To Hedge or not to Hedge Against an Uncertain Future Abrupt Change

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Moving toward a Consideration of "So What?"

- We have heard differing views of the science, the likelihood of abrupt change, the value of paleo-climate analysis, etc….
- We have heard debates about "one point", alternative explanations from hypothetical alternative smart people, etc….
- We have heard pleas for careful articulation of the confidence with which conclusions can be advanced, etc….
- We have heard about the difficulties of monitoring and detection, etc….

Don’t Bury the Lead…..Session 3

- SO WHAT? – or, **SO WHAT DO WE DO NOW?** especially in terms of near-term policy and long term agendas?
- The capacity to mitigate (or adapt) for that matter, depends on a large number of determinants; perhaps the most important of which is *the ability of decision-makers to manage information and exploit their access to risk spreading mechanisms.*
- Given what we have covered here and learned since the NAS study, can we help????

A Taxonomy of Risk Spreading Mechanisms

- Standard view for impacts – spread costs across states of nature.
- In economic terms – spread costs across large populations, especially through a risk-neutral institution for which expected net revenue can be zero.
- In the climate arena – perhaps across time with an options value sub-text.

A Taxonomy of Sources of Uncertainty in our Understanding of the Climate System

- Within the climate arena (and elsewhere)
  - *Model uncertainty*
  - *Calibration uncertainty*
  - *Prediction uncertainty*
  - *Projection uncertainty*
- Could now add implementation uncertainty and scale uncertainty – impacts are site specific and path dependent.

Proposal: Apply a Risk-based Decision-Analytic Approach to Climate Policy

- The idea is to envision a “act – learn – act – learn …….” approach.
- The “act” parts are derived in terms of “buying insurance” to minimize the expected economic cost of adjustment.
- The approach, therefore, does not necessarily rely on economic estimates of damages.
- Rather it could depend on the possibility that there are experiments that we do not want to try on our only planet – a socio-political-economic decision.

Economic Foundations

- Risk management is a well established economic approach based entirely on economic efficiency in the face of uncertainty:
  - Portfolio analysis: this is why we diversify our portfolios and why mutual funds exist
  - Insurance: fixed premiums provide coverage against *economic consequences of events, not the events themselves*.

More Context

- Risk management is not the "precautionary principle" in disguise.
- It is not exactly cost-benefit analysis, though cost-benefit analysis can be modified to incorporate well-defined uncertainty.
- Risk management simply recognizes that variance in outcomes is costly; the degree to which depends on your aversion to risk.
- The application here, though, relies on learning (or the evolution of decision criteria) and (predictable) adjustment criteria.

Learning????

- Potential damages play a role with multiple metrics allowed.
- “Keeping doors open” with some likelihood can be one possible metric.
- The likelihood of crossing a threshold of “intolerable” abrupt impacts or abrupt change itself can be another metric.
- Economic damages of “not implausible” abrupt changes or elaborating the dimensionality abrupt change can be metrics.

Monitoring and Detection

- Would be nice, but these have their own problems.
- Monitoring and detection can sometimes be informed by the boundaries of policy robustness so that prediction is “simplified” to “differential diagnoses” at some level of confidence (determined by relative risk and timing).
- Timing can be adjusted by hedging (insurance) against the cost of adjustment given new information or a more urgent policy perspective.

A Decision-making Hypothesis

- In a cost-benefit approach, uncertainty can be an impediment to action, especially if there is a view that scientific uncertainty will diminish over time.
  - "Confuse if not convince" – not constructive skepticism.
- In a risk management approach, uncertainty is a reason to act (hedge) in the near term.
  - More uncertainty (e.g., another smart person with an alternative explanation) can support hedging.

But is There an Example of a Risk Management Approach at a Macro Scale?

"For example, policy A might be judged as best advancing the policymakers' objectives, conditional on a particular model of the economy, but might also be seen as having relatively severe adverse consequences if the true structure of the economy turns out to be other that the one assumed. On the other hand, policy B might be somewhat less effective under the assumed baseline model … but might be relatively benign in the event that the structure of the economy turns out to differ from the baseline. *These considerations have inclined the Federal Reserve policymakers toward policies that* ***limit the risk*** *of deflation even though the baseline forecasts from most conventional models would* ***not project such an event."***

Greenspan, A., *Opening Remarks*, Federal Reserve Bank of Kansas City, Jackson Hole, WY, August 28-30, 2003, pages 3-4

More Help – Focusing Attention on the Information Processing Determinant

"…the conduct of monetary policy in the United States has come to involve, at its core, crucial elements of risk management. This conceptual framework emphasizes understanding as much as possible the many sources of risk and uncertainty that policymakers face, quantifying those risks *when possible*, and assessing the costs associated with each of the risks. … … This framework also entails, in light of those risks, a strategy for policy directed at maximizing the probabilities of achieving over time our goals…" (page 37)

Greenspan, A., "The Conduct of Monetary Policy", *American Economic Review* **94**: 33-40, 2004.

An Aside – The Risk of Deflation

- The primary cost would fall on millions of borrowers (small businesses and individuals) who would have to pay back loans with dollars that are worth more in real terms.
- There are benefactors: lenders (big institutions) who get higher than expected returns on the loans that they hold.
- *Not unlike mitigation of climate change where the benefits are widely distributed across the "little guys" and the costs are concentrated in large energy companies.*

More on the Risk of Deflation

- In point of fact, ***none*** of the models that the FED (Greenspan) reviews see any chance of deflation along baseline scenarios or across wide ranges of sensitivity analyses – but Greenspan still leads the FED to hedge at the expense of slightly less robust economic activity (a shared cost).
- *In the climate arena, there are models that generate abrupt and perhaps irreversible change along baseline scenarios*

Three Examples – Hedging and the Value of Information under Uncertainty

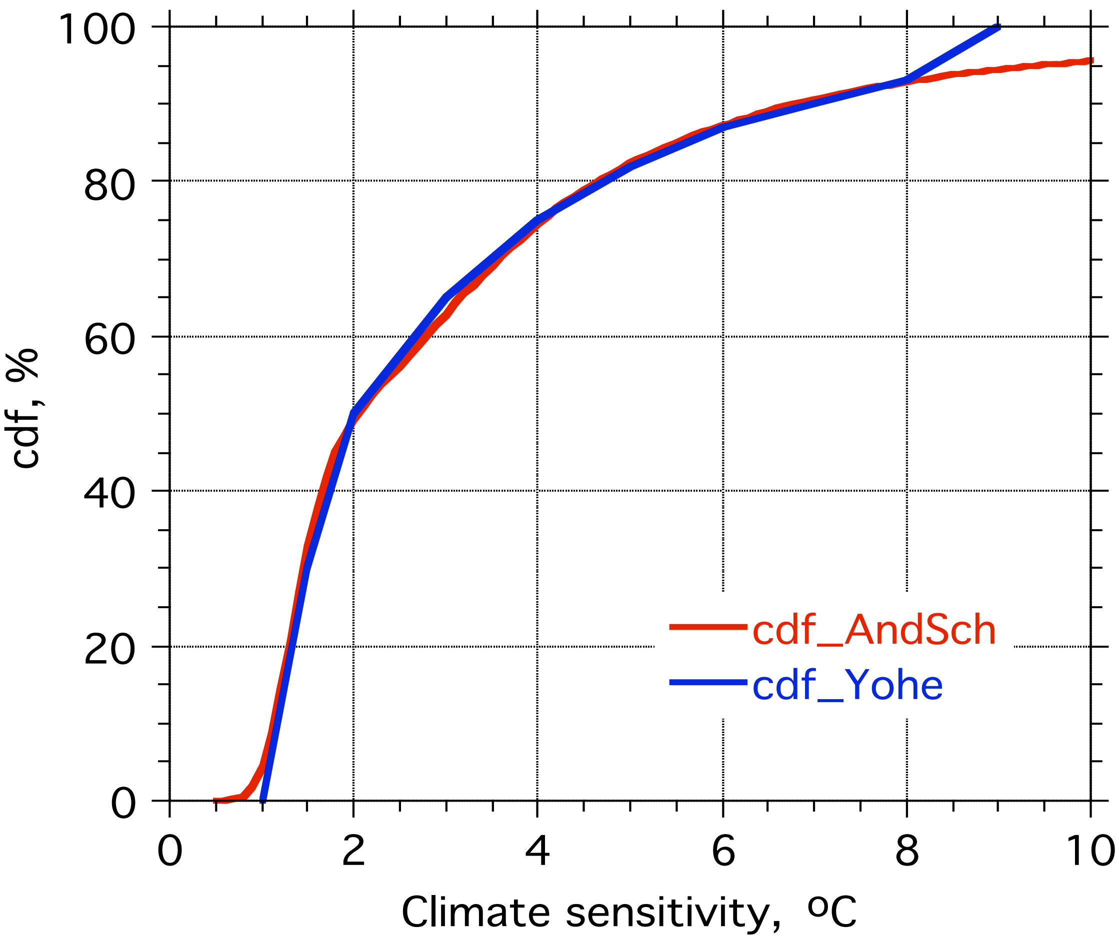
- Near-term policy with alternative temperature targets (equally likely at this point) and uncertainty about the climate sensitivity.
- Mitigation, the likelihood of a THC collapse, and result diagnostics – where to look to learn about the likelihoods???
- The “willingness to pay” for mitigation in a site-specific and path dependent context.

Assessing Policy in Terms of Uncertainty

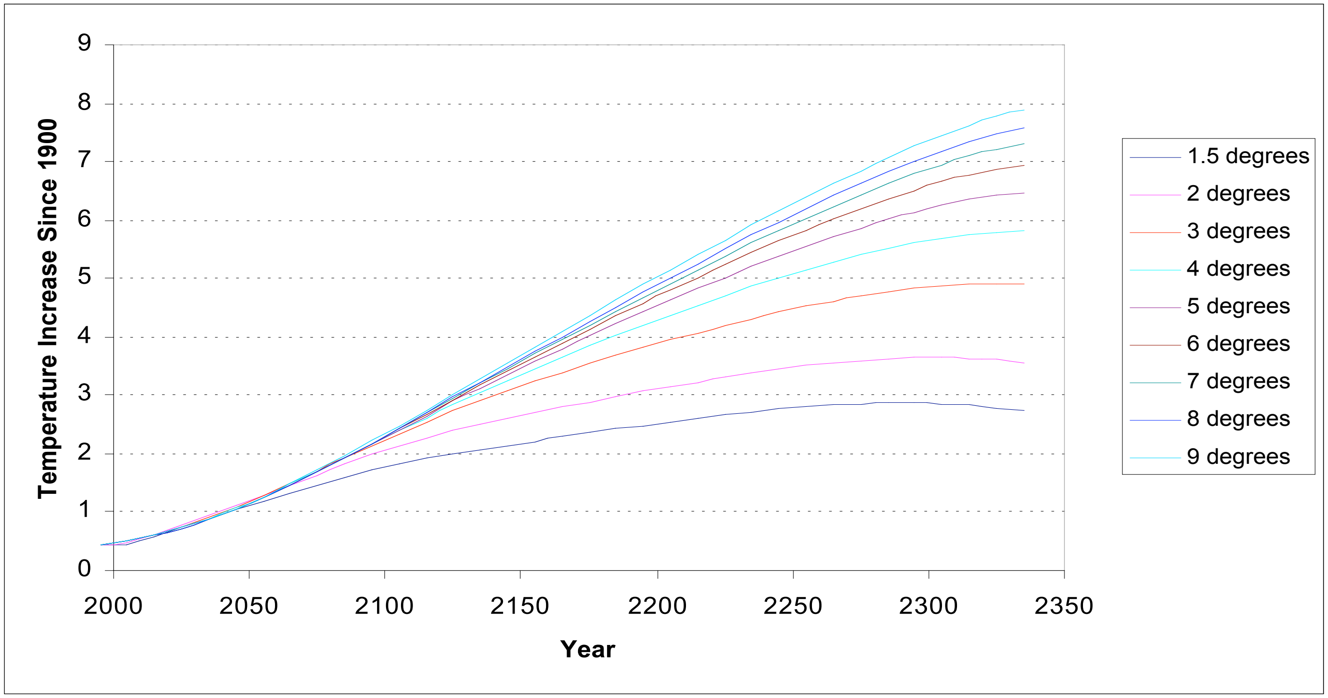
(Yohe, Andronova and Schlesinger, *Science*, October 15, 2004)

- Start with a new CDF of climate sensitivity.
- The question: What does the expanding uncertainty mean for near term mitigation?
- The method:
  - *Begin policy in 2005*
  - *Uncertainty and ultimate temperature target revealed in 2035*
  - *Track the associated least cost adjustment*

A CDF of Climate Sensitivity



Unregulated Temperature Trajectories along the DICE Baseline Emissions Scenario



The Experiment

- Hedging strategies are evaluated in terms of robustness – the range of futures that they can handle with ***“reasonable” adjustment costs***
- Hedging is also evaluated in terms of “keeping doors open” – temperature targets that are still possible
- The critical comparison is between a favored hedging strategy and doing nothing between 2005 and 2035

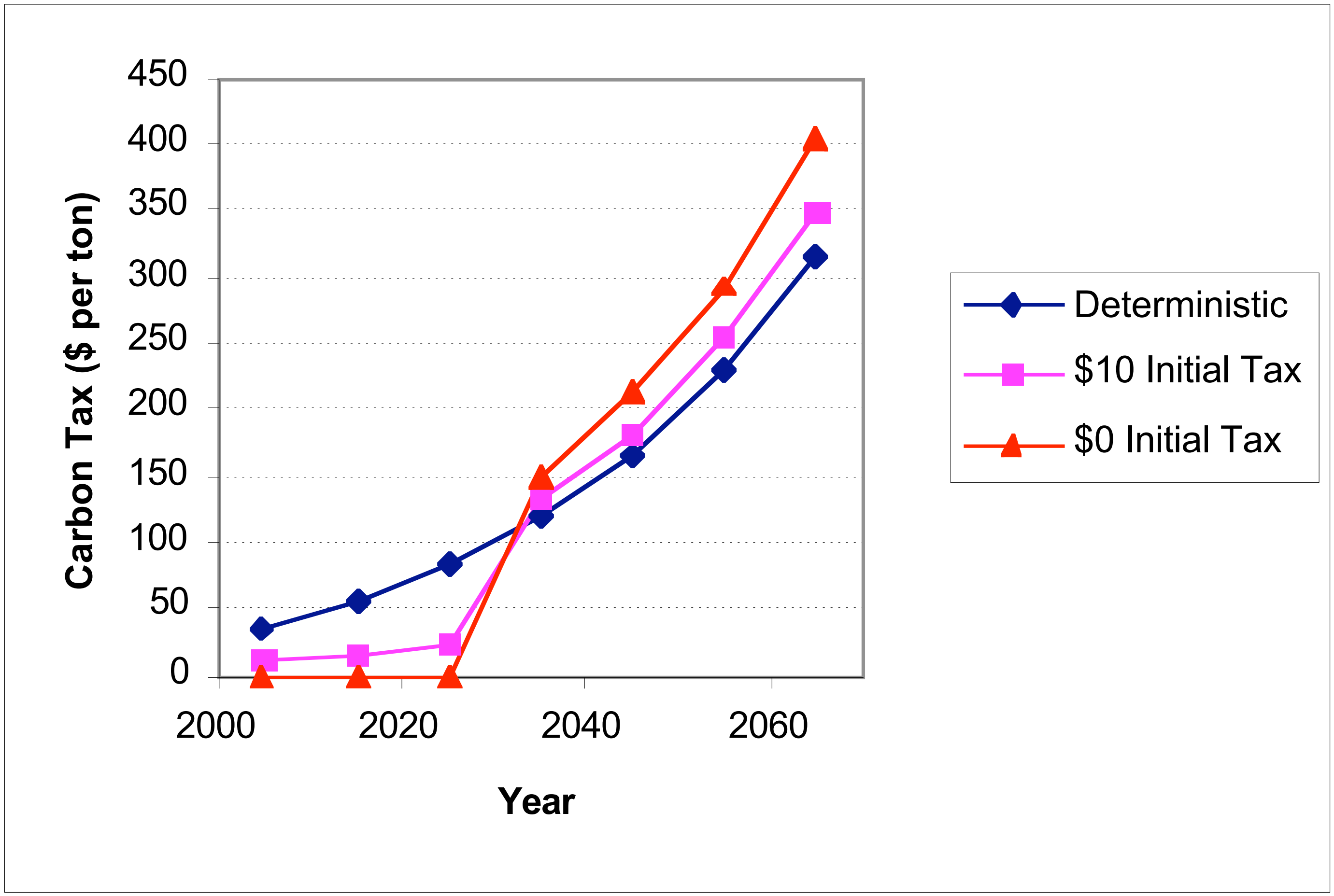
More Specifics

- Set near-term policy assuming that temperature and climate sensitivity will be revealed in 2035
- Choices for the near-term are expressed in terms of a initial carbon tax.
- An initial global tax of $10 per ton of carbon maximizes expected global GDP
  - Targets of 2, 2.5, 3, and 3.5 degrees are assumed to be equally likely choices in 2035
  - Climate sensitivity according to the CDF

Compare this Strategy with "Doing Nothing" over the Near Term

- The alternative considers a zero tax through 2035 followed by an adjustment designed then to achieve temperature targets at least cost.
- The $10 initial tax will increase at the rate of interest until 2035, and then require a similar adjustment – will be too high in some cases and too low in others.

An Example – Hedging or Not to Meet a 3 Degree Target with a 6 Degree Sensitivity



Discounted Adjustment Cost with No Mitigation through 2135 (billions of dollars)

Climate Sensitivity	Ultimate Temperature Target 2	2.5	3	3.5
1.5	$32	$11	$3	$0
2	$38	$22	$16	$4
3	$180	$29	$18	$22
4	IL	$60	$24	$24
5	IL	$142	$25	$25
6	IN	IL	$27	$28
7	IN	IL	IL	$34
8	IN	IL	IL	$35
9	IN	IL	IL	$38

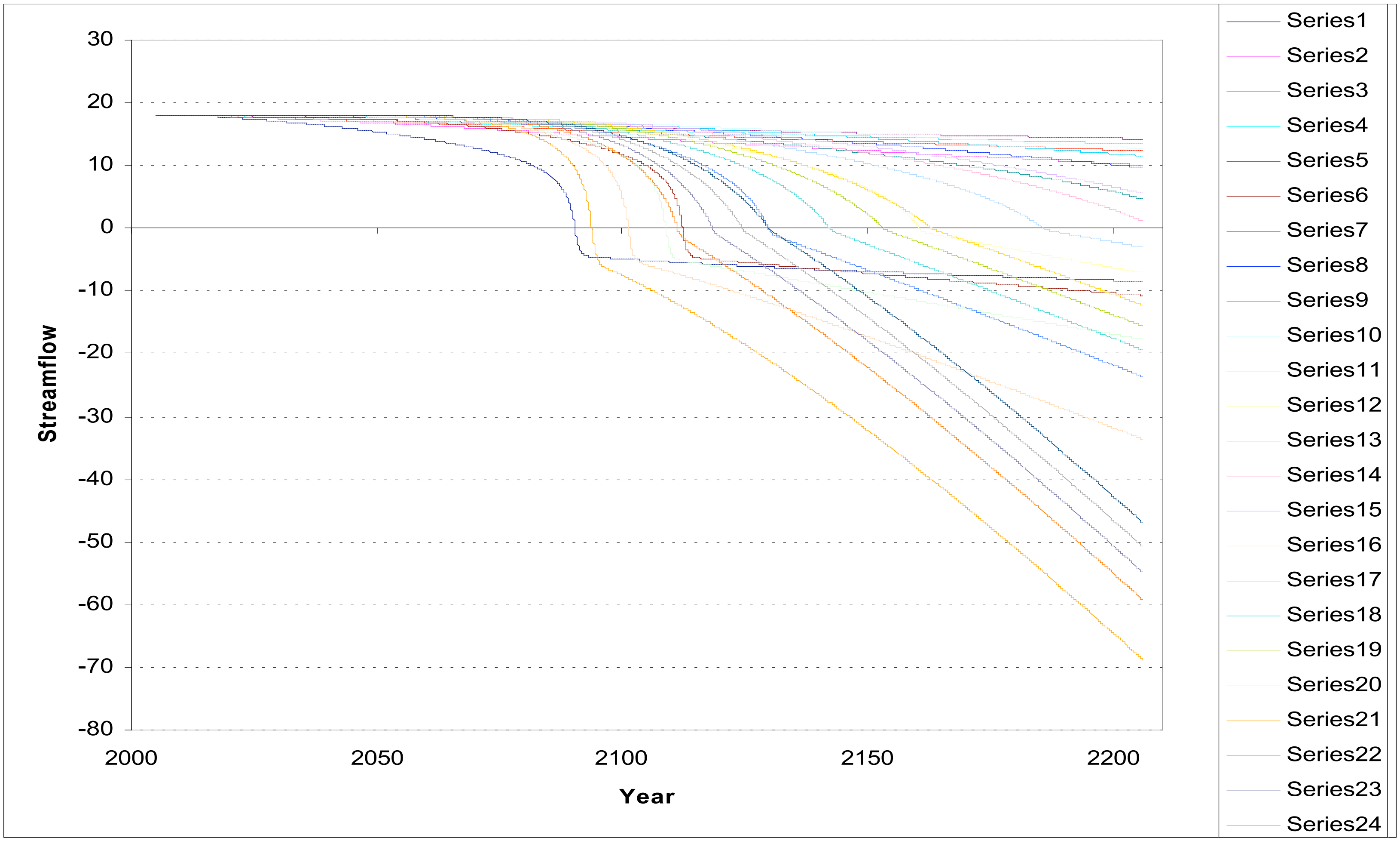
Discounted Adjustment Cost with $10 Initial Tax (billions of dollars)

Climate Sensitivity	Ultimate Temperature Target 2	2.5	3	3.5
1.5	$0	$0	$0	$0
2	$2	$1	$0	$0
3	$4	$3	$1	$0
4	IL	$6	$2	$0
5	IL	$12	$3	$0
6	IN	IL	$4	$1
7	IN	IL	$6	$3
8	IN	IL	$9	$5
9	IN	IL	$12	$9

Focus on Doors & Adjustment Costs Rather than Expected Net Benefits

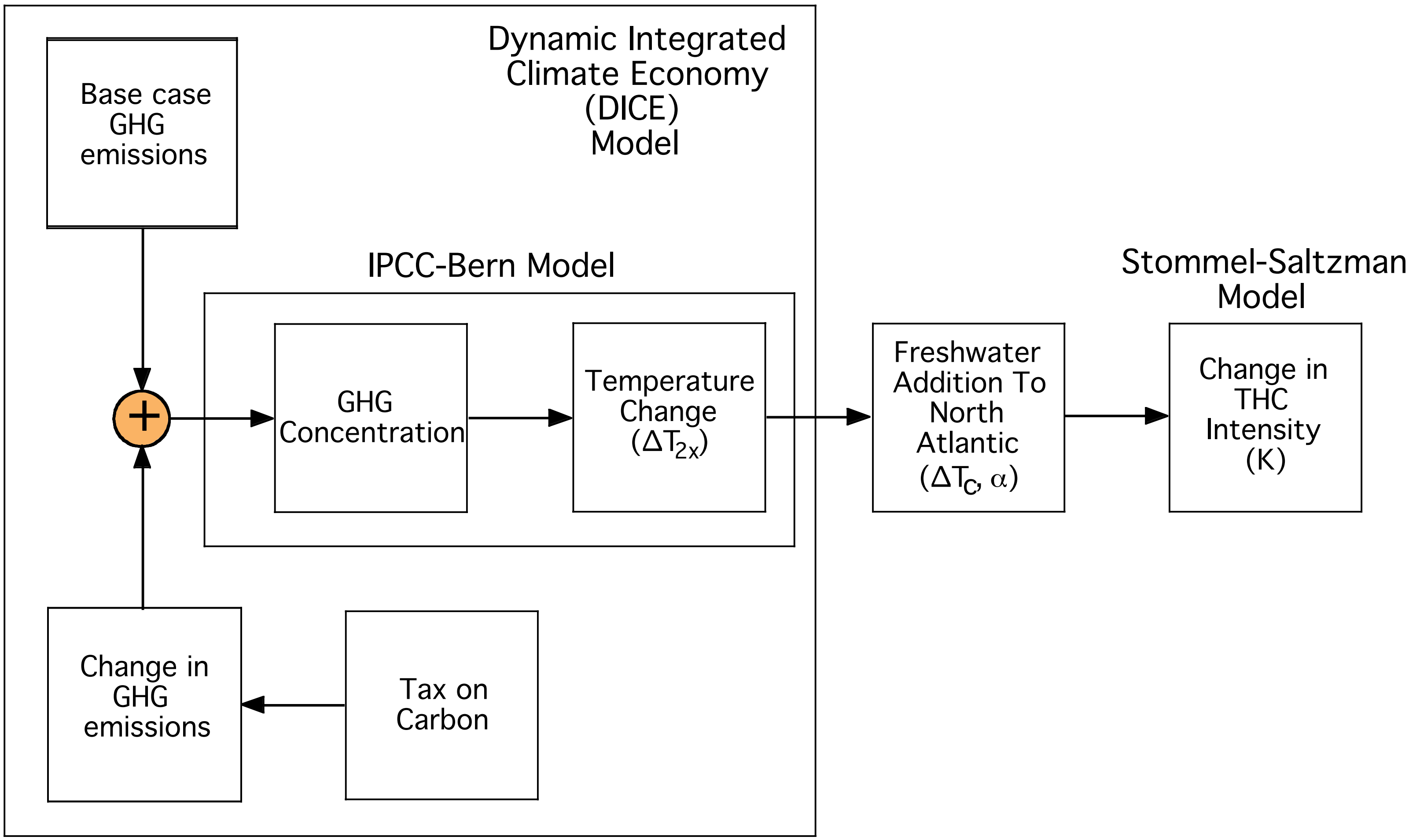
- Allows a consideration of the likelihood of abrupt change and a social view of whether it is a "tolerable" experiment.
- But it is not a "tolerable windows" approach because it envisions adjustments later – and the expected cost of adjustment is one key decision parameter.
- The other decision parameter is the cost maintaining the feasibility of potentially desirable targets.

Another Example: Collapsing MOC along a DICE Baseline Emissions Pathway



The Modeling Structure

(Yohe, Andronova and Schlesinger, 2005)



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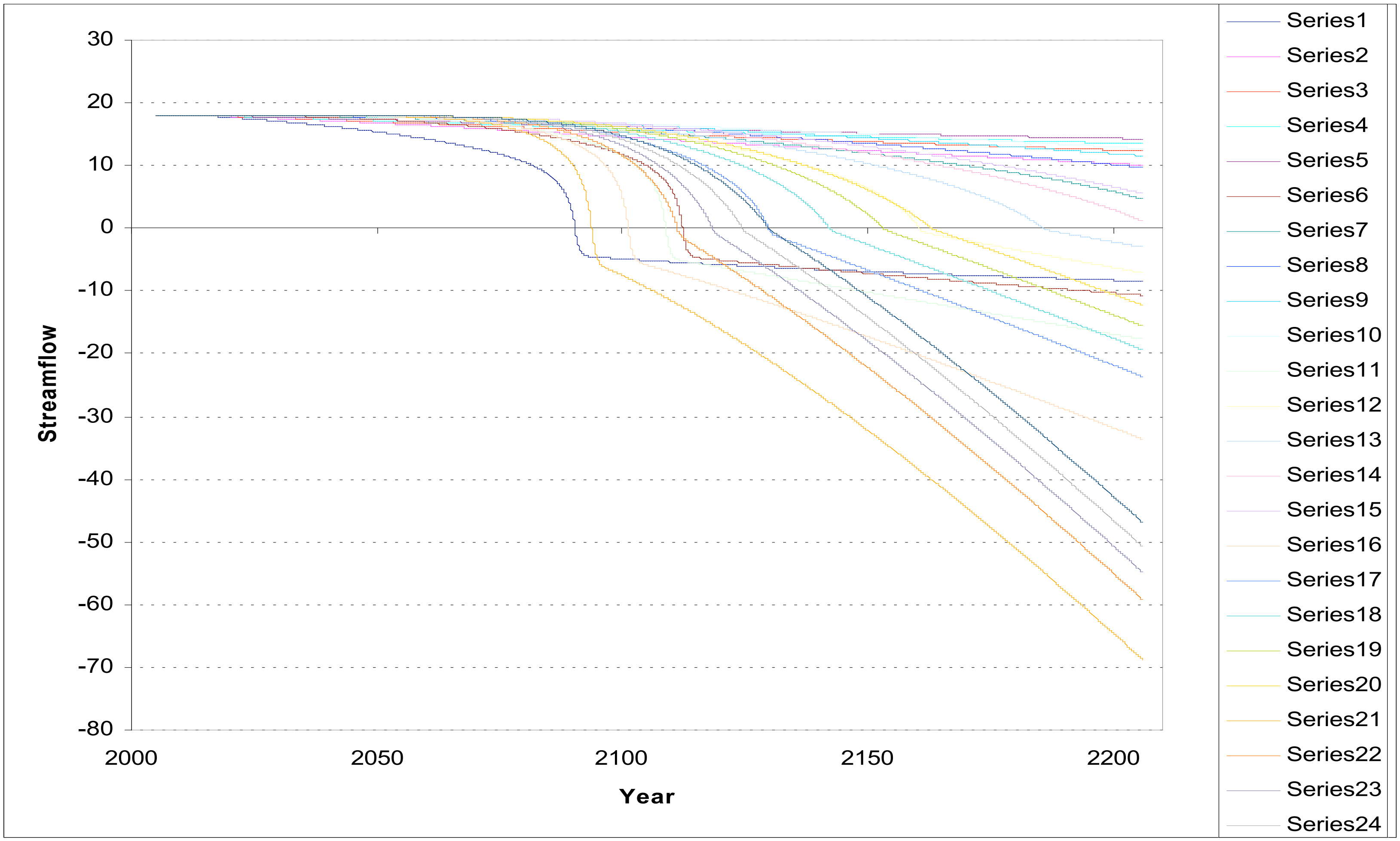
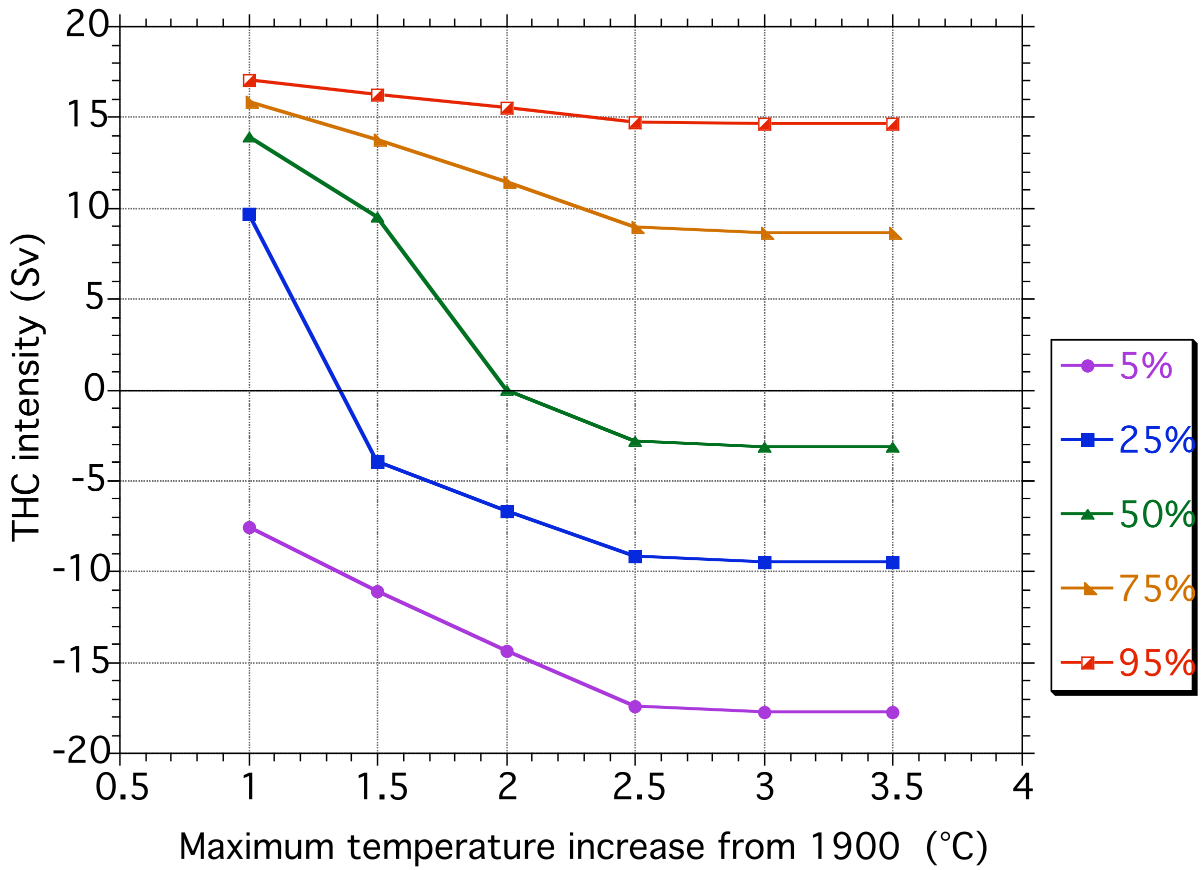
Four Sources of Uncertainty

- Climate sensitivity distributed as before.
- Three within the Stommel-Saltzman model:
  - K: ratio of the transport coefficient for the gyre circulation and eddies; taken to be uniformly distributed over 0, 0.5, 1, 1.5, 2, 2.5.
  - _: hydrolic sensitivity in the freshwater addition equation; taken to be uniformly distributed between 0.0 and 0.6 degrees C in 0.1 degree increments.
  - $\_T_C$: critical temperature change in the same equation; taken to be uniformly distributed between 0.2 and 1.0 degrees C in 0.2 degree increments

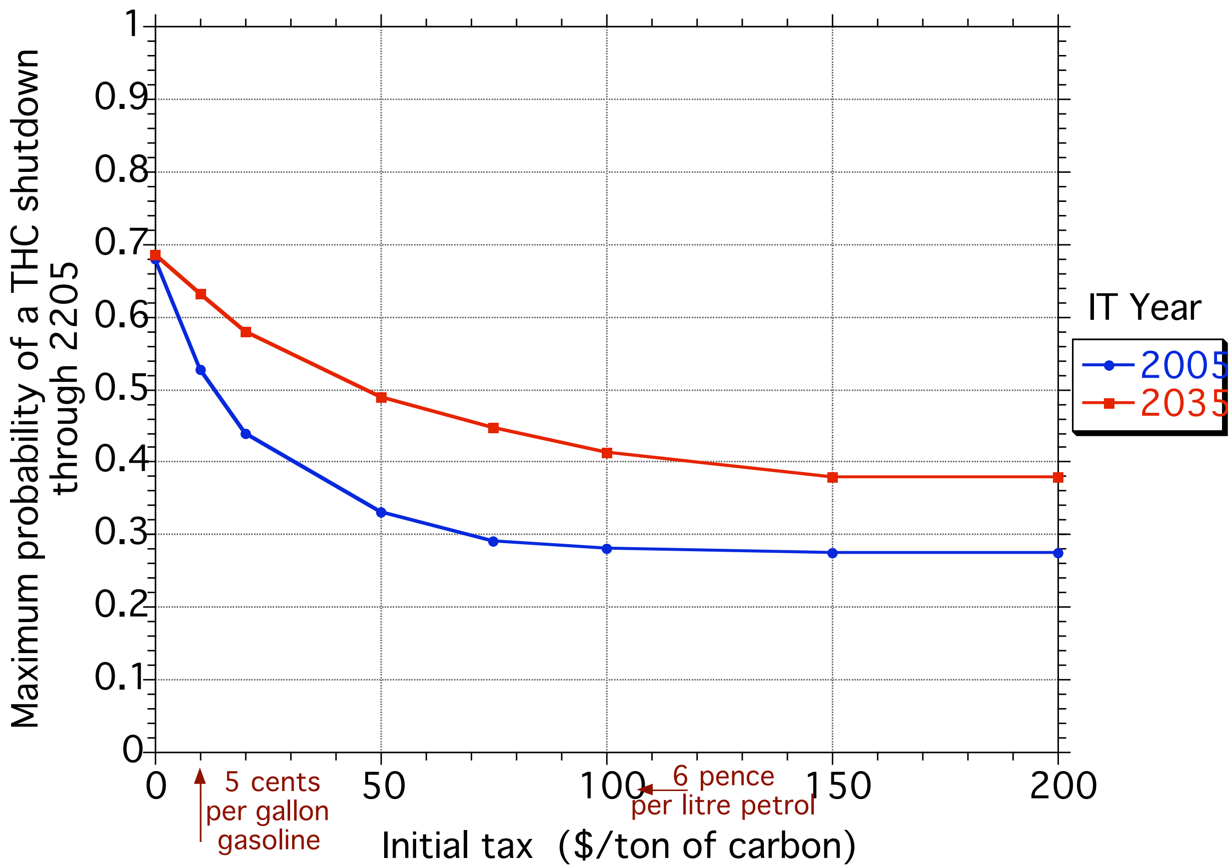
These Runs are for an Emissions Path that Mimics A1B through 2070 or so with a 3 degree Climate Sensitivity



Summary Results



Summary Results in a Policy Context



Take Home Messages

- Delay can be “expensive” in terms of the likelihood of a THC collapse.
- The results are highly sensitive to the specification of uncertainty – this highlights the value of information about specific parts of the model:
  - The range for K created the largest uncertainty
  - The range for _Tc created the smallest uncertainty

More Detailed Diagnostics for Policies Initiated in 2005

Source of Uncertainty	Range of Minimum Probability of a Collapse of the THC
Climate Sensitivity	15% to 45%
The parameter K	2% to 82%
The parameter ?	8% to 40%
The parameter $?T_c$	20% to 31%

The Real Take-home Messages

- Focus attention on what might make the doors close more quickly and more tightly.
- Focus attention on the ability of near-term policy to keep them open.
- Remember…there are two ways why adjustments of near-term policy as the future unfolds might be small:
  - 1. More adequate preparation.
  - 2. Couldn't get there anyway.

A Third Illustration: Adaptation in Ghana and the Implicit Value of Mitigation.

- Reporting on results from a recently completed senior thesis by Benjamin Brown at Wesleyan.
- Contributions from Kenneth Strzepek (University of Colorado) and Roger Jones (CSIRO in Australia) are gratefully acknowledged.
- Also thanks for the time that the Environment Ministry in Ghana devoted to Ben during his two trips there and for the material that they provided.

Two Results – A Taste of What is Possible

- It is possible that climate change will increase the expected productivity of an adapting economic activity in expected value even in a developing country (i.e., not just in the U.S.); as a result, people can argue that mitigation would cause harm, at least in the medium run.
- *It is also entirely possible that uncertainty reflected in the distribution of productivity across a range of climate futures is sufficiently large that a risk-averse society will* ***nonetheless*** *see quantifiable value in mitigation.*

Two Stylized Facts

- In 1982-83, 1997-98 the droughts in Ghana forced the Akosombo dam, which provides a major proportion of the country's energy, to produce between 0 and 50% of its baseline output.
- Furthermore, with anticipated increases in future energy demand, the government has had to entertain various dam projects with an eye toward meeting future energy needs.

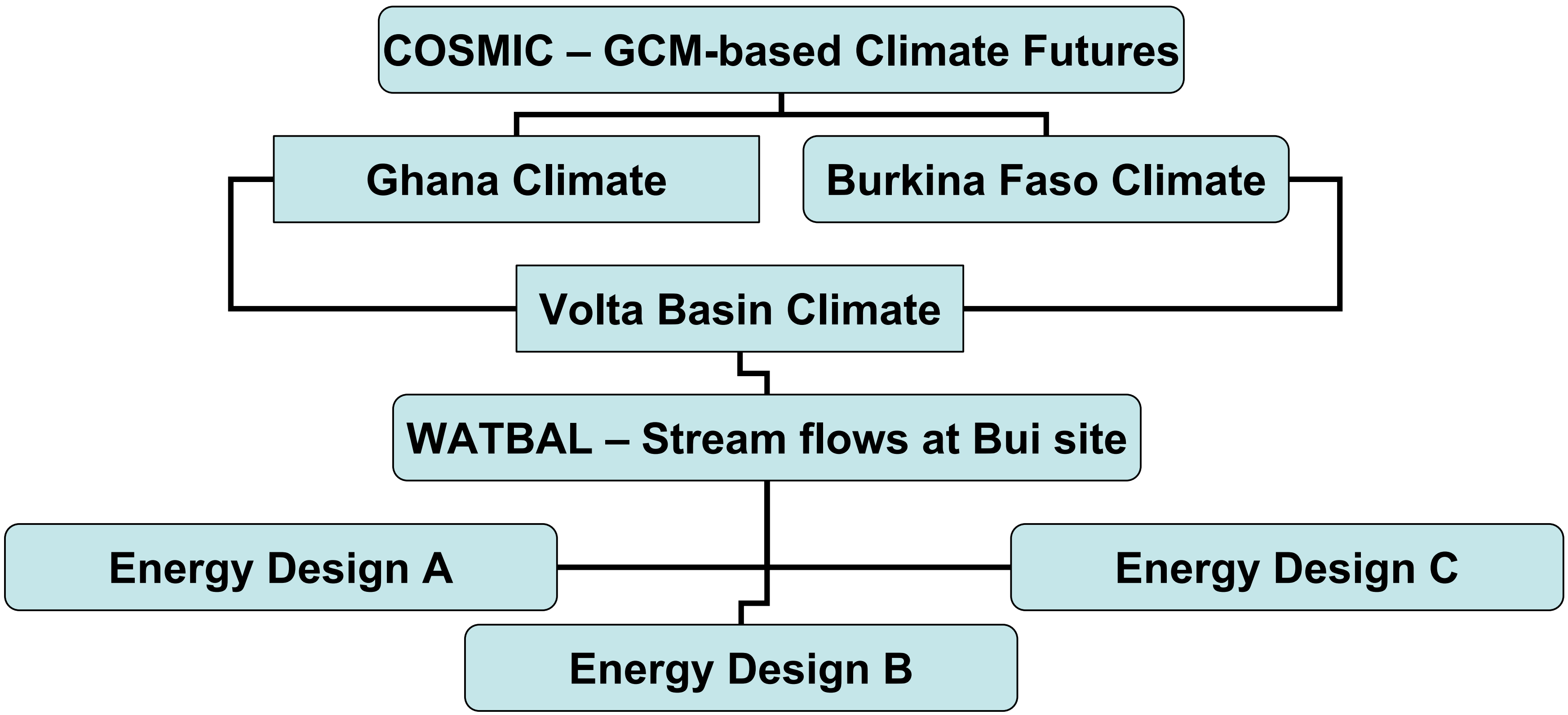
The Bui Dam Proposal

- Building some sort of dam at the Bui site has again surfaced as the most prominent and likely energy project.
- The largest proposed design will produce 388 MW. This would be half the size of the dam at Akosombo and would increase Ghana’s total electrical output by 25%.
- It would lie upstream from Akosombo on the Black Volta River in the Southern region of Ghana.

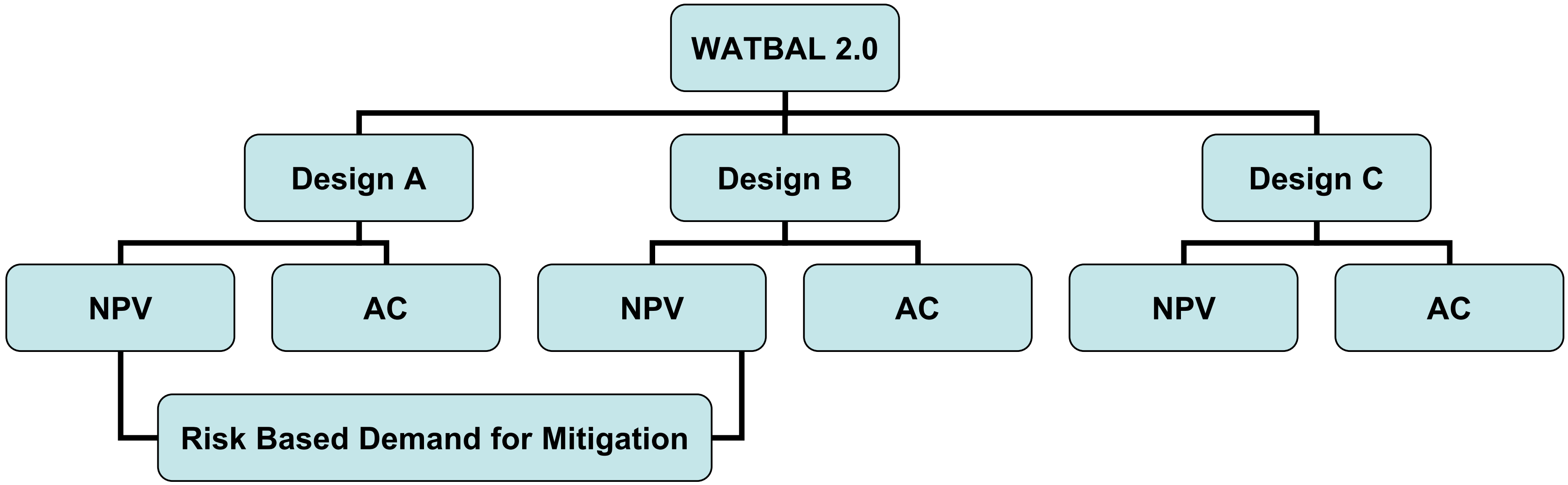
Comparing Three Alternative Designs

Details	Bui A	Bui B	Bui C
Power Capacity (MW)	326	388	196
Expected Annual Energy Output (GWH/Year)	889	1044	548
Initial Investment Cost (Millions $)	370	480	230
Yearly Operation and Maintenance Costs (% of initial investment)	0.52%	0.52%	0.33%
Expected Average Costs (cents/KWH)	5.21	5.76	4.78
Expected Net-Present Value (millions $)	254	250	189

The Modeling Approach

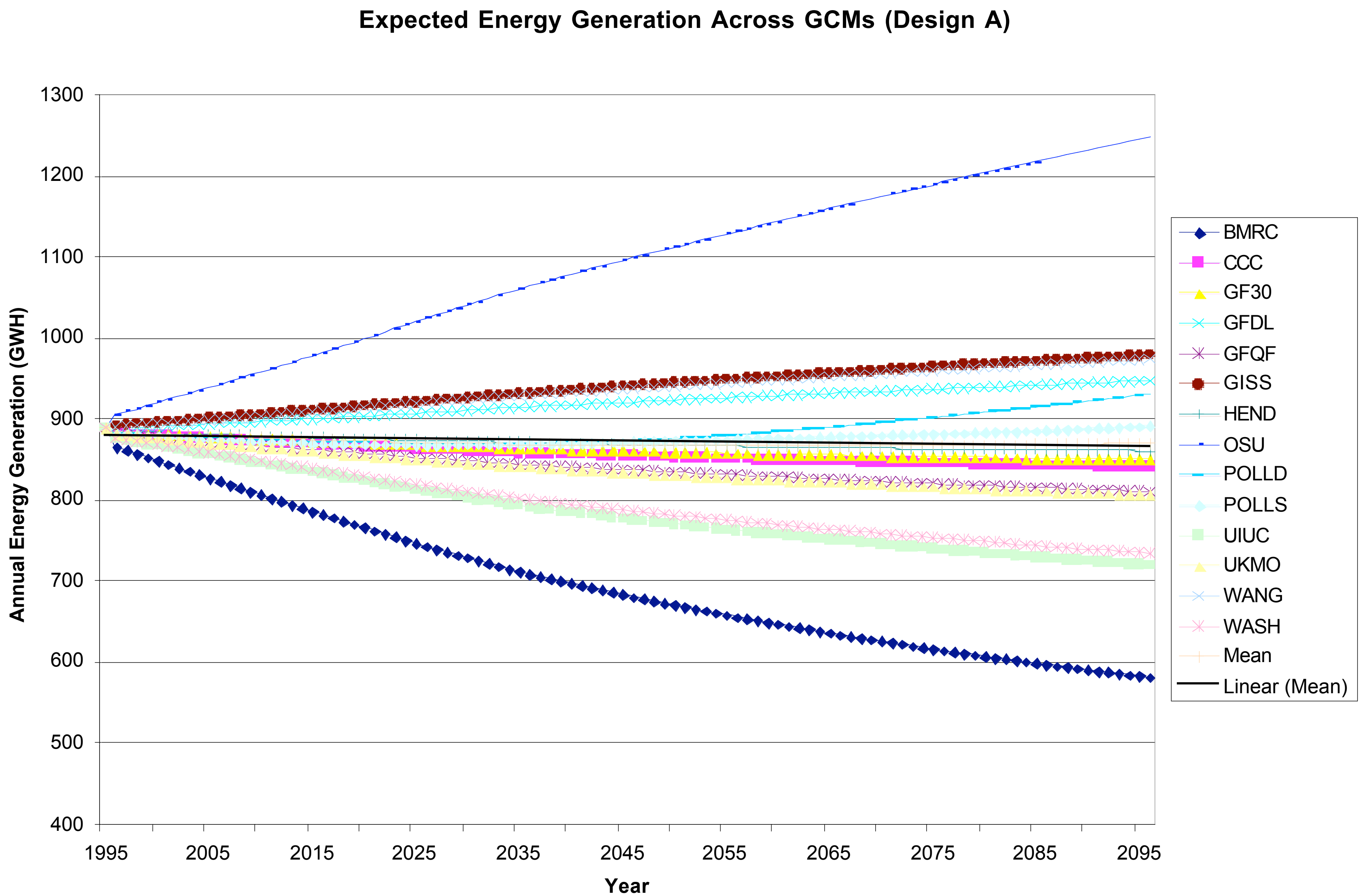


Details for Evaluation



The Modeling Modules

- COSMIC – Schlesinger and Williams
  - 14 Different GCMs produce monthly transients for precipitation and temperature for Ghana and Burkina Faso.
  - For each, used 4 probabilistically weighted emissions trajectories (S1, S3, S5 and S7) reported in COSMIC from Yohe (1996).
  - For each, used 4 probabilistically weighted climate sensitivities (1.5, 2.5, 3.5 and 4.5 degrees) to reflect Yohe, Andronova and Schlesinger (2004).



Expected Energy Generation Across GCMs (Design A)
Annual Energy Generation (GWH)
1300
1200
1100
1000
900
800
700
600
500
400
1995
2005
2015
2025
2035
2045
2055
2065
2075
2085
2095
Year
BMRC
CCC
GF30
GFDL
GFQF
GISS
HEND
OSU
POLLD
POLLS
UIUC
UKMO
WANG
WASH
Mean
Linear (Mean)

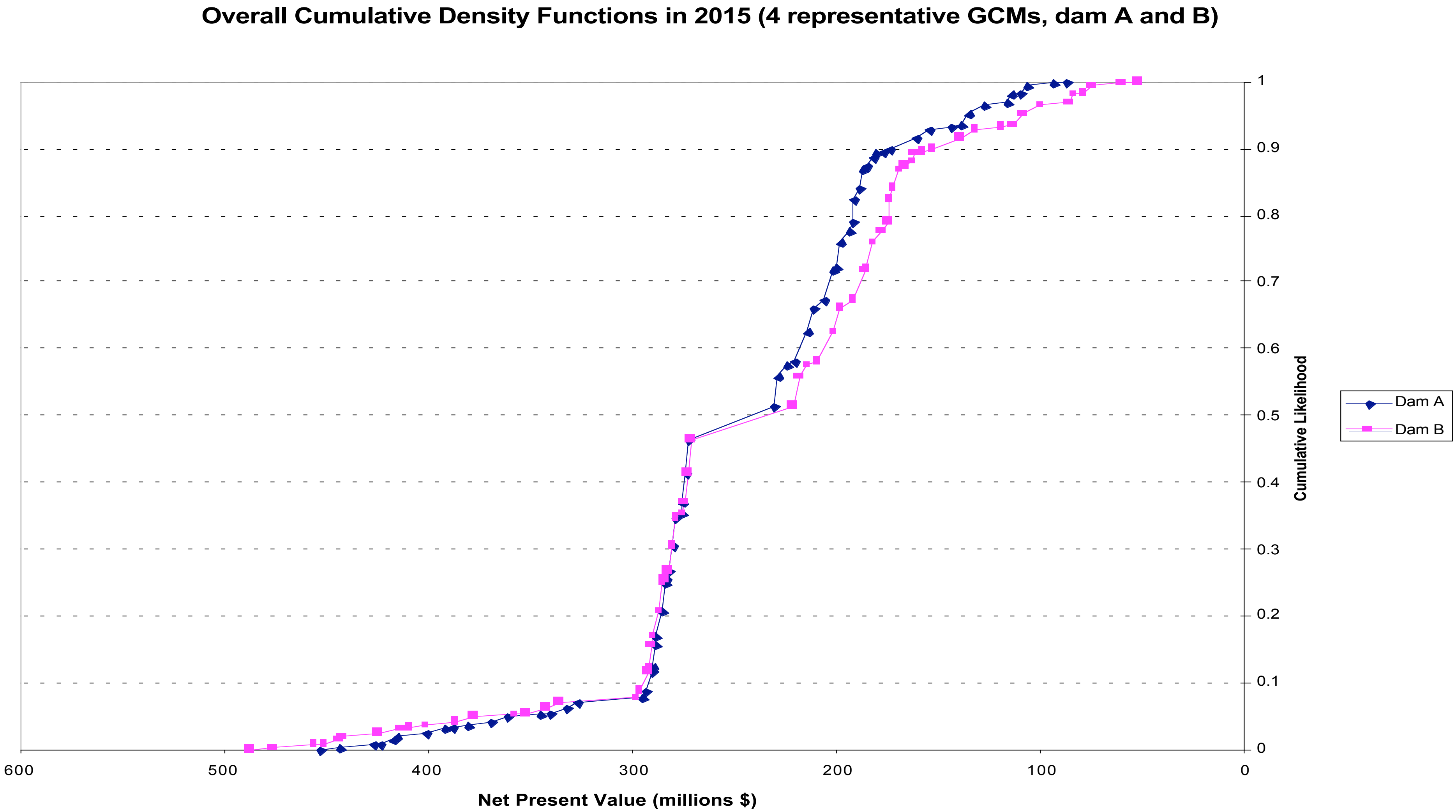
Representing Global Mitigation

- Mitigation scenarios were defined by WRE trajectories for concentration targets of 450, 550 and 650 ppm.

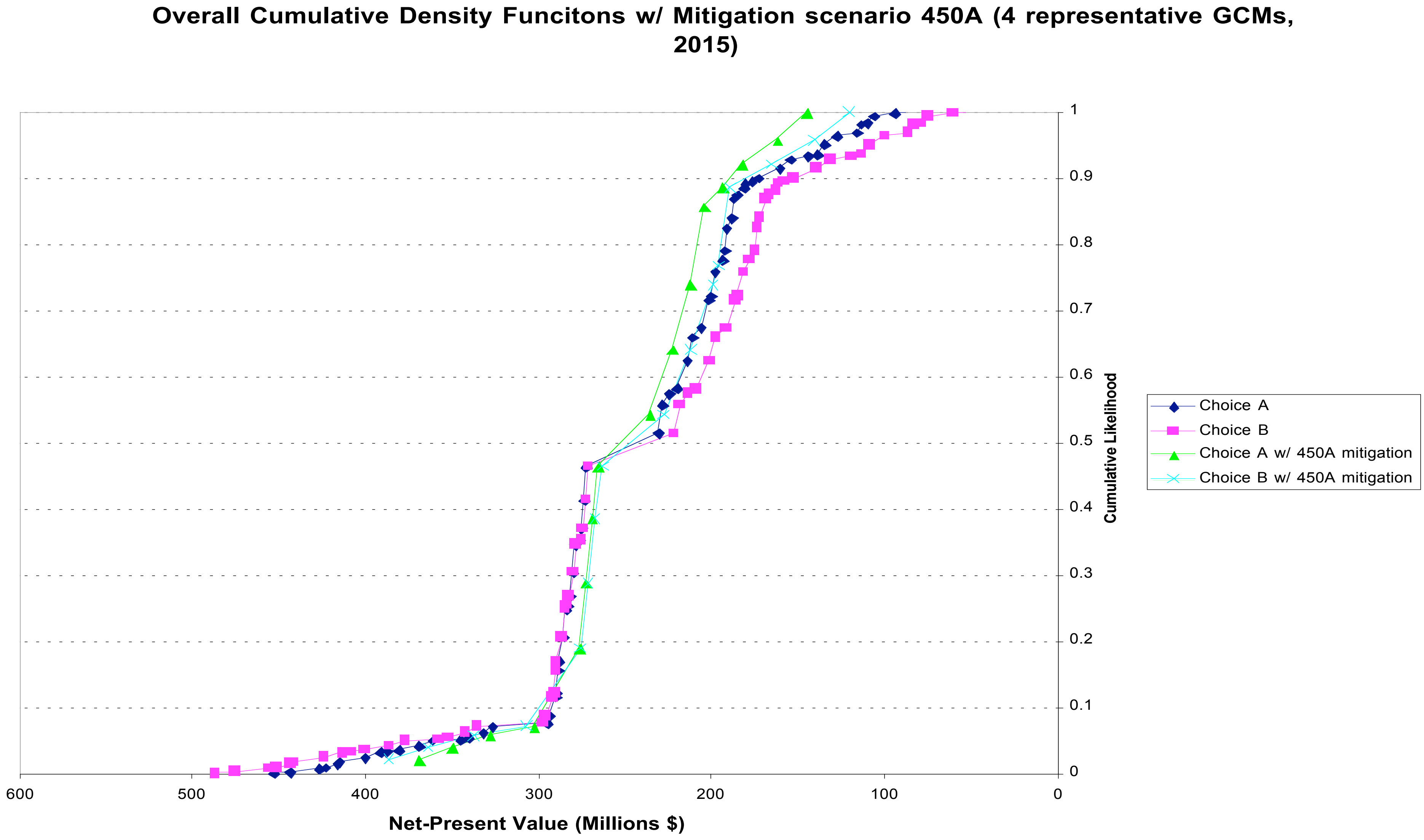
- COSMIC can accommodate these, and the old IPCC runs.

- A new version of COSMIC can work from the SRES futures.

Aggregate NPV Cumulative Density Functions w/o Mitigation



NPV CDFs with Mitigation scenario 450A



CDF Suggestions about Mitigation

- Mitigation provides benefits in the “bad” climate scenarios as shown by the upper portion of the curve.
- Mitigation decreases the value that would accrue from “good” climate scenarios as displayed by the lower portion of the cdfs.

A Risk-based Metric for the Value of Mitigation

- A “willingness to pay” metric can be calculated for any level of mitigation.
- Step 1: Compute the “certainty equivalent” NPV without mitigation.
- Step 2: Compute the “certainty equivalent” NPV assuming that a specific mitigation target is achieved along WRE a trajectory.
- The WTP is the difference between the two.

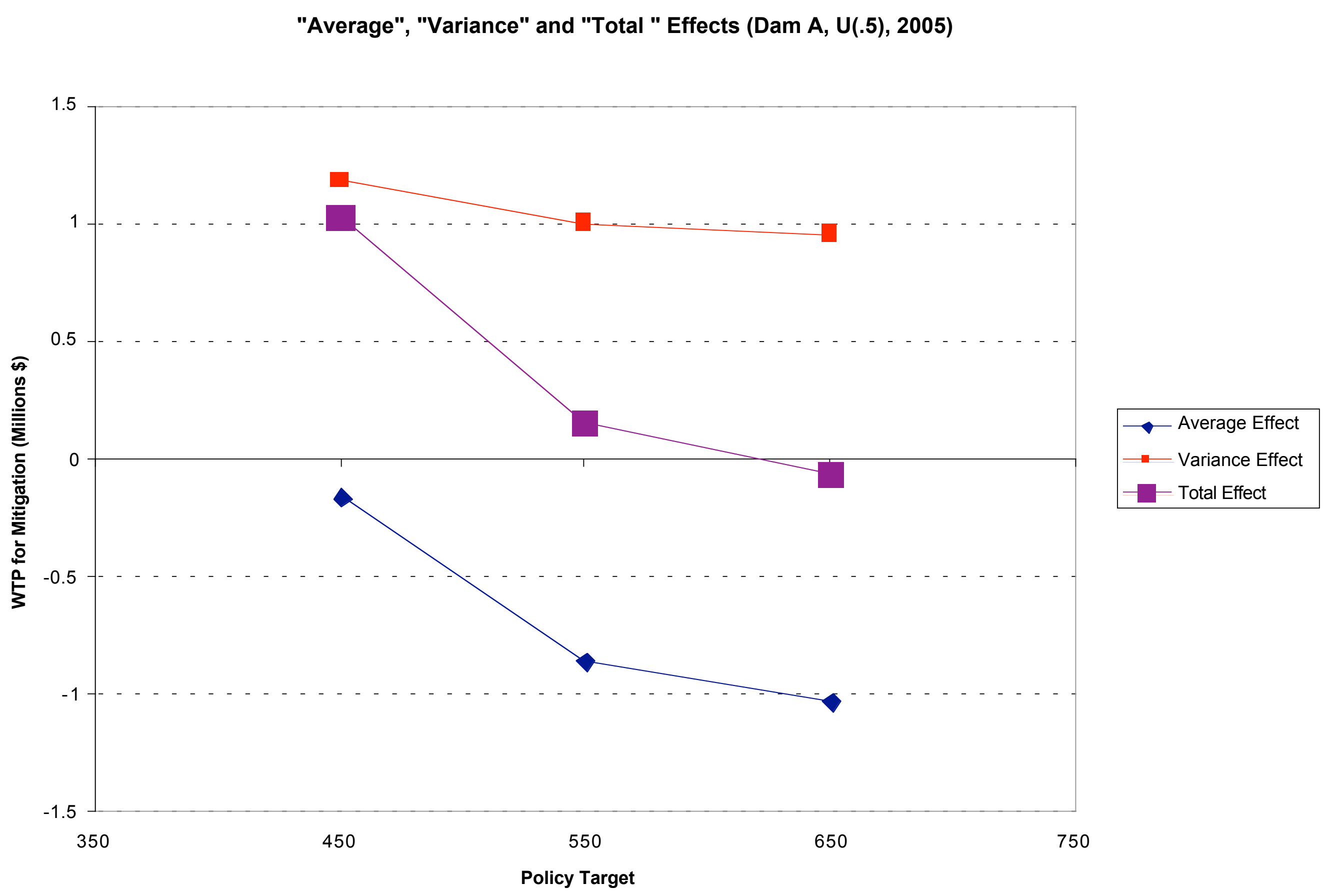
A Decomposition of the Willingness to Pay: Average and Variance Effects

- Mitigation does not create mean preserving change in cdf’s.
- In general, mitigation makes bad scenarios better faster than it hurts good scenarios.
- Nonetheless, the possibility exists that mitigation hurts the average NPV because the good news is better than the bad news is bad, particularly in the near to middle term – the “average effect”.

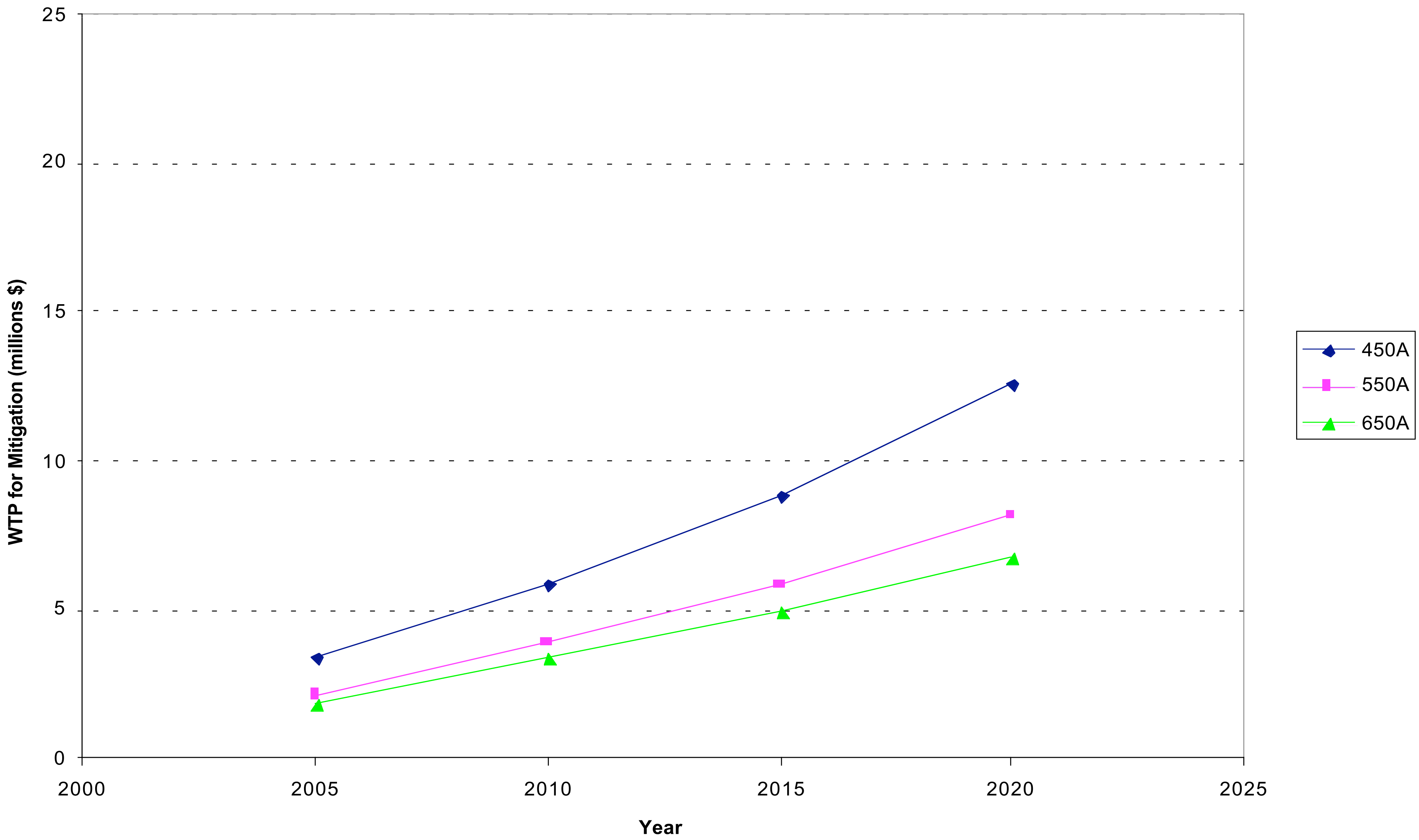
Effects, continued

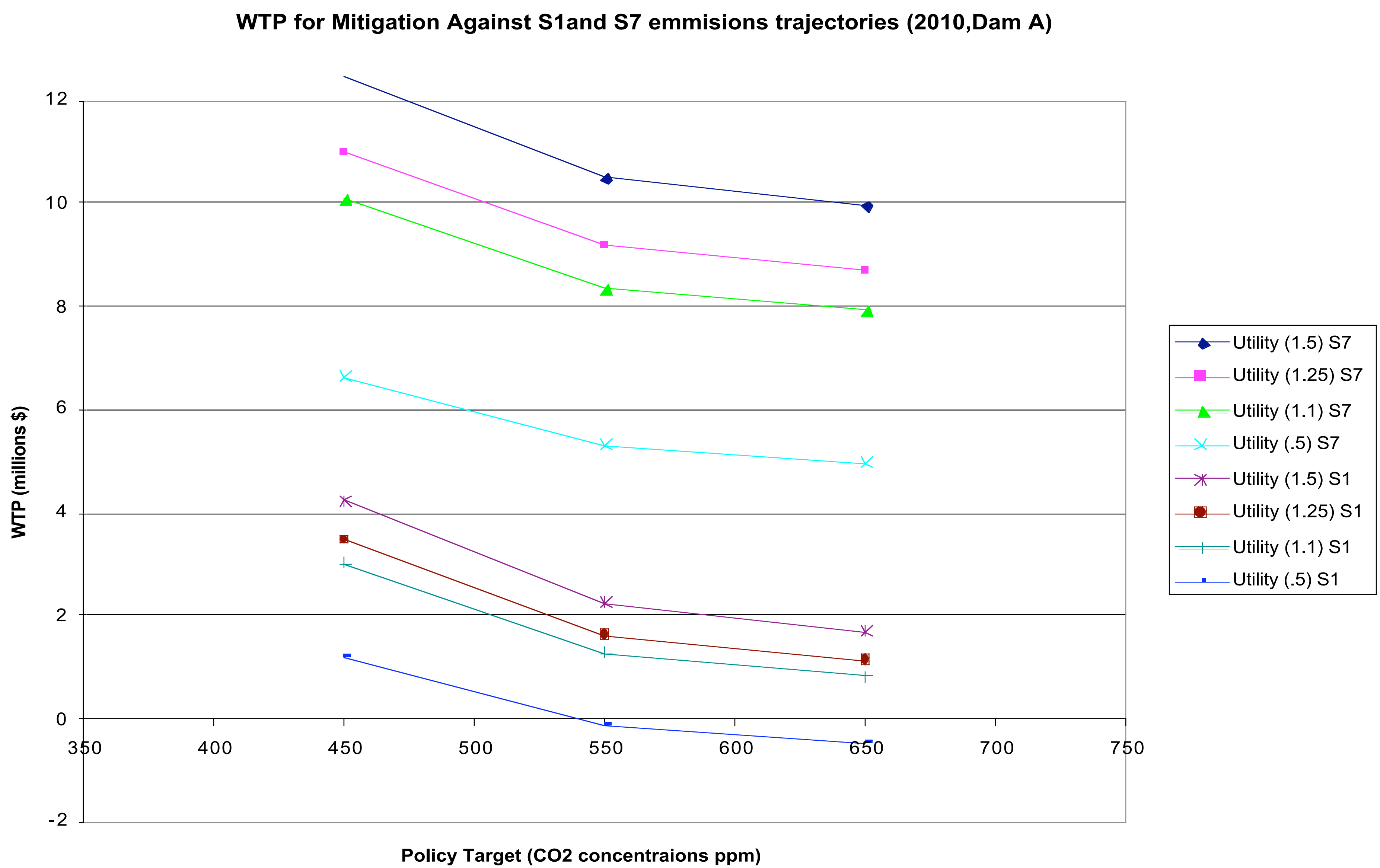
- Mitigation unambiguously reduces variance, though, and produces a “variance effect” that always favors mitigation.
- Variance effects climb with delays in construction because the high variance years are moved closer in the discounting calculations.
- Average effect falls with time because rate of increase in mean falls with time.
- Only variance effect changes with relative risk aversion.

A Representative Portrait of Average, Variance, and Total Effects



Willingness to pay for Mitigation at different construction dates (Utility{1.5}, Dam A)





WTP for Mitigation Against S1and S7 emmisions trajectories (2010,Dam A)
WTP (millions $)
12
10
8
6
4
2
0
-2
350
400
450
500
550
600
650
700
750
Policy Target (CO2 concentraions ppm)
Utility (1.5) S7
Utility (1.25) S7
Utility (1.1) S7
Utility (.5) S7
Utility (1.5) S1
Utility (1.25) S1
Utility (1.1) S1
Utility (.5) S1

The "Willingness to Pay" Metric for the Value of Mitigation

- WTP increases with construction delay.
- WTP increases at an increasing rate for more stringent policy targets.
- WTP increases for more risk-averse decision-makers.
- WTP is higher along higher emissions scenarios.

So What do We Do?

More to come in this session, but preliminarily…

- Think about what to monitor in the context of what is important for the adjustment criteria:
  - Look to assess the plausibility of damaging tails
  - Look to exploit places where differential diagnosis along decision thresholds exist
- Explore the tradeoffs between detection (type I vs type II errors) and the manipulating the pace of climate change (hedging) for specific abrupt changes.
- Look to provide information that matters per the metrics that decision-makers find important.

So What do We Do?

More to come in this session, but preliminarily…

- Look for synergies across the approaches taken by decision-makers to other problems.
  - Be sensitive to the observation that the decision may be locked in by the analytic approach taken.
- The single-point problem.
  - Look for techniques to assess confidence in hypotheses.
  - This can be the global coherence question revisited for analyses that can offer explanations for widely scattered (spatially and temporally) single points from a single internally consistent model.

So What do We Do?

More to come in this session, but preliminarily…

- Do the different hypothesized mechanisms for explaining observed abrupt events matter with respect to solidifying the attribution links that define the policy levers (e.g., temperature or concentration targets)? I expect not.
- Do the different hypothesized mechanisms for explaining observed events matter with respect to defining the impacts of abrupt change in terms of the metrics that are important for decision makers? I expect so.

What’s Coming in this Session

- Michael Vellinga: “Climate and vegetation impacts of potential MOC changes”
- Richard Tol: “What are the projected economic impacts of abrupt climate change?”
- Rob Lempert: “Robust/reliable decision-making in the face of uncertain MOC changes”
- David Budescu: “Psychology of decision-making and overconfidence”

What’s Coming in this Session

- Don Ludwig: “Economic analysis on nonconvex systems: What have we learned?”
- Jurgen Scheffran: “Interactive decision-making under uncertainty on dangerous climate change”
- James Todd: “NOAA research addressing potentially abrupt climate change”