Osher Lifelong Learning Institute, Spring 2022

Climate Change Economics

California State University – East Bay
March 30 and April 6, 2022

Jon Haveman, Ph.D.
National Economic Education Delegation

NATIONAL ECONOMIC EDUCATION DELEGATION

1

National Economic Education Delegation

- **Vision**
  - One day, the public discussion of policy issues will be grounded in an accurate perception of the underlying economic principles and data.
- **Mission**
  - NEED unites the skills and knowledge of a vast network of professional economists to promote understanding of the economics of policy issues in the United States.
- **NEED Presentations**
  - Are nonpartisan and intended to reflect the consensus of the economics profession.

NATIONAL ECONOMIC EDUCATION DELEGATION

2

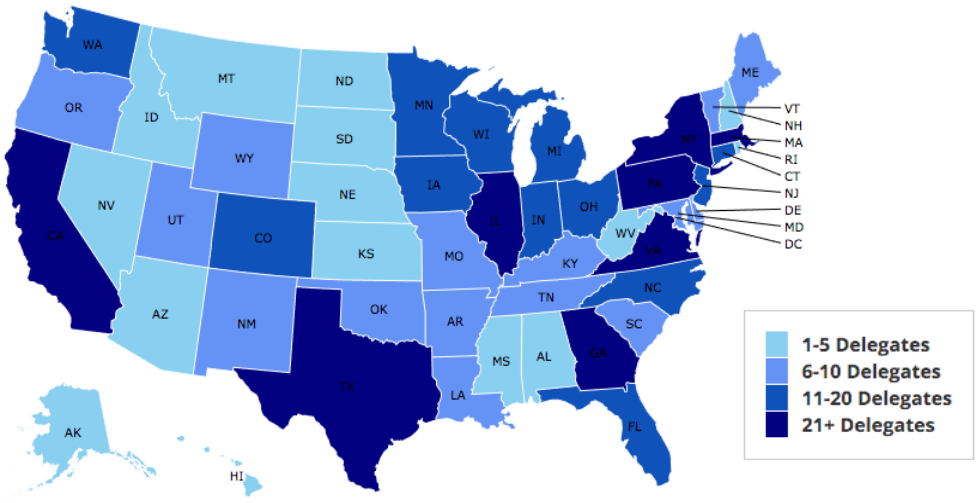
Who Are We?

- **Honorary Board: 54 members**
  - 2 Fed Chairs: Janet Yellen, Ben Bernanke
  - 6 Chairs Council of Economic Advisers
    - Furman (D), Rosen (R), Bernanke (R), Yellen (D), Tyson (D), Goolsbee (D)
  - 3 Nobel Prize Winners
    - Akerlof, Smith, Maskin
- **Delegates: 651+ members**
  - At all levels of academia and some in government service
  - All have a Ph.D. in economics
  - Crowdsource slide decks
  - Give presentations
- **Global Partners: 49 Ph.D. Economists**
  - Aid in slide deck development

NATIONAL ECONOMIC EDUCATION DELEGATION

3

Where Are We?



NATIONAL ECONOMIC EDUCATION DELEGATION

4

Available NEED Topics Include:

- Coronavirus Economics
- US Economy
- Climate Change
- Economic Inequality
- Economic Mobility
- Trade and Globalization
- Minimum Wages
- Immigration Economics
- Housing Policy
- Federal Budgets
- Federal Debt
- Black-White Wealth Gap
- Autonomous Vehicles
- US Social Policy

Credits and Disclaimer

- **This slide deck was authored by:**
  - Shana Mcdermott, Trinity University
  - Sarah Jacobson, Williams College
  - Sharon Shewmake, Western Washington University
- **This slide deck was reviewed by:**
  - Jason Shogren, University of Wyoming
  - Walter Thurman, North Carolina State University
- **Disclaimer**
  - NEED presentations are designed to be nonpartisan.
  - It is, however, inevitable that the presenter will be asked for and will provide their own views.
  - Such views are those of the presenter and not necessarily those of the National Economic Education Delegation (NEED).

Outline

- Climate change science
- Impacts of climate change
- Economics of responding to climate change
- Addressing the sources of our emissions
- Climate change policy
- Policy in action

7

Economics Informs Almost Everything

- Prices
- Incentives
- Externalities
- Cost-Benefit Analysis
- Growth
- Inflation
- Interest Rates
- Climate Change
- International Trade
- Immigration
- Housing
- Education
- Health Care
- Gun Control

8

How Can Economists Contribute to Thinking about Climate Change?

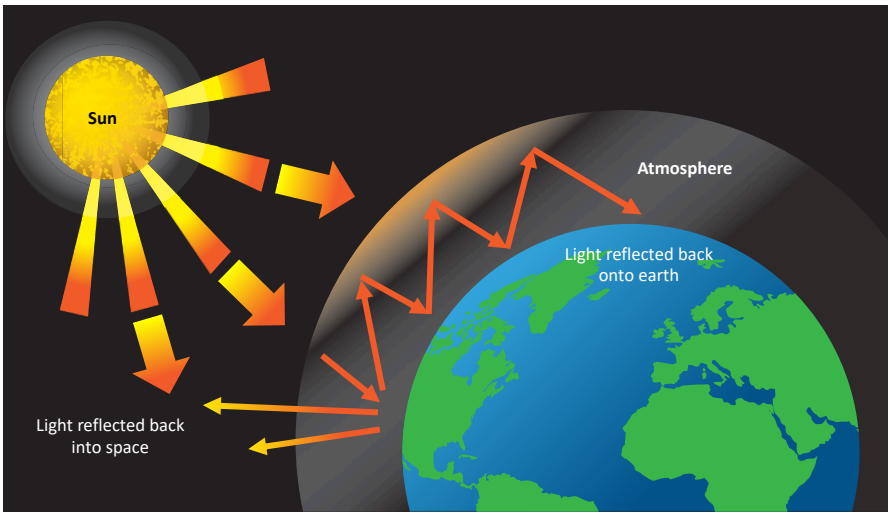
- **By assessing behavioral reactions to climate change.**
- **By measuring the damage and estimating the economic costs of fighting climate change.**
- **By designing smart policies that minimize costs.**
  - Balance economic growth with GHG emission mitigation.

9

Climate Change: A Little Science

10

The Atmospheric Greenhouse Effect



NATIONAL ECONOMIC EDUCATION DELEGATION

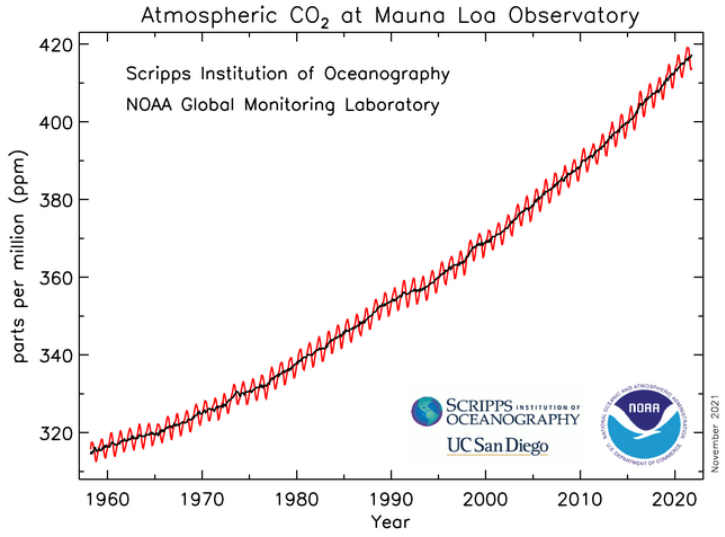
11

Uncertainty

NATIONAL ECONOMIC EDUCATION DELEGATION

12

Atmospheric CO_2 Concentrations Up To Now

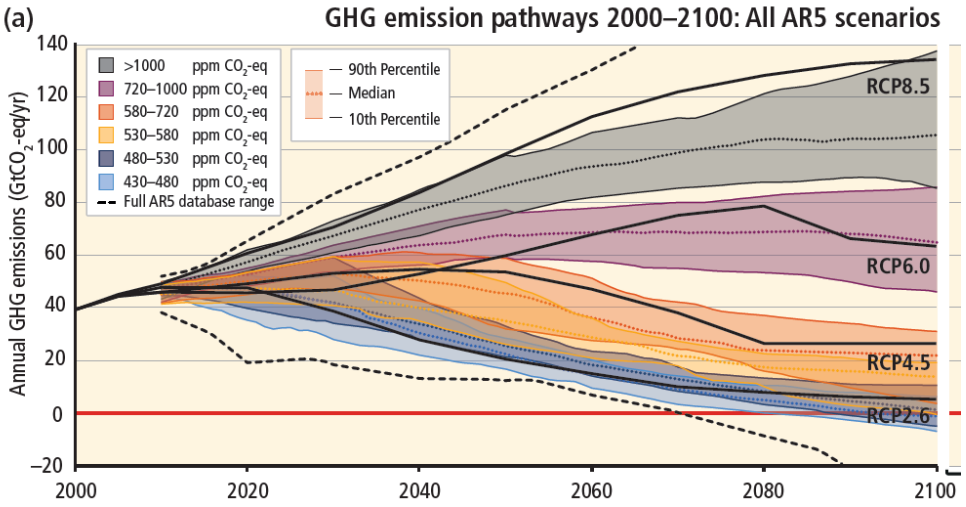


NATIONAL ECONOMIC EDUCATION DELEGATION

Source: NOAA

13

Emissions Trajectories into the Future



NATIONAL ECONOMIC EDUCATION DELEGATION

Source: IPCC Assessment Report 5

14

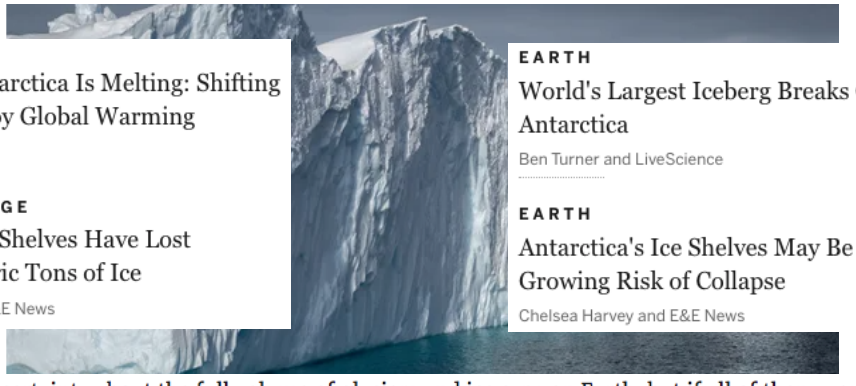
What Do Greenhouse Gas Emissions Do to the Planet?

- **Increased temperatures**
  - Sea level rise
  - Storm surges
- **Altered precipitation patterns**
- **More variable weather**
- **More / more powerful storms**
- **Carbon dissolves in ocean**

15

Icebergs Are Significant Contributors

"If the West Antarctic Ice Sheet collapsed, the most widely cited estimate of the resulting global mean sea-level rise that would result is 3.2 meters," said Powell.



EARTH
The Reason Antarctica Is Melting: Shifting Winds, Driven by Global Warming
Annie Sneed

CLIMATE CHANGE
Antarctica's Ice Shelves Have Lost Millions of Metric Tons of Ice
Chelsea Harvey and E&E News

EARTH
World's Largest Iceberg Breaks Off of Antarctica
Ben Turner and LiveScience

EARTH
Antarctica's Ice Shelves May Be at Growing Risk of Collapse
Chelsea Harvey and E&E News

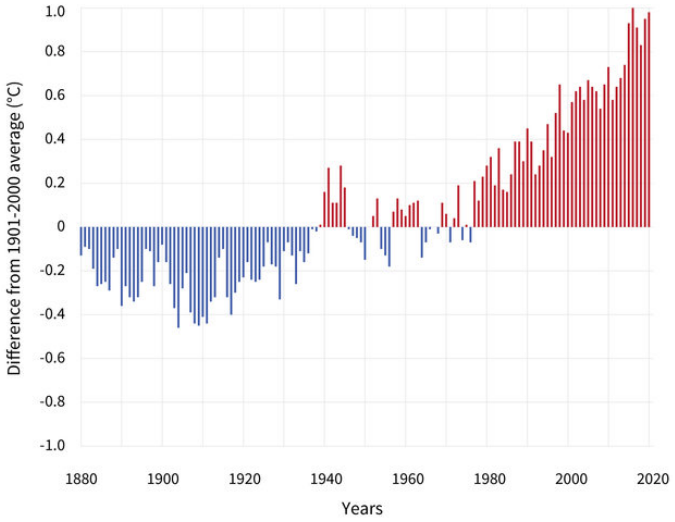
There is still some uncertainty about the full volume of glaciers and ice caps on Earth, but if all of them were to melt, global s level would rise approximately 70 meters (approximately 230 feet) flooding every coastal city on the planet.

https://www.scientificamerican.com/article/what-to-know-about-antarcticas-conger-ice-shelf-collapse/

16

The Earth is Clearly Warming

Global Average Surface Temperature



NATIONAL ECONOMIC EDUCATION DELEGATION

Yearly surface temperature compared to the 20th-century average from 1880–2020. Blue bars indicate cooler-than-average years; red bars show warmer-than-average years. NOAA Climate.gov graph, based on data from the National Centers for Environmental Information.

17

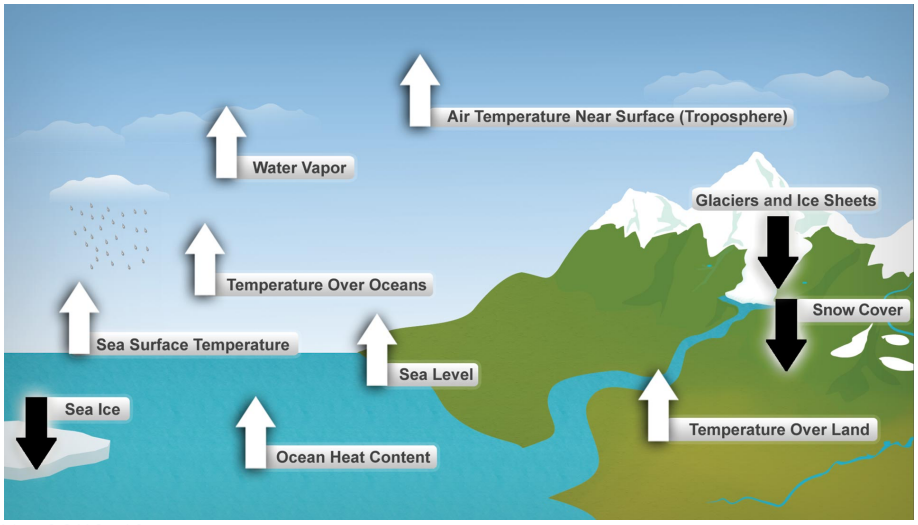
17

Impacts of Climate Change

NATIONAL ECONOMIC EDUCATION DELEGATION

18

Global Warming Indicators



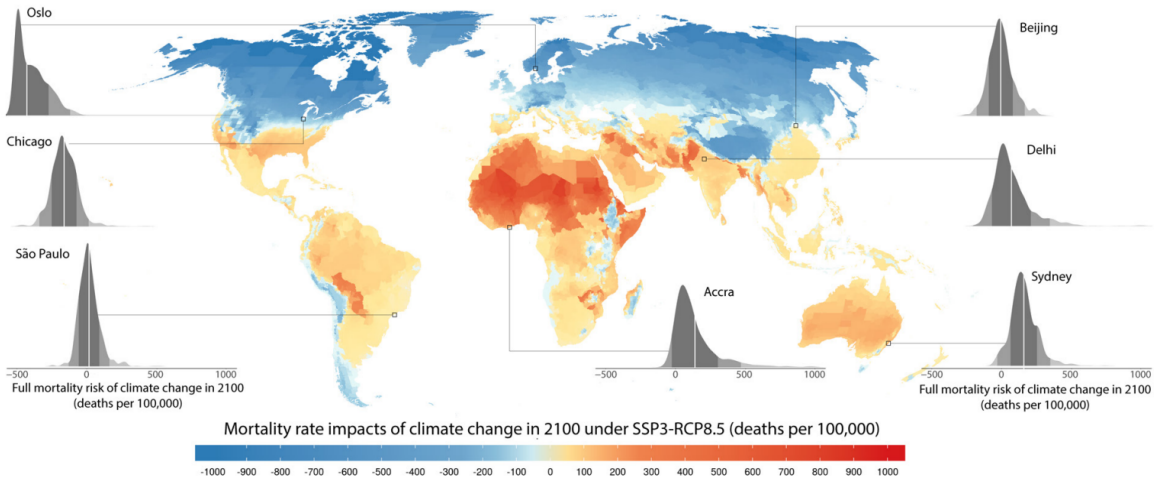
19

How These Impacts Affect Humans

- Agriculture
- Fisheries
- Coastal damages
- Direct health effects, including sickness and death (temperature & drought; also pollution)
- Indirect health effects (vector-borne disease)
- Reduced fresh water availability
- Wildfires
- Shifting zones for important ecosystems, and desertification
- Reduced worker productivity
- Increased violence
- Some of these may cause human migration and/or conflict

20

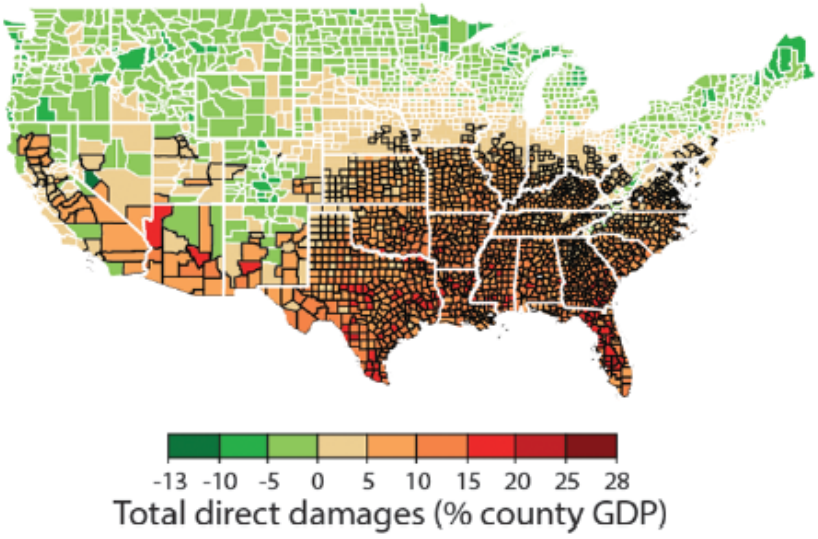
How Damages Will Vary Globally: Mortality as an Example



NATIONAL ECONOMIC EDUCATION DELEGATION

21

How Damages Will Vary in the US



NATIONAL ECONOMIC EDUCATION DELEGATION

22

Projected Effects Vary Across the U.S. but Are Estimated at 1.2% of GDP per 1C Increase

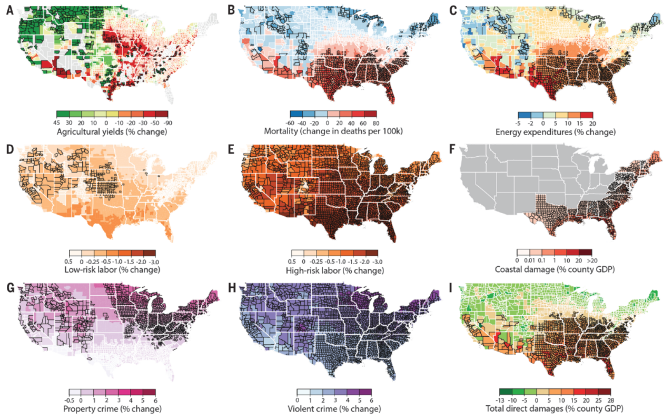
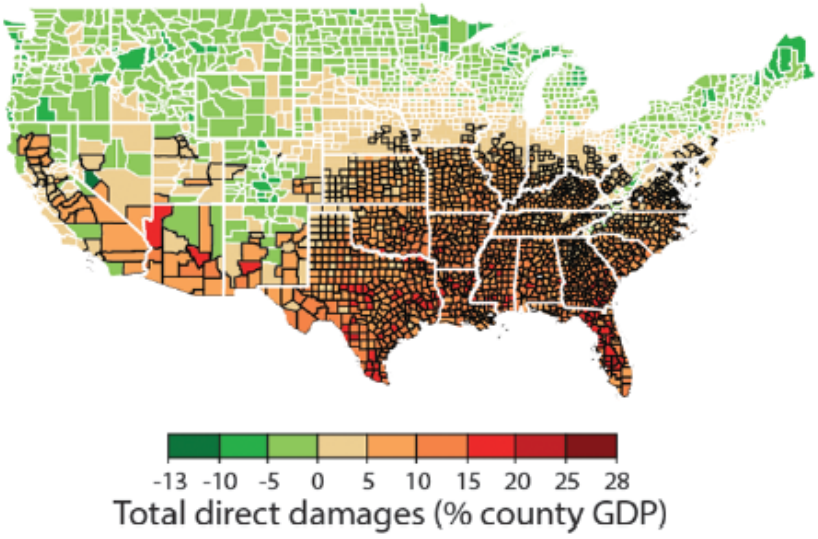


Fig. 2. Spatial distributions of projected damages. County-level median values for average 2080 to 2099 RCP8.5 impacts. Impacts are changes relative to counterfactual "no additional climate change" trajectories. Color indicates magnitude of impact in median projection; outline color indicates level of agreement across projections (thin white outline, inner 66% of projections disagree in sign; no outline, ≥83% of projections agree in sign; black outline, ≥95% agree in sign; thick white outline, state borders; maps without outlines shown in fig. S2). Negative damages indicate economic gains. (**A**) Percent change in yields, area-weighted average for maize, wheat, soybeans, and cotton. (**B**) Change in all-cause mortality rates, across all age groups. (**C**) Change in electricity demand. (**D**) Change in labor supply of full-time-equivalent workers for low-risk jobs where workers are minimally exposed to outdoor temperature. (**E**) Same as (D), except for high-risk jobs where workers are heavily exposed to outdoor temperatures. (**F**) Change in damages from coastal storms. (**G**) Change in property-crime rates. (**H**) Change in violent-crime rates. (**I**) Median total direct economic damage across all sectors [(A) to (H)].

NATIONAL ECONOMIC EDUCATION DELEGATION

23

How Damages Will Vary in the US



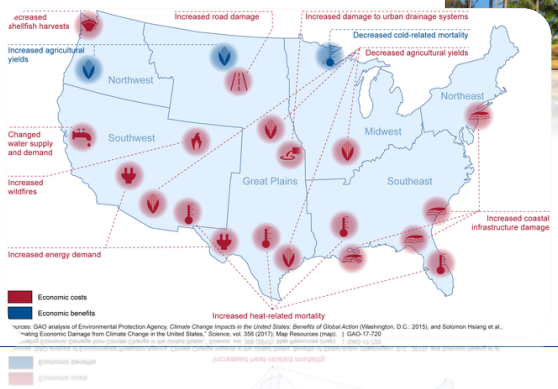
NATIONAL ECONOMIC EDUCATION DELEGATION

24

24

Most Vulnerable People and Places

- Tropical areas
- Low-lying coastal areas
- Low-income people

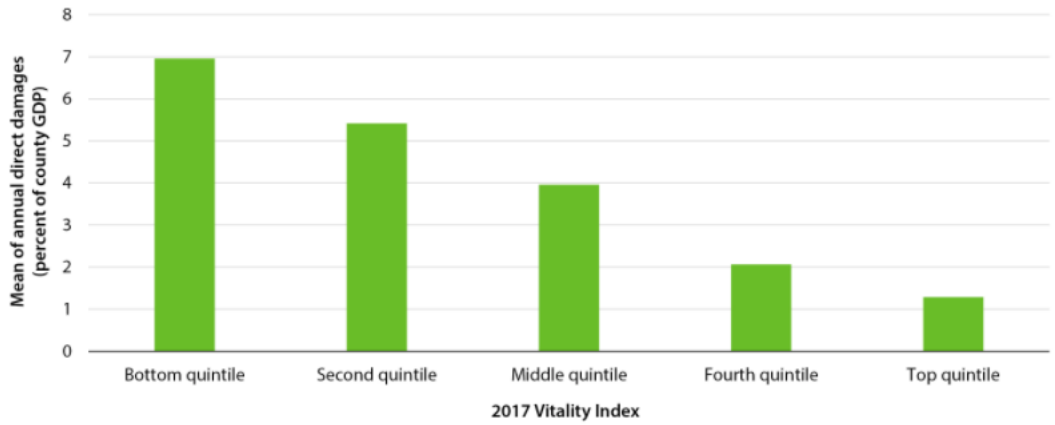


NATIONAL ECONOMIC EDUCATION DELEGATION

25

FIGURE 2.

Economic Damages to U.S. Counties from Climate Change in 2080–99 by Quintile of Economic Vitality Index



Source: Hsiang et al. 2017; Nunn, Parsons, and Shambaugh 2018; authors' calculations.

Note: Vitality quintiles are population-weighted. Figure assumes the mean estimate for average annual GDP loss during 2080–99 under RCP 8.5, which corresponds to roughly 3.2°C to 5.4°C of warming relative to preindustrial levels.

THE HAMILTON PROJECT BROOKINGS

Stanford | Institute for Economic Policy Research (SIEPR)

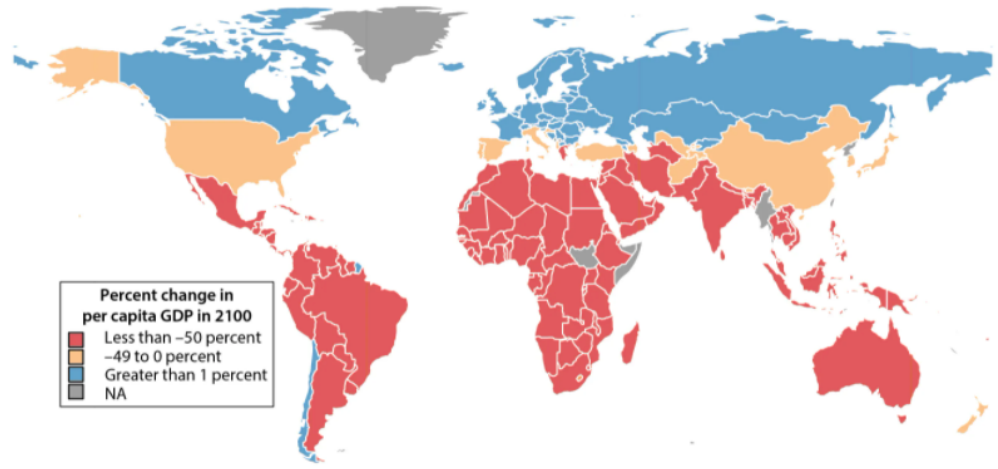
NATIONAL ECONOMIC EDUCATION DELEGATION

26

https://www.brookings.edu/research/ten-facts-about-the-economics-of-climate-change-and-climate-policy/

26

Climate Change Effect on per Capita GDP in 2100 by Country



Source: Burke, Hsiang, and Miguel (2015); authors' calculations.

Note: Country-level estimates for GDP per capita in 2100. Figure assumes RCP 8.5, which corresponds to roughly 3.2°C to 5.4°C of warming. GDP loss is associated with the warming from a baseline of 1960–2010 average temperatures. As explained in Burke, Hsiang, and Miguel (2015), estimates include growth-rate effects over the period through 2100.

THE HAMILTON PROJECT BROOKINGS Stanford | Institute for Economic Policy Research (SIEPR)

NATIONAL ECONOMIC EDUCATION DELEGATION

27

27

Economics & Climate Change

NATIONAL ECONOMIC EDUCATION DELEGATION

28

28

A Climate Change Ladder

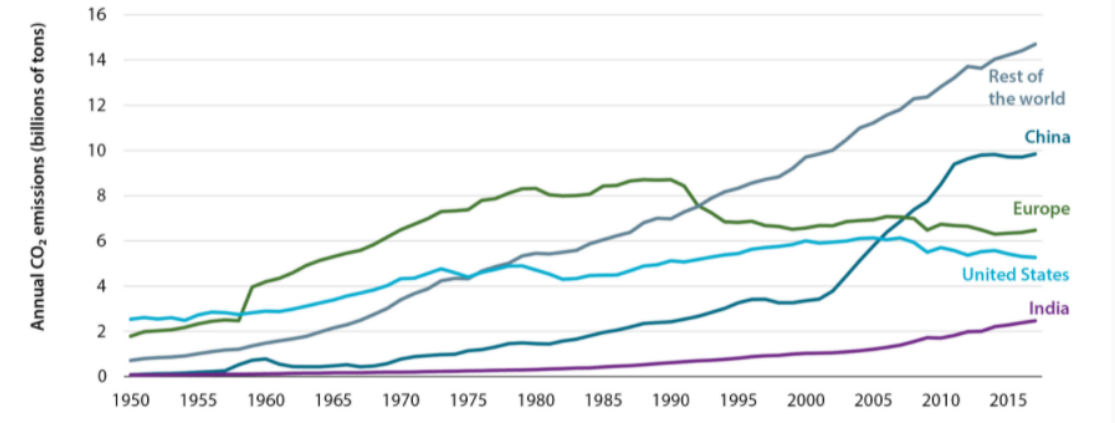
- **Emissions**
- **Mitigation (a.k.a. Abatement)**
- **Adaptation**
- **Damages**

29

Sources of the Global Flow of Emissions

FIGURE D.

Annual CO2 Emissions by Geographic Region, 1950–2017



Source: Ritchie and Roser 2017; authors' calculations.

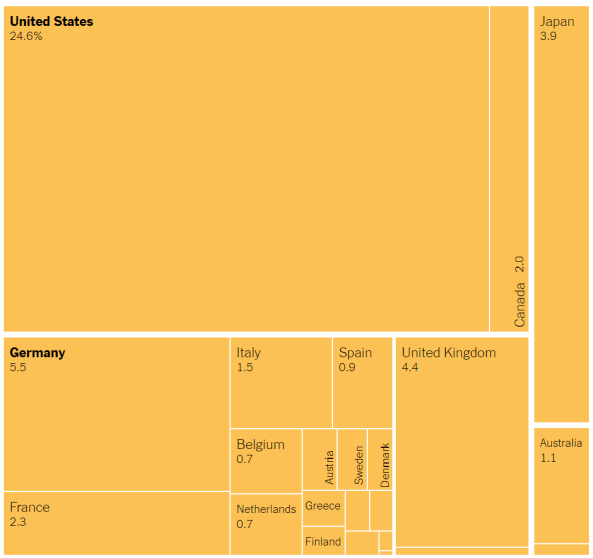
Note: "Europe" includes all 50 member countries as determined by the United Nations. "Rest of the world" includes all countries not in another group.

THE HAMILTON PROJECT BROOKINGS Stanford | Institute for Economic Policy Research (SIEPR)

30

Sources of the Global Stock of Emissions

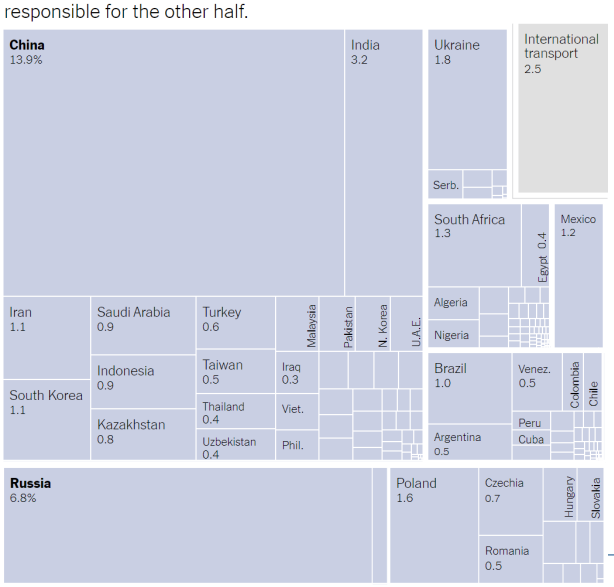
23 rich, developed countries are responsible for half of all historical CO_2 emissions.



NATIONAL ECONOMIC EDUCATION DELEGATION

Sources of the Global Stock of Emissions

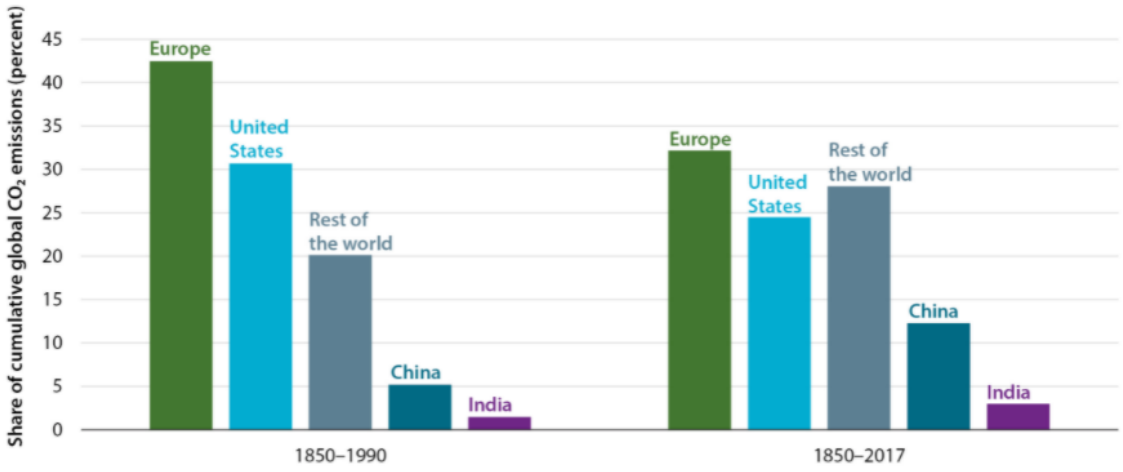
More than 150 countries are responsible for the other half.



NATIONAL ECONOMIC EDUCATION DELEGATION

FIGURE C.

Share of Cumulative CO2 Emissions by Geographic Region, 1850–1990 and 1850–2017



Source: Ritchie and Roser 2017; authors' calculations.

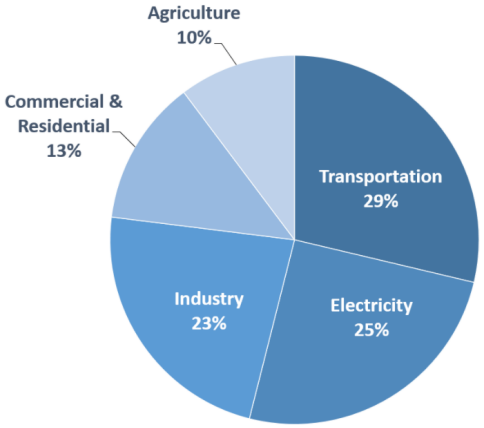
Note: "Europe" includes all 50 member countries as determined by the United Nations. "Rest of the world" includes all countries not in another group.

NATIONAL ECONOMIC EDUCATION DELEGATION

33

33

Total U.S. Greenhouse Gas Emissions by Economic Sector in 2020

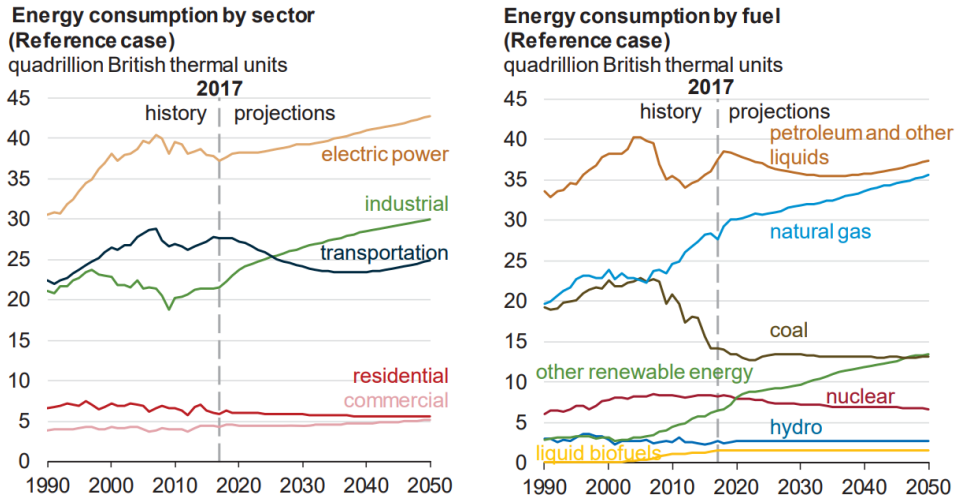


NATIONAL ECONOMIC EDUCATION DELEGATION

Total Emissions in 2019 = 6,558 Million Metric Tons of CO2 equivalent. Percentages may not add up to 100% due to independent rounding.

34

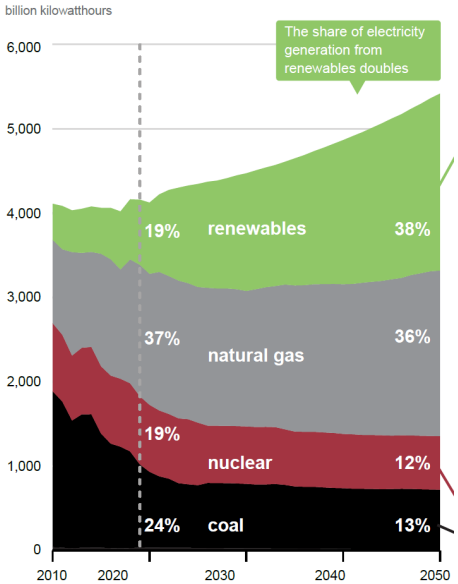
Fossil Fuels Dominate U.S. Energy Production



NATIONAL ECONOMIC EDUCATION DELEGATION

35

US Electricity Sources



NATIONAL ECONOMIC EDUCATION DELEGATION

36

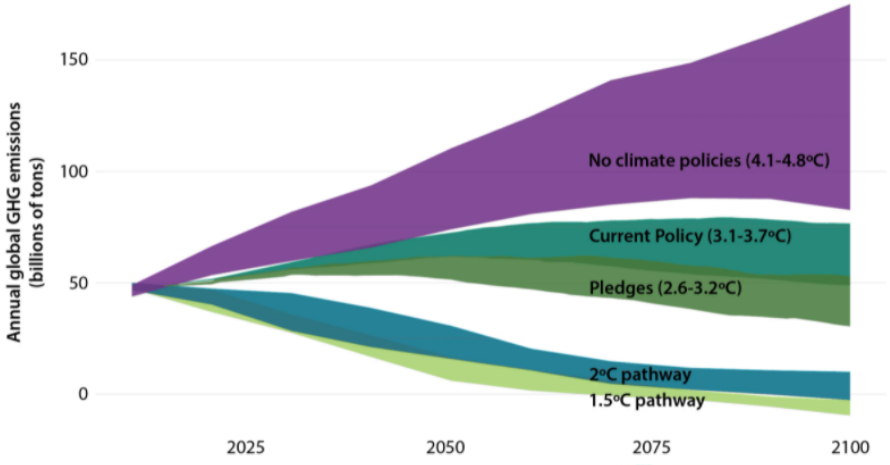
A Climate Change Ladder

- Emissions
- **Mitigation (a.k.a. Abatement)**
- Adaptation
- Damages

37

Mitigation is Crucial

FIGURE E.
Historical and Projected Annual Global GHG Emissions under Selected Policy Scenarios, 2010–2100



Source: Ritchie and Roser 2017.
Note: These temperature estimates are relative to preindustrial temperatures. "Pledges" refers to the pledges made in the 2015 Paris Agreement.

THE HAMILTON PROJECT BROOKINGS Stanford | Institute for Economic Policy Research (SIEPR)

38

Econ 101: When Everything Is Simple, No Regulation Is Needed for Efficiency

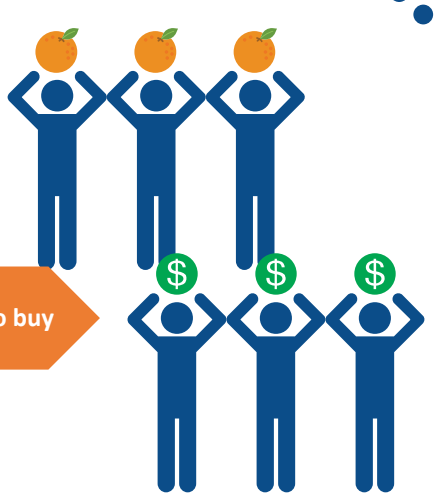
- Simple transactions: buyer and seller feel all costs and benefits of sales
- They choose based on the costs & benefits they feel
- → Efficient number of transactions! (Maximizes social benefits)

39

How Much Pollution Does Society Want? Analogy: How Many Oranges Does Society Want?

- People grow and sell oranges for a price that at least covers costs (***supply***).
- People will not pay more for them than what they consider to be their value (***demand***).
- Prices let ***supply*** and ***demand*** balance out. The price settles where:

# of oranges people want to sell = # of oranges people want to buy



- This is the "right" number of oranges for society.
- Prices reflect scarcity and the social value of the resource.

40

The First Theorem of Welfare Economics

…is that private markets are perfectly efficient on their own, with no interference from government, provided certain conditions are met.

Economic Efficiency: When the sum of the profits of buyers and the profits of sellers is maximized.

*You can't make anyone better off without making someone worse off.

41

What are "certain conditions"?

No public goods
No externalities
No taxes
No monopoly buyers or sellers
No information problems
No transaction costs
No common property
No increasing returns to scale

No other 'distortions' between the costs paid by buyers and the benefits received by sellers.

42

Characteristics of Goods

Excludable: Goods that you can exclude people from using.

Rival: One person's use of the good diminishes other's ability to use the good.

Public Goods (Not Rival or Excludable): Benefits additional users at no cost to society.

Common Resources (Rival, but not Excludable): Common property, or open access resources, where anyone can extract or harvest the resource freely and no one recognizes the full cost of using the resource.

43

Characteristics of Goods & Environmental Economics

Externalities: some costs or benefits of producing, consuming, or disposing of a good or service are *external to the market*.

Missing Markets Problem: some goods (or inputs) into production are not sold on a market. Firms and individuals then sometimes value the good at what they pay for it, $0, instead of what it is worth.

44

Examples of Externalities

- **Negative Externalities:**
  - Heating your house
  - Smoking
  - Getting a dog
  - Pig farming
- **Positive Externalities**
  - Education
  - Growing apples
  - Getting a vaccination
  - Basic scientific research

45

Pigouvian Taxes

- **Internalize negative externalities.**
  - Make the buyers of the good that produces an externality pay for the externality.
    - Creates a market of sorts for the externality.
      - Government is the caretaker of clean air, for example.
      - Cigarette's pollute the air, so smokers pay the government for the right to pollute the air.
- **It does this by equalizing "marginal social cost (MSC)" with "marginal social benefit (MSB)".**
  - With no externality: MSB = MSC
  - With a negative externality: MSB < MSC
    - My actions cost society more than I am paying to undertake them.

46

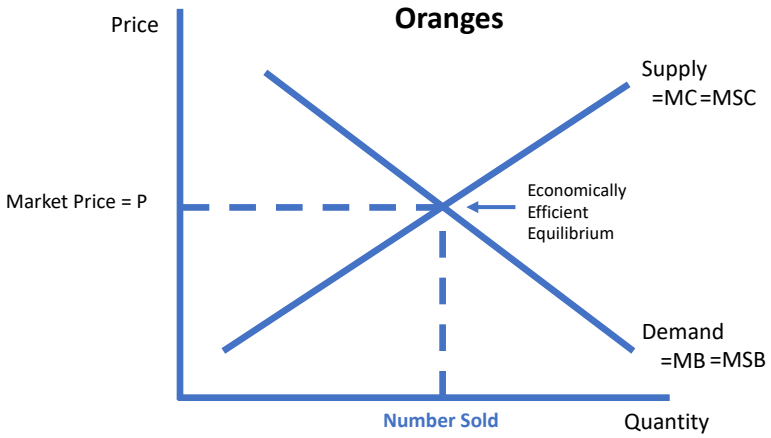
Marginal Social Cost and Social Benefit?

- **Marginal:** refers to the costs and benefits of the last unit sold.
- **Marginal Cost (MC):** refers to the cost of making the last unit sold.
- **Marginal Benefit (MB):** refers to the value the consumer puts on buying the last unit.

- **Social cost:** the impact, in dollar terms, of consuming the last unit sold.

- With a negative externality:
  - MSB = MB
  - MSC = MC + Social cost

How Does A Pigouvian Tax Work?



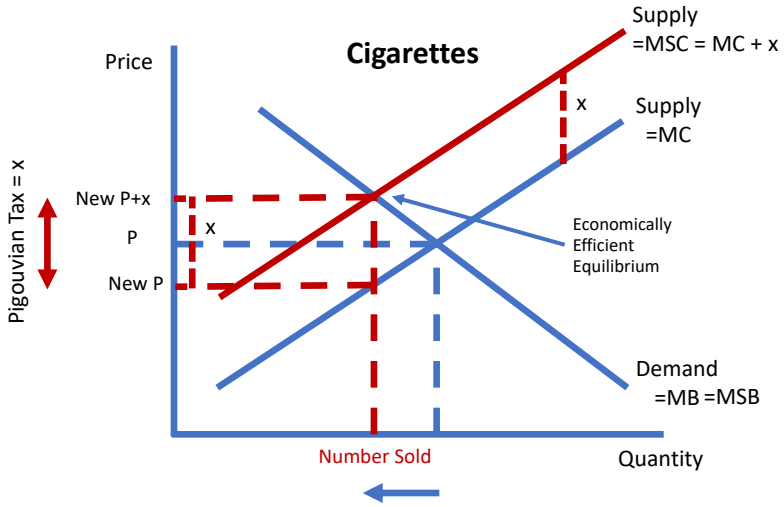
A market with no externalities.

MSC = MC
MSB = MB

MSB = MSC

No Pigouvian tax is necessary.

How Does A Pigouvian Tax Work?



A market with a **negative** externality.

X = social cost
MSC = MC+x
MSB = MB
MSB < MSC

A Pigouvian tax is necessary to set MSB = MSC.

49

How Does A Pigouvian Tax Work?

1) A Pigouvian tax raises the cost of buying the item.
2) The higher cost results in less of the item being purchased.
3) With lower consumption, comes less of the externality.

Key: Consumer is now paying for all of the costs associated with the good.

Note: the tax REDUCES the amount of the externality. It does not eliminate it.

How much of a cost should we bear to get rid of a $5 externality?

Answer: $5

50

Electricity Is Different From Oranges

- **Many sources of electricity generate pollution.**
- **Pollution is an EXTERNALITY:**
  - a side effect (cost or benefit) that affects someone else when something is bought or sold.
  - This is a ***market failure.***
- **The price of electricity does not reflect all of the costs.**
  - Electricity is too cheap.
  - There is too much pollution.

NATIONAL ECONOMIC EDUCATION DELEGATION

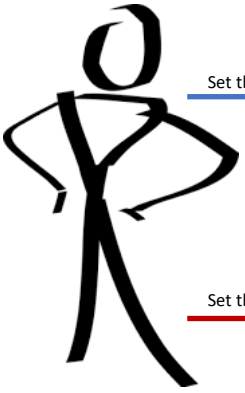
51

Addressing a Negative Externality

$.14/Kwh

Social cost = $.02/Kwh

$.16/Kwh



Set thermostat to: 68 degrees

Set thermostat to: 65 degrees

The social cost of $.02/Kwh has been INTERNALIZED.

NATIONAL ECONOMIC EDUCATION DELEGATION

52

52

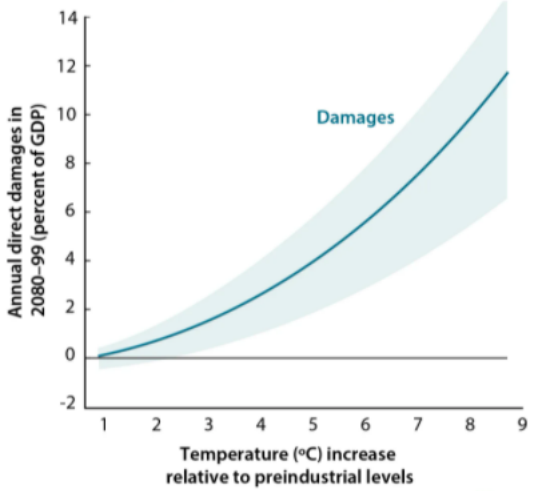
Social Cost of Carbon

- **The expected cost of damages from each unit of greenhouse gas emissions.**
- **Current EPA estimate: ~$51 per metric ton of CO_2 (but estimates vary a lot!)**
  - About $157/car per year.
  - $32 Billion for all vehicles in the US.
- **Reduce emissions until the cost of reducing emissions is greater than $51 per metric ton.**
- **Price of emissions rises with level of emissions in the atmosphere.**

NATIONAL ECONOMIC EDUCATION DELEGATION

53

FIGURE 1.
U.S. Economic Damages from Climate Change in 2080–99 by Temperature Increase



Source: Hsiang et al. 2017.
Note: The shaded area represents a 90 percent confidence interval around the central estimate for a given temperature increase. Costs associated with mitigation are excluded.

THE HAMILTON PROJECT BROOKINGS Stanford Institute for Economic Policy Research (SIEPR)

NATIONAL ECONOMIC EDUCATION DELEGATION

54

54

Pros and Cons of A Pigouvian Tax

- **Pros:**
  - **Fosters market efficiency**:
    - Pigouvian taxes promote market efficiency by incorporating the additional costs imposed by negative externalities.
  - **Discourages harmful activities**:
    - In certain cases, Pigouvian taxes may effectively discourage the activities that lead to negative externalities. For example, the introduction of a carbon tax may place a significant burden on a company that produces substantial emission gases. Therefore, a company may decide to transfer to operations that produce fewer emission gases.
  - **Generates additional government revenue**:
    - Pigouvian taxes generate additional revenues for the government. The additional funds may be used to subsidize initiatives and programs that will further challenge negative externalities.

55

Pros and Cons of A Pigouvian Tax

- **Cons:**
  - **Hard to measure:**
    - In theory, Pigouvian taxes must be equal to the costs generated by the negative externality. However, in the real world, the precise measurement of such costs is not always possible. Thus, in practice, the taxes are less effective than in theory.
  - **Political issues:**
    - The imposition of Pigouvian taxes is frequently associated with political problems. Government attempts to introduce such taxes generally face resistance from lobbyists who support parties that can be affected by the taxes (e.g., tobacco producers). Therefore, such taxes are not always an optimal solution from a political perspective.

56

A Climate Change Ladder

- Emissions
- Mitigation (a.k.a. Abatement)
- **Adaptation**
- Damages

57

Adaptation Reduces Damages

- Human *adaptations* are costly actions that can reduce damages from climate change.
- The net cost to society is the cost of adaptation plus the cost of the remaining damages.
- People will take some actions on their own, up to the point where they find it worthwhile.
- Some responses require government involvement: large-scale actions or actions with shared benefits.
- Adaptation is already underway.

58

Individual-Level Adaptation

- **Perhaps you…**
  - Stay inside more.
  - Turn on the air conditioning.
- **Farmers may:**
  - Plant at different times.
  - Plant new crops.
- **Businesses may:**
  - Give outdoor workers water / shade breaks.
- **Everyone might:**
  - Think about moving to a safer place.

NATIONAL ECONOMIC EDUCATION DELEGATION

59

Public Adaptation

- **Governments can help:**
  - When collective action is less costly than everyone acting alone.
  - When individual action is not possible or likely.
  - When some people can't protect themselves.
- **Sea walls**
- **Ecosystems that provide protection**
- **Supporting low-income and vulnerable populations**
- **Moving residents of a town**

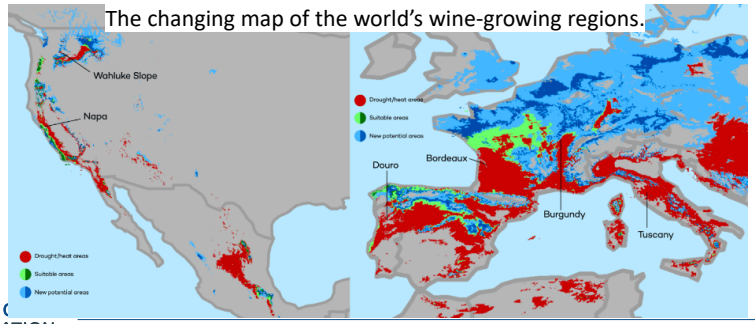
NATIONAL ECONOMIC EDUCATION DELEGATION

60

Market Based Adaptation

- **Prices and costs influence behavior.**
  - Where to live.
  - Where/when/what to plant.
- **Avoid barriers to market adjustment.**
  - Trade barriers, immigration restrictions, federal flood insurance, agricultural subsidies, and zoning regulations.

The changing map of the world's wine-growing regions.

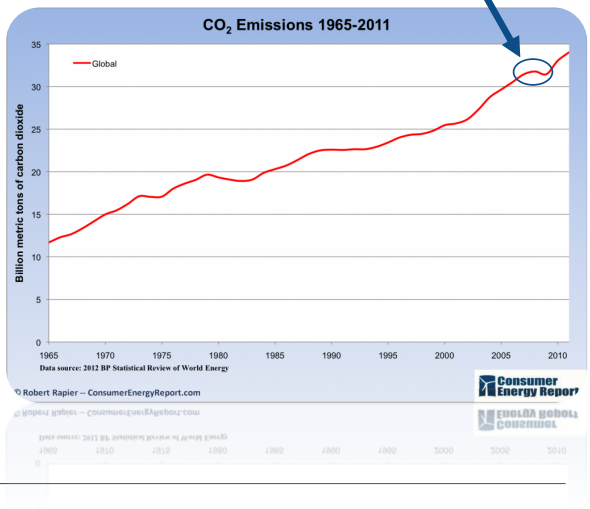


International Climate Policy Goals

- **Intergovernmental Panel on Climate Change (IPCC)**
  - Global effort to fight climate change
  - Reports on consensus of climate science, including economics
- **IPCC report in 2007:**
  - Recommended goal: < 2 degrees C (3.6 degrees F)
  - Industrialized countries should reduce GHG emissions between 25% and 40% below 1990 levels by 2020.
- **2016 Paris Agreement:**
  - Basic goal of 2 degrees C: requires 40-70% GHG reduction 2010 → 2050
  - Reach goal of 1.5 degrees C: requires 70-95% GHG reduction 2010 → 2050
- **IPCC report in 2018:**
  - Temperature has already increased by 1.0 degrees C - Recommended: < 1.5 C

Recent Progress on Climate Goals

- **IPCC's Fifth Assessment Report (2014)**
  - Goals from previous report (2007) were met!
  - … but mainly because of the Great Recession…
  - … which is not the preferred method of reducing emissions.

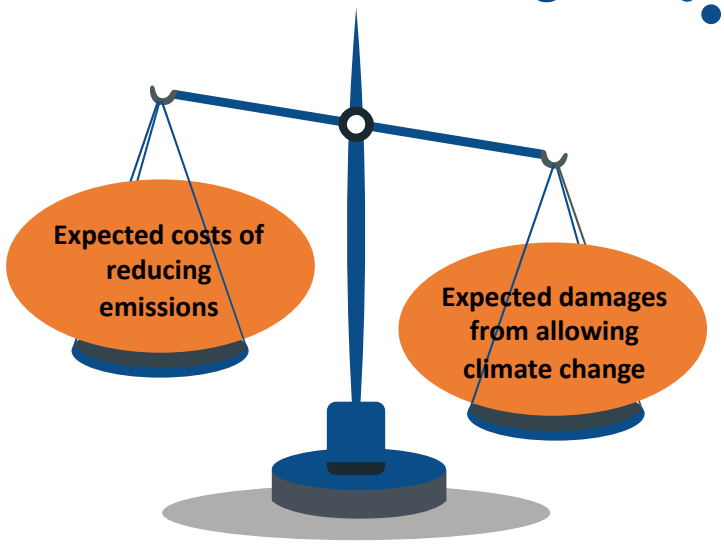


NATIONAL ECONOMIC EDUCATION DELEGATION

63

How Economists Decide How Much to Fight Climate Change

- **Cost Benefit Analysis**
- **Weigh:**



NATIONAL ECONOMIC EDUCATION DELEGATION

64

Cost-Benefit Analysis of Fighting Climate Change

- **Most economic models suggest the costs of keeping warming below 2°C are relatively small.**
  - Costs amount to **1 - 4% of global GDP by 2030**.
- **Costs of acting to keep warming below 2°C are almost certainly less than future economic damages they would avoid.**
  - Damages estimated to be between: **7 - 20% of worldwide GDP**.
- **Caveats:**
  - Putting a monetary value on priceless things
  - Inequality
  - Uncertainty and risk

NATIONAL ECONOMIC EDUCATION DELEGATION

65

66

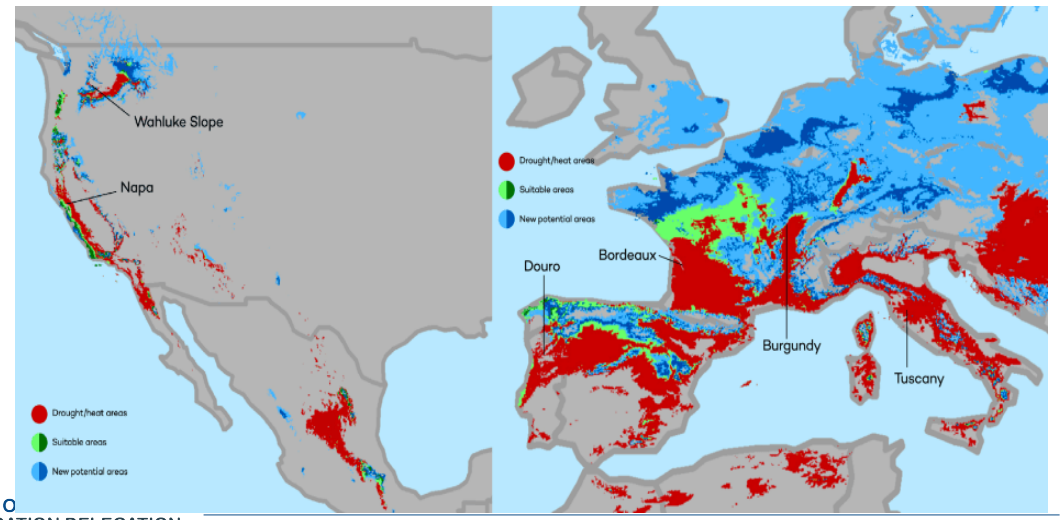
A Climate Change Ladder

- Emissions
- Mitigation (a.k.a. Abatement)
- Adaptation
- Damages

67

This is What Precisely Wrong Looks Like

The changing map of the world's wine-growing regions.



68

Air Travel

- **Warmer weather makes air travel more difficult and more costly.**
  - Warmer weather means that:
    - Planes need to be lighter.
    - Runways need to be longer.
    - Schedules may need to be adjusted to earlier and later in the day.
  - Specific events:
    - June 2021 – Heat Dome – Seattle/Portland
      - Flights cancelled and delayed, ramp employees can't work.
    - 2018 – London – many flights cancelled.
    - 2017 – Phoenix – many flights cancelled.
  - It's not just the Middle East anymore.
  - Spillover effects onto the rest of the economy.
    - Business travel as well as shipping of goods.

69

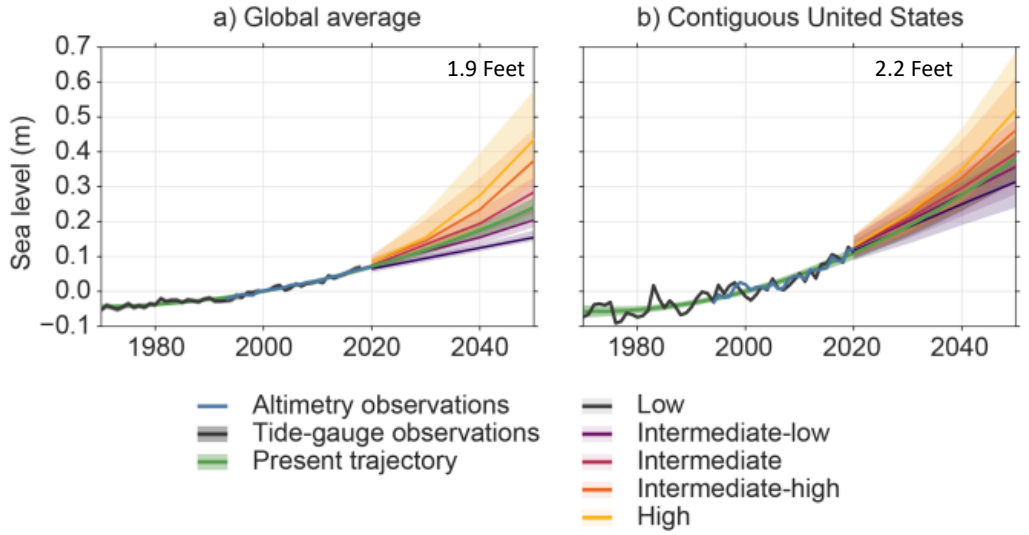
Extreme Heat Events

1960s	2010s
Average 2/year	Averaged 6/year
	- On average one day longer than in the 1960s.
	- Season for heat waves more than 47 days longer.

And more intense heat waves are on the way.

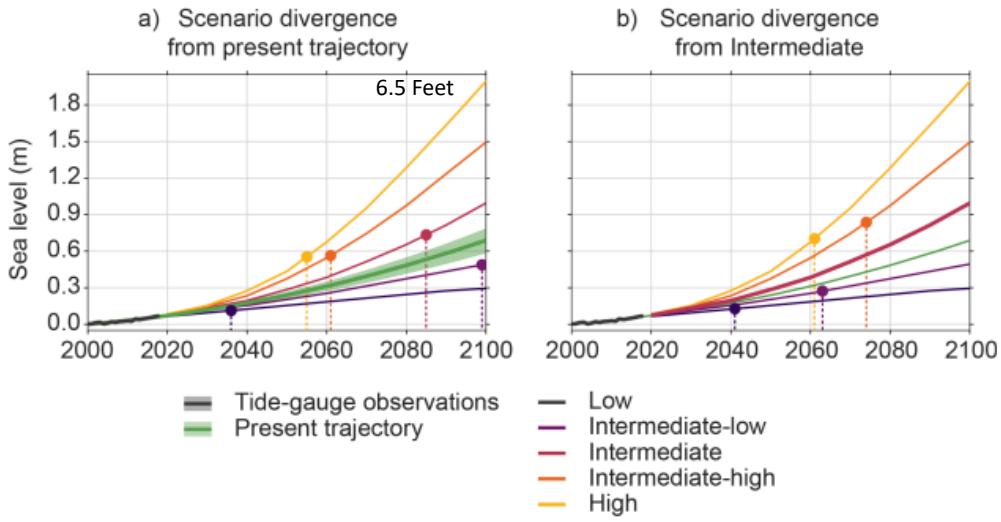
70

Sea Level Rise – to 2050



71

Sea Level Rise – to 2100



72

Silicon Valley is Vulnerable

NATIONAL ECONOMIC EDUCATION DELEGATION

73

73

Silicon Valley: Facebook's Vulnerability

NATIONAL ECONOMIC EDUCATION DELEGATION

74

74

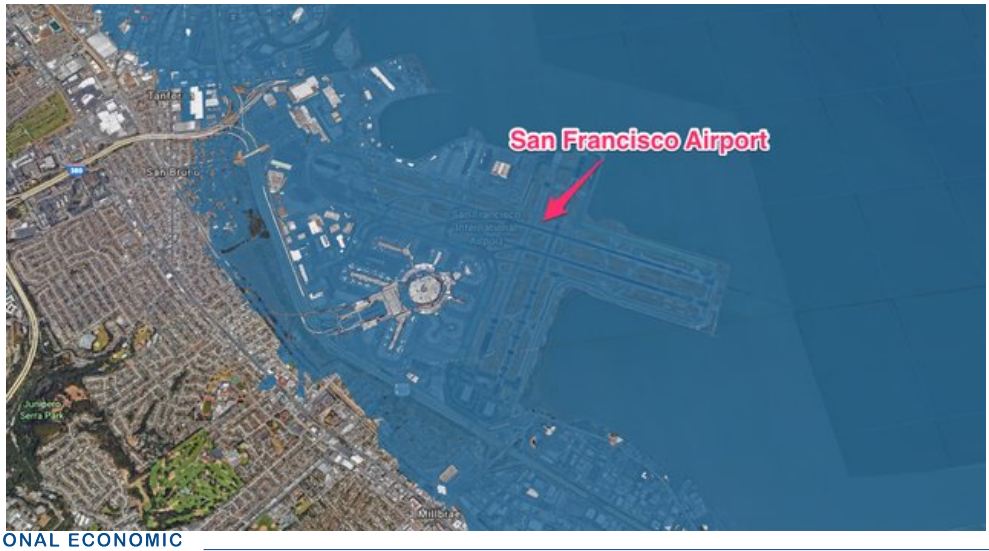
Silicon Valley: In Just A Couple of Decades

75

Silicon Valley: End of the Century

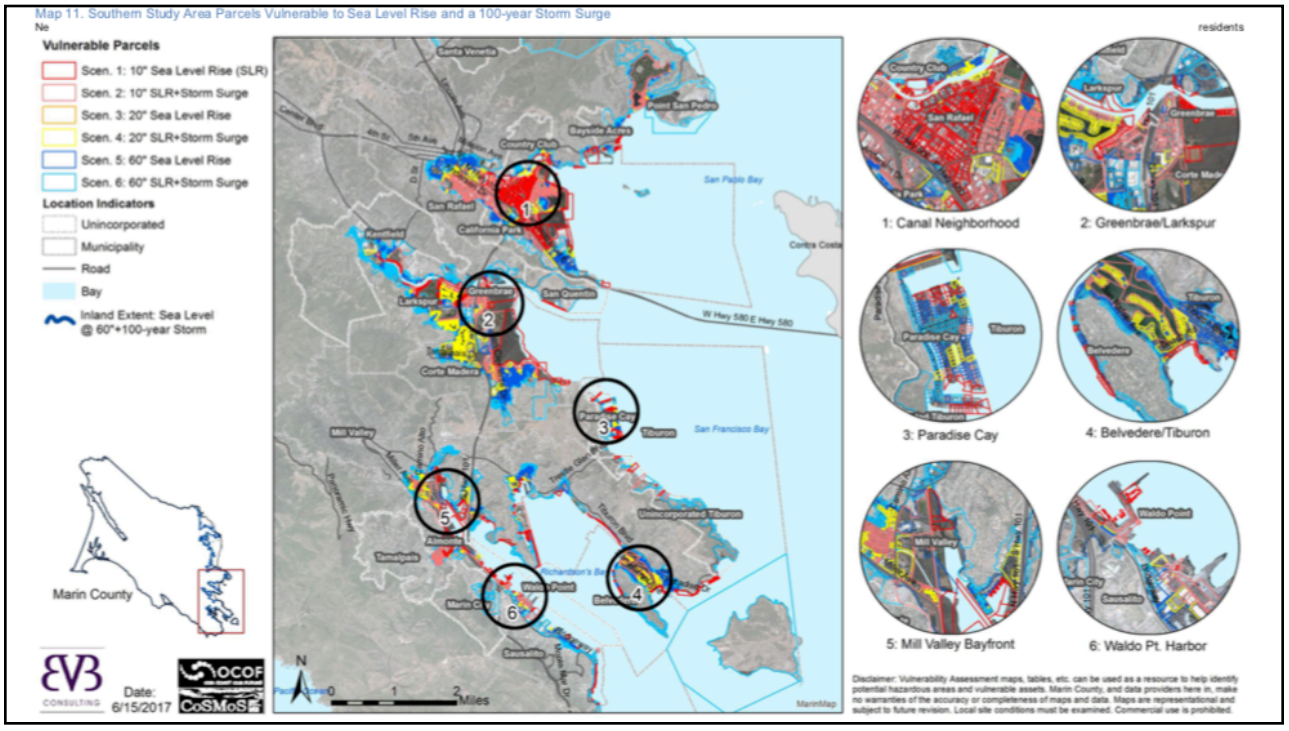
76

Lots of Infrastructure is Vulnerable



NATIONAL ECONOMIC EDUCATION DELEGATION

77



78

Downhill Skiing: Sierra Nevadas

- **By the end of the century:**
  - Temperatures will likely rise 6-9 degrees F.
  - Rain-to-snow transition will rise by 1,500 to 3,000 feet.
    - No snowpack below 6,000 feet.
  - 60% reduction of the snowpack.

- **Implications not only for the ski industry, but for water in the Bay Area.**
  - The Sierras are (as of now) a massive water reservoir.

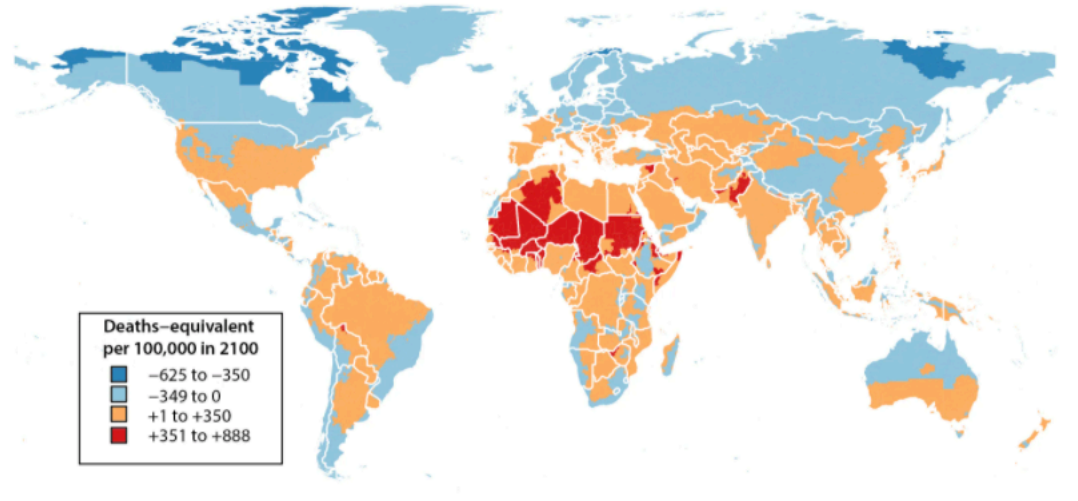
Food Insecurity

Climate change	Impacts
Increase in average temperature	Reduced quantity and reliability of agricultural yield
	Increased heat stress in livestock
	Destruction of crops or lowering crop productivity
	Decline in certain fish stocks due to increased sea temperature
Change in amount of rainfall	Reduced water availability for crop and livestock
	Heavy reliance on irrigation
	Poor quality of crops due to deteriorating water quality
Increased severity of drought	Decreased crop yield
	Increased probability of fire
Increased intensity of extreme events	Soil erosion
	Increased land degradation and desertification
	Inability to cultivate land
	Damage to crops and food stores

Source: National Institute for Health

FIGURE 4.

Mortality Impacts from Climate Change in 2100 by Region



Source: Carleton et al. 2018; authors' calculations.

Note: The map shows impact-region estimates for mortality rates in 2100. Figure assumes the mean estimate under RCP 8.5, which corresponds to roughly 3.2°C to 5.4°C of warming. Negative values refer to lives saved from climate change (e.g., fewer deaths as a result of fewer dangerously cold days).

THE HAMILTON PROJECT BROOKINGS Stanford | Institute for Economic Policy Research (SIEPR)

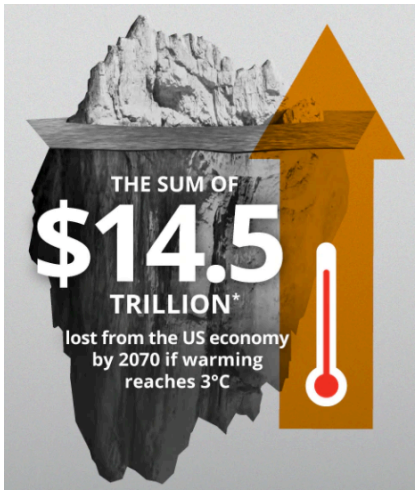
EDUCATION DELEGATION

81

https://www.brookings.edu/research/ten-facts-about-the-economics-of-climate-change-and-climate-policy/

81

One Estimates of Costs and Benefits



NATIONAL ECONOMIC EDUCATION DELEGATION

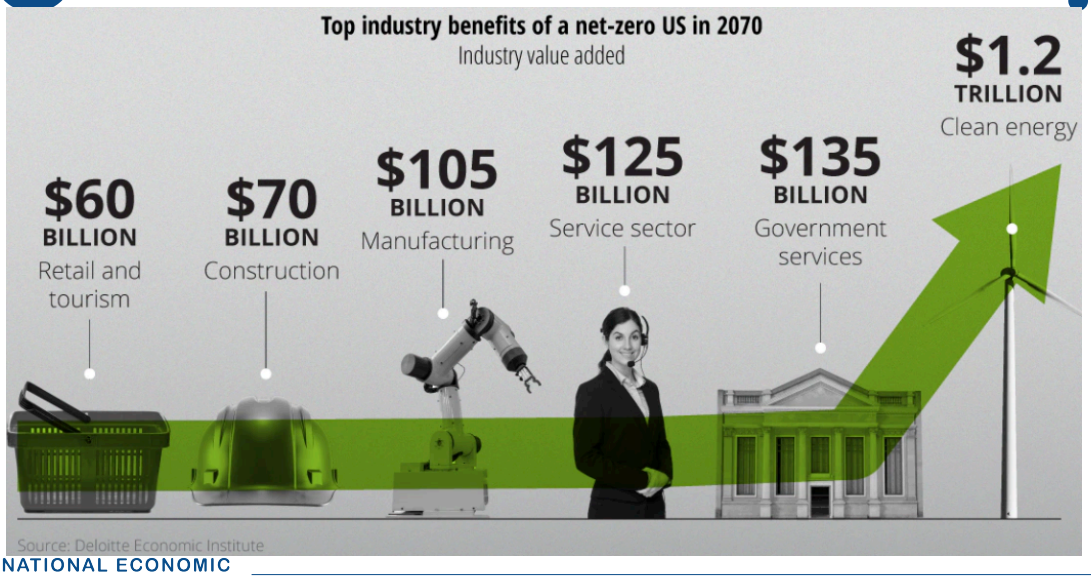
*Present value of GDP over 50 years

Source: Deloitte Economic Institute

82

82

Where do the Benefits Accrue?



NATIONAL ECONOMIC EDUCATION DELEGATION

Economic Growth and Climate Change Action Are Compatible

- Abating greenhouse gas emissions is costly…

  … but climate change damages are even more costly.

- Economic growth comes with consequences that we have to deal with, including climate consequences.
- Economies with environmental regulations can still be dynamic.
- Goal: design policies that reach climate goals at the least possible cost.

NATIONAL ECONOMIC EDUCATION DELEGATION

Reducing Emissions: Policy Focused on Mitigation

NATIONAL ECONOMIC EDUCATION DELEGATION

85

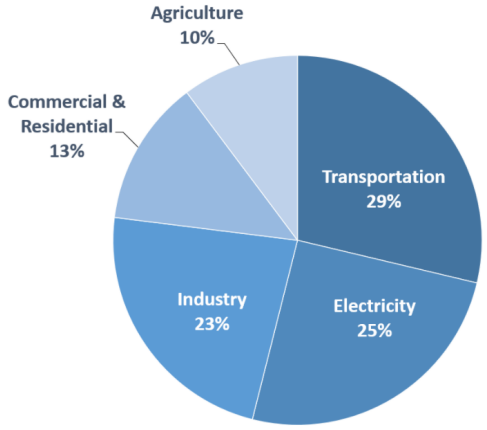
Global Net Emissions Are What We Care About

- **For climate impacts, we don't care where they are emitted, only how much**
  - There may be other local impacts
- **Gross emissions (greenhouse gas sources): how much greenhouse gases (including CO2) we put out**
- **Greenhouse gas sinks: ways to pull CO2 out of the air**
  - Existing: oceans, forests
  - Increase sinkage by planting trees, or other measures

NATIONAL ECONOMIC EDUCATION DELEGATION

86

Total U.S. Greenhouse Gas Emissions by Economic Sector in 2020



NATIONAL ECONOMIC EDUCATION DELEGATION

Total Emissions in 2019 = 6,558 Million Metric Tons of CO2 equivalent. Percentages may not add up to 100% due to independent rounding.

87

Which Emissions Should We Cut?

- List all possible ways to reduce emissions
- Figure out how much each can reduce in total
- Figure out how much each costs per unit of emissions reduced
- Line them up in order: cheapest to costliest ("marginal abatement cost curve")
  - → Tackle first the cheapest ones!

NATIONAL ECONOMIC EDUCATION DELEGATION

88

Average Abatement Costs for Selected Policy Options

$/Ton of Emissions Reduction

		Low estimate	High estimate
Agriculture	Reforestation	1	10
	Agricultural emissions policies	51	67
	Livestock management policies	73	73
Clean energy	Renewable portfolio standards	0	195
	Wind energy subsidies	2	266
	Clean Power Plan	11	11
	Renewable fuel subsidies	102	102
	Low carbon fuel standard	102	2971
	Solar photovoltaics subsidies	143	2151
Energy efficiency	Behavioral energy efficiency	-195	-195
	CAFE Standards	-110	318
	Cash for Clunkers	277	430
	Weatherization assistance program	359	359
Fossil fuel	Methane flaring regulation	20	20
	Reducing federal coal leasing	34	70

NATIONAL ECONOMIC EDUCATION DELEGATION

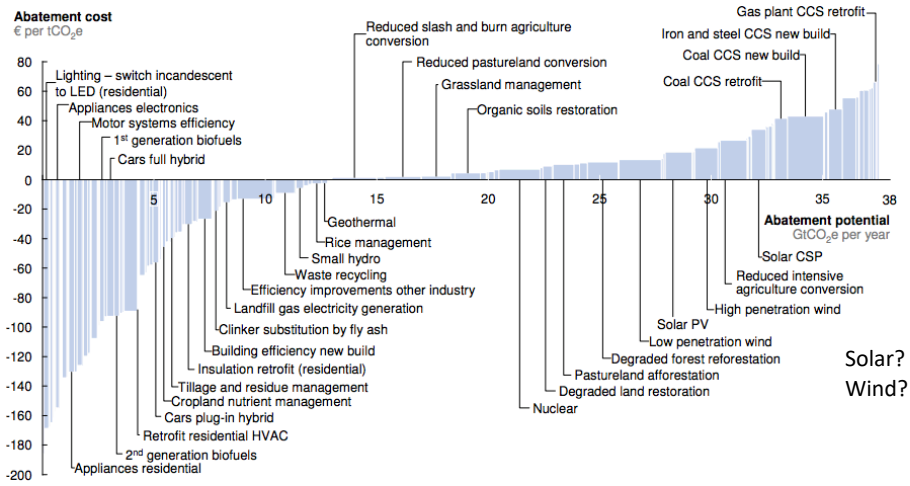
89

https://www.brookings.edu/research/ten-facts-about-the-economics-of-climate-change-and-climate-policy/

89

Global GHG Abatement Cost Curve

Lighting
Appliances
Hybrid cars



Solar?
Wind?

Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €80 per tCO_2e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.
Source: Global GHG Abatement Cost Curve v2.1

NATIONAL ECONOMIC EDUCATION DELEGATION

90

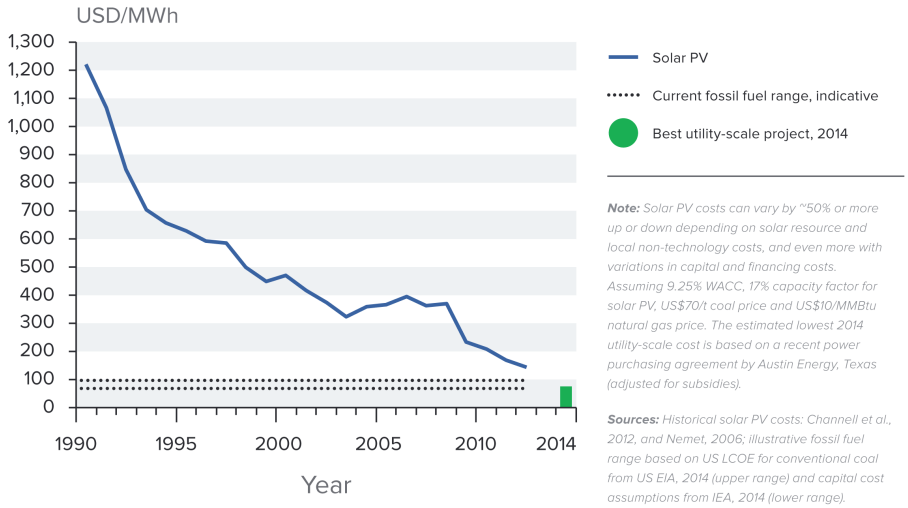
But Are Costs So Easy to Assess?

- **Difficult to project future costs for new technology**
  - Costs of renewables have been dropping fast
- **Investments in research and development and infrastructure (e.g., EV charging) can lower future costs**
- **Barrier to expanding renewable energy: intermittency**
  - Battery technology under development

NATIONAL ECONOMIC EDUCATION DELEGATION

91

Indicative Solar Costs Over Time



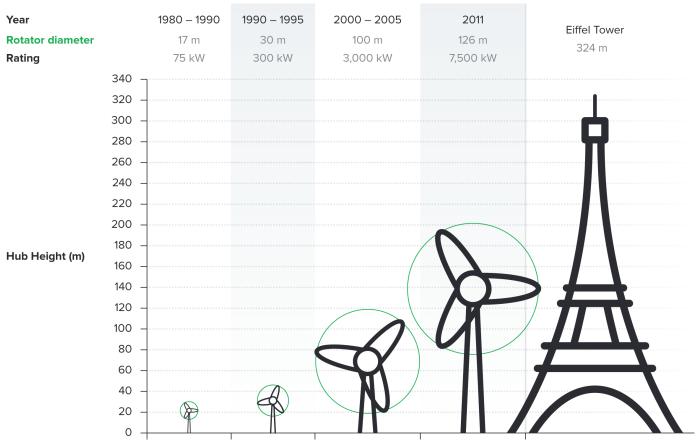
Note: *Solar PV costs can vary by ~50% or more up or down depending on solar resource and local non-technology costs, and even more with variations in capital and financing costs. Assuming 9.25% WACC, 17% capacity factor for solar PV, US$70/t coal price and US$10/MMBtu natural gas price. The estimated lowest 2014 utility-scale cost is based on a recent power purchasing agreement by Austin Energy, Texas (adjusted for subsidies).*

Sources: *Historical solar PV costs: Channell et al., 2012, and Nemet, 2006; illustrative fossil fuel range based on US LCOE for conventional coal from US EIA, 2014 (upper range) and capital cost assumptions from IEA, 2014 (lower range).*

NATIONAL ECONOMIC EDUCATION DELEGATION

92

Wind Turbines Have 100 Times More Power Generation Capabilities Than 30 Years Ago

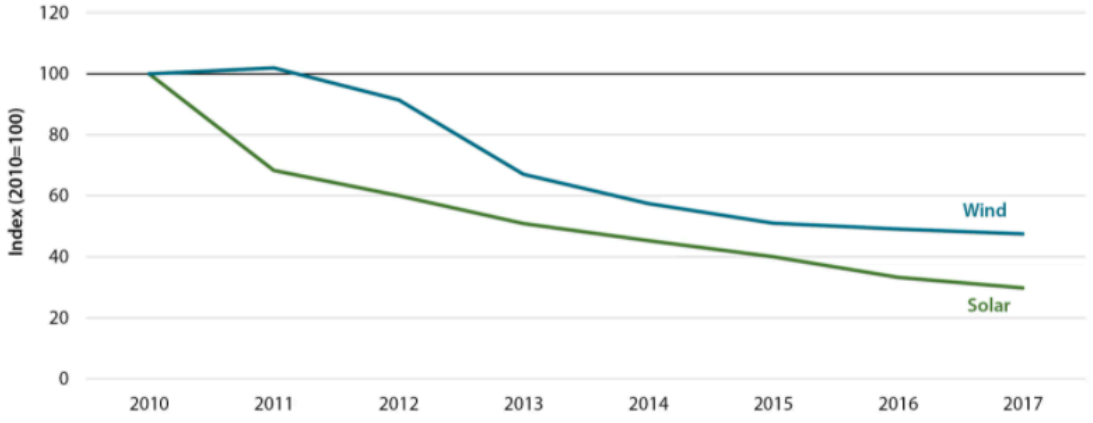


Source: Adapted from the European Wind Energy Association.

NATIONAL ECONOMIC EDUCATION DELEGATION

93

Change in Levelized Cost of Energy for Solar and Wind, 2010–17



Source: Bolinger and Seel 2018; Wiser and Bolinger 2018.

Note: These estimates are for the unsubsidized costs (i.e., they do not include federal tax credits). Levelized cost of energy (LCOE) is a common metric of energy production that allows for comparison across different sources of energy. The LCOE measures the lifetime costs of a given project per unit of energy produced.

THE HAMILTON PROJECT BROOKINGS Stanford | Institute for Economic Policy Research (SIEPR)

NATIONAL ECONOMIC EDUCATION DELEGATION

94

https://www.brookings.edu/research/ten-facts-about-the-economics-of-climate-change-and-climate-policy/

94

Challenges with Renewable Energy

- **It's intermittent - only produced if there is sun or wind.**
- **Energy is needed all day and night, with peak times.**
- **Limited w/o storage.**
  - Creative storage options are under development.

NATIONAL ECONOMIC EDUCATION DELEGATION

95

Geoengineering and Carbon Capture

- **Technical pathways to reduce climate change without reducing emissions**
- **Carbon capture: captures CO2 emissions and stores them or "utilizes" them (for energy, pressure, etc.)**
  - Not yet proven at scale
- **Solar geoengineering: make the atmosphere reflect more light to regain earlier thermal balance**
  - Totally theoretical
  - Potentially risky

NATIONAL ECONOMIC EDUCATION DELEGATION

96

Infrastructure and Climate Change

- **$90 trillion in investment will be needed for U.S. infrastructure, 2015-2030.**
- **Add $4 trillion (< 5%) to make it low-carbon infrastructure.**
  - This would also reduce climate damage to infrastructure.
  - Railway, urban transport, renewables.
- **The electrical grid is particularly troublesome.**
  - It is outdated and not suited for renewable energy storage.
  - Those with solar panels use the grid but contribute little to its upkeep.

NATIONAL ECONOMIC EDUCATION DELEGATION

97

Climate Change Policy

NATIONAL ECONOMIC EDUCATION DELEGATION

98

Policies That Reduce Emissions: Directly

- **Regulation**
  - Emissions standards or limits
    - E.g., CAFE standards
- **Market-oriented policies**
  - Putting a price on emissions
    - Subsidizing green energy (*e.g.*, feed-in tariffs)
    - Tax or cap & trade

99

How Does a Carbon Tax Work?

- **Activities to be covered are determined.**
- **The price of emissions is determined.**
  - Presumably some relation to the social cost of polluting.
- **Emissions are measured.**
- **Taxes are determined.**
- **Q: What to do with the tax revenue?**

100

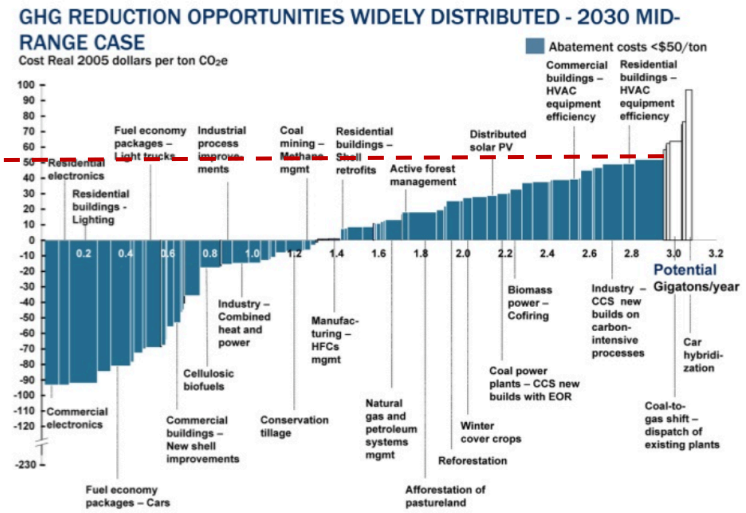
How Does Cap and Trade Work?

- **Activities to be covered are determined.**
- **Acceptable emissions levels are indicated.**
- **"Permits" that allow acceptable emissions levels are issued.**
  - How?
    - According to historical emissions?
    - Evenly across emitters?
    - Sold at some price?
- **A "market" is developed.**
- **Those desiring to emit will have to buy sufficient permits to accommodate their emissions.**
- **Those wishing to abate will offer their permits on the "market".**
  - The price of a permit indicates:
    - The benefit of eliminating further emissions.
    - The cost of emitting.
- **Gov't agency determines equality of permits in possession and emissions.**

101

Putting a Price on Carbon

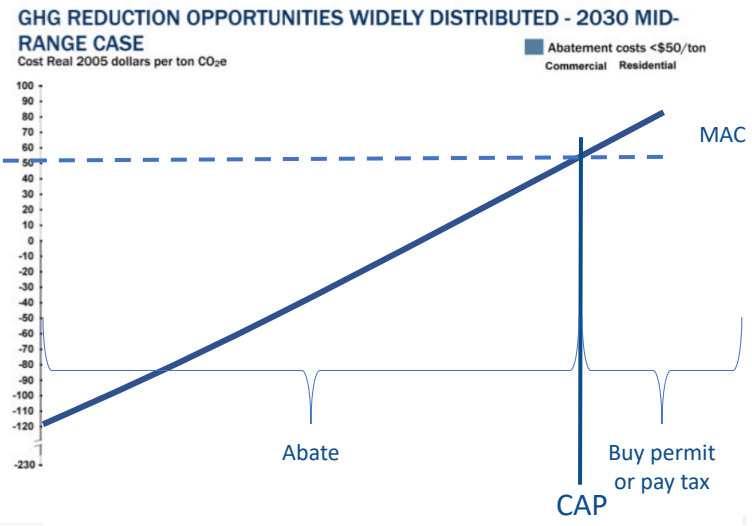
Suppose a Social Cost Of Carbon of $50



102

Putting a Price on Carbon

TAX
=
Permit Price
=
Carbon Price



NATIONAL ECONOMIC EDUCATION DELEGATION

103

Carbon Prices: the Good and Bad

- **Good:**
  - Provide price signal to lower emissions.
  - They yield low-cost reductions in emissions.
  - They spur innovation in clean technologies.
- **Bad:**
  - Firms might leave to flee regulation.
  - It is necessary to monitor emissions.
  - Potentially regressive
    - Costs may weigh more heavily on low-income households.

NATIONAL ECONOMIC EDUCATION DELEGATION

104

Both Policies are Work Through Prices

NATIONAL ECONOMIC EDUCATION DELEGATION

105

Full video: https://www.youtube.com/watch?v=XHK1OBSBpwc

105

Carbon Tax and Cap & Trade: the Differences

	Carbon Tax	Cap & Trade

NATIONAL ECONOMIC EDUCATION DELEGATION

106

Carbon Tax and Cap & Trade: the Differences

	Carbon Tax	Cap & Trade
Carbon Price	Certain	Uncertain
Emissions	Uncertain	Certain
Ease of Implementation	May be easier to implement	
Additional concerns	1) Always generates revenue 2) May require legislation to change 3) Predictability	1) Susceptible to lobbying. 2) Only generates revenue if government sells permits. 3) Cap can be changed by regulator. 4) Less certainty over future. 5) Regulations reduce efficacy of Cap & Trade

NATIONAL ECONOMIC EDUCATION DELEGATION

107

One Other Thing: Cap and Trade vs. Carbon Tax

- **Emissions regulations and Cap and Trade can work at cross purposes.**
  - Regulations that lower emissions from big polluters…
    - Lower the demand for permits
    - Lowers the price of permits
    - Reduces incentives for other industries to cut emissions
- **Regulations can undermine the effectiveness of Cap and Trade.**
- **The same is not true of a carbon tax.**
  - Though regulations might cut tax revenue, revenue is not the goal of the carbon tax.

NATIONAL ECONOMIC EDUCATION DELEGATION

108

108

Command and Control vs. Incentive-Based Regulation

- **Equity**
- **Efficiency**

109

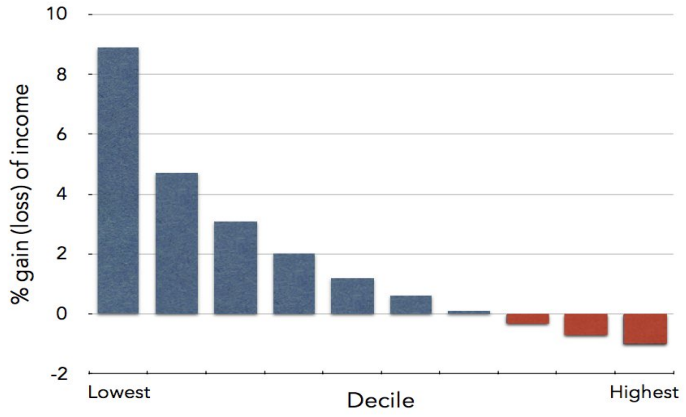
Command and Control vs. Incentive-Based Regulation

- **Equity**
  - Both have may regressive impacts (low-income families bear costs that are a larger percent of their incomes vs hi-income families)
    - However, new evidence increasingly questions this.
  - Cap and trade and carbon tax can generate revenues that can be used to offset the regressivity.
    - E.g.: “carbon dividend”
  - Command and control regulations do not.

110

Revenue Dividend Eliminates Regressivity

IMPACT OF CARBON DIVIDENDS ON U.S. FAMILY INCOMES



Source: U.S. Treasury, 2017

111

Command and Control vs. Incentive-Based Regulation

- **Efficiency.**
  - Both can achieve the same amount of emissions reduction.
  - Incentive-based policies can achieve emissions reduction at much lower cost.
    - Example: CAFÉ Standards vs Carbon Tax
      - Tax is significantly more efficient.
      - Why?

112

Efficiency: CAFÉ vs Carbon Tax

- **CAFÉ = Corporate Average Fuel Efficiency**
  - A fuel economy standard mandating that an auto-maker's vehicle fleet must meet minimum fuel economy standards.
- **Horse Race**
  - Tax on fuel applies to ALL vehicles, not just new.
  - Rebound Effect:
    - Driving a more efficient vehicle lowers the cost per mile driven
      - leading to more miles driven.
  - Slower turnover of inefficient vehicles: higher cost of new.
- **Summary**
  - A given level of emission reductions **costs 3-14 times more with CAFÉ** standards than under a comparable carbon tax.

Policies That Reduce Emissions: INDirectly

- **Subsidizing R&D**
- **Grid / infrastructure**
- **Energy efficiency mandates and subsidies**
- **Mandating renewable energy (*e.g.*, renewable portfolio standards)**
- **Land use policies**

Atlanta and Barcelona Have Similar Populations but Very Different Carbon Productivity

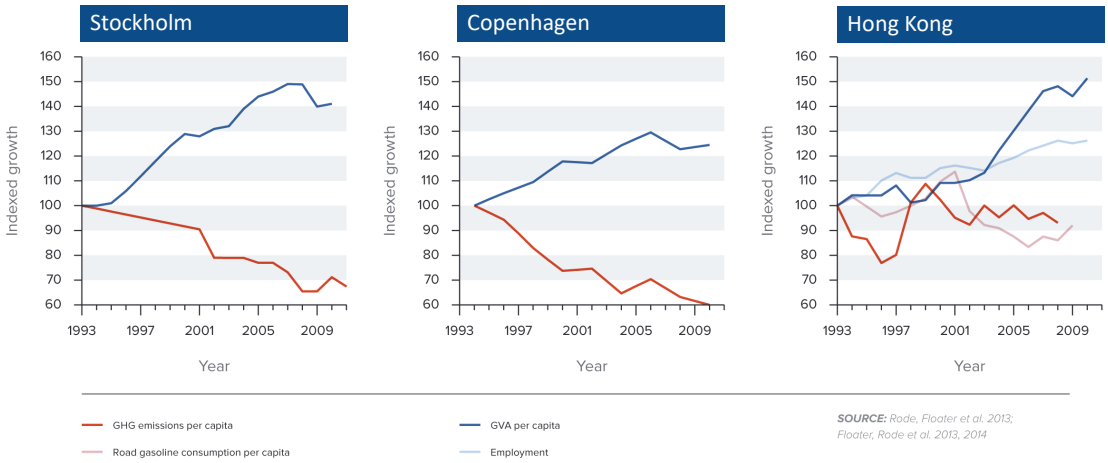
Atlanta			Barcelona		
Built-up area			Built-up area		
					
Population	**Urban area**	**Transport carbon emissions**	**Population**	**Urban area**	**Transport carbon emissions**
2.5 million	**4,280** km^2	**7.5** tonnes CO_2/person (public + private transport)	**2.8** million	**162** km^2	**0.7** tonnes CO_2/person (public + private transport)

NATIONAL ECONOMIC EDUCATION DELEGATION

Source: New Climate Economy Report, 2014

115

Compact and Connected Urban Pathways Can Go Hand-in-hand with Economic Growth



SOURCE: Rode, Floater et al. 2013; Floater, Rode et al. 2013, 2014

NATIONAL ECONOMIC EDUCATION DELEGATION

116

Land Use: Restoration Is Possible

South Korea restored its forest cover from 35% to 64% of the country's total area

NATIONAL ECONOMIC EDUCATION DELEGATION

117

Example: Nature-based Schoolyards

What is the Market Failure associated with School Greening?
- Positive Externalities and Public Goods

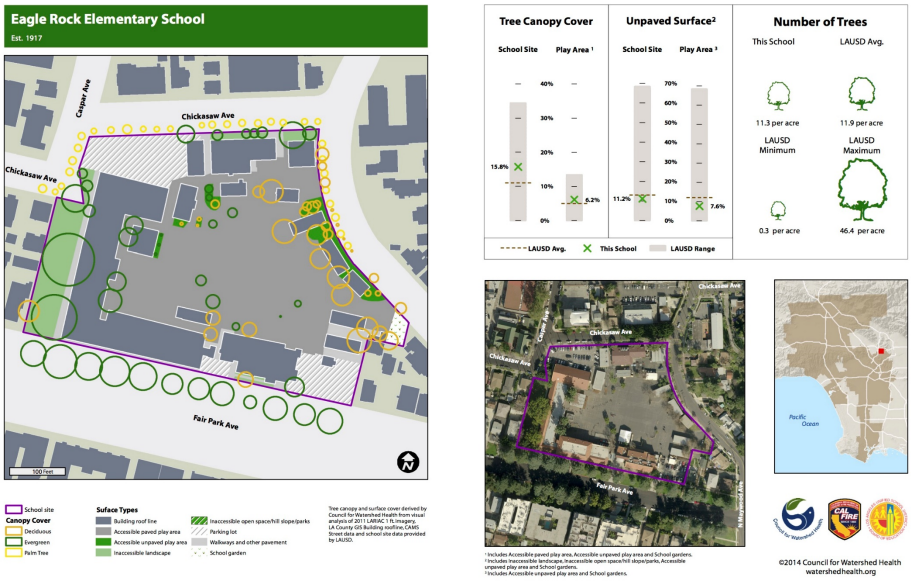
Goods with positive externalities are underprovided by the market.

School Greening Benefits Include
- Improving children's social, physical and educational well-being.
- Actively managing storm water.
- Mitigating urban heat island effects and climate change
- Increasing renewable energy production,
- Providing wildlife habitat and related ecosystem services.

NATIONAL ECONOMIC EDUCATION DELEGATION

118

118



NATIO EDUCATION DELEGATION

Image: Council for Watershed Health

119

NATIONAL ECONOMIC EDUCATION DELEGATION

120

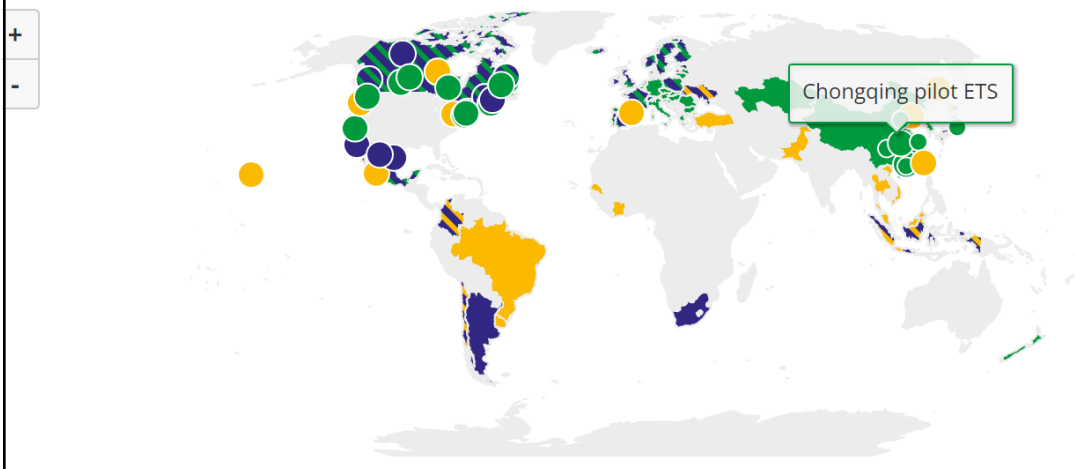
Climate Change Policy in Action

NATIONAL ECONOMIC EDUCATION DELEGATION

121

Incentive-Based Climate Policies Right Now

Summary map of regional, national and subnational carbon pricing initiatives



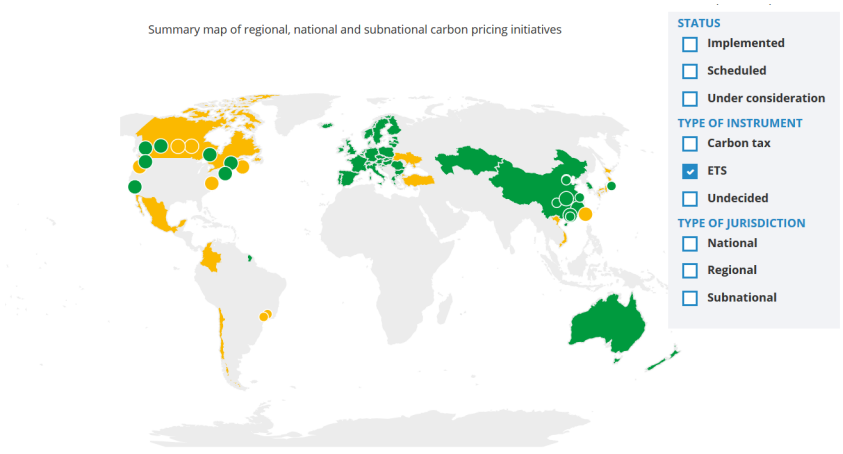
122

Cap and Trade

NATIONAL ECONOMIC EDUCATION DELEGATION

123

Cap and Trade Policies Around the World



ETS implemented or scheduled for implementation
ETS or carbon tax under consideration

ETS = Emissions Trading System = Cap and Trade

NATIONAL ECONOMIC EDUCATION DELEGATION

Source: World Bank - Carbon Pricing Dashboard

124

European Union's Emissions Trading Scheme

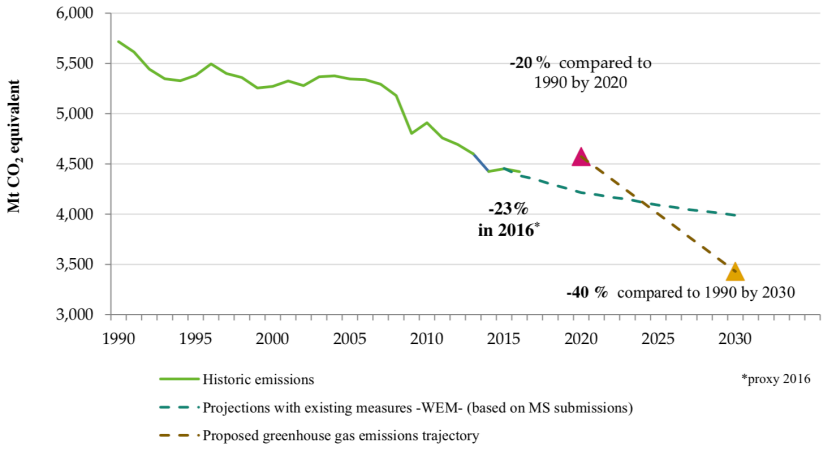
4%

of global greenhouse gas emissions Circa 2005

NATIONAL ECONOMIC EDUCATION DELEGATION

125

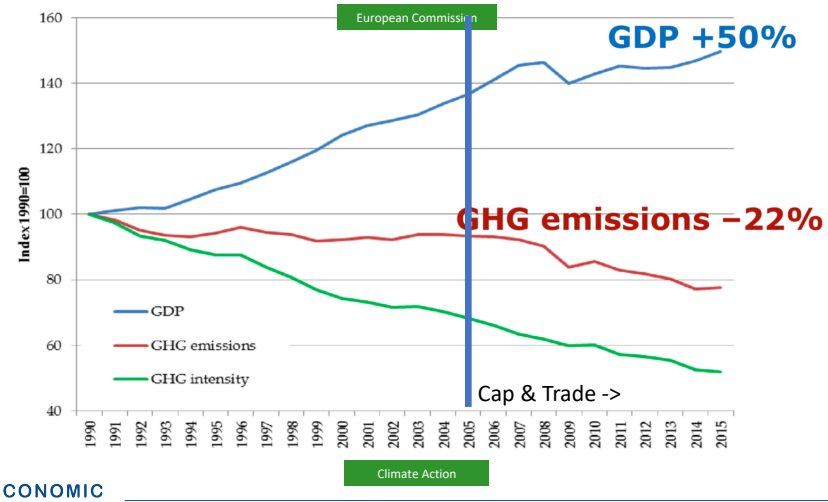
Progress Towards Meeting Europe 2020 And 2030 Targets (EU Total GHG Emissions)



NATIONAL ECONOMIC EDUCATION DELEGATION

126

EU Has Decoupled Economic Growth from Greenhouse Gas Emissions



NATIONAL ECONOMIC EDUCATION DELEGATION

127

California's Cap and Trade System: 2012+

0.7%

of global greenhouse gas emissions

NATIONAL ECONOMIC EDUCATION DELEGATION

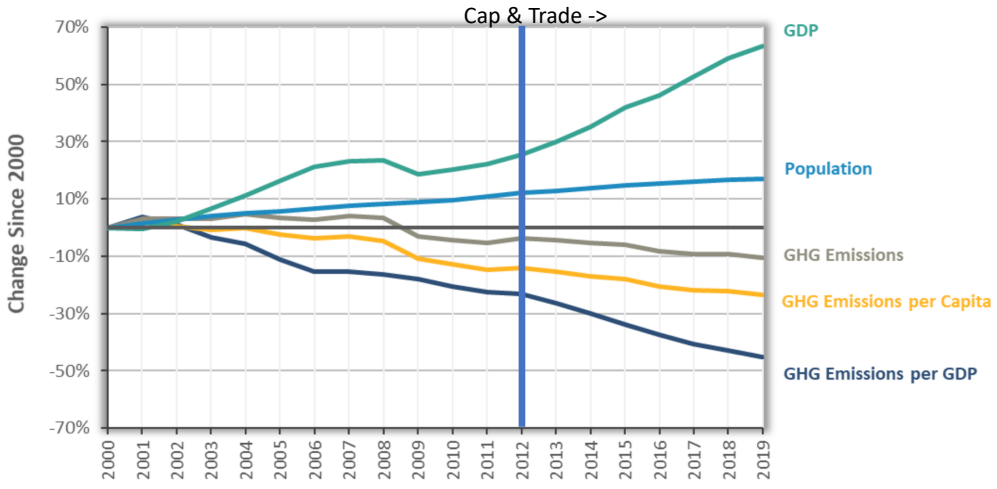
128

California's System Is Flexible

- **California's goals:**
  - Reduce emissions to 1990 levels by 2020
  - An 80% reduction in emissions from 1990 levels by 2030
- **California's Tools:**
  - Cap and Trade
  - Renewable Portfolio Standard
  - Clean Cars Program
  - Low Carbon Fuel Standard

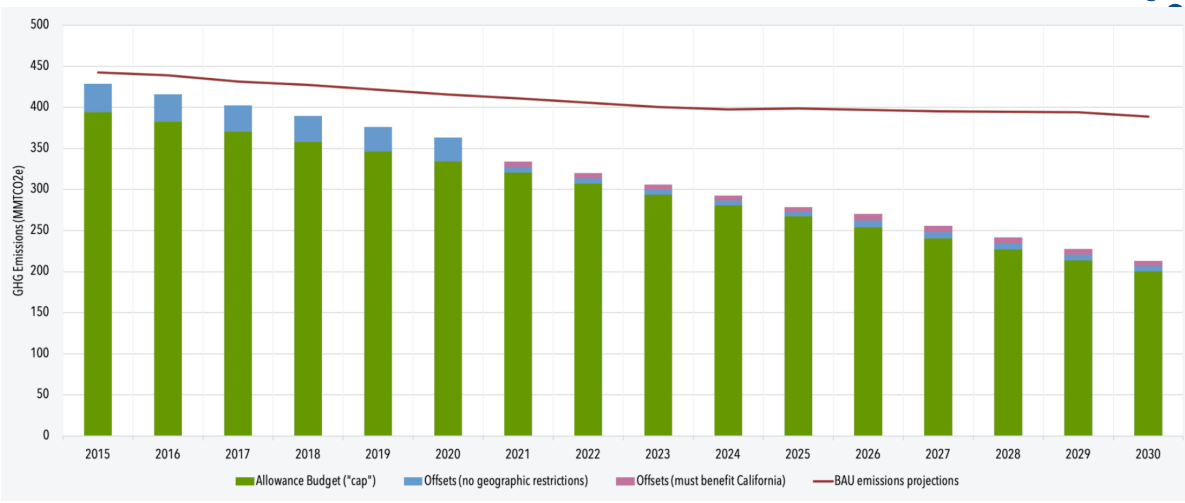
129

Change in California GDP, Population, and GHG Emissions since 2000



130

Projected trends in California's emissions



131

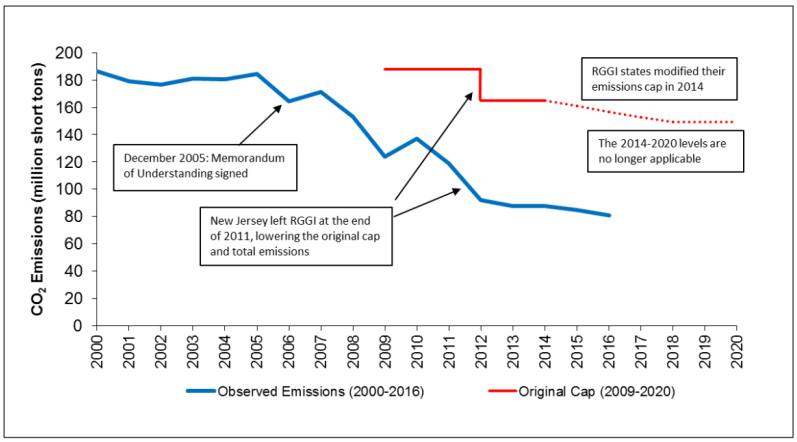
RGGI: the Regional Greenhouse Gas Initiative

- **Participants: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont**
  - 7% of US emissions
- **Covers power plants**
- **First implemented in 2009**
- **Caused emissions reduction of 24% below what they would have been**

132

RGGI's Effect on Emissions

Figure 1. Observed Emissions Compared to the Original Emissions Cap

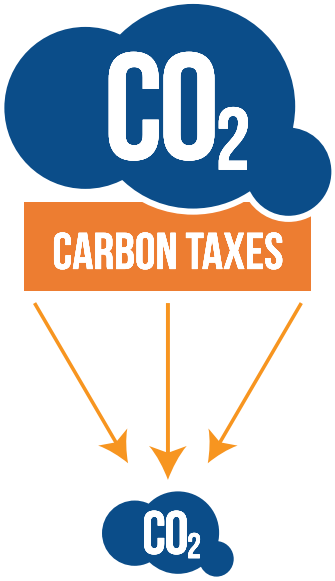


Source: Prepared by CRS; observed state emission data (2000-2016) provided by RGGI at http://www.rggi.org.

NATIONAL ECONOMIC EDUCATION DELEGATION

133

Carbon Tax



NATIONAL ECONOMIC EDUCATION DELEGATION

134

Worldwide Carbon Taxes

28
carbon tax programs

25
national jurisdictions covered

5.5%
of global greenhouse gas emissions

NATIONAL ECONOMIC EDUCATION DELEGATION

135

British Columbia's Carbon Tax Policy

0.1%
of global greenhouse gas emissions

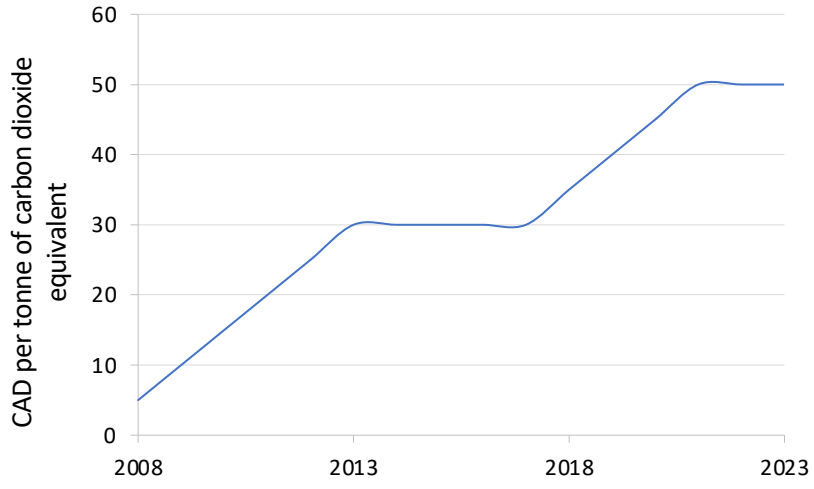
NATIONAL ECONOMIC EDUCATION DELEGATION

136

> “Tax the pollution we do not want, and return the money for what we do want — money in people’s pockets, jobs and investment.”
>
> - B.C. Government - Carbon Tax Brochure

137

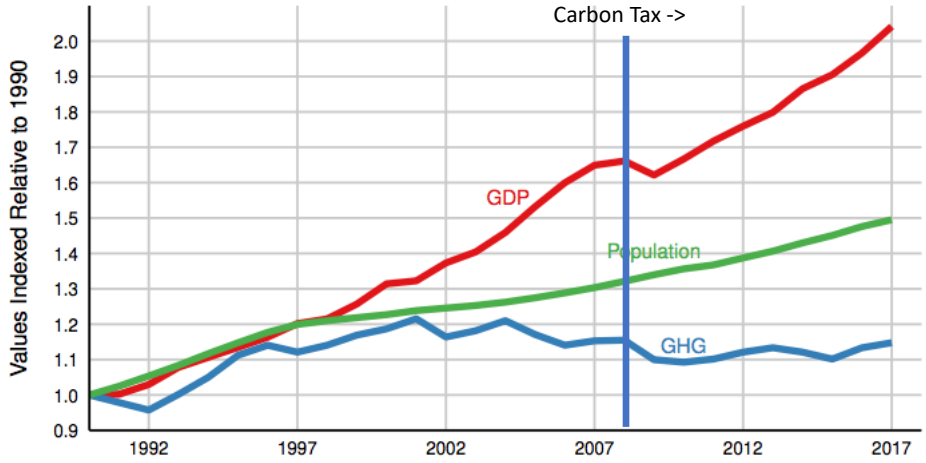
British Columbia's Tax on Carbon



NATIONAL ECONOMIC EDUCATION DELEGATION

138

Relative Greenhouse Gas Emissions, GDP & Population Size: British Columbia



NATIONAL ECONOMIC EDUCATION DELEGATION

139

Sweden's Carbon Tax Policy

Oldest Carbon Tax

NATIONAL ECONOMIC EDUCATION DELEGATION

140

Sweden's Carbon Tax Policy

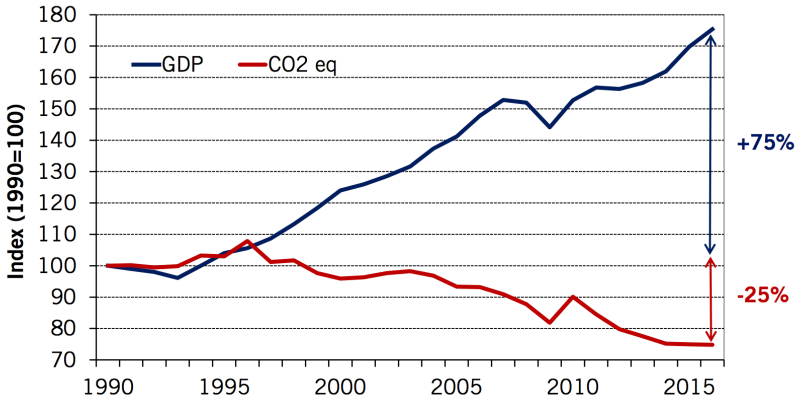
Started in 1991

Currently at $140/ton

NATIONAL ECONOMIC EDUCATION DELEGATION

141

Real GDP and Domestic CO_2eq Emissions[1] In Sweden, 1990-2016



[1] In accordance with Sweden's National Inventory Report, submitted under the UNFCC and the Kyoto Protocol. CO_2 = approx. 80 % of total CO_2eq emissions. Preliminary data for 2016.

Sources: Swedish Environmental Protection Agency, Statistics Sweden

NATIONAL ECONOMIC EDUCATION DELEGATION

142

U.S. Carbon Tax Plans

- Climate Leadership Council
- Citizens Climate Lobby
- States and municipalities: Washington state, Oregon, Washington, DC

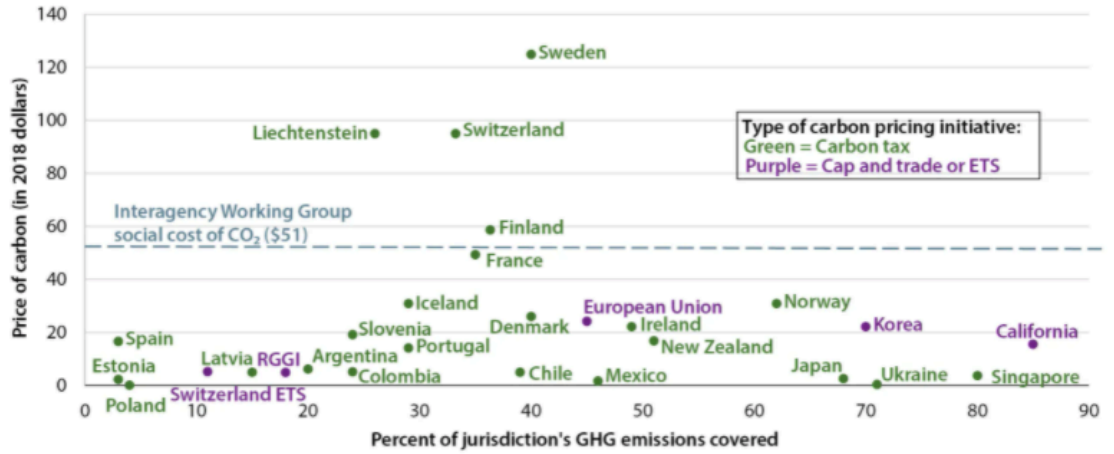
NATIONAL ECONOMIC EDUCATION DELEGATION

143

> **“Economic policies will be central to accomplishing the goals we choose.”**
>
> - Harris and Roach (2007)

144

Prices for Selected Carbon Pricing Initiatives



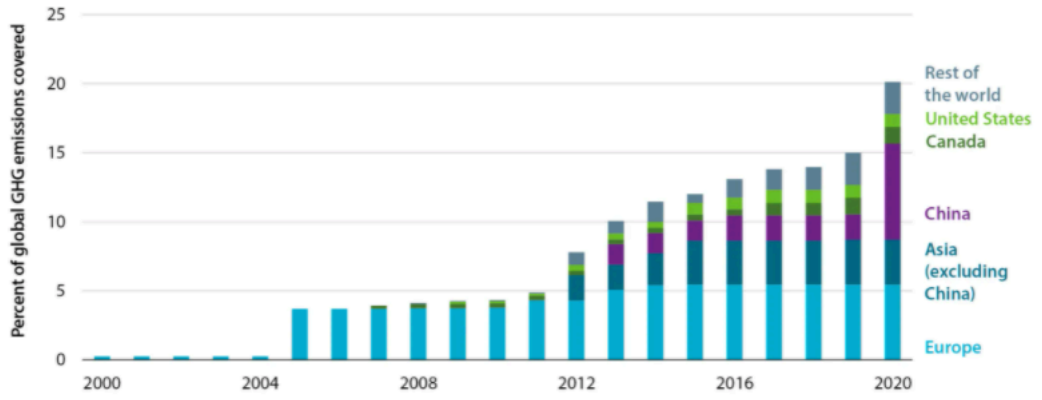
Source: World Bank 2019.
Note: All values are adjusted to 2018 dollars using the CPI-U-RS. This chart shows selected subnational, national, and regional programs. For Mexico and Norway, their point represents the average between their upper and lower carbon prices. For Denmark, the point represents the carbon price for fossil fuels. For Finland, the point represents the price for fossil fuels except transportation fuel. For Argentina, the point represents most liquid fuels.

NATIONAL ECONOMIC EDUCATION DELEGATION

145

FIGURE 9.

Share of Global GHG Emissions Covered by Implemented and Scheduled Carbon Pricing Initiatives, 2000–20



Source: World Bank 2019.
Note: Emissions regarded as priced are those subject to an explicit price as part of a carbon tax or cap and trade system. Emissions subject to an indirect price through other regulatory policies are not considered to be priced.

NATIONAL ECONOMIC EDUCATION DELEGATION

https://www.brookings.edu/research/ten-facts-about-the-economics-of-climate-change-and-climate-policy/

146

Summary

- Climate change is real, is caused by human actions, and has impacts we're already feeling.
- We need to reduce emissions to balance the costs of action against the costs of inaction.
- Scientists and the IPCC recommend that we work to keep warming below 1.5 degrees celcius.
  - *Economists believe that this goal is well worth the costs!*

NATIONAL ECONOMIC EDUCATION DELEGATION

147

Summary – *continued*

- There are many ways to reduce emissions.
- Economics-inspired policies can help us do this at the lowest cost.
- Taxes and cap and trade are proven effective tools to fight climate change!
- Other tools may also be necessary.

NATIONAL ECONOMIC EDUCATION DELEGATION

148

Thank you!

Any Questions?

www.NEEDelegation.org
Jon D. Haveman
Jon@NEEDelegation.org

Contact NEED: info@NEEDelegation.org

Submit a testimonial: www.NEEDelegation.org/testimonials.php

Become a Friend of NEED: www.NEEDelegation.org/friend.php

149