Global warming as an opportunity
Cheryl Beth Silverman Memorial Lecture
The Academy of Natural Sciences, Drexel University, May 8, 2019
Raymond Najjar

Cartoon by Joel Pett, 2009
Earth is rapidly warming

Source: NASA

Source is https://data.giss.nasa.gov/gistemp/graphs/
But the warming is not uniform

Source: NASA

https://data.giss.nasa.gov/gistemp/animations/
The greenhouse effect in three steps

1. Solar radiation warms Earth

2. Earth’s radiation absorbed in atmosphere

3. Atmosphere’s radiation further warms Earth—by 60 °F
CO₂ levels now are higher than they have been for at least 800,000 years

Humans are the cause of global warming

The greenhouse effect is well established

1824: Joseph Fourier describes natural greenhouse effect

1858–1861: Eunice Foote and John Tyndall identify greenhouse gases

1896: Svante Arrhenius estimates greenhouse effect of fossil fuel CO₂

1938: Guy Callendar documents warming and CO₂ increase
Arctic sea ice is rapidly melting

Source: NASA

https://svs.gsfc.nasa.gov/4686
Most of the heat from global warming is going into the ocean

Change in total heat content since 1961 ($10^{21}$ Joules)

skepticalscience.com after Church et al. (2011)

Sea level is accelerating

Global Mean Sea Level Change

- Adjusted Tide Gauge Data
- Satellite Radar Altimetry

- 0.6 mm/yr (1900–1930)
- 1.4 mm/yr (1930–1992)
- 3.3 mm/yr (1993–2018)

http://www.columbia.edu/~mhs119/SeaLevel/
“Sunny day” flooding in Miami

Photo source: Grist
United States
COASTAL FLOOD DAYS

8726 FLOODS
Since 1950

67% HUMAN-CAUSED

Orange shows human-caused global sea level rise effects.
Flooded areas across 27 states must top NWS "wetlands" thresholds.
Source: Kopp et al. 2016 (PNAS), NOAA, & Climate Central.
Corals bleach—lose their symbiotic algae—when they are stressed


Degree heating weeks are a bit complicated. First you compute the mean annual cycle in SST at monthly resolution. Second, of these 12 months, you find the month with the highest mean SST and you call it the maximum monthly mean (MMM) SST. The bleaching threshold is 1 deg C above the MMM. Third, you look at the past 12 weeks and find all of the half-week periods in which the 50-km SST is above the threshold. Call the exceedance DT. For each half week period, you multiply DT by 0.5 weeks. Then you add up all of these products to get DHW. Source: https://coralreefwatch.noaa.gov/satellite/education/tutorial/crw24_dhw_product.php
Massive coral bleaching occurred during 2014–2017

DHW = Degree Heating Weeks (°C - weeks)

- 0 < DHW < 4: Coral bleaching likely (4 < DHW < 8)
- Coral mortality likely (8 < DHW)

Eakin et al. (2018)

Tree rings tell the story of drought

- Human influence on global droughts goes back 100 years
- 2012–2014 California drought worst in 1200 years

Marvel et al. (2019) and Griffin and K.J. Anchukaitis (2014)

Image:
https://www.esrl.noaa.gov/gmd/education/info_activities/pdfs/PSA_tree_rings.pdf


Increasing extremes: salty areas getting saltier, fresh areas are getting fresher

Durack et al. (2012) 1950–2000 salinity change (g kg⁻¹)

Record high ocean temperatures intensified Harvey and increased its flooding rains on land

“Harvey could not have produced so much rain without human-induced climate change”

Trenberth et al. (2018)

In the US West, climate change has doubled the area burned by forest fires.


Fire image credit: Credit: Mike McMillan/USFS. https://climate.nasa.gov/news/2315/study-fire-seasons-getting-longer-more-frequent/

A growing majority of Americans think global warming is happening and are worried.

https://climatecommunication.yale.edu/publications/a-growing-majority-of-americans-think-global-warming-is-happening-and-are-worried/
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Summers in Pennsylvania will feel like those of the Southeast US by mid-century if heat trapping emissions trends continue.
The US and EU have emitted about 50% of the CO2...

... but make up only about 10% of the population.

Source: Global Carbon Project


Image: Robert Fullerton/Shutterstock
We have cleaned up our own messes before
Cleanup of the Delaware River allowed the return of the American Shad

https://www.nj.gov/drbc/edweb/shad-return.html
Good news: the ozone hole is shrinking!

[Graph showing the decrease in the area of the ozone hole over time]

NASA image

https://ozonewatch.gsfc.nasa.gov/statistics/annual_data.html
Why? Because levels of (human-produced) chlorofluorcarbons are dropping.

https://www.esrl.noaa.gov/gmd/hats/combined/CFC11.html
This is happening much less often than it used to

Ozone: 28% decrease
NO₂: 52% decrease
CO: 82% decrease
SO₂: 83% decrease
Lead: 89% decrease

Median change in US: 1980-2010

Data source: www.epa.gov/air/eie
The Clean Air act reduced emissions and created $170 - $430 billion per year in health benefits—all while energy use went up and costs went down!

Opportunities
When damages to agriculture and health are considered, new electricity based on non-fossil sources is cheapest

Costs of new US electricity

![Bar chart showing costs per kWh for different energy sources: Coal, Gas, Nuclear, Solar, Wind.](Shindell (2015))

Less fossil fuel, less nitrogen pollution, fewer harmful algal blooms, fewer dead zones

The cost to install solar has plummeted

Price history of silicon PV cells in US$ per watt

Source: Bloomberg New Energy Finance & pvenergytrend.com
Renewables are cheap!

Costs of new installations in dollars per megawatt-hour

<table>
<thead>
<tr>
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<th>2018</th>
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<tr>
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</table>

Use of efficient light bulbs is skyrocketing ...

Department of Energy data
Graphic from NY Times:
Department of Energy data
Graphic from NY Times:
Food systems are responsible for one-quarter of greenhouse gas emissions

http://lfs-teg-collab.sites.olt.ubc.ca/files/2015/12/Slide5.jpg
Sources of greenhouse gas emissions from U.S. food choices


Cuisines that are easy on the planet

Vietnam

India

Venezuela

Lebanon

https://www.nytimes.com/2019/04/30/climate/these-five-cuisines-are-easier-on-the-planet.html
Cuisines that are easy on the planet

https://www.nytimes.com/2019/04/30/climate/these-five-cuisines-are-easier-on-the-planet.html

Image: Getty Images;

- $4.32 per person per year in Medicare savings for every 1% increase in forest cover
- Up to $9 billion in savings per year for the US
What if we kept our cars parked for trips less than one mile? In the US, each year we would save
• $900 million in fuel and maintenance costs
• 2 million metric tons of CO$_2$ emissions

Walkable & bikable communities are healthier and cleaner

https://www.epa.gov/greenvehicles/what-if-we-kept-our-cars-parked-trips-less-one-mile
Action
https://www.papowerswitch.com/
https://citizensclimatelobby.org/energy-innovation-and-carbon-dividend-act/
Paris Climate Conference 2015

Agreement to keep global warming well below 2.0 °C (3.6 °F)

Image source: www.cop21paris.org/
CLIMATE SUMMIT

WHAT IF IT'S A BIG HOAX AND WE CREATE A BETTER WORLD FOR NOTHING?

- ENERGY INDEPENDENCE
- PRESERVE RAINFORESTS
- SUSTAINABILITY
- GREEN JOBS
- LIVABLE CITIES
- RENEWABLES
- CLEAN WATER, AIR
- HEALTHY CHILDREN
- ETC. ETC.

Joel Pett, 2009