Uncertainty methods in EPA's impacts and benefits work

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On-going work examining uncertainty in climate change impacts and damages

- Communication of benefits as well as costs
  - Improved understanding of what would be gained from GHG mitigation
- Uncertainty in temperature change for multiple socio-economic/ emissions scenarios
  - "Can developed economies combat dangerous anthropogenic climate change without near-term reductions from developing economies?" (Waldhoff and Fawcett, 2011)
  - Probability of temperature of attaining different temperature changes as a function of start periods for mitigation in developed and developing economies with multiple policy scenarios (Calvin, Fawcett, Waldhoff)
- Multi-model impacts/damages project
  - Purpose is to incorporate and clearly communicate multiple sources of uncertainty in domestic climate change impacts

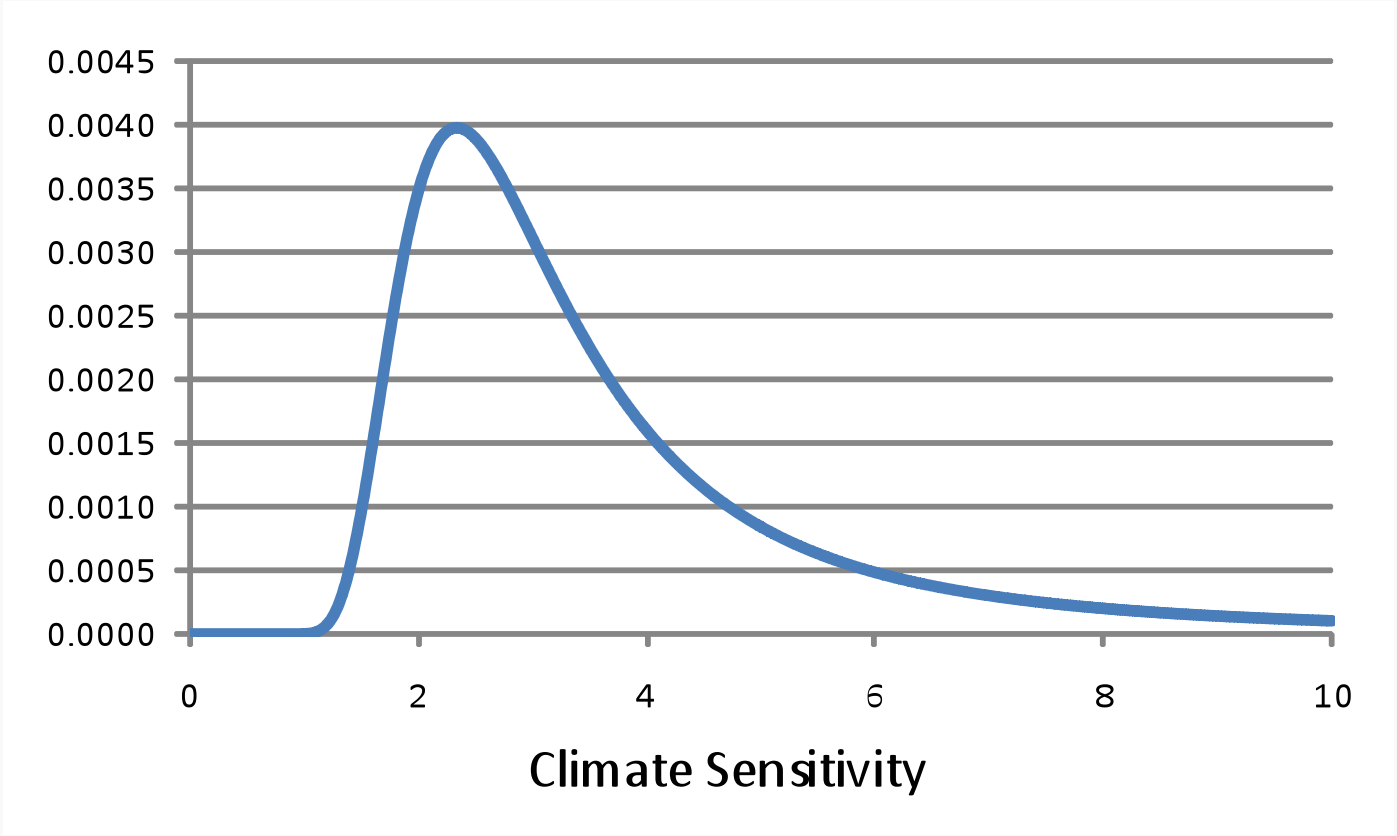
Temperature change uncertainty: Motivation

- Developing economy greenhouse gas emissions are growing rapidly relative to developed economy emissions
  - This has led some to suggest that emissions mitigation in developed economies would be ineffective without the participation of developing economies or have no appreciable impact on global average temperature change
- To examine this we estimate the effect of developed country leadership in reducing the likelihood of observed global mean temperature exceeding 2°C under three global emissions scenarios
- The effect of early mitigation action on the part of developed economies, even without significant emissions mitigation from developing economies until 2050, significantly reduces the probability of large temperature changes in 2100 and increases the probability of lower temperature changes, as compared to a no policy scenario

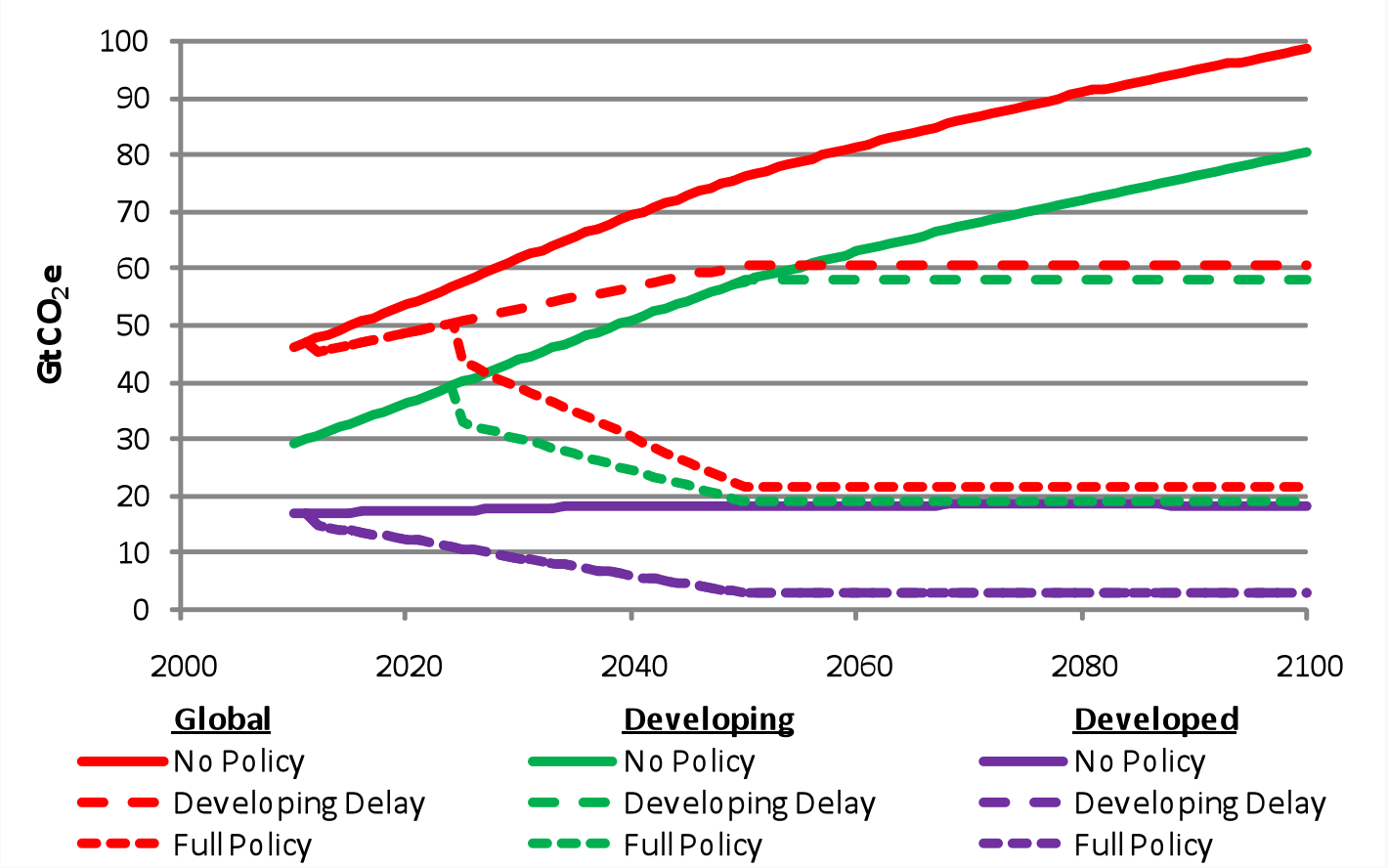
Development of distributions for temperature change

- **Scenarios**
  - **No policy scenario**
    - GHG emissions pathways through 2100 from the MiniCAM's EMF 22 no policy scenario
  - **Full participation scenario**
    - Commitments made at the 2009 MEF: "the G8 leaders agreed to reduce their emissions 80% or more by 2050 as its share of a global goal to lower emissions 50% by 2050"
    - US emissions caps from the Senate APA; 83% below 2005 levels in 2050
    - Net reductions in developed economy emissions is 83% below 2005 levels by 2050.
    - Developing countries caps at 2015 levels in 2025; linearly reduce emissions to 26% below 2005 levels by 2050 (50% global reduction target agreed upon at the MEF)
  - **Developing economy delay scenario**
    - Developed economies adopt the same targets as in the full participation case
    - Developing economies do not adopt any climate policies until 2050 after which their emissions are held constant at 2050 no policy levels.
  - *Stylized scenarios demonstrate emissions could occur with many potential futures; None of the scenarios are stabilization scenarios*
- **Distribution for radiative forcing**
  - Roe and Baker (2007)

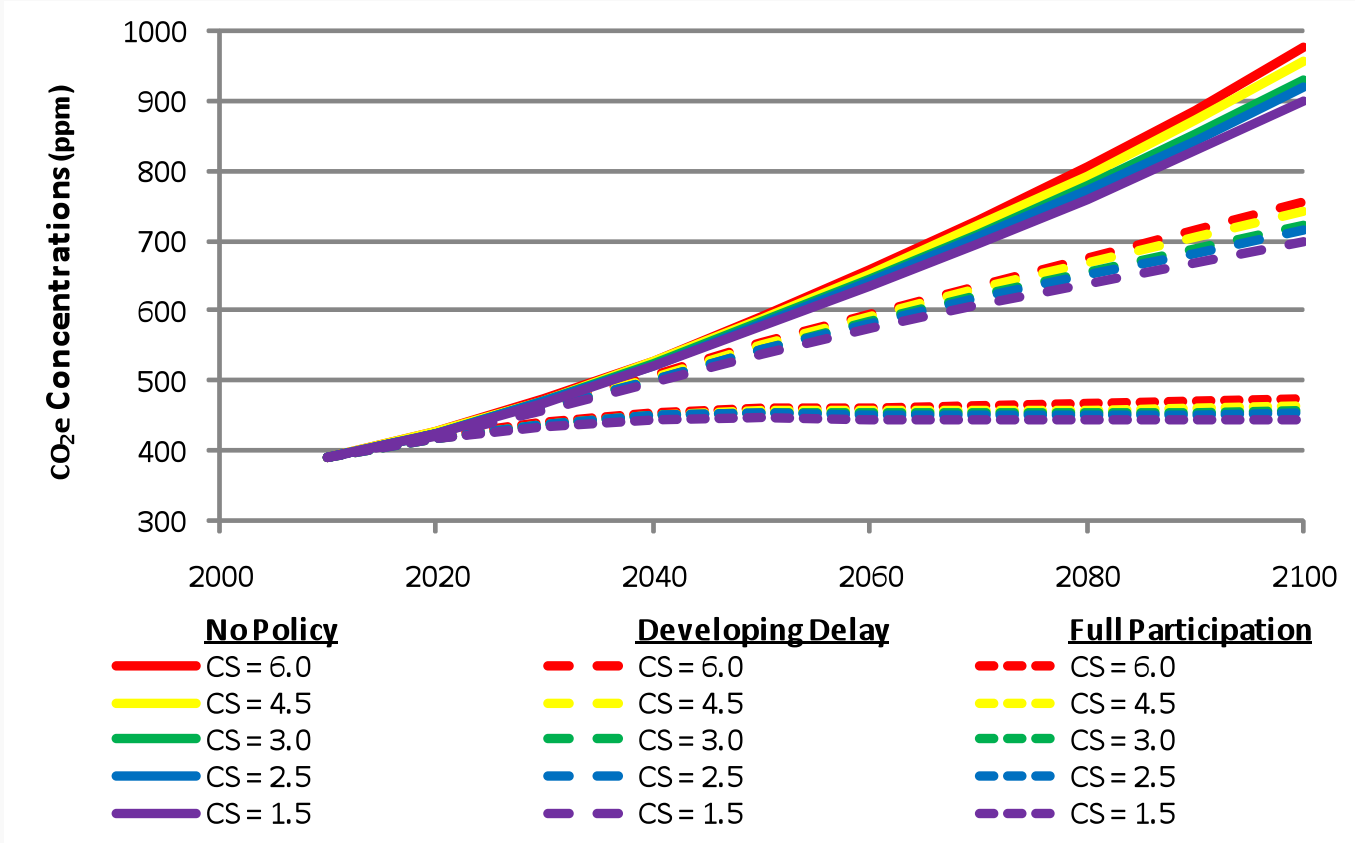
Distribution of CS, Roe and Baker (2007)



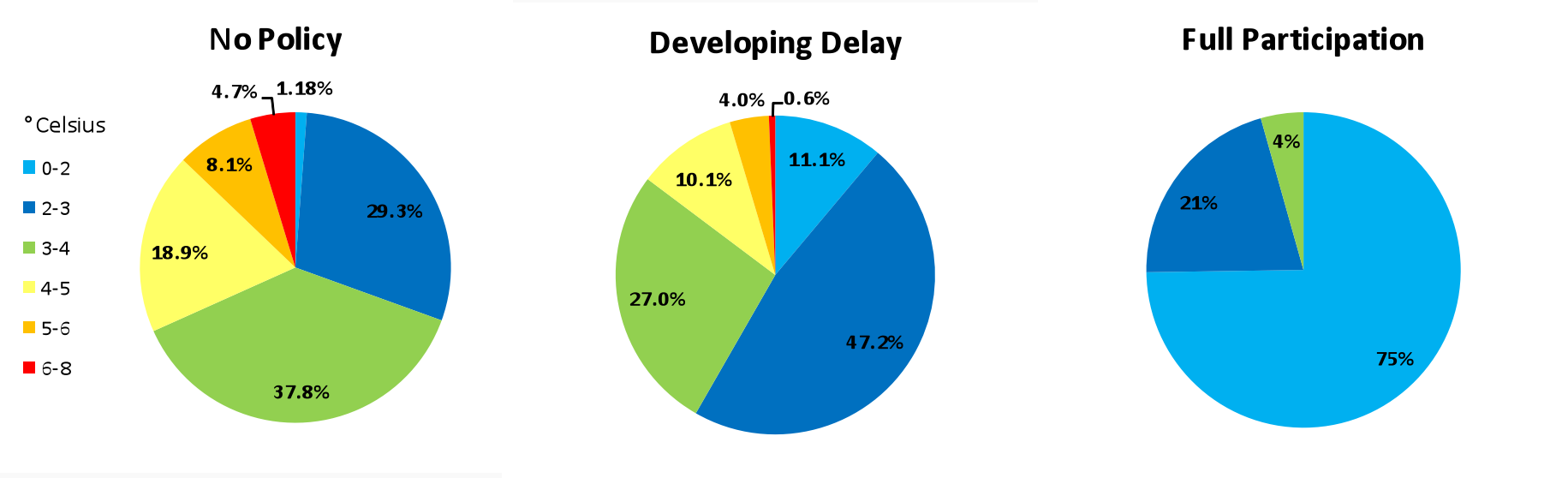
Annual GHG emissions under alternate policy scenarios



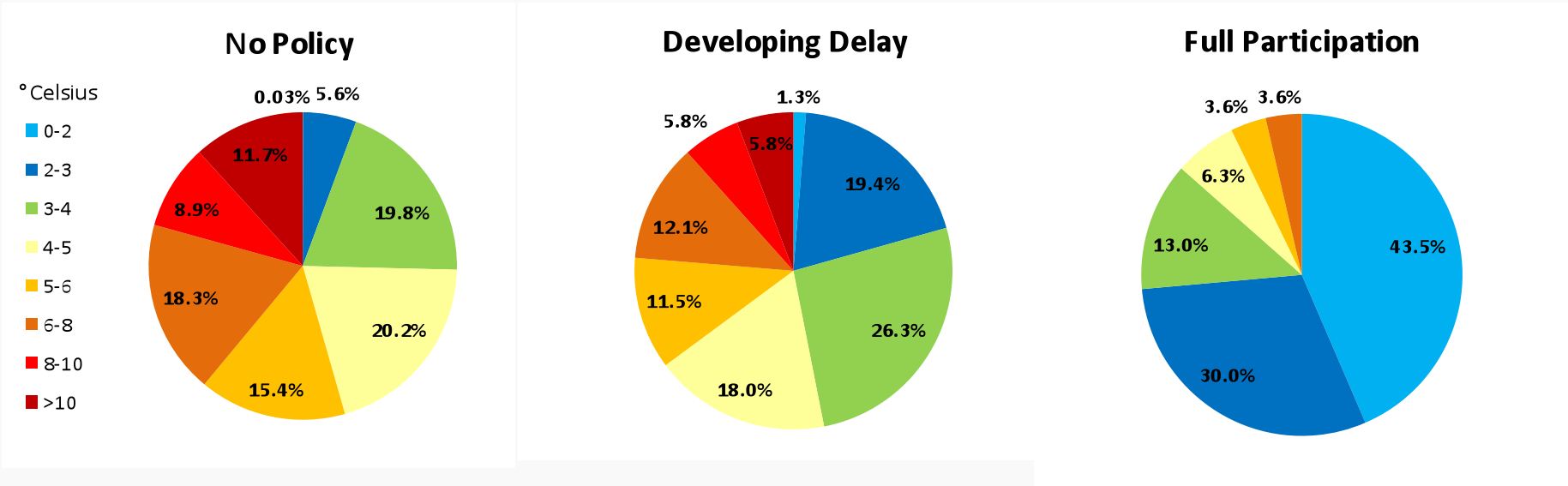
CO_2e concentrations under alternate scenarios and climate sensitivities



Probability of observed temperature changes in 2100



Probability of equilibrium* temperature change in 2100



* Long-term equilibrium temperature change assuming radiative forcing held constant at 2100 levels.

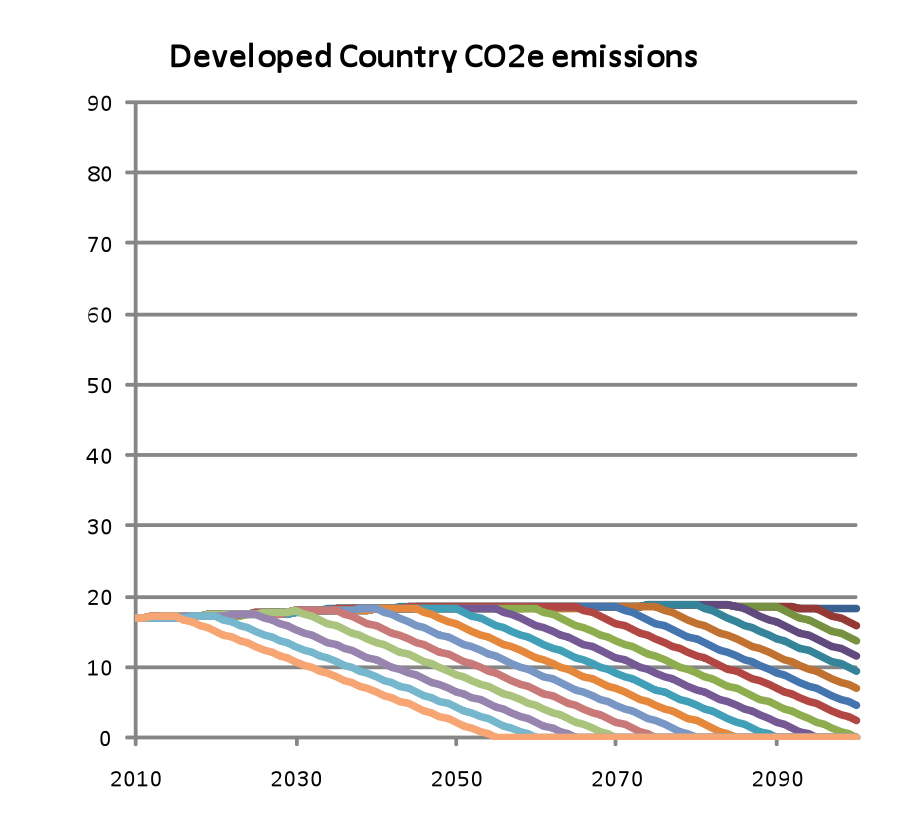
Conclusions

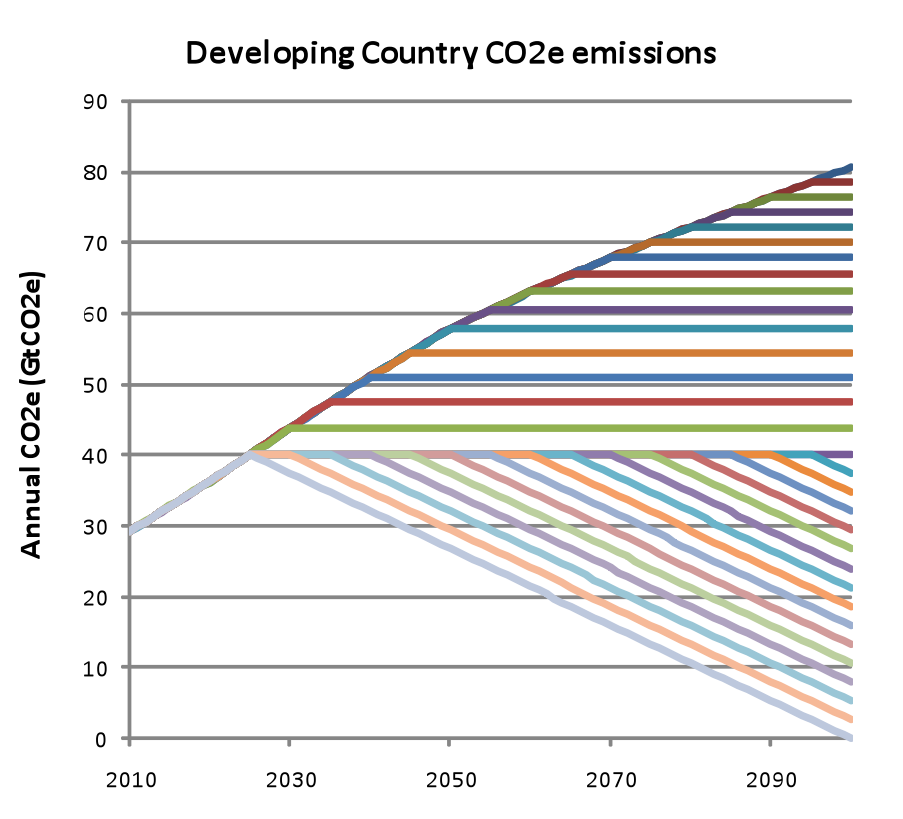
- Early carbon mitigation efforts by developed economies will considerably affect the distribution over future climate change, whether or not developing countries begin mitigation efforts in the near term
  - Appreciable reduction in the probability of more extreme levels of temperature change and increase the probability of lower global average temperature change
  - The risk of the worst temperature changes are greatly reduced even under the developing economy delay scenario
- The potential for this delay should not be used as a reason to prevent mitigation action in developed economies

Further development of temperature change uncertainty

- Model uncertainty in temperature distribution for multiple emissions mitigation scenarios and starting periods
  - Uncertainty over climate sensitivity
  - Mitigation scenarios with different starting periods: developing delay and full participation
  - Representing a spectrum of beginning action in both developed and developing countries
- Develop an on-line interactive graphic for EPA
  - Allows the user to manipulate the start date of beginning action and see the resulting change in the probability of different temperature outcomes for policy scenarios
- Costs of alternate start and mitigation scenarios are not included but are planned for future work

Emissions pathways with alternate start dates

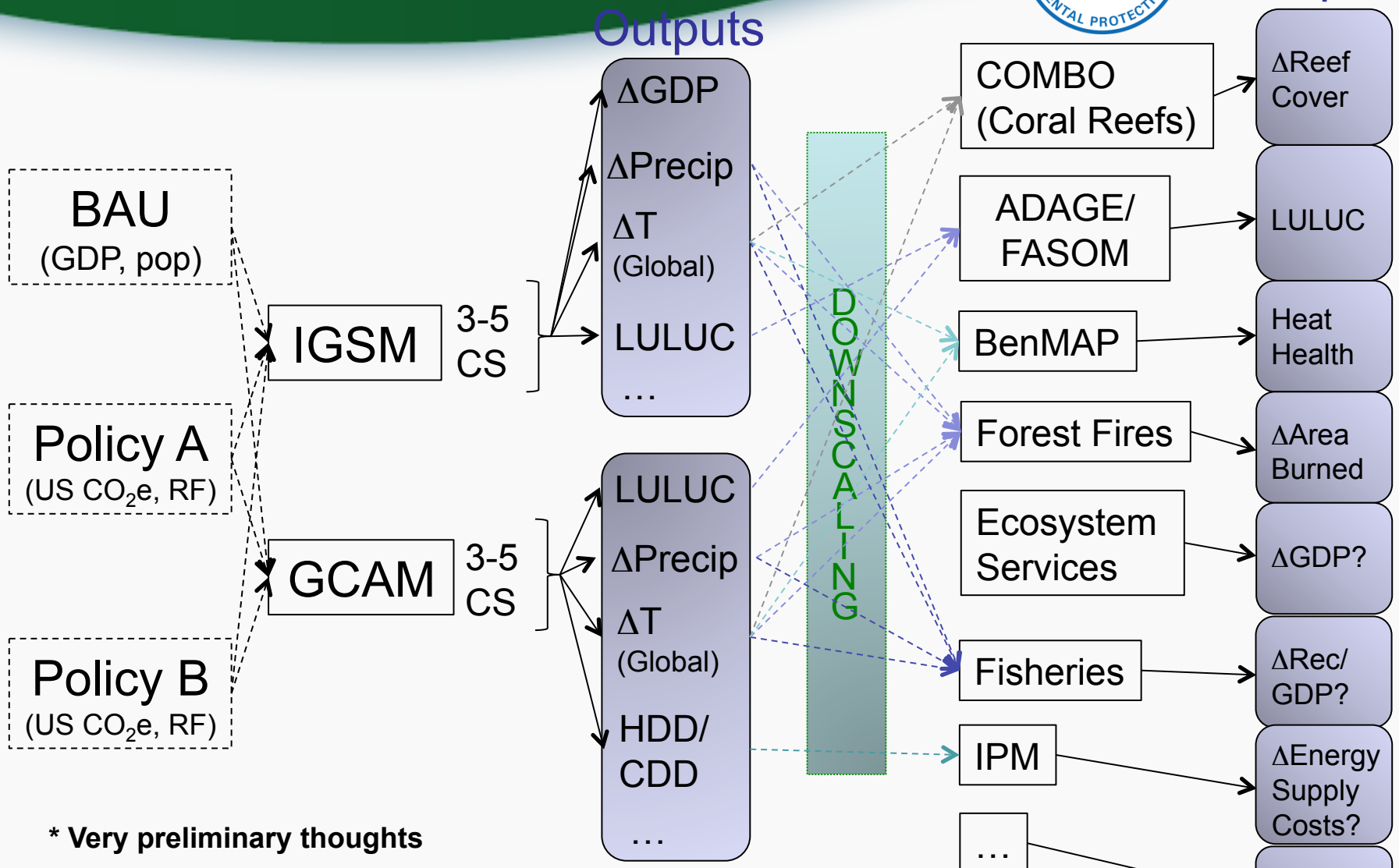




Use of this work in future EPA analyses

- EPA has recently initiated a project that will estimate domestic climate change impacts and damages using a suite of models
- Multiple sectors and scenarios will be considered
- A primary goal is to incorporate uncertainty through every stage of this process
  - Communicate uncertainty, both quantified and unquantified, to both decision-makers and the public
  - Important to communicate uncertainty in a way that will improve decision making

Draft diagram of uncertainty methods in EPA's impacts project*



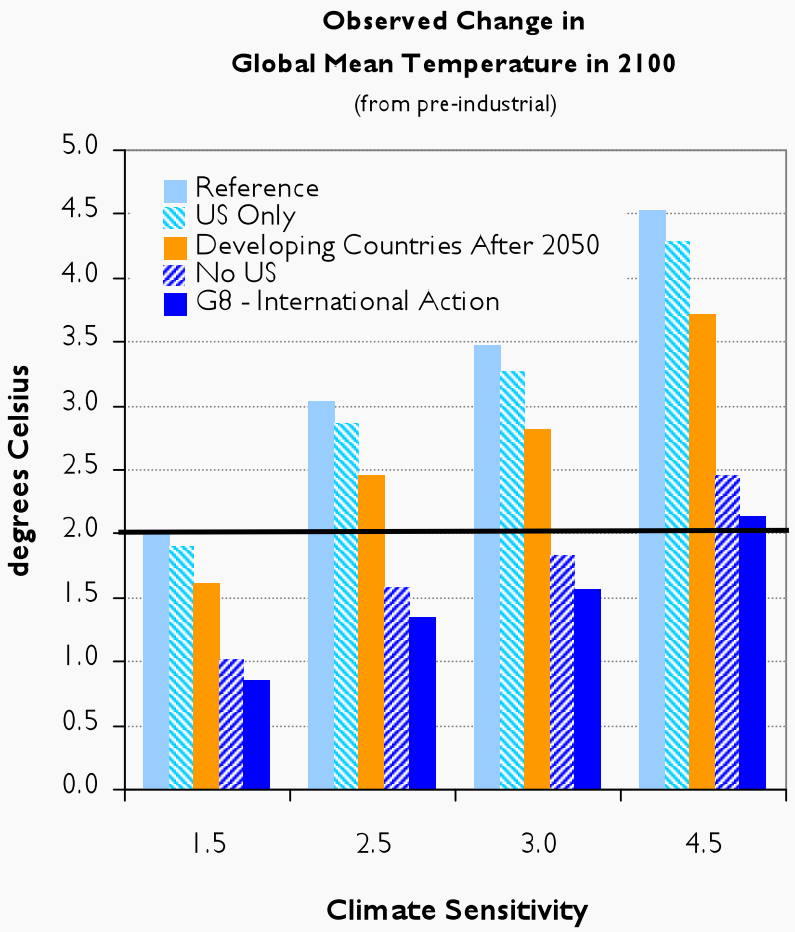
*** Very preliminary thoughts**

Model and scenario uncertainty

- Three scenarios, beginning with IA models
  - BAU harmonized on population and GDP
  - Two policies (4.5 W/m^2 and 3.7 W/m^2 ?) harmonized on US emissions and global RF
  - Three to five climate sensitivies
  - 18 to 30 sets of IA results
- Scenario uncertainty represented in sectoral models
  - Impacts models (e.g. COMBO, Freshwater fisheries) to use multiple IA outputs as inputs to generate sectoral impacts
- Model uncertainty
  - In addition to multiple scenarios, some sectors have impacts from multiple models (e.g. Agriculture/Forestry/LULUC, Energy)

Global Mean Temperature Change in 2100

Impacts of International Action Assumptions (MAGICC)



- This chart demonstrates projections of observed temperature changes (from pre-industrial time) in 2100 under various assumptions about the climate sensitivity. A climate sensitivity (CS) of 3.0° C is deemed "most likely" by the IPCC.
- For any given climate sensitivity, lower emissions result in less temperature change.
- Under the G8 – international goals (reducing global emissions to 50% below 2005 by 2050), a 2 degree target in 2100 is attainable for climate sensitivities of 3° C or lower.
- The temperature and GHG concentrations in these scenarios will keep rising after 2100 – continued GHG reductions will be necessary to stabilize temperatures and concentrations.
- At a CS of 3.0° C, in order to achieve an equilibrium temperature change of 2 degrees CO_2e concentrations must be stabilized below 457 ppm.
  - This would require continued abatement beyond the level needed to stabilize concentrations at 2100 levels.
  - It would be possible to reduce CO_2e concentrations after 2100 below 457 ppm by even further reducing GHG emissions in the next century. An 'overshoot' scenario such as this would further reduce the equilibrium temperature change, making it possible to achieve the 2 degrees C target even with a climate sensitivity of 3.0° C.
  - See Appendix 5 for equilibrium temperature impacts.

Emissions, abatement, and RF for alternate policy scenarios

2010 – 2100 Cumulative greenhouse gas emissions and abatement (GtCO2e)

	2010 - 2100 Cumulative GHG Emissions			2010 - 2100 Cumulative GHG Abatement		
	Developed	*Developing*	*Global*	*Developed*	*Developing*	*Global*
No Policy	1,646	5,284	6,930	-	-	-
Developing Delay	516	4,679	5,195	1,130	606	1,736
Full Participation	516	2,120	2,635	1,130	3,165	4,295

Total Radiative Forcing (W/m2)

	RF in 2100 Under Alternate Climate Sensitivities				
	CS = 1.5	**CS = 2.5**	**CS = 3.0**	**CS = 4.5**	**CS = 6.0**
No Policy	6.3	6.4	6.5	6.6	6.7
Developing Delay	4.9	5.1	5.1	5.3	5.4
Full Participation	2.5	2.6	2.7	2.8	2.8