HONR 229L: Climate Change: Science, Economics, and Governance

Discussion #18: The Economics of Climate Change

Ross Salawitch

rjs@atmos.umd.edu

Class Web Site: http://www.atmos.umd.edu/~rjs/class/honr229L

ELMS Page: https://myelms.umd.edu/courses/1269254

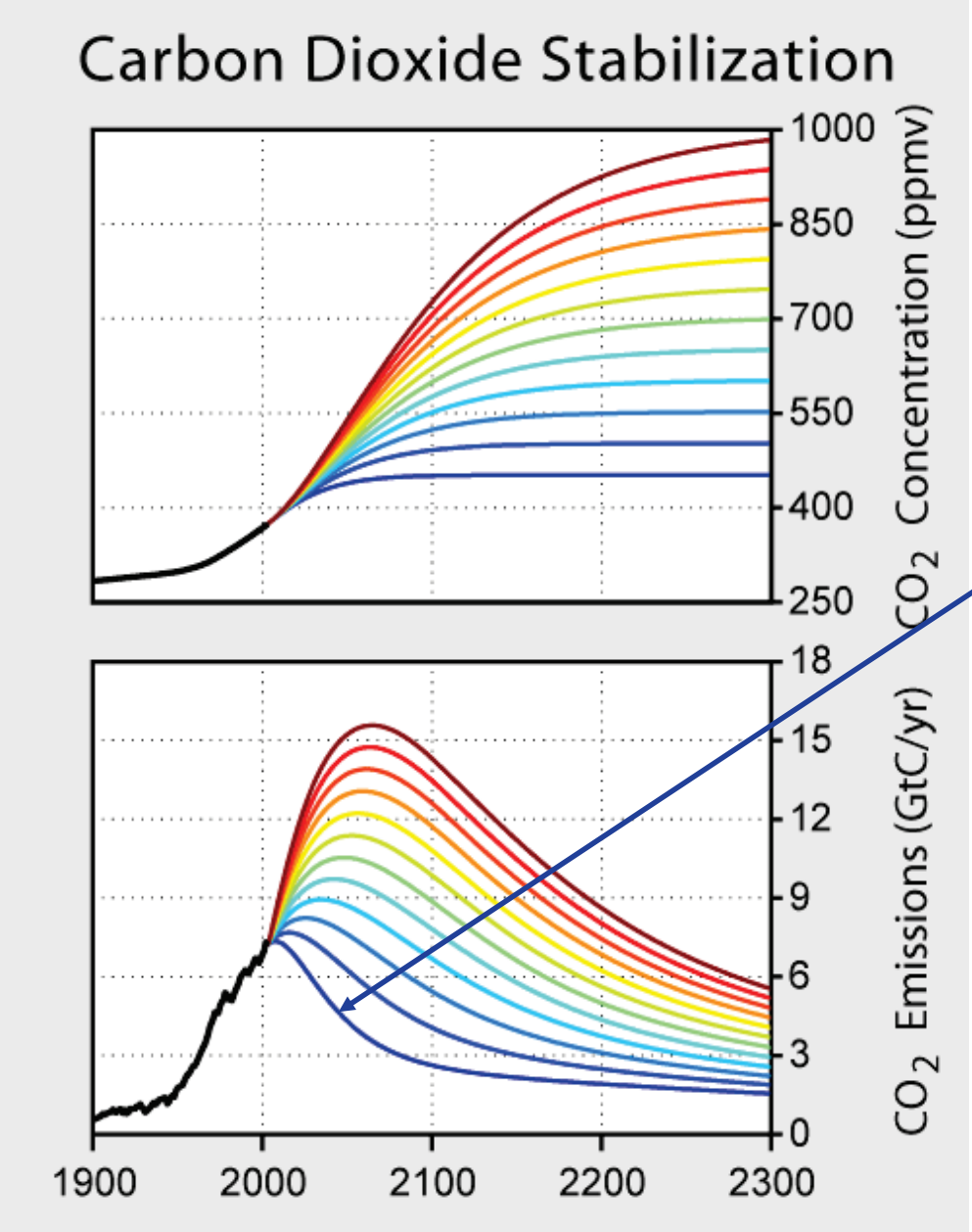
https://twitter.com/graphicrecorder/media

31 October 2019

Pg 28 of the reading states:

Stabilizing greenhouse gas emissions is insufficient; at the current rate of emissions carbon dioxide and other greenhouse gases will continue to accumulate in the atmosphere.

Stabilizing accumulations of greenhouse gases will require a significant cut *below present emission levels*.



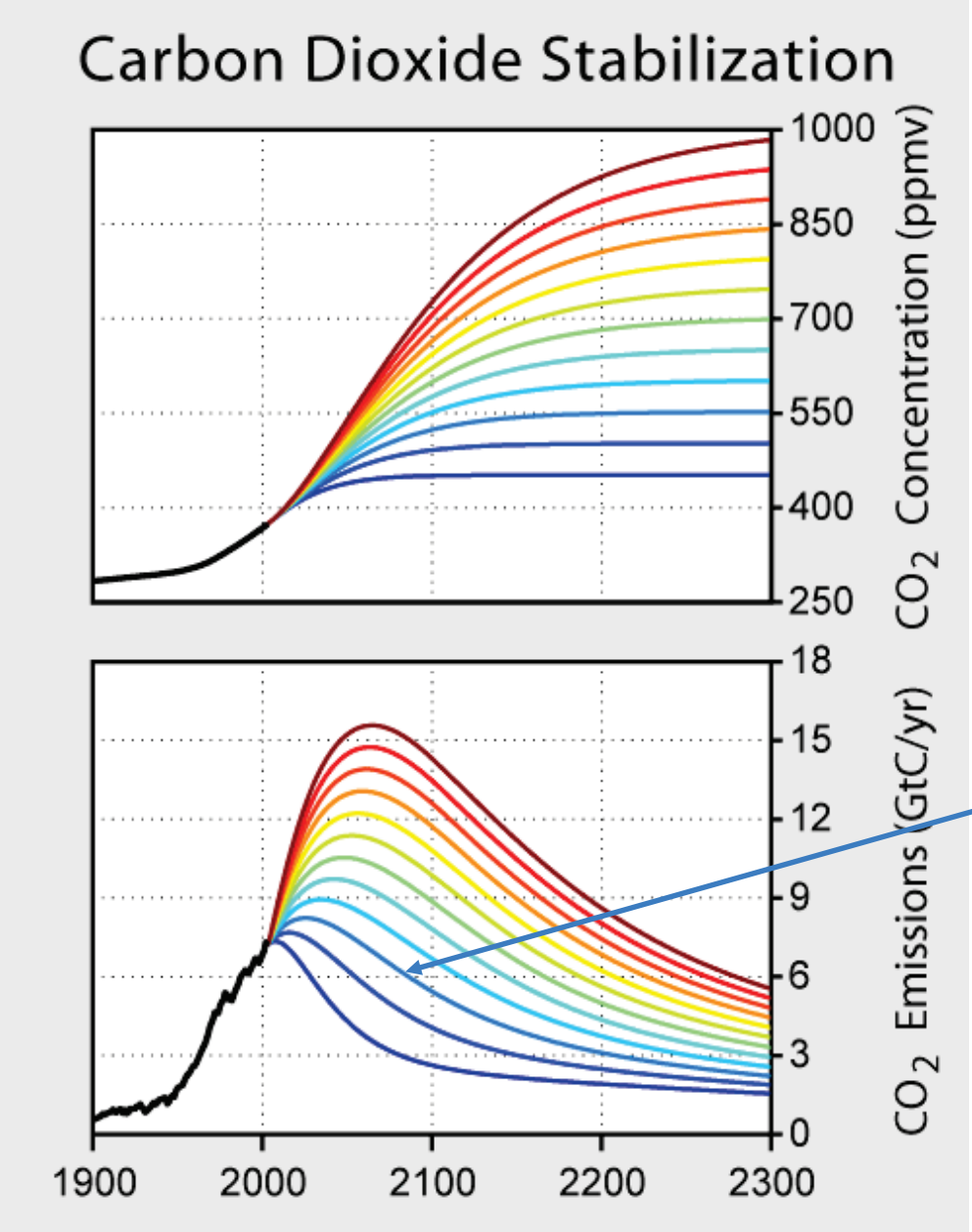
CO_2 is long lived:

society must reduce emissions soon or we will be committed to dramatic future increases!

Our reading highlighted stabilization of CO_2 at 450 ppm.

To achieve 450 ppm requires steep, near immediate declines in the global emission of CO_2 from combustion of fossil fuels.

Created by Robert Rohde, for a defunct website called Global Warming Art



CO_2 is long lived:

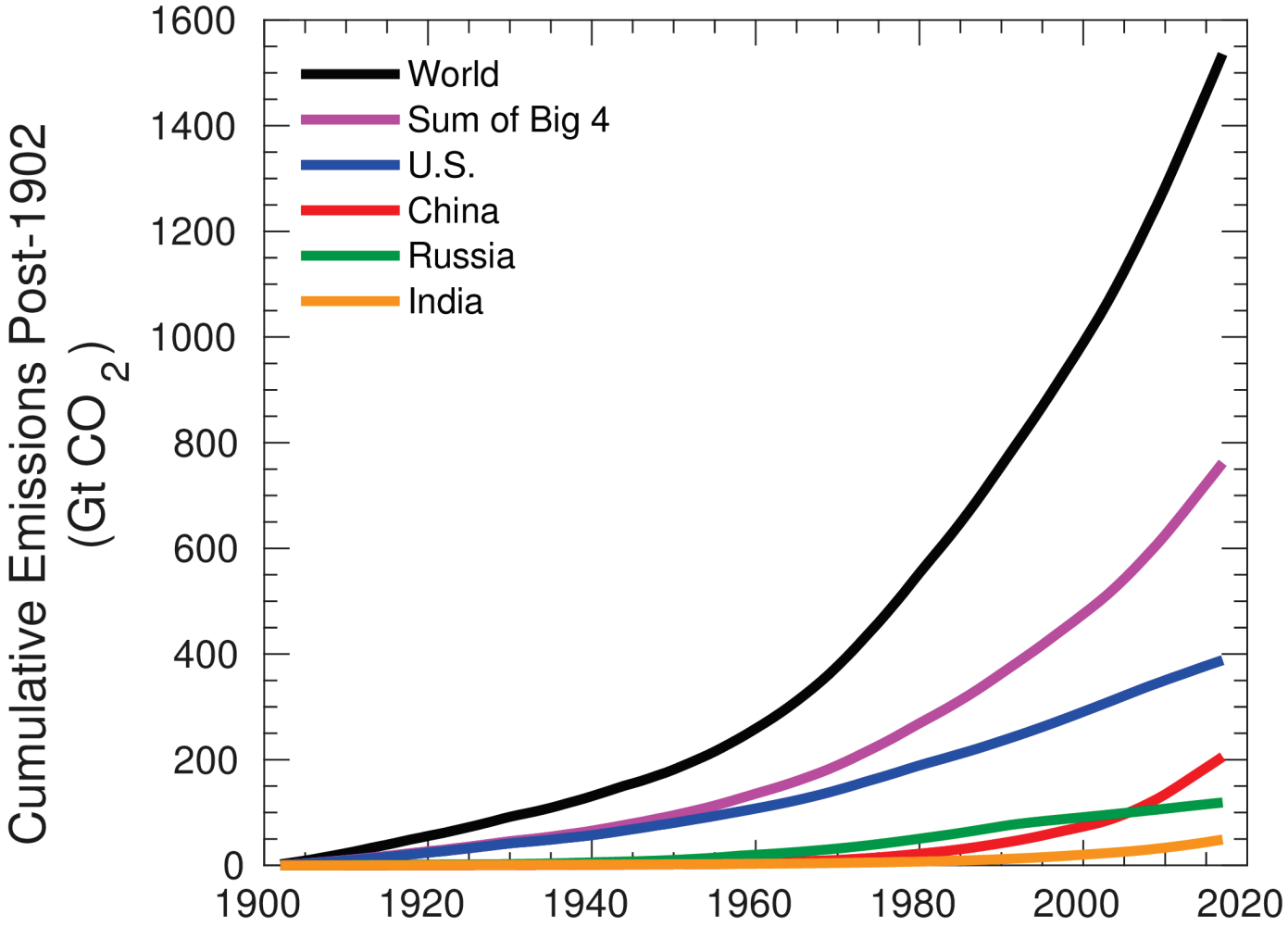
society must reduce emissions soon or we will be committed to dramatic future increases!

Our book Paris Climate Agreement: Beacon of Hope shows that if all pledges are followed and the carbon efficiency of the world's economies continues to improve, CO_2 would stabilize at about 550 ppm, which is about twice pre-industrial.

To stabilize at 550 ppm requires steep cuts in the global emission of CO_2 well before you all have reached my age.

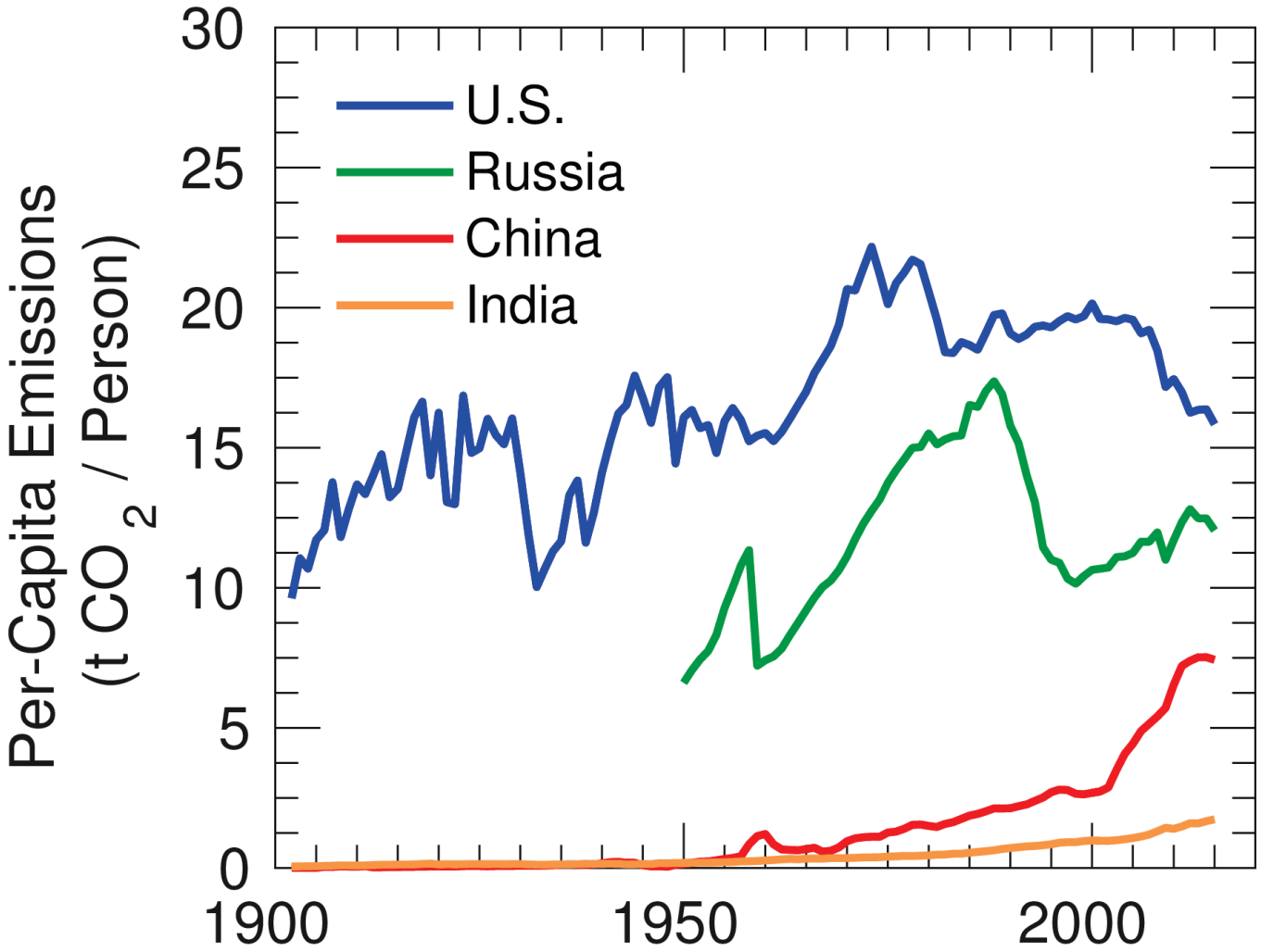
Created by Robert Rohde, for a defunct website called Global Warming Art

Cumulative Carbon Emission, Big Four, 1902 to present



Data Sources: Carbon Dioxide Information Analysis Center: http://cdiac.ess-dive.lbl.gov/trends/emis/tre_coun.html
Global Carbon Project: http://www.globalcarbonproject.org/carbonbudget/17/data.htm

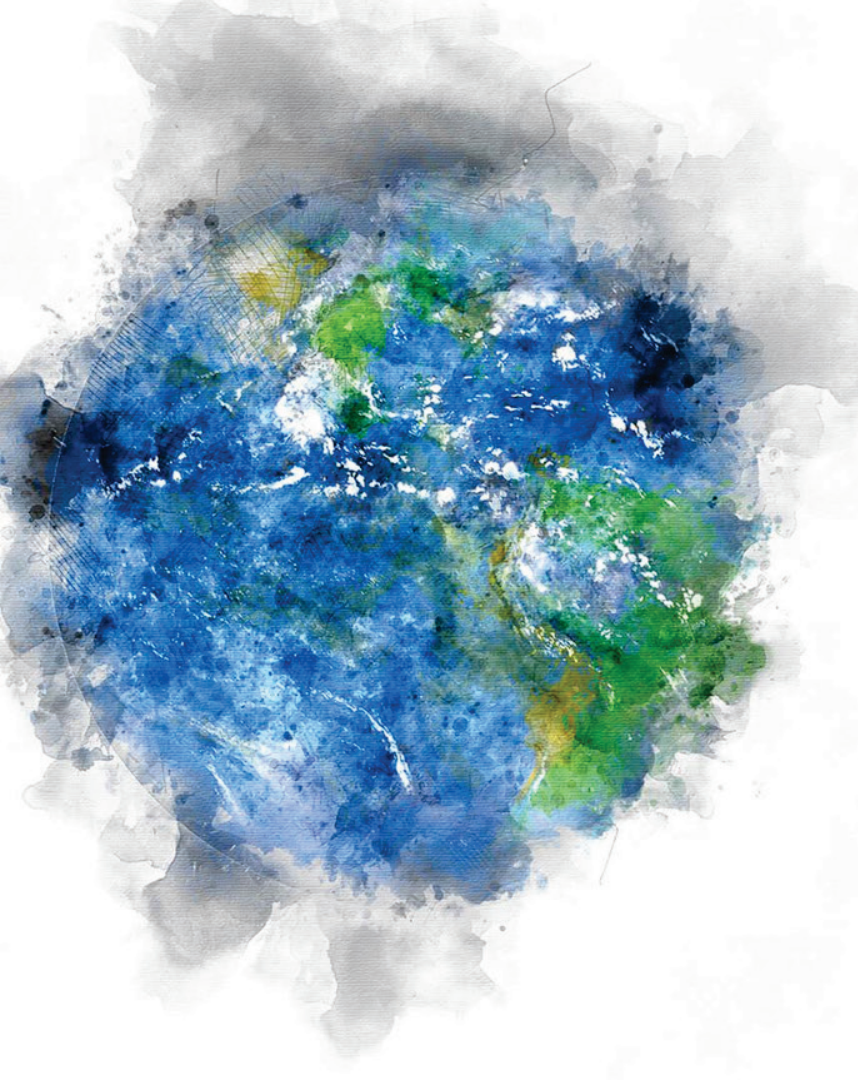
Per Capita Carbon Emission, Big Four, 1902 to present



Data Sources: Carbon Dioxide Information Analysis Center: http://cdiac.ess-dive.lbl.gov/trends/emis/tre_coun.html
Global Carbon Project: http://www.globalcarbonproject.org/carbonbudget/17/data.htm

Stern Review

- There is still time to avoid the worst impacts of climate change, if we take strong action now
- The cost of stabilising climate are significant but manageable; delay would be dangerous and much more costly
  - Stabilisation will require ~80% drop in F.F. emissions
  - Could cost ~1% of GDP if we begin to take strong action now ← 2007 ☹
- International action needed and it need not cap aspirations for growth of poor countries
  - Carbon markets in rich countries should deliver financial support for low-carbon development through the Clean Development Mechanism
- Key elements of future international frameworks should include:
  - Emissions trading
  - Technology cooperation (this occurred in the effort to save the ozone layer)
  - Action to reduce deforestation (critically important, but not easy to accomplish)
  - Adaptation (some change is coming; poorest countries most vulnerable)



The Economics of Climate Change

Amanda Oyler

Attendance Ticket Question Three

a) What was emission of CO_2 in 2015 from the OECD group nations?

b) What was emission of CO_2 in 2015 from the non-OECD group of nations?

In year 2015, the total population of OECD nations was 1.28 billion people, and the total population of non-OECD nations was 5.92 billion people.

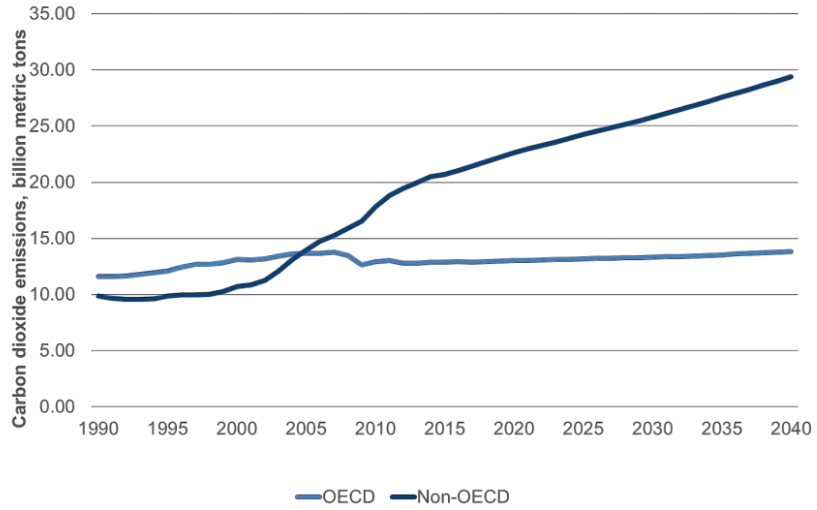
c) What was the per-capita emission of CO_2 for people living in the OECD nations in year 2015?

d) What was the per capita emission of CO_2 for people living in non-OECD nations in 2015?

e) If the economy of non-OECD nations were to expand such that the per-capita emission of CO_2 were to equal to that of the developed world, compute the resulting global emission of CO_2.

Attendance Ticket Question Three

Figure 12. Energy-Related Carbon Dioxide Emissions, Projected to 2040



Source: EIA, 2016.
Note: The Organization for Economic Cooperation and Development (OECD) includes primarily industrialized countries, and non-OECD comprises the rest of the world, including developing countries and including China.

13x10^9 Metric Tons CO2

Produced by OECD countries

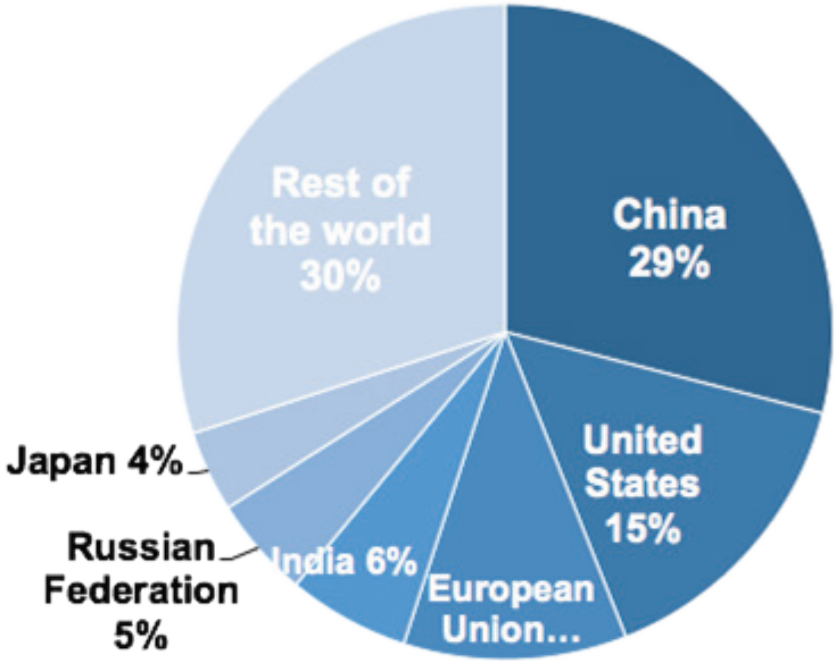
2 1x10^9 Metric Tons CO2

Produced by non OECD countries

Approximately 7.3 x10^10 Metric Tons CO2 Total

If non OECD countries emitted the same amount as OECD countries

Percentage of Global CO2 Emissions by Country/Region, 2014



http://www.bu.edu/eci/files/2019/06/The_Economics_of_Global_Climate_Change_Figures.ppt

What moral obligation do we as a society have? Do certain countries have more of an obligation than others?

Attendance Ticket Question One

William Nordhaus, recipient of the 2018 Nobel Prize in Economics, is quoted as stating the most damaging aspects of climate change lie well outside the conventional marketplace.

a) Name the four specific areas of concern;

b) What other concerns does he add to this list?

1. Sea level rise
2. Hurricane intensification
3. Ocean acidification
4. Loss of biodiversity
5. Concerns about earth's tipping points


So who is really affected?

Which Industries Does Climate Change Affect?

- Property values/Realty
- Insurance Industry
- Fishing industry/Ecotourism
  - Coral reefs, oyster hatcheries
- US Forest Service
  - Spent half budget on firefighting
- Healthcare system
  - Increased deaths and disease
- Agricultural Industry
  - How do we feed the world?

10% of global GDP lost

seen most in agricultural, forestry, fishing, coastal real estate and transportation sectors

Current global GDP is 85.8 trillion

https://data.worldbank.org/indicator/ny.gdp.mktp.cd

What groups of people do the emissions of greenhouse gases affect?

- **Everyone!!**
- **People in developing nations**
  - **Fewer resources to adapt/mitigate**
  - **Lack of technology**
  - **Higher risk of flooding and hunger**

Cost Benefit Analysis

- Weighs the consequences of projected increases in carbon emissions vs the cost of current policy actions to stabilize or reduce CO2 emissions.

- The estimated benefits must then be compared to the costs of taking action.

Controversy over Cost Benefit Analysis

- Models only show effects of climate change monetarily or by GDP
- Puts a dollar amount on human health and life
- Omits many significant ecological impacts of climate change
- Difficult to monetarily measure costs of sea level rise, ocean acidification or biodiversity

Avoided Costs

- The monetary benefits of preventing damage

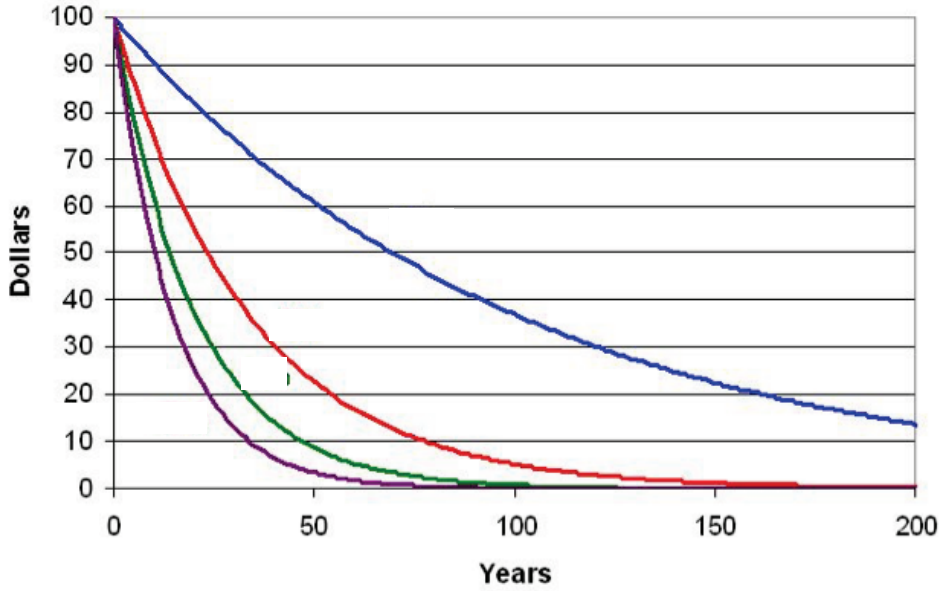
Marginal Abatement Costs

- Cost of reduction of one extra unit of carbon for various measures such as energy efficiency and shifts towards renewables

Discount Costs

- Evaluation of future costs and benefits
- What is this?

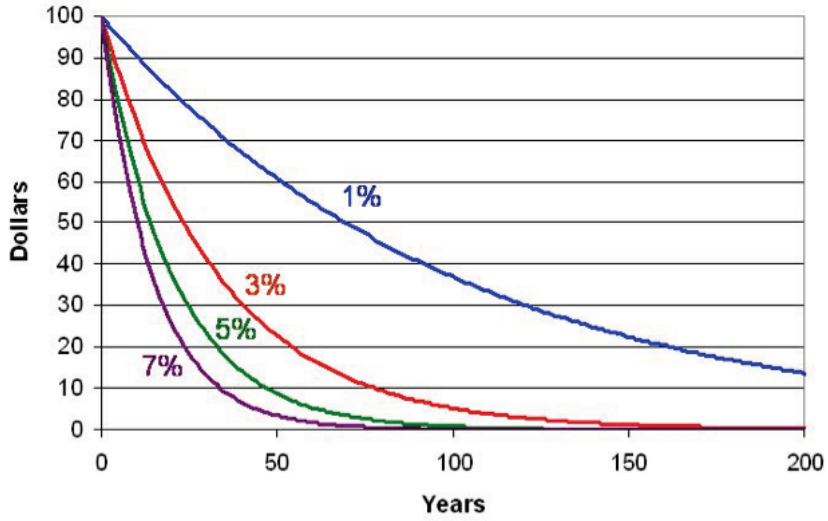
Figure 14: Present Value of a Future $100 Cost or Benefit: The Effects of Different Discount Rates



Discount Costs

- High discount rate=low present valuation for benefits mainly in the long term and high present valuation for short term costs
- Low discount rate = higher present valuation for long term benefits

Figure 14: Present Value of a Future $100 Cost or Benefit: The Effects of Different Discount Rates



So what are we going to do about our greenhouse gas emissions?

Attendance Ticket Question Two

This week's reading describes three differences between the Stern Review and earlier work of Nordhaus.

a) What are the three differences?

b) Pick one of these differences and explain why it is important for society to consider this issue, when deciding how to address climate change.

1. Stern recommends immediate and substantial policy action
2. Stern heavily weighs the damage of potentially catastrophic impacts of climate change
3. Stern suggests carbon taxes that are two to seven times higher than those of Nordhaus.

Cost of Stabilizing or Reducing Atmospheric CO2

- Predicted costs of stabilizing atmospheric CO2 range from 3.4% decrease to 3.9% increase in global GDP.
- Cost estimates for Paris Agreement is 1.5-4% of world's GDP
- Cost of adaptation for developing nations could rise to $140-300bill/year by 2030 and up to $500 bill/year by 2050

Policy Responses: Mitigation and Adaptation

Mitigation

- Reducing emissions
- Increasing energy efficiency
- Enhancing natural carbon sinks

Adaptation

- Sea walls
- Shifting cultivation to adapt to weather changes
- Creating infrastructure to assist in responding to climate change related disasters.

Carbon Tax

- A per unit tax on carbon pollutants
- Raises price of carbon based energy sources
- Incentivizes energy conservation/efficiency
- Shifts demand for fossil fuels to other sources
- Based on social cost of carbon
  - EPA estimates social cost of carbon between $11-$212, median of $50.5 per ton
- Revenue Neutral Tax Shift

Carbon Tax

- Easy to understand, relatively transparent
- Implemented quicker
- Provides price predictability
- "Tax"
  - Requires adjustments to tax rate

Table 4. Alternative Carbon Taxes on Fossil Fuels

Impact of Carbon Price on Retail Price of Gasoline	
kg CO_2 per gallon	8.89
tonnes CO_2 per gallon	0.00889
$/gal., $50/tonne tax	$0.44
$/gal., $100/tonne tax	$0.88
Retail price (2016) per gallon	$2.20
% increase, $50/tonne tax	20.2%
% increase, $100/tonne tax	40.4%
Impact of Carbon Price on Retail Price of Coal	
kg CO_2 per short ton	2100
tonnes CO_2 per short ton	2.1
$/short ton, $50/tonne tax	$105
$/short ton, $100/tonne tax	$210
Retail price (2016) per short ton	$40
% increase, $50/tonne tax	262.5%
% increase, $100/tonne tax	525.0%

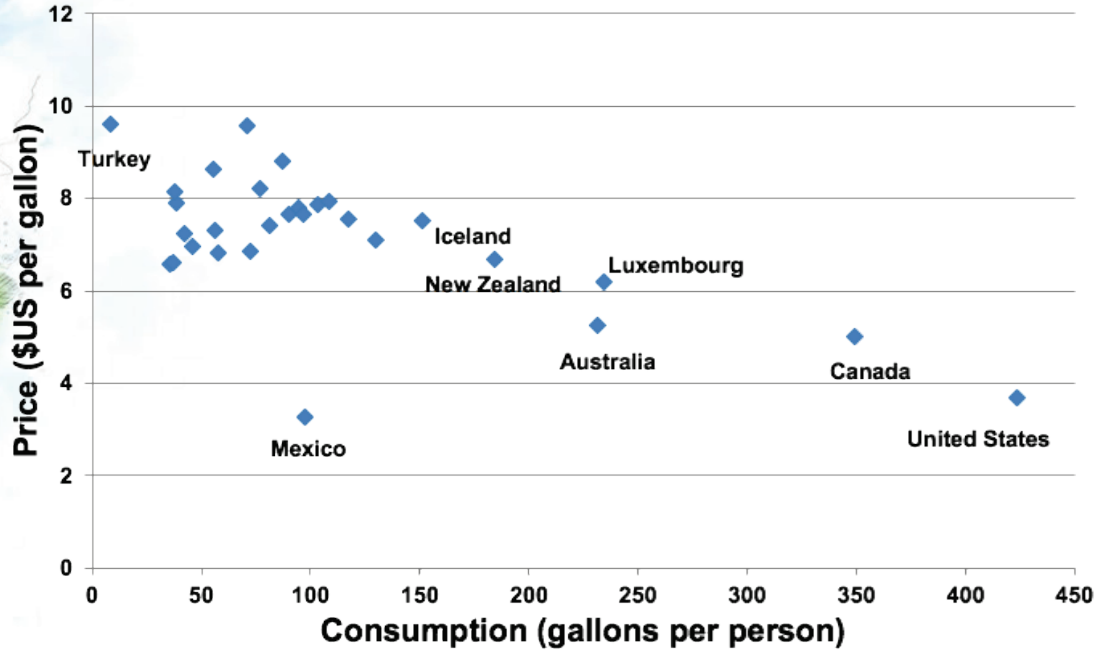
Carbon Tax

- Easy to understand, relatively transparent
- Implemented quicker
- Provides price predictability
- "Tax"
  - Requires adjustments to tax rate

Table 4. Alternative Carbon Taxes on Fossil Fuels

Impact of Carbon Price on Retail Price of Gasoline	
kg CO_2 per gallon	8.89
tonnes CO_2 per gallon	0.00889
$/gal., $50/tonne tax	$0.44
$/gal., $100/tonne tax	$0.88
Retail price (2016) per gallon	$2.20
% increase, $50/tonne tax	20.2%
% increase, $100/tonne tax	40.4%
Impact of Carbon Price on Retail Price of Coal	
kg CO_2 per short ton	2100
tonnes CO_2 per short ton	2.1
$/short ton, $50/tonne tax	$105
$/short ton, $100/tonne tax	$210
Retail price (2016) per short ton	$40
% increase, $50/tonne tax	262.5%
% increase, $100/tonne tax	525.0%

Figure 18: Gasoline Price Versus Consumption in Industrial Countries, 2012



Is it feasible for the U.S. to implement a carbon tax? (similar to France)

Cap and Trade

- Emitting firms are allocated a specific emission level
- Total number of permits would equal desired goal
- Permits are targeted upstream to largest emitters
  - Oil producers
  - Coal mines
  - Natural gas drillers
  - Power companies
- Free permits vs Auctioned permits
- Trade of permits

Cap and Trade

- Technological change can reduce price of permits
  - Potential for increased pollution
- Takes years to implement
  - Pilot Programs exist
- Price volatility
- Less political opposition than tax
- Favored by business
  - Potential for free permits
- Emissions are certain

Additional Policy Tools

- Subsidies for non carbon fuels
- Standard efficiency for machinery and appliance
- Research expenditures to advance green technology
- Technology transfer to developing nations

Attendance Ticket Question Three

Compare and contrast the Carbon Taxation and Cap & Trade of carbon emissions, and which policy option *you* think should be pursued to transition society away from fossil fuels.

If you conclude that neither option should be pursued and state why you would prefer to see this other option implemented

Thanks!

Any questions?

The Economics of Climate Change

Last Word: Ross Salawitch

31 October 2019

Adaptive Measures

London's **flood risk management** plan for the Thames River would cost the city about $2.3 billion in its first 25 years.

https://www.preventionweb.net/news/view/33648

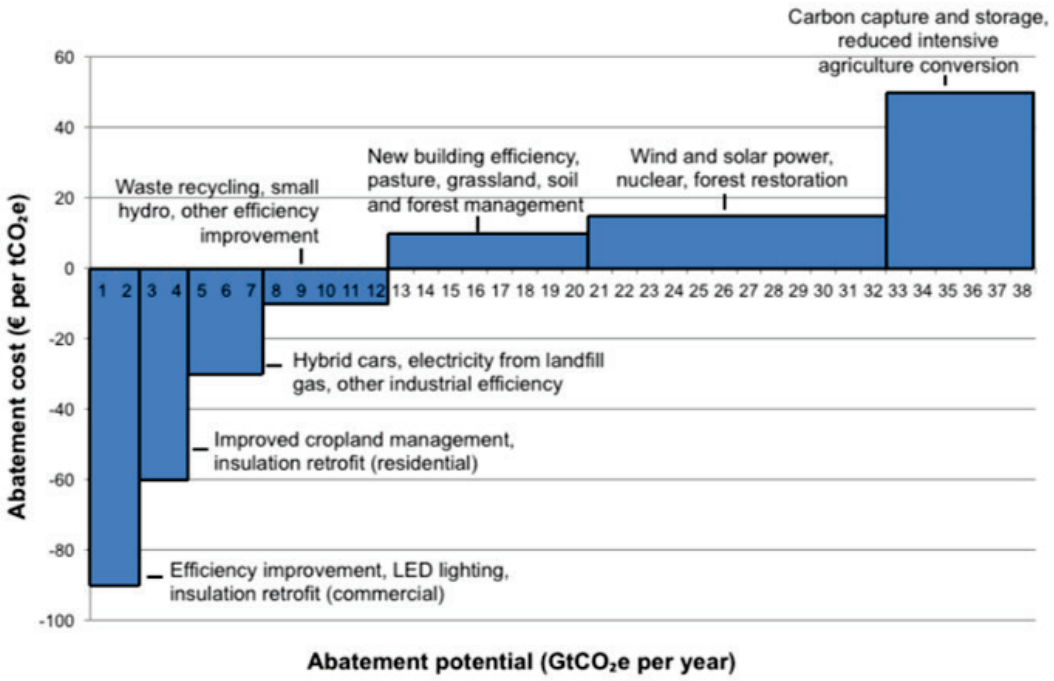
Adaptive Measures

Rotterdam: **Flood management**, accessibility for ships and passengers, adaptive buildings, urban water systems, and quality of life within the city. The city set aside about $40 million for implementation of the plan's near-term projects.

https://www.preventionweb.net/news/view/33648

Figure 21 provides pictorial representation of various CO_2 emission abatement options, tied to both costs and emission reduction for year 2030. If all these options were to be implemented, the yearly CO_2 **savings** are estimated to be **38 billion tons per year**. This is from a projected level of **70 billion tons per year** in 2030.

Figure 21. Global Greenhouse Gas Abatement Cost Curve for 2030



Source: Adapted from McKinsey & Company, 2009, and 2013.
Note: Costs are estimated in euros, but the analysis covers worldwide reduction possibilities.

1€ (2009) = 1.39$ (2009)

1.39$ (2009) = 1.66$ (2019)

http://www.in2013dollars.com/us/inflation/2009?amount=1.39

Pacala and Socolow: CO_2 Stabilization Wedges

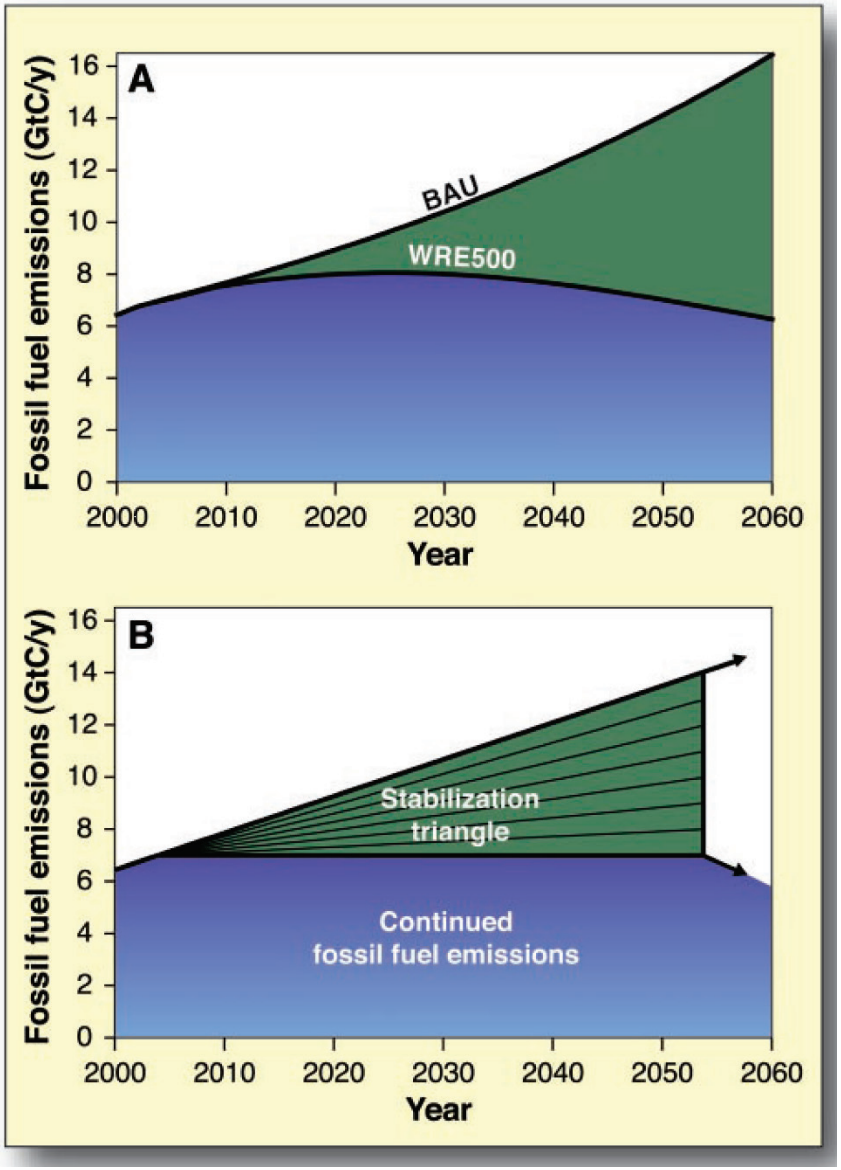


Fig. 1. (**A**) The top curve is a representative BAU emissions path for global carbon emissions as CO_2 from fossil fuel combustion and cement manufacture: 1.5% per year growth starting from 7.0 GtC/year in 2004. The bottom curve is a CO_2 emissions path consistent with atmospheric CO_2 stabilization at 500 ppm by 2125 akin to the Wigley, Richels, and Edmonds (WRE) family of stabilization curves described in (*11*), modified as described in Section 1 of the SOM text. The bottom curve assumes an ocean uptake calculated with the High-Latitude Exchange Interior Diffusion Advection (HILDA) ocean model (*12*) and a constant net land uptake of 0.5 GtC/year (Section 1 of the SOM text). The area between the two curves represents the avoided carbon emissions required for stabilization. (**B**) Idealization of (A): A stabilization triangle of avoided emissions (green) and allowed emissions (blue). The allowed emissions are fixed at 7 GtC/year beginning in 2004. The stabilization triangle is divided into seven wedges, each of which reaches 1 GtC/year in 2054. With linear growth, the total avoided emissions per wedge is 25 GtC, and the total area of the stabilization triangle is 175 GtC. The arrow at the bottom right of the stabilization triangle points downward to emphasize that fossil fuel emissions must decline substantially below 7 GtC/year after 2054 to achieve stabilization at 500 ppm.

Pacala and Socolow, Science, 2004

http://www.princeton.edu/mae/people/faculty/socolow/Science-2004-SW-1100103-PAPER-AND-SOM.pdf

Pacala and Socolow: CO_2 Stabilization Wedges

Action	Details
	Energy efficiency and conservation
Economy-wide carbon-intensity reduction (emissions/$GDP)	Increase reduction by additional 0.15% per year (e.g., increase U.S. goal of 1.96% reduction per year to 2.11% per year)
1. Efficient vehicles	Increase fuel economy for 2 billion cars from 30 to 60 mpg
2. Reduced use of vehicles	Decrease car travel for 2 billion 30-mpg cars from 10,000 to 5000 miles per year
3. Efficient buildings	Cut carbon emissions by one-fourth in buildings and appliances projected for 2054
4. Efficient baseload coal plants	Produce twice today's coal power output at 60% instead of 40% efficiency (compared with 32% today)
	Fuel shift
5. Gas baseload power for coal baseload power	Replace 1400 GW 50%-efficient coal plants with gas plants (four times the current production of gas-based power)
	CO_2 Capture and Storage (CCS)
6. Capture CO_2 at baseload power plant	Introduce CCS at 800 GW coal or 1600 GW natural gas (compared with 1060 GW coal in 1999)
7. Capture CO_2 at H_2 plant	Introduce CCS at plants producing 250 MtH_2/year from coal or 500 MtH_2/year from natural gas (compared with 40 MtH_2/year today from all sources)
8. Capture CO_2 at coal-to-synfuels plant	Introduce CCS at synfuels plants producing 30 million barrels a day from coal (200 times Sasol), if half of feedstock carbon is available for capture
Geological storage	Create 3500 Sleipners

Pacala and Socolow: CO_2 Stabilization Wedges

Action	Details
	Nuclear fission
9. Nuclear power for coal power	Add 700 GW (twice the current capacity)
	Renewable electricity and fuels
10. Wind power for coal power	Add 2 million 1-MW-peak windmills (50 times the current capacity) "occupying" 30×10^6 ha, on land or offshore
11. PV power for coal power	Add 2000 GW-peak PV (700 times the current capacity) on 2×10^6 ha
12. Wind H_2 in fuel-cell car for gasoline in hybrid car	Add 4 million 1-MW-peak windmills (100 times the current capacity)
13. Biomass fuel for fossil fuel	Add 100 times the current Brazil or U.S. ethanol production, with the use of 250×10^6 ha (one-sixth of world cropland)
	Forests and agricultural soils
14. Reduced deforestation, plus reforestation, afforestation, and new plantations.	Decrease tropical deforestation to zero instead of 0.5 GtC/year, and establish 300 Mha of new tree plantations (twice the current rate)
15. Conservation tillage	Apply to all cropland (10 times the current usage)

To meet commonly discussed abatement paths, **carbon productivity must increase from approximately $740 GDP per ton of CO2** today to **$7,300 GDP** per ton of CO2e **by 2050**—a tenfold increase.

This will require approximately **0.6–1.4 percent of global GDP by 2030.**

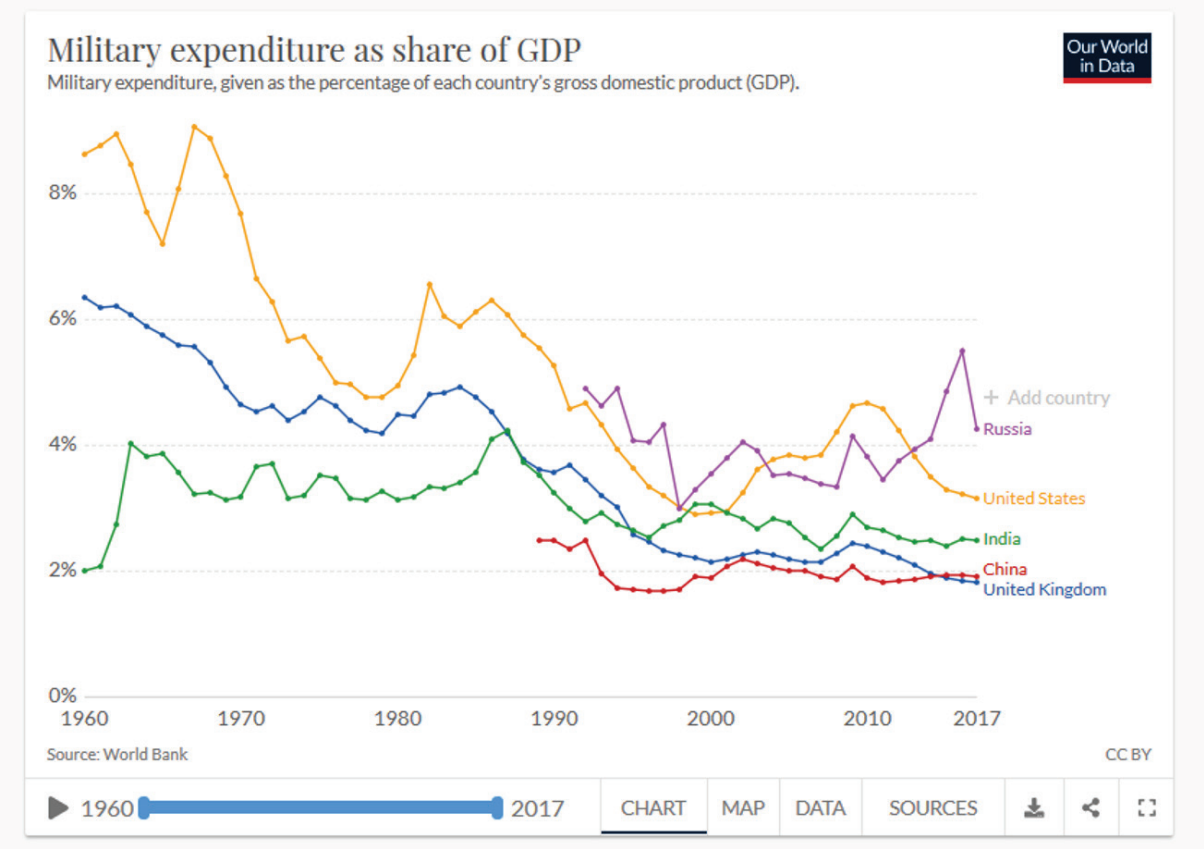
What percentage of GDP does the U.S. spend on it's military and defense?

https://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/the-carbon-productivity-challenge
https://ourworldindata.org/military-spending

To meet commonly discussed abatement paths, **carbon productivity must increase from approximately $740 GDP per ton of CO2** today to **$7,300 GDP** per ton of CO2e **by 2050**—a tenfold increase.

This will require approximately **0.6–1.4 percent of global GDP by 2030.**

What percentage of GDP does the U.S. spend on it's military and defense?



https://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/the-carbon-productivity-challenge
https://ourworldindata.org/military-spending

Cap and Trade vs Carbon Tax

From an economic point of view, these two policies are vastly different

Cap and trade regulates _____

Carbon tax regulates _____

Comparison of Architectures for Greenhouse Gas Regulation

Instrument	*Economic wisdom*	*Allocation*	*Monitoring*	*Enforcement*
General approach:				
Cap and Trade (Kyoto)	**Pro:** Best way to empower market forces to control a "threshold" problem, but **Con:** tight quantity limits could force the economy to bear high costs **Con:** Identification and agreement on a dangerous threshold are not imminent	**Con:** Perhaps impossible to negotiate an allocation that would not cause some major emitting nations to withdraw	**Pro:** Easy to monitor permit trades; easy to monitor emissions if trading is restricted to fossil fuel CO_2 only **Con:** Kyoto Protocol includes six greenhouse gases—impossible to monitor all fluxes reliably if trading	**Pro:** Can rely on national legal systems in "liberal" nations if buyer liability is the rule. **Con:** If sellers are liable for noncompliance then system will require international enforcement institutions of unprecedented strength
Coordinated taxes	**Pro:** Most Efficient instrument when managing a "stock" problem; risks of climate change are mainly a function of the slowly growing "stock" of CO_2 in the atmosphere	**Pro:** Easier to allocate commitments because not distributing semi-permanent assets	**Con:** Very difficult to monitor real impact of taxes that are applied to economies in tandem with other tax and investment policies	**Con:** Requires strong and intrusive international institutions

The Collapse of the Kyoto Protocol
and the Struggle to Slow Global Warming
David G. Victor, Princeton University Press, 2001

Cap and Trade vs Carbon Tax

From an economic point of view, these two policies are vastly different

Cap and trade regulates amount emitted

Carbon tax regulates _____

Comparison of Architectures for Greenhouse Gas Regulation

Instrument	*Economic wisdom*	*Allocation*	*Monitoring*	*Enforcement*
General approach:				
Cap and Trade (Kyoto)	**Pro**: Best way to empower market forces to control a "threshold" problem, but **Con**: tight quantity limits could force the economy to bear high costs **Con**: Identification and agreement on a dangerous threshold are not imminent	**Con**: Perhaps impossible to negotiate an allocation that would not cause some major emitting nations to withdraw	**Pro**: Easy to monitor permit trades; easy to monitor emissions if trading is restricted to fossil fuel CO_2 only **Con**: Kyoto Protocol includes six greenhouse gases—impossible to monitor all fluxes reliably if trading	**Pro**: Can rely on national legal systems in "liberal" nations if buyer liability is the rule. **Con**: If sellers are liable for noncompliance then system will require international enforcement institutions of unprecedented strength
Coordinated taxes	**Pro**: Most Efficient instrument when managing a "stock" problem; risks of climate change are mainly a function of the slowly growing "stock" of CO_2 in the atmosphere	**Pro**: Easier to allocate commitments because not distributing semipermanent assets	**Con**: Very difficult to monitor real impact of taxes that are applied to economies in tandem with other tax and investment policies	**Con**: Requires strong and intrusive international institutions

The Collapse of the Kyoto Protocol
and the Struggle to Slow Global Warming
David G. Victor, Princeton University Press, 2001

Cap and Trade vs Carbon Tax

From an economic point of view, these two policies are vastly different

Cap and trade regulates amount emitted

Carbon tax regulates price of emission

Comparison of Architectures for Greenhouse Gas Regulation

Instrument	*Economic wisdom*	*Allocation*	*Monitoring*	*Enforcement*
General approach:				
Cap and Trade (Kyoto)	**Pro**: Best way to empower market forces to control a "threshold" problem, but **Con**: tight quantity limits could force the economy to bear high costs **Con**: Identification and agreement on a dangerous threshold are not imminent	**Con**: Perhaps impossible to negotiate an allocation that would not cause some major emitting nations to withdraw	**Pro**: Easy to monitor permit trades; easy to monitor emissions if trading is restricted to fossil fuel CO_2 only **Con**: Kyoto Protocol includes six greenhouse gases—impossible to monitor all fluxes reliably if trading	**Pro**: Can rely on national legal systems in "liberal" nations if buyer liability is the rule. **Con**: If sellers are liable for noncompliance then system will require international enforcement institutions of unprecedented strength
Coordinated taxes	**Pro**: Most Efficient instrument when managing a "stock" problem; risks of climate change are mainly a function of the slowly growing "stock" of CO_2 in the atmosphere	**Pro**: Easier to allocate commitments because not distributing semipermanent assets	**Con**: Very difficult to monitor real impact of taxes that are applied to economies in tandem with other tax and investment policies	**Con**: Requires strong and intrusive international institutions

The Collapse of the Kyoto Protocol
and the Struggle to Slow Global Warming
David G. Victor, Princeton University Press, 2001

Regional Greenhouse Gas Initiative "RGGI"

http://www.rggi.org

- RGGI caps CO_2 emissions from region's fossil fuel power plants (> 25 Mega Watt)
  - Regional CO_2 emissions held constant from 2009 through 2014
  - Beginning 2014 regional CO_2 emissions decrease for a total reduction of 10% by 2018
  - All fossil fuel fired facilities must own allowances equal to their annual CO_2 emissions
- 10 States are part of RGGI
  - Each state has an emissions cap
  - Regional market for CO_2 emission allowances
- Maryland joined on 20 April 2007
  - Bill passed in Annapolis
  - Participation governed by Md Dept of the Environment (MDE)

State	Emissions Cap (Tons CO_2)
CT	10,695,036
DE	7,559,787
MA	26,660,204
ME	5,948,902
NH	8,620,460
NJ	22,892,730
NY	64,310,805
RI	2,659,239
VT	1,225,830
MD	*37,505,984*
TOTAL	188,078,977

http://www.mde.state.md.us/programs/Air/ClimateChange/RGGI/Pages/RGGIElements.aspx

Regional Greenhouse Gas Initiative "RGGI"

http://www.rggi.org

- RGGI caps CO_2 emissions from region's fossil fuel power plants (> 25 Mega Watt)
  - Regional CO_2 emissions held constant from 2009 through 2014
  - Beginning 2014 regional CO_2 emissions decrease for a total reduction of 10% by 2018
  - All fossil fuel fired facilities must own allowances equal to their annual CO_2 emissions
- **9 States are now part of RGGI**
  - Each state has an emissions cap
  - Regional market for CO_2 emission allowances
- Maryland joined on 20 April 2007
  - Bill passed in Annapolis
  - Participation governed by Md Dept of the Environment (MDE)
- Then Gov Christie removed NJ in 2011

State	Emissions Cap (Tons CO_2)
CT	10,695,036
DE	7,559,787
MA	26,660,204
ME	5,948,902
NH	8,620,460
~~NJ~~	~~22,892,730~~
NY	64,310,805
RI	2,659,239
VT	1,225,830
MD	***37,505,984***
TOTAL	**165,186,247**

http://www.nytimes.com/2011/05/27/nyregion/christie-pulls-nj-from-greenhouse-gas-coalition.html

Regional Greenhouse Gas Initiative "RGGI"

http://www.rggi.org

- RGGI caps CO_2 emissions from region's fossil fuel power plants (> 25 Mega Watt)
  - Regional CO_2 emissions held constant from 2009 through 2014
  - Beginning 2014 regional CO_2 emissions decrease for a total reduction of 10% by 2018
  - All fossil fuel fired facilities must own allowances equal to their annual CO_2 emissions
- **9 States are now part of RGGI**
  - Each state has an emissions cap
  - Regional market for CO_2 emission allowances
- Maryland joined on 20 April 2007
  - Bill passed in Annapolis
  - Participation governed by Md Dept of the Environment (MDE)
- Then Gov Christie removed NJ in 2011

2016

State	Emissions Cap (Tons CO_2)
CT	4,182,1205
DE	2,862,188
MA	10,238,857
ME	2,327,102
NH	3,372,166
NY	24,967,083
RI	1,819,759
VT	460,509
MD	***14,385,683***
TOTAL	**64,615,467**

http://www.rggi.org/docs/CO2AuctionsTrackingOffsets/Allocation/2017_Allowance-Distribution.xls

Regional Greenhouse Gas Initiative "RGGI"

http://www.rggi.org

- RGGI caps CO_2 emissions from region's fossil fuel power plants (> 25 Mega Watt)
  - Regional CO_2 emissions held constant from 2009 through 2014
  - Beginning 2014 regional CO_2 emissions decrease for a total reduction of 10% by 2018
  - All fossil fuel fired facilities must own allowances equal to their annual CO_2 emissions
- **9 States are now part of RGGI**
  - Each state has an emissions cap
  - Regional market for CO_2 emission allowances
- Maryland joined on 20 April 2007
  - Bill passed in Annapolis
  - Participation governed by Md Dept of the Environment (MDE)
- Then Gov Christie removed NJ in 2011

2017

State	Emissions Cap (Tons CO_2)
CT	4,042,095
DE	2,858,274
MA	10,079,934
ME	2,249,216
NH	3,259,302
NY	24,315,220
RI	1,005,431
VT	463,472
MD	***13,701,106***
TOTAL	**62,452,795**

https://www.rggi.org/sites/default/files/Uploads/Allowance-Tracking/2018_Allowance-Distribution.xls

Regional Greenhouse Gas Initiative "RGGI"

http://www.rggi.org

- RGGI caps CO_2 emissions from region's fossil fuel power plants (> 25 Mega Watt)
  - Regional CO_2 emissions held constant from 2009 through 2014
  - Beginning 2014 regional CO_2 emissions decrease for a total reduction of 10% by 2018
  - All fossil fuel fired facilities must own allowances equal to their annual CO_2 emissions
- **9 States are now part of RGGI**
  - Each state has an emissions cap
  - Regional market for CO_2 emission allowances
- Maryland joined on 20 April 2007
  - Bill passed in Annapolis
  - Participation governed by Md Dept of the Environment (MDE)
- Then Gov Christie removed NJ in 2011

2018

State	Emissions Cap (Tons CO_2)
CT	3,905,571
DE	2,761,772
MA	9,550,650
ME	2,173,277
NH	3,149,261
NY	23,494,281
RI	1,160,448
VT	447,824
MD	***13,701,106***
TOTAL	**60,344,190**

https://www.rggi.org/sites/default/files/Uploads/Allowance-Tracking/2018_Allowance-Distribution.xls

Regional Greenhouse Gas Initiative "RGGI"

http://www.rggi.org

- RGGI caps CO_2 emissions from region's fossil fuel power plants (> 25 Mega Watt)
  - Regional CO_2 emissions held constant from 2009 through 2014
  - Beginning 2014 regional CO_2 emissions decrease for a total reduction of 10% by 2018
  - All fossil fuel fired facilities must own allowances equal to their annual CO_2 emissions
- **9 States are now part of RGGI**
  - Each state has an emissions cap
  - Regional market for CO_2 emission allowances
- Maryland joined on 20 April 2007
  - Bill passed in Annapolis
  - Participation governed by Md Dept of the Environment (MDE)
- Then Gov Christie removed NJ in 2011

2019

State	Emissions Cap (Tons CO_2)
CT	3,772,461
DE	2,611,556
MA	9,223,560
ME	2,099,237
NH	3,041,970
NY	22,693,866
RI	1,652,960
VT	414,945
MD	***12,961,983***
TOTAL	**58,472,538**

https://www.rggi.org/sites/default/files/Uploads/Allowance-Tracking/2019_Allowance-Distribution.xls

How Do the RGGI Auctions Operate?

The auctions operate in a single-round, uniform-price sealed-bid format. Each participant has one opportunity to submit one or more undisclosed bids as well as the quantity of allowances (in multiples of 1,000) that they are willing to purchase at that price.

The bids are then ranked from high to low and allowances are tentatively awarded in this order until cumulative demand is greater than the supply of allowances offered for sale. All allowances are then sold at a clearing price determined by the value of the highest rejected bid.

Bidder	Bidder's Offering price	Number of Allowances	Cumulative Demand
Edward	$7.50	10,000 ✓	10,000
Ann	$6.25	10,000 ✓	20,000
Charlie	$6.10	5,000 ✓	25,000
Edward	$5.50	15,000 ✓	40,000
Diane	$4.75	10,000 ✓	50,000
Charlie	$4.75	10,000 ✓	60,000
Bernie	$4.50	15,000 ✓	75,000
Ann	$4.10	20,000 ✓	95,000
Edward	$3.95	10,000 /	105,000
Bernie	$3.70	20,000 ✗	125,000
Diane	$3.50	20,000 ✗	145,000

100,000 CO_2 allowances are available for sale at auction.

Cumulative demand is met at Edward's $3.95 bid, so all bids above this are winning bids, and allowances will be awarded in the full amount requested. Edward will also be awarded the remaining 5,000 allowances toward his $3.95 bid.

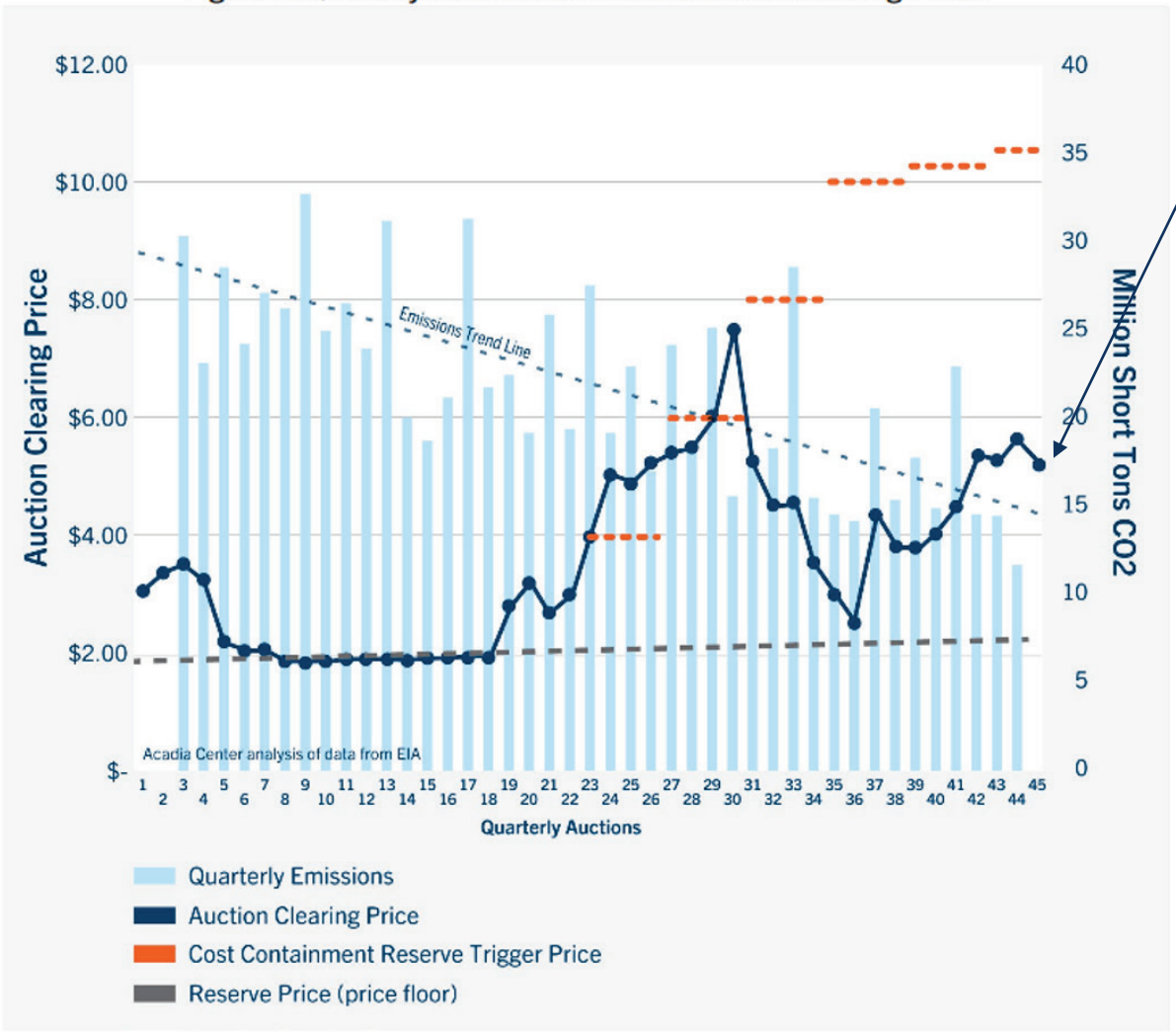
This auction has awarded all 100,000 CO_2 allowances which were offered; with an additional 45,000 more allowances being sought for purchase than were available.

All 100,000 allowances will be awarded at the clearing price of $3.95. The total proceeds from this auction are $395,000.

http://www.mde.state.md.us/programs/Air/ClimateChange/RGGI/Pages/RGGI-Auctions.aspx

$5.20 per tonne of CO_2 was final clearing price for Auction 45 on 4 Sept 2019

Figure 2: Quarterly RGGI Emissions and Auction Clearing Prices



https://www.rggi.org/auctions/auction-results

Regional Greenhouse Gas Initiative "RGGI"

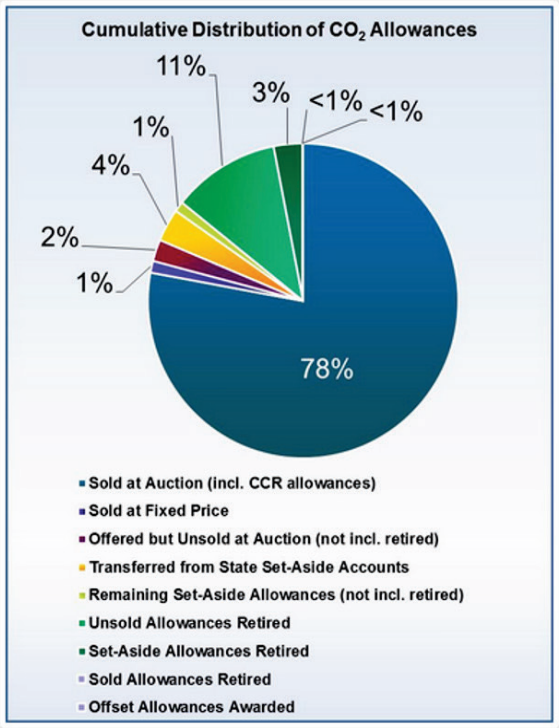
http://www.rggi.org

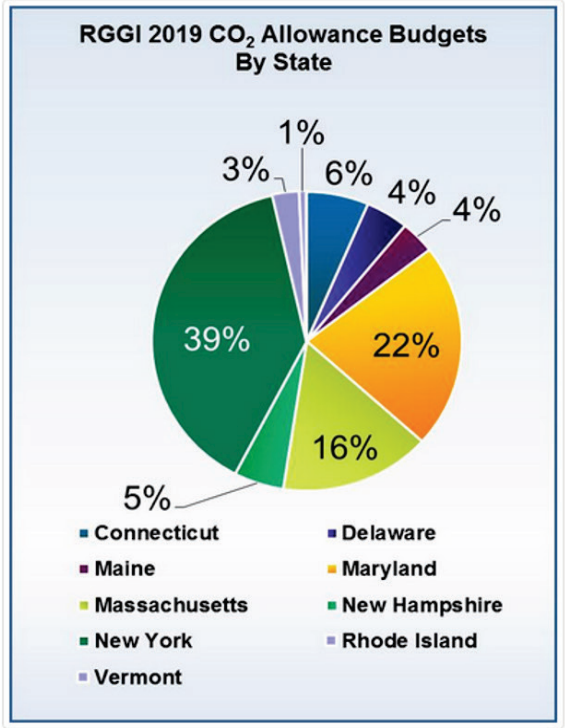
RGGI, Inc. | Program Overview and Design | Auctions | Allowance Tracking | Investments | News & Releases

CO_2 allowances are issued by each RGGI state in an amount defined in each state's applicable statute and/or regulations. Together, all the CO_2 allowances issued by all the RGGI states comprise the RGGI cap.

Most allowances are distributed at auction, but a limited amount may be held in set-aside accounts and distributed according to state-specific programs. For a list of state-specific set-aside programs, see this summary document.

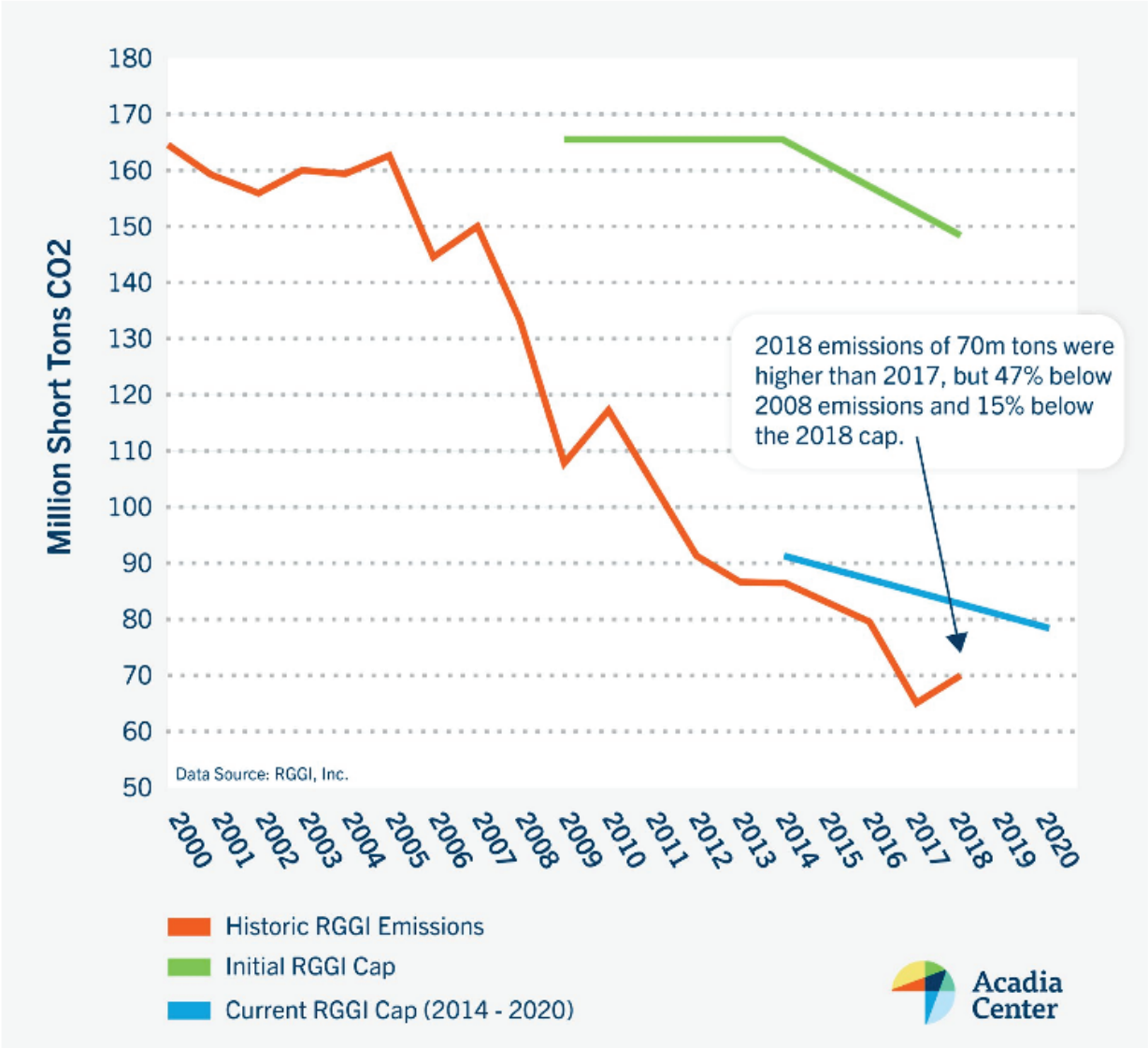
The trackers below offer more detail on the distribution of allowances, organized by allocation year. Note that the allocation year of the allowance does not necessarily equal the year that the allowance was distributed. Trackers are updated to account for any changes to the status of past allocation years' allowances (such as retirement or distribution from set-aside accounts).





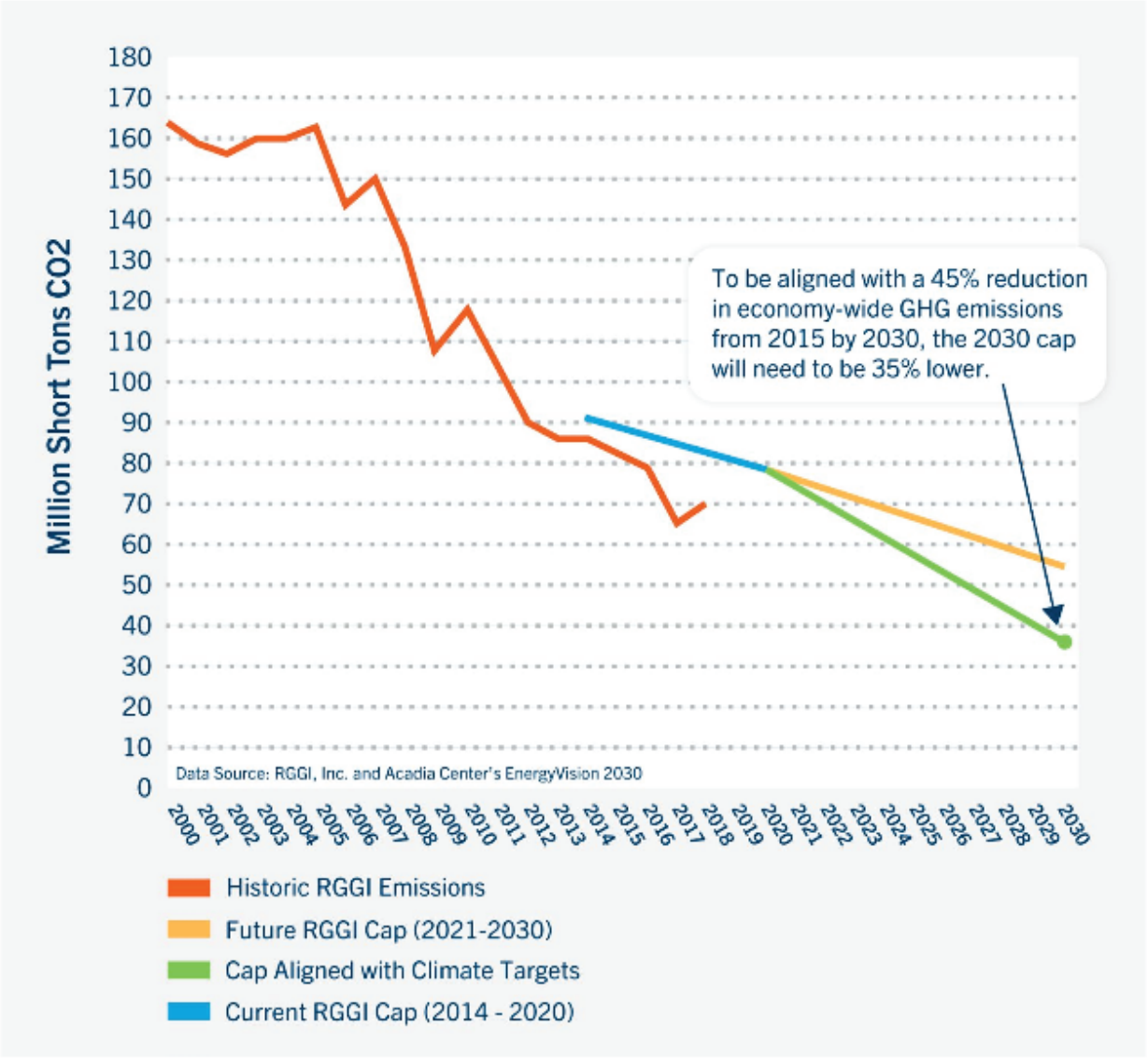
https://www.rggi.org/allowance-tracking/allowance-distribution

Figure 1: RGGI Cap and Historic Emissions – Nine RGGI States



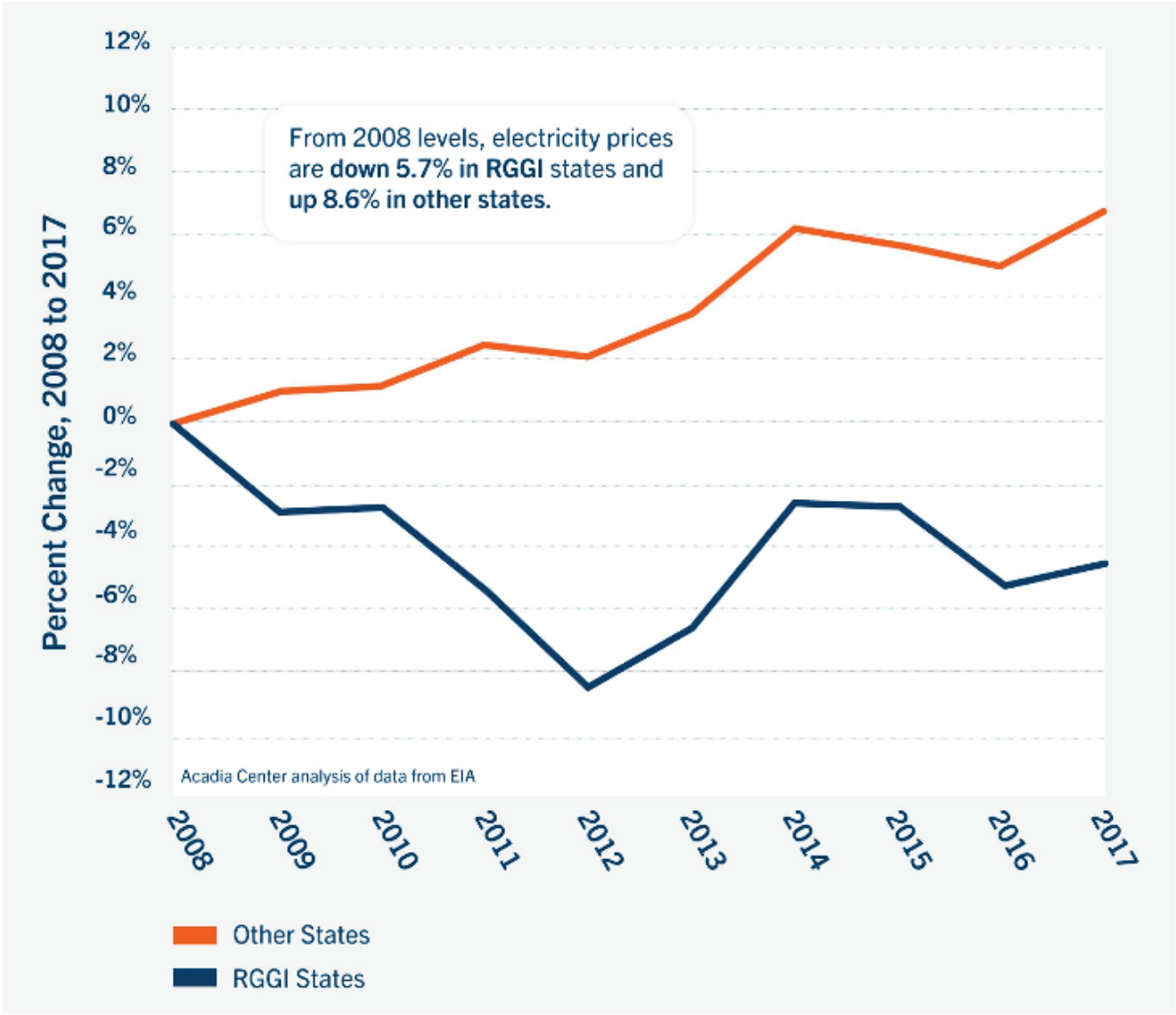
https://acadiacenter.org/wp-content/uploads/2019/09/Acadia-Center_RGGI_10-Years-in-Review_2019-09-17.pdf

Figure 3: Aligning the Future RGGI Cap with Climate Targets



https://acadiacenter.org/wp-content/uploads/2019/09/Acadia-Center_RGGI_10-Years-in-Review_2019-09-17.pdf

Figure 5: Volume-Weighted Electricity Prices, 2008 to 2017



https://acadiacenter.org/wp-content/uploads/2019/09/Acadia-Center_RGGI_10-Years-in-Review_2019-09-17.pdf

Maryland RGGI, 2016 Revenue Allocation

2016 Revenue Millions of $	Allocation
39.7	Energy Assistance
17.4	Renewable Energy, Climate Change, Resiliency, Energy Education
8.7	Energy efficiency, low and moderate income
8.7	Energy efficiency, other sectors
5.0	Administration
79.5	Total

44% of revenue went to efforts that could lead to reduced emissions of GHGs

http://mgaleg.maryland.gov/pubs/budgetfiscal/2016fy-budget-docs-operating-D13A13-Maryland-Energy-Administration.pdf

Maryland RGGI, 2019 Revenue Allocation

2019 Revenue Millions of $	Allocation
26.0	Energy Assistance
5.6	Renewable Energy, Climate Change, Resiliency, Energy Education
5.0	Energy efficiency, low and moderate income
5.2	Energy efficiency, other sectors
4.0	Administration
45.8	Total

34% of revenue went to efforts that could lead to reduced emissions of GHGs

http://mgaleg.maryland.gov/pubs/budgetfiscal/2019fy-budget-docs-operating-D13A13-Maryland-Energy-Administration.pdf

More States are Joining RGGI

Welcoming Additional States

There are currently nine states participating in the RGGI market, but that number is poised to grow to 11 by 2021. New Jersey is set to be the first addition, with the New Jersey Department of Environmental Protection adopting regulations in the summer of 2019 to rejoin the RGGI program on January 1st, 2020.[xix] This will mark New Jersey's return to the program, as the state participated in RGGI as a founding member until then-Governor Christie removed the state from the program in 2011. It appears likely that Virginia will follow New Jersey, with regulations approved to participate in a carbon trading program linked with the RGGI market.[xx] Virginia's participation in the RGGI market is expected to begin on January 1st, 2021.

https://acadiacenter.org/wp-content/uploads/2019/09/Acadia-Center_RGGI_10-Years-in-Review_2019-09-17.pdf

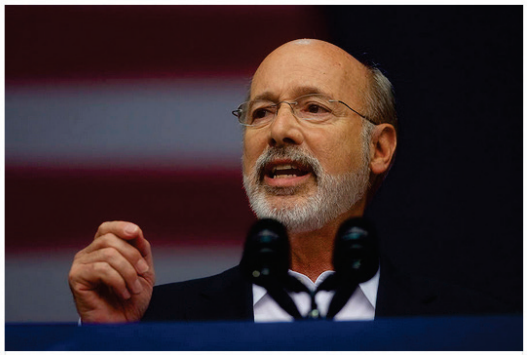
More States are Joining RGGI

A Major Fossil Fuel State Is Joining RGGI, the Northeast's Carbon Market

Pennsylvania is the nation's No. 2 natural gas producer, and No. 3 in coal. Its governor says 'we need to get serious' about the climate crisis.

BY MARIANNE LAVELLE Follow @mlavelles

OCT 3, 2019



"If we want a Pennsylvania that is habitable for our children and grandchildren, where temperatures aren't in the 90s in October ... where flooding doesn't destroy homes and businesses over and over again, we need to get serious right now about addressing the climate crisis," Pennsylvania Gov. Tom Wolf said. Credit: Mark Makela/Getty Images

https://insideclimatenews.org/news/03102019/pennsylvania-rggi-coal-gas-power-plant-emissions-carbon-cap-trade-regulation