

Using IA models for policy analysis: recent U.S. experience

JGCRI INTEGRATED ASSESSMENT TECHNICAL WORKSHOP

OCT 21ST, 2014

Cost Effectiveness

Energy Economics

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International, U.S., and E.U. Climate Change

Control Scenarios: Results from EMF 22

Guest Editors: Leon Clarke, Christoph Böhringer
and Thomas F. Rutherford

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CONTENTS

Editorial

- Introduction to the EMF 22 special issue on climate change control scenarios
L. Clarke and J. Weyant S63

International Scenarios

- International climate policy architectures: Overview of the EMF 22 International
Scenarios
L. Clarke, J. Edmonds, V. Krey, R. Richels, S. Rose and M. Tavoni S64

- Feasible climate targets: The roles of economic growth, coalition development
and expectations
G.J. Blanford, R.G. Richels and T.F. Rutherford S82

- Implications of delayed participation and technology failure for the feasibility,
costs, and likelihood of staying below temperature targets—Greenhouse
gas mitigation scenarios for the 21st century
V. Krey and K. Riahi S94

- 2.6: Limiting climate change to 450 ppm CO₂ equivalent in the 21st century
*K. Calvin, J. Edmonds, B. Bond-Lamberty, L. Clarke, S.H. Kim, P. Kyle, S.J. Smith,
A. Thomson and M. Wise* S107

Contents continued on the outside back cover



Includes the Journal of
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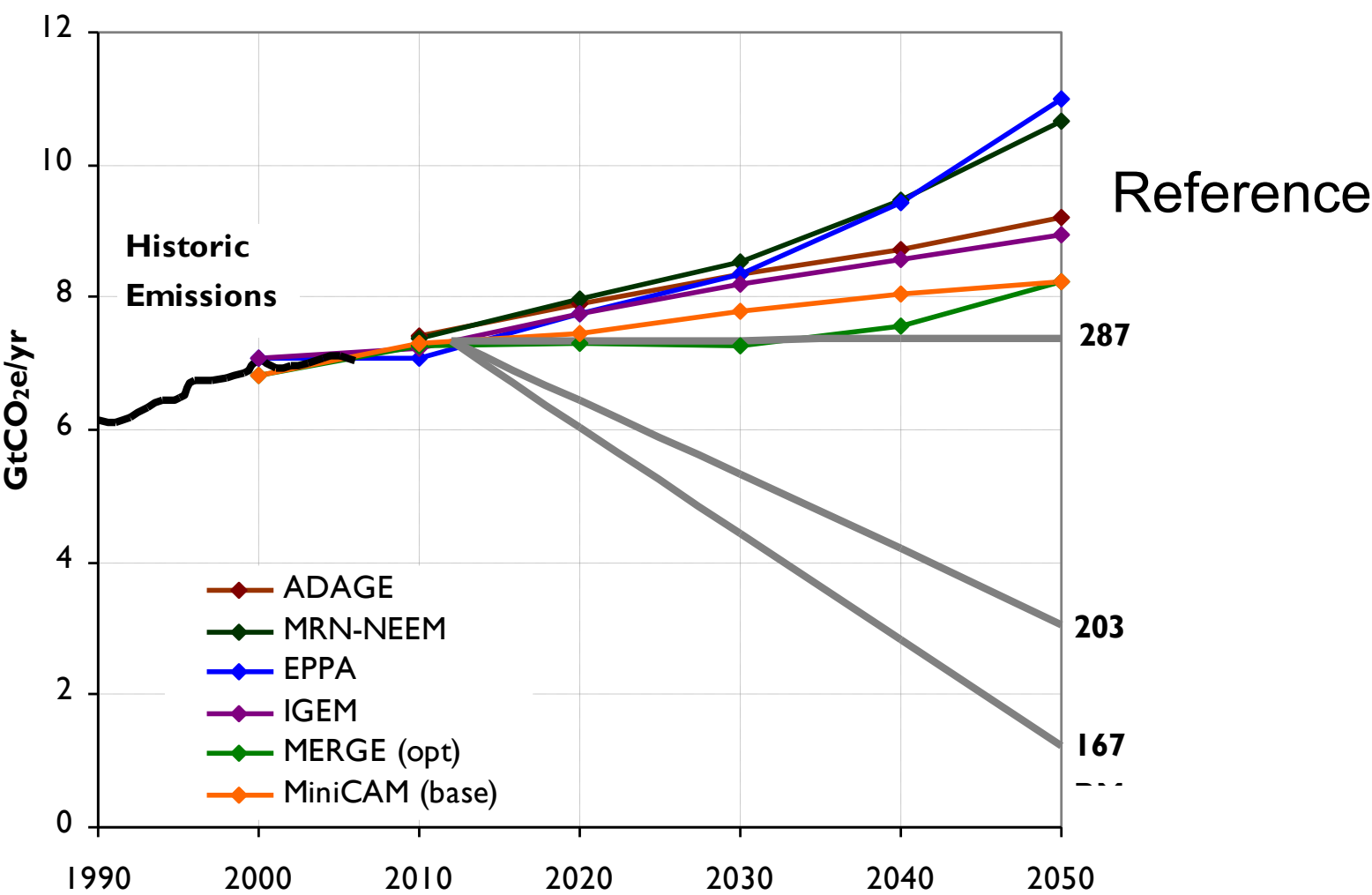


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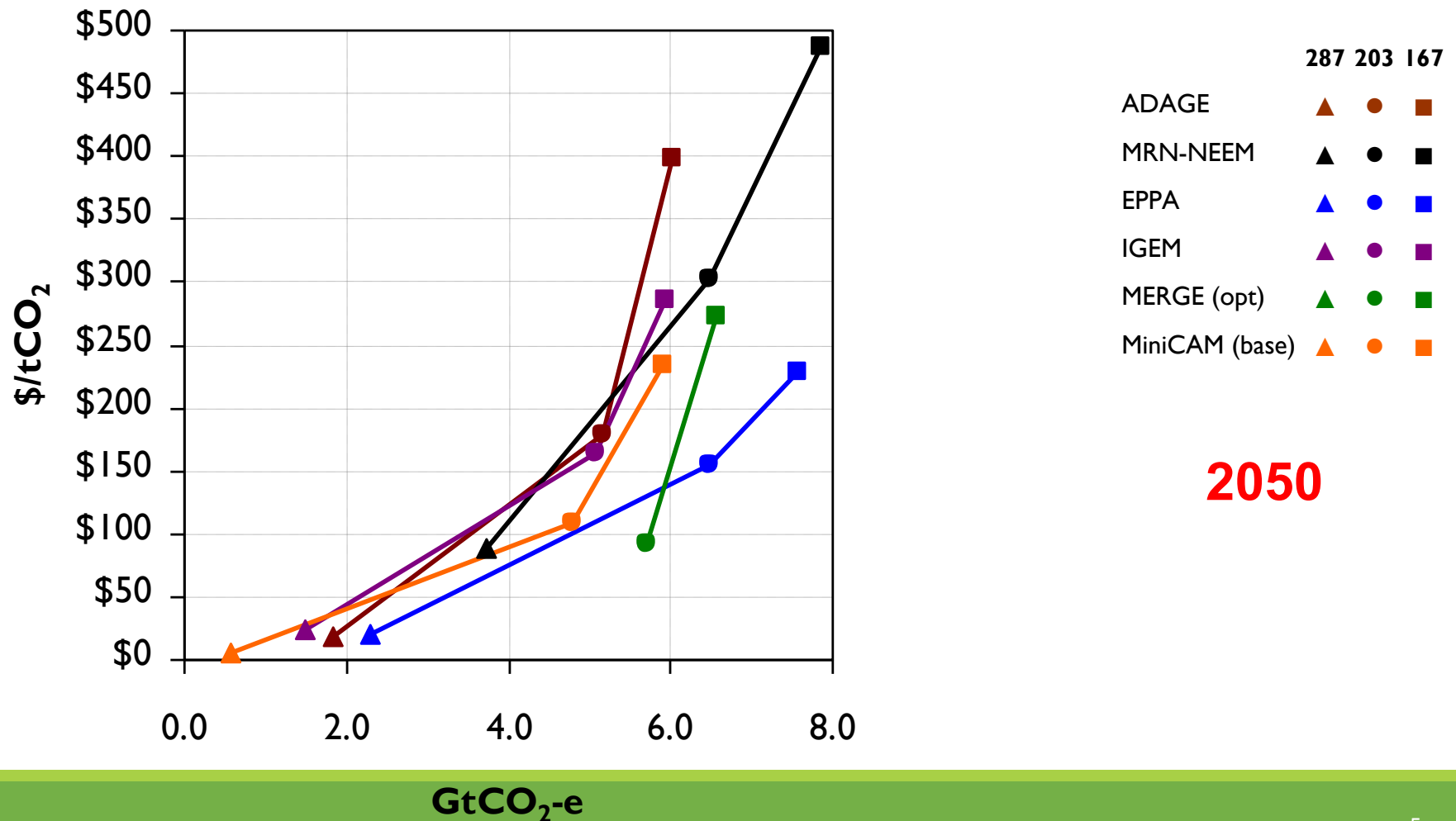
EMF 22

Published 2009

Emissions Pathways across Models



Marginal Abatement Cost Functions



THE ENERGY JOURNAL



THE EMF24 STUDY ON U.S. TECHNOLOGY AND CLIMATE POLICY STRATEGIES

Introduction to EMF 24

Allen A. Fawcett, Leon E. Clarke, and John P. Weyant

Technology and U.S. Emissions Reductions Goals: Results of the EMF 24 Modeling Exercise

Leon E. Clarke, Allen A. Fawcett, John P. Weyant, James McFarland, Vaibhav Chaturvedi, and Yuyu Zhou

Overview of EMF 24 Policy Scenarios

Allen A. Fawcett, Leon E. Clarke, Sebastian Rausch, and John P. Weyant

Interaction Effects of Market-Based and Command-and-Control Policies

Sugandha D. Tuladhar, Sebastian Mankowski, and Paul Bernstein

Technology Assumptions and Climate Policy: The Interrelated Effects of U.S. Electricity and Transport Policy

Mark Jaccard and Suzanne Goldberg

Greenhouse Gas Mitigation Options in the U.S. Electric Sector: A ReEDS Analysis

Patrick Sullivan, Caroline Uriarte, and Walter Short

Investigating Technology Options for Climate Policies: Differentiated Roles in ADAGE

Martin T. Ross, Patrick T. Sullivan, Allen A. Fawcett, and Brooks M. Depro

A Clean Energy Standard Analysis with the US-REGEN Model

Geoffrey J. Blanford, James H. Merrick, and David Young

Assessing the Interactions among U.S. Climate Policy, Biomass Energy, and Agricultural Trade

Marshall A. Wise, Haewon C. McJeon, Katherine V. Calvin, Leon E. Clarke, and Page Kyle

U.S. CO₂ Mitigation in a Global Context: Welfare, Trade and Land Use

Ronald D. Sands, Katja Schumacher, and Hannah Förster

Markets versus Regulation: The Efficiency and Distributional Impacts of U.S. Climate Policy Proposals

Sebastian Rausch and Valerie J. Karplus

Impacts of Technology Uncertainty on Energy Use, Emission and Abatement Cost in USA: Simulation results from Environment Canada's Integrated Assessment Model

Yunfa Zhu and Madanmohan Ghosh

EMF 24

Published 2014

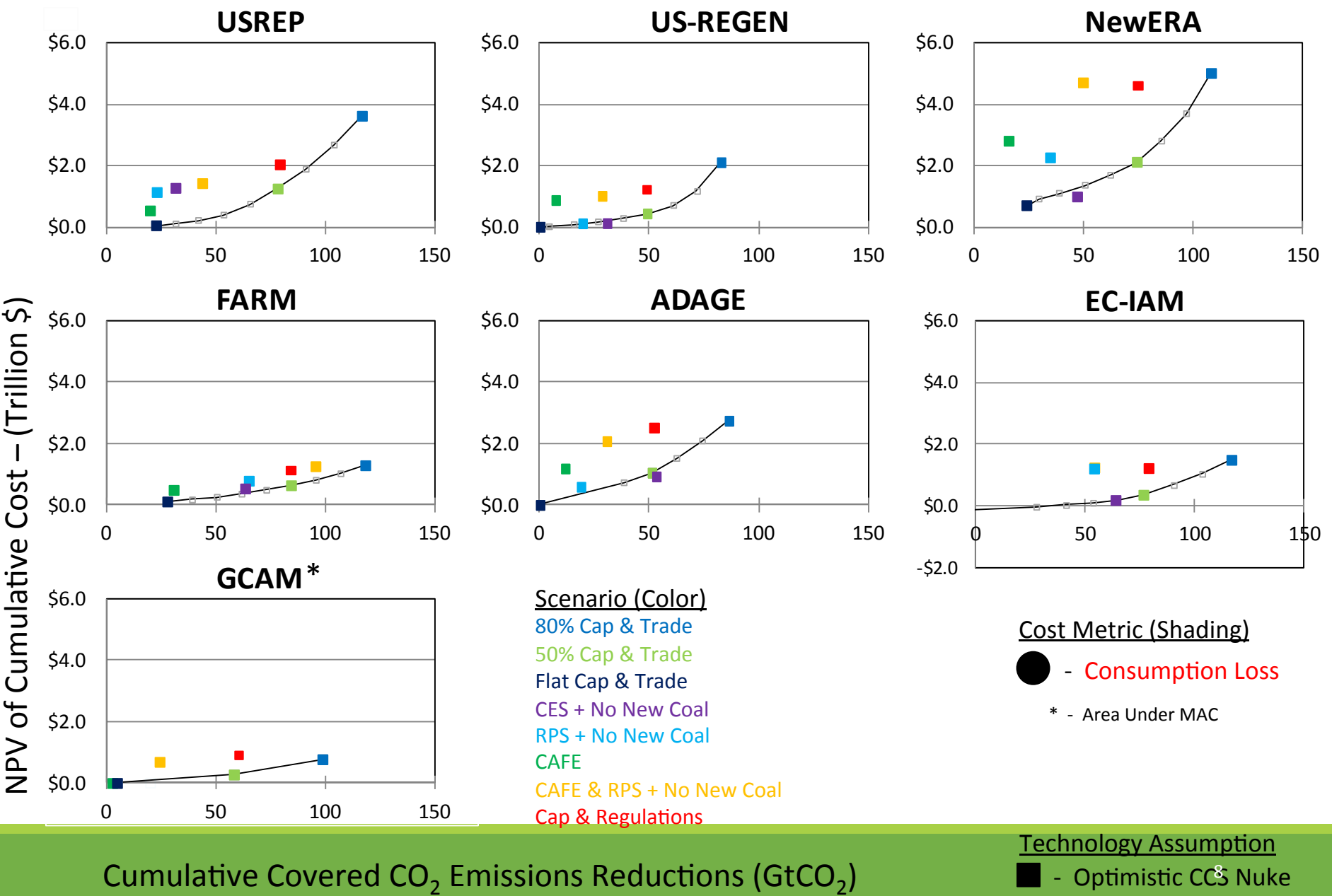
Overview of Scenarios

Technology								
	Optimistic	Single Technology Sensitivities				Combined Sensitivities		Pessimistic
End Use Technology	Optimistic	Pessimistic	Optimistic	Optimistic	Optimistic	Optimistic	Pessimistic	Pessimistic
CCS	Optimistic	Optimistic	Pessimistic	Optimistic	Optimistic	Pessimistic	Optimistic	Pessimistic
Nuclear energy	Optimistic	Optimistic	Optimistic	Pessimistic	Optimistic	Pessimistic	Optimistic	Pessimistic
Wind & Solar	Optimistic	Optimistic	Optimistic	Optimistic	Pessimistic	Optimistic	Pessimistic	Pessimistic
Bioenergy	Optimistic	Optimistic	Optimistic	Optimistic	Pessimistic	Optimistic	Pessimistic	Pessimistic
Policy Dimension								
Baseline								
0% Cap & Trade								
10% Cap & Trade								
20% Cap & Trade								
30% Cap & Trade								
40% Cap & Trade								
50% Cap & Trade								
60% Cap & Trade								
70% Cap & Trade								
80% Cap & Trade								
Transportation								
Electricity (RPS)								
Electricity (CES)								
Sectoral Policies (RPS & CAFE)								
Sectoral Policies + 50% Cap & Trade								

LEGEND

Baseline Scenarios
Cap & Trade Scenarios
Regulatory Scenarios
Combined Scenarios

Net Present Value of Cumulative Cost vs. Cumulative Abatement



Social Cost of Carbon (SCC)

What is the Social Cost of Carbon?

- The SCC provides a measure of the marginal damage from CO₂ emissions – and thus the marginal benefit of abatement.
 - The SCC is the theoretically consistent value to compare with the marginal cost of abatement in benefit cost analysis.
- Specifically, the SCC is the monetized value of future worldwide economic damages associated with a one-ton increase in CO₂ emissions in a particular year discounted to the present.
 - This is identical to the avoided damages associated with a one-ton decrease.
- It is intended to be a comprehensive measure of climate change damages, including (but not limited to):
 - changes in net agricultural productivity
 - net energy demand
 - human health
 - property damages from increased flood risk
 - the value of ecosystem services.

Why do we need an estimate of SCC?

- Setting the stringency of regulations requires a framework for comparing benefits and costs.
 - Benefit-cost analysis (BCA) provides a consistent framework for comparing regulatory designs that have both different costs and emission reductions of multiple pollutants.
- Since 1981, BCA must be conducted for all significant U.S. Federal regulations (E.O. 12866)
- The SCC is an estimate of the benefits of reducing emissions of CO₂, which allows those benefits to be considered in BCA.
 - Without a SCC, the benefit to society of reducing CO₂ emissions are treated as zero –effectively ignoring climate change damages.
- In 2008, the Ninth Circuit Court remanded a fuel economy rule to DOT for failing to monetize CO₂ reductions in the RIA.
 - The court stated, “[w]hile the record show that there is a range of values, the value of carbon emissions reduction is certainly not zero.”

Overview of USG SCC Analytic Process

- Used 3 “integrated assessment models” (IAMs) - PAGE, DICE, and FUND models - each given equal weight
- Applied a common set of assumptions in each model for:
 - Trajectories of future population, economic growth and CO₂ emissions
 - Equilibrium climate sensitivity – a measure of the climate system’s response to increased concentrations of GHGs in the atmosphere
 - Discount rates
- All other features of the IAMs were left unchanged
- It was decided the SCC used for Federal rulemaking should reflect global damages from CO₂ emissions, not just those that would occur in the U.S.

Integrated Assessment Models (IAMs)

- IAMs combine climate processes, economic growth, and feedbacks between the two in a single modeling framework
 - IAMs are highly simplified representations of the potential economic damages from climate change and limited by the current state of research
 - Despite their inherent uncertainties and limitations, they are the best tools currently available for estimating the SCC
- DICE, FUND, and PAGE are by far the most widely used and widely cited IAMs that can link physical impacts to economic damages for the purposes of estimating SCC (NAS 2010, Tol 2008)
 - Other IAMs generally do not include damage functions (e.g., MIT's IGSM and PNNL's GCAM)

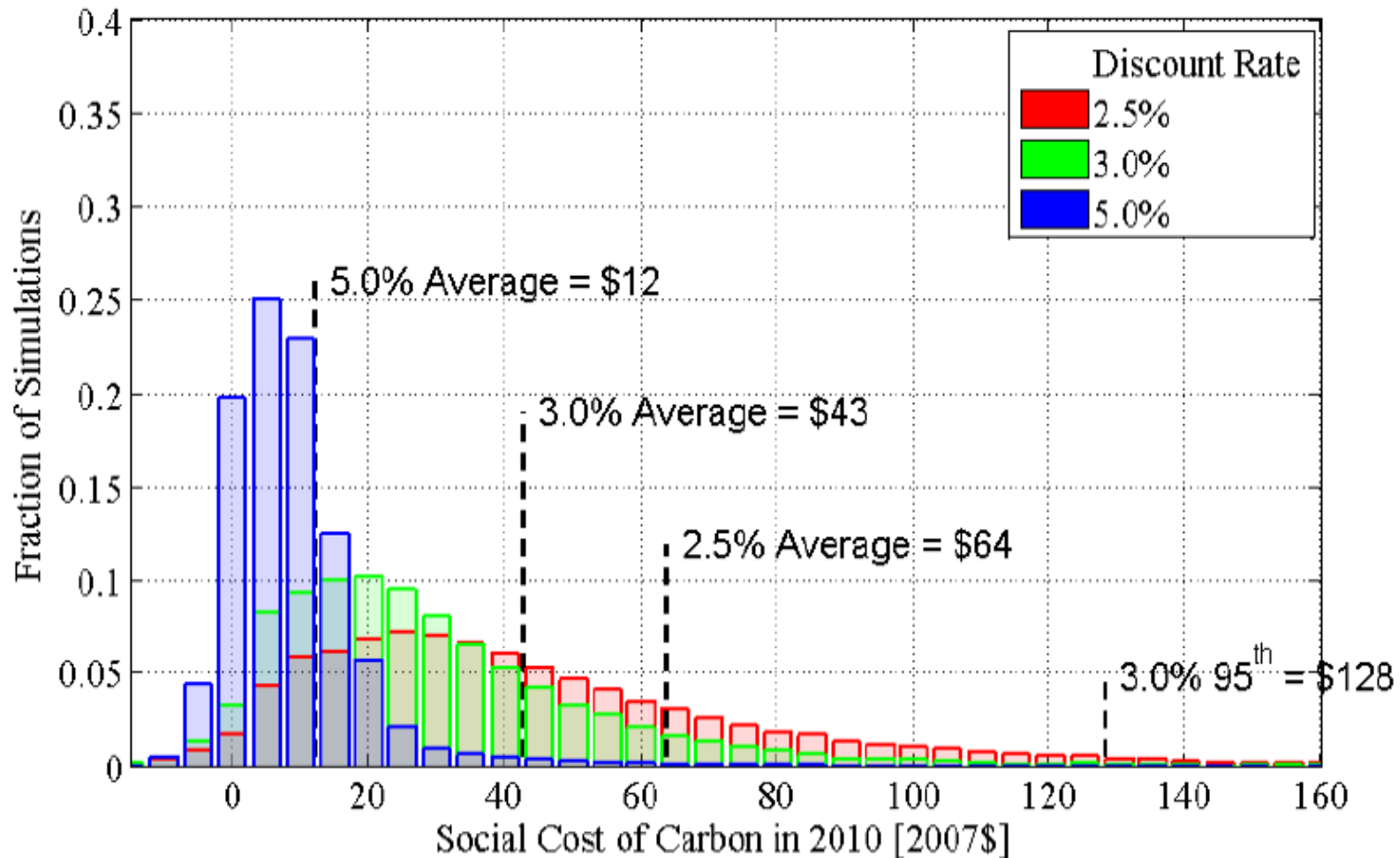
Use of SCC Estimates to Date

- Final USG SCC estimates (2010 and 2013 update) have been used in 40+ Federal RIAs to date:
 - 14 EPA regulatory actions
 - 5 EPA/DOT joint regulatory actions
 - 1 FAA regulatory action
 - 28 DOE regulatory actions
- A few examples of Federal use in non-regulatory context
 - e.g., BCA of proposed projects in DOT's Transportation Investment Generating Economic Recovery (TIGER) discretionary grant program
- They are also starting to be used in analyses and discussions outside Federal agencies
 - e.g. by states, regional organizations, other nations, international organizations, NGOs, and academic researchers, recent public hearings and court cases.

Updated USG SCC Estimates

- For 2020, the revised SCC values are: \$12, \$43, \$64, & \$128 (2007\$).

Distribution of SCC Estimates for 2020 (2007\$/ton CO₂)*



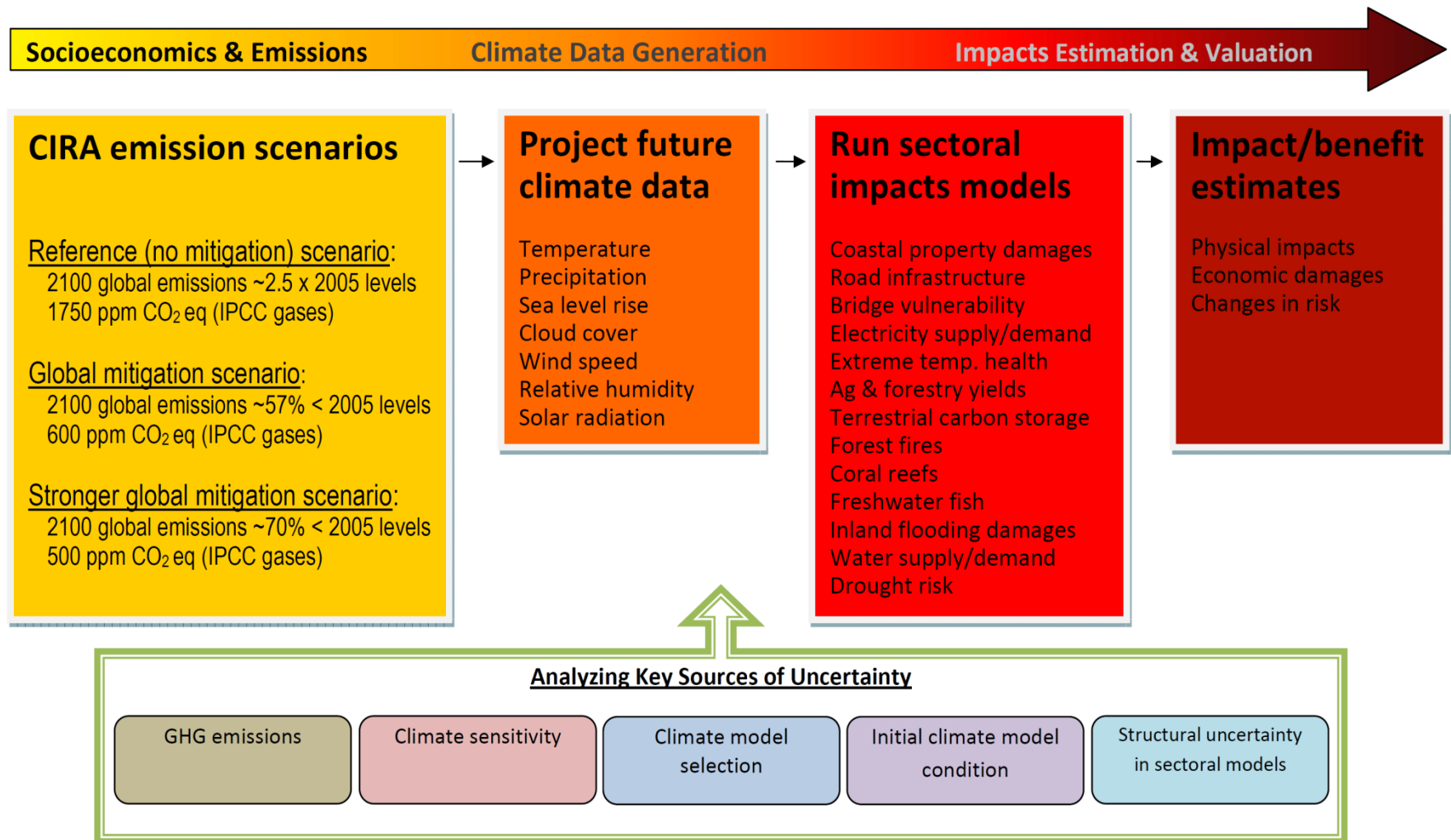
* Includes Nov 2013 technical correction.

Climate Change Impacts and Risk Analysis Project *(CIRA)*

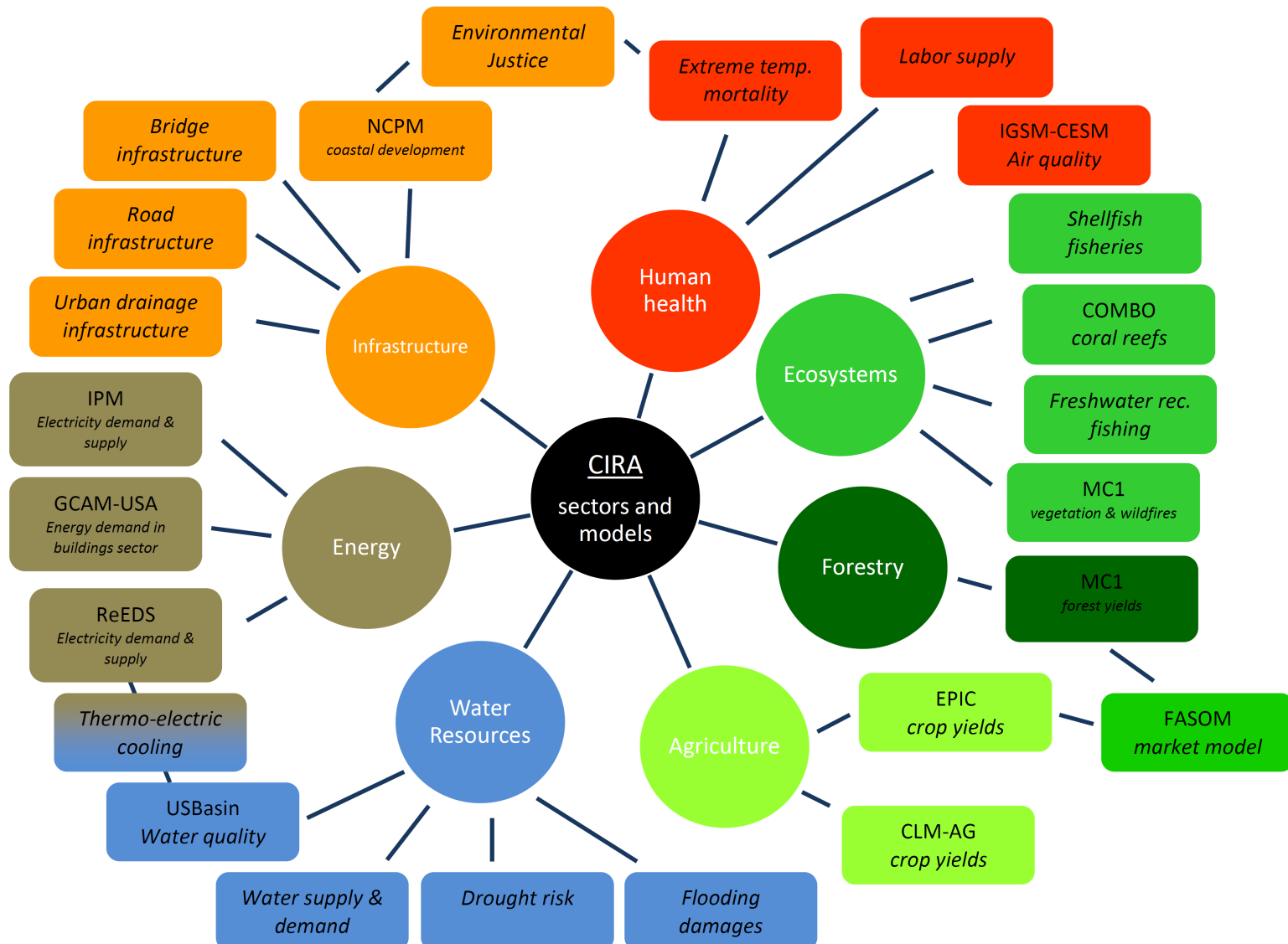
Overview of CIRA

- CIRA is an EPA-led, collaborative modeling effort to analyze how climate change impacts and risks in the U.S. change under different global GHG mitigation scenarios.
 - CIRA describes the costs of inaction (and benefits of mitigation and adaptation) in terms of physical effects, economic damages, and changes in risk.
- The project uses consistent economic, emission, and climate data to estimate impacts under scenarios with and without GHG mitigation.
 - The project also addresses key sources of uncertainty, including emissions pathway, climate sensitivity, climate projection, and impacts model.
- CIRA examines regional impacts in the U.S. across sectors (e.g., water resources, human health, ecosystems, energy) where science is strong and modeling capacity can be leveraged.
- The underlying components of CIRA have been (or are being) published in the scientific literature, including a special issue of *Climatic Change*.

Overview of the CIRA Process



Current CIRA Sectors/Models



CIRA in Context:

Complement to SCC

Both efforts use model-based approaches to estimate mitigation benefits and address climate and model uncertainty, however the approaches differ in important ways:

	CIRA	SCC
Geographic scope	U.S. regional + global	Global
Applicability and usage	<ul style="list-style-type: none"> • Significant global action. • Informs analysis and helps tell story of benefits of mitigation. 	<ul style="list-style-type: none"> • Assess marginal changes in GHG trajectories. • Meant to provide a comprehensive metric for benefit-cost analysis. • Limited communication tool.
Characterization of impacts	<ul style="list-style-type: none"> • Highly specific for U.S. • Meaningful physical impacts (e.g., heat mortality, drought, habitat loss). • Physical + monetized estimates. 	<ul style="list-style-type: none"> • Too aggregated for U.S. specific impacts. • Only monetized estimates. • Often difficult to see underlying physical impacts.
Coverage of impacted sectors	Detailed U.S.- and sector-specific coverage. A number of known impacts not included (e.g., vector-borne disease, catastrophic events).	Aims to measure economic damages from all impact sectors; in practice models do not capture all important damages.
Approach to impact estimates	Bottom-up modeling: directly modeled at sector level using consistent data, assumptions, and scenarios.	Aggregated damage functions developed from available literature (with inconsistent inputs, data, etc.).

In the future, results from CIRA's impact analyses may help inform aggregate damage functions used in the SCC models' estimates.

Project Status

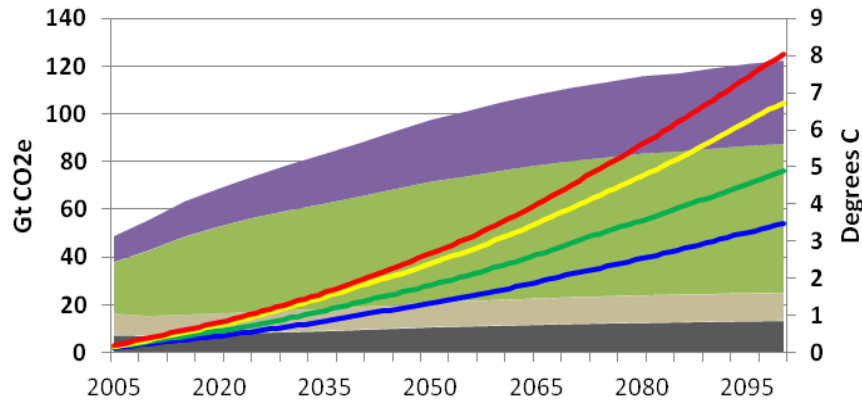
- Completing publication of 11 papers in a special issue of *Climatic Change* to describe CIRA.
 - Papers cover: emissions, carbon cycle, climate projections, climate extremes, water resources, electric power, infrastructure, extr temp mortality, and ecosystems.
 - Many of the underlying components of CIRA (IA and sectoral models) have previously been published in the scientific literature (~30 papers).
- Complete and publish ‘in-progress’ sectoral analyses: agriculture, forestry, water quality, air quality.
 - Convening a focus issue of ERL on ag/forestry components.
- Working to communicate results to decision makers and the public.

CIRA

Examples of Results

CIRA Global Emissions Scenarios

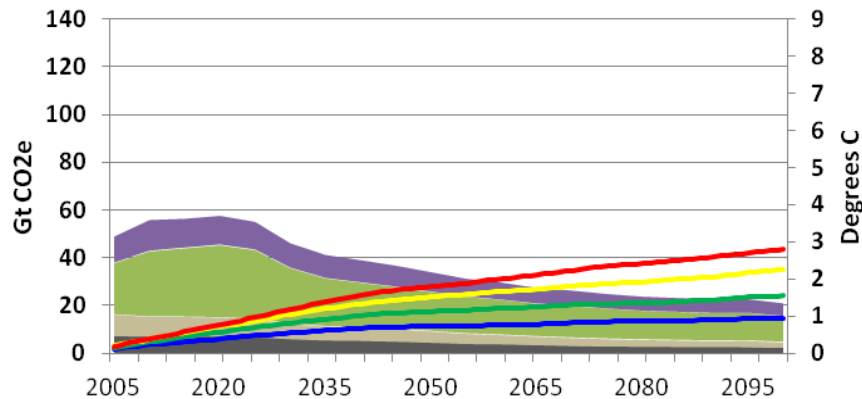
Reference



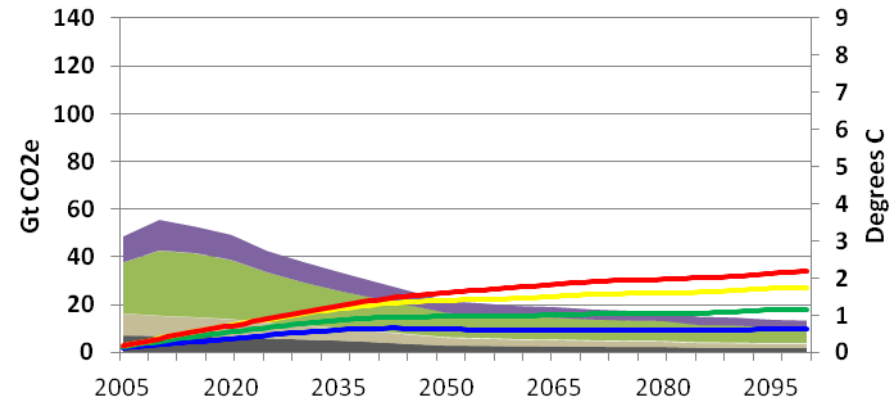
Three global emissions scenarios are used (no explicit assumptions about individual country commitments):

- **Reference scenario (RF 10 W/m² / ≈RCP8.8)**
 - 2100 global emissions ~ 2.5 x 2005 levels
 - 2100 U.S. emissions ~ 1.8x 2005 levels
 - 2100 GHG concentrations (IPCC gases) ~1750 ppm
- **Global mitigation scenario (RF 4.5 W/m² / ≈RCP4.2)**
 - 2100 global emissions ~ 57% below 2005 levels
 - 2100 U.S. emissions ~ 67% below (38% in 2050)
 - 2100 GHG concentrations (IPCC gases) ~ 600 ppm
- **Stronger global mitig. scenario (RF 3.7 W/m² / ≈RCP3.6)**
 - 2100 global emissions ~ 73% below 2005 levels
 - 2100 U.S. emissions ~ 73% below (60% in 2050)
 - 2100 GHG concentrations (IPCC gases) ~ 500 ppm

Mitigation Scenario



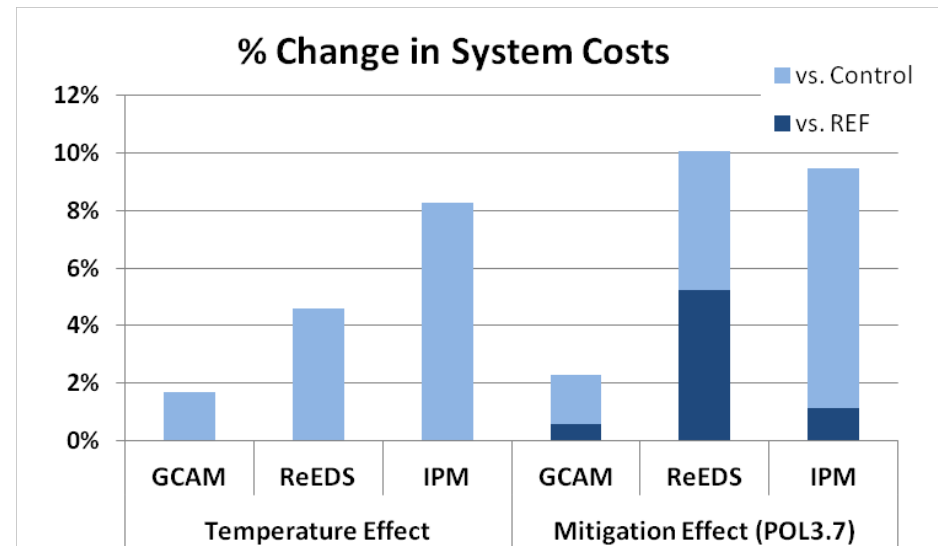
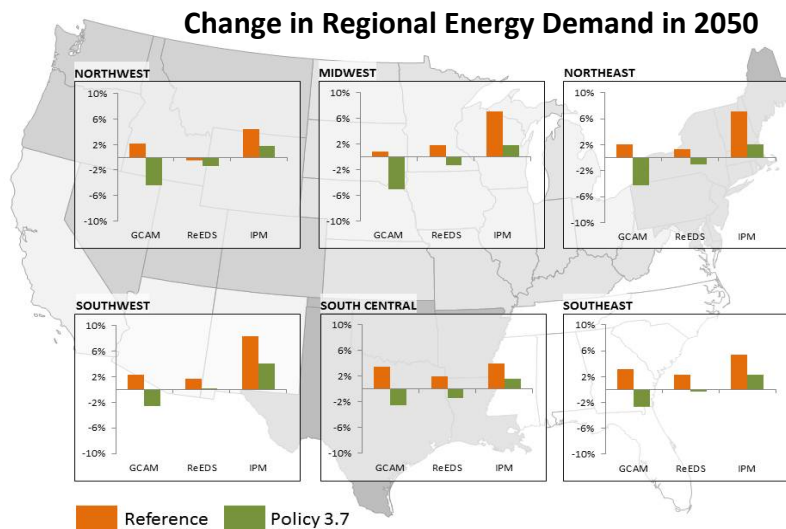
Stronger Mitigation Scenario



■ USA ■ Other Developed ■ Other G-20 ■ Rest of World
 ■ Temp CS2.0 ■ Temp CS3.0 ■ Temp CS4.5 ■ Temp CS6.0

Climate Impacts on Electricity Demand and Supply using multiple models: GCAM, ReEDS, & IPM

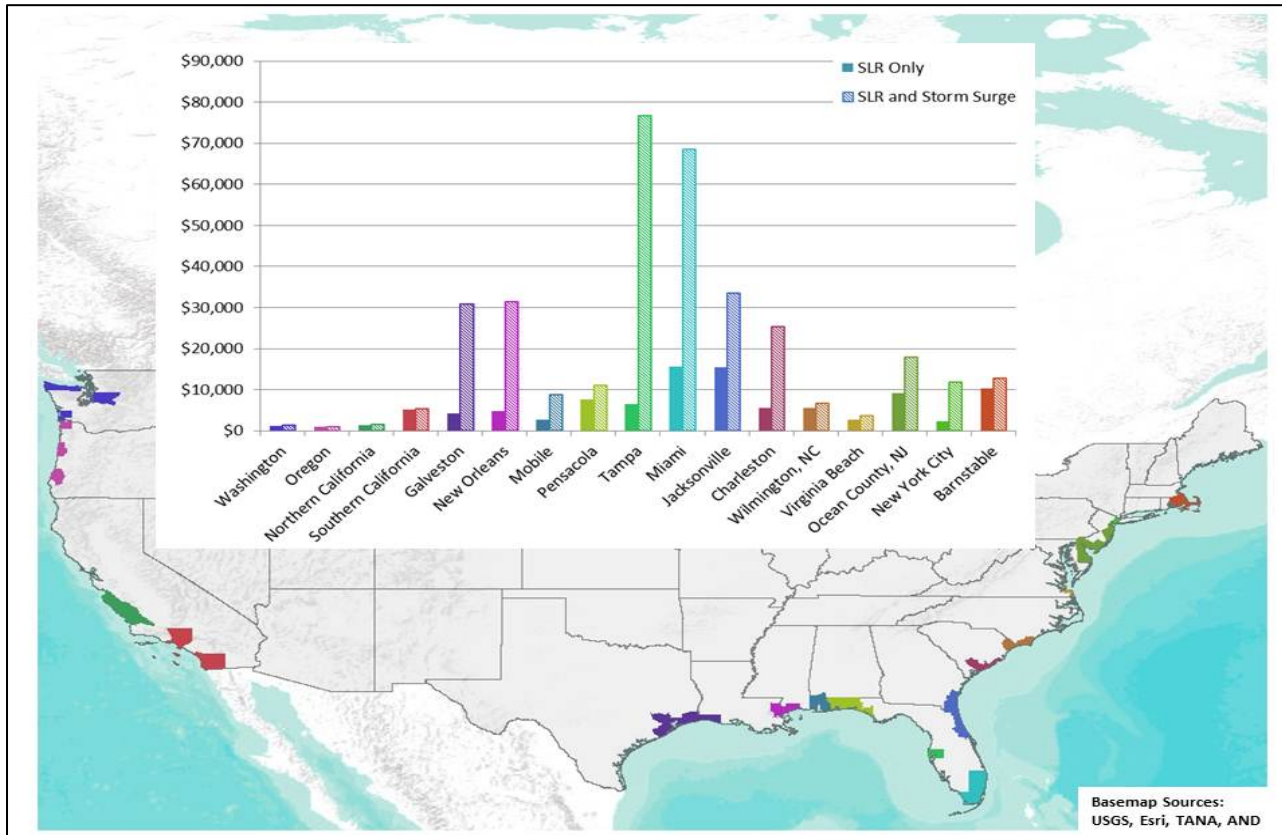
- Projected temperature changes increase electricity demand for air conditioning and lower the demand for heating. This effect is frequently omitted from demand projections.
- Electricity demand increases 1.5%–6.5% nationally in 2050 when the air temperature projections from the Reference scenario are included in power sector models (left figure).
- Meeting this additional demand raises power system costs by 1.7%–8.3% across the models (cumulative costs discounted at 3% from 2015–2050, right figure).
- Including temperature effects in baseline scenarios is important. Under the Stronger Mitigation scenario, the change in power system costs from the Reference (0.6%–5.2%) is lower than the change in costs from a Control (2.3%–10.1%) that does not account for temperature effects.



- Temp Effect compares Reference with Control case
- Mitigation Effect compares Stronger Mitigation vs. REF and Control
- System costs include capital, operations, maintenance, and fuel

Coastal Property Damages and Adaptation Response Costs

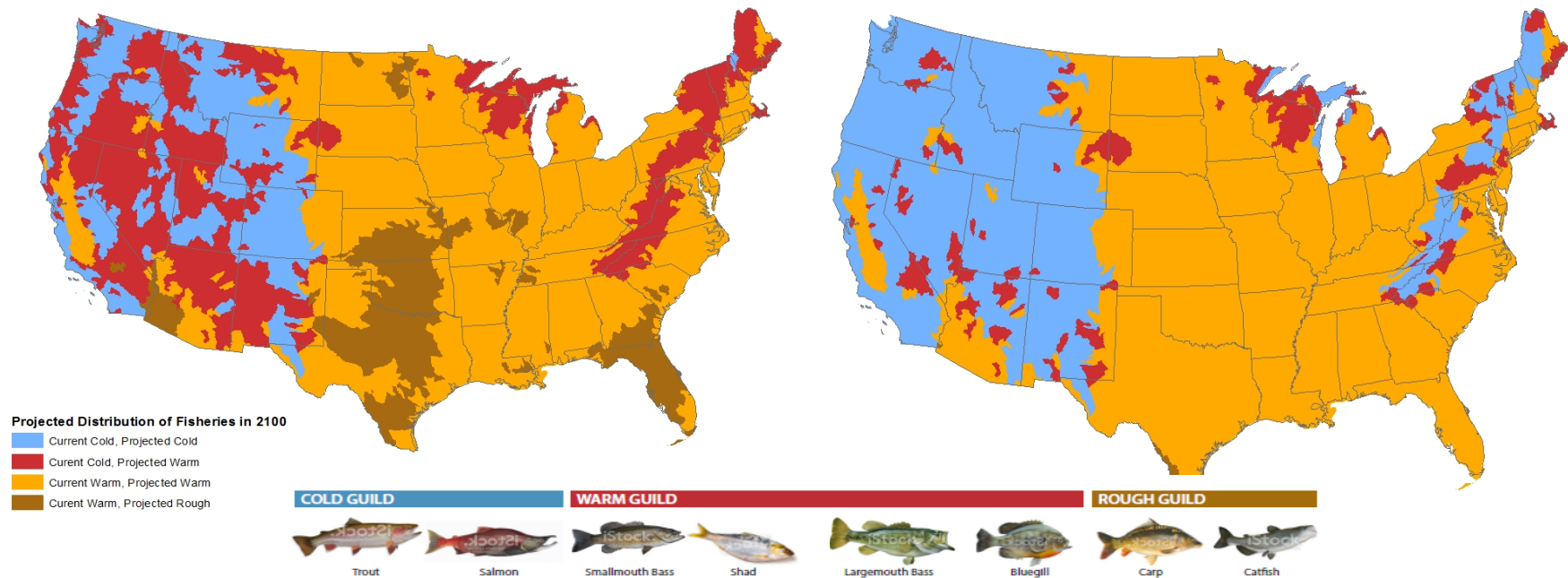
- The cumulative, discounted cost of inaction (no adaptation) in the face of SLR and storm surge through 2100 is estimated at \$4.25 trillion.
- When adaptation is included, the economic impacts through 2100 for the REF are \$85B (for SLR only–140cm) and \$690B (for SLR+storm surge). Mitigation (POL3.7) avoids \$7.5B (SLR only–95cm) or \$20B (SLR+storm surge) of these costs.
- Areas projected to be abandoned have a higher percentage of socially vulnerable populations than areas likely to be protected.



Total costs (abandoned land + adaptation costs) by 2100 under Reference, discounted at 3% (\$ million)

Freshwater Recreational Fishing

- Significant changes to the spatial distribution of where fish are today.
- Coldwater fish habitat declines by ~62% by 2100 under the reference, but only by 12% and 11% under the GHG mitigation scenarios.
 - Mitigation preserves coldwater habitat in most of Appalachia & the Mountain West.
- The stronger mitigation scenario (POL3.7) avoids \$324M (disc. at 3%) in total recreational fishing damages by 2100 compared to the reference.



International Analysis

Thank You

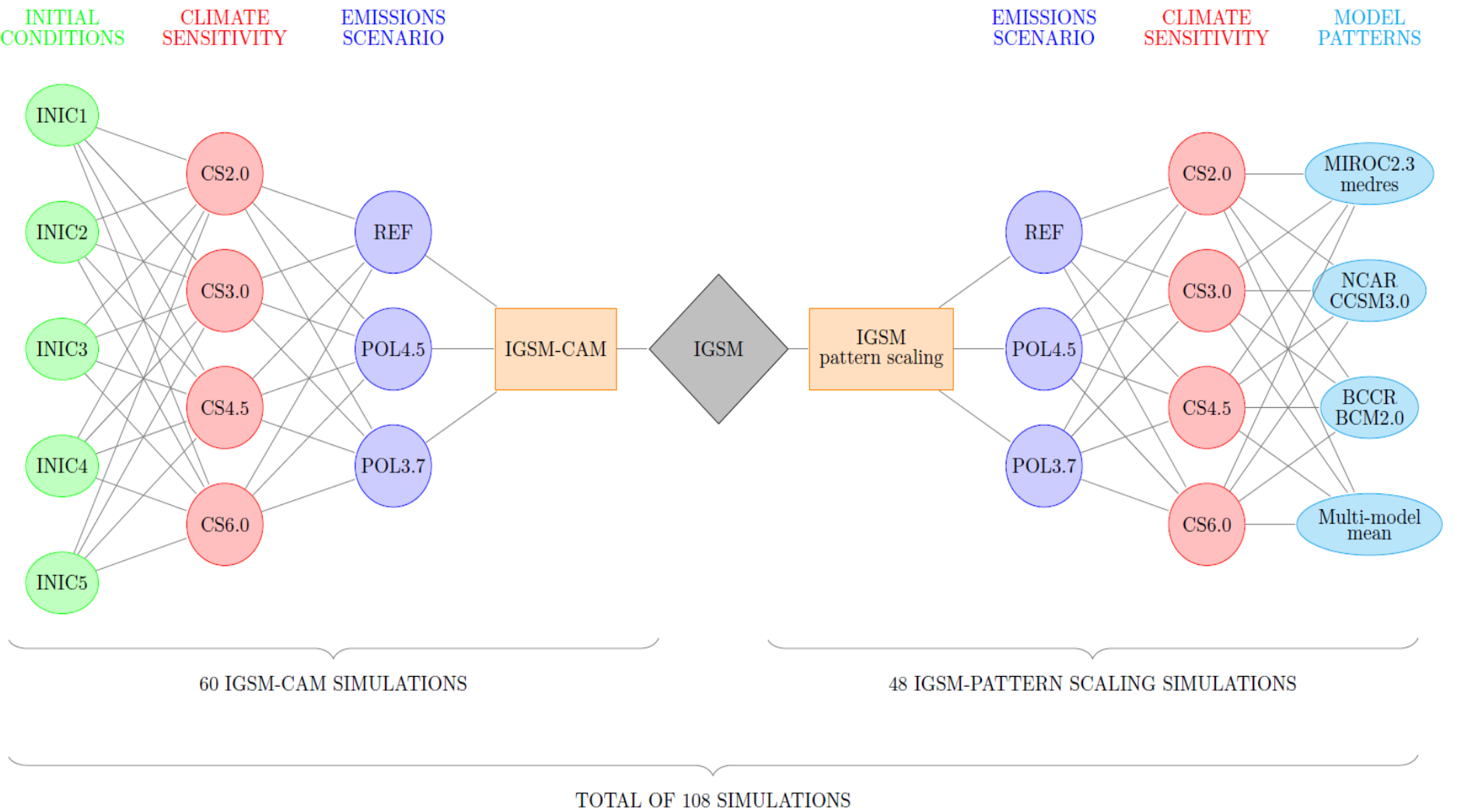
Appendix

CIRA Key Messages

- Across a large majority of sectors, global GHG mitigation provides both monetary and risk-reduction benefits in the United States:
 - GHG mitigation scenarios evaluated would prevent or reduce adverse impacts throughout the 21st century compared to the Reference case.
 - The estimated monetized benefits of mitigation are large for some sectors (\$170B in 2100 for temp. mortality), modest for others (\$320M* by 2100 for freshwater fishing), and negative for one (\$11B* in disbenefits by 2100 for carbon storage).
- Benefits of GHG mitigation increase over time:
 - Emission scenarios follow similar paths through 2040, but diverge considerably thereafter, generating increasing benefits in most sectors.
- Adaptation can reduce net overall costs, highlighting the importance of a complementary approach with mitigation.
 - Cost-effective adaptation measures substantially reduce impacts under all scenarios, especially in the infrastructure sector. For example, damages to coastal development from SLR and storm surge under the Reference with no adaptation are estimated to be over \$4T* through 2100, but reduced to \$690B* with adaptation.
- Spatial and temporal scale are important:
 - Impacts are not equally distributed spatially: aggregating nation-wide impacts and damages can miss important regional scale impacts.

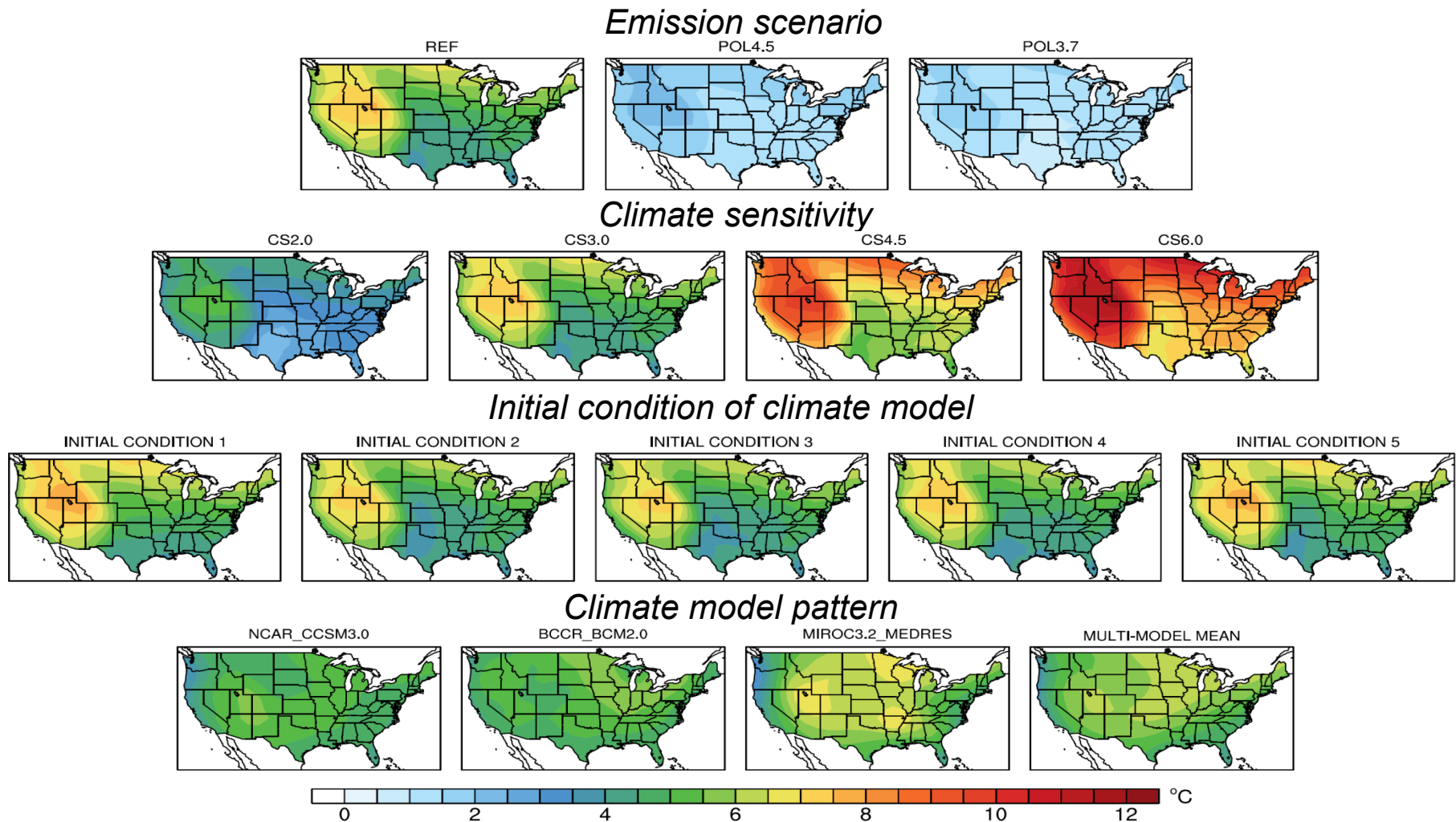
** discounted at 3%, \$2005*

Experimental Design of the CIRA Uncertainty Framework



Analyzing Key Sources of Uncertainty in Projecting Temperature

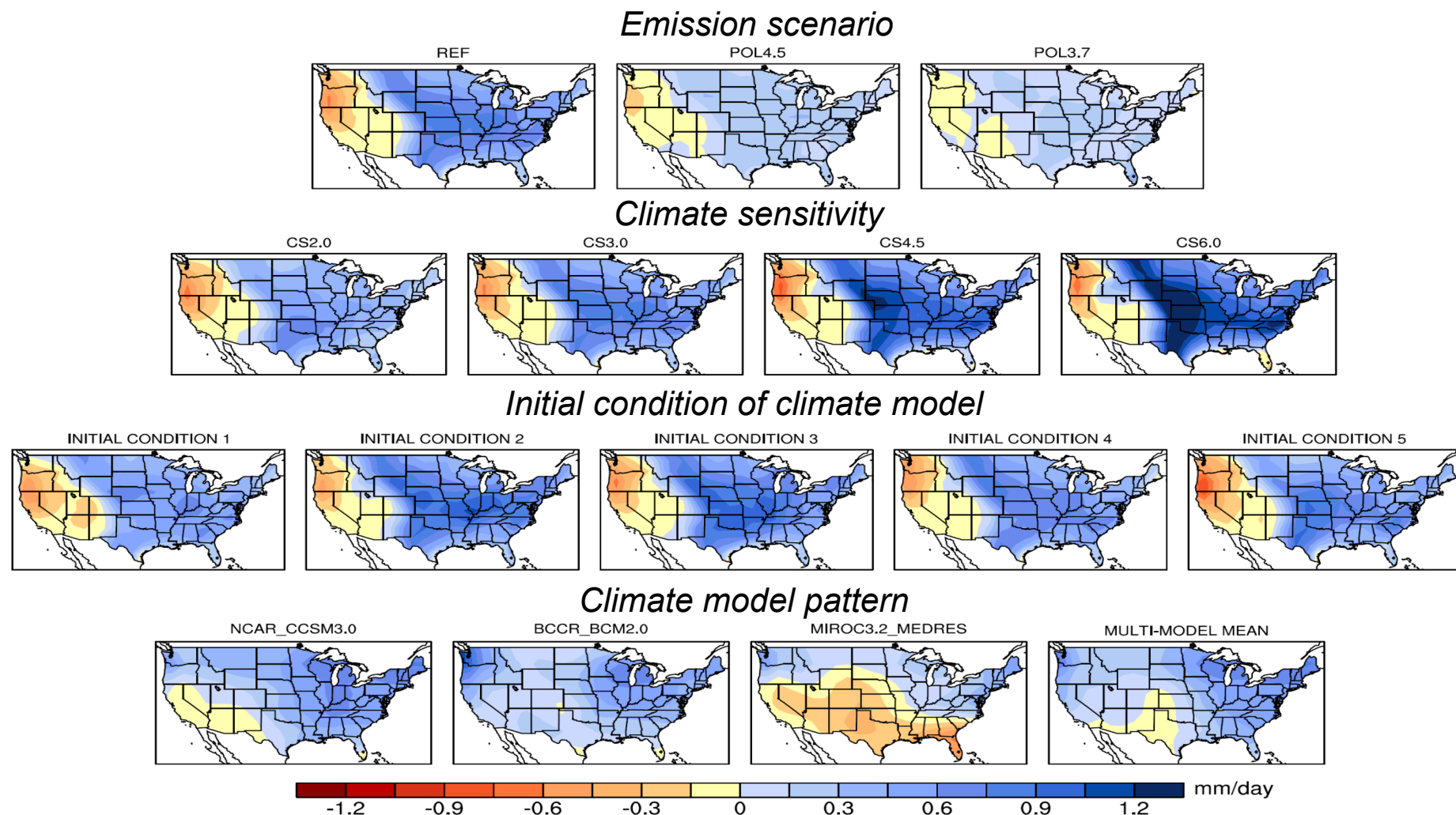
Changes in temperature ($^{\circ}\text{C}$) in 2100 relative to present day



- Both GHG mitigation scenarios greatly reduce warming compared to the reference.
- The different climate sensitivity values show a wide range in the magnitude of future warming.
- Differences between the five initial conditions are less than 1.0°C .
- Different models show relative agreement in magnitude of temperature change, but with different patterns.

Analyzing Key Sources of Uncertainty in Projecting Precipitation

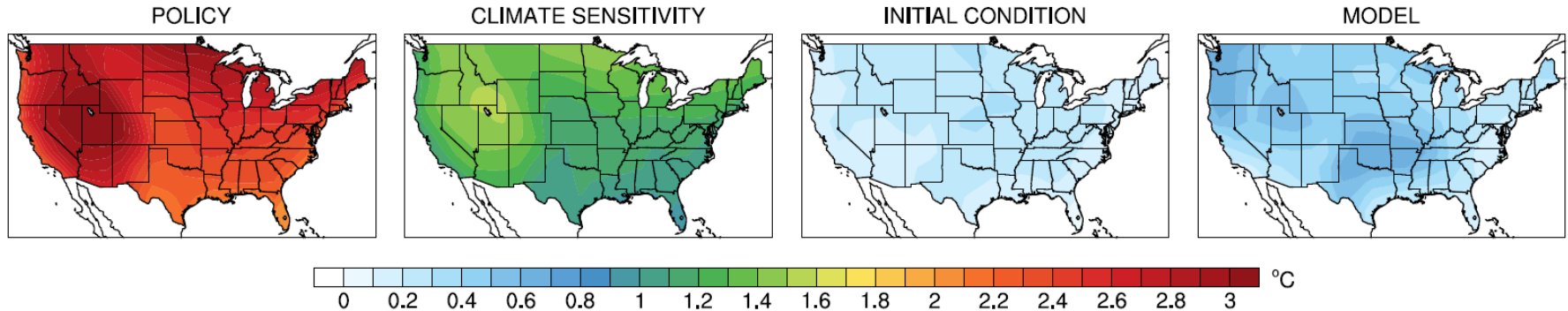
Changes in precipitation (mm/day) in 2100 relative to present day



- Implementation of either policy leads to decreases in the magnitude of precipitation change across U.S.
- The impact of climate sensitivity appears to be strongly localized, while initial conditions have a larger impact on regional precipitation changes than on temperature.
- Climate model pattern shows largest spatial heterogeneity across the U.S.

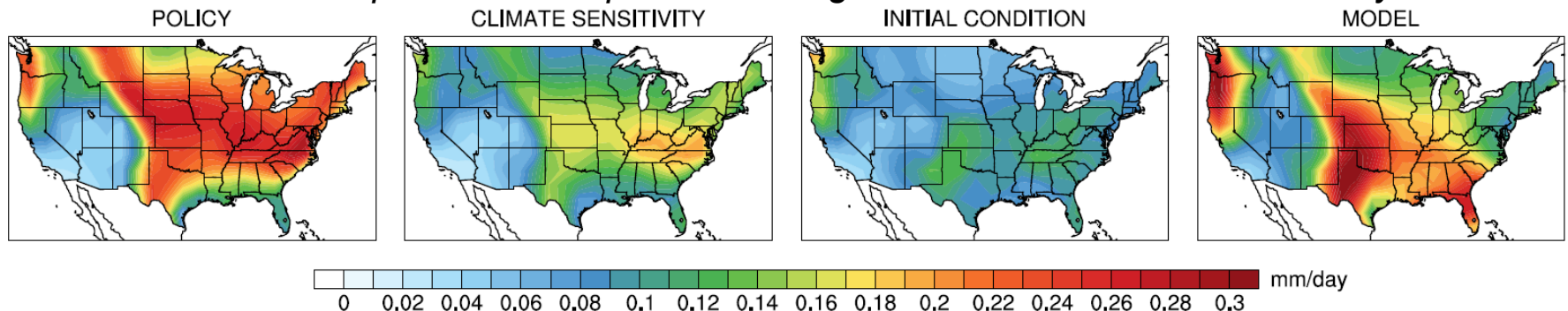
Relative Importance of Uncertainty Sources Analyzed

Mean Spread of Temperature Change for Each Source of Uncertainty*



- The mean spread (1991-2010 mean vs. 2091-2110 mean) displays little spatial heterogeneity. The largest source of uncertainty is the policy (mean spread between 2.0 and 3.0 °C), with the spread from climate sensitivity selection also being substantial (values between 1.0 and 1.7 °C).

Mean Spread of Precipitation Change for Each Source of Uncertainty



- The mean spread of each source is more heterogeneous. The choice of policy and of models are the largest contributors of uncertainty in precipitation changes, with a mean spread >0.2mm/day in most of U.S.
- A particular feature is the small spread in the Southwest, indicating that this region shows the least amount of uncertainty in precipitation changes.

* The mean spread is the S.D. across a source of uncertainty averaged over the other sources of uncertainty.