Coping with Uncertainty and Risk within the EPA

Steven Rose

(US EPA)

Outline

- Backdrop
- Default problem statement
- Uncertainties
- State of knowledge
- Benefits for incremental emissions reductions
- Non-incremental reductions
- Cost uncertainty

Backdrop

- Supreme Court decision – Under the Clean Air Act, EPA must make an endangerment determination regarding GHGs from vehicles
- President Bush's 20-in-10 policy – 20% reduction in gasoline consumption in 10 years
- 9th Circuit Court decision – DOT's implied zero marginal benefit value is arbitrary and capricious
- Proposed standards – DOT vehicle efficiency, DOE appliance efficiency, EPA renewable fuels standard (forthcoming)
- EPA Advanced Notice of Proposed Rulemaking – GHG regulation and the Clean Air Act
- DOI Endangered Species Act listing of polar bears
- Climate legislative proposals
- President Bush: "Yet even if we reduced our own emissions to zero tomorrow, we would not make a meaningful dent in solving the problem without concerted action by all major economies" (April 6, 2008).

Default problem statement

- Maximize welfare (MB = MC)
- But…substantial uncertainty
  - Undermines application of CBA criteria for efficiency, and even positive net benefits
- Also, who's welfare?
  - Domestic decision-makers and a global externality imply sub-optimal climate decisions

Uncertainties

- Socioeconomic
  - Demographics
  - Elasticities
  - Preferences
  - Technological – e.g., costs, R&D, diffusion, current vs. new technology
  - Resource availability and productivity
- Emissions and sequestration
- Biophysical response – e.g., climate, carbon cycle, nitrogen cycle, biogeophysical, terrestrial
- Impacts – net effects, feedbacks
- Policy – climate and non-climate
- Historic vs. projected uncertainty

Benefits of incremental GHG emissions reductions?

- Confronted by policies with incremental reductions in global emissions – e.g., 1%/yr CO2 starting around 2010

  - Is there a measurable benefit?
  - Is there a climate signal?
    - Answer could have significant legal implications
  - Is there a value?

Climate signal? Not looking too good.

MULTI-MODEL AVERAGES AND ASSESSED RANGES FOR SURFACE WARMING

©IPCC 2007: WG1-AR4
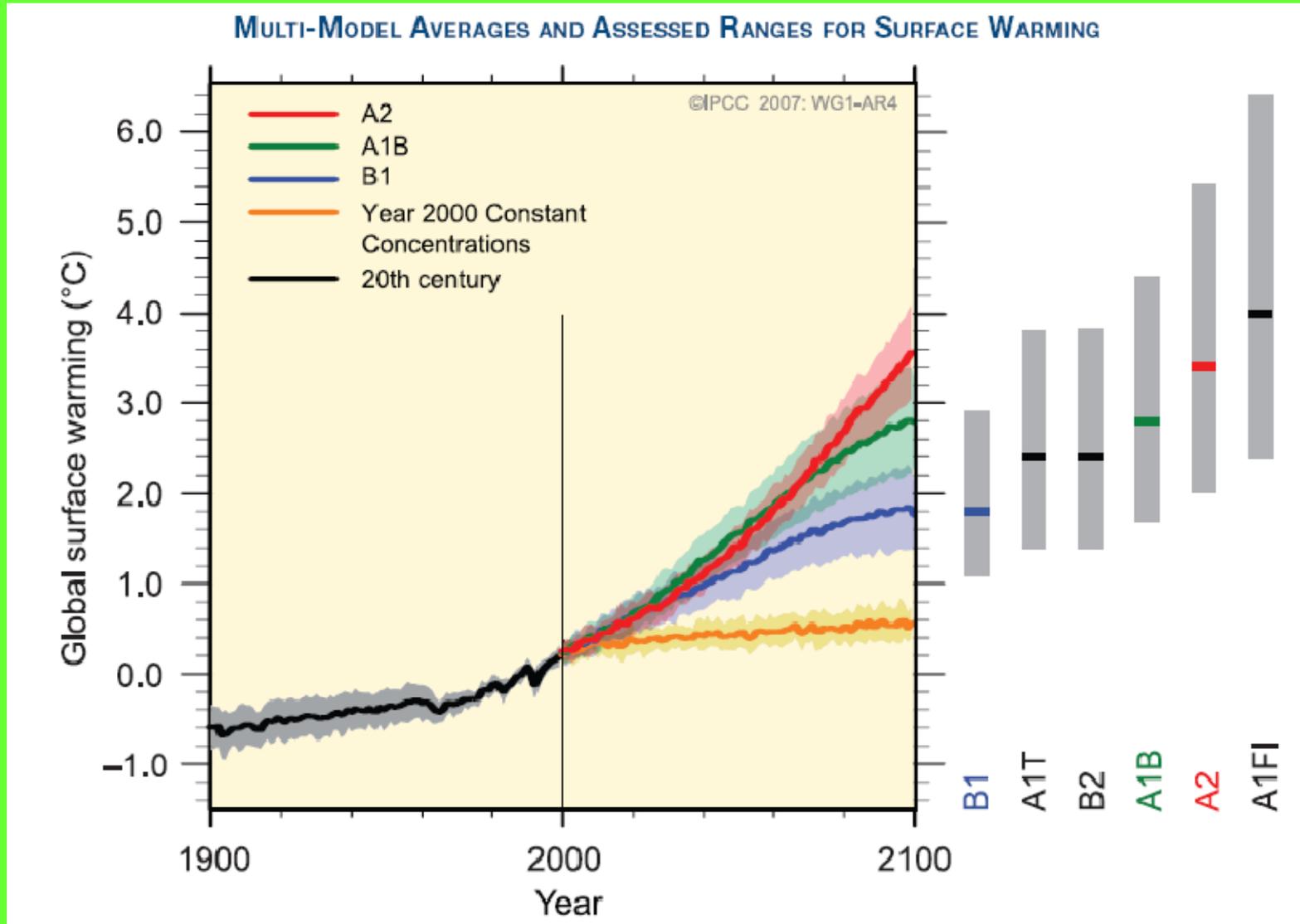
Climate signal?
Shifting the distribution
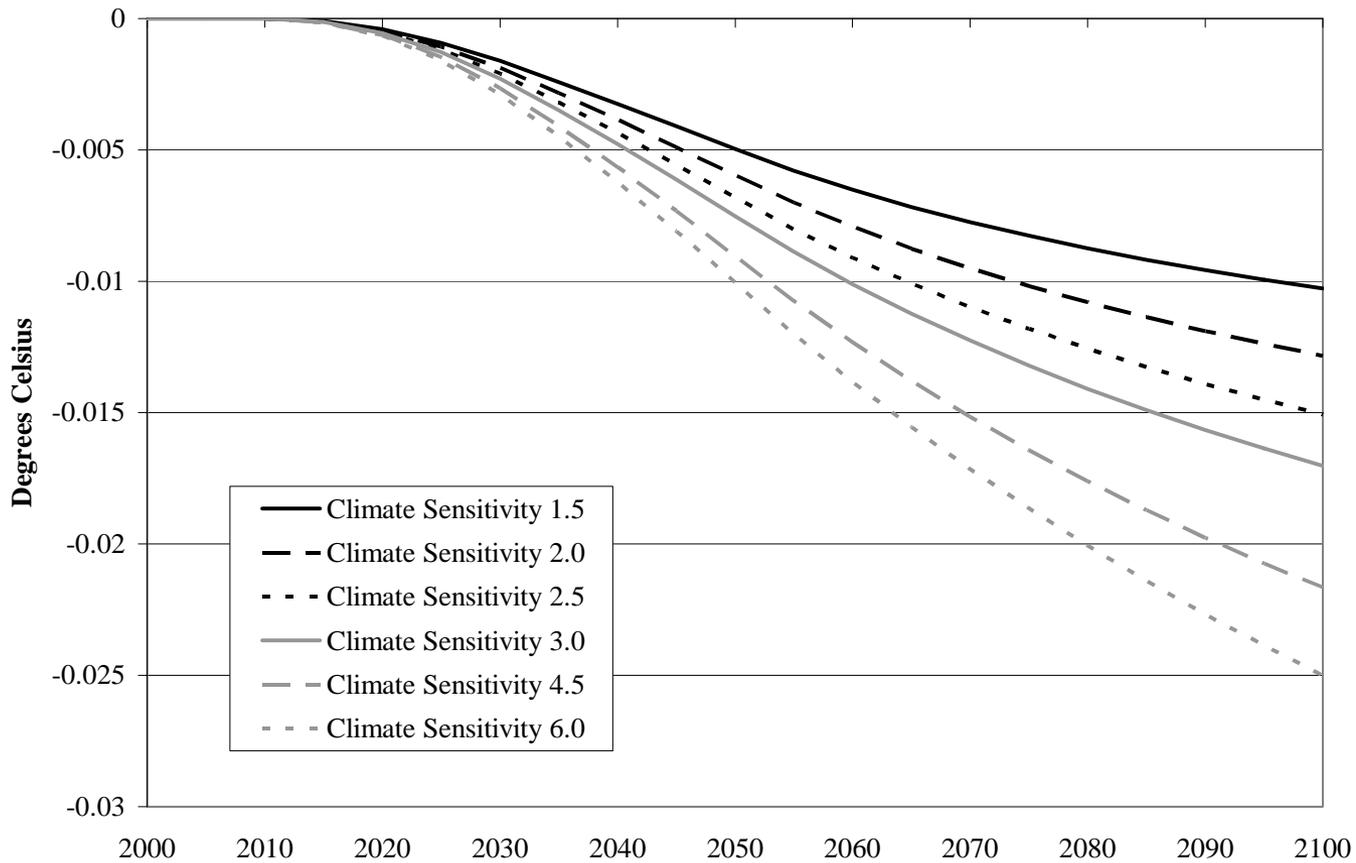
Clamoring for a number

The number is…

(drum role please)

4.75

units?

(my son's age)

A value? A metric?

- Projected net GHG emissions reductions incremental to total global emissions
- Projected global climate signal incremental, but discernable (e.g., shift in the distribution of projected GMST)
- Conceptually appropriate to consider the social cost of carbon (SCC)
  - SCC = the net present value of climate change impacts over 100+ years of one additional net global ton of GHGs emitted to the atmosphere at a particular point in time.
  - Conceptually appropriate metric for monetizing the benefits of _incremental_ global GHG emissions reductions
- Estimating the SCC requires global modeling frameworks with consistent integrated socioeconomics, emissions, climate change, and impacts
  - Model global emissions? You've got to be kidding.
  - Inherently, large uncertainties
  - Current capability limited to aggregated integrated models due to data limitations
- Global SCCs are all that exist in the peer reviewed literature
  - A global SCC value internalizes the global and temporal externality of U.S. GHG emissions/reductions
- Also asked to develop domestic SCC estimates

Developed two sets of marginal benefit estimates (i.e., the social cost of carbon)

1. Refined IPCC/Tol global meta analysis range
   - Refined Tol (2005) and Tol (2008) meta analyses – Tol (2005) used in IPCC (2007)
   - Subset of estimates considered: peer reviewed, approximately 2-3% consumption discount rates, more recent studies (> 1995), un-weighted (i.e., unity weighted) regional aggregations

2. Consistent set of domestic & global ranges based on the FUND model
   - Ability to define assumptions & sensitivities
     - Ramsey discounting with consumption discount rates calibrated to approximately 2% & 3%* to match inter-generational discounting guidance, and 7% per OMB request
     - IPCC (2007) climate sensitivity range:
       - 1.5°C to 6.0°C (IPCC "likely" range is 2°C to 4.5°C, "very unlikely" to be less than 1.5°C, and "values substantially higher than 4.5°C cannot be excluded")
     - Socioeconomic and emissions baselines: FUND and IPCC SRES: A1b, A2, and B2 (B1 considered a policy case so not used)
     - EPA value of statistical life = $4.8 million (1990$)
     - Global estimate is the un-weighted sum of regional estimates
   - Best available estimates given current modeling frameworks. Future work to update parameters where possible and evaluate omitted impacts is planned.

Actual consumption discount rates vary by region and time period. For example, the 2005 consumption discount rates ranged from 1.8 – 5.5% across regions and baselines (and from 2.7 – 2.9% for the U.S.)

Refined meta analysis range
(for emissions reductions in 2005)

*Fisher-Tippett kernal estimate of the
probability density functions*
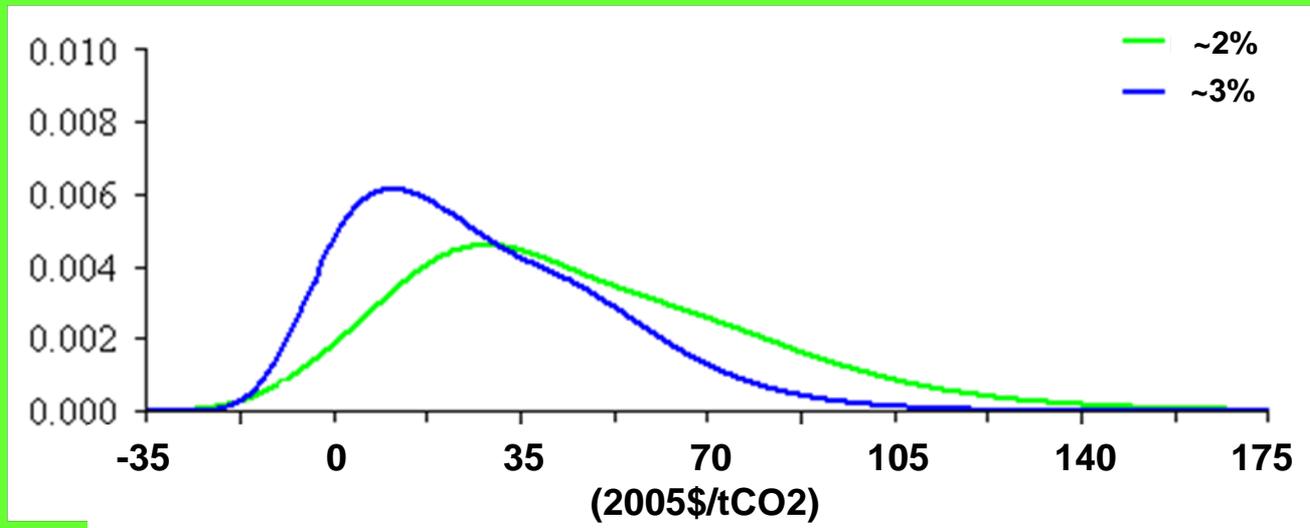
Summary of EPA estimates
(various emissions years and discount rates, 2006$)

		~ 2%			~ 3%			~ 7%		
		Low	Central	High	Low	Central	High	Low	Central	High
Meta global	2007	-3	68	159	-4	40	106	n/a	n/a	n/a
FUND global	2007	-6	88	695	-6	17	132	-3	-1	5
FUND domestic	2007	0	4	16	0	1	5	0	0	0

- Meta: Low (5th), Central (mean), High (95th)
- FUND: Low and High (min and max from the sensitivity analysis), Central (weighted average)

Summary of EPA estimates
(various emissions years and discount rates, 2006$)

		~ 2%			~ 3%			~ 7%		
		Low	Central	High	Low	Central	High	Low	Central	High
Meta global	2007	-3	68	159	-4	40	106	n/a	n/a	n/a
	2017	-2	91	213	-3	53	142	n/a	n/a	n/a
	2022	-2	105	247	-2	62	165	n/a	n/a	n/a
	2030	-1	134	314	-2	78	209	n/a	n/a	n/a
	2040	-1	179	421	-1	105	281	n/a	n/a	n/a
FUND global	2007	-6	88	695	-6	17	132	-3	-1	5
	2017	-4	118	934	-4	23	178	-2	-1	7
	2022	-4	136	1083	-4	26	206	-2	-1	9
	2030	-3	173	1372	-3	33	261	-1	0	11
	2040	-2	232	1843	-2	44	351	-1	0	15
FUND domestic	2007	0	4	16	0	1	5	0	0	0
	2017	0	6	22	0	1	7	0	0	0
	2022	0	7	26	0	2	9	0	0	0
	2030	0	9	32	0	2	11	0	0	0
	2040	0	12	44	0	3	15	0	0	0

- Estimates for reductions in subsequent years are higher due to a larger marginal effect on net damages (IPCC suggests 2-4%/yr; 3% applied above)
- DOT and DOE proposed rule estimates: $7/tCO2 in 2011 (2006$), range $0 - $14

Difficult to apply in setting standards

- Ranges of estimates are appropriate, based on alternative assumptions of key scientific and economic parameters
  - Appropriate to reflect results from multiple models

- "Very likely" underestimated due to omitted impacts, including non-market values and the value of changes in the likelihood of threshold impacts (e.g., species extinction, catastrophic events) or weather variability

- Deterministic estimates, not capturing changes in risk

- Data deficiencies – data not available for every major region (transfer assumptions used), more aggregate relationships modeled (e.g., global mean temperature changes and national net agricultural impacts)

- Direct benefits captured, not capturing global economic & social feedbacks, nor domestic WTP for international impacts or potential implications for other country action

- Estimates changing over time and non-CO2 gases have different values

- The estimates are relevant for incremental policies off of the baseline, they are not estimates of "optimal" marginal benefits

FUND impacts

- A variety of impacts are not modeled in FUND, many due to data limitations (primarily physical data), some impacts based on older studies

Table 2: Lists of Impacts Modeled and Omitted from Current FUND Modeling

Impacts currently modeled in FUND	Examples of impacts omitted from current FUND modeling*
- Agricultural production - Forestry production - Water resources - Energy consumption for space cooling & heating - Sea level rise dry land loss, wetland loss, and coastal protection costs - Forced migration due to dry land loss - Changes in human health (mortality, morbidity) associated with diarrhea incidence, vector-borne diseases, cardiovascular disorders, and respiratory disorders - Hurricane damage - Loss of ecosystems/biodiversity	- Catastrophic events (e.g., Antarctic ice sheet collapse) - Risks from extreme weather (e.g., death, disease and economic damage from droughts, floods, and fires) - Air quality degradation (e.g., increased ozone effects including premature mortality, forest damage) - Increased infrastructure costs (e.g., water management systems, roads, bridges) - Increased insurance costs - Social and political unrest abroad that affects U.S. national security - Damage to foreign economies that affects the U.S. economy - Domestic valuation of international impacts - Costs from uncertainty and changes in risk - Arctic sea ice melt and global transportation & trade

* A comprehensive review of included and omitted impact categories in current marginal benefits modeling is planned.

Can uncertainty analysis help?

- Boil it down to a single number
    - Robust enough for setting standards?
    - Not likely to ever pin down the correct estimate

- However, valuable for valuing changes in risk

- What uncertainties can be meaningfully characterized?

- In our plans…

Thinking about trade-offs across global impacts
(Estimates higher with A2 baseline, lower with A1b)

Preliminary FUND global marginal benefits by sector, climate sensitivity (CS), and discount rate for marginal change in emissions in 2005 (assuming FUND baseline)
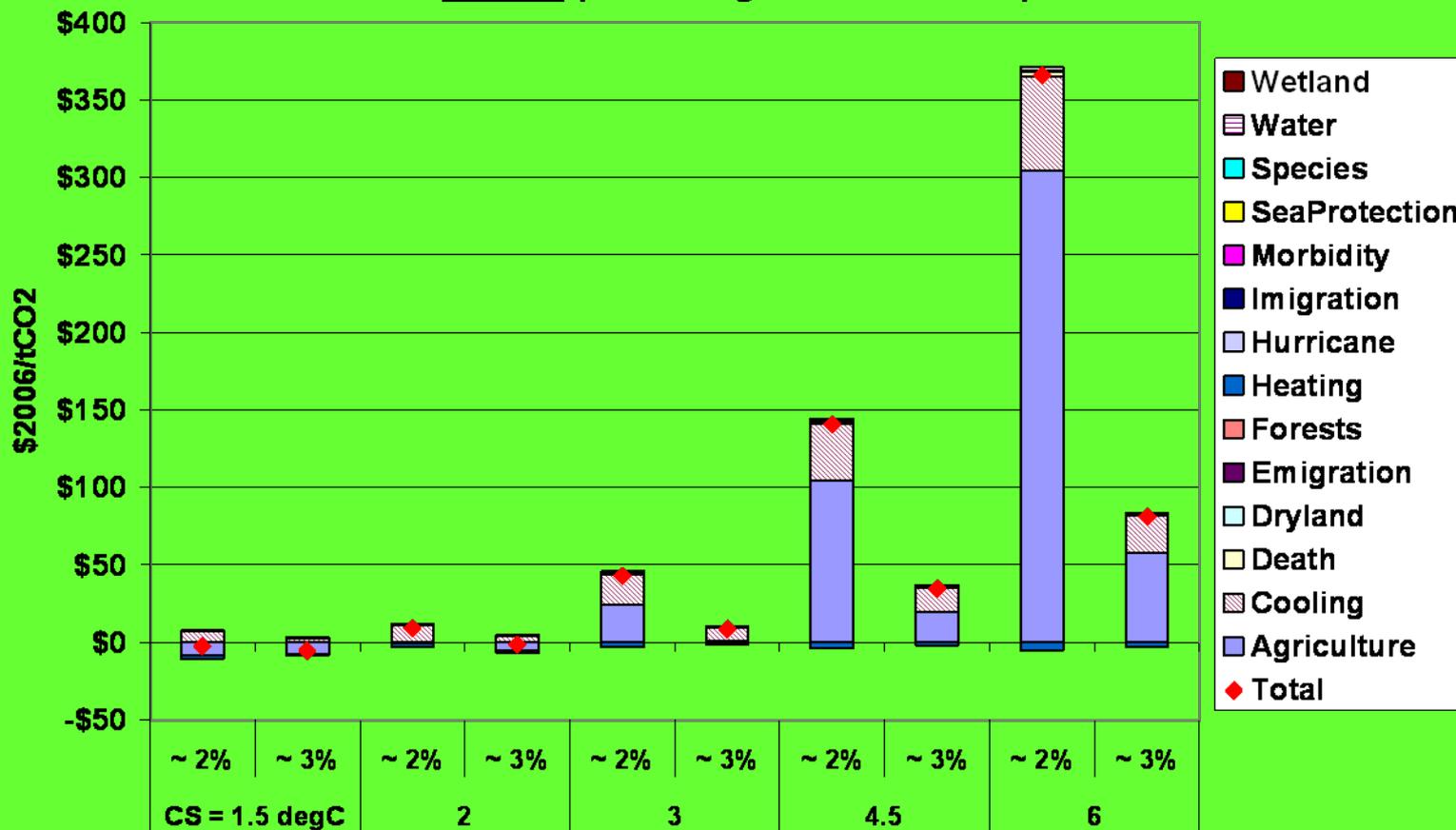
Thinking about trade-offs across US impacts
(Estimates higher with A2 baseline, lower with A1b)

Preliminary FUND US marginal benefits by sector, climate sensitivity (CS), and discount rate for marginal change in emissions in 2005 (assuming FUND baseline)
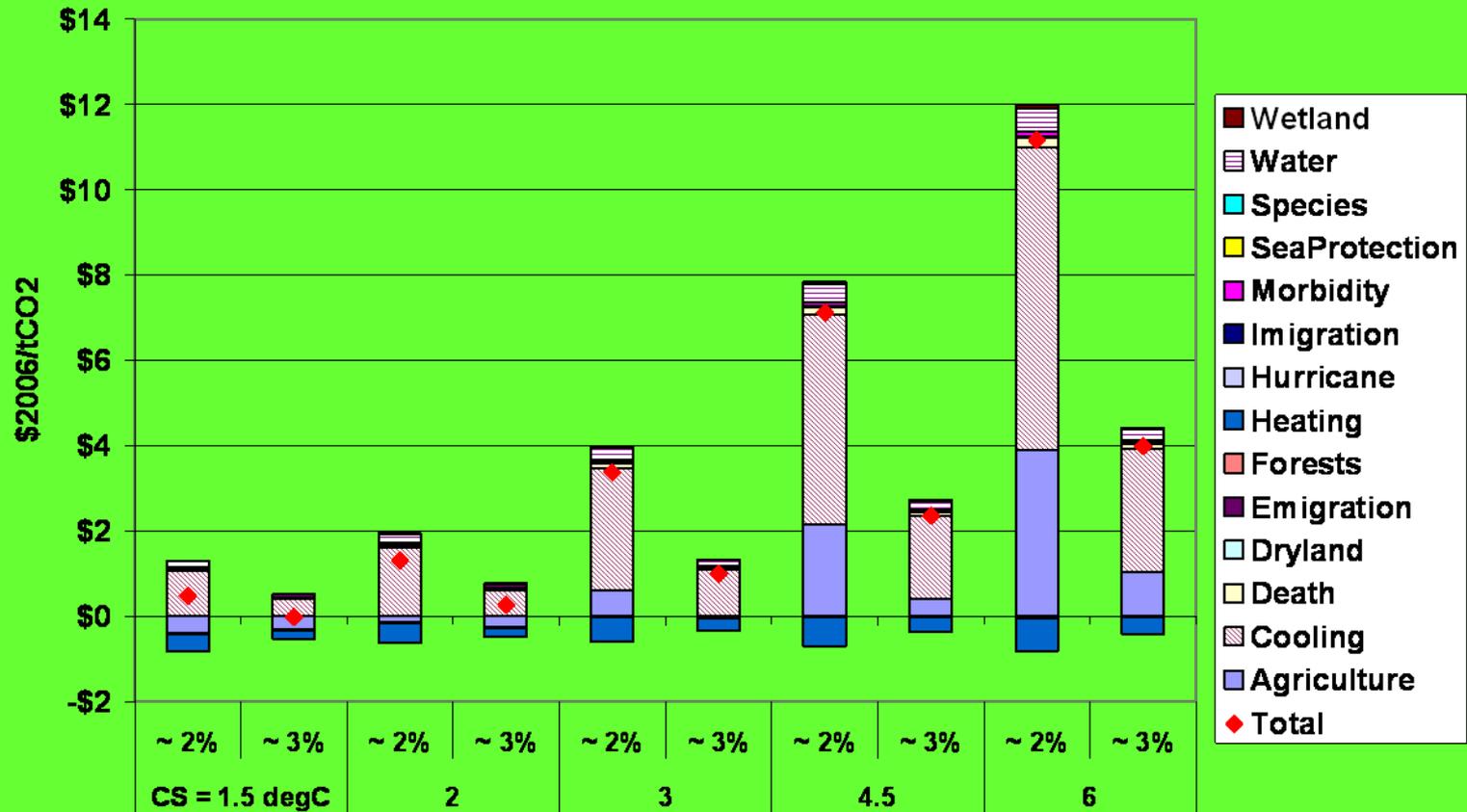
Non-incremental policies

- "What is the cost of inaction?"
- "What are the benefits of legislative proposals?"

- Tough to lean on the information available for quantifying benefits

- Optimal price path? Conceptually attractive, but given uncertainties (quantified and unquantified) difficult to believe that true social optimum

- More structural, integrated assessment frameworks are needed that capture biophysical and economic feedbacks
  - Combined with complementary domestic bottom-up analyses

State of knowledge

- Not a sliding scale

Global average annual temperature change relative to 1980-1999 (°C)

WATER
- Increased water availability in moist tropics and high latitudes
- Decreasing water availability and increasing drought in mid-latitudes and semi-arid low latitudes
- Hundreds of millions of people exposed to increased water stress

ECOSYSTEMS
- Up to 30% of species at increasing risk of extinction — Significant† extinctions around the globe
- Increased coral bleaching — Most corals bleached — Widespread coral mortality
- Terrestrial biosphere tends toward a net carbon source as: ~15% — ~40% of ecosystems affected
- Increasing species range shifts and wildfire risk
- Ecosystem changes due to weakening of the meridional overturning circulation

FOOD
- Complex, localised negative impacts on small holders, subsistence farmers and fishers
- Tendencies for cereal productivity to decrease in low latitudes — Productivity of all cereals decreases in low latitudes
- Tendencies for some cereal productivity to increase at mid- to high latitudes — Cereal productivity to decrease in some regions

COASTS
- Increased damage from floods and storms
- About 30% of global coastal wetlands lost‡
- Millions more people could experience coastal flooding each year

HEALTH
- Increasing burden from malnutrition, diarrhoeal, cardio-respiratory and infectious diseases
- Increased morbidity and mortality from heat waves, floods and droughts
- Changed distribution of some disease vectors
- Substantial burden on health services

† Significant is defined here as more than 40%.   ‡ Based on average rate of sea level rise of 4.2mm/year from 2000 to 2080.

State of knowledge

Category	CO$_2$ concentration at stabilisation (2005 = 379 ppm)[b]	CO$_2$-equivalent concentration at stabilisation including GHGs and aerosols (2005 = 375 ppm)[b]	Peaking year for CO$_2$ emissions[a,c]	Change in global CO$_2$ emissions in 2050 (percent of 2000 emissions)[a,c]	Global average temperature increase above pre-industrial at equilibrium, using 'best estimate' climate sensitivity[d,e]	Global average sea level rise above pre-industrial at equilibrium from thermal expansion only[f]	Number of assessed scenarios
	ppm	ppm	year	percent	°C	metres	
I	350 – 400	445 – 490	2000 – 2015	-85 to -50	2.0 – 2.4	0.4 – 1.4	6
II	400 – 440	490 – 535	2000 – 2020	-60 to -30	2.4 – 2.8	0.5 – 1.7	18
III	440 – 485	535 – 590	2010 – 2030	-30 to +5	2.8 – 3.2	0.6 – 1.9	21
IV	485 – 570	590 – 710	2020 – 2060	+10 to +60	3.2 – 4.0	0.6 – 2.4	118
V	570 – 660	710 – 855	2050 – 2080	+25 to +85	4.0 – 4.9	0.8 – 2.9	9
VI	660 – 790	855 – 1130	2060 – 2090	+90 to +140	4.9 – 6.1	1.0 – 3.7	5

- Model uncertainty, not uncertainty

Managing Risk

- What level of risk is "acceptable?"
  - What metric? Concentrations, temperature change, or impacts?
  - If defined, carbon prices are the shadow price for benefits.
  - Will include non-economic and non-scientific considerations
- Need to quantify the effects of mitigation and adaptation on uncertainty and risk

Cost uncertainties

E.g.,
- Model uncertainty
- Policy
  - International action
  - Program design
- Technology
- Reference

Source: USEPA Analysis of Senate Bill S.2191 (http://www.epa.gov/climatechange/economics/economicanalyses.html)

Table: Allowance Price Comparison (2005 $/tCO2e)

	2015	2020	2025	2030	2035	2040	2045	2050
1) EPA Reference								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2) S. 2191								
ADAGE	$29	$37	$48	$61	$77	$98	$125	$159
IGEM	$40	$51	$65	$83	$106	$135	$173	$220
3) S.2191 w/ Low International Action								
ADAGE	$27	$35	$44	$56	$72	$92	$117	$149
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4) S.2191 w/ Unlimited Offsets								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	$11	$15	$19	$24	$30	$39	$50	$63
5) S.2191 w/ No Offsets								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	$77	$98	$126	$160	$205	$261	$333	$425
6) S.2191 Constrained Nuclear & Biomass								
ADAGE	$39	$49	$63	$80	$101	$129	$164	$208
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7) S.2191 Constrained Nuclear & Biomass, and CCS								
ADAGE	$55	$69	$88	$112	$142	$181	$229	$290
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8) S.2191 Constrained Nuclear & Biomass, and CCS + Beyond Kyoto + Natural Gas Cartel								
ADAGE	$55	$70	$88	$112	$142	$180	$228	$288
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
9) Alternative Reference								
ADAGE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
IGEM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
10) S.2191 Alt. Ref.								
ADAGE	$22	$28	$36	$46	$59	$75	$95	$121
IGEM	$35	$45	$57	$73	$93	$118	$151	$193

Summary

- Currently sensitivity analyses
- Uncertainty analysis
  - Can we boil it down to a defensible value?
  - Ranking policies vs. optimal policy
  - Particularly valuable for quantifying changes in risk (and valuing those changes)
- What are the key uncertainties?
  - Depends on the question
  - Depends on the platform
  - Different uncertainties at different scales
    - Need to characterize
    - Which at one scale confound utility of information at another scale

Reading list

- Advance Notice of Proposed Rulemaking: Regulating Greenhouse Gas Emissions under the Clean Air Act (http://www.epa.gov/climatechange/anpr.html)
  - Technical Support Document on the Benefits of Reducing GHG Emissions (www.regulations.gov)
  - Draft Technical Support Document - Endangerment Analysis for Greenhouse Gas Emissions under the Clean Air Act (www.regulations.gov)
- USEPA Analysis of Senate Bill S.2191 (http://www.epa.gov/climatechange/economics/economicanalyses.html)
- DOT (NHTSA) Average Fuel Economy Standards, Passenger Cars and Light Trucks, MY 2011-2015 (http://www.nhtsa.dot.gov/portal/site/nhtsa/menuitem.43ac99aefa80569eea57529cdba046a0/)

Extra slides

Crosswalk to Tol (2005) SCC estimates

- Adjusting Tol's composite density function mean to 2006\$, CO_2 units, and later emissions years (using 3% growth)

	Tol (2005) mean	Meta Central			FUND Central		
		~ 2%	~ 3%	~ 7%	~ 2%	~ 3%	~ 7%
2007	25	68	40	n/a	88	17	-1
2017	33	91	53	n/a	118	23	-1
2022	38	105	62	n/a	136	26	-1
2030	49	134	78	n/a	173	33	0
2040	65	179	105	n/a	232	44	0

- Remaining differences from EPA estimates due to:
  - Set of studies considered (we used Tol, 2008)
  - Range of discount rates (Tol covers all discount rates)
  - Non-equity weighted estimates (Tol includes them)
  - Year of study (Tol includes all years)
  - Sensitivity analysis (EPA FUND covers broader range of assumptions)