

Pricing Carbon Conference Wesleyan University

Economic Rationale to Pricing Carbon

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An Overture for the Weekend

- The Wesleyan Statement of Principle:
 - Price carbon as transparently as possible
 - Use the revenue to ameliorate regressive incidence and promote R&D in new technologies and their global diffusion.
 - Indicate convincingly that the price of carbon will increase persistently and predictably over time
 - Nonetheless, anticipate and indeed design transparent procedures that facilitate iterative mid-course corrections based on
 - New and evolving science
 - Evidence of success from existing policies and programs

Outline of My Remarks

- Pricing carbon is necessary by not sufficient
- America's Climate Choices – Limiting
 - Price carbon
 - Complement pricing with R&D support
 - Medium term emissions budgets
 - Application of Hotelling's exhaustible resources result
 - Factor in equity concerns
- Other (inferior) approaches
 - Subsidize emissions reductions
 - Just regulate through the Clean Air Act

Outline of My Remarks

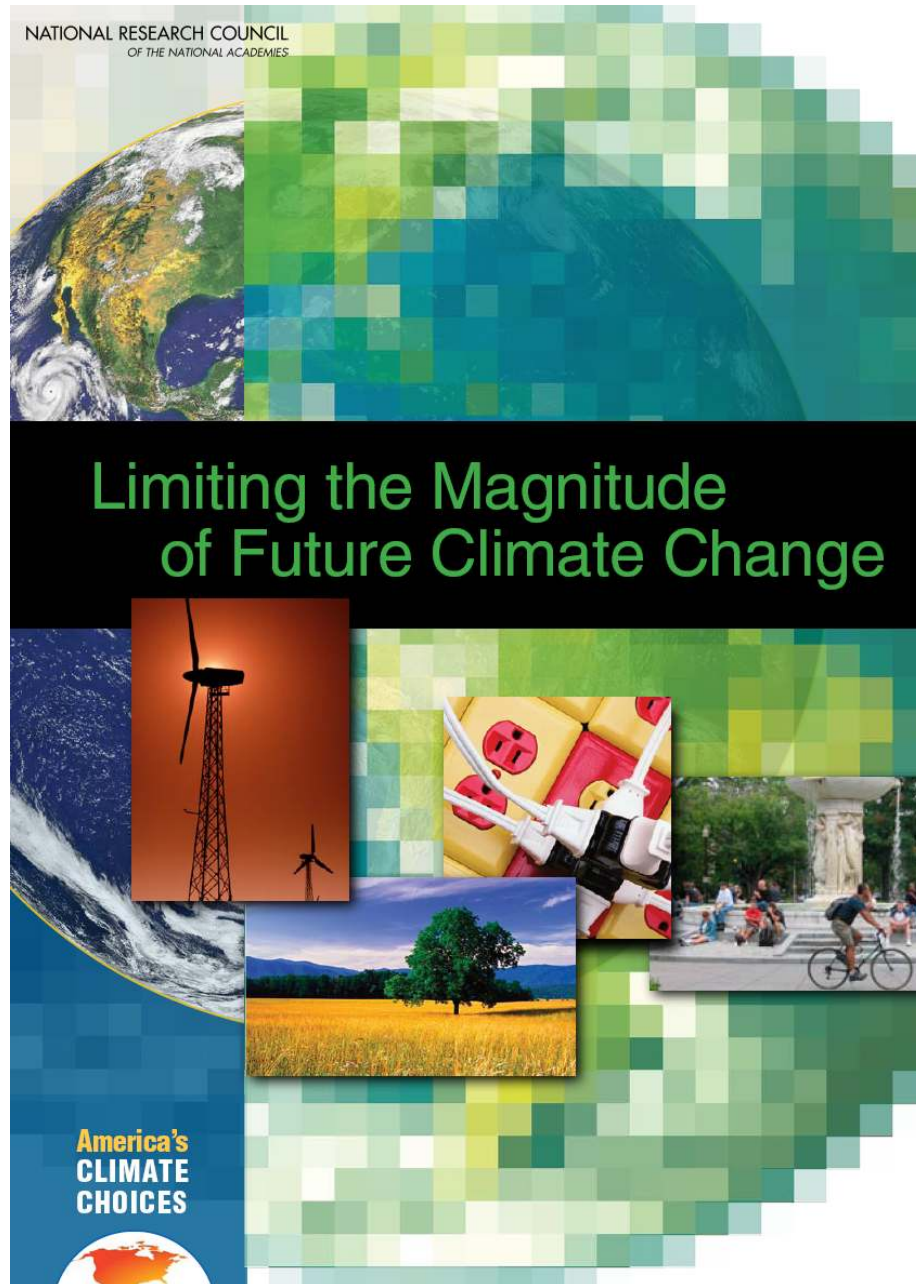
- Cap and Trade versus Carbon Taxes
 - Economic fundamentals given uncertainty – prices versus quantities
 - Sulfur emissions versus carbon emissions
 - Clarity in the price signal and the power of price elasticities of (derived) demand
- Political economy arguments
- Reminder – Investment in mitigation (limiting) is an investment in moving the distributions of future temperatures down.

A Point of Departure from the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC; 2007)

- Responding to climate change involves an *iterative risk management process* that includes *both adaptation and mitigation* and takes into account climate change damages, co-benefits, sustainability, equity, and attitudes to risk.

**Another
Point of
Departure:**

**The Limiting
Panel of
America's
Climate
Choices
(ACC; 2010)**



Panel Membership

Robert Fri (*Chair*), Resources for the Future

Marilyn Brown (*Vice Chair*), Georgia Institute of Technology

Doug Arent, National Renewable
Energy Laboratory

Ann Carlson, UCLA

Majora Carter, Majora Carter Group

Leon Clarke, Pacific Northwest
National Laboratory

Francisco de la Chesnaye, Electric
Power Research Institute

George Eads, Charles Rivers Assoc.

Genevieve Giuliano, University of
Southern California

Andrew Hoffman, University of Michigan

Robert Keohane, Princeton University

Loren Lutzenhiser, Portland State Univ.

Bruce McCarl, Texas A&M University

Mack McFarland, DuPont

Mary Nichols, CA Air Resource Board

Edward Rubin, Carnegie Mellon Univ.

Thomas Tietenberg, Colby College (Ret.)

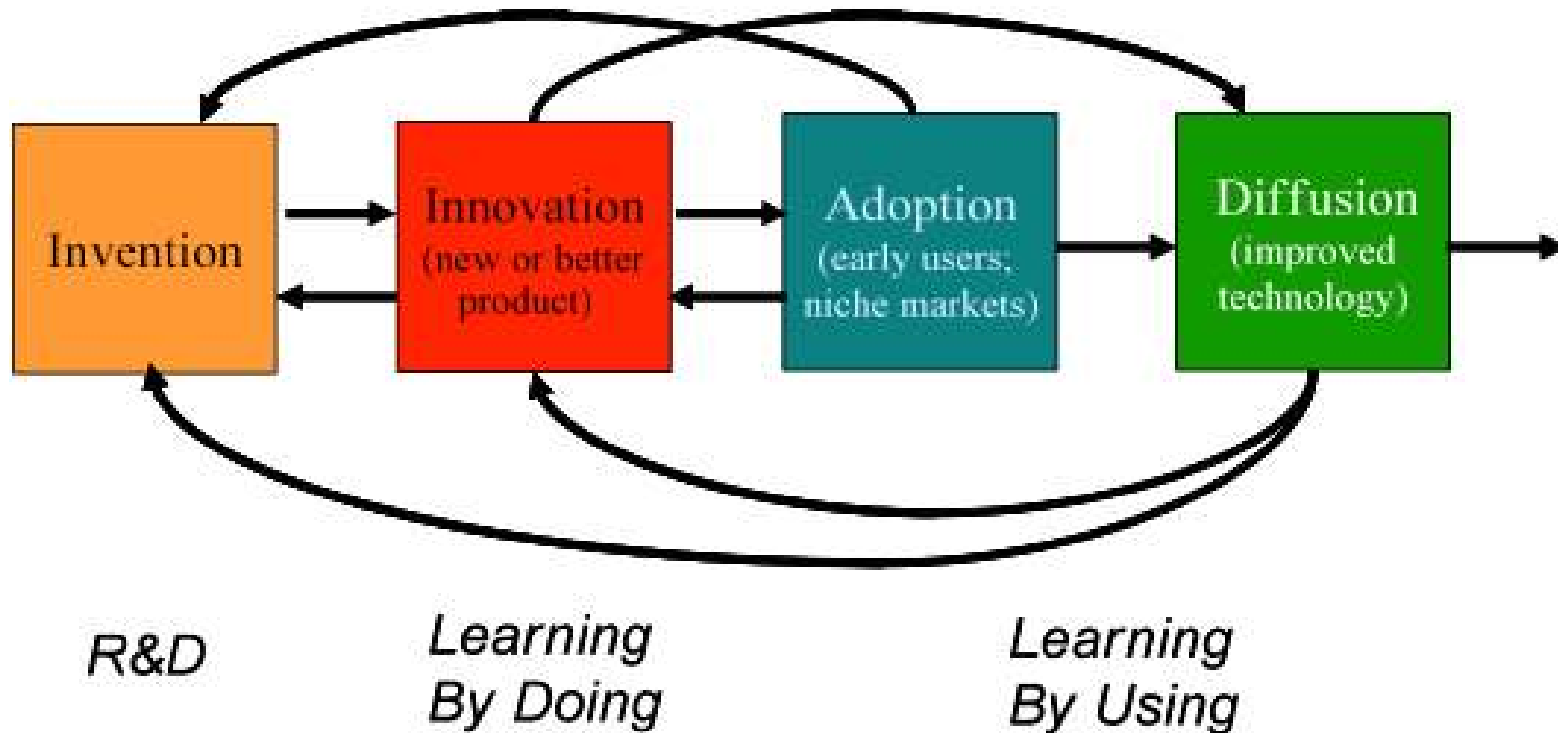
James Trainham III, Sundrop Fuels, Inc.

Core Recommendations – ACC (2010)

{ indicates a place to allocate revenue}*

1. **Adopt a mechanism for setting an economy-wide carbon pricing system** {agnostic about how}
2. **Complement the carbon price with policies that: ***
 - realize the practical potential for energy efficiency and low-emission energy sources in the electric and transportation sectors;
 - establish the feasibility of carbon capture and storage and new nuclear technologies;
 - accelerate the retirement, retrofitting or replacement of GHG emission-intensive infrastructure.
3. **Create new technology choices by investing heavily in research and crafting policies to stimulate innovation. ***

The Innovation Cycle



Core Recommendations (cont...)

{** indicates recognition of the need to iterate}

4. Consider potential equity implications when designing and implementing climate change limiting policies, with special attention to disadvantaged populations. *
5. *Establish the United States as a leader to stimulate other countries to adopt GHG reduction targets.*
6. Enable flexibility and experimentation with policies to reduce GHG emissions at regional, state, and local levels. **
7. Design policies that balance durability and consistency with flexibility and capacity for modification as we learn from experience. **

Setting Goals

What is a 'safe' amount of climate change?

How does GHG concentration translate into global temperature change and other key impacts?

How does a given level of emissions translate into atmospheric GHG concentrations?

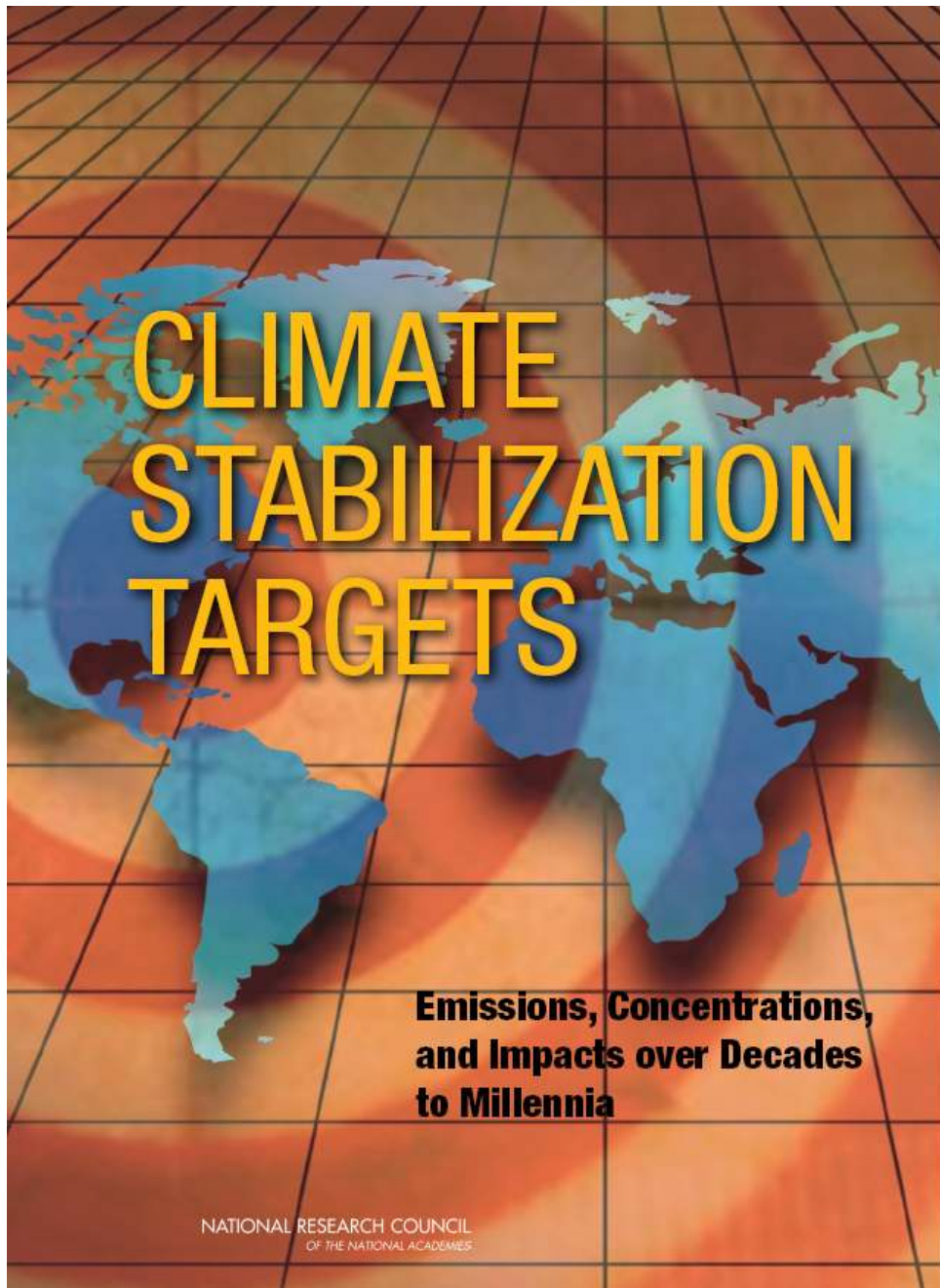
What is a 'reasonable' share of U.S. emission reductions relative to the global targets?

Target: limiting global mean temperature increase
(e.g., 2 deg, 3 deg)

Target: limiting global atmospheric GHG concentrations
(e.g., 450ppm, 550 ppm)

Target: limiting global GHG emissions
(e.g. global emission budget, or percent reduction)

Target: limiting U.S. GHG emissions
(e.g. national emission budget, or percent reduction)



Climate Stabilization Targets:

**Emissions, Concentrations,
and Impacts over Decades
to Millennia**

Report from The National
Academies
Board on Atmospheric Sciences and
Climate

Committee Members

- **SUSAN SOLOMON (Chair)**, National Oceanic and Atmospheric Administration, Boulder, CO
- **DAVID BATTISTI**, University of Washington, Seattle, WA
- **SCOTT DONEY**, Woods Hole Oceanographic Institution, Woods Hole, MA
- **KATHARINE HAYHOE**, Texas Tech University, Lubbock, TX
- **ISAAC M. HELD**, Geophysical Fluid Dynamics Laboratory, Princeton, NJ
- **DENNIS P. LETTENMAIER**, University of Washington, Seattle, WA
- **DAVID LOBELL**, Stanford University, Stanford, CA
- **DAMON MATTHEWS**, Concordia University, Montreal, Quebec
- **RAYMOND PIERREHUMBERT**, University of Chicago, Chicago, IL
- **MARILYN RAPHAEL**, University of California, Los Angeles, CA
- **RICHARD RICHEL**, Electric Power Research Institute, Inc., Washington, DC
- **TERRY L. ROOT**, Stanford University, Stanford, CA
- **KONRAD STEFFEN**, University of Colorado, Boulder, CO
- **CLAUDIA TEBALDI**, Climate Central, Vancouver, British Columbia
- **GARY W. YOHE**, Wesleyan University, Middletown, CT

Warming and Stabilization Targets

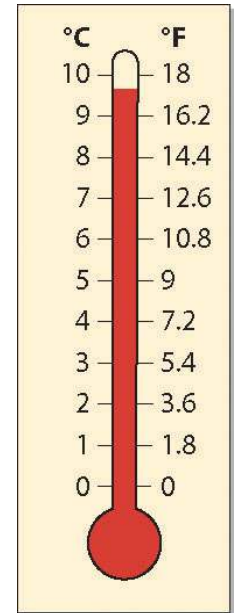
How much risk is acceptable?

A value judgment (not addressed by the scientific community in its assessments).

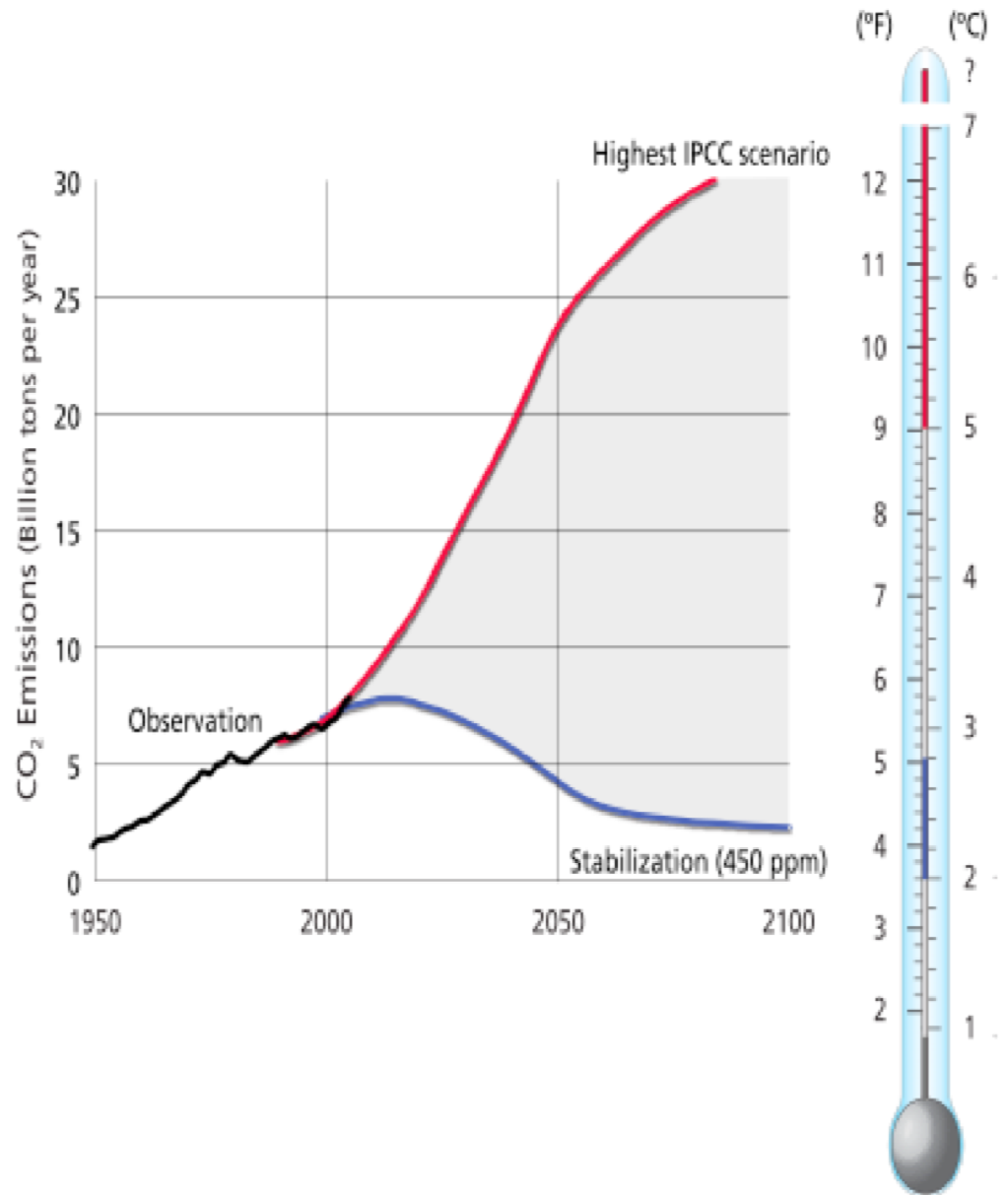
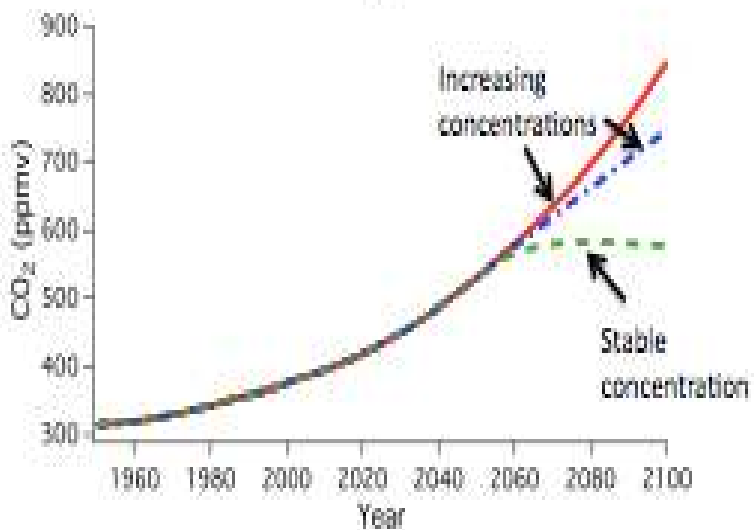
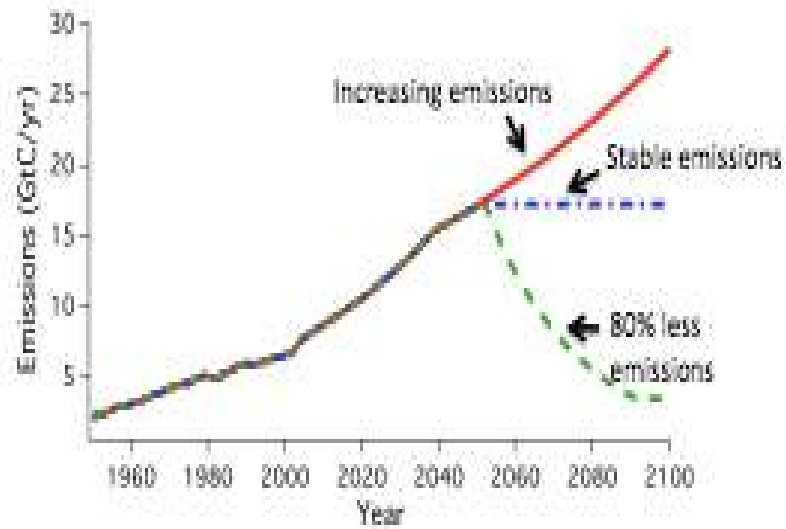
What is at risk?

A science judgment (must be addressed as far as the scientific literature allows).

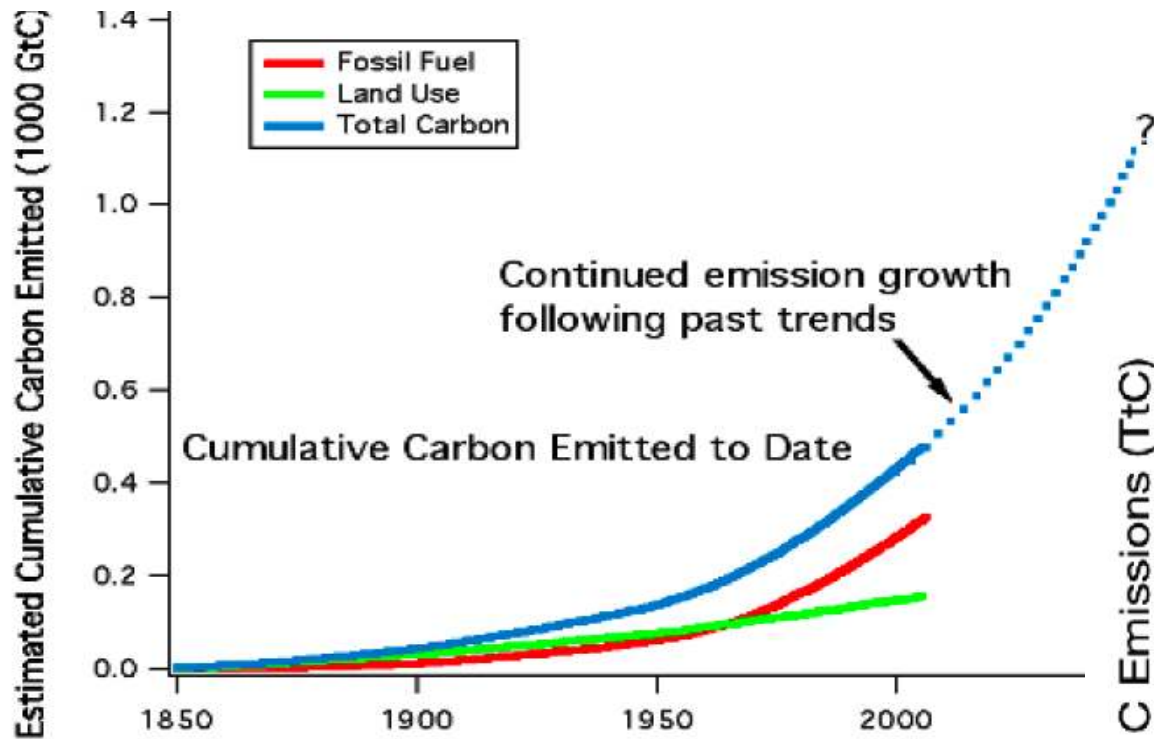
Choices depend on processing these two questions through applicable decision processes.



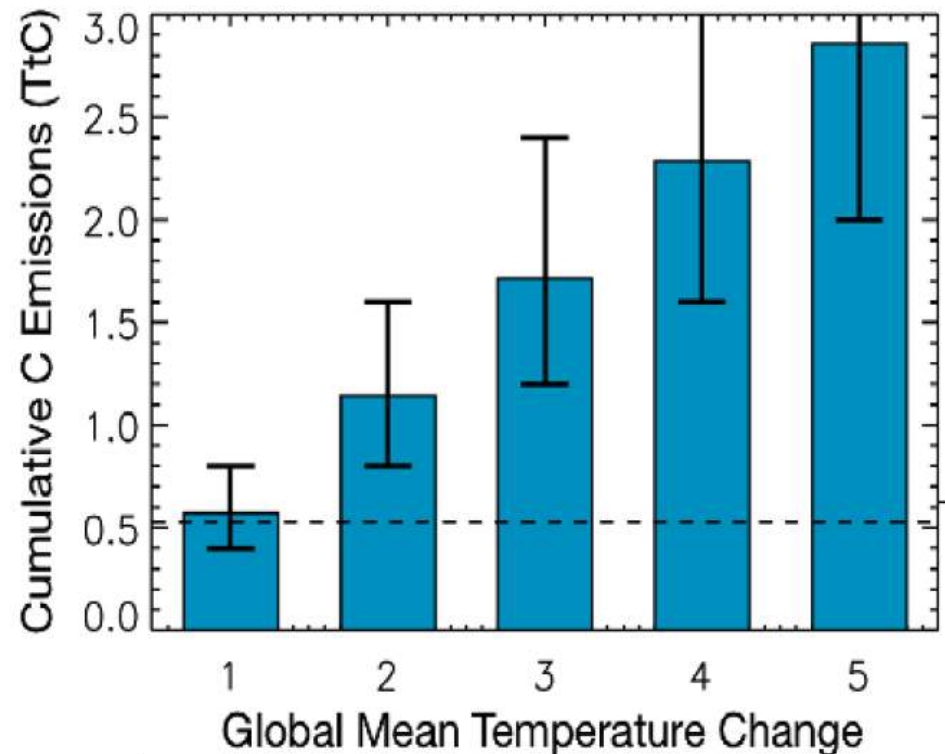
A Range of Possible Futures



Framing the Long Term: Cumulative Carbon *Budgets*



Global mean temperature change is almost linearly related to cumulative carbon emission, and is independent of the time over which the emissions occur (because radiative forcing decreases logarithmically with increasing CO₂ concentrations, but this is balanced by weakening carbon sinks at higher CO₂).



Transient and Equilibrium Warming: What We Observe versus What Will Happen

CO ₂ -equivalent concentration (ppmv)	Best estimate transient warming (°C)	Estimated likely range of transient warming (°C)	Best estimate equilibrium warming (°C)	Estimated likely range of equilibrium warming (°C)
350	0.5	0.4-0.7	1	0.7-1.4
450	1.1	0.9 -1.5	2.2	1.4-3.0
550	1.6	1.3-2.1	3.1	2.1-4.3
650	2	1.6-2.7	3.9	2.6-5.4
1000	3	2.4-4.0	5.9	3.9-8.1
2000	4.7	3.7-6.2	9.1	6.0-12.5

Wait to observe severe impacts? A future with about twice as much warming and double the impacts.....

Key Findings

- Different stabilization levels can lock the Earth and many future generations of humans into large impacts, some of which can occur very slowly over time.
- Observed climate changes as greenhouse gas emissions increase reflect only about half of the eventual total warming that would occur for stabilization at the same concentrations; deep emission reductions (>80%) would be required to stabilize carbon dioxide concentrations at any chosen target level (e.g., 450 ppmv, 550 ppmv, 650 ppmv, 750 ppmv, etc.).....

Key Findings, continued

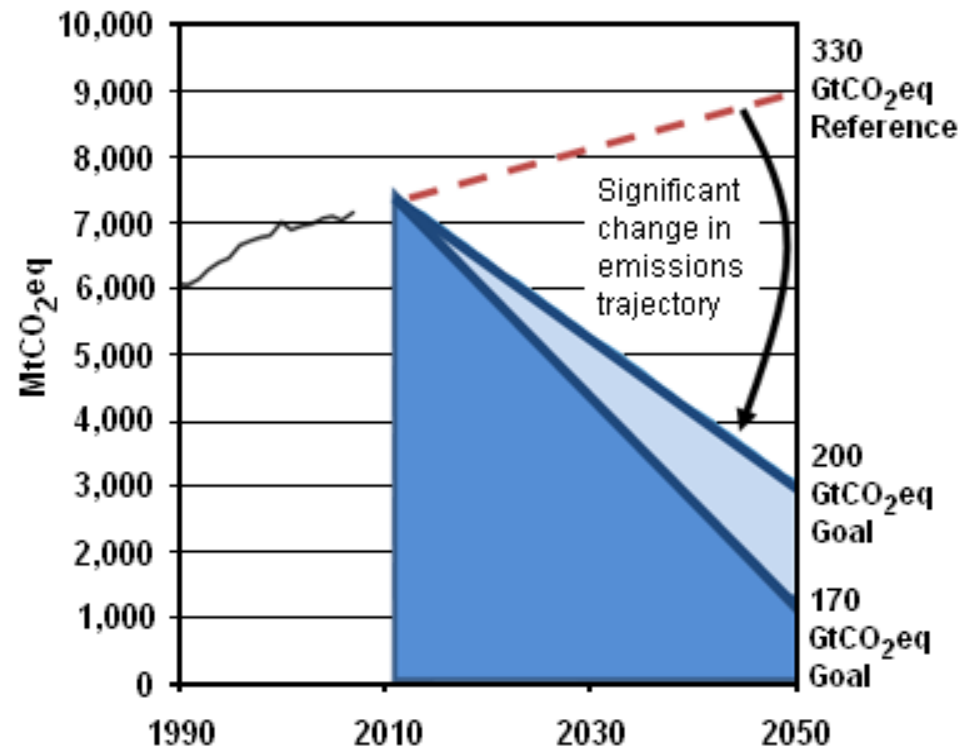
- Scientific progress has resulted in increased confidence in understanding how global warming levels of 2, 3, 4, 5°C, or more would affect wildfire area, Arctic sea ice retreat, reduced crop yields, coral bleaching, stream-flow, rainfall patterns, and eventual sea level rise, providing improved information for science and society.

Translation into a Medium-Term Emissions Budget for the United States

ACC Limiting Panel suggests that the U.S. establish a 'budget' for cumulative GHG emissions over a set period of time.

..... a 'representative' budget range of: 170 - 200 gigatons (Gt) of CO₂-eq for 2012 - 2050.

Business-as-usual emissions would consume either budget well before 2050.



Energy Mixes in 2050 for the Two Budgets

They are Possible – but NOT Easy

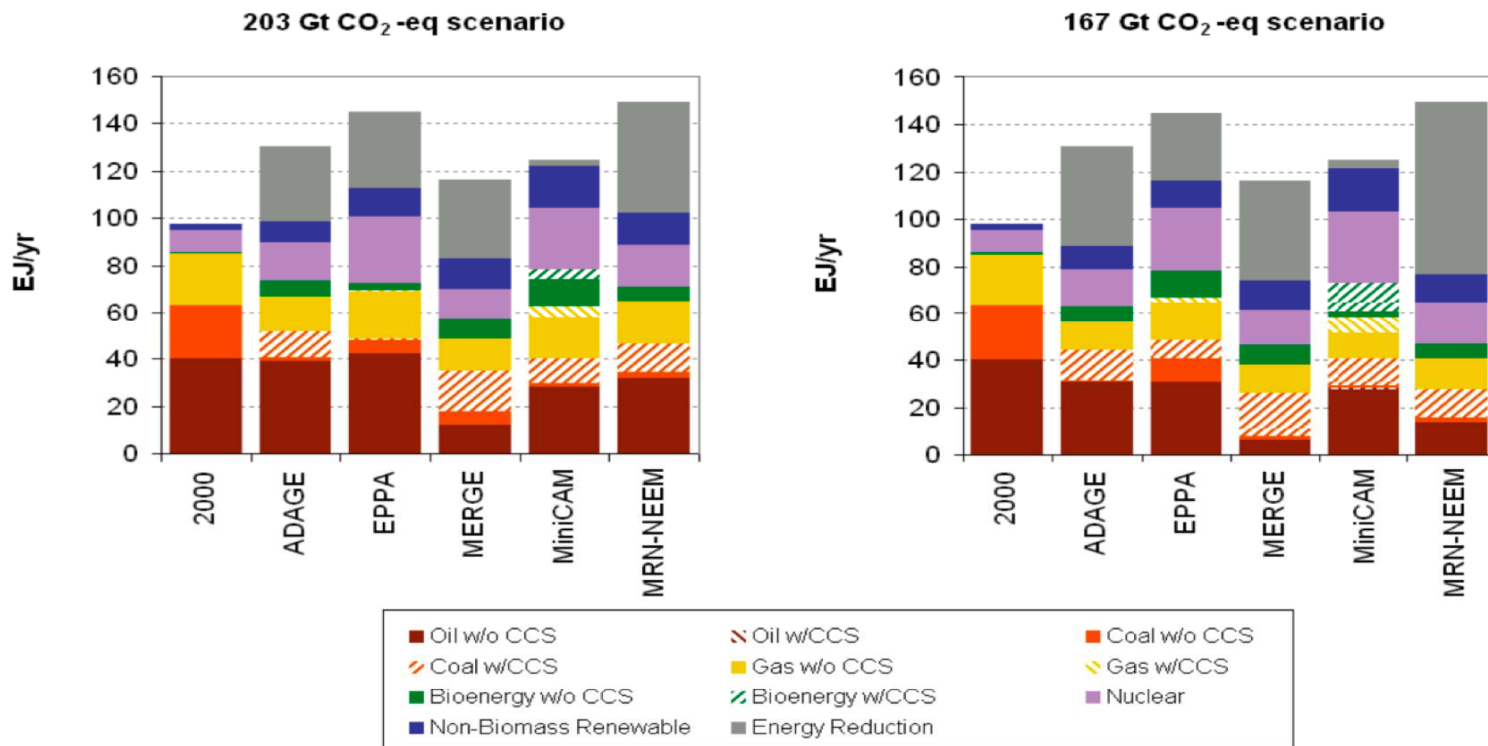


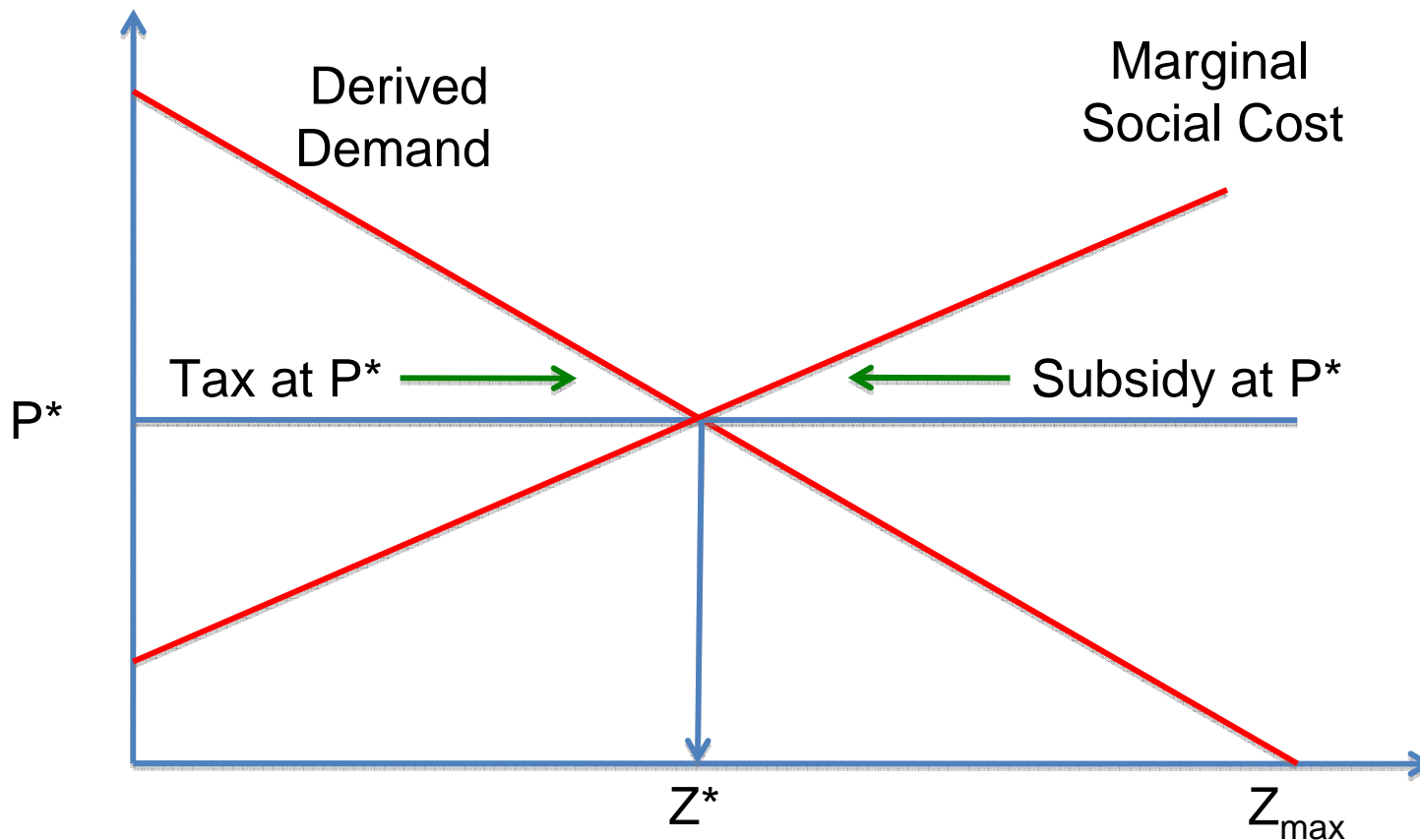
Figure 3.3 Model projections (from the EMF22 study) of the mix of energy technologies that may be used in 2050, under scenarios with emission budgets of 203 and 167 Gt CO₂-eq. For comparison, the first column in each graph shows the U.S. energy technology mix in 2000. A wide variety of future energy mix scenarios are possible, but all cases project a greater role for energy efficiency, renewable energy, fossil fuels with CCS, and nuclear power. Adapted from Fawcett et al. (2009). See also <http://emf.stanford.edu> for further details.

Some Bad Ideas

- Subsidize emissions reductions (from an unabated maxima) rather than tax residual emissions
 - Equivalent in partial equilibrium but
 - Subsidies reduce average production cost and therefore create contrary opportunities to increase product demand
- Apply the Clear Air Act to impose a collection of source specific regulations
 - Inefficient allocation of resources (expensive way to achieve a specific emissions target)
 - Concrete and complacency

Tax (A Price) versus an Equivalent Subsidy

The price (subsidy) P^* and the quantity Z^* are certainty equivalents



An Illustration of Inefficiency in Well-meaning Regulations

{Source: Viscusi (1996)}

Regulated Substance	Agency	Initial Annual Risk	Lives Saved Per Year	Cost per Life Saved
Passive restraints	NHTSA	9.1 in 100,000	1850	\$300,000
Airplane seat flammability	FAA	1.6 in 10 mil	37	\$600,000
Benzene emissions	EPA	2.1 in 100,000	0.31	\$2.8 mil
Benzene in manufacturing	OSHA	8.8 in 10,000	3.8	\$17.1 mil
Asbestos	EPA	2.9 in 100,000	10	\$104 mil
Formaldehyde	OSHA	6.8 in 10 mil	0.01	\$72 bil

Reasons to Price Carbon

- The price of carbon can be a socially significant and economically important indication of the long-term objective
- Appropriate (at least internally consistent) accounting of the carbon implications of other government policies and/or regulations must be quantified somehow.
- The price of carbon support economic incentives for R&D into carbon-saving and/or carbon sequestering technologies; it also portends their subsequent success in global market penetration.

How to Price for Carbon in an Iterative Environment: Three Alternatives for the Medium Term Question Inspired by the Hotelling Solution

- The “social cost of carbon” – the cost of inaction
- The “shadow price” of governmentally chosen (politically negotiated) targets.
- ***Exploit Hotelling’s (1931) exhaustible resource result for cumulative budgets because it is concentrations that drive climate change.***

The Hotelling Result

- Question: How can we optimally allocate an exhaustible resource over time – e.g., how to minimize the cost of achieving a cumulative carbon emission budget over a specified period of time?
- Answer: Compute an “optimal scarcity rent” for the *targeted total consumption* (usually denoted λ); add a multiple of this rent that increases with the rate of interest to the price of the resource *year in and year out*; to a first order approximation:

$$P(t) = P_C + \lambda \cdot (1+r)^t.$$

The Power of Price Elasticity in that Environment

- Elasticities are measured as ratios of percentage changes:
 - $\eta = \{\text{\%-age change in quantity}/\text{\%-age change in price}\}$
- Magnitudes differ with context and timeframe, but all < 0 and grow with timeframe
- Persistent \%-age increase in the price of carbon compounds over time so the effect is larger than the sum of annual estimates.

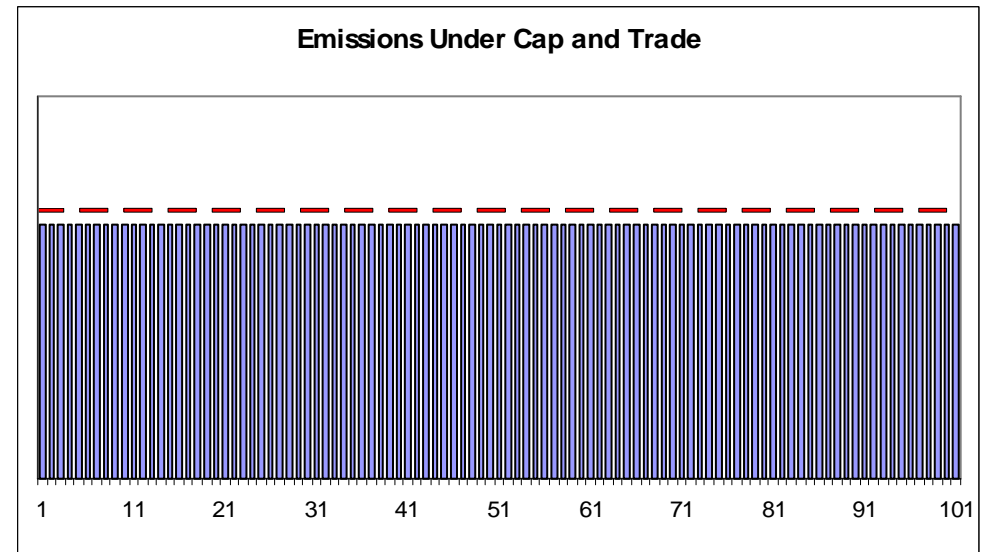
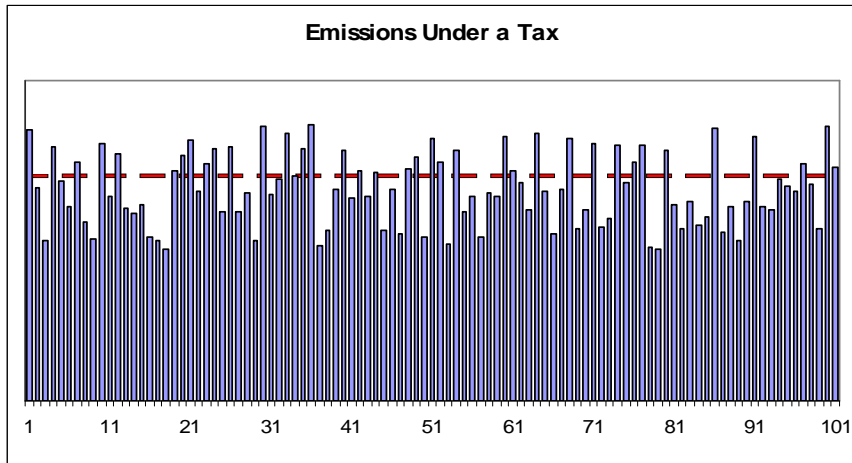
Current State of Affairs

- One current price is \$20/T of carbon dioxide – price paid for sequestering in hard geological formations in continental US – a provision in the first stimulus package signed by President Bush up to roughly \$1.5 billion per year.
- There are some markets around (e.g. Reggie – around \$3-\$5/T of carbon).
- EPA concluded pursuant to the “endangerment finding” that the range of estimates of the social cost of carbon range could be presented by four alternatives: \$5; \$21; \$35 and \$65 per ton of CO₂ for 2007 in 2007\$ – Anthoff, et al. (2009): \$70 – In both, the price increases over time at 2%-4% per year.

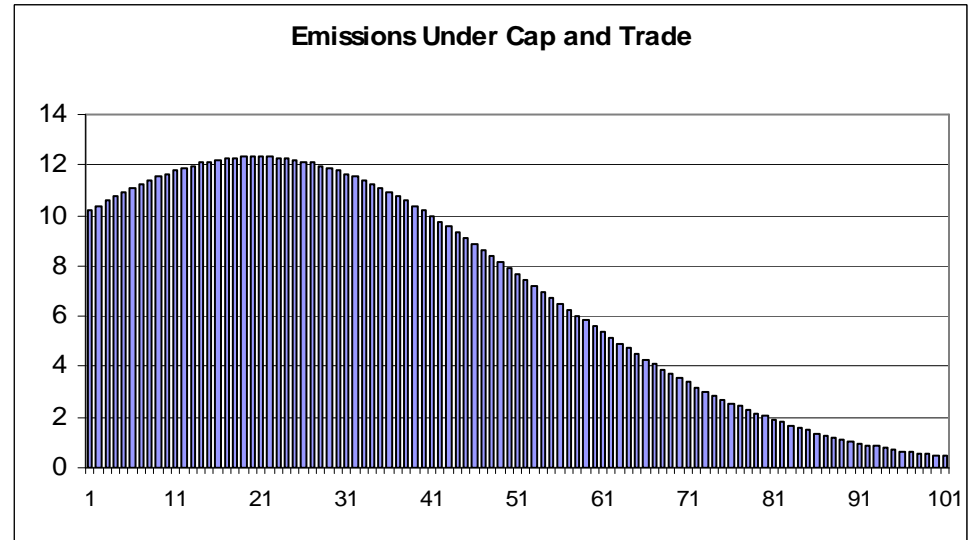
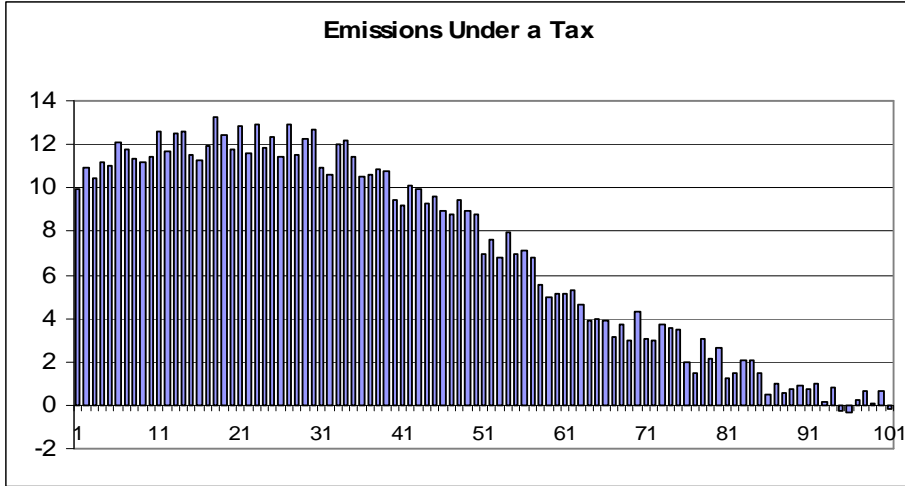
Policy Design – Permits versus Taxes

- Cap and trade schemes are preferred to taxes when variability in emissions increases expected damages – e.g., SO_x emissions. They allow the maximum amount of flexibility subject to the constraint that total emissions are fixed; the price of permits varies.
- Taxes are preferred when variability does not matter too much because they
 - Allow maximally efficient flexibility in quantity with certain price
 - Are easier to administer
- Variability in carbon emissions cause no *additional* harm because cumulative emissions determine concentrations.
- The atmosphere does the the requisite smoothing.
- Taxes do not mask the persistent long term trend with interannual variability.

Variability Hurts for Sulfur Emissions



These Two Trajectories are Equivalent for Climate Policy



So

- *There is no fundamental economic reason to use cap and trade (for which the price trajectory could be uncertain) rather than a tax (that increases predictably over time and thereby reduces the policy uncertainty facing investors in new energy supply and carbon sequestration technologies).*
- *The critical component of the policy is that the price increases predictably and persistently and visibly over relatively long periods of time (at the rate of interest or the anticipated rate of increase of the social cost of carbon).*

And

- *A tax applied to carbon at the points its entry into the economy is simpler to administer than cap-and-trade imposed at the points (orders of magnitude greater in number) where it leaves the economy.*
- *Caveat – the cap-and-trade market does, to first approximation, undo any distortions that Congress might create when it designs the system; distortions caused by Congress in its design of a tax system are permanent.*

Policy Design – What to do with the Revenue from a Carbon Tax

- What to do with the revenue {up to \$120 billion in US in 2011 at \$15 per tonne of CO₂ to get to \$30 per tonne by early the 2020's at 5% per year}:
 - Invest in R&D on new technologies (pure science and applied development programs)
 - Buy back sequestered carbon (at the same price) to create the correct incentives
 - Offer income tax credits for low income families (even if they currently owe no tax)
 - Offer medium term help for those connected to industries that are vulnerable to climate policy – but not so that they can continue to do what they are doing.
- ***Overcome the allergic reaction to “taxes” ???***

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