Estimating avoided impacts from GHG mitigation

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

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Objectives and Drivers

- EPA routinely estimates the benefits of reducing air pollution in meaningful ways (e.g., <u>avoided</u> premature deaths, respiratory illness, economic loss).

- CIRA project aims to produce analogous estimates for GHG mitigation.
  - To date, EPA and the general climate community have had limited ability to show specific and full range of avoided impacts under GHG mitigation scenarios.
  - Climate change presents unique challenges compared to traditional EPA analyses (e.g., global nature, wide-reaching impacts, long time scales).
  - CIRA complements SCC, but differs in purpose and approach (more on this later).

- CIRA will develop and communicate credible, robust, and meaningful climate impact and benefit estimates to inform policy.

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.
- CIRA uses *internally consistent* economic, emission, and climate scenarios to estimate impacts under scenarios with and without GHG mitigation.
  - The project also addresses key sources of uncertainty:
    - *Scientific: multiple climate sensitivities (2.0, 3.0, 4.5, and 6.0)*
    - *Model: Use of multiple IA and sectoral models where possible*
    - *Variability: Analysis of changing temperature and precipitation patterns*
  - The limited number of other comprehensive impact analysis efforts do not emphasize consistency and the exploration of uncertainty to the same extent as CIRA.
- 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.

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	• Significant global action. • Informs analysis and helps tell story of benefits of mitigation.	• Assess marginal changes in GHG trajectories. • Meant to provide a comprehensive metric for benefit-cost analysis. • Limited communication tool.
Characterization of impacts	• Highly specific for U.S. • Meaningful physical impacts (e.g., heat mortality, drought, habitat loss). • Physical + monetized estimates.	• 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.

Overview of the CIRA Process

Socioeconomics & Emissions → Climate Data Generation → Impacts Estimation & Valuation

CIRA emission scenarios

Reference (no mitigation) scenario:
- 2100 global emissions ~2.5 x 2005 levels
- 1650 ppm CO_2 eq (IPCC gases)

Global mitigation scenario:
- 2100 global emissions ~57% < 2005 levels
- 600 ppm CO_2 eq (IPCC gases)
- **4.5 W/m²**

Stronger global mitigation scenario:
- 2100 global emissions ~70% < 2005 levels
- 500 ppm CO_2 eq (IPCC gases)
- **3.7 W/m²**

→

Project future climate data

- Temperature
- Precipitation
- Sea level rise
- Cloud cover
- Wind speed
- Relative humidity

→

Run sectoral impacts models

- Coastal property damages
- Road infrastructure
- Bridge vulnerability
- Electricity supply/demand
- Extreme temp. health
- Ag & forestry yields
- Terrestrial carbon storage
- Forest fires
- Coral reefs
- Freshwater fish
- Inland flooding damages
- Water supply/demand
- Drought risk

→

Impact/benefit estimates

- Physical impacts
- Economic damages
- Changes in risk

Analyzing Key Sources of Uncertainty

- GHG emissions
- Climate sensitivity
- Climate model selection
- Initial climate model condition
- Structural uncertainty in sectoral models

CIRA Impact Sectors & Sectoral Models

CIRA Impact Sector Coverage

- **Human health**
  - Thermal stress (mortality)
  - Air quality
  - Vector-borne disease
  - Extreme event morbidity, mortality
  - Environmental justice / vulnerable populations
  - Thermal stress (labor productivity)
- **Agriculture**
  - Crop yield (U.S.)
  - Crop yield (global)
  - Livestock production
  - Carbon storage
- **Forests**
  - Change in production
  - Change in CO_2 storage
  - Wildfire
- **Freshwater Resources**
  - Drought
  - Flooding damages
  - Water supply and demand
  - Water quality
- **Ecosystems**
  - Species (coral, freshwater fish, others)
  - Biodiversity
  - Other acidification effects
- **Energy**
  - Temperature effects on energy (electricity) supply and demand
  - Precipitation and system effects on hydro power
  - Change in water flow effects on cooling capacity
  - Climate and system effects on wind and solar generation
- **Infrastructure**
  - Roads and bridges
  - Coastal property and infrastructure
  - Urban drainage
  - Inland property damages from floods
  - Waterways
  - Telecommunication infrastructure
- **Tourism**
  - Coral reef recreation
  - Recreational fishing
  - Other recreation (e.g., winter, boating, birding)
- **Other extreme events**
  - Residual damages post extreme events (e.g., hurricanes)
  - Catastrophic climate change (e.g., ocean circulation shutdown)
  - National security risks (e.g., mass migration)

Key
Existing CIRA capacity
In development
Not currently in CIRA

Process and Status of CIRA Development

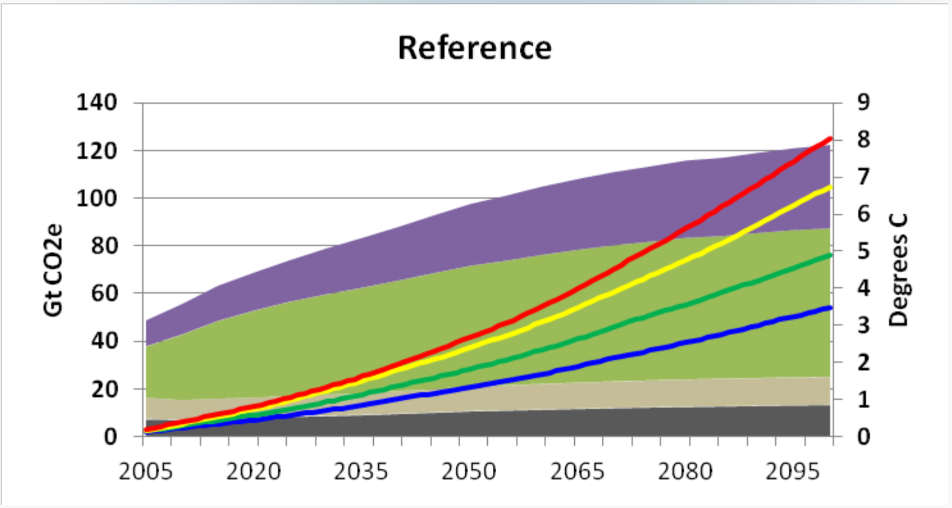
- Held two meetings in 2011 and 2012 with our collaborators to agree on approach, review preliminary results, and get feedback.
  - Collaborators include climate modelers, integrated assessment modelers, and sectoral impact specialists.
- Internally consistent socioeconomic, emission, and climate scenarios were developed with MIT and DOE's Pacific Northwest National Lab.
  - All sectoral models use population, GDP, and emissions data from EPPA
  - Climate inputs consistent with all socio-economic and emissions scenarios
- Sectoral model runs completed — including follow-up QA/QC exercises and sensitivity analyses.
- 12 papers, each describing different elements of CIRA, currently in peer review for a special journal issue in *Climatic Change*.
  - Anticipate publication starting summer/fall 2013.

Important Limitations and Caveats

- CIRA is a policy analysis tool and different from the comprehensive climate science assessments conducted by IPCC and USGCRP.
- Although some of the sectoral models used can estimate impacts at regional (multi-state) to sub-regional (state to county) scales, none of the CIRA results should be used for local scale vulnerability assessment. The CIRA analyses are specifically designed to answer national-scale impacts and benefits questions.
- CIRA does not currently have the capacity to analyze marginal levels of mitigation (e.g., for use with EPA regulatory actions).
- CIRA results likely underestimate the benefits of avoided climate change; there are known impacts that are not currently included.
- The CIRA climate projections employ a limited number of climate models.
- While adaptation is not extensively addressed in the CIRA project, some of the impact estimates produced by the sectoral models do include adaptation costs.

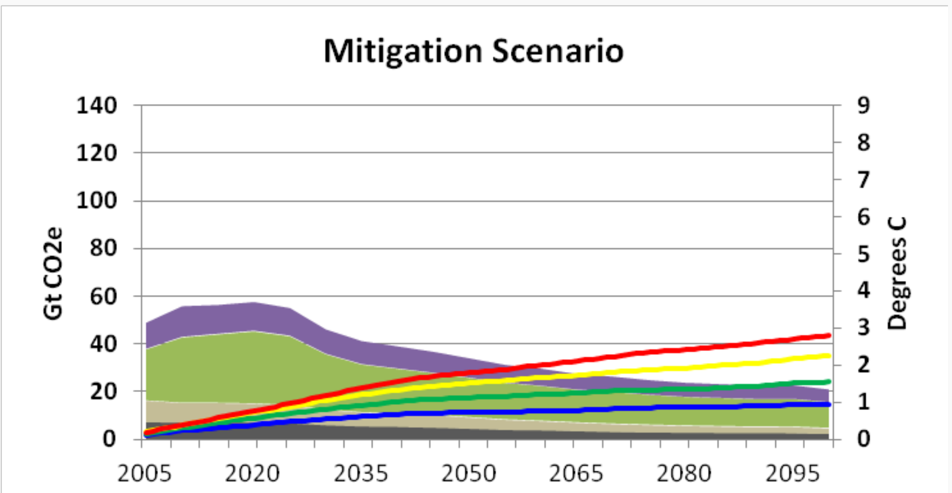
Sample CIRA Results

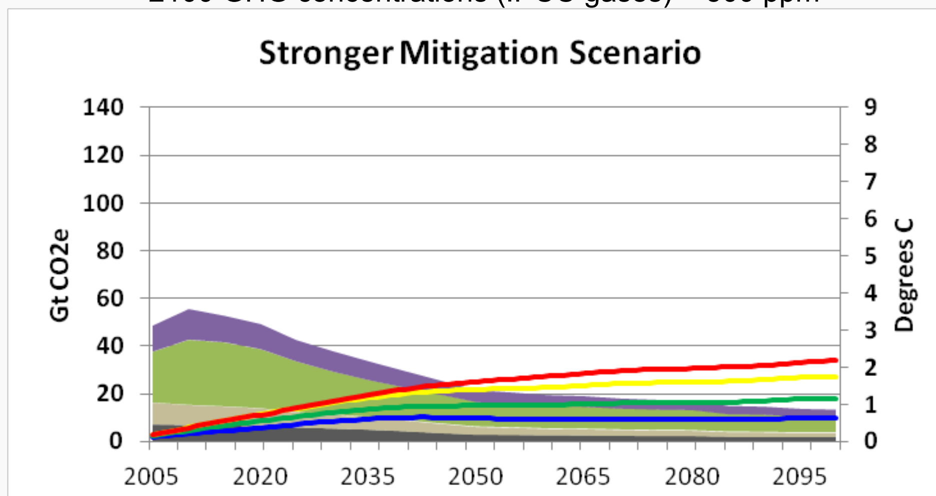
CIRA Emissions Scenarios
(IGSM Results)



Three global emissions scenarios are used:

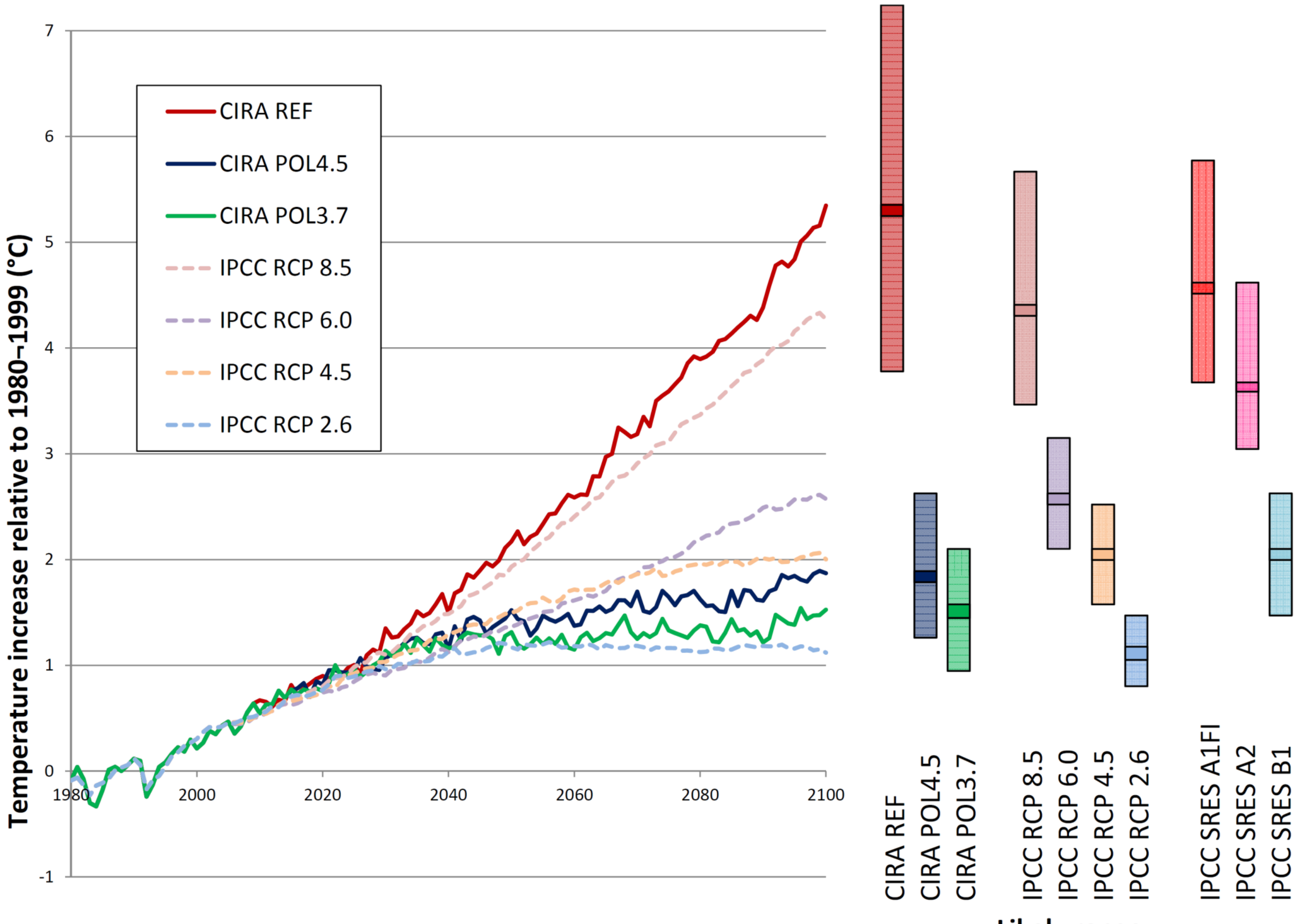
- **Reference (no mitigation) scenario**
  - 2100 global emissions ~ 2.5 x 2005 levels
  - 2100 U.S. emissions ~ 1.8x 2005 levels
  - 2100 radiative forcing ~ 10 W/m^2
  - 2100 GHG concentrations (IPCC gases) ~1650 ppm
- **Global mitigation scenario**
  - 2100 global emissions ~ 57% below 2005 levels
  - 2100 U.S. emissions ~ 67% below (38% in 2050)
  - 2100 radiative forcing ~ 4.5 W/m^2
  - 2100 GHG concentrations (IPCC gases) ~ 600 ppm
- **Stronger global mitigation scenario**
  - 2100 global emissions ~ 73% below 2005 levels
  - 2100 U.S. emissions ~ 73% below (60% in 2050)
  - 2100 radiative forcing ~ 3.7 W/m^2
  - 2100 GHG concentrations (IPCC gases) ~ 500 ppm





Anthropogenic emissions: CO_2 (fossil and industrial), CH_4, N_2O, HFCs, SF_6, and PFCs Emissions (CO_2-equivalent). Temp anomaly vs. 1991-2010 avg.

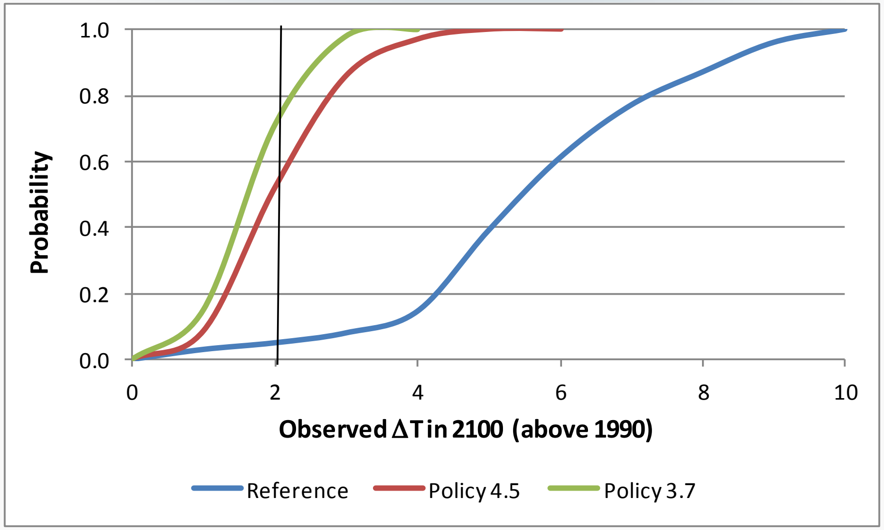
Comparison of CIRA Scenarios to RCPs and SRES

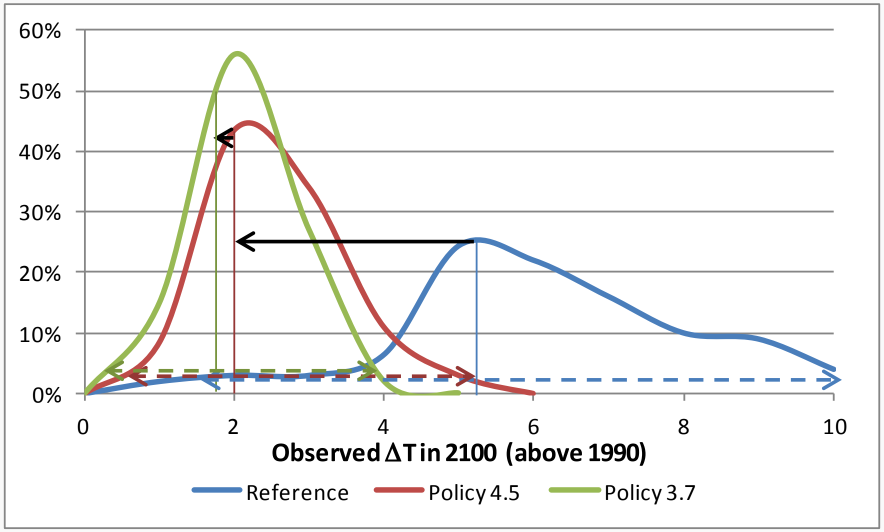


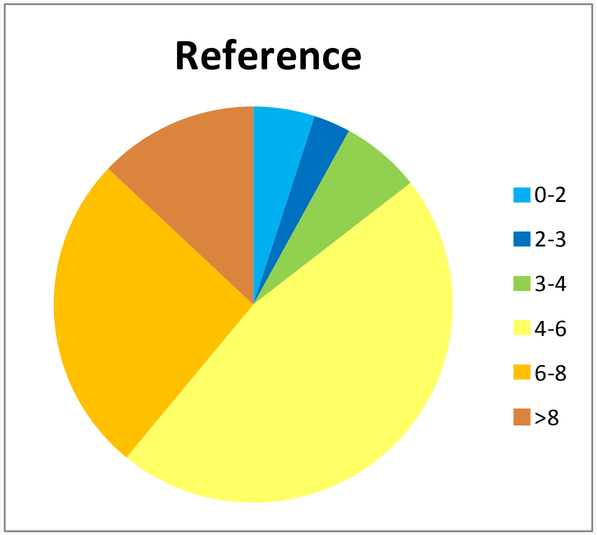
[IPCC ranges adapted from Rogelj et al. 2012]

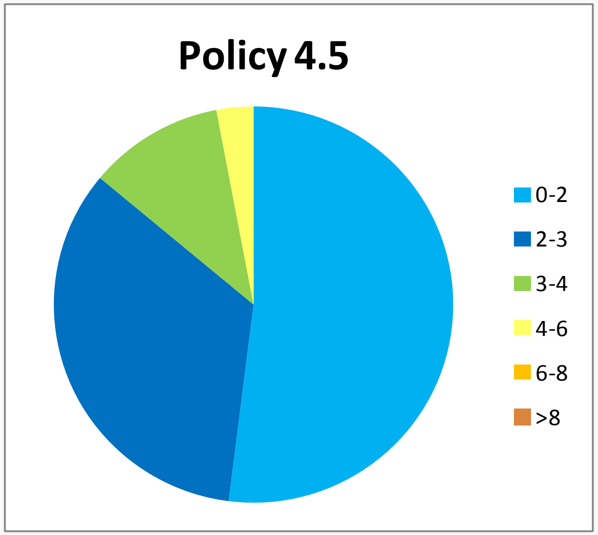
*Likely ranges for CIRA scenarios represent year 2100 values for climate sensitivity 2 and 4.5˚C

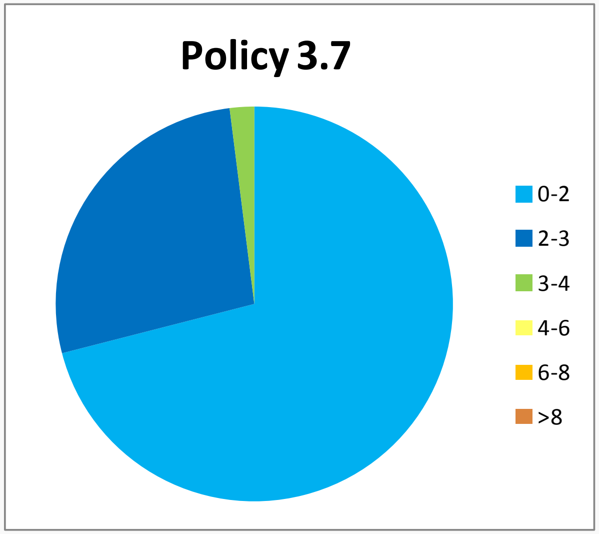
Presentation of Results
(Global Average ΔT from 1990, IGSM)





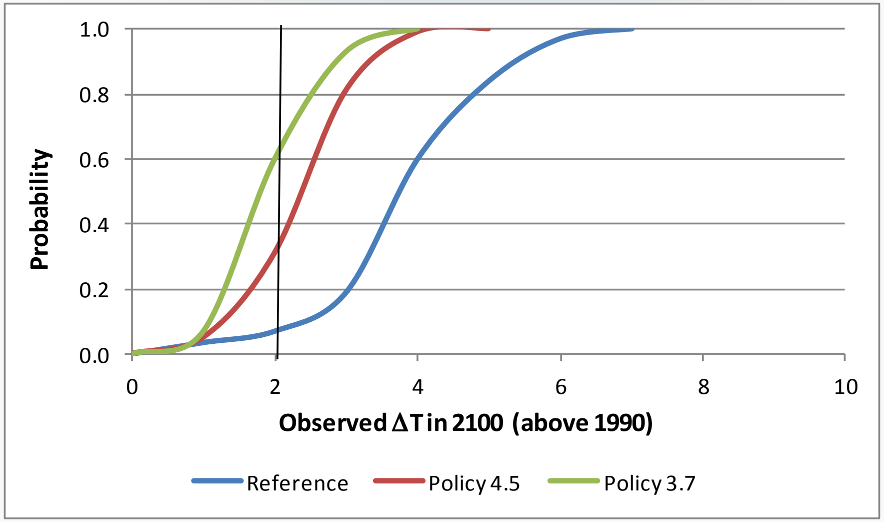


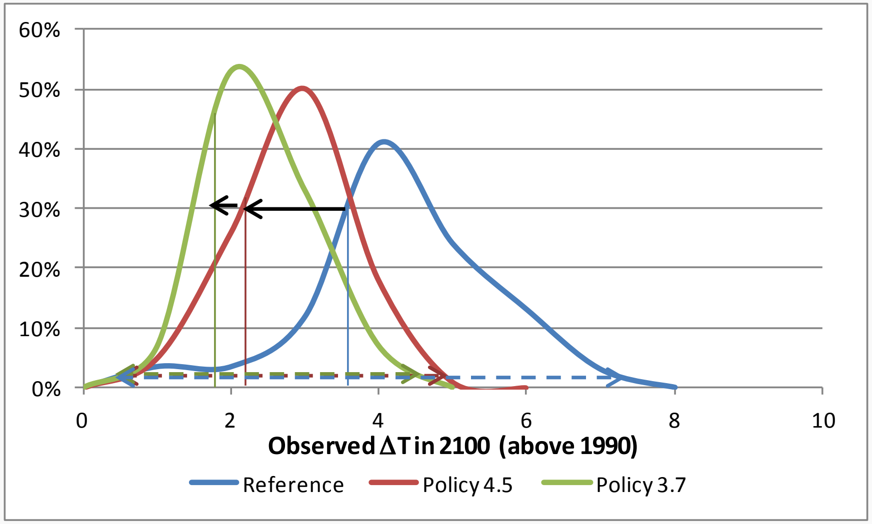


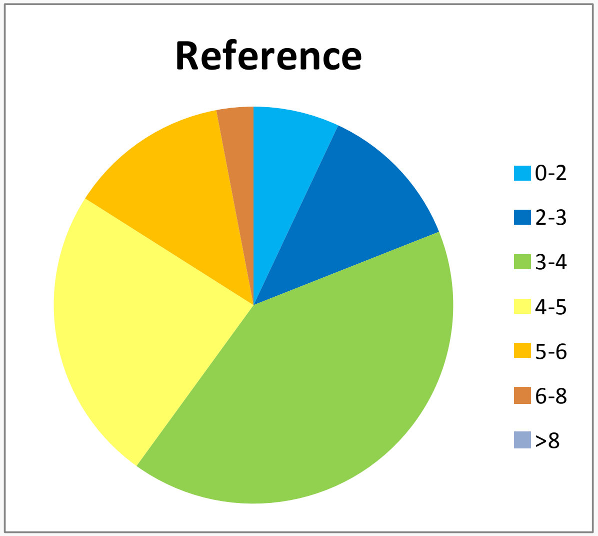


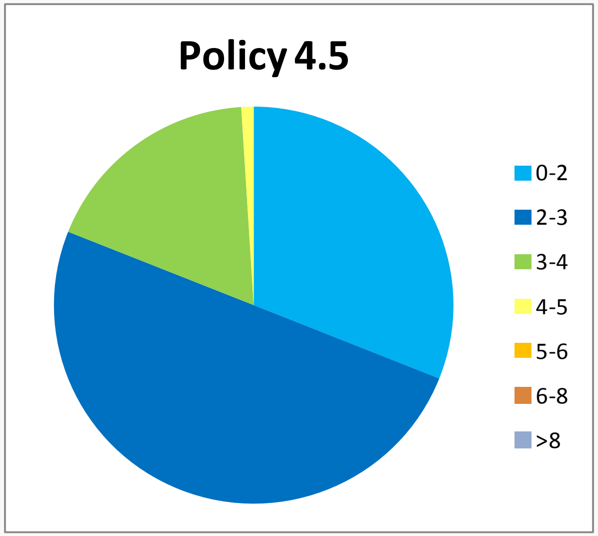
Presentation of Results (Global Average ΔT from 1990, GCAM)

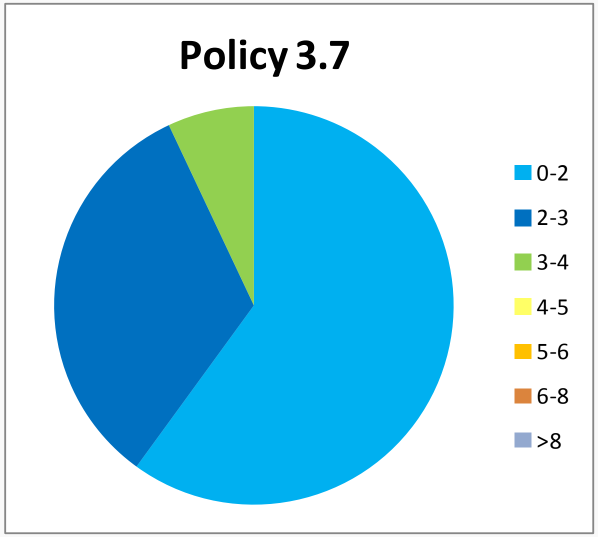
Note: GCAM Reference GDP/Pop harmonized to IGSM





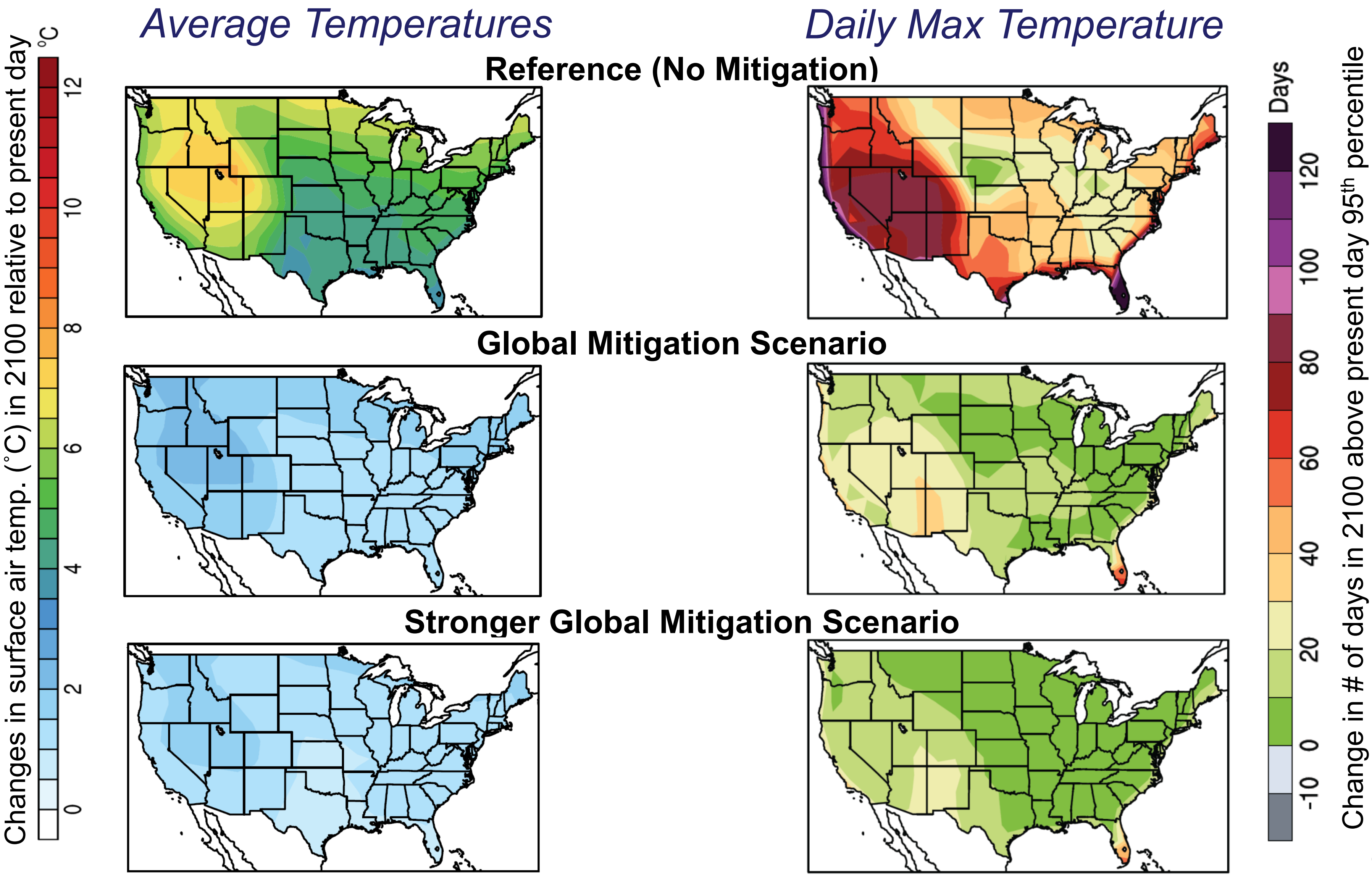






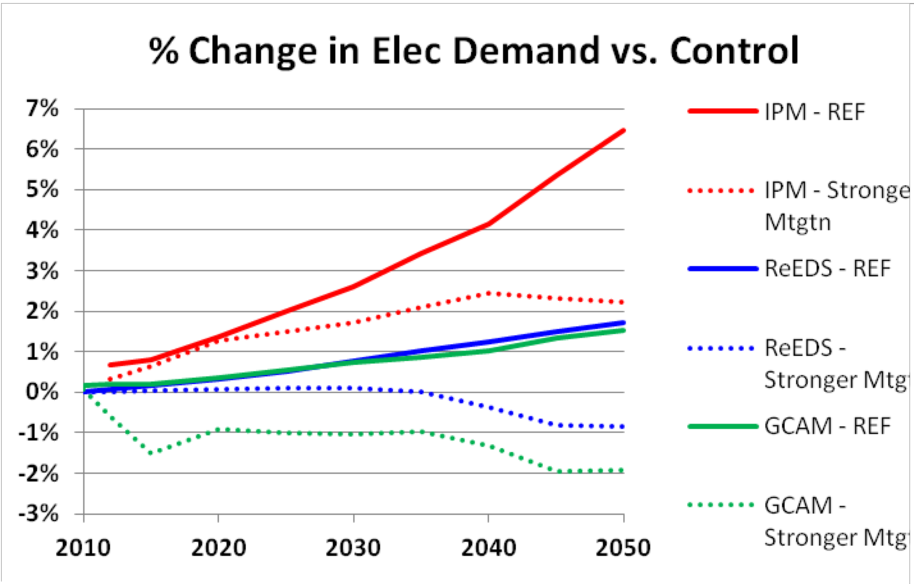
Changes in Temperature in 2100

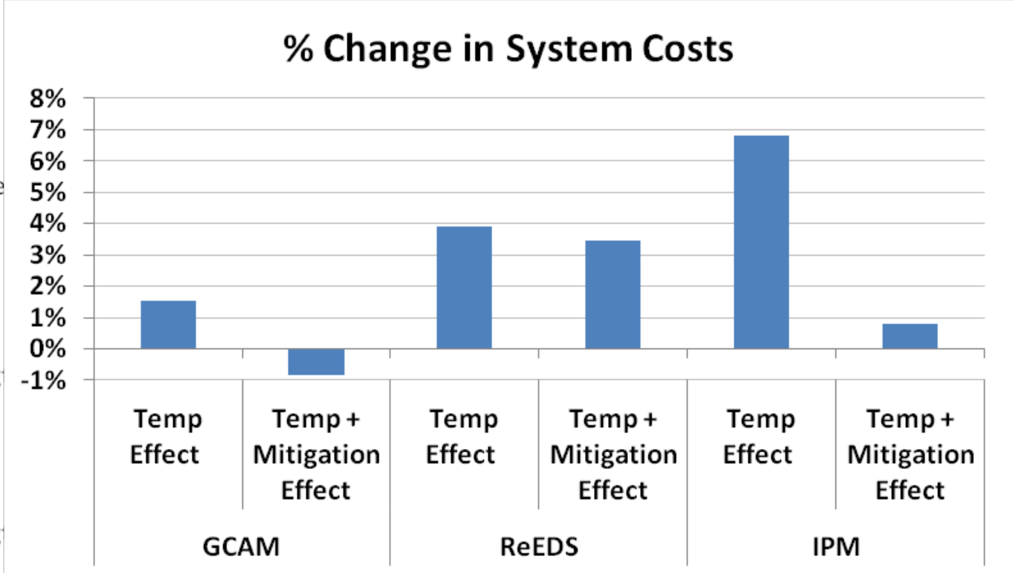
- With no mitigation, avg. temps increase substantially & hottest days become more frequent.
- These changes are substantially reduced under both mitigation scenarios.



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 1.5%–6.8% across the models (discounted at 5%, cumulative costs from 2012–2050, right figure).
- The change in power system costs from including temperature effects is greater than the change in power system costs from implementing the Stronger Mitigation scenario (-0.8%–3.5%, right figure).



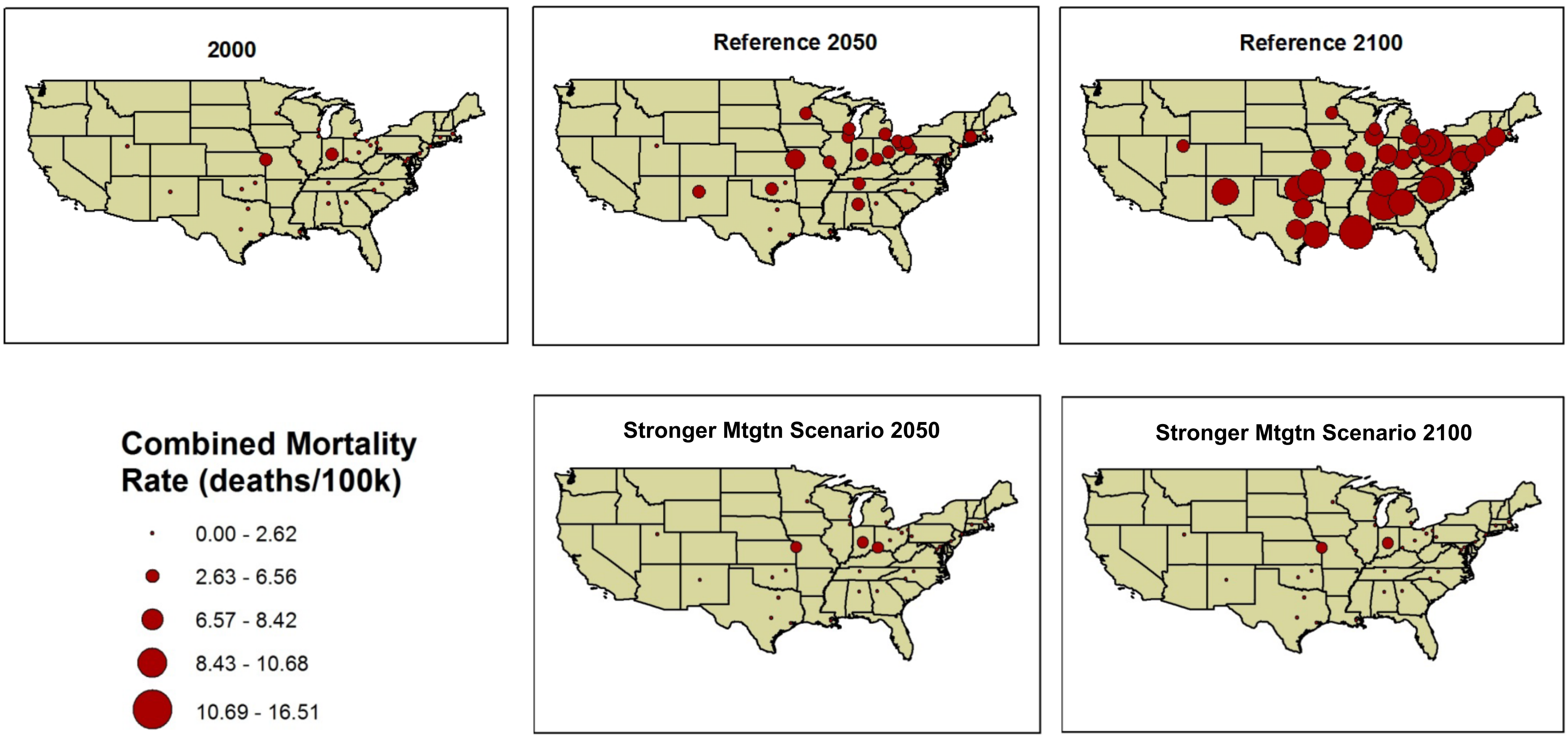


- Temp Effect compares Reference with Control case
- Temp + Mitigation Effect compares Stronger Mitigation vs. REF
- System costs include capital, operations, maintenance, and fuel.

** Internal * Deliberative **

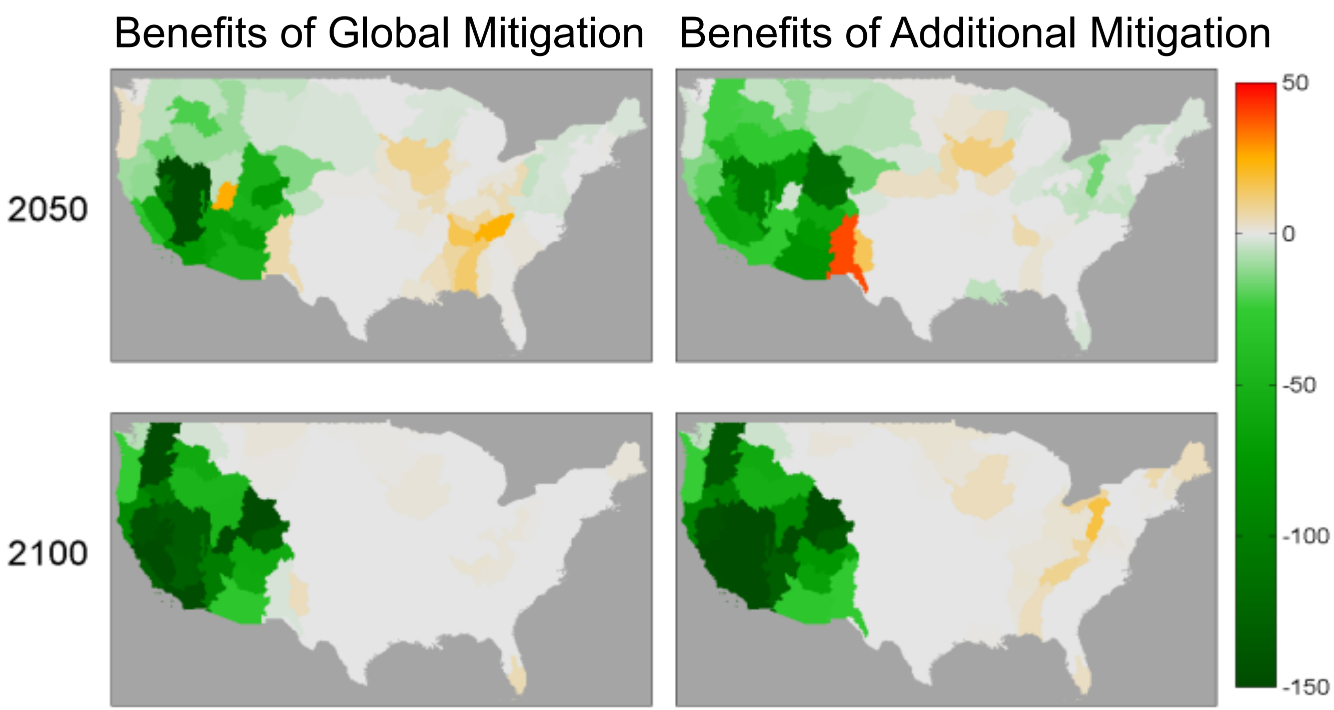
Extreme Temperature Mortality

- Dramatic increase in projected heat mortality over time; cold mortality continues to diminish.
- Results suggest a considerable annual risk reduction for ETM that grows over time with GHG policy implementation.
- Does not fully consider the effect that adaptation would have in reducing mortality.



Changes in Drought Risk Through 2100

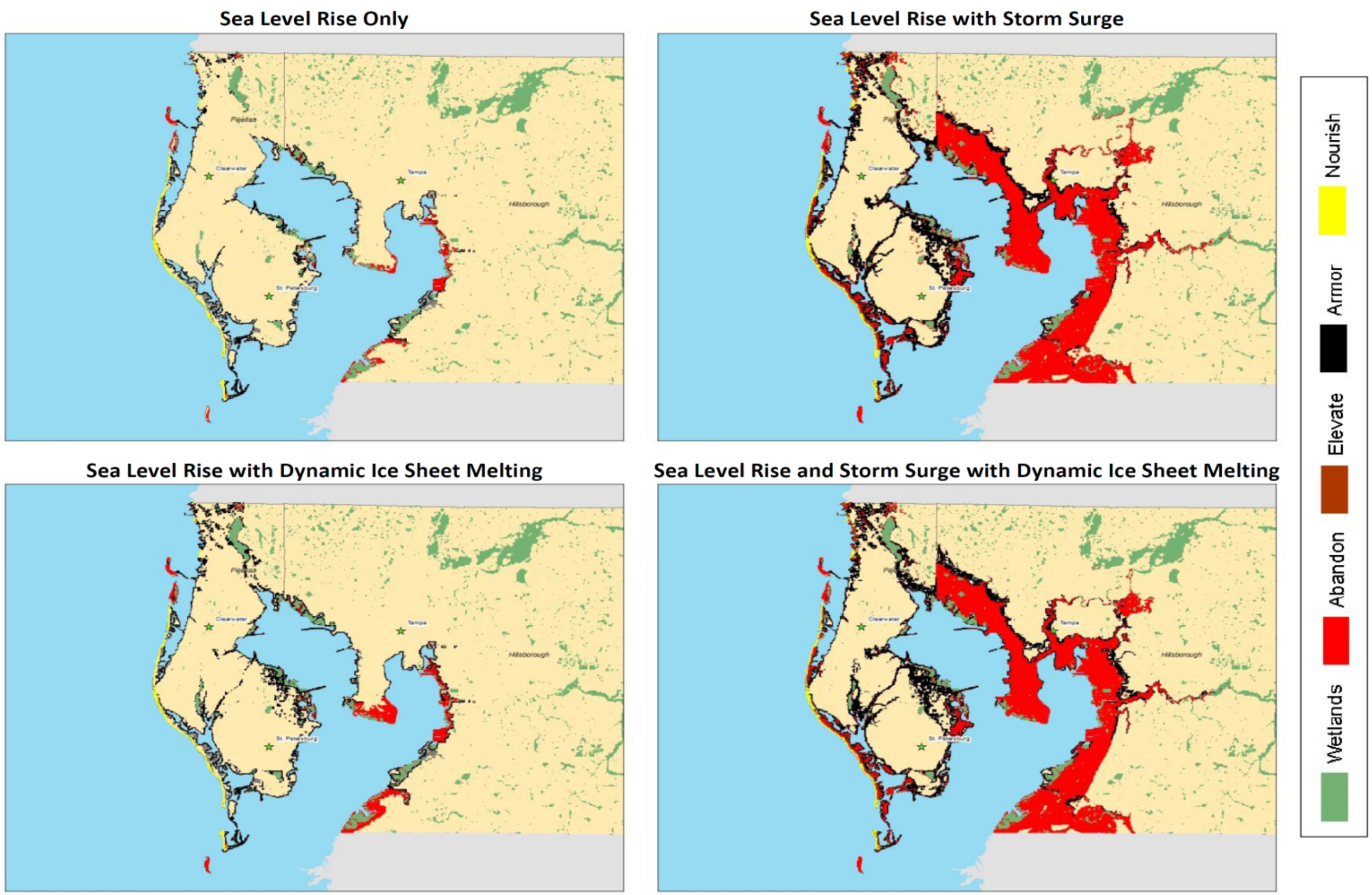
- Drought risk is estimated using the Palmer Drought Severity Index (PDSI, measured by changes in both precipitation and temperature).
- In the figures below, green represents reductions in drought risk associated with the GHG mitigation policies compared to the reference scenario.
- Largest increases in drought frequency under the reference case are in the southwestern U.S., which is also where the largest benefits of mitigation occur.
- Given the ‘wetness’ of the climate model used, these are likely to be underestimates of impacts/benefits.



Change in the # of PDSI drought months in a 30-yr period due to mitigation (policy-reference)

Coastal Property Damages and Adaptation Response Costs

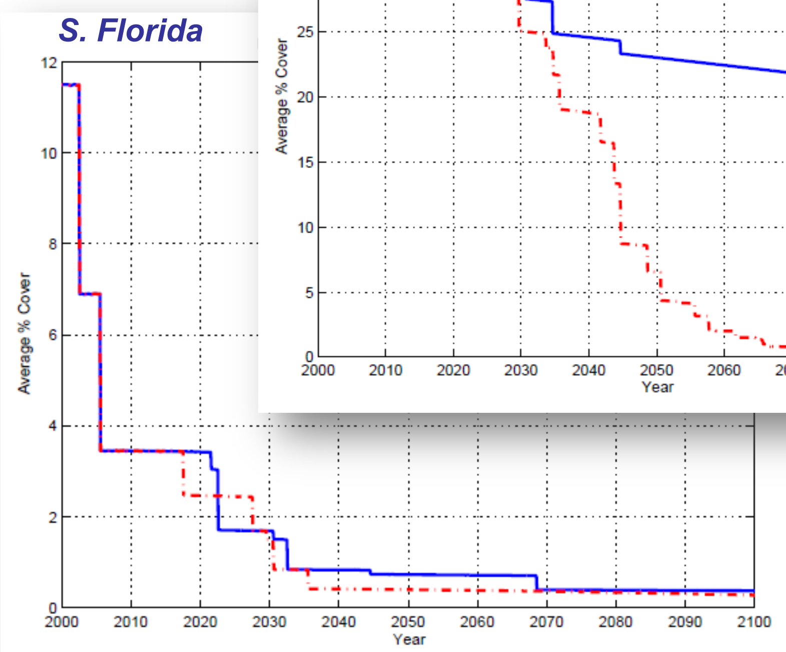
- The cumulative, undiscounted economic impacts of sea level rise through 2100 for the reference scenario (140cm) are $450B. Mitigation avoids $57B (mitigation scenario) or $68B (stronger mitigation scenario) of these costs.
- Inundation risks and economic damages increase as storm surge is incorporated.
- Areas projected to be abandoned have a higher percentage of socially vulnerable populations than areas likely to be protected.

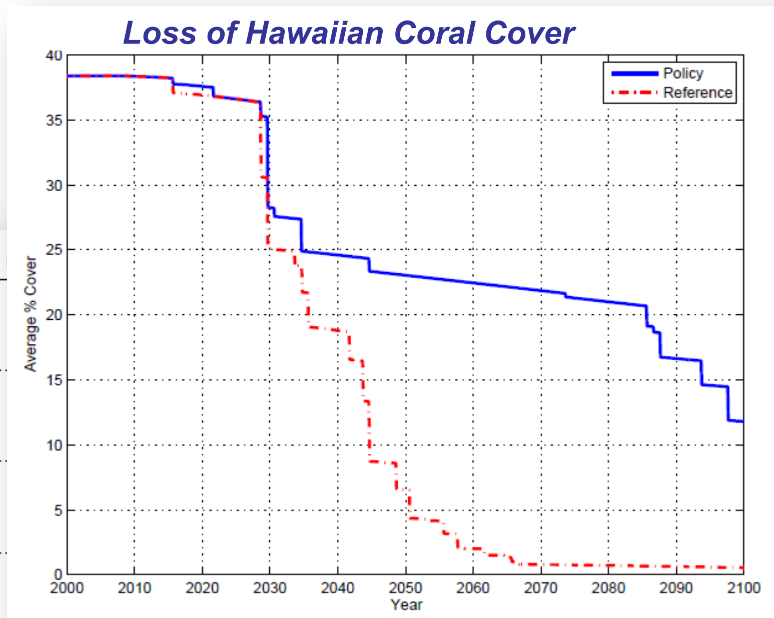


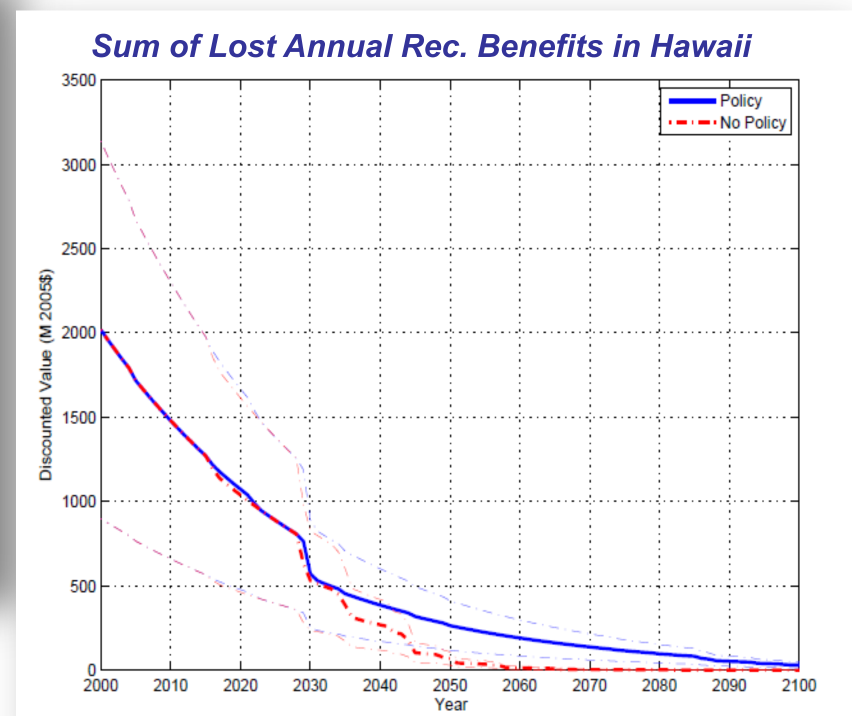
** Internal * Deliberative **

Estimated Decline in U.S. Coral Reefs

- GHG mitigation delays Hawaiian coral reef loss compared to the reference.
- The stronger mitigation scenario (3.7 W/m^2) avoids ~$98B (undisc.) by 2100 [$18B disc. at 3%] in lost recreational value for all 3 regions, compared to the reference.
- GHG mitigation provides only minor benefit to coral cover in South Florida and Puerto Rico *(not shown)*, as these reefs are already being affected by climate change, acidification, and other stressors.

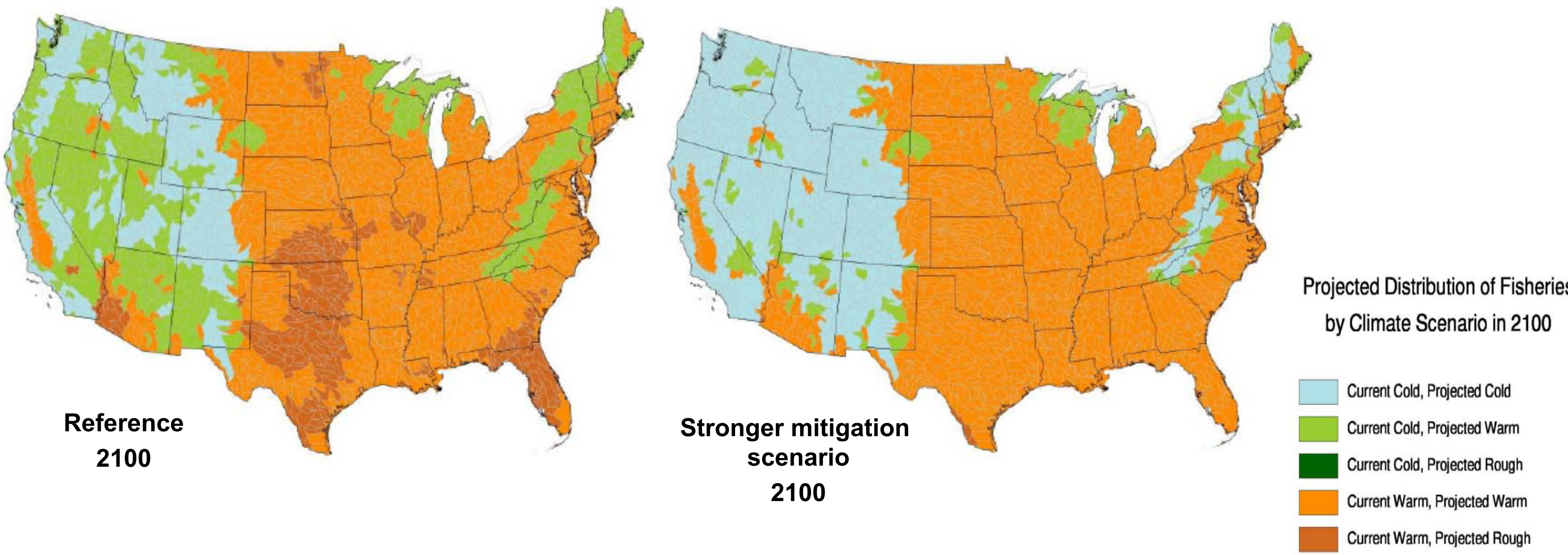






Freshwater Recreational Fishing

- 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 (3.7 W/m^2) avoids \$2.3B (undiscounted) in recreational fishing damages compared to the reference cumulatively by 2100.



Next Steps

- Complete special issue journal publication process.
- Coordinate with external groups interested in CIRA, including those engaged in impacts/benefits work.
- Develop materials to communicate findings (briefing packages, background documentation).
- Continue work on CIRA runs for additional impact sectors not included in the *Climatic Change* special issue, e.g.:
  - Move agriculture and forestry sectors forward.
  - Start work on new sectoral models:
    - Air quality
    - Water quality
    - Water scarcity analysis
    - Outdoor recreation
  - Identify next steps to address highest priority sectoral gaps (e.g., power sector cooling and renewables, labor productivity, extreme event recovery costs, additional ecosystem impacts).

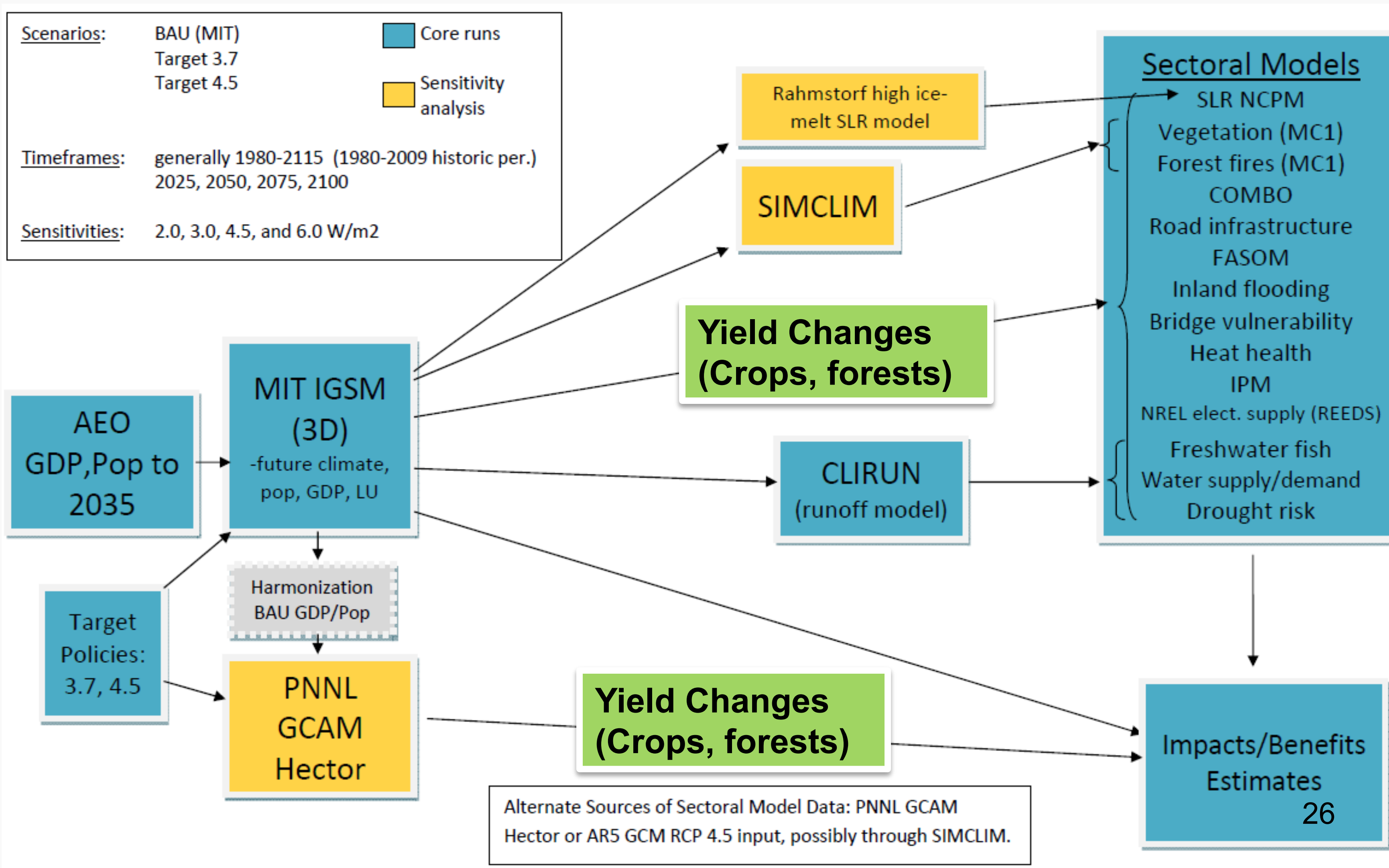
Next Steps (con't)

- Explore opportunities for "CIRA 2.0"
  - Broader use of CIRA scenarios
    - Expand geographic coverage beyond the U.S.
    - Include more impact sectors.
  - New scenarios, e.g.
    - Further assess key sources of uncertainty (e.g., climate models employed).
    - Additional sensitivities?
    - Additional policy cases?
    - Explore potential for reduced form models to analyze 'smaller' (non-global) mitigation levels.
  - Incorporate of climate impacts feedback into economy-wide models.
  - Use CIRA outputs to inform SCC damage functions.
  - Possible CIRA 2.0 kickoff meeting early 2014.

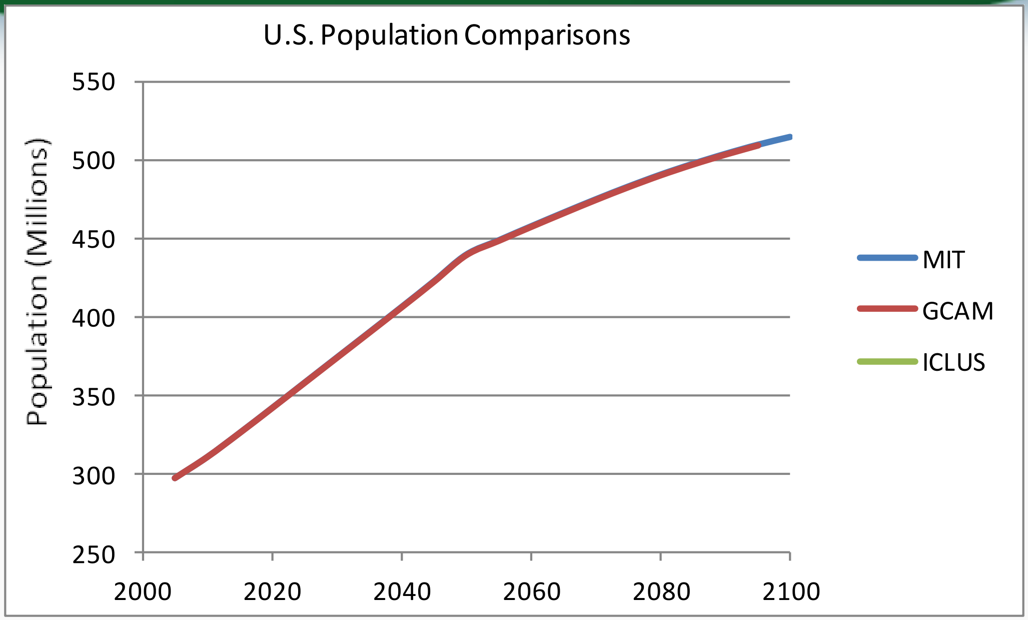
Thank You

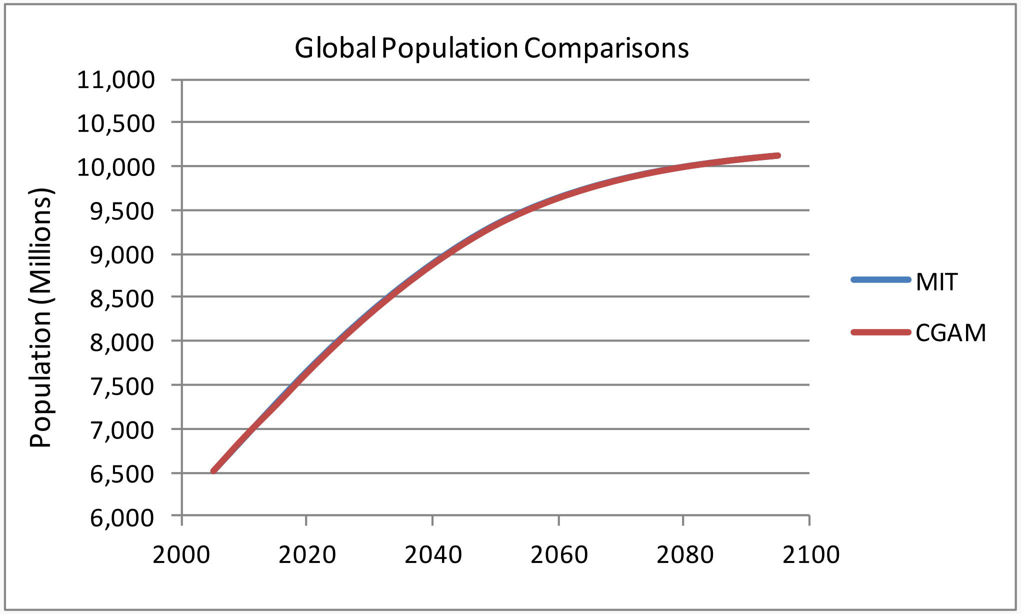
Appendix

CIRA Operational Schematic



Population





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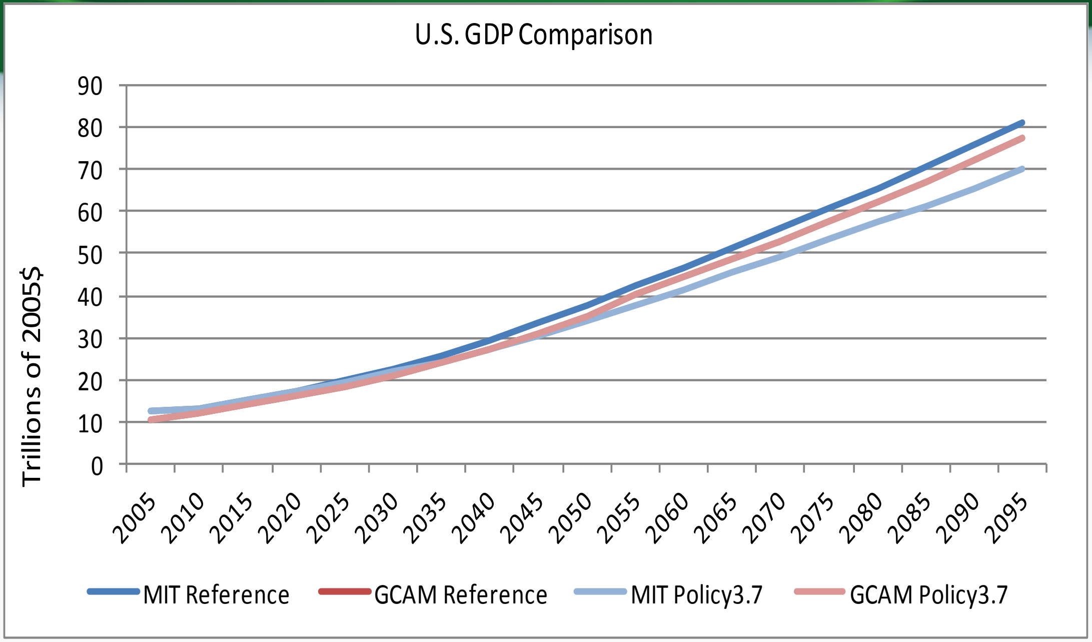
GDP


U.S. GDP Comparison
Trillions of 2005$
90
80
70
60
50
40
30
20
10
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
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2070
2075
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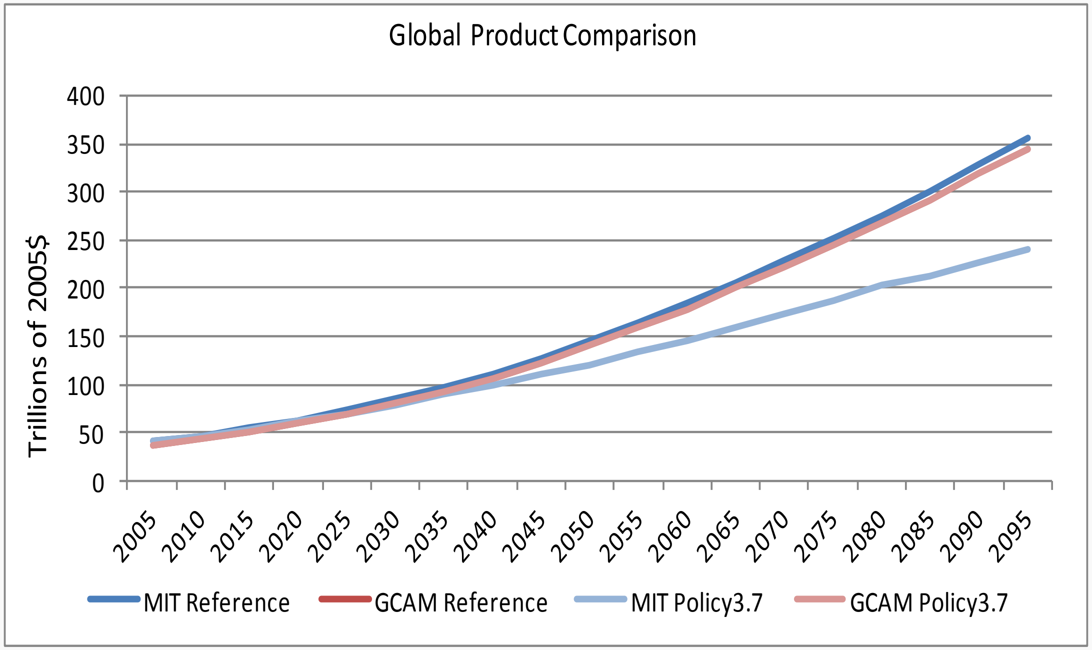
MIT Reference
GCAM Reference
MIT Policy3.7
GCAM Policy3.7


Global Product Comparison
Trillions of 2005$
400
350
300
250
200
150
100
50
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
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2060
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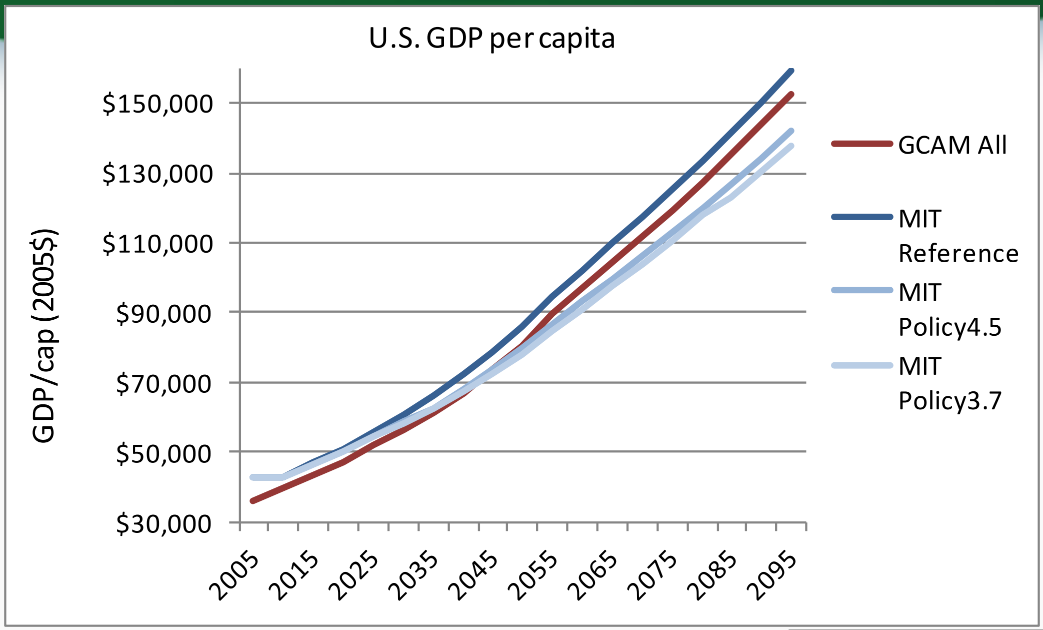
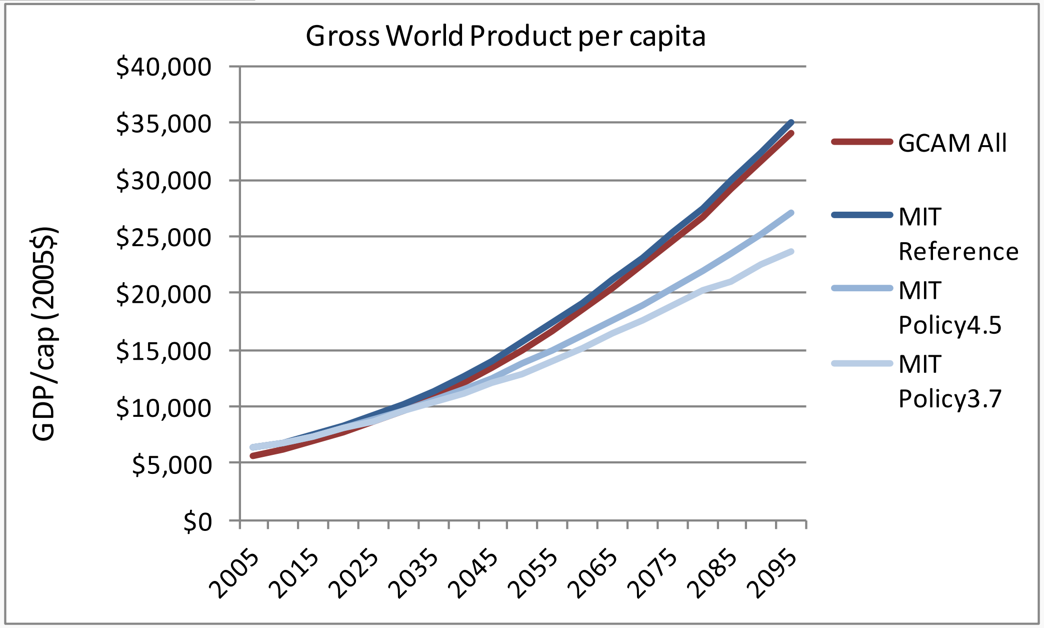
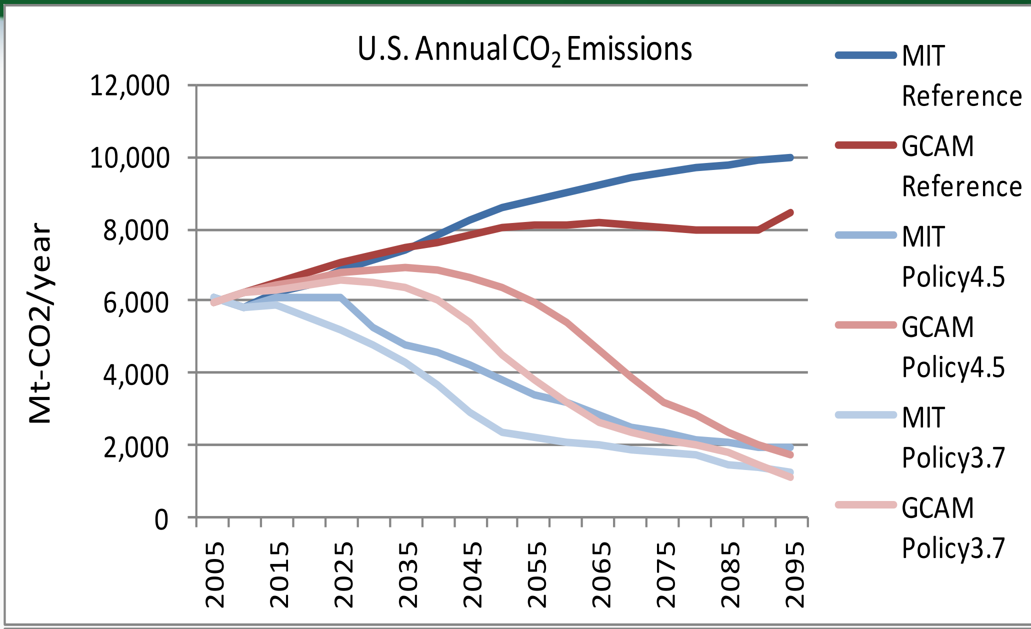
2090
2095
MIT Reference
GCAM Reference
MIT Policy3.7
GCAM Policy3.7

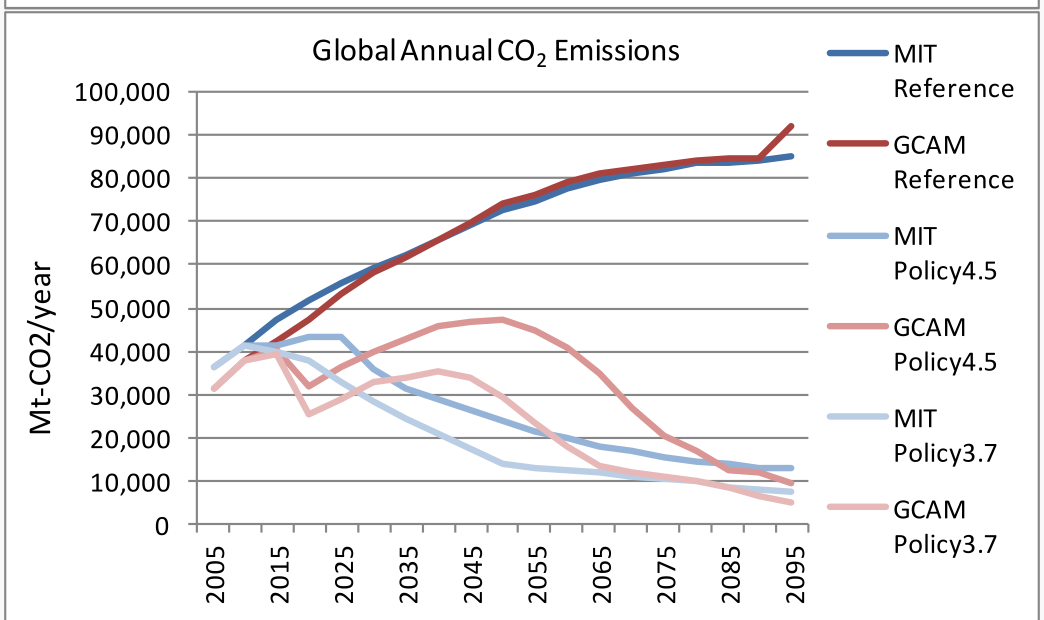
GDP per capita

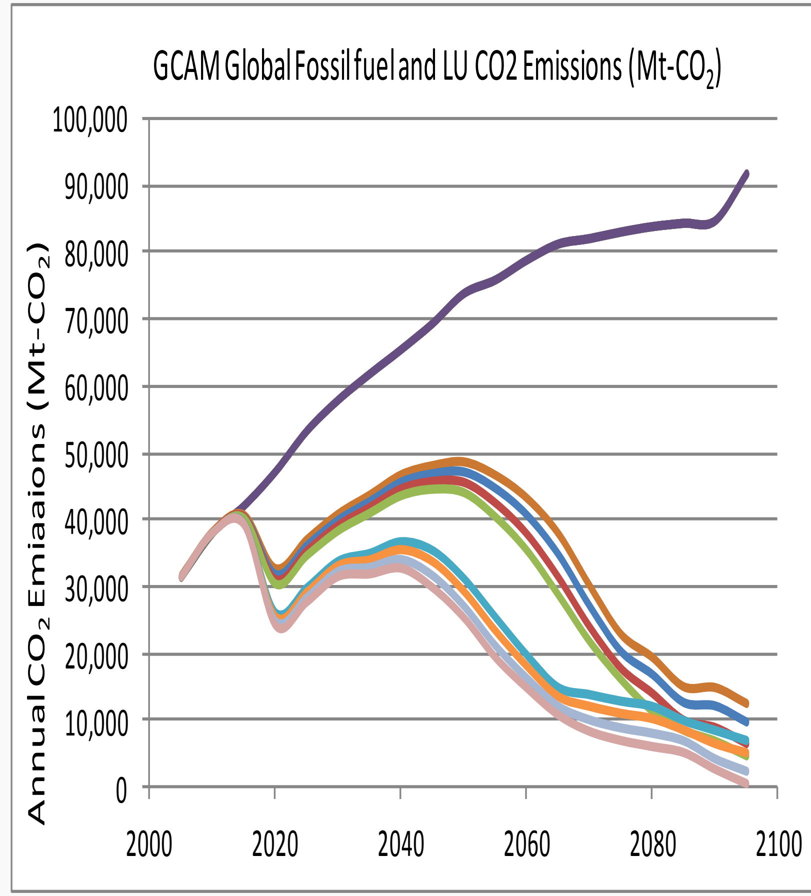




CO_2 Emissions

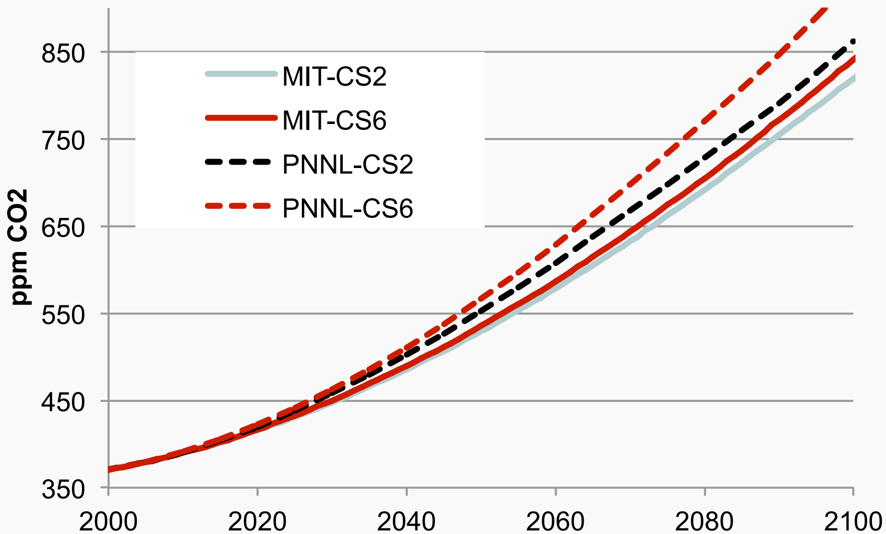




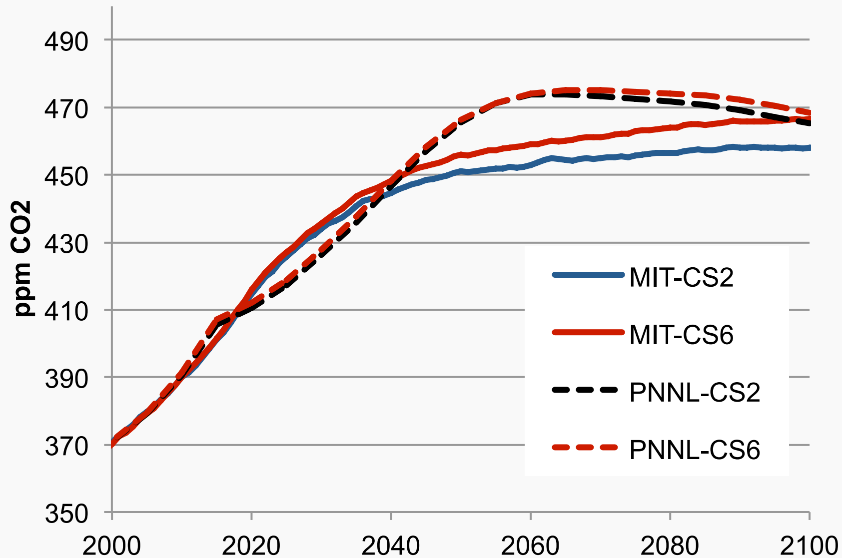


CO_2 Concentrations

Reference

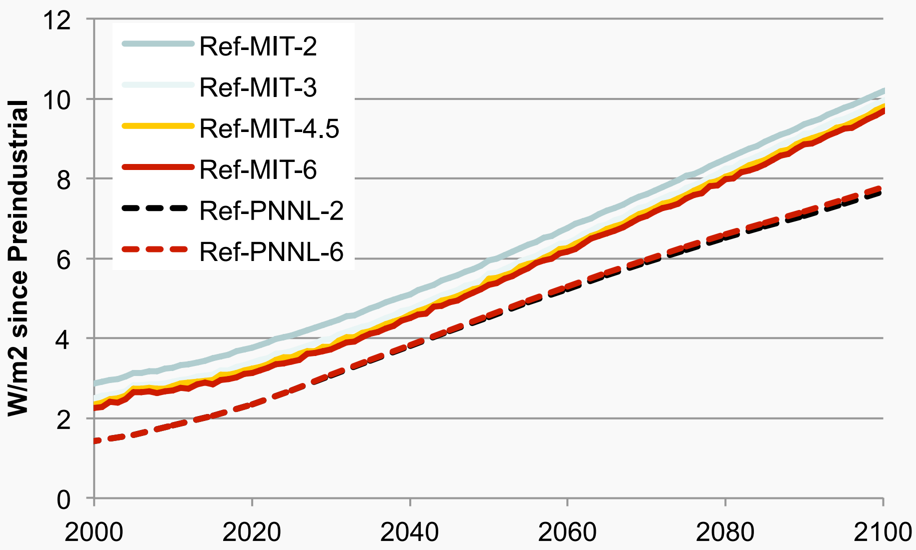


3.7 Policy

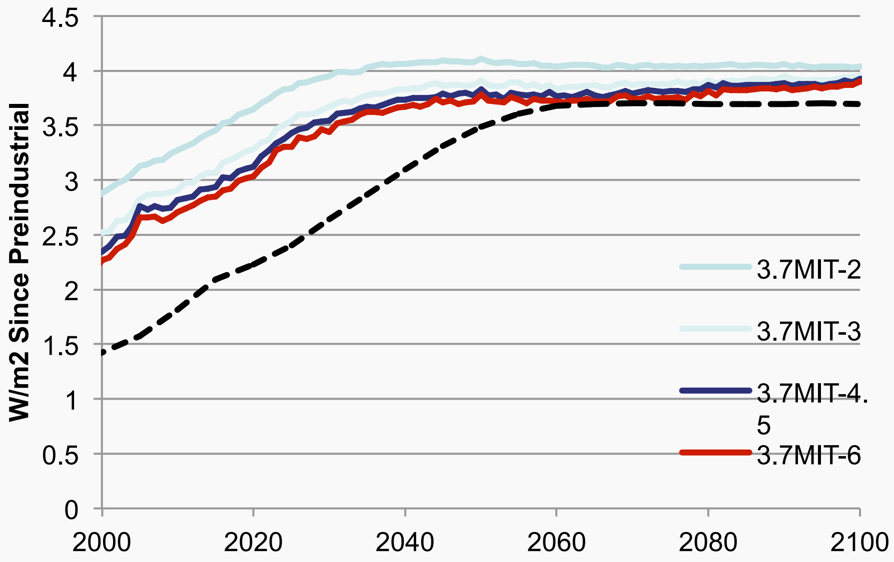


Forcing

Reference

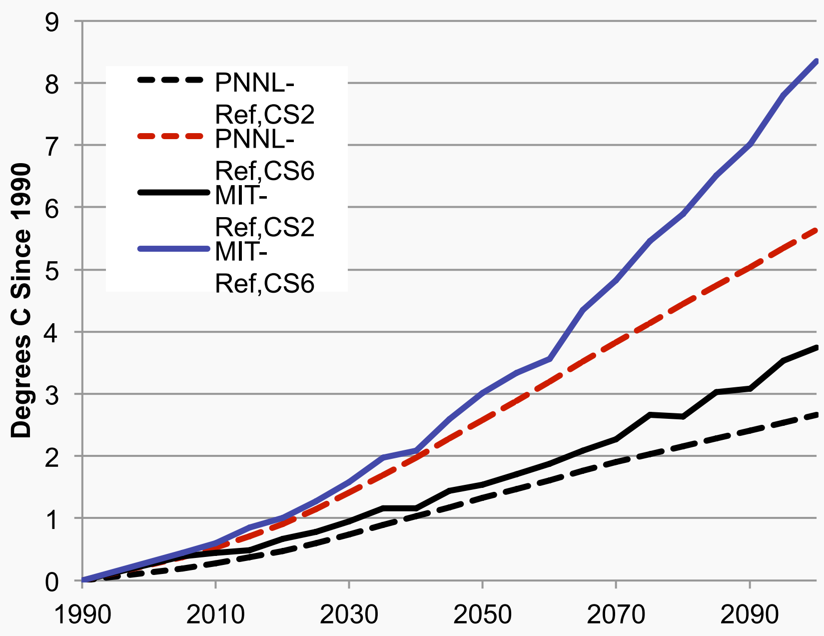


3.7 Policy

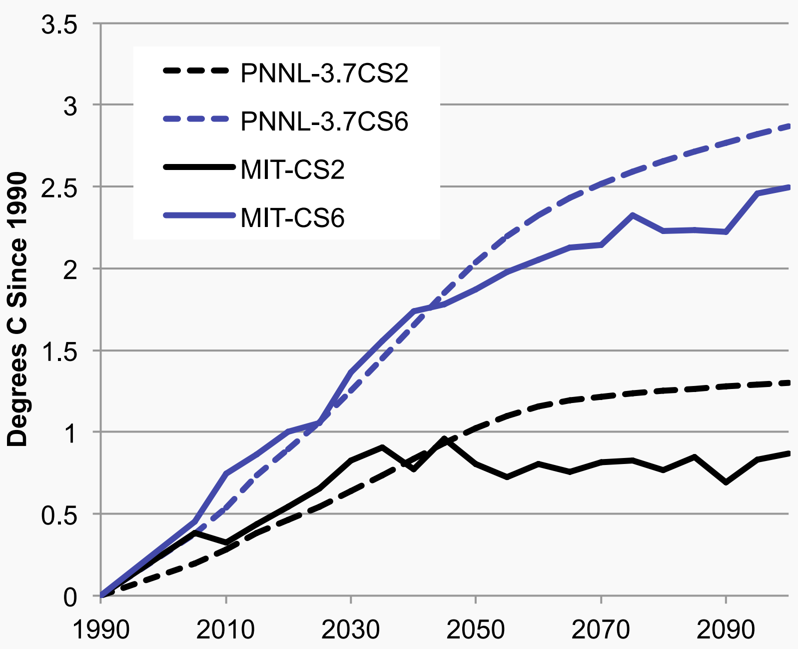


Temperature

Reference



3.7 Policy



Sea Level Rise