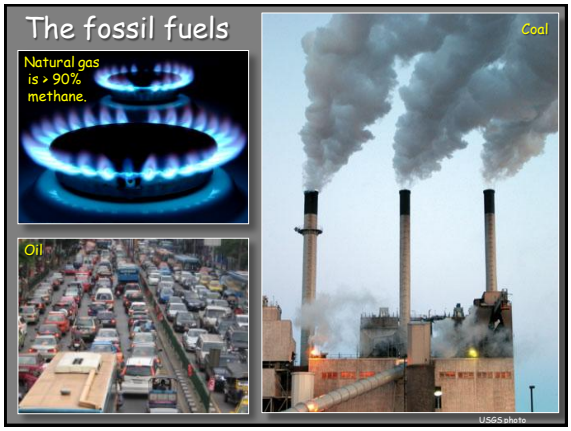


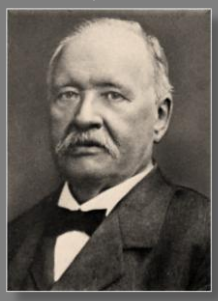
1822
French mathematician

Joseph Fourier

discovered that CO_2 traps heat in the atmosphere.

1896
Swedish chemist*
Svante Arrhenius
calculated that doubling CO_2 in the atmosphere would cause a 5°C fever.

* Nobel Prize, 1903



However, for the next fifty years, most experts believed that oceans would absorb fossil fuel CO_2 and thereby limit any warming.

1957
Scripps oceanographer
Roger Revelle
and geophysicist
Hans Suess
showed the oceans worked too slowly, that atmospheric CO_2 from fossil fuels would surely increase to produce significant global warming.

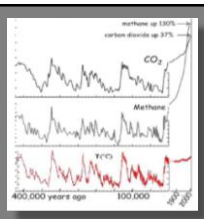
Nice clear warning by 1958

The 1958 movie short subject on Global Warming, directed by Frank Capra.

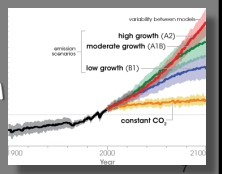
But their time frame was "a few centuries before big trouble."

The global warming story is usually told via our high-tech triumphs

- *— CO_2 levels*
- *— temperature*
- *— forecast models*

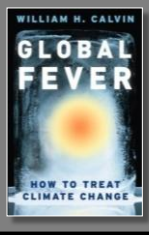


But I think this framing of the problem is a serious mistake.



Why is this a tactical mistake?

- People love to complain about the accuracy of weather forecasts and assume that climate forecasts deserve similar witticisms.
- The problem has been framed as "warming," but the numbers seem small.
- But heat waves are going to be the least of our problems. This is fever and its fatal complications.
- It's something we must *cure*, not just live with.



But we don't need a thermometer to see the large climate changes since 1950 in:

- High winds
- Major floods
- Wildfires
- Drought

Their trends *alone* make it clear that we will soon be in deep trouble unless we respond immediately.

50 years of *global* climate change

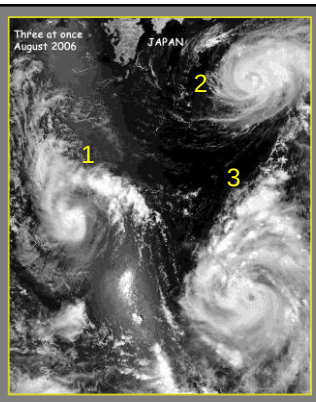
- High winds
- Heavy weather floods
- Wildfires
- Drought
- Ice melting

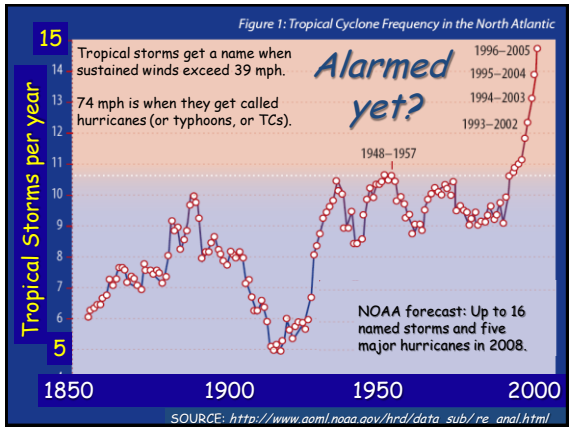
- *Then temperature and CO_2 equivalents*
- *What to do — and how quickly.*

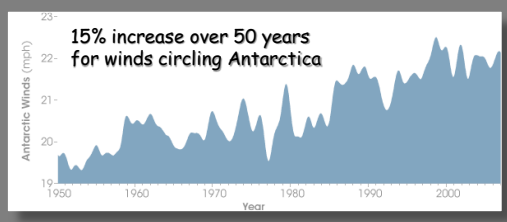
Utah I-15 wind 4/23/99 Credit: Marta Storwick/Standard-Examiner via Associated Press

Blown-over garbage truck, near Bill Gates' house in 1999

High Winds







For 50 years, winds circling Antarctica have been increasing, driven by both global warming and changes in the upper atmosphere caused by the ozone hole. (Graph by Robert Simmon, based on National Centers for Environmental Prediction (NCEP) data.)

http://earthobservatory.nasa.gov/Study/OceanCarbon/page4.html

Nonlinearity

If wind speed increases 20%, from 50 mph to 60 mph, the damage goes up not 20% but 500%.

[6X insurance claims]

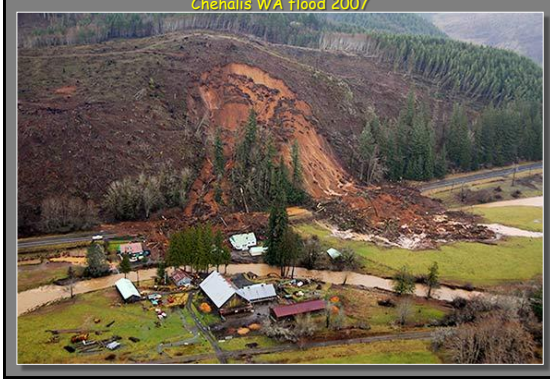
Something blown loose from one building may hit another building if it doesn't hit the ground first, giving a cascade of damage.

Heavy Weather

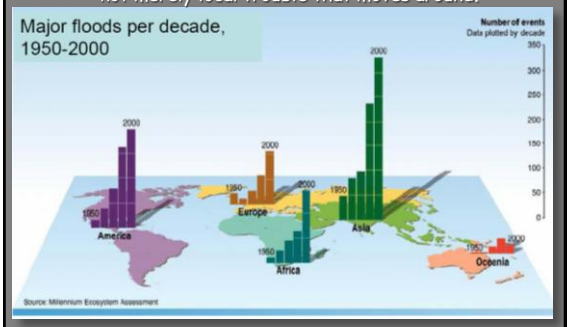
The heavens opened
(US government photo)

Logged hillside collapse

Chehalis WA flood 2007



So it is a global climate change,
not merely local trouble that moves around.

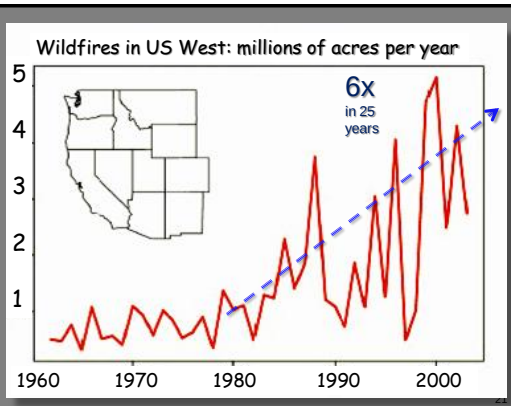


Floods have been increasing for 50 years.

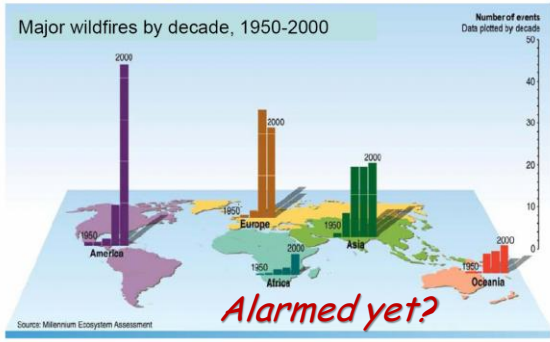
Fire managers predict bad year for blazes

Sat May 10, 2008 2:37pm EDT

David S. Roberts, San Diego County 2007

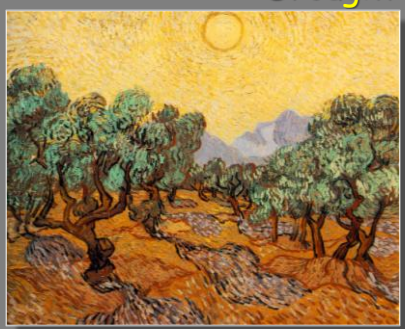


Harm is already occurring (continued)

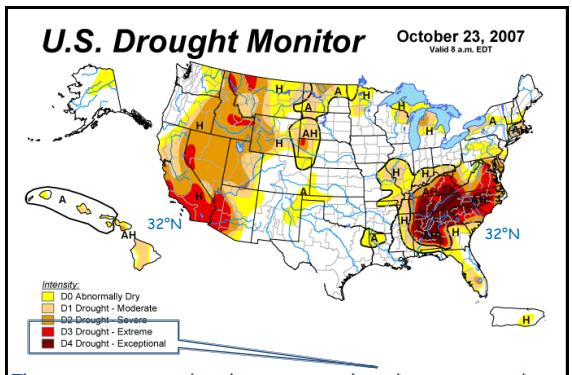


The trend has been sharply upward everywhere.

Drought



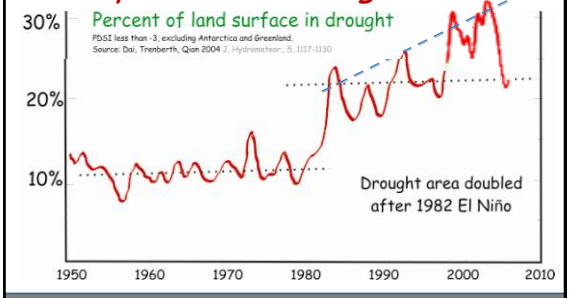
Vincent van Gogh, Olive Trees with Yellow Sky and Sun, 1889



The two most severe drought stages are plotted next, averaged over all of the global land surface except where ice sheets live.

The 1983 stepwise doubling of global drought

Abrupt climate change

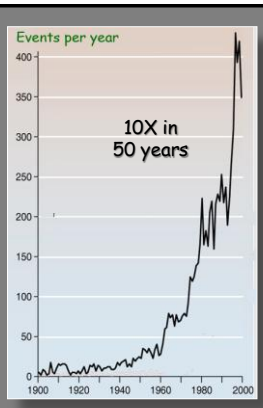


A half-century of global climate change

1. High winds (up 40%)
2. Heavy weather floods (up 10x)
3. Wildfires (up 10x)
4. Drought (abrupt doubling in 1983)
5. Ice melting (Arctic sea ice down 40%, Greenland melt area up 67%)

Those who aren't alarmed yet haven't been paying attention.

(Some try to re-frame the issues so narrowly as to avoid mentioning those 5.)



"All disasters" includes

- Drought*
- Earthquake
- Heat waves *
- Famine *
- Flood *
- Infestations *
- Land slides *
- Volcanic eruptions
- Storm surge *
- Wild fires *
- High winds *

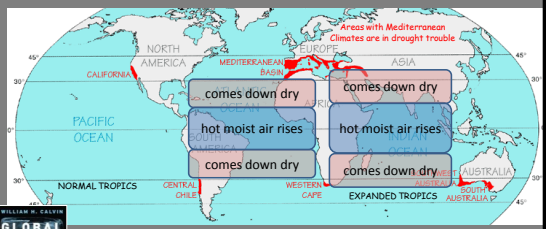
* increased by global fever

But the index does not include tornados.

http://en.wikipedia.org/wiki/Image:Trends_in_natural_disasters.jpg

www.spc.noaa.gov/wcm/

The expansion of the overheated tropics

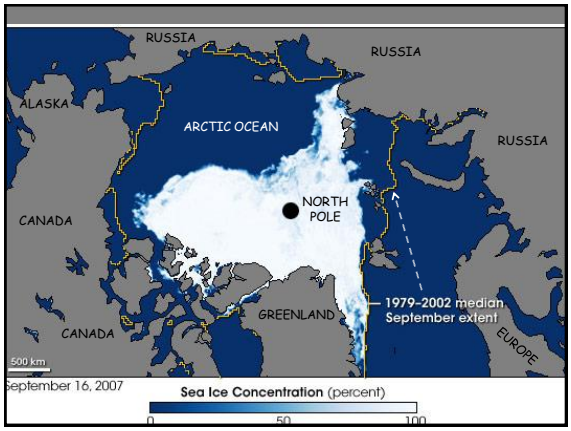


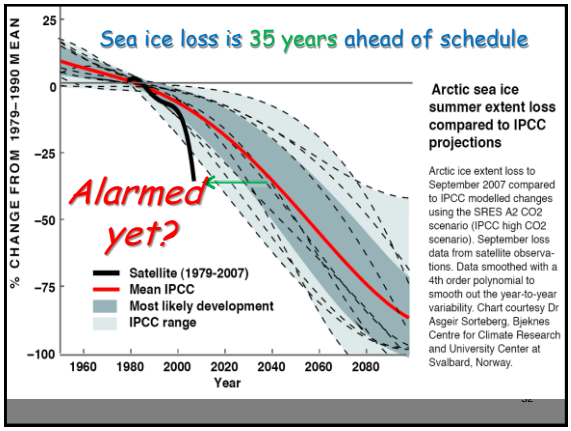
Alarmed yet?

Climate Briefings

How hot is it?

William H. Calvin
University of Washington
Global-Fever.org



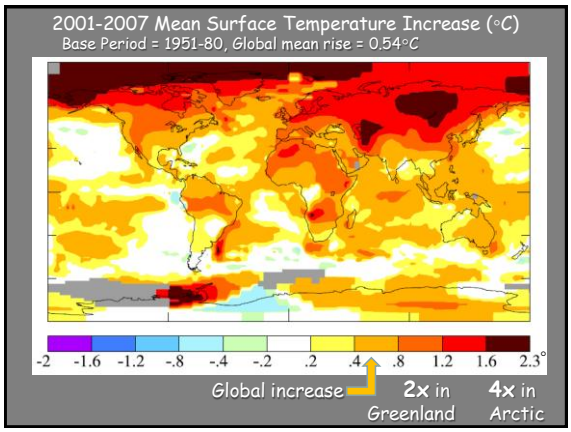


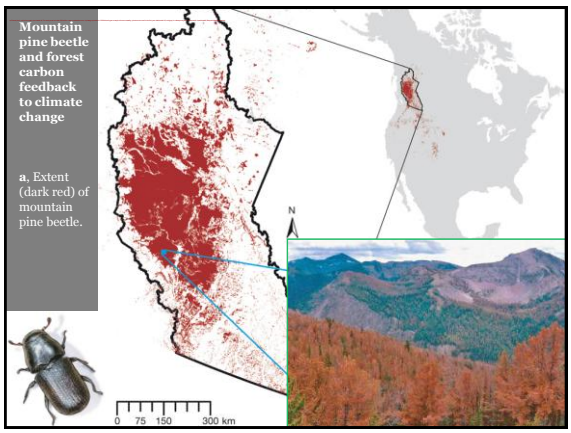
"Alarmists"?

Climate scientists have repeatedly *underplayed* threats, not overstated them.

What has outpaced climate scientists' most dire projections?

1. Arctic sea ice loss
2. Sea level rise since 1990
3. Carbon emissions since 1990 grew even faster than pessimistic Business As Usual scenarios.
4. Carbon emissions since 1956 (5X increase meant that present problems took only 50 years to arrive, not 200-300 years).

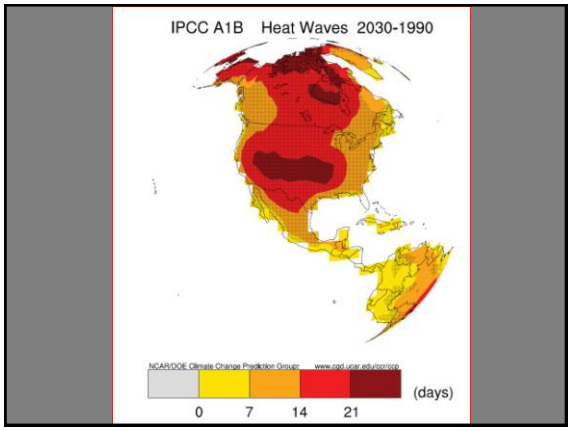




It's also getting warmer

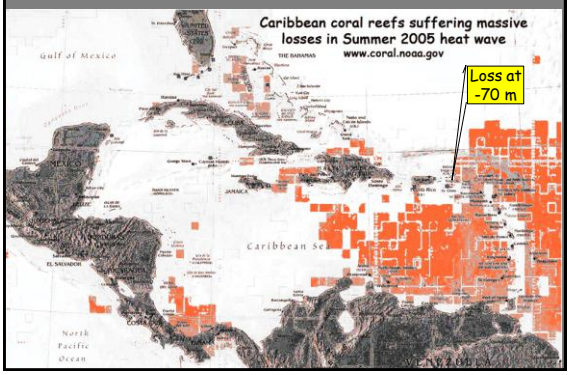
The 2003 heat wave in Europe killed 35,000 people.

Salvador Dalí *The Persistence of Memory.* 1931



Heat waves also kill coral.

Caribbean 2005 coral disaster



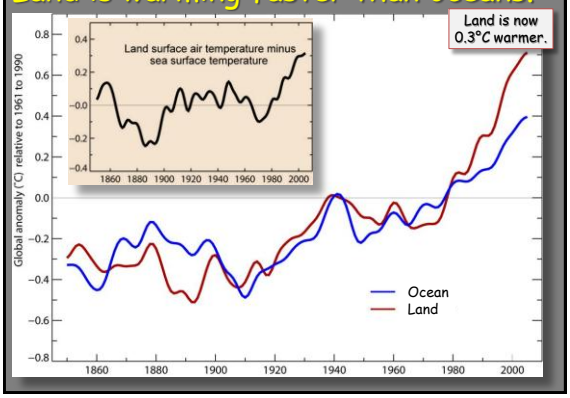
Timothy Keeney, NOAA's deputy assistant secretary for oceans and atmosphere, said 25 percent of all marine species need coral reefs to live and grow, while 40 percent of the fish caught commercially use reefs to breed.

Since NOAA's last report in 2005, the Caribbean region has lost at least 50 percent of its corals, largely because sea temperatures have risen, Keeney said.

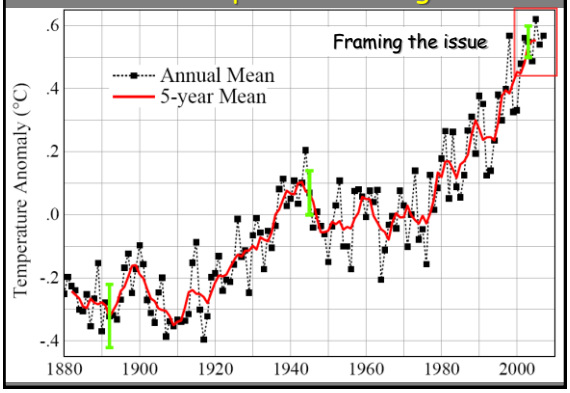
(NOAA press release, July 2008)

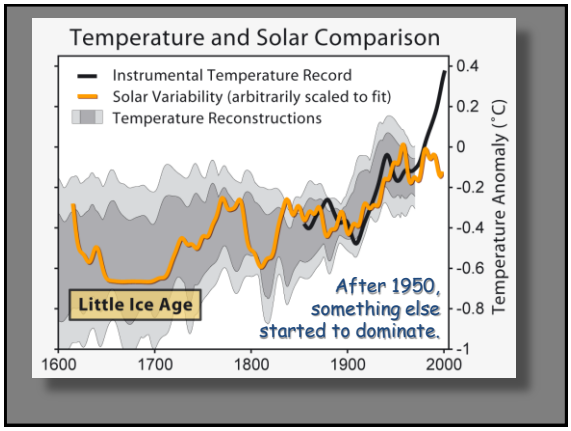
41

Land is warming faster than oceans.



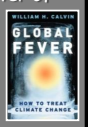
Global temperature change





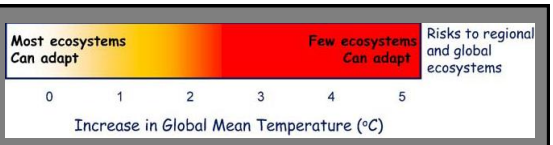
Global Mean Annual Temperature

Hold thermometer 1 meter above surface, average over globe (70% ocean). The interior of continents run a fever about twice that of coastal areas. So for a global fever of 2°C, think 4°C for the interior (about 7°F).



With a 2° fever (likely by 2050), we lose all of the mountain glaciers, all of the coral reefs, and create enough climate refugees to trigger resource wars and genocides.

A 1.6° fever will take Greenland into the local summer temperature range that produced a 6 m rise in sea level 125,000 years ago. (More later.)

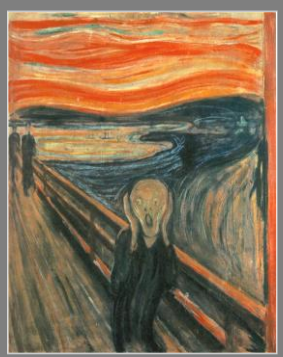


"At a rate of warming of 0.3°C per decade [reaching 3°C by 2100], only 30% of all impacted ecosystems can adapt [fast enough], and only 17% of all impacted forests."

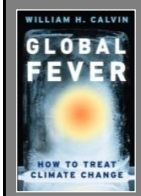
R. Leemans, B. Eickhout , "Another reason f
impacts on ecosystems for different levels o
Global Environmental Change 14 (2004) 21
doi:10.1016/j.gloenvcha.2004.04.009

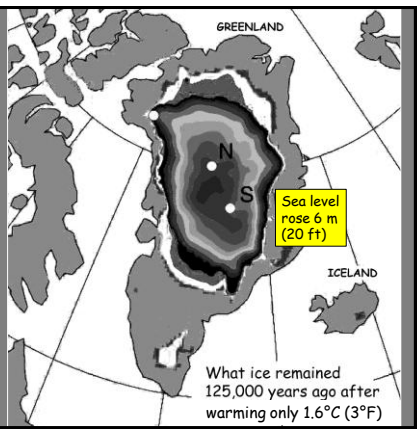
Alarmed yet?

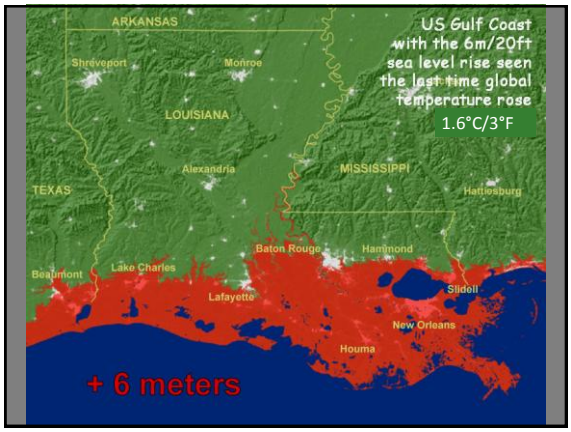
Sea Level Rise Refugees

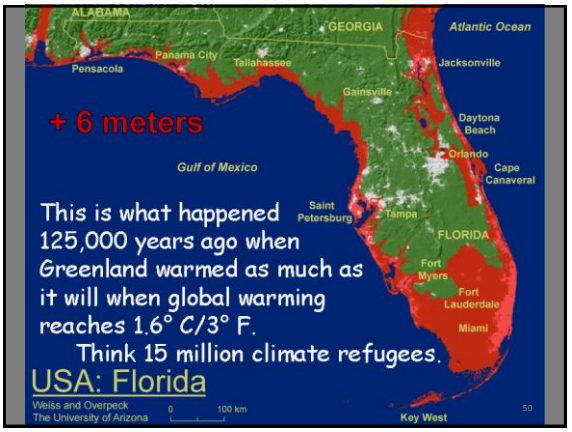


Edvard Munch, *The Scream*

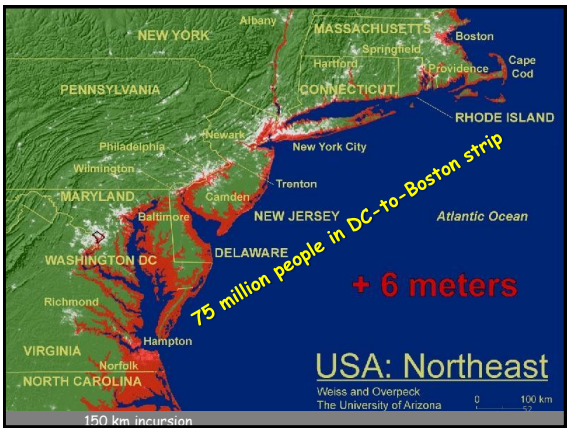




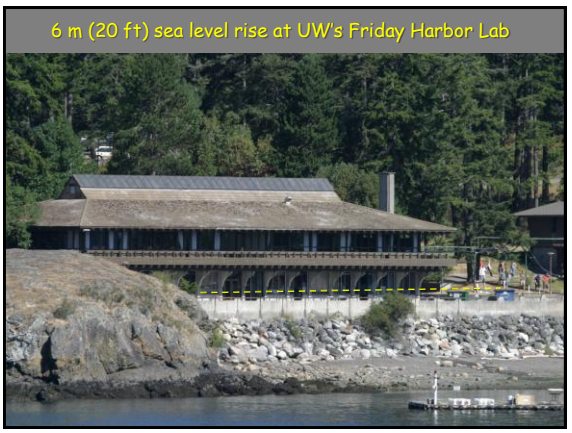

ARKANSAS
Shreveport
Monroe
LOUISIANA
TEXAS
Alexandria
MISSISSIPPI
Hattiesburg
Baton Rouge
Hammond
Beaumont
Lake Charles
Lafayette
Slidell
New Orleans
Houma
US Gulf Coast with the 6m/20ft sea level rise seen the last time global temperature rose 1.6°C/3°F
+ 6 meters


ALABAMA
GEORGIA
Atlantic Ocean
Panama City
Tallahassee
Pensacola
Jacksonville
Gainsville
+ 6 meters
Daytona Beach
Orlando
Gulf of Mexico
Cape Canaveral
This is what happened 125,000 years ago when Greenland warmed as much as it will when global warming reaches 1.6° C/3° F.
Think 15 million climate refugees.
Saint Petersburg
Tampa
FLORIDA
Fort Myers
Fort Lauderdale
Miami
USA: Florida
Weiss and Overpeck
The University of Arizona
0
100 km
Key West
50

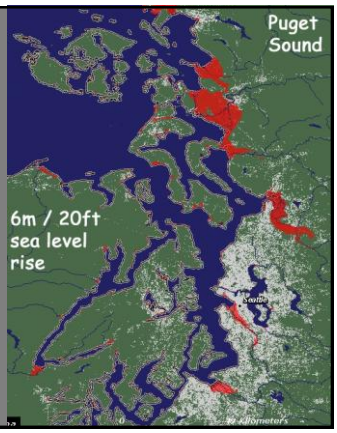

East and Gulf Coasts have very shallow slopes, so a 20 ft rise goes far inland.
Jamestown VA
Colonial Landscape
National Geographic, May 2007
Photograph by George Steinmetz


NEW YORK
Albany
MASSACHUSETTS
Boston
Springfield
Hartford
Providence
Cape Cod
PENNSYLVANIA
CONNECTICUT
RHODE ISLAND
Philadelphia
Newark
New York City
Wilmington
Trenton
MARYLAND
Camden
Baltimore
NEW JERSEY
Atlantic Ocean
WASHINGTON DC
DELAWARE
75 million people in DC-to-Boston strip
+ 6 meters
Richmond
Hampton
VIRGINIA
Norfolk
NORTH CAROLINA
USA: Northeast
Weiss and Overpeck
The University of Arizona
0
100 km
150 km incursion


GLOBAL FEVER
White House
Capitol Hill
Are they alarmed yet?
For Washington DC, dikes might suffice.
But for 12,000 miles of coastline along the gently-sloping East and Gulf Coasts…?
6 m (20 ft) rise in sea level

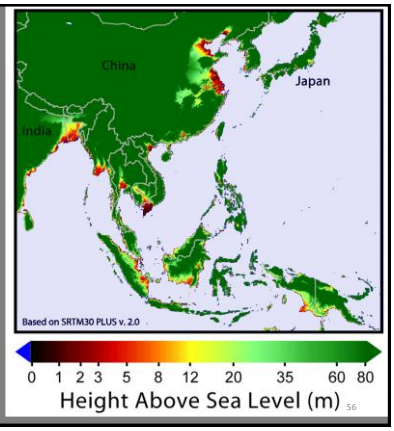

6 m (20 ft) sea level rise at UW's Friday Harbor Lab

At least, not very many people live in the low-lying areas of Washington State.



Many river deltas in Asia will be inundated.

70 million climate refugees, just from Bangladesh.



Any major downsizing usually involves

1. Famine
2. Pestilence
3. War
4. Genocide

Albrecht Dürer
The Revelation of St John: The Four Riders of the Apocalypse, 1497-98, Woodcut, 39 x 28 cm, Staatliche Kunsthalle, Karlsruhe

Majority hits on minorities

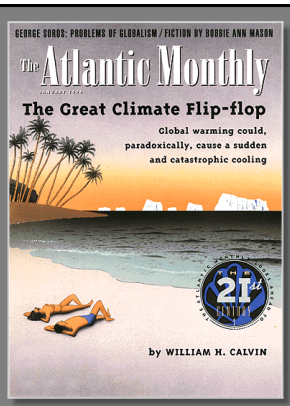
- Immigrants from Zimbabwe are better educated, so favored by employers.
- 1 in 4 is unemployed in South Africa.

A bad time to be any kind of a minority.

Francisco de Goya
El Tris de Mayo 1808

That's the kind of world we must avoid.

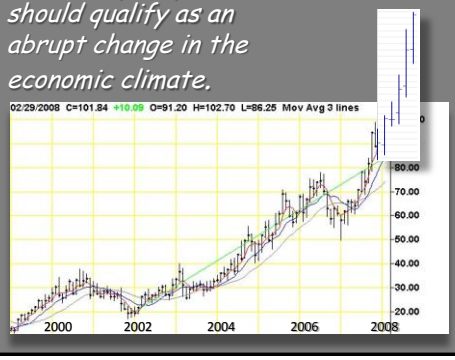
Abrupt Changes in Climate



The price of crude oil

10X in only 10 years should qualify as an abrupt change in the economic climate.

$142 on June 27



The people who study the abrupt climate shifts of the past have an aphorism:

Climate is like a drunk:

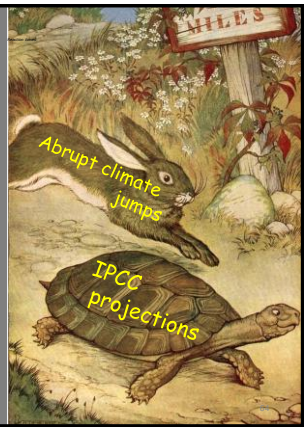
Left alone, it sits.

Forced to move, it staggers.

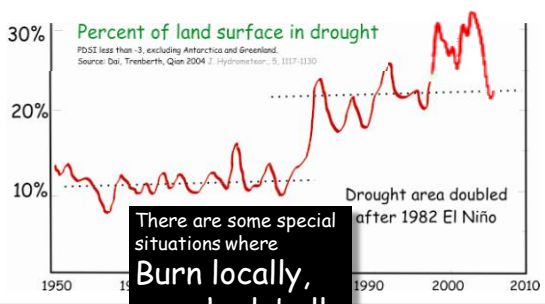
The Tortoise and the Hare is a fable attributed to Aesop. The hare soon left the tortoise far behind and decided to take a nap midway through the course. The tortoise, crawling slowly but steadily, won the race.

Think of our race finish line, however, as the drop off for a fast descent into Hell. The hare jumps and naps, but the tortoise's progress is slow and sure.

- The IPCC reports treat climate as if it moved in a stately manner like a tortoise.
- They all assume that the Hare conveniently takes a long nap.
- *That is not a safe assumption.*



The 1983 stepwise increase in global drought



There are some special situations where

Burn locally, crash globally

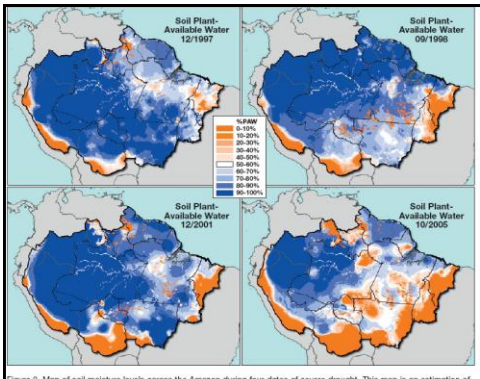
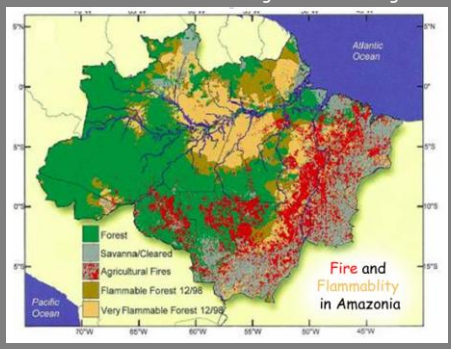


Figure 2. Map of soil moisture levels across the Amazon during four dates of severe drought. This map is an estimation of the percentage of maximum, plant-available soil water (PAW) to 10m depth based on cumulative monthly rainfall and evapotranspiration, updated from Nepstad et al. 2004. Field studies indicate that drought-induced tree mortality begins when PAW declines to 30 per cent of its maximum value (Nepstad et al. 2007), mapped here as tan to brown. Soil moisture depletion is overestimated along the Andes because of data shortages and interpolation errors.

Daniel C. Nepstad (2007), "The Amazon's Vicious Cycles: Drought and Fire in the Greenhouse." A report to the World Wide Fund for Nature (WWF), p.7

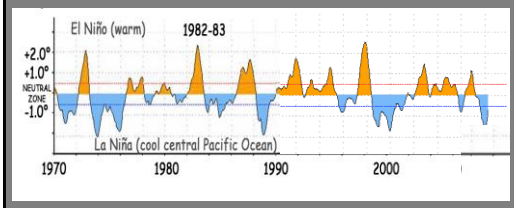
The Amazon is drying & burning under the influence of deforestation & climate-change-induced drought



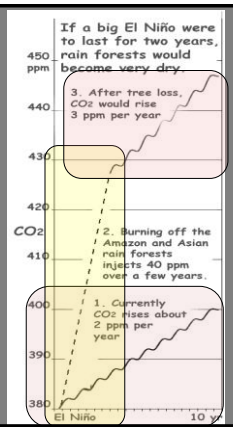
Just after 1998 El Niño Nepstad et al., *Forest Ecology & Management* 154, 2001

How to rearrange atmospheric circulation in only a few months

All it takes is a big El Niño.



If a big one lasted two years instead of one….



Burn locally, crash globally

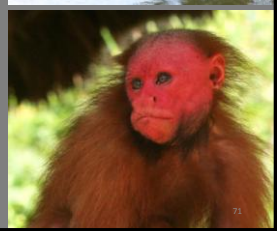
On top of that, a 50% increase in the *rate of CO_2 growth thereafter*, due to loss of carbon sinks.

50% increase in excess CO_2 within a few years

We could lose our maneuvering room and go into a tailspin.

Matt Collins in *Scientific American* 2008

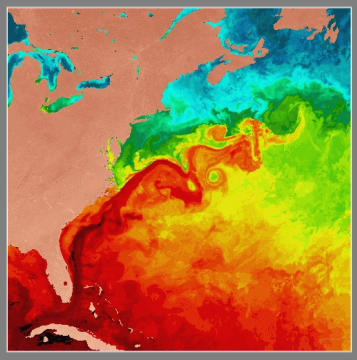
The Big Burn also causes a mass extinction event: *about half of all Amazon species will go extinct.*



Three of the six species of apes live in SE Asia forests.

Here, orangutan and siamang.

What to do?



Gulf Stream in false color

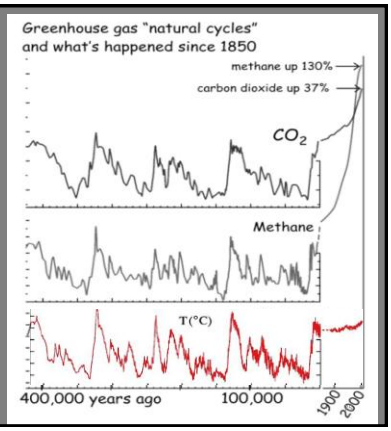
Policies for restoring climate

1. New-style coal plants?
   a. CCS has 40% efficiency hit
2. Not just CO2 but CO2e (methane, nitrous); makes agriculture just as bad a GHG problem as transportation.
3. Transportation Goes Electric
4. Taking carbon out of circulation

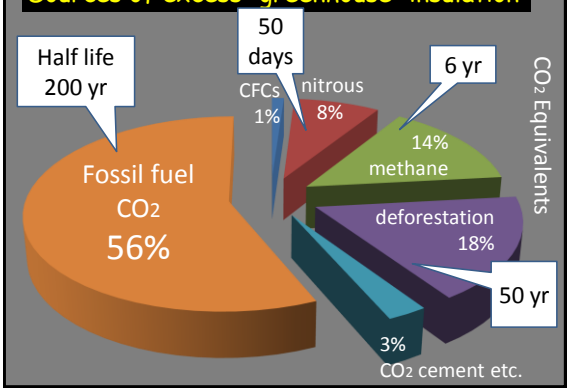
Spike in Methane and in CO_2.

Since methane is 23X as potent as CO_2, can multiply concentration by 23 and add to CO_2.

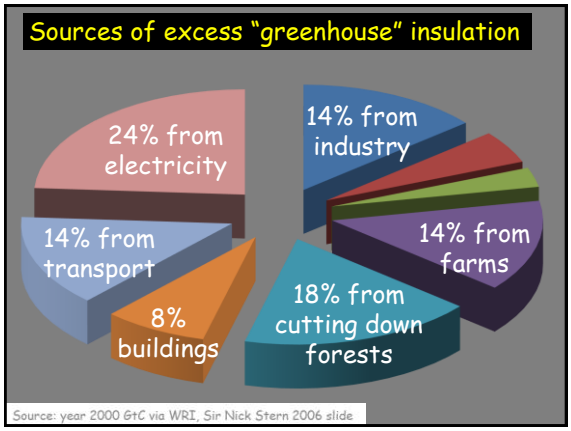
Can do "CO_2 equivalents" for N_2O and others.

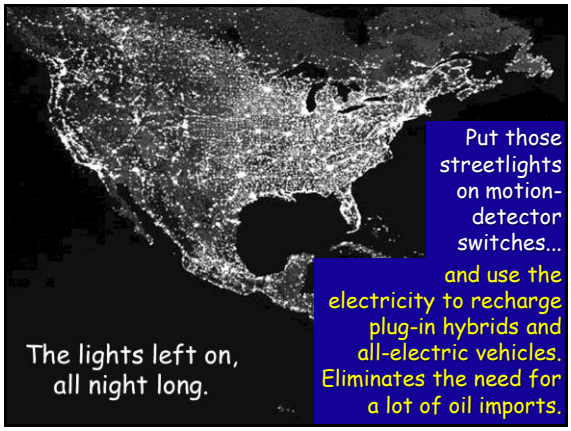


Sources of excess "greenhouse" insulation



Sources of excess "greenhouse" insulation





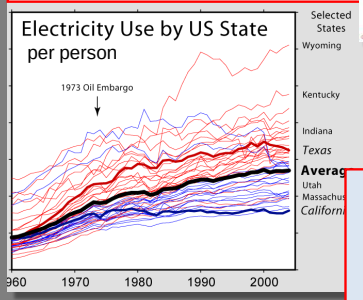
Transportation goes electric

Plug-in hybrid (Prius with extra batteries, recharged overnight in garage)

the elephant in the room

"A large issue with influence over a discussion that is not mentioned by the participants."

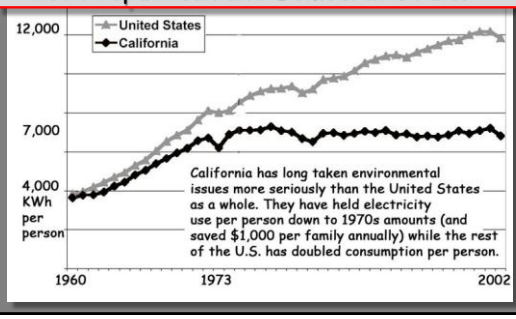
The elephant in the room is an _

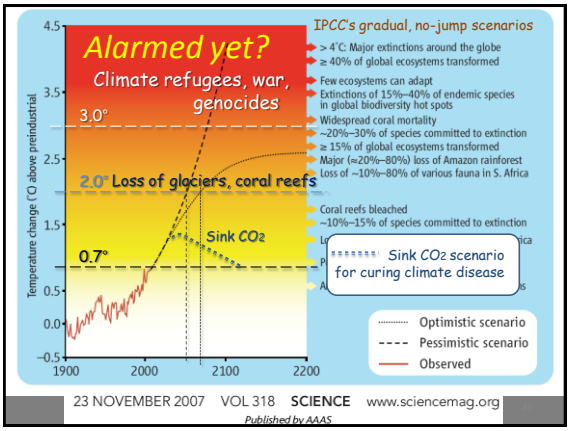


Different attitudes toward using policy to promote a "public good"?

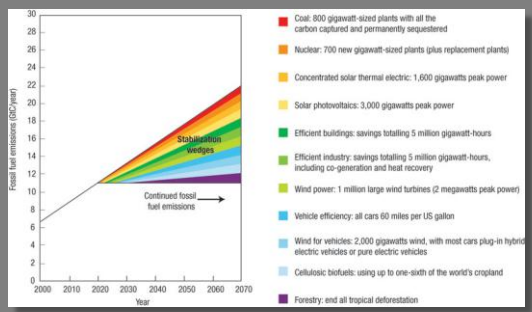
Public policy makes a big difference.

The case of post-1973 California under both Republican and Democratic rule.

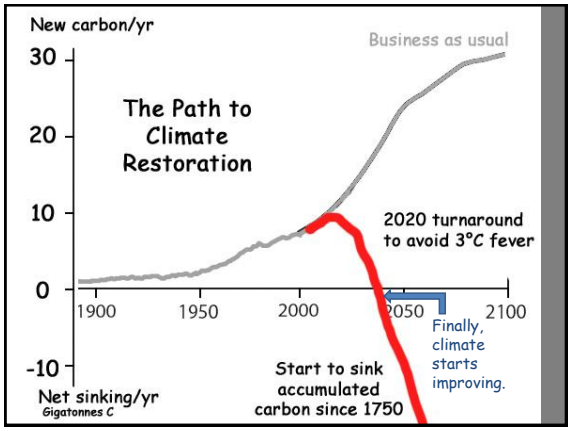




Wedges strategy for "stabilization."



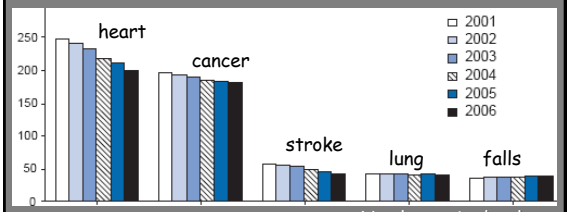
Joseph Romm, *Nature Reports Climate Change*, 19 June 2008



The Climate Optimist

J. M. W. Turner
Norham Castle

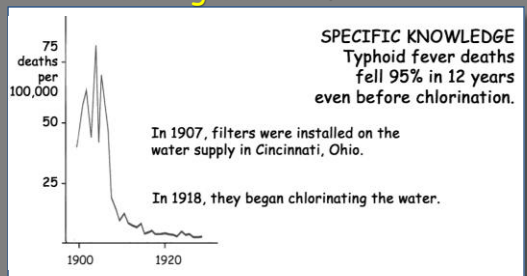
A progress report



For the leading causes of death, there has been a drop of 10-20% in only 6 years.

No change in deaths from a fall or from asthma-bronchitis-emphysema (80% of the lung deaths are ex-smokers).

Infections used to be the leading cause of death.



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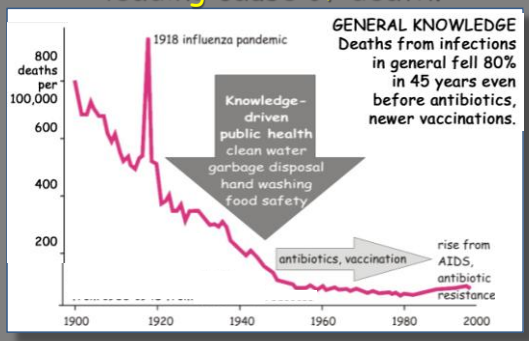


The climate optimist

pp.274-5 in c

In the 1960s and 1970s, we

1. discovered the *genetic code*, *continental drift*, and *chaos theory*,
2. put *communication satellites* in geosynchronous orbits,
3. *went to the moon*,
4. *did heart transplants*,
5. *invented the Internet, personal computers*, *email* and *spreadsheets*.

The climate optimist

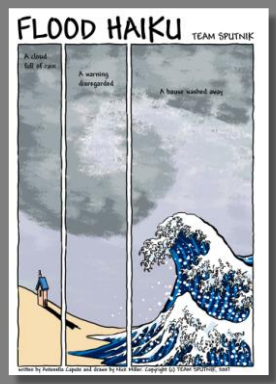
pp.274-5 in *Global Fever*

- Much can happen in only twenty years.
- With our current scientific momentum, the *Third Industrial Revolution* has likely started — but now it needs to be *fast and focused.*

Climate Briefings

Getting out of this mess

William H. Calvin
University of Washington
Global-Fever.org

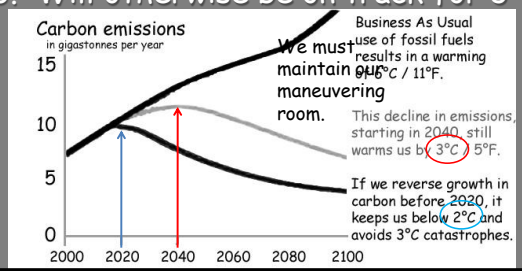


REDUCING EMISSIONS IS NOT ENOUGH:
Must take excess carbon *out of circulation*

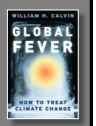
1. ~~Plant many more trees~~
2. Manage the ocean to sink more CO_2
3. Wave-driven pump to carry surface waters down to depths.
4. Artificial photosynthesis
5. Burn *biomass,* capture and store CO_2
6. Pipe untreated sewage to deep ocean.

Requires a big effort up front because

1. Already in danger zone for jumps.
2. Need safety margin for later.
3. Will otherwise be on track for 3°C



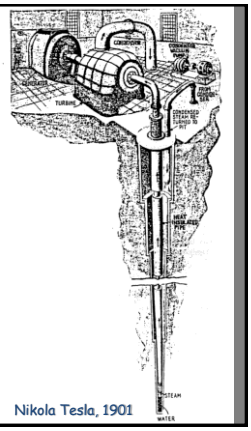
Why the *Climate Fix* needs to be primarily *Technofix*



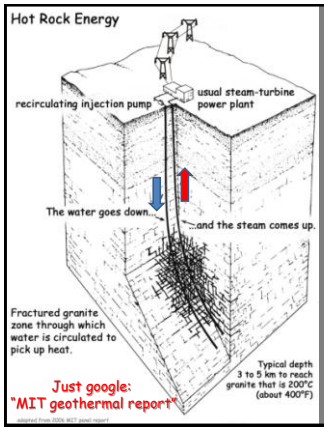
1. Need to bypass Tragedy of the Commons stalemates like Kyoto.
2. Need something that will prevent developing countries from repeating our mistakes. Some governments will prove incompetent so need cheap innovations.
3. Need big progress in next ten years.
   - Clone and give away existing solutions in exchange for banning fossil fuel extraction.

400°F pizza oven

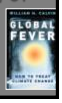
Hot Rock Geothermal



Nikola Tesla, 1901



- Deep geothermal ("heat mining") pumps down water, gets steam back up to run steam turbine.
- No pollution, small footprint, steady output.
- Also suitable for developing countries.

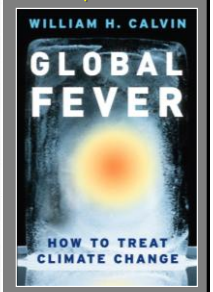


Ranking the Major C-free Candidates
for turning around emissions growth by 2020

		Ability to expand	Public view	Down side	Ups & downs	Foot print	Storage needed	Enough by 2020?
ENERGY	Hot Rock Energy	huge	Just another well?	Year of small EQs?	very stable	very small	none	•••• to ••
	Nuclear	10X	caution	many	steady	mining	spentfuel	••• to •
	Solar	lots	OK	few	night, clouds	multi use	some	••
	Wind	lots	ugly	noise, bird kills	fickle & unstable grid	multi use	some	••
	Biofuels	compete with food	organic fuel	not C-neutral	drought	huge	some	•
	High-rise Hydro	nearly full	nice lakes	dam failure	drought	large	lakes	no
	Coal but capture the CO_2	large	caution	storage burp	steady	67% more coal	huge	no
OTHERS	Plankton iron blooms	large	caution	side effects?	likely	fleet of ships	some	•
	Plug-in hybrid cars	large	very good	mining battery				•••
	Compressed air car	large	none yet	air tanks				•
	Improve efficiency	good	in favor	slow grind	–			•
	Energy Diet	limited	a pain	easy to fail	yo-yo			no

Not comprehensive. Opinionated. Likely outdated (updates at *Global-Fever.org*).

The table is from Chapter 19 in



Global-Fever.org

Thanks to science, we have good abilities to look ahead — and backpaddle furiously.

URGENT: There is not time for mass education or for researching a best or safest solution to our climate crisis.

We are already into a planetary emergency and must respond with the vigor with which countries have prepared for war.

President Franklin D. Roosevelt used the metaphor of a "four alarm fire up the street" that needed to be extinguished immediately, whatever the cost.

> From a standing start in late 1941, the automakers converted—in a matter of months, not years—more than 1,000 automobile plants across thirty-one states . . . In one year, General Motors developed, tooled, and completely built from scratch 1,000 Avenger and 1,000 Wildcat aircraft . . . GM's duck `was designed, tested, built, and off the line in ninety days' . . . Ford turned out one B-24 [bomber] every 63 minutes.
>
> —Jack Doyle, *Taken for a Ride*, 2000

Now there's a source of optimism: *We did it before.*

The End

My books and talks may be found at:

WilliamCalvin.com