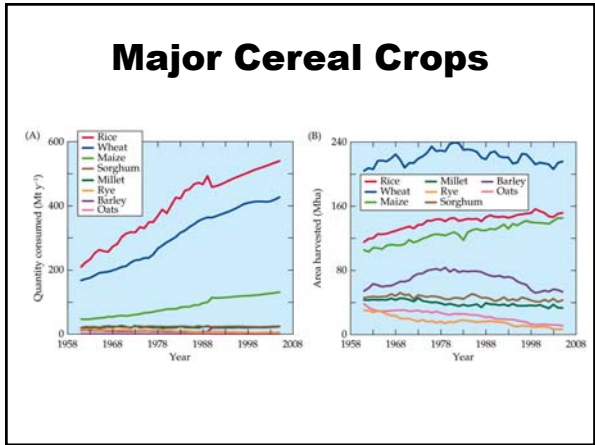
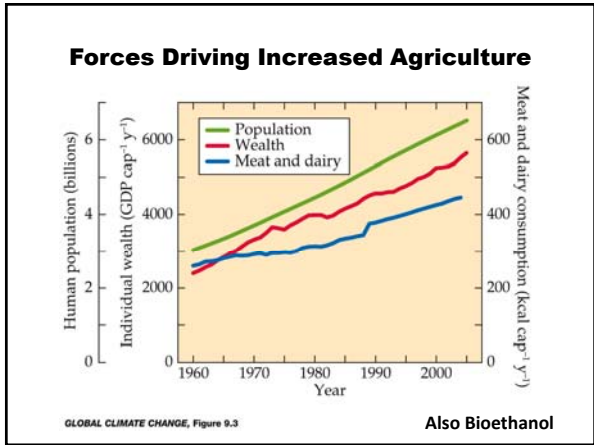


Sources of Emissions

- Here energy includes power generation and transportation
- Waste is garbage and sewerage
- Agriculture produces ~20% of total
 - Biggest Agricultural CO₂ source is decay after deforestation
 - Biggest Agriculture CH₄ sources are livestock and rice cultivation
 - Biggest N₂O source is nitrogen fertilizer
 - Needed to accommodate decreased N uptake in high CO₂



Agricultural GHG Source Mechanisms

- Nitrogen Fertilization
 - Past breeding for bigger yields increased NO₃⁻ demand
 - Led to over fertilization
 - Denitrification by anaerobic bacteria NO₃⁻ → NO₂⁻ → NO → N₂
 - Newer cultivars and better nitrogen management can increase yields without requiring more nitrate
- Minimum Tillage
 - Leave plant residues in fields reducing use of tractors and (generally) improving soil quality
- Biomass burning both to clear fields and after timbering
- Livestock (ruminants) produce CH₄ by fermentation.
 - Reducing fiber and carefully chosen antibiotics can reduce emissions
- Deforestation results in CO₂ emission through burning or decomposition of slash
 - Control has potential to reduce human CO₂ emissions by ~14%

Rice Cultivation

- Most widely eaten grain
- Wetland Rice fields are flooded to control weeds and provide enough H₂O for this C3 crop.
- Fields dry at maturity for harvest
- Culturally important
- Methanogenesis, e.g.

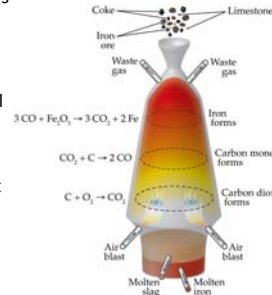
$$\text{CH}_3\text{COOH} \rightarrow \text{CO}_2 + \text{CH}_4$$
 Is a big issue
- Not much room for improvement here

Industrial Emissions

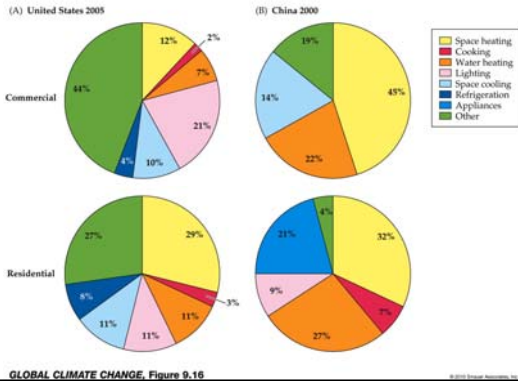
- Emissions have grown in absolute terms
 - But declined as a fraction (40% to 37%) since 1970
- Keys to limiting emissions are
 - Better maintenance
 - Replacement of inefficient legacy equipment
 - Equipment lifetimes are 10-50 yr
- Cogeneration and heating with waste heat from industry

Metallurgy

- Most metal ores are oxides (Fe_2O_3 , hematite) or sulfides (Cu_2S , chalcocite).
- In iron smelting, the Fe_2O_3 is reduced with CO , releasing CO_2
- In copper smelting, the sulfur is oxidized to SO_2
- Both require heat from coal (Fe) or natural gas (Cu)
- Iron also needs carbon as a reducing agent
- GHG production is inherent in metallurgy, although some marginal efficiencies are possible
- Recycling scrap takes a fraction of the energy required to smelt metal from ore



Energy for Homes and Enterprises



Ways to Improve Efficiency

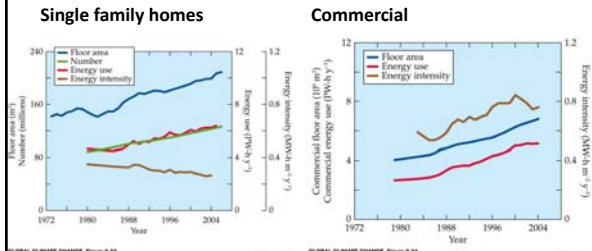
- Reduce leakage of heated or cooled air
- Manipulate solar heating (1000 W m^{-2} at noon)
 - Solar water heating
 - Warming in winter by letting sunlight shine in windows
 - Reducing AC demand by shading windows in summer
 - Plant deciduous trees around house
 - Architectural modifications so that building absorbs sunlight passively in winter and is shaded in summer
- Replace legacy HVAC systems (and other appliances) with more efficient units
- These measures, combined, with lighting upgrades can reduce consumption by ~50%

LED Lighting Revolution

- Combined blue and yellow LEDs can make white light.
- 60 W equivalent costs \$8 and actually uses 10W. Lasts 10-20 yr
- Equivalent compact fluorescent draws 15 W and lasts 2-5 yr
 - Mercury pollution
- 60 W incandescent bulbs phased out. Last ~1 yr in heavy use



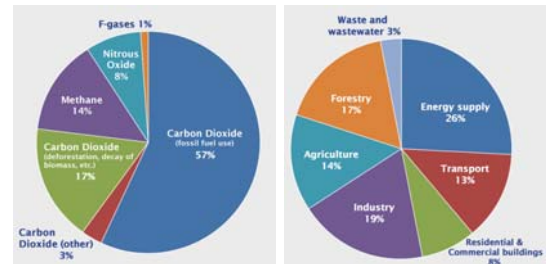
Energy Intensity (W m^{-2})



Geoengineering

- Mostly Hogwash
- Place sunshades in space to reduce solar heating
- Inject SO_2 into the stratosphere to mimic volcanic cooling
- Seed oceanic stratus clouds to make them last longer and be whiter (Twomey effect)
- Fertilize oceans to increase photosynthesis and use biological pump to move carbon into the deep sea
 - Use wave driven pumps to bring nutrient-rich water from depths to stimulate phytoplankton

Green House Gasses and Sources From IPCC



SUMMARY

- Agriculture & Forestry, industry, and buildings account for 58% of emissions
 - Ag & forestry emit most CH_4 from anaerobic bacteria in soils and animal guts
 - And most NO_3 from nitrogen fertilizer
 - Rice cultivation is a big CH_4 emitter
- Industrial savings mostly stem from better maintenance and replacement of inefficient legacy equipment
- Metallurgical savings are small, apart from recycling scrap
- Buildings can realize significant savings from solar heating and LED lighting
- Geoengineering would be a better option for a more advanced civilization