Finding Solutions in the Face of an Uncertain Future

Some Thoughts on Assessing Sensitivity and Responding to Climate Stress under Profound Uncertainty

Gary Yohe
Wesleyan University
July 22, 2005
Aspen Global Change Institute

Context

- Evaluate a range of response options that could help a system cope with a vector of external stresses.
- Of particular interest, though, will be the components of the stressors that are related to climate; for each, climate variability and climate change may be important.
- Climate variability can be the manifestation of climate stress on a system in today's environment; climate change will take this manifestation into an unknown future.

An Underlying Presumption

- Assessing response options presumes that the research community can identify systems under stress and assess their relative exposures and sensitivities.
- The hope is that these assessments produce understandings of processes and model representations of what is going on.
- Another hope: that these models provide way of representing a response option or two (or three…..).

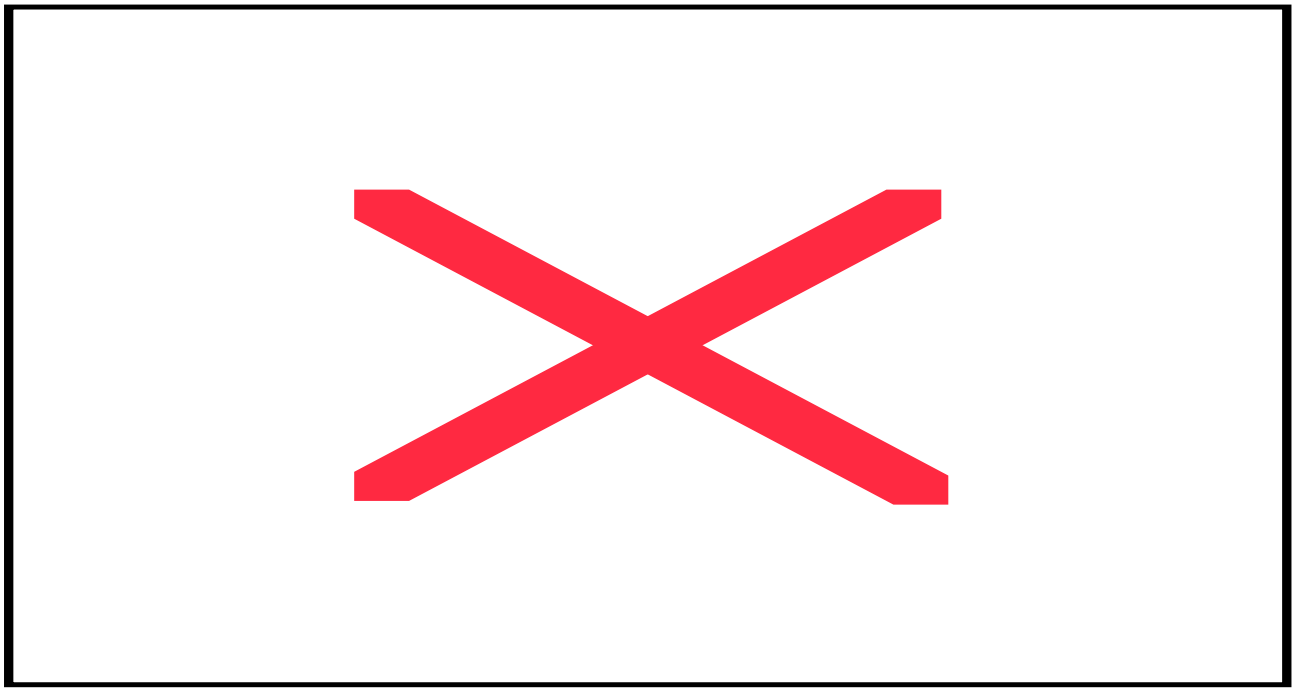
Uncertainty Facing a Given Researcher

- A researcher with a model of how a system might work faces:
  - Calibration uncertainty:
    - **producing estimates with error bars for critical parameters that describe the process.**
  - Prediction uncertainty:
    - **using estimates to predict outcomes for drivers selected from within the realm of experience.**
  - Projection uncertainty:
    - **using estimates to predict outcomes for drivers selected from beyond the realm of experience.**

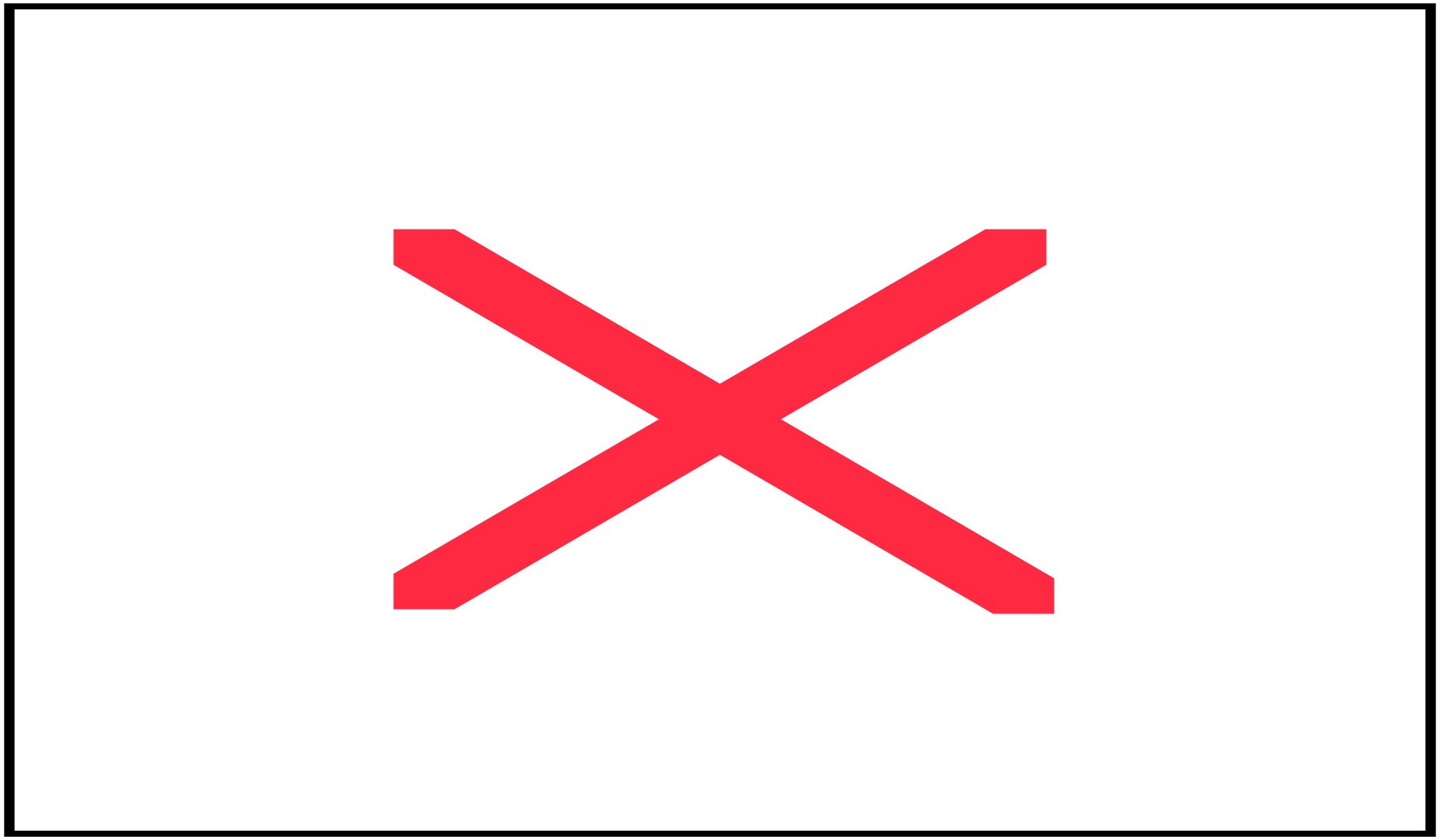
More Uncertainties for the Research & Decision-making Communities

- Given the tasks of assessing systems' sensitivities and exposures to climate change and anticipating the need to propose and evaluate responses designed to reduce either (sensitivity or exposure), the research and decision-making communities face:
  - Model uncertainty:
    - **different views of process.**
  - Climate uncertainty:
    - **climate variability along with climate change.**
  - Implementation uncertainty:
    - **will a response work as advertised?**

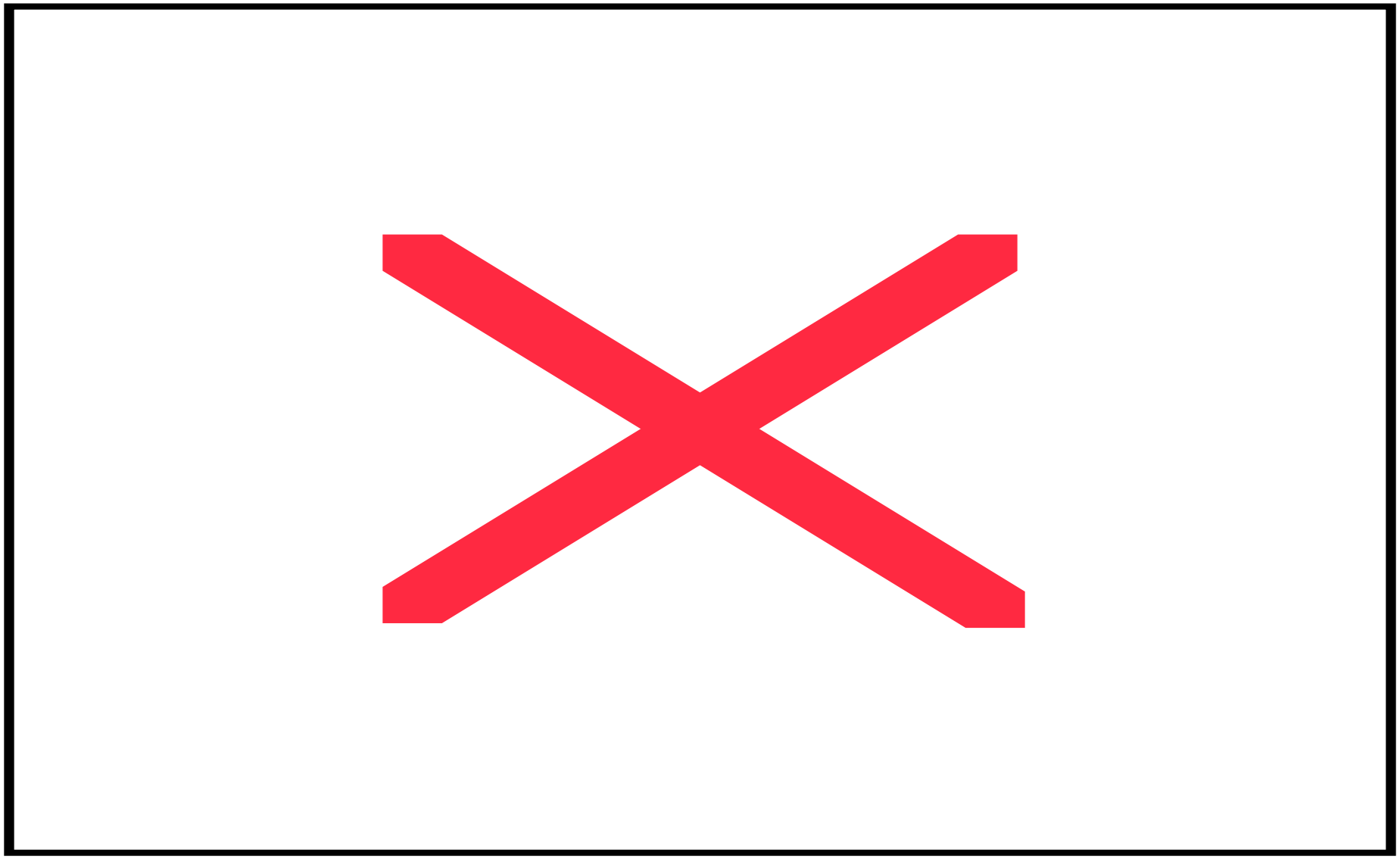
An Example of Climate Uncertainty: Unregulated Temperature Trajectories



An Example of an Output Metric: Aggregate NPV w/o Mitigation



An Example of Using the Output Metric: NPV with Mitigation (450A)



The Determinants of Adaptive Capacity: A TAR View of the World

- Determinants include:
  - Available options
  - Resources and their distribution
  - Governance structure and allocation of authority
  - Human capital
  - Social capital
  - ***Access to risk spreading mechanisms***
  - ***Ability of decision-makers to manage information***
  - Public perception

An Approach to Assessing Sensitivities Based on Thresholds – More TAR

- Begin with thresholds of tolerable short-term experience (variance which is reflected in climate variability)
- Let **E** = $\{X_1 , X_2 , \ldots, X_n\}$ be a representative vector of climate-related variables that describe the current environment of some system.
- Let V be the range of experience vectors **E** for which a system feels “tolerable” stress; i.e., manifestations of current climate that do not threaten the system.
- Now let f(**E**) represent a density function that reflects the current distribution of the climate variability variables captured in **E**.

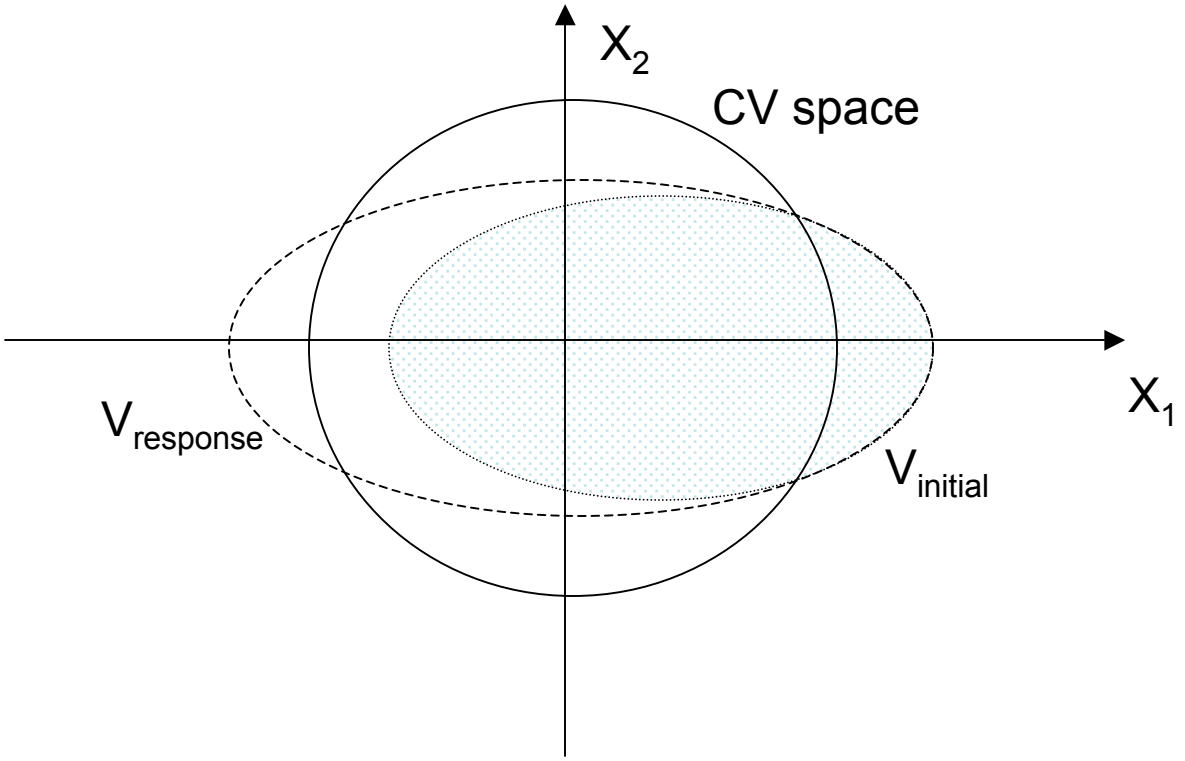
Defining a Sustainability Index

- The sustainability of the system given f(**E**) and the boundaries of tolerance given by V can be characterized by the likelihood that, in any given period, the observed vector **E** will fall within V.
- A preliminary "sustainability index" (denoted SI) can be defined as:

$$SI = \int_{V} f(\mathbf{E})\, d\mathbf{E}.$$

- There may exist a minimum SI, denoted SI_{sus}, below which the system is doomed to complete collapse because intolerable experiences are too frequent to allow sufficient recovery.

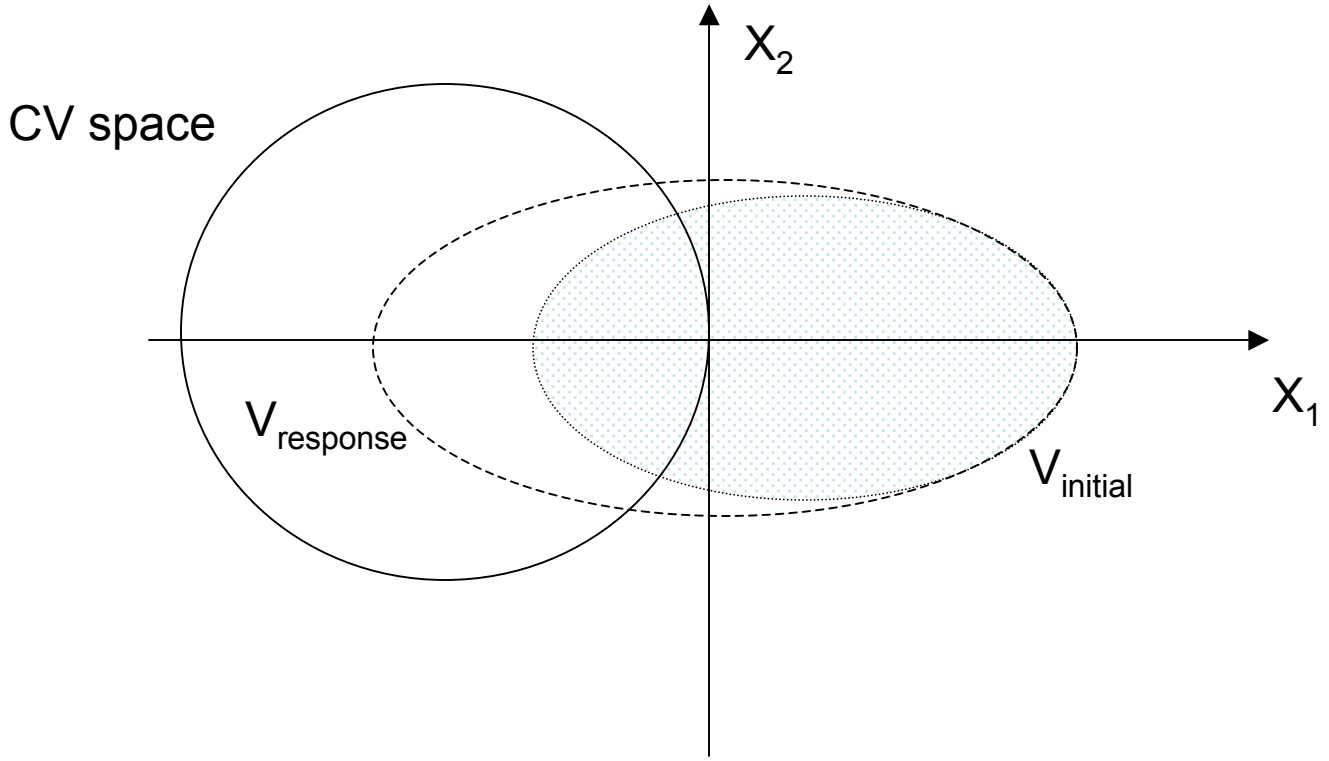
Vulnerability and CV Spaces



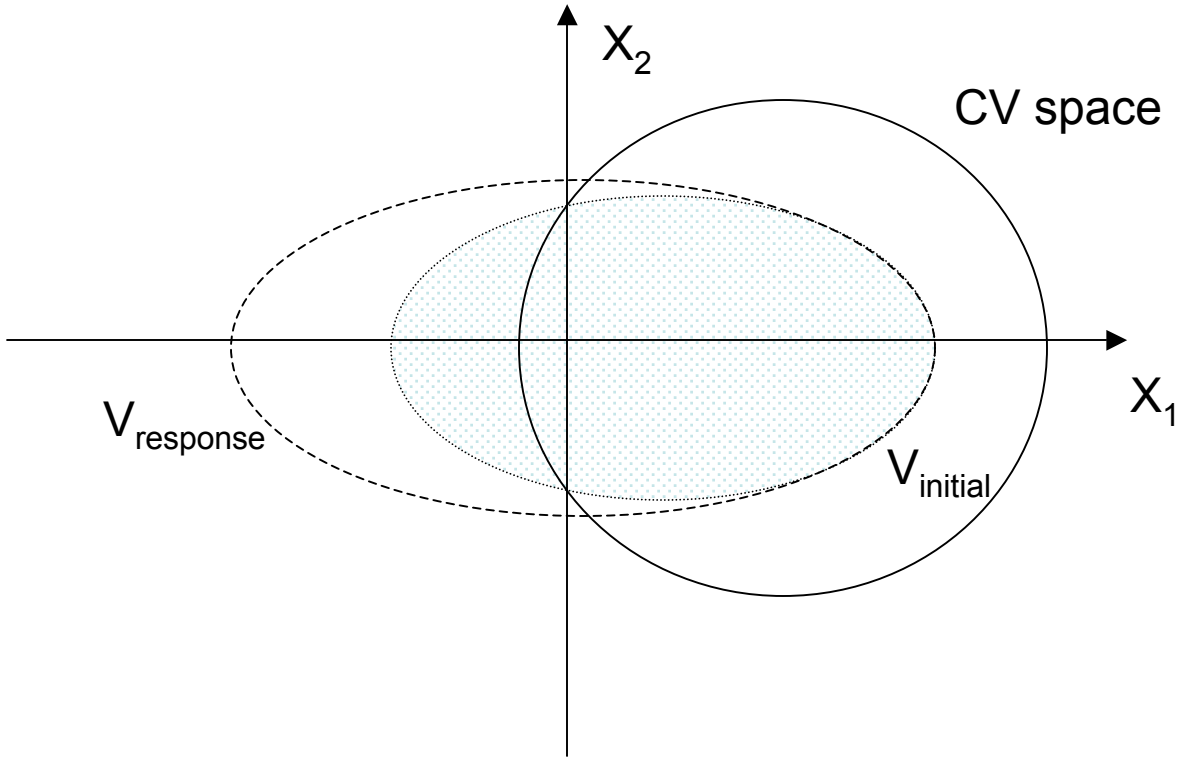
Hypothetical Scenarios

- S1: Climate change moves the mean of X_1 down over time; no change in the critical boundary thresholds except that a specific response can expand the lower boundary to accommodate lower values of X_1.
- S2: Climate change moves the mean of X_1 up over time; no change in the critical boundary thresholds except that a specific response can expand the lower boundary to accommodate lower values of X_1.

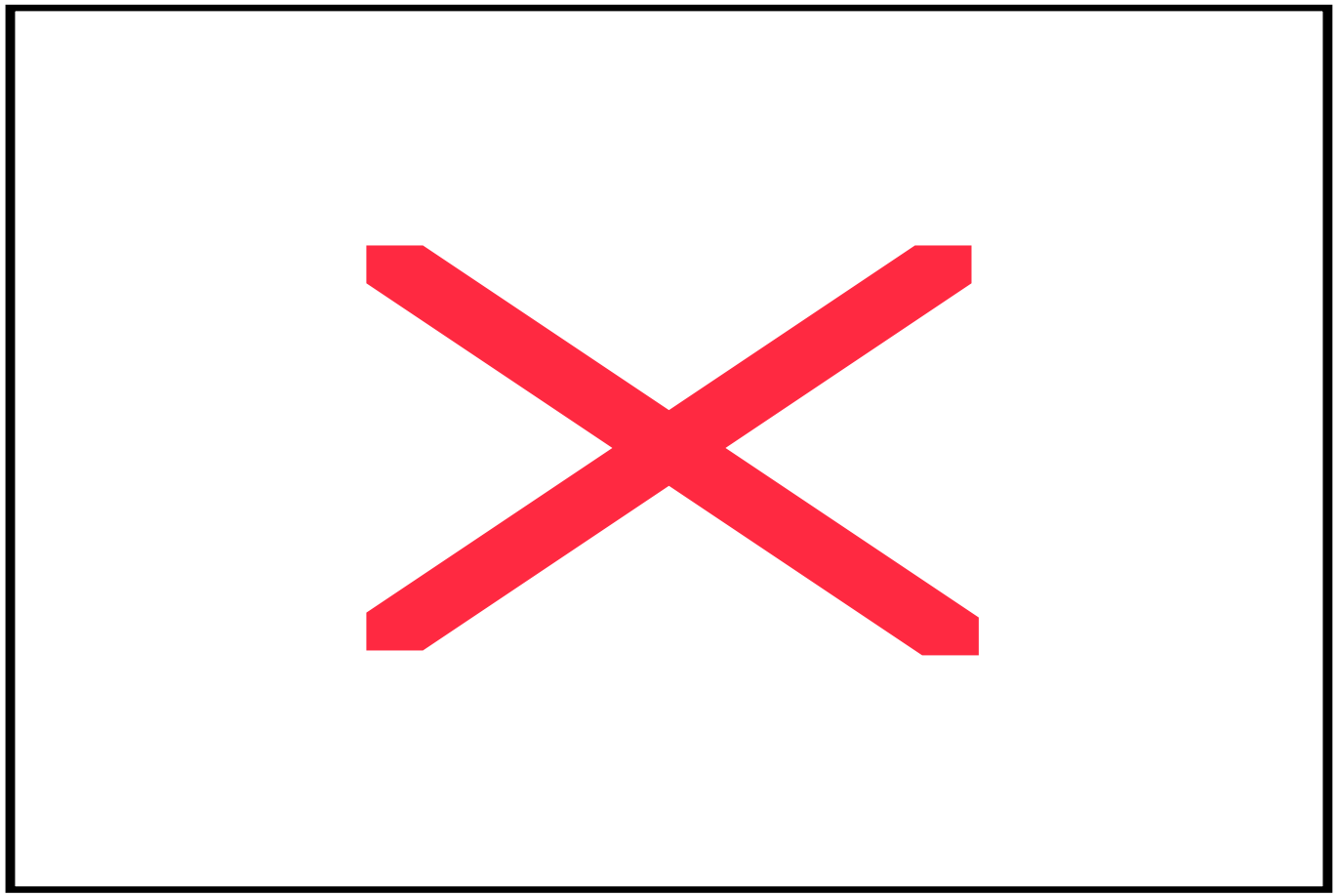
Vulnerability and CV Spaces along S_1 Climate Change Reducing the Mean of X_1



Vulnerability and CV Spaces along S_2 Climate Change Increasing the Mean of X_1



Sustainability Indices

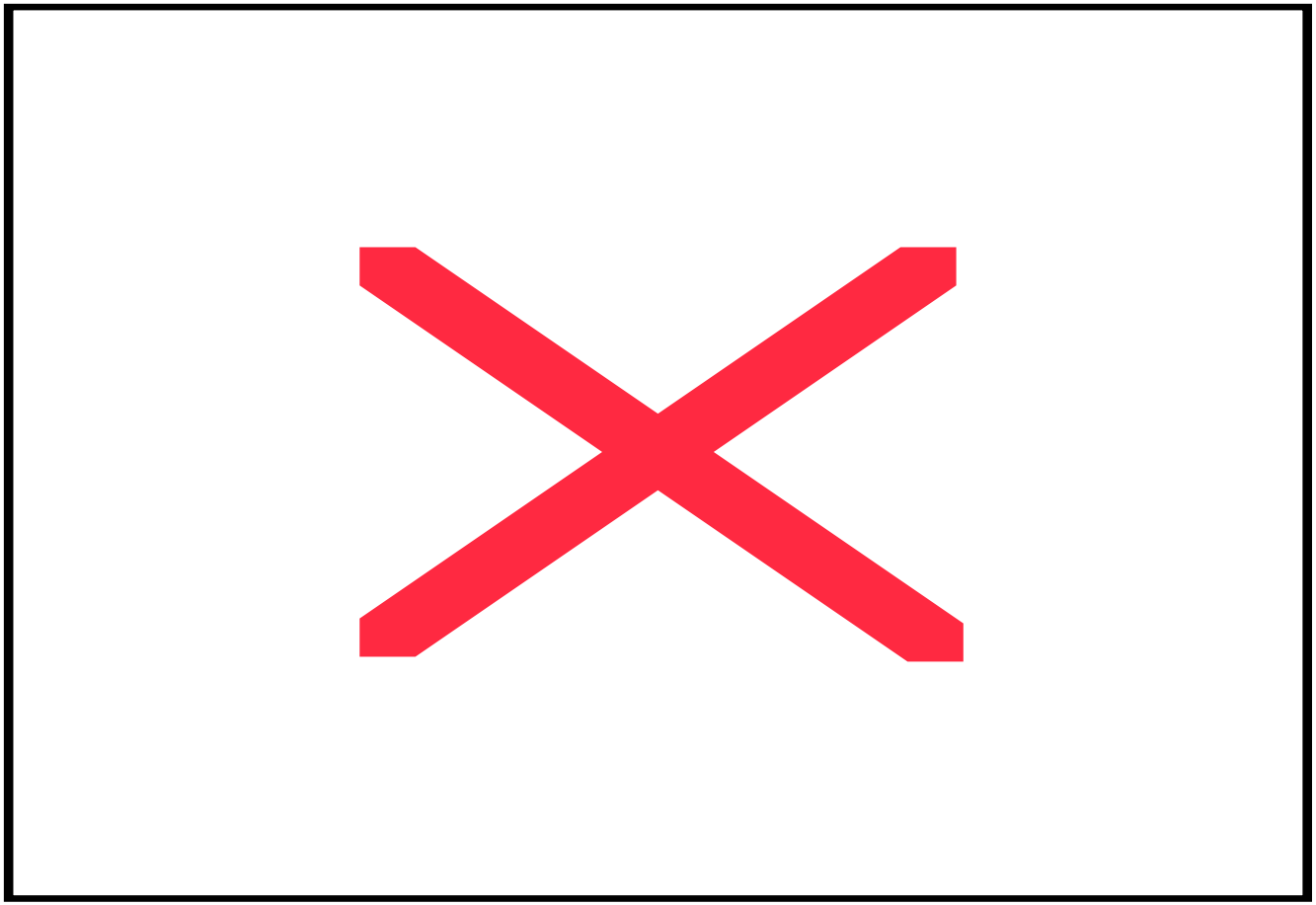


A Taxonomy of Approaches with which to Represent Climate Uncertainty

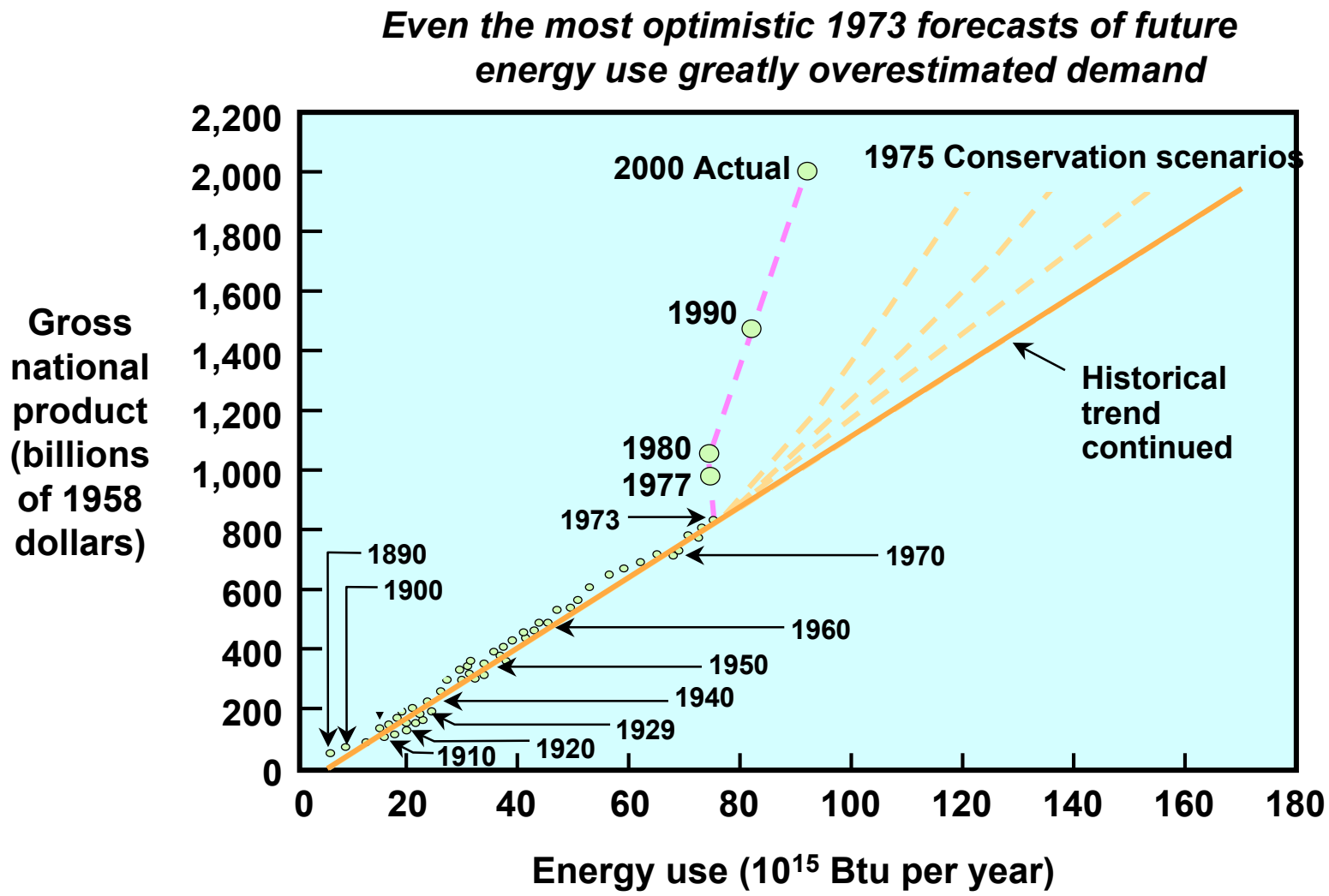
- Cover the range of “not-implausible” futures.
- Adopt the consensus view of the future.
- Adopt the most popular view of the future.

- *In all cases, not just the limiting ones, it is possible systematically to underestimate uncertainty.*
  - the EMF-14 story.

The Underlying Runs for the NPV Distributions: Expected Energy Generation



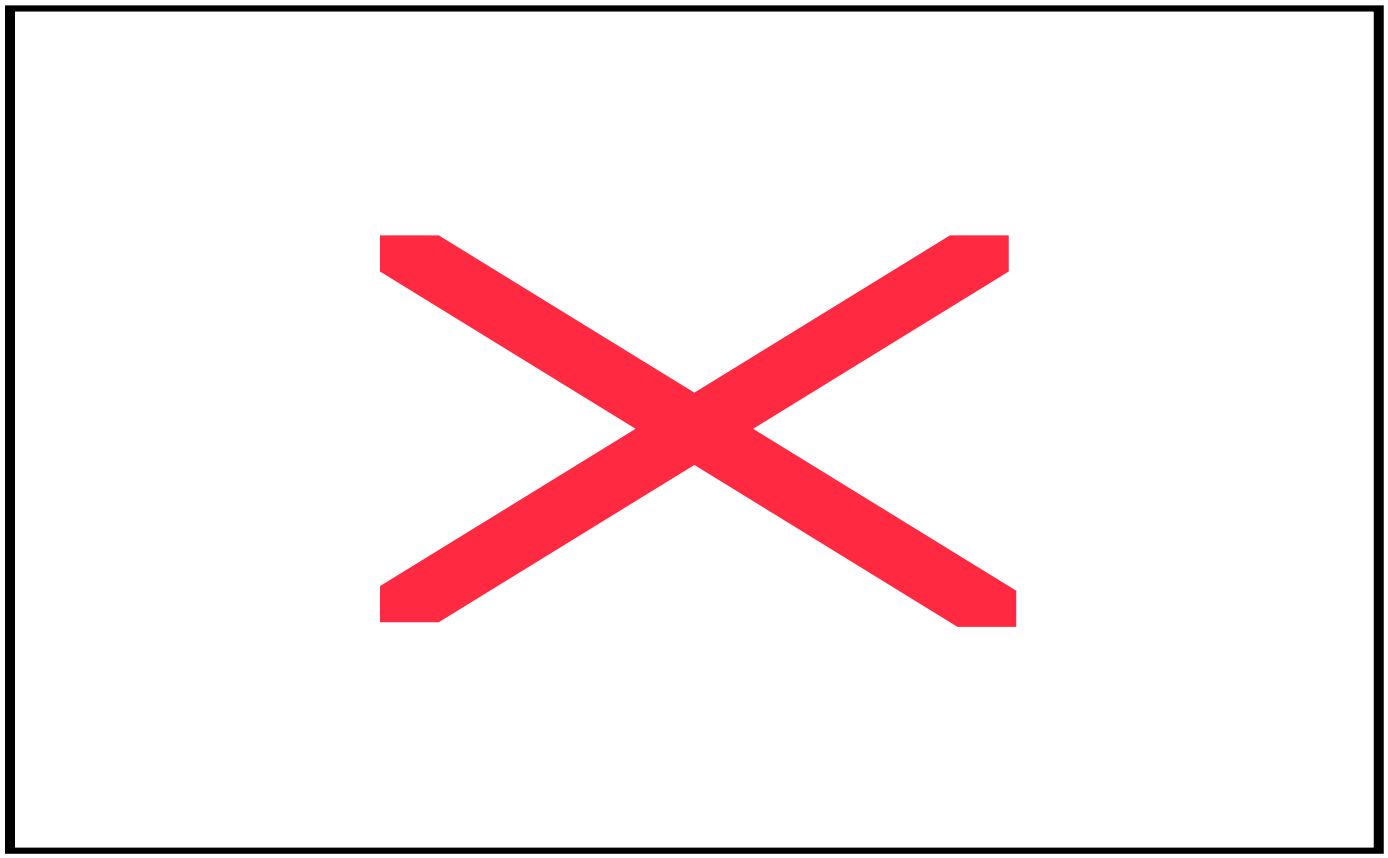
Decision-makers Sometimes Face Novel Situations (Robert Lempert)



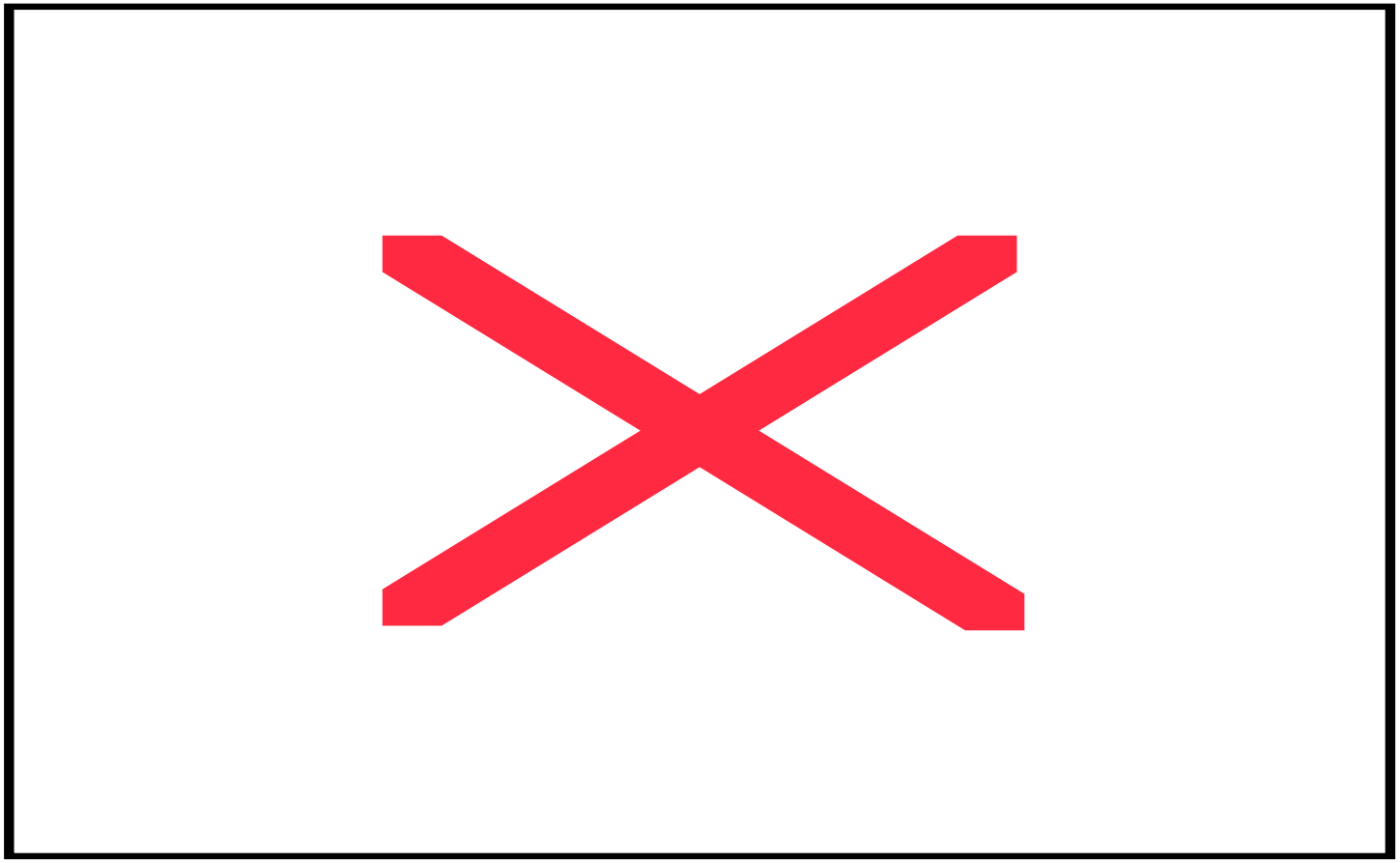
A Taxonomy of Responses with Respect to Uncertainty

- Robust: handle all most possible futures and process descriptions *cum* calibrations.
- Diversified: one response for a collection of representative possible futures.
- Adaptive Management Strategies: strategies that include near-term hedging (at a cost) plus predictable adjustments downstream.

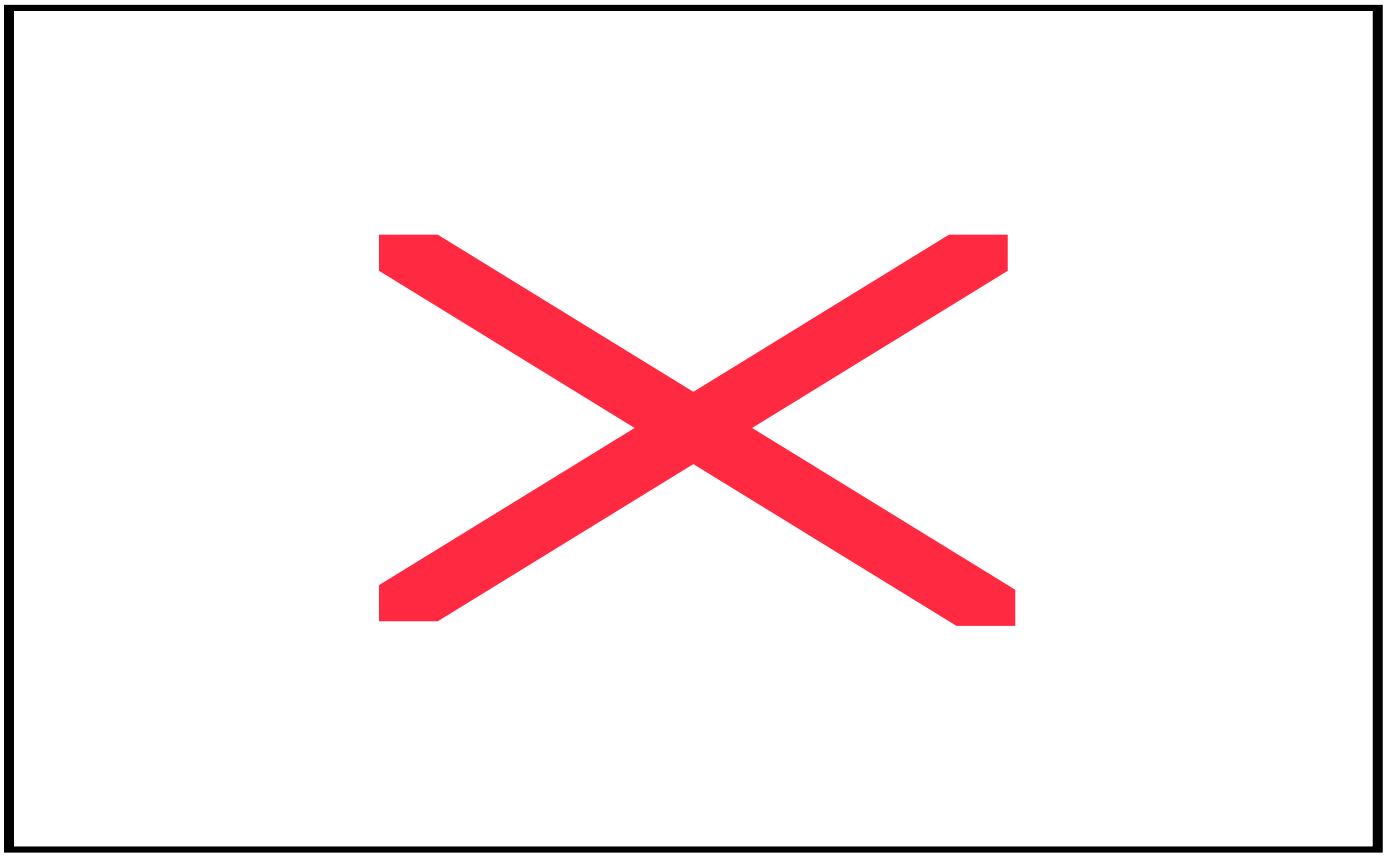
A Cartoon of a Robust Response



A Cartoon of the Diversified Extreme

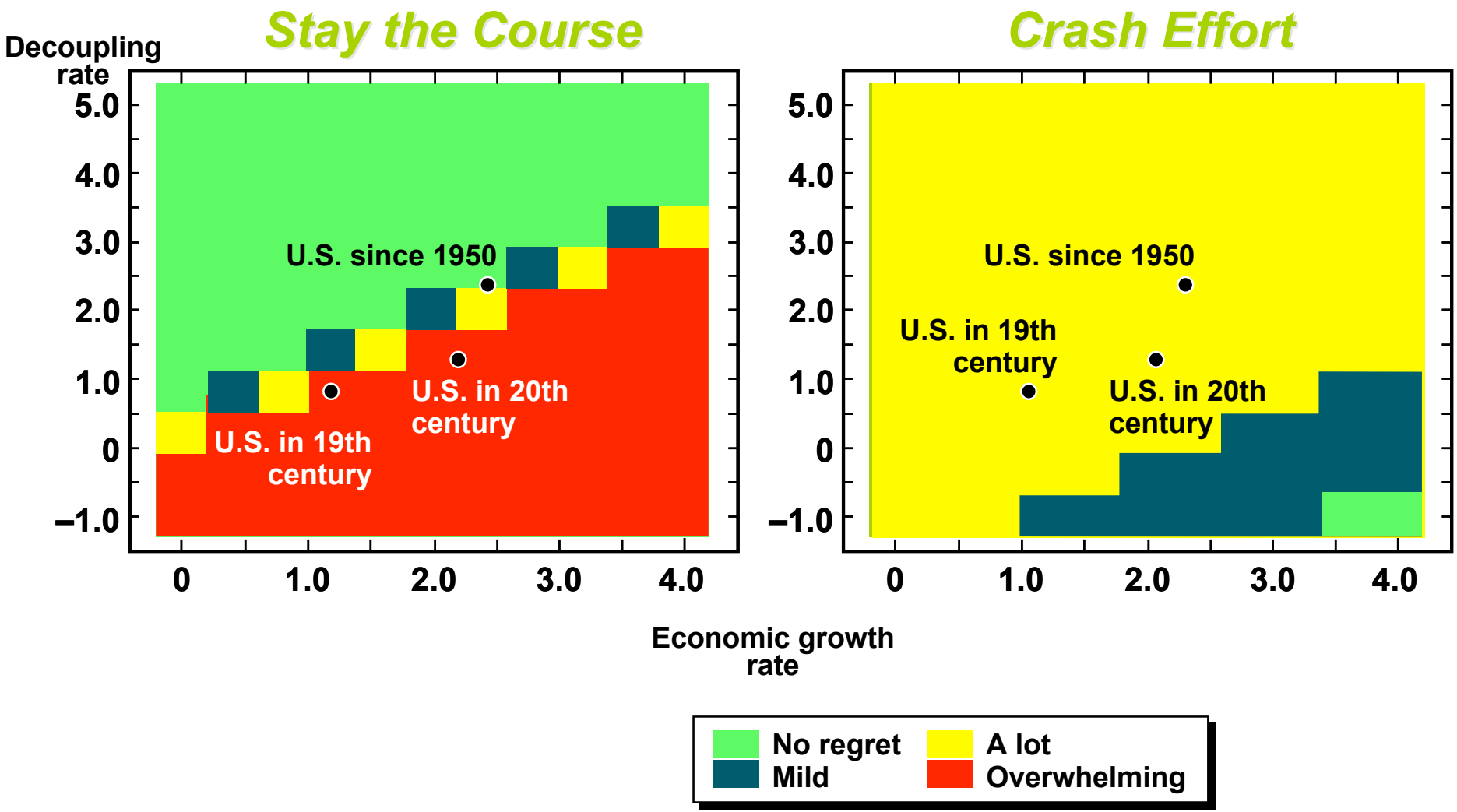


An Intermediate Case

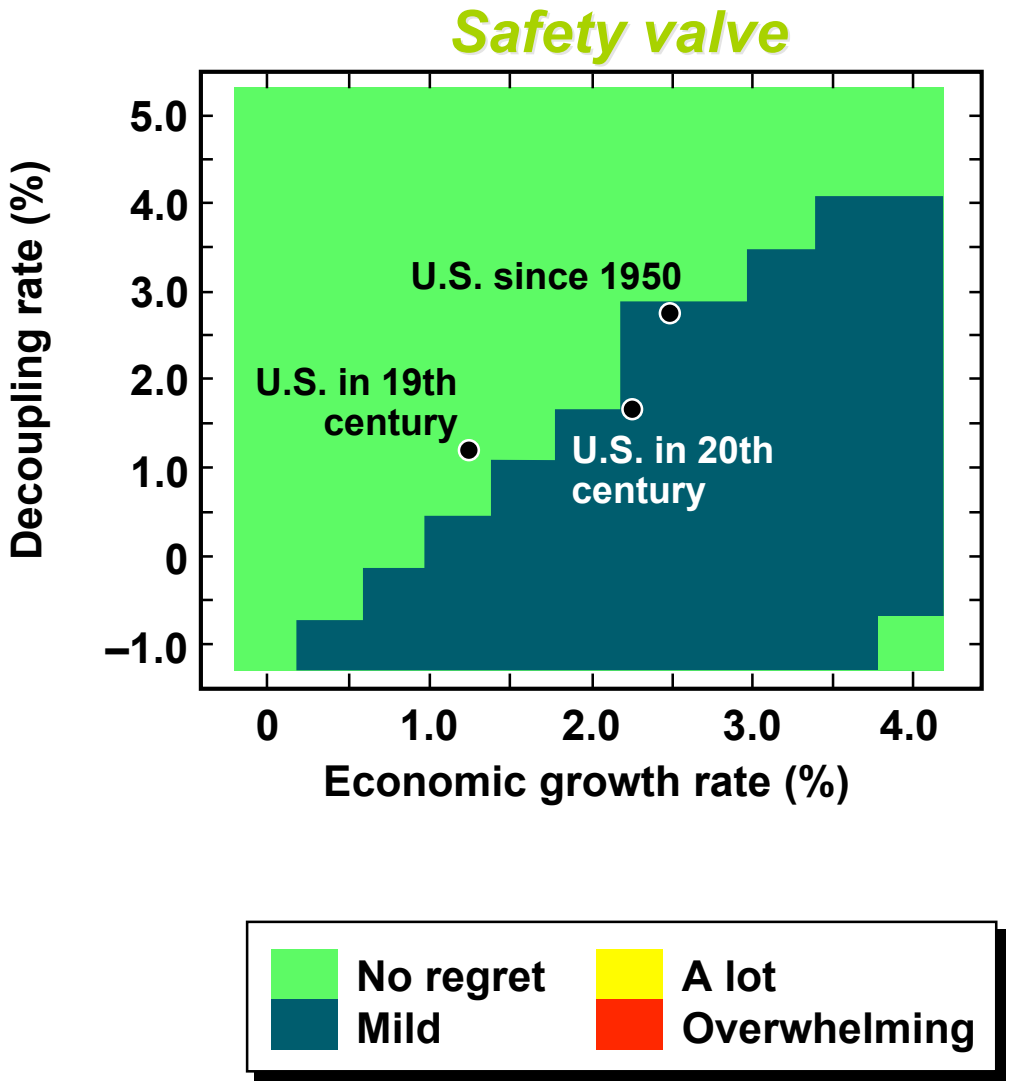


No “Fixed” Strategy Is Robust

(Robert Lempert)



"Safety Valve" Strategy Appears Highly Robust (Robert Lempert)



Issues with Adaptive Management

- System collapse before response adjustment.
- Identifying which variables to monitor.
- Defining and implementing decision criteria
  - Type I error: adjust incorrectly
  - Type II error: refrain from adjusting incorrectly
- Separate “signal” from “noise”; back to worrying about:
  - Model uncertainty
  - Calibration uncertainty
  - Prediction uncertainty

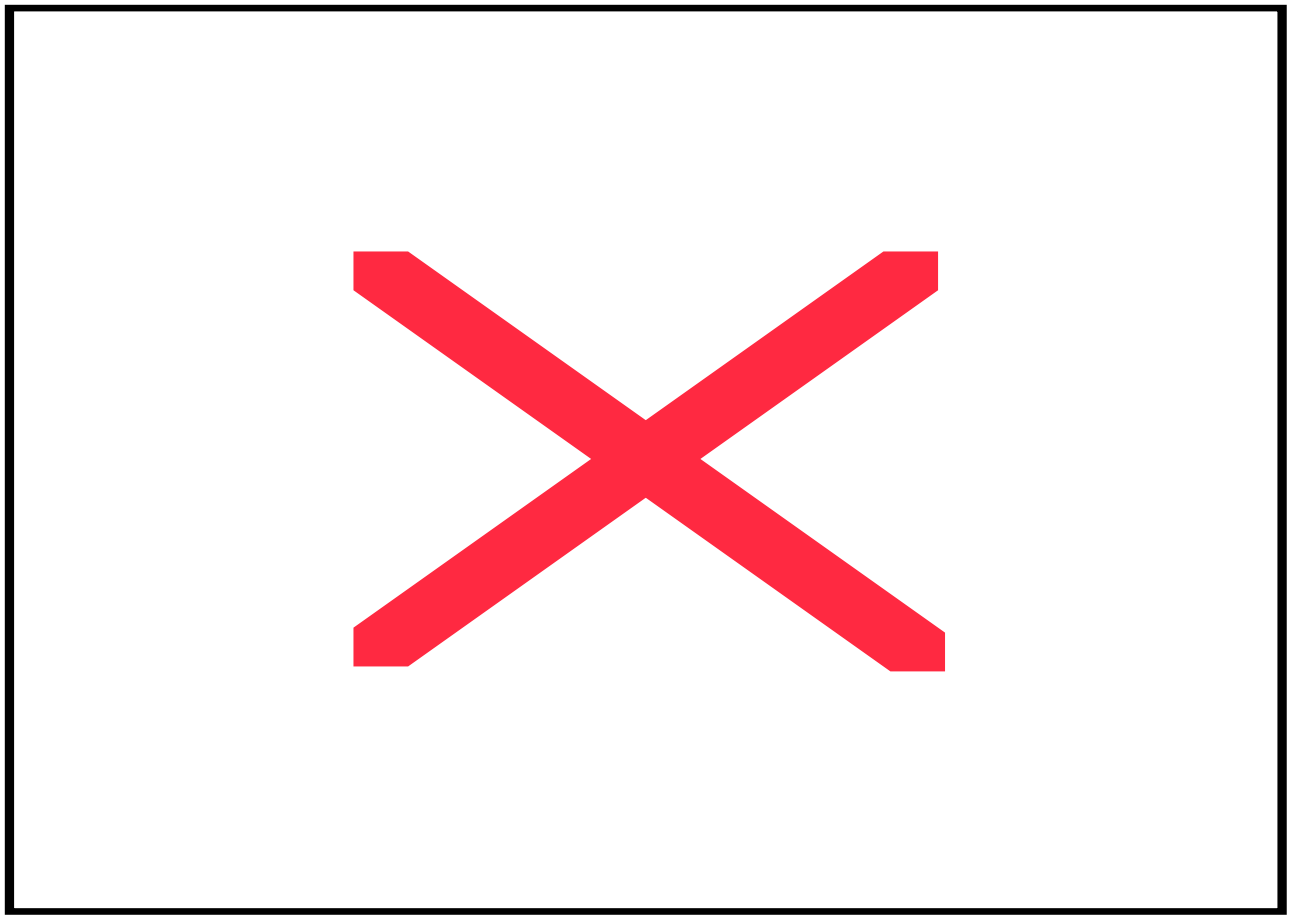
Projection uncertainty

Climate uncertainty

A Taxonomy of Evaluative Metrics

- Expected outcome – another version of consensus …. misses extremes that may be more critical
- Likelihood of crossing critical thresholds …. illustrated by the sustainability index above
- Expected “utility” of outcomes …. something that recognizes that variance as well as mean matters (relative aversion to risk, absolute aversion to risk, piecewise linear approximations defined by thresholds).

Illustrative “Utility” Functions



Thanks for your attention!