Nuclear Power is an Essential Tool to Mitigate Climate Change

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Why I'm Concerned

Futurist orientation

-What we do now will create a **future that is heaven or hell for our descendents**.

-We have a small window in time to lock in a sustainable future in which most of the things that our ancestors prayed to God for are nearly in our own grasp.

-Our society revels in living only for the moment – "Hell, believe in life after death, no one believes in life after the next quarter" (friend at a dinner party).

-Iroquois councils: "Let us make a decision that is good not just for today or tomorrow or just this generation and the next but is **good for seven generations hence**"

-Authored ***Our Improbable Universe*** to encourage preservation of this incredible reality that took 14 billion years to evolve out of the Big Bang (see **ImprobableUniverse.com).**

-Want a world that works well for our children and that can evolve happily into an unlimited future (i.e. descendents thriving many billions of years from now).

Want justice for:

-Our descendents & our ancestors (we owe them; everything they prayed for we have)

-For the impoverished **human victims** of climate change (Bangladesh, sub-Sahara etc.)

-For **other species** that are now **facing extinction because our mindlessly behavior.**

Human induced climate change is now scientific fact

- **Not one out of 926** peer review articles surveyed by Science in 2005 disagreed with the U.N. IPCC conclusion that **it is happening and we are causing most of it.**
- ***Climate Change,*** W. Collins etal., Scientific American, p64, August 2007.
  - IPCC now assigns >90% probability to its consensus (low balled) conclusions
  - There will be more change but its magnitude is in our hands
  - We now have almost 50% more CO_2 than before the industrial revolution
  - **Eleven of the last 12 years are the warmest on record**
  - The last 50 years has been the **warmest half century in 1300 years**
  - 1906-2005 trend is +1.33 degrees F (+/- 0.31 or 4.5 standard deviation)
  - Onlt 30% of the arctic has sea ice right now.
  - Sea level is up 1" in the last decade (**+20ft if Greenland melts**)
  - Warmest 12 months on record (since 1892) in US.
- Consequences are now measurable. The future will hold:
  - Almost everywhere animals and farming will be **mis-matched to the climate**
  - More **extreme weather** (tornados,hurricanes, heat waves, drought, floods, etc)
  - Economic stress induced **wars** (e.g. even the Pentagon is concerned)
  - **Catastrophic tipping points** with incalculable consequences may be passed
  - **??**

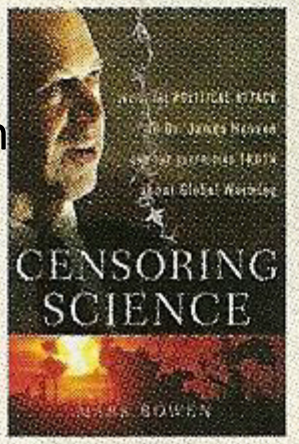
Censorship Abounds!!

- We have the Golden Rule. Those with the gold make the rule. It costs a 2 billion dollars to run an election now.
- Fossil fuel interests pay “experts” to create the impression of scientific controversy. Their lack of qualifications in climatology goes unnoticed by media.
- National Geographic ran the first major media story on climate change 6 years ago (very good). Others have since followed. What took so long?
- Environmental ads are frequently refused by TV carriers because of the fear that other sponsors will take offense.
- Philip Mote (IPCC Nobel laurite) was scrubbed from a presentation at a high school in Montana (NY Times, 1/15/08).
- *Age of Warming*, CBS, 7pm, 1/20/08.

CENSORING SCIENCE: Inside the Political Attack on Dr. James Hansen and the Truth of Global Warming

MARK BOWEN

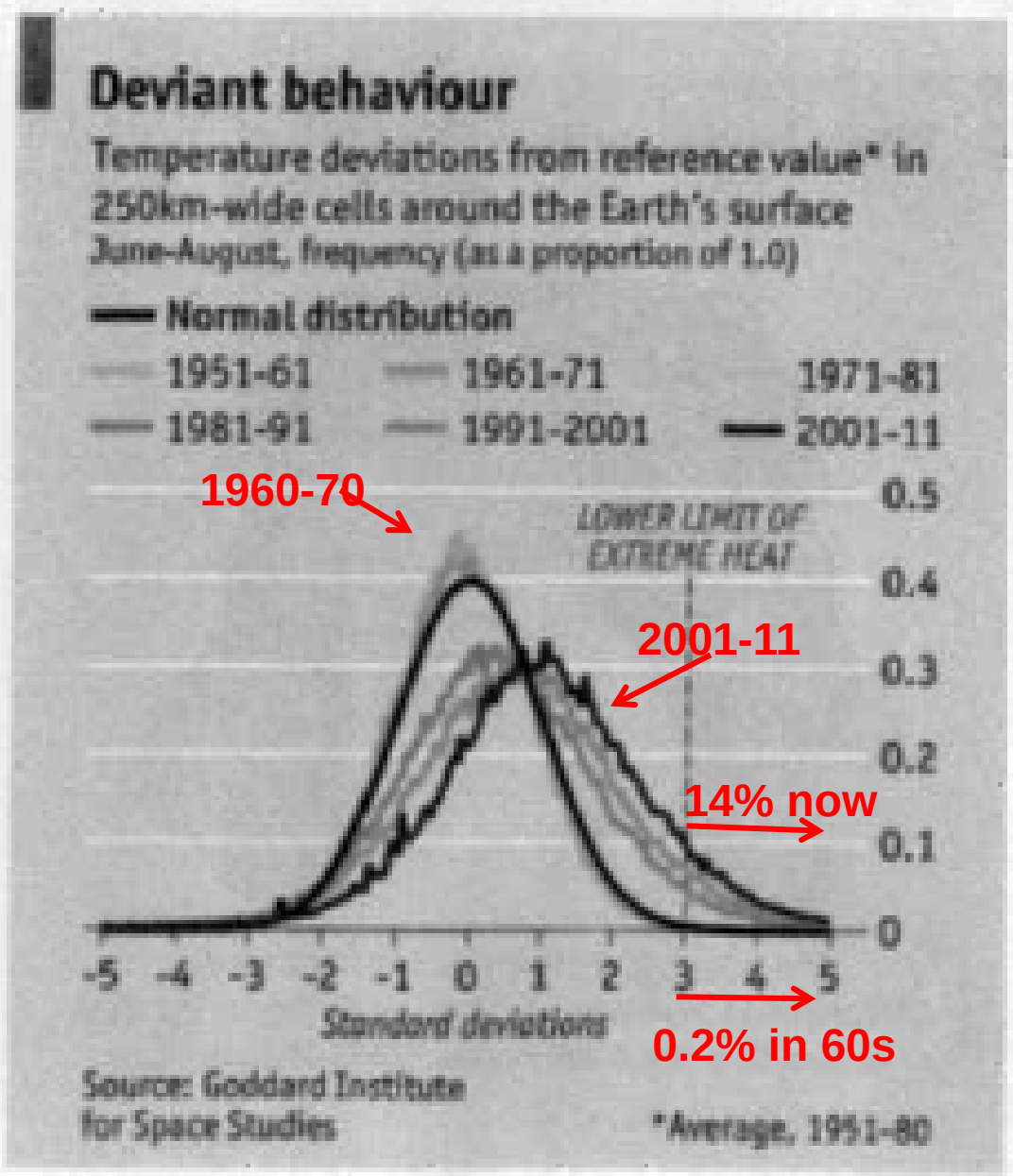
Reports of U.S. presidential administrations' successful attempts to discredit and censor scientific evidence about global warming over the past 3 decades have come to light since 2005. James Hansen, director of NASA's Goddard Institute for Space Studies and professor of earth sciences at Columbia University, testified to the Senate in 1988 that global warming required immediate attention. In the years that followed he was repeatedly silenced by government agencies.



Hansen's complete story is now told by writer and physicist Bowen, author of *Thin Ice*. The tale covers the science behind climate change, how to mitigate its effect, and the struggle that Hansen faced to get public attention. The book quotes an e-mail sent to Hansen from a NASA administrator that advised: "One way to avoid bad news: stop the measurements!" ***Dutton, 2008, 324 p., hardcover, $25.95.***

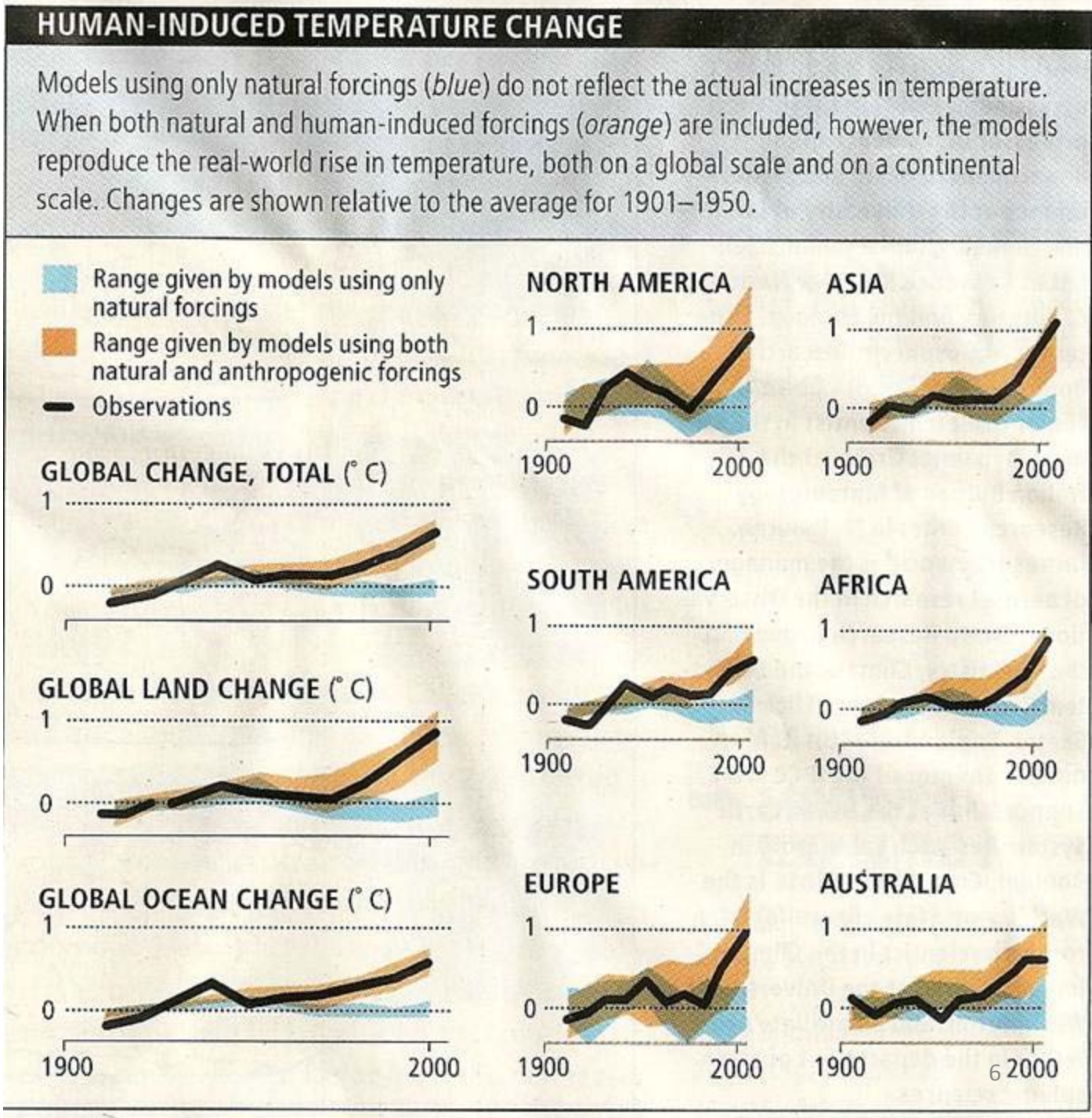
Hansen's latest analysis shows "Extreme Heat Waves" increased from 0.2% of land area (1960-70) to 14% (2000-2011)

- Extreme Heat Wave is defined as being the 0.2% of the hottest of what happened in 1960-1970 (i.e. at and beyond 3 standard deviations from the Norm curve)
- Only the first 4 months of 8/11 to 8/12 (the hottest 12 months on record) is not included here.
- The extreme heat of the present is a harbinger of what's coming.
- What was 3 sigma is now nearly 1 sigma



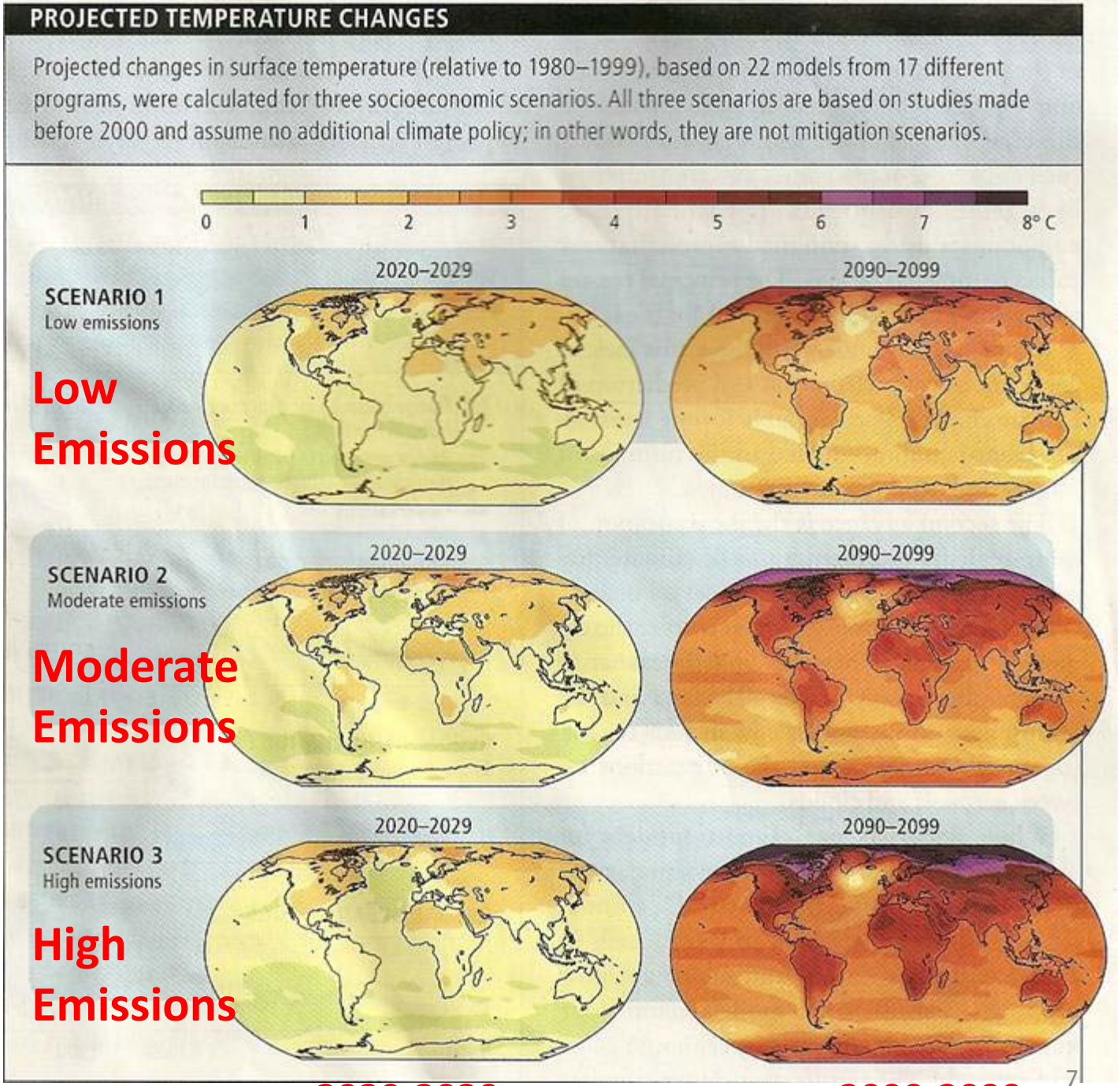
Models without human activity included (blue) cannot explain the across the board temperature increase since 1900.

We are responsible!!



Future projection scenarios if no action is taken

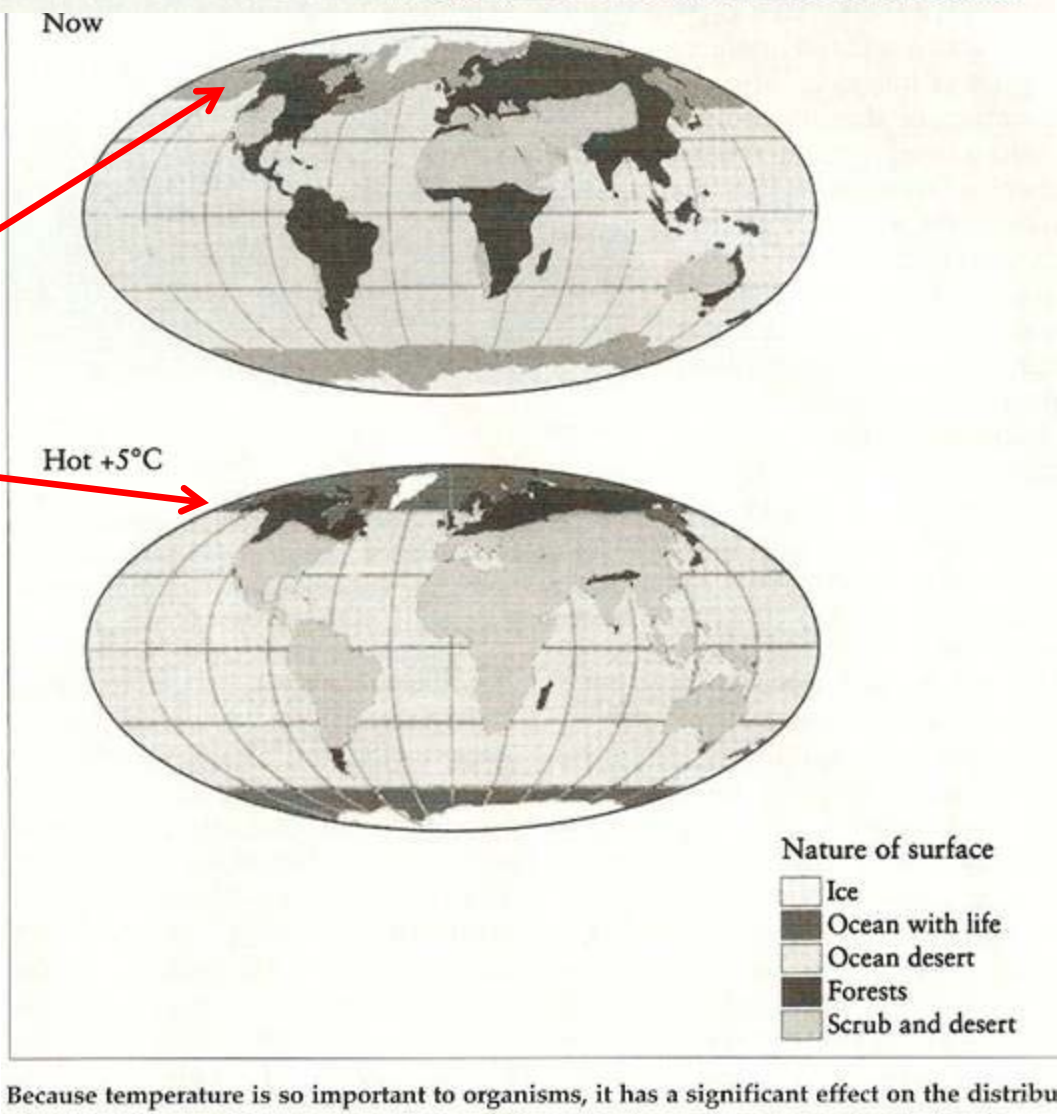
- **Low Emissions**
- **Moderate Emissions**
- **High Emissions**



2020-2030 **2090-2099**

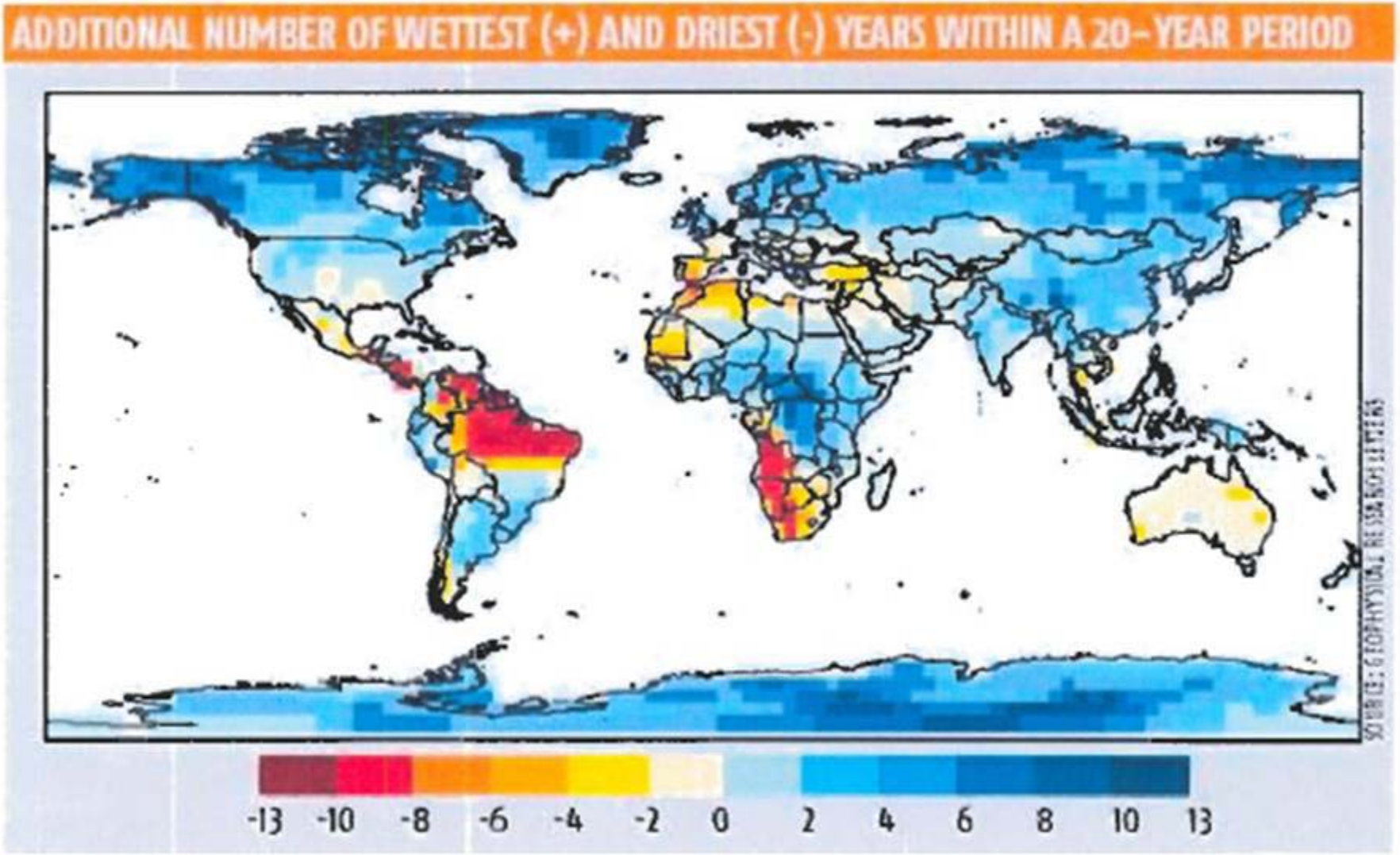
THE REVENGE OF GAIA: Earth's Climate Crisis and the Fate of Humanity. James Lovelock. Foreword by Sir Crispin Tickell. xiii + 177 pp. Basic Books, 2006. $25.

Forests (dark regions) will exist only in a small regions at high latitudes 100 years from now for moderate emission scenarios

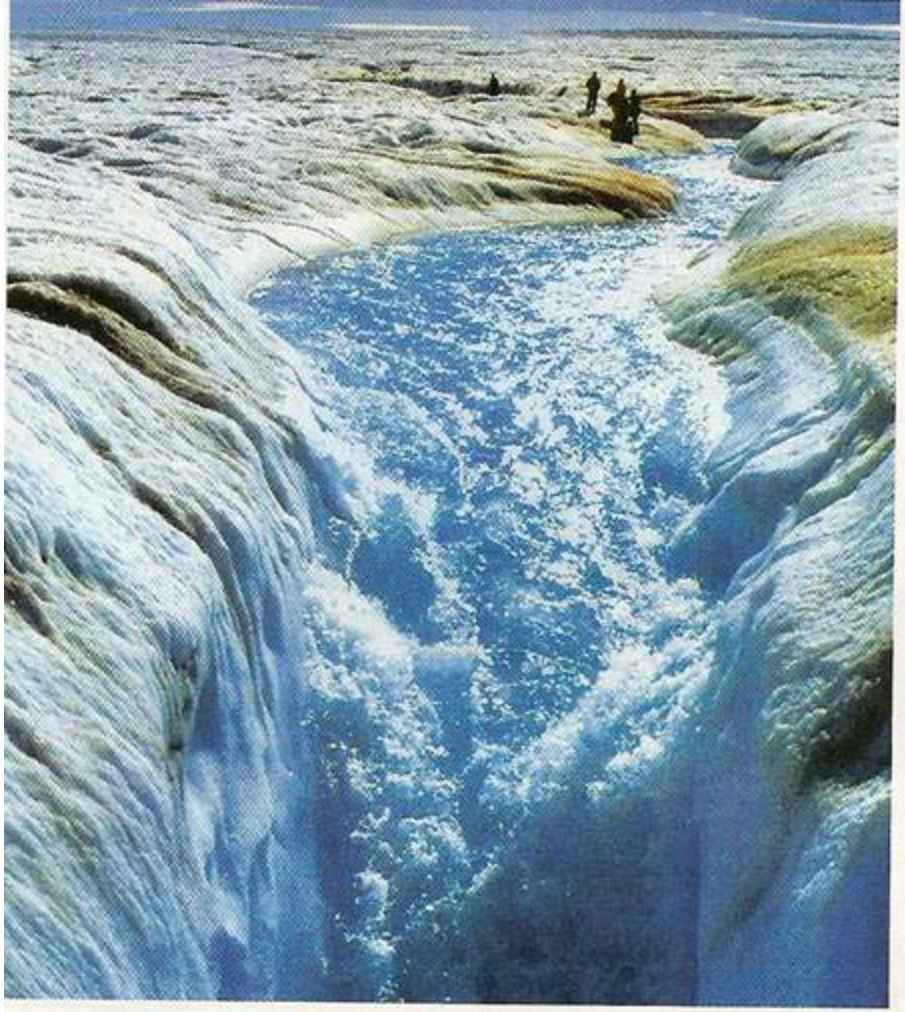


Because temperature is so important to organisms, it has a significant effect on the distribu tion of life on Earth. These three sketch maps were drawn to compare the distributions o plant and ocean algal life on the world as it is now *(middle)*, on a world cooler by five degree Celsius *(top)* and on a world five degrees hotter than now *(bottom)*, as our world may be b the end of this century. From *The Revenge of Gaia*.

Rain Projection for 2100



Greenland's glaciers are melting at an accelerating rate and the lubrication at their base is speeding their flow to the sea



Greenland's melting glaciers are shown here releasing torrents of water. Partly as a result of this melting, sea levels have risen a few centimeters each year for the past decade. According to James Lovelock, if we reach a tipping point at which irreversible change sets in, Earth could become hot enough to melt most of the Greenland ice and some of the West Antarctica ice, adding enough water to raise sea levels by 14 meters. From *The Revenge of Gaia*.

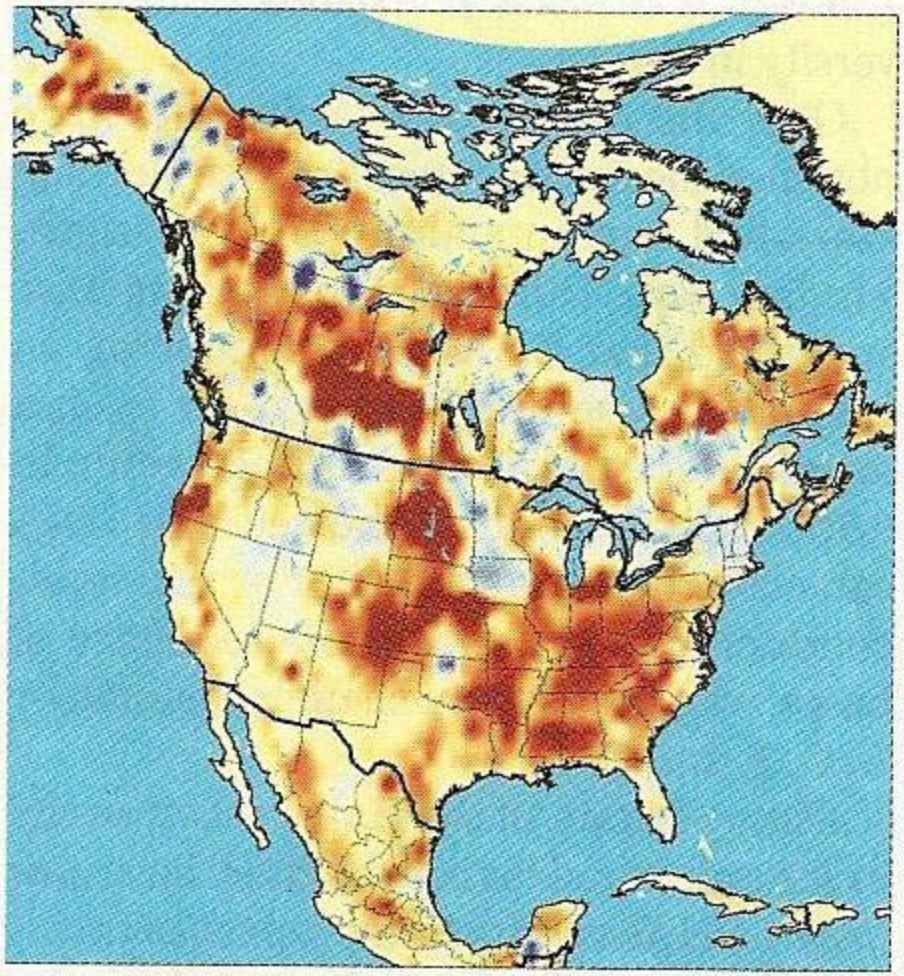
cease to be regulated and the model system swiftly drops to the equilibrium state of the dead planet."

This process is described not merely as the failure of an inanimate controlling mechanism but as the illness or senescence of the goddess Gaia. She is suffering from a "fever brought on by a plague of people." Or perhaps Gaia is exasperated rather than sick: "Like an old lady who has to share her house with a growing and destructive group of teenagers, Gaia grows angry, and if they do not mend their ways she will evict them."

Is there any hope of forestalling this disaster? Lovelock has elaborate and specific prescriptions. (They take up nearly half the book.) First and most important is to give up burning carbon and shift the world economy to nuclear power. For long-distance transportation, he suggests we scrap the jet airliner and build a new generation of sailing ships. It's also crucial that we reduce the

Some Tipping Effects (Bad makes it worse)

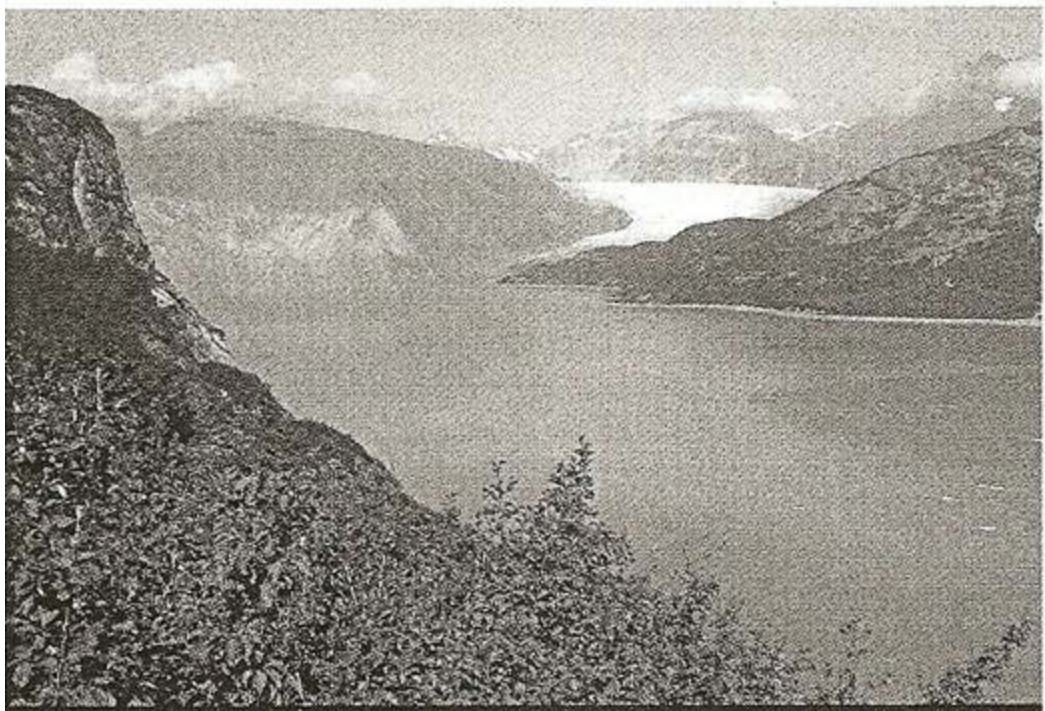
- Open water in the arctic absorbs more sun light (70% now).
- Warm tundra emits carbon dioxide and methane.
- Methane Hydrate deposits in deep cold water will start releasing methane as the ocean warms.
- Drought reduces the ability of forests to absorb carbon dioxide
- If the Gulf Stream stops, Europe will freeze before it cooks
- ??????????????????????



HOT ZONES Red areas depict lower-than-average carbon sequestration in North American ecosystems during the summer of 2002, a time when nearly half of the continent was experiencing massive drought.

Alaska's Muir Glacier has retreated 800 meters in 63 years.

98% of the glaciers in the world are now in similar retreat.

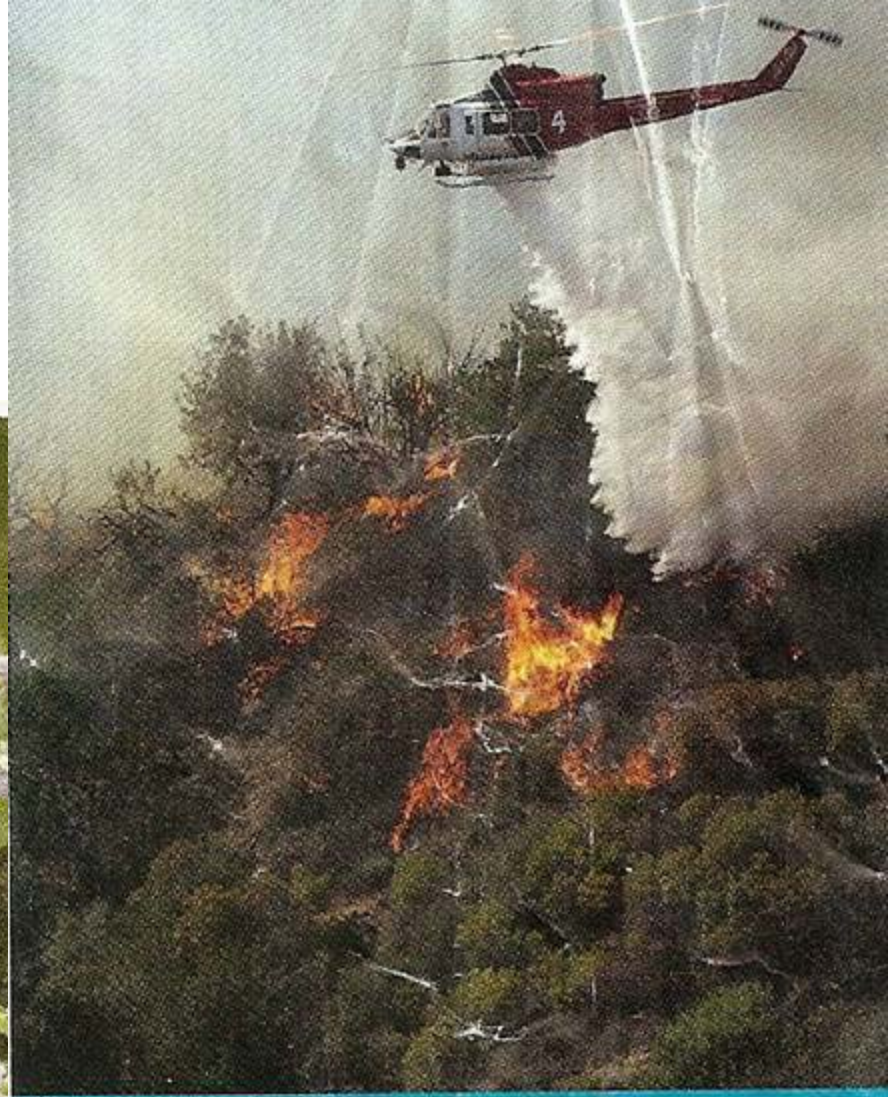


RETREAT: Alaska's Muir Glacier pulled back 12 kilometers and thinned more than 800 meters between August 1941 [top] and August 2004 [bottom]. The global average temperature increased about 0.1 °C per decade in that period.

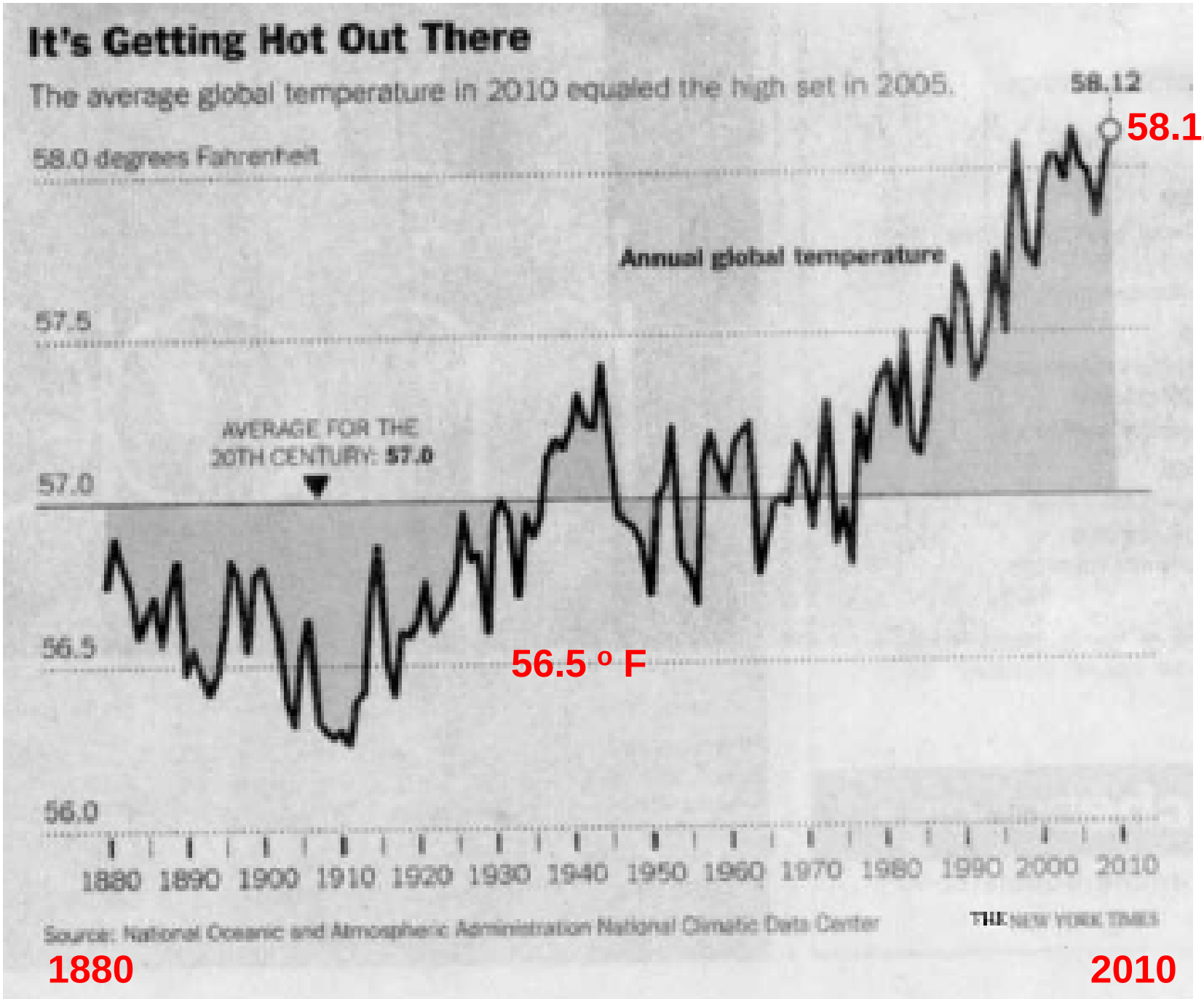
Some more evidence

- Lilacs bloom 6 days sooner in 1993 vs 1959
- The forest fire season in the west is 78 days longer than 30 years ago
- Spring has advanced ~3 weeks in Europe

EARLY BLOOMERS — Climate change has already left fingerprints on North American plants. For example, lilacs advanced their first blooms 1.8 days a decade between 1959 and 1993.



BURNING UP — During the past 30 years, the western United States' wildfire season has lengthened by 78 days, according to research cited in the latest international report on the impacts of climate change. This water drop is on a fire this March in Los Angeles.


It's Getting Hot Out There
The average global temperature in 2010 equaled the high set in 2005.
58.12
58.12 º F
58.0 degrees Fahrenheit
Annual global temperature
57.5
AVERAGE FOR THE 20TH CENTURY: 57.0
57.0
56.5
56.5 º F
56.0
1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010
Source: National Oceanic and Atmospheric Administration National Climatic Data Center
THE NEW YORK TIMES
1880
2010

Days/yr exceeding 100 °

(US Global Change Research Program)

- Today (red=100 days/yr)
  - 100 days/yr in Phoenix
- Low emissions 2080-99
  - >120 days/yr Phoenix
  - 90 in parts of Texas
- High emissions 2080-99
  - >120/yr Ariz. , & much of N.M. & Texas
  - >90/ yr all of Texas and most of the regions where climate change denial is rife

and air-conditioning—protects us enormously. But what about those who don't live well—the people in trailer parks sitting on their porches surrounded by mosquitoes?"

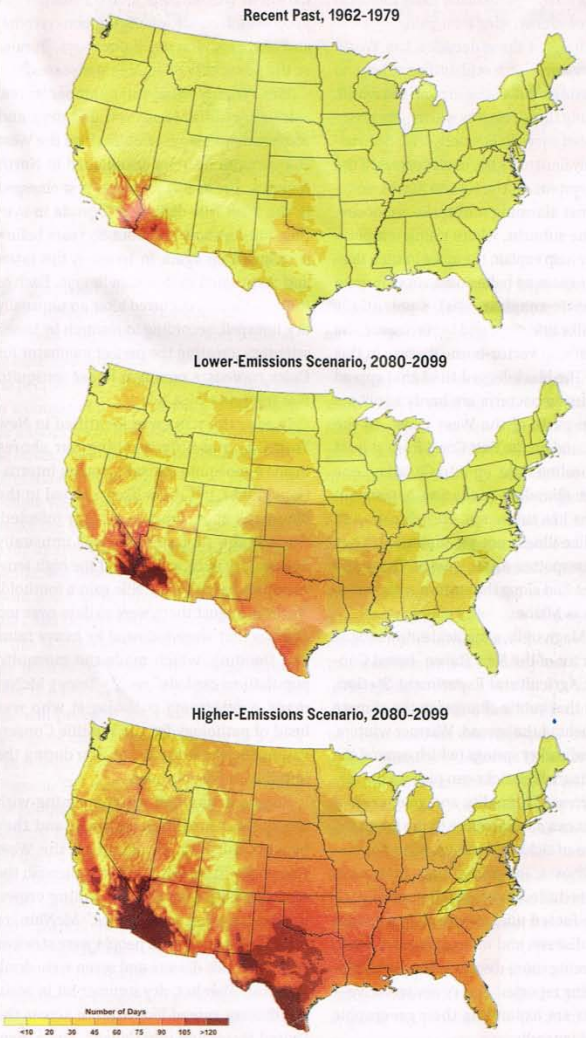
The potential risk was great. Brownsville is becoming a test lab for how this country will respond to the surge of new and renewed infectious diseases. As soon as it became clear that patient zero was a case of indigenous dengue hemorrhagic fever, American health officials began collaborating with counterparts in Matamoros (a Mexican city just across the Rio Grande with a population of nearly three-quarters of a million), dispatching teams to do a blood-sampling survey to uncover the overall extent of dengue infections. They knocked on doors throughout Brownsville, in Matamoros, and in the *colonias*, the squalid shantytowns that line the border. There, residents live in cramped quarters, with poor sanitation, no running water, and no paved roads. The old tires, rusty buckets, and plastic containers that litter the encampments collect stagnant water, making them ideal breeding grounds for mosquito larvae.

Health officials discovered that nearly 1,300 people were infected with dengue fever as of the end of August 2005. The results of a random survey were even more startling: The officials found that 76 percent of the residents surveyed in Matamoros had dengue antibodies, indicating prior exposure to the virus. They also found evidence of past dengue infection in nearly 40 percent of those tested in Brownsville. Of the 24 Brownsville residents who had never traveled outside the United States, 25 percent tested positive for dengue—which meant the illness was now firmly entrenched here. Patient zero was merely the visible manifestation of a tropical disease that had already put down roots in the United States.

Despite the thousands who have been stricken, most Americans are not aware of dengue—yet. But epidemic outbreaks throughout Latin America—in Brazil, Mexico, Honduras, Paraguay, Costa Rica, Bolivia, and Cuba—now hit nearly a million people annually. Inexorably, the disease has been extending its reach farther north. Cases are being reported with increasing frequency in Puerto Rico and Florida and now number in the thousands there. Dengue cases have been confirmed in almost every state and as far up as Maine, Minnesota, and Washington.

U.S. GLOBAL CHANGE RESEARCH PROGRAM; COMPOSITE FROM THE IMAGE WORKS

THE 100° DAYS OF SUMMER



Regional climate forecasts for the United States, created in 2009 by scientists working with the U.S. Global Change Research Program, predict an increase in the number of days above 100 degrees Fahrenheit in the decades ahead. The top map shows conditions during the 1960s and 1970s, when greenhouse-gas emissions were lower than today. If emissions continue to rise without significant controls, parts of Texas might experience more than 100 of these ultrahot days by 2080. Even if emissions are slowed, much of Texas would still experience 60 such days a year, as the middle map depicts. These record-hot temperatures could increase risk of epidemics by creating more breeding grounds for disease-carrying mosquitoes and ticks.

Some Potential Tipping Points

- Melting of white regions creates more warmth
  - Arctic ocean (it's a done deal – polar bear is doomed)
  - Greenland ice cap
  - Antarctic ice cap
- Methane releases
  - Arctic tundra (permafrost)
  - Methylhydrate deposits in the ocean
- Stopping the Gulf Stream will freeze Europe (warm and fresh arctic water won't sink as it does now)
- Climate induce deforestration adds CO_2
- **??**

Late Paleocene Thermal Maximum

- 55 million years ago
- Major extinction and radiation of species
- +10^{o}C global temperature rise
- Oceanic methylhydrate deposits released a huge amount of methane
- Deposits on continental shelf fringes at depth > 400 m
- A 10^{o} C rise in ocean temperature will repeat the event and lock in huge climate change for thousands of years
- One of the worst Tipping Events that we are playing with

Carbon Imbalance ~70% (accumulates)

- The ocean absorbs (in surface waters) ~ **30%**
- **Residence time in the atmosphere ~400 years**
- The biosphere absorbs and emits about the same (little net change)

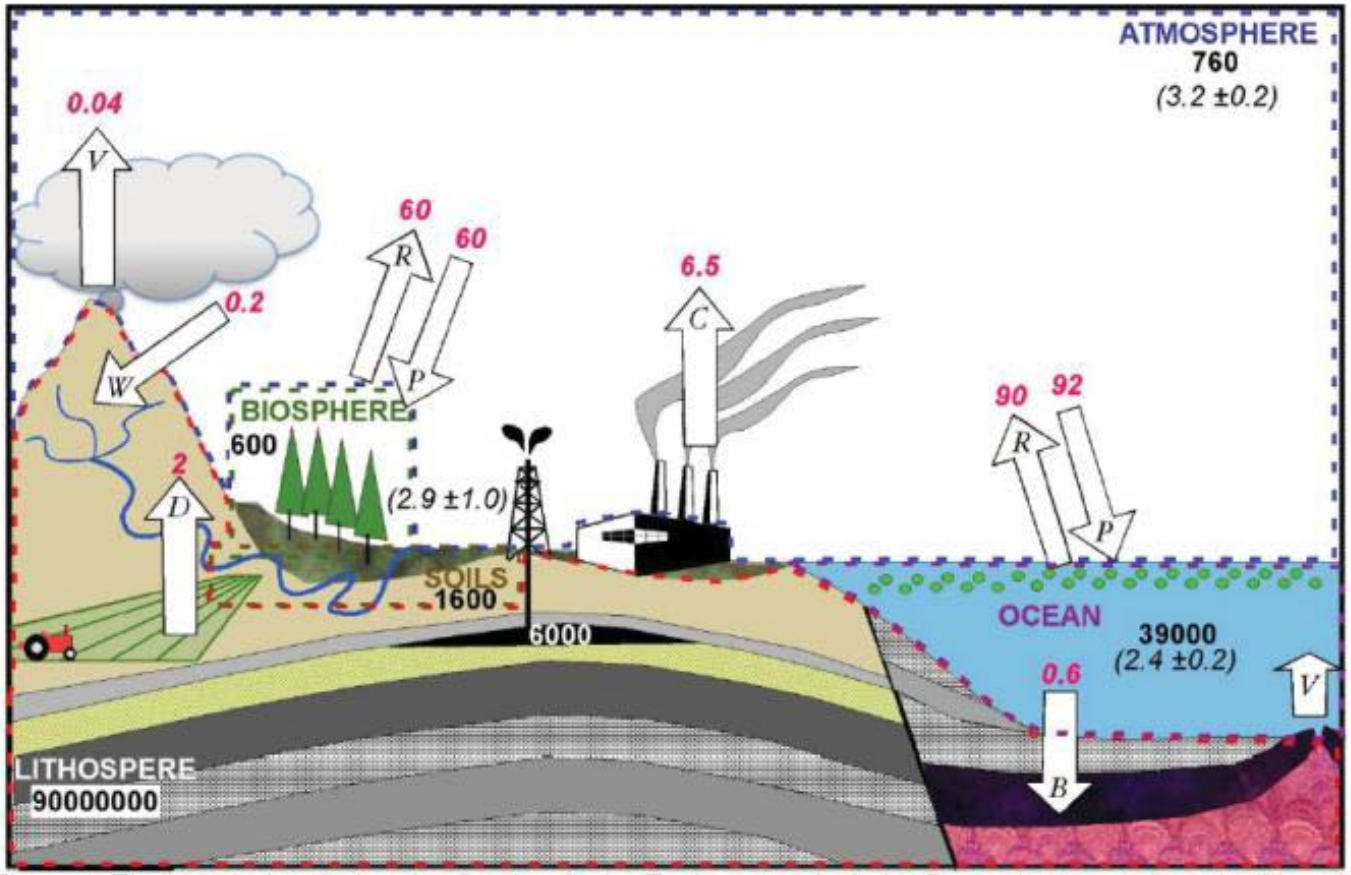
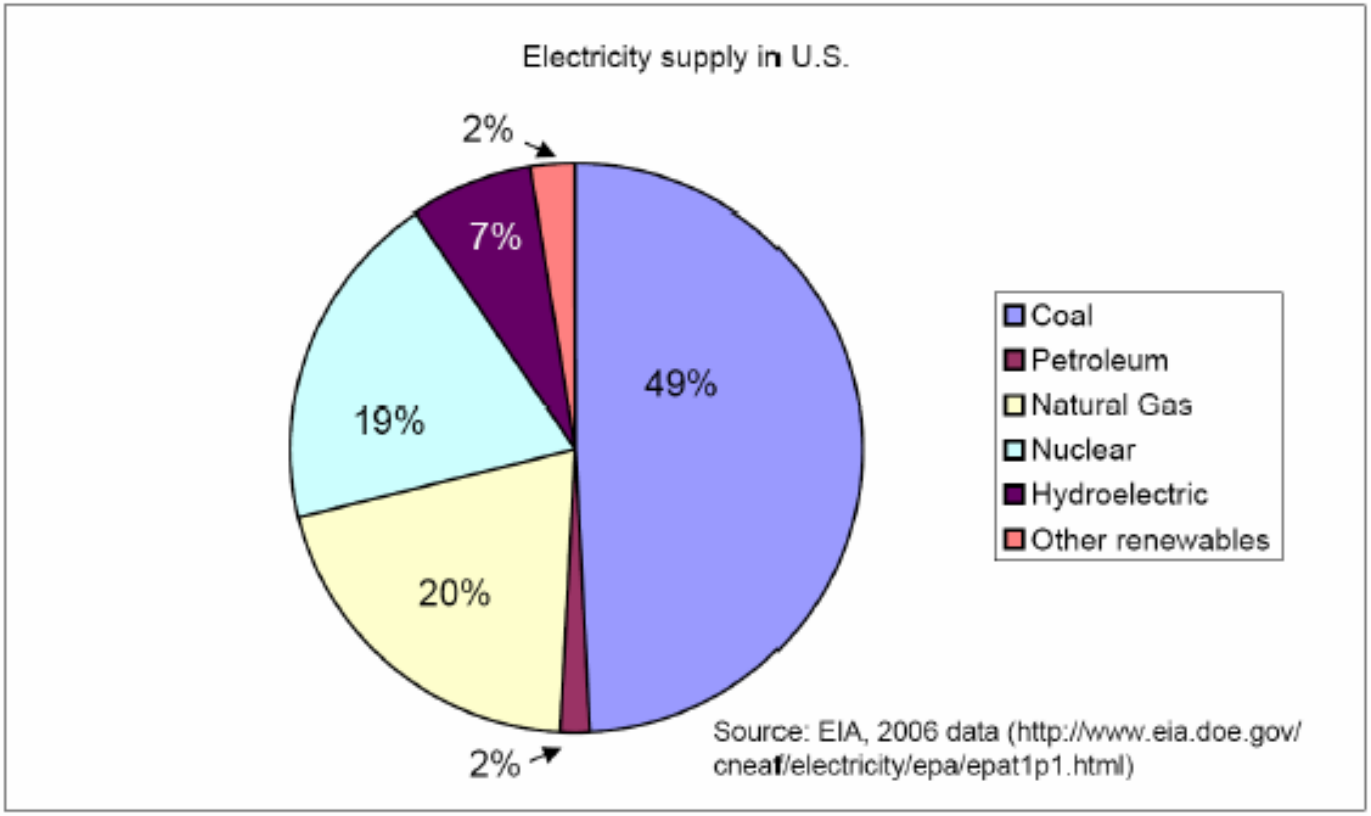


Figure 1. The biogeochemical cycle of carbon in the Earth system includes five major reservoirs – the lithosphere (including fossil fuel reserves), oceans, atmosphere, biosphere, and soils. The reservoir masses in Gt C are shown in black (or white). The figure illustrates five major natural fluxes of carbon – volcanism (V), silicate weathering (W), carbon burial in sediments (B), photosynthesis (P), and respiration (R). Carbon fluxes in Gt/yr are shown in red. Anthropogenic fluxes include fossil fuel combustion and cement manufacture (C) and deforestation (D). Also shown (in italics) are increases in carbon mass within atmosphere, biosphere and soils, and oceans since industrialization [based on Houghton 2005, Archer 2007, and IPCC 2007].

Where does our electricity come from?



- Note: not much oil used for electricity
- "Solar (or wind) not oil" does not make sense unless you have a viable energy carrier (e.g. H_2) or storage (e.g. battery)
- Implication for plug-in hybrid electric vehicles (PHEVs) and electric vehicles: more "secure" but not necessarily "greener"

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Slide courtesy of Aimee Curtright – Rand Corporation

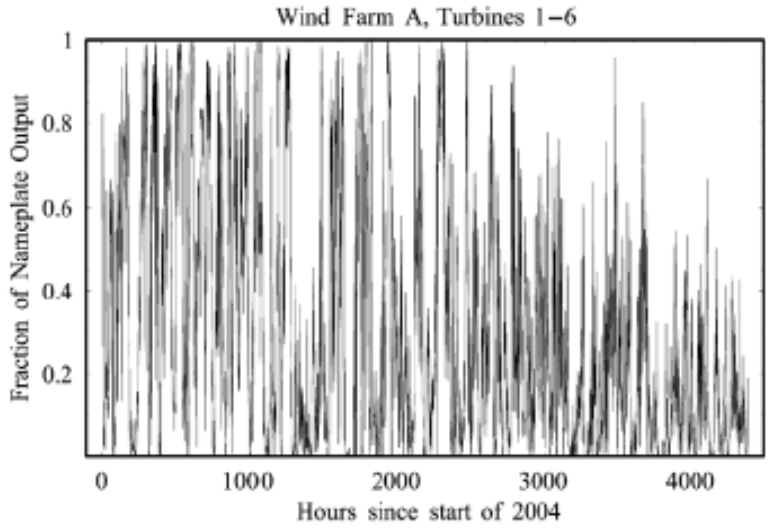
Some Costs of Burning Coal

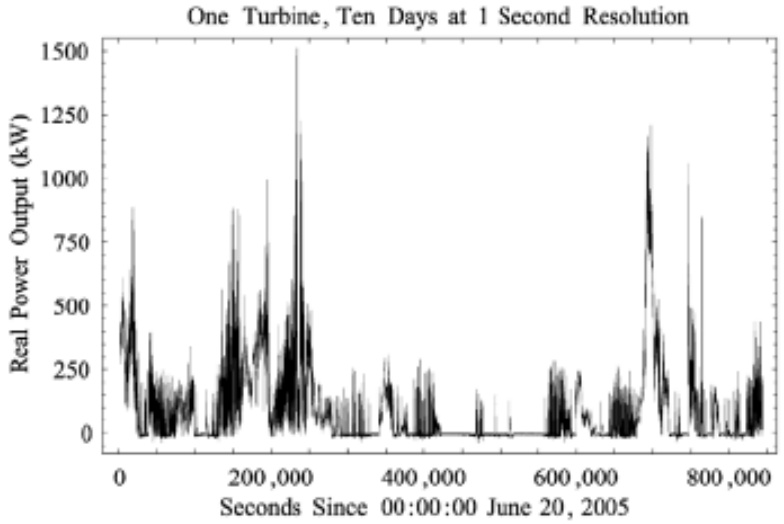
- **13,000 premature deaths/year** from air pollution (Clean Air Task Force)
- Mercury tainted fish
- Acid rain kills lakes streams, and forests
- Oil is required to extract and transport it
- Ruined landscapes and water pollution (TVA ash disaster)
- Scores of mining fatalities/year
- Potential Global Warming costs in the next couple of centuries:
  - **100 trillion dollars to relocate ½ billion people** if Greenland melts
  - Collapse of most forests below the arctic circle
  - The **worst mass extinction** since the dinosaurs
  - **Desertification** of much of America and the world
  - Extreme weather (worse tornados and hurricanes)
  - The **4 Horsemen** of the Apocalypse (war, famine, disease, pestilence)
  - Potential collapse of civilization (*See Collapse*, etc)
  - **Tipping Points ??**
- **We need an alternative Now!! It must be off the shelf!!**

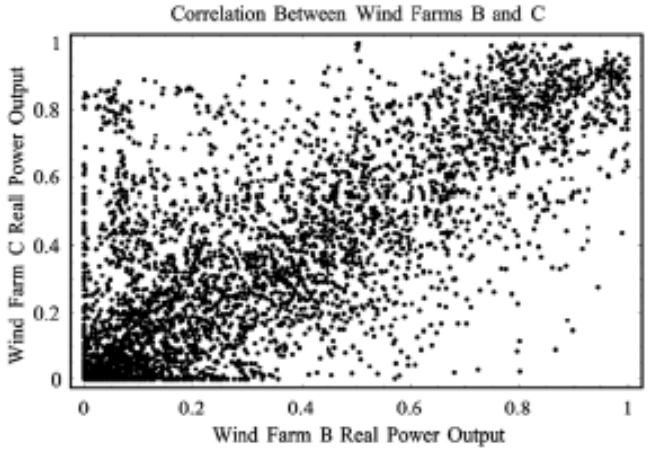
Some Electric Energy Alternatives and Their Problems

- Solar will be niche for quite a long time.
  - **Requires a storage mechanism** that does not exist (night time & cloudy days).
  - Capital cost/watt is many times higher than alternatives.
  - Photovoltaic materials and processing chemicals are quite toxic.
- Wind can be cost competitive as a supplemental source but it **requires a storage mechanism** that does not exist in order to be a large percentage.
- Waves are difficult to exploit due to **storms that destroy** the machinery.
- Geothermal and tidal have very **few suitable sites.**
- Hydro electric is almost **fully exploited** here.
- Not enough farm land for Biofuel and it actually increases CO_2 in many cases
- Fossil fuel **carbon sequestration** will help but:
  - It is **not proven yet** (retention time ?, ultimate costs?, safety?, etc.)
  - Raises costs to greater than that of nuclear
  - Failure of the repository could be devastating (e.g. Lake Cameroon)
- **Nuclear is the only off the shelf source of "Baseload Power"** (always there)
  - More expensive than coal initially but it is competitive in the long run
  - Radiation leaks from reactors or repositories are a manageable hazard
  - Nuclear proliferation is a risk but commercial reactors are not the problem
  - No fatalities from commercial plants in 50 years in America.

Wind is intermittent, even on the second timescale, and is geographically correlated







Source: Apt, J. "The spectrum of power from wind turbines," Journal of Power Sources 169 (2007) 369–374.
See also: http://www.nytimes.com/2007/11/23/business/23wind.html?ex=1196485200&en=8034d5a5a359a6a3&ei=5070

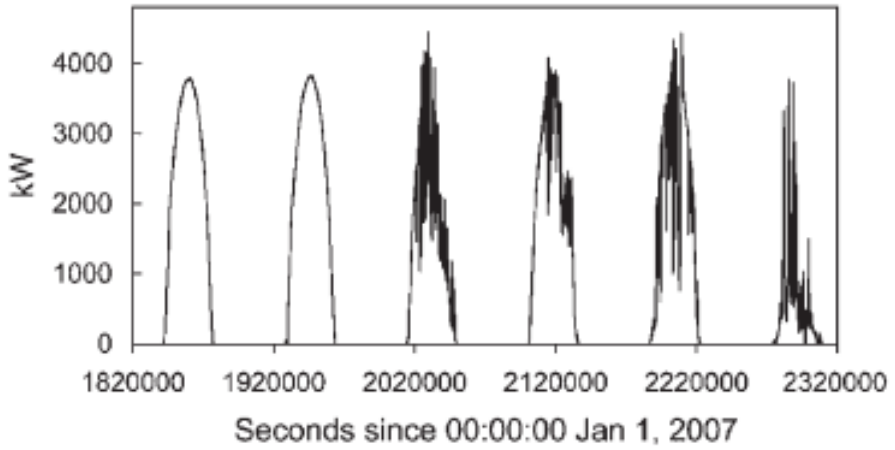
Slide courtesy of Aimee Curtright – Rand Corporation

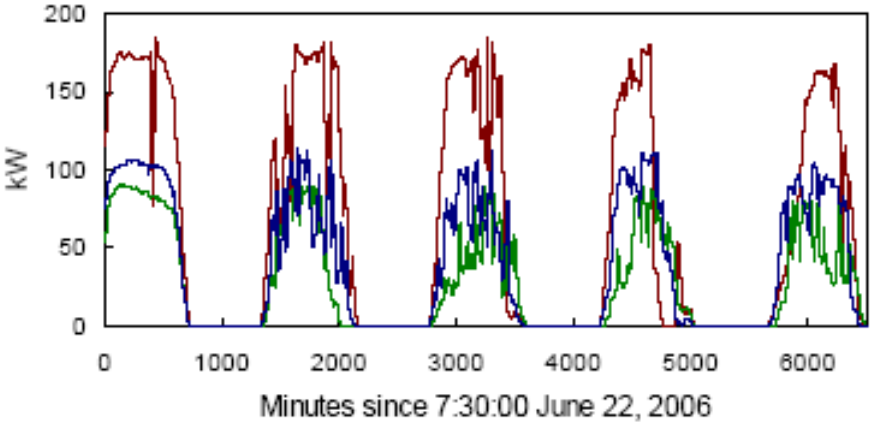
PV is intermittent in both day/night cycle and on fast timescales, and is geographically correlated

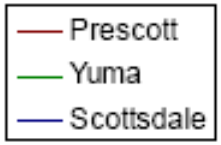
Data

(1) Single, large site:
4.6 MW, 44 acres

(2) Multiple, smaller sites:
~100-200 kW







Distance and output power correlation between 3 pairs of APS sites

	Prescott	Yuma
Scottsdale	110 km, 0.70	280 km, 0.73
Yuma	290 km, 0.57	

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Slide courtesy of Aimee Curtright – Rand Corporation

Bio-fuels Can't Do It

- Ethanol from corn (sugar cane is better)
  - Uses almost as much fossil fuel as is produced
    - Distillation (should use waste heat from a nuclear plant)
    - Tractors and trucks use diesel
    - Fertilizer production needs energy
  - There is not enough land or water
- Bio-diesel
  - Rain forest is being cut for palm and soy (50 year break even)
- Food cost are creating political instability in the 3d world (Pakistan)
- Developments might change these negatives but they aren't here

Nuclear Fusion

- Essentially unlimited energy from heavy water in the ocean
- X100 improvement/decade for 60 years
- ITFR will achieve a sustained burn in 2025
- Many materials engineering problems remain
- It could be coming out of the wall in ~50 years

Commercial Nuclear Reactor Accidents

- Chernobyl
  - Dozens of heroic fire fighters were the principal direct victims.
  - It had no containment vessel.
  - Inherently unstable design (graphite moderator caused run away).
  - Safety mechanisms were deliberately turned off for a test ordered by Moscow.
  - Evacuations and corrective actions were delayed for >3 days because the closed society enabled the authorities to hide it until radiation readings in UK & Norway lead to western news reports. Thousands of preventable cancers resulted from this (i.e. 5,000 Belarus thyroid cancers (~250 deaths) could have been avoided by banning milk products or by issuing potassium-iodide pills)
- Three Mile Island
  - Very little radiation was released (no fatalities… estimate~1/10,000 of a life)
  - Sensor design flaws that confused the operators are now corrected in USA
- Fukushima
  - Maximum allowed worker exposure ~250mSv→1.3 % life cancer risk each
  - 130 Japanese cancers total over a life time (estimated range is 15 to 1000)

Cumulative Radiation &Air Pollution Hazard (**80 year life exp**.)

Nuclear bomb fallout USA cancer fatalities

- 70 **billion** Curies → **14,000** USA
- This mortality is (**over a life time**):
  - 2.5% of CT scan fatalities (**0.6M**)
  - 0.4% of background radiation (**3.6M**)
  - 0.015% of USA cancer deaths

Reactor melt down USA fatalities

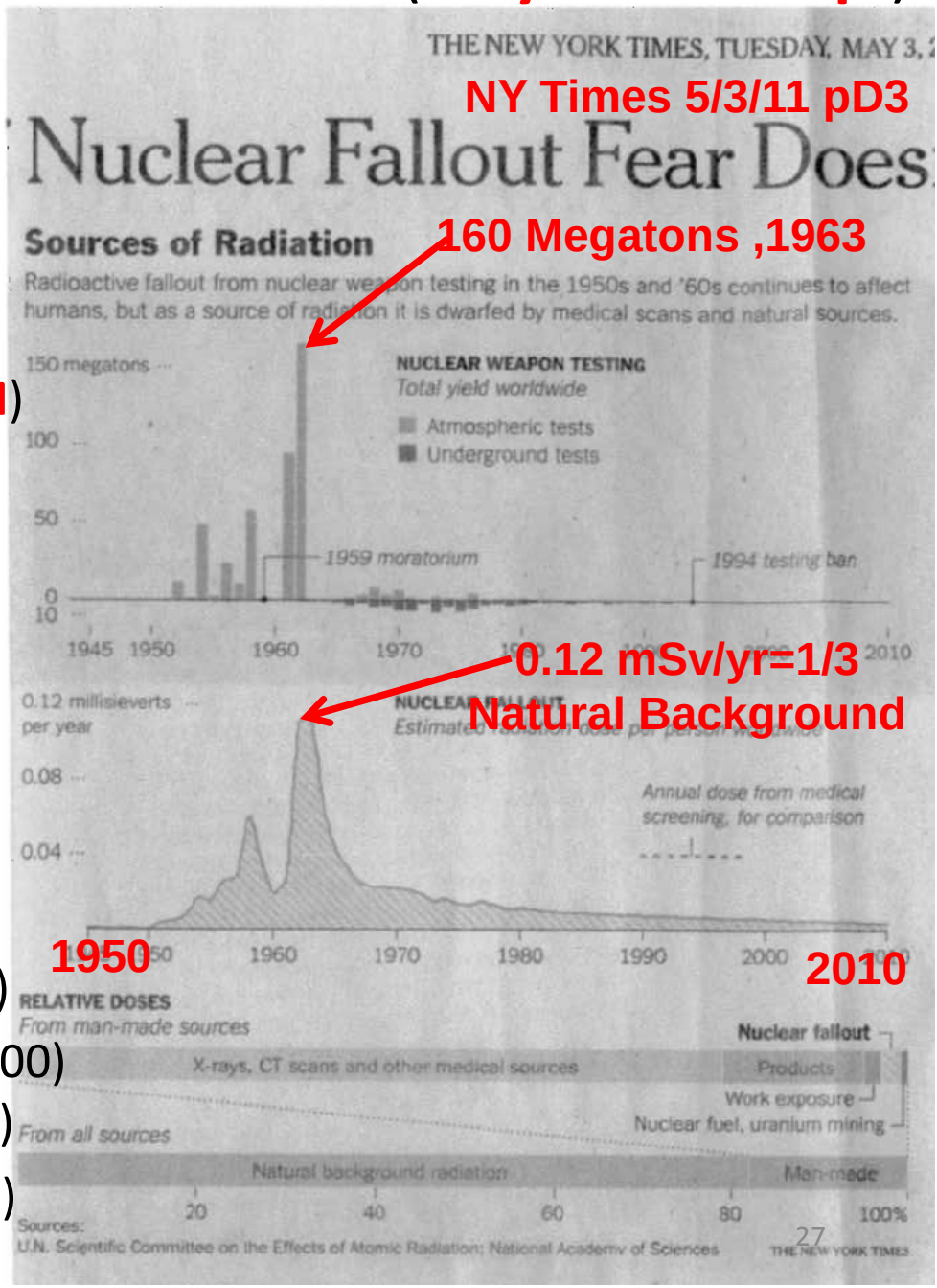
- Chernobyl 100 MCuries → **20** deaths
- Fukushima 20 MCuries → **4** deaths
- Three Mile Is. 50 Curies(x10)→**0.0001**

USA Coal Burning

- Fly ash radiation → **40,000** deaths
- Air pollution→**1M**(asthma,emphysema)

Fukushima Japanese deaths **~130** (15→1,000)
(John Hoeve&Mark Jacobson at Stanford U.)

Chernobyl European deaths **~4,000** (or less)



Nuclear Waste Disposal

- The Yucca Mountain repository is safer than its site. It is in a nuclear test range where hundreds of nuclear bombs have been tested.
- The safety criteria are that a water well not register more than 10% more radiation than background for 10,000 years. Whose going to move in and dig a well there?
- Reprocessing of cooled (e.g. 1 century) fuel rods would
  - Increase repository capacity by hundreds (**< 100 tons/year** for USA now)
  - Allow burning of the longest lived isotopes in 4th Generation Reactors (i.e. ADS)
  - Is not a proliferation risk with proper controls or design (i.e. Thorium reactors)
  - Is standard procedure in Europe
  - Would provide feed stock for future breeder reactors
  - Is much more cost effective than capturing and sequestering CO_2 (7 billion tons/year)
- Nuclear repositories will never release more than a tiny fraction of the radiation that burning coal does. Coal deposits contain high concentrations of uranium and thorium and their decay products because plants concentrate uranium from the soil (~500 USA fatal cancers/year caused by coal burning released radiation)
- **Coal burning air pollution causes ~10,000 fatalities per year**.

Availability of Nuclear Fuel

- A pound of uranium ($90) is equivalent to 10 tons of coal and is 1/10th the price.
- At $50/lb the world reserves (35,000,000 tons) are equivalent to almost a trillion tons of coal. That is about the **amount of carbon in the air today**.
- **At x10 higher price** (equiv. to the price of coal) estimated reserves rise x**300**
- The price is now $90/lb and $200,000,000 is being invested annually in exploration. This is piddling by comparison to oil exploration investments (tens of billions/year).
- **Breeder reactors** ultimately will increase the energy available by x**100**
- Accelerator Driven Systems can breed uranium from thorium (x**100 more energy**)
- Any claims of insufficient reserves are disingenuous anti-nuclear propaganda.

U.S. Forward-Cost Uranium Reserves by State, December 31, 2003

	$30 per pound			$50 per pound		
State(s)	Ore (million tons)	Grade[a] (percent U_3O_8)	U_3O_8 (million pounds)	Ore (million tons)	Grade[a] (percent U_3O_8)	U_3O_8 (million pounds)
Wyoming	41	0.129	106	238	0.076	363
New Mexico	15	0.280	84	102	0.167	341
Arizona, Colorado, Utah	8	0.281	45	45	0.138	123
Texas	4	0.077	6	18	0.063	23
Other[b]	6	0.199	24	21	0.094	40
Total	**74**	**0.178**	**265**	**424**	**0.105**	**890**

Some Future Reactor Technologies

- Westinghouse's AP1000 is x100 safer than present US reactors
  - Gravity driven emergency cooling water
  - Modern control systems
- High temperature gas cooled reactors cannot melt down
- Accelerator Driven Systems (ADS)
  - Cannot run away
  - Can burn low grade fuel (does not need enrichment – no proliferation)
  - Can breed thorium to uranium that cannot be used in a bomb
  - Can burn up the long lived waist from other reactors
- Thorium Breeder Reactors
  - Much less long lived waste (x2000 less Actinides)
  - Much less nuclear weapons risk (fuel can't make bombs)
  - X10 more fuel available

Westinghouse AP1000

- x100 safer
- Modern control system
- Passive emergency cooling (gravity fed **cannot melt down like Fukushima did**)
- Cost competitive with coal in long run (50yr)

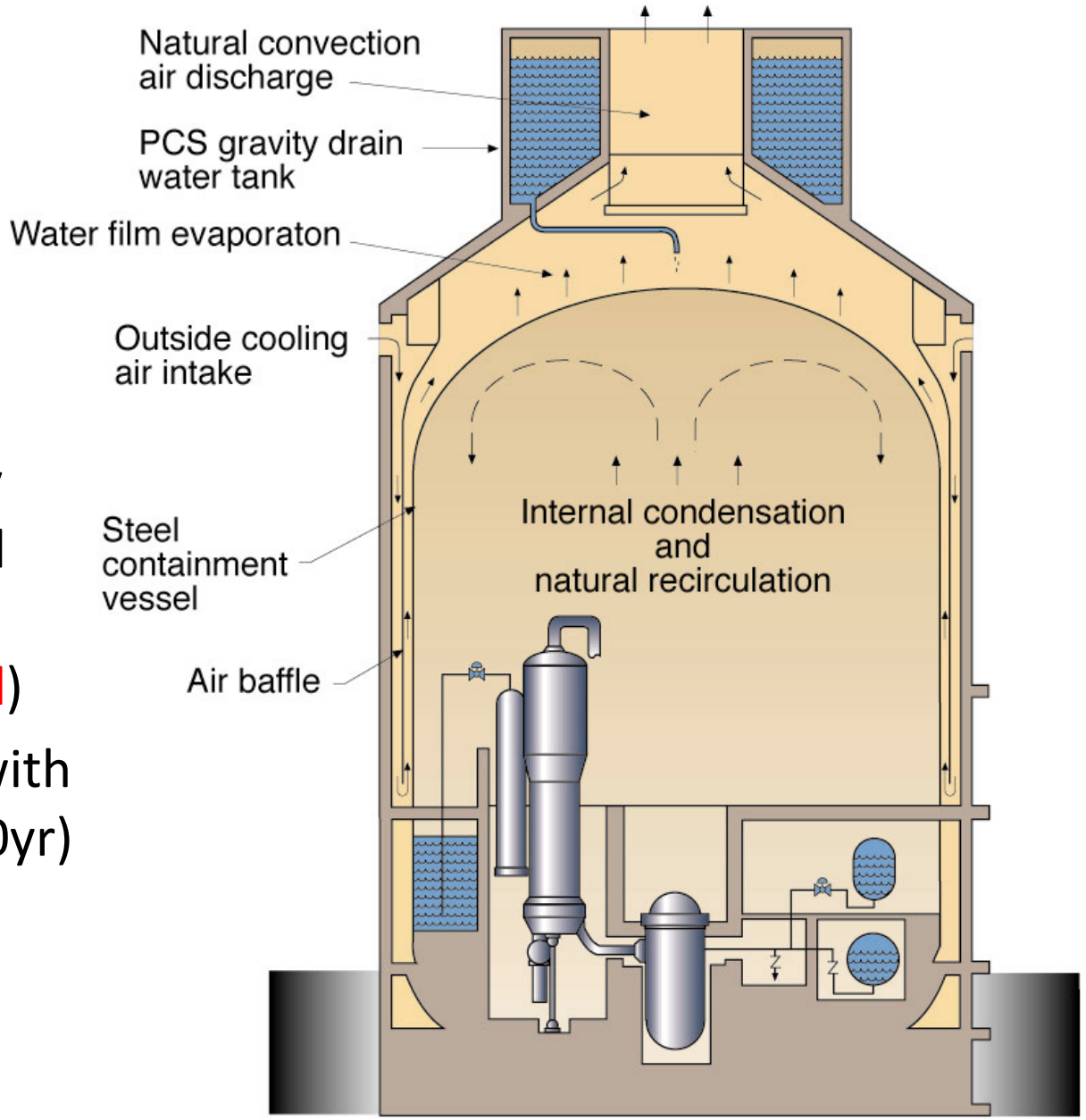
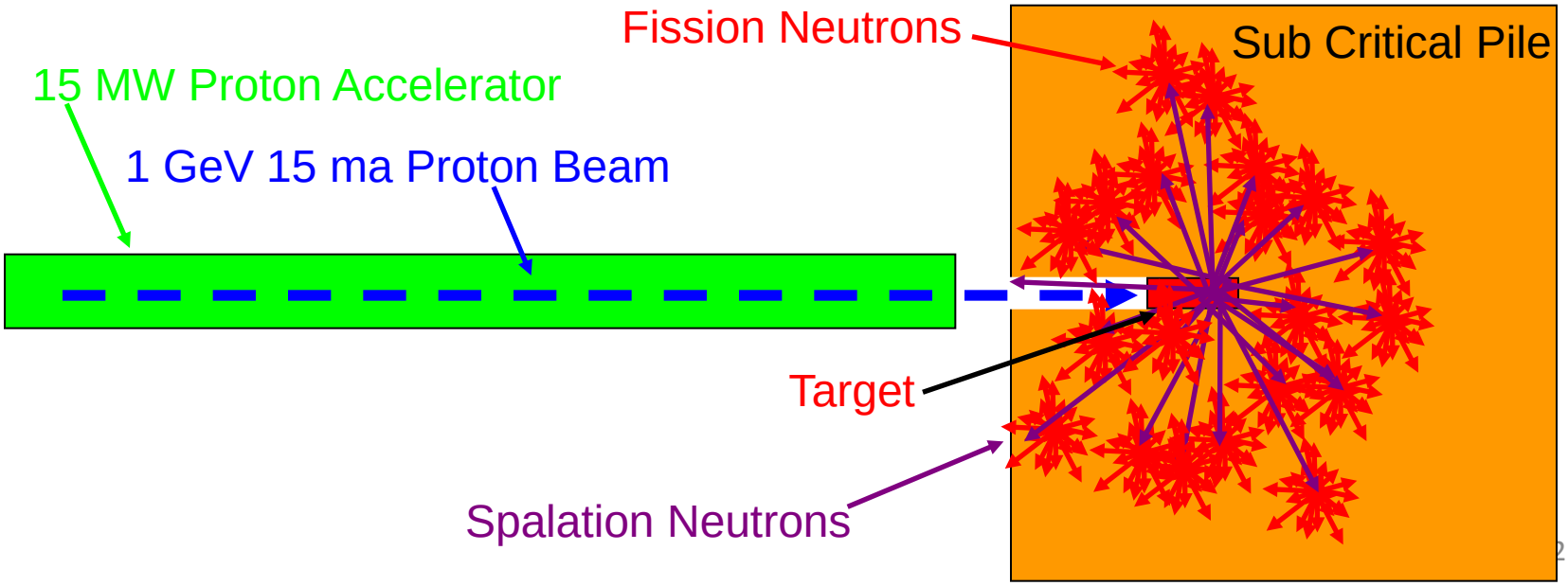


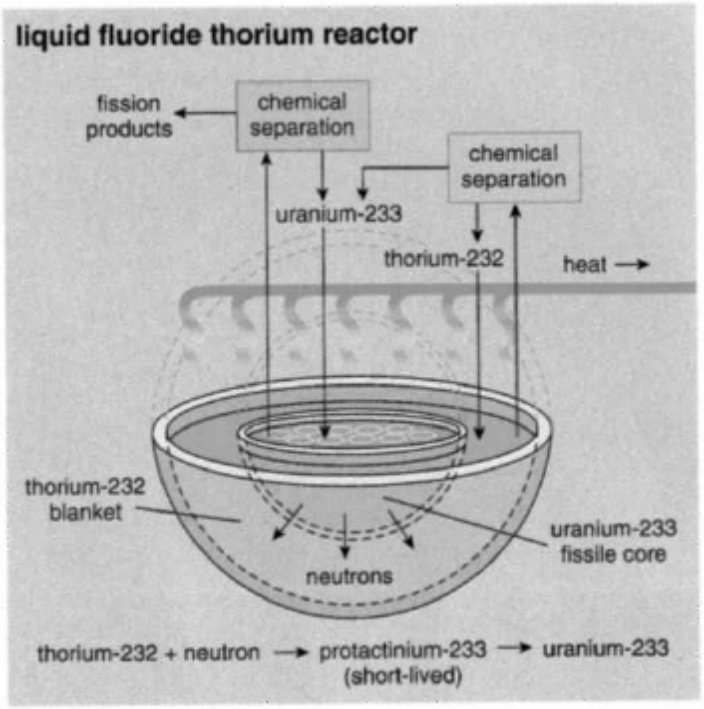
Figure 3. AP600 Passive Containment Cooling System

Accelerator Driven System (ADS)

- Cannot run away
  - Sub critical reactor (low power density to)
  - Fission stops when the proton beam is turned off
- Can burn low grade fuel (does not need enrichment – no proliferation)
- Can breed thorium uranium that cannot be used in a bomb
- Can burn up the long lived waist from other reactors
- Each incident proton produces ~40 spalation neutrons
- Each spalation neutron produces ~30 fission events (for 97% of critical)
- A few percent of the power is needed for the proton accelerator



Liquid salt Thorium Breeder looks goc



Radio-activity

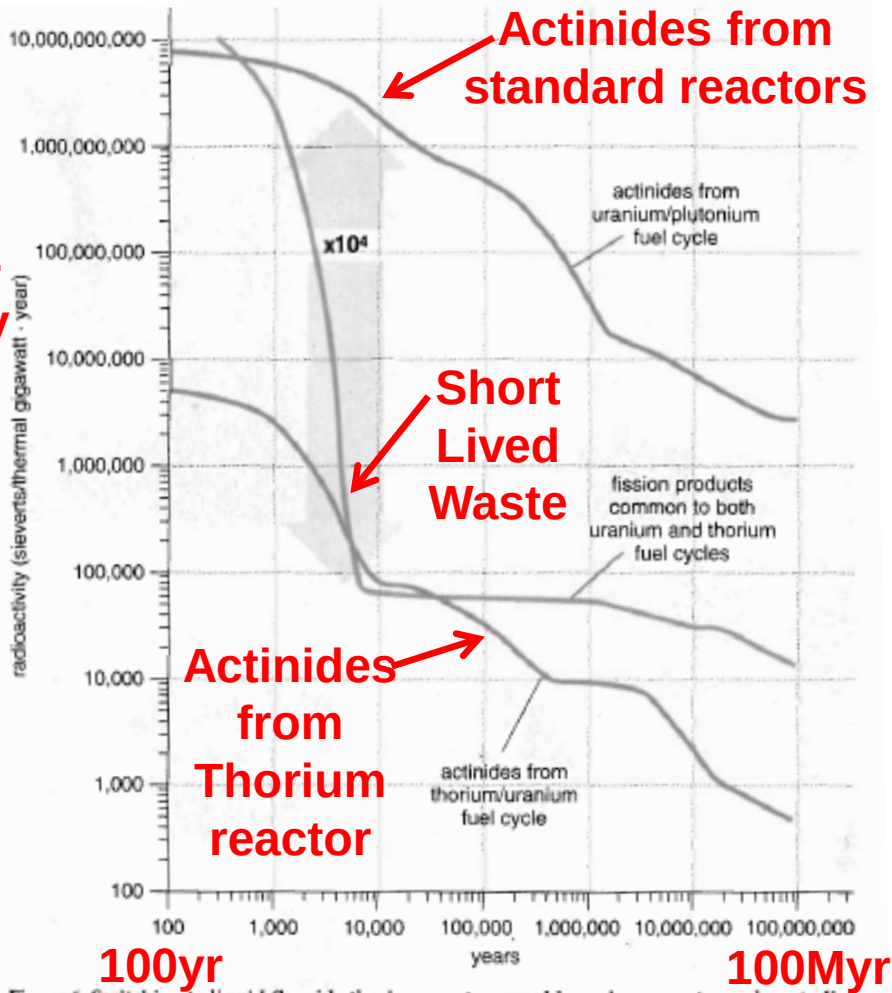


Figure 6. Switching to liquid fluoride thorium reactors would go a long way toward neutralizing the nuclear waste storage issue. The relatively small amount of waste produced in LFTRs requires a few hundred years of isolated storage versus the few hundred thousand years for the waste generated by the uranium/plutonium fuel cycle. Thorium- and uranium-fueled reactors produce essentially the same fission products, whose radiotoxicity is displayed in blue on this diagram of radiation dose versus time. The purple line is actinide waste from a light-water reactor, and the green line is actinide waste from a LFTR. After 300 years the radiotoxicity of the thorium fuel cycle waste is 10,000 times less than that of the uranium/plutonium fuel cycle waste. The LFTR scheme can also consume fissile material extracted from light-water reactor waste to start up thorium/uranium fuel generation.

- The bred U_{233} cannot be used for bombs because it is contaminated with very radioactive U_{232}
- Long lived actinides are down by x2000 so the waste can be buried for ~5000 years
- No pressurization is safer

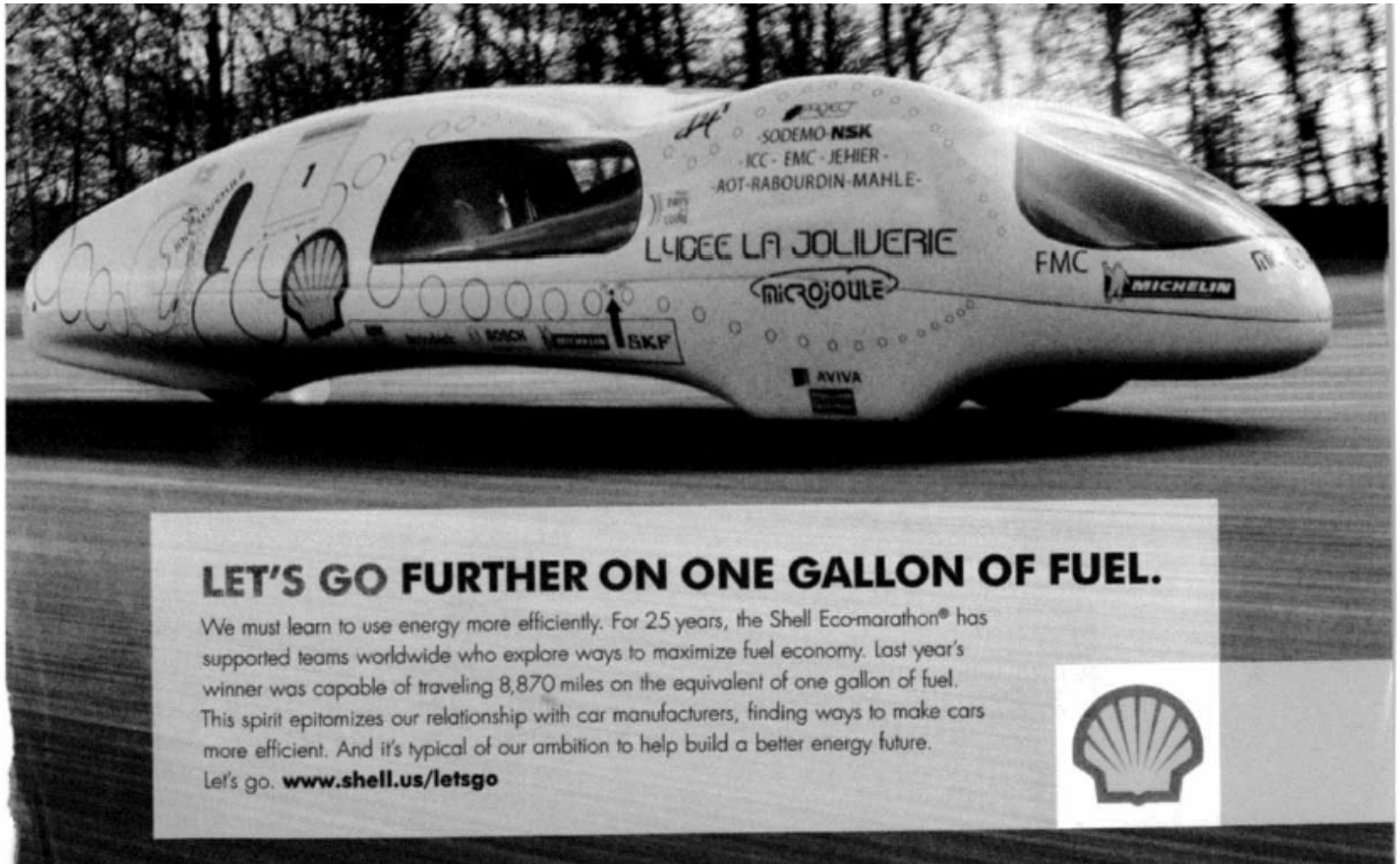
* See "Liquid Fluoride Thorium Reactors", Robert Hargraves & Ralph Moir, American Scientist, V98, p304, July2010. Also by Hargraves is "Thorium-energy cheaper than coal", UK Amazon

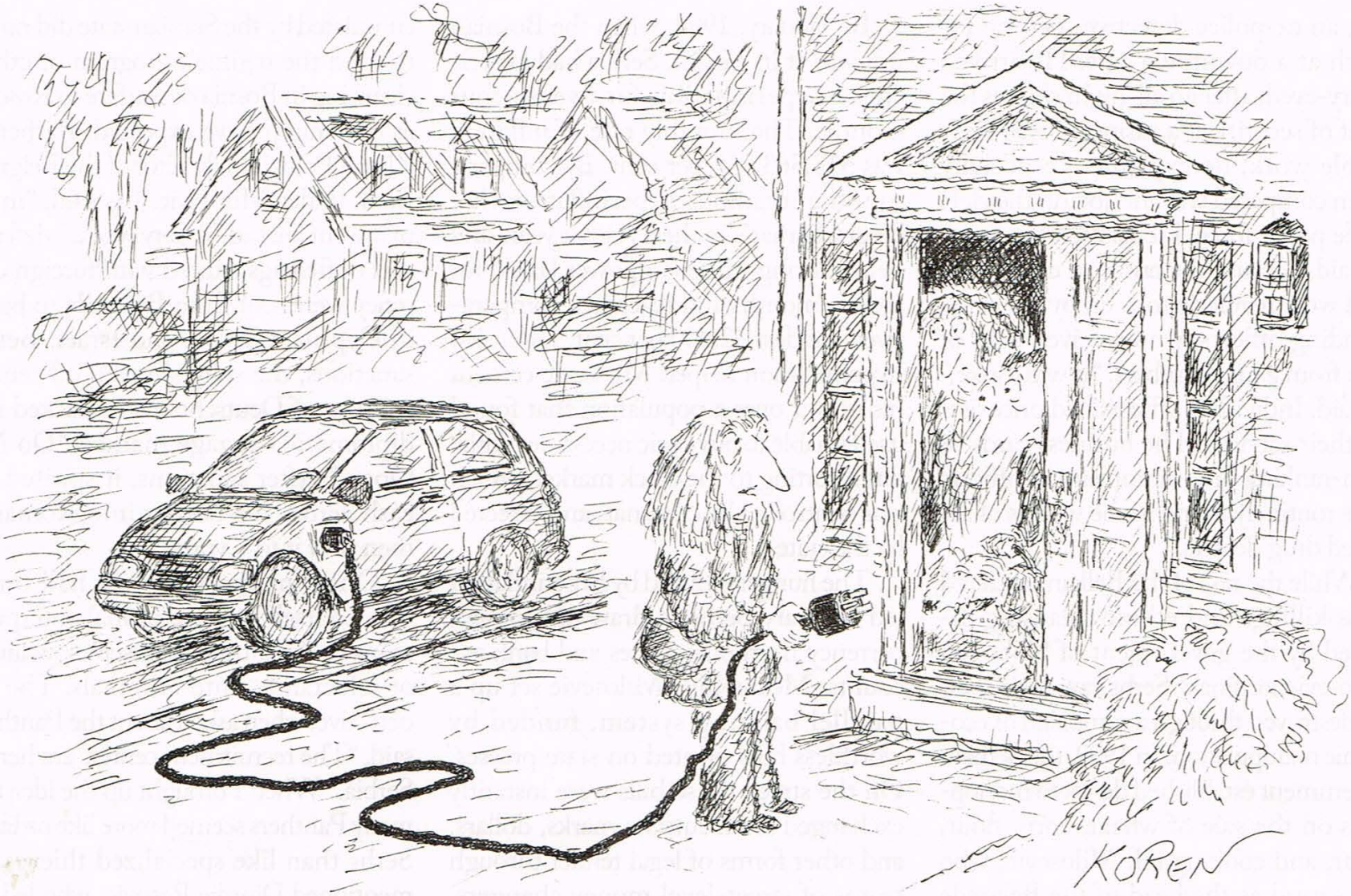
Recommendations

- **Build nuclear reactors instead of coal plants & replace old reactors**
- Develop other green sources that make engineering & economic sense
  - Wind
  - Thermal solar power plants (solar panels where practical…hot water heaters are good)
  - Tidal (where geology permits)
  - Carbon sequestration coal plants, cement plants, and blast furnaces (where geology permits)
- Proactive government policies
  - Nuclear power incentives and liability insurance
  - Carbon tax (power plants, processes, vehicles, etc.)
  - Cap and trade
  - Research (i.e. Energy Storage ,Thorium Reactors, Accelerated Driven System, Fusion, etc)
- Energy efficiency
  - Plug in Hybrids
  - Heat pumps with in ground heat sources
  - Insulation
  - LEDs
  - >100 Passenger miles/gallon jets and turbo-props (can be as good as high speed rail)
  - Etc.
- If all else has failed, Geo-engineering with iron fertilization of the desert like regions of the oceans (see The Climate Fixers, Michael Specter, New Yorker, p96, May 14, 2012).

Future cars will be plug in hybrids (not pure electric)

- $1/gal equivalent for electricity
- Carbon free electricity (hydro, wind, solar, nuclear, tides, etc)
- A Pries can go 40mph with 5hp so a small gas motor gives long range
- This car gets 8,870 mpg (first one built by French kids >20 years ago)





"I'm only a few miles from home. Could I borrow a socket?"

Some Things You Can Do

- **Conservation!!**
- Hybrid cars (I'm getting 55 mpg in a Prius)
- Plug in hybrids will get >100 mpg
- Geothermal heat pumps are very efficient
- Educate your friends and representatives
- Solar hot water heaters make $s and sense
- Plant trees
- Buying carbon offsets encourages alternatives
- **Support nuclear power !!**

Carbon-Offset Comparisons

Of the 13 carbon-offset companies analyzed by the Tufts Climate Initiative, 4 were recommended, and 6 others were recommended "with reservations." The 2 highest-rated companies are German and Australian; the other 5 cited below are the recommended U.S.-based companies.

COMPANY	EMISSIONS CALCULATIONS	SAMPLE PROJECT	PRICE PER TON OF CO_2 OFFSET
Atmosfair *atmosfair.de*	"excellent"	Large-scale solar cookers in India	$17.30
Climate Friendly *climatefriendly.com*	"excellent"	Wind farms in Australia and New Zealand	$14.50
NativeEnergy *nativeenergy.com*	"very good"	Wind farm on the Rosebud Sioux reservation, S.D.	$12
MyClimate *my-climate.com*	"acceptable, but emissions likely underestimated"	Micro-hydropower systems in the Indian Himalaya	$18
CarbonCounter *carboncounter.org*	"too low"	Reforestation in Oregon's Deschutes River basin	$10
Carbonfund *carbonfund.org*	"too low"	Low-income solar-powered housing in Chicago	$5.50
TerraPass *terrapass.com*	"too low"	Converting cow manure to electricity in Minnesota	$10

AVERAGE ANNUAL HOUSEHOLD POUNDS OF CARBON DIOXIDE SAVED

1,000
If you recycle glass, plastic, and paper.

800
If you take the bus to work instead of driving.

720
If you line-dry half your laundry loads instead of using the dryer.

700
If you maintain a tight seal on your refrigerator door and keep the appliance's coils clean.

55
If you replace a 75-watt incandescent lightbulb with a 20-watt compact fluorescent bulb.