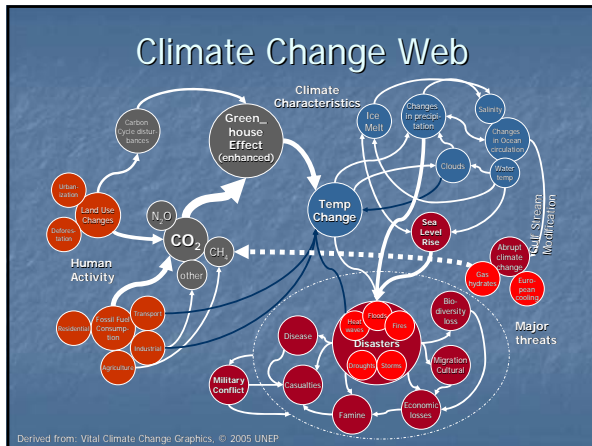
PERMANN, BROWNIE CREEK, 1950-2000
 Mean annual ground temperature

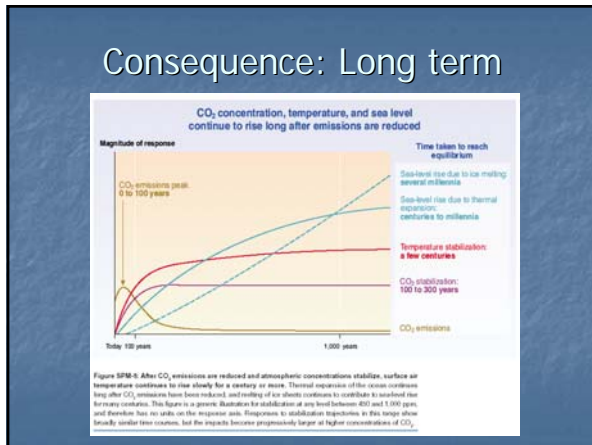
Y-axis: Mean Annual Ground Temperature (°C)

X-axis: Year

Legend: Permafrost, No permafrost

Source: http://www.arctic.noaa.gov/essay_romanovsky.html





Scenarios: 2100



	Strict Controls	Modest Controls	Few Controls
Population	6.4B	11.3B	11.3B
Energy source	Fossil fuels nearly phased out	Shift to natural gas and solar energy	Reliance on coal
Deforestation	Little deforestation	Less deforestation	Tropical forests cleared
Energy Efficiency	Substantial	Gains in efficiency	Few gains in efficiency
Economic growth	1-2% annual	2-3% annual	>3% annual
Human CO ₂ emissions	5B tons/yr	20B tons/yr	35B tons/yr
2100 CO ₂	480 ppm	680 ppm	900 ppm
Temperature	+1°C	+1.5°C	+3.5°C

The three small graphs on the right show:

- EMISSIONS:** CO₂ emissions (Gt C) from 2000 to 2100 for the three scenarios.
- CONCENTRATIONS:** CO₂ concentration (ppm) from 2000 to 2100 for the three scenarios.
- IMPACTS:** Temperature change (°C) from 2000 to 2100 for the three scenarios.

Global Action/Inaction

- History
 - 1979 1st World Climate Conference
 - 1988 IPCC formed (UN)
 - 1990 IPCC report
 - 1992 Rio Summit
 - Convention of Climate Change calling for signatory countries to stabilize their greenhouse gas emissions at 1990 levels by the year 2000
 - Kyoto Conference & Protocol
 - Commitment for developed countries to reduce GWG emissions to 1990 levels, and then a further 5% by 2012
 - 2004 ratified by Russia... 2005 in effect (>55% of emissions)
 - US & Australia not yet ratified

What are we waiting for?

- "Is there global warming? I'm not 99% sure, but I am 90% sure....Why do we need 99% certainty when nothing else is that certain? ...If there were only a 5% chance the chef slipped some poison in your dessert, would you eat it?".
 - Stephen Schneider, climatologist at Stanford's Institute for International Studies




Global warming: a global environmental policy /economic dilemma

- To reach Kyoto Protocol
 - US reduced GDP of 0.4-2% of GDP without C-trading; 0.24-0.9% with C-trading (GDP₂₀₁₀ ~ \$13.8T)
 - Developed countries in Europe: GDP impact of 0.3-1.5% without C-trading; 0.1-0.8% with C-trading (GDP₂₀₁₀ ~ \$14T)
- Cost to stabilize depends on at what concentration; for 2050
 - 450 ppm: 1-4% of GDP
 - 550 ppm: 0-1.75% of GDP
 - 650 ppm: 0-1.5% of GDP
 - 750 ppm: 0-1% of GDP
- International coordination across diverse countries needed to reduce incentive for countries to free ride on the greenhouse gas control efforts of other countries.
 - Developed vs. Developing countries
 - China will pass the US as the leading emitter ~2020: increased energy use by over 200% from 1970-1990...75% (high sulfur) coal!
 - Resistant because sees this as an attempt to limit China's emergence as a world power
- What's the cost of doing nothing?

Cap & Trade

- European Union, began in 2005
 - Electricity, pulp & paper, steel, cement, petroleum refining (boilers only), and lime production
 - Covers more than 12,000 installations in 25 countries
 - Covers ~45% of EU emissions
 - 70MT of CO₂ allowances traded in first year at avg. of €15/ton – more than \$1 billion in value has traded hands this year – price hit €30/ton
 - Market now €5B → €14B by 2012
 - Becomes mandatory in 2008
 - Penalties: €100/ton + obligation to offset in following year + negative PR
- California
 - Global Warming Solutions Act (AB32)
 - By 2020 reduce GWG emissions by 25% from 1990 levels
 - Est. to be \$27 dollars/ton in 2012 and may increase to more than \$39 dollars/ton in 2020.
 - 91% of businesses surveyed say CA should develop a cap & trade system


What's equal reducing 1MT CO₂?

- 216K cars/yr
- 114M gal gasoline
- 2.3M barrels oil
- Electricity used by 193K CA households
- 26M trees grown for 10 years
- 556K tons waste recycled

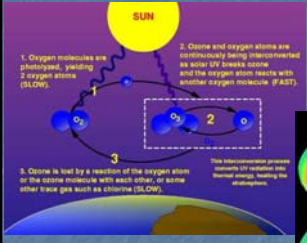
- Cal. Air Resources Board

Ozone Depletion

- Stratospheric ozone depletion is caused by emissions of chlorinated fluorocarbons (CFCs) such as Freon and related compounds. Ozone (O₃) in the upper atmosphere is destroyed, leading to "ozone holes" above the North and South Poles.
- Ozone loss increases the amount of ultraviolet (UV) light falling on the Earth, leading to increases in cancers and cataracts in animals and humans. The UV light also reduces the productivity of plants, affects marine algae and affects the biota in high latitudes.



Ozone Depletion

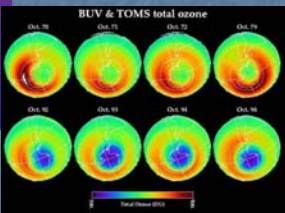


1. Oxygen molecules are photolyzed, yielding 2 oxygen atoms (SLOW).

2. Ozone and oxygen atoms are continuously being interconverted as solar UV breaks ozone, and the oxygen atom reacts with another oxygen molecule (FAST).

3. Ozone is lost by a reaction of the oxygen atom or the ozone molecule with each other, or with other trace gas such as chlorine (SLOW).

This interconversion process removes UV radiation and thermal energy, heating the atmosphere.



BUV & TOMS total ozone


Oct 79 Oct 81 Oct 83 Oct 85 Oct 87 Oct 89 Oct 91 Oct 93 Oct 95 Oct 97

Total Ozone (DU)

www.met.sjsu.edu/~cordero/education/education.htm

Water Resources


- UNITED STATES
 - 25% of groundwater not replenished
 - Subsidies for agriculture cause increased depletion
 - Ancient groundwater of the Ogallala is being depleted to grow corn and wheat
 - Distribution inefficiencies
 - Water goes to poor economic payback uses
 - "Salting up" Ag lands
 - Overdrafting
 - The ground has sunk (subsidence) in the San Joaquin valley, Central US, and lost aquifers for all time



- Groundwater pollution has been caused by surface pollution, Solid and hazardous waste


WORLD

- 1.5 billion people don't have safe drinking water; 5 million/year die from waterborne diseases.
- Shortages----a cause for war



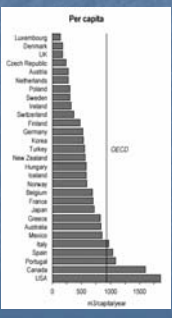
Water Pollution

- Eutrophication is caused by the addition of excess nutrients to water leading to reduction of available oxygen.
- Nitrogen and phosphorous compounds from municipal wastewater and agriculture pollute surface waters. This results in algal blooms that lower the quantity of dissolved oxygen.
- Eutrophication removes the oxygen from the water, killing fish and other aquatic organisms.




Intensity of Freshwater Resources

- At world level, it is estimated that water demand has risen by more than double the rate of population growth in this century. Agriculture is the largest user of water world-wide; global needs for irrigation have increased by over 60 % since 1960.
- 1.2B people have inadequate access to clean drinking water
- 2.5B people lack proper toilets/sewerage systems
- 5M die each year from water-related diseases (cholera, dysentery)



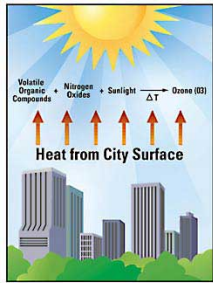
Air Pollution

- Photochemical smog is caused by the emissions of nitrogen oxides and volatile organic substances that generate ground level ozone (O₃) in the presence of sunlight.
- Other air pollutants (referred to as "criteria air pollutants" by the U.S. E.P.A.) include dust particles and sulfur dioxide (SO₂).
- Smog and air pollutants increase the incidence of asthma in humans and reduce the photosynthetic capacity of plants.




Ozone Formation

- Ozone Precursors
 - VOCs
 - NOx
- Can be transported hundreds of miles
- Effects
 - Lung irritation/inflammation
 - Chronic exposure can cause permanent lung damage
 - Low-level exposure can aggravate asthma
 - Interferes with plant respiration
 - Damages forests – more susceptible to disease




Air Pollution

- Acid rain (acid precipitation) is caused by the release of acidic gases, primarily from burning fossil fuels.
- The acids dissolve aluminum and other metals from soils to the level at which they become toxic to plants and to aquatic organisms. Acidic rain dissolves cement and minerals in the built environment.




Human Health Effects

- Non-cancer causing substances can include skin irritants, growth inhibitors, and hormone disrupting chemicals (endocrine disruptors)
 - DES, DDT, PCBs
- Potential toxic effects can include transient irritation, physical or mental disability, inhibition of physical or mental development, temporary or permanent disability and/or death.



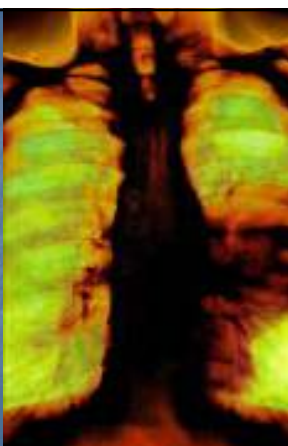
Human Toxins

- Metals
 - Kidney, blood system, central nervous system damage
 - ex.: lead & mercury
 - Mercury:
 - Deteriorates the nervous system
 - Impairs hearing, speech, vision and gait
 - Causes involuntary muscle movements
 - Corrodes skin and mucous membranes
 - Causes chewing and swallowing to become difficult
- Chlorinated solvents
 - Kidney, liver, central nervous system damage
 - ex., dioxins




Human Genetic Health Effects

- Carcinogens are cancer causing substances that can cause permanent disability and/or death.
 - Arsenic, asbestos, benzene
- Mutagens are substances that can cause genetic mutation. Most carcinogenic substances are also mutagenic.
- Teratogens are substances that cause defects in developing babies in the womb.
 - Lead, mercury




Biodiversity & Ecotoxicity

- Biodiversity reduced when the number of plant or animal species is reduced
- Ecotoxicity is the effect of toxic substances on plants, animals and other biota in the natural environment.
- The range of possible effects is large and methods of assessing these impacts are still developing. Some methods use data from tests on specific indicator species, and others extrapolate impacts on plant populations.



Biodiversity

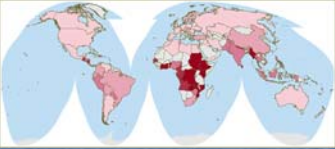
- UNITED STATES
 - 55% of wetlands lost
 - 371,000 additional acres lost/yr
- WORLD
 - 25-50% of world's wetlands drained, built upon, or seriously polluted.
 - 1.5 million species extinct by 2015
 - Rate if extinction is 1,000x the average rate in Earth's history
 - Forest degradation= species extinction
 - 25% of world's prescription drugs are substances extracted from plants.
 - \$40 billion in sales/yr (includes \$14 billion in the U.S.)
 - Less than 3% of plants species studied for human use
 - We knowingly destroy possibilities, cures, and billions of years of evolution



Reduced Biodiversity Causes

- Land clearing
 - Urban development
 - Mining
 - Other human activity
- Timber harvesting / clear cutting in old growth forests
 - Wood products
 - Fuel
- Pollution of air, soil or waterways
- Fisheries
 - Decrease in fish stocks from over-fishing
 - N. Atlantic yield dropped 95% in 1990s

Share of Woodfuels in National Energy Consumption



Percent share: < 10, 10 - 25, 25 - 50, > 75, Data incomplete

http://earthtrends.wri.org/text/ENG/maps/219_1g.htm

Threatened Species

- Mammals
 - 1,137
- Birds
 - 1,192
- Plants
 - 5,714
- Reptiles
 - 293
- Amphibians
 - 157
- Fish
 - 742

Percent of Total Land Area Protected (all designations), 2003

Land Degradation

- Habitat alteration (also referred to as land use) is the physical modification or destruction of natural habitats.
- Ecosystems are destroyed to provide for agriculture, roads and urban growth. Habitat alteration is the primary cause of the loss of biodiversity on the planet.
- Topsoil
 - Non-sustainable agriculture can erode topsoil at a rate faster than natural processes replenish it.

Protection of Land

Protected areas, OECD, % of total area

IUCN categories:

- Ia-VI
- Strict nature reserves (Ia)
- Wilderness areas (Ib)
- National parks (II)
- Natural monuments (III)
- Habitat/species management areas (IV)
- Protected landscapes/seascapes (V)
- Managed resource protected areas (VI)

Protected areas


OECD: 12.6% of total area

Rest of the World: 9.9% of total area

Resource Depletion


Minerals

- Metal ores are converted into metal alloys that are eventually oxidized or dispersed as waste that is often not recycled.



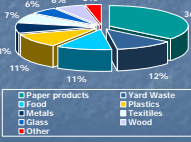
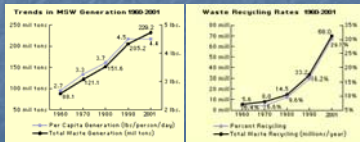
Mineral Use & Disposal

- UNITED STATES
 - U.S. requires 5.2 billion tons of new fuel and nonfuel mineral resources (21 tons/American)
 - Import 50% or more of 24 of its most important nonfuel minerals.
 - Overburden = environmental degradation
 - U.S. Accounts for 33% of the solid waste: 11 billion tons/year, 44 tons/person)
 - 98.5% from agriculture and mining, oil and natural gas production and industrial activities.
 - U.S. Materials Landfilled:
 - Paper And Paperboard (38% By Volume), Plastic (18%), Metals (14%), Yard Waste (11%), Food (4%), Glass (2%), Other Materials (13%)
 - 17% recycled
 - 66% dumped
 - 17% burned
 - Total cost for recycled, dumped and burned = \$30 billion/yr



Solid Waste Rates

- In 2001, U.S. residents, businesses, and institutions produced more than 229 million tons of Municipal Solid Waste (MSW)
- 4.4 pounds of waste per person per day, up from 2.7 pounds per person per day in 1960.

Root Causes of Unsustainability

- Over-population
- Over-consumption
- Poverty
- Inefficiency
- Addiction to fossil fuels
- Oversimplification of earth's life support systems
- Poor political and economic management
- Failure to have market prices represent the overall environmental cost of an economic good or service
- Our urge to dominate and control nature
- Depletion of nonrenewable resources
- Depletion and degradation of earth capital (renewable resources)
- Political and economic systems that reward unsustainable economic growth.

Sustainability

SUSTAINABILITY, OR THE WISE USE OF "NATURAL CAPITAL" CANNOT BE ACCOMPLISHED BY POLLUTION CLEANUP AND WASTE MANAGEMENT.

Requires:

- Pollution prevention
- Waste prevention,
- Recycling,
- An educated and involved public
 - to keep government/business honest!
- And a wise legislature whose prime interest is
- The long term health of the public and of the environment on which they depend.



Sustainable Development

- "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs."
 - United Nations World Commission on Environment and Development
- Sustainable development is "a process of managing a portfolio of assets to preserve and enhance the opportunities people face." Sustainable development includes economic, environmental, and social sustainability, which can be achieved by rationally managing physical, natural, and human capital
 - World Bank



2005 Yale Environmental Sustainability Index

- 21 indicators from 76 data points

Environmental Systems <ul style="list-style-type: none"> • Air quality • Biodiversity • Land Use • Water Quality • Water Quantity 	Stress Reduction <ul style="list-style-type: none"> • Air Pollution • Ecosystem • Population Pressure • Waste & Consumption • Water Stress • Nat Res. Mgmt 	Social & Institutional Capacity <ul style="list-style-type: none"> • Envir. Governance • Eco-Efficiency • Private Sector Responsiveness • Science & Technology • International Collaboration • Greenhouse Gas Emission • Transboundary Environmental Pressures
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Human Vulnerability

- Environmental Health
- Human Sustenance
- Envir. Natural Disaster

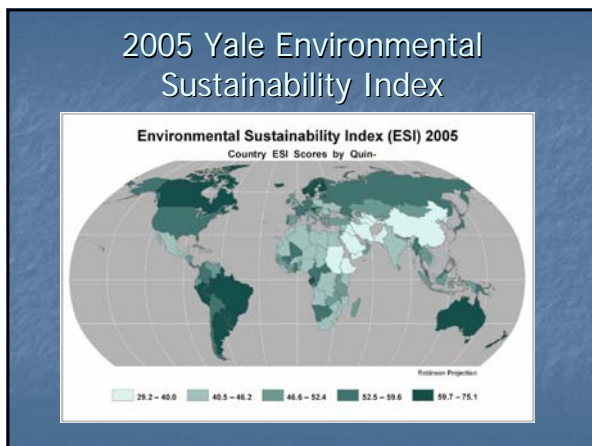
- Policy tool for benchmarking nations
- Useful for identifying best practices

<http://www.yale.edu/esi/>

2005 Yale Environmental Sustainability Index


1. Finland	11. Brazil	21. Ireland	31. Germany
2. Norway	12. Gabon	22. Lithuania	32. Namibia
3. Uruguay	13. Australia	23. Colombia	33. Russia
4. Sweden	14. New Zealand	24. Albania	34. Botswana
5. Iceland	15. Latvia	25. Cent Afr. Rep.	35. P.N. Guinea
6. Canada	16. Peru	26. Denmark	36. France
7. Switzerland	17. Paraguay	27. Estonia	37. Portugal
8. Guyana	18. Costa Rica	28. Panama	38. Malaysia
9. Argentina	19. Croatia	29. Slovenia	39. Congo
10. Austria	20. Bolivia	30. Japan	40. Netherlands

45. **United States**



Openness of Information

- Pollutant Release and Transfer Register (PRTTR)
 - government-operated system to collect and disseminate data on environmental releases & transfer of toxic chemicals from industrial facilities
- Provides important information about whether facilities are obeying the standards that limit releases into air and water
- Reflects a growing interest worldwide in promoting greater corporate environmental accountability at the facility level



Homework

- Imagine that you've live to the year 3000. What's the world like from an environmental standpoint? Looking back on this era, which specific environmental impacts do you think we should have been the most active in controlling or stopping? Describe why.
 - Limit to 1 page, single spaced
 - 3 points for content/technical accuracy (incl. level of detail); 1 point for creativity; 1 point for grammar/spelling

Environmental Impact Categories		
Ecological damage Global warming Ozone depletion Acid rain Water eutrophication Habitat alteration Ecotoxicity	Human health damage Smog & air pollutants Carcinogens Health damaging substances	Resource depletion Fossil fuel Fresh water Minerals Topsoil
