

Earth's Climate: Past, Present and Future

OLLI South Spring 2017:

week 7 (May 11th) & week 8

Paul Belanger

Solutions – part A:

The Ultimate Primary Focus: Energy and Sequestration of CO₂

Announcements

The March





Energy and Environment

EPA website removes climate science site from public view after two decades

By **Chris Mooney** and **Juliet Eilperin** April 29 at 8:28 AM 



Most Read

- 1 EPA website removes climate science site from public view after two decades



- 2 The most common reason people quit their \$200,000 tech jobs



- 3 Representative



Backup sites

- <http://www.epaarchive.cc/climatechange/>
- https://19january2017snapshot.epa.gov/climatechange_.html

Controversy over NY Times hiring

Secure | <https://www.nytimes.com/2017/04/28/opinion/c>

Create a Meetup AHPS Precipitation An Wx WxCoder III - observat

The Opinion Pages | Climate of Complete Certainty

13.  OP-ED COLUMNIST Climate of Complete Certainty

14.  How Trump Has Reshaped the Presidency, and How It's Changed Him, Too

15. 

The Opinion Pages | OP-ED COLUMNIST

Climate of Complete Certainty

 **Bret Stephens** APRIL 28, 2017

https://www.nytimes.com/2017/04/28/opinion/climate-of-complete-certainty.html?em_pos=large&emc=edit_ty_20170429&nl=opinion-today&nid=57511464&ref=headline&te=1

Niskanen Center

Sample topics:

- MARCH 23, 2015 *THE CONSERVATIVE CASE FOR A CARBON TAX*
- *IN DEFENSE OF CARBON TAXES: MANHATTAN INSTITUTE EDITION*
- *DIRECTING THE ANGER OVER TRUMP'S CLIMATE EXECUTIVE ORDERS*
- *A GUIDE TO THE CLIMATE DEBATE*
- *NUCLEAR'S (4TH GENERATION) COMEBACK TOUR*
- *DIRECTING THE ANGER OVER TRUMP'S CLIMATE EXECUTIVE ORDERS*
- *THE OBAMA CLIMATE LEGACY*

The Intercept

- **HOW A PROFESSIONAL CLIMATE CHANGE DENIER DISCOVERED THE LIES AND DECIDED TO FIGHT FOR SCIENCE: - MUST READ**
 - STORY OF JERRY TAYLOR BROTHER OF HEARTLAND'S LOBBYIST JAMES TAYLOR
- [HTTPS://THEINTERCEPT.COM/2017/04/28/HOW-A-PROFESSIONAL-CLIMATE-CHANGE-DENIER-DISCOVERED-THE-LIES-AND-DECIDED-TO-FIGHT-FOR-SCIENCE/](https://theintercept.com/2017/04/28/how-a-professional-climate-change-denier-discovered-the-lies-and-decided-to-fight-for-science/)

Climate Connections

click on link for more

Worrisome first quarter of 2017 climate trends

The year is off to a toasty start globally ... and not in a comforting way for those concerned about another year of high temperatures, sea ice record lows at both Poles, and mounting risks to coral reefs.



By [Zeke Hausfather](#)

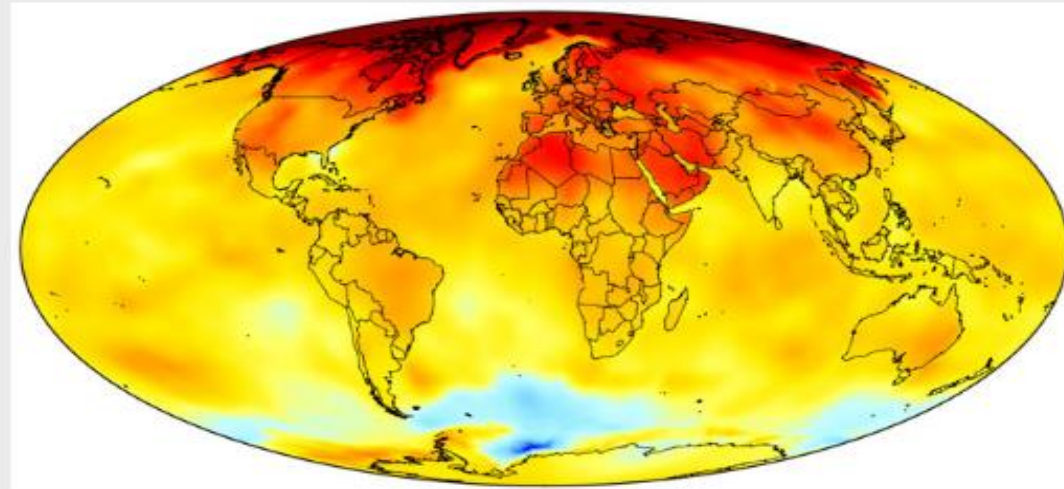
Thursday, April 27, 2017

TOPICS

[Oceans](#), [Polar Ice](#), [Science](#)

Recent Posts

- [Reversing climate change](#)
- [Columnist: 'Swamped' coastal Louisiana](#)
- [Georgia island confronts 'blue](#)



With the first quarter of 2017 now past, the year is shaping up to be one of climate extremes: high temperatures, low sea ice, and coral bleaching.

<https://www.yaleclimateconnections.org/2017/04/worrisome-first-quarter-of-2017-climate-trends/>

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Solutions – part A

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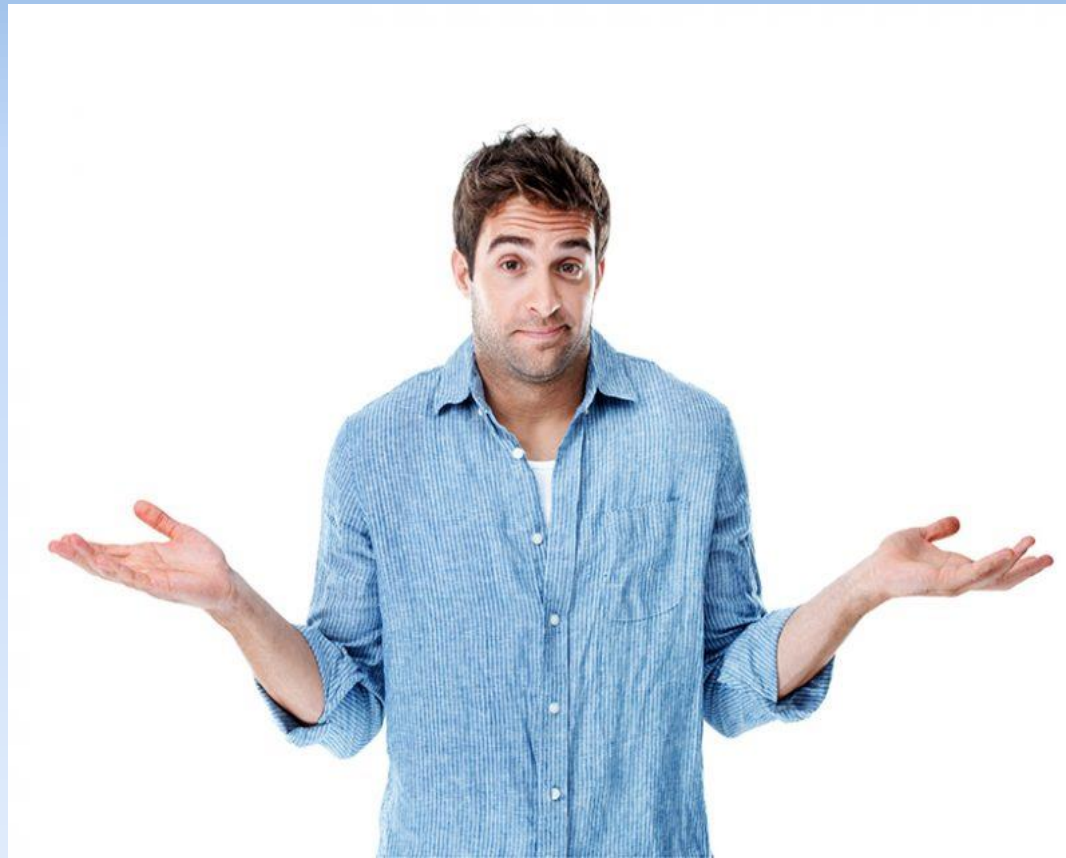
1. Economics
 - of doing nothing (solely adapting) vs. the economics of mitigation
 - Actuality: it WILL be a combination
2. Capitalism, GDP/growth based economics vs. “Herman Daly” economics (no-growth/steady-state)
3. Solutions? Paradigm shift? From we can't/too expensive to WE CAN
4. There is promise, but at what cost? (One might be surprised).
 - Energy
 - Mitigation – Agricultural revolution/biofuels: Biochar for Carbon Dioxide Removal (CDR)

The economics/the solutions? Continued

Next week: Solutions – part B

5. Geoengineering:
 - Solar Radiation Management (SRM) and
 - Carbon Dioxide Removal (CDR)
6. Biochar vs. BECCS solutions SEE MY BIOCHAR LINK IN OTHER PAGES:
http://denverclimatestudygroup.com/?page_id=28
7. Efficiency – the single quickest way to reduce:
 - What NREL is doing: Efficiency, Solar, wind, other
8. Other strategies:
 - CCL – carbon fee/dividend
 - Cap and trade?
9. Gloom and Doom? NO! IT'S A CHALLENGE, and humanity has always been challenged and we are an adaptable species that has met the challenge over and over again!

How to Overcome our Inertia and Apathy



The American Public and Climate Change

Yale Program on Climate Change Communication

Climate Change and the American Mind
- November, 2016

- 70% believe global warming is occurring
- 55% understand it is caused by human activity
- **Only 5% believe anything can or will be done**

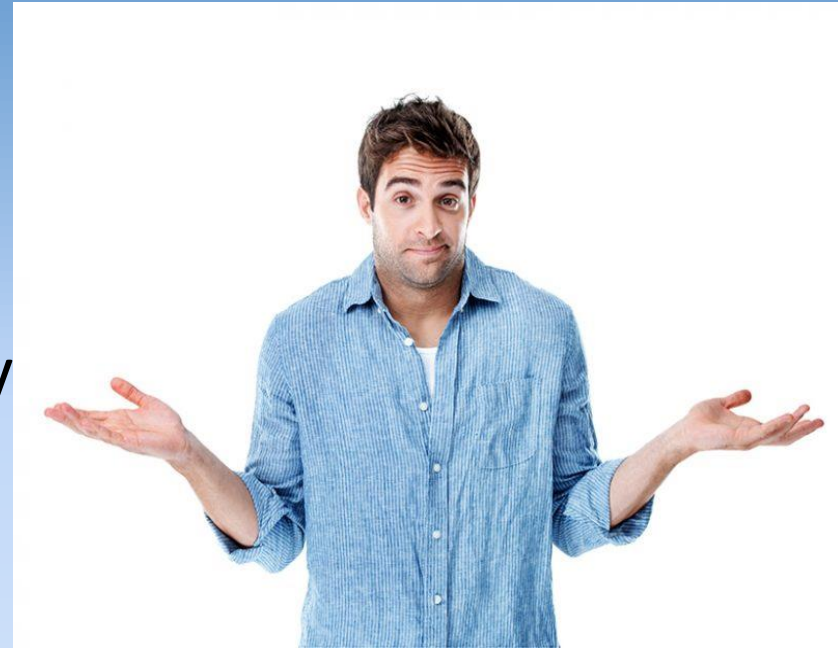
<http://climatecommunication.yale.edu/>

Kathleen Wells, Denver CCL, 2017

APATHY / INERTIA

WHY?

- IT'S too late
- It's too big a problem
- It's up to the government
- I'm not long for here anyway
- It's too expensive
- I'm too busy



<https://eos.org/articles/climate-scientists-new-hurdle-overcoming-climate-change-apathy>

APATHY / INERTIA vs. good motives:

- IT'S our planet
- It's the right thing to do
- I CARE FOR FUTURE GENERATIONS!
- It's for our grandkids, or dogs or cats
- I believe in promoting the best of human values by example



<https://eos.org/articles/climate-scientists-new-hurdle-overcoming-climate-change-apathy>

SOLUTIONS TO APATHY

#1 - CHANGE OUR WAY OF THINKING

Changing World Views

....We live in Colorado where you can find fossils of fish, reptiles, mastadons (sic) and dinosaurs in our mountains that used to be under a friggin (sic) ocean.

....You're just now figuring out that things change on this planet? **They always have, they always will**, and it's the height of arrogance to think you can do anything about it.

<http://www.denverpost.com/2017/05/05/keegan-hed-goes-here-2/> Excerpt from Ctaj – Mtg broker comments in reply to DP 5/7/201 Teresa Keegan Op-Ed There's no such thing as settled science, and that's a fact

Changing World Views

....and it's the height of arrogance to think you can do anything about it.

Well – after this week and next I hope you become convinced that **YES WE CAN!**

<http://www.denverpost.com/2017/05/05/keegan-hed-goes-here-2/> Excerpt from Ctaj – Mtg broker comments in reply to DP 5/7/201 Teresa Keegan Op-Ed There's no such thing as settled science, and that's a fact

Changing World Views

World view Backfire effect

<https://www.youtube.com/watch?v=CtSk03efSqQ&feature=youtu.be>

Decisions

- David Grinspoon:

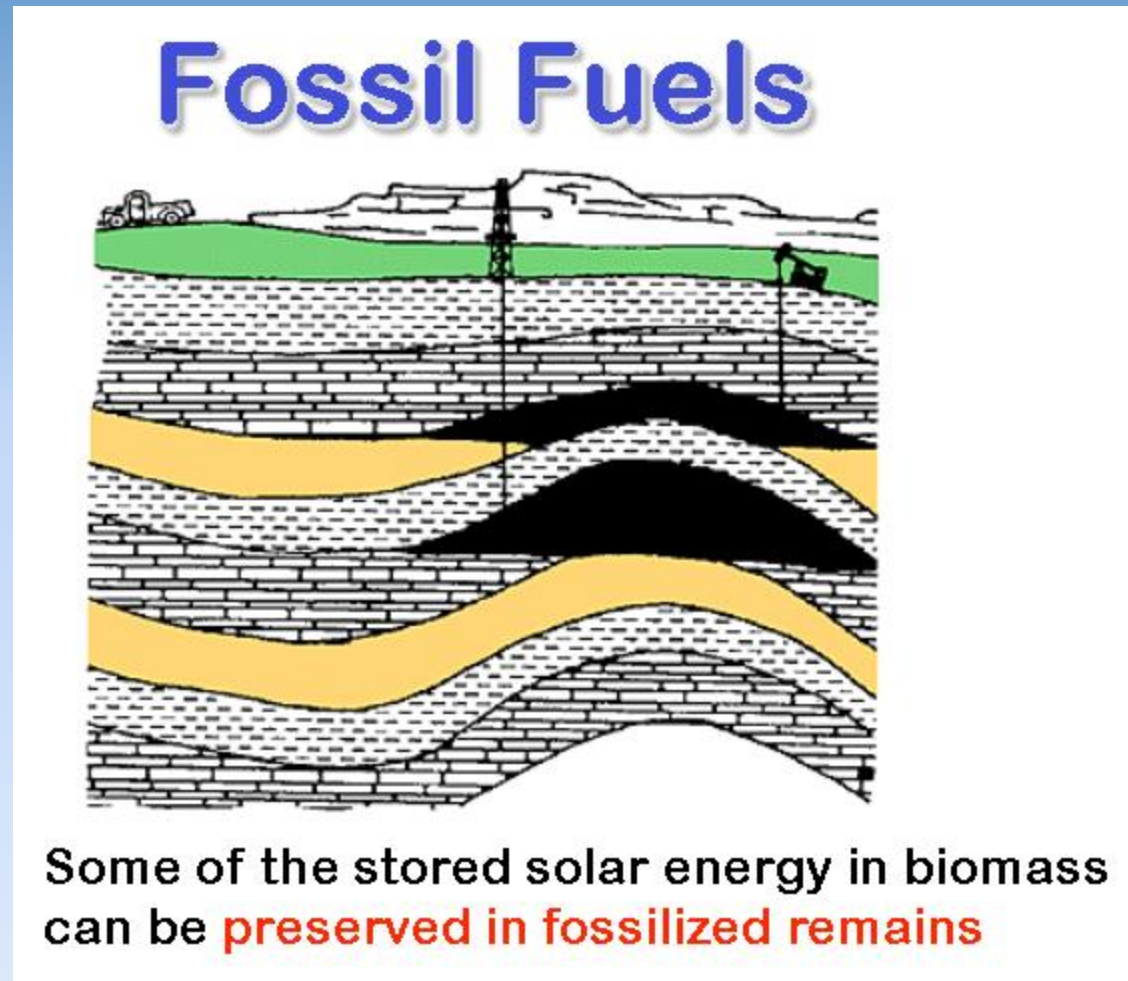
“The decisions we make today will have an impact not only on this 21st century but on the 22nd and 23rd centuries and beyond”

FIRST

- **I hope you are convinced**
 - **climate change is happening at an unprecedented rate**
 - **There are unknown implications of ocean acidification at these rates of change**
 - **There are economic repercussions**
 - **due to sea level rise**
 - **increased incidents of severe weather**
 - **Agricultural**
 - **Etc.**

Fossil fuels: oil, gas, coal

- We owe a lot to fossil fuels
- It's only recently we've fully appreciated its consequences
- It's time for change!



Job Creation

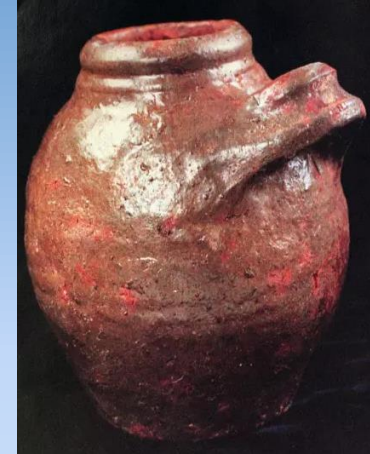
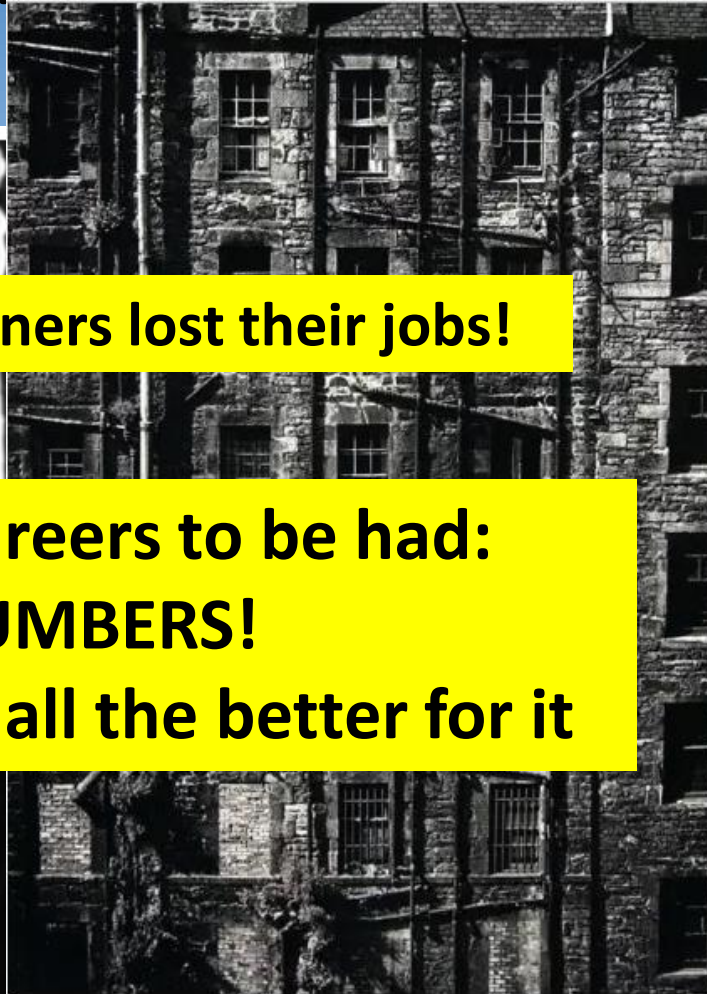
- A reading: Richard Alley's a Terrible shower – transitions are not without difficulty – but also with opportunity
- <http://denverclimatestudygroup.com/wp-content/uploads/2015/10/A-terrible-shower.pdf>
- For more on solutions in Energy and jobs go to my other course – especially weeks 5 and 6; week 8 not posted yet @ http://denverclimatestudygroup.com/?page_id=2224 Monday classes
Spring 2017

Gardyloo “Gardez L’eau”: The grim story of unsanitary Edinburgh



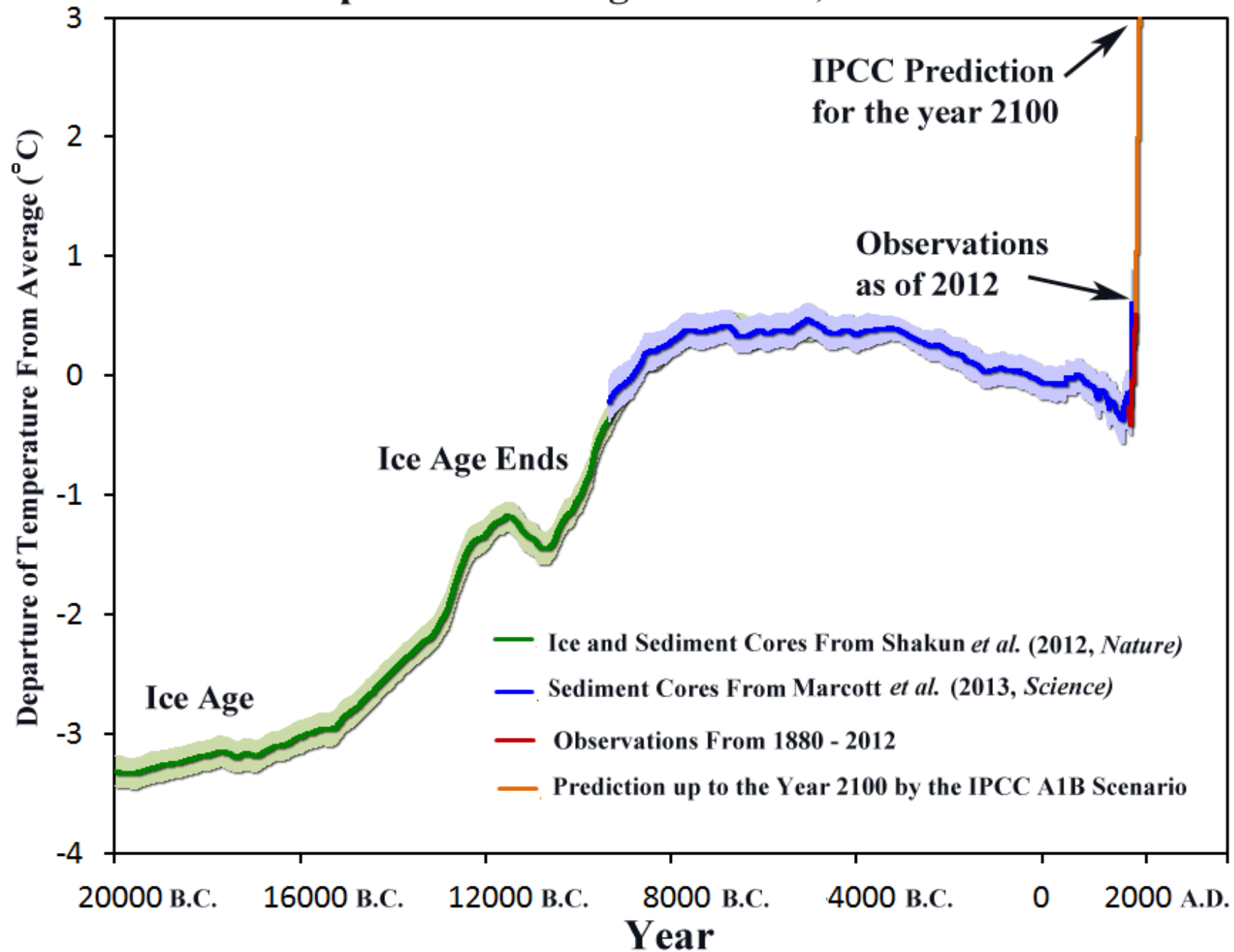
The street cleaners lost their jobs!

**But new careers to be had:
PLUMBERS!
And we were all the better for it**



<http://www.scotsman.com/heritage/people-places/gardyloo-the-grim-story-of-unsanitary-edinburgh-1-4073295>

Global Temperature Change From 20,000 B.C. to 2012 A.D.

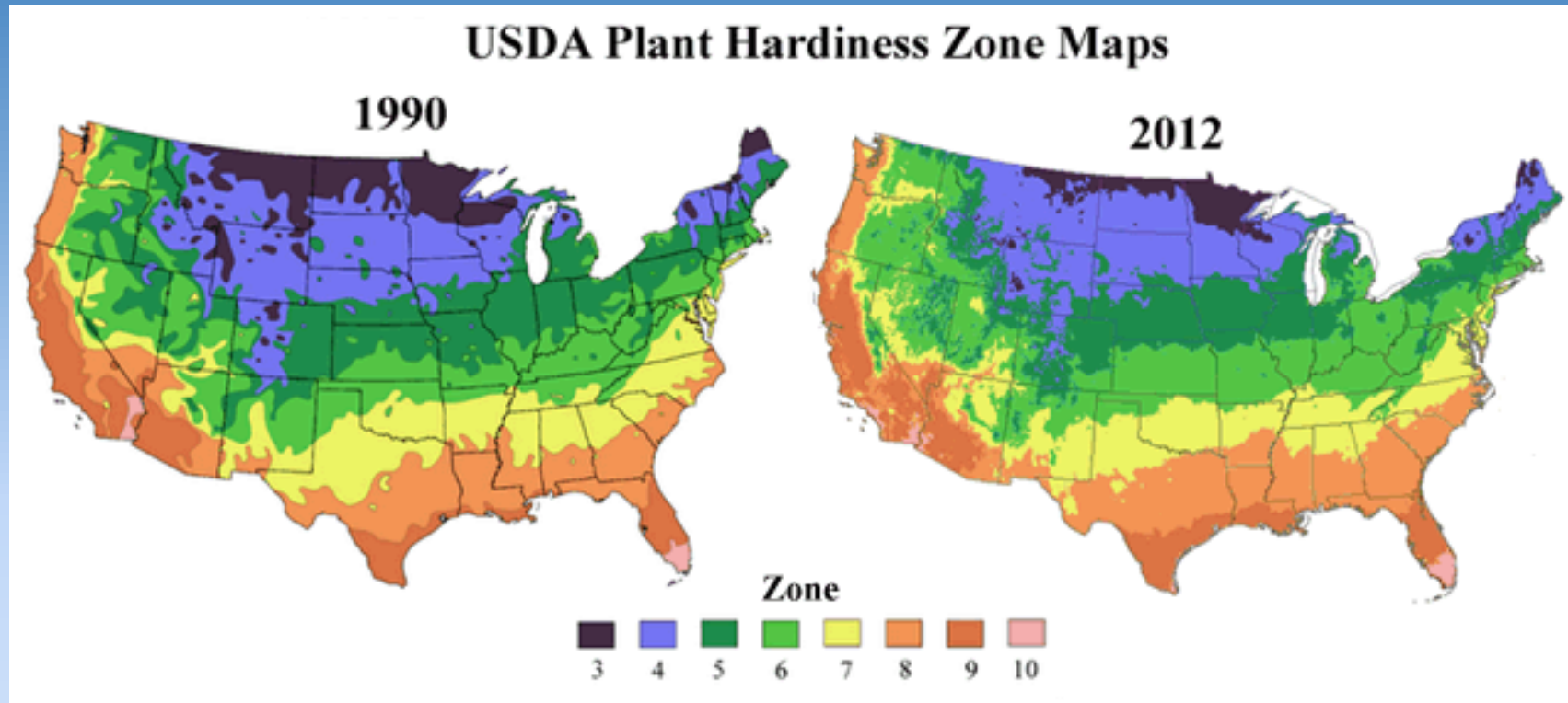


Compare next 2 slides

- Notice the difference between 2012 and 2015 – 3 YEARS!

Plants and Animals are Responding to a Warming Climate

1990 vs. 2012

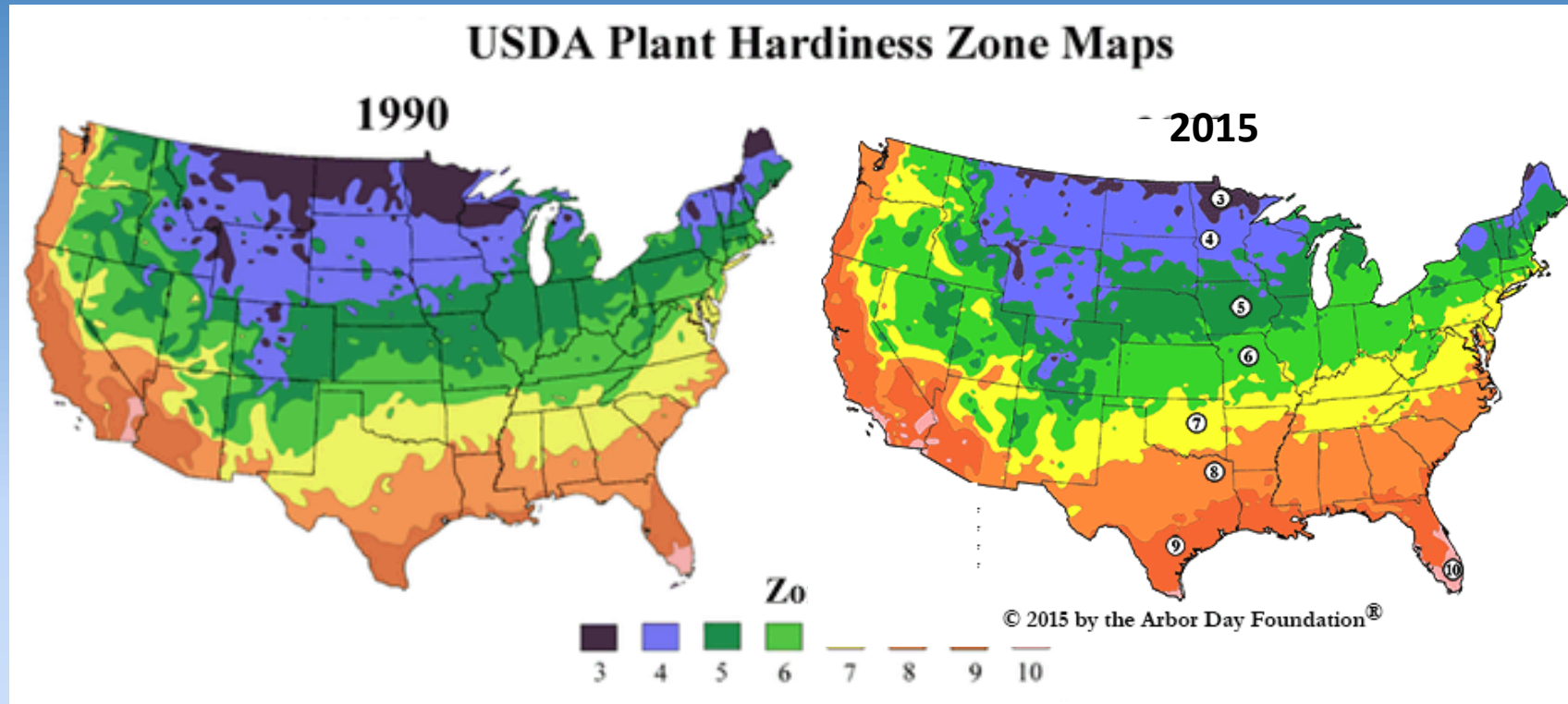


Spring is springing forward: Spring events, like bird and butterfly migrations, flower blooming times, and frog mating, have been advancing by about three days per decade over the past 30 years.

Source: Jeong et al., 2011, "Phenology shifts at start vs. end of growing season in temperate vegetation over the Northern Hemisphere for the period 1982–2008"

Plants and Animals are Responding to a Warming Climate

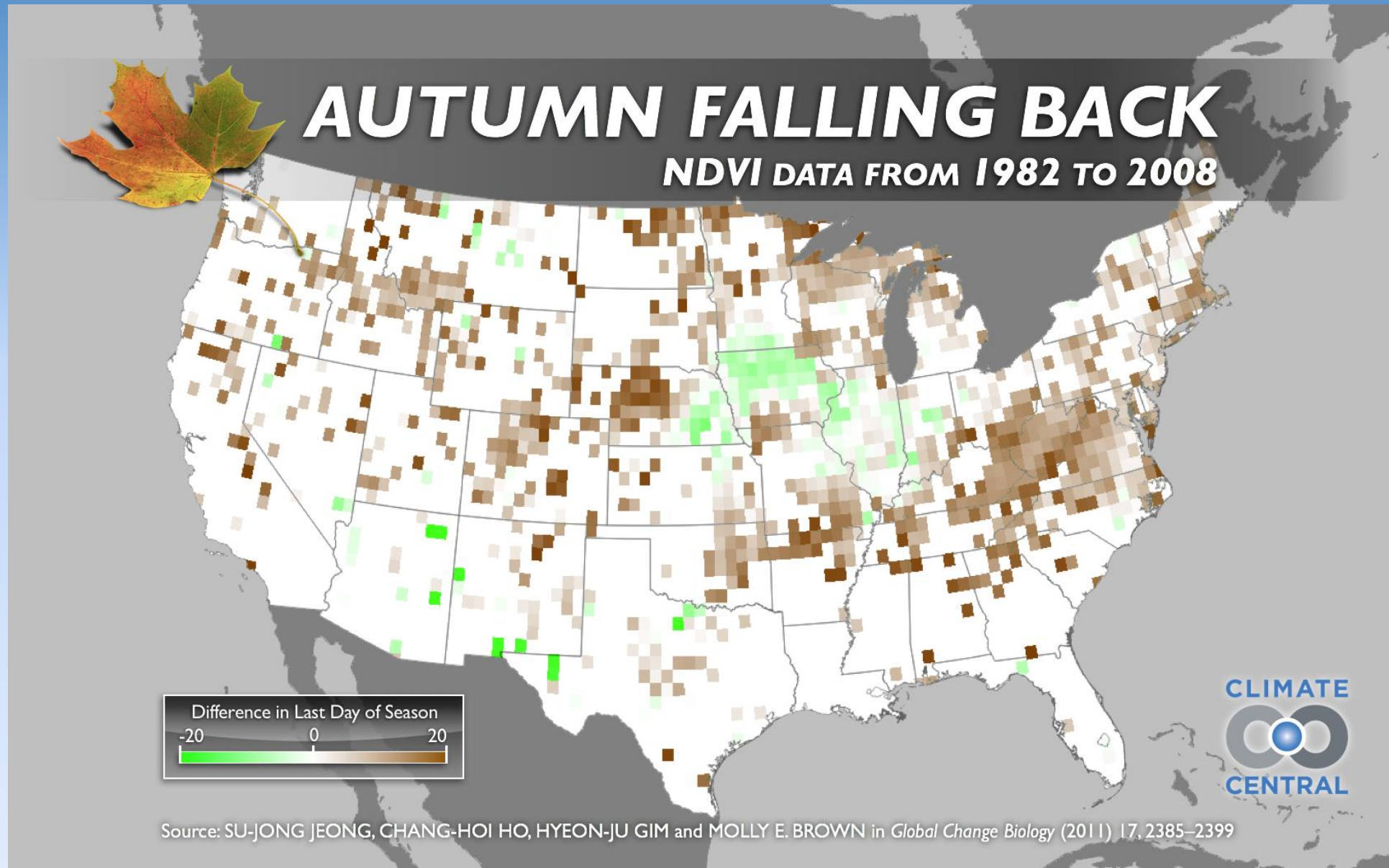
1990 vs. 2015



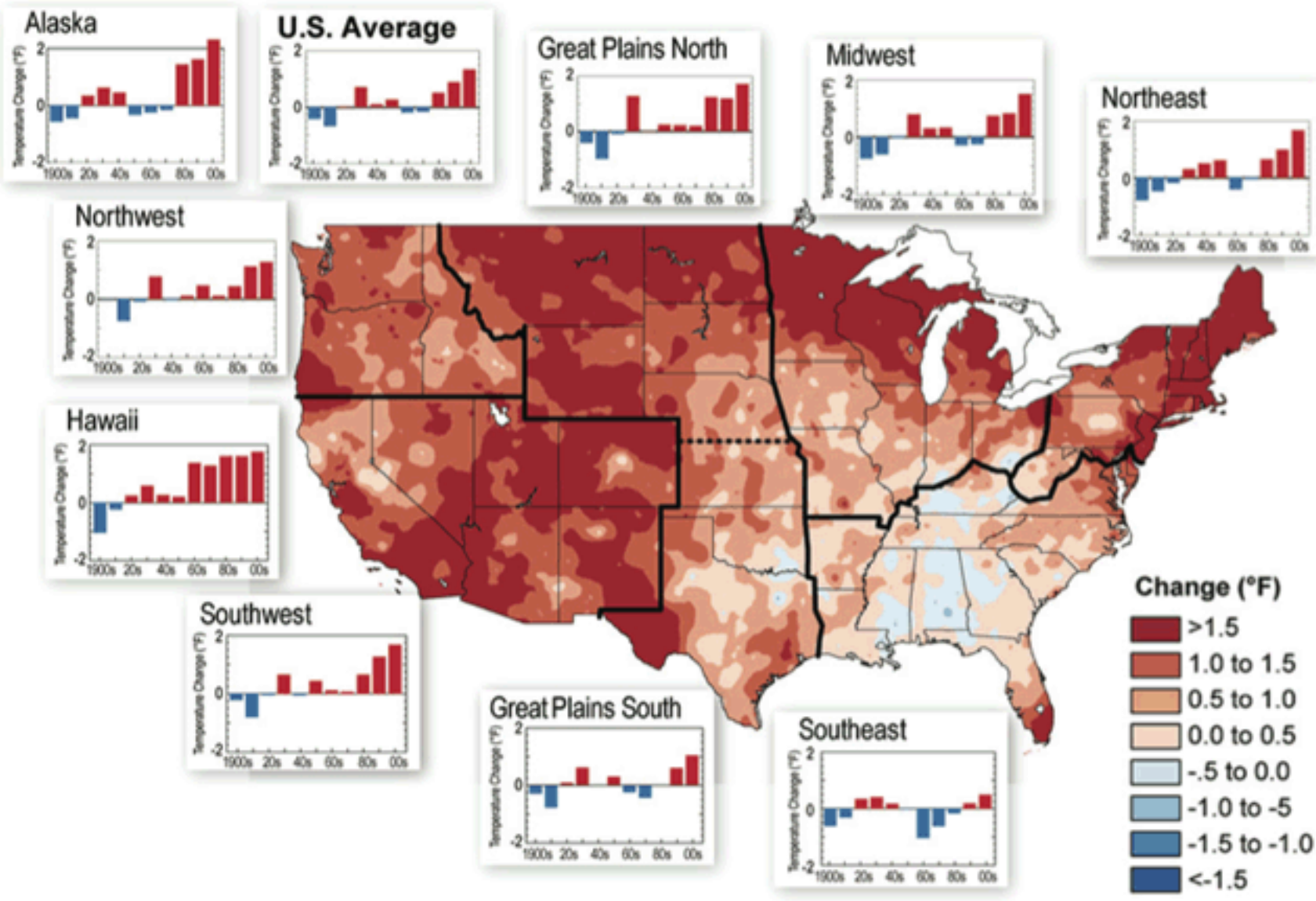
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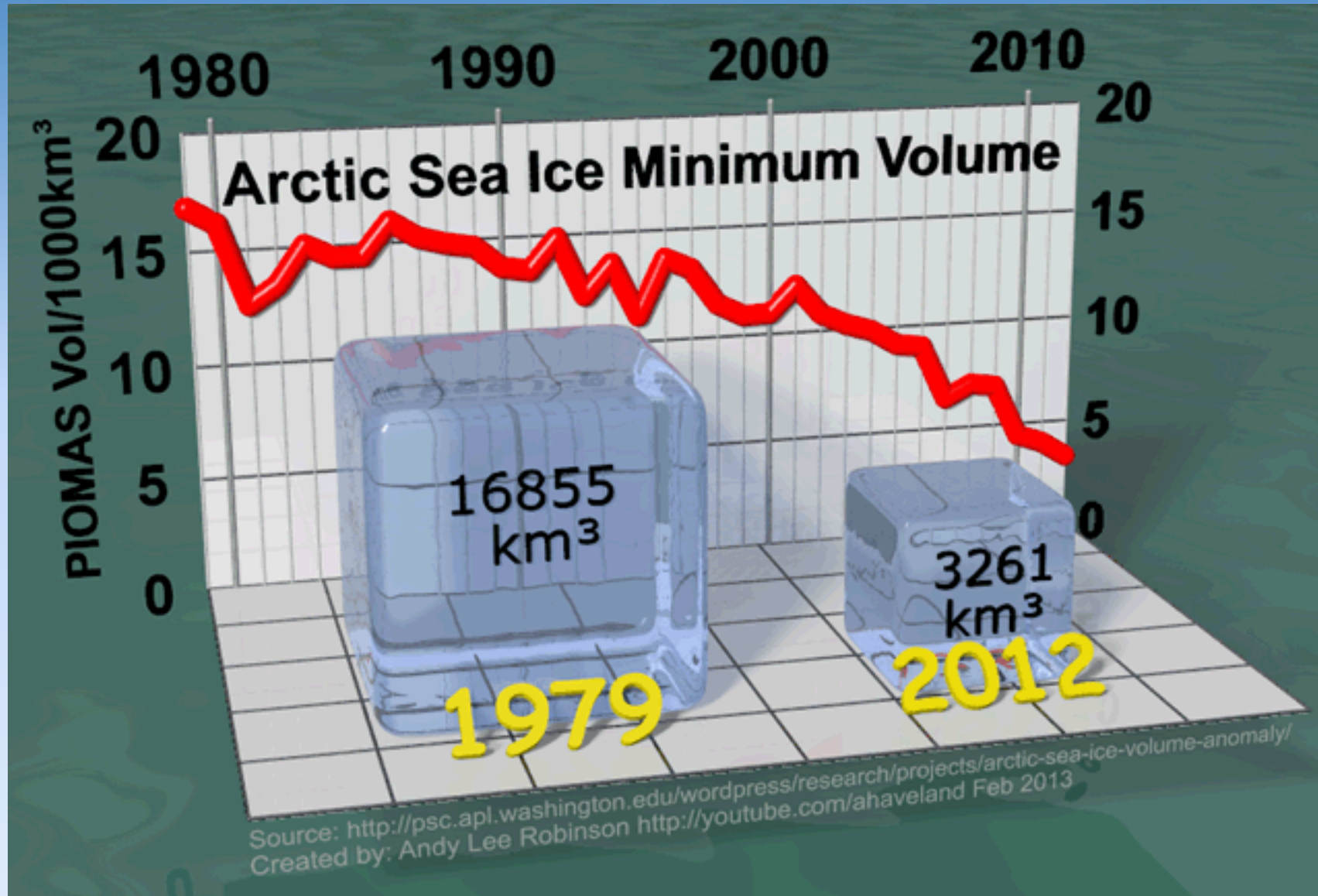
Fall is falling back: From 2000 - 2008, the end of the growing season was delayed by 2.3 days. In the U.S., fall now occurs ten days later than it did 30 years ago.



U.S. Temperature Change, 1900 - 2011

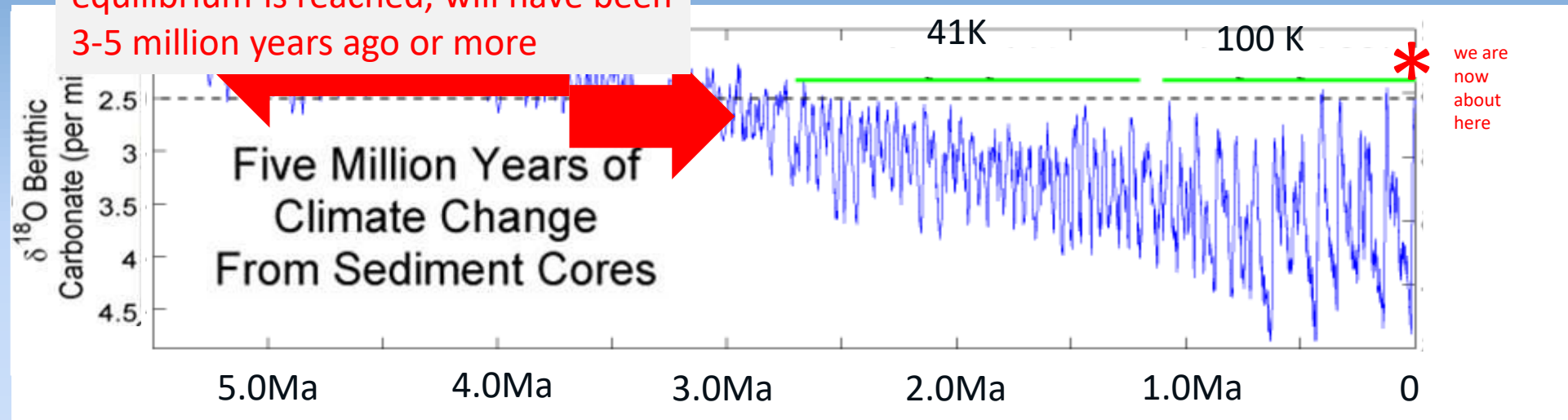


Arctic Sea Ice Volume has Shrunk by 5x; Extent by 2x



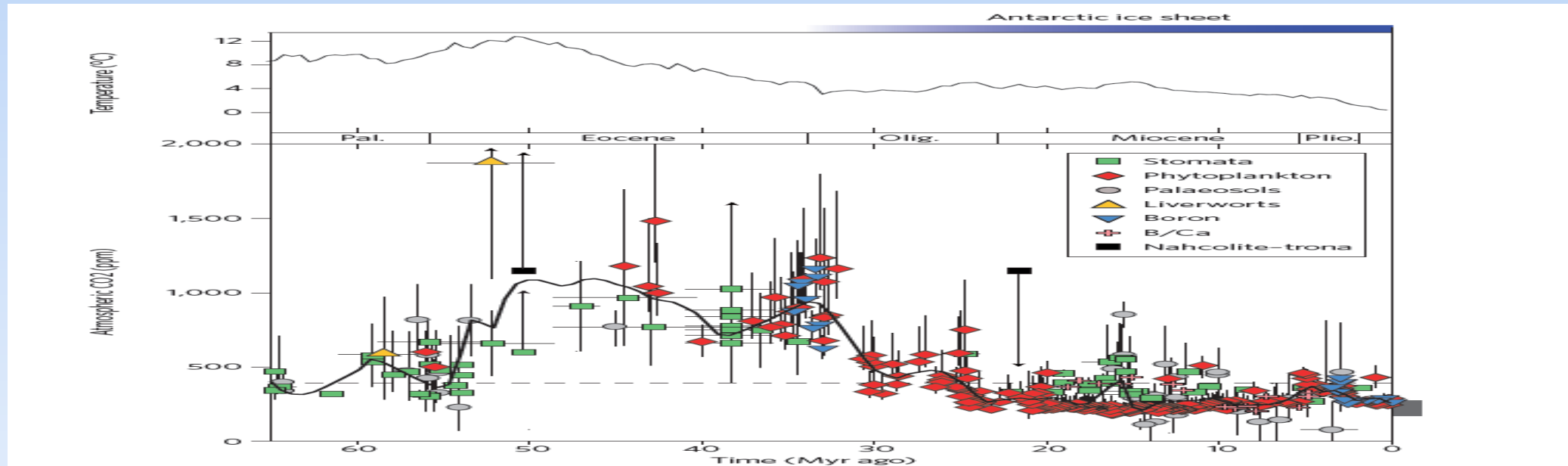
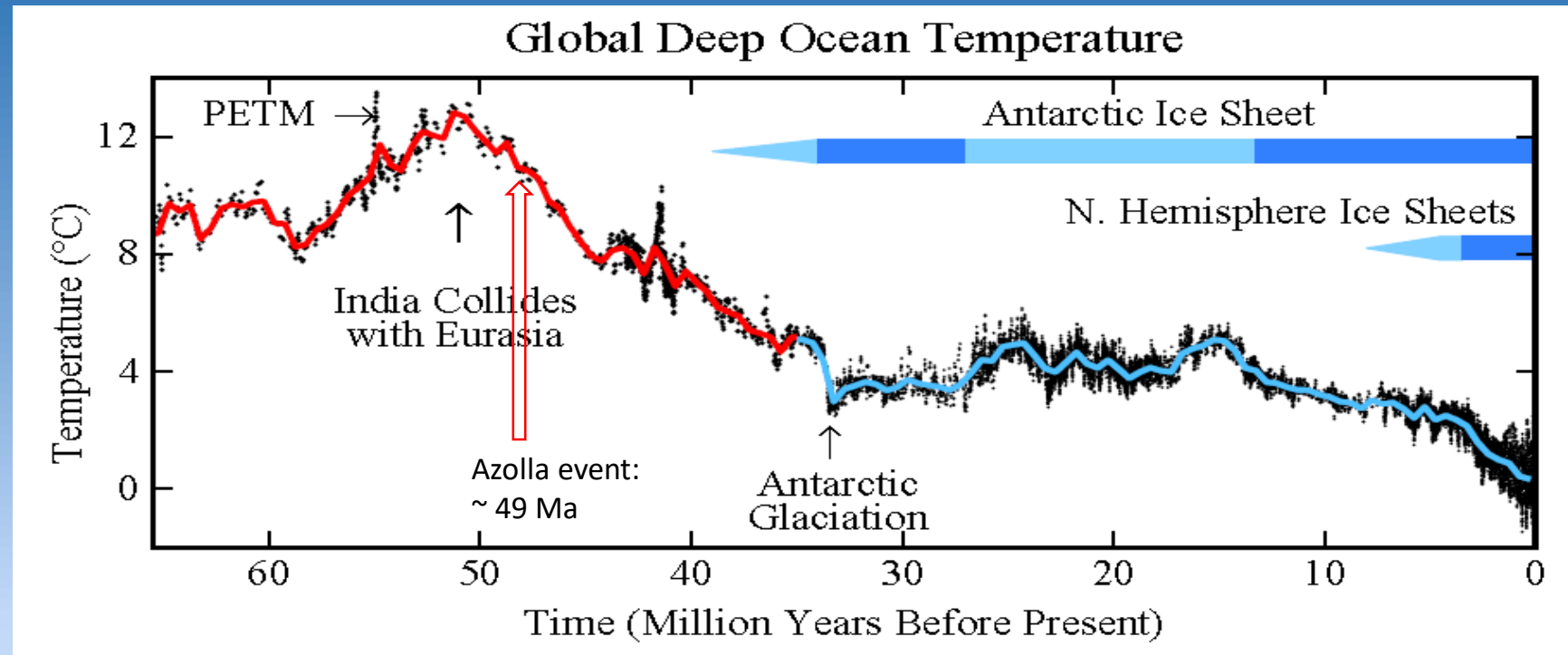
Climate Changes from Ocean Sediment Cores, since 5 Ma. Milankovitch Cycles

the last time inferred temperatures will have been this high – once equilibrium is reached, will have been 3-5 million years ago or more



When CO₂ levels get below ~400-600 ppm Orbital parameters become more important than CO₂

DATA



**The Debate Should Not Be About Whether
Climate Change Is Happening...**



...Rather, What Are We Going to Do About It?

HHMI

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Solutions – part A

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Economics

- See week 7 links, EEE links and AR5-WG2:
 - **Economic related reports:**
 - [2015 The Social Cost of Carbon study summary](#)
 - [2007.03.18 Discount Rate and Climate Change DLC](#)
 - **Stern Report:** [sternreview report complete](#)
 - Nordhaus briefly describes the “free rider” problem and his proffered solution as a lead-in to his recent review of the book, *Climate Shock*. Here’s the link to the NY Review of Books website: <http://www.nybooks.com/articles/archives/2015/jun/04/new-solution-climate-club/>
 - In a different format, Nordhaus produced a 30-slide PowerPoint version for his Presidential address to the AEA last January. Available at <http://carbon-price.com/wp-content/uploads/2015-01-04-Nordhaus-ClimateClubAEA-v2-slides.pdf>
 - [2015-01-04-Nordhaus-ClimateClubAEA-v2-slides](#)
 - **MIT: GOOGLE LIST OF LINKS:** https://scholar.google.com/scholar?q=mit+report+on+climate+change+economics&hl=en&as_sdt=0&as_vis=1&oi=scholar&sa=X&ved=0CBsQgQMwAGoVChMIkMfkl8i9yAIVSuJjCh1x7wKk
 - **IPCC AR5 WG2:** <http://www.ipcc.ch/report/ar5/wg2/#.UuAsbxDn9hE>

Notes

- Stern/Nordhaus – promote support a high discount rate – doing something NOW
- IPCC acknowledges adaptation will be a must (the change is in the bank and accumulating interest)
- Bjorn Lomborg – Danish economist (not a denier) argues for spending later – i.e. no discount rate
 - https://en.wikipedia.org/wiki/Bj%C3%B8rn_Lomborg
 - <http://www.desmogblog.com/bjorn-lomborg>
- Which leads to whether or not we need a paradigm shift (#3)

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Solutions – part A

1. Economics

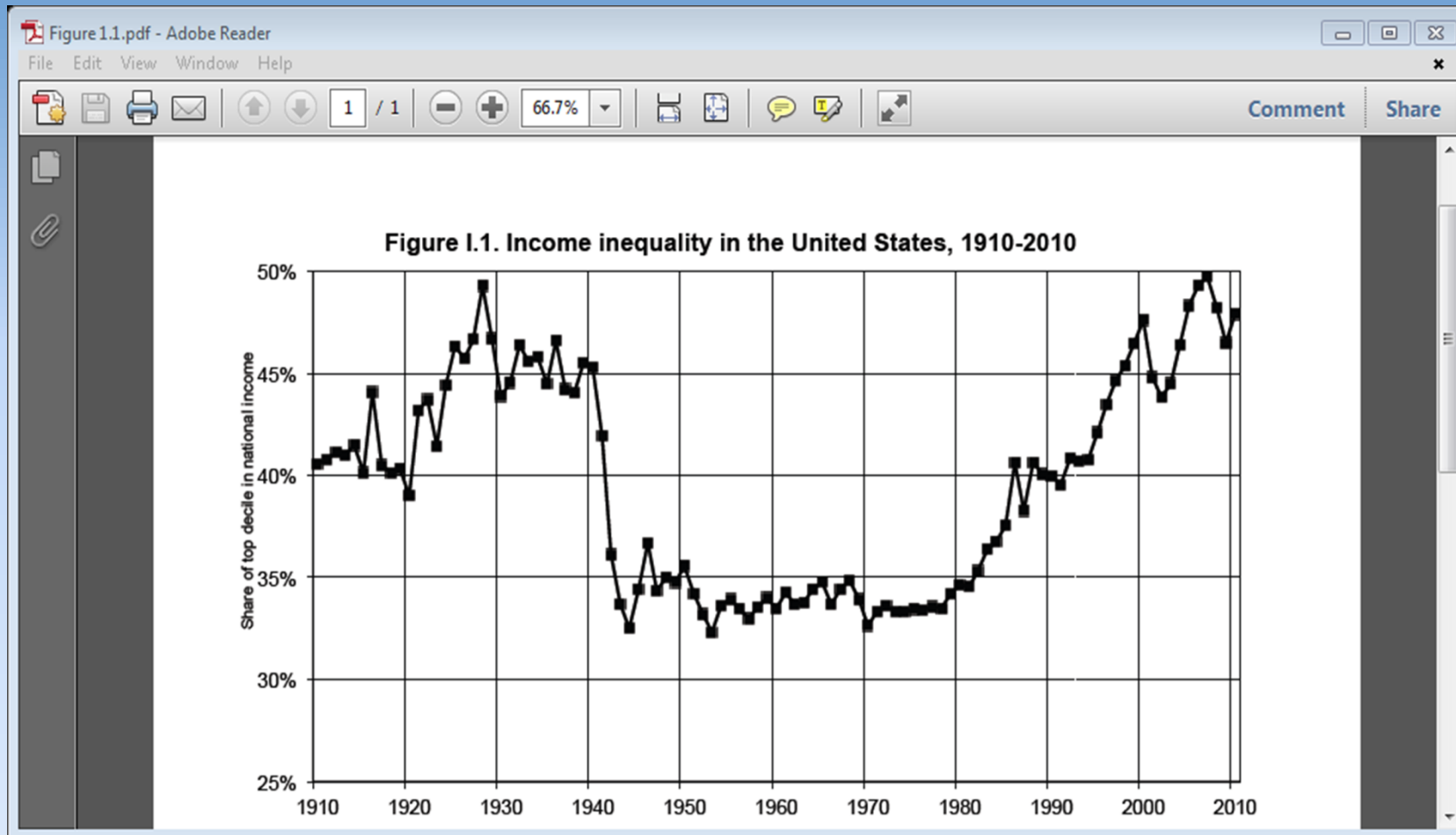
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Courtesy of Gary Wyngarden: Capitalism vs. the Planet

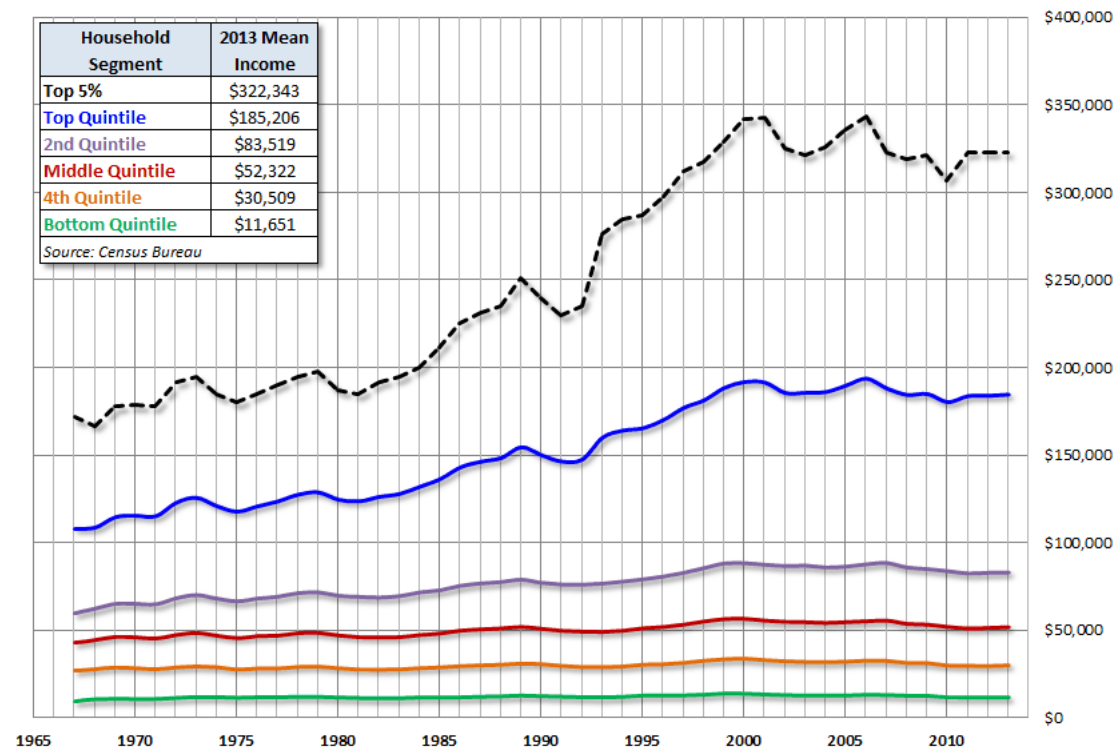
Source: Census Bureau
Data from 1967-2013

Real (Inflation-Adjusted) Mean Household Income By Quintile and Top 5%

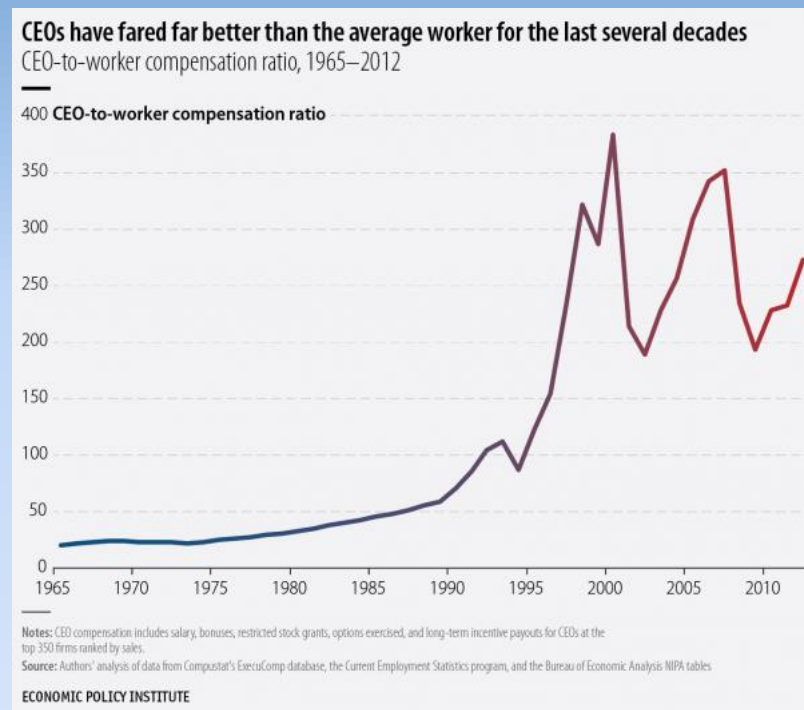
dshort.com

Household Segment	2013 Mean Income
Top 5%	\$322,343
Top Quintile	\$185,206
2nd Quintile	\$83,519
Middle Quintile	\$52,322
4th Quintile	\$30,509
Bottom Quintile	\$11,651

Source: Census Bureau



Courtesy of Gary Wyngarden: Capitalism vs. the Planet



Courtesy of Gary Wyngarden: Capitalism vs. the Planet

Global Footprint

see <http://www.footprintnetwork.org/en/index.php/GFN/page/glossary>

- Human activities consume resources and produce waste
- Ecological Footprint Accounting addresses whether the planet is large enough to keep up with the demands of humanity.
- Biocapacity represents the planet's biologically productive land areas including our forests, pastures, cropland and fisheries
- Biocapacity can then be compared with humanity's *demand* on nature: our [Ecological Footprint](#). The Ecological Footprint represents the productive area required to provide the renewable resources humanity is using and to absorb its waste.

- Our current global situation: *Since the 1970s, humanity has been in ecological overshoot with annual demand on resources exceeding what Earth can regenerate each year.*
- It now takes the Earth one year and six months to regenerate what we use in a year.
- We maintain this overshoot by liquidating the Earth's resources. Overshoot is a vastly underestimated threat to human well-being and the health of the planet, and one that is not adequately addressed.

- For 9 billion people (midrange projection for 2050) to live at North American/Western European standards will require 5 planets.

Drawbacks of Capitalism

- Wealth and Income Distribution
- Largely ignoring the ecological impacts and biocapacity of the planet

Growth Dilemma

- Growth is unsustainable in its current form
- De-growth is unstable

Obama quoted in episode of Years of Living Dangerously (paraphrased): “It’s difficult in a Democracy to do something/pass something where the pay-back is 10 or more years out”

The solution: steady state economics?

- Herman Daly's steady state economics see:
 - https://en.wikipedia.org/wiki/Herman_Daly
 - <http://steadystate.org/herman-daly/>
 - <http://steadystate.org/category/herman-daly/>

The problem: how to effect that change

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- Actual will likely be a combination

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Need for a paradigm shift

- **Kerry Emanuel quote on p. 76: “...costs may be high and those paying them are not likely to be serious beneficiaries of their own actions. Indeed, there are few, if any, historical examples of civilizations consciously making sacrifices on behalf of descendents (sic) two or more generations removed.”**
- That’s what the discount rate is about. **In that regard we need a social paradigm shift**
 - If we are so concerned about leaving a national debt to our children and grandchildren, shouldn’t we put the costs of climate change as part of that equation?
 - For those that don’t accept climate change maybe it would be a good thing to limit CO₂ into the atmosphere anyway, especially at the rates we are putting it into the atmosphere – BECAUSE OF OCEAN ACIDIFICATION issues and the law of unintended consequences!

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Renewables:

- Photovoltaics (PV)
- Concentrated solar power (CSP)
- Wind
- Geothermal
 - Ground source
 - Deep thermal

Hawaii becomes First State to Mandate 100% Renewable Energy.

See NREL slides for more details: <http://denverclimatestudygroup.com/wp-content/uploads/2015/04/OSHER-10.14.15.pdf>

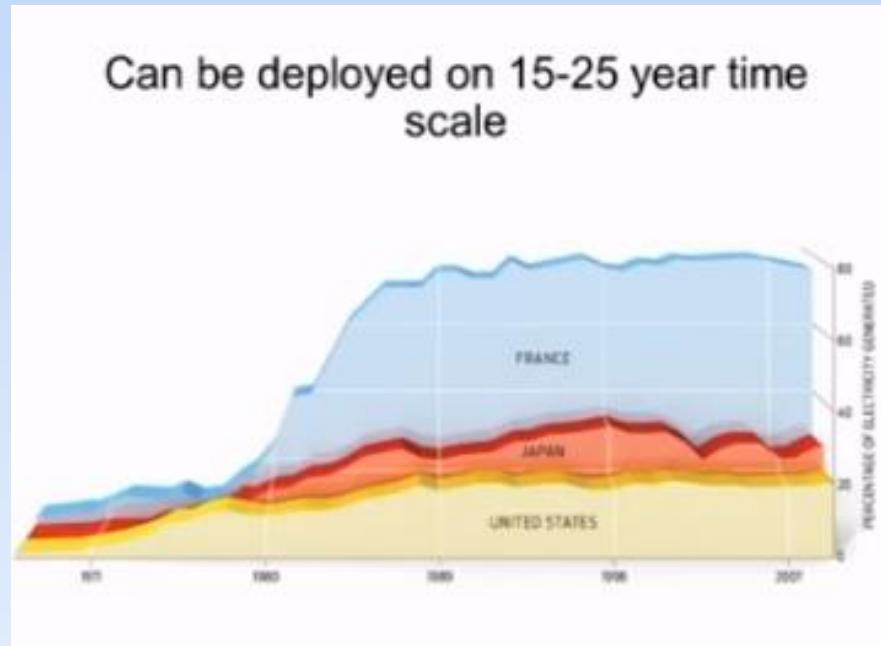
Renewables:

- The myth of Baseload
<https://www.youtube.com/watch?v=deWtgphedJM&feature=youtu.be> ; see other related videos at <http://energysouldbe.org/>
- Wind power:
7/7/2015 — A: Colorado Matters: Could Conservative Denver Billionaire (Phil Anschutz) Become West's Climate Hero?
It's an argument of engaging energy companies vs. "dissing" them for renewables. See more at: <http://www.cpr.org/news/story/could-conservative-denver-billionaire-become-vests-climate-hero#.dpuf>
 - **excerpt:** "This will generate four times the amount of power that comes out of Hoover Dam. It would supply every household in Los Angeles and San Francisco combined with green power."

Colorado changes in renewable energy

Other non-carbon sourced energy to consider?

- Non Carbon based: Nuclear (fission and fusion)
 - Fission: Very Controversial
 - Fusion: clean / difficult to achieve
 - Need national policy change on reprocessing
 - See Kerry video at 56 minutes for discussion and conclusions thereafter:
<https://www.youtube.com/watch?v=7so8GRCWA1k>



However – POTENTIAL big game changers in Energy and Carbon Dioxide Removal

1. Energy – from fusion
2. Mitigation in the form of carbon dioxide removal (CDR), agricultural changes and biofuels

1. Energy – from fusion

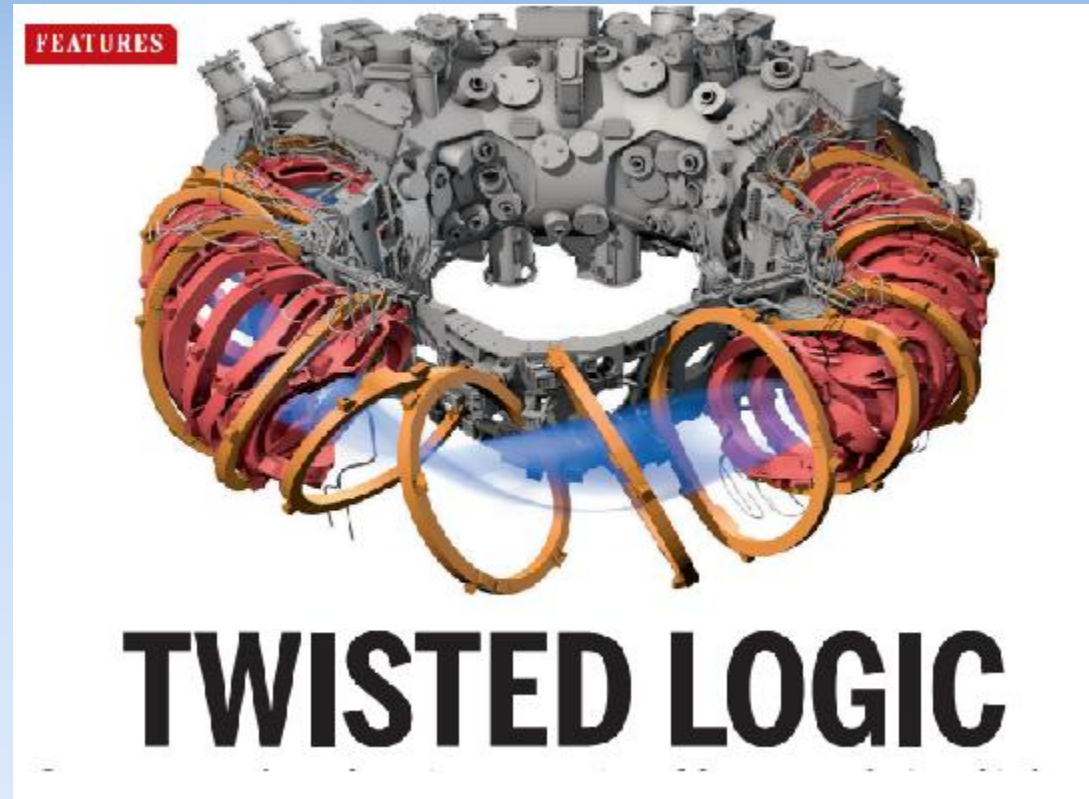
Lockheed Martin Compact Fusion breakthrough?

- <http://www.lockheedmartin.com/us/products/compact-fusion.html>
- <http://aviationweek.com/blog/high-hopes-can-compact-fusion-unlock-new-power-space-and-air-transport>
- <http://aviationweek.com/fusion-podcast>



1. More on Fusion:

Fusion article in Science: Twisted Logic [Science-2015-Clery-369-7](#)

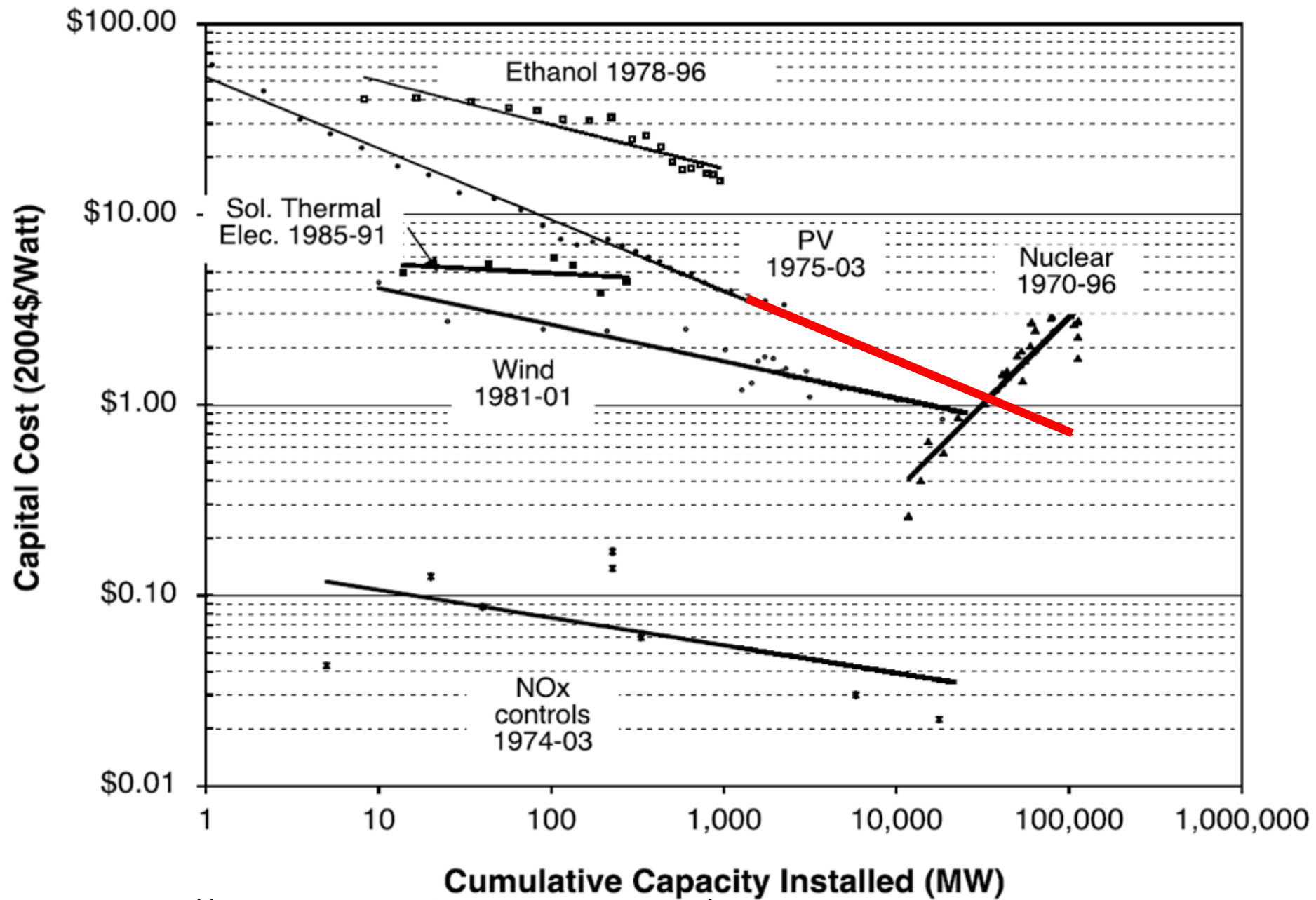


Will we ever get there?

- **Fusion reactors: Not what they're cracked up to be**

- <http://thebulletin.org/fusion-reactors-not-what-they%E2%80%99re-cracked-be10699>
- State not able to replicate Sun
- State Tritium cannot be fully replenished
- Huge parasitic power consumption
- Some forms (deuterion-tritium) do have radiation damage and waste
- Etc.

BUT
WE MAY NOT NEED IT?



<https://carbonremoval.files.wordpress.com/20>

14/12/energy-learning-curves.png

Storage options

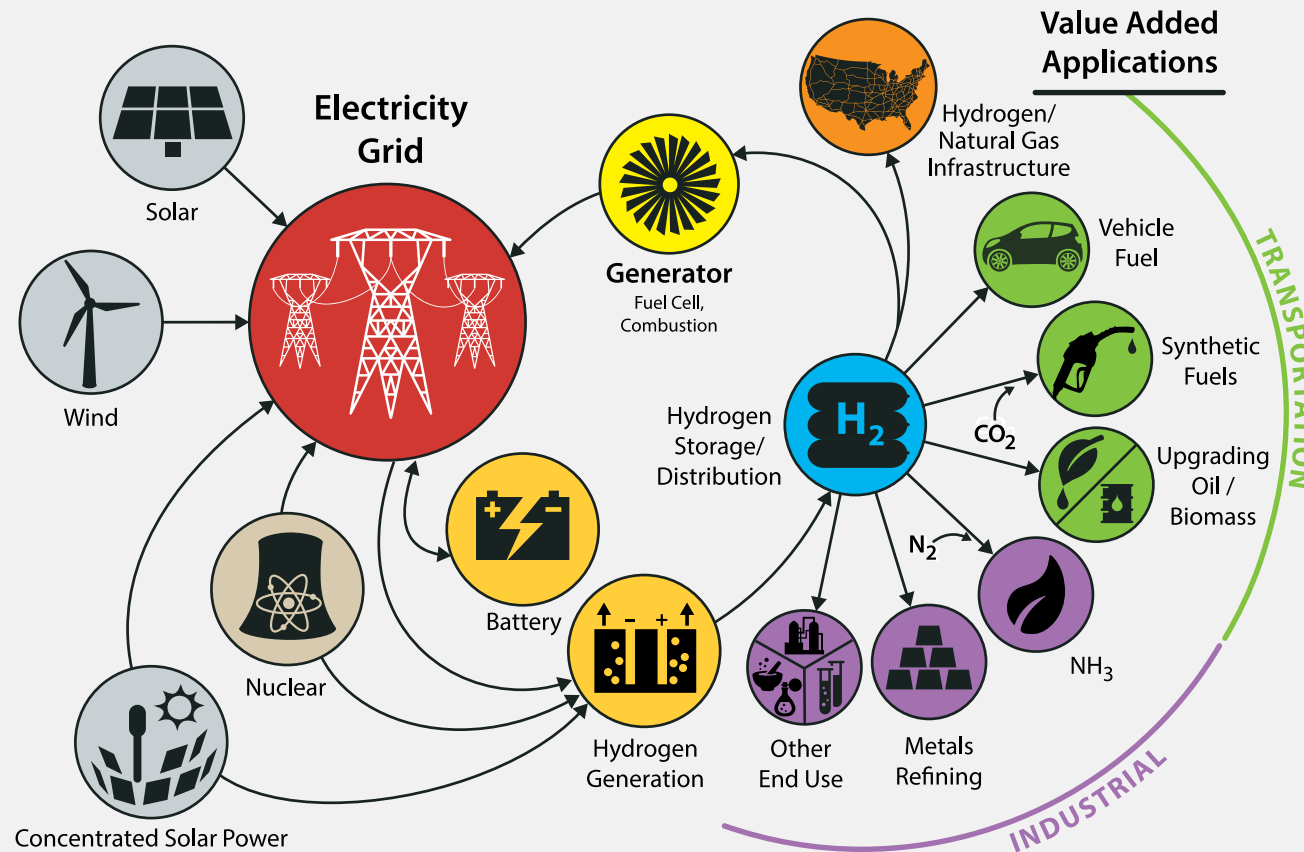
- https://en.wikipedia.org/wiki/Energy_storage
- [2Methods](#)
 - [2.1Outline](#)
 - [2.2Mechanical storage](#)
 - [2.3Thermal storage](#)
 - [2.4Electrochemical](#)
 - [2.5Other chemical](#)
 - [2.6Electrical methods](#)
 - [2.7Interseasonal thermal storage](#)
 -

BACKUP OR GRID

- Balanced power is necessary: not too much, not too little
- SOLUTION – EITHER
 - Backup:
 - Battery,
 - Compressed Air,
 - Re-pumped Hydro,
 - H₂ (this can be 2-way for excess power or needed power)
 - Rubber Bands, etc.
 - Grid

Future Energy System – Commodity H₂

Future H₂ at Scale Energy System



WHY HYDROGEN?

- Hydrogen is an ideal clean energy carrier—connecting diverse energy sources to diverse applications
- It can play a unique and critical role in addressing many of the energy sector's greatest challenges

TODAY'S ENERGY SYSTEM

- Renewable energy—particularly wind and solar—offer great promise but have challenges associated with variable and concurrent generation
- Options to achieve deep decarbonization while meeting society's multi-sector energy demands are limited, particularly in the industrial and transportation sectors

FUTURE H₂ AT SCALE ENERGY SYSTEM

- Connects low-carbon energy sources to all of the energy sectors
- Uses carbon-free, renewable inputs to service all of society's energy needs, in particular the difficult to decarbonize sectors of industry and transportation
- Does not compete with other options—rather, it enables increased renewable penetration
- Can decrease 45% of all U.S. carbon emissions by 2050

Ken Regelson videos

- CRES YouTube: Many videos on
 - <https://www.youtube.com/channel/UCr81EUb2qVJVfmmlJMxEHVw/videos>
- Energy Should Be web page: <http://energyshouldbe.org/>
 - Why Storage is Key for a Renewable Energy Future:
https://www.youtube.com/watch?v=Yc_hULwykvQ&t=14s
 - To Allow Lots of Renewables, Baseload Coal & Nuclear Must Go:
<https://youtu.be/deWtgpheDJM>
 - Etc.

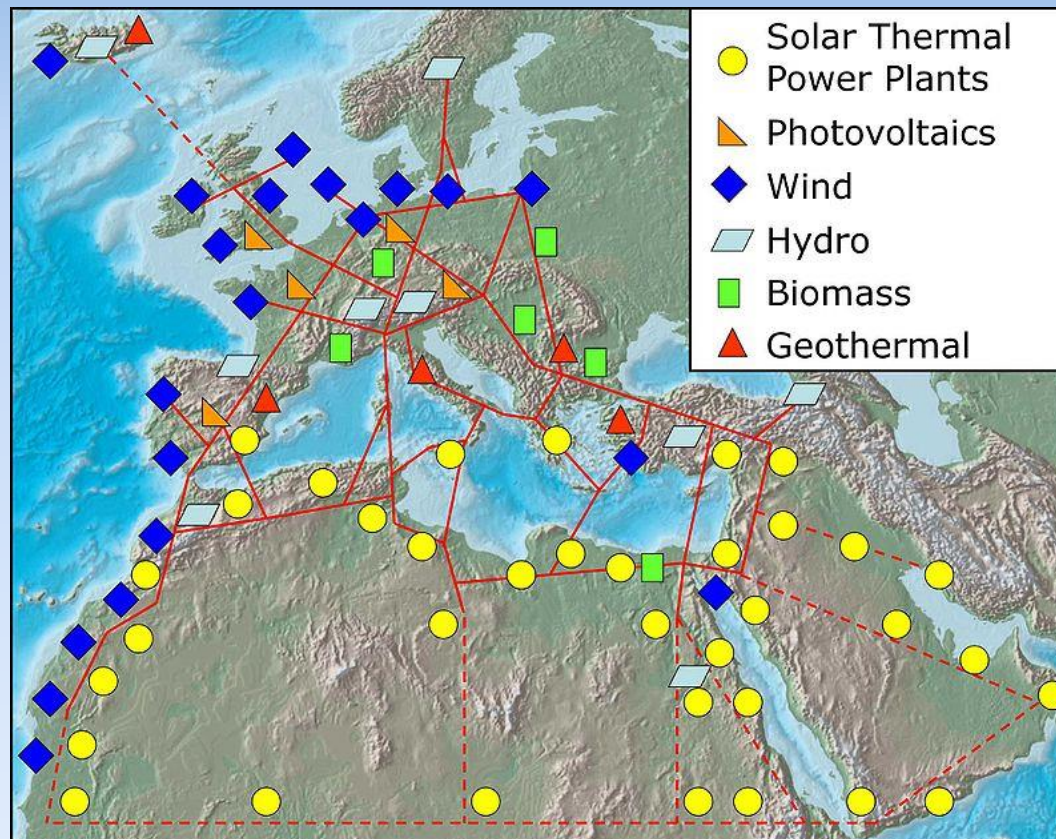
Grid: Big or Small?

- A case for small?
- <http://www.wbur.org/bostonomix/2017/04/19/microgrid-joint-base-cape-cod>

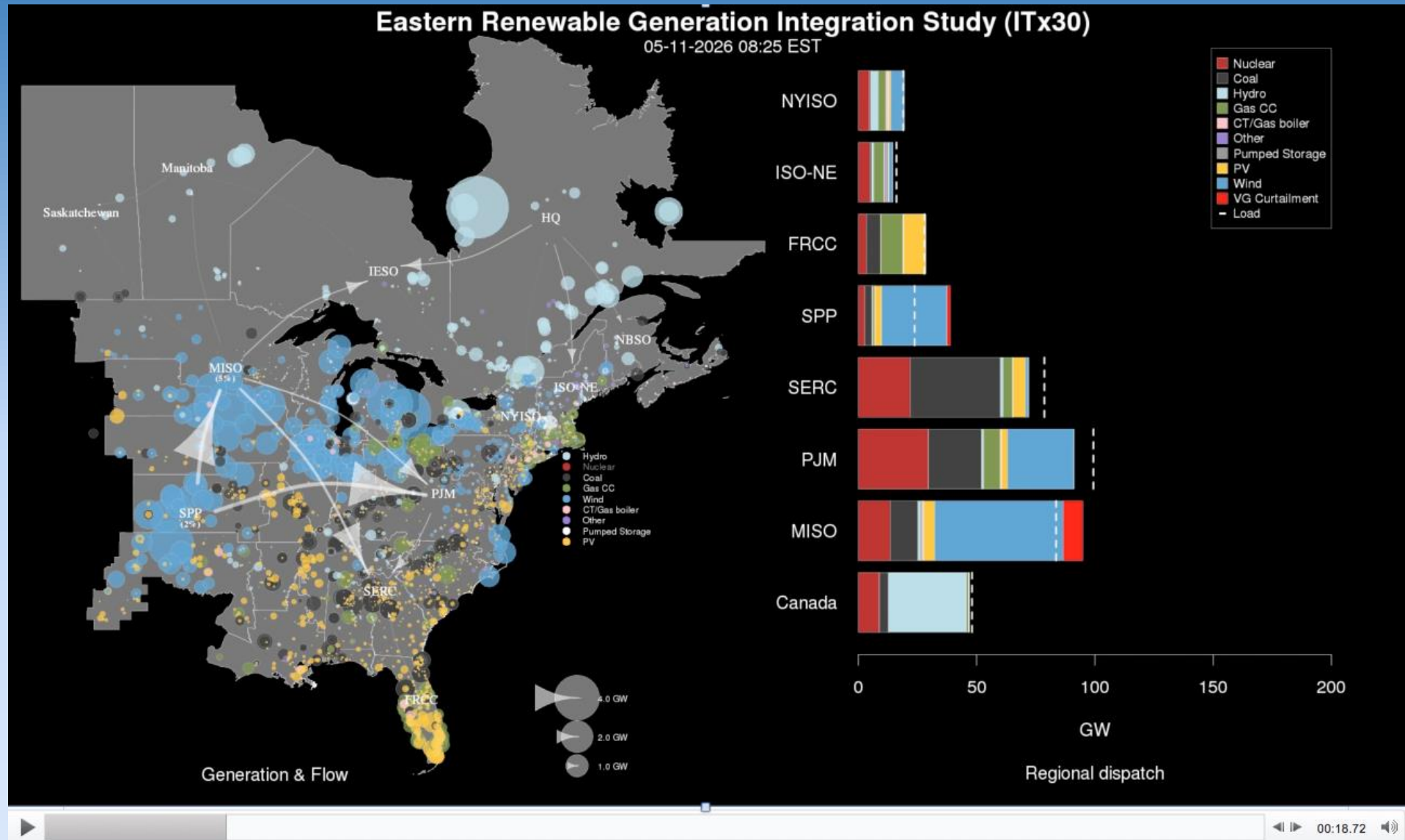
Grid: Big or Small?

- Case for super-grid:

https://en.wikipedia.org/wiki/Super_grid



Click on next slide for simulation



Click on slide for ERGIS Visualization



EA Too big – see me / bring a flash drive Y

MAY 11 - MAY 13, 2026
HIGH VARIABLE GENERATION

2. Carbon Dioxide Removal (CDR)

Biochar

- See week 7, 2014
http://denverclimatestudygroup.com/?page_id=776
- And biochar tab: http://denverclimatestudygroup.com/?page_id=28





2. Carbon Dioxide Removal (CDR)



- <https://en.wikipedia.org/wiki/Biochar>:

“**Biochar** is [charcoal](#) used as a [soil amendment](#). Like most charcoal, biochar is made from [biomass](#) via [pyrolysis](#). Biochar is under investigation as an approach to [carbon sequestration](#) to produce [negative carbon dioxide emissions](#).^[1] Biochar thus has the potential to help mitigate [climate change](#) via carbon sequestration.^{[2][3]} Independently, biochar can increase [soil fertility](#) of [acidic soils](#) (low pH soils), increase agricultural productivity, and provide protection against some foliar and soil-borne diseases.^[4] Furthermore, biochar reduces pressure on [forests](#).^[5] Biochar is a stable solid, rich in [carbon](#), and can endure in soil for thousands of years.^[1]”

The rest – next week, week 8