Energy Basics

(1 March 2011)

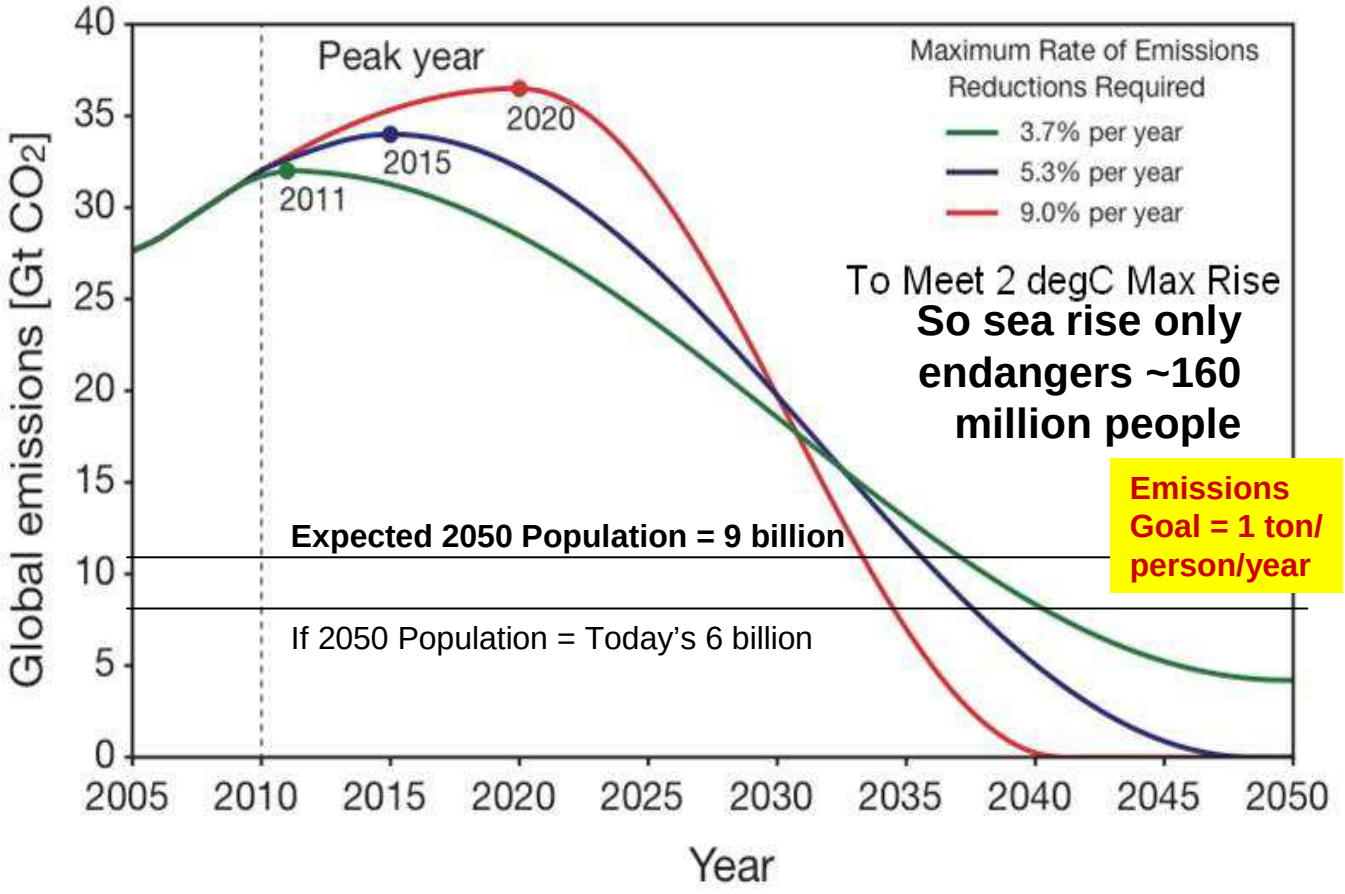
What we should know to help ourselves, our towns & our families.
What we must know to choose products, companies, jobs & votes.

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

Eugene Kranz,
Apollo 13
Flight Director,
April 1970.

Dr. Alexander Cannara
cannara@sbcglobal.net
650-400-3071

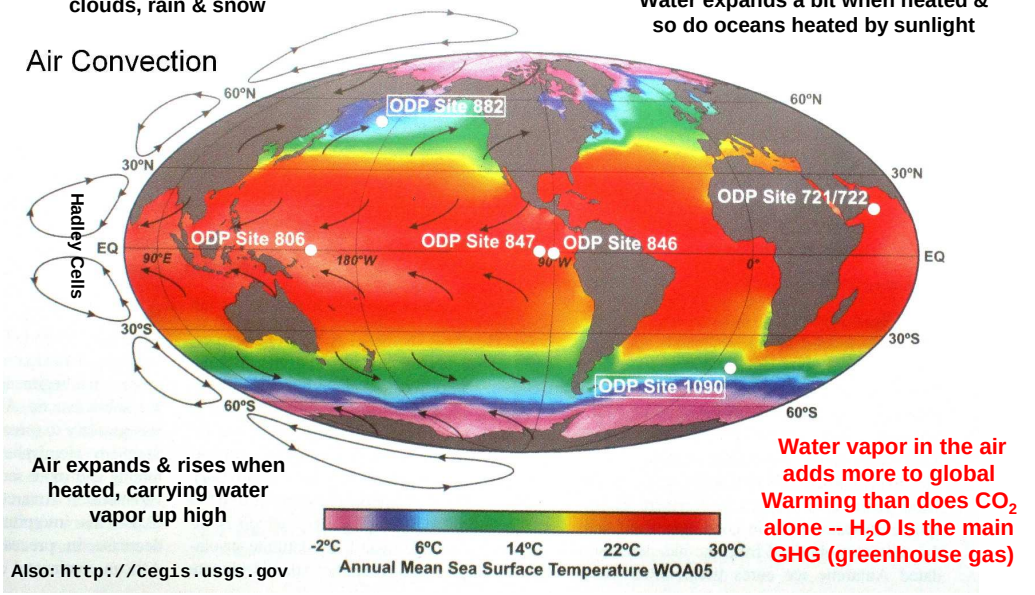
31 Mar. revision. **The problem to work – 1 ton of CO_2 per capita/year by 2050…**
http://download.copenhagendiagnosis.org/default.html (1st edition, p51)
http://tinyurl.com/2a7lswe (latest projections)



Global Warming & Sea Rise

Air convection carries water vapor up to cool & form clouds, rain & snow

Water expands a bit when heated & so do oceans heated by sunlight

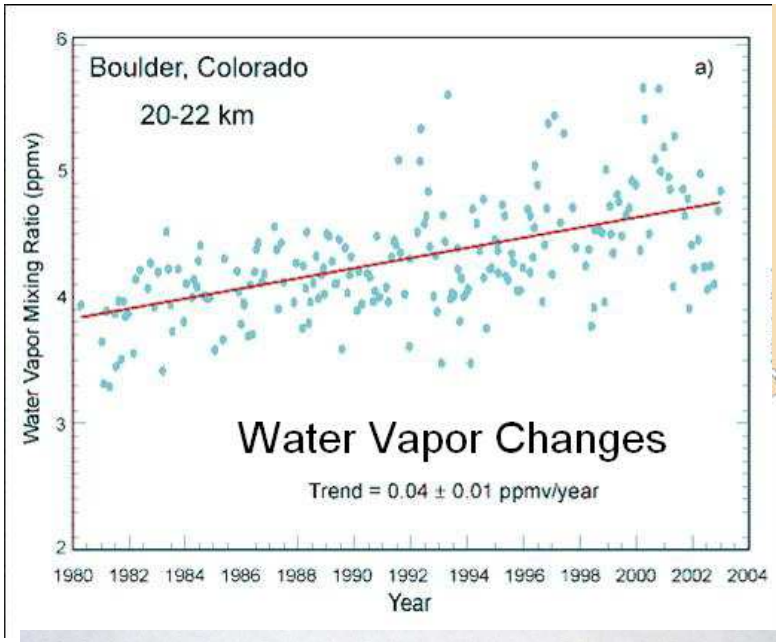


Air expands & rises when heated, carrying water vapor up high

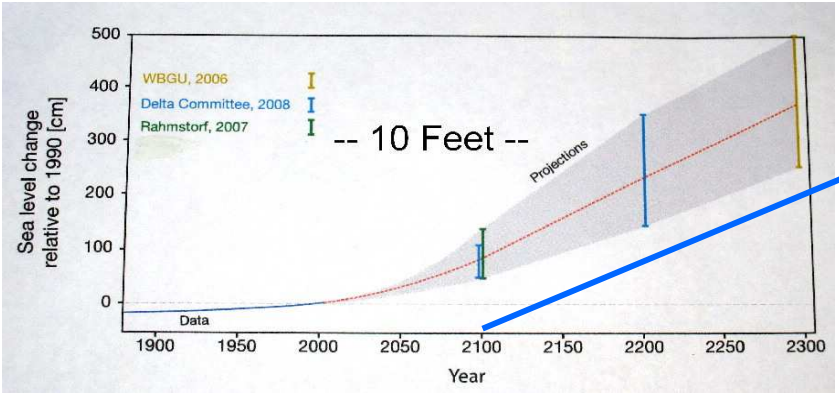
Water vapor in the air adds more to global Warming than does CO_2 alone -- H_2O Is the main GHG (greenhouse gas)

Also: `http://cegis.usgs.gov`

Our Future Bay in This Century



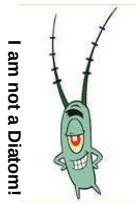
BCDC, `http://tinyurl.com/24pctg8`



Anything that heats air or water adds to global warming, glacier melting & seas rising

Warming Warnings

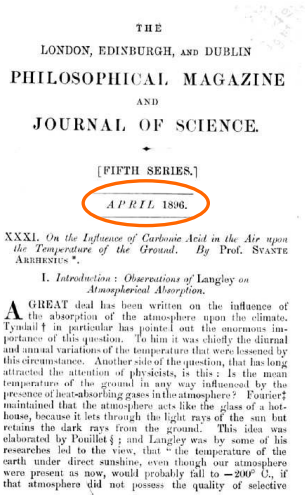
- Tyndall & Chamberlin (1800s)…
  - www.aip.org/history/climate/co2.htm
  - http://earthguide.ucsd.edu/globalchange/global_warming/03.html
- Arrhenius (1896, 1905)…



On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground

Svante Arrhenius

Philosophical Magazine and Journal of Science
Series 5, Volume 41, April 1896, pages 237-276.



THE
LONDON, EDINBURGH, AND DUBLIN
PHILOSOPHICAL MAGAZINE
AND
JOURNAL OF SCIENCE.

[FIFTH SERIES.]

APRIL 1896.

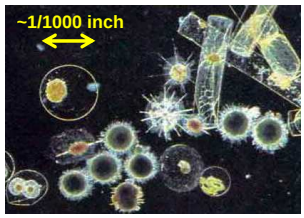
XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* By Prof. SVANTE ARRHENIUS *.

I. *Introduction: Observations of* Langley *on Atmospherical Absorption.*

A GREAT deal has been written on the influence of the absorption of the atmosphere upon the climate. Tyndall † in particular has pointed out the enormous importance of this question. To him it was chiefly the diurnal and annual variations of the temperature that were lessened by this circumstance. Another side of the question, that has long attracted the attention of physicists, is this: Is the mean temperature of the ground in any way influenced by the presence of heat-absorbing gases in the atmosphere? Fourier‡ maintained that the atmosphere acts like the glass of a hot-house, because it lets through the light rays of the sun but retains the dark rays from the ground. This idea was elaborated by Pouillet§; and Langley was by some of his researches led to the view, that "the temperature of the earth under direct sunshine, even though our atmosphere were present as now, would probably fall to −200° C., if that atmosphere did not possess the quality of selective

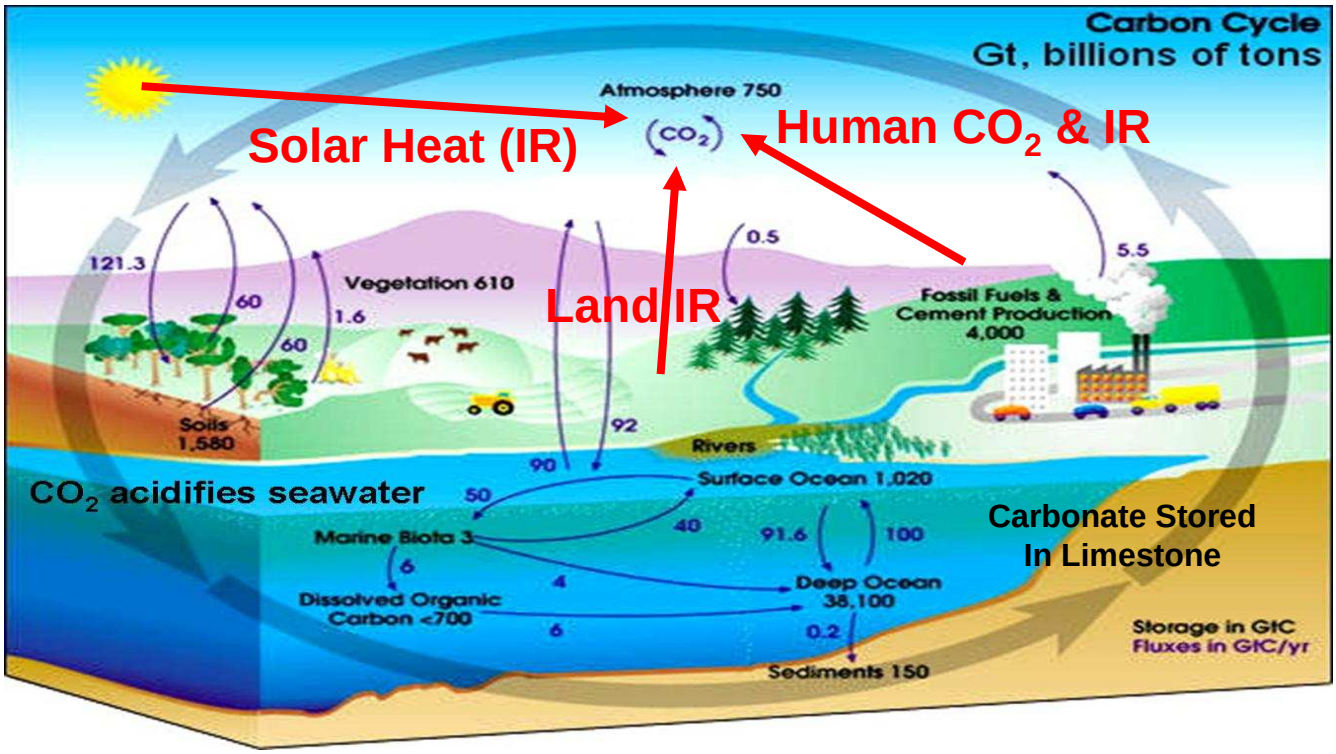
***"Carbonic Acid" is what CO_2 makes when combined with water* – soda pop.**

Since seas dissolve CO_2 well, they become more acidic every year we overload the natural Carbon Cycle (among plants, air, water & land) by burning fossil Carbon compounds made millions of years ago by plants, especially ocean Plankton…



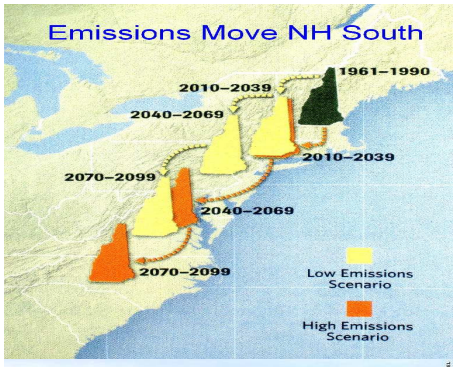
Plankton are the initial prey for almost all fish larvae. Their Carbonate shells sink when they die, removing Carbon to sea floors & they make most of our Oxygen.

Plankton & algae produced most of the Oxygen we have to breath, starting <2 billion years ago, with the earliest photosynthesizing ocean organisms. Land plants later evolved & helped. <u>All fossil fuels we now dig up were made this way</u>. These creatures range from under an inch to 1/1000000 inch in size. They make Carbonate shells/skeletons from CO_2 in seawater. But only can do it if the acidity of the water is low. Our fossil-fuel burning Is adding CO_2 faster than they can use it, so their Carbonate structures will soon begin to dissolve, if we don't get our act together. **What do you think happens if Plankton dissolve away?**

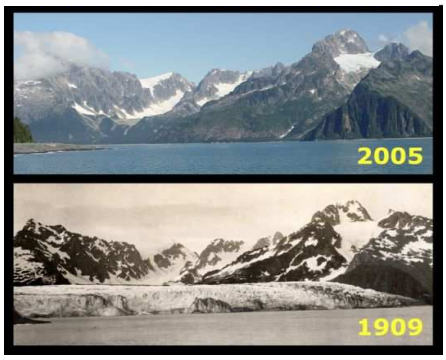


Warming Warnings

New Hampshire Moves to Carolina

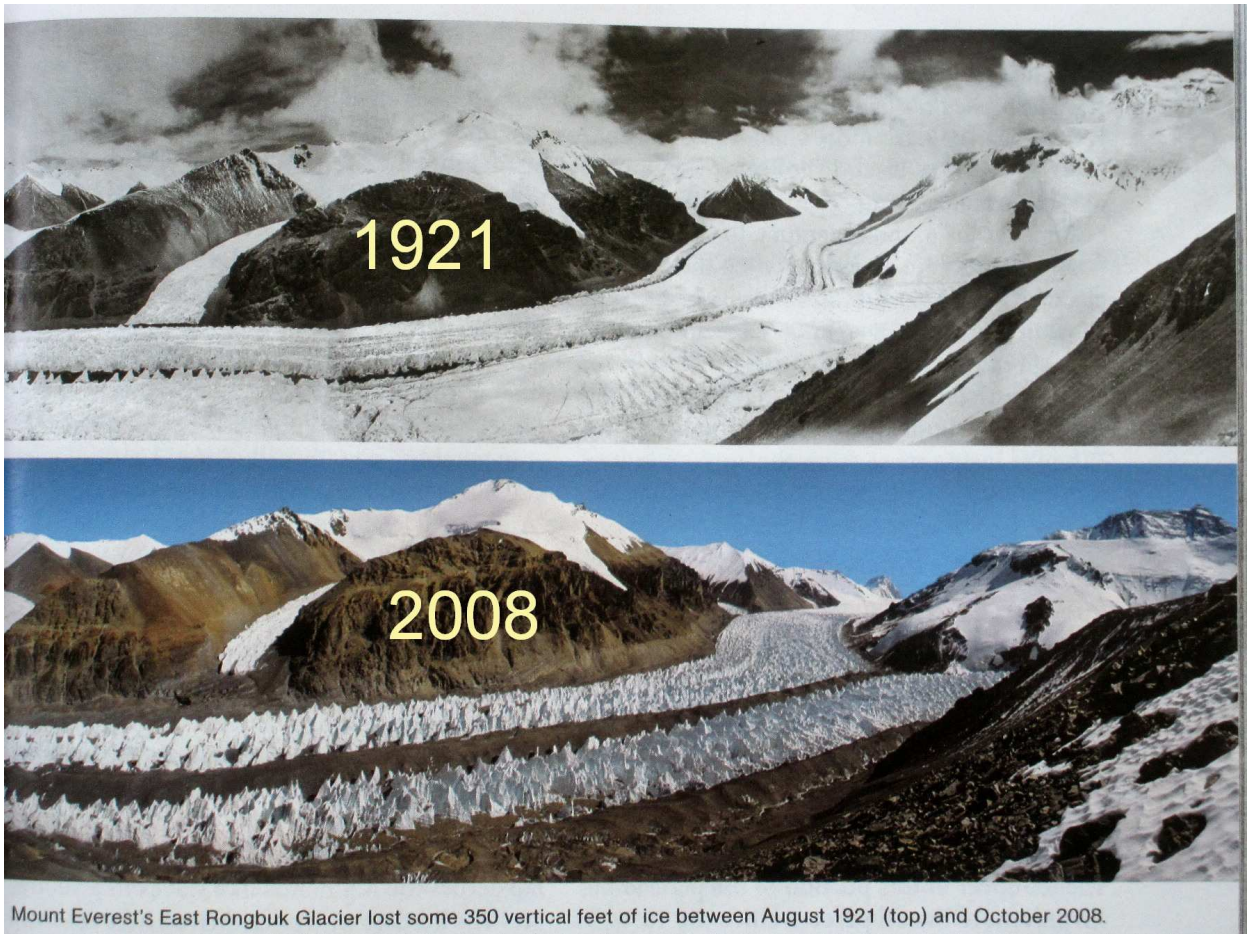


Alaska's Northwestern Glacier Melts



8/5/2010 Greenland Sheds 'Manhattan'

Everest's East Glacier

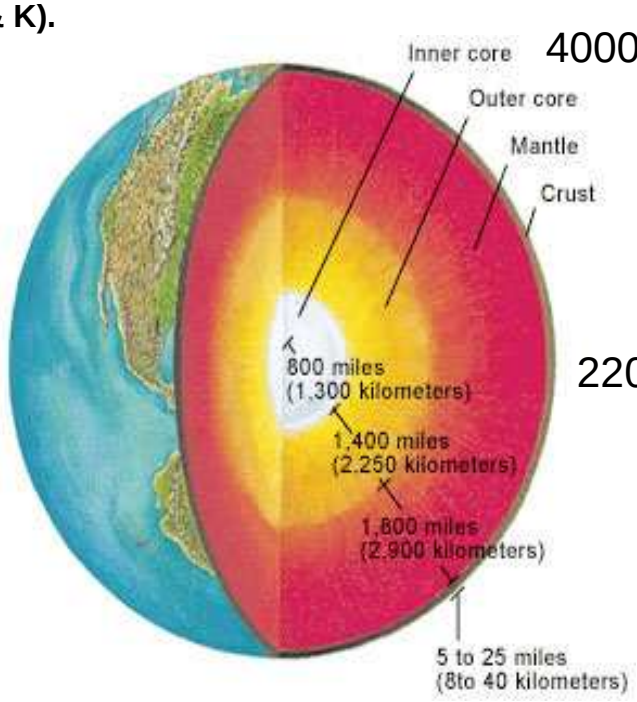


Mount Everest's East Rongbuk Glacier lost some 350 vertical feet of ice between August 1921 (top) and October 2008.

Energy Sources on Earth

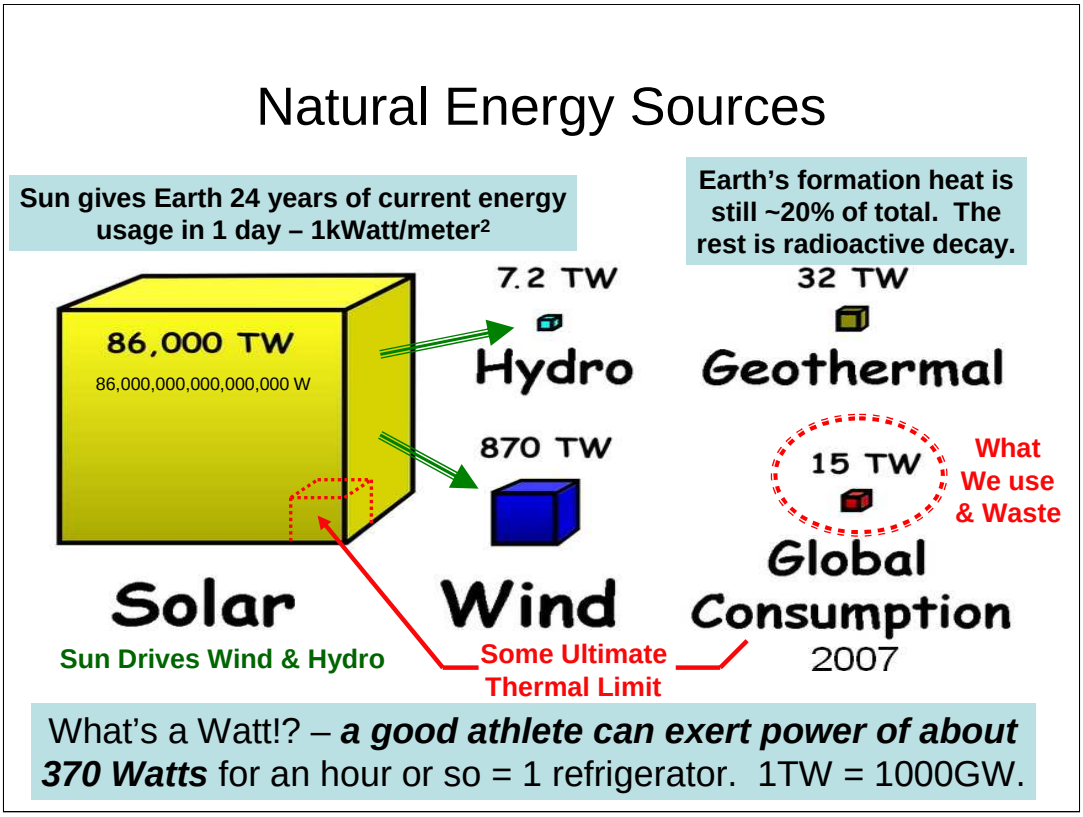
- ***Natural*** (three of significance)
  - **Sunlight** (infrared & visible light)
  - **Geothermal** (nuclear decay, volcanism)
  - **Chemical** (mineralization, sea/air, life…)
  - Space (cosmic rays, solar flares, meteors…)
- ***Derived Naturally*** (unrelated to humans)
  - **Fire** (hydrocarbon 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> (Th, U & K).



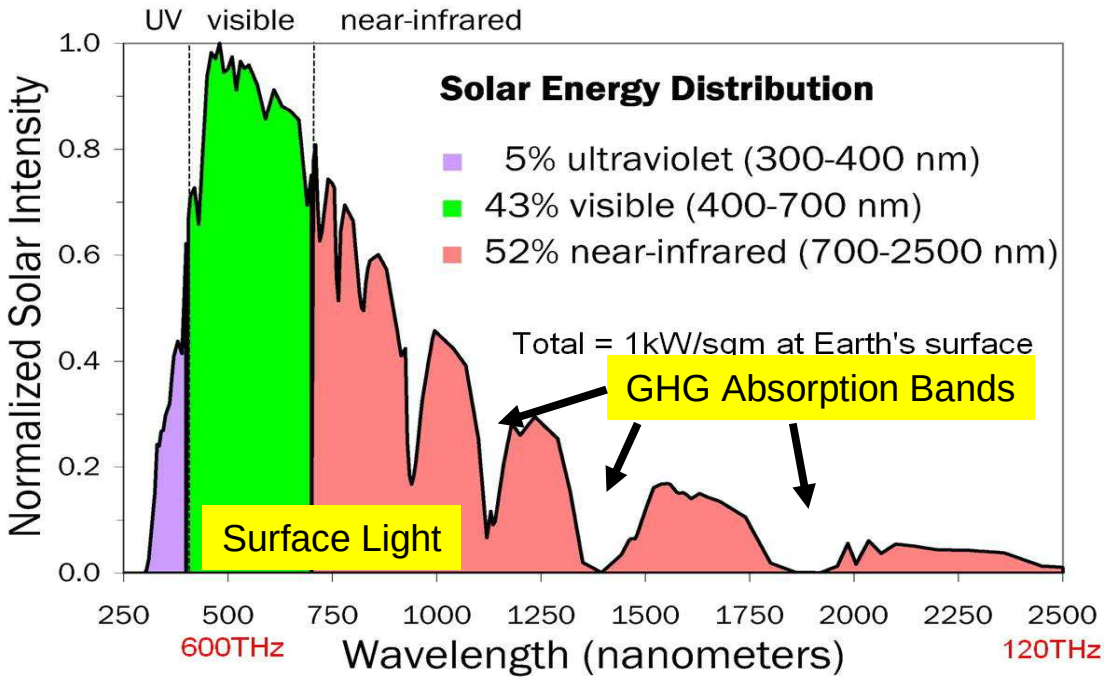
The mostly iron outer core convects, generating the magnetic field that protects life from the solar wind of million-mph protons, which otherwise would have stripped our atmosphere long ago, much as it has Mars'. And, our air protects us from Xrays, etc.

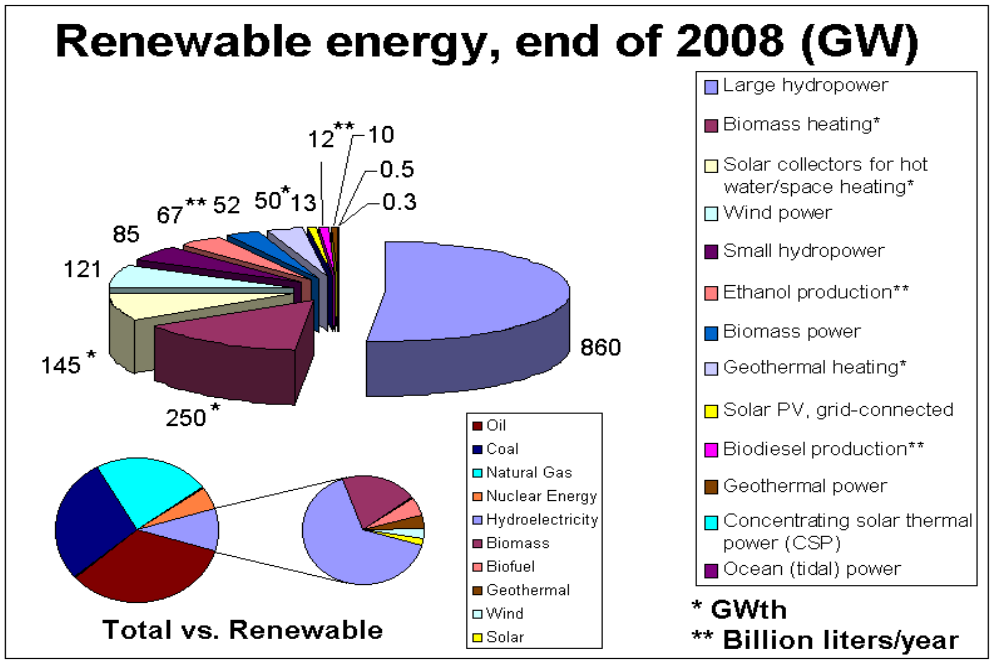
Geothermal energy derives from running heat engines on the thermal energy available in the temperature difference between the upper mantle & the surface. Generally this is simply derived from groundwater, heated in regions where the upper mantle is only thousands of feet from the surface – often volcanic realms. But, it's not free, endless, or without emissions or heat & energy waste.



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, hydro & non-tidal water currents are all derived from incoming solar light radiation (1366W/m^2 in orbit, 1kW/m^2 on surface)…





What's a GW? -- a GigaWatt, short for 1,000,000,000 Watts. A large power plant can generate that. 1 TW = 1000 GW.

"**Renewable**" generally refers to solar-energy derivatives – wind, hydro, solar. But all these have finite limits. Geothermal/tidal: similarly not truly renewable.

Behavior varies daily, hourly & quicker, but far steadier than wind…

http://tinyurl.com/3znad4b

And, though we currently use just 15TW of power, while the sun gives us thousands of times more, ***there's a true limit to how much energy humans can ever use, since almost all our energy produces heat and our planet is small***. Only electromagnetic (light/radio…) energy that passes freely out into space through our atmosphere can be considered safely gone from the planet. The vast amount of the remainder we generate simply becomes heat, inevitably warming the planet. Thus, we not only need to find environmentally safe & lasting energy sources, we must also hew a line that limits our total energy generation to a very small fraction of incoming solar energy – the 86,000TW (86 Quads). We still have room to go beyond 15/86000, but likely not more than 100TW (~0.1%) – 7 times our current energy generation. Yet, we do waste about half of our present 15TW, so getting that under control gives us more breathing room, before overheating our planet regardless of GHGs.

Renewables often have high construction burdens – a 5MW wind turbine needs ~400 tons of steel & 1000 cu yards of concrete, both produced via CO_2 emitting processes; plus ~10 acres of land. They also consume resources while in operation. **Biofuels** in particular consume water, nutrients, trace elements and maintenance/harvesting/transport energy, producing CO_2 & methane along the way.

Power & Energy

- ***Energy*** is just power exerted over time.
  - The good athlete's 370W for an hour = 370 Watt-Hours – a tiring work experience.
  - **Energy = Work = Power x Time**.
- **Electric** energy is usually measured in ***KiloWatt-Hours*** (kWHrs -- kilo means 1000).
- The 370W athlete exerts about 1/2 ***Horsepower*** (Hp). One Hp = 746 Watts – can lift 550lbs 1 ft in 1 second.
  - Lightbulbs & engines are typically rated in Watts or kW now, even though Hp was typical for engines.
  - A 100Hp engine delivers 74.6kW of power.
  - Boiling away a pound/pint of water takes 628 Watt-Hours.
- Science uses various **units** defined for consistent calculations – meter, kilogram, Watt, kWHr, second....
- Industry/governments use units that arise from tradition – foot, pound, Hp, Btu, second (everyone likes seconds)…

Water's Latent Heat – energy stored in its ***state changes***…

334,000Joule/kg – ***melting/freezing (42.2WHrs/lb).***

2,260,000Joule/kg – ***boiling/condensing (628WHrs/lb)*** – nearly twice the energy density of the next best, Ammonia, exactly why steam was chosen for the Industrial Revolution (also used by modern, vapor-recovery home furnaces).

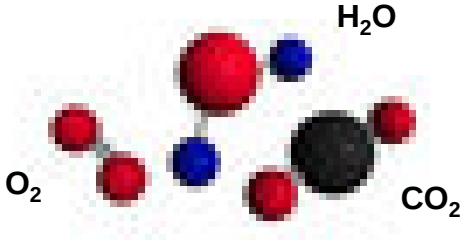
Latent energy of ***nuclear fission is >1,000,000,000WHrs/lb***.

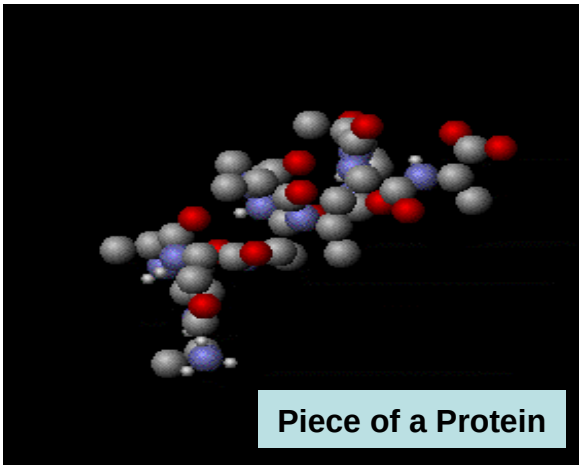
Latent energy of ***nuclear fusion is >1,000,000,000,000,000WHrs/lb.***

Normal human experience is of a material's **heat capacity**, which is molecular energy contained in all the various ways a molecule can vibrate…

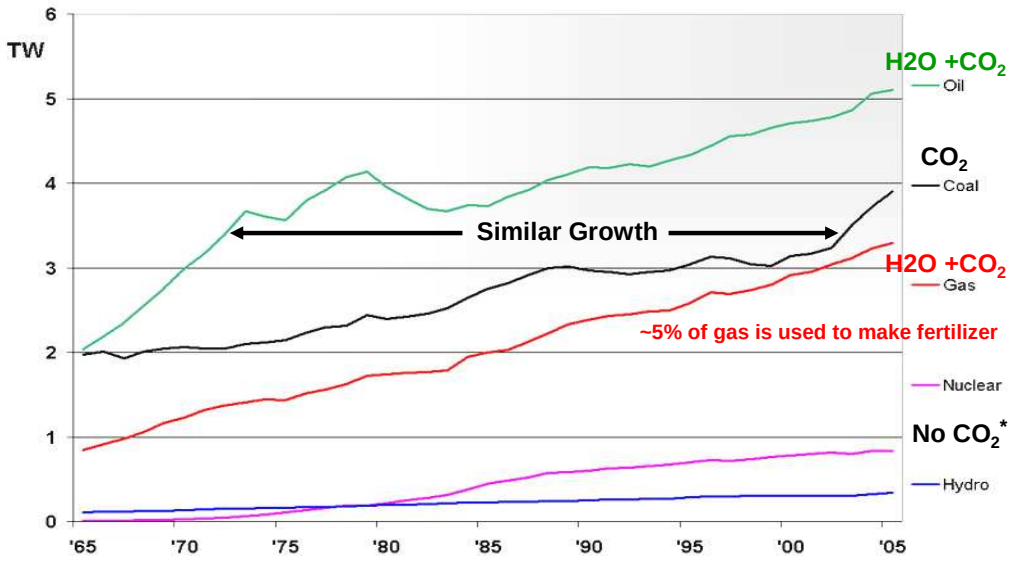
http://en.wikipedia.org/wiki/File:Thermally_Agitated_Molecule.gif

The more ways a molecule can vibrate, the more energy it can store. Water has many vibrational modes (degrees of freedom), so is a great GHG. A microwave oven tickles water's strong vibrational resonance at 2450MHz.





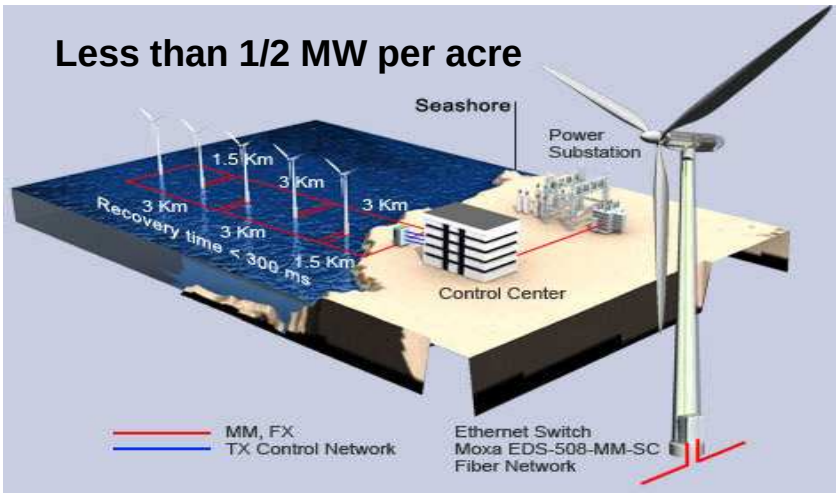
Exploited Power Sources

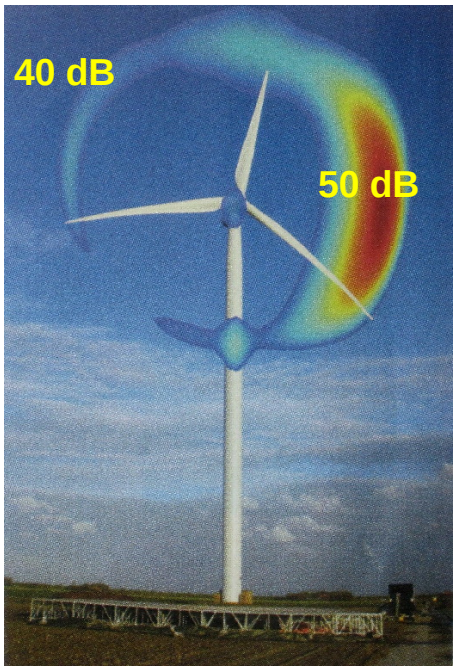


* CO_2 is produced in project construction.

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.

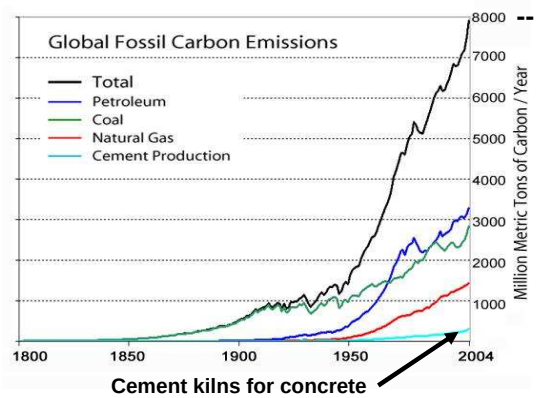
<u>Farm-like variable sources</u>, like wind/wave, need an elaborate control system to manage individual generator contributions to grid output – e.g., phase & amplitude: And, they lose energy in transmission lines & idling loads from grid.





Wind-Machine Noise (dB above human threshold, 40dB = 100 times, 50dB = 1000 times):

Energy & Carbon Dioxide Production



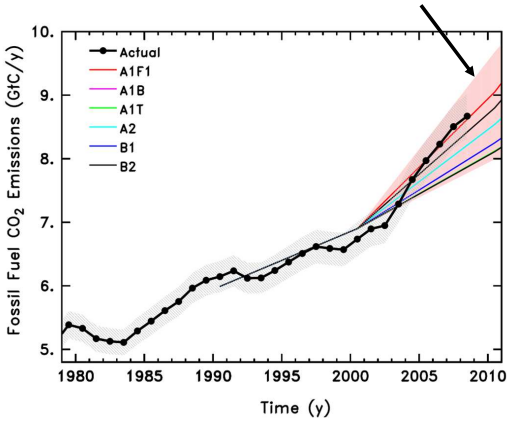
-- 8 GigaTons (16,000,000,000,000 lbs)

Cement kilns for concrete

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

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

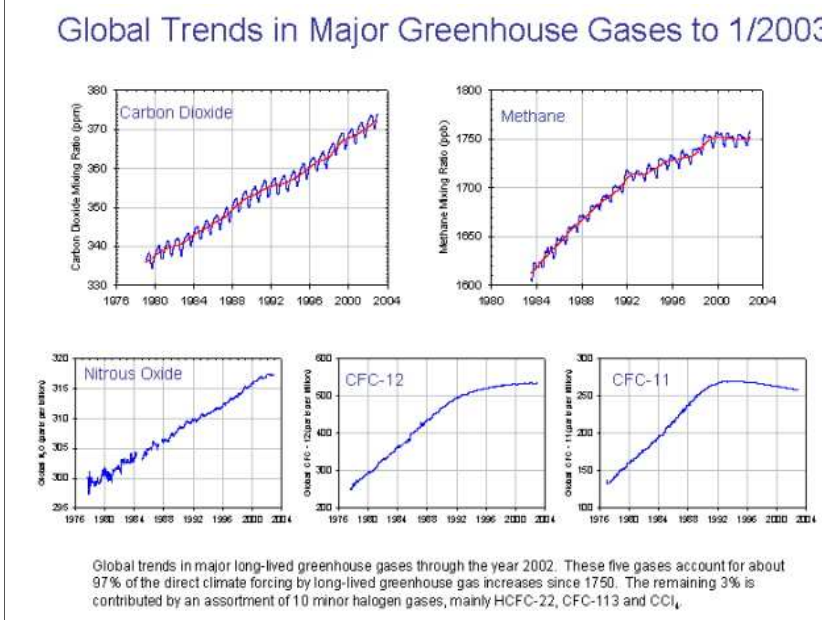
We're now emitting near worst forecast



A GigaTon = 1 billion tons (440 trillion balloons). 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 & have increased ocean acidity 30% in industrial times.

Some GHG History

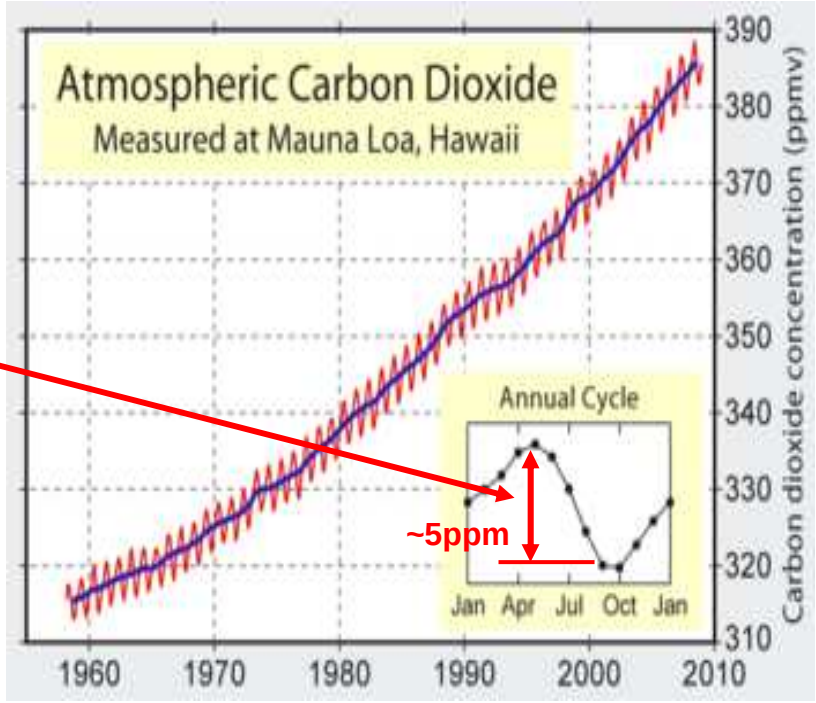


Methane (CH_4) Is 25-100 times as powerful a GHG as CO_2, and Nitrous Oxide is 100 times CO_2.

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 & viewpoints to measure realities that affect all Earthlings. Our recent awareness stems from the U. of Hawaii's measurements of CO_2, beginning in 1957 – the first IGY (International Geophysical Year), when scientists worldwide began the intensive studies of our planet that we now depend on to pick a sensible future.

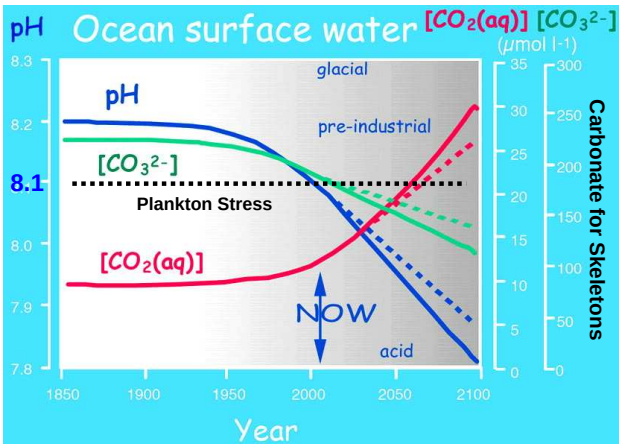
Note the important fact the ***Annual Cycle*** exposes -- it shows **what we might wish natural, sea & land photo-synthesizing organisms to do for us each year** to reduce CO_2 levels. it's about 5ppm/year, if no natural sources of CO_2 existed & **we stopped all hydrocarbon combustion**.



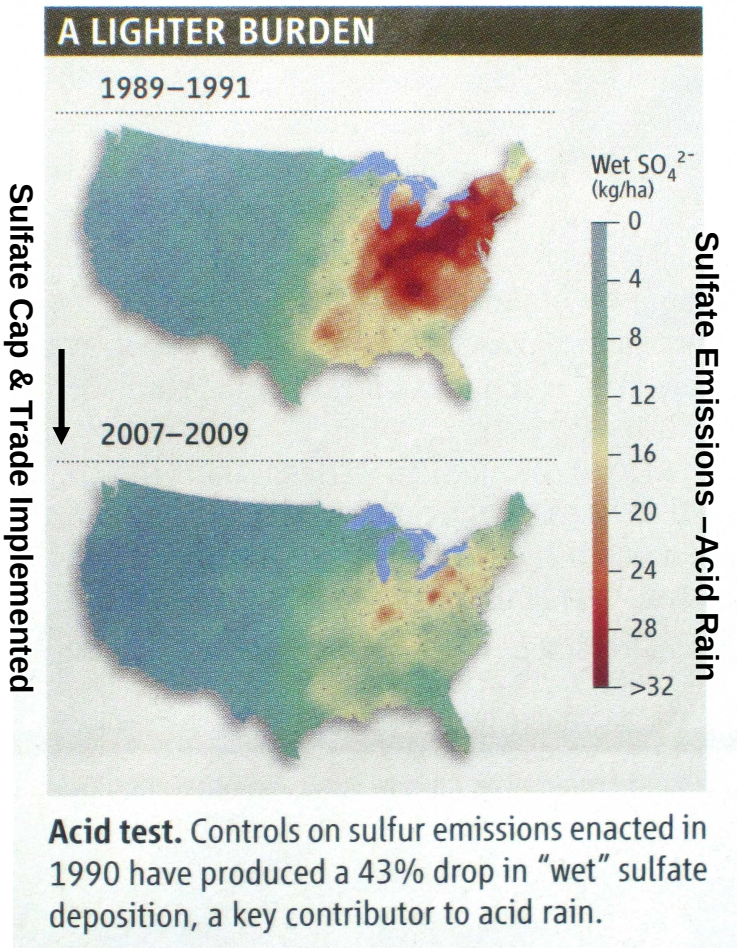
Other Emissions Effects

(in process)

Combustion byproducts – NOx, mercury, radioactive, ash…
Acid Rain – NOx now dominant from agricultural fertilizer…
Tropical disease range increases…
More acidic seawater prevents plankton growth, sea life = 70% human protein source…



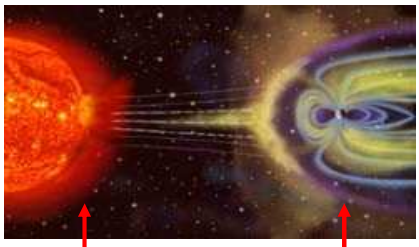
Cap & Trade can work – power-plant Sulfur emissions example…



Acid test. Controls on sulfur emissions enacted in 1990 have produced a 43% drop in "wet" sulfate deposition, a key contributor to acid rain.

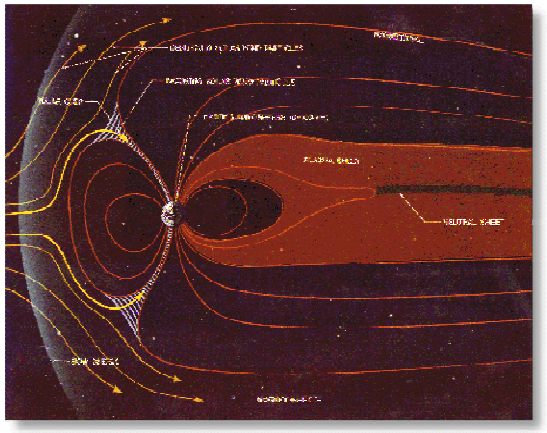
Our Protected Status

- ***Without Earth's molten iron core & magnetic field***…
  - Sun's proton wind would strip our atmosphere away, like Mars.
  - Without an atmosphere, life would be blasted with solar protons, xrays & cosmic rays/particles, except >20ft under seas & lakes.
  - And, everything would freeze anyway – no greenhouse effect.



93 million miles

Solar flares send Megatons of protons our way at >1,000,000 mph
http://tinyurl.com/2u7yqv3

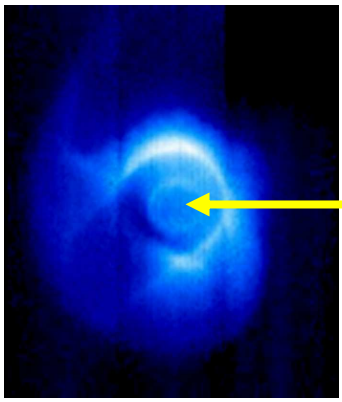


The auroras near either pole are the result of the solar wind getting deflected by our magnetic field & solar protons colliding with air molecules, ionizing them so they glow when they recover their lost electrons…..

Aurora from below

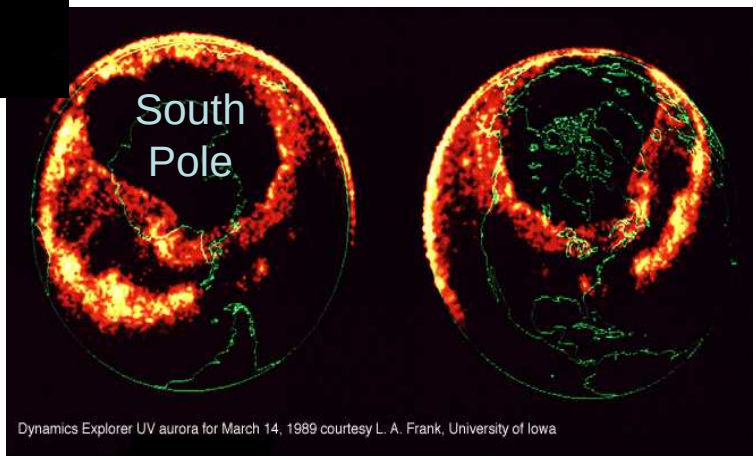
Us from space

Sun



Tiny Earth

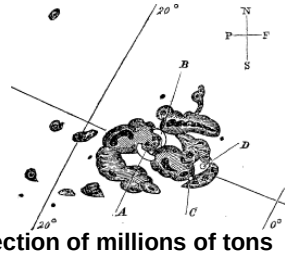
Aurora (in UV) from space



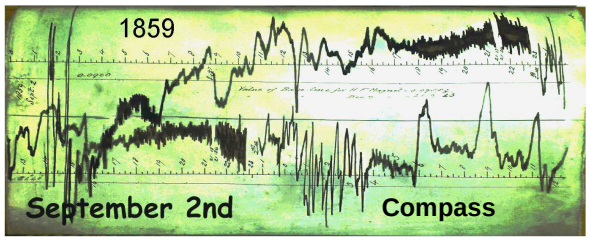
Dynamics Explorer UV aurora for March 14, 1989 courtesy L. A. Frank, University of Iowa

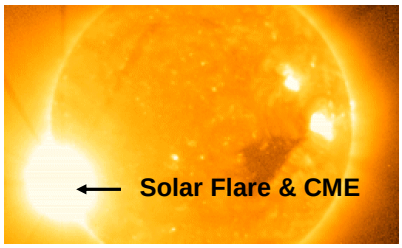
Sometimes, not so Protected

- ***Sunspots*** sketched by Richard Carrington on Sept. 1, 1859, copyright Royal Astronomical Soc.:



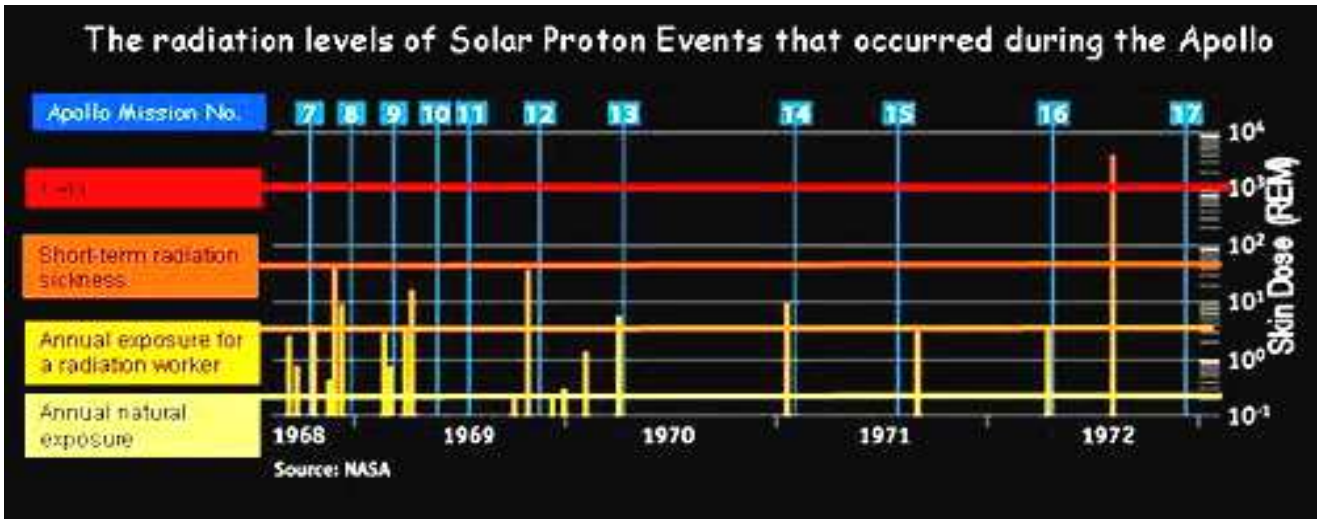
Suddenly, two brilliant beads of blinding white light appeared over the sunspots. Before dawn the next day, skies all over Earth erupted in red, green & purple auroras so brilliant newspapers could be read easily. Stunning auroras pulsated even over Cuba, El Salvador & Hawaii. Telegraphs worldwide went haywire. Sparks shocked operators & set telegraph paper afire. A Coronal-Mass Ejection of millions of tons of protons had accompanied each bright Solar Flare Carrington saw. The CME, arriving at ~5 million mph, shook Earth's magnetic field, induced huge electric currents in all electrical systems & drove compasses wild. <u>The result today?</u>





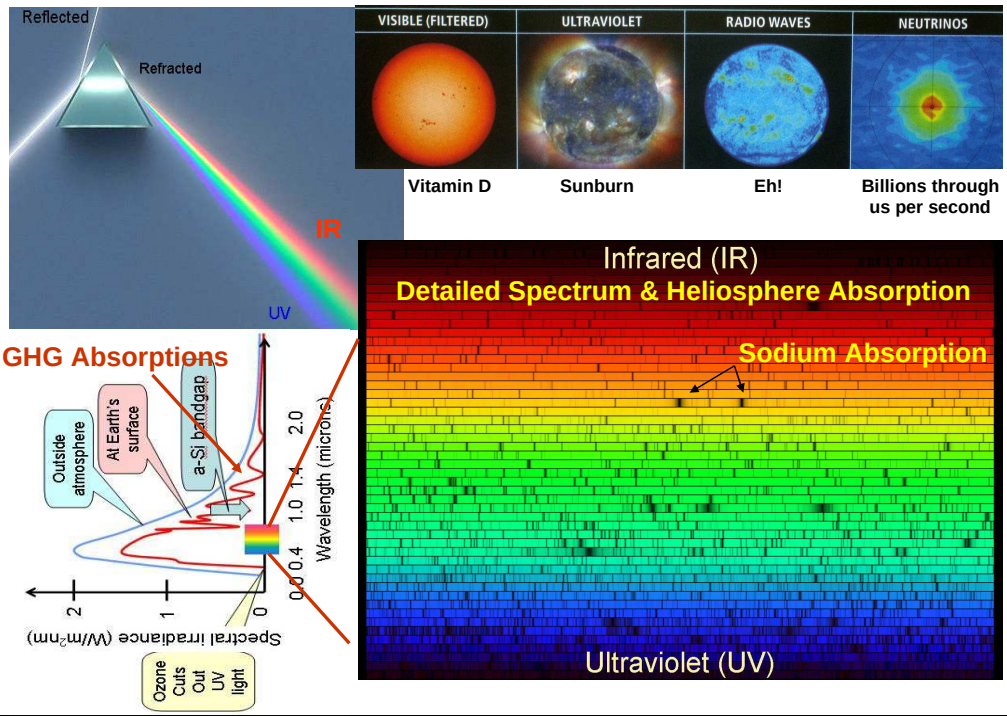
http://en.wikipedia.org/wiki/Solar_storm_of_1859

Apollo astronauts were plain lucky (even Apollo 13)…

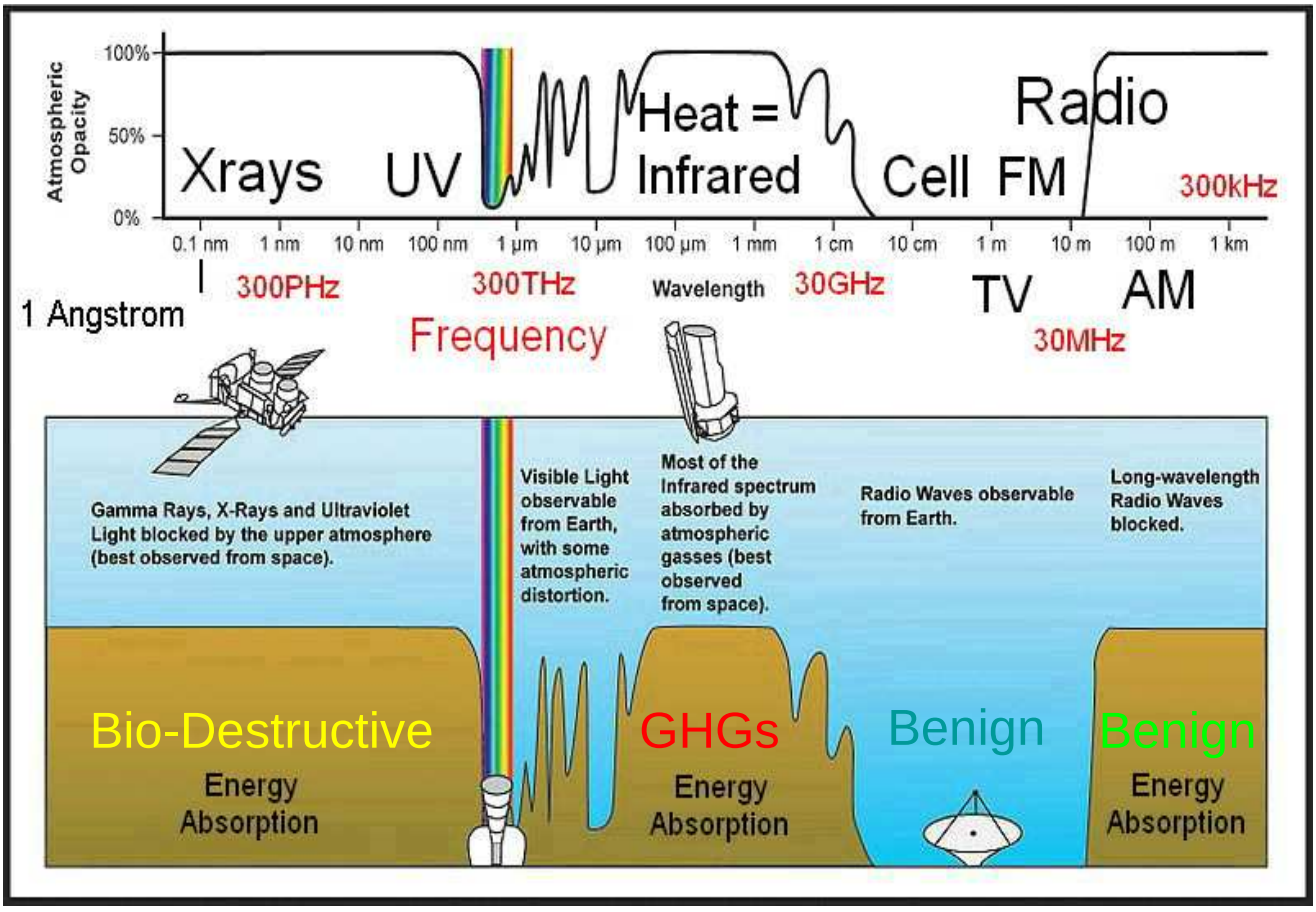


Space travel is extremely risky & CME monitoring/prediction essential. Spacewalking astronauts might just have mins-hrs, after seeing a flare flash. A huge solar flare on 4 Aug 1972, knocked out telephone communication across Illinois. A flare on 13 Mar 1989, caused geomagnetic storms that disrupted power transmission from Hydro Québec, blacking out 6 million people for 9 hours, even melting power transformers in New Jersey. That August, another flare affected computers, halting trading on Toronto's stock exchange. In December 2005, Xrays from another solar storm disrupted satellite-to-ground communications & GPS. Intelsat's Galaxy 15 was rendered uncontrollable on 8 April 2010 by a solar flare. Those were <u>peanuts compared to another Carrington-class flare</u>. This is why **we now have satellites monitoring the Sun 24/7** -- SOHO, Hinode, STEREO, ACE, SDO -- **managing our increasing risk.**

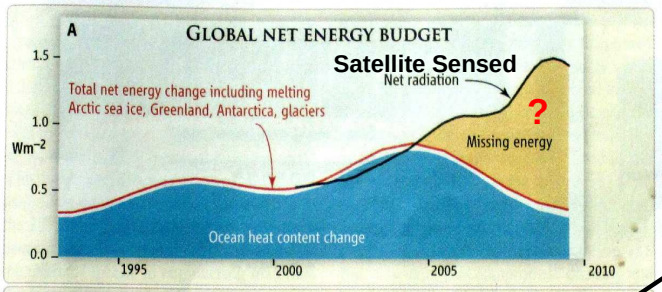
The Sun's Radiant-Energy Output

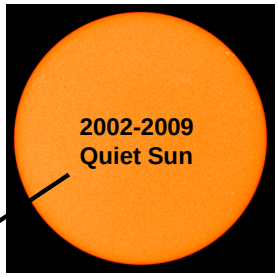


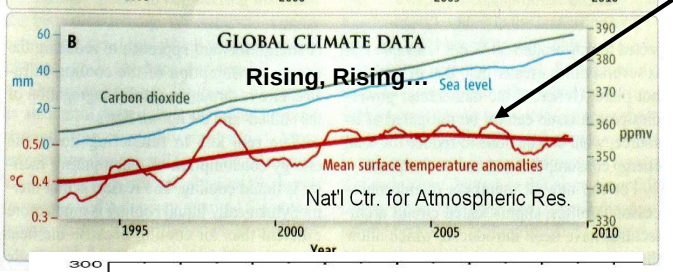
All Radiant Energy (Electromagnetic Spectrum)

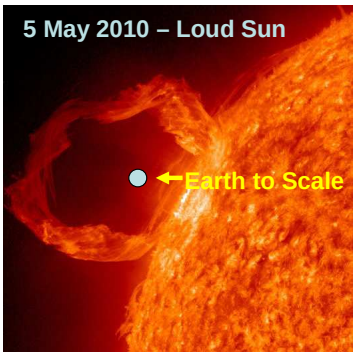


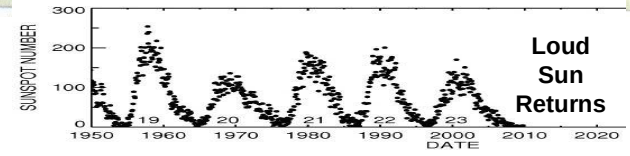
Earth's Energy Balance



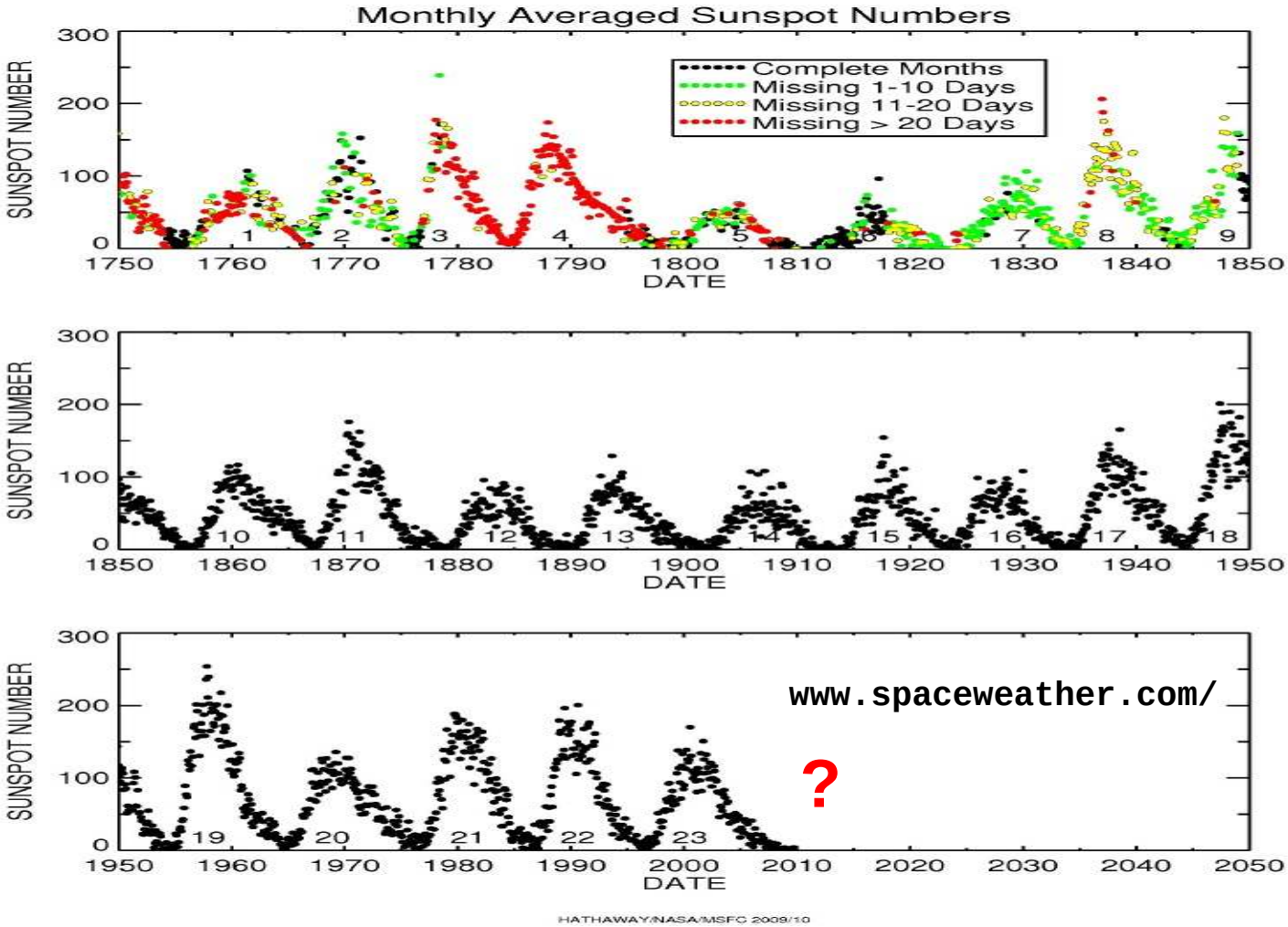








Sunspot history is important:



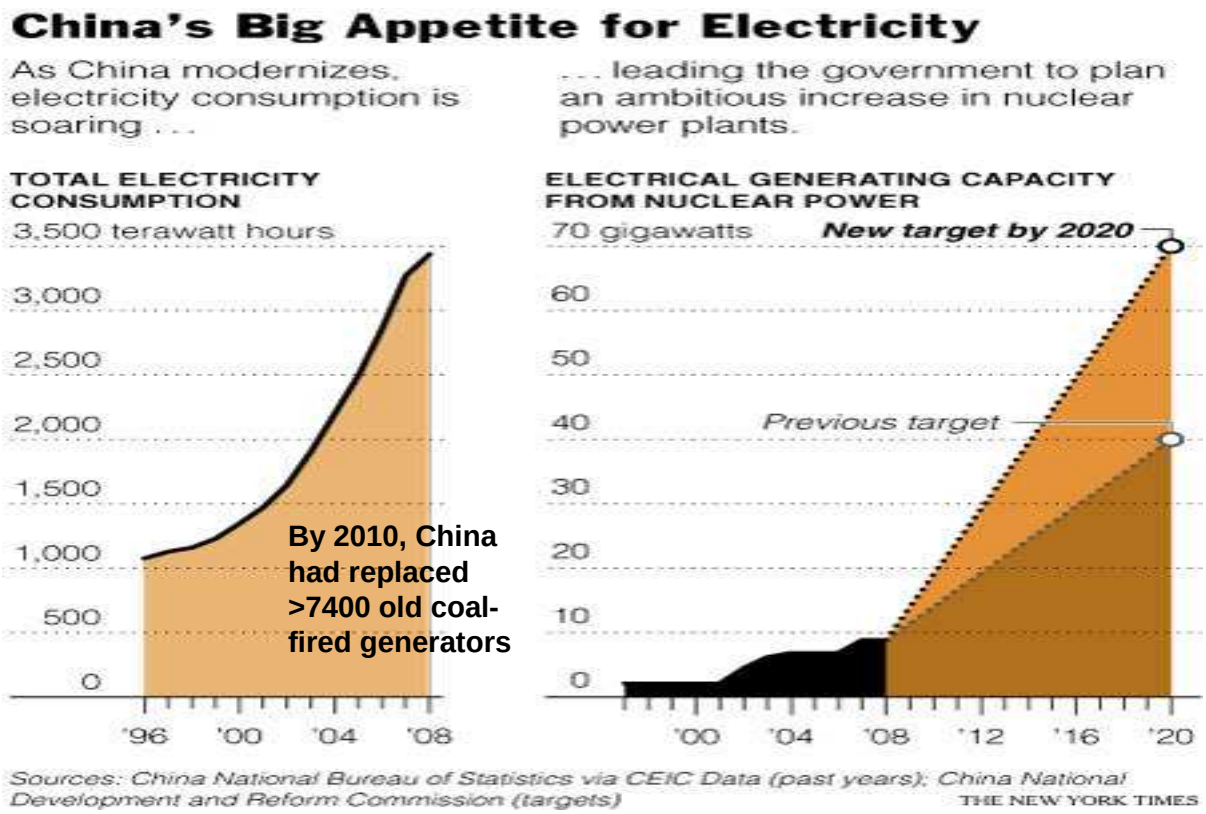
Power & Energy Units

- ***Power***:
  - **Watt, kW, MW (**a million Watts**), GW** (a billion Watts), **TW** (a trillion Watts – humans now use about 15 TW all day long).
  - Human body radiates ~400 Btu/Hr, or 150W.
  - **1 "Ton"** of A/C cooling = 12,000Btu/Hr.
- ***Energy***:
  - **kWHr, MWHr, GWHr**…
    - A typical home uses about 30kWHr/day of electricity.
  - **Therms**: 1 Therm = 29.3kWHr, or 100,000Btu.
    - A typical home uses 1-2 Therms/day in gas heating.
  - **Btu** (British thermal units) = the energy used to raise 1 pound of water 1 degree F. 3.4Btu = 1Watt-Hour.
  - **kilo-Calorie** = 1 'food calorie' = 1.16 Watt-Hour.

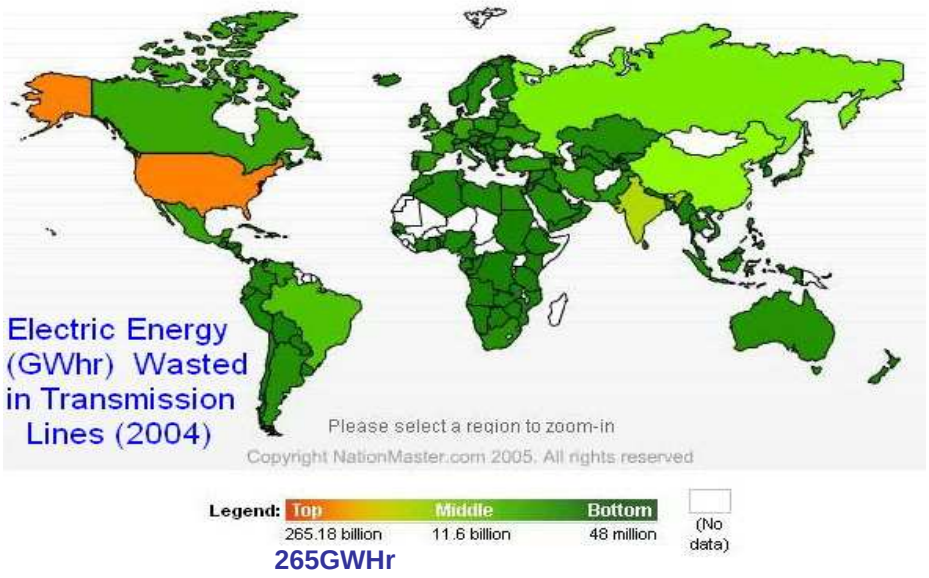
Reddy Kilowatt:
(Atlanta P & L)

http://tonto.eia.doe.gov/kids/energy.cfm?page=about_energy_conversion_calculator-basics

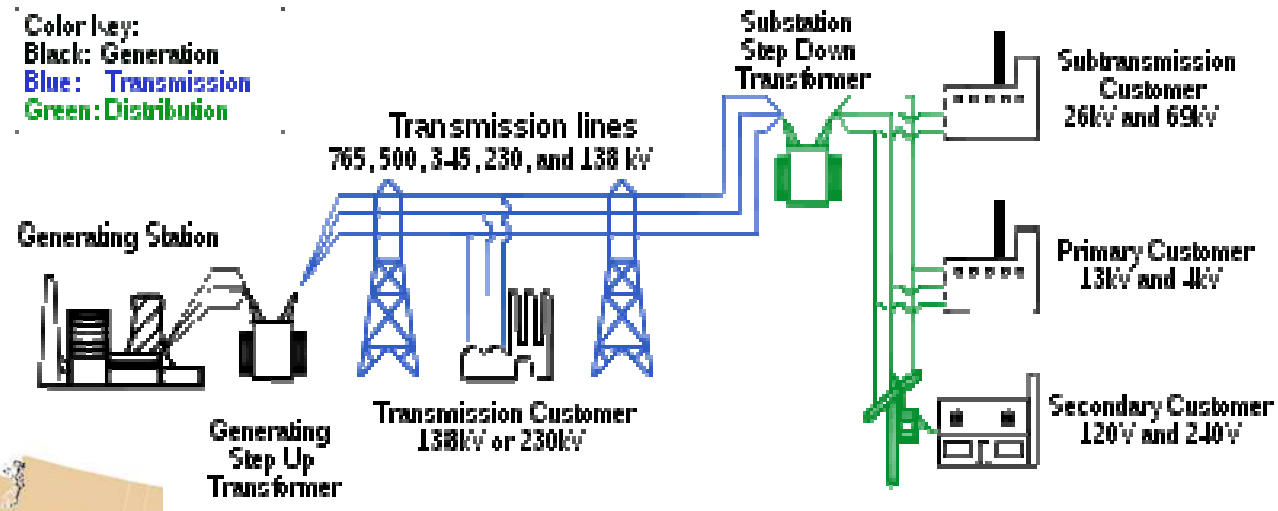
Energy is not a property of an object, like color or size. It's work relative to other objects that interact with it. Energy is a relative property of objects in a group.

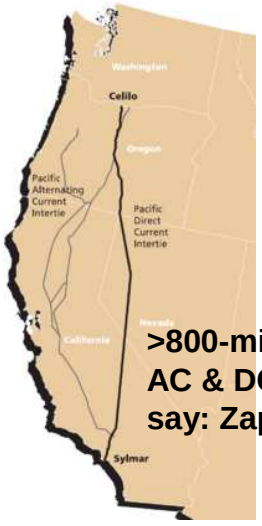


Wasted Electric-Transmission Energy



Transmission-line losses in Calif. average ~7% of generated power. But distributed, urban generation (solar electric, safe nuclear…) can recoup the loss.



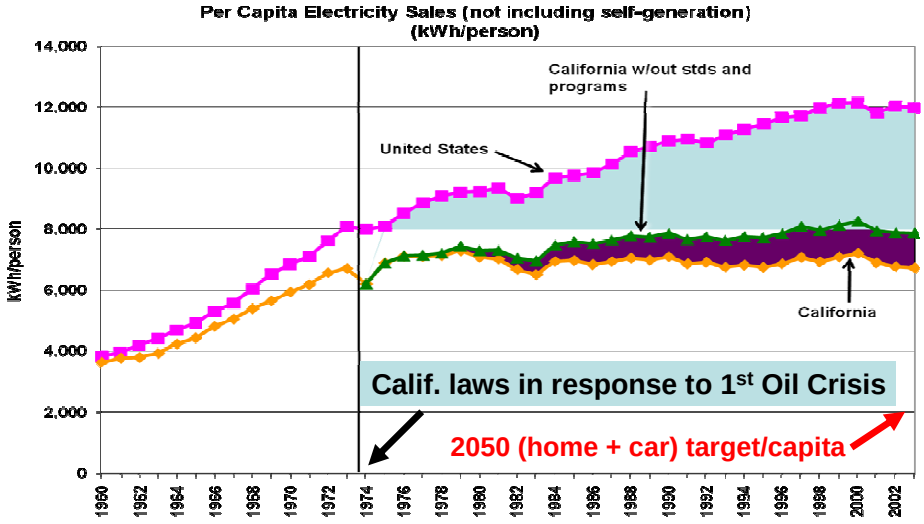


>800-mile Pacific AC & DC Interties say: Zap me now!

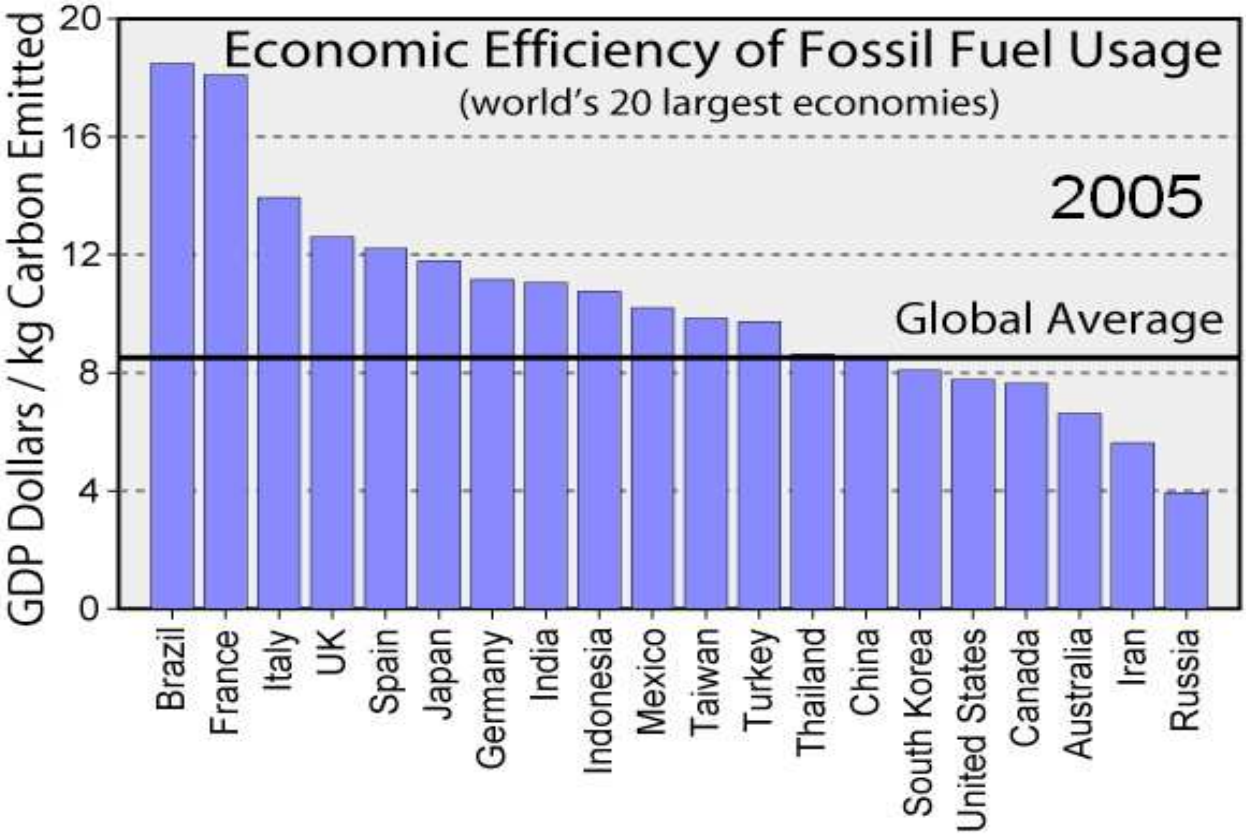
Cross-country cables act as antennas, so transmission systems are susceptible to solar-induced geomagnetic storms – some have been doozys in our electro-techy age, but none yet near to the ***Carrington Event of 1859***. Satellites & pipelines are vulnerable too. Check http://spaceweather.com/ **1989 remains of a Quebec transformer:**

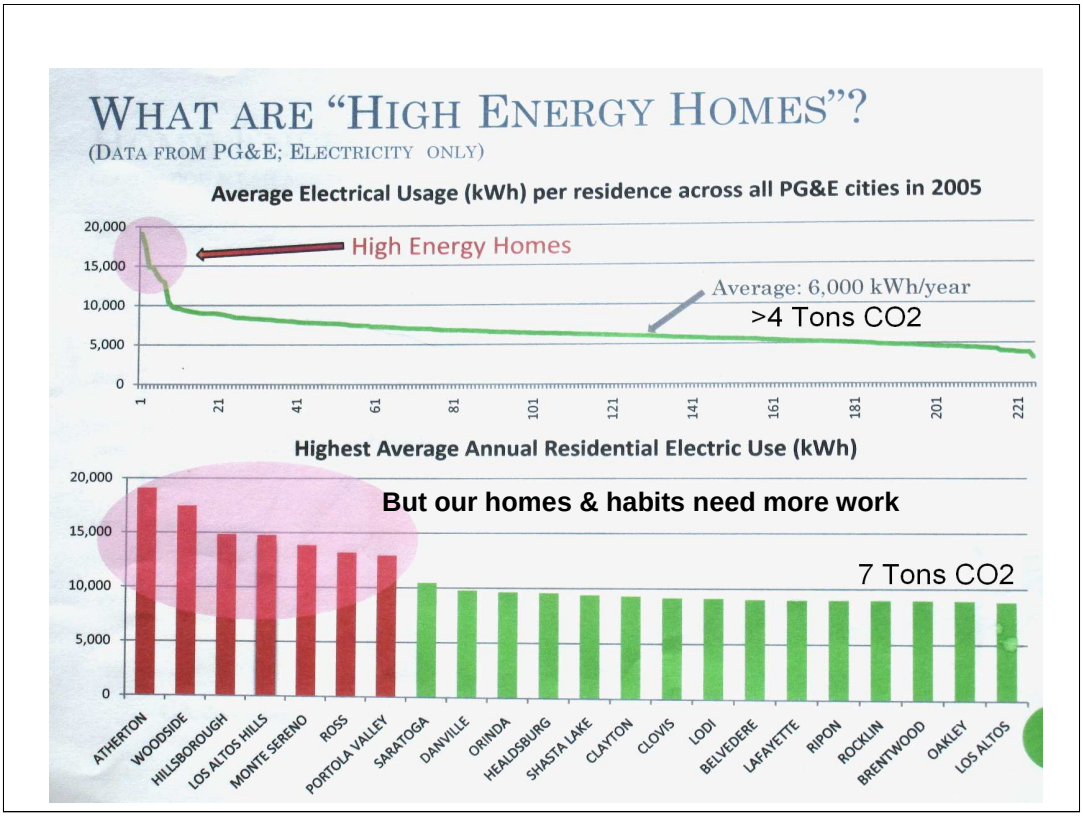
Personal Energy

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

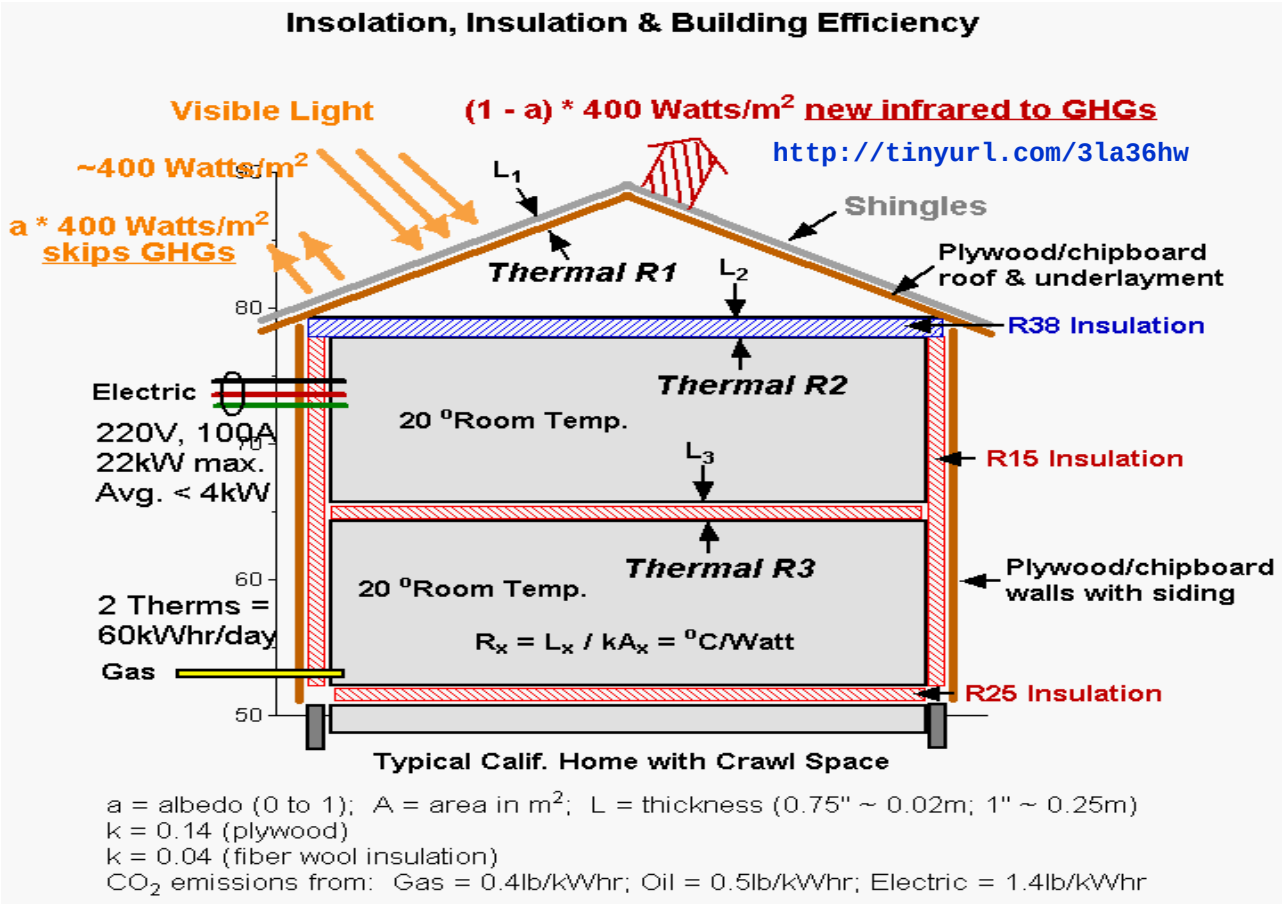


Despite Calif's great lead, referenced to the rest of the US, **we're still far from the overall CO_2 emissions target for 2050** – 6500kWHrs/percapita/year translates now (@1.1lbs/kWHr) to 3.5 tons/year of CO_2, just for electric use, not counting home/business heating or vehicles. An average Calif.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





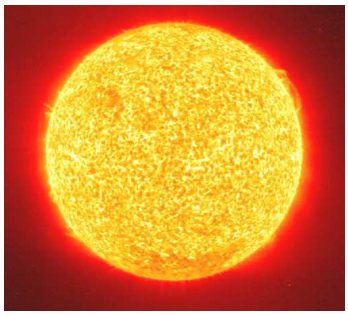
To the extent non-GHG emitting energy sources displace fossil-fueled sources, we can consume more than the ~1800kW/Hr per capita/year that corresponds to the 1 ton CO_2 (@1.1lb/KwHr) 2050 target, including heating emissions.



Energy Rate & Density

- ***Rates*** are everything in nature (and banking).
- ***Power*** is the rate of doing work.
- ***Energy Density*** is the power available per second in a standard volume of some material.
  - Arrange these from highest to lowest energy density…

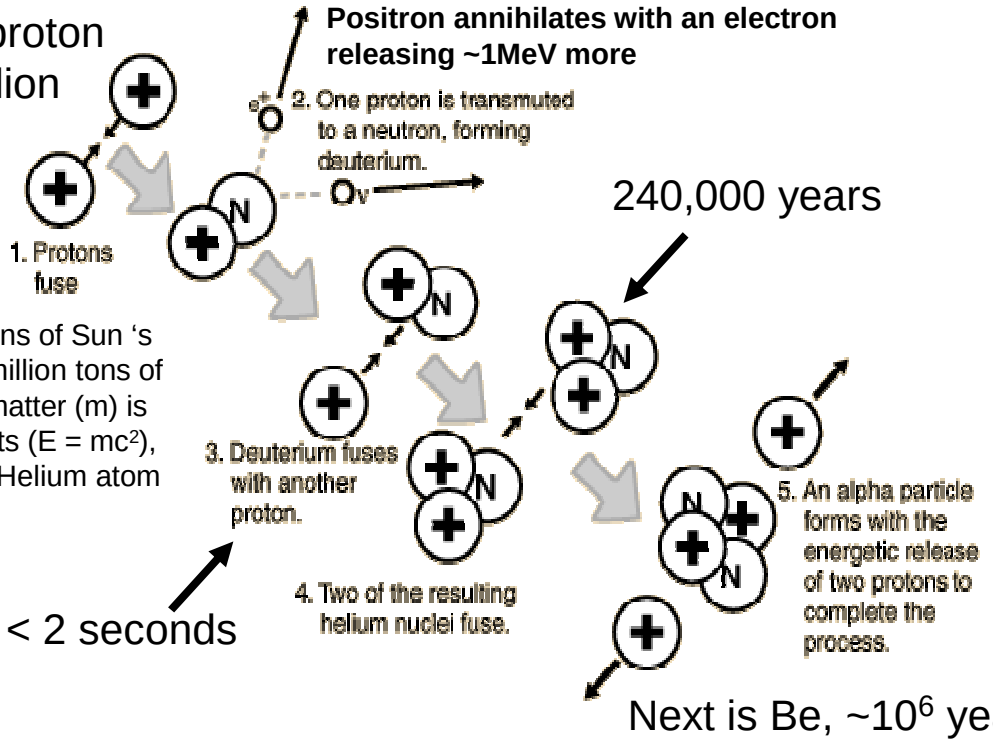





Bright bluish spark is concentrated, hinting at extreme energy density. Sun is low – about ¼ the energy density of a resting human's body heat (260uW/cm^3).

Sun's fusion is hugely powerful, but infrequent (~8 billion years per hydrogen atom). And the sun is huge, so energy density (<200W/m^3 in core) is lower than a candle's! That's one reason it's been around for over 4 billion years, turning Hydrogen into Helium, then Beryllium, plus neutrinos and gamma rays (light, which takes many thousands of years, losing energy, while escaping the Sun).

Sun's average proton pair waits ~8 billion years to fuse

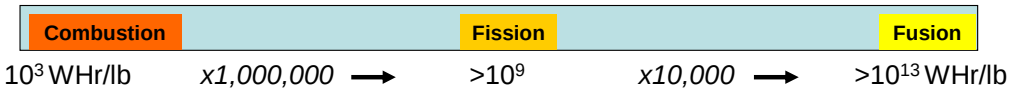


Each second, 600 million tons of Sun 's Hydrogen fuse to form 596 million tons of Helium -- 4 million tons of matter (m) is converted into 3.9x10^{26} Watts (E = mc^2), which is just 1 picoWatt per Helium atom produced.

Courtesy Wikipedia & Institute for Advanced Study at Princeton

Using Energy-Dense Sources = Good

- Energy density 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 – **low density**.
  - A cubic foot of ***natural gas*** (@1/2psi) = 0.3kWHr
    - = 1028 Btus (0.15lb of CO_2) – **low density**.
  - 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*** = **40,000,000,000kWHr** (**no CO_2**)
    - Deuterium-Tritium fusion (>14MeV/atom pair).
    - Plenty to last beyond Sun's lifetime (problem is Tritium production).
- 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.

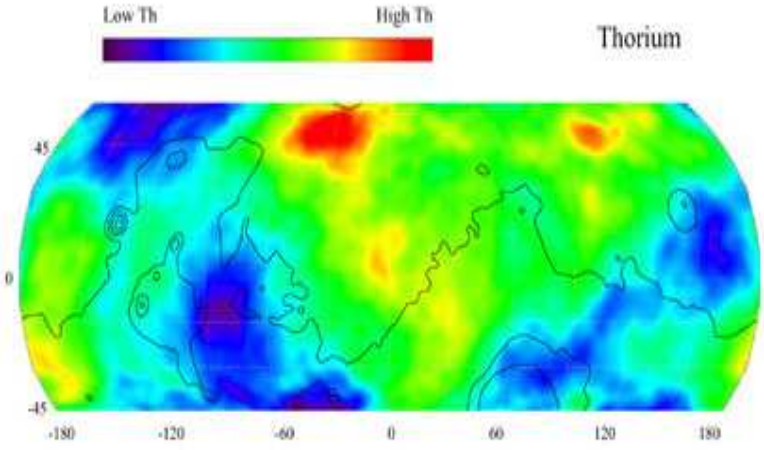
Burning Hydrogen with Oxygen generates more power/pound (15 kWHr) than typical fuels, but the needed Hydrogen volume is so great that compression into reasonable storage containers (@5000-10,000 psi) consumes energy (0.8 to 3 kWHr/lb – x2 to liquefy) & makes Hydrogen less attractive as a simple fuel.

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

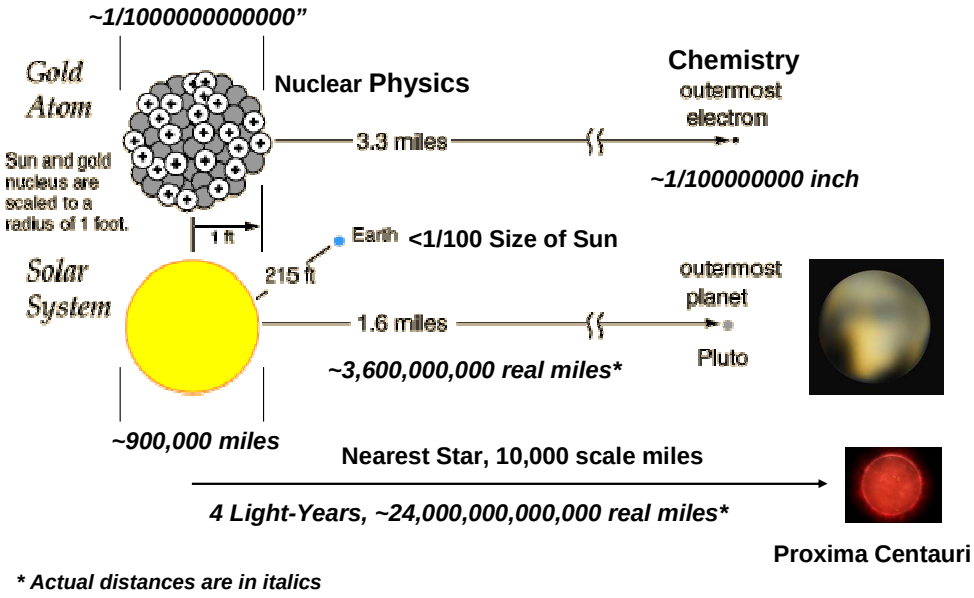
When used in a reactor to breed U233 for fission, Thorium has so high an energy density that 12 grams (about 4 pennies) provides enough energy to supply a typical American's needs for a decade. And, that much Thorium can be found in about any cubic meter of rock on Earth, Moon or Mars…



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

- Thorium in Mars dirt

A Worldly Scale



Neutrons Help Nuclear Stability

Gold, 79

Bismuth

Star Fusion

Supernova Shocks

Instability, Radioactive Decay

Neutrons = Protons

Iron, 26

U & Pu Fission

Protons Define the Elements

Hydrogen, 1

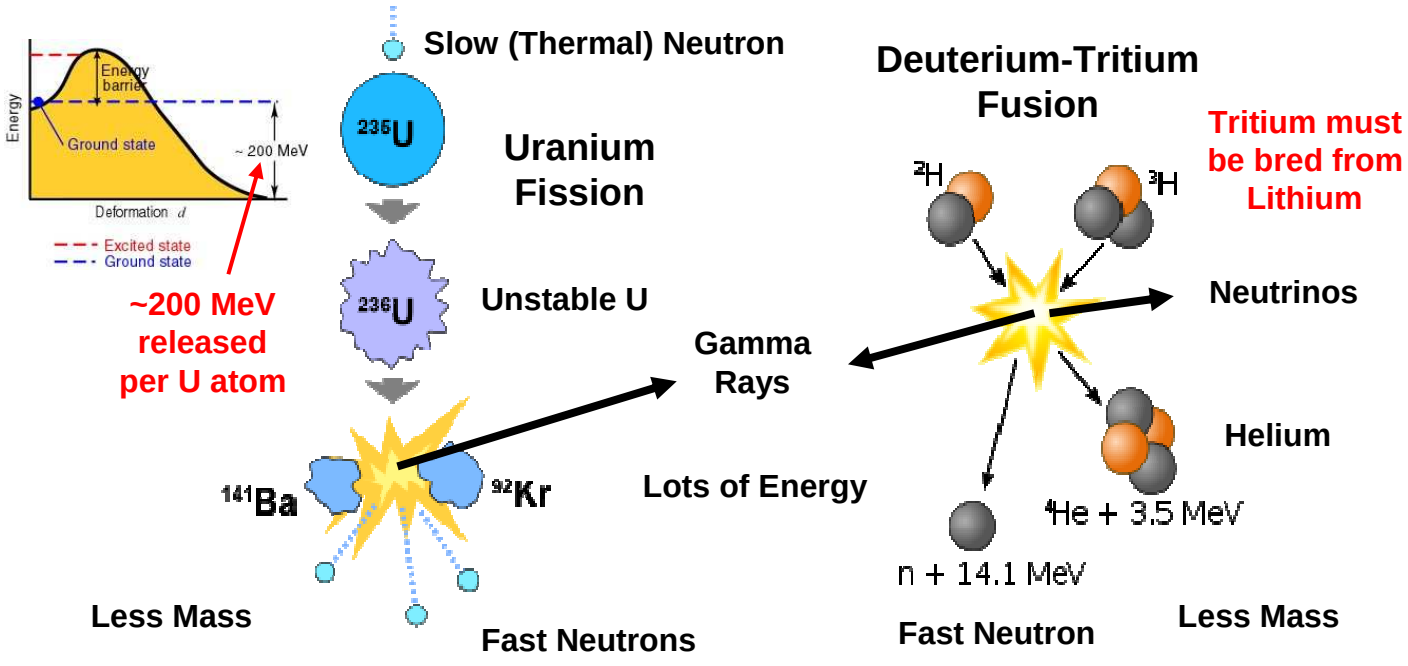
Uranium, 92

Energy & Efficiency

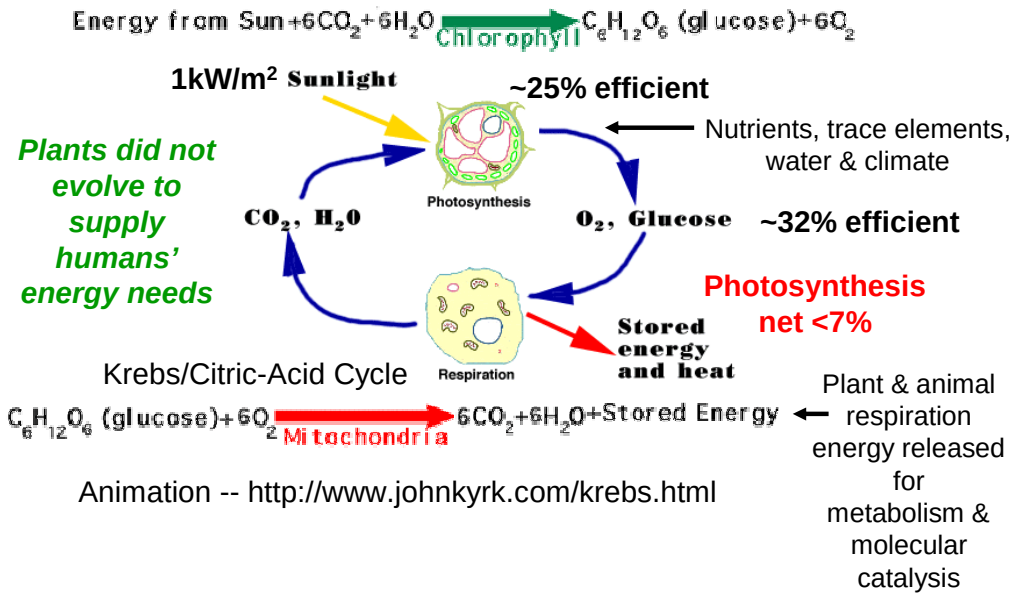
- ***Potential Energy:*** gravitational, mechanical, chemical, electrical, magnetic, nuclear ($E = mc^2$).
- ***Kinetic Energy:*** relative motion ($E = ½ mv^2$)
- ***Thermal Efficiency*** of energy conversion:
  - From heat to motion: **1 – T^oK_{cold} / T^oK_{hot}**
    - Very good combustion engine: 1 – 300/600 = 50%
  - From motion to electricity: about 90%
    - From generator to customer: about 93%
  - Overall efficiency = 0.5 x 0.9 x 0.93 = 42%
    - Typical power station converts less than 40% of its fuel's thermal kW to electrical kW & transmission loses about 7% more.
- Combustion is a poor starting point, except for simple heating needs (furnace, cooking, jet).

General relativistic energy: $\mathbf{E = (p^2c^2 + m^2c^4)^{1/2} + k} = mc(v^2 + c^2)^{1/2} + k$

p = momentum of a mass m moving at relative speed v. k = 'dark' energy, initially included by Einstein as an inherent 'pressure' of space to prevent gravitational collapse, then removed by him as his "greatest blunder", but then reborn in recent decades, via deep space observations of accelerating universal expansion. But both **nuclear fission & fusion show the correctness of $E = mc^2$** – the atoms/particles after each reaction total less mass than what entered the process, but fly away with high relative energies (measured in MeV)…



Plant Energy – Photosynthesis Inefficient



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 than 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.

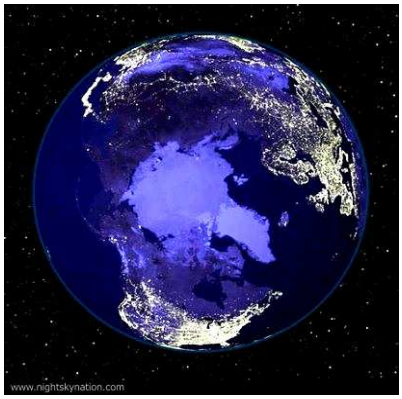
Using plants for combustible products for power generation fails both the energy-density & efficiency requirements. It also denies the reality that by 2050 we'll need new, arable land & water to feed 3 billion more people, and that 'new' land area equals all Brazil.

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…

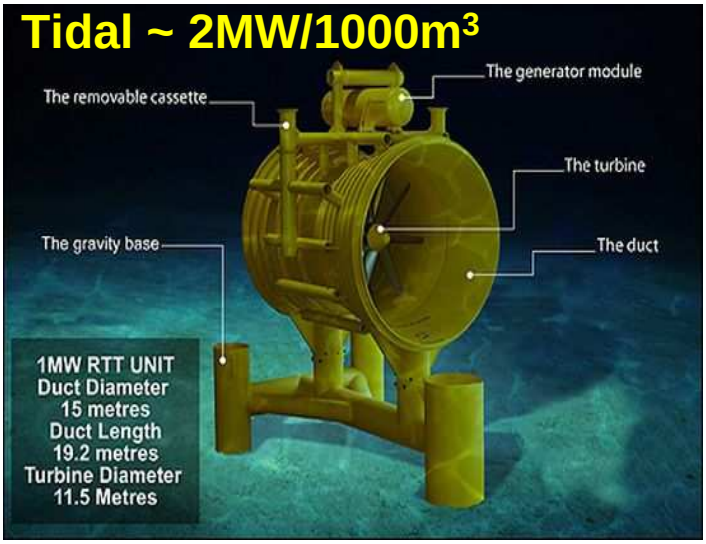
• If we use combustible fuels to get 15TW electric, then we generate ~45TW of heat (thermal efficiency ~30%), plus many GigaTons of CO_2 & H_2O (GHGs), plus various environmental damages.

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



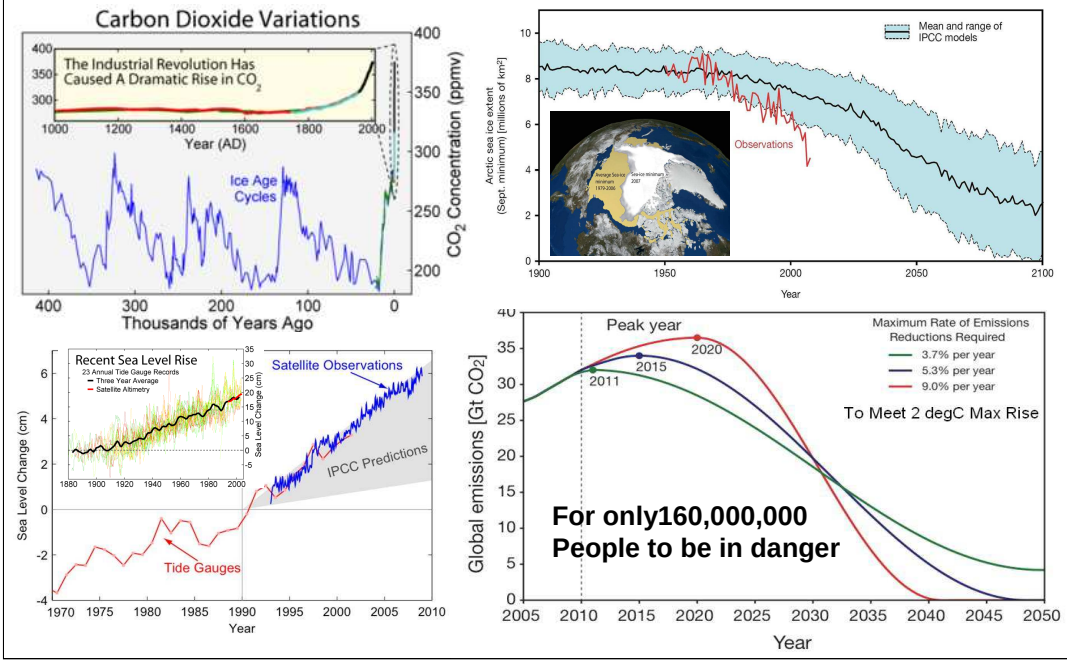
Most 'renewables' aren't & gobble lots of space, even species, to make up for low & intermittent power density…

Watch California wind vary, live!...
www.caiso.com/outlook/SystemStatus.html

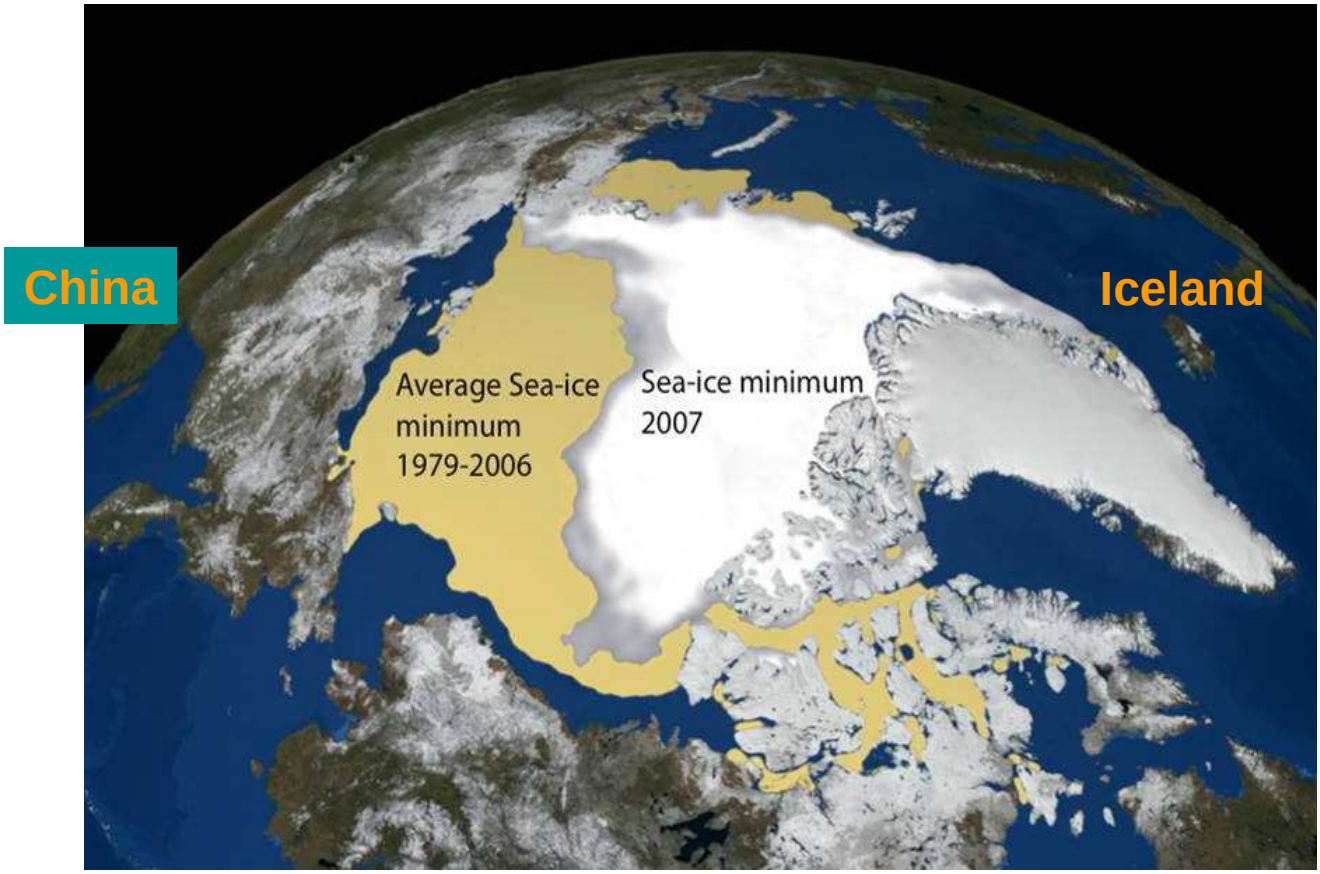


Solar electric ~ 200W/m² (@20% eff.)
Example is 240,000m², >60 acres
2/3MW/acre
3.1MW/acre theoretical maximum

Why Energy from Fire Must Go



China & Iceland are in negotiations to set up a Chinese logistics port in Iceland to allow **direct shipment of Chinese goods across an unfrozen Arctic:**



Common-Sense Choices

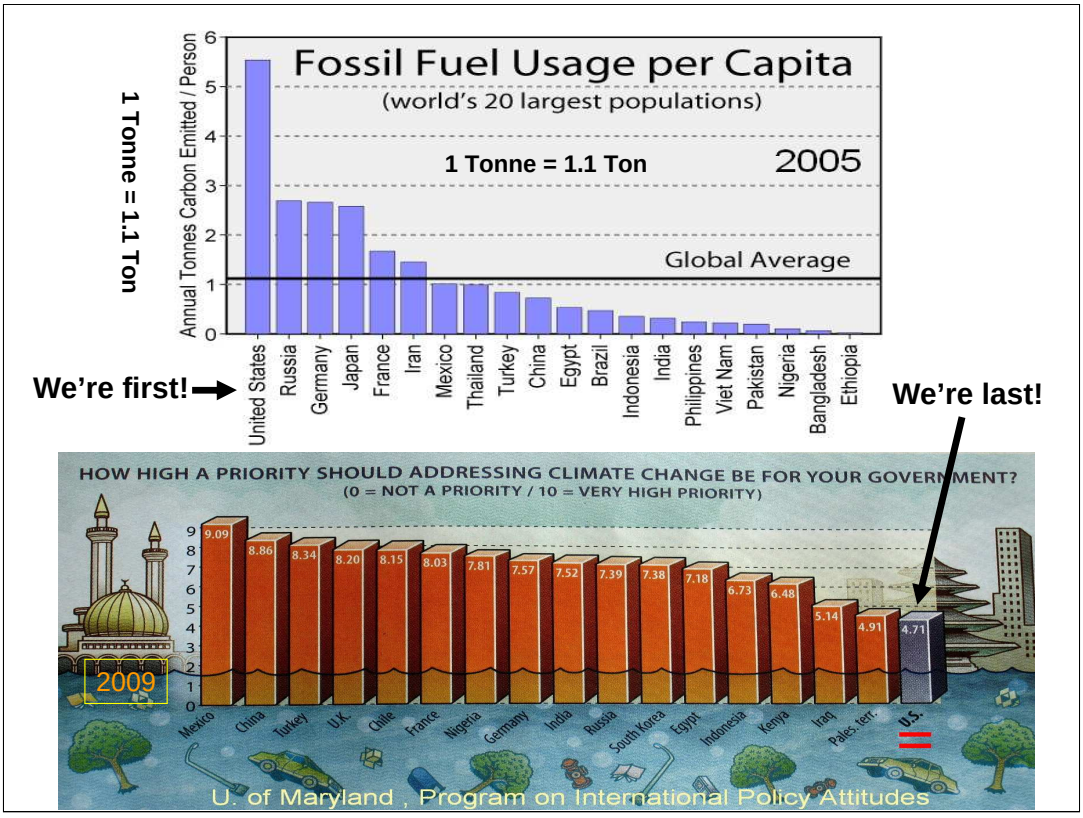
- It takes ~**1 kWHr to make a one-liter, empty plastic** bottle, cap & packaging (per Beverage Marketing Corp.).
- 900,000 tons of plastic bottled the 31 billion liters of water Americans drank in 2006, using 31 billion kWhrs of energy -- equal to burning 17 million barrels of oil, or running 3 large power stations all year, just to make bottles.
- Bottling water created more than 2.5 million tons of CO_2 in 2006 -- equal to 5 million cars running for a year.
- A plastic bottle uses twice as much water in its production as it holds -- every liter sold used 3 liters of water.
- With transportation & cooling, the energy cost of a plastic bottle equals filling it 1/4 full with oil & burning that.
- **The wise choice?** Drink water from fountains, pitchers, glasses, or anything but a pre-filled plastic bottle.

Recycling a plastic bottle saves about 360WHrs – a good workout in the gym. Using your own bottle, of any kind, saves far more.

Recycling aluminum cans, foil, anything, **saves >90%** of their production energy, or 400WHrs. So one aluminum can represents ~440WHr of production energy cost & corresponding CO_2 emission. **~100 billion cans are made each year in the USA, consuming over 40 billion KWHrs** (40TWHrs) – more than plastic but with a higher & repeatable recycling return.

The bottle of shame:

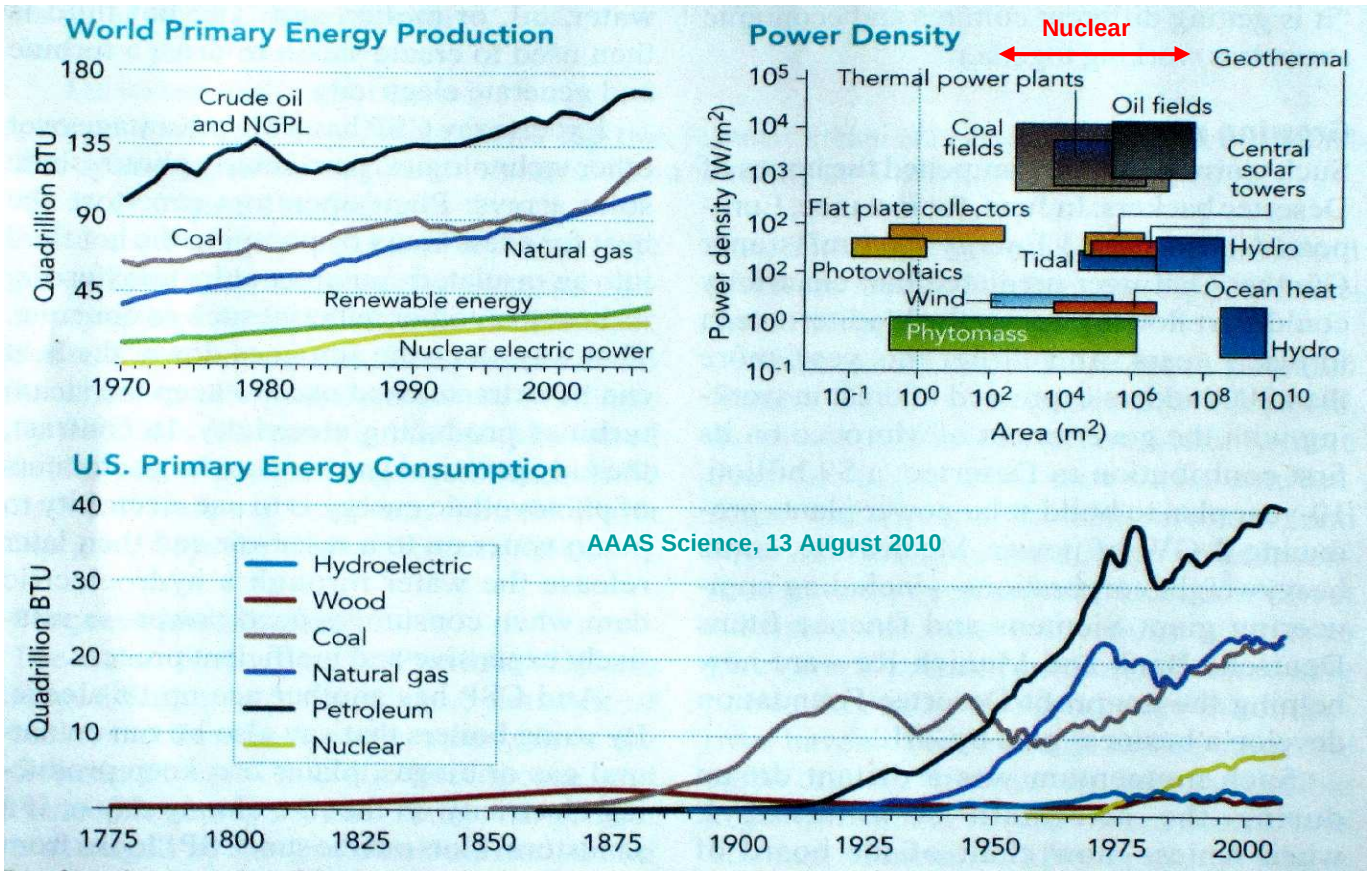
~3 Prius miles



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 & storage, but ***Power Density is environmentally key***:



Vehicle Energy

- Vehicles need directed forces: f = ma, E = fx
  - Support/lift – non space (ground, water, air)
  - Thrust/braking – friction/fluid-drag (~speed^2)
  - Roll/pitch/steering (course control)
- Forces derive from power sources/constraints
  - On board drive
    - Stored energy – fuel, electrical/mechanical storage
    - External energy – electromagnetic feed (wired, light, magnetic, fluid flow)
  - External drive
    - Mechanical – wind, cable, gravity
    - Electromagnetic – linear motor, light

Constraints are roadway, rails, 3D frames, etc.

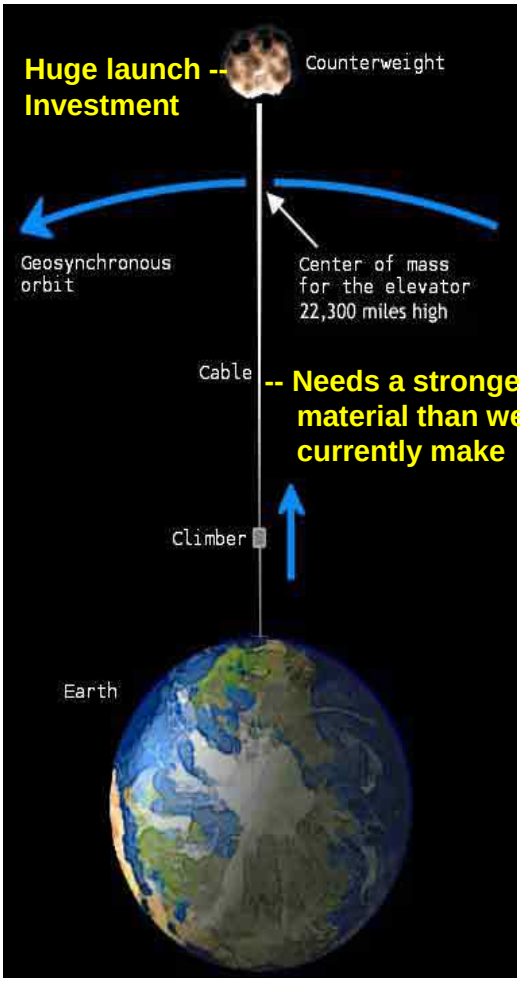
http://www.learner.org/interactives/parkphysics/coaster/

Vehicle Energy

- ***Vehicle Control*** – thrust, roll, pitch, yaw
  - On board – 3-axis plus accel/decel thrusts
  - External – surface (lift, pitch), rails (lift, pitch & yaw/course), 3D track (lift, roll, pitch & yaw – amusement park ride)
- ***On-board fuel***
  - Flexible cruising (within range of fuel sources)
  - Lower efficiency (fuel used to move itself)
- ***External fuel***
  - No route dependency (within fuelled region)
  - High efficiency (only vehicle, motor & payload move)
  - Energy generation centralized, distribution not (electric railway)
  - Vehicles limited by energy-distribution capacity
    - But power feedback from descending/braking vehicles possible
- ***External fuel & drive***
  - Highest efficiency (within drive region – cable car, elevator)
  - Vehicles limited by dedicated drive facilities (space elevator)

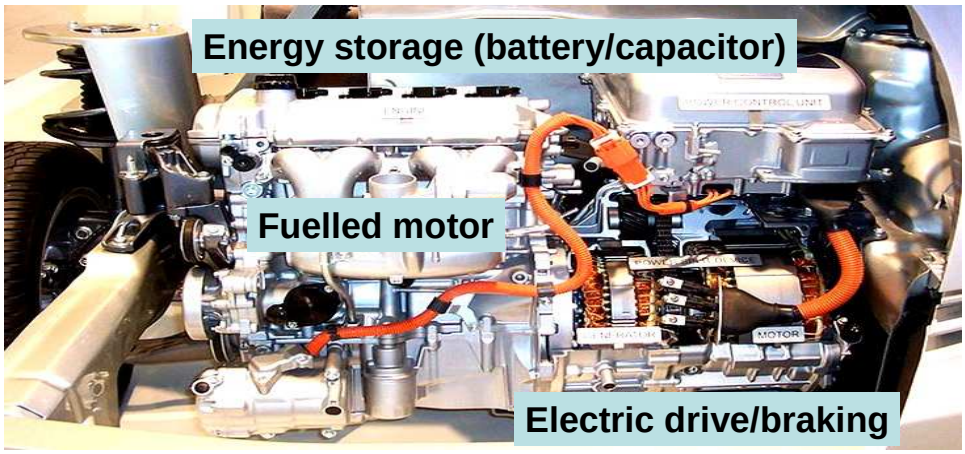
For rockets, Specific Impulse of fuel is critical. Nozzle exit velocity is key. In space, ion accelerators far better than chemical rockets.

If a material strong enough can be made into a cable, the **Space Elevator** solves the problem of inexpensive payload orbiting, E < mGh – what a ride!…

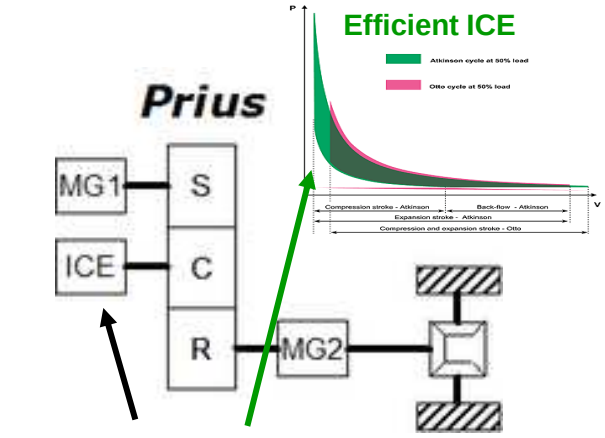


Vehicle Energy

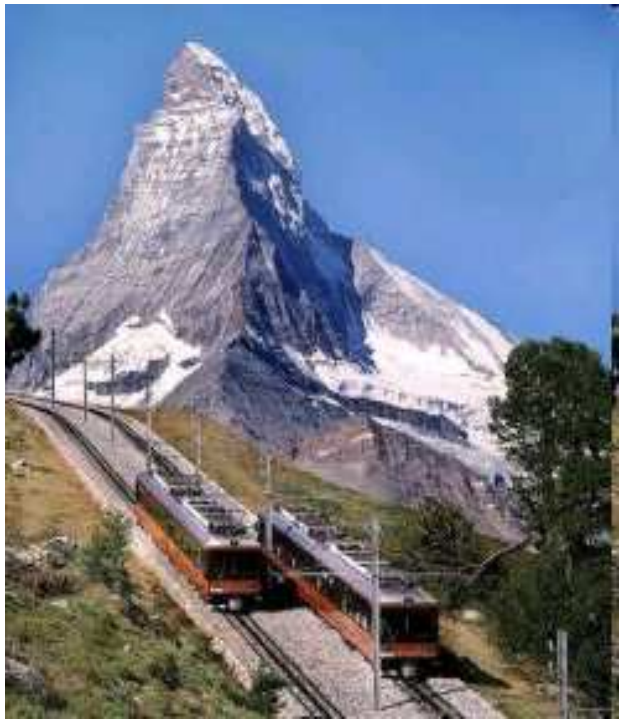
- ***Hybrid*** road vehicles combine current advantages
  - Minimize size/use of low-efficiency heat engine
  - Convert momentum to 'fuel' via mechano-electric (regenerative) braking (negative thrust) to charge batteries/capacitors
  - Maintain cruise flexibility of onboard-fuelled motor



Electric drive offers the ability to generate on slowing, using electromagnetic braking, thus charging onboard batteries or returning power to other vehicles via shared track, catenary, etc. The Matterhorn watches as a descending tram generates some of the ascending one's power…



Atkinson-Cycle Engine (more complete expansion)



Turning gravity to grid power and back again

Vehicle Energy

- ***Combustion***-engine efficiency is low
  - ~30% of fuel's energy provides thrust
    - Over **$.60 of every fuel $ wasted as exhaust heat**
  - But fuel's energy density high – ~6kWHr/lb
    - Fast refuelling
    - Light weight for useful range
- ***Electric*** motor/generator efficiency high ~90%
- ***Electric storage*** currently low density
  - Batteries heavy, range ~½ of fuelled vehicle's
  - High-density electronic storage in development
    - Ultra-capacitor, nano-tech batteries
- ***All-electric*** efficiency depends on grid efficiency
  - Fuelled generation ~30% efficient, hydro far better
  - Non-fuelled generation reduces GHG production
- ***Bicycle*** - .06 kWHr/mi, ½ the energy to walk a mile

Nuclear/combustion/geo/solar-thermal-powered electric generation -- **60-70% waste heat**, plus 7% transmission loss to customers. **Thermal-to-mechanical energy conversion has low thermodynamic efficiency**, due to realizable combustion & exhaust temperatures…

Thermal Efficiency = 1 – T_{cold}/T_{hot} – Carnot Cycle, ~40% for best internal-combustion engines. A steam engine gave ~6% overall efficiency in getting energy out of coal. A diesel generator gives <40% of its fuel's ~36kWHr/lb…

~48lbs CO_2/hr

20kWHr output from burning 2.4 gal/hr = **86kWHr thermal input**, at **23% efficiency**. So 77% of fuel's energy Wasted out exhaust.

Electric motors/generators depend on directed electromagnetic forces, not the randomly diffused forces of fluids under explosive expansion in all directions, or even of heated & cooled fluids in sealed engine cycles, such as the Stirling engine.

Vehicle Energy (Car)

- ***A typical sedan*** needs just 25-30Hp (19-22kW) to cruise freeways:
  - Fueled efficiency is about 125 people-mi/gal -- ***3-4 people-mi/thermal kWHr***
  - Electric efficiency -- ***11-12 people-mi/kWHr***
    - Ignoring generator/grid efficiency, with 85% drive efficiency
    - For combustion generation grid, same as fueled, unless braking is regenerative, adding ~15% efficiency for urban routes
    - Better for mixed hydro/combustion/solar…
- ***CO_2 cost*** of delivered electric kWHrs:
  - 1.4 lb/kWHr (EPA, thermal power generation)
  - 0.87 lb/kWHr (PG&E mixed sources, N. Calif.)
  - <0.5 lb/kWHr (construction-burdened renewables)
- ***Vehicular CO_2*** burden:
  - Fueled -- 1/5-1/3 lb/person-mi
  - Electric – 0-1/3 lb/person-mi, depending on electricity source & regenerative braking.

A loaded sedan can travel at 60mph with 36KW delivered to the wheels. For 60 miles, that's 36kWHr energy used per hour – the heat energy of a gallon of gasoline. So, that's 60mpg for the car, maximum and about 20lb of CO_2.

But any heat engine will have an efficiency of about 33%, so such an engine will only get 20mpg, emitting ~60lbs of CO_2, as is typical today.

If we use an electric drive, with 85% efficiency, and efficient electrical storage on board, the car can easily exceed that overall energy & emissions efficiency, depending on generation/charging source and use of regeneration.

1 car's CO_2 emissions are balanced by ~10 acres of forest (4x picture)…

Vehicle Energy (Bus, Train, Ship)

- ***Surface vehicles*** need not generate supporting forces against gravity.
- Efficiency depends on <u>occupancy relative to capacity</u> & losses due to the medium the vehicle travels on.
  - Road/tire losses - flexing, bump damping, steel wheels/rails best
  - Water - viscosity/friction, currents, wave action
- ***Person-mpg*** (or per kWHr) is a good measure:
  - **Bus** - 50-300 p-mpg (1-8 p-mi/thermal kWHr, fueled)
  - **Train** - 2/3 p-mi/kWHr (no regeneration, power losses included)
  - **Light Rail** - 25 p-mi/kWHr (no regen, >33 p-mi/kWHr w/regen)
  - **Freight Train** - 400 ton-mpg (11 ton-mi/thermal kWHr, fueled)
    - ~130 p-mi/thermal kWHr (1 ton ~12 people)
  - **Ship** – ~14 p-mpg (0.4 p-mi/thermal kWHr, fueled)
- Fueled-engine efficiency is sensitive to driver technique.

Fueled p-mi/kWHr would be doubled if non-thermal energy was used.

Freight trains pull cars whose mass is mostly payload, Passenger trains are far less efficient, per payload lb, thus light rail.

<u>Light rail is over twice as efficient as an electric sedan</u>, even when regenerative braking is fully used.

x3 p-mi/kWHr

Vehicle Energy (Aircraft, Rocket)

- ***Aircraft*** need to generate lift via air flow…
  - **Helicopter** -- ~18 p-mi/gal (1/2 p-mi/kWHr, thermal)
    - Control is via rotor thrust changes
  - **Winged** – ~.2mpg (747) to ~.3 (F14), or 40 p-mpg (747) <1 (F14)
    - Control is via airfoils
    - Drag is primary energy loss

- ***Rockets*** must generate lift & control via thrust…
  - Space Shuttle is ~16% energy efficient launching it plus payload, but just 4% efficient for payload alone:
    - Cost for 1 orbital launch = $1/2 billion, mostly for fuel
  - If the Shuttle were used to transport people/freight to another hemisphere, energy use would be ~8.4 kWHr/mi per lb of payload (~.008 p-mi/kWHr thermal).
  - Rockets can eject any materials for thrust – the higher the exhaust's relative velocity, the higher the thrust/unit mass: Specific Impulse is key – ion engines are best but use ~100x energy per unit of exhaust mass to get 100x SI.

Ion engines -- getting somewhere far away, very efficiently, even solar-electric powered…

www.newscientist.com/article/dn17918-rocket-company-tests-worlds-most-powerful-ion-engine.html

Ion Engines
SI = 3000 – 30,000

There goes $500,000,000, at 4% efficiency…

Chemical Engines
SI = 200 - 500

‘Renewables’ Revealed

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

All Abandoned – No Cleanup

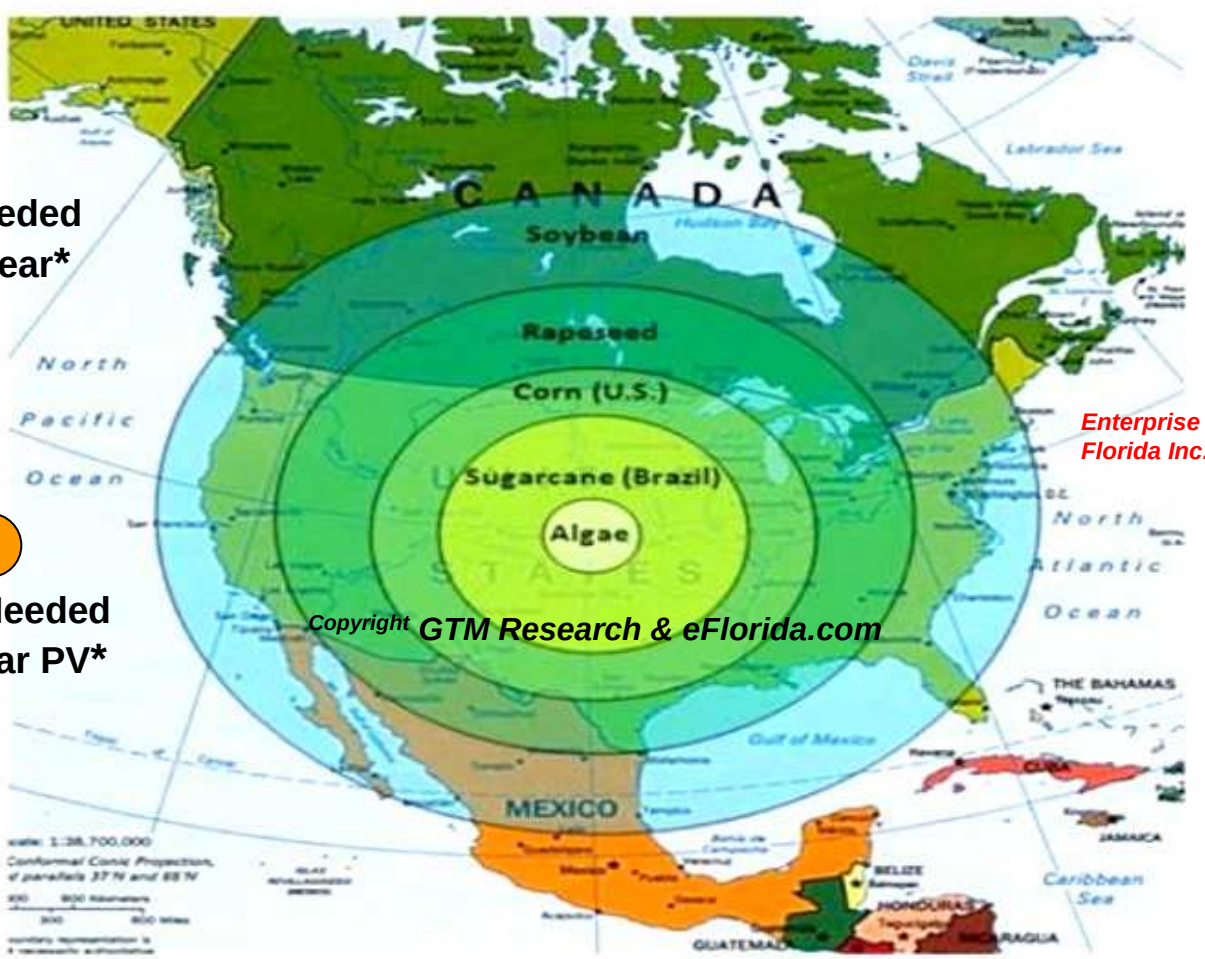
Carrizo Plain Solar, Calif.

Wind, Tehachapi, Calif.

Land Area Needed To Replace US Fossil Fuels With Biofuels…

Area Needed for Nuclear*

Area Needed for Solar PV*

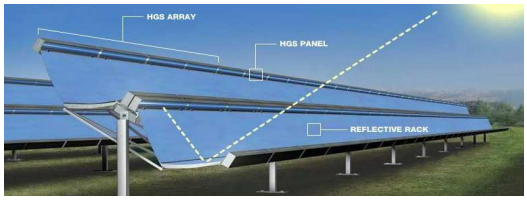


Enterprise Florida Inc.

*** All mining, construction, power & vehicular uses included .**

‘Renewables’ Revealed

320kW Wave Machine, <3kW/m²
~300kW/1000m³ < 1/6 Tidal Gen.

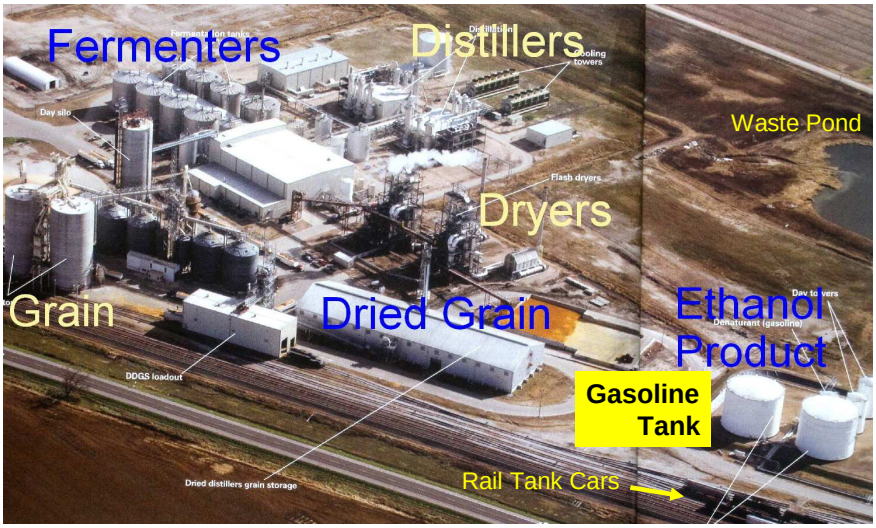


Concentrating & Tracking
Solar, >0.2kW/m² today (>0.4 military)
(1 kW/m² max possible at surface)

Inevitable transmission losses…
& abandonment…

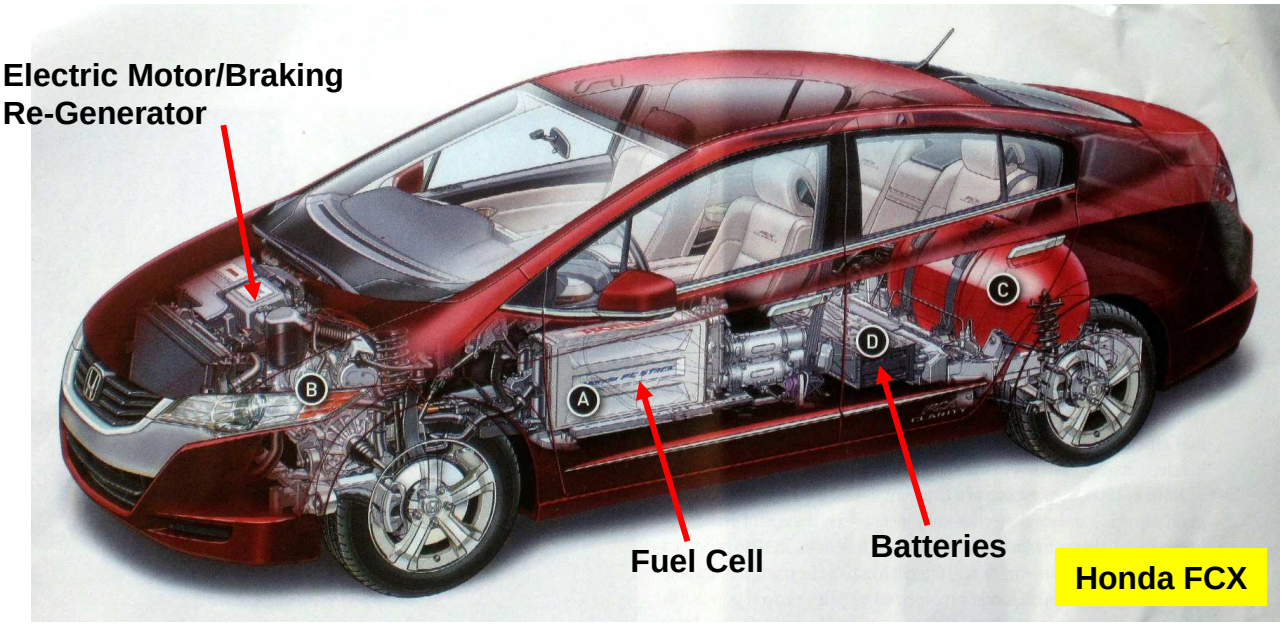
‘Renewables’ Revealed

Growing grain to make alcohol by fermentation & distillation would waste > 1/3 of US food-producing land & ~99% of that sunlight’s energy…



And, the output alcohol must be denatured by adding gasoline, which itself is refined & railed in – all fossil fueled!

A **Hydrogen-powered car** has great pollution behavior, but wastes ~1/3 of Hydrogen’s energy in combustion with Oxygen (15kWH/lb) simply by needing extreme compression to thousands of PSI so useful amounts can be carried in a tank (C below). Producing the Hydrogen itself is extremely energy demanding as well…



The on-board fuel cell is also less than 50% efficient, which means the Hydrogen + electric-drive system starts off well behind an all-electric vehicle, whose energy source is primarily the grid (currently ~40% efficient). Fortunately, electric drive offers energy recovery during braking, as long as adequate storage (batteries, ultra capacitors…) are on board too. Sitting near a 5000 psi storage tank may be uncomfortable, and convenient refilling poses infrastructure costs & dangers.

Home Energy Keys

- ***Recycling:*** 7.5 kWHr to make 1 lb of aluminum
  - In 2001, 50+ billion cans wasted -- energy equivalent of 16 million barrels of oil, for a million cars or the electricity for 2.7 million homes for a year
- ***Architecture:*** use environment wisely
  - ***Insulation*** – ceilings, walls, floors, windows
- ***Appliances:*** avoid electricity for heating
  - Gas is often best for dryers & water/room heating
- ***Lighting*** – ~8% of usage, so use skylights, LEDs, fluorescents, dimmers on halogens, occupancy detectors sometimes
  - LED color spectrum getting better & more natural
  - See CA Title 24 for various requirements
- ***Food*** – choices greatly affect world energy use

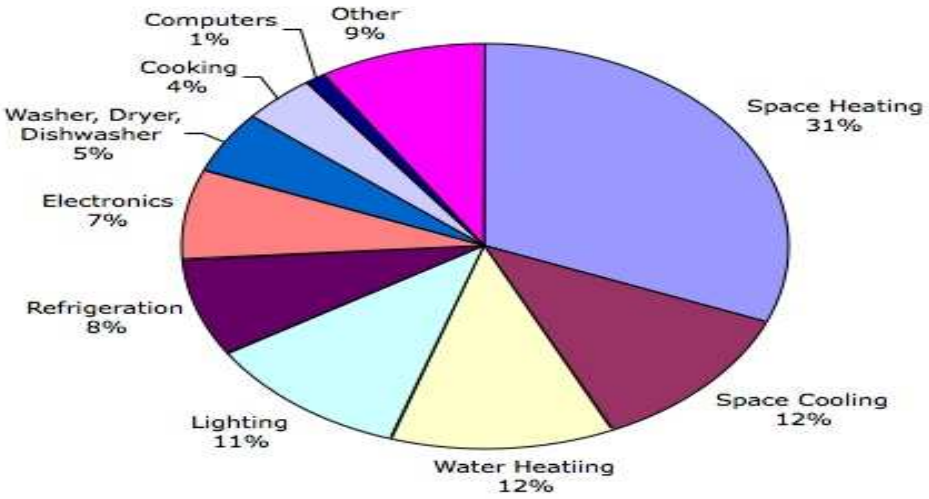
Between 1990 & 2000, Americans wasted a total of 7.1 million tons of cans: enough to manufacture 316,000 Boeing 737s, enough to reproduce the world's entire commercial air fleet 25 times…

www.container-recycling.org/publications/trashedcans/sample.htm

www.cancentral.com/funFacts.cfm

Recycling aluminum retains >90% of its entrained energy. But, many other household items are often poorly recycled: mattresses, rugs, windows, building materials, odd plastics, electronics, appliances… A great deal of energy is wasted by not recycling non-food materials.

Set a plan of action: **ww1.eere.energy.gov/consumer/tips/home_energy.html**



Residential Energy Usage, 2006

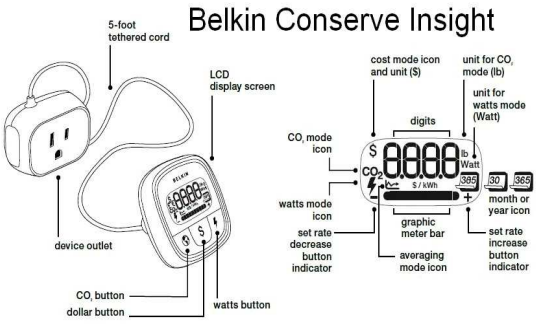
National Academy of Sciences

Home Energy Accounting

- Our everyday tools can be chosen & used efficiently…
  - Best tool – on/off switch, power strip
  - Next best – sensor (thermostat, presence/absence…)
  - Third best – timer, standby mode

Watt & Watt-Hour Meter

Estimate Emissions Too -- $30

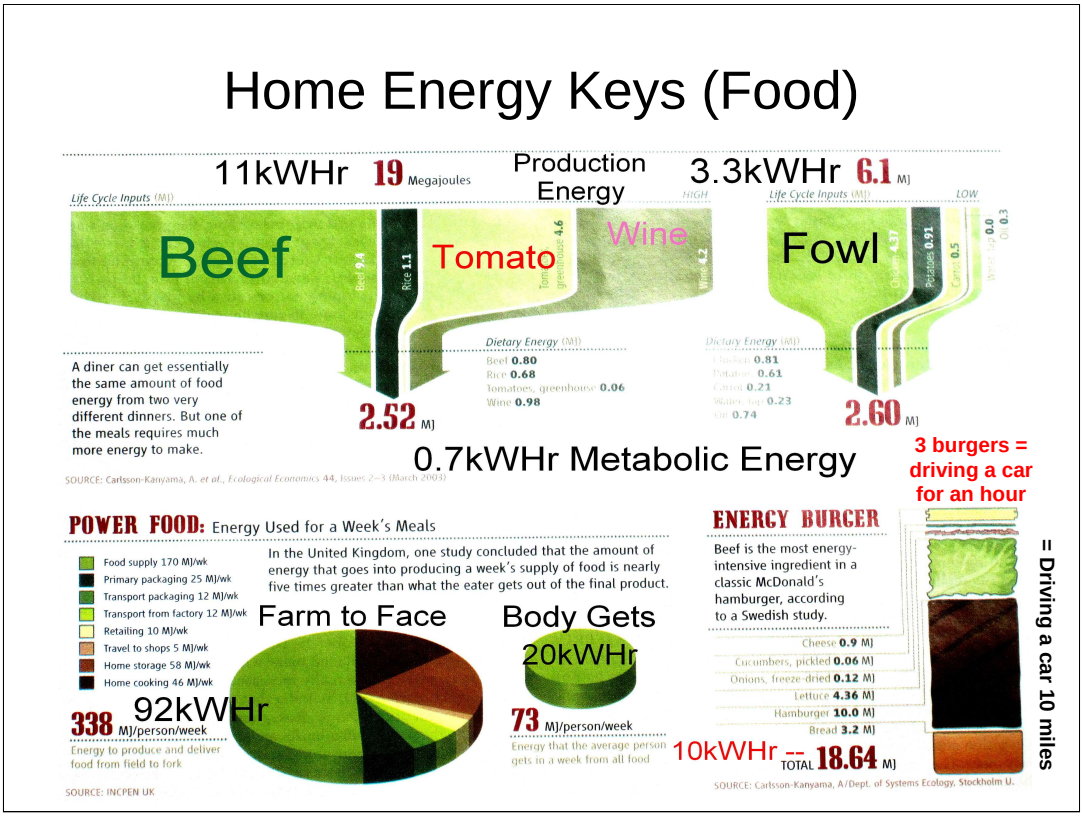


Typical electrical-device energy consumption (Watts)…

Device	***On***	***Charge***	***StdBy***	***Off*****
Old Laptop	60	42	34	<1
New Laptop	24	>24	2	<1
15″ Monitor*	22	---	1.5	0
19″ Monitor*	27	---	1	0
Desktop PC	93-130***	---	69	3
Fax/Scan/Printer	10-15	---	6	<1
Photo Printer	6-22	---	5	<1
3-Speaker PC Audio	9	---	6	6
DSL Interface	5	---	---	<1
Basic 802.11 Router	5	---	---	<1
500-Watt UPS	8+	8+	---	8
Home Wireless Phone	3	5	5	5
Cellphone Charger	5	5	---	<1
DTV Cable Box	5	---	4	4
DTV Satellite Box	9	---	7	7
HDTV Satellite Box	19	---	16	16
13″ LCD* DTV	19	---	2	2
24″ LCD* HDTV	51	---	<2	<2
Plasma HDTV	350+	---	<2	<2
Electronic Air Cleaner	21-44	---	---	0
Paper Shredder	100-200	---	3	0
Electric Toothbrush	2	2+	2	2
Electric Dryer	1000-3000	---	3	2
Gas Dryer	200-700	---	3	2
Electric Washer	200-700	---	3.5	3
Toaster Oven	1500-1700	---	---	<1
Clock Timer	3	---	3	3

* Backlit LCD
** Not unplugged
*** Booting/disc busy

The Sneaky Column



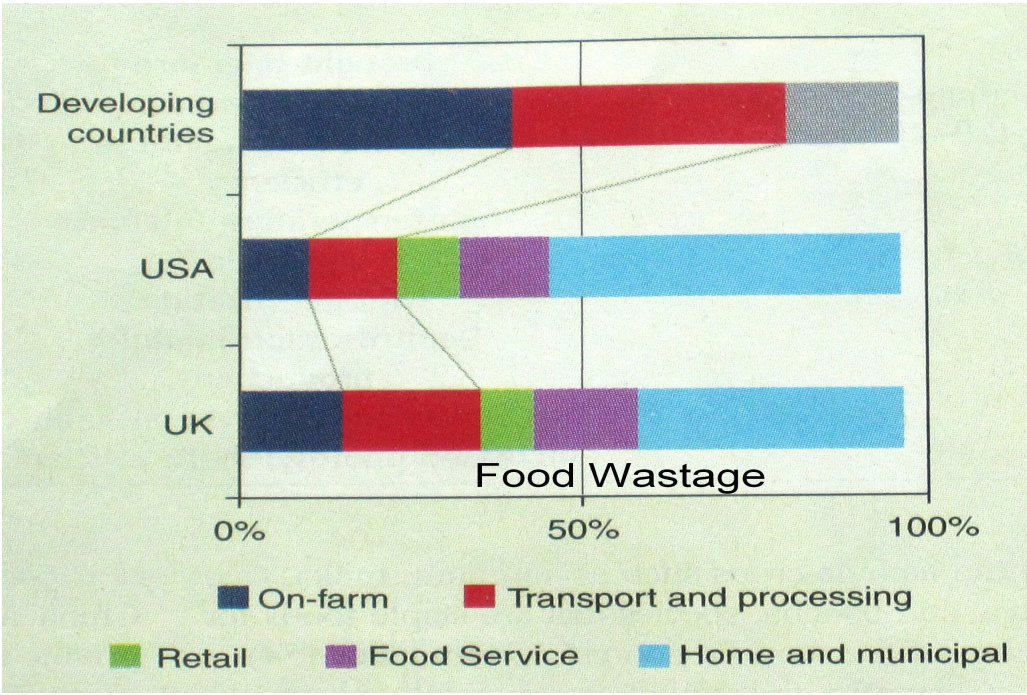
AAAS Science, 12 Feb 2010, p809.

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.

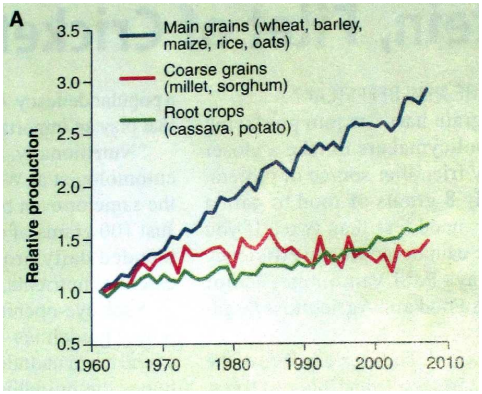
Food wastage even contributes to energy loss, because it's now so high…

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

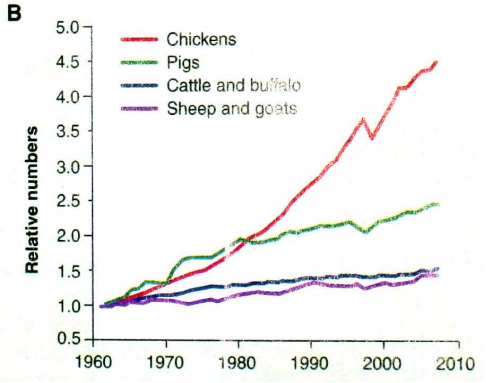


Home Energy Keys (Food History)

Vegetables

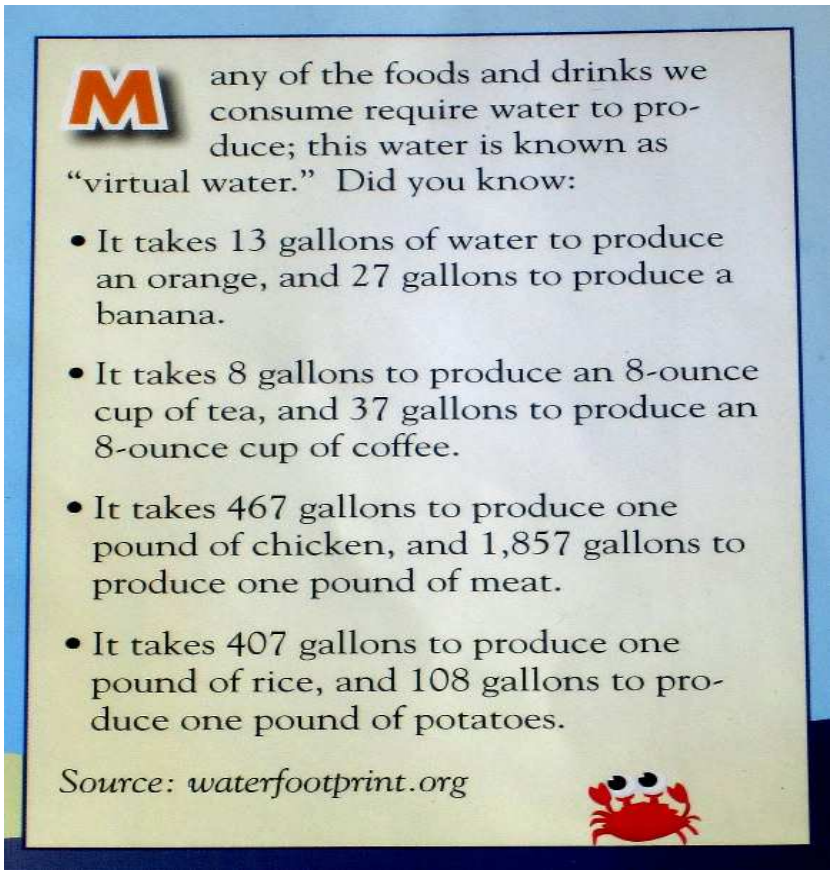


Meats



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

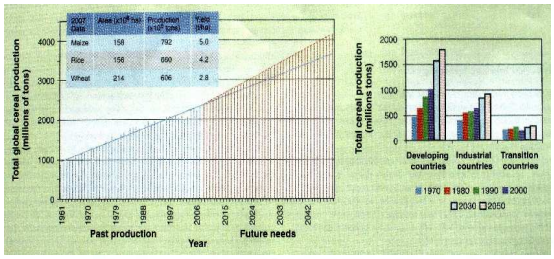
As population increases to 9 billion in 2050, **new, arable land as large as all Brazil** will have to be found & cultivated. Then, there's **fresh water**…



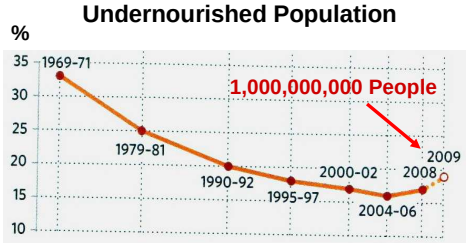
It takes ~100 times more water to produce 1 gal of 'biofuel' as to produce 1 gal of diesel.

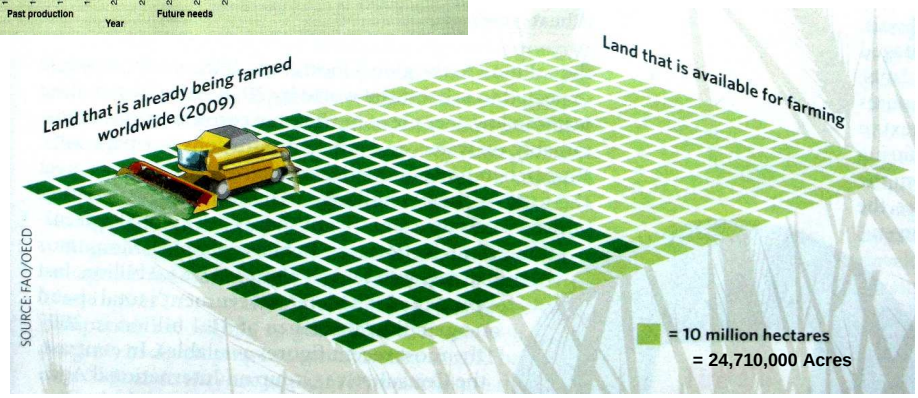
Food Production Limits

Cereal Need & Production

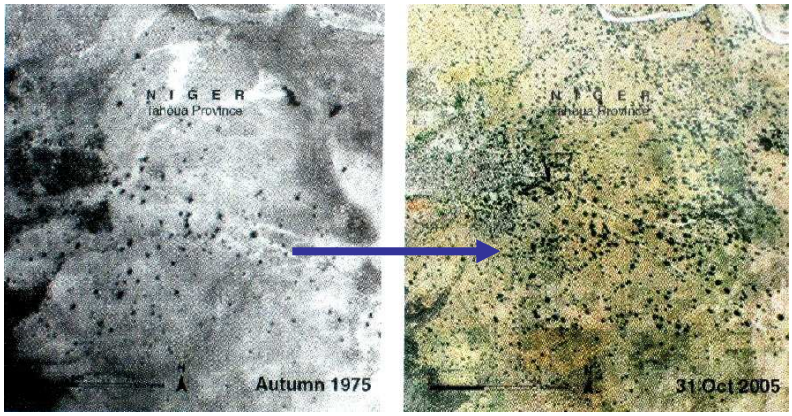


Undernourished Population



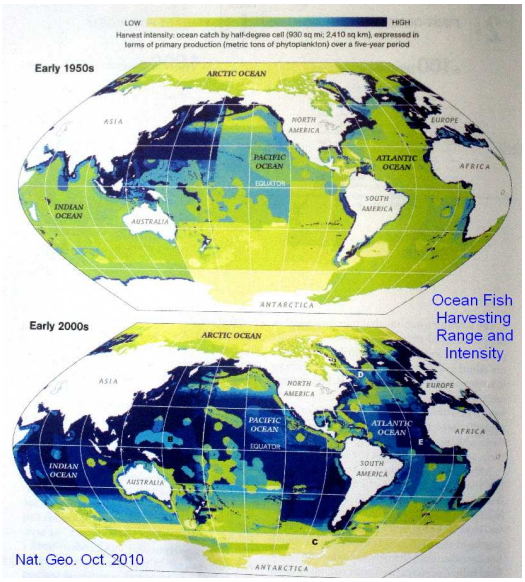


Improved Land/Water Management in Niger



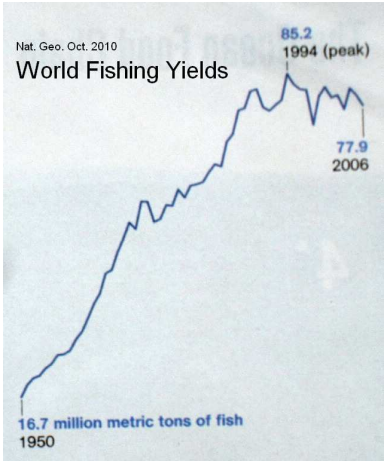
Asian Crops

Food Production Limits

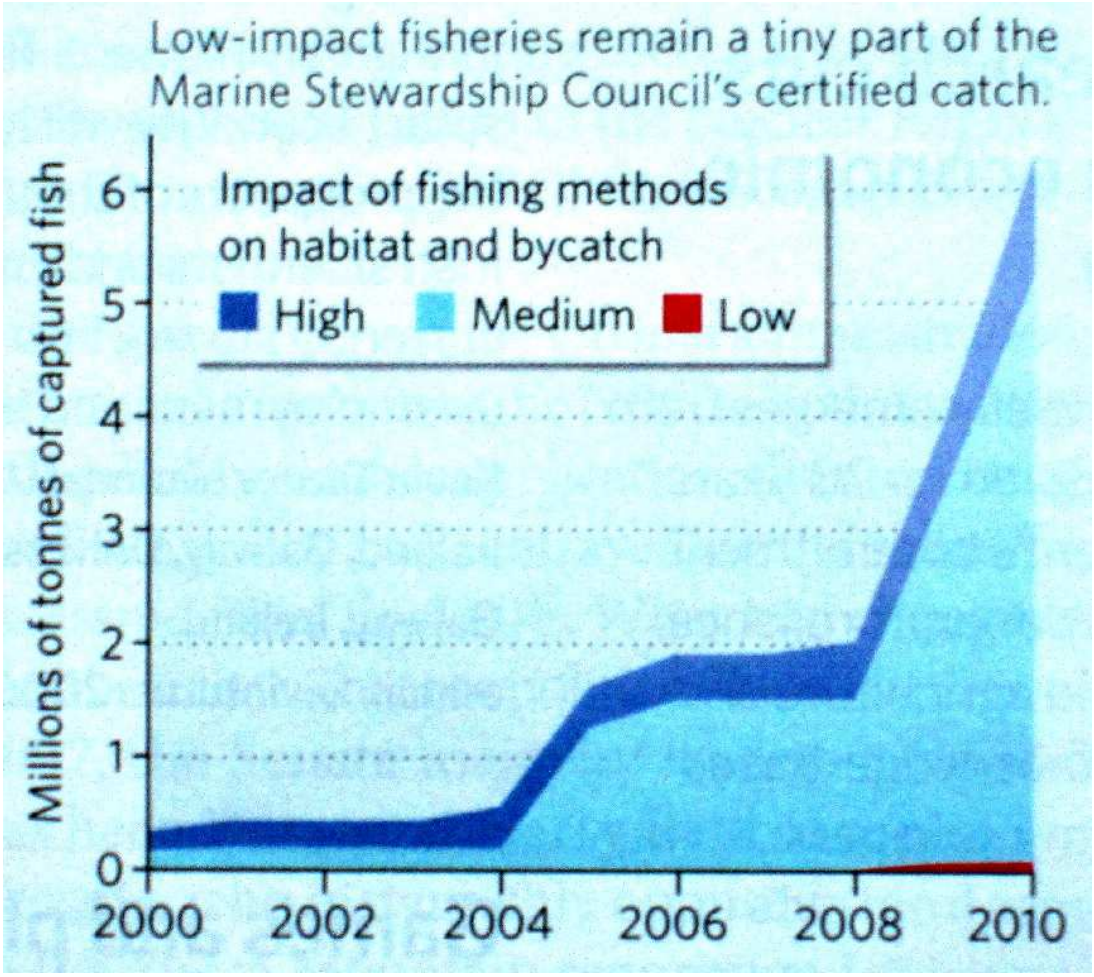


Fishing Areas now Cover the Globe

Fishing Yields Declining from Overexploitation & Acidification



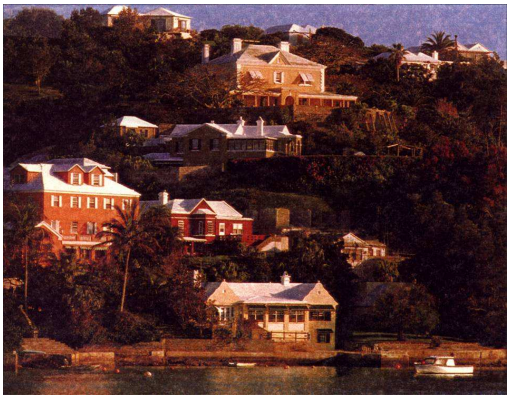
~70% of All Humans' Protein Intake Comes from Sea Life



Architecture & Energy

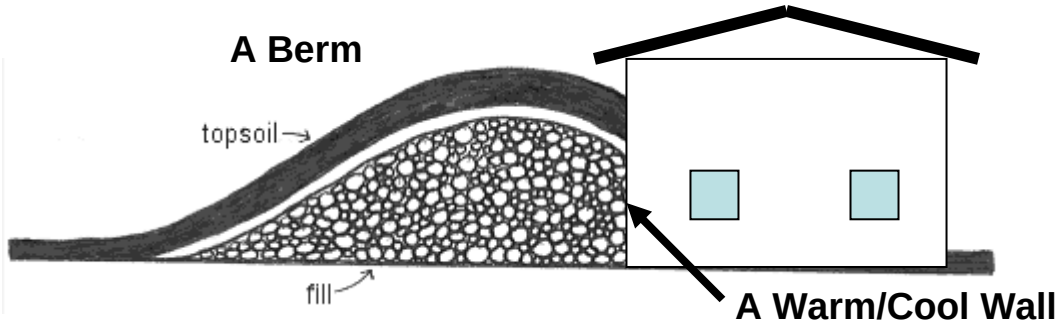
- Using the local environment can save big
  - Structural design, finishing & landscaping
  - Natural energy capture: solar, heat pump

Free Light, Heat & Cooling

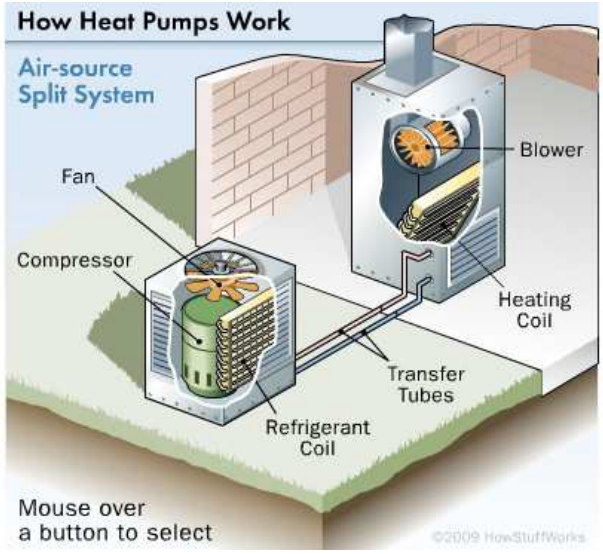


Free Light

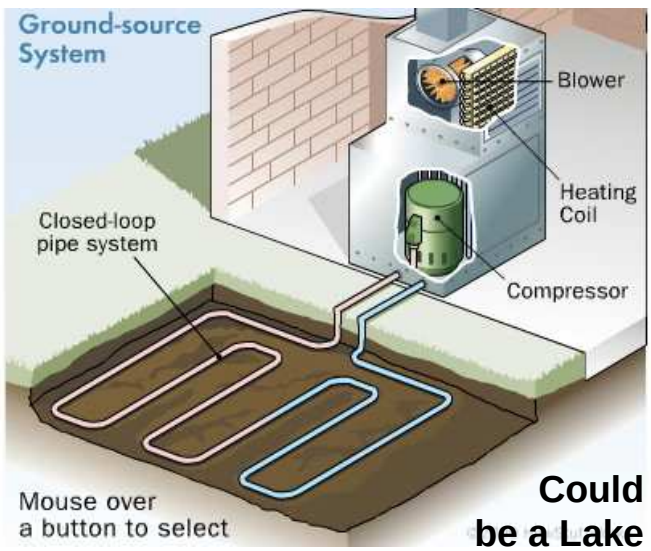
A few feet down, Earth's outer crust is cooler that Summer air & warmer that Winter air – so the ancient ***berm*** & modern ***heat pump*** **(reversable A/C)**…



Air Can Be used in Some Climates

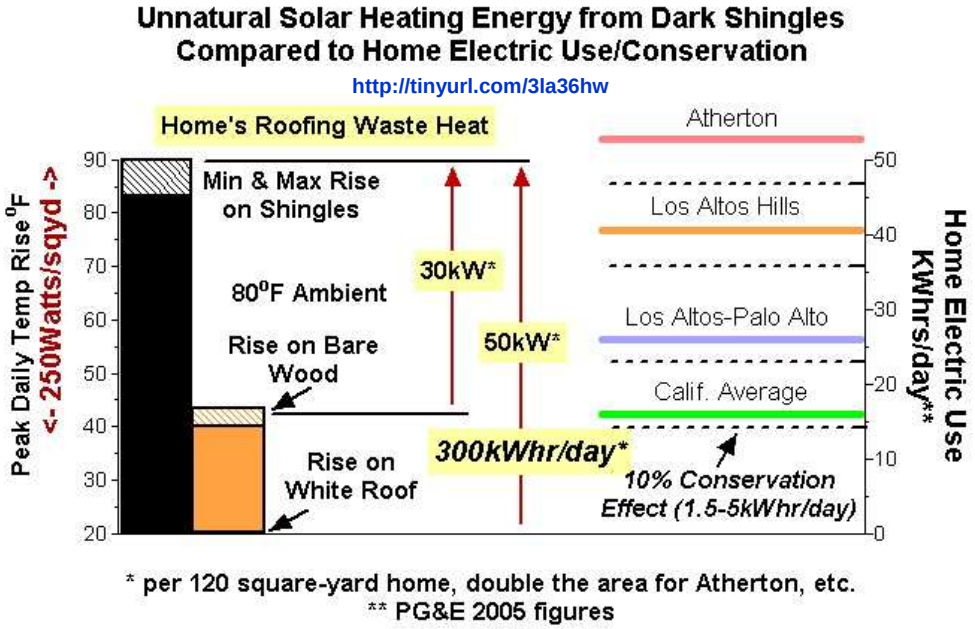


Ground Is Better (45-75°F)



Could be a Lake

Home Energy (Roof vs Utility)



Human structures now cover ~3% of land surface, so the solar energy they absorb & re-radiate as heat (IR) adds more to global warming -- as much as do the CO_2 emissions of all world's vehicles for > a decade. We need to improve roof/paving reflectivity & shading, everywhere…

	Solar Reflectivity Increase	CO_2 Offset by 100 m^2 (~120 sq yards)	CO_2 Offset Globally
White Roof	0.40	10 tons (~2 cars)	
Average Roof	0.25	6.3 tons	**24 Gt**
Cool Pavement	0.15	4 tons	20 Gt
Total Potential	--	–	**44 Gt**

Value of 44 Gt CO_2 at \$25/t ~ \$1 Trillion

100 gallons Gasoline/year => ~1 ton CO_2

Global CO_2 emissions in 2009 ~24Gt

(Akbari, Menon, Rosenfeld. *Climatic Change*, 2008)

The Reflectivity Problem

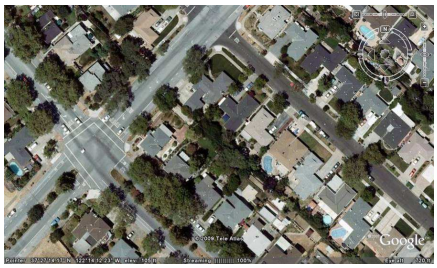
- So much land (~3%) is human structure & alteration:
  - Solar input ~1kW/m^2

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.

Sun-heated surfaces, except white/shaded.

Residential Now:

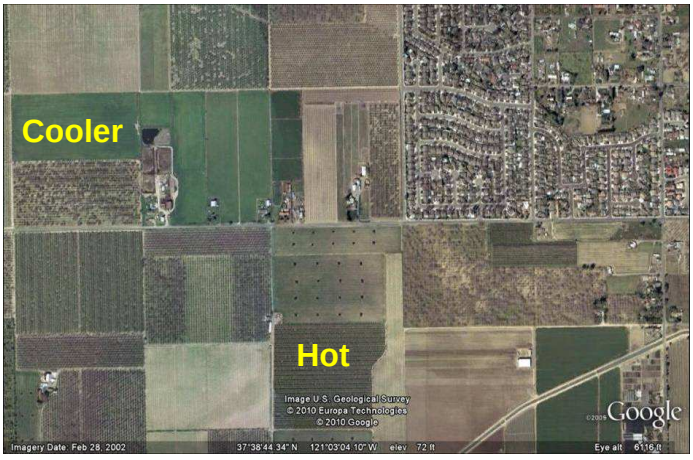


Commercial Now:

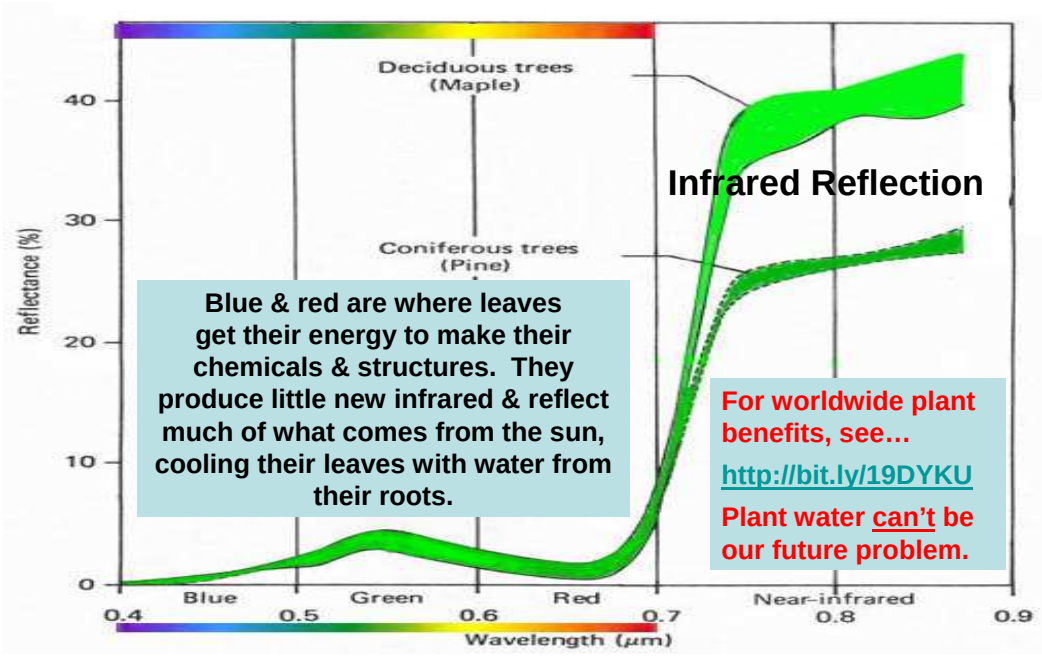
Even farming & gardening methods have large effects.

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

Typical Farming Nets ~50% Solar Heating



Plants Naturally Do the Right Thing



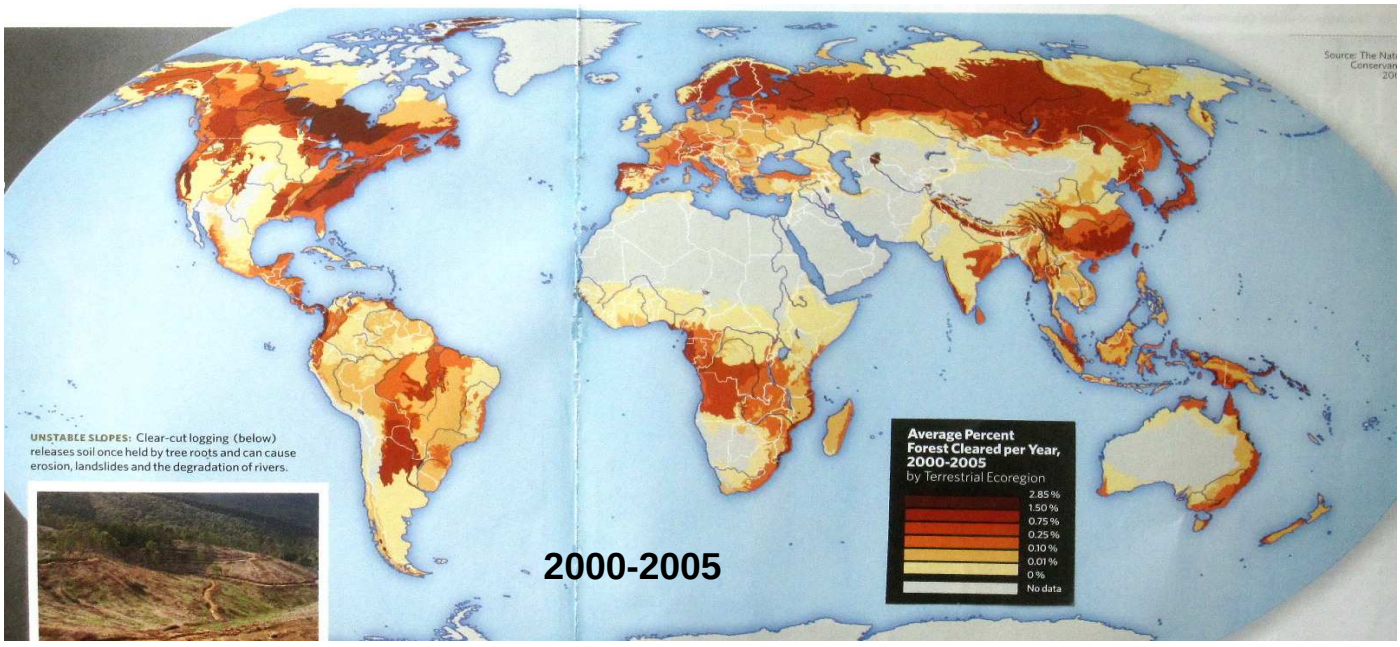
Blue & red are where leaves get their energy to make their chemicals & structures. They produce little new infrared & reflect much of what comes from the sun, cooling their leaves with water from their roots.

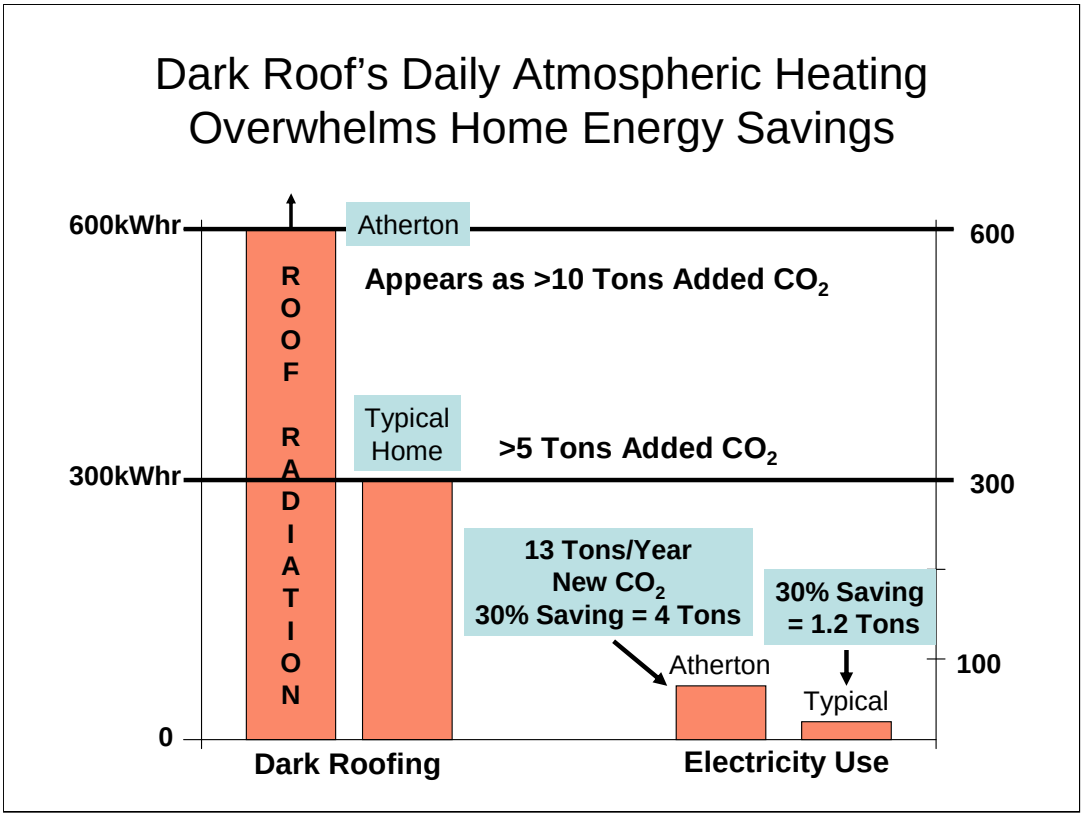
For worldwide plant benefits, see…

http://bit.ly/19DYKU

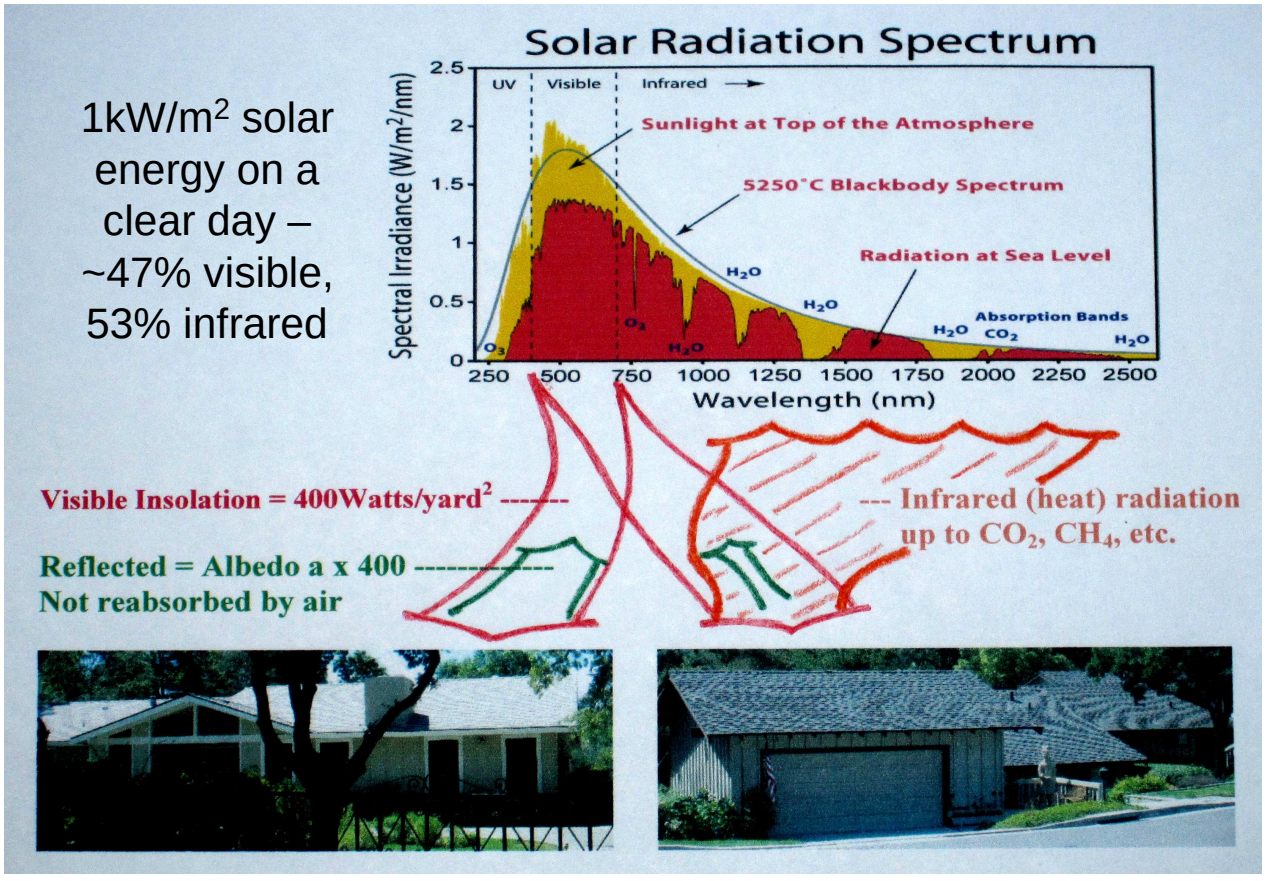
Plant water can't be our future problem.

Deforestation drives Earth's heat balance in the wrong direction…





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.



Large Roof Painted for <$1600

Before

Roof temp in direct sun > 144F

After

Roof temp in direct sun < 94F
Over 60kW air heating saved.

Area: ~ 3000 square feet, in 5 sections. Shingles: composite, mixed ages.
Materials used: 48 gallons of Henry 555 aluminized roof paint (oil based); 2 gallons of standard paint thinner; heavy-bristled, 12" floor brush; 6" paint brush; gloves.

Infrared Thermometer…

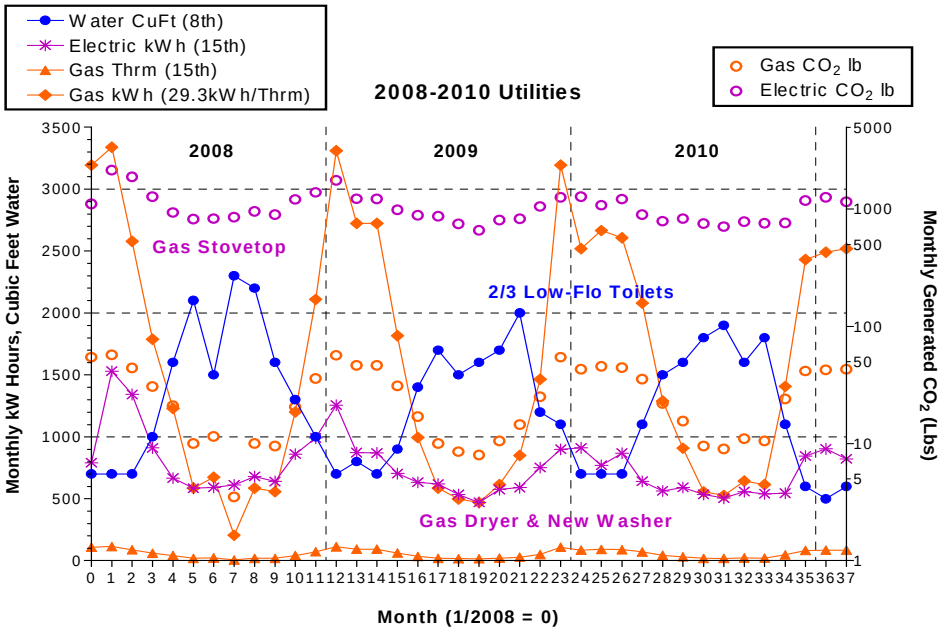
Pros:

Cost is ~1/10 of full shingle replacement.
Shingling life extended many years, even if old,
perhaps for life of house.
Yearly re-roofing savings at least $1000.
Environmental benefit huge -- no re-roofing every 15-30 years:
Shingle manufacturing impact avoided (> 2 tons/home).
Removal & old/new shingle trucking avoided (> 4 tons/home).
Shingle recycling/dumping avoided (> 2 tons/layer/home).
Some summer A/C savings, depending on how poor home ceiling insulation is.
Interior energy savings can be estimated using the ~50oF drop in roof T.
Granulated shingling loses no more granules into gutters, etc.
Global warming reduced by more than interior energy conservation can:
Saving about 300kWhr of atmospheric heating per sunny day per home.
Internal energy consumption/saving of a few kWhrs is peanuts in comparison.
A car is equivalent to 6-10 tons of CO2 per year – roof heating adds at least that.
Increasing home roof's reflectivity 40% is equal to not driving a car for a year+.
Think about that. http://www.energy.ca.gov/commissioners/rosenfeld_docs/index.html
Shading or making roof/paving more reflective, **immediately makes the atmosphere appear to contain less of all GHGs**, not just CO2.

Cons:

Allergies of occupants to oil-based paint while drying for a few days.
Need broom, drop cloths & really scuzzy clothing.
Must clean & recycle cans.
Not tested for wood shingles.

Example of Appliance Effects



The above example is for a 2000ft^2 home housing 5 adults. About 50% is reasonably insulated. Heating is gas/forced-air. No A/C. Electric stovetop & dryer were converted to gas (2008-2009). Monthly CO_2 production is ~½ ton (using EPA's 1.4lb/kWHr), making ~6 tons/year, as does the average Calif. home. The home has 9 skylights, 90% double-pane windows & reflective roofing. A sunroom addition helps winter heating slightly.

4 occupants drive cars the typical amount, so total CO_2 production is ~20 tons vehicular (100 gal gas = 1 ton CO_2) & ~6 tons residential energy.

26 tons/year now, needing reduction to 5 by 2050, suggests lots of work to do, especially in transport.

Glazing can now be chosen to alter its light transmission In 2 ways: auto-chromic & electro-chromic. However, dark windows/skylights absorb energy & externally radiate heat just like a dark roof. Reflective shades are better, both In Summer & Winter. And, deciduous trees are big help too.

Energy Storage

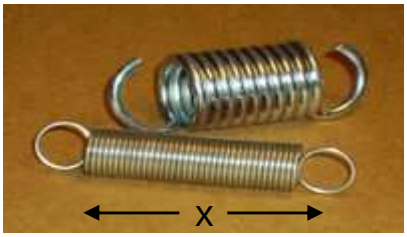
- Any cyclic/diurnal generation needs:
  - Complementary generation
    - Wind & solar often overlap from morning through evening
  - Continuous, minimum generation (base load)
    - Hydro, nuclear fission (fusion in development)
  - Storage, when generation exceeds loads
    - Pumped-storage reservoirs
    - 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: **http://tinyurl.com/ycts2uy**
      - Combined with advanced batteries
    - **www.electricitystorage.org/site/home/**

Examples -- `www.technologyreview.com/biztech/18086/`

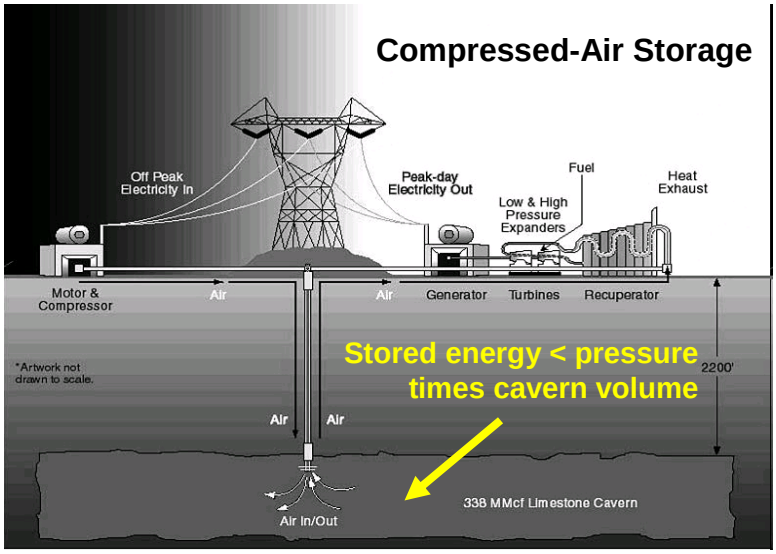
An Ultra Capacitor ($E = \frac{1}{2} CV^2$)

Utility-Scale Battery & Invertor

Springs ($E = \frac{1}{2} kx^2$)…



Compressed-Air Storage



Safe Nuclear Power

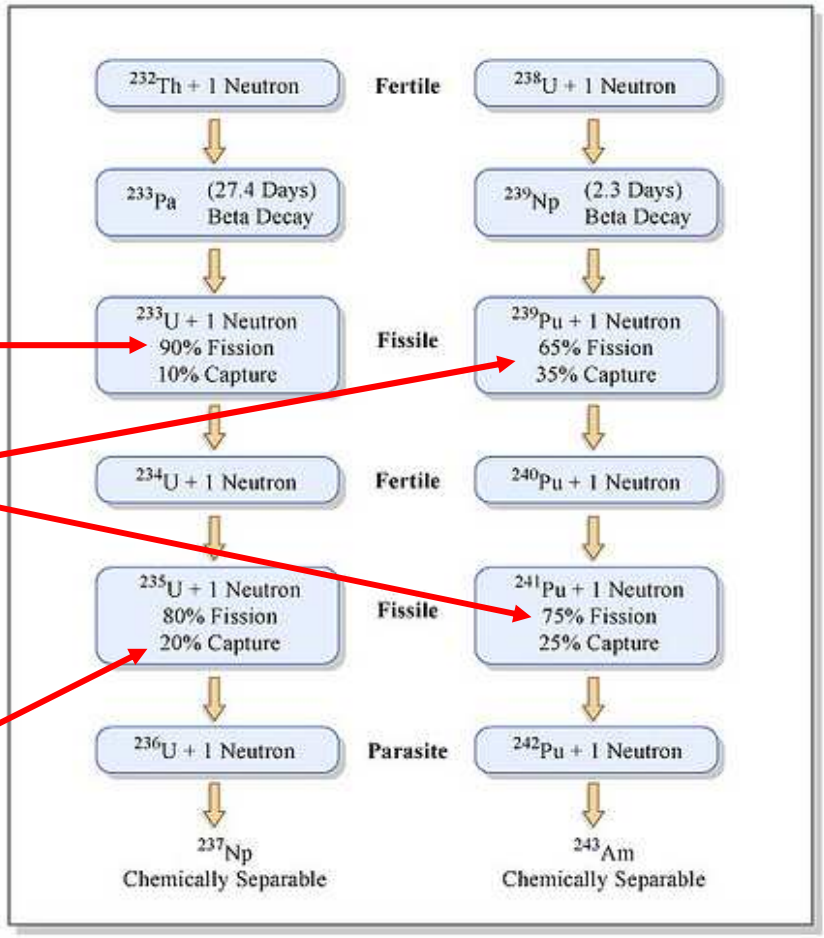
- 20% of US generation, >70% of French (reprocessing)
  - China, India, Japan…
- High energy density, 24-hour source
- Fission is only realistic choice today
  - Fusion's Tritium-breeding efficiency problem – neutron budget
  - Safest choices: no meltdown, no weapons, low waste, low cost
    - Current Uranium cycle in LWR/BWR wasteful & expensive
    - Solid fuel creates fabrication, operation & cleanup problems
    - **Liquid/molten fuel** becomes an easier, safer chemistry problem
- Safest fission begins at the lowest fissile nucleus: U_{233}
  - U_{233} doesn't occur in nature because of ~160k-year half life
  - U_{233} is easily created from $Thorium_{232}$ via slow neutron/proton
  - Thorium & Uranium can be converted to salts
  - Salts are extremely stable in high radiation & temperature
    - **Molten salt** is an ideal power-reactor material: thermal efficiency

Thorium bred to U233 with a neutron (via Protactinium decay), or directly via proton accelerator

Next neutron hitting U233 has a very high probability of causing fission & releasing energy, but U238 bred to Plutonium is much less likely to fission, thus building up higher-mass Pu & waste, all of which has bomb-making potential

Because Thorium starts at mass 232 & fission stops at mass 236, Plutonium is rarely produced (20% of 10% = 2%), but then mostly fissioned

Starting fission with $Thorium_{232}$ vs $Uranium_{238}$



Thorium-U_{233} Based Fission

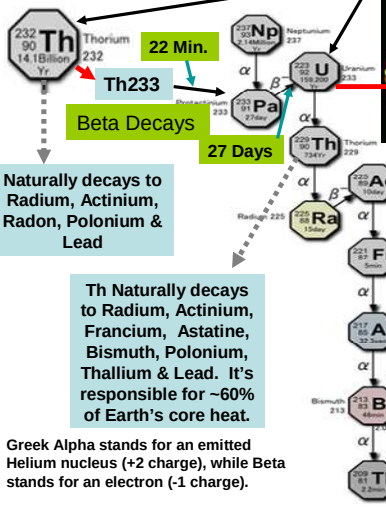
Abundant, Cheap, low radioactivity

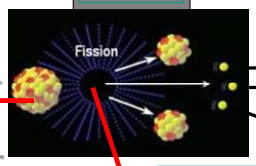
Breeding Th232 to fissionable U233

Slow neutrons

Graphite

Feedback chain





Fast neutrons

Naturally decays to Radium, Actinium, Radon, Polonium & Lead

98% of events

Gamma & particle radiation + nuclear fragments of mass 89 to 156

Alternatively, injected protons can breed Th_{232} directly to U_{233}

Th Naturally decays to Radium, Actinium, Francium, Astatine, Bismuth, Polonium, Thallium & Lead. It's responsible for ~60% of Earth's core heat.

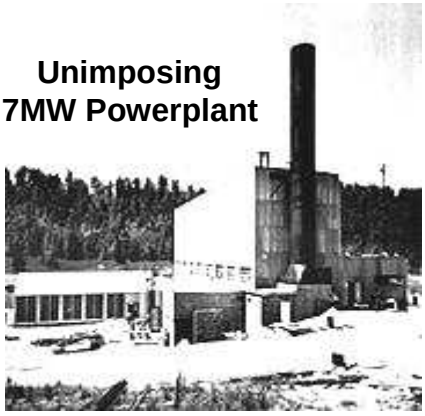
3,200,000kWHrs/lb 4,300,000HpHrs/lb (gasoline, 6kWHrs/lb)

Greek Alpha stands for an emitted Helium nucleus (+2 charge), while Beta stands for an electron (-1 charge).

Bismuth 209 is the heaviest, non-radioactive element

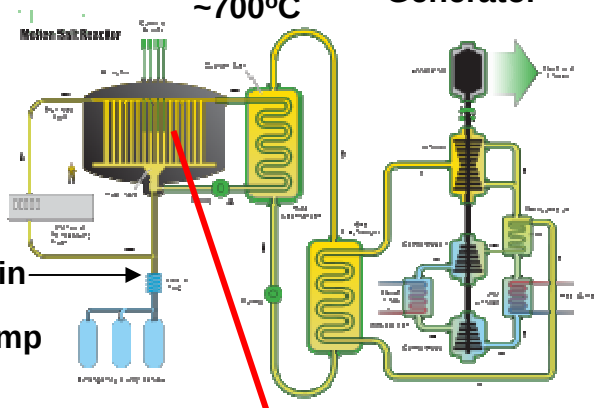
7.4MW Liquid Fluoride, Molten-Salt Reactor (MSRE) at Oak Ridge, TN ~1960, -- **ran for 4 years**…

Unimposing 7MW Powerplant



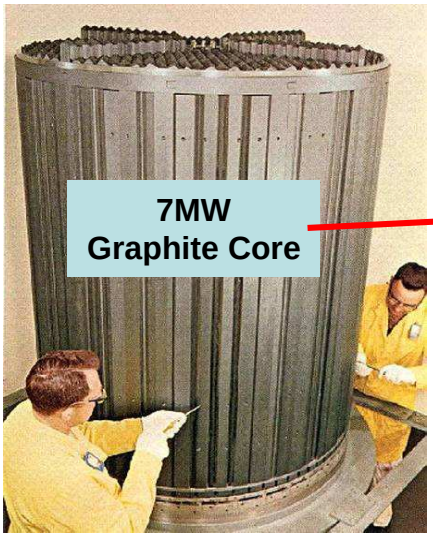
~700ºC

Generator

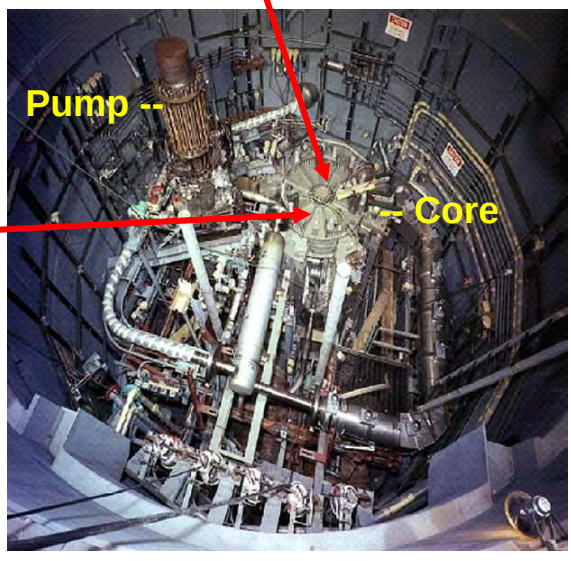


Salt Drain

Sump



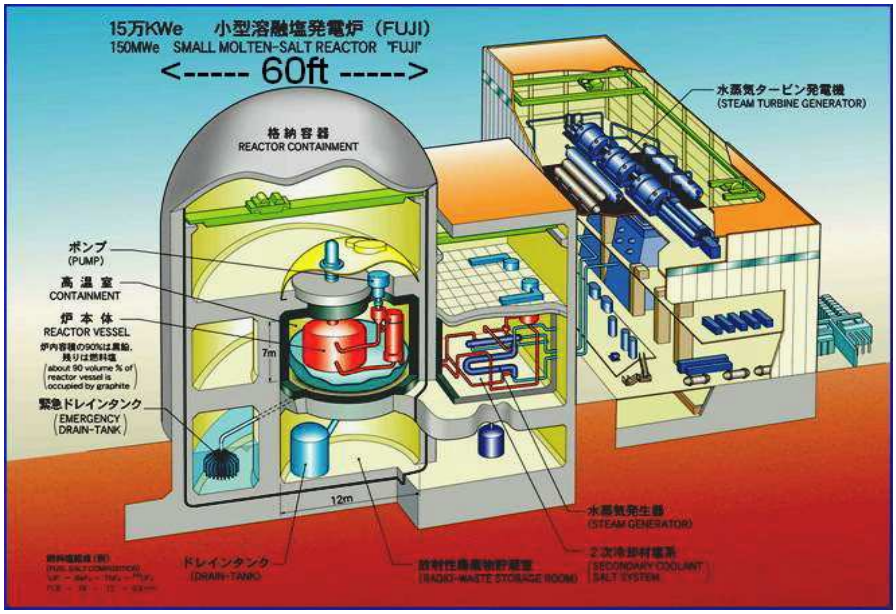
7MW Graphite Core



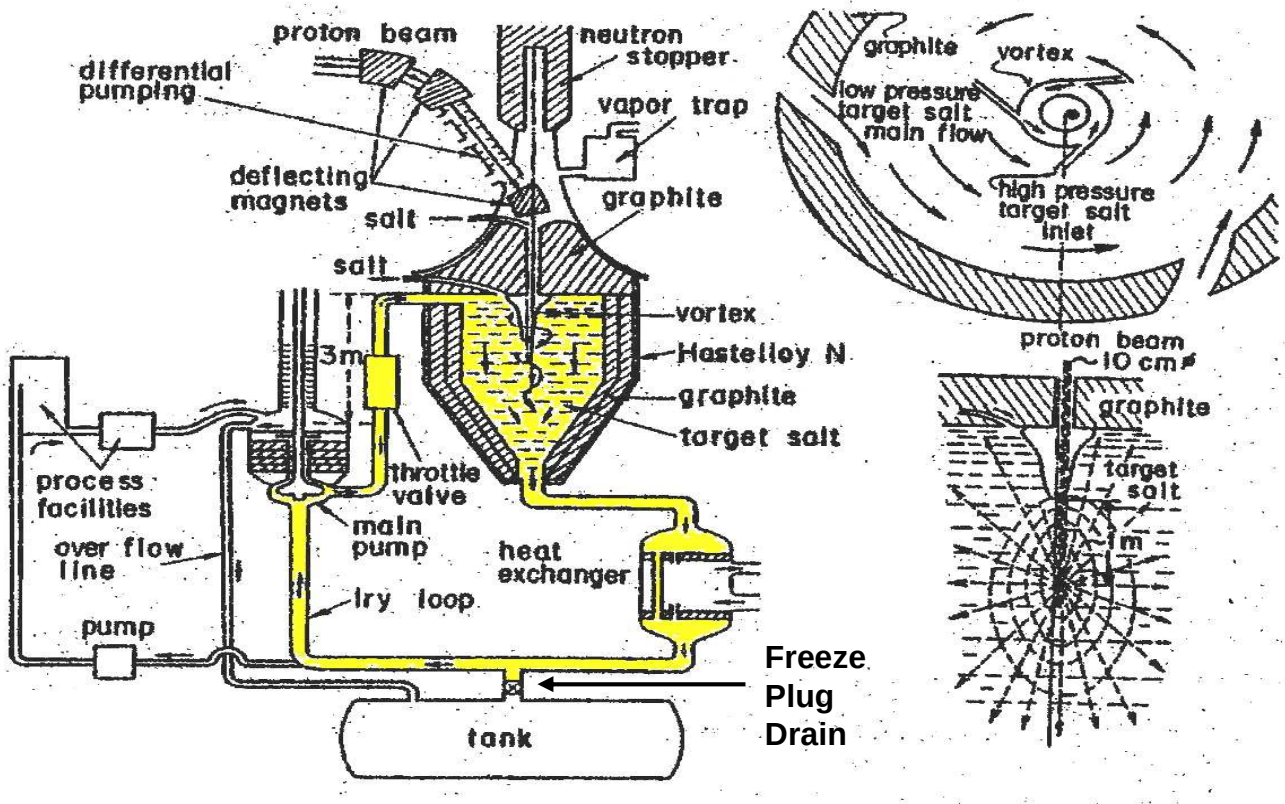
Pump --

-- Core

Japanese Thorium MSR

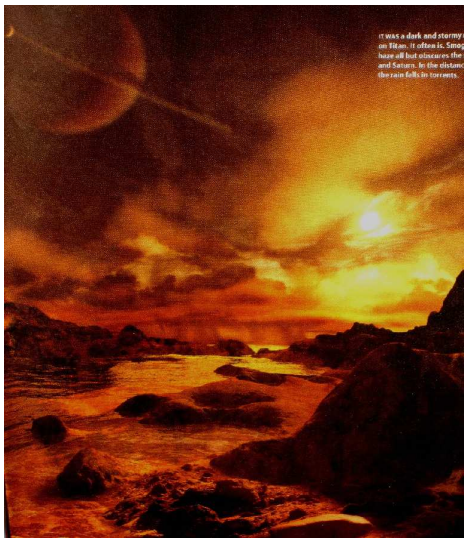


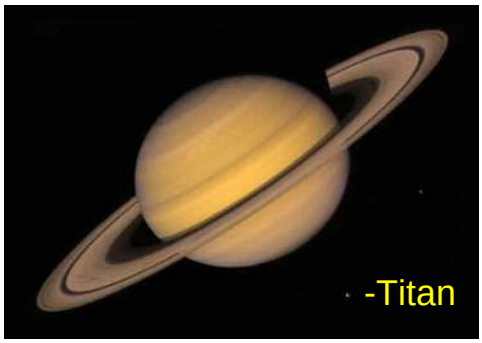
For 30 years total:	FUJI-U3 (1GWe)	Relative to 1GWe BWR
Fissile requirement	7.8 t (reusable)	32%
Pu production	4 kg	0.1%
MA (Np/Am/Cm) production	23 kg	4 %

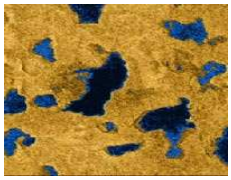


Other Worlds (for Reference)

- Saturn's 3200mi moon ***Titan*** is like Earth, except methane stands in for water and it's 200°C colder…





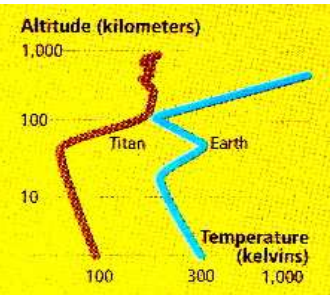


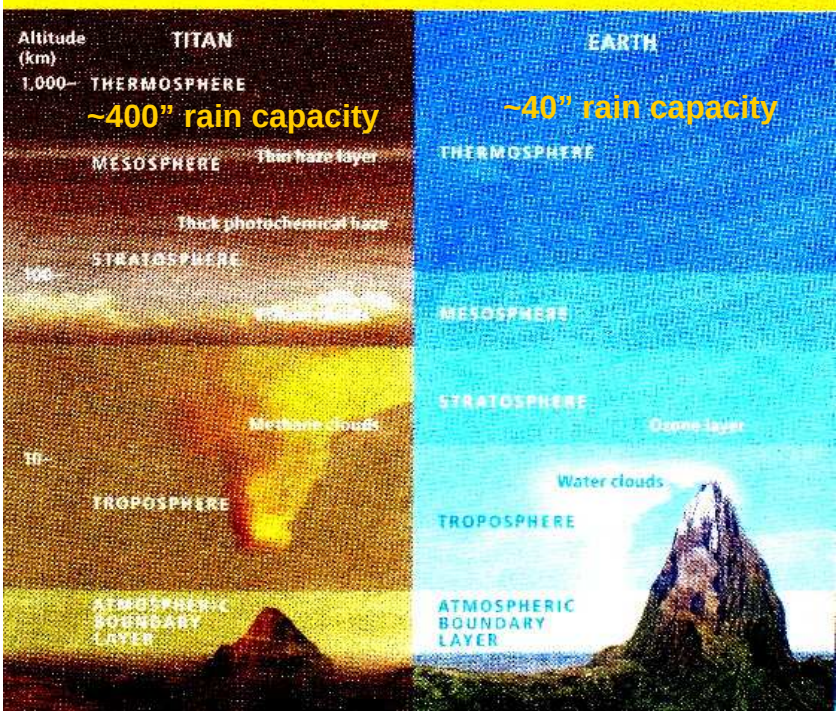
- CH_4 Lakes

Titan Rocks

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

Titan's atmosphere, like Earth's, has a troposphere (a lower, dynamic layer where weather takes place) and a stratosphere (a stable layer heated by solar ultraviolet radiation). These and other layers are defined by the change of temperature with height (*right*). Titan's atmosphere is more than 200 degrees colder and, because of the satellite's weaker gravity, vertically stretched. Multiple layers of haze, consisting of hydrocarbon particulates akin to smog, play the same role as Earth's ozone layer.



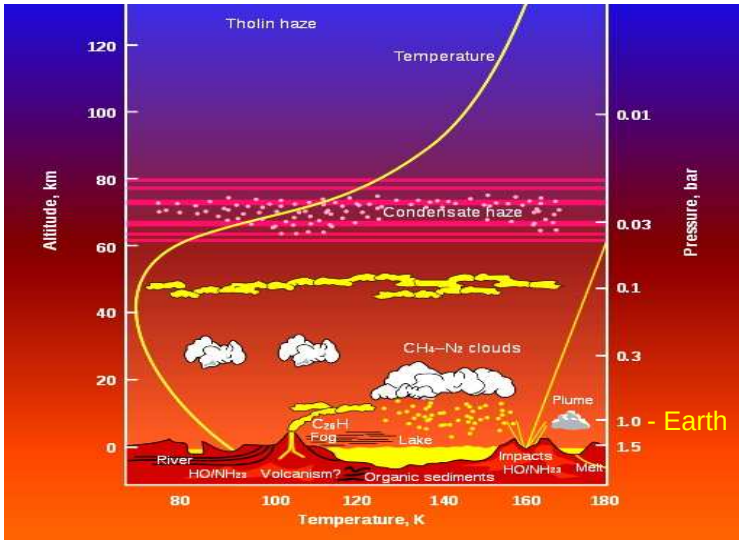


Other Worlds (for Reference)

- ***Titan*** is 9x farther from our Sun, so gets **1/81 our solar energy**: ~17W/m^2, but it still can have Sun-driven weather…

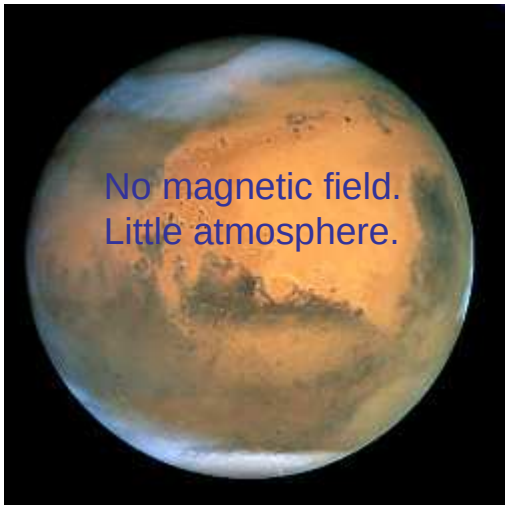
Titan's atmosphere can hold ~400" of Methane/Ethane before raining, but weak sun can only evaporate ~1/2" of the liquids per year. Rains are very, very infrequent, but more than huge.

Earth's air can only hold ~1" of water, but sun raises ~40" per year. Rains are frequent & moderate.

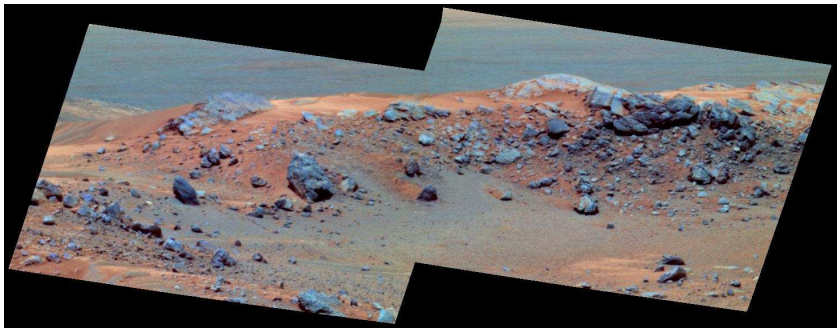


Mars:

CO_2 & H_2O Icecaps



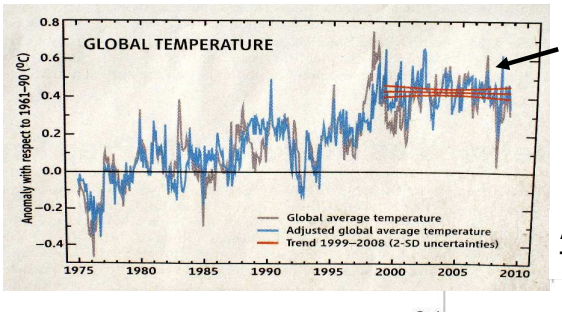
6800 mi



220-320K 1 Bar

186-268K .01 Bar

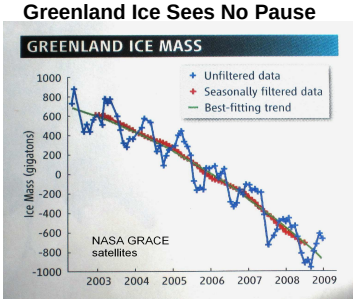
Our Climate Realities & Myths

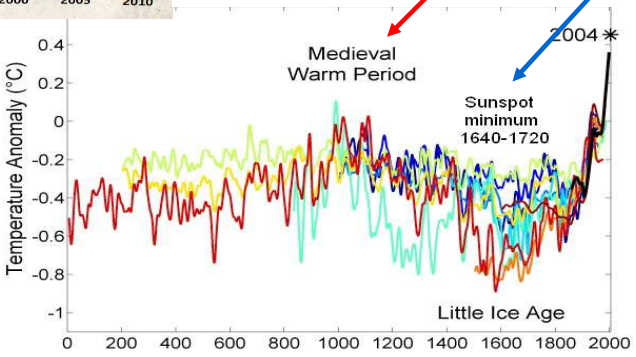


The Current Warming 'Pause' Means We Can Relax?

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

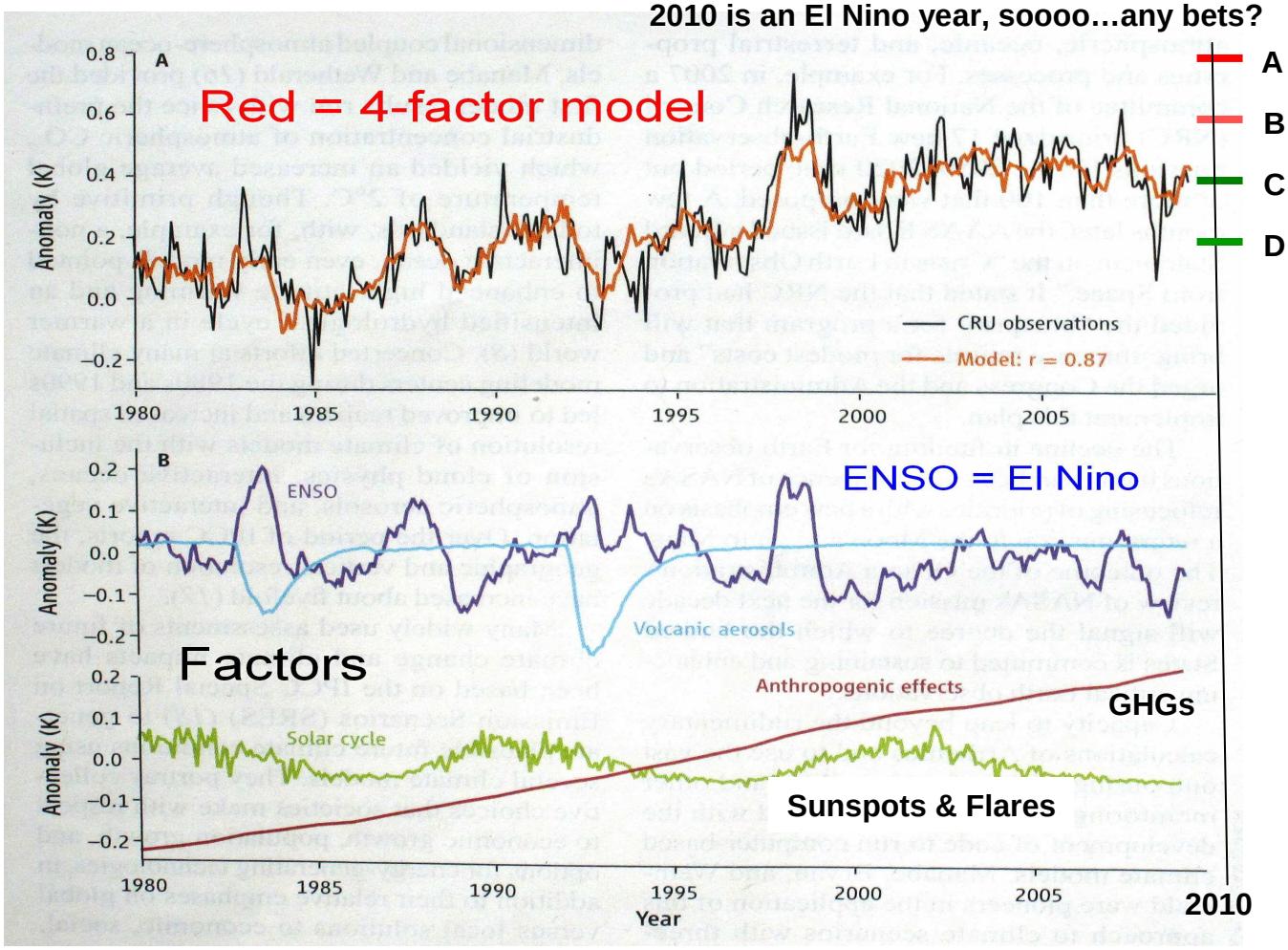
Greenland Ice Sees No Pause



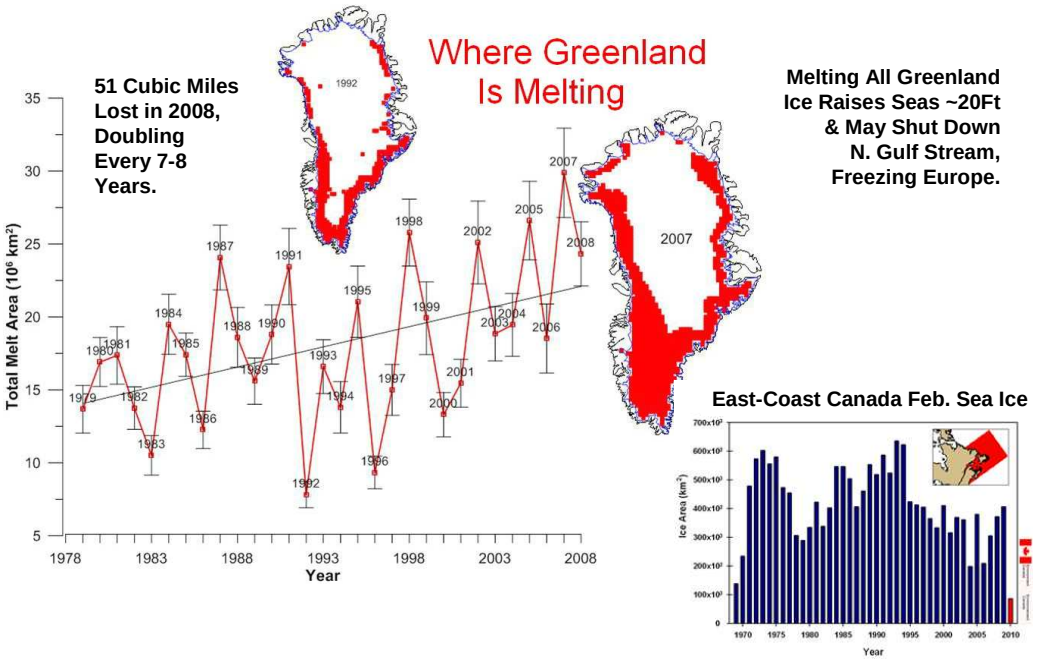


If we include just 4 climate components (El Nino, Volcanism, Sun activity & GHG increase) we have a remarkable result…

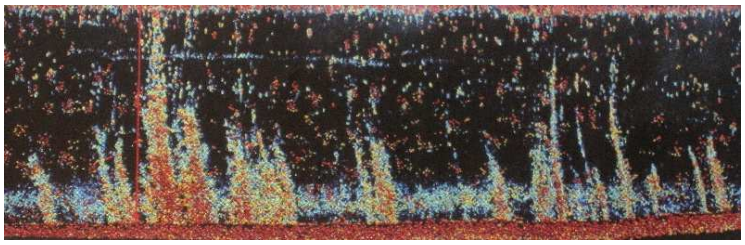
2010 is an El Nino year, soooo…any bets?



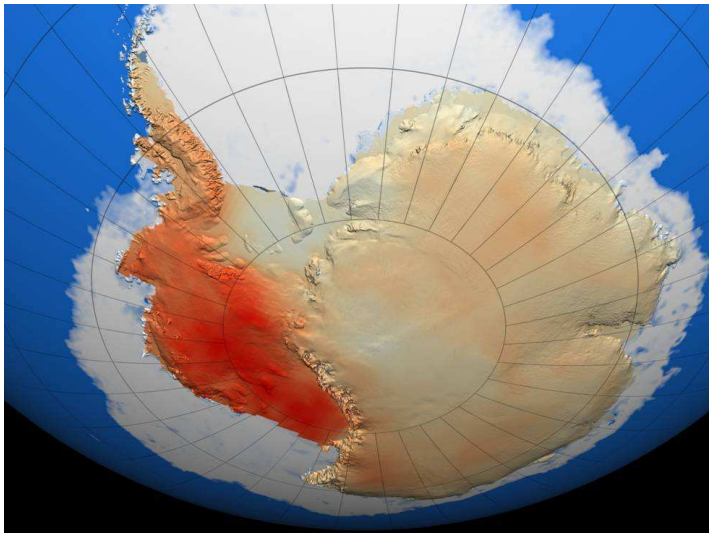
Our Climate Realities & Myths



Arctic Seabed Methane Rising

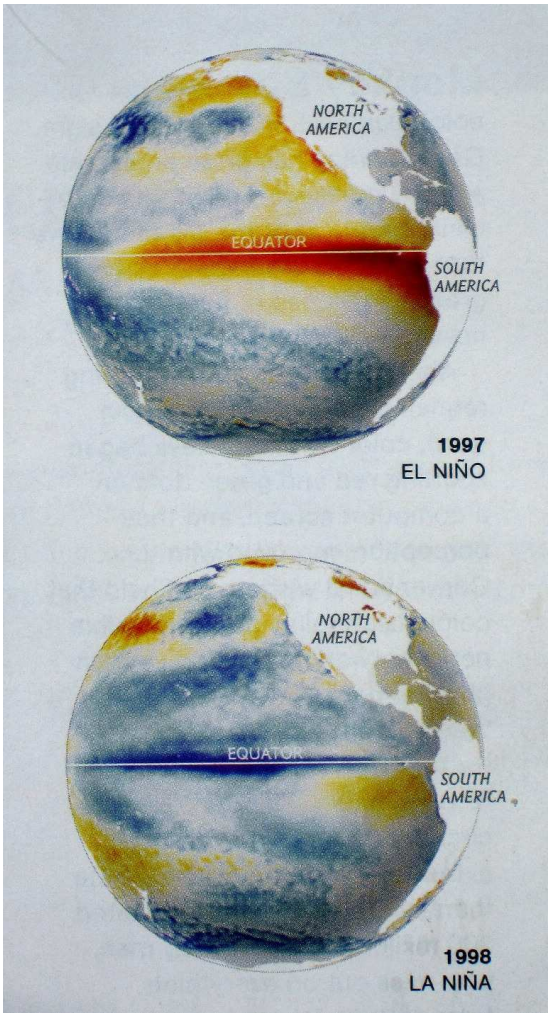


Where Antarctica is Warming



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

2010 El Nino = Storms + Heat



17 April 1970

Our 2050 Picture?...

Do's & Don'ts

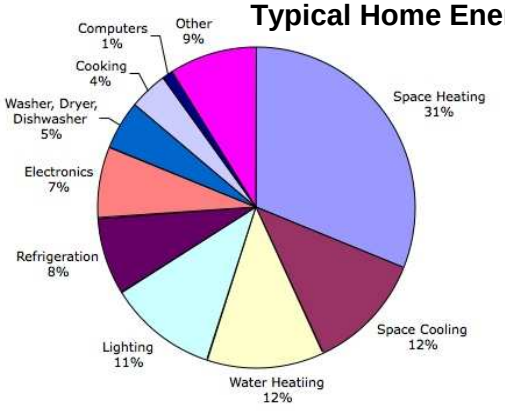
Do

Insulate home walls, floors & ceilings
Use insulating skylights & windows
Insulate 1-pane windows with curtains
Consider installing a heat pump
Drive efficiently, walk or ride bike/train/bus
Paint a roof or change to whiter gravel
Plant shade trees
Use gas heating/cooking or microwave
Buy a wattmeter & check your gizmos
Turn off/unplug all items when unused
Turn off furnace pilot light in summer
Use condensation-recovery gas heaters
Do your own garden/lawn maintenance
Collect rainwater & consider greywater
Recycle everything from cans to debris
Use items made of recycled materials
Use consumer-test appliance ratings
Take a local college course on energy
Write representatives about energy issues
Adlib: _____

Don't

Drive unnecessarily
Use car A/C or stay in D at stops
Put on a new dark roof or gravel
Cut down shade trees, even for solar
Remove lawns/trees for 'dry' gardens
Use artificial grass
Use a leaf blower or gas lawnmower
Use plastic-bottled water
Use electric heat/dryer/range
Leave gizmos' power blocks plugged in
Trust computer 'sleep' mode – turn it off
Put anything recyclable in the garbage
Trust Energy-Star[tm] appliance ratings
Be fooled by energy fads
Adlib: _____

Typical Home Energy Use



Heat Pump: