Energy and Environmental Degradation

- Global warming and fossil fuel
- Energy and quality of life
- Need to sequester CO$_2$ from fossil fuels
- Biofuels are of limited utility
- Hydroelectric power is losing its green appeal
- Electric cars need better batteries
- Hydrogen presents engineering challenges
- Nuclear power comes with safety and security risks
- Wind power is soaring
- Solar power may shine
- Energy conservation is the key
Global Warming and Consequences

> 4°C: Major extinctions around the globe
≥ 40% of global ecosystems transformed
Few ecosystems can adapt
Extinctions of 15%-40% of endemic species in global biodiversity hot spots
Widespread coral mortality
~20%-30% of species committed to extinction
≥ 15% of global ecosystems transformed
Major (≈20%-80%) loss of Amazon rainforest
Loss of ~10%-80% of various fauna in S. Africa
Coral reefs bleached
~10%-15% of species committed to extinction
Loss of 8% of freshwater fish habitat in N. America
Polar ecosystems increasingly damaged
Amphibian extinctions increasing on mountains

Source: Modified from IPCC Working Group II's 2007 Technical Summary, Figure TS.6

From Science, 23 November 2007
Temperature change over the past 50 years is covered only by models (pink shading) that include human-made forces.

From IPCC Report 2007
Can we avoid the worst in global warming?

Probability (black curve) and uncertainty range (colored bars) of going over the ‘optimistic’ IPCC scenario (global warming of 2 °C by the year 2100), shown as a function of integrated carbon emissions from 2009 to 2049. One GtC means 3.7 Gt of CO₂.

Figure 26.1: Energy consumption and carbon emission in the U.S.A. in 2003. A total of 5.772 Gt of CO$_2$ means the U.S.A. alone were releasing 20% of the world’s yearly “allowance” (7 Gt of carbon) for a 50% chance of exceeding the “optimistic” IPCC scenario. However, the U.S.A. accounts only for 4% of the world population. Thus, if other countries would release corresponding amounts of CO$_2$, global warming would become catastrophic. From Shinner & Citro (2006).
Figure 26.2: Total Primary Energy Supply (TPES) worldwide measured in Exajoules (EJ; 1 EJ = 10^{18} Joules). From Smil (2003). The upper curve shows what would happen if energy supply per capita would increase world-wide to the current level of the G7 countries. Even with the lowest curve, global warming will probably exceed the IPCC’s “optimistic scenario” if fossil fuel remains our primary energy source.)
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Figure 26.3: Life expectancy and energy consumption per capita in different countries.
(1 kgoe = 1 kilogram of oil equivalent)

Figure S26.a: Infant mortality and energy consumption per capita in different countries.
(1 kgoe = 1 kilogram of oil equivalent)

From Smil (2003)
Figure S26.b: Average per capita food availability and energy consumption in different countries.
(1 kgoe = 1 kilogram of oil equivalent)

From Smil (2003)
Figure S26.c: Human development index and energy consumption in different countries.

(1 kgoe = 1 kilogram of oil equivalent)

From Smil (2003)
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Update 26.1

CO₂ currently released into the atmosphere by electric power plants using fossil fuel can be captured and stored. CO₂ already in the air can be “scrubbed” out by capture machines with recyclable filters (Lackner, 2012). A combination of both technologies can probably halt further air carbonization while driving up energy costs by 10-50 %.
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Figure 26.6: Energy production, its footprint, and its power density (= energy per time per area).

From Smil (2003)
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**Q:** How many charcoal briquettes do you throw in the air as you drive a conventional family sedan?

**Assumptions:**
- Car speed: 65 miles per hour
- Fuel efficiency: 25.5 miles per gallon
- Charcoal briquettes are 100% carbon

**Data:**
- Octane buoyant density at 10°C: 0.711 kg/liter
- Carbon share of octane ($C_8H_{18}$) weight: 0.842
- Weight of 1 charcoal briquette: 32.21 grams
- 1 gallon = 3.79 liter

**A:** 3 briquettes per minute, or 1 briquette per 20 seconds
Figure 26.7: Hydrogen and electricity as intermediate energy carriers for automobiles. From Smil (2003).
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Figure 26.8: Hydrogen as an energy carrier.
Figure S26.d: Building hydrogen tanks for cars is an engineering challenge.
"From Scientific American, May 2004"
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Figure 26.9: Wind is a clean, renewable source of energy.

This photo of a wind farm in Taft, Texas, was shot by Ashley Saenz, after taking BIO 346 in Spring 2011.
Update 26.2: In 2012, total U.S. wind power capacity surpassed 60GW, of which 12 GW were installed in Texas. For comparison: A large nuclear reactor produces 1 GW. Power density is high because land under turbines can be used for other purposes. Cost of generated electricity is competitive: 4 cents per kilowatt hour.
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world and US shipments of PV cells

"From Smil (2003)"
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Keeping Carbon in Check

Total carbon amounts in the atmosphere – and the resulting global warming - will reach catastrophic levels (brown curve) if current carbon emissions per year continue.

(From Socolow and Pacala, 2006)
To prevent catastrophic levels of atmospheric carbon, worldwide emissions must be kept below 7 billion tons per year now and reduced to an equilibrium level of about 3 billion tons per year after 50 years (blue curve).
Energy and Environmental Degradation

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- The future of fossil fuels
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WELL-TO-WHEELS ENERGY EFFICIENCY

Total energy efficiency includes not only vehicle operation but also the energy required to produce fuel. Extracting oil, refining gasoline and trucking that fuel to filling stations for internal-combustion engines is more efficient than creating hydrogen for fuel cells.

"From Scientific America, May 2004"
TOTAL EMISSIONS OF VEHICLES

Emissions of greenhouse gases (carbon dioxide or equivalent) vary depending on the combined effects of the vehicle's operation and the source of the fuel. Fuel-cell vehicles emit no greenhouse gases themselves, but the creation of the hydrogen fuel can be responsible for more emissions overall than conventional gasoline internal-combustion engines are. (The Energy Department calculates that ethanol derived from corn has almost no greenhouse gas emissions, because carbon emitted by ethanol use is reabsorbed by new corn.)
From Smil (2003)
Figure 26.4: Shares of crude oil reserves.

From Smil (2003)
Figure 26.5: Peter Odell’s forecast of natural gas production.

*From Smil (2003)*
Q: How many charcoal briquettes do you throw in the air per minute as you drive your automobile?

Assumptions:
Car speed: 65 miles per hour
Fuel efficiency: 25.5 miles per gallon

Data:
Octane buoyant density at $10^0\text{C}$: 0.711 kg/litre
Carbon share of octane ($\text{C}_8\text{H}_{18}$) weight: 0.842
Weight of 1 charcoal briquette: 32.21 grams
1 gallon = 3.79 litre

A: Three briquettes per minute, or one briquette every 20 sec.
"From Science, 305: 969 (2004)"
consumption of industrial, commercial, and household energy

"From Smil (2003)"
Fig. S24.a: Polar Ice between the north pole and Alaska/Canada is thawing 3x faster now than 20 years ago. Methane previously locked up in permafrost land is now bubbling to the surface, adding large amounts of a potent greenhouse gas to the atmosphere.

Figure 26.9: Wind is a clean, renewable source of energy.

Power density is high because areas under turbines can be used for grazing livestock and other purposes. This wind farm is near Sweetwater, Texas.

Courtesy of Morgan Gomez, BIO 346 student in Sp 2012