Congressional Budget Office

## Goldman Lecture in Economics, Wellesley College

# Preparing for Our Common Future: Policy Choices and the Economics of Climate Change

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# The Basic Science of Climate Change

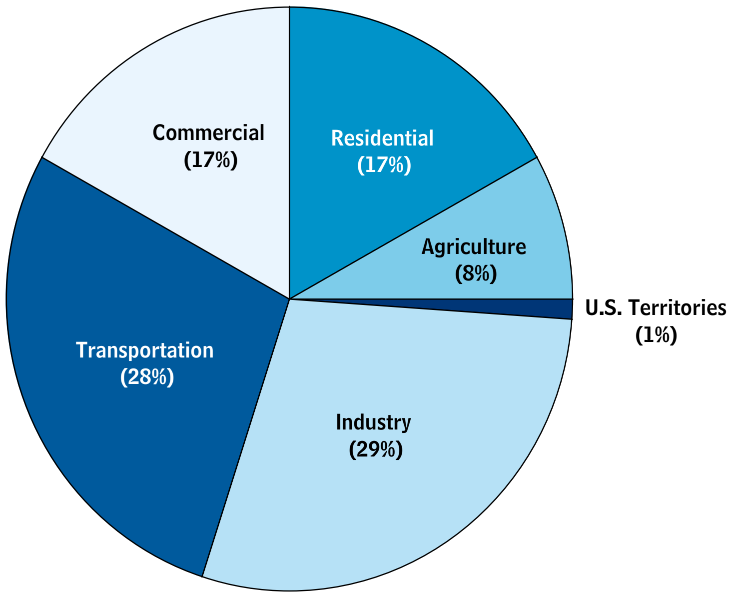
- **Growing emissions of greenhouse gases (GHGs) are accumulating in the atmosphere**
- **Mainly from fossil fuel use and land use**
- **Growing concentration of GHGs will change and warm the global climate**
- **Global climate change represents one of our most serious long-term risks**

# Numerous Greenhouse Gases from Diverse Sources

## Percentage of Total GHGs ($CO_2e$, 2006)

| | |
|---|---|
| $CO_2$ | 84.80 |
| $CH_4$ | 7.90 |
| $N_2O$ | 5.20 |
| HFCs | 1.80 |
| PFCs | 0.09 |
| $SF_6$ | 0.25 |
| Total | ~100.00 |

## Emissions by Sector, 2006*




*Approximately 33% of total GHG emissions are connected to electricity production

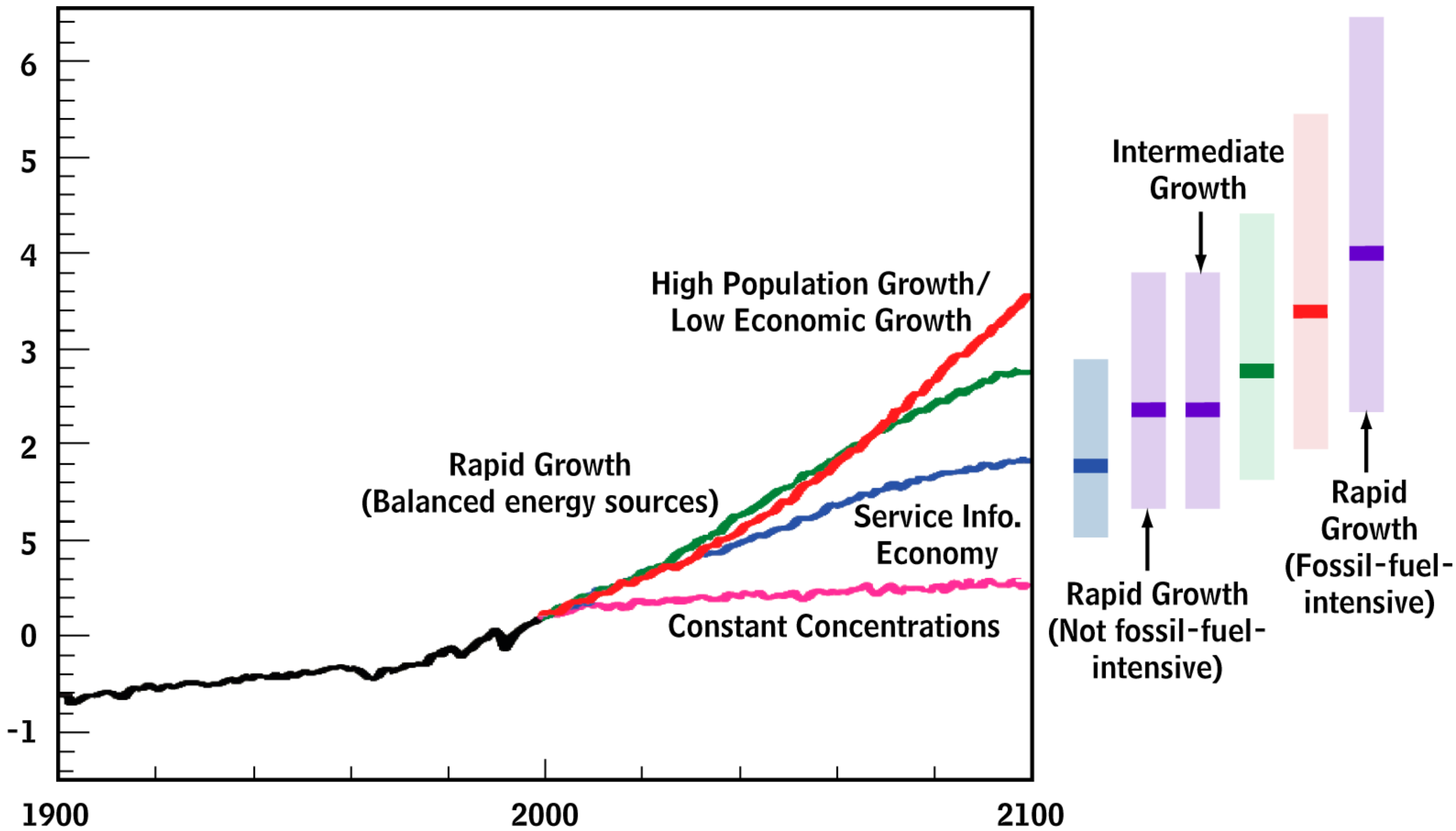
Source: Data from EPA.

# The Basic Science of Climate Change: Baseline Information

- **Virtually impossible to account for 20th-century changes in climate without attributing a significant but uncertain share to anthropogenic GHG emissions**
- **Only about half of warming already set in motion has occurred to this point**
- **Much more warming than that is likely, however**
  - Reducing *emissions* from current levels would still mean rising *concentration*

# Historical and Projected Climate Change Under Various Scenarios

Global Surface Warming (°C)




Source: IPCC (2007).

# The Basic Science of Climate Change: Potential Impacts

- **Projected change in global climate ranges from modest to very dramatic**
  - Likely temperature increase over next century:
    - 0.3 $^{o}$C to 6.4 $^{o}$C
  - Potential decline in global GDP from 4 $^{o}$C increase:
    - 1 percent to 5 percent
  - Small chance of much larger damages

## The Basic Science of Climate Change: Uncertainty in Outcomes

- **Significant uncertainty in distribution of changes**
  - Across seasons and regions
  - In ranges and extremes of temperature and precipitation
  - In the potential for abrupt shifts
  - In the effects on human and natural systems
- **Possibility of nonlinearities in system**
- **Also, significant uncertainty in the economic valuation of damages and mitigation/adaptation costs**

# Some Potential Impacts as a Function of Different Changes in the Global Average Temperature

- **1 ºC Increase**
  - Risk of extinction in up to 30 percent of all species
  - Grain production will tend to increase at higher latitudes and decrease at lower latitudes
- **2 ºC Increase**
  - Likely increase in worldwide coastal flooding
  - Widespread mortality of coral
- **3 ºC Increase**
  - Approximately 30 percent of global coastal wetlands lost
  - Substantial public health impacts due to malnutrition, altered development of infectious diseases, and increased natural disasters

# Climate Change, Econ 101

- **Negative externality**
  - Uncertainty over effects
  - Effects occur over a long time span
- **Significant free-rider problem**
  - Effective response likely to require international collective action

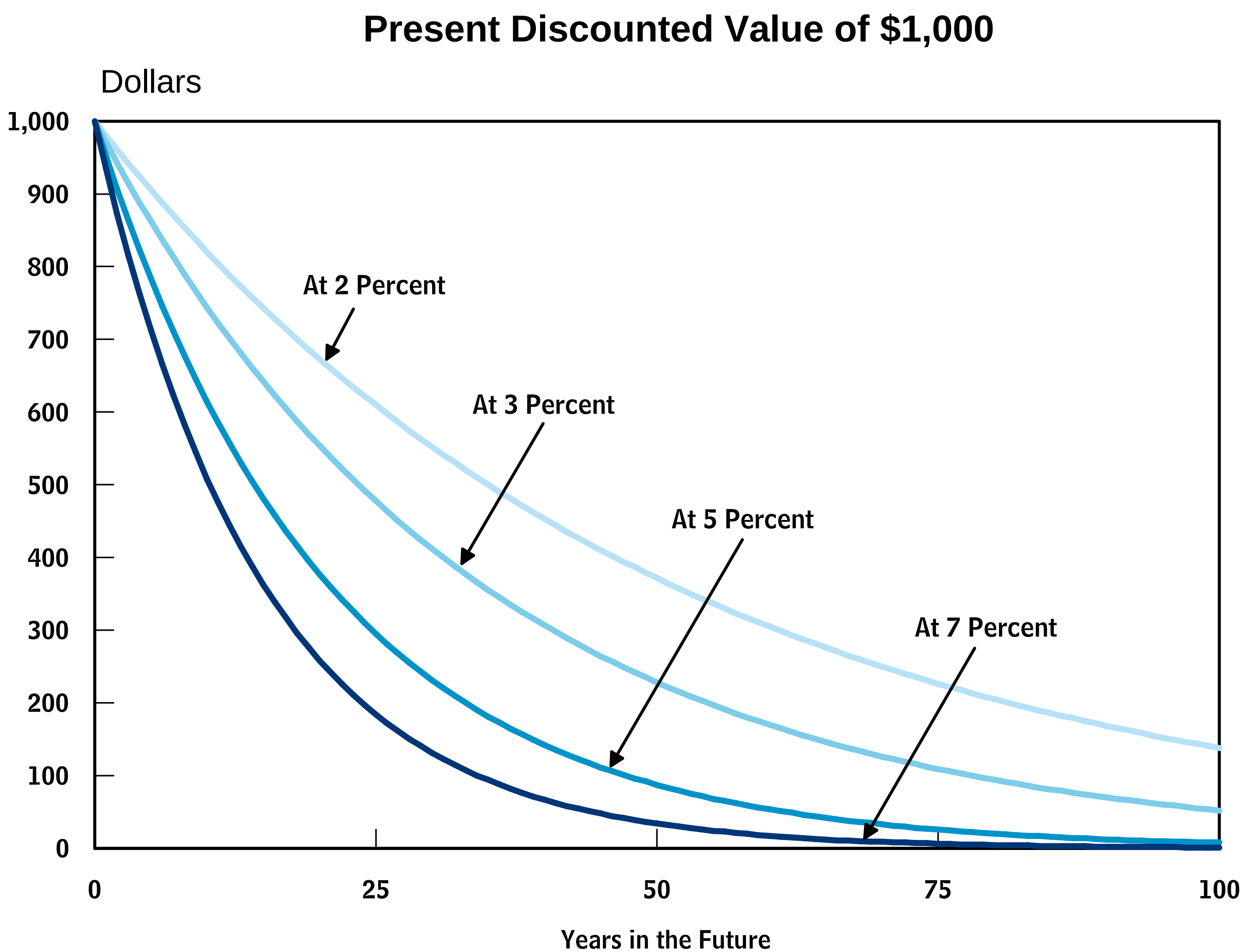
# Responding to Climate Change

- **Three potential responses, not all mutually exclusive**
  - Research: continued study of problem's scope and mitigation/adaptation options
  - Mitigation: emission reductions and sequestration
  - Adaptation: adapt to warming that will occur
- **For each response, optimal policy would balance expected marginal costs against expected future discounted marginal damages**
  - Does one consider global costs/benefits or just domestic?

# The Economics of Climate Change: Discounting (continued)

- **Assessment of what action should be taken today is sensitive to one's choice of discount rate**
  - Opportunity cost of avoiding damages (or compensating future generations for damages) is the real risk-adjusted rate of return on long-term investments
  - Adjustment for uncertainty about the future returns implies a lower implicit discount rate and more recommended mitigation today

# The Economics of Climate Change: Discounting (continued)

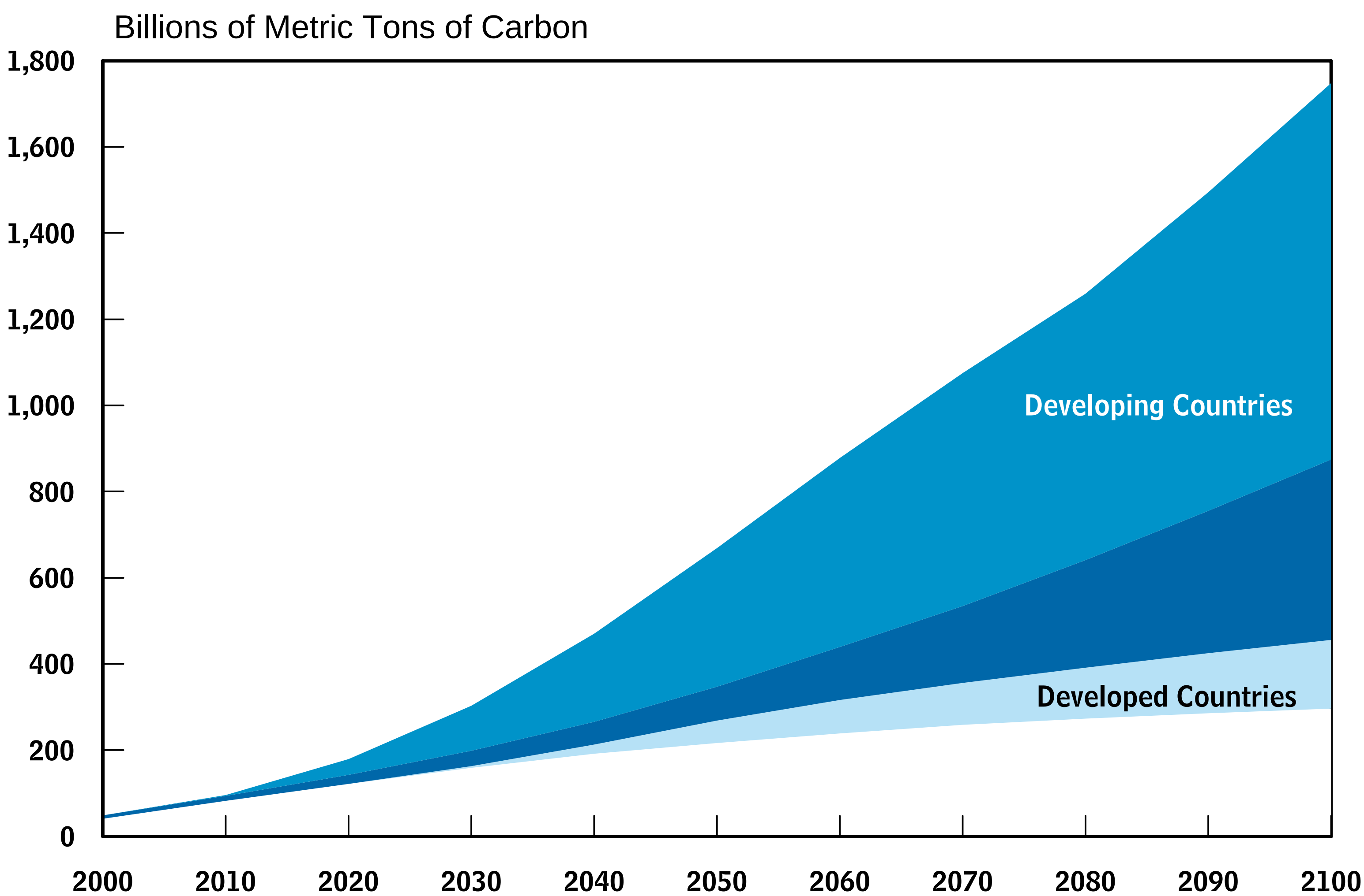


# The Economics of Climate Change: Discounting (continued)

- Alternate view: Valuation of future benefits should be viewed primarily as a decision about equity rather than as a traditional investment decision
- But viewed as an equity issue, inconsistencies arise relative to how other intergenerational trade-offs are analyzed

- **Developed countries have already contributed a very large share of historical emissions**
  - Per capita incomes/emissions in developed countries (especially the United States) are much higher than those of most developing countries
  - The US has about 5 percent of the world's population, but accounts for more than 20 percent of global GHG emissions (and also more than 20 percent of global GDP)

# Range of Uncertainty in Cumulative $CO_2$ Emissions, Developed vs. Developing Countries



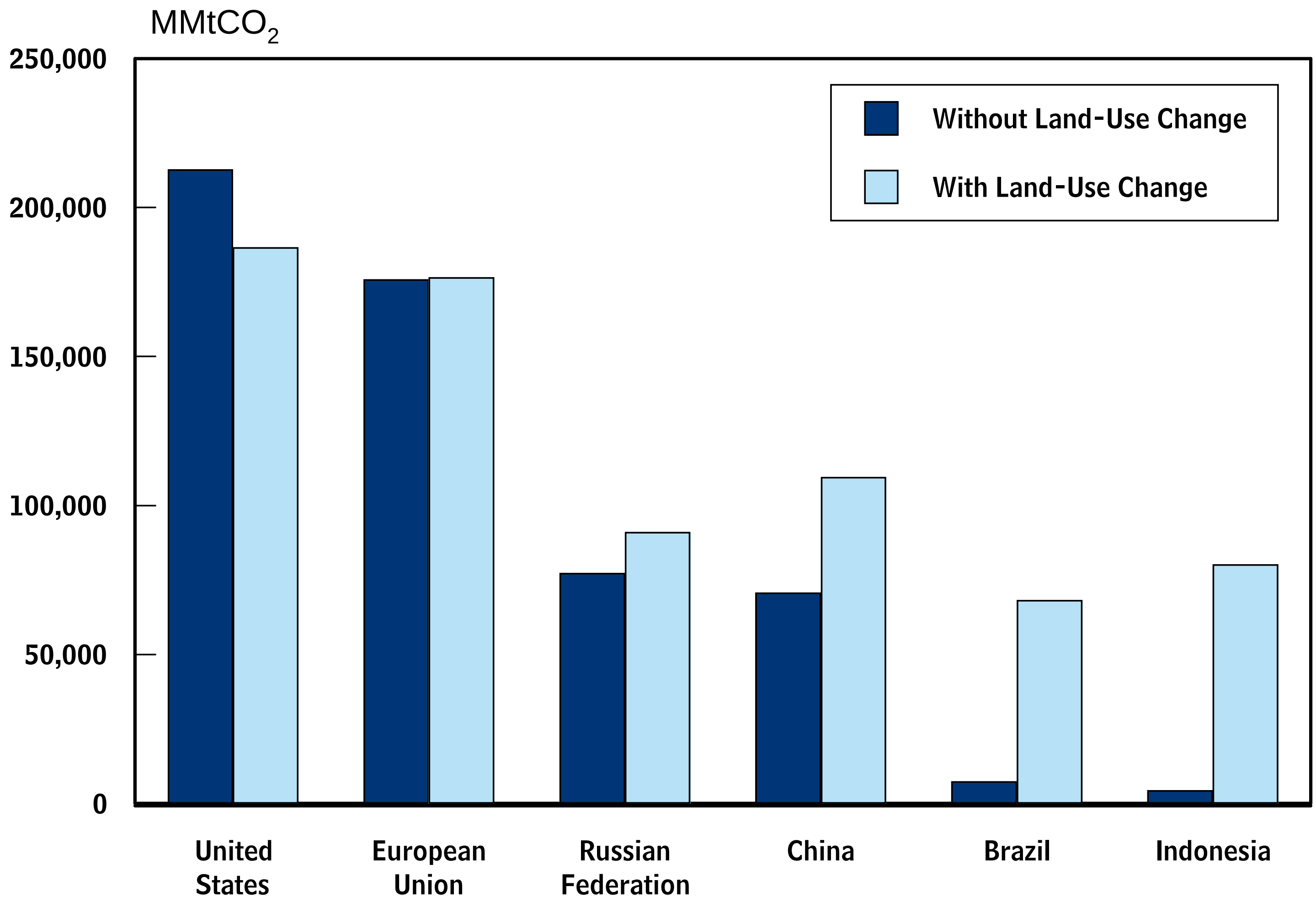
## The Economics of Climate Change: Distributional Issues and International Coordination (continued)

- **Developing countries' per capita emissions are very low**
  - But growing rapidly and will ultimately dominate in the aggregate
  - Many opportunities for low-cost reductions
- **Developing countries' damages from climate change are likely to be larger, especially relative to income**

# The Economics of Climate Change: Distributional Issues and International Coordination (continued)

- **Some conflict over distribution of costs between developed and developing nations is inevitable**
- **But to create a substantial impact on global emissions, the number of nations that need to coordinate is relatively small**

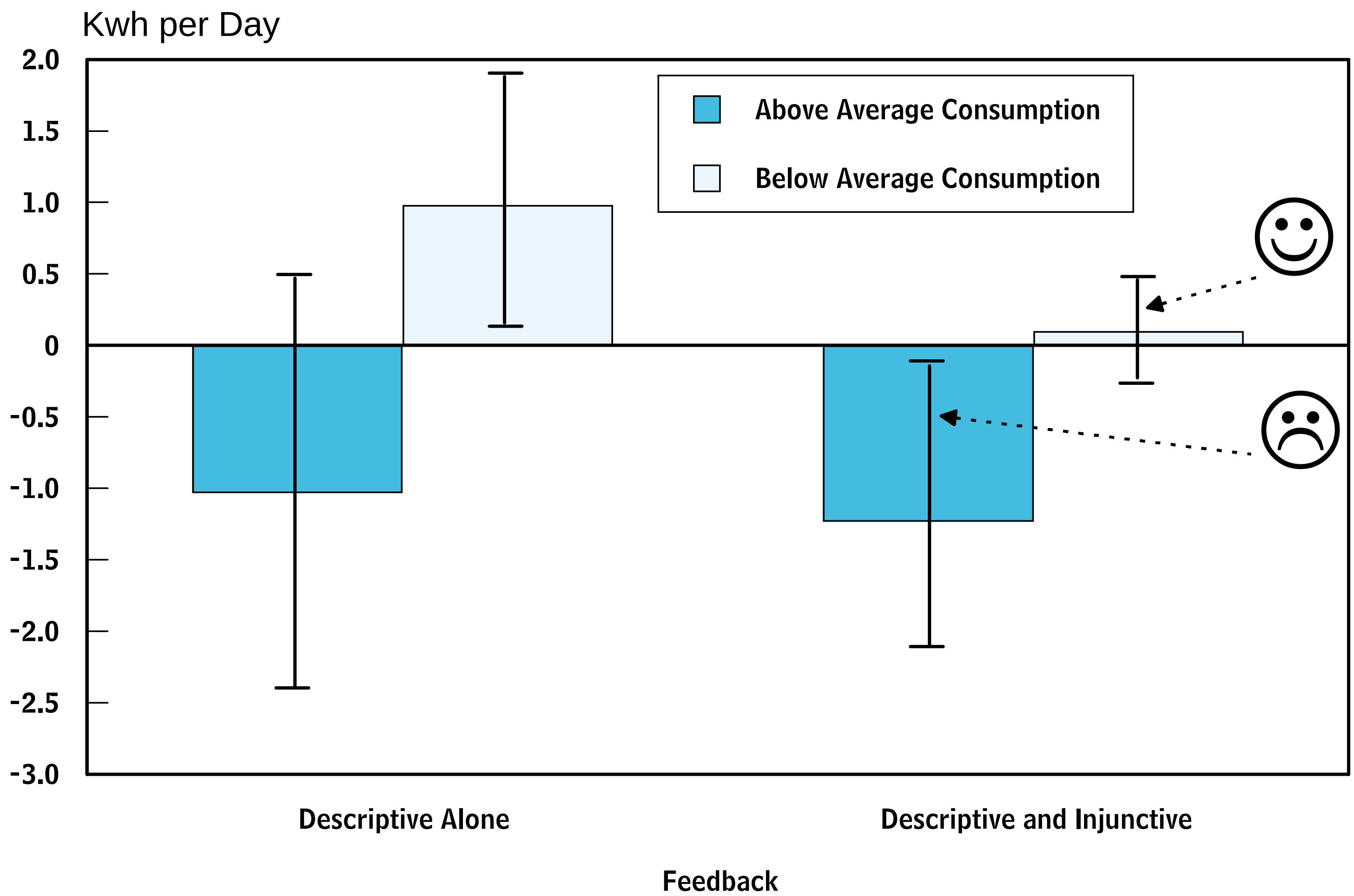
# Cumulative $CO_2$ Emissions by Selected Countries, With and Without Land-Use Change, 1950 to 2000



# Policy Responses to Climate Change: Mitigation

- **Can influence behavior of consumers through creation of new social norms**
- **Can raise price or restrict quantity — and, in theory, reach the same outcome**
  - Carbon tax
  - Cap and trade

# Change in Energy Consumption and Behavioral Economics




Source: Schultz and others (2007).

# Cap and Trade 101: What Is Cap and Trade?

- **The basic contours of a cap-and-trade program are straightforward**
  - A **CAP** limits the total amount of emissions. Allowances equal to that total amount are auctioned or otherwise allocated to emission sources
  - Emission sources may then **TRADE** allowances with other emission sources
- **Emission sources must hold allowances (either allocated or purchased) equal to or greater than their emissions or else be subject to penalties**

# Cap and Trade 101: An Illustrative Example

- **Two sources of emissions: Firm A and Firm B**
- **Under "business as usual" (BAU), each firm emits 4 units. The total emissions of the two firms thus equal 8 units.**
- **New Policy: A cap-and-trade system is instituted to reduce emissions by 50% from current levels**

# Cap and Trade 101: An Illustrative Example (continued)

- **Assumptions**
  - Two allowances are auctioned or allocated to each firm
  - Three times as costly for Firm B to reduce emissions as Firm A, such that

**Firm A**

| Emissions | Total Cost | Marginal Cost |
|---|---|---|
| 4 (BAU) | 0 | 0 |
| 3 | 1 | 1 |
| 2 | 3 | 2 |
| 1 | 6 | 3 |
| 0 | 10 | 4 |

**Firm B**

| Emissions | Total Cost | Marginal Cost |
|---|---|---|
| 4 (BAU) | 0 | 0 |
| 3 | 3 | 3 |
| 2 | 9 | 6 |
| 1 | 18 | 9 |
| 0 | 30 | 12 |

## Cap and Trade 101: An Illustrative Example (continued)

- **If no trading was allowed, each firm would have two allowances, and each firm would emit two units**
- **Total cost associated with 50% emission reduction**
  - Firm A: $3
  - Firm B: $9
  - Total: $12

## Cap and Trade 101: An Illustrative Example (continued)

- **If trading is permitted, Firm A will sell one allowance to Firm B**
  - Firm A will hold 1 allowance and will emit 1 unit
  - Firm B will hold 3 allowances and will emit 3 units
- **Total cost associated with 50% emission reduction**
  - Firm A: $6
  - Firm B: $3
  - Total: $9

# Cap and Trade 101: An Illustrative Example (continued)

- Savings with trading: $3 ($12 without trading versus $9 with trading)
- Emission sources will trade to point at which marginal costs of reducing emissions are equalized
- Trading offers the lowest-cost means of achieving the environmental objective

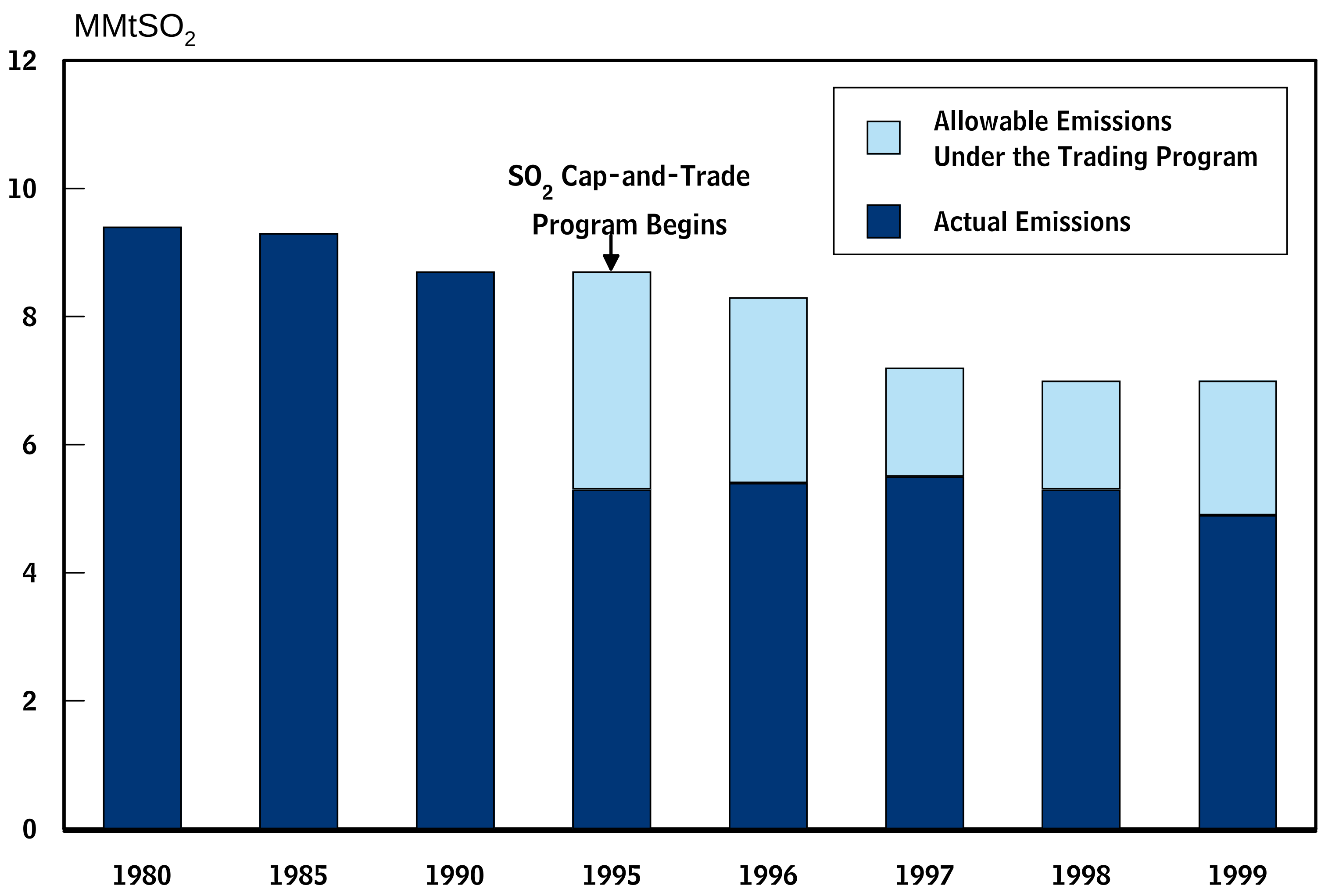
## Cap and Trade 101: Where Should the Cap Be Set?

- **Economists' answer: Cap should be set where the marginal cost equals the marginal benefit of emission reduction**
- **But ascertaining the marginal benefits of environmental improvement in dollar terms is a difficult task**

# Working Examples of Cap and Trade: The U.S. Acid Rain Program and $SO_2$ Emissions

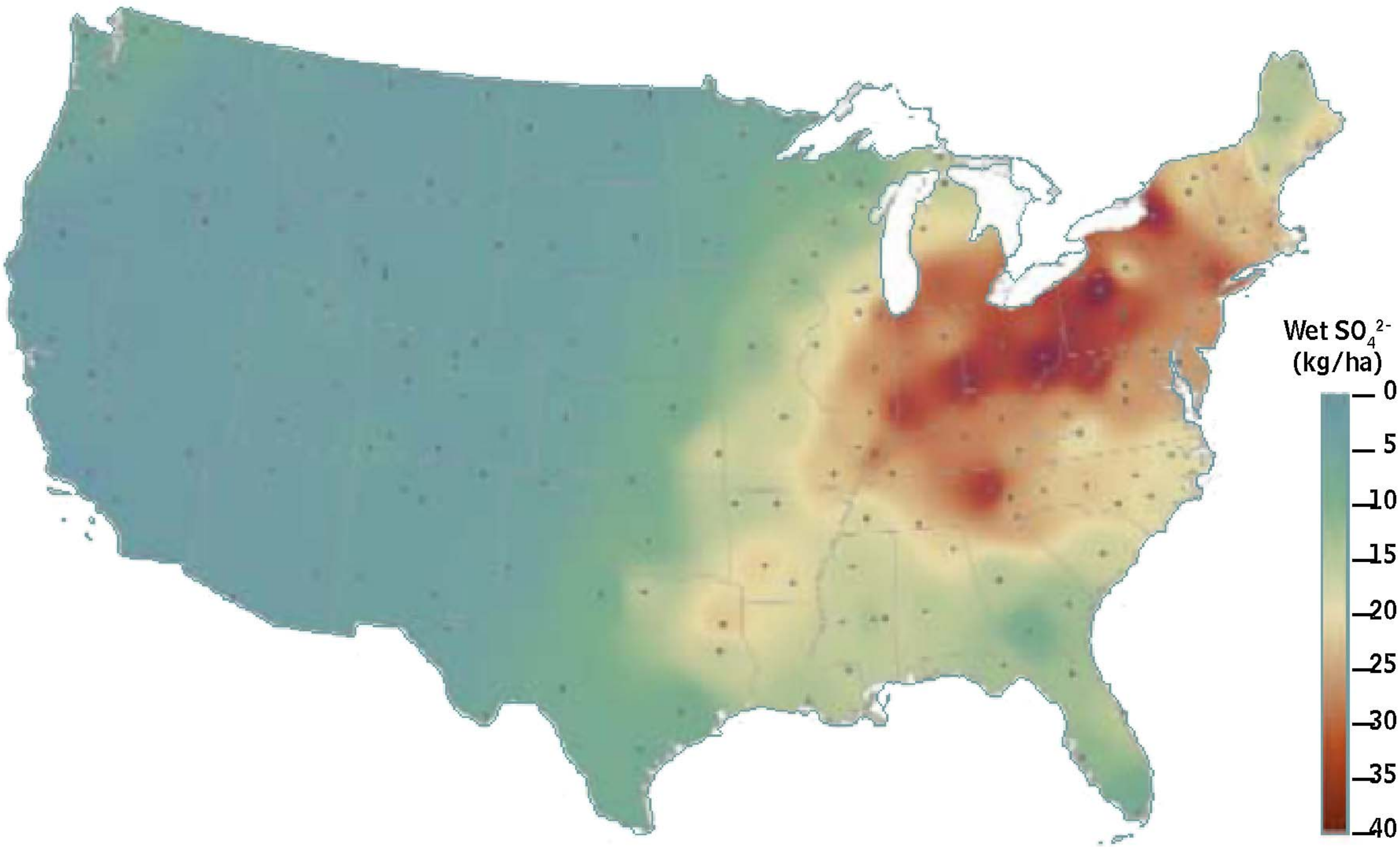
- **The Clean Air Act Amendments of 1990 established a cap-and-trade program to reduce overall atmospheric levels of $SO_2$ and $NO_2$ to 50% of 1980 levels**
- **The program has met (and even exceeded) its goals**
  - Emissions have declined 40% since 1990; acid rain levels have declined 65% since 1976
  - Prior to the program's launch, the expected market price for $SO_2$ allowances was between $579-$1,935 per ton; the actual market price as of March 2008 was $380 per ton

# $SO_2$ Emissions Under the Acid Rain Program

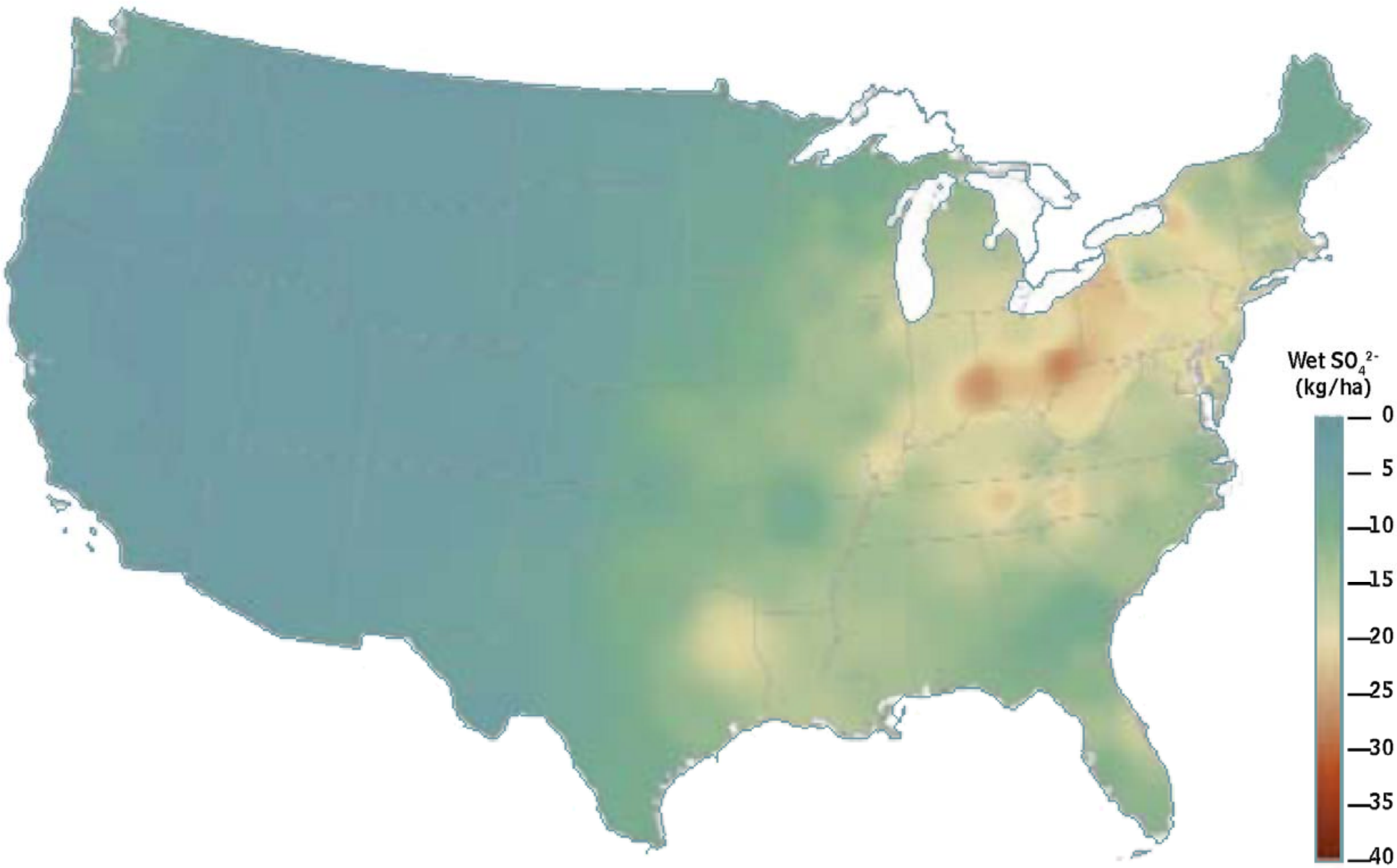



Source: Data from EPA.

# The Acid Rain Program: Baseline Acid Rain Concentrations, 1989 to 1991 Average



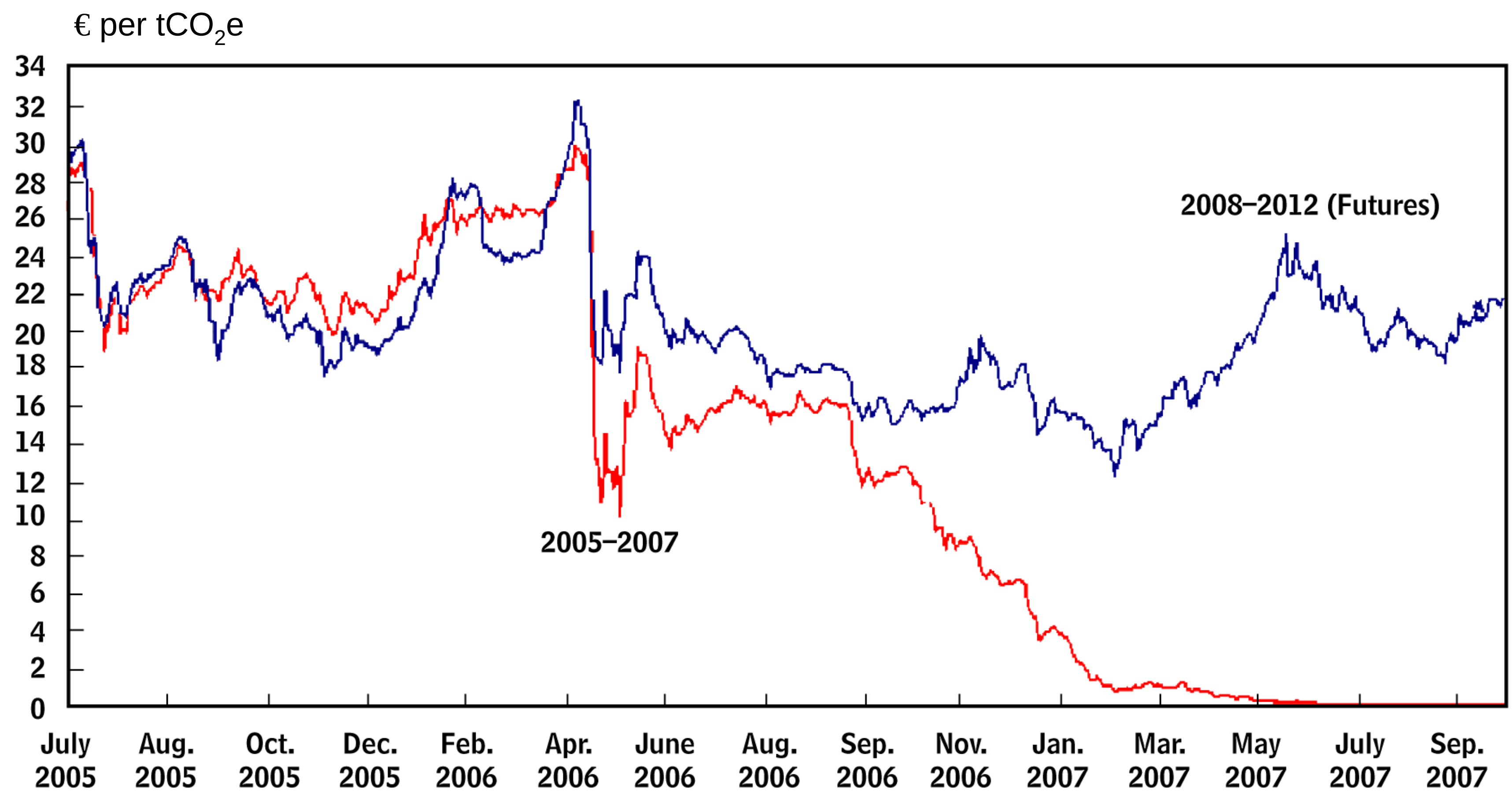
# The Acid Rain Program: Acid Rain Concentrations After Cap and Trade, 2000 to 2002 Average



# Other Examples of Cap and Trade: European Union Emission Trading System (EU-ETS)

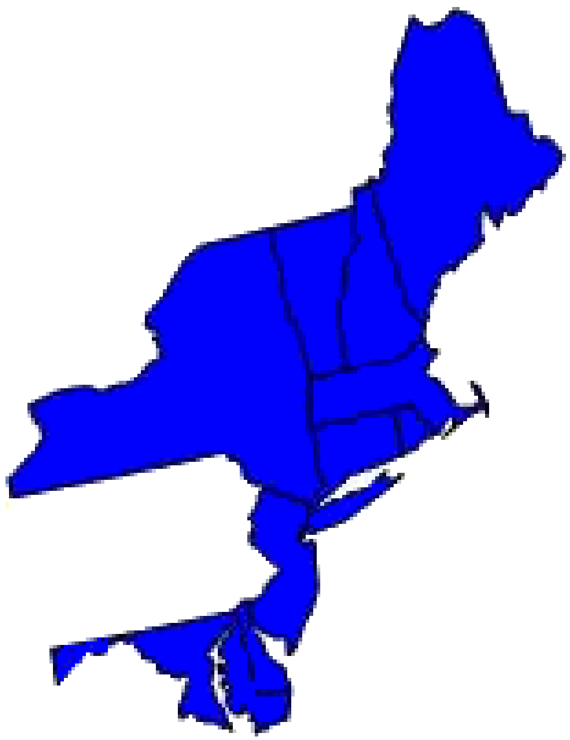
- **World's first $CO_2$ cap-and-trade program**
- **EU-ETS began with a three-year trial period (2005–2007); will be used to meet binding requirements of the Kyoto Protocol beginning with the second trading period (2008–2012) and beyond**
- **Early Difficulties**
  - High price volatility
  - Overallocation of allowances (and lack of banking) leads to collapse of the allowance price in first period

# EU-ETS: Allowance Prices in Period One and Period Two, 2005–2007




Source: Mission Climat of Caisse des Dépôts (2008).

# Working Examples of Cap and Trade: Regional Greenhouse Gas Initiative (RGGI)



- **RGGI involves 10 Northeastern states, from Maryland to Maine**
- **Starting date is January 1, 2009**
- **Covers emissions for all fossil-fuel-fired electricity-generating plants 25MW and larger**
- **Cap will "stabilize" emissions until 2014 (188 million allowances) and then reduce emissions 10% by 2018 (169 million allowances)**

# Cap and Trade: Two Key Decisions About Policy Design

- **Degree of flexibility in annual caps**
  - Include a floor and/or a ceiling for the price of an allowance?
  - Allow firms to bank and/or borrow allowances?
- **Allowance allocation**
  - How to set initial number of allowances?
  - Sell the allowances or give them away?
  - Who gets free allowances or auction revenues?

# How Much Flexibility to Allow in Annual Emissions?

- **Cap and trade sets limit on emissions; price of emissions is uncertain**
- **Meeting strict annual targets can add significantly to total cost, with little offsetting benefit**
  - Cost of meeting an annual cap is likely to vary significantly from year to year
  - In terms of climate effects, annual fluctuations in emissions matter little compared with multiyear trends
  - Inflexible caps would require too few reductions in low-cost years (when meeting the cap is easy) and too many reductions in high-cost years

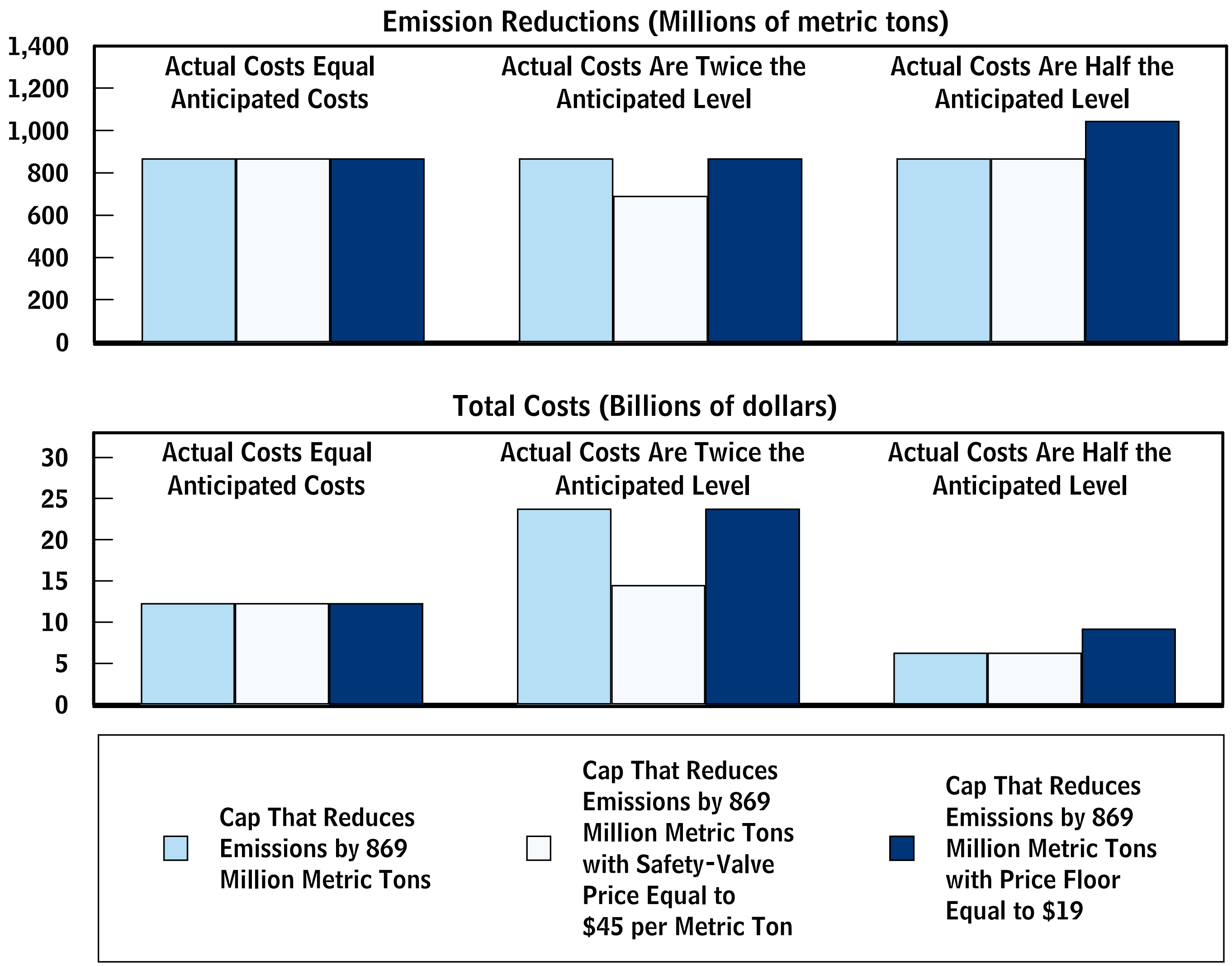
# Flexible Cap Designs Could Lower the Cost of Meeting Long-Run Targets

- **Price floors and ceilings could provide timing flexibility and more certainty about allowance prices**
  - Floor would tighten cap in low-cost years; ceiling would loosen cap in high-cost years
  - Floor and ceiling could be adjusted periodically to ensure that emissions are on track to achieve long-term targets

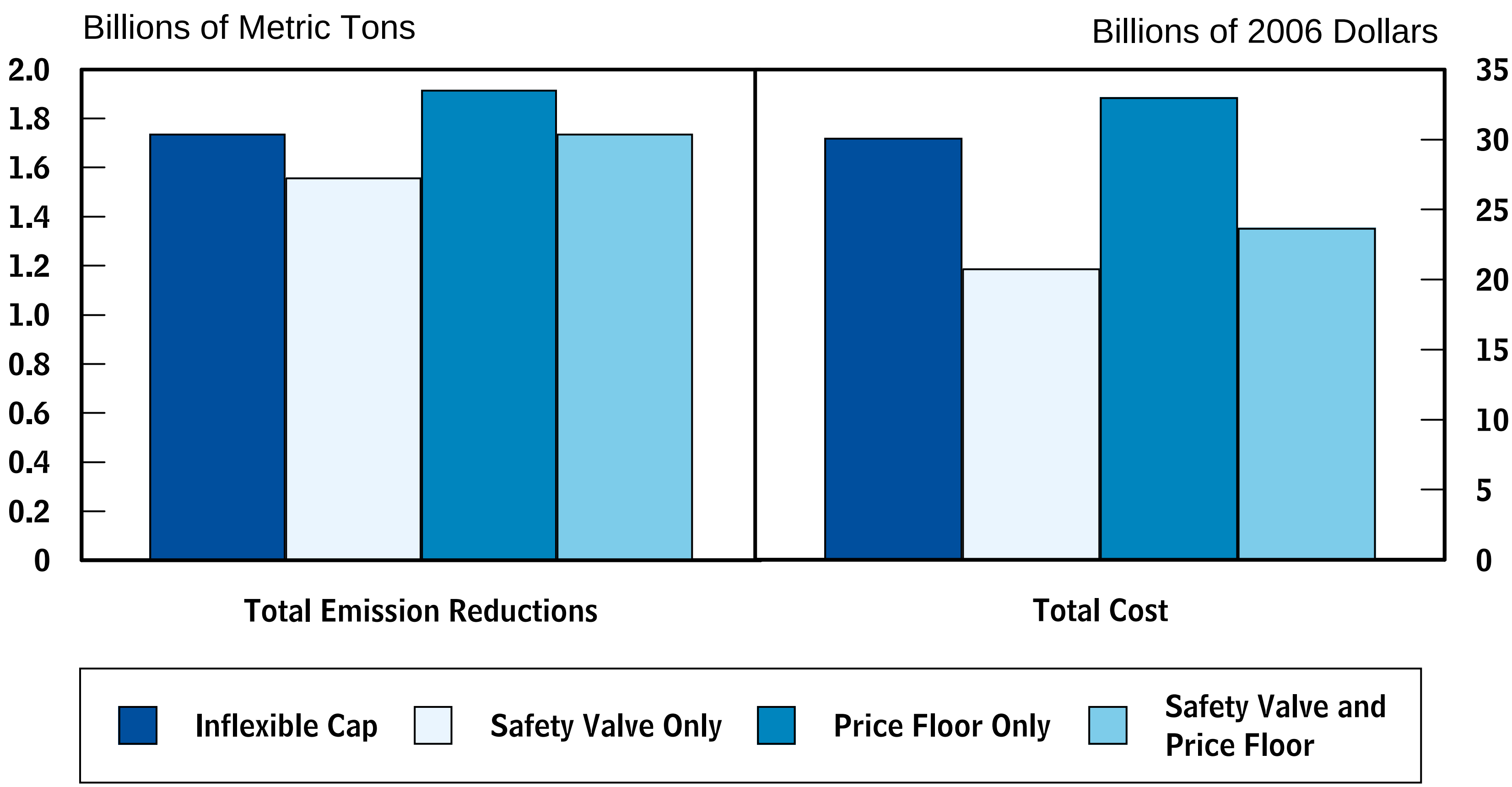
# Flexible Cap Designs Could Lower the Cost of Meeting Long-Run Targets (continued)

- **Banking and borrowing allow firms to shift emission reductions across years**
  - Banking would allow firms to exceed required reductions in low-cost years and save the allowances for use in future years
  - Borrowing would allow firms to use future allowances in current year if allowance prices were high

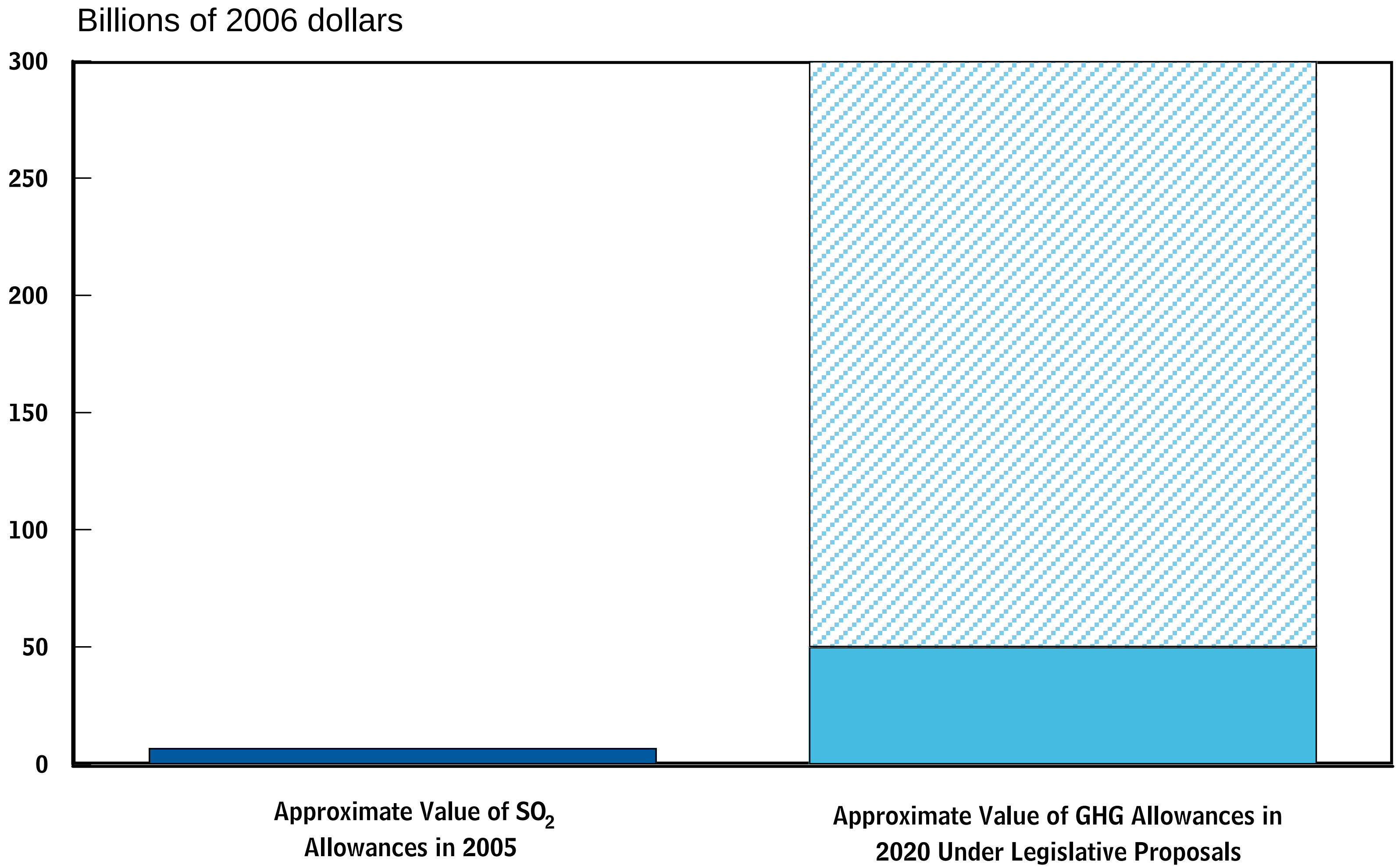
# Illustrative Comparison of Various Policies to Reduce $CO_2$ Emissions Under Different Cost Conditions in 2018



# Illustrative Comparison of Total Emission Reductions and Total Costs and After One High-Cost and One Low-Cost Year



# Allocation Matters: Amount of the Allowance Value (Income) Transferred Likely to Be Large



## Allocation Matters: How to Allocate the Allowances?

- **Someone will receive the value of the allowances**
  - Determined by policymakers' decisions
- **Someone will pay for the allowances**
  - Determined by market forces

## Allocation Matters: Who Will Receive the Allowance Value?

- **"If I'm going to have buy those permits from the government, I'm going to have to turn around and charge the customers a lot more than I would if I just had those allowances allocated for free."**

*— Bruce Braine, American Electric Power*

Source: National Public Radio (2007).

## Allocation Matters: Who Will Pay for Allowances?

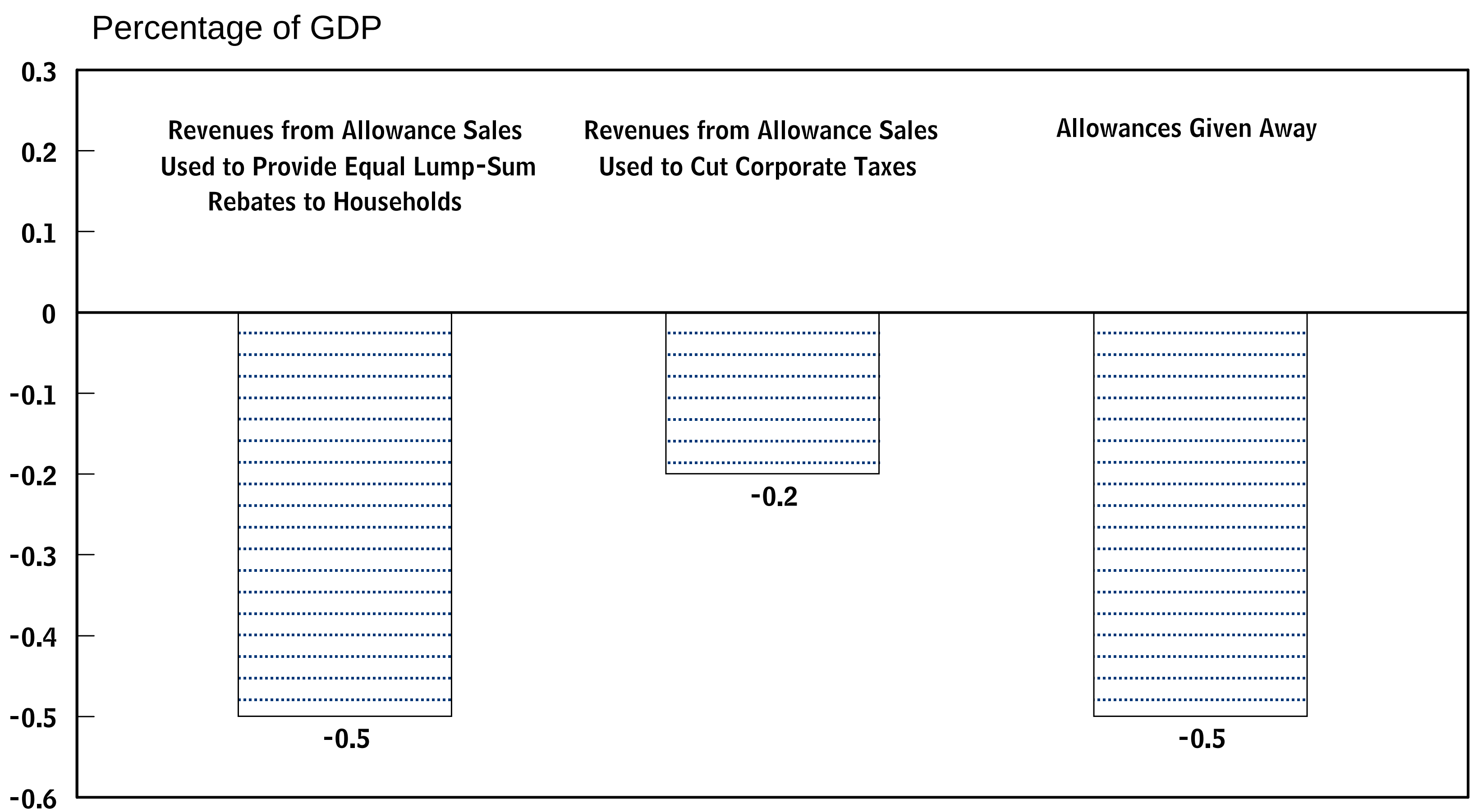
- **Cost of holding an allowances would become a part of doing business**
- **Market forces would determine who bears the allowance cost**
  - Primarily borne by consumers in form of price increases
    - Disproportionate burden on low-income households
  - Workers and shareholders could experience transitional costs

# Consumer Price Increases Would Be Regressive

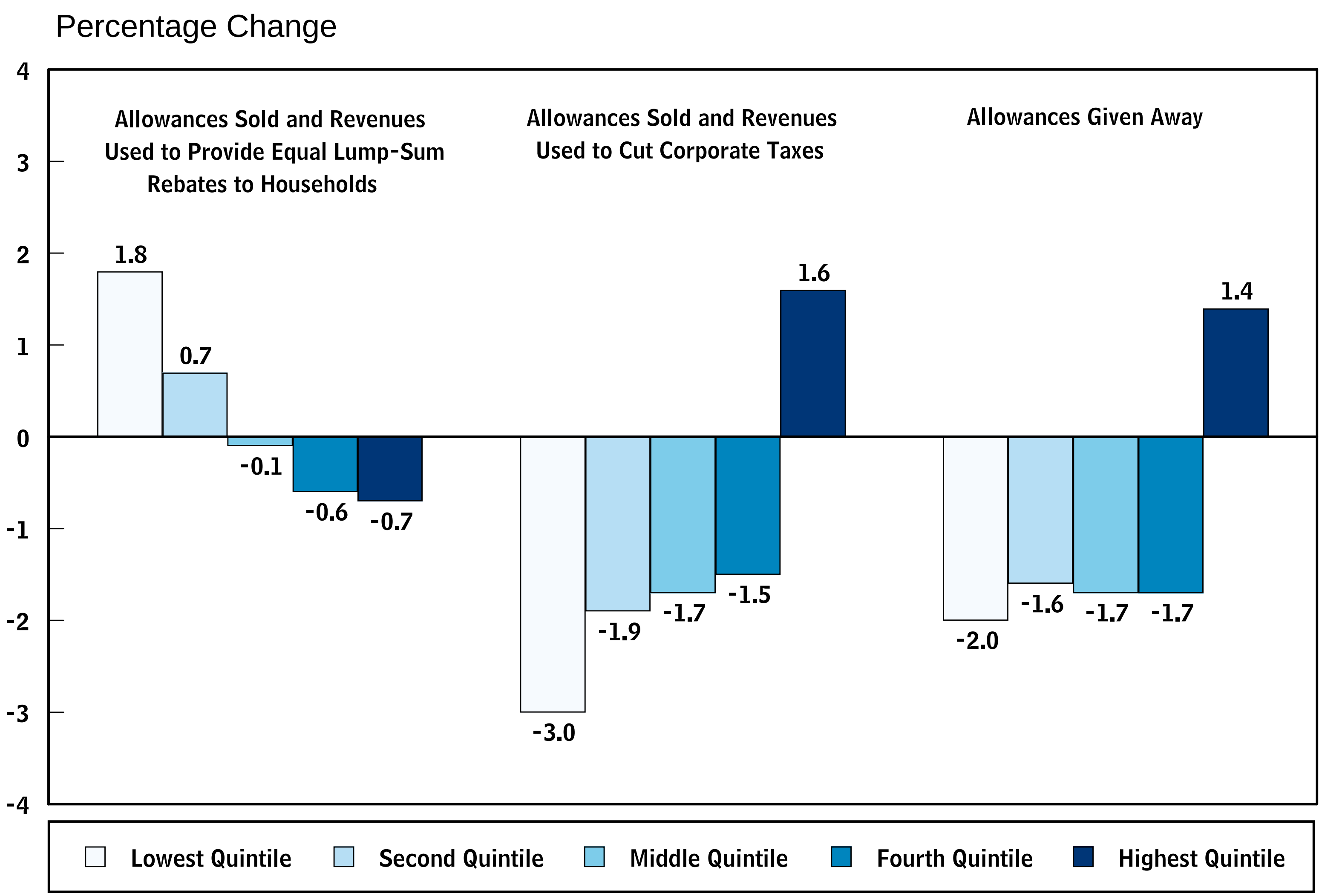
*Illustrative Example Showing Increase in Average Household Costs from a 15 Percent Decrease in Carbon Emissions*

| | Average for Income Quintile | | | | |
|---|---|---|---|---|---|
| | **Lowest** | **Second** | **Middle** | **Fourth** | **Highest** |
| Cost Increase in 2006 Dollars | 680 | 880 | 1,160 | 1,500 | 2,180 |
| Cost Increase as a Percentage of Income | 3.3 | 2.9 | 2.8 | 2.7 | 1.7 |

# Efficiency Cost of a 15 Percent Cut in $CO_2$ Emissions, with Revenues Used in Different Ways



# Effects of a 15 Percent Cut in $CO_2$ Emissions on Average After-Tax Real Household Income



## Conclusions: Timing Flexibility Matters

- **Requiring that firms meet an inflexible cap could substantially increase cost while providing little additional benefit**
- **Design features can allow timing flexibility**
  - Banking and borrowing could help in some situations, though borrowing typically limited because of enforcement concerns
  - Price floor and ceiling could address wide array of situations and be adjusted over time to keep emissions on track to meet long-run cap

## Conclusions: Allocation Matters

- **Value of allowances likely to be large**
  - Policymakers determine who receives their value
  - Market forces determine who bears their cost
- **Selling allowances would allow policymakers to capture their value, which could help to lower overall economic costs and offset costs to low-income households**

# Conclusions: Allocation Matters (continued)

- **Freely allocating allowances would be equivalent to selling them and distributing the revenues to producers**
  - Free allocations would not prevent price increases
  - Free allocations to producers could create windfall profits