

05-Environmental Impacts

Text: Chapter 5

ECEGR 3500

Electrical Energy Systems

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» Overview

- Emissions from Power Plants
- Greenhouse Effect
- Environmental Concerns of Hydropower
- Environmental Concerns of Nuclear Power

» 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

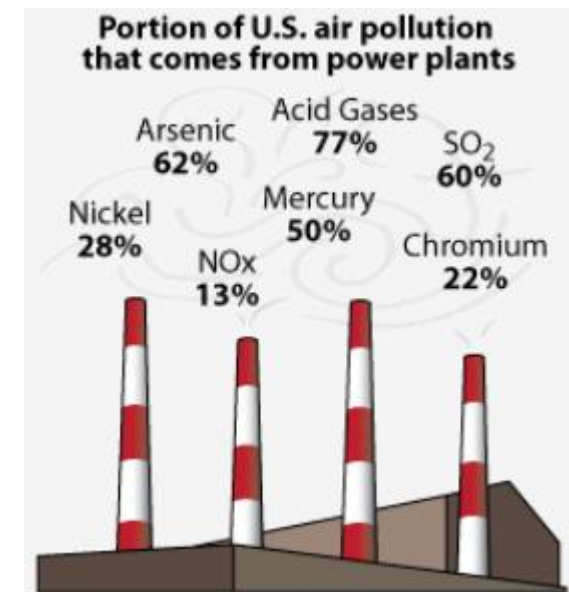
→ Introduction—Which is greener?

- 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 from Power Plants

» 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

» Ashes

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

» 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 (SO_2 and SO_3) are formed during combustion
$$\text{S} + \text{O}_2 \longrightarrow \text{SO}_2$$

» 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

» 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

»» Acid Rain

SO₂ and NO_x cause acid rain

$2\text{SO}_2 + \text{O}_2 \longrightarrow 2\text{SO}_3$ (sulfur dioxide reacts with oxygen)

when it reaches the clouds, it reacts with water

$\text{SO}_3 + \text{H}_2\text{O} \longrightarrow \text{H}_2\text{SO}_4$ (sulfuric acid!)

for NO_x

$3\text{NO}_2 + \text{H}_2\text{O} \longrightarrow 2\text{HNO}_3 + \text{NO}$ (nitric acid!)

» 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

» Reducing NO_x and SO₂

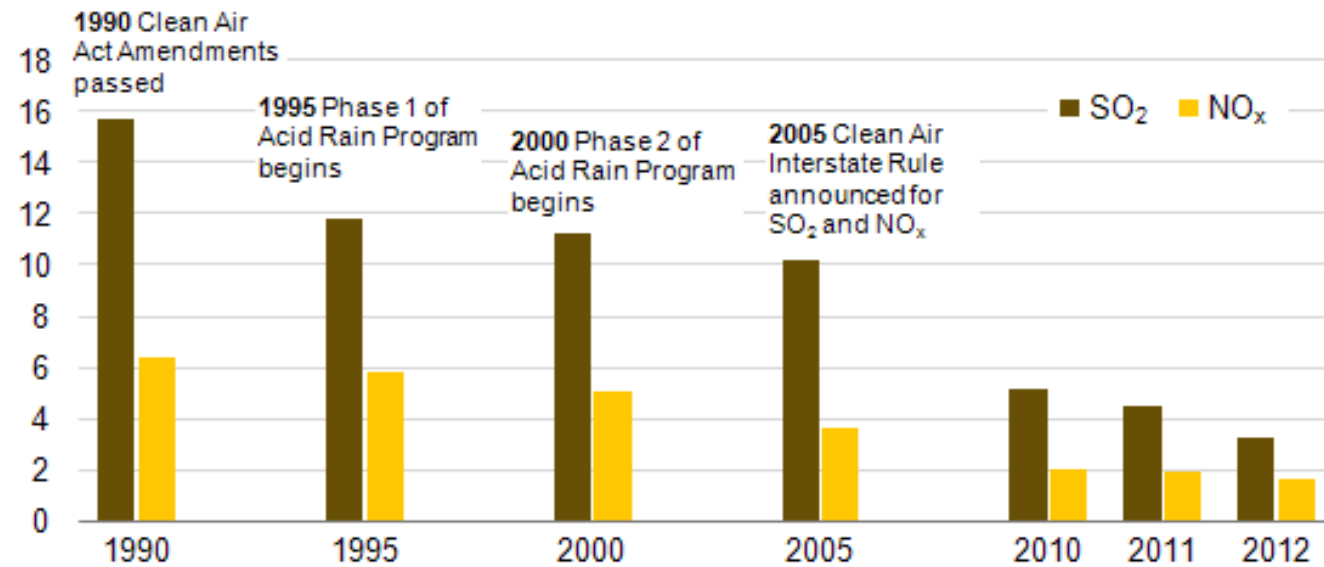
- NO_x and SO₂ can be reduced at power plants by technical means
 - Flue-gas desulfurization (FGD) (scrubbers)
 - Switching to lower sulfur coal (or increasing the share of low-sulfur coal)
 - Selective catalytic reduction (SCR)
 - Selective non-catalytic reduction
 - Low NO_x burners
- Non-technical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

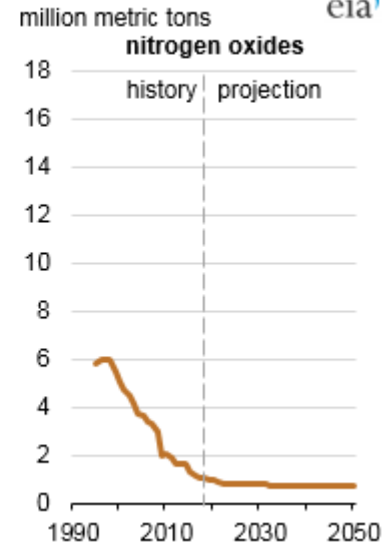
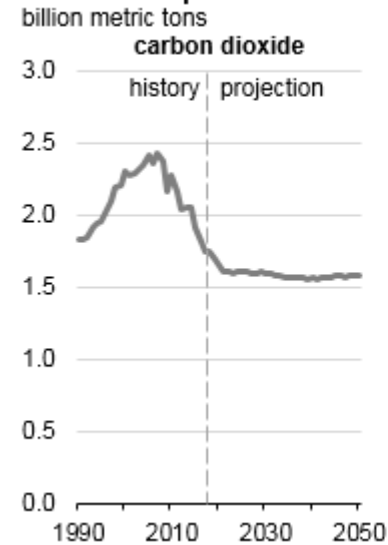
→ Reducing NO_x and SO₂

SO₂ and NO_x emissions from the electric power sector
million short tons



eia

U.S. electric power sector emissions



eia

» Ozone

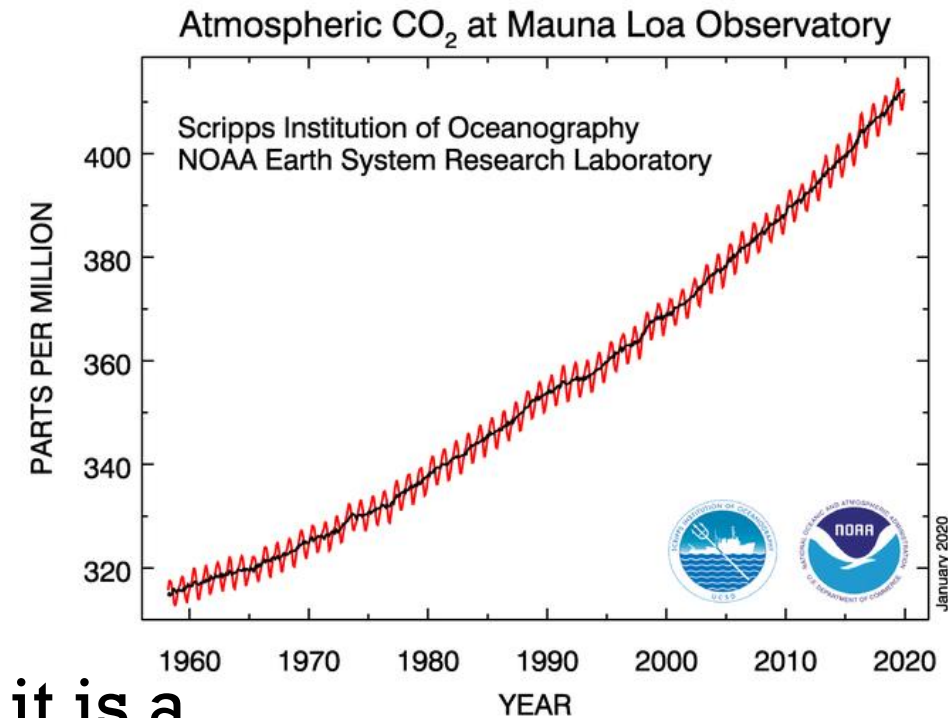
- NO_2 released by power plants can create ozone in the troposphere (where it is damaging as a secondary pollutant)
- $\text{NO}_2 + \text{sun light} \longrightarrow \text{NO} + \text{O}$
- $\text{O} + \text{O}_2 \longrightarrow \text{O}_3$
- Ozone contributes to smog, is harmful to vegetation and to humans
- Ozone is naturally recycled back into NO_2
- $\text{NO} + \text{O}_3 \longrightarrow \text{NO}_2 + \text{O}_2$

Carbon Dioxide

- Carbon dioxide is released when hydrocarbons are combusted



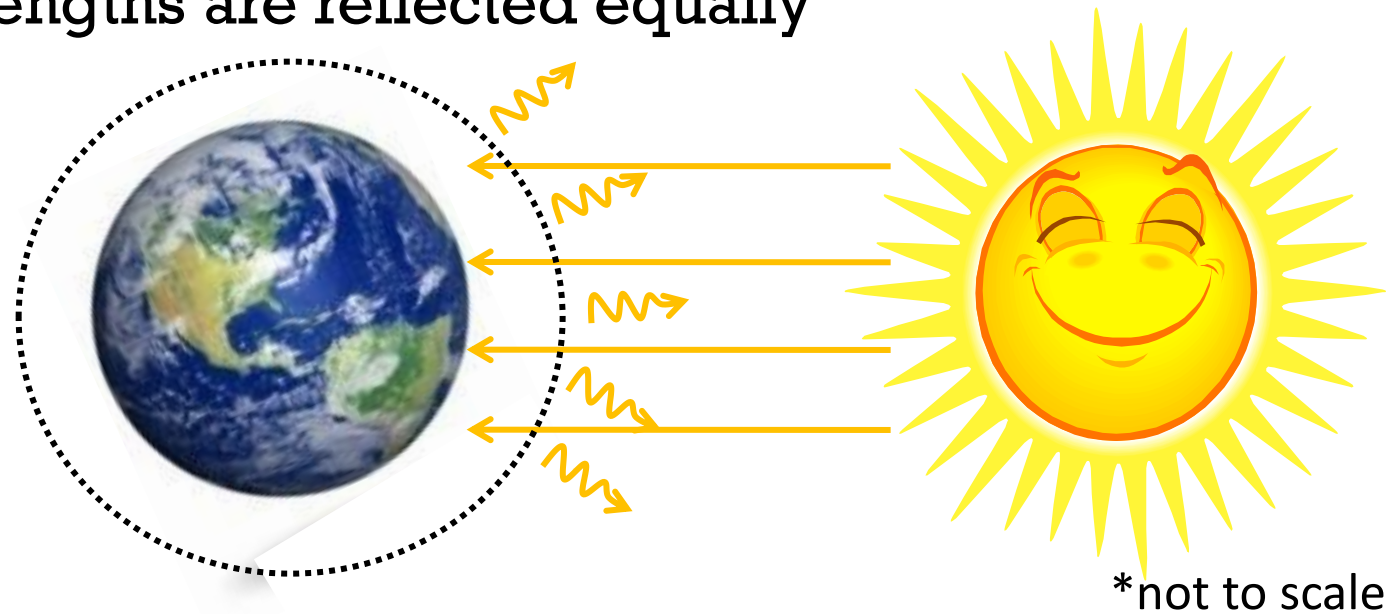
- Carbon dioxide is helpful to plants, but it is a greenhouse gas
 - CO₂ concentration in 18th century ~280 ppm
 - Current CO₂ concentration: 412 ppm



Greenhouse Effect

Greenhouse Effect

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



Greenhouse Effect

top of the atmosphere

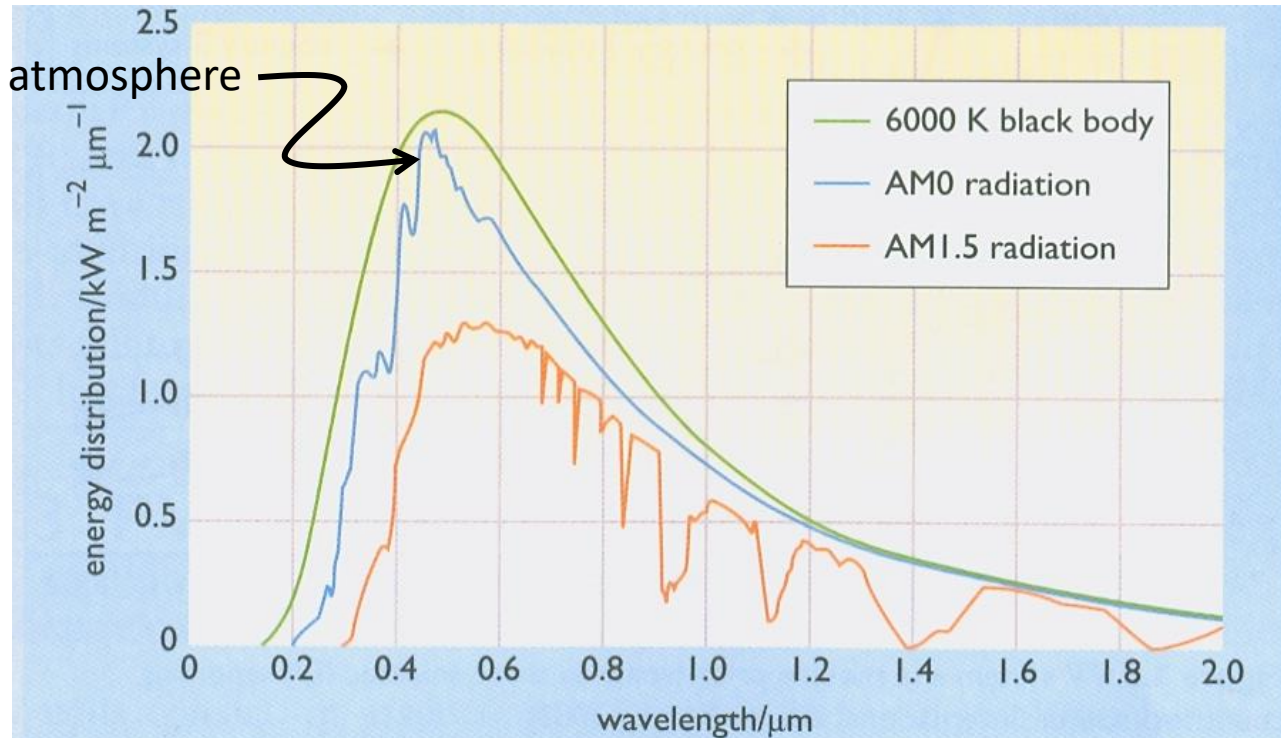


Figure 3.8 The spectral power distributions of solar radiation corresponding to Air Mass 0 and Air Mass 1.5. Also shown is the theoretical spectral power distribution that would be expected, in space, if the sun were a perfect radiator (a 'black body') at 6000 °C

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

Greenhouse Effect

- Earth's surface heats and re-radiates heat back into space
 - Longwave infrared radiation



*not to scale

Greenhouse Effect

- 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

→ 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

» 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 5g/MWh

Environmental Concerns of Hydropower

» 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)

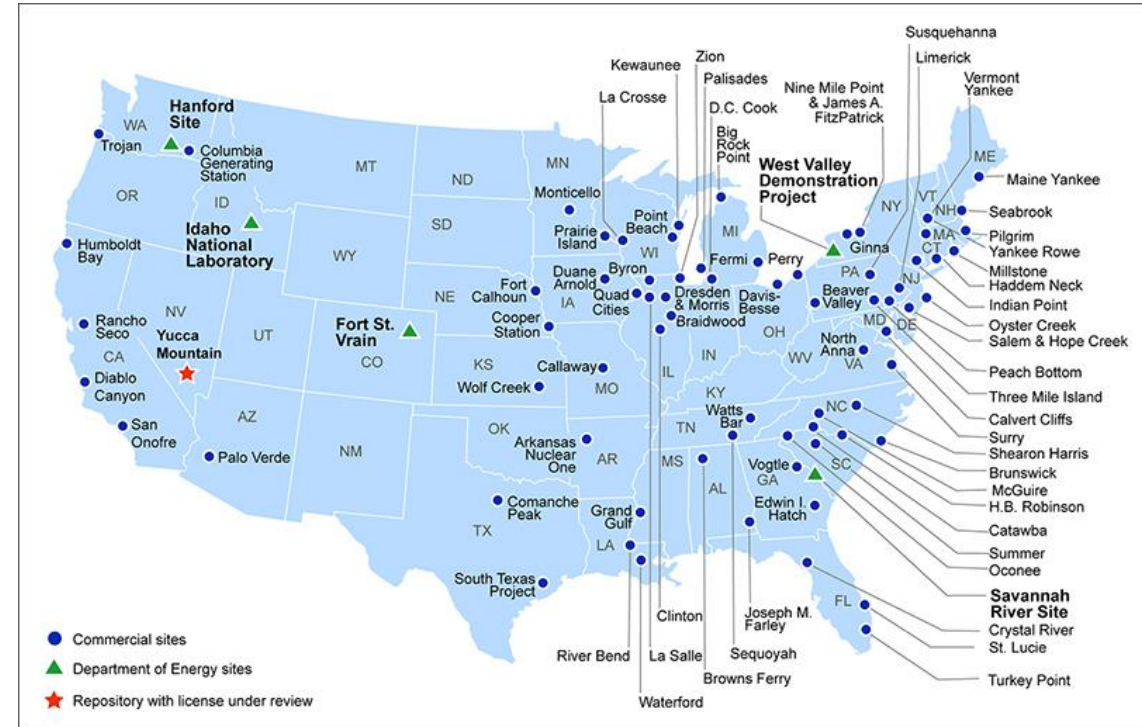
Environmental Concerns of Nuclear Power

» 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



Source: *npr.org*