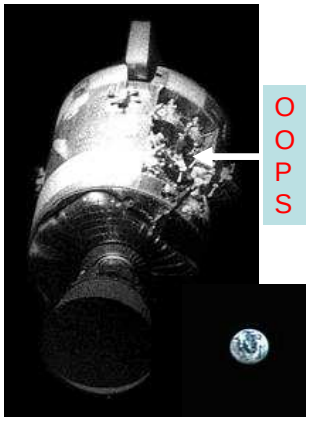
Energy Basics

(30 March 2010)

What we should know to help ourselves, our towns & our families.
What we must know to choose products, companies & jobs.

"Let's work the problem.
Let's not make things worse by guessing."

Eugene Kranz,
Apollo 13
Flight Director,
April 1970.



Dr. Alexander Cannara
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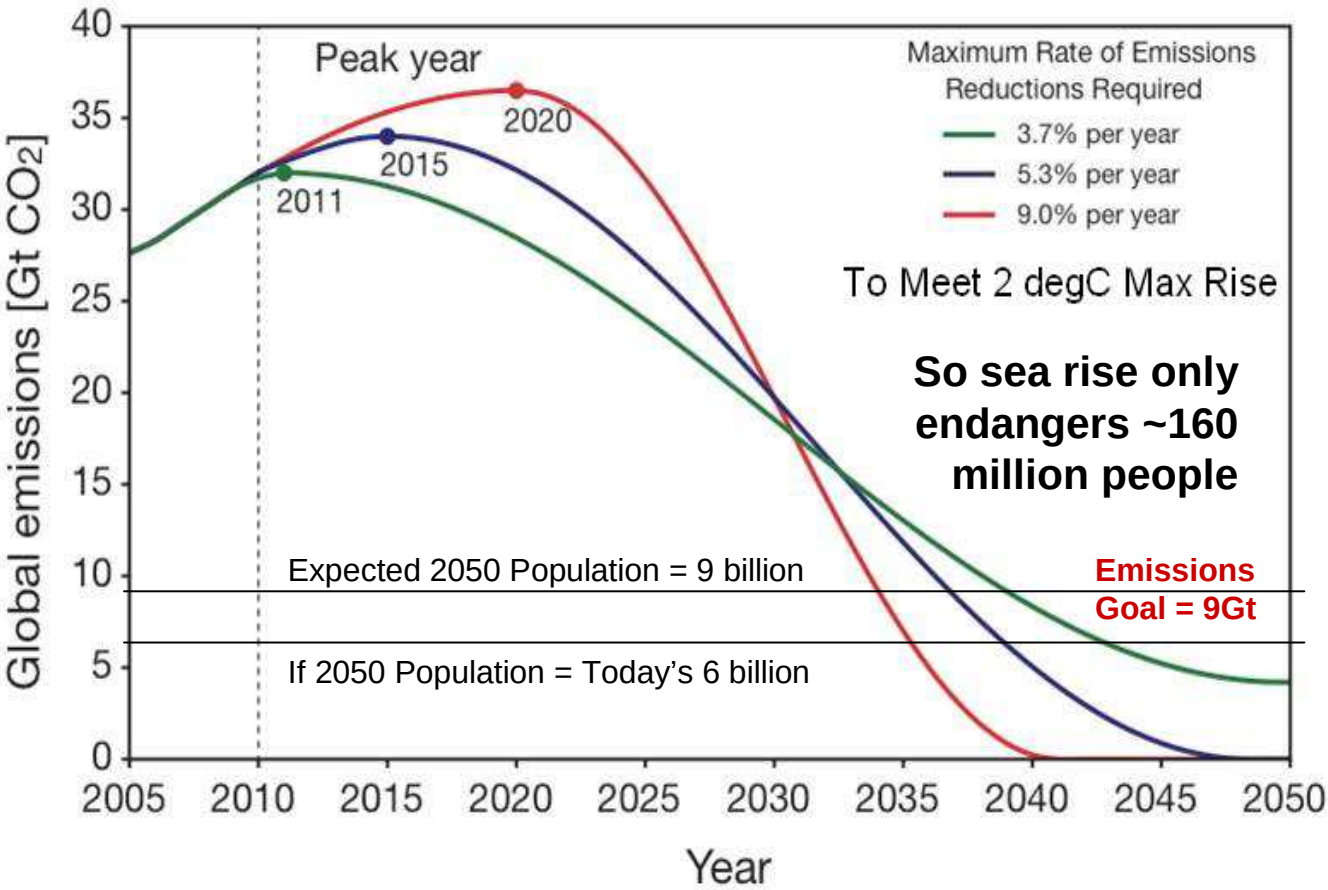
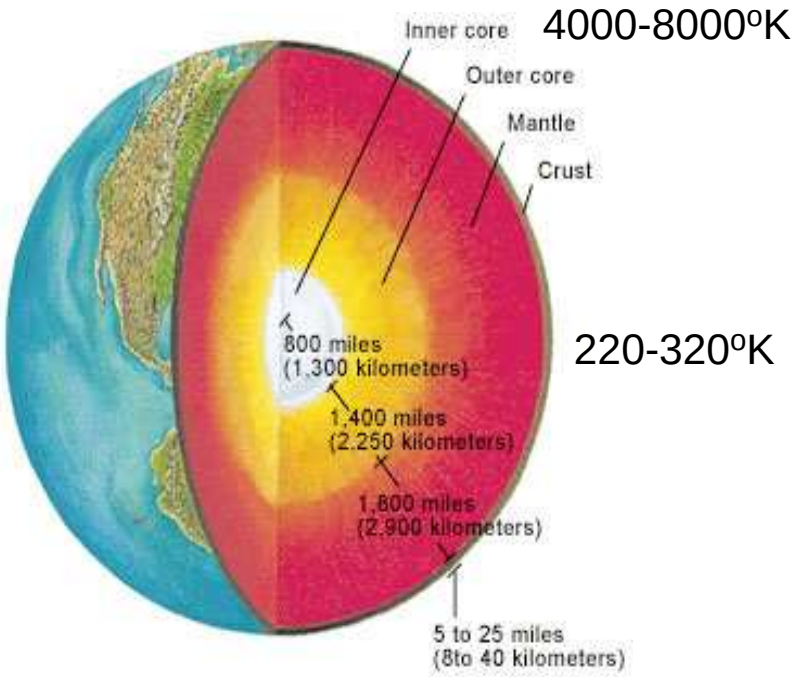
30 Mar. revision. **The problem to work – 1 ton of CO_2 per capita/year by 2050…**
www.copenhagendiagnosis.org/ (p53)



Energy Sources on Earth

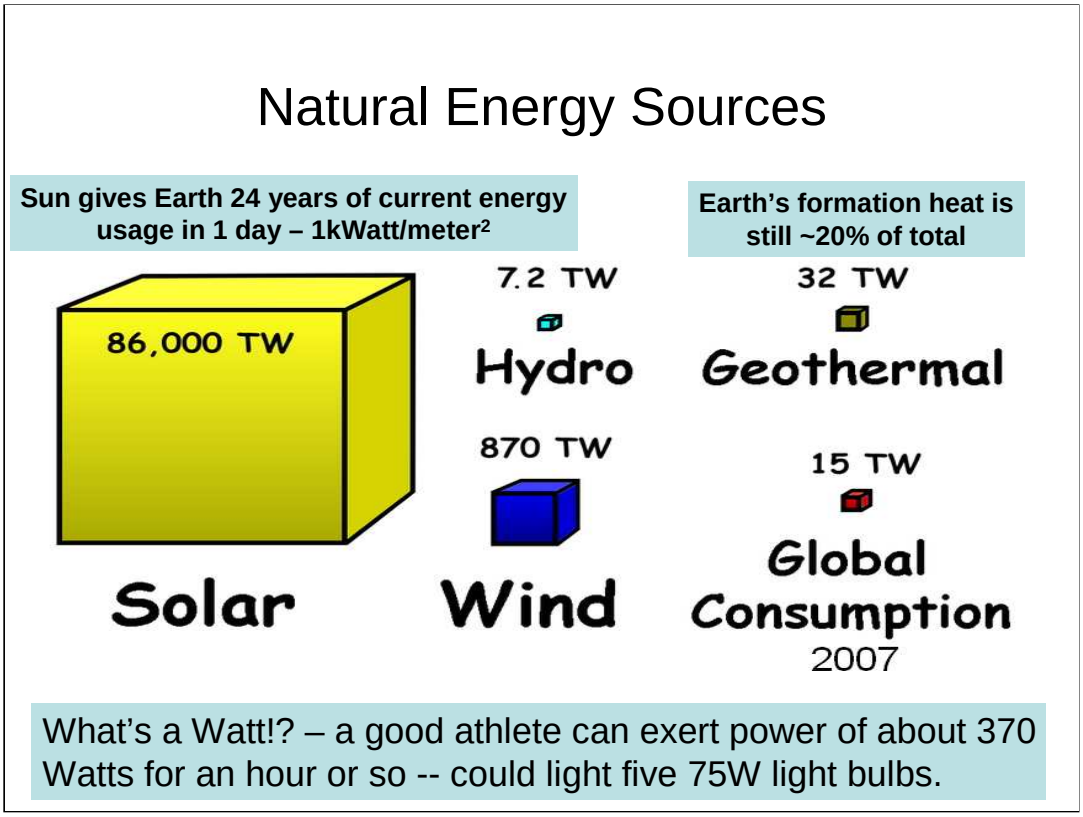
- ***Natural*** (three of significance)
  - **Sunlight** (infrared & visible light)
  - **Geothermal** (nuclear decay, volcanism)
  - **Chemical** (mineralization, sea/air, life…)
  - Space (cosmic rays, solar flares, meteors…)
- ***Derived Naturally*** (unrelated to humans)
  - **Fire** (hydrocarbon life releasing oxygen via sunlight)
  - **Weather & Water** (sunlight-induced flows)
  - **Gravitational** (tides, falls)
- ***Unnatural*** (human harnessed)
  - **Heat**: Fire, Chemical, Nuclear
  - '**Renewable**': natural, cyclic sources (not infinite)

Earth's inner heat is primarily due to <u>radioactive elements decaying</u>.



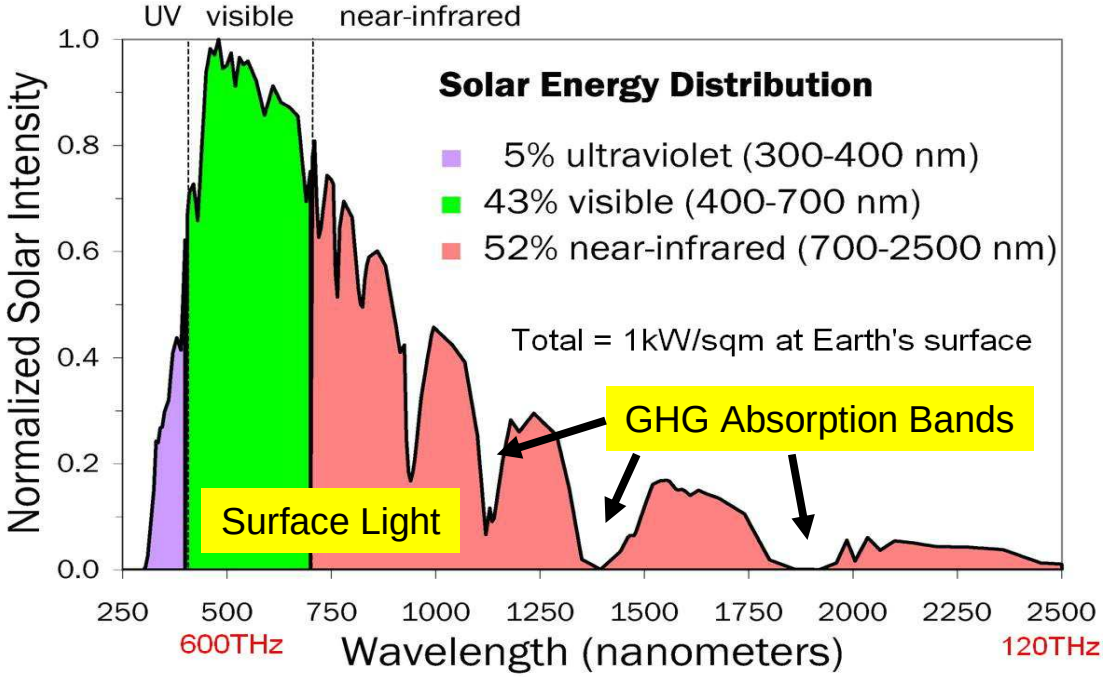
The mostly iron core convects, generating the magnetic field that protects life from the solar wind of million-mph protons, which otherwise would have stripped our atmosphere long ago, much as it has Mars'. And, our air protects us from Xrays, etc.

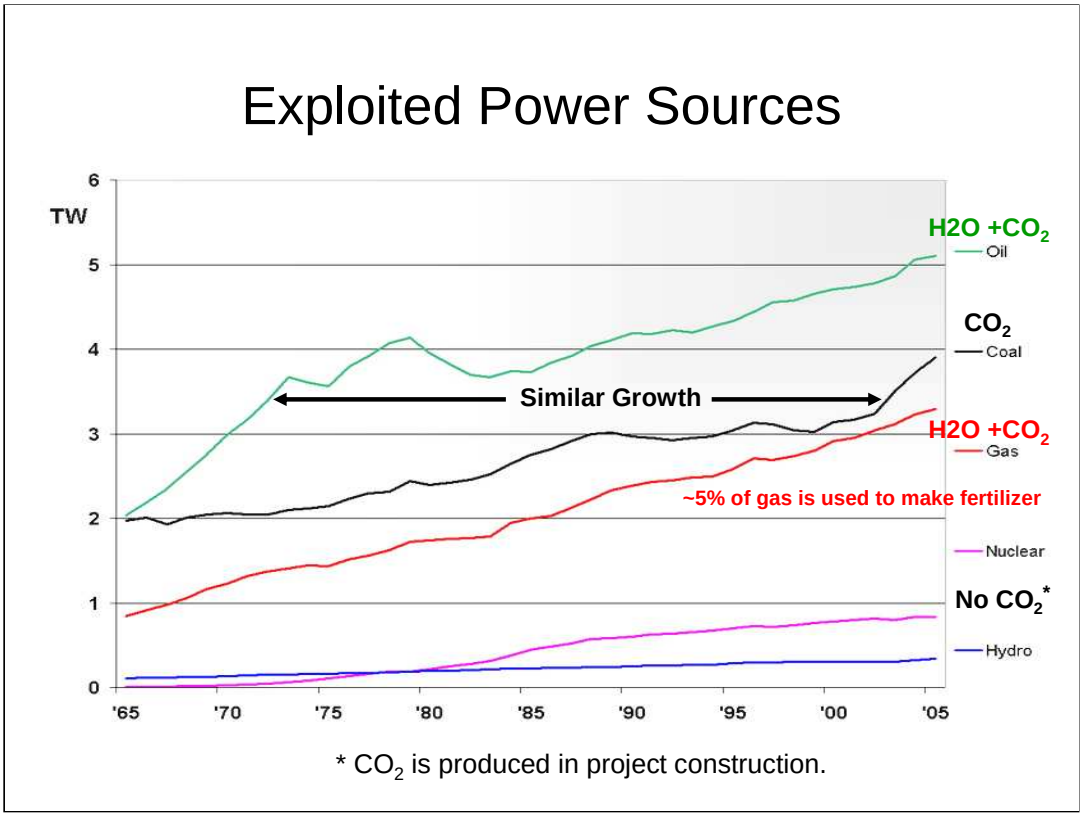
Geothermal energy derives from running heat engines on the thermal energy available in the temperature difference between the upper mantle & the surface. Generally this is simply derived from groundwater, heated in regions where the upper mantle is only thousands of feet from the surface – often volcanic realms.



Solar light energy ultimately is either reflected (from snow/ice/clouds), or absorbed (by plants/land/water/air). Absorption by air gives us the greenhouse effect, keeping us warmer than we would be without an atmosphere that contains so much water vapor and other "greenhouse gasses" (GHGs), like CO_2, CH_4, N_2O, CFCs, HFCs…

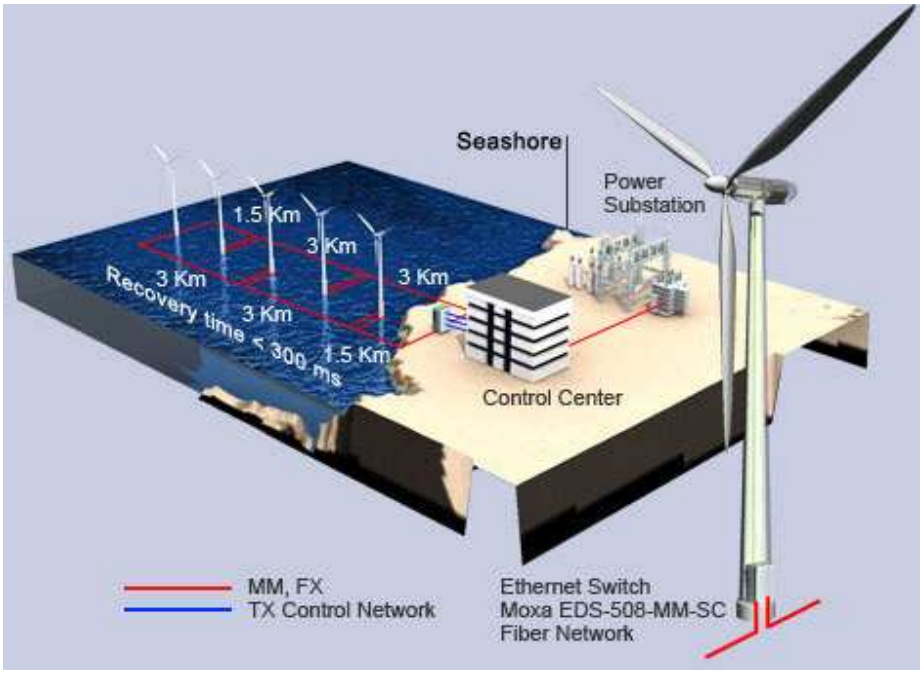
Wind, clouds & non-tidal water currents are all derived from incoming solar light radiation…



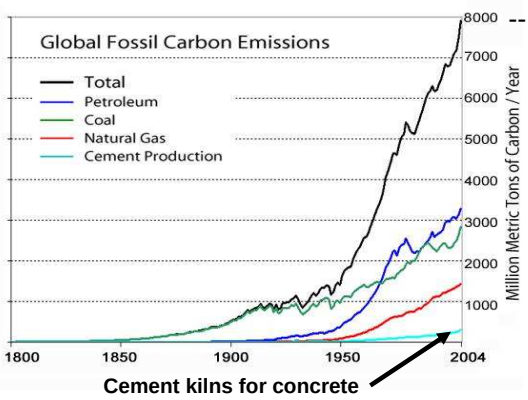


Each **kWHr of energy delivered to a home from a combustion generation** station (gas, oil, coal) **created 1.4lbs of CO_2** (EPA). Fuel burned for heating at the home creates less, per kWHr -- for gas, 0.5lb/kWHr; for oil, a bit more; and for coal, still more. So <u>for heating</u>, it's best to <u>use natural gas, and never electricity</u> or coal. Mixed generation sources can reduce CO_2 emissions per delivered kWHr – PG&E claims 0.87lbs/kWHr in N. Calif.

<u>Farm-like variable sources</u>, like wind/wave, need an elaborate control system to manage individual generator contributions to grid output – e.g., phase & amplitude:



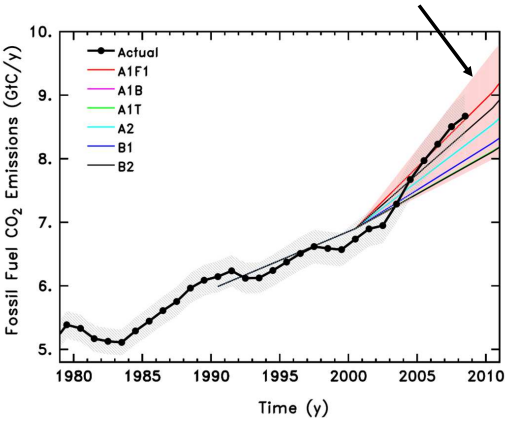
Energy & Carbon Dioxide Production



-- 8 GigaTons

What's a ton of CO_2?
440,000 kids' balloons full of it.

We're now emitting near worst forecast



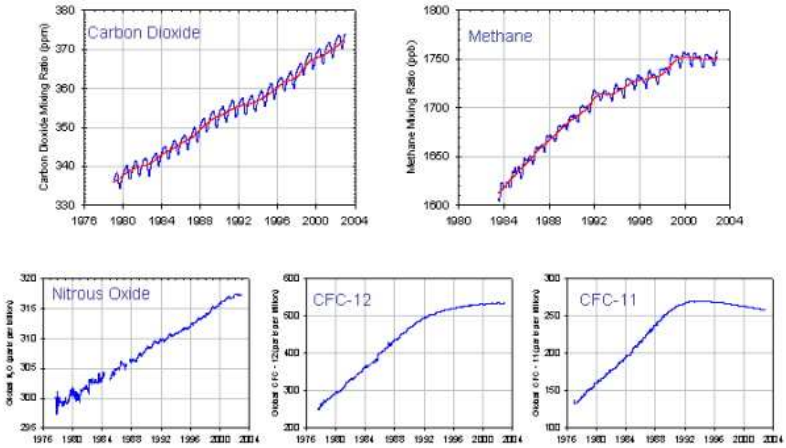
What ~1/10 lb of CO_2 looks like in balloons

A GigaTon = 1 billion tons. A metric ton = 2200lbs.

Note that <u>energy production is not the sole source of emissions</u> – concrete requires fired kilns to produce the Portland Cement that actually binds the constituents in concrete when water is added. The kilns run at 1450°C and convert limestone ($CaCO_2$) & some aluminum silicate to cement by freeing CO_2 from the limestone & allowing calcium oxide to bind with the freed silicate (SiO_2). Thus <u>cement kilns not only emit CO_2</u> by burning hydrocarbon fuel, but by releasing the 80-90% of limestone's CO_2 that came directly from skeletal fragments of marine organisms. These organisms' skeletons got their CO_2 from ancient air & sea. We're putting it back far faster than they can, or did, absorb it.

Some GHG History

Global Trends in Major Greenhouse Gases to 1/2003



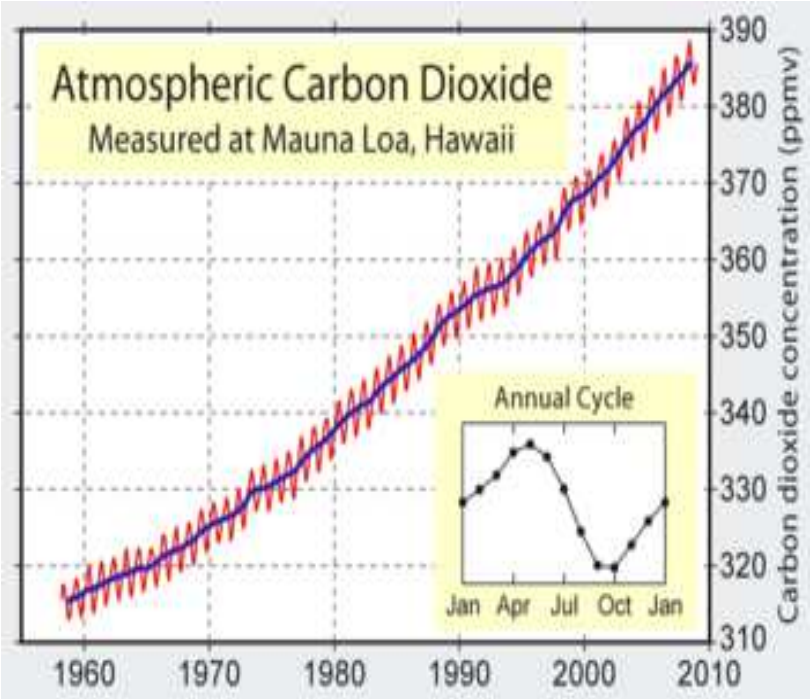
Global trends in major long-lived greenhouse gases through the year 2002. These five gases account for about 97% of the direct climate forcing by long-lived greenhouse gas increases since 1750. The remaining 3% is contributed by an assortment of 10 minor halogen gases, mainly HCFC-22, CFC-113 and CCl_4.

Methane (CH_4) Is 25-100 times as powerful a GHG as CO_2, and Nitrous Oxide is 100 times CO_2.

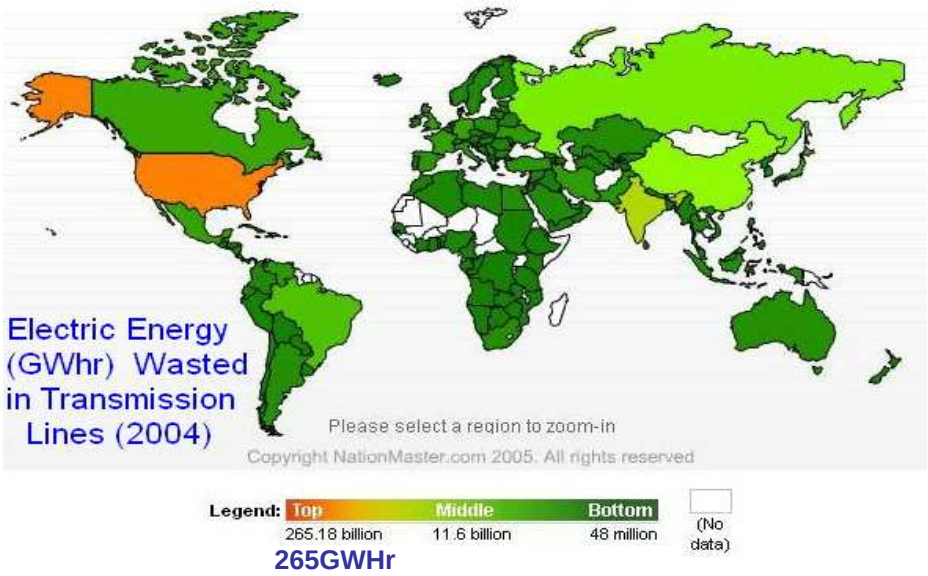
Note the Montreal Protocol effectively limited CFCs, but N_2O from fertilizer is the new Ozone depleter now, and the new HFCs are 4000 times CO_2.

We owe our improving awareness of Earth's climate to scientists' work since Tyndal. The Space Age has given us invaluable tools and viewpoints for measurements of the realities that affect all Earthlings. Our recent pioneering stems from the U. of Hawaii's measurements of CO_2, beginning in 1957 – also the first International Geophysical Year, when scientists worldwide began the intensive studies of our planet that we now depend on to pick a sensible future.

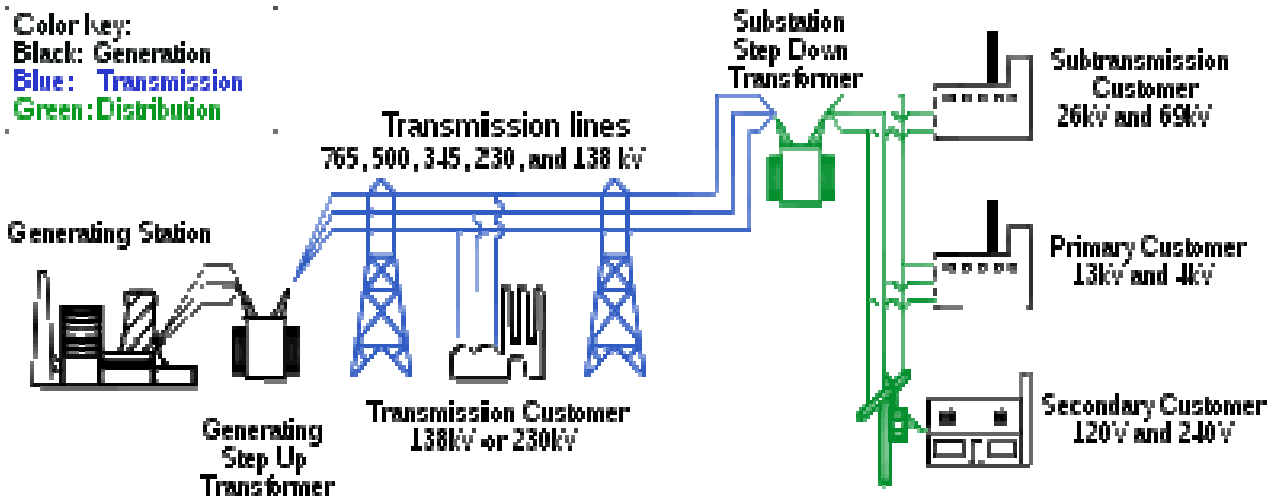
Note the important fact exposed by the "Annual Cycle" vignette – it shows what we could depend on natural, sea & land photosynthesizing organisms to do each year for us to reduce CO_2 levels. it's about 5ppm/year, if no natural sources of CO_2 existed.



Wasted Electric-Transmission Energy



Typical **transmission-line losses in Calif. average 7%** of generated power. distributed, small generation (solar electric, safe nuclear…) in urban locales can recoup much of this loss.

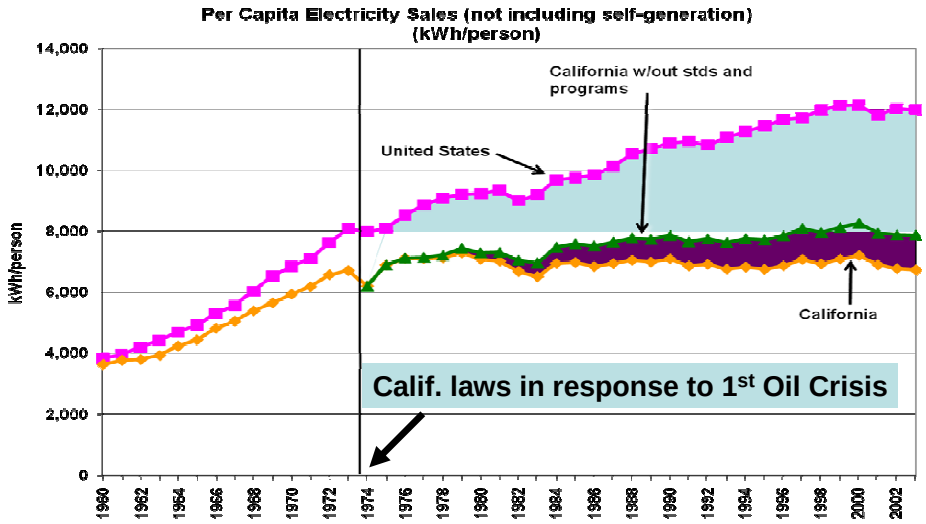


Because their cross-country cables act as antennas, transmission systems like this are susceptible to solar-induced geomagnetic storms – some have been doozys in in our electro-techy age, but none yet near to the **Carrington Event of 1859**. And now, even pipelines are vulnerable.

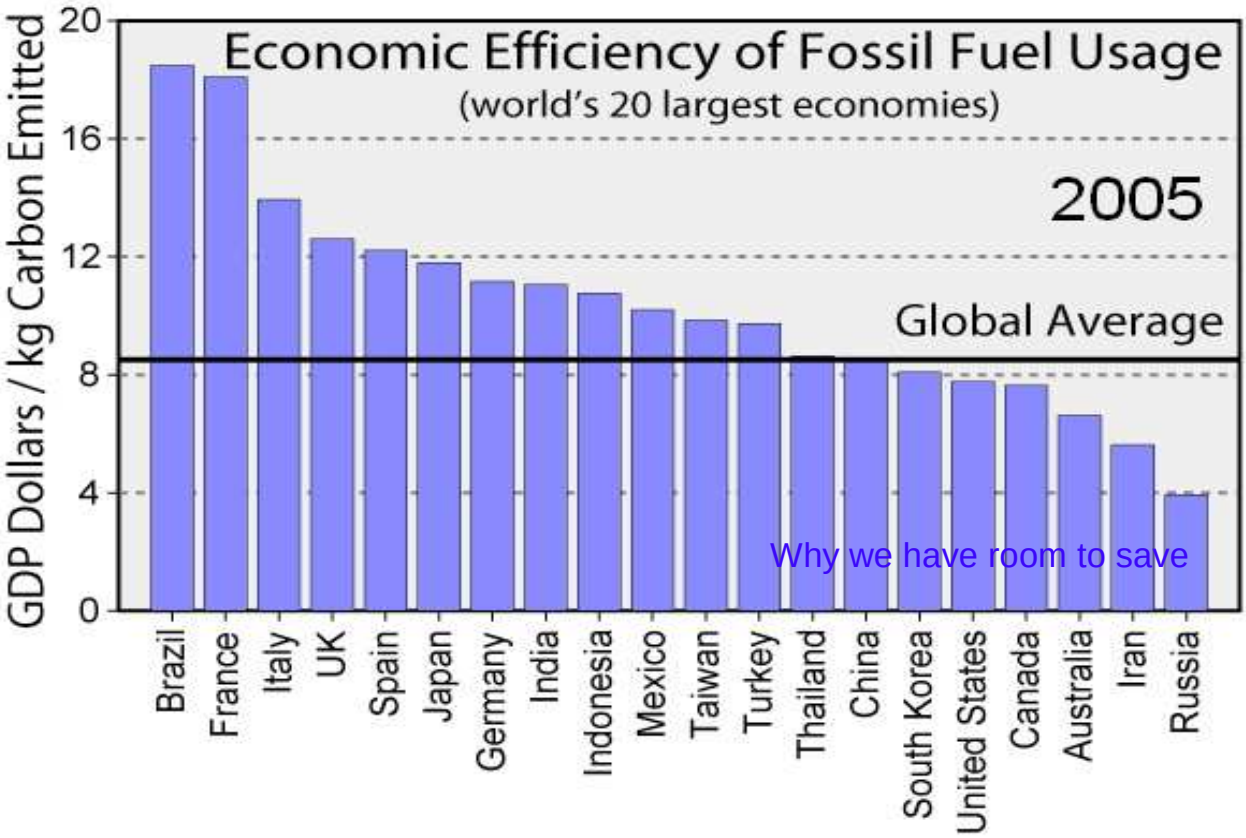
1989 remains of a Quebec transformer:

Personal Energy

- Californians have been doing relatively well…
  - http://docs.nrdc.org/energy/files/ene_10030901a.pdf



Despite Calif's great lead, referenced to the rest of the US, we're still far from the overall CO_2 emissions target for 2050 – 6500kWHrs/percapita/year translates now (@1.1lbs/kWHr) to 3.5 tons/year of CO_2, just for electric use, not counting home/business heating or vehicles. An average Calif. home, heated with gas, generates over 100lbs per capita/year; a car: >5 tons.



Reality & Choices

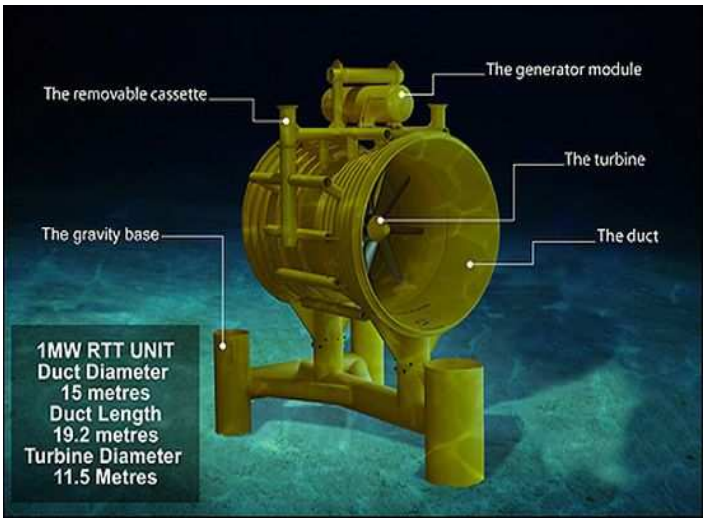
- About 170,000 lbs of vegetation + 700,000 years of sedimentary/tectonic processing made oil for 1 gallon of fuel (35kWHr or ~ 50 Prius miles).
- What 15TeraWatts looks like to Polaris aliens…

• If we use combustible fuels to get 15TW electric, then we generate ~45TW of heat (thermal efficiency ~30%), plus many GigaTons of CO_2 & H_2O (GHGs), plus various environmental damages.

• If we use solar energy, we need over 10,000 square miles of good solar cells per continent, plus nightly storage.

Most 'renewables' aren't & gobble lots of space, even species, to make up for low & intermittent power density…

Tidal – 2MW/1000m^3:

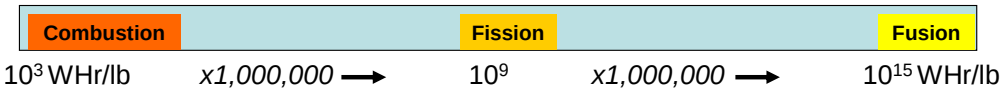


Wind – 1/2MW/acre, 130W/m^2 max.

Solar electric – 200W/m^2 (@20% eff.)
Example is 240,000m^2, >60 acres
2/3MW/acre:

Using Energy-Dense Sources = Good

- Protects the environment & reduces cost.
  - 1 gallon of ***gasoline/diesel*** oil = 35kWHr (+20lbs of CO_2)
    - 6 lbs, 1/8 cubic foot, about 6kWHr per pound.
  - A cubic foot of ***natural gas*** (@1/2psi) = 0.3kWHr
    - = 1028 Btus (0.15lb of CO_2).
  - 1 pound of ***Thorium/Uranium*** = 3,200,000kWhr (no CO_2)
    - When fissioned (typical reactors waste >90% of Uranium mined).
    - Plenty to last for millennia: 0.02lb = a decade of personal energy.
  - 1 pound of ***Hydrogen*** = 4,000,000,000,000kWHr (no CO_2)
    - Deuterium-Tritium fusion (>14MeV/atom pair).
    - Plenty to last beyond Sun's lifetime.
- Low-density sources: solar, wind, wave/tide, geothermal – consume land/sea areas at about 1 square mile/GW.



1MeV = 1.6×10^{-13}Joule. 1 Joule = 1 Watt-Second = 1/3600 WHr.

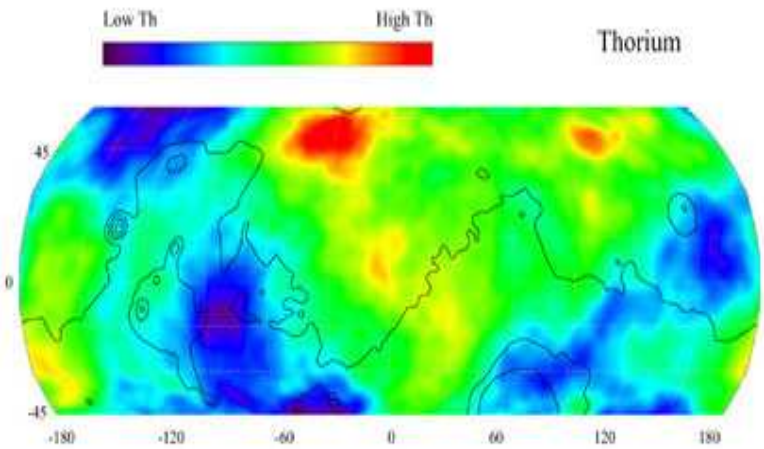
Burning Hydrogen with Oxygen generates more power/pound (15 kWHr) than typical fuels, but the needed Hydrogen volume is so great that compression into reasonable storage containers (@5000-10,000 psi) consumes energy (0.8 to 3 kWHr/lb – x2 to liquefy) & makes Hydrogen less attractive as a simple fuel.

www.hydrogen.energy.gov/pdfs/9013_energy_requirements_for_hydrogen_gas_compression.pdf

And, the water vapor emitted is still a GHG – the dominant one on Earth.

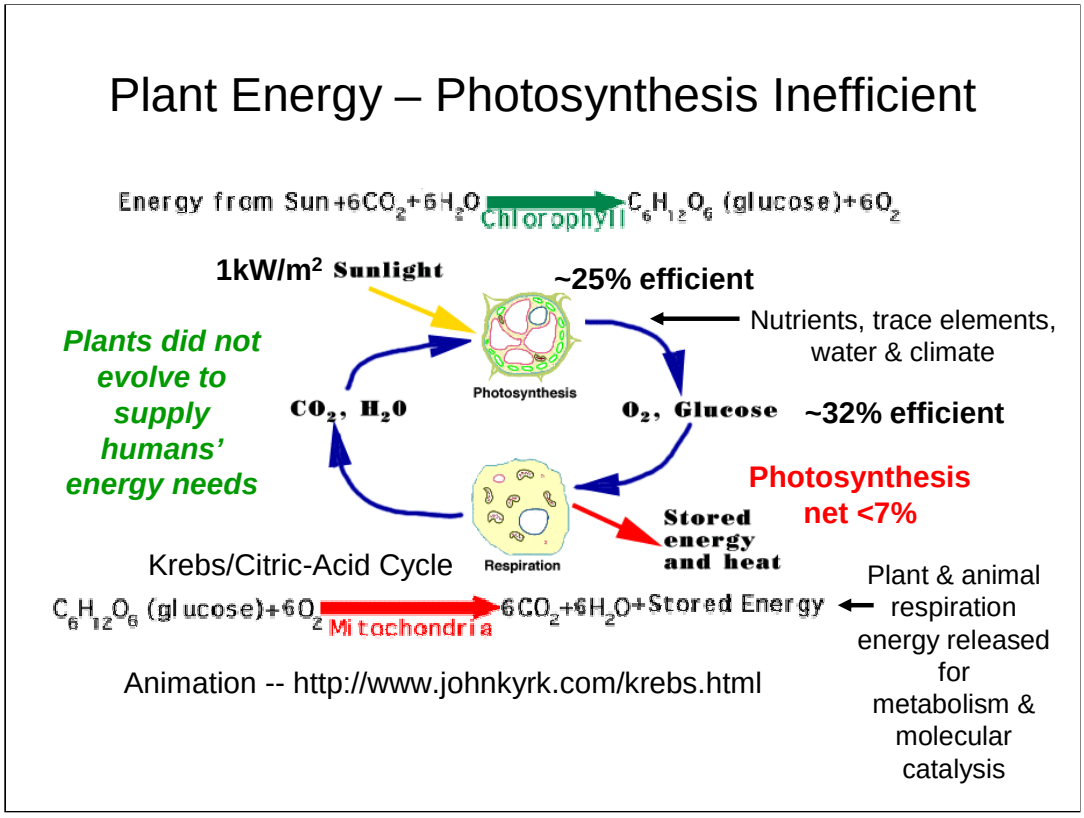
Thorium MSR -- http://tinyurl.com/yb2qgex

When used in a reactor to breed U233 for fission, Thorium has so high an energy density that 12 grams (about 4 pennies) provides enough energy to supply a typical American's needs for a decade. And, that much Thorium can be found in about any cubic meter of rock on Earth, Moon or Mars…



½ Oz. Thorium runs 1 American's life for 1 decade

- Thorium in Mars dirt



See: **http://en.wikipedia.org/wiki/Photosynthetic_efficiency**

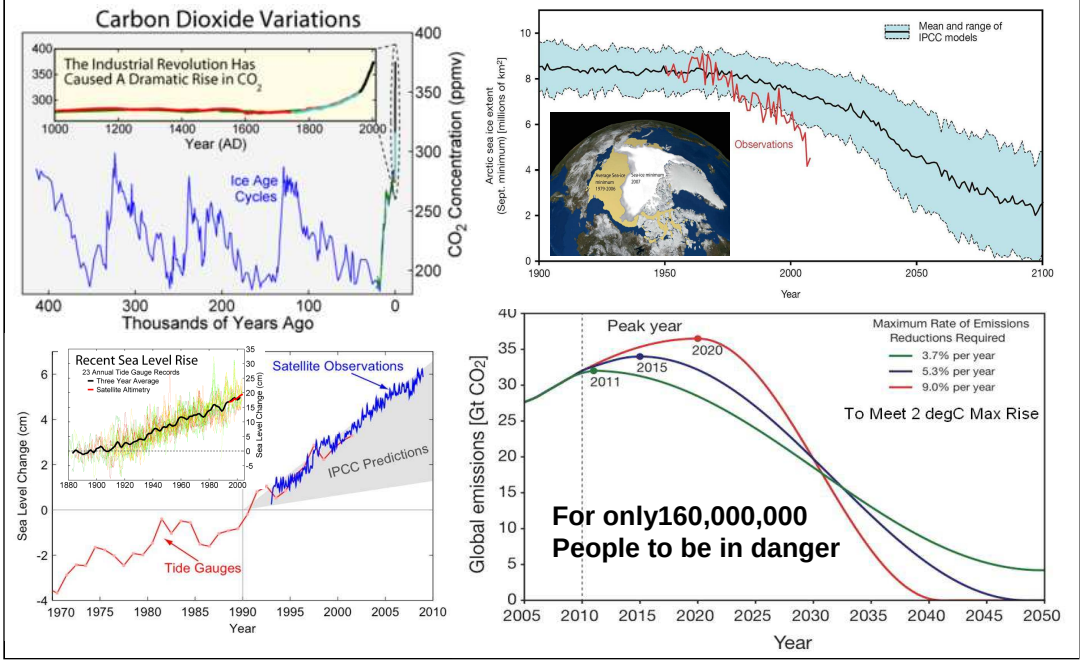
Most crop plants store ~0.25% to 0.5% of sunlight in the product (corn kernels, potato starch, etc) sugar cane is exceptional in several ways to yield peak storage efficiencies of ~8%. Corn and Sugar Cane are examples of C4 plants, which evolved somewhat more efficient energy storage from the more common C3 (Calvin cycle) predecessors.

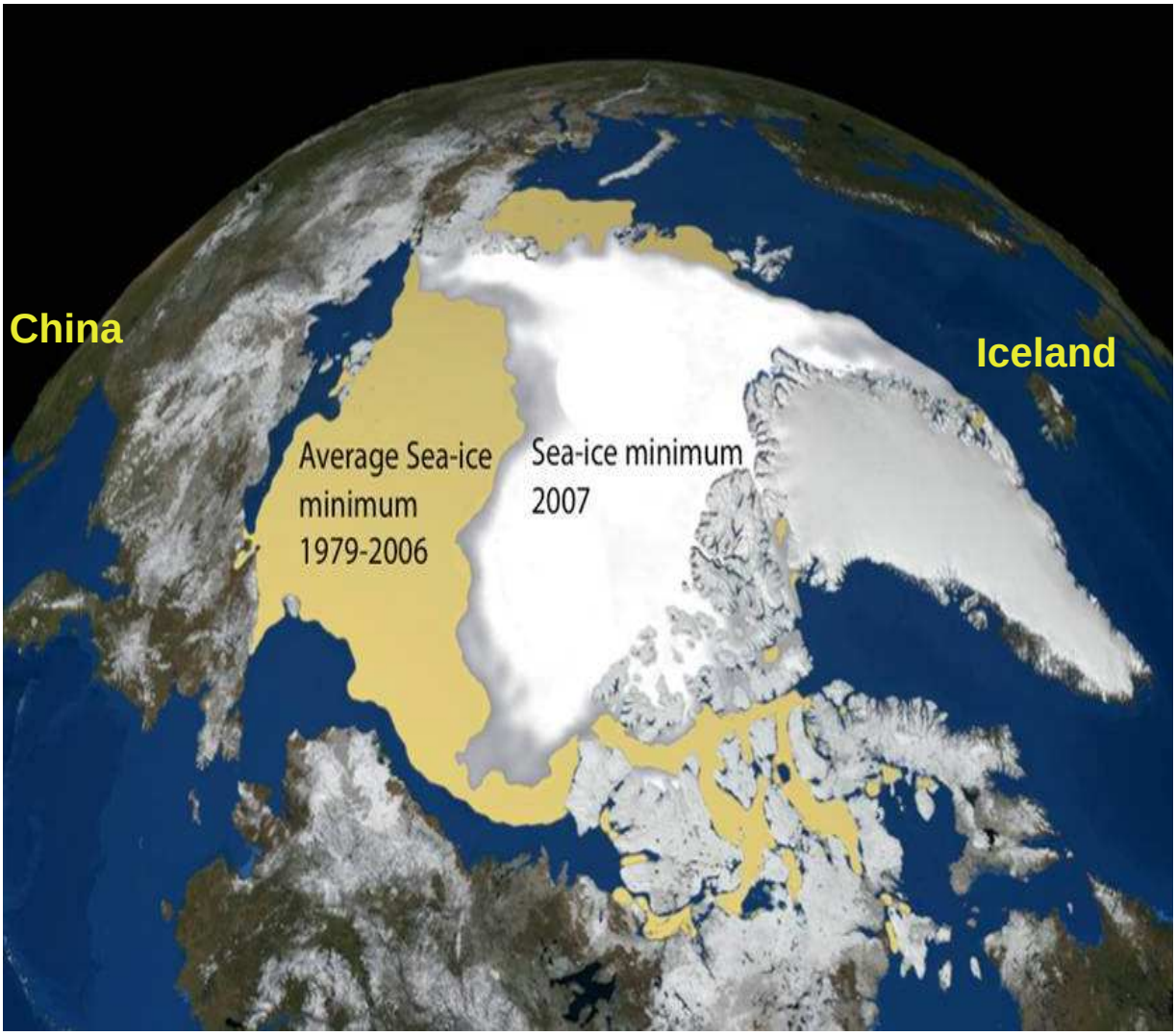
Plantations producing 600 gallons of biodiesel per acre per year effectively convert just 0.3% of the incident solar energy to the fuel's thermal energy, of which only ~30% delivers output power in a combustion engine. Couple this with the need for continual supply of water, nutrients & trace elements to fields, and the no-win character of biodiesel becomes clear. It's not only two orders of magnitude less efficient that current solar power generation, it competes with food production and fails to even be "carbon neutral'.

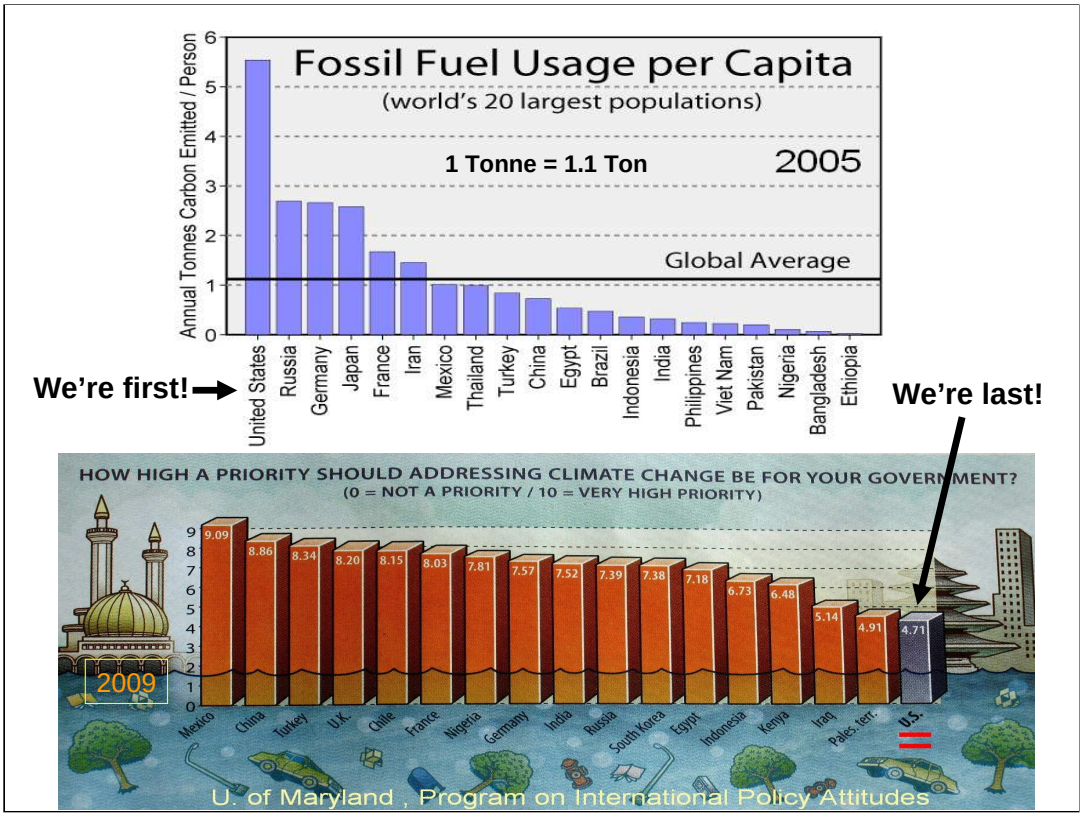
"Biomass" combustion has the same fundamental defects and in addition, adds thermal heating to the atmosphere at a 4:3 ratio, compared to petroleum-based fuels.

Using plants for combustible products for power generation fails the energy-density requirement.

Why Energy from Fire Must Go

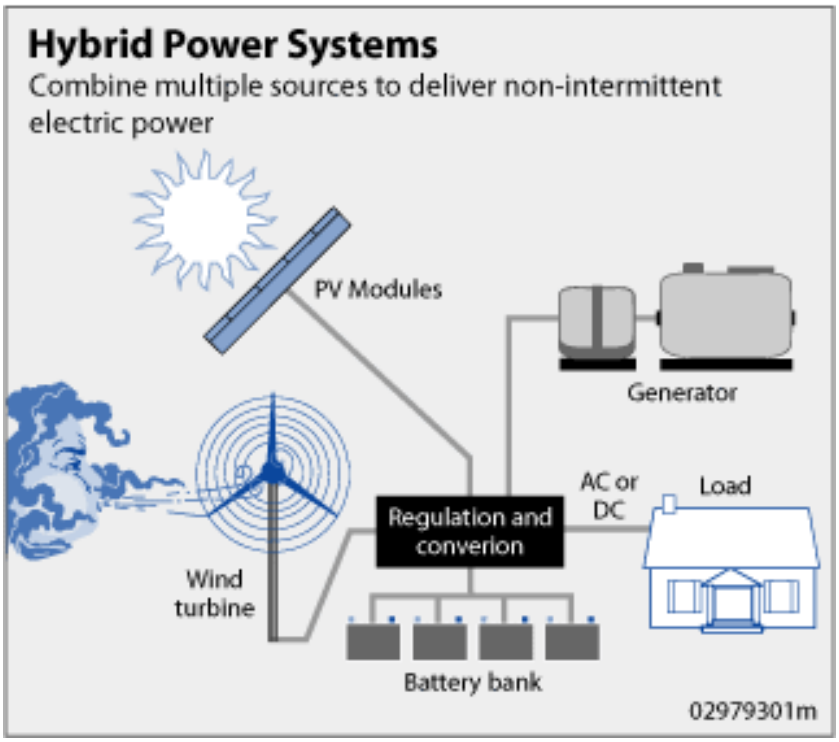






Other countries see chart 1 and say *"Why should we limit ourselves?"*
We look at chart 2 and we say, *"Whatever".*

Some folks are implementing small systems that minimize use of fossil fuels by exploiting solar, wind and storage. The <u>generator can be the power grid</u>.



‘Renewables’ Revealed

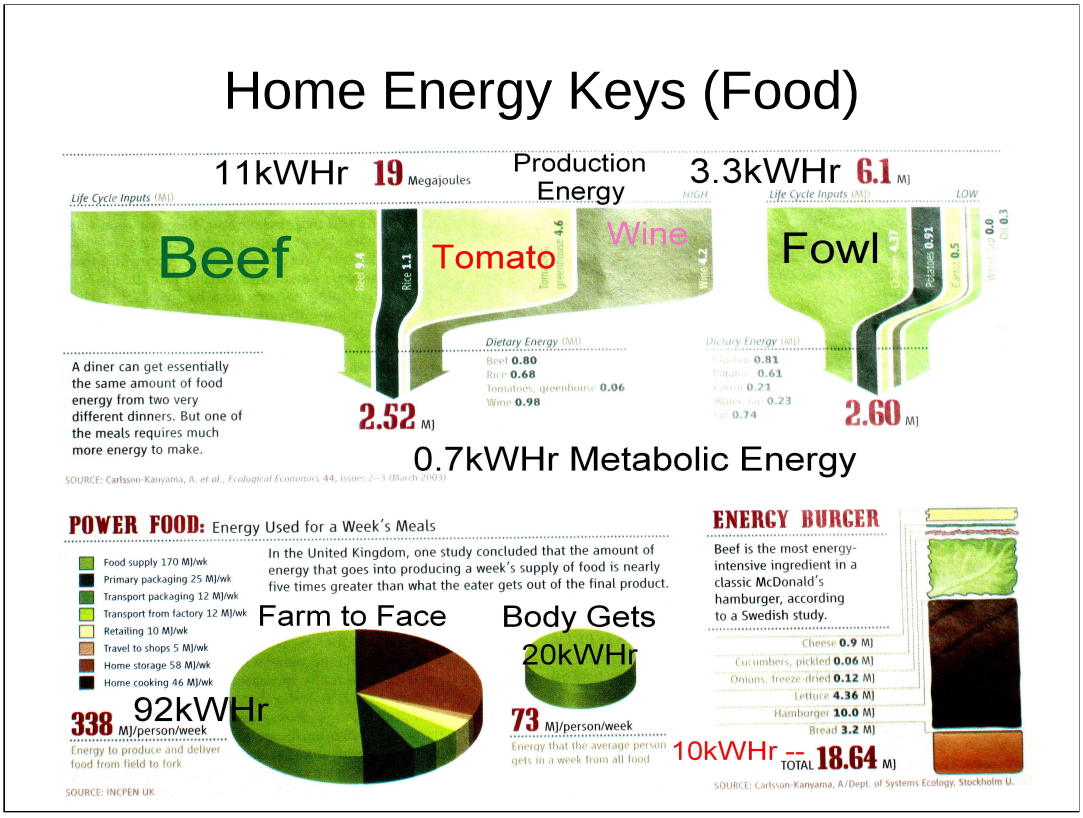
- Subsidies now, remediation later
- Comparison of sources
  - Overall efficiency
  - Overall environmental impact
  - Security
  - Longevity
  - Economics/competition
- Comparison of applications
  - Stationary/mobile
  - Distributed/concentrated
  - Dependence on present sources

Land Area Needed To Replace US Fossil Fuels With Biofuels…

Area Needed for Nuclear*

Area Needed for Solar PV*

*** Power & vehicular uses included**



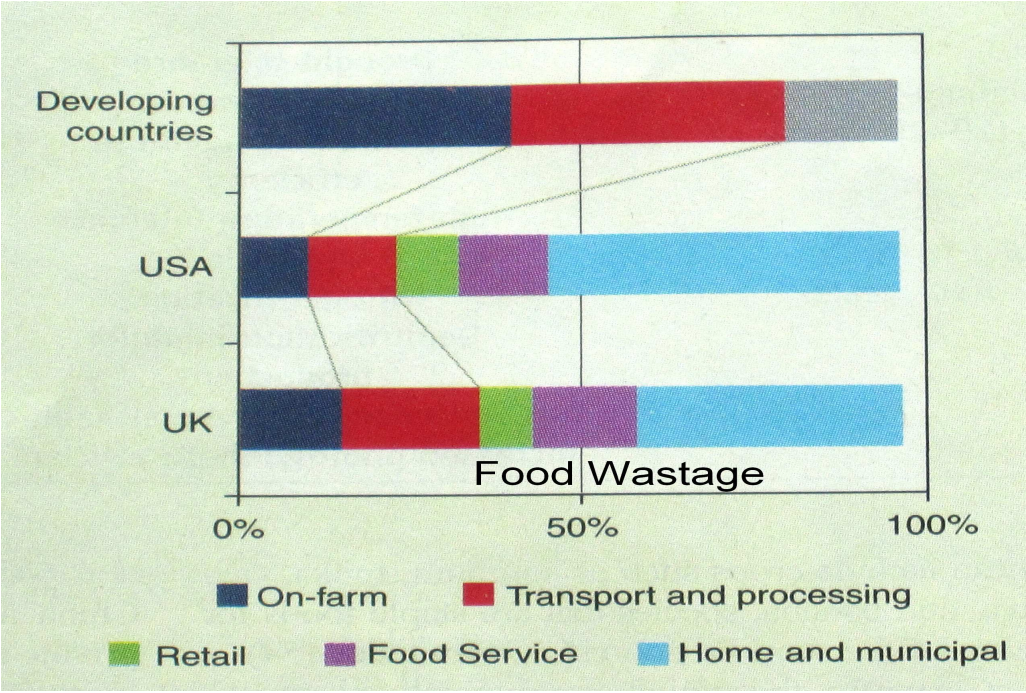
AAAS Science, 12 Feb 2010, p809.

An average home uses 30kWHr of electricity/day – 3 burgers worth!

A half-gallon of OJ is responsible for ~4lb of CO_2, over 30% being from nitrate fertilizer production – choose calcium-nitrate instead.

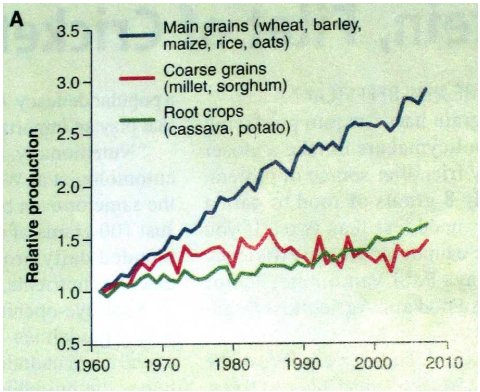
Food wastage even contributes to energy loss, because it's now so high…

http://sciencenow.sciencemag.org/cgi/content/full/2009/1125/1

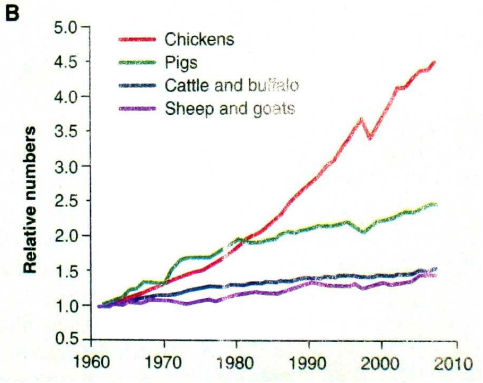


Home Energy Keys (Food History)

Vegetables

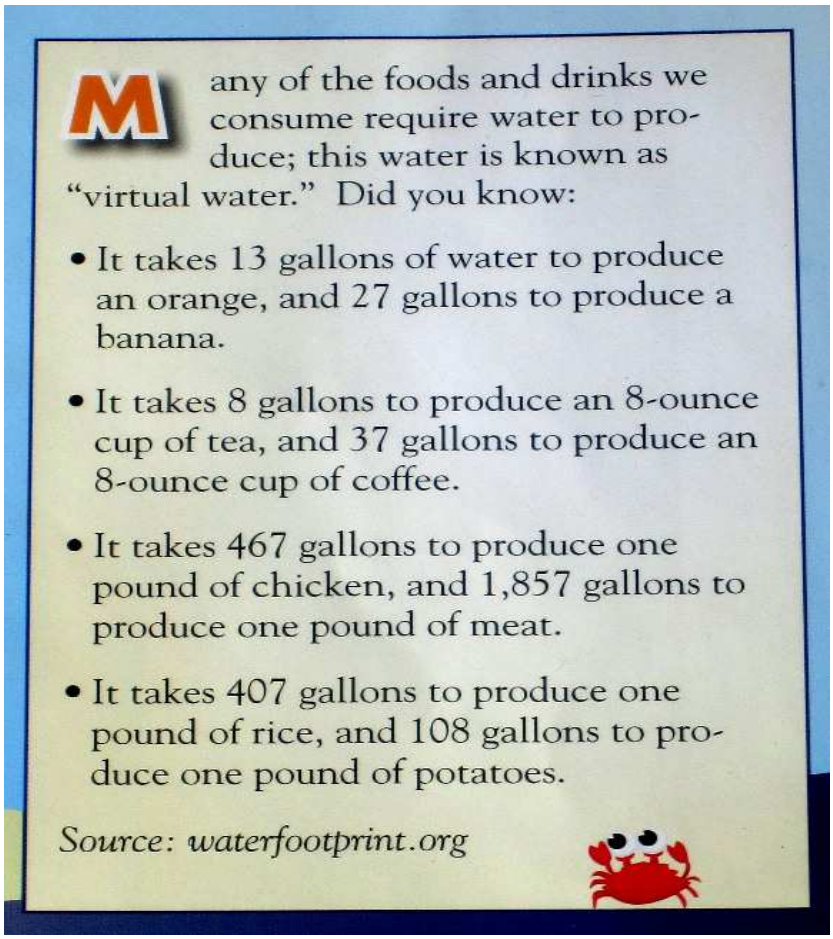


Meats



Rice & Corn are most demanding of water/soil.
Cattle, pigs & chickens demand grain, water & energy.

As population increases to 9 billion in 2050, ***new, arable land as large as all Brazil*** will have to be found & cultivated. Then, there's **fresh water**…



Many of the foods and drinks we consume require water to produce; this water is known as "virtual water." Did you know:

- It takes 13 gallons of water to produce an orange, and 27 gallons to produce a banana.
- It takes 8 gallons to produce an 8-ounce cup of tea, and 37 gallons to produce an 8-ounce cup of coffee.
- It takes 467 gallons to produce one pound of chicken, and 1,857 gallons to produce one pound of meat.
- It takes 407 gallons to produce one pound of rice, and 108 gallons to produce one pound of potatoes.

Source: waterfootprint.org

The Reflectivity Problem

- So much (~3%) human structure & land alteration:
  - Insolation ~1kW/m^2

Sun-heated surfaces, except white/shaded.

Residential Now:

Local Lands Before Us

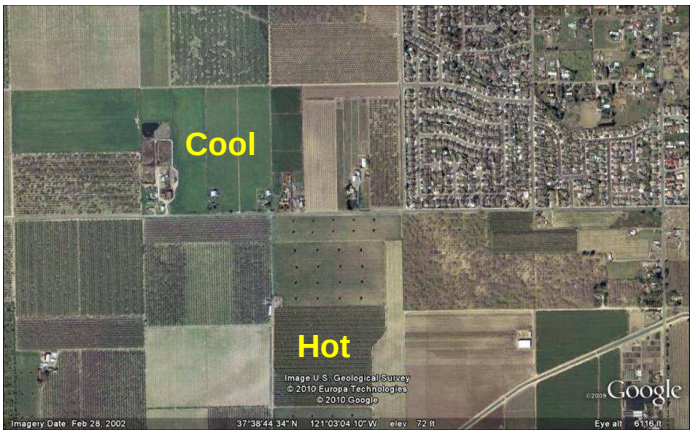
Sun's IR energy largely reflected, visible used to store plant sugars & structures, and to release O_2 & H_2O. Air temperature & ground naturally cool.

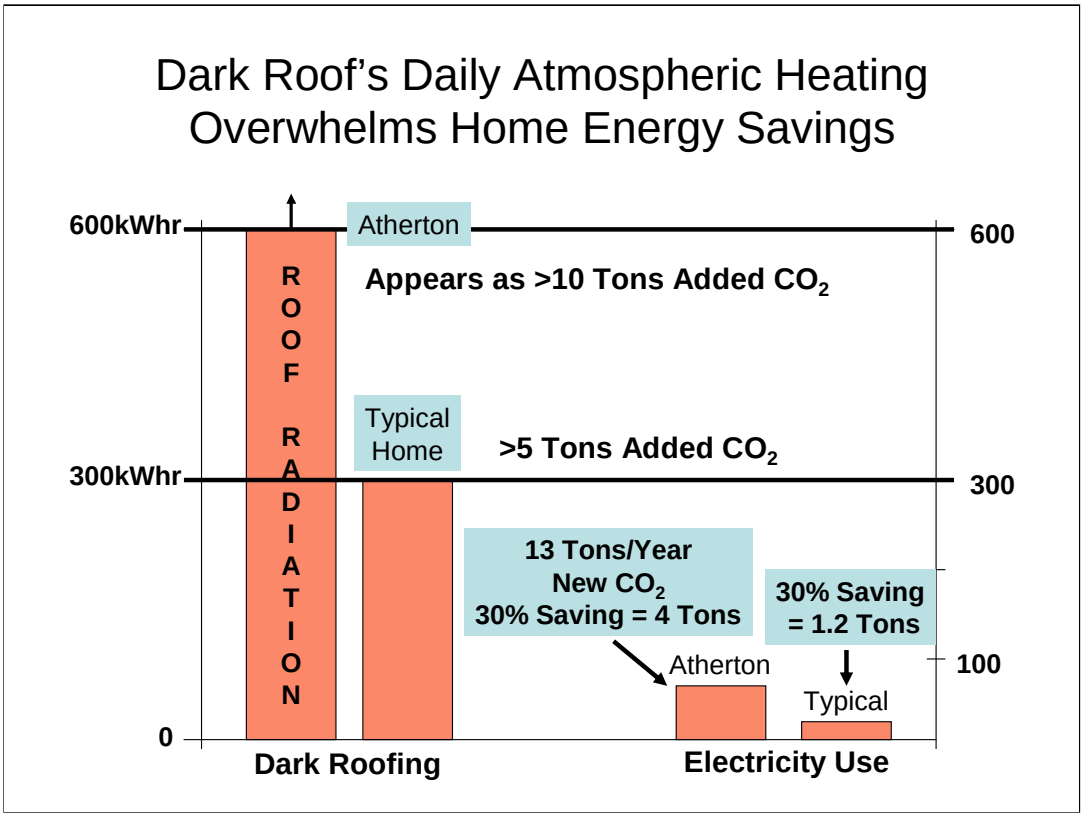
Commercial Now:

Even farming & gardening methods have large effects.

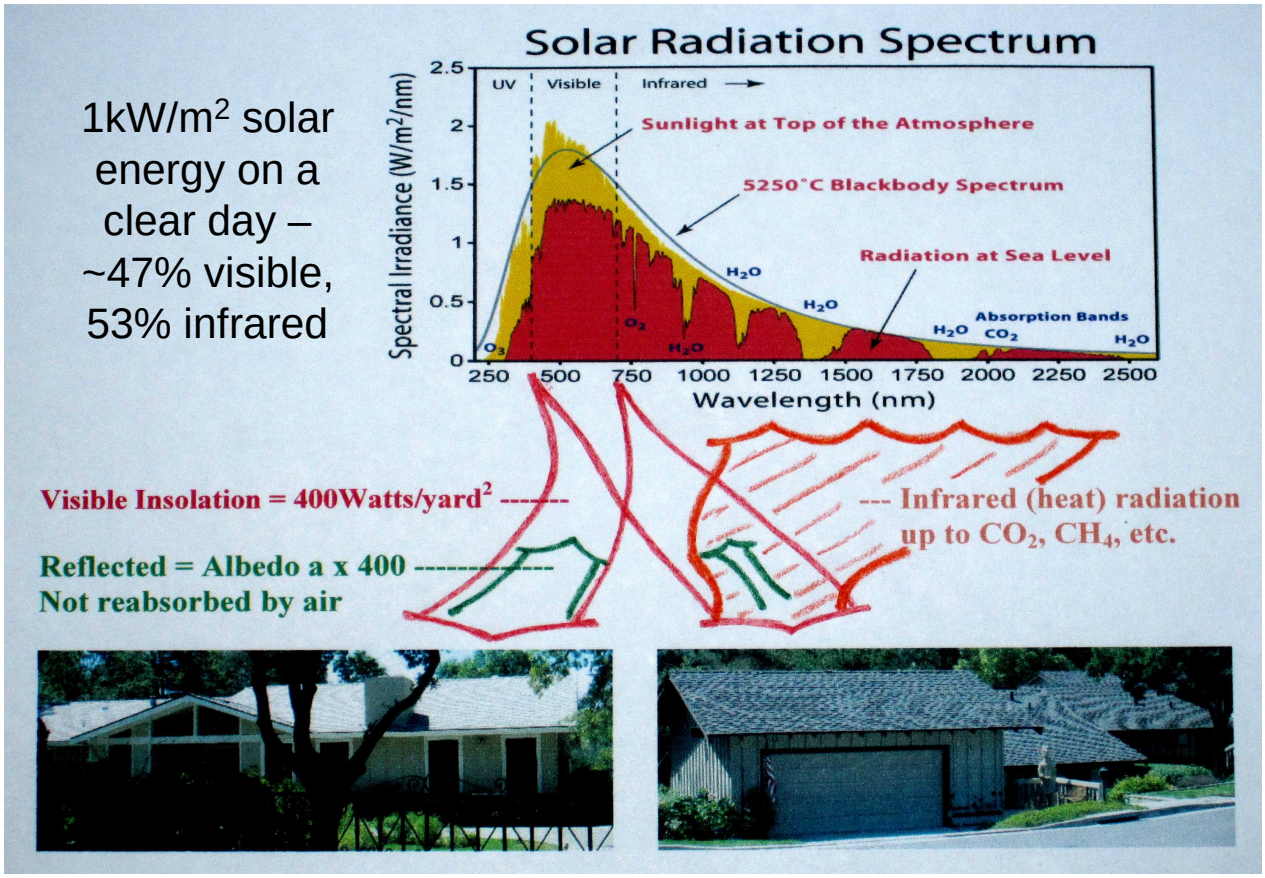
Always Hot in Sun – Saving Some Water, But Adding to Warming

Typical Farming Nets ~50% Solar Heating





Roof heating equivalence to CO_2 tonnage derived from CEC "Cool Roofs…" reports by Art Rosenberg. Electric kWHr CO_2 equivalence from EPA at 1.4lb/kWhr. PG&E below 0.9lb/kWHr in N. Calif.



Energy Storage

- Any cyclic/diurnal generation needs:
  - Complementary generation
    - Wind & solar often overlap from morning through evening
    - Noisy – gusts, redirections, clouds
  - Continuous, minimum generation (base load)
    - Hydro, nuclear fission (fusion in development)
  - Storage, when generation exceeds loads
    - Pumped-storage reservoirs
    - Thermo/chemical (batteries, etc. in development)
    - Mechanical – spring, counter-weight, gas,
      - Flywheel: **www.velkess.com/**
    - Low energy density, efficiency, safety
    - Electronic (ultra-capacitor) – safe, low impact
      - Helped by nano-technology
      - Combined with advanced batteries
    - **www.electricitystorage.org/site/home/**

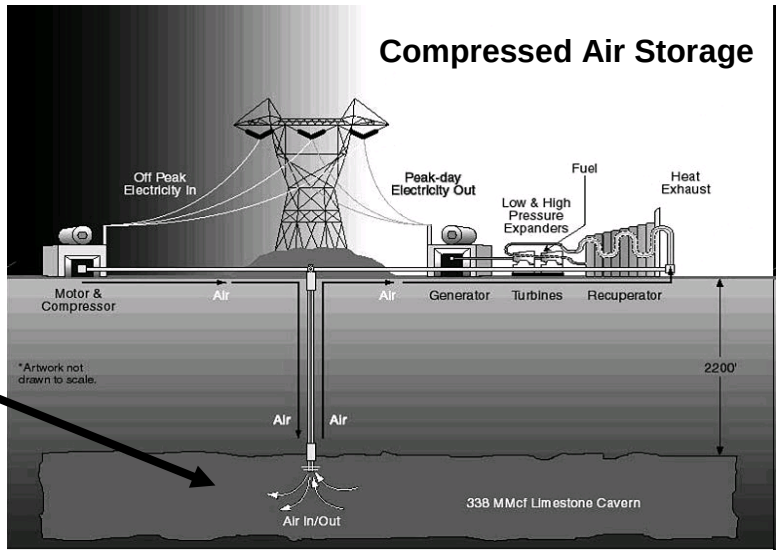
www.technologyreview.com/biztech/18086/

An ultra capacitor ($E = ½ CV^2$)…

Springs ($E = ½ kx^2$)…

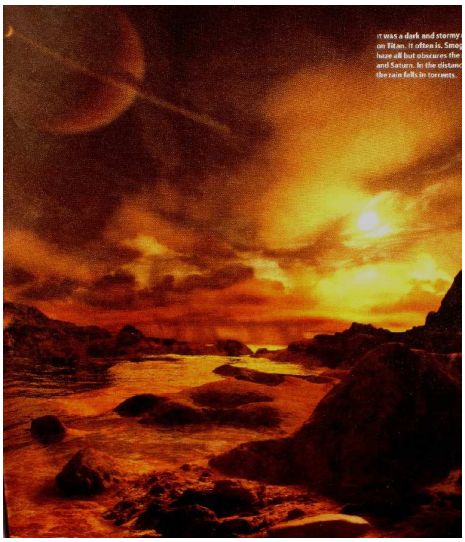
← x →

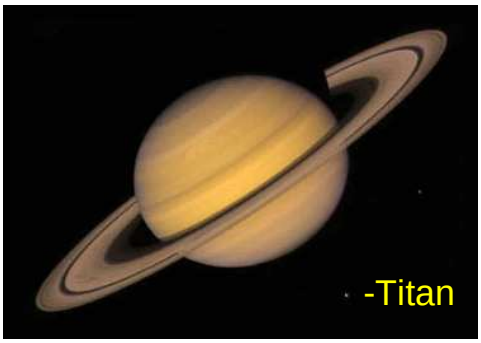
Stored energy < pressure times cavern volume

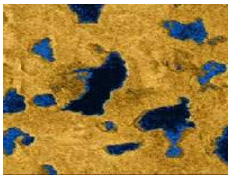


Other Worlds (for Reference)

- Saturn's 3200mi moon ***Titan*** is like Earth, except <u>methane stands in for water</u> and it's 200ºC colder…





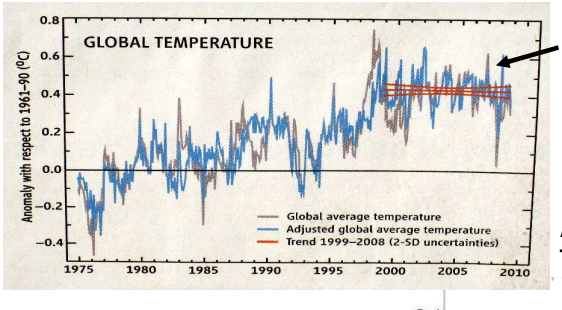


- CH_4 Lakes

Titan Rocks

in 'sand' of organics from Sun-altered CH_4 & C_2H_6

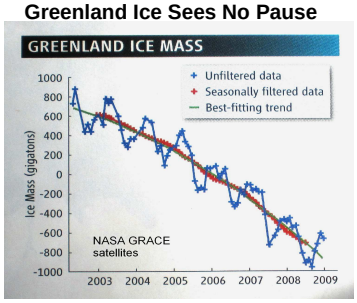
Our Climate Realities & Myths

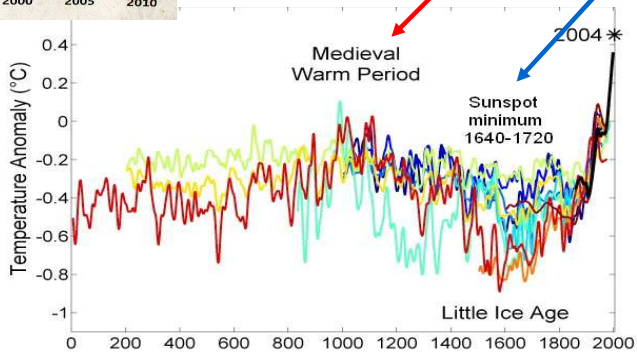


The Current Warming 'Pause' Means We Can Relax?

After All, We've Had Warm Times & Cool Times Before…

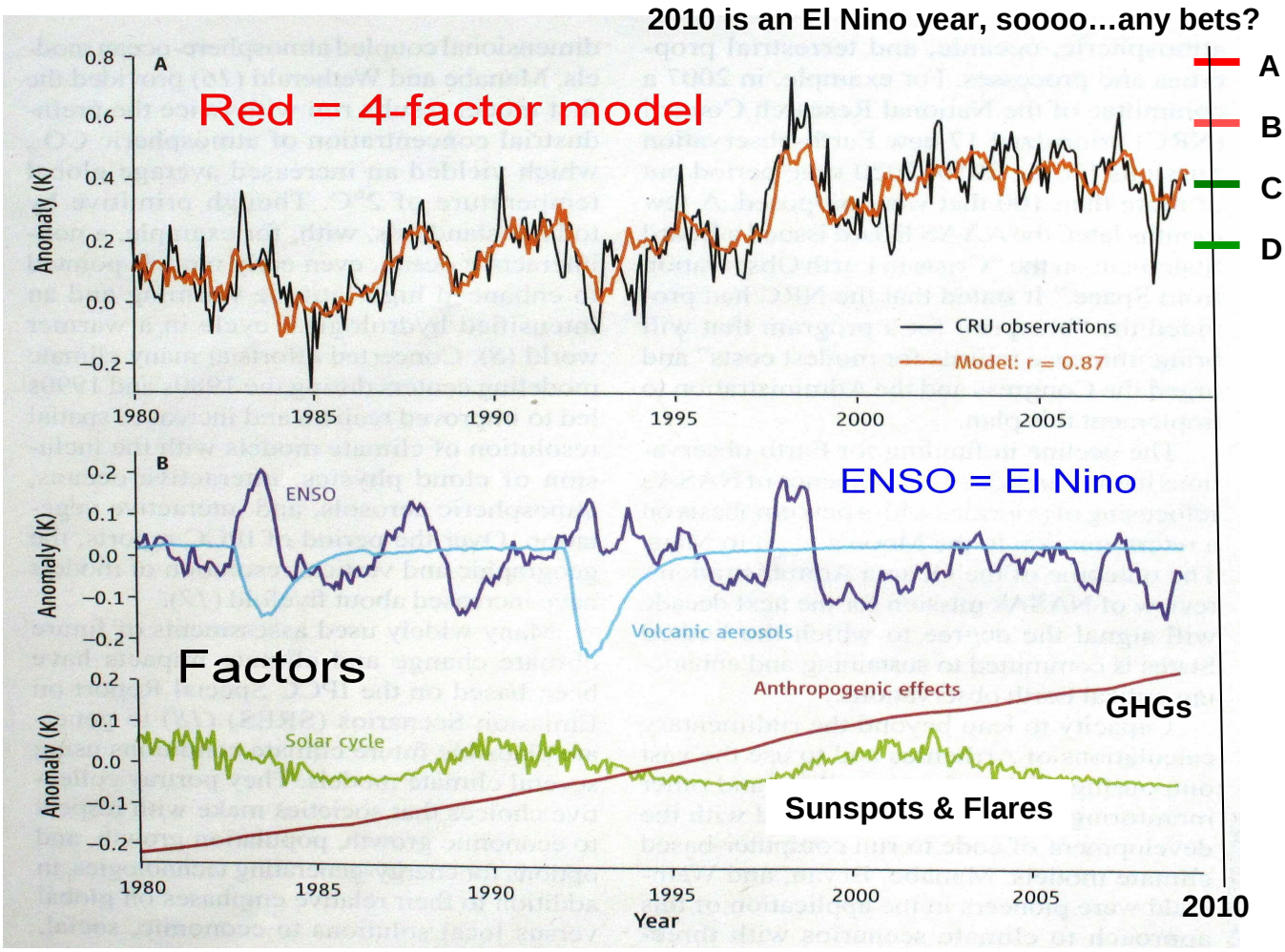
Greenland Ice Sees No Pause



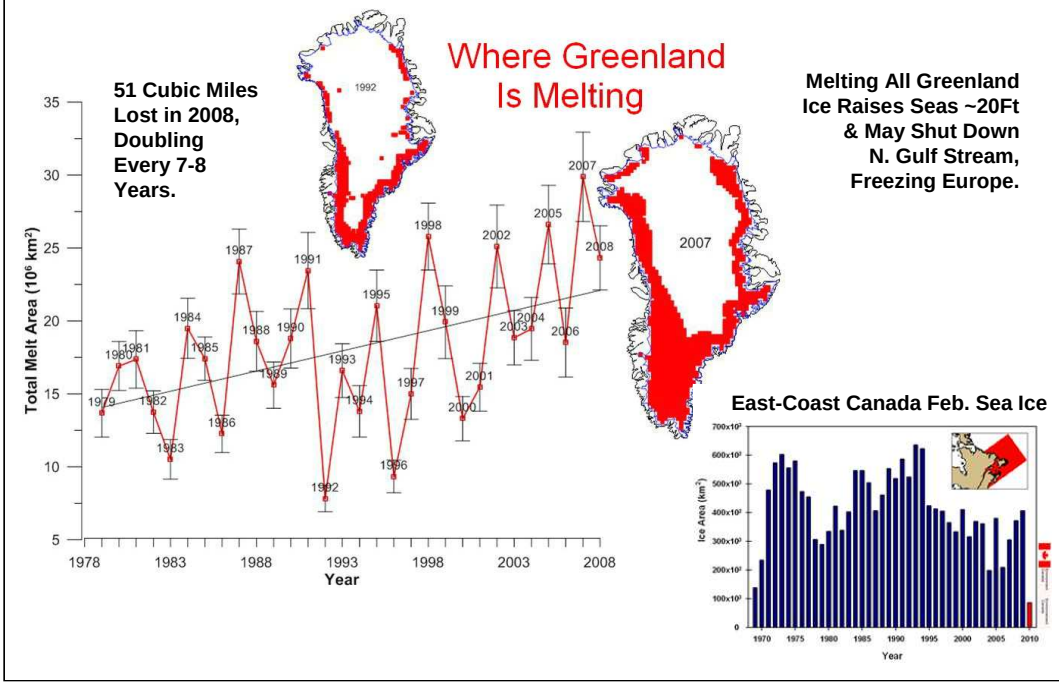


If we include just 4 climate components (El Nino, Volcanism, Sun activity & GHG increase) we have a remarkable result (AAAS 2009)…

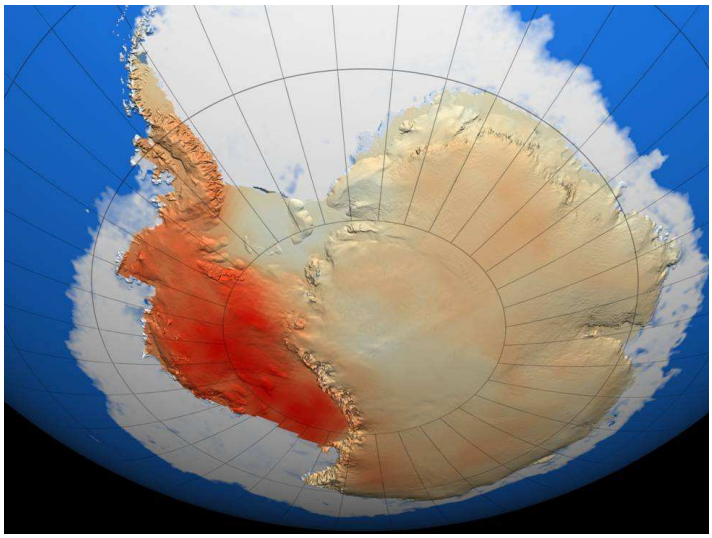
2010 is an El Nino year, soooo…any bets?



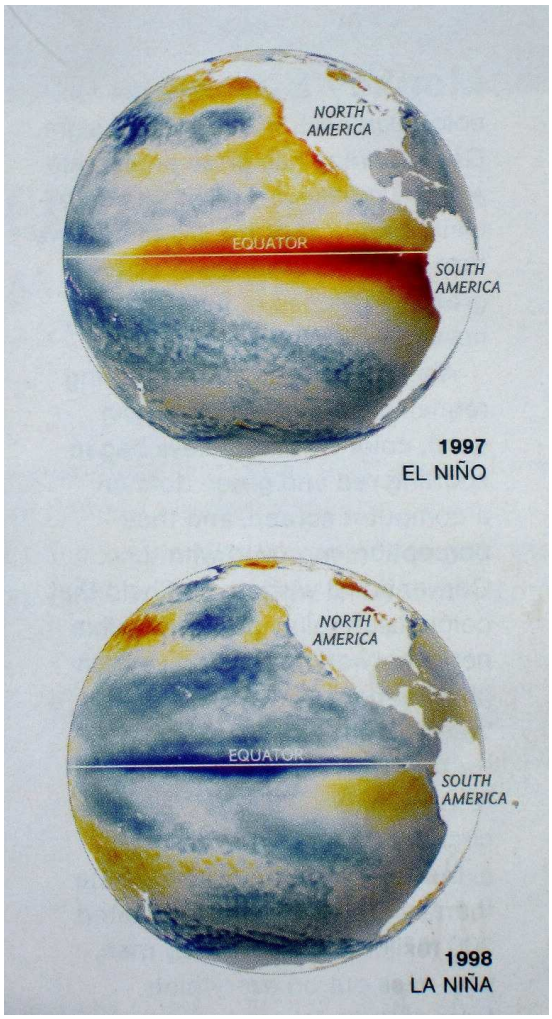
Our Climate Realities & Myths



Where Antarctica is Warming



2010 El Nino = Storms



Cooler Eastern Pacific = La Nina & Fewer North-American Storms (like our last few years)

17 April 1970

2050 Picture?...