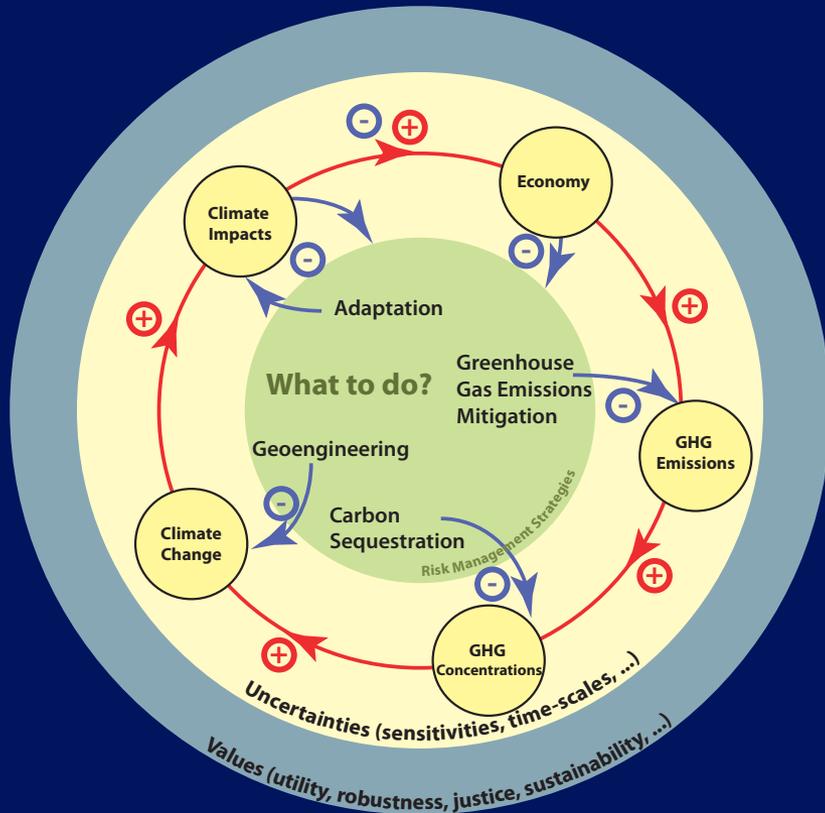# Interplay Among Limits to Adaptation, Mitigation, and Geoengineering:
Initial Thoughts on an Experimental Design to Facilitate Ethical-Epistemic Analyses

Robert Lempert

Lauren Fleishman

RAND

July 30, 2013

SCRiM Seeks to Inform Sustainable, Scientifically and Economically Sound, and Ethically Defensible Risk Management Strategies

- One SCRiM project examines how limits to adaptive capacity might inform views regarding mitigation and geo-engineering strategies

- Rich topic for coupled ethical-epistemic analyses because it engages a wide range of values, spatial and temporal scales, and jurisdictions.

Considering Limits to Adaptation Intermixes Physical and Social Processes

Adger et. al. (2009) offer four propositions concerning limits to adaptation:

1. Any limits to adaptation depend on the goals of adaptation. Such goals emerge from diverse values

2. Adaptation need not be limited by uncertainty

3. Social and individual processes often represent key limits to adaptation

4. Systematic undervaluation of loss of place and culture disguises real, experienced but subjective limits to adaptation

Note that climate-related changes are virtually certain to occur alongside other significant social transformations.

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Interplay of Adaptation, Geoengineering, and Mitigation Involves an Even Richer Set of Factors

For example:

- Early adaptation efforts may involve existing organizations pursuing non-controversial goals, but as climate stresses increase goals may become more diverse and controversial

- Successful mitigation requires collective action beyond existing jurisdictional boundaries in ways many find uncomfortable

- Geoengineering might reduce some risks, but also allows some groups to transfer new risks to others

'Optimal' solar-radiation management (SRM) scenarios for the summer for the 2070s. Ricke et al. Nature GeoSci 2010

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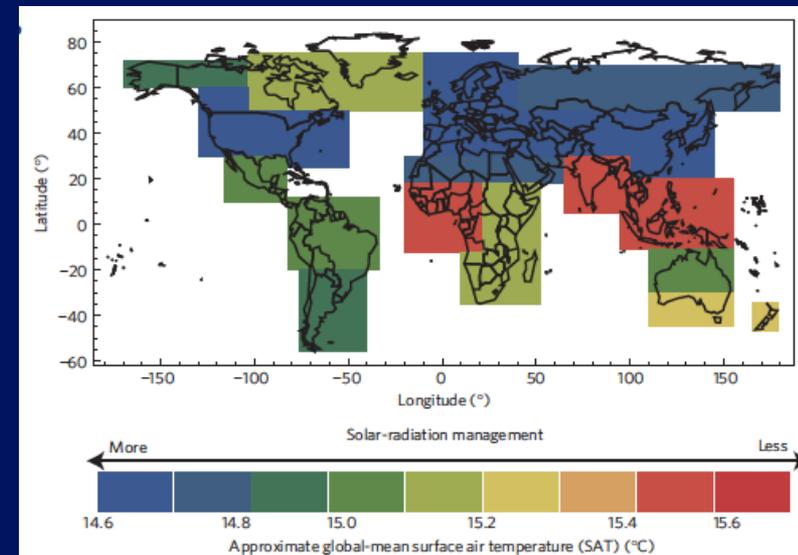
Research Plan Aims to Address These Issues

- Build decision support tools that illuminate tradeoffs by linking:

  - Place-based analyses of adaptation options (such as the one DJ just showed you)

  - Global models of the effects of mitigation and geo-engineering strategies

  - Robust decision making framework for identifying vulnerabilities and tradeoffs among response options

- Use mental model interviews to:

  - Proxy for deliberation with stakeholders

  - Support design of decision support tools

  - Evaluate impact of tools on peoples' thinking about interplay of mitigation, geo-engineering, and limits to adaptation

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Outline

- **How RDM Can Facilitate Coupled Ethical-Epistemic Analysis**

    - **Embed analysis in process of stakeholder engagement**

    - **Do the Analysis Backwards**

- **Mental Models Approach as Proxy for Full Deliberation**
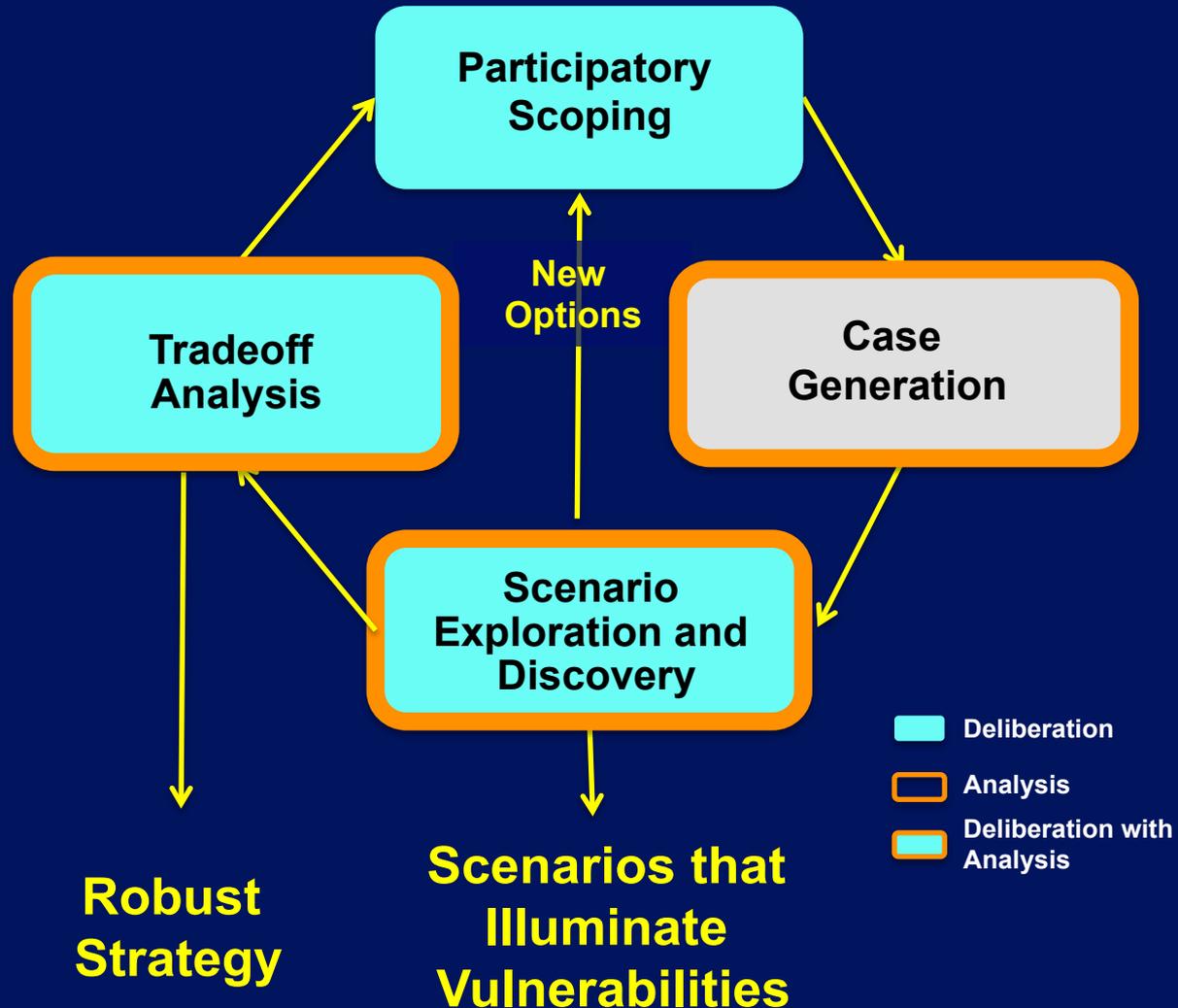
- **Observations**

Sen's <u>Idea of Justice</u> Offers Principles of Ethical Reasoning That Seem Appropriate Here

- Ethical reasoning should recognize as fundamental attributes:
  - Diversity of priorities, goals, and values
  - Irreducible uncertainty regarding consequences of our actions

- Ethical reasoning should pursue relational, not transcendental reasoning
  - Transcendental reasoning seeks agreement on vision of ideally just world, and uses this vision to guide choice of near-term actions
  - Relational reasoning seeks agreement on which non-ideal options before us are more just than others

- Public deliberation proves central this process of social choice, and works best when it:
  - Facilitates re-examination and iterative assessment
  - Demands clear explication of reasoning, logic, and values
  - Recognizes "open impartiality" that accepts legitimacy and importance of views of others

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Robust Decision Making (RDM) Helps Inform Such Relational Reasoning

Key idea -- conduct the analysis "backwards":

- **Start with strategy**

- **Use analytics to identify scenarios where strategy fail to meet its goals**

- **Use these scenarios to identify and evaluate responses**

Participatory Scoping

Tradeoff Analysis

New Options

Case Generation

Scenario Exploration and Discovery

Robust Strategy

Scenarios that Illuminate Vulnerabilities

Legend:
- Deliberation
- Analysis
- Deliberation with Analysis

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8

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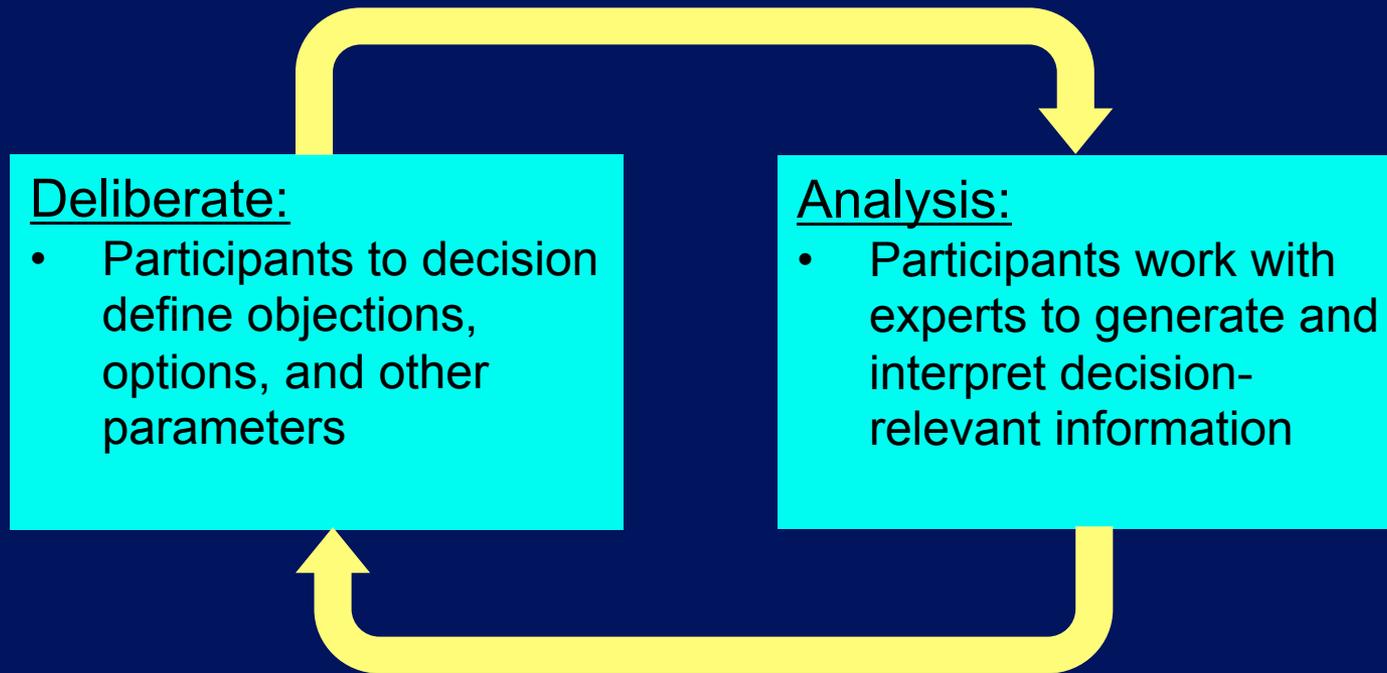- **Mental Models Approach as Proxy for Full Deliberation**

- **Observations**

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'Decision Support' Concept Helps Organize Insights from Cognitive and Organizational Literatures

- **Decision support** represents a set of processes intended to create the conditions and appropriate use of decision-relevant information (p. 34)
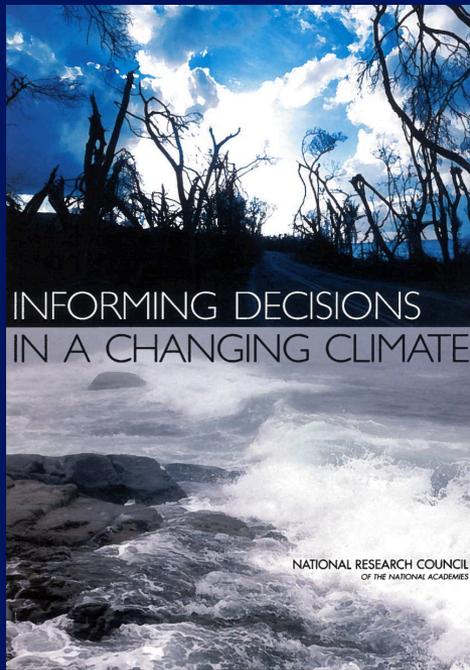
- Information is decision-relevant if it yields deeper understanding of a choice or, if incorporated into making a choice, yields better results for decision makers and their constituencies (p. 35)

NRC (2009)

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When Goals are Changing and Emerge from Collaboration, "Deliberation with Analysis" Offers an Effective Decision Support Process

Deliberate:
- Participants to decision define objections, options, and other parameters

Analysis:
- Participants work with experts to generate and interpret decision-relevant information

NRC (2009) p. 78

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RDM Follows Deliberation with Analysis Process

1. **Start with proposed policy and its goals**

2. **Identify futures where policy fails to meet its goals**

Deliberate:
- Participants to decision define objections, options, and other parameters

Analysis:
- Participants work with experts to generate and interpret decision-relevant information

3. **Identify policies that address these vulnerabilities**

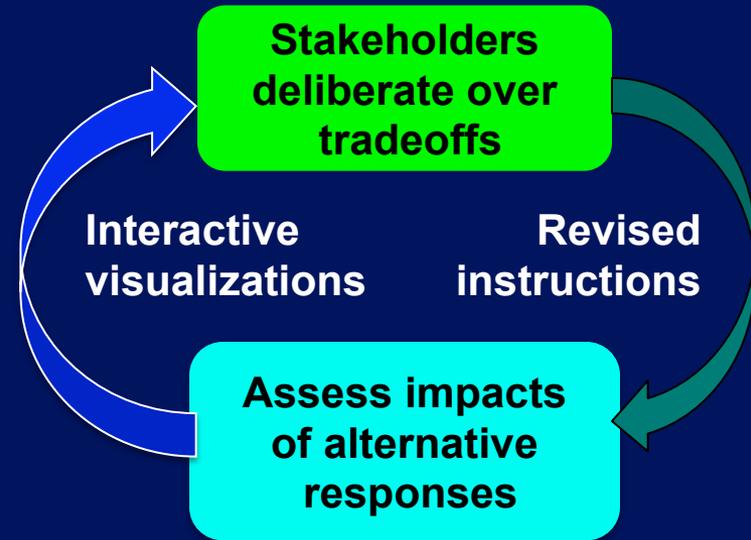4. **Evaluate whether new policies are worth adopting**

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Decision Support Process Helped Louisiana Develop Master Plan for a Sustainable Coast

Louisiana faces increased flooding risk and serious coastal land loss due to sea level rise, land subsidence, lack of river-borne sediments, and any changes in storm intensity

- *RAND helped the state develop a comprehensive coastal master plan*

Dozens of workshops with many stakeholders over two years

Stakeholders deliberate over tradeoffs

Interactive visualizations

Revised instructions

Assess impacts of alternative responses

Planning Tool and Risk Assessment Model

Compares consequences alternative combinations of 100's of responses

Planning Tool
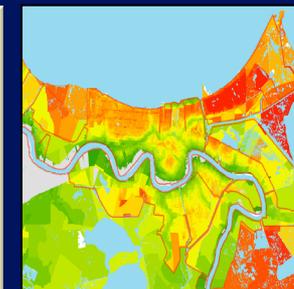
Integrates scientific information from multiple sources to estimate risk to different communities and industries
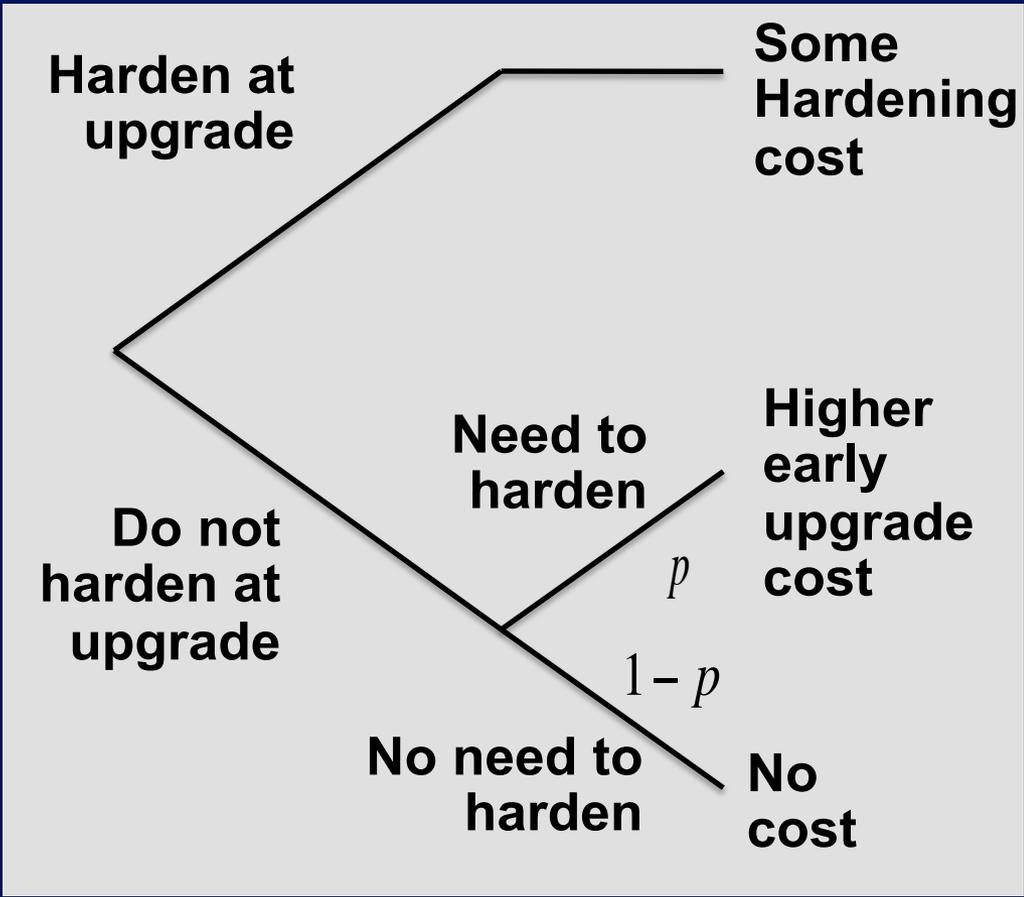
Outline

- **How RDM Can Facilitate Coupled Ethical-Epistemic Analysis**

  - **Embed analysis in process of stakeholder engagement**

    - **Louisiana Master Plan for a Sustainable Coast**

  - **Do the Analysis Backwards**

    - *Enabling systematic consideration of multiple points of view*

- **Mental Models Approach as Proxy for Full Deliberation**

- **Observations**

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Should Port of Los Angeles Harden Terminals Against Risk of Extreme Sea Level Rise?
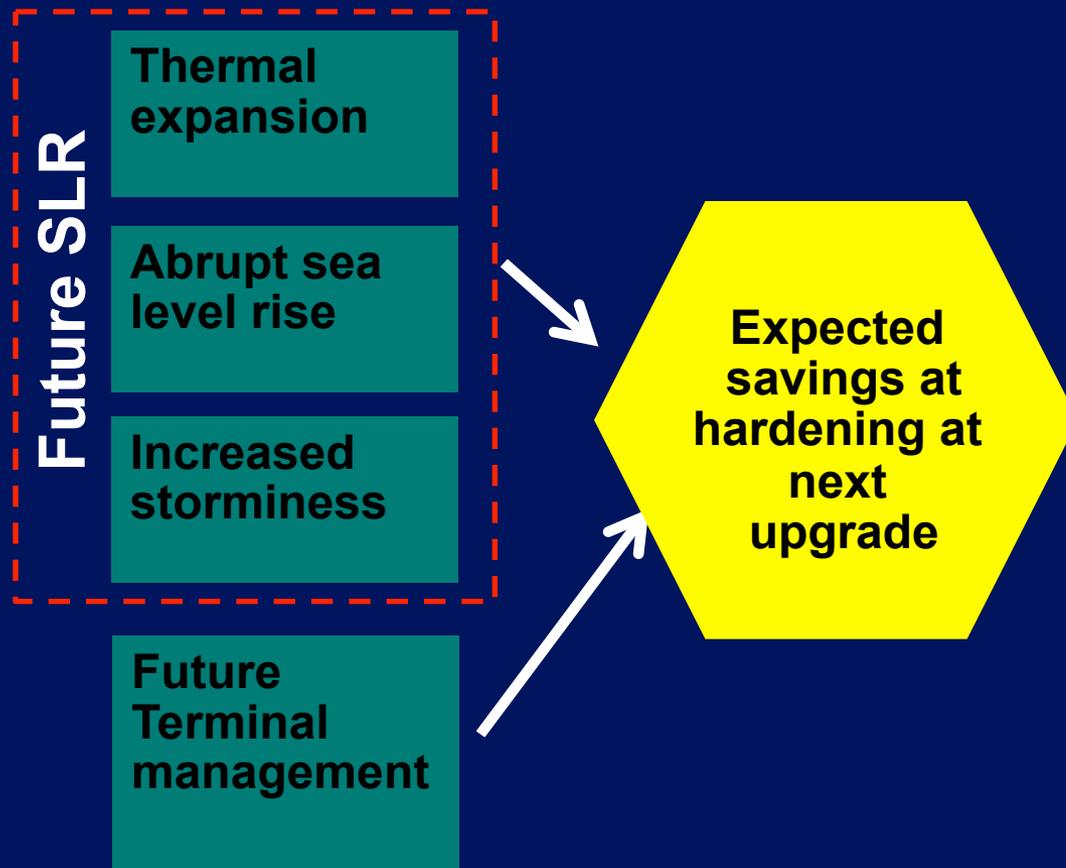
Decision Challenge

- **Terminals are high above current sea level, so relatively invulnerable to all but the most extreme SLR**

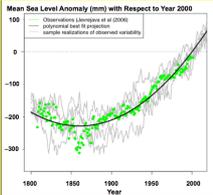- **Cost to harden at next upgrade is much lower than retrofitting between upgrades**

Harden at upgrade → **Some Hardening cost**

Do not harden at upgrade

Need to harden — p → **Higher early upgrade cost**

No need to harden — $1-p$ → **No cost**

Lempert, Robert, Ryan L. Sriver, and Klaus Keller. 2012. "Characterizing Uncertain Sea Level Rise Projections to Support Investment Decisions." California Energy Commission. Publication number: CEC-500-2012-056

We Built a Simple Model to Evaluate Decision

Future SLR

- Thermal expansion
- Abrupt sea level rise
- Increased storminess

Future Terminal management

Expected savings at hardening at next upgrade

Harden at next upgrade if we expect savings

# Consider Parameters with Different Types of Uncertainty

Future SLR

Uncertainty	RDM Characterization of Uncertainty
SLR in 2011	Well characterized joint probability distribution
Normal Rate of SLR	
Normal SLR Acceleration	
Rate of Abrupt SLR	Deeply uncertain: 0 - 30 mm/year
Year Abrupt SLR Begins	Deeply uncertain: 2010 - 2100
Increased storminess	Deeply uncertain: Set of GEV distributions with scale ranging from 517mm to 569 mm;

Future Terminal Management

Uncertainty	RDM Characterization of Uncertainty
Lifetime	Deeply uncertain: 30 - 100 years
Maximum Allowable Overtop Probability	Deeply uncertain: 5 - 50%/year
Decision Year	Known at decision time: e.g. 2020
Height Above Mean Sea Level	Known at decision time: e.g. 2,804 mm
Current Hardening Cost	Known at decision time: e.g. 1%
Discount Rate	Known at decision time: e.g. 5%

# *A Few Cases in the Sample Favor Hardening at the Next Upgrade*

- **Ran 500 case sample**

  - **Varied five deeply uncertain parameters**

  - **Used distributions for parameters with well-characterized uncertainties**

- **Calculated expected savings for each case**
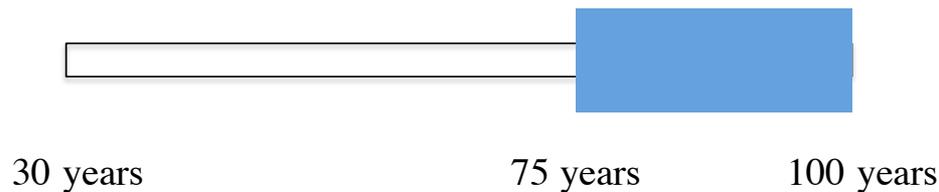

Mean Savings from Early Upgrade
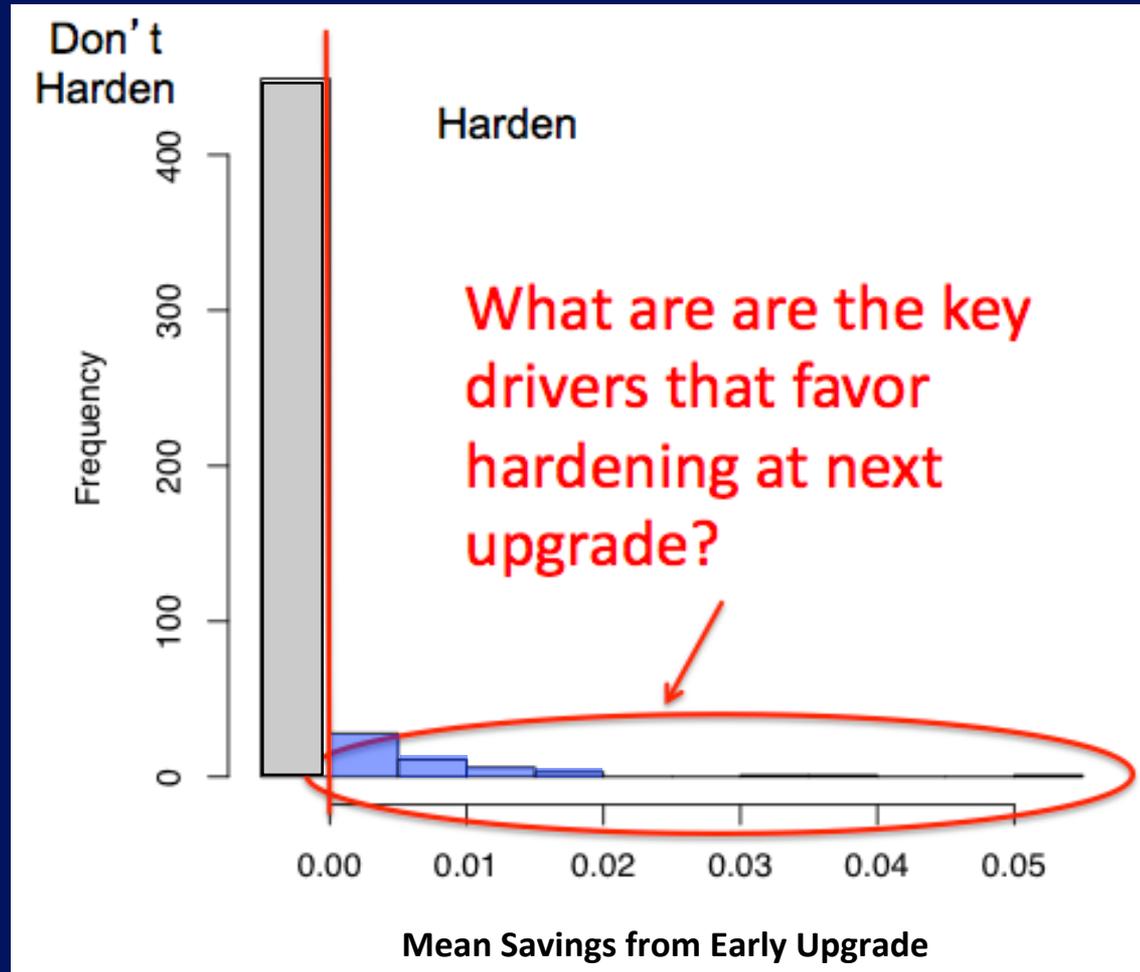
Approach Identifies Scenario Where Hardening at Next Upgrade Passes Cost-Benefit Test

Rate of Abrupt SLR $\geq 14\dfrac{mm}{yr}$

$c*-0.3\dfrac{mm}{yr}(t*-2010)\geq 14\dfrac{mm}{yr}$

$-27\dfrac{mm}{yr}$ $14\dfrac{mm}{yr}$ $30\dfrac{mm}{yr}$
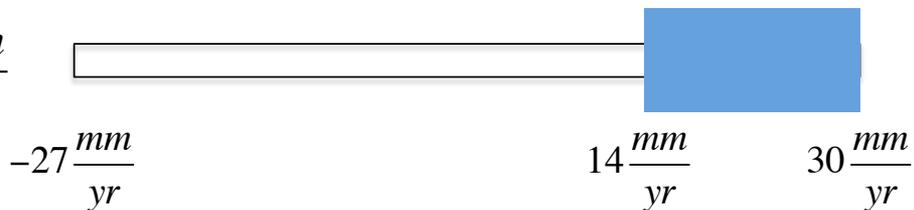
Terminal Lifetime ≥ 75 years

30 years   75 years   100 years

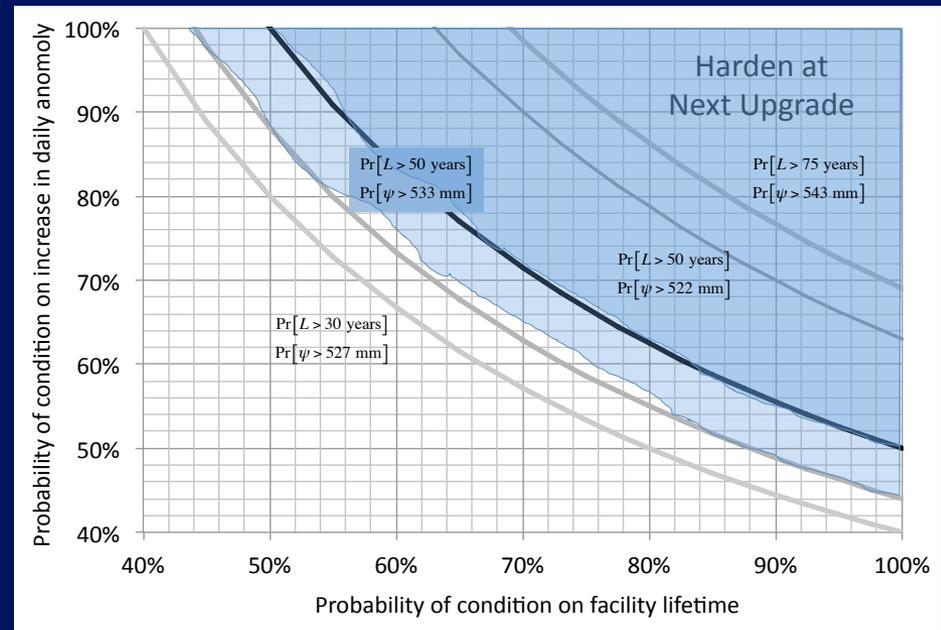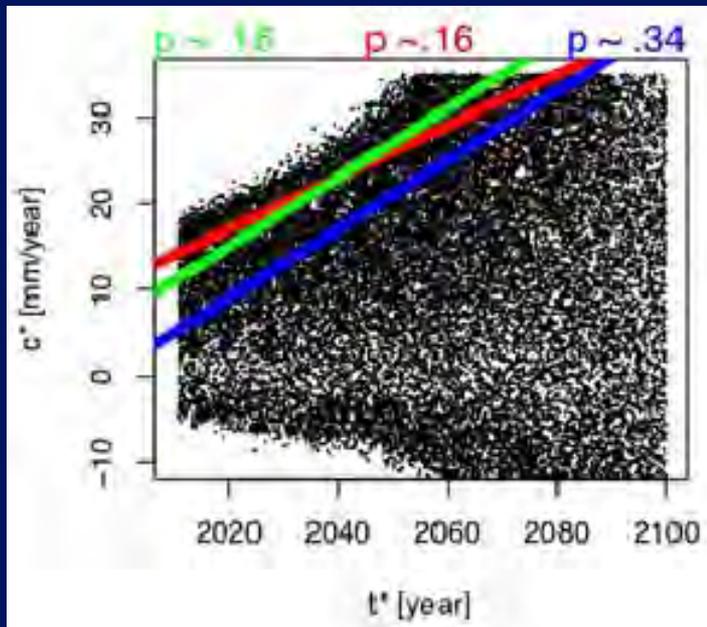**Increased storminess** $543mm$

$543mm$

$517mm$ $569mm$

Range required to
pass cost-benefit test

Evidence Suggests this Scenario is Insufficiently Likely to Justify Hardening

Available science suggests probability of exceeding abrupt SLR threshold ~ 16%

Passing cost benefit test thus requires high probability of long lifetime and increased storminess

Little evidence to suggest actual likelihood lies in blue region

Backwards Analysis Designed to Allow Systematic Consideration of Multiple Points of View

- Analysis that produces these scenario maps explicitly consider a set of multiple pdf's

- Such sets, and associated visualizations, help couple quantitative analysis to a deliberative process that accepts the legitimacy and importance of multiple points of views and diverse values
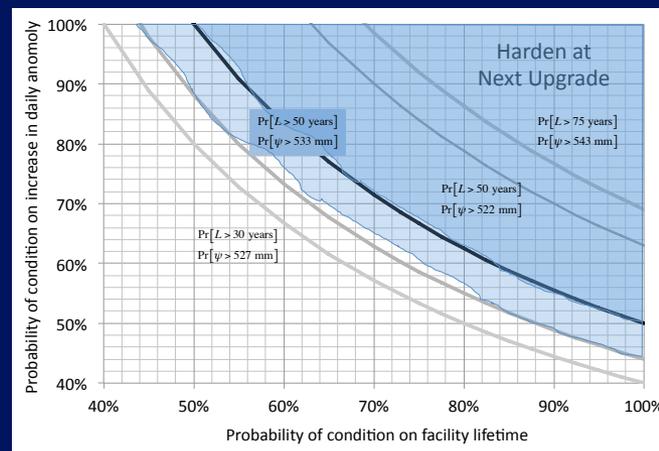
Lempert, Robert, David G. Groves, Jordan Fischbach. 2013. <u>Is it Ethical to Use a Single Probability Density Function?</u> RAND WR-922-NSF

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Backwards Analysis Designed to Allow Systematic Consideration of Multiple Points of View

- Analysis that produces these scenario maps explicitly consider a set of multiple pdf's

- Such sets, and associated visualizations, help couple quantitative analysis to a deliberative process that accepts the legitimacy and importance of multiple points of views and diverse set of values

Current work generalizing these single-attribute policy region maps to maps for multi-attribute "pareto-satisficing" policies

Kasprzyk, J. R., S. Nataraj, P. M. Reed and R. J. Lempert (2013). "Many-Objective Robust Decision Making for Complex Environmental Systems Undergoing Change." Environmental Modeling and Software 42: 55-71.

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This SCRiM Project Requires Alternative to Full Deliberation Because it Addresses a Much Wider Range of Stakeholders

Louisiana stakeholders willing to attend many meetings and would often fit in one room

When considering interplay among adaptation, mitigation, and geo-engineering, the relevant stakeholders can't be assembled in one room

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The Mental Models Approach (MMA) is an established method for informing decisions
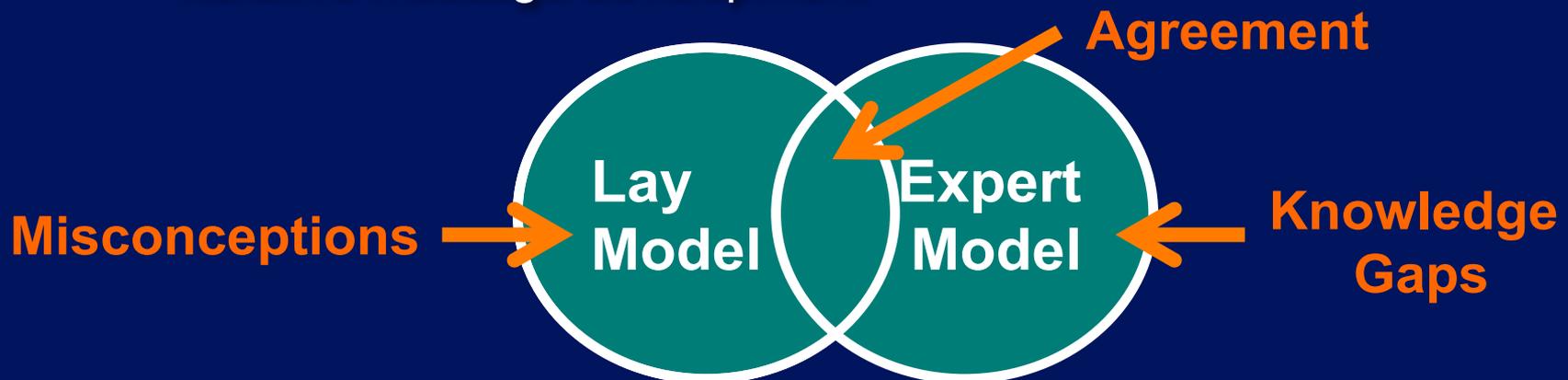
1. **Normative: what should people know?**

   - Literature review and expert panel ➜ expert model

2. **Descriptive: what do people already know?**

   - Qualitative interviews and quantitative surveys; identify relevant wording and decision contexts ➜ lay model

3. **Prescriptive: what do people still need to know?**

   - Compare expert and lay model ➜ Identify gaps and misconceptions
   - Iterative message development

Agreement

Misconceptions ➜ **Lay Model** **Expert Model** ⬅ **Knowledge Gaps**

Morgan, M. Granger, Baruch Fischhoff, A. Bostrom, and C. J. Atman, *Risk Communication: A Mental Models Approach*, New York: Cambridge University Press, 2002.

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A Mental Model is an Influence Diagram of Decision-Relevant Processes

Example mental model of decisions relevant to protection against unplanned pregnancy

Expert Model

Krishnamurti et al., Social Science and Medicine, (2008)

Expert and Lay Mental Model Can Differ

Example mental model of decisions relevant to protection against unplanned pregnancy

Lay Model

Influences not considered by expert
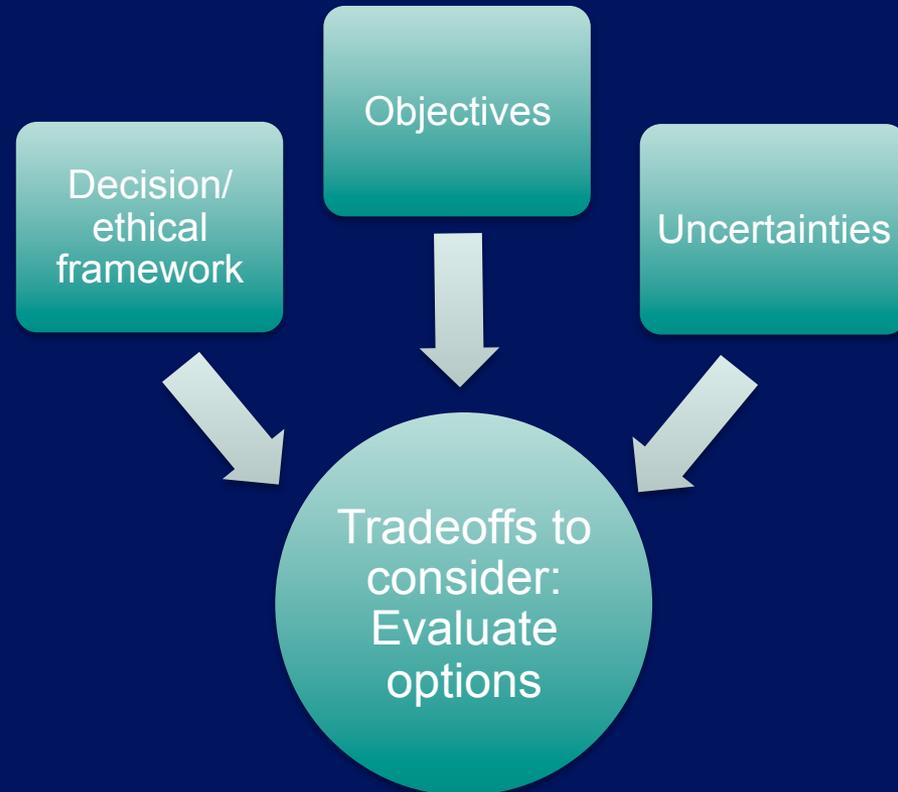
Krishnamurti et al., Social Science and Medicine, (2008)
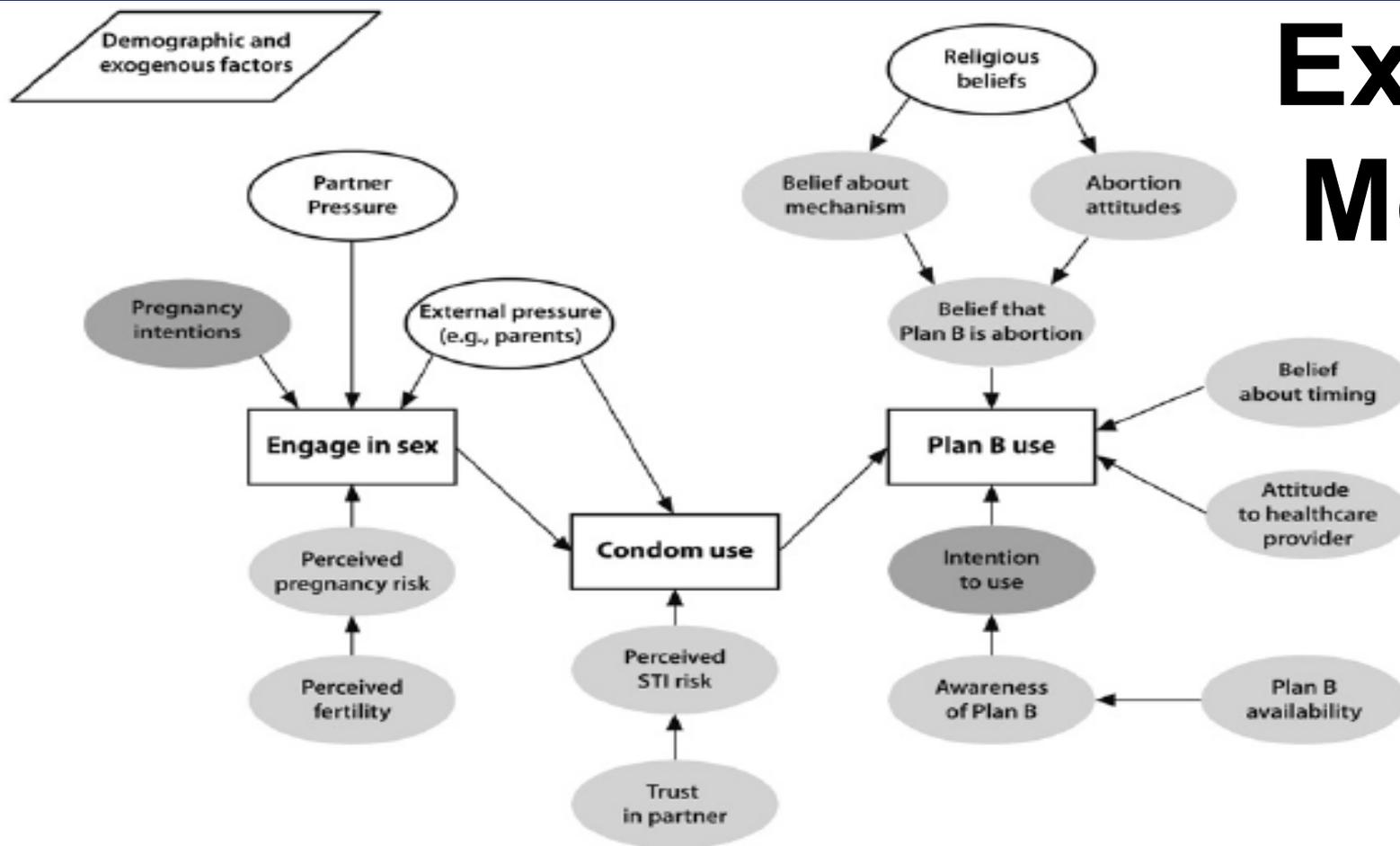
Mental Models Interviews Can Provide Useful Input to Model Development and Use

MMA interviews can:

- Probe decision/ethical frameworks, uncertainties (and their importance), objectives, options

- Examine how different mitigation and geoengineeing options should be evaluated in the context of differing climate adaptive capacity

- Inform gap analysis between what is currently in the models, and what might reasonably be included to expand the range of views considered

Objectives

Decision/ ethical framework

Uncertainties

Tradeoffs to consider: Evaluate options

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Focus Initial Interviews on SCRiM Modelers

More Ideal process

MMA interviews with <u>stakeholders</u>

Build models and decision support tools

MMA interviews with stakeholders with and without decision support tools

Year 1

Year 5

More practical process

MMA interviews with <u>modelers</u>

Build models and decision support tools

MMA interviews with stakeholders with and without decision support tools

Year 1

Year 5

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Semi-Structured Interviews Inform Illustrative Mental Models

- Modified mental model interviews with twelve SCRiM model team leaders will cover the following concepts:

  – Overall comparison, distribution of outcomes in time and space, uncertainties, ethical/epistemic principles, values, assumptions, performance measures and stakeholders & decision-makers

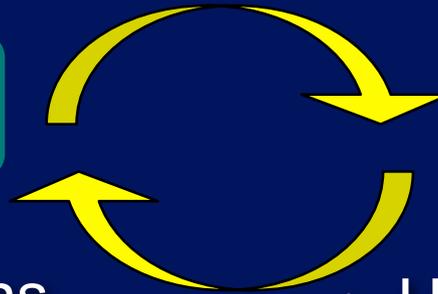|	POSSIBLE OUTCOMES/PERFORMANCE METRICS		
	Risks	Costs	Effectiveness/ Benefits
	Direct human (e.g., human health), indirect human (e.g., infrastructure), natural environment (e.g., biodiversity)	Financial upfront costs, externalities, opportunity costs	Mitigating climate change impacts, limiting future emissions, feasibility
Geoengineering			
Adaptation	*Project leaders will use this table to structure their thinking while answering questions about a number of topics*		
Mitigation			

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Some Common Themes Emerging in Pilot Tests

- **Common themes include:**

  - **Judgments about feasibility of options strongly influence preferences among options**

  - **Concern about preferences of people not yet born**

  - **Tend to phrase tradeoffs as overall human welfare vs. other considerations, such as the natural environment, particularly vulnerable human populations, etc.**

  - **Concern with unknown unknowns such as dramatic technology shifts**

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We envision an iterative two-way information flow with Modelers

Modelers

Interviewers

- Uncertainties, options, assumptions, potential objective functions

- What topics should we probe on in interviews (e.g. time element)?

- How should we present decision challenge to interviewees?

- Uncertainties, options, assumptions, objectives

- Decision/ethical frameworks: what are the tradeoffs, which tradeoffs are most difficult to make?

- Misconceptions/knowledge gaps

- Wording: how they talk about it

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Can Our Science and Models Usefully Contribute to Policy Debates in Democratic Societies?

Mill saw representative government as a "cognitive process, fashioned to maximize the production, accumulation, and implementation of politically relevant truths" *Stephen Homes*
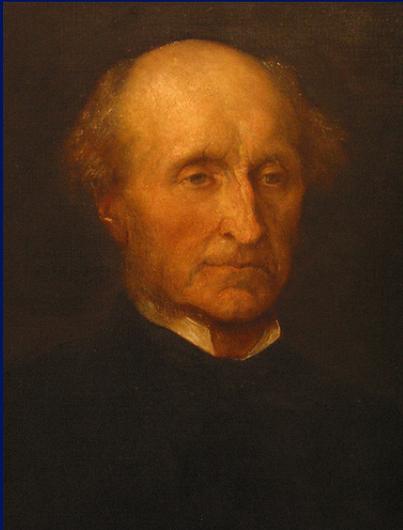
Lippman doubted whether the common voter pays enough attention to be trusted with many of the most important questions facing society

Decision Structuring: Work with Decision Stakeholders to Define Objectives/Parameters

1. Decision Structuring

Deliberation with Decision Stakeholders

- **Metrics** that reflect decision makers' goals
- Management **strategies** (levers) considered to pursue goals
- **Uncertain factors** that may affect ability to reach goals
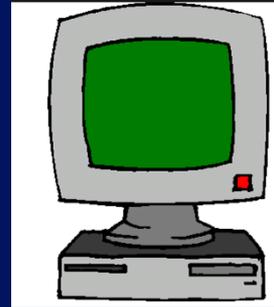- **Relationships** among metrics, levers, and uncertainties

Information needed to organize simulation modeling
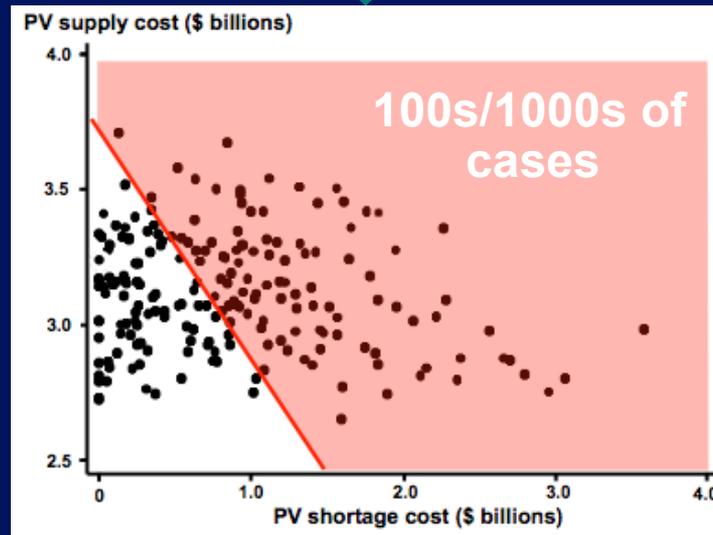
Also called "XLRM"

Case Generation: Evaluate Strategy in Each of Many Plausible Futures

Simulating Futures

- **Strategy**
- **Plausible assumptions**
- **Potential outcomes**

2. Case Generation

100s/1000s of cases

PV supply cost ($ billions)

PV shortage cost ($ billions)

Large database of simulations model results (each element shows performance of a strategy in one future)

Scenario Generation: Mine the Database of Cases to Identify Policy-Relevant Scenarios

1. Indicate policy-relevant cases in database of simulation results

2. Statistical analysis finds low-dimensional clusters with high density of these cases

Uncertain input variable 2

3. Scenario Discovery
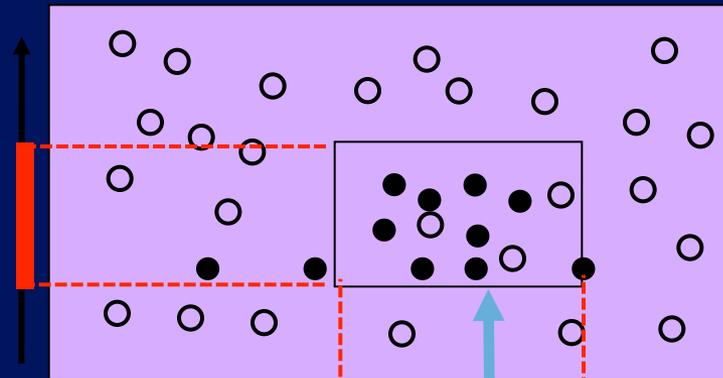
Uncertain input variable 1

3. Clusters represent scenarios and driving forces of interest to decisionmakers

Scenarios that illuminate vulnerabilities of proposed strategy

Parameter 2

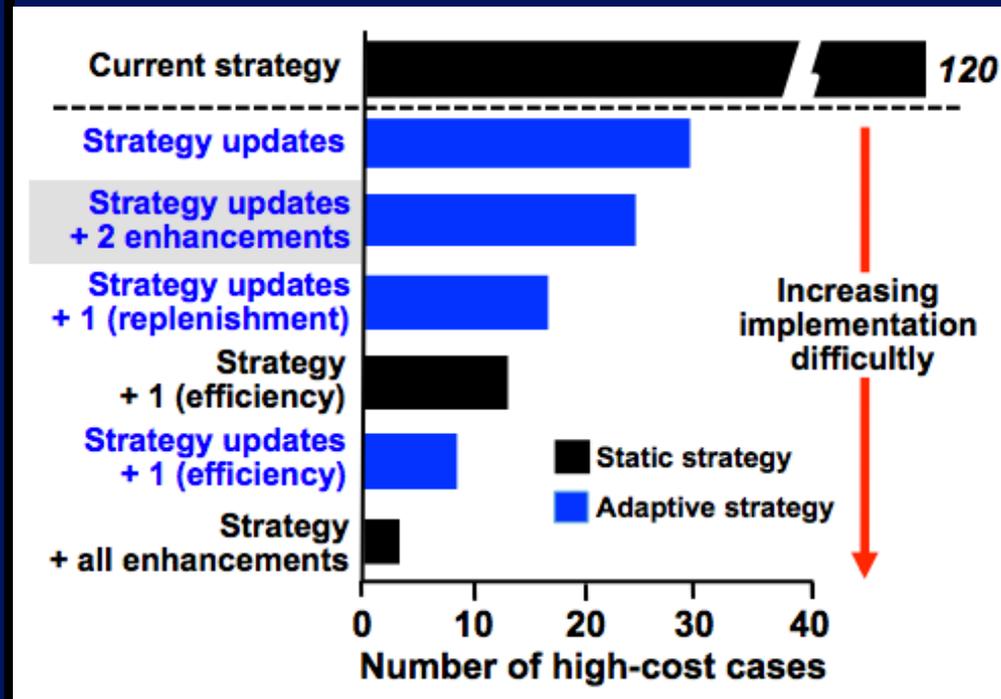Strategy successful

Strategy less successful

Parameter 1

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Tradeoff Analysis: Allow Decisionmakers to Compare Tradeoff Among Strategies

Visualization helps decisionmakers compare strategies

4. Tradeoff Analysis

Strategy	Number of high-cost cases
Current strategy	120
Strategy updates	
Strategy updates + 2 enhancements	
Strategy updates + 1 (replenishment)	
Strategy + 1 (efficiency)	
Strategy updates + 1 (efficiency)	
Strategy + all enhancements	

Increasing implementation difficulty

Static strategy
Adaptive strategy

Number of high-cost cases

Robust strategy or information to enable decision-makers to make more robust strategy