Energy and the Environment

PHYS 4400, Principles and Varieties of Solar Energy
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Some near-term topics

Energy conversion
Need for energy conversion
Value of energy efficiency
**Environmental impacts and challenges**
Fossil energy
Greenhouse effect
Global climate change
Weather vs. climate
Understanding energy

When we talk about energy, our language refers to energy generation and energy consumption. Physically, these phrases refer to energy recovery (or development) and energy conversion.

Examples:

• We establish systems for bringing fuels (such as coal, natural gas, and wood) to power plants where the energy is converted to electricity;

• Mining, drilling, hydraulic fracturing, pumping, biomass harvesting -- these are all methods we use to recover (or gather) fuels (primary energy sources) – petroleum, natural gas, nuclear fuel, wood and plant matter;

• These fuels are then subjected to various processes which convert their stored energy content (chemical energy, or mass energy) to (most commonly) thermal energy to generate steam which drives turbines which generate electricity.
Environmental impacts and challenges

- Energy conversion processes and technologies always impact the environment, but in widely varying ways.

- **Environment** consist of air, water, soil, flora and fauna.

- Energy conversion processes include photosynthesis, photovoltaic energy conversion, combustion, hydrodynamic power, nuclear fission.

- **Water quality:** the combustion of coal emits substantial quantities of pollutants into the air, which ultimately enter the water supply (lakes, oceans) through rainfall. **Nuclear and coal plants** use copious amounts of water – in some cases the water is expelled at an elevated temperature, and in other cases the water is depleted through evaporation.


  “For every three units of energy produced by the reactor core of a U.S. nuclear power plants, two units are discharged to the environment as waste heat. Nuclear plants are built on the shores of lakes, rivers, and oceans because these bodies provide the large quantities of cooling water needed to handle the waste heat discharge.”

  http://www.ucsusa.org/nuclear_power/nuclear_power_technology/got-water-nuclear-power.html

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Environmental impacts and challenges (cont.)

Environmental impacts of coal.

The main human activity that emits CO₂ is the combustion of fossil fuels (coal, natural gas, and oil) for energy and transportation, although certain industrial processes and land-use changes also emit CO₂. The main sources of CO₂ emissions in the United States are described below.

- **Electricity.** Electricity is a significant source of energy in the United States and is used to power homes, business, and industry. The combustion of fossil fuels to generate electricity is the largest single source of CO₂ emissions in the nation, accounting for about 40% of total U.S. CO₂ emissions and 33% of total U.S. greenhouse gas emissions in 2009. The type of fossil fuel used to generate electricity will emit different amounts of CO₂. To produce a given amount of electricity, burning coal will produce more CO₂ than oil or natural gas.

- **Transportation.** The combustion of fossil fuels, such as gasoline and diesel to transport people and goods, is the second largest source of CO₂ emissions, accounting for about 31% of total U.S. CO₂ emissions and 26% of total U.S. greenhouse gas emissions in 2010. This category includes transportation sources such as highway vehicles, air travel, marine transportation, and rail.

- **Industry.** Many industrial processes emit CO₂ through fossil fuel combustion. Several processes also produce CO₂ emissions through chemical reactions that do not involve combustion, for example, the production and consumption of mineral products such as cement, the production of metals such as iron and steel, and the production of chemicals. Various industrial processes accounted for about 14% of total U.S. CO₂ emissions and 20% of total U.S. greenhouse gas emissions in 2010. Note that many industrial processes also use electricity and therefore indirectly cause the emissions from the electricity production.

Note: All emission estimates from the [Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010](http://www.epa.gov/climatechange/ghgemissions/gases/co2.html)
Air quality

From [http://www.epa.gov/hg/about.htm](http://www.epa.gov/hg/about.htm): “Health effects of mercury. Mercury exposure at high levels can harm the brain, heart, kidneys, lungs, and immune system of people of all ages. Research shows that most people's fish consumption does not cause a health concern. However, it has been demonstrated that high levels of methylmercury in the bloodstream of unborn babies and young children may harm the developing nervous system, making the child less able to think and learn.”
The Greenhouse Effect

Solar radiation: 343 Watts per m²
Some of the solar radiation is reflected by the atmosphere and the Earth's surface
Outgoing solar radiation: 103 Watts per m²
Some of the infrared radiation passes through the atmosphere and out into space
Outgoing infrared radiations: 240 Watts per m²

Solar radiation passes through the atmosphere
Incoming solar radiation: 240 Watts per m²
About half the solar radiation is absorbed by the Earth's surface
Absorption solar radiation: 168 Watts per m²
Some of the infrared radiation is absorbed and re-emitted by the greenhouse gas molecules.
Radiation is converted to heat energy, causing the emission of longwave (infrared) radiation back to the atmosphere

http://www.elmhurst.edu/~chm/vchembook/globalwarmA5.html


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Greenhouse effect (continued)

- Climate change has been linked principally to the generation and emission of so-called greenhouse gases.
- The most substantial greenhouse gas, due to its prevalence and direct quantitative accounting through our use of fossil fuels, is CO$_2$.

Symmetric mode, bending mode, and asymmetric mode. Corresponding “energies” are 667 cm$^{-1}$ for the bending mode, and 2349 cm$^{-1}$ for the asymmetric mode.

Energies expressed in units of cm$^{-1}$ (called wavenumber units) are based on the fact that the energy of a photon depends on the wavelength (since $\hbar$ and $c$ are constants). Larger values of wavenumbers corresponds to higher energy, with 10,000 cm$^{-1} \rightarrow 1$ μm.

An energy of 2349 cm$^{-1}$ can be converted to show the wavelength (e.g. in μm) by $(1/2349)$ cm = $4.26 \times 10^{-4}$ cm = $4.26 \times 10^{-6}$ m = 4.26 μm.

Fig. 1 Vibrational modes of CO$_2$
Global climate change

The most general definition of climate change is a change in the statistical properties of the climate system when considered over long periods of time, regardless of cause. - http://en.wikipedia.org/wiki/Climate_change
Global warming

Earth’s weather system has been observed to be warming over the past > 100 years. The weather system includes the atmosphere and the oceans.
Global warming (cont.)


Weather vs. climate

Weather refers to the atmospheric conditions over a short period of time (e.g., “the weather forecast”), such as week or a little longer. The climate of a region refers to the average weather over a period of many years or even decades.

Weather conditions vary quite widely around climate averages.

Over long periods of time, we have observed changes in the climate for many regions on earth, leading to glaciers receding, reduced average snowfalls, and (typically) increased average temperatures.