

05-Environmental Impacts

Text: Chapter 5
ECEGR 3500
Electrical Energy Systems
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» Overview

- Fossil Fuel Power Plants
- Hydro Electric Power Plants
- Nuclear Power Plants
- Wind Power Plants

» Introduction

- Every human activity has some effect on the environment
- Energy exploration, procurement, conversion, distribution and end-use all have environmental consequences
- Power plants exist in a continuum of environmental impact, some are less impactful than others or are impactful in different ways

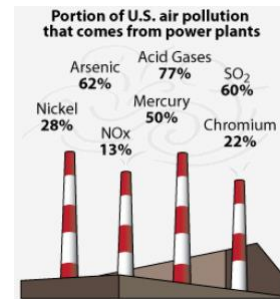
» Introduction—Which is greener?

- Redwood trees vs solar panels
 - <http://archive.wusa9.com/news/article/69130/0/Redwood-Trees-vs-Solar-Panels>
- Salmon vs wind power
 - <http://www.opb.org/news/blog/ecotrope/bpa-shuts-off-wind-power-to-make-way-for-hydro/>

» Emissions

- Combustion of fossil fuels can cause unwanted, harmful or damaging chemicals to be emitted to the atmosphere, including

- Sulfur oxides
- Nitrogen oxides
- Ozone
- Carbon dioxide
- Particulates



Source: www.epa.gov

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» Sulfur Oxides

- Sulfur is often found in coal, oil and natural gas
 - Coal contains about 6 percent sulfur
 - Powder River Basin in Wyoming has low-sulfur coal and is shipped to power plants around the U.S.
- Sulfur oxides (SO₂ and SO₃) are formed during combustion

$$\text{S} + \text{O}_2 \longrightarrow \text{SO}_2$$

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» Sulfur Oxides

- Sulfur dioxide is corrosive, colorless and malodorous
- 73% of sulfur dioxide is from power plants
- Can cause acid rain
- Inhaling large amounts can lead to lung and respiratory tract damage within a few minutes of exposure
- See 1952 London disaster linked to sulfur dioxide exposure, which killed 4000 people
- Sulfur emissions from power plants are closely monitored under a quota system

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» Nitrogen Oxides

- Nitrogen oxides (NO_x) are also released during combustion of fossil fuels
- NO_x is highly toxic
- NO_2 is corrosive and irritates the eyes, nose, throat and respiratory tract
- NO_2 causes smog and acid rain

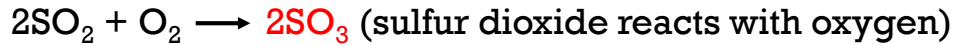
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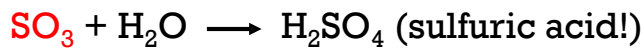
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»» Acid Rain

SO₂ and NO_x cause acid rain



when it reaches the clouds, it reacts with water



for NO_x



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»» Acid Rain

- Acid rain damages, crops, agricultural lands, buildings (and anything else outside), fish
- Acid rain is most common in the Northeast and Midwest (where there are heavy concentrations of coal-fired power plants)



(a)



(b)

Source: *Electric Energy: An Introduction*, M. El-Sharkawi

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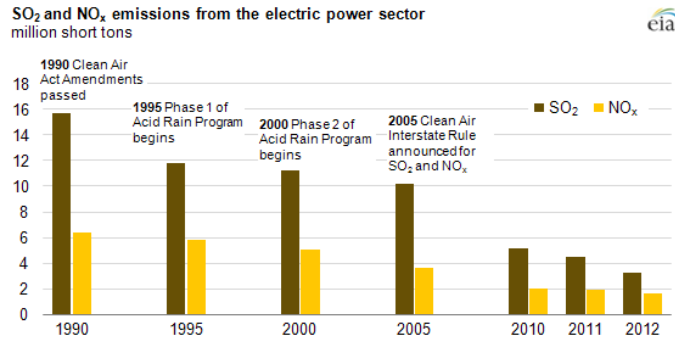
» Reducing NO_x and SO₂

- NO_x and SO₂ can be reduced at power plants by technical means
 - Flue-gas desulfurization (FGD) (scrubbers)
 - Switching to lower sulfur coal (or increasing the share of low-sulfur coal)
 - Selective catalytic reduction (SCR)
 - Selective non-catalytic reduction
 - Low NO_x burners
- Non-technical means
 - Cap-and-trade program (1990 Clean Air Act Amendments)

» Scrubbers

- After combustion, an aqueous mixture of lime/limestone is sprayed through the emissions
- Some of the sulfur is absorbed in the mixture (calcium in the limestone)
- By product (synthetic gypsum) can be used in wallboard, cement, as a soil amendment or sent to a landfill

»» Reducing NO_x and SO₂



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»» Ozone

- NO₂ released by power plants can create ozone in the troposphere (where it is damaging as a secondary pollutant)
- NO₂ + sun light → NO + O
- O + O₂ → O₃
- Ozone contributes to smog, is harmful to vegetation and to humans
- Ozone is naturally recycle back into NO₂
- NO + O₃ → NO₂ + O₂

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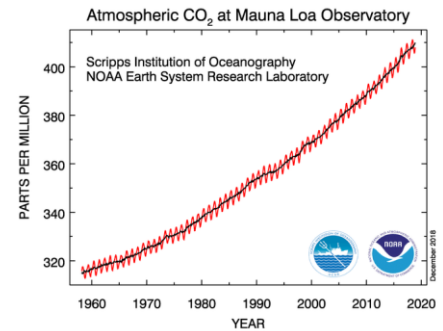
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Carbon Dioxide

- Carbon dioxide is released when hydrocarbons are combusted



- Carbon dioxide is helpful to plants, but it is a greenhouse gas
 - CO₂ concentration in 18th century ~280 ppm
 - Current CO₂ concentration: 408 ppm



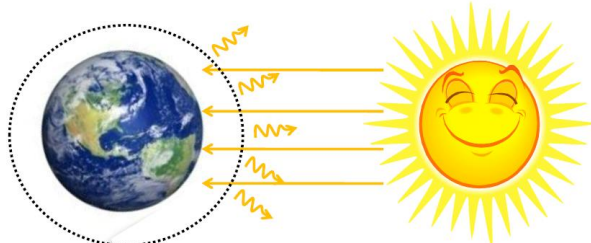
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Carbon Dioxide

- Earth receives radiation from the sun
 - Wide range of wave lengths: 250-5000 nm
- Atmosphere reflects about 30%
 - Not all wavelengths are reflected equally



*not to scale

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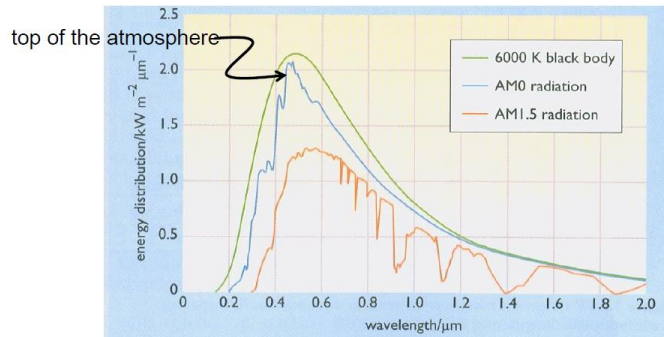


Figure 3.8 The spectral power distributions of solar radiation corresponding to Air Mass 0 and Air Mass 1.5. Also shown is the theoretical spectral power distribution that would be expected, in space, if the sun were a perfect radiator (a 'black body') at 6000 °C

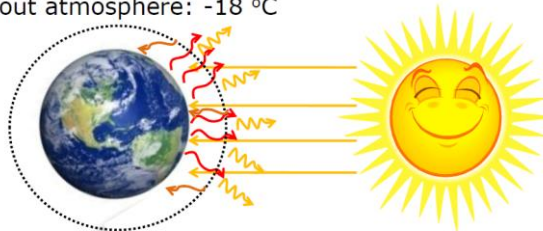
Source: *Renewable Energy: Power for a Sustainable Future*, G. Boyle

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- Atmosphere blocks some of this radiation from being re-radiated back to space
- Average surface temperature
 - with atmosphere: 15 °C
 - without atmosphere: -18 °C



*not to scale

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» Greenhouse gases

- Greenhouse gases: atmospheric gases that keep longwave infrared radiation from escaping

- Common Greenhouse gases
 - Water vapor (responsible for 60%-80% of the greenhouse effect)
 - Carbon dioxide
 - Methane
 - N₂O
 - Ozone

» Ashes

- Particulates are released during combustion, including
 - Iron
 - Titanium
 - Zinc
 - Lead
 - Nickel
 - Arsenic
 - Silicon
 - Mercury
 - Chromium

» Emissions by Power Plants

- Natural gas plants generally have lower harmful emissions than coal-fired power plants (approximate values)
 - CO₂: coal 1000kg/MWh; natural gas 500kg/MWh
 - NO_x: coal and natural gas 2kg/MWh
 - SO₂: coal 7kg/MWh; natural gas 0.5kg/MWh

» Hydro

- Flooding
 - Displacement of people, loss of land use
 - Decaying plants emit greenhouse gases
- Water Flow
 - Water flow is restricted, which is often harmful to downstream ecosystems
- Silt
 - Silt is trapped behind the dam. Silt is an important downstream fertilizer and it helps prevent erosion

» Hydro

- **Oxygen Depletion**
 - Oxygen is depleted at the bottom of the reservoir, harming the fish and aquatic vegetation
- **Nitrogen**
 - Spilled water increases nitrogen content of the water, which is harmful to fish
- **Fish**
 - Migration of many fish species are impacted by dams (even with fish ladders)

» Nuclear Power

- **Release of radioactive material**
 - Concern in boiling water reactors (steam is in contact with fuel rods)
- **Loss of coolant “China Syndrome”**
 - Caused by interruption of water flow (pipes or pumps malfunction)
 - Fuel rods in the core overheat and melt through the containment structure and/or cause hydrogen to separate from water, possibly leading to an explosion

» Disposal of Radioactive Waste

- Spent fuel rods contain cesium and rubidium (half life of thousands of years) and can remain hot for hundreds of years
 - 2000 tons per year from power plants in the U.S.
 - 71,862 tons total
- Storage is challenging—radioactive waste must not leak out of containment structures
- Spent fuel rods are stored on site at the power plants in the U.S. (there is no national depository (see Yucca Mountain))
 - Spent fuel pools
 - Dry cask storage