

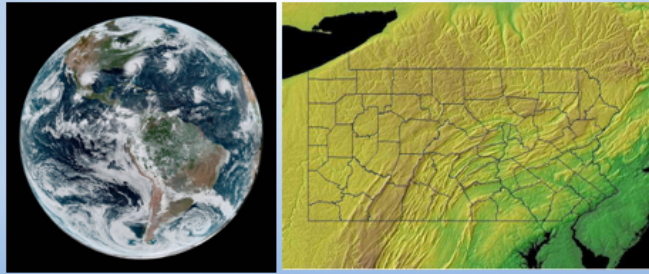
# Managing the threats of climate change in Pennsylvania

Raymond Najjar

The Pennsylvania State University

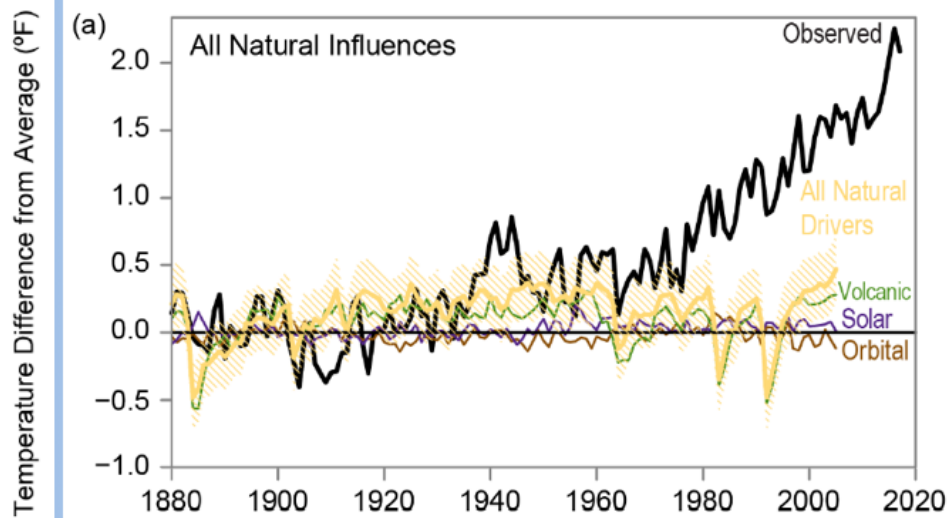
Mifflin County Public Library

November 12, 2019



<https://www.nasa.gov/topics/earth/images/index.html>  
Geology.com

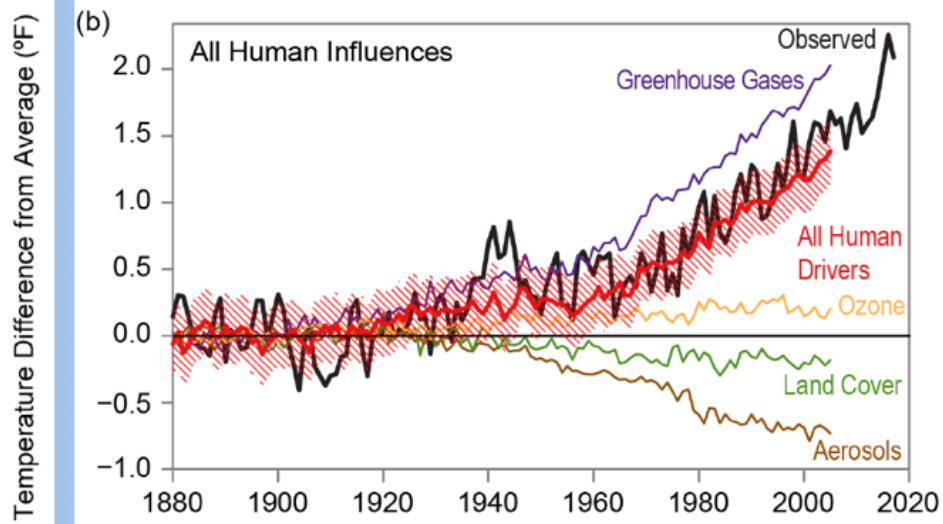
## We cannot explain observed warming with natural drivers ...



Fourth National Climate Assessment, Hayhoe et al. (2018)

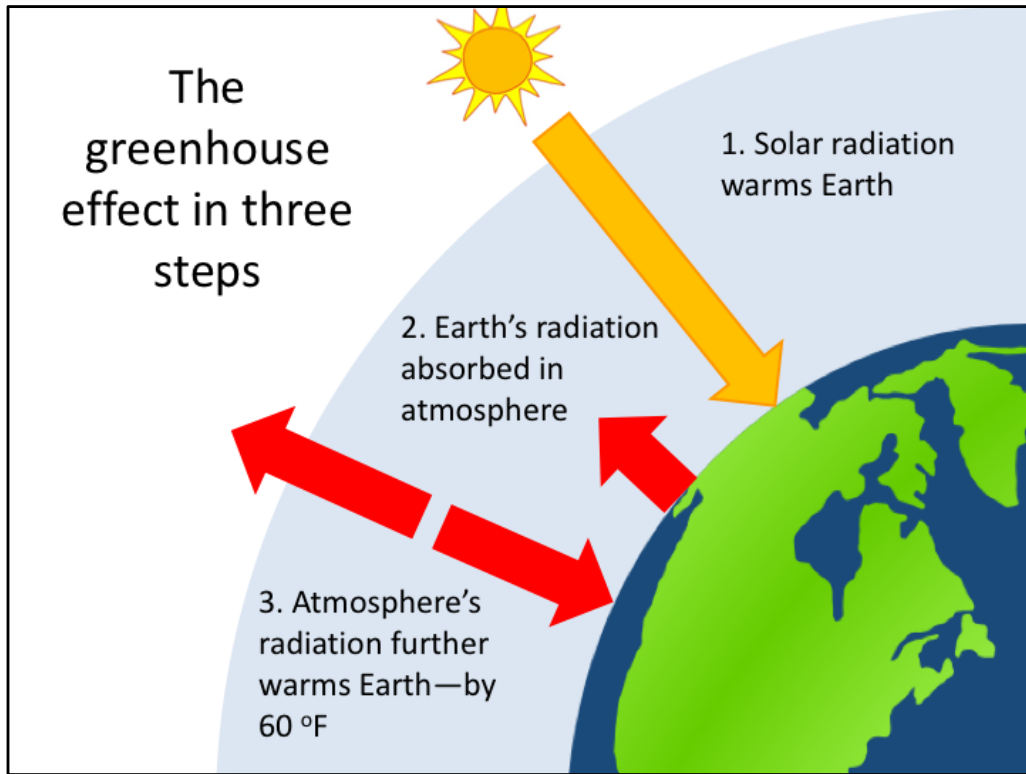
Hayhoe, K., Wuebbles, D.J., Easterling, D.R., Fahey, D.W., Doherty, S., Kossin, J., Sweet, W., Vose, R., Wehner, M., 2018. Our changing climate. In: D.R. Reidmiller, C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, B.C. Stewart (Editors), Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment. US Global Change Research Program, Washington, DC, USA, pp. 72–144.

... but we can with human drivers



Fourth National Climate Assessment, Hayhoe et al. (2018)

Hayhoe, K., Wuebbles, D.J., Easterling, D.R., Fahey, D.W., Doherty, S., Kossin, J., Sweet, W., Vose, R., Wehner, M., 2018. Our changing climate. In: D.R. Reidmiller, C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, B.C. Stewart (Editors), Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment. US Global Change Research Program, Washington, DC, USA, pp. 72–144.





## 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

“Many lines of evidence demonstrate that it is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century.”

“For the period extending over the last century, there are no convincing alternative explanations supported by the extent of the observational evidence.”

Fourth National Climate Assessment, Wuebbles et al. (2017)

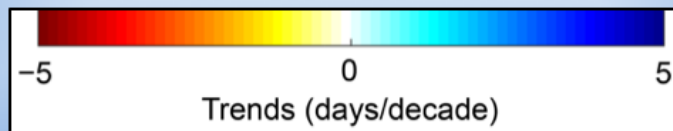
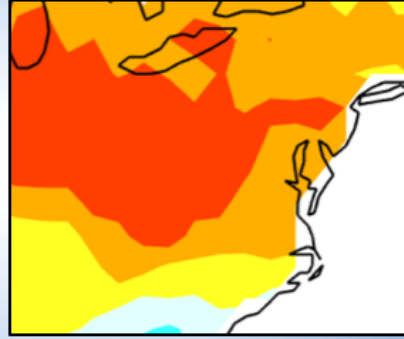
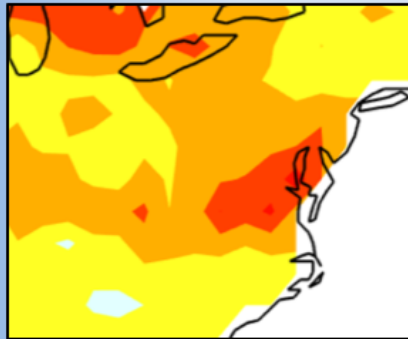
Wuebbles, D.J., Easterling, D.R., Hayhoe, K., Knutson, T., Kopp, R.E., Kossin, J.P., Kunkel, K.E., LeGrande, A.N., Mears, C., Sweet, W.V., Taylor, P.C., Vose, R.S., Wehner, M.F., 2017. Our globally changing climate. In: D.J. Wuebbles, D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, T.K. Maycock (Editors), Climate Science Special Report: Fourth National Climate Assessment, Volume I. U.S. Global Change Research Program, Washington, DC, USA, pp. 35–72.

## Plants are leafing out and blooming earlier

1981–2010 trends of three indicator plants

**First leaf**

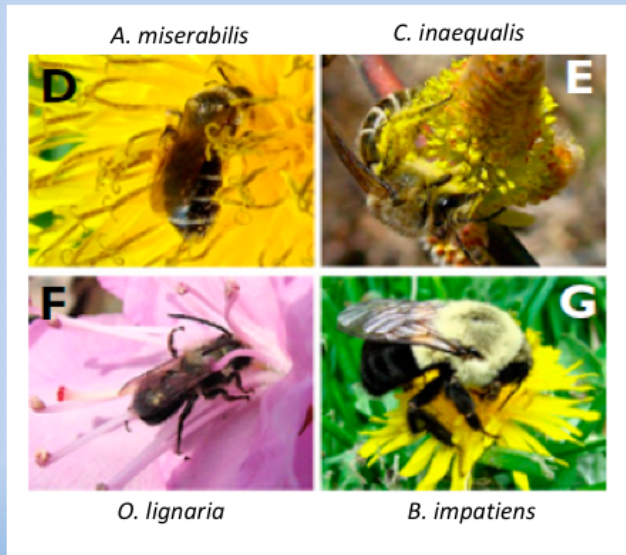
**First bloom**



Fourth National Climate Assessment, Lipton et al. (2018)

Lipton, D., M. A. Rubenstein, S.R. Weiskopf, S. Carter, J. Peterson, L. Crozier, M. Fogarty, S. Gaichas, K.J.W. Hyde, T.L. Morelli, J. Morissette, H. Moustahfid, R. Muñoz, R. Poudel, M.D. Staudinger, C. Stock, L. Thompson, R. Waples, and J.F. Weltzin, 2018: Ecosystems, Ecosystem Services, and Biodiversity. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 268–321. doi: 10.7930/NCA4.2018.CH7

Native bees in Northeast US are arriving in spring 10 days earlier than they used to



Bartomeus et al. (2011)

Bartomeus, I., Ascher, J.S., Wagner, D., Danforth, B.N., Colla, S., Kornbluth, S., Winfree, R., 2011. Climate-associated phenological advances in bee pollinators and bee-pollinated plants. *Proceedings of the National Academy of Sciences* 108, 20645-20649.

Birds in Western PA became smaller by 1.3% on average due to warming from 1961 to 2007



Scarlet tanager: 2% smaller



Rose-breasted grosbeak: 2% smaller

Van Buskirk et al. (2009, 2010)

Van Buskirk, J., Mulvihill, R.S., Leberman, R.C., 2010. Declining body sizes in North American birds associated with climate change. *Oikos* 119, 1047-1055.

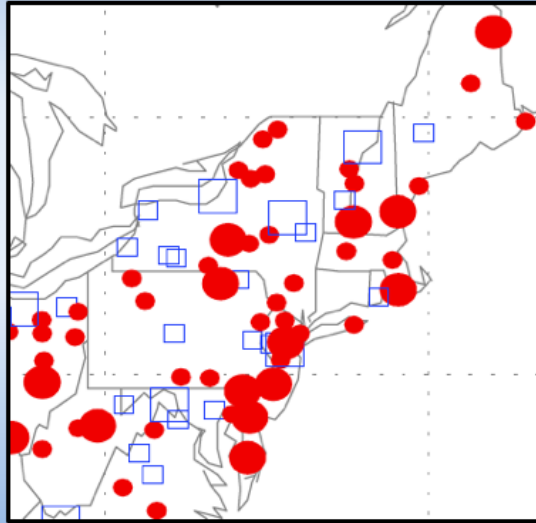
Van Buskirk, J., Mulvihill, R.S., Leberman, R.C., 2009. Variable shifts in spring and autumn migration phenology in North American songbirds associated with climate change. *Global Change Biology* 15, 760-771.

The ratio of snow to total precipitation is mostly decreasing in the Northeast US

1949–2005 trend

● Decreasing

□ Increasing



Feng and Hu (2007)

Feng, S., Hu, Q., 2007. Changes in winter snowfall/precipitation ratio in the contiguous United States. *Journal of Geophysical Research: Atmospheres* 112, doi: 10.1029/2007jd008397.

With warming and snowpack reduction, Snowshoe Hare range in Pennsylvania has contracted



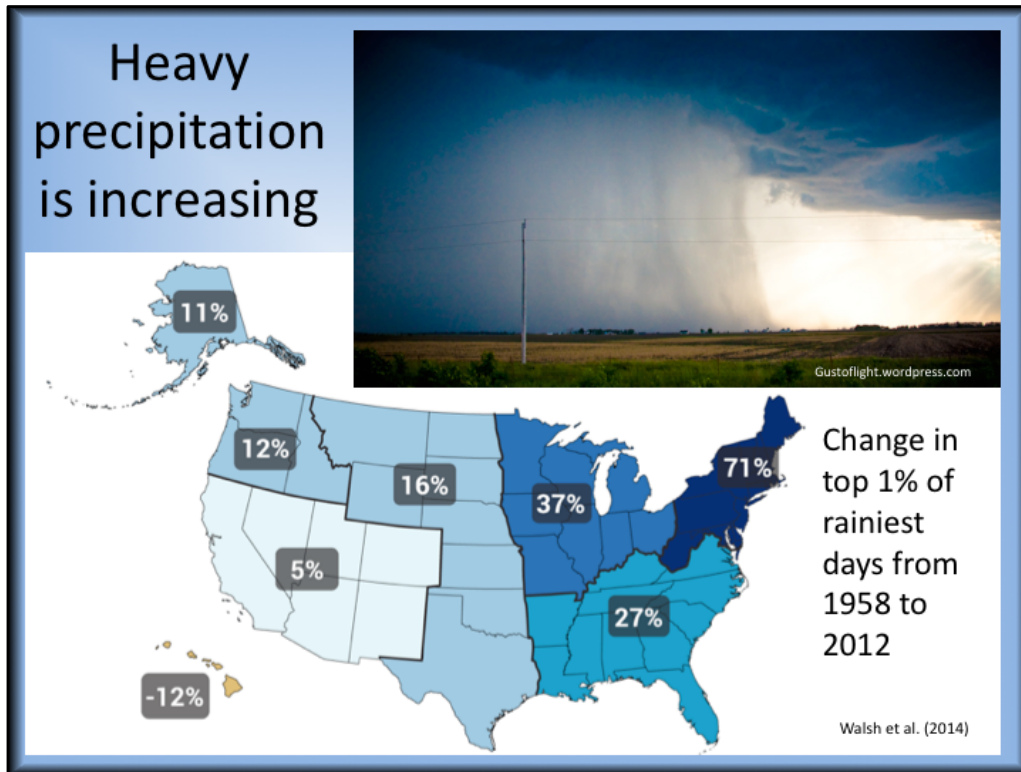
Diefenbach et al. (2016), Fourth National Climate Assessment (Lipton et al. 2018)

Diefenbach, D.R., Rathbun, S.L., Vreeland, J.K., Grove, D., Kanapaux, W.J., 2016. Evidence for range contraction of snowshoe hare in Pennsylvania. *Northeastern Naturalist* 23, 229-249.

Lipton, D., M. A. Rubenstein, S.R. Weiskopf, S. Carter, J. Peterson, L. Crozier, M. Fogarty, S. Gaichas, K.J.W. Hyde, T.L. Morelli, J. Morissette, H. Moustahfid, R. Muñoz, R. Poudel, M.D. Staudinger, C. Stock, L. Thompson, R. Waples, and J.F. Weltzin, 2018: Ecosystems, Ecosystem Services, and Biodiversity. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 268–321. doi: 10.7930/NCA4.2018.CH7

Photo credit: L. S. Mills research photo by Jaco and Lindsey Barnard, University of Montana Mills Research Lab.

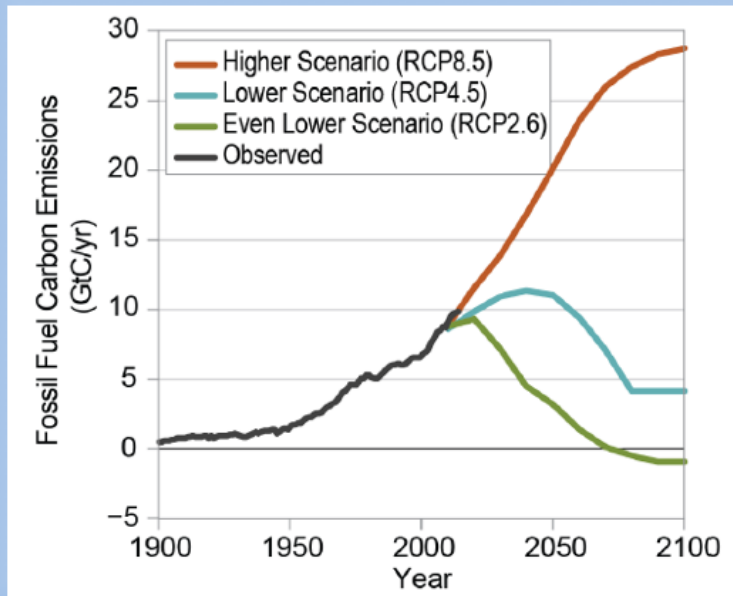




Walsh, J., Wuebbles, D., Hayhoe, K., Kossin, J., Kunkel, K., Stephens, G., Thorne, P., Vose, R., Wehner, M., Willis, J., Anderson, D., Doney, S., Feely, R., Hennon, P., Kharin, V., Knutson, T., Landerer, F., Lenton, T., Kennedy, J., Somerville, R., 2014. Chapter 2: Our Changing Climate. In: J.M. Melillo, 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.



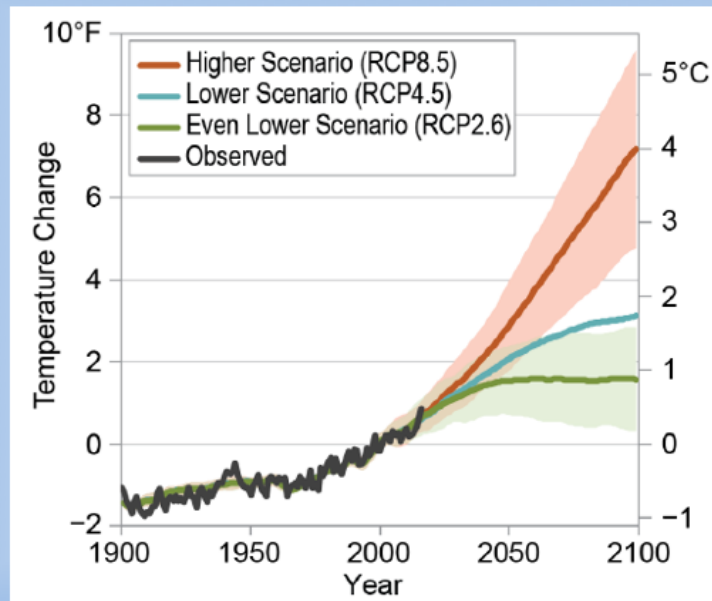
## Three possible emissions futures ...



Fourth National Climate Assessment, Wuebbles et al. (2017)

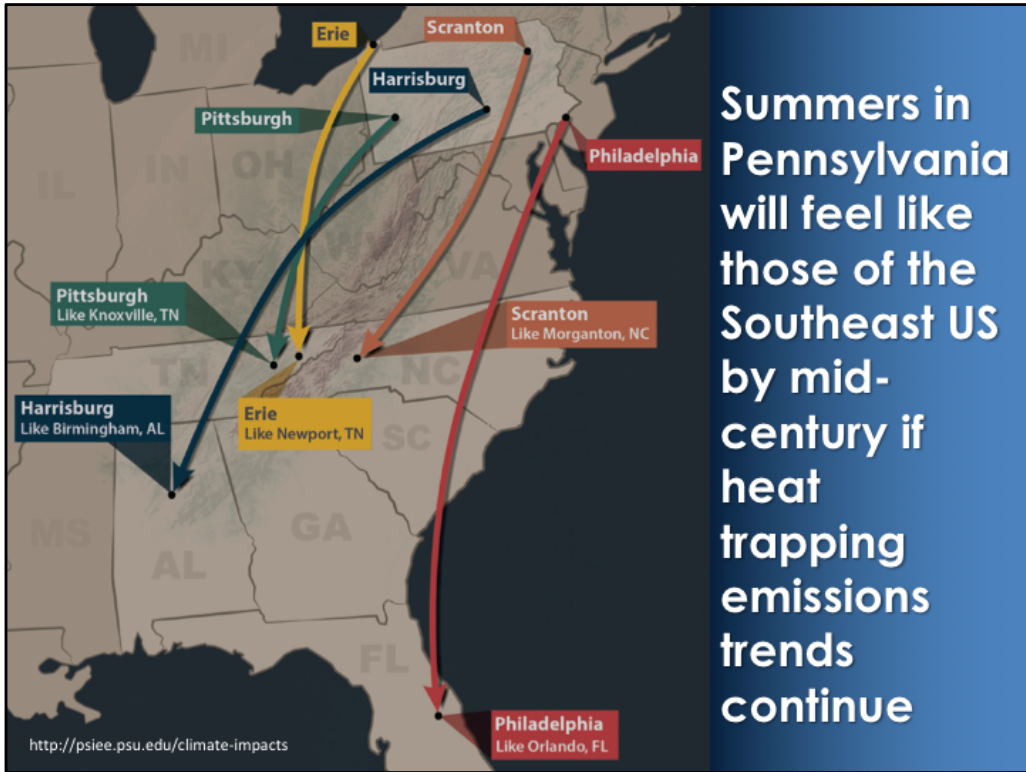
Wuebbles, D.J., Easterling, D.R., Hayhoe, K., Knutson, T., Kopp, R.E., Kossin, J.P., Kunkel, K.E., LeGrande, A.N., Mears, C., Sweet, W.V., Taylor, P.C., Vose, R.S., Wehner, M.F., 2017. Our globally changing climate. In: D.J. Wuebbles, D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, T.K. Maycock (Editors), Climate Science Special Report: Fourth National Climate Assessment, Volume I. U.S. Global Change Research Program, Washington, DC, USA, pp. 35–72.

## ... lead to very different climate futures



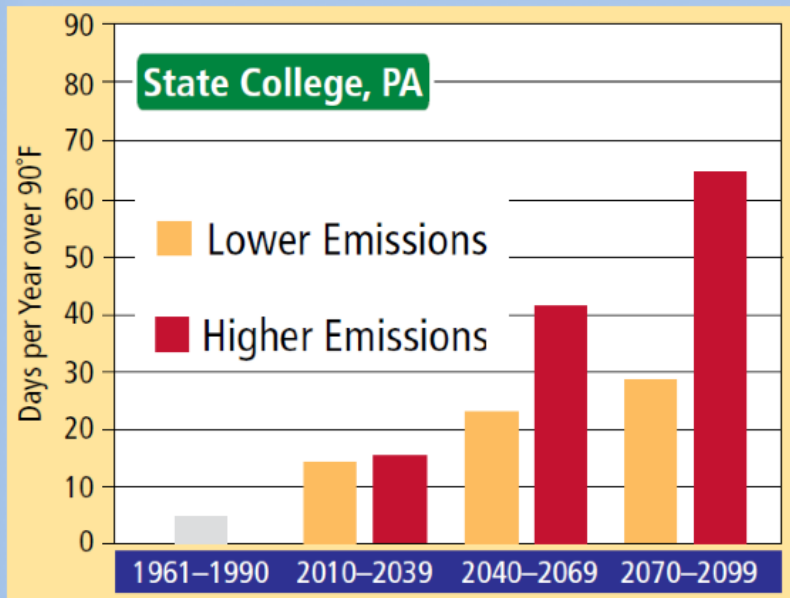
Fourth National Climate Assessment, Wuebbles et al. (2017)

Wuebbles, D.J., Easterling, D.R., Hayhoe, K., Knutson, T., Kopp, R.E., Kossin, J.P., Kunkel, K.E., LeGrande, A.N., Mears, C., Sweet, W.V., Taylor, P.C., Vose, R.S., Wehner, M.F., 2017. Our globally changing climate. In: D.J. Wuebbles, D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, T.K. Maycock (Editors), Climate Science Special Report: Fourth National Climate Assessment, Volume I. U.S. Global Change Research Program, Washington, DC, USA, pp. 35–72.



Summers in Pennsylvania will feel like those of the Southeast US by mid-century if heat trapping emissions trends continue

## Emissions really matter, especially in the long run

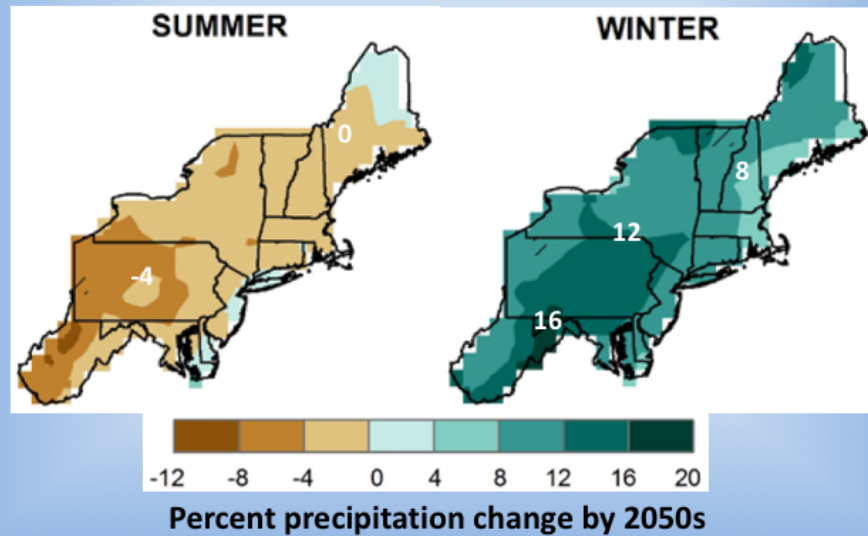


Union of Concerned Scientists (2008)

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

Expect summers to be drier ...

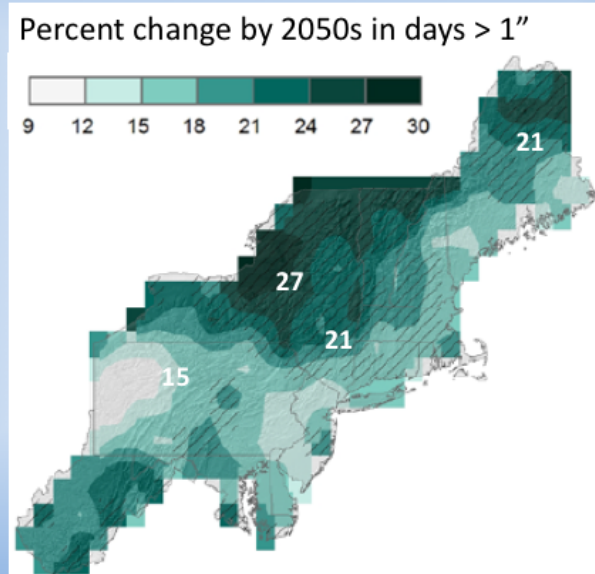
... and winters to be wetter



Kunkel et al. (2013)

Kunkel, K.E., Stevens, L.E., Stevens, S.E., Sun, L., Janssen, E., Wuebbles, D., Rennells, J., DeGaetano, A., Dobson, J.G., 2013. Regional Climate Trends and Scenarios for the U.S. National Climate Assessment, Part 1. Climate of the Northeast U.S., NOAA Technical Report NESDIS 142-1. U.S. Department of Commerce, Washington, D.C., 79 pp.

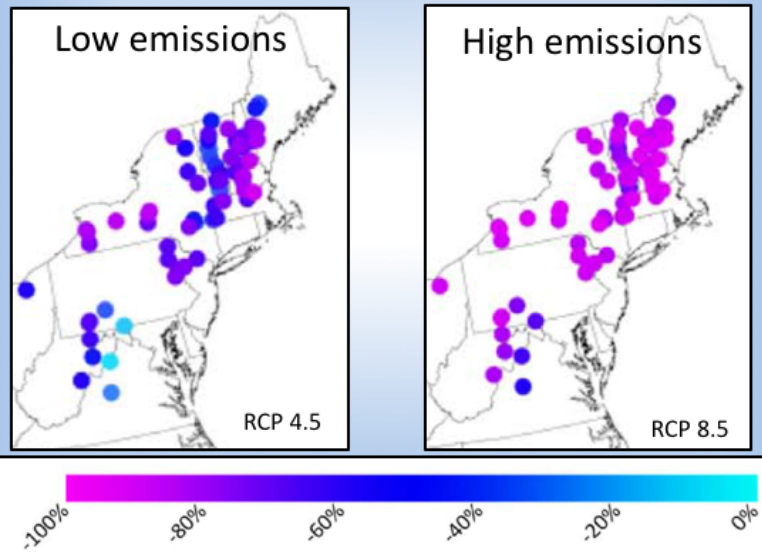
## Expect heavy downpours to continue to increase



Kunkel et al. (2013)

Kunkel, K.E., Stevens, L.E., Stevens, S.E., Sun, L., Janssen, E., Wuebbles, D., Rennells, J., DeGaetano, A., Dobson, J.G., 2013. Regional Climate Trends and Scenarios for the U.S. National Climate Assessment, Part 1. Climate of the Northeast U.S., NOAA Technical Report NESDIS 142-1. U.S. Department of Commerce, Washington, D.C., 79 pp.

## Projected change in downhill skiing season length by 2090



Wobus et al.  
(2017)

Wobus, C., Small, E.E., Hosterman, H., Mills, D., Stein, J., Rissing, M., Jones, R., Duckworth, M., Hall, R., Kolian, M., 2017. Projected climate change impacts on skiing and snowmobiling: A case study of the United States. *Global environmental change* 45, 1-14.

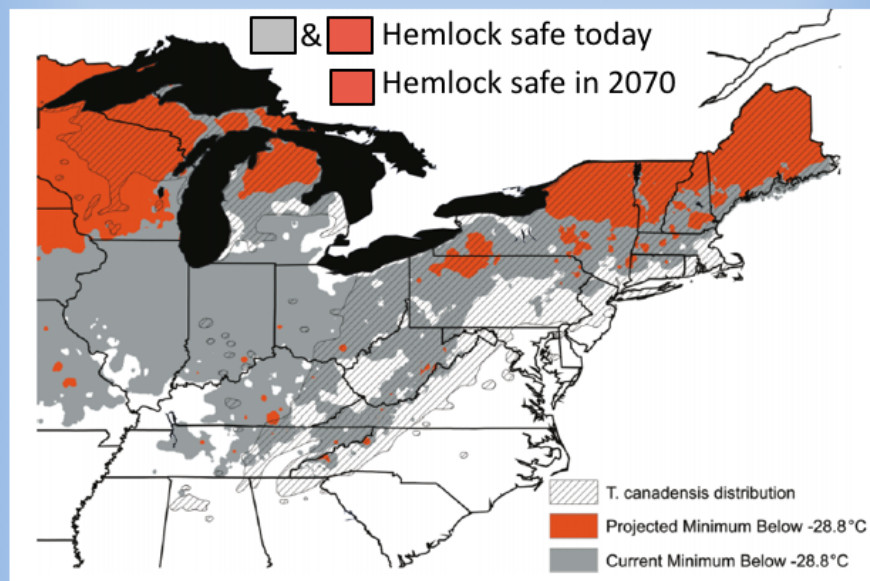
## The woolly adelgid harms the Eastern Hemlock tree (PA state tree)



[savingshemlocks.org](http://savingshemlocks.org)



## Warming winters allow the woolly adelgid to do more damage



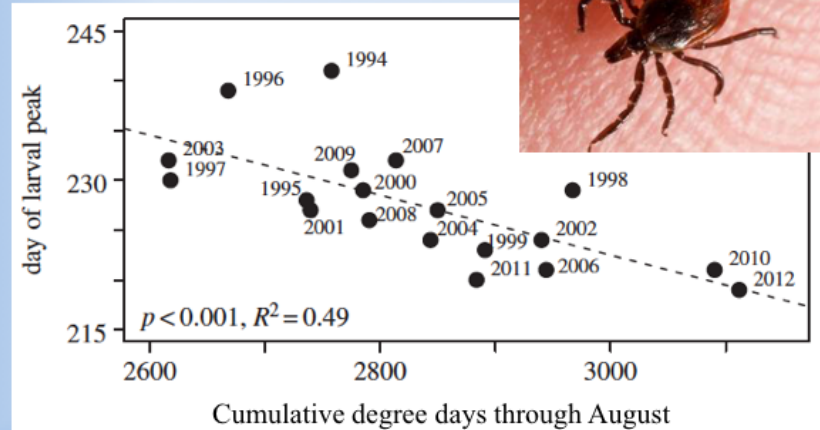
Dukes et al. (2009) A2 scenario, 2070, average of nine GCMs

Dukes, J.S., Pontius, J., Orwig, D., Garnas, J.R., Rodgers, V.L., Brazee, N., Cooke, B., Theoharides, K.A., Stange, E.E., Harrington, R., 2009. Responses of insect pests, pathogens, and invasive plant species to climate change in the forests of northeastern North America: What can we predict? *Canadian Journal of Forest Research* 39, 231-248.

In Millbrook, NY, warming has led to an earlier larval peak of the blacklegged (deer) tick, the major Lyme disease transmitter



Earlier  
larval  
peak



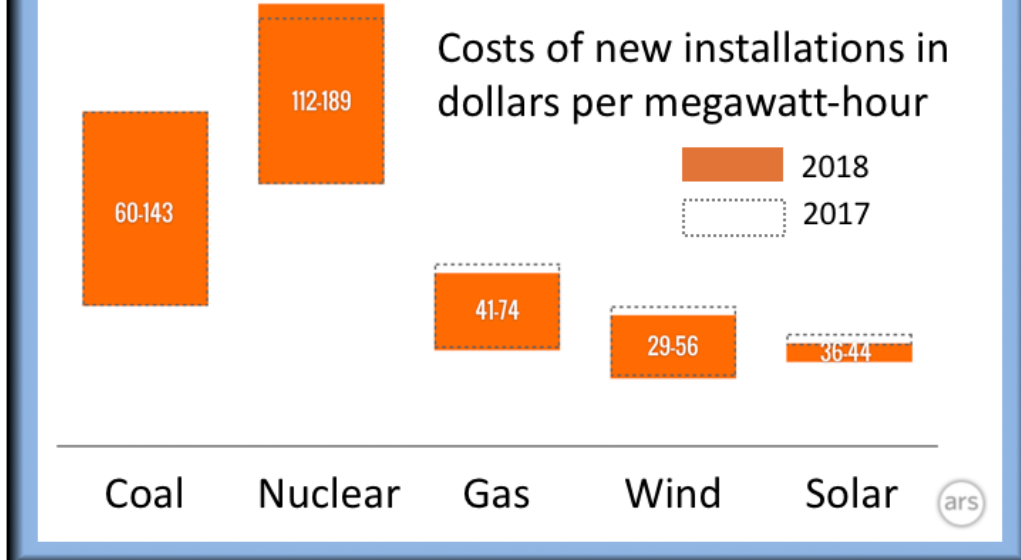
Warmer years

Levi et al. (2015)

Levi, T., Keesing, F., Oggenfuss, K., Ostfeld, R.S., 2015. Accelerated phenology of blacklegged ticks under climate warming. *Philosophical Transactions of the Royal Society B: Biological Sciences* 370, 20130556.

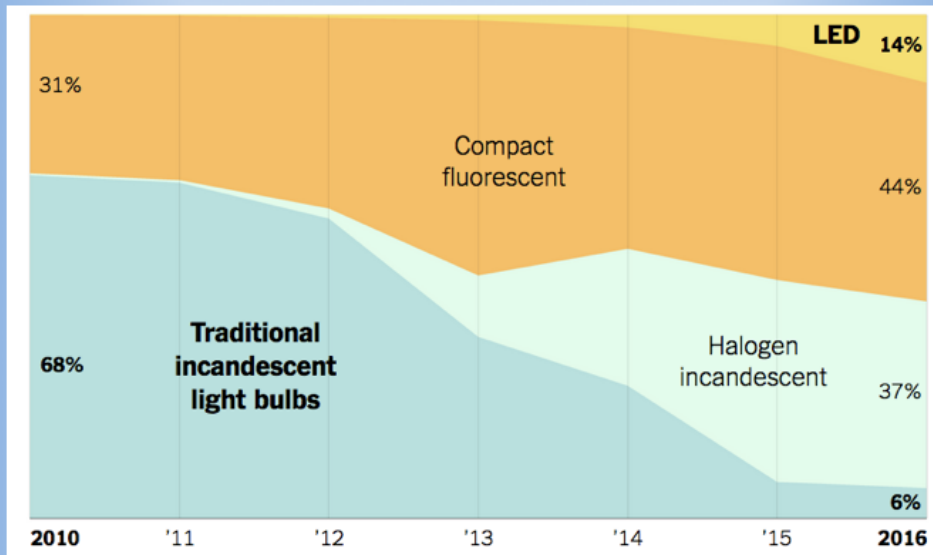
Opportunities

## 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 ...

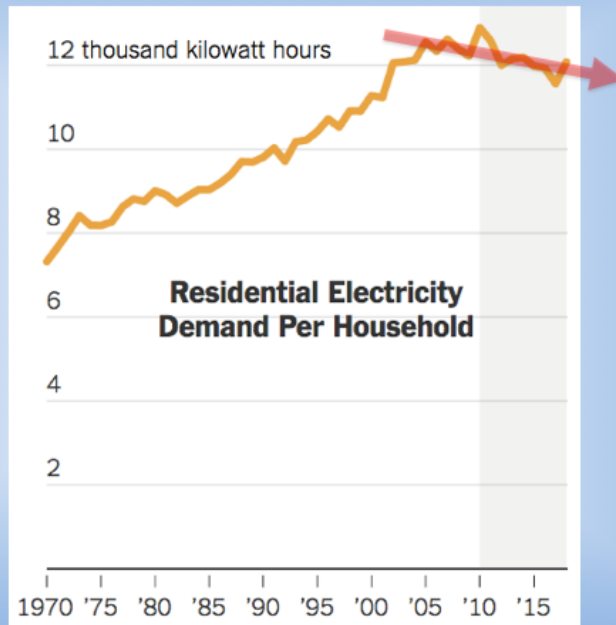


Department of Energy data

Graphic from NY Times:

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

... and reducing electricity costs

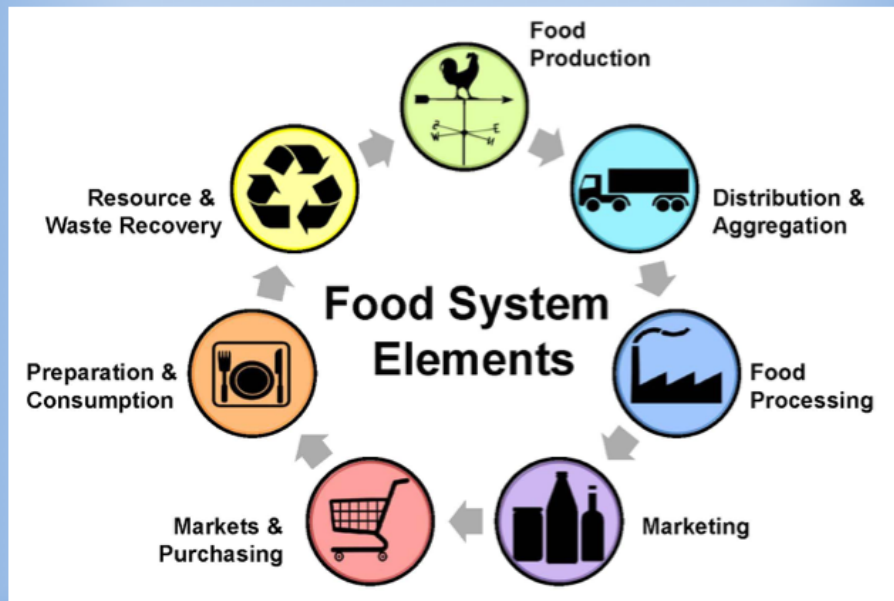


Department of Energy data

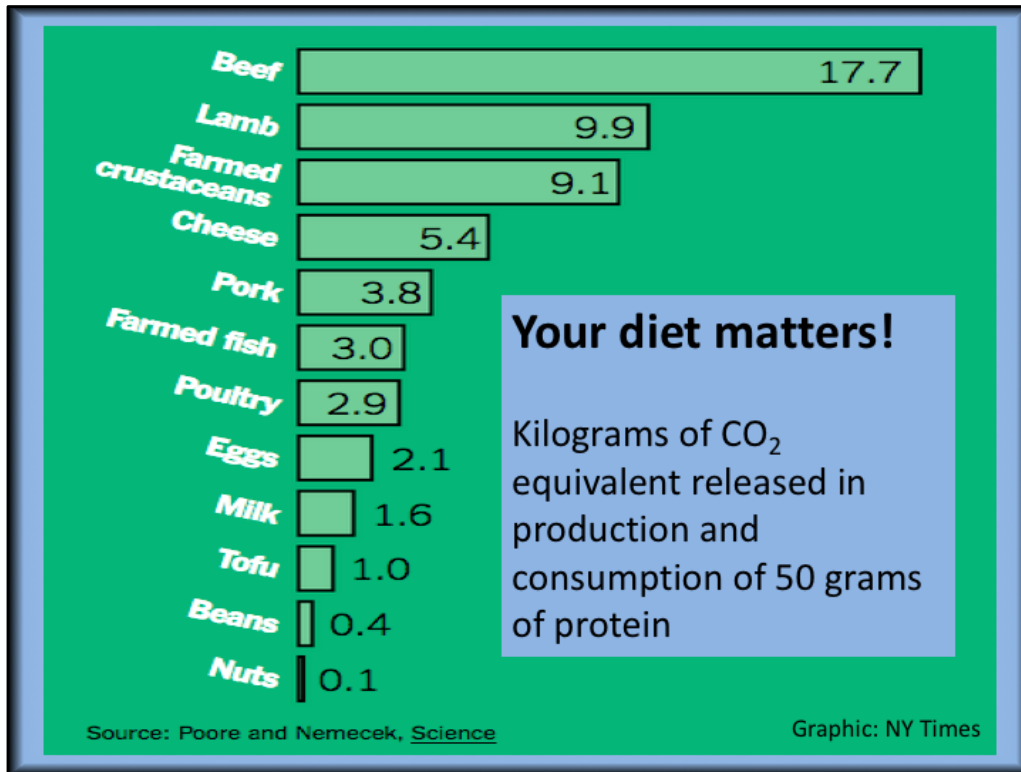
Graphic from NY Times:

<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>



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>



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)



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;



Action

Get your energy from a renewable source

# PA PowerSwitch

Pennsylvania Public Utility Commission

Shop.



Switch.



Save.



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

## Protest



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

Join climate action groups and support emissions reductions policies



## 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:

**EFFECTIVE**



**GOOD FOR PEOPLE**



**GOOD FOR THE ECONOMY**



**REVENUE NEUTRAL**



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





**Support the Paris Agreement**

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

 UCAR  
UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH

Source: COP21 Paris

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

We have cleaned up  
our own messes before



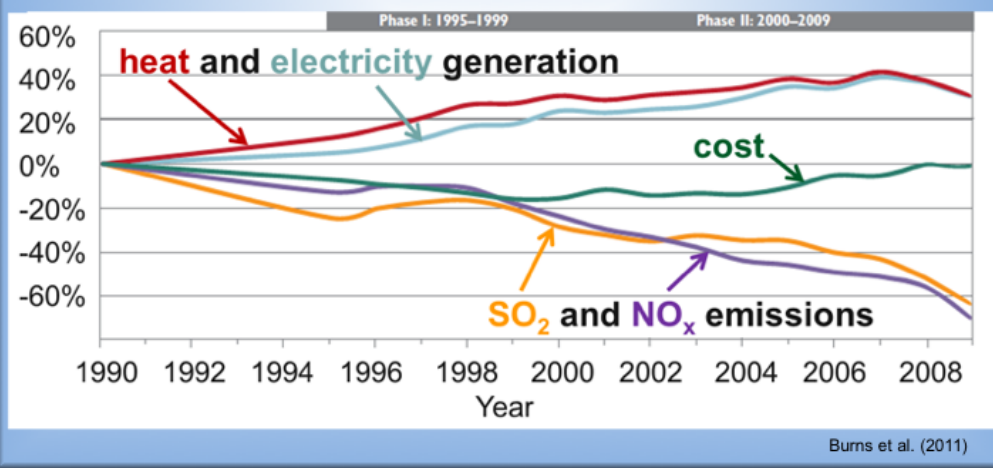
## “Smog episodes”

October 1948: Pollution from zinc mills in Donora, PA combined with a temperature inversion, leads to 20 deaths

Source: Donora Smog Museum



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.

## Take-home messages

1. Pennsylvania has followed the global warming trend
2. Impacts are already being felt
3. Human-induced climate change will continue to occur regardless of emissions scenario; further adaptation is necessary.
4. The climate of the mid century and beyond is very sensitive to the emissions scenario.
5. Solving the climate crisis is an opportunity to make the world better
6. Good science and good policy has gotten us out of environmental messes before