

# Global warming as an opportunity

Cheryl Beth Silverman Memorial Lecture

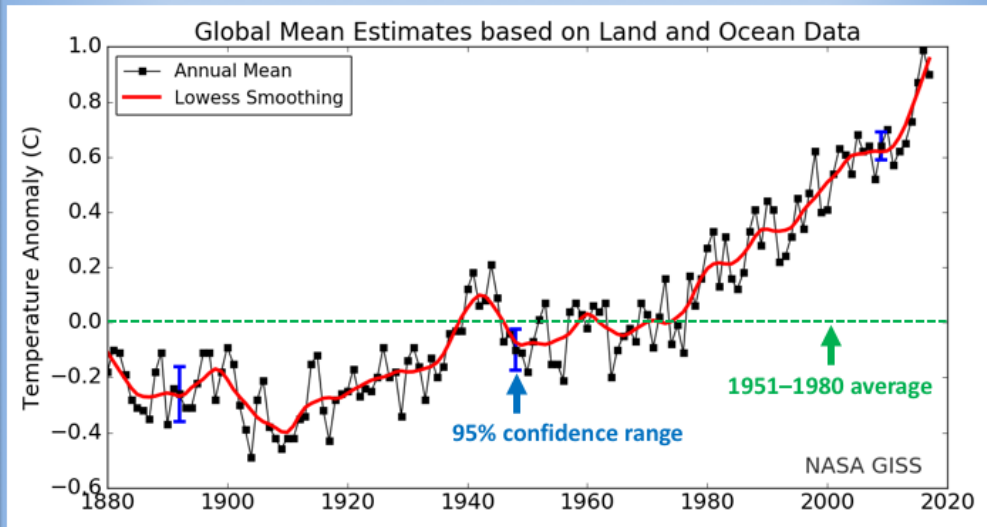
The Academy of Natural Sciences, Drexel University, May 8, 2019

Raymond Najjar



Cartoon by Joel Pett, 2009

# Earth is rapidly warming

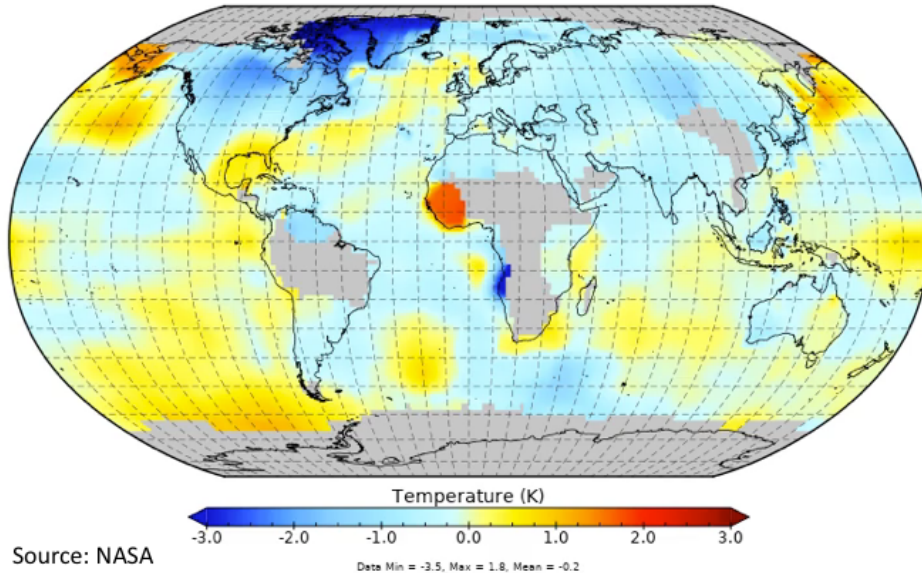


Source: NASA

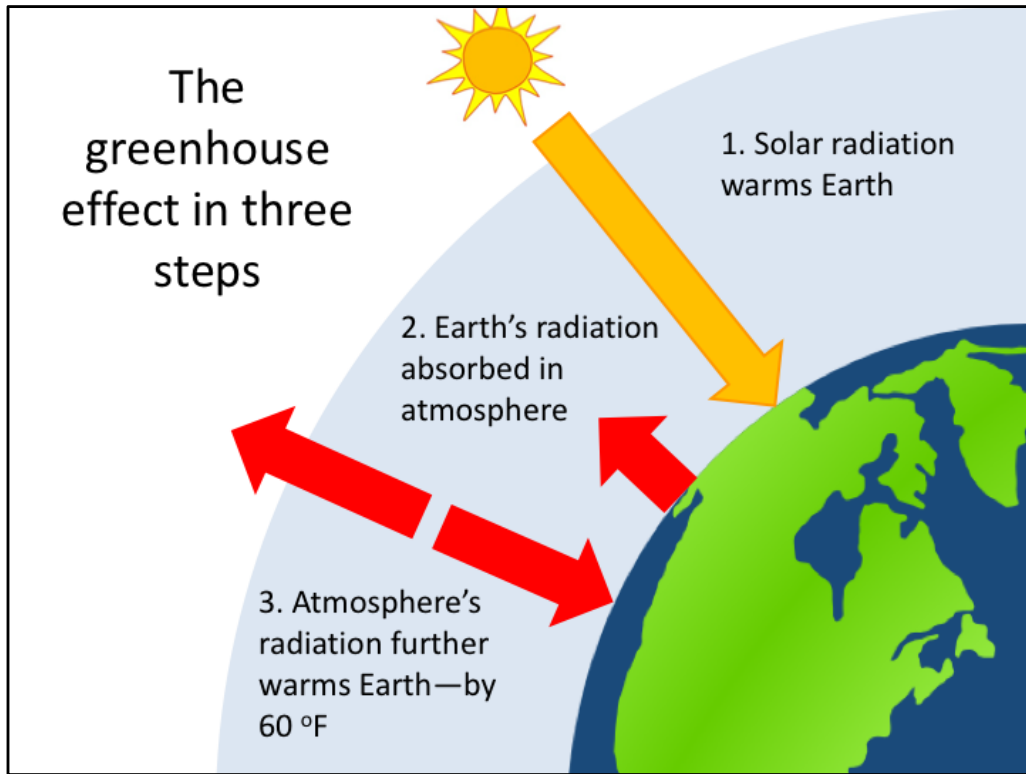
Source is <https://data.giss.nasa.gov/gistemp/graphs/>

## But the warming is not uniform

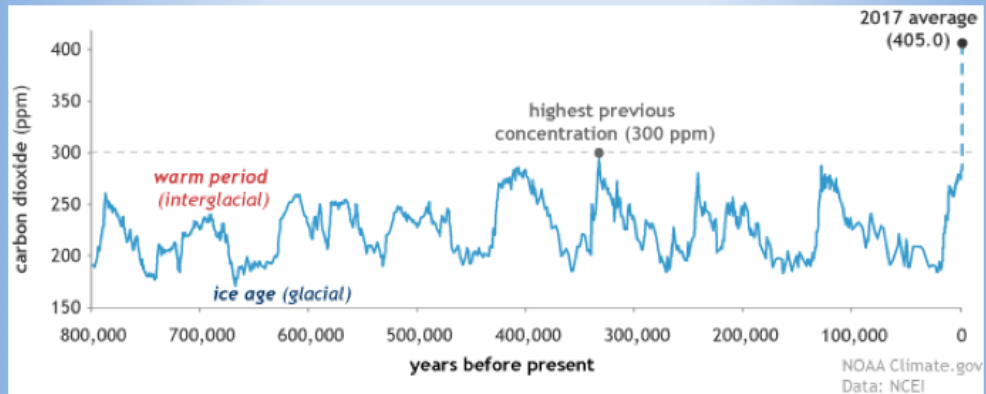
Annual Surface Temperature Anomaly base 1951-1980  
1880-1884



<https://data.giss.nasa.gov/gistemp/animations/>

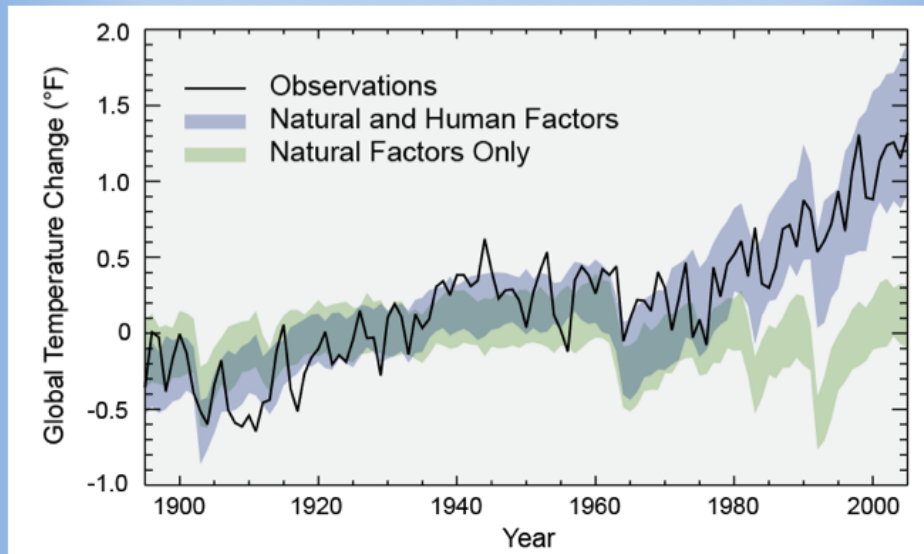


CO<sub>2</sub> levels now are higher than they have been for at least 800,000 years



<https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide>

## Humans are the cause of global warming



Shading = 5<sup>th</sup> to 95<sup>th</sup> percentile of models

Walsh et al. (2014)

Walsh, J., Wuebbles, D., Hayhoe, K., Kossin, J., Kunkel, K., Stephens, G., Thorne, P., Vose, R., Wehner, M., Willis, J., Anderson, D., Doney, S., Feely, R., Hennon, P., Kharin, V., Knutson, T., Landerer, F., Lenton, T., Kennedy, J., Somerville, R., 2014. Chapter 2: Our Changing Climate. In: J.M. Melillo, T.C. Richmond, G.W. Yohe (Editors), *Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program, pp. 19-67.

## The greenhouse effect is well established

**1824:** Joseph Fourier describes natural greenhouse effect



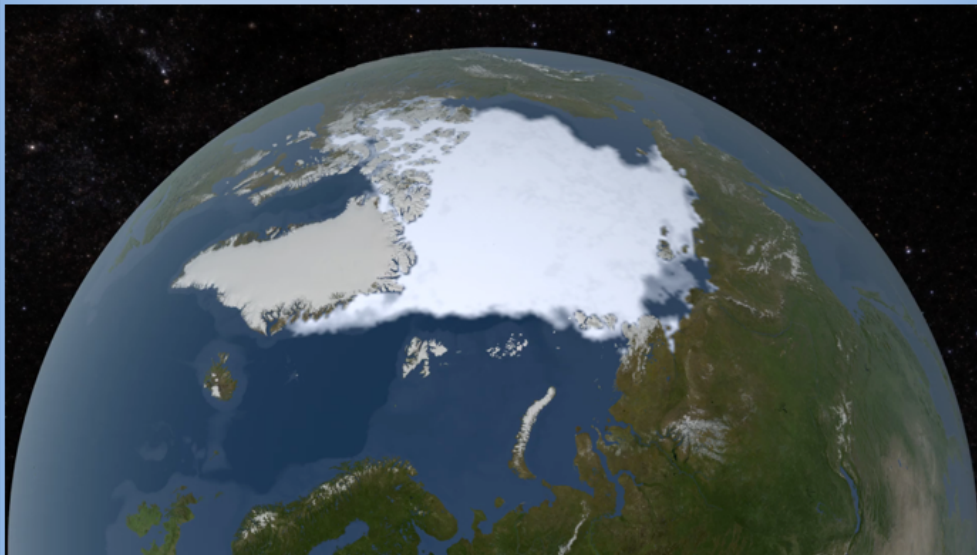
**1858–1861:** Eunice Foote and John Tyndall identify greenhouse gases

**1896:** Svante Arrhenius estimates greenhouse effect of fossil fuel CO<sub>2</sub>



**1938:** Guy Callendar documents warming and CO<sub>2</sub> increase

## Arctic sea ice is rapidly melting

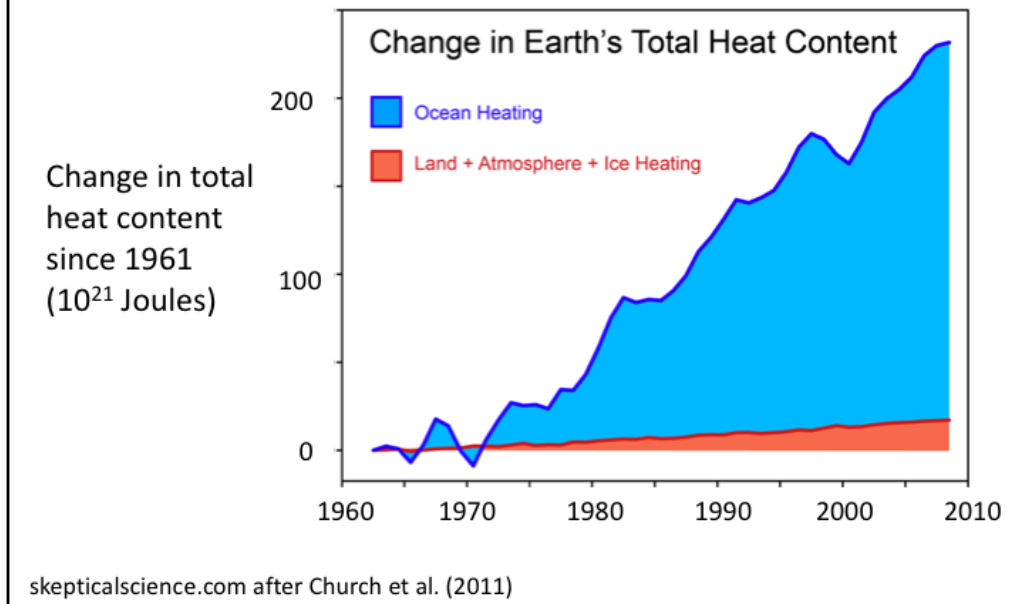


Source: NASA

<https://svs.gsfc.nasa.gov/4686>

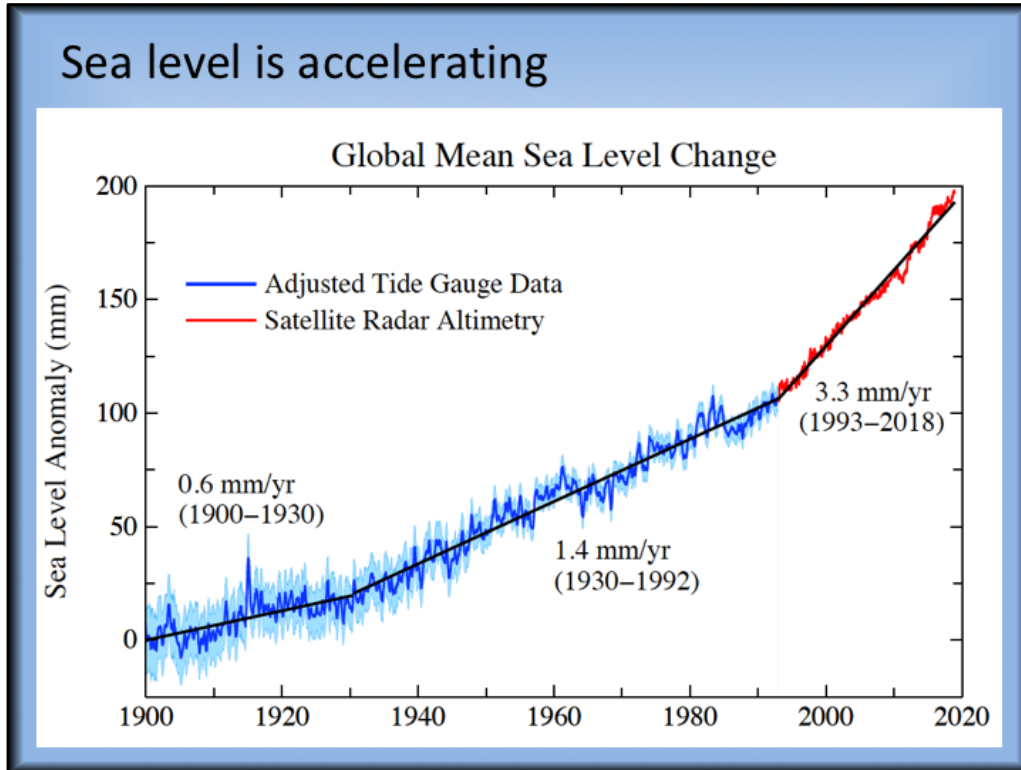


## Most of the heat from global warming is going into the ocean



Church, J.A., White, N.J., Konikow, L.F., Domingues, C.M., Cogley, J.G., Rignot, E., Gregory, J.M., van den Broeke, M.R., Monaghan, A.J., Velicogna, I., 2011. Revisiting the Earth's sea-level and energy budgets from 1961 to 2008. *Geophysical Research Letters* 38, L18601.

## Sea level is accelerating



<http://www.columbia.edu/~mhs119/SeaLevel/>

## “Sunny day” flooding in Miami



Photo source: Grist

United States  
**COASTAL FLOOD DAYS**



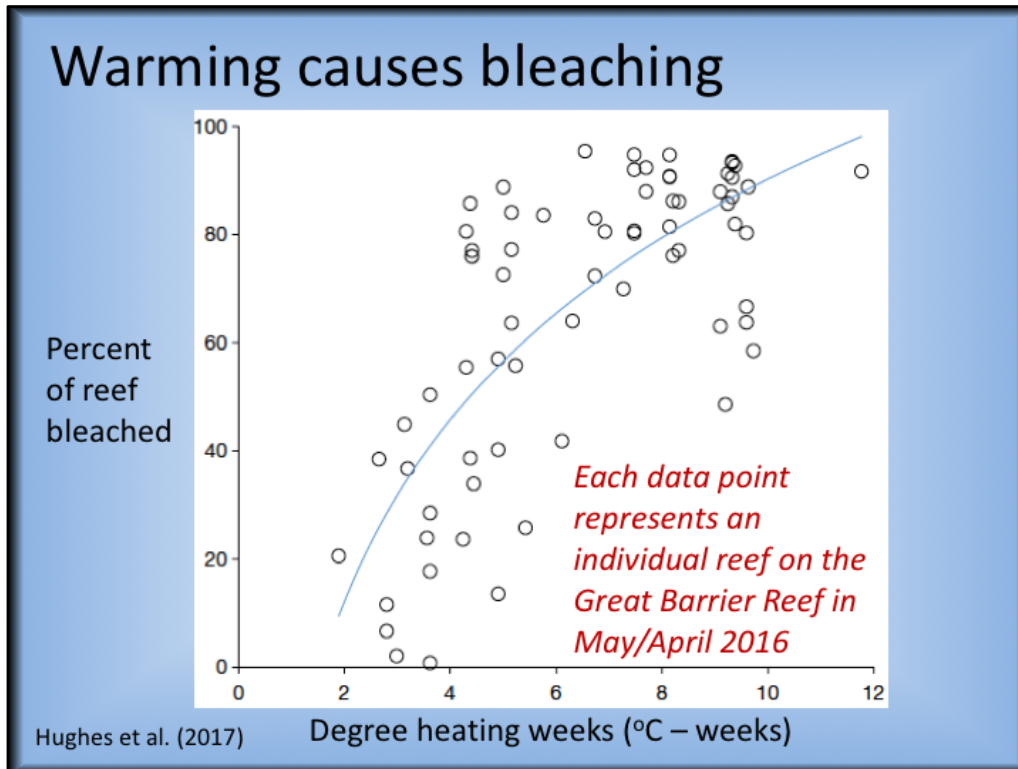
Orange shows human-caused global sea level rise effects  
Floods totaled across 27 sites; must top NWS 'nuisance' thresholds  
Source: Kopp et al. 2016 (PNAS), NOAA, & Climate Central

CLIMATE  CENTRAL

## Corals bleach—lose their symbiotic algae—when they are stressed



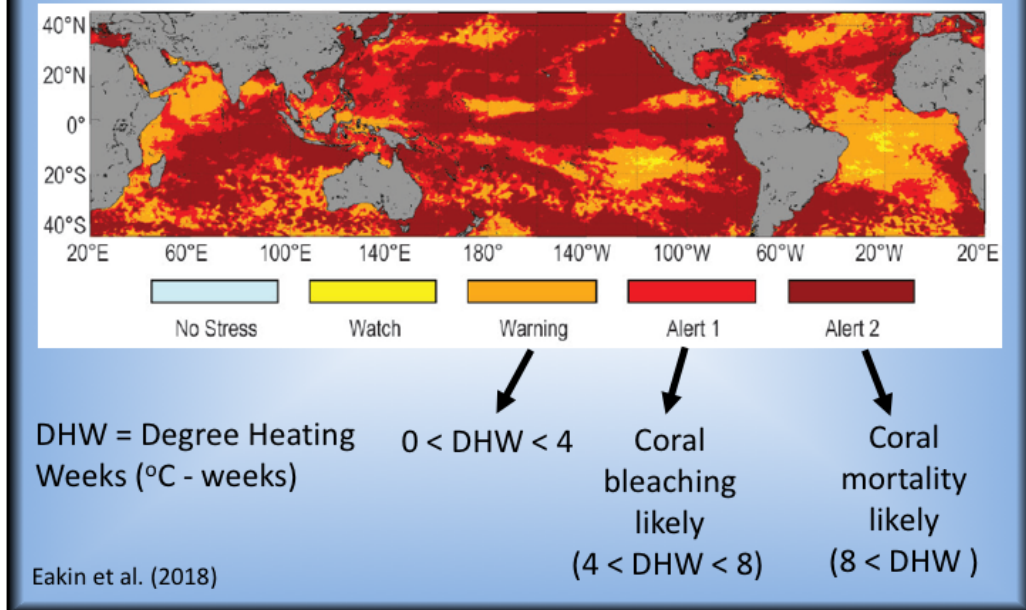
Photo of a fire coral that experienced severe bleaching in the 2016 mass bleaching event. The Ocean Agency / XL Catlin Seaview Survey / Richard Vevers.  
<https://www.vox.com/science-and-health/2017/4/18/15272634/catastrophic-coral-bleaching-great-barrier-reef-map>



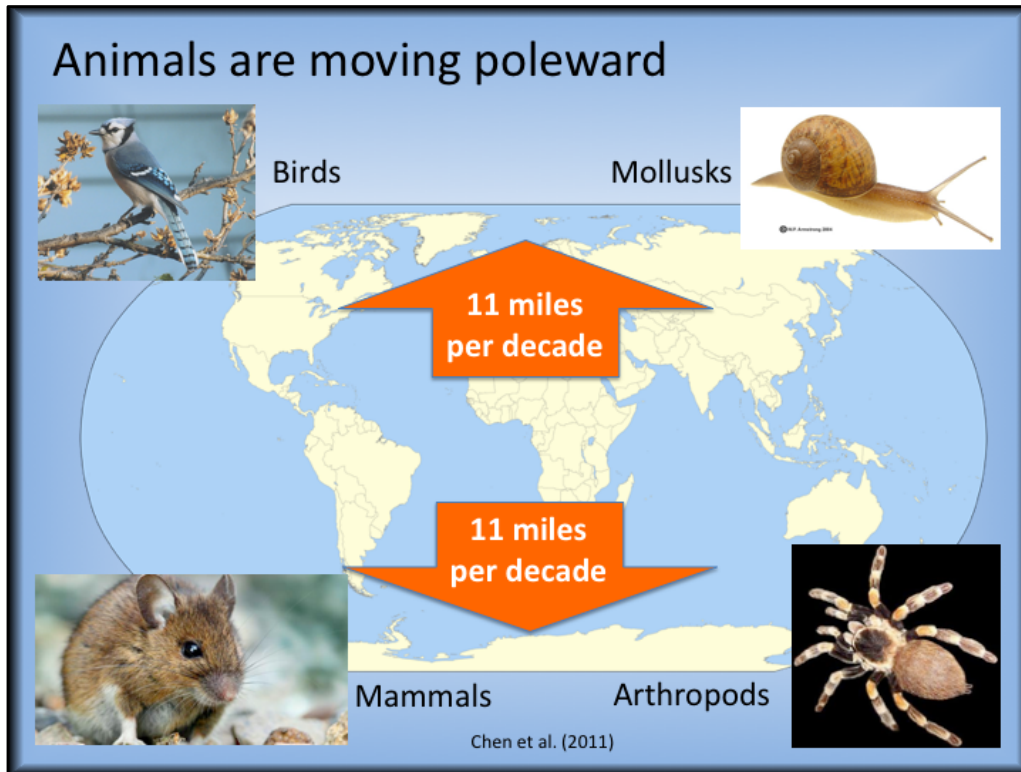
Hughes, T.P., Kerry, J.T., Álvarez-Noriega, M., Álvarez-Romero, J.G., Anderson, K.D., Baird, A.H., Babcock, R.C., Beger, M., Bellwood, D.R., Berkelmans, R., Bridge, T.C., Butler, I.R., Byrne, M., Cantin, N.E., Comeau, S., Connolly, S.R., Cumming, G.S., Dalton, S.J., Diaz-Pulido, G., Eakin, C.M., Figueira, W.F., Gilmour, J.P., Harrison, H.B., Heron, S.F., Hoey, A.S., Hobbs, J.-P.A., Hoogenboom, M.O., Kennedy, E.V., Kuo, C.-y., Lough, J.M., Lowe, R.J., Liu, G., McCulloch, M.T., Malcolm, H.A., McWilliam, M.J., Pandolfi, J.M., Pears, R.J., Pratchett, M.S., Schoepf, V., Simpson, T., Skirving, W.J., Sommer, B., Torda, G., Wachenfeld, D.R., Willis, B.L., Wilson, S.K., 2017. Global warming and recurrent mass bleaching of corals. *Nature* 543, 373–377.

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](https://coralreefwatch.noaa.gov/satellite/education/tutorial/crw24_dhw_product.php)

## Massive coral bleaching occurred during 2014–2017



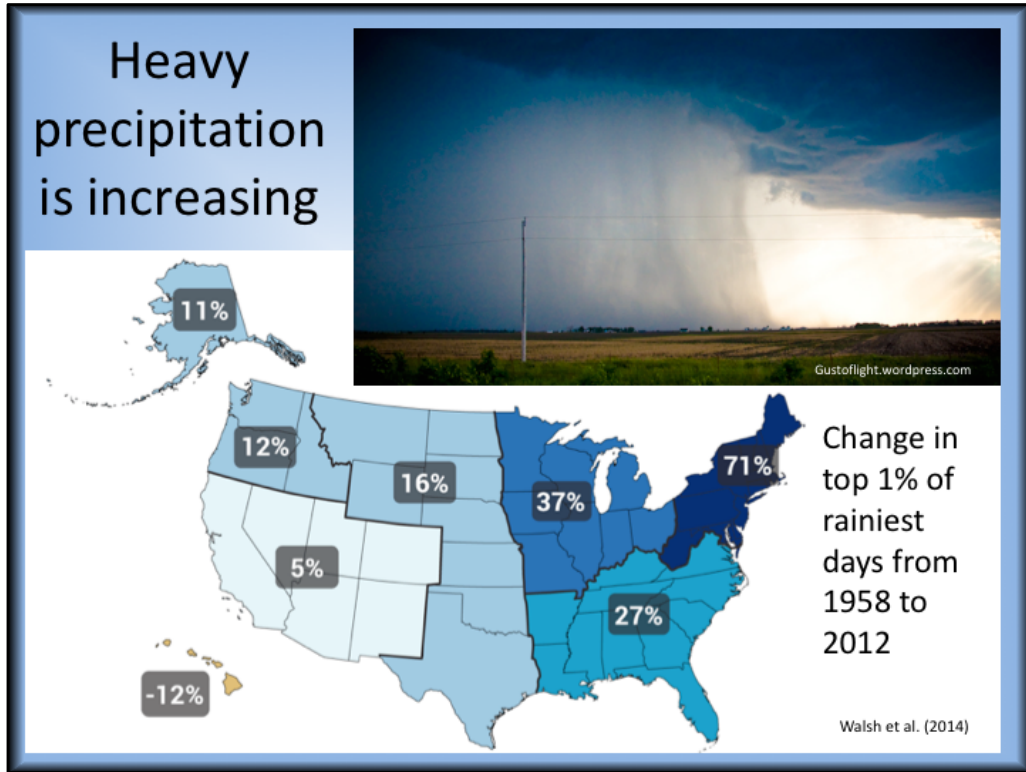
Eakin, C.M., Liu, G., Gomez, A.M., De La Cour, J.L., Heron, S.F., Skirving, W.J., Geiger, E.F., Marsh, B.L., Tirak, K.V., Strong, A.E., 2018. Sidebar 3.1: Unprecedented Three Years of Global Coral Bleaching 2014–17. *Bulletin of the American Meteorological Society* 9, S74–75.



Images: [www.encyclopedia.com](http://www.encyclopedia.com), [waynesword.palomar.edu](http://waynesword.palomar.edu), [dispatch.com](http://dispatch.com), [liveanimalist.com](http://liveanimalist.com), [en.wikipedia.org](http://en.wikipedia.org)

Chen, I.C., Hill, J.K., Ohlemüller, R., Roy, D.B., Thomas, C.D., 2011. Rapid range shifts of species associated with high levels of climate warming. *Science* 333, 1024-1026.





Walsh, J., Wuebbles, D., Hayhoe, K., Kossin, J., Kunkel, K., Stephens, G., Thorne, P., Vose, R., Wehner, M., Willis, J., Anderson, D., Doney, S., Feely, R., Hennon, P., Kharin, V., Knutson, T., Landerer, F., Lenton, T., Kennedy, J., Somerville, R., 2014. Chapter 2: Our Changing Climate. In: J.M. Melillo, T.C. Richmond, G.W. Yohe (Editors), Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, pp. 19-67.

## Tree rings tell the story of drought

First year  
**Rainy season**  
**Dry season**  
Fire scar



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

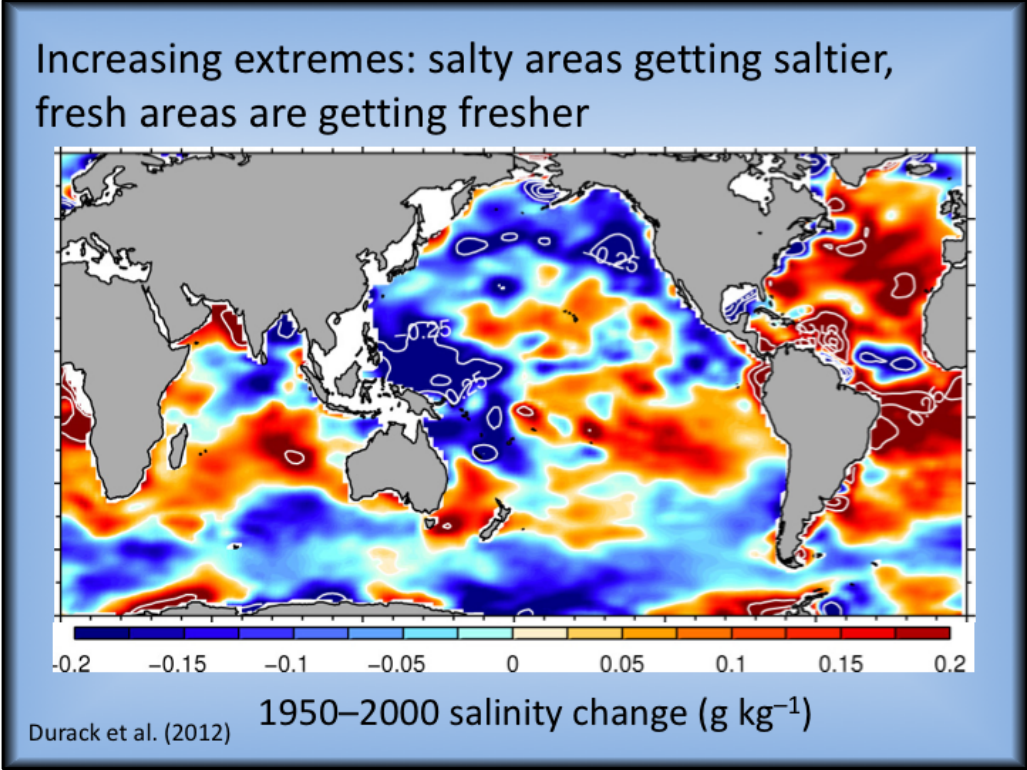
Marvel et al. (2019) and Griffin and K.J. Anchukaitis (2014)

Image:

[https://www.esrl.noaa.gov/gmd/education/info\\_activities/pdfs/PSA\\_tree\\_rings.pdf](https://www.esrl.noaa.gov/gmd/education/info_activities/pdfs/PSA_tree_rings.pdf)

Marvel, K., Cook, B.I., Bonfils, C.J.W., Durack, P.J., Smerdon, J.E., Williams, A.P., 2019. Twentieth-century hydroclimate changes consistent with human influence. *Nature* 569, 59-65.

Griffin, D., Anchukaitis, K.J., 2014. How unusual is the 2012–2014 California drought? *Geophysical Research Letters* 41, 9017-9023.

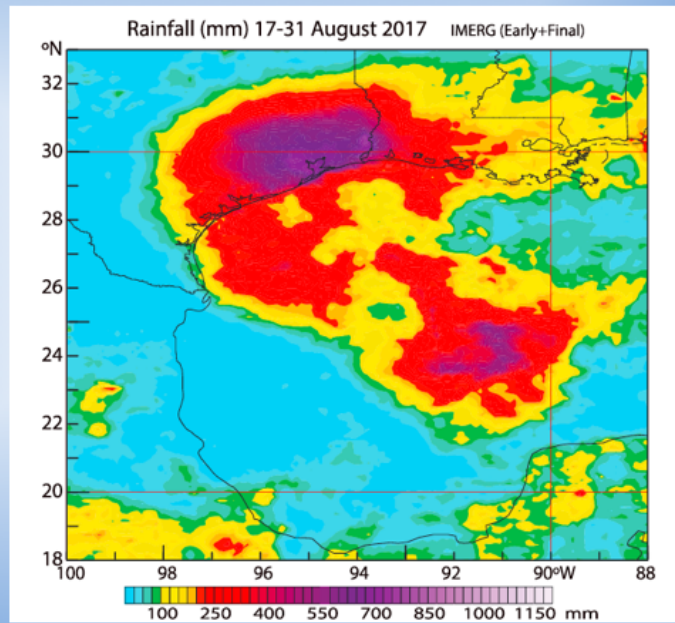


Durack, P.J., Wijffels, S.E., Matear, R.J., 2012. Ocean Salinities Reveal Strong Global Water Cycle Intensification During 1950 to 2000. *Science* 336, 455-458.

## 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)

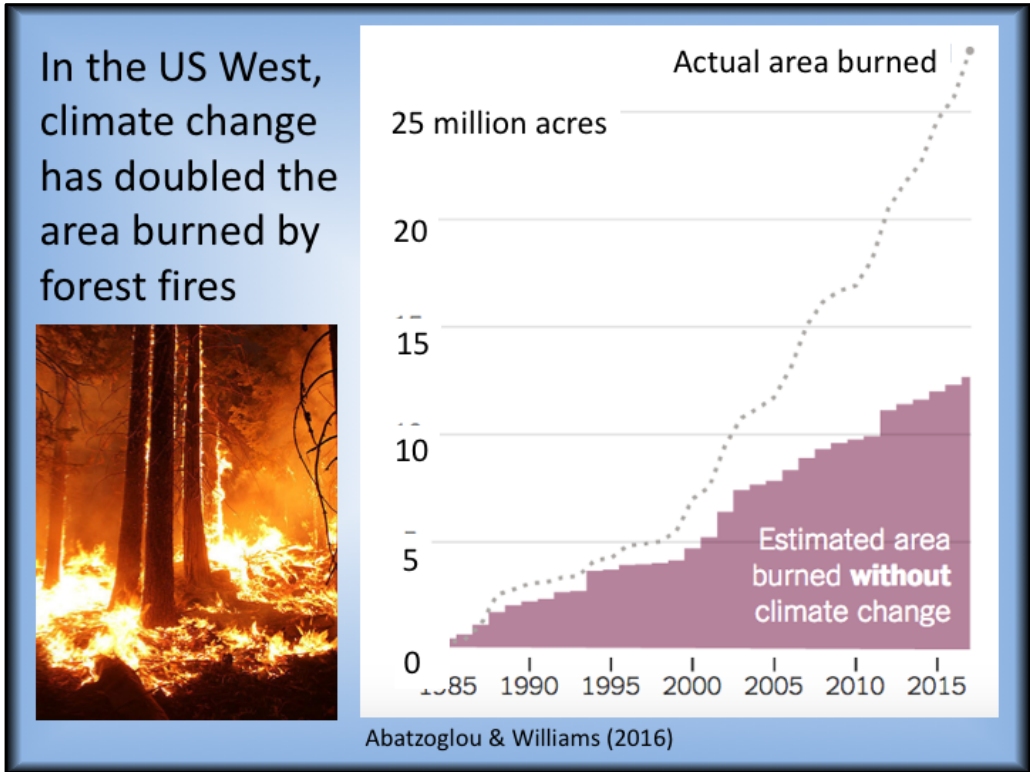


Trenberth, K.E., Cheng, L., Jacobs, P., Zhang, Y., Fasullo, J., 2018. Hurricane Harvey Links to Ocean Heat Content and Climate Change Adaptation. *Earth's Future* 6, 730-744.



Image: <https://abcnews.go.com/International/hurricane-maria-strengthens-category-ravaging-puerto-rico/story?id=49997188>

Keellings, D., & Hernández Ayala, J. J. (2019). Extreme rainfall associated with Hurricane Maria over Puerto Rico and its connections to climate variability and change. *Geophysical Research Letters*, 46, 2964–2973.  
<https://doi.org/10.1029/2019GL082077>



Abatzoglou, J.T., Williams, A.P., 2016. Impact of anthropogenic climate change on wildfire across western US forests. *Proceedings of the National Academy of Sciences* 113, 11770-11775.

Graphic: <https://www.nytimes.com/interactive/2018/11/27/climate/wildfire-global-warming.html>

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

Norway: 34% richer

Increasing wealth gap  
among countries due  
to climate change

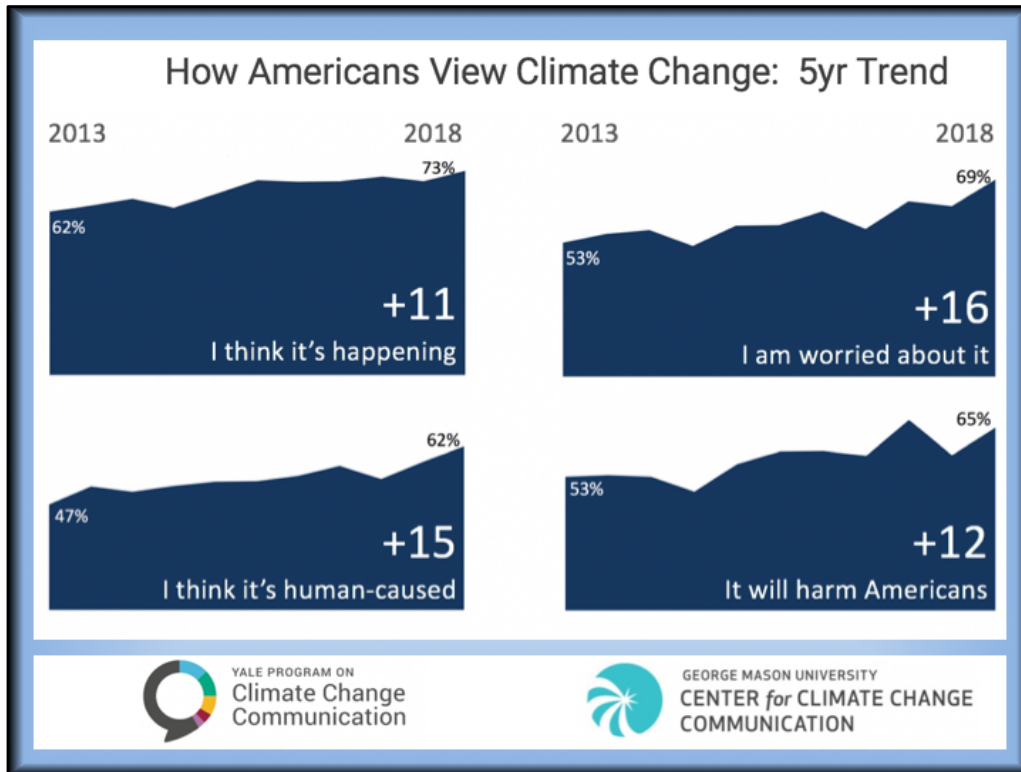


Nigeria: 29% poorer

Diffenbaugh & Burke (2019)

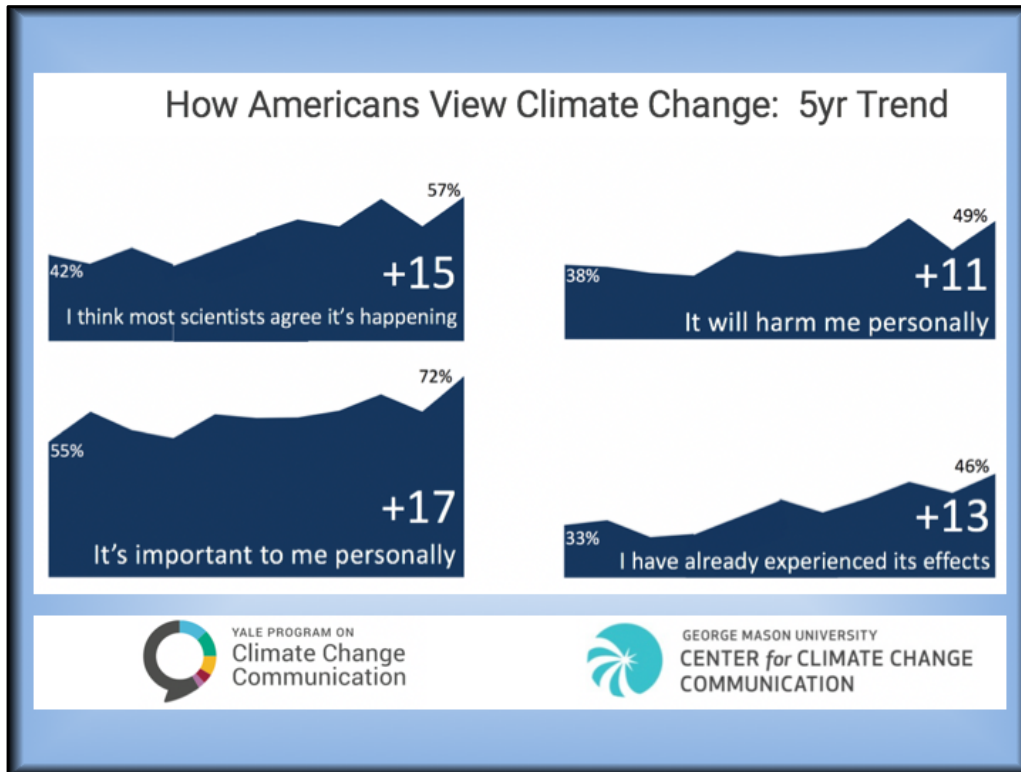
Diffenbaugh, N.S., Burke, M., 2019. Global warming has increased global economic inequality. *Proceedings of the National Academy of Sciences*, 201816020.

Images: <https://www.nytimes.com/2019/04/22/climate/climate-change-global-wealth-gap.html?smid=nytcore-ios-share>

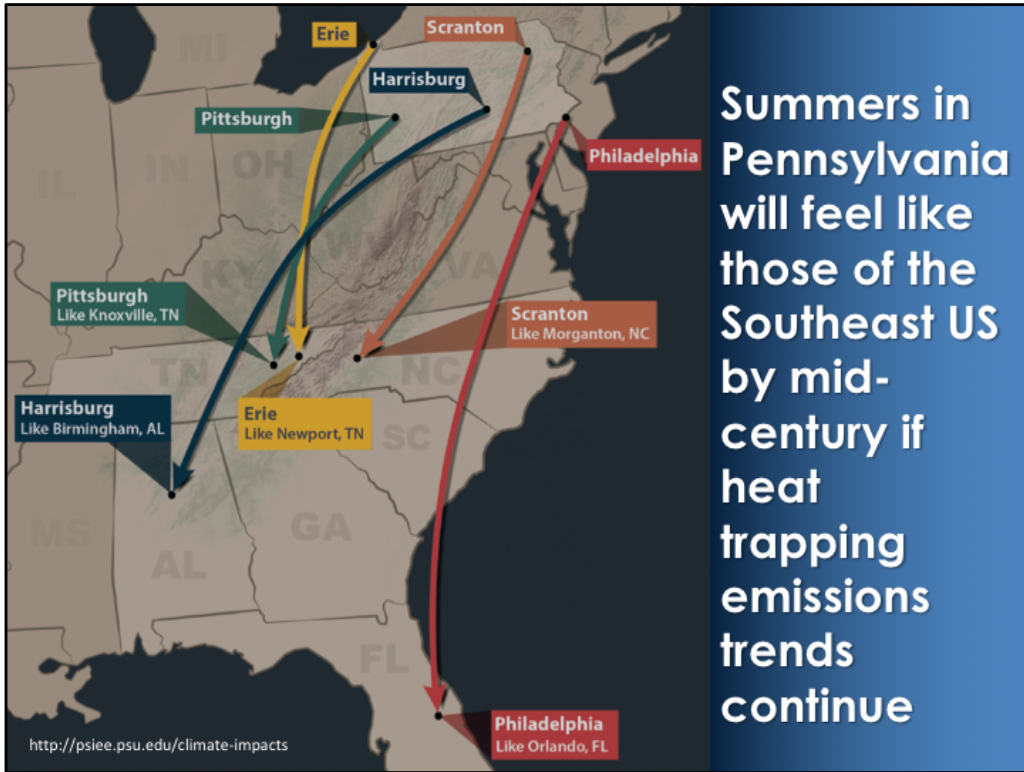


<https://climatecommunication.yale.edu/publications/a-growing-majority-of-americans-think-global-warming-is-happening-and-are-worried/>

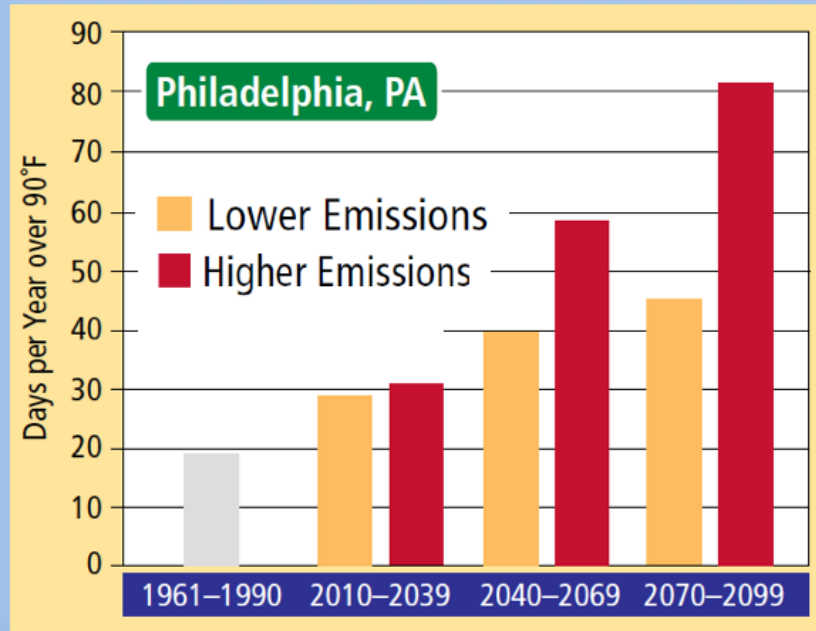




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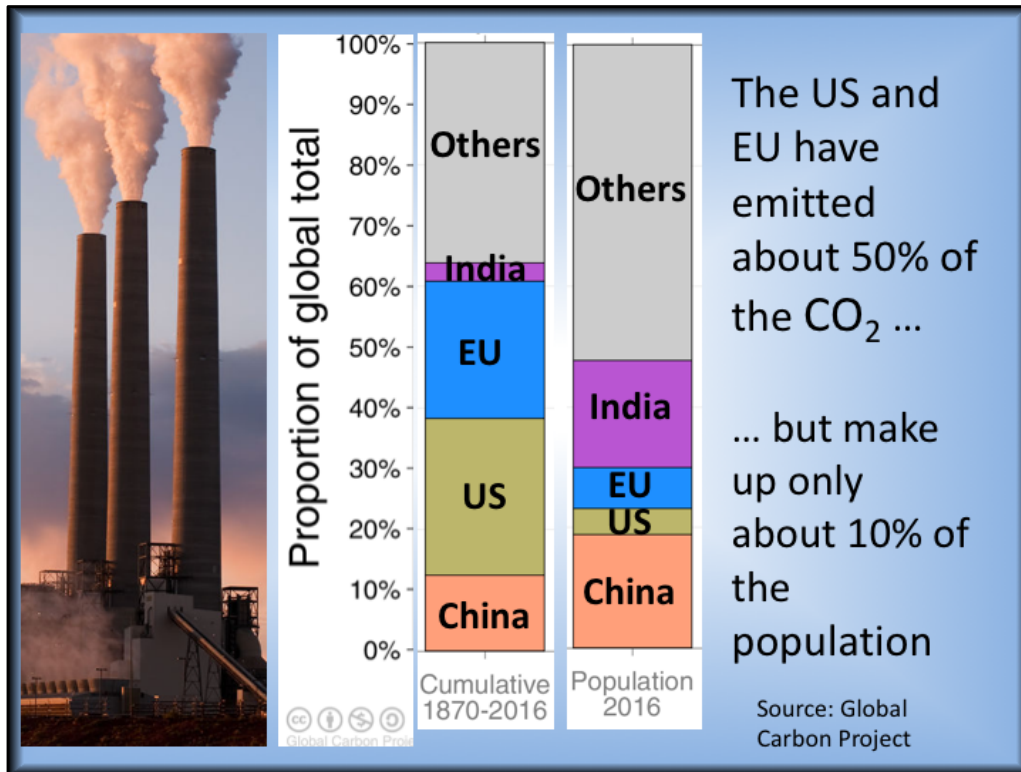


## Emissions really matter, especially in the long run



Union of Concerned Scientists (2008)

Union of Concerned Scientists, 2008. Climate Change in Pennsylvania: Impacts and Solutions for the Keystone State. Cambridge, MA, 54 pp.



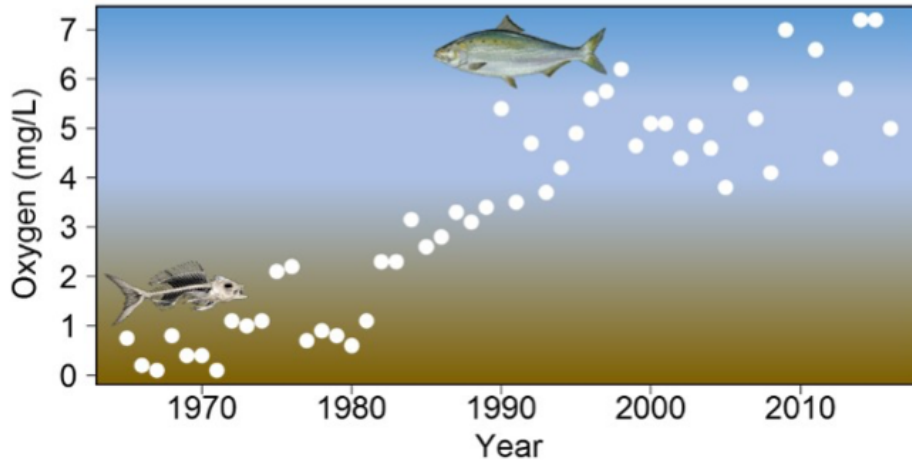
[https://www.globalcarbonproject.org/carbonbudget/18/files/GCP\\_CarbonBudget\\_2018.pdf](https://www.globalcarbonproject.org/carbonbudget/18/files/GCP_CarbonBudget_2018.pdf)

Image: Robert Fullerton/Shutterstock

We have cleaned up  
our own messes before

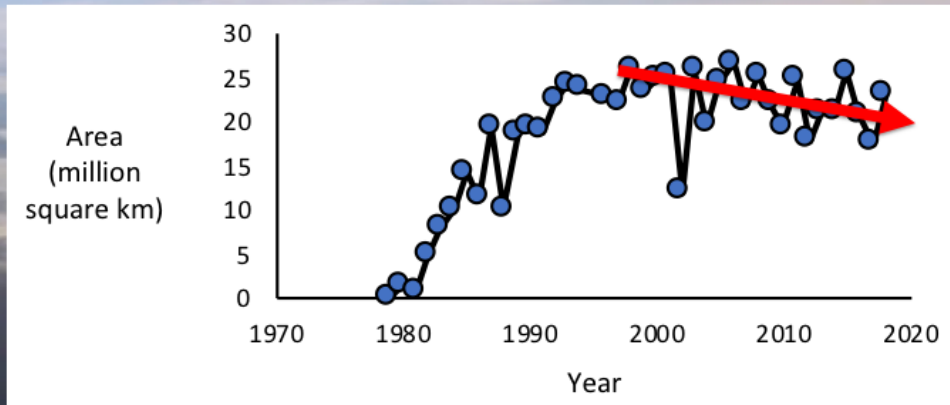
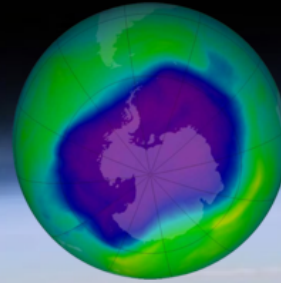
Cleanup of the Delaware River allowed the return of the American Shad

### July Oxygen at Ben Franklin Bridge



<https://www.nj.gov/drbc/edweb/shad-return.html>

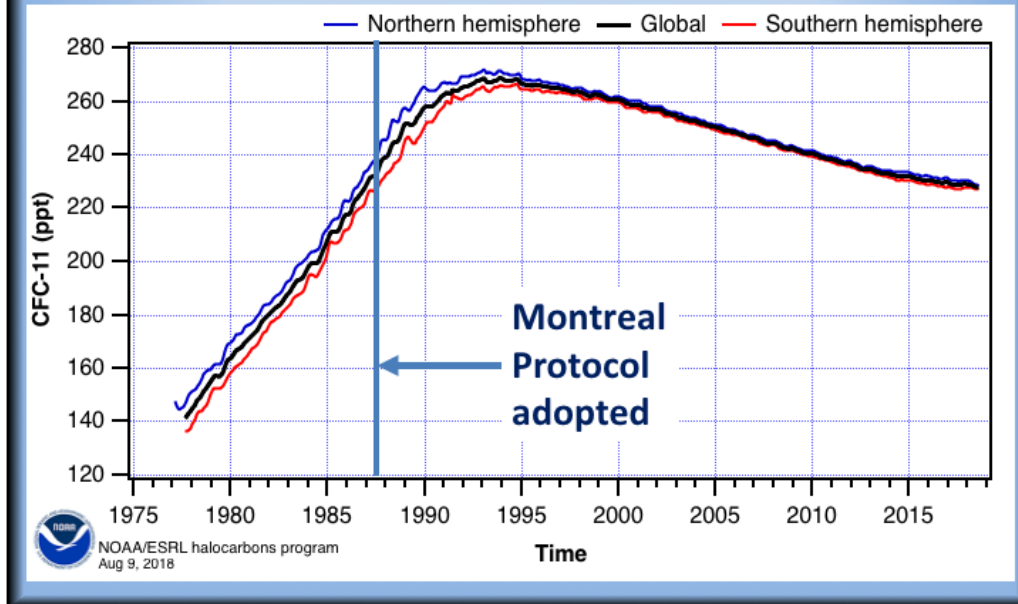
Good news: the ozone hole is shrinking!



NASA image

[https://ozonewatch.gsfc.nasa.gov/statistics/annual\\_data.html](https://ozonewatch.gsfc.nasa.gov/statistics/annual_data.html)

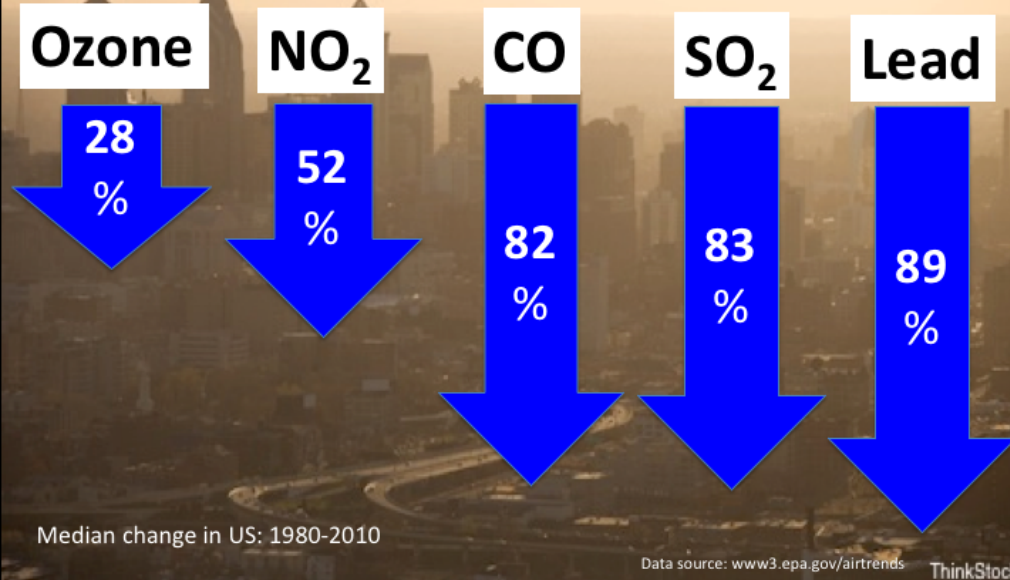
Why? Because levels of (human-produced) chlorofluorocarbons are dropping.



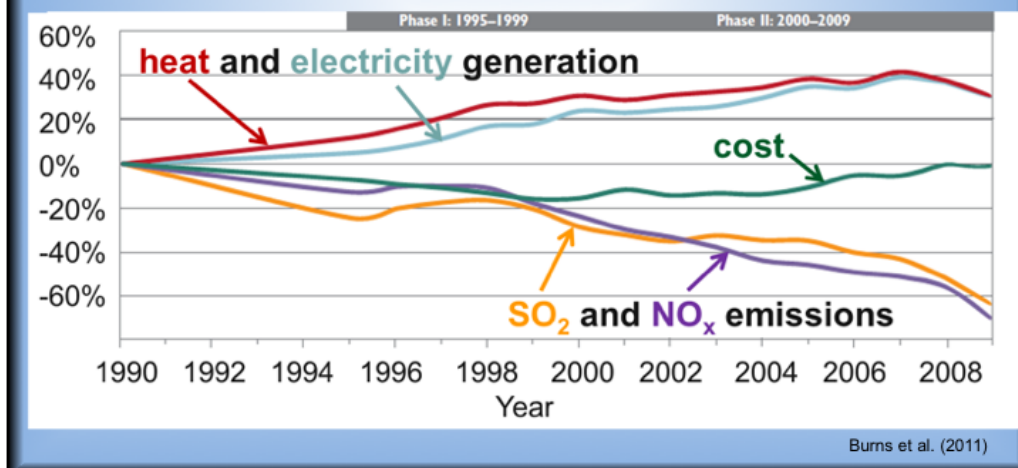
<https://www.esrl.noaa.gov/gmd/hats/combined/CFC11.html>



This is happening much less often than  
it used to



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!



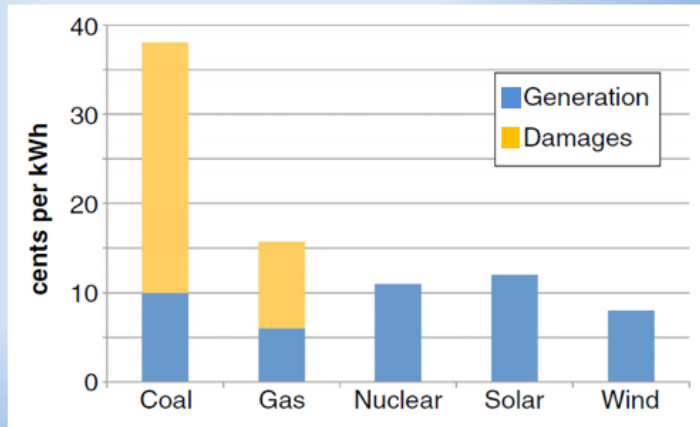
Burns, D.A., Baron, J.S., Cosby, B.J., Fenn, M.E., Lynch, J.A., 2011. National Acid Precipitation Assessment Program Report to Congress 2011: An Integrated Assessment. National Science and Technology Council, United States Government, Washington, D.C., 114 pp.



Opportunities

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

*Costs of new US electricity*



Shindell (2015)

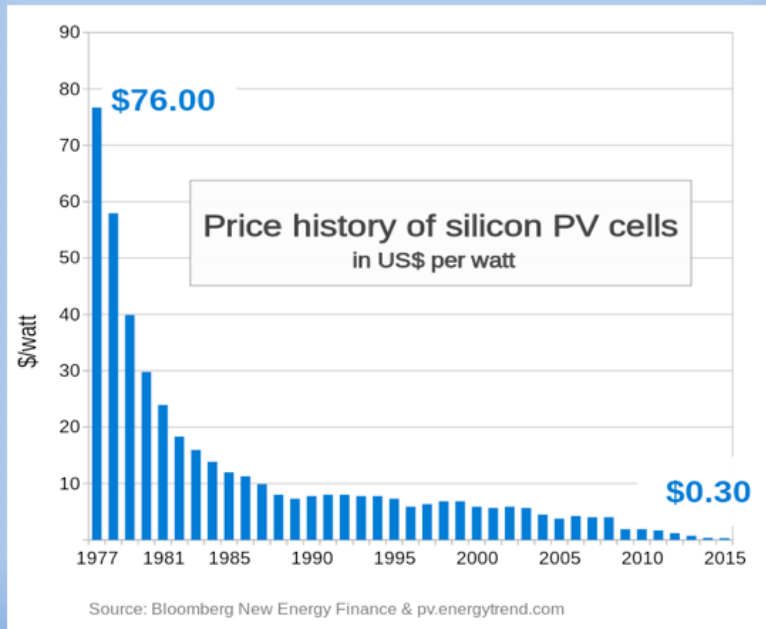
Shindell, D.T., 2015. The social cost of atmospheric release. *Climatic Change* 130, 313–326.

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

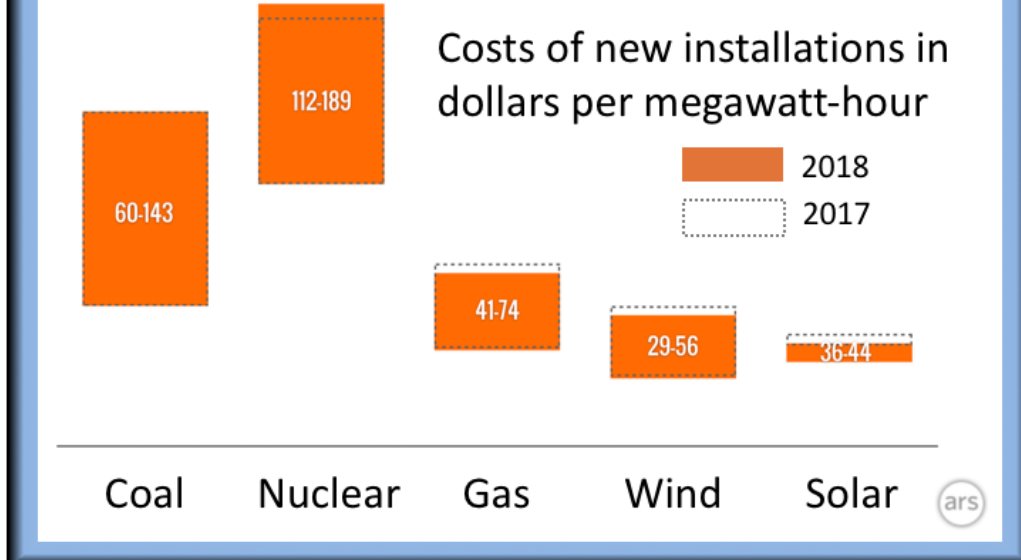


[https://www.cleveland.com/metro/2017/10/lake\\_erie\\_algal\\_bloom\\_cleanup\\_1.html](https://www.cleveland.com/metro/2017/10/lake_erie_algal_bloom_cleanup_1.html)

## The cost to install solar has plummeted

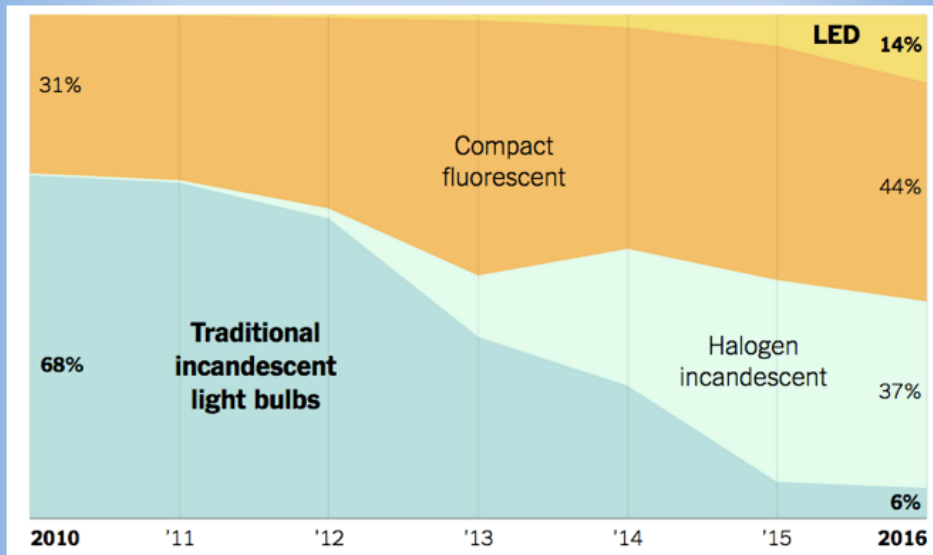


## Renewables are cheap!



<https://arstechnica.com/information-technology/2018/11/new-year-same-story-cost-of-wind-and-solar-fall-below-cost-of-coal-and-gas/>

## Use of efficient light bulbs is skyrocketing ...



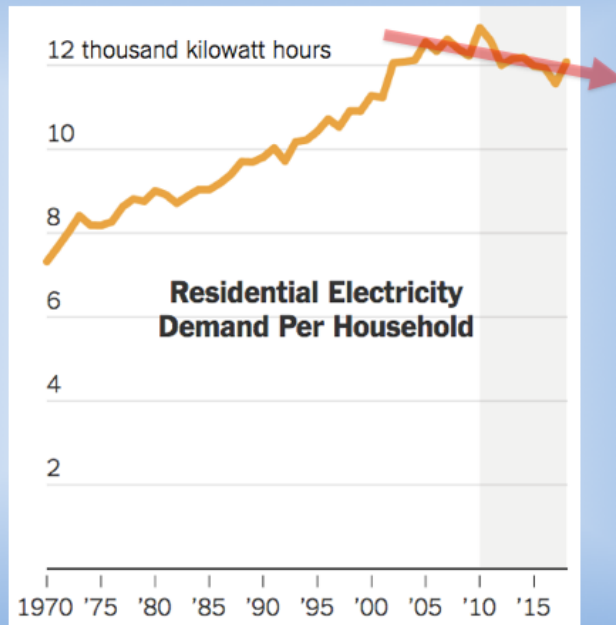
Department of Energy data

Graphic from NY Times:

<https://www.nytimes.com/interactive/2019/03/08/climate/light-bulb-efficiency.html>



... and reducing electricity costs

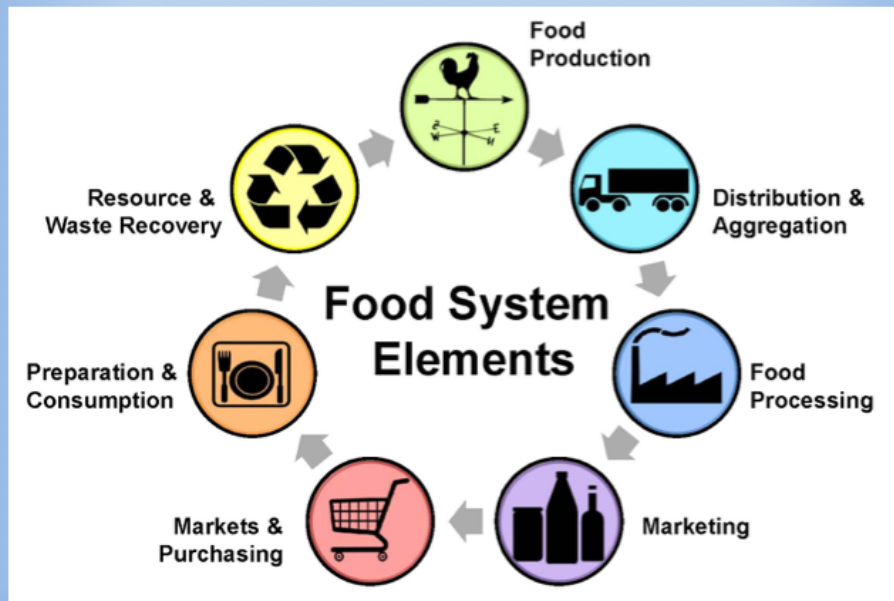


Department of Energy data

Graphic from NY Times:

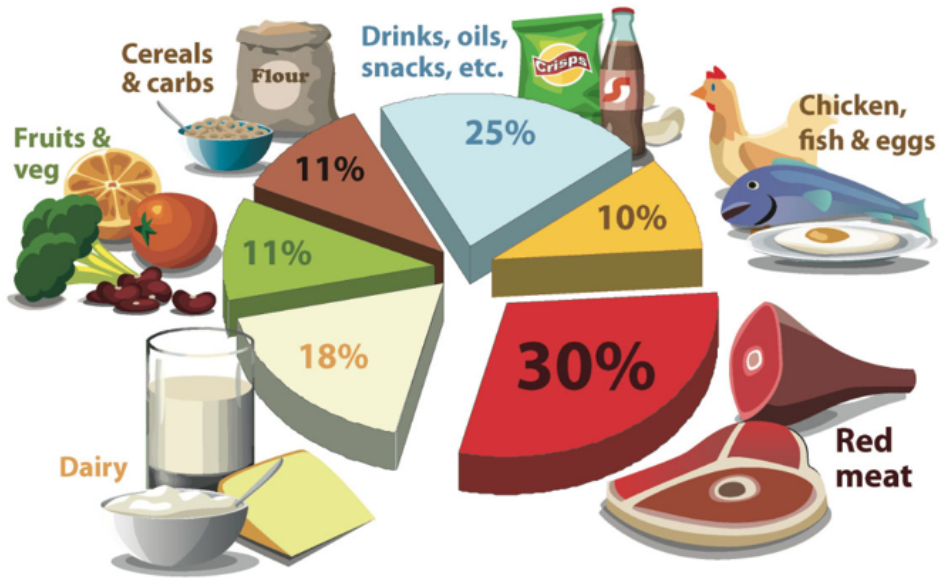
<https://www.nytimes.com/interactive/2019/03/08/climate/light-bulb-efficiency.html>

Food systems are responsible for one-quarter of greenhouse gas emissions



<http://lfs-teg-collab.sites.olt.ubc.ca/files/2015/12/Slide5.jpg>

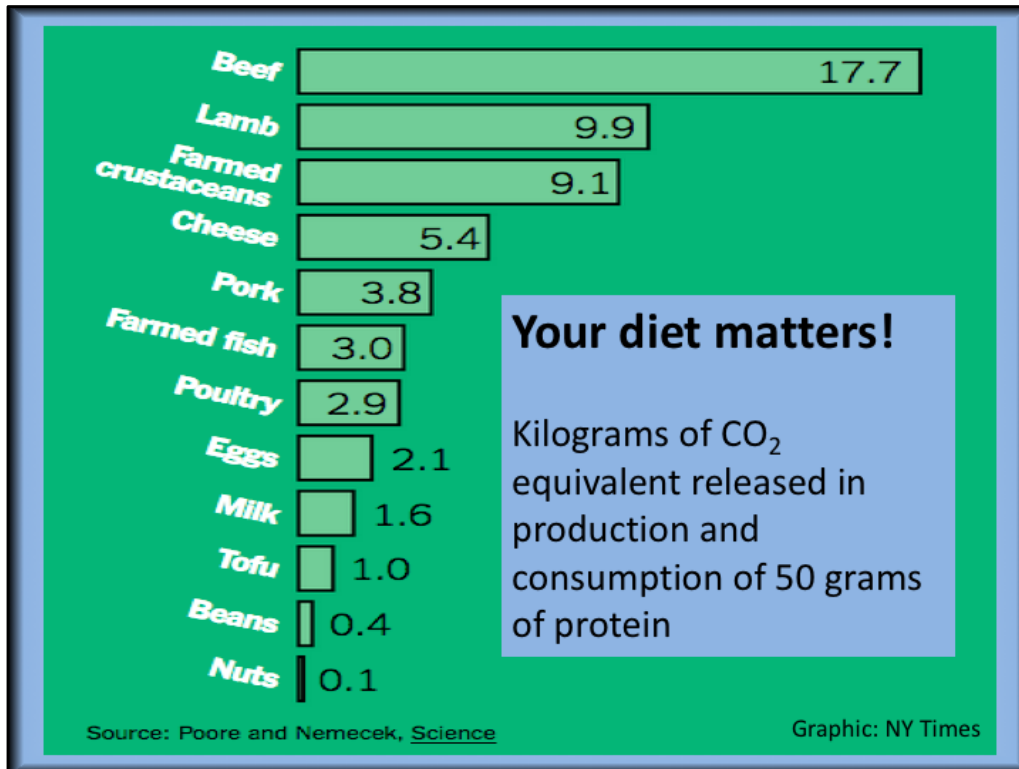
## Sources of greenhouse gas emissions from U.S. food choices



Adapted from: Weber and Matthews (2008) *Food-Miles and the Relative Climate Impacts of Food Choices in the United States*. *Environmental Science & Technology*, 42 (10), 3508-3513.

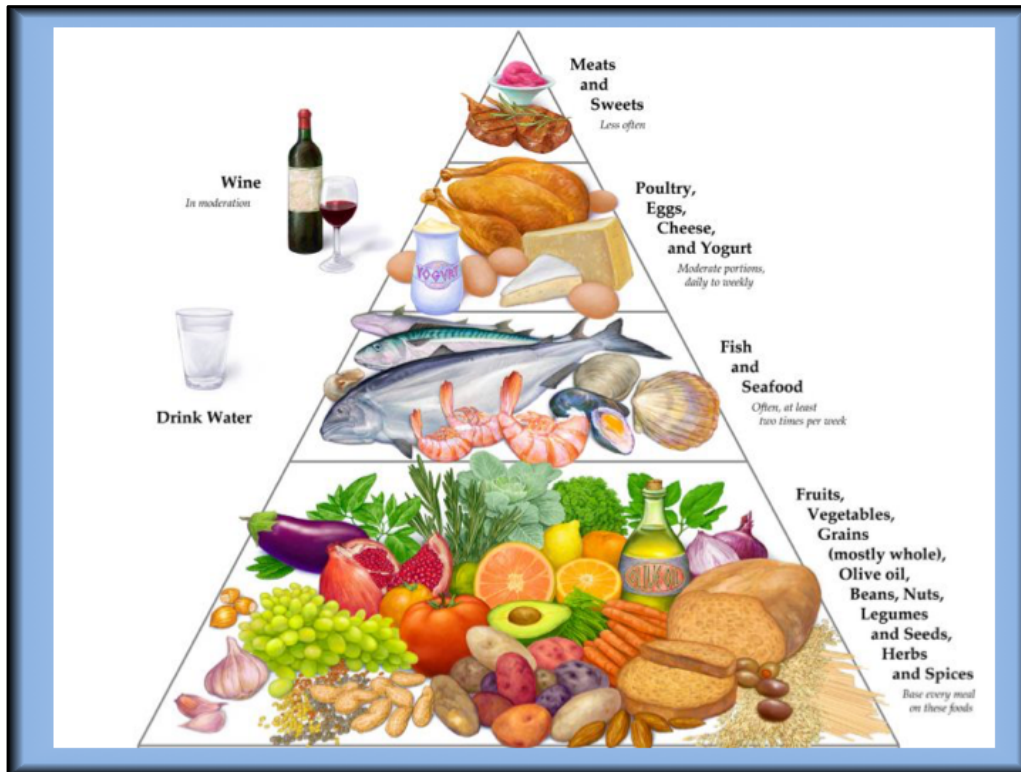
JOHNS HOPKINS  
Center for a Livable Future  
B. 4318

<http://www.foodsystemprimer.org/food-production/food-and-climate-change/index.html>



Poore, J., Nemecek, T., 2018. Reducing food's environmental impacts through producers and consumers. *Science* 360, 987-992.

Graphic: <https://www.nytimes.com/interactive/2019/04/30/dining/climate-change-food-eating-habits.html>



[http://queenscarehealthcenters.org/wp-content/uploads/2015/03/Med\\_pyramid\\_flyer.jpg](http://queenscarehealthcenters.org/wp-content/uploads/2015/03/Med_pyramid_flyer.jpg)

## Cuisines that are easy on the planet



<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>



Douglas A. Becker, Matthew H.E.M. Browning, Ming Kuo, Stephen K. Van Den Eeden. Is green land cover associated with less health care spending? Promising findings from county-level Medicare spending in the continental United States. *Urban Forestry & Urban Greening*, 2019; 41: 39 DOI: [10.1016/j.ufug.2019.02.012](https://doi.org/10.1016/j.ufug.2019.02.012)

Image: Getty Images;



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<sub>2</sub> 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

# PA PowerSwitch

Pennsylvania Public Utility Commission

Shop.



Switch.



Save.



<https://www.papowerswitch.com/>



<https://www.wesa.fm/post/pa-youth-join-global-student-strike-demand-action-climate-change>







<https://www.wesa.fm/post/pa-youth-join-global-student-strike-demand-action-climate-change>


**Energy Innovation AND Carbon Dividend Act**

THE BIPARTISAN CLIMATE SOLUTION

H.R. 763

This bill will drive down America's carbon pollution and bring climate change under control. It is:

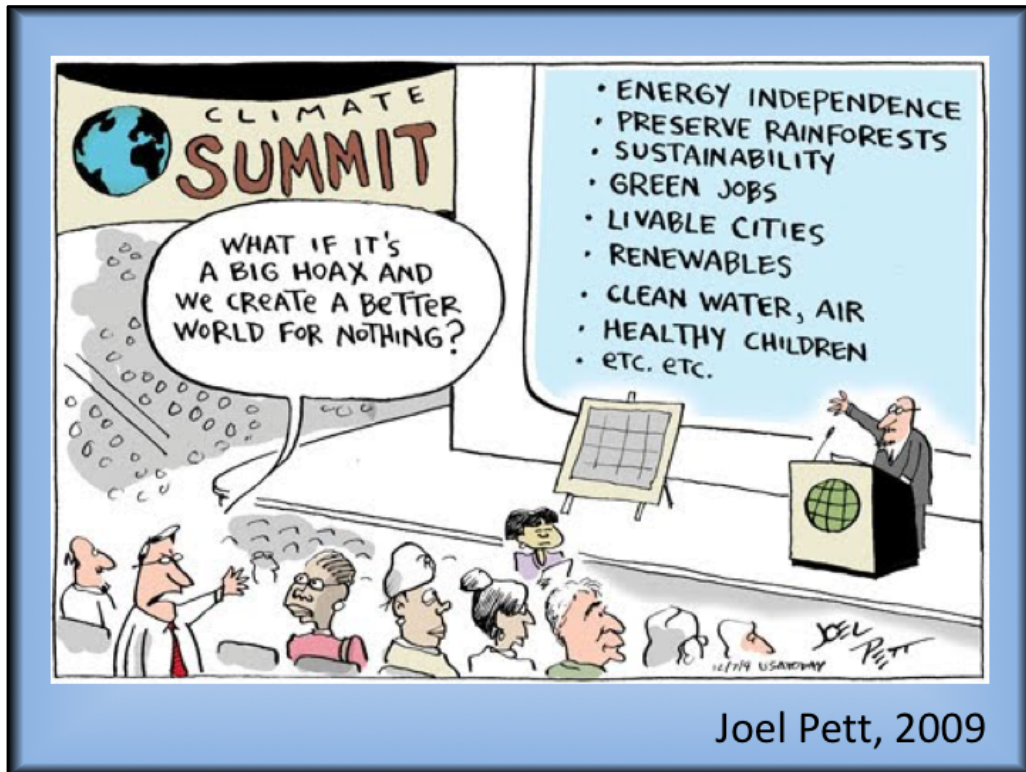
<b>EFFECTIVE</b>	<b>GOOD FOR PEOPLE</b>	<b>GOOD FOR THE ECONOMY</b>	<b>REVENUE NEUTRAL</b>
			

 **Citizens' Climate Lobby**

<https://citizensclimatelobby.org/energy-innovation-and-carbon-dividend-act/>



Image source: [www.cop21paris.org/](http://www.cop21paris.org/)



Joel Pett, 2009