

RAND

INFRASTRUCTURE, SAFETY,
AND ENVIRONMENT

Long-Term Water Management Under Climate Uncertainty

Robert Lempert
Senior Scientist
RAND

Workshop on Uncertainty in Climate Policy Analysis
Snowmass
Aug 6-7, 2008

Collaborators

- **David Groves, RAND**
- **Sandy Berry, RAND**
- **Debra Knopman, RAND**
- **Lynne Wainfain, RAND**
- **David Yates, NCAR**
- **Claudia Tebaldi, NCAR**

Climate Change Poses Significant Planning Challenge for Water Managers

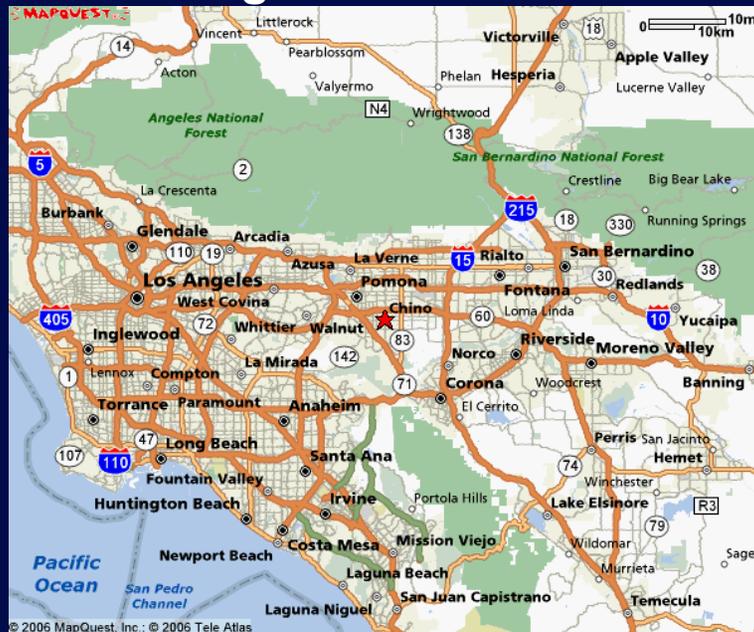
- **Climate change will likely have large but uncertain impacts on supply and demand for water**
- **“Stationarity is dead”**
 - Most agencies already include climate (often implicitly) in many decisions
 - Amidst all the uncertainty one thing we do know for sure -- tomorrow’s climate will not be like the past’s
- **Relaxing this assumption poses key challenges**
 - How do you adjust plans based on uncertain climate projections?
 - How do you communicate these plans, especially when uncertain long-term benefits require near-term costs?

Outline

- **Climate vulnerability and response option analysis for Inland Empire Utilities Agency (IEUA)**
 - What impacts may climate change have on IEUA's current plans?
 - What should IEUA do in response?
- **Evaluating impacts of analysis on decision makers**

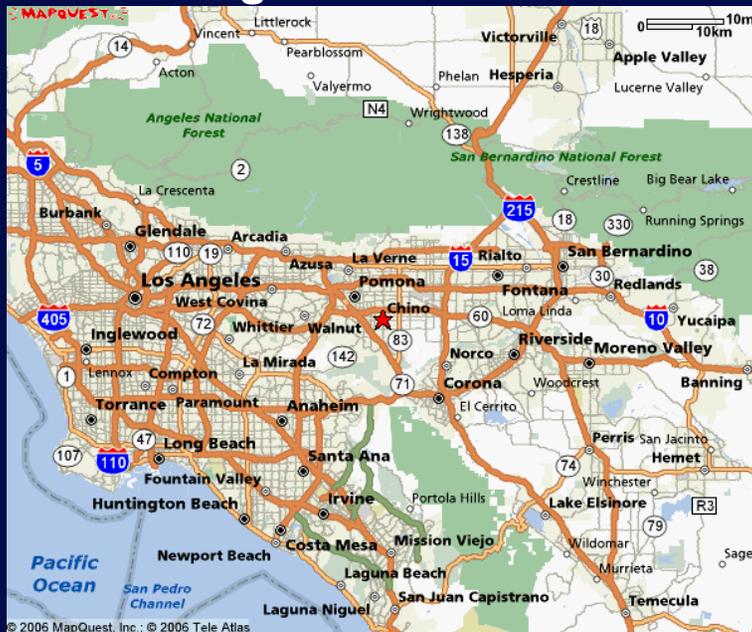
Conducted Vulnerability and Options Analysis for Inland Empire Utilities Agency (IEUA)

- IEUA currently serves 800,000 people
 - May add 300,000 by 2025
- Water presents a significant challenge



Conducted Vulnerability and Options Analysis for Inland Empire Utilities Agency (IEUA)

- IEUA currently serves 800,000 people
 - May add 300,000 by 2025
- Water presents a significant challenge

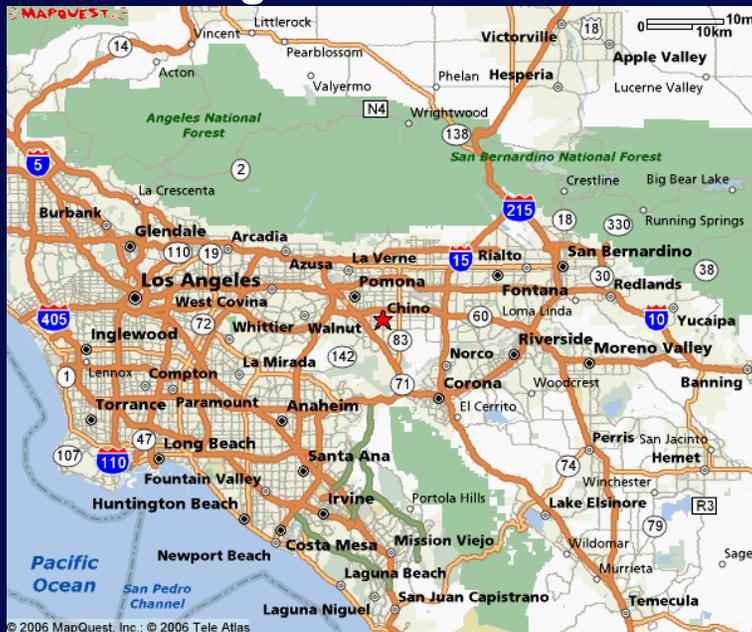


– Current water sources include:

- Groundwater 56%
- Imports 32%
- Recycled 1%
- Surface 8%
- Desalter 2%

Conducted Vulnerability and Options Analysis for Inland Empire Utilities Agency (IEUA)

- IEUA currently serves 800,000 people
 - May add 300,000 by 2025
- Water presents a significant challenge

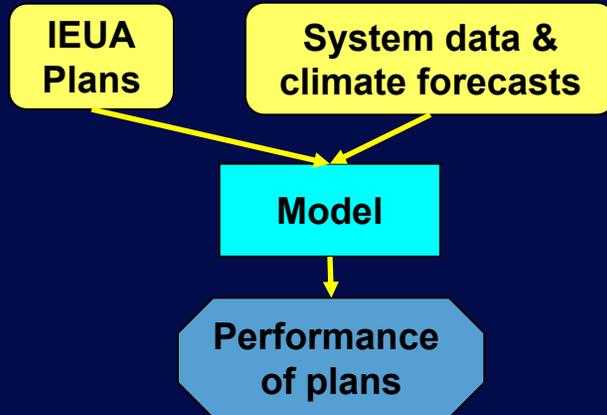


– Current water sources include:

- **Groundwater 56%** ✓
- Imports 32% ✓
- **Recycled 1%** ✓
- Surface 8%
- Desalter 2%

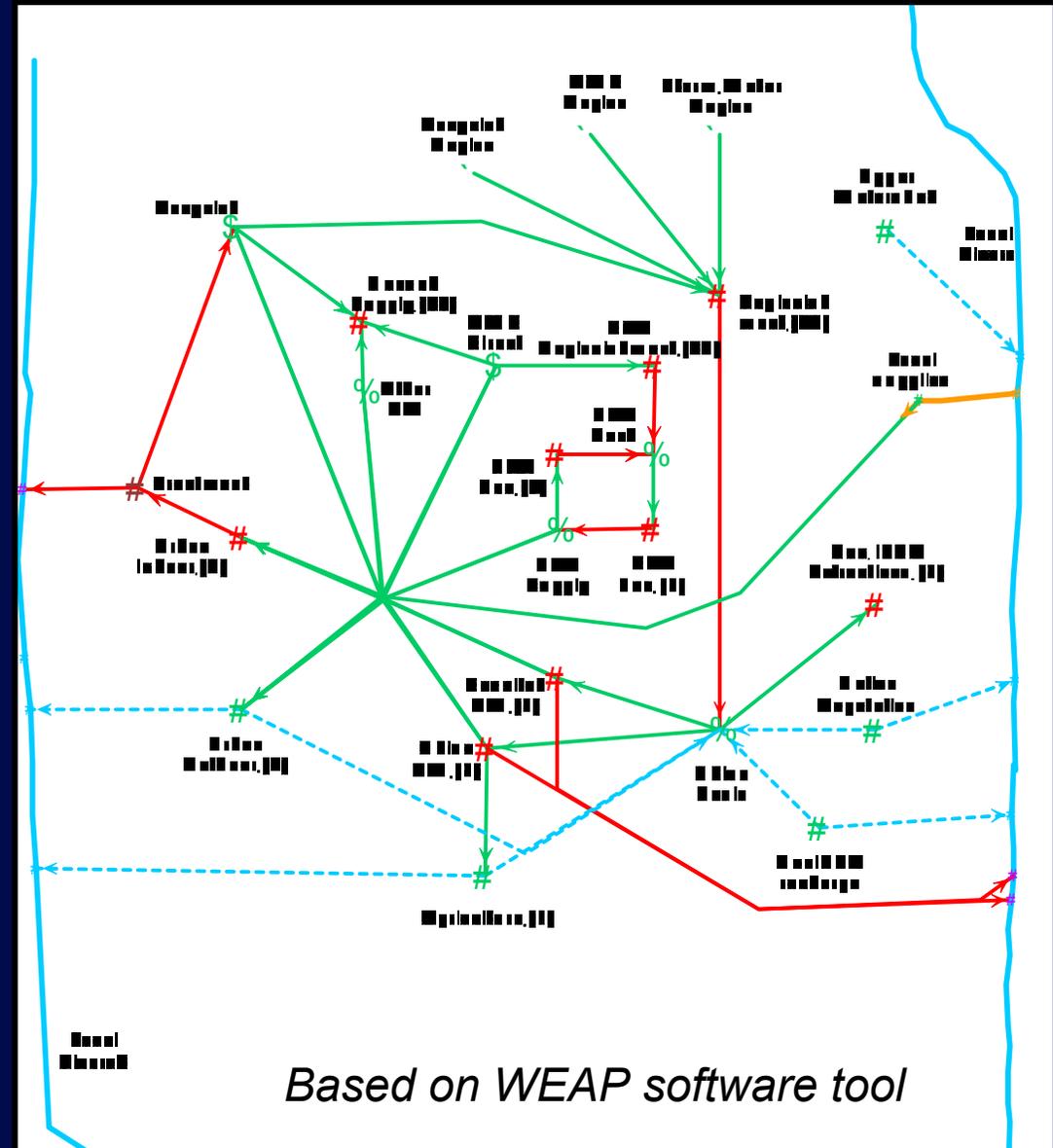
Focus of IEUA's 20 year plan

We Built a Model to Assess Performance of IEUA Plans in Different Future States of World

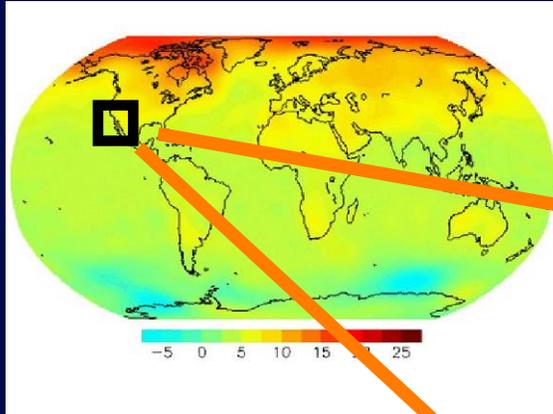


— Model projects future water supply and demand for IEUA service area

- Consistent with IEUA management plans and assumptions
- Reflect plausible trends of climate change

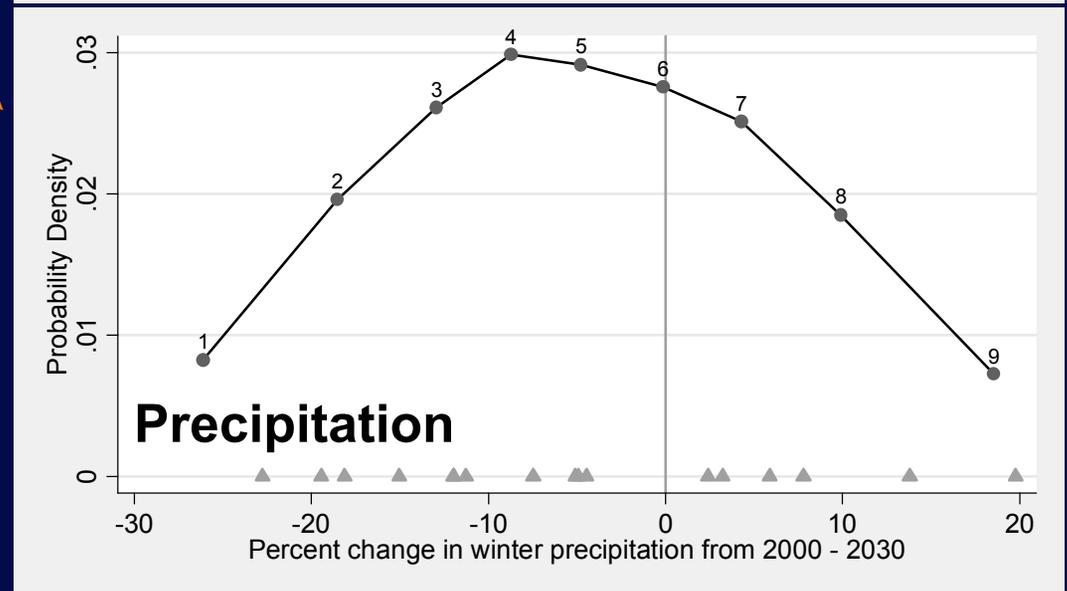
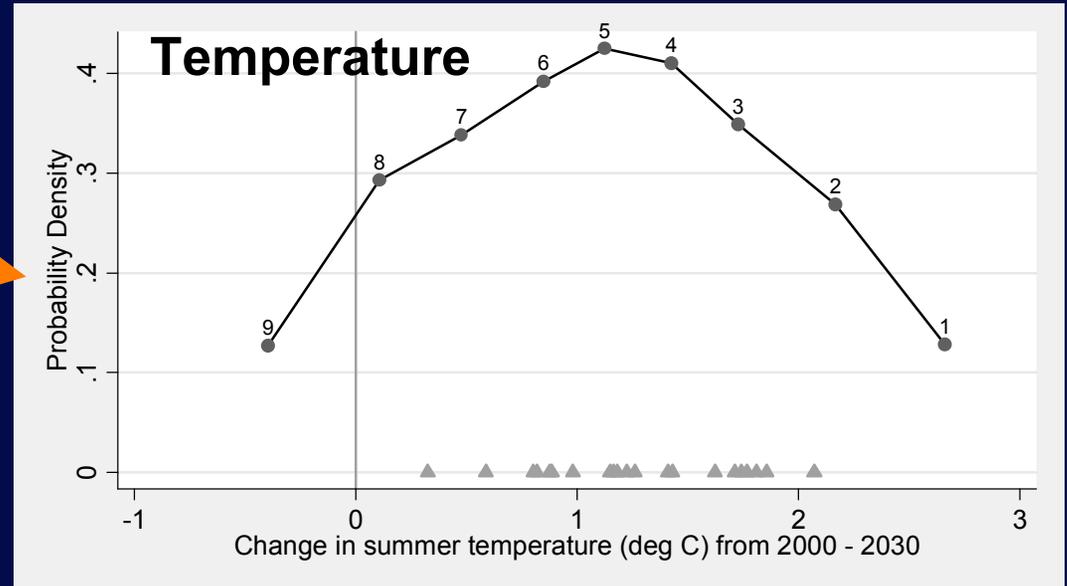


GCMs Project Plausible Temperature and Precipitation Ranges for Southern California



- Derived from forecasts from 21 GCMs with A1B emissions scenario
- Each forecast weighted by ability to reproduce past climate and level of agreement with other forecasts

(Tebaldi et al.)

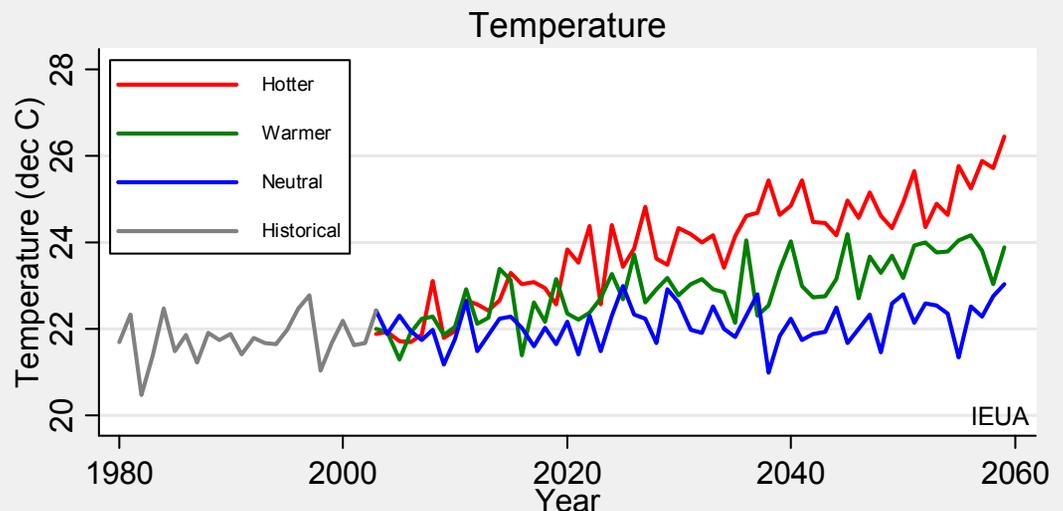
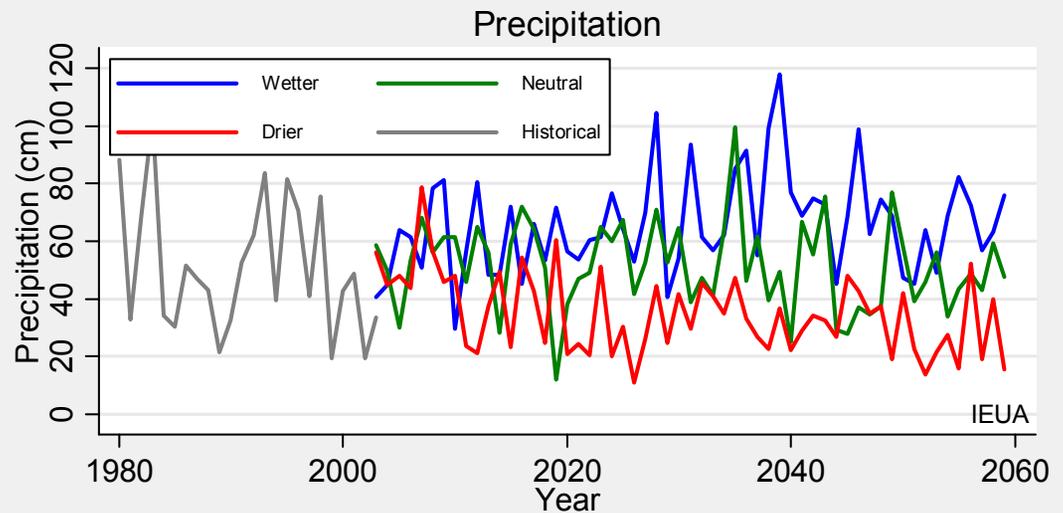


Generate Future Weather Sequences by Resampling Historic Local Climate Records

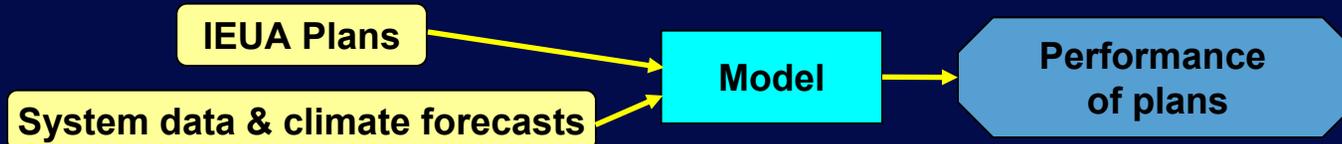
KNN method produces hundreds of local weather sequences

- Daily and monthly variability that matches historic Chino climate
- Temperature and precipitation trends that match climate model forecasts

(Yates et al.)

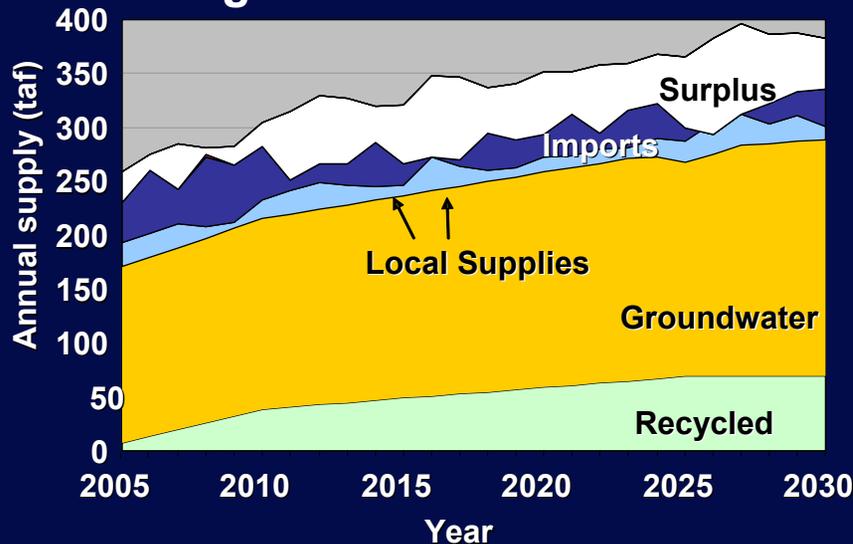


Model Assess Performance of IEUA Plans in Many Different Scenarios



Scenario A

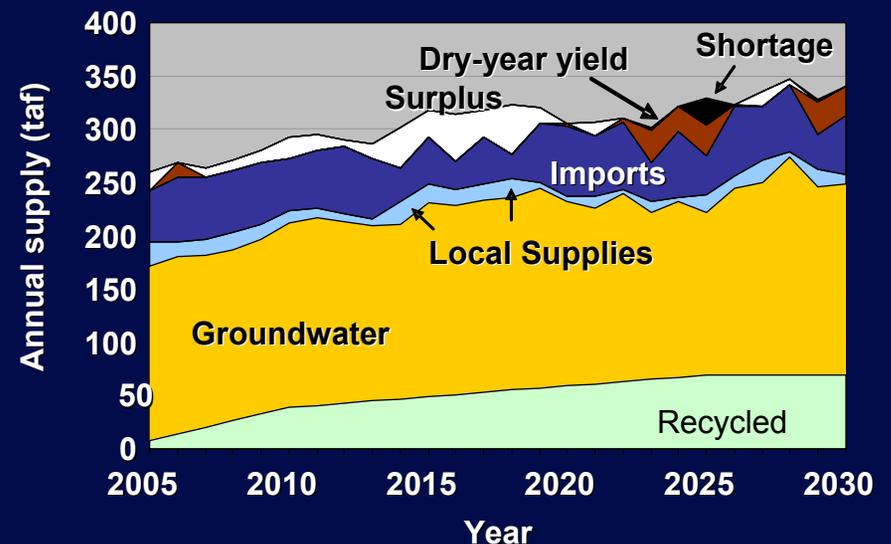
Plan generates surpluses in benign future climate



Temp: +0.7°C Precip: +3%

Scenario B

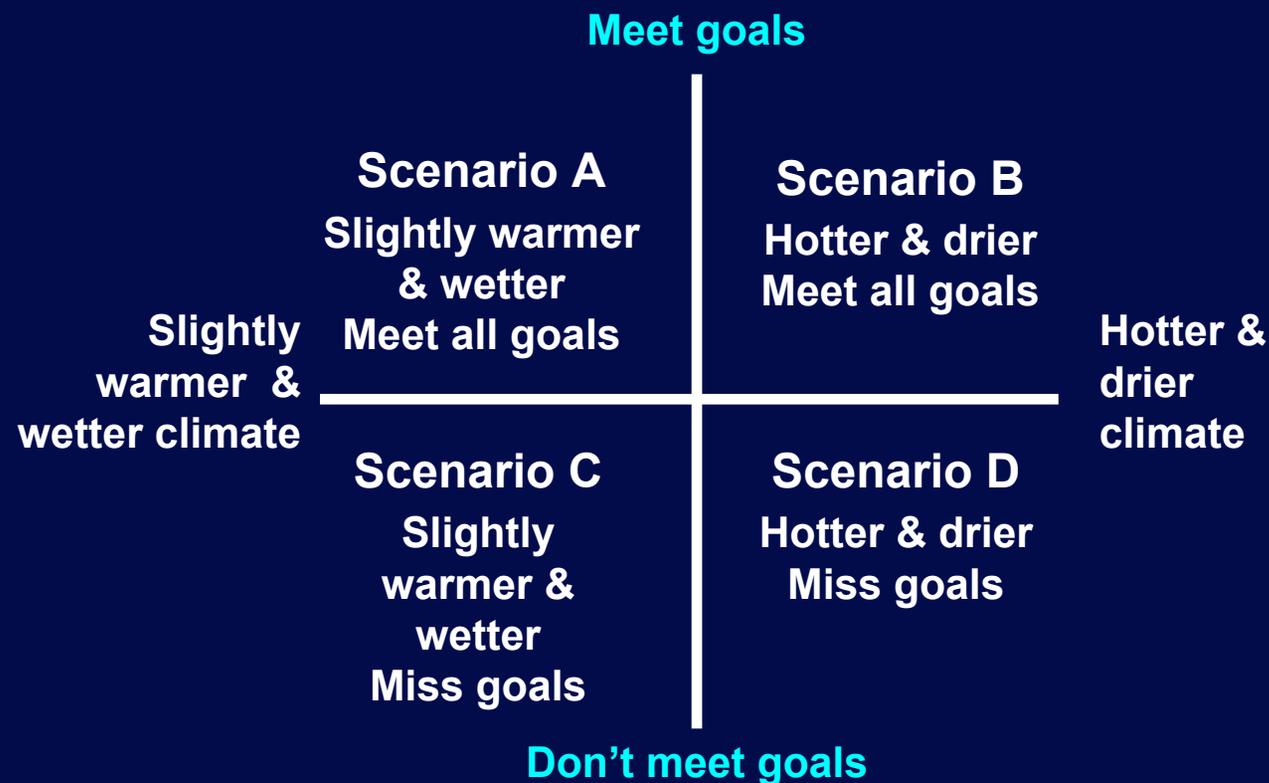
Plan suffers shortages in adverse future climate



Temp: +1.6°C Precip: -10%

First Developed “Standard” Scenarios Based on Estimates of Key Driving Forces

- Qualitatively choose the most important driving forces
- Constructed “scenario matrix” based on these driving forces



These “Standard” Scenarios Suggest That Climate Change Could Significantly Affect IEUA

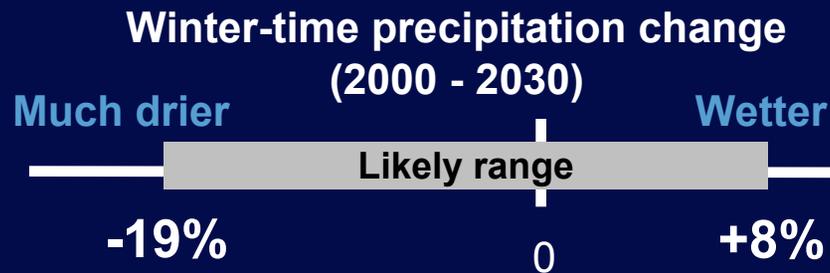
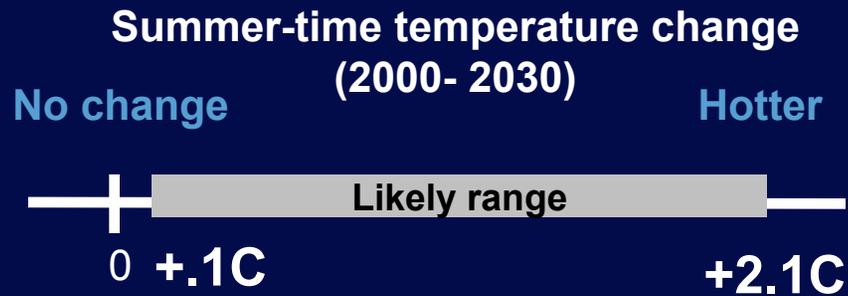
- Meeting goals of 2005 UWMP could help manage risks



Many Uncertain Factors Could Impact the Performance of Current IEUA Plan

Natural Processes	<ul style="list-style-type: none">• Future temperatures• Future precipitation• Changes in groundwater processes
Performance of Management Strategies	<ul style="list-style-type: none">• Development of aggressive waste-water recycling program• Implementation of groundwater replenishment
Costs of Future Supplies and Management Activities	<ul style="list-style-type: none">• Imported supplies• Water use efficiency

Planners in S. California, for Instance, Face a Range of Possible Future Climate Conditions



*Results based on statistical summary of 21 of the world's best
Global Climate Models*

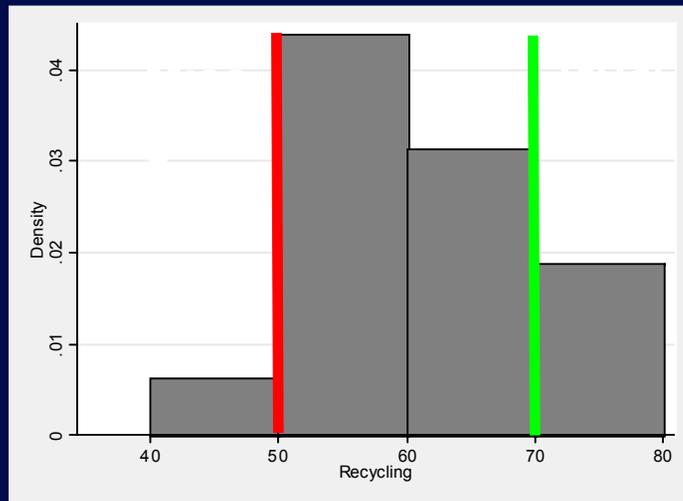
Many Uncertain Factors Could Impact the Performance of Current IEUA Plan

Natural Processes	<ul style="list-style-type: none">• Future temperatures• Future precipitation• Changes in groundwater processes
Performance of Management Strategies	<ul style="list-style-type: none">• Development of aggressive waste-water recycling program• Implementation of groundwater replenishment
Costs of Future Supplies and Management Activities	<ul style="list-style-type: none">• Imported supplies• Water use efficiency

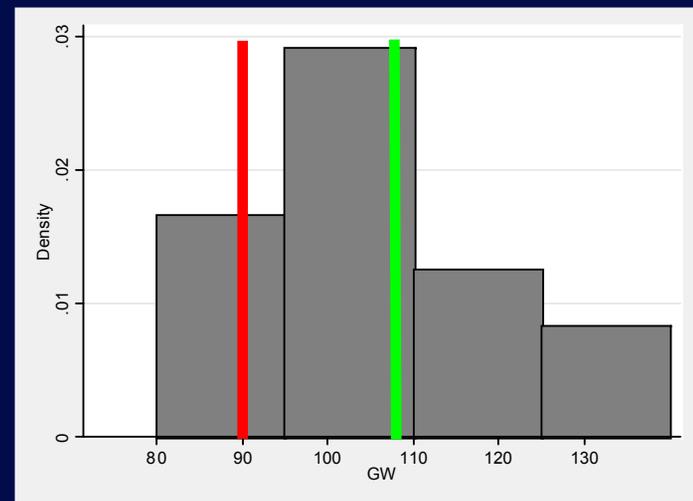
Conducted Elicitations Among IEUA's Planners and Community to Estimate Likelihood of Achieving Goals

Probability of meeting UWMP goals

Recycling



Replenishment



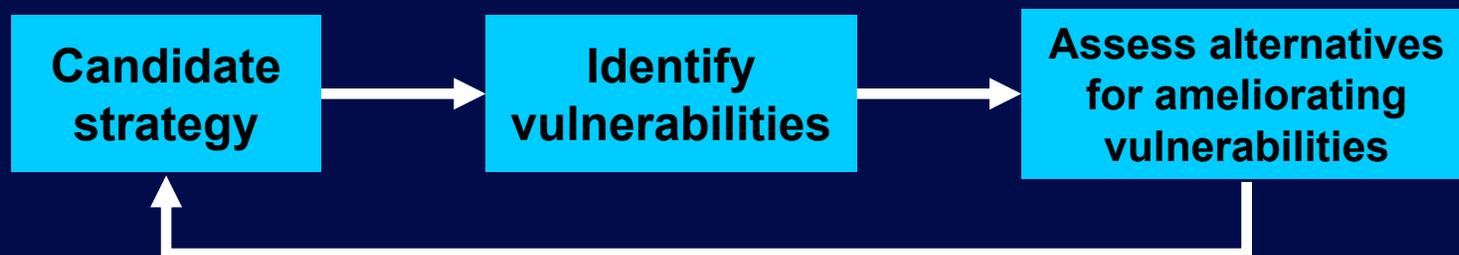
Groves, Knopman, Lempert, Berry, and Wainfan, RAND TR-505-NSF, 2007.

Many Uncertain Factors Could Impact the Performance of Current IEUA Plan

Natural Processes	<ul style="list-style-type: none">• Future temperatures• Future precipitation• Changes in groundwater processes
Performance of Management Strategies	<ul style="list-style-type: none">• Development of aggressive waste-water recycling program• Implementation of groundwater replenishment
Costs of Future Supplies and Management Activities	<ul style="list-style-type: none">• Imported supplies• Water use efficiency

Robust Decision Making (RDM) Enables Good Decisions Under Deep Uncertainty

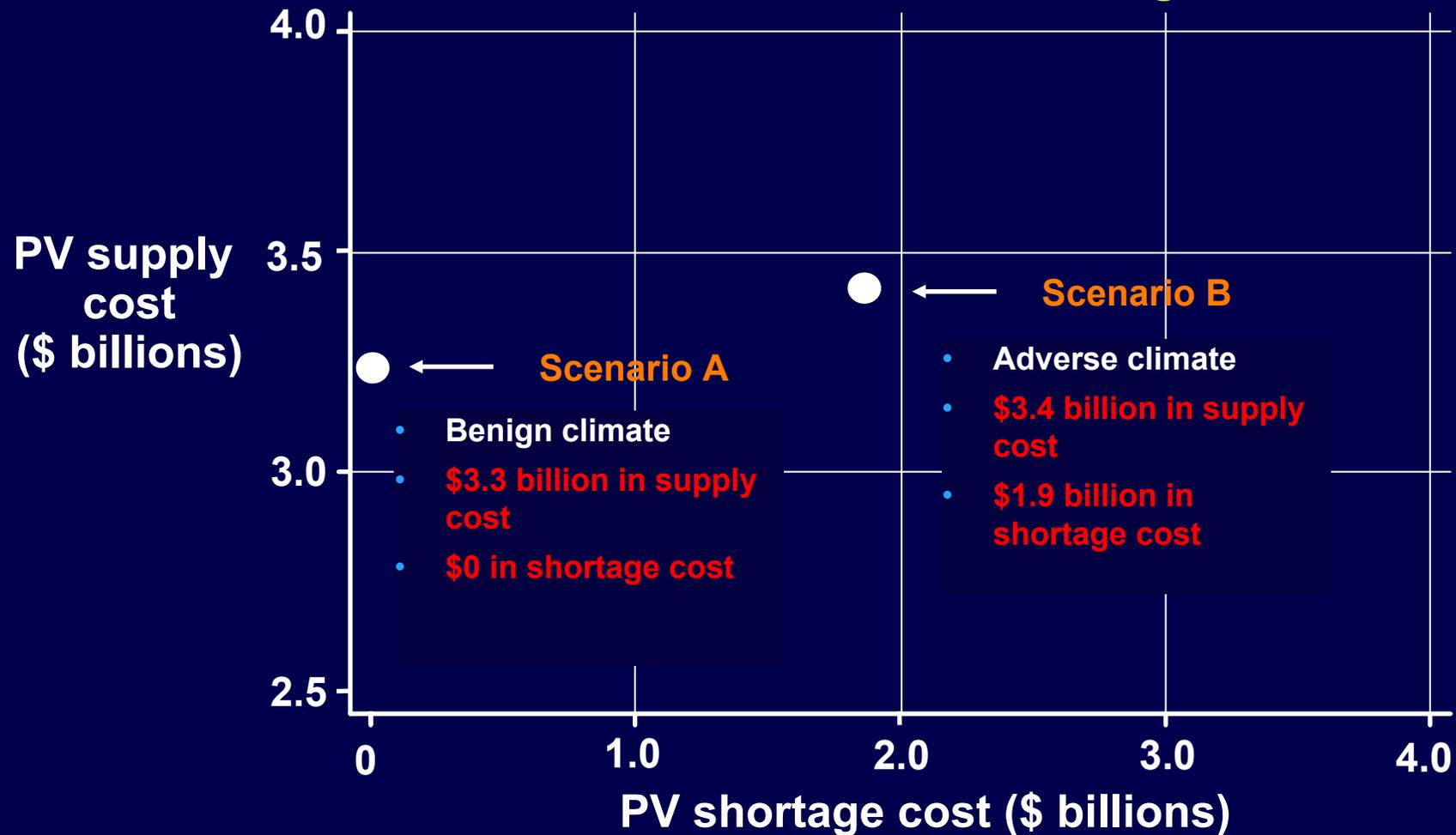
- **Deep uncertainty obtains when**
 - Decision makers don't know or agree on the system model or the probability distributions for the inputs to the model
- **RDM is a quantitative decision analytic approach that**
 - Identifies robust strategies, ones that work reasonably well compared to the alternatives across a wide range of plausible scenarios



- **RDM combines key advantages of scenario planning and quantitative decision analysis in ways that**
 - Decision makers find credible
 - Contribute usefully to contentious debates

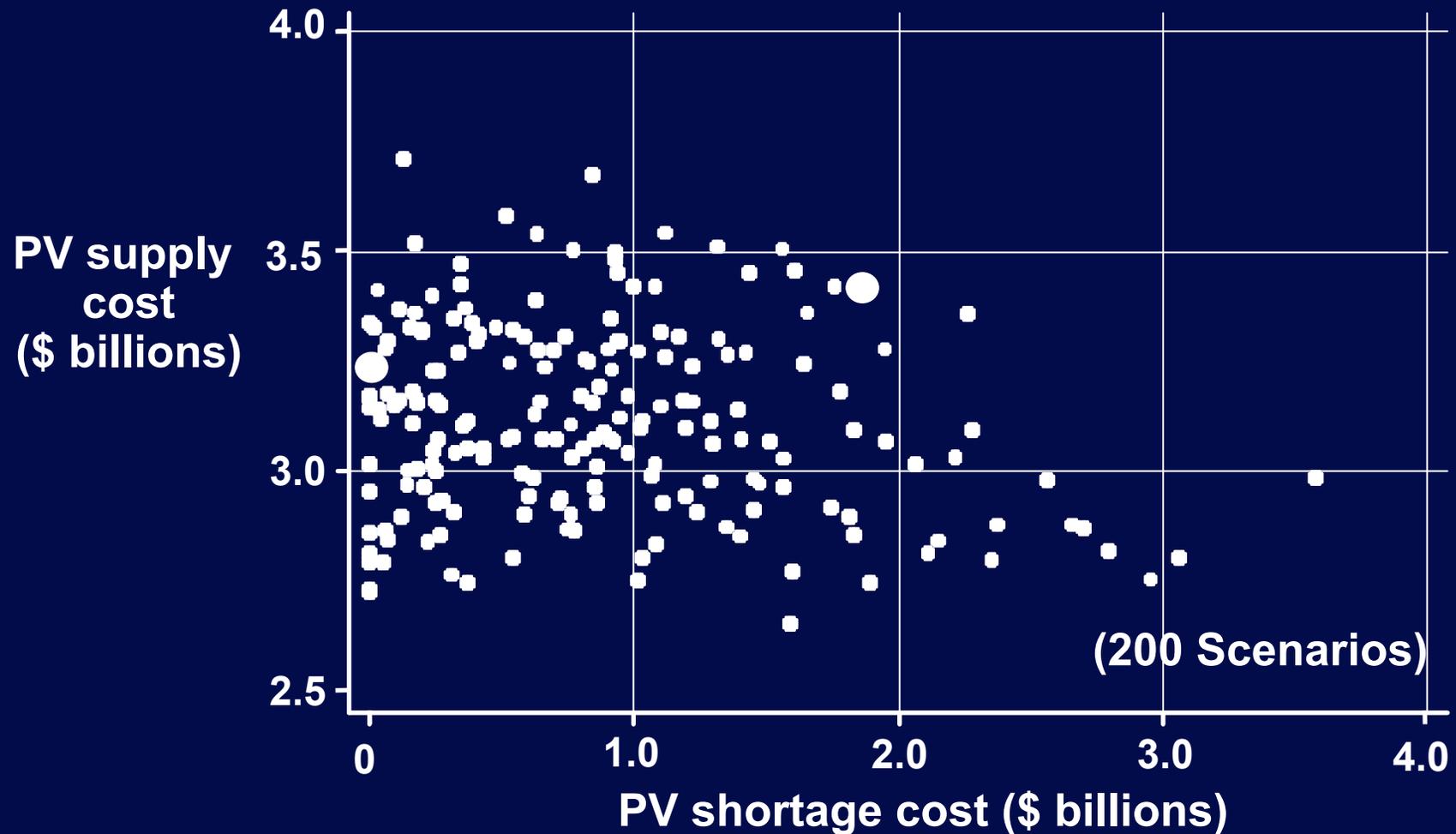
“Scenario Maps” Help Decision Makers Visualize How Plans Evolve Over Many Futures

Current IEUA 2005 Urban Water Management Plan



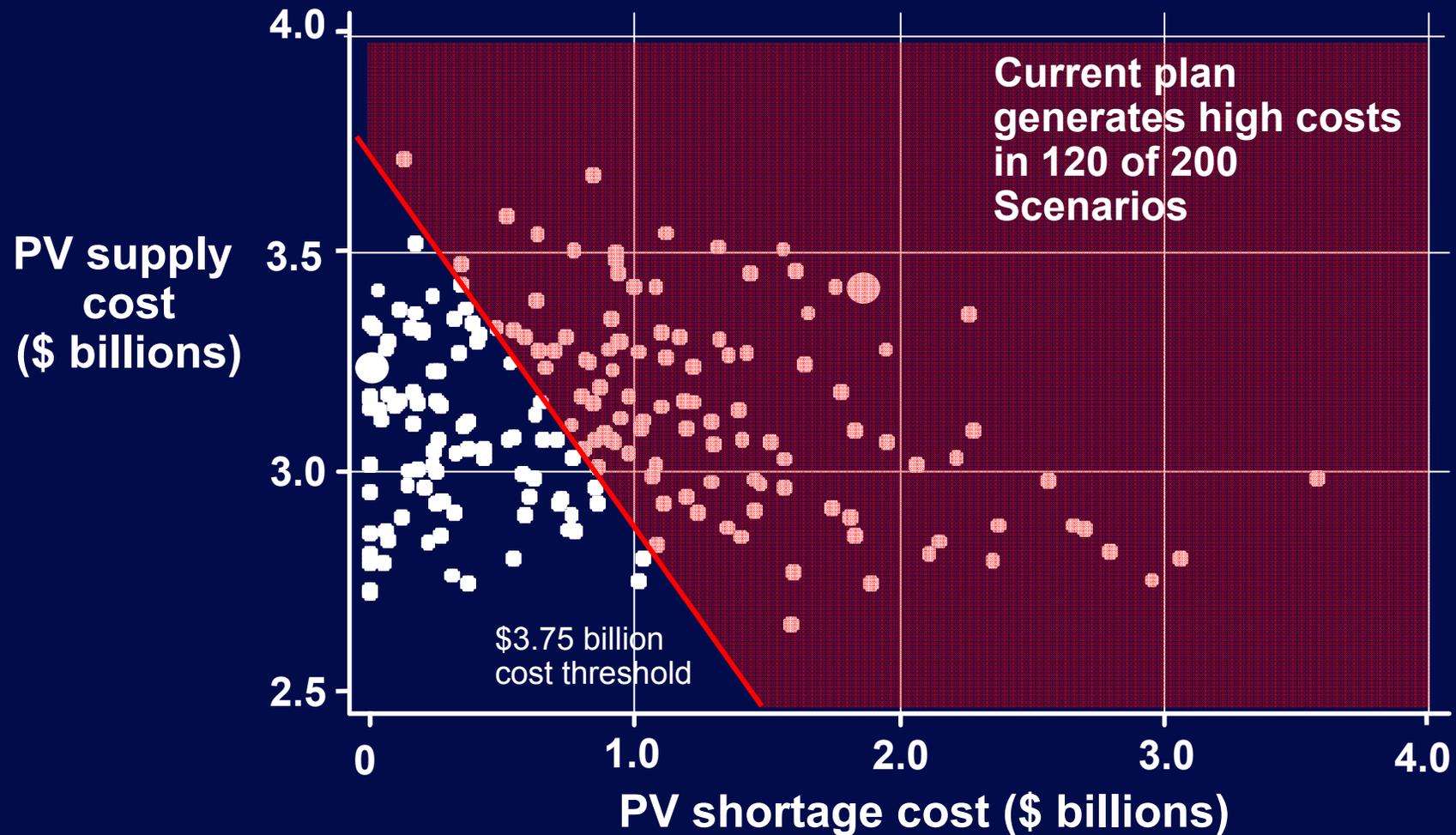
“Scenario Maps” Help Decision Makers Visualize How Plans Evolve Over Many Futures

Current IEUA Plan



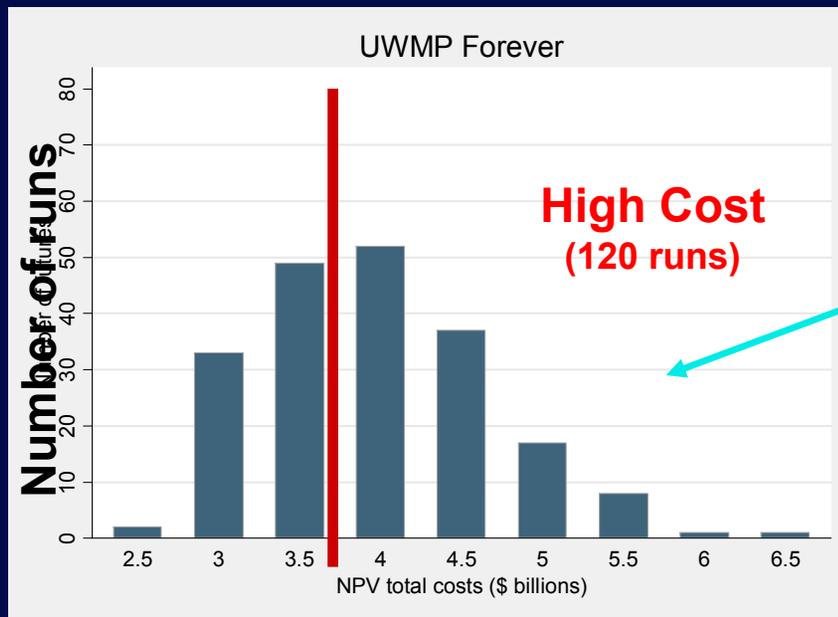
“Scenario Maps” Help Decision Makers Visualize How Plans Evolve Over Many Futures

Current IEUA Plan



Discover Key Scenarios in Ensembles of Many Model Runs

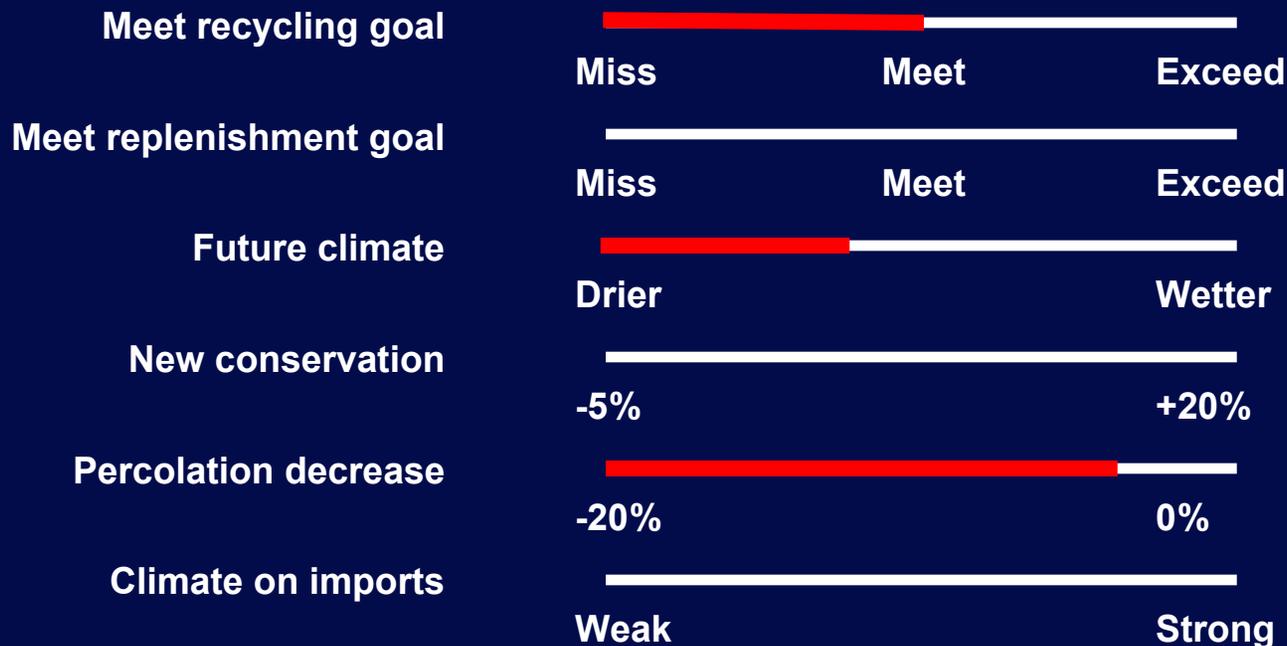
1. Ran the model 200 times under different combinations of uncertain factors (e.g. temperature and precipitation trends and others)
2. Used statistical algorithms to identify conditions that lead to 2005 UWMP to perform poorly
3. These factors become key driving forces for “policy-relevant” scenarios



Statistical analysis suggests factors that contribute most to these undesirable outcomes

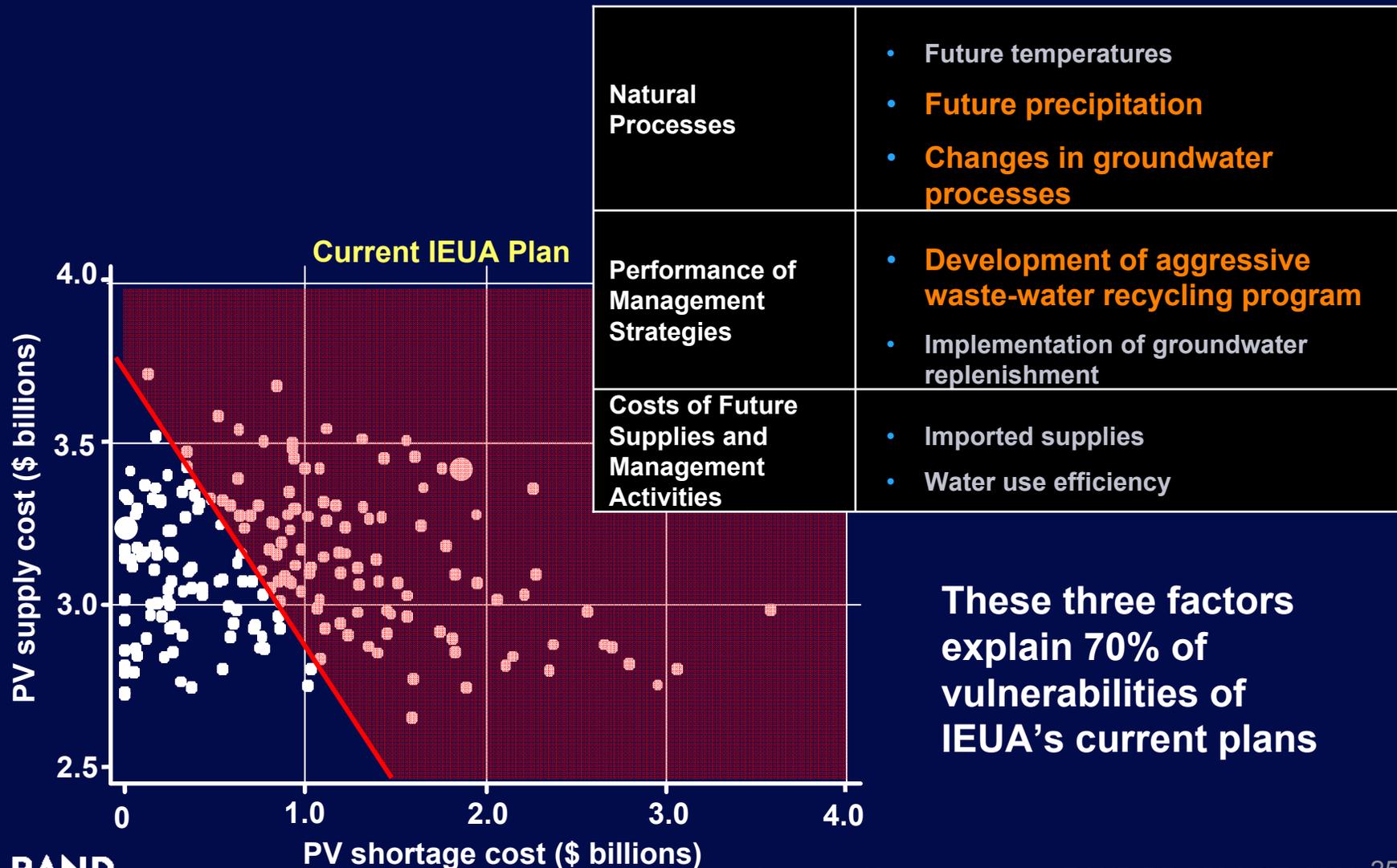
Analysis Suggests Factors That Cause Severe Shortages for IEUA's 20 Year Plan

Climate-related uncertainties facing IEUA



Explains 70% of high cost cases

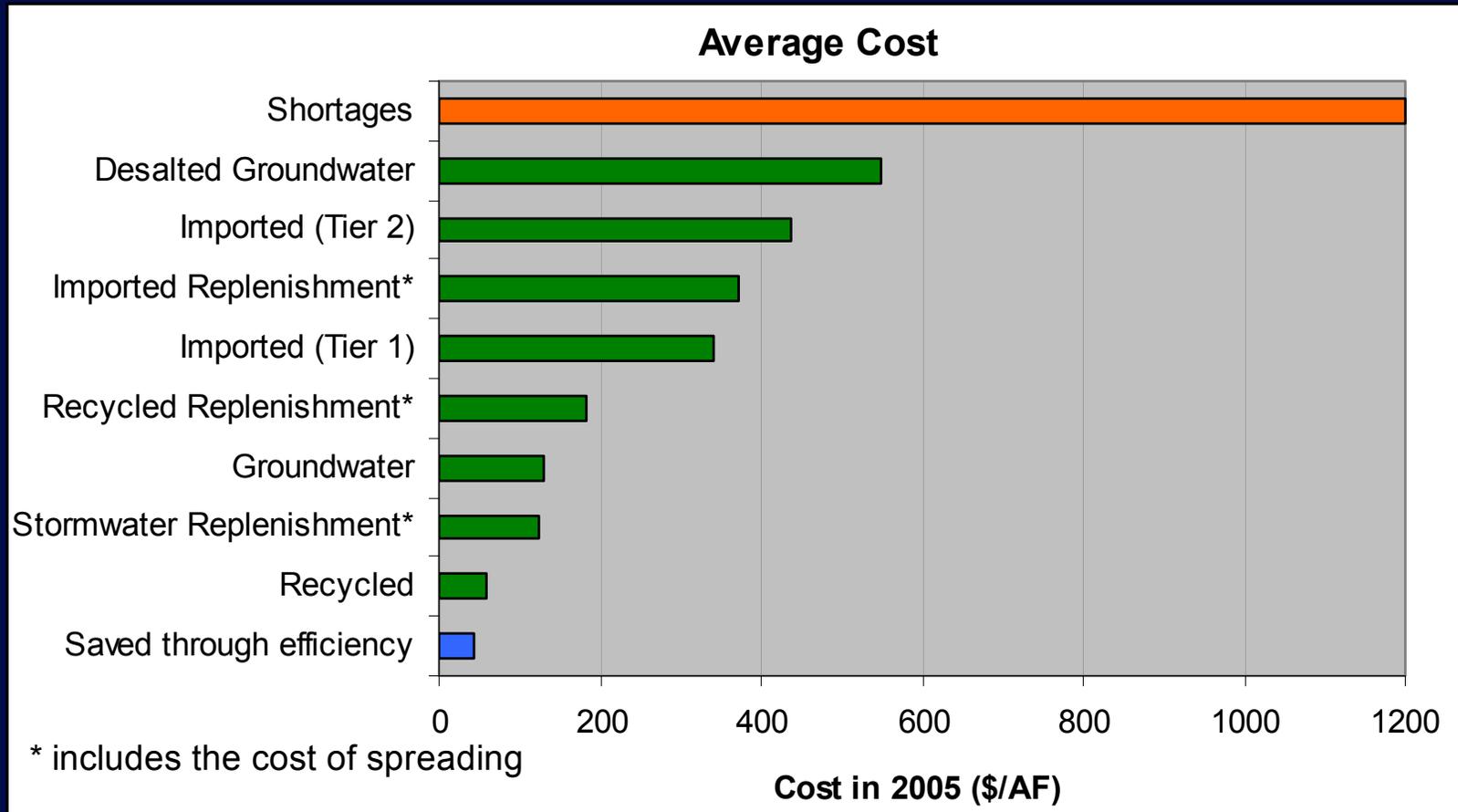
Statistical Analysis Suggests Key Factors That Create Vulnerabilities for Existing Plan



Response Options May Help IEUA Address These Vulnerabilities

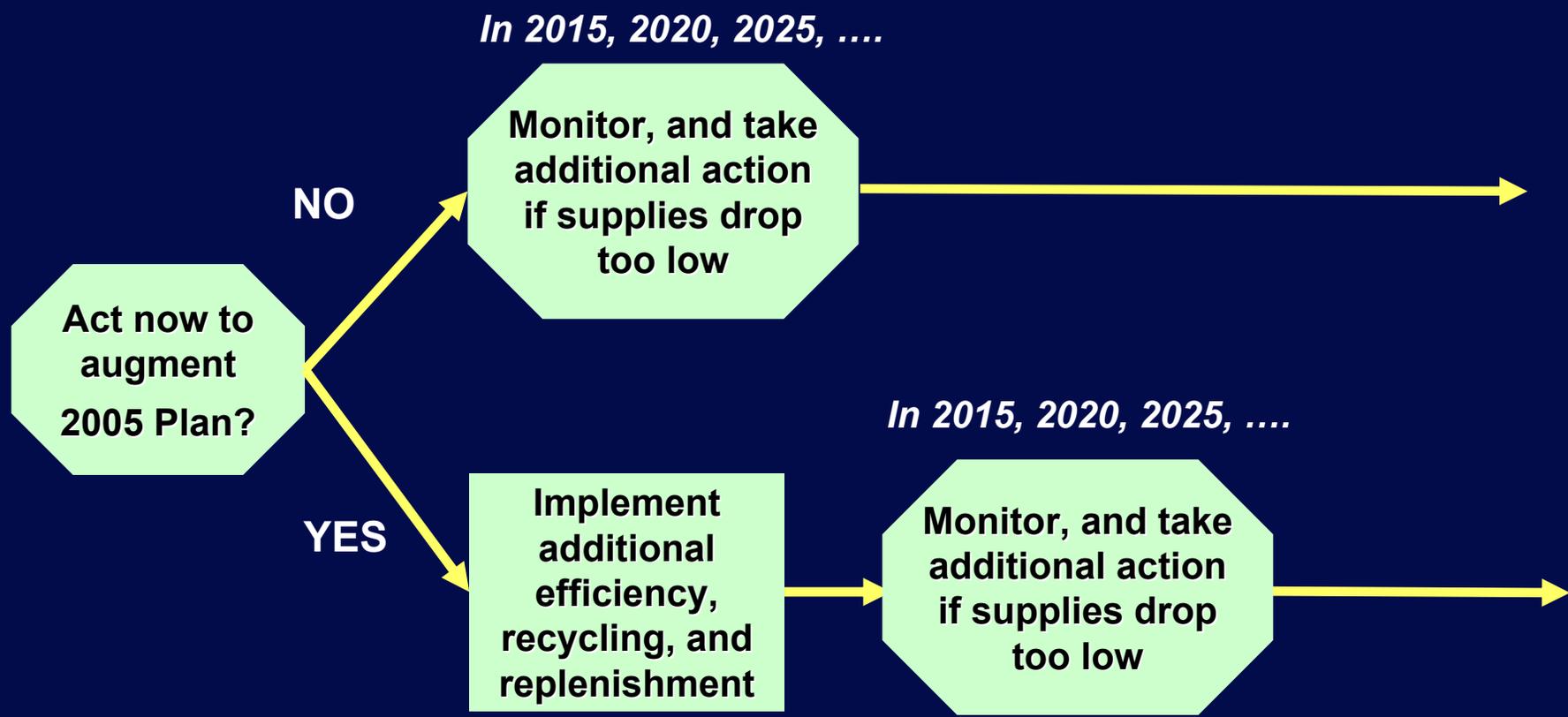
Improve Water Use Efficiency	<ul style="list-style-type: none">• Strengthen landscape ordinances for new construction• Retrofit indoor devices• Retrofit outdoor landscapes
Expand Recycled Water Use System	<ul style="list-style-type: none">• Speed up system expansion
Improve Groundwater Management	<ul style="list-style-type: none">• Increase size of Metropolitan Dry Year Yield (DYY) program• Increase allowable fraction of recycled water for replenishment• Increase capture of storm-water for replenishment

Can Quantify Some, But Not All, Of These Costs

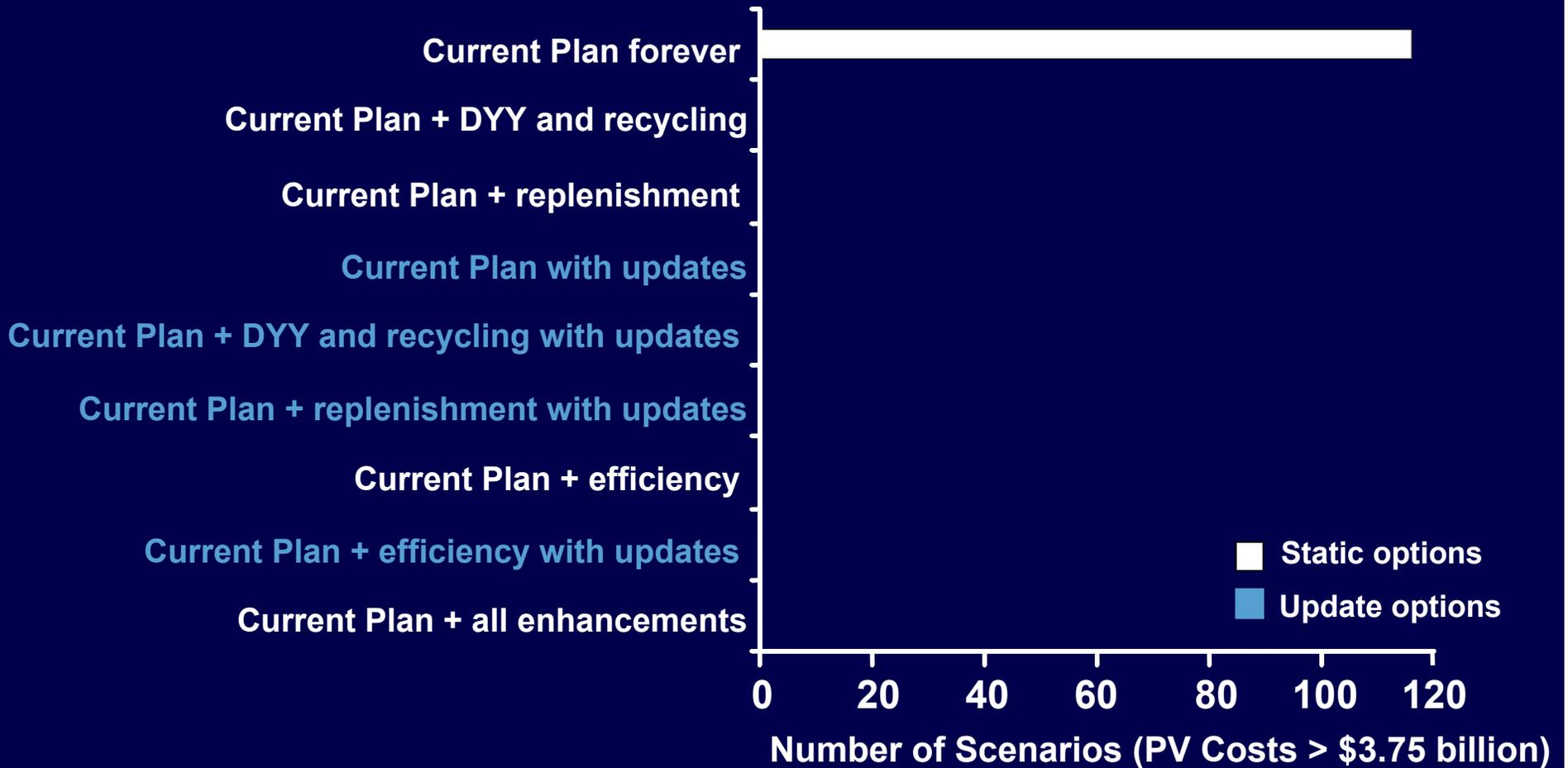


Costs increase over time

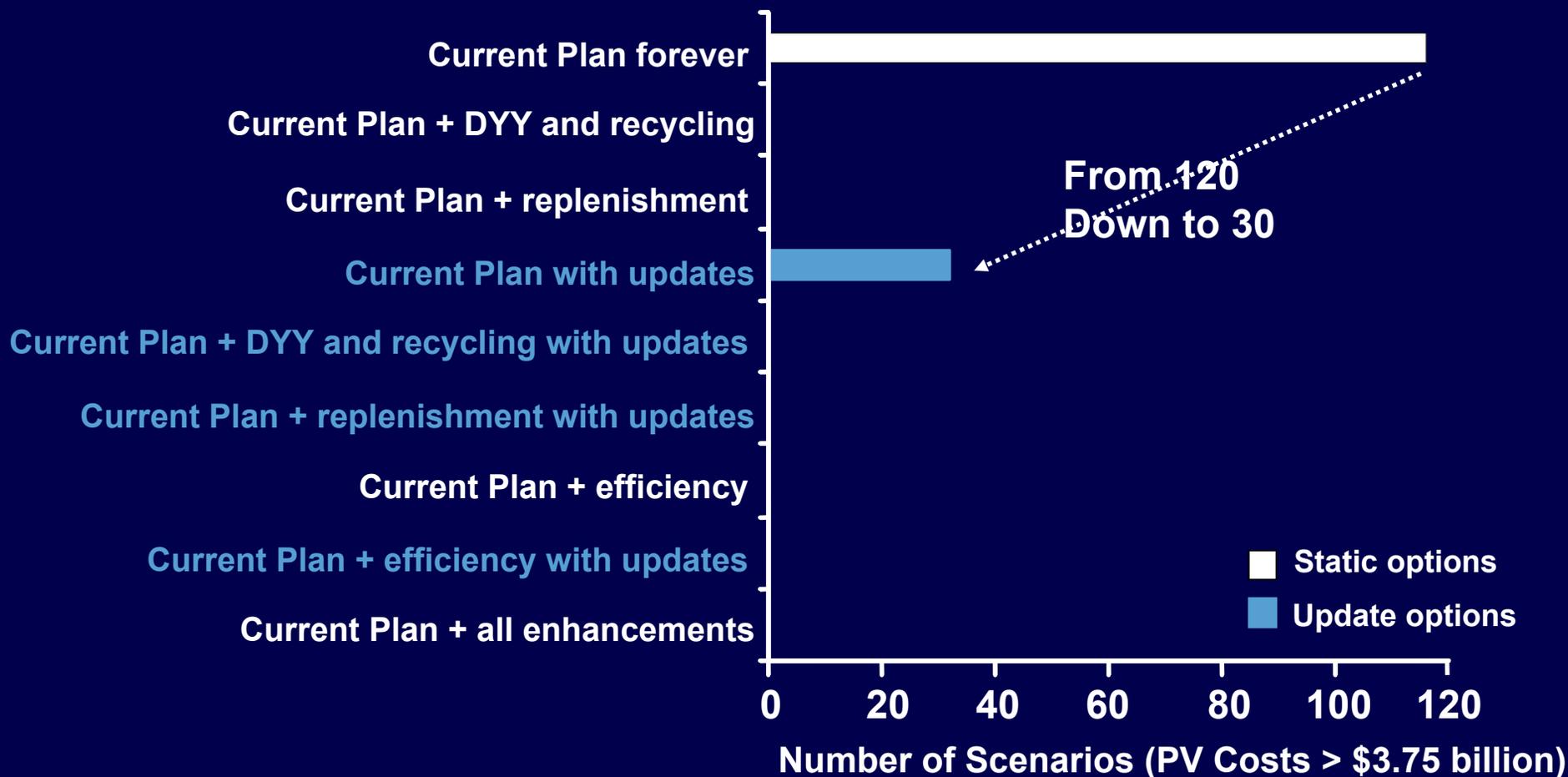
Should IEUA Act Now or Later to Reduce Potential Climate Vulnerabilities?



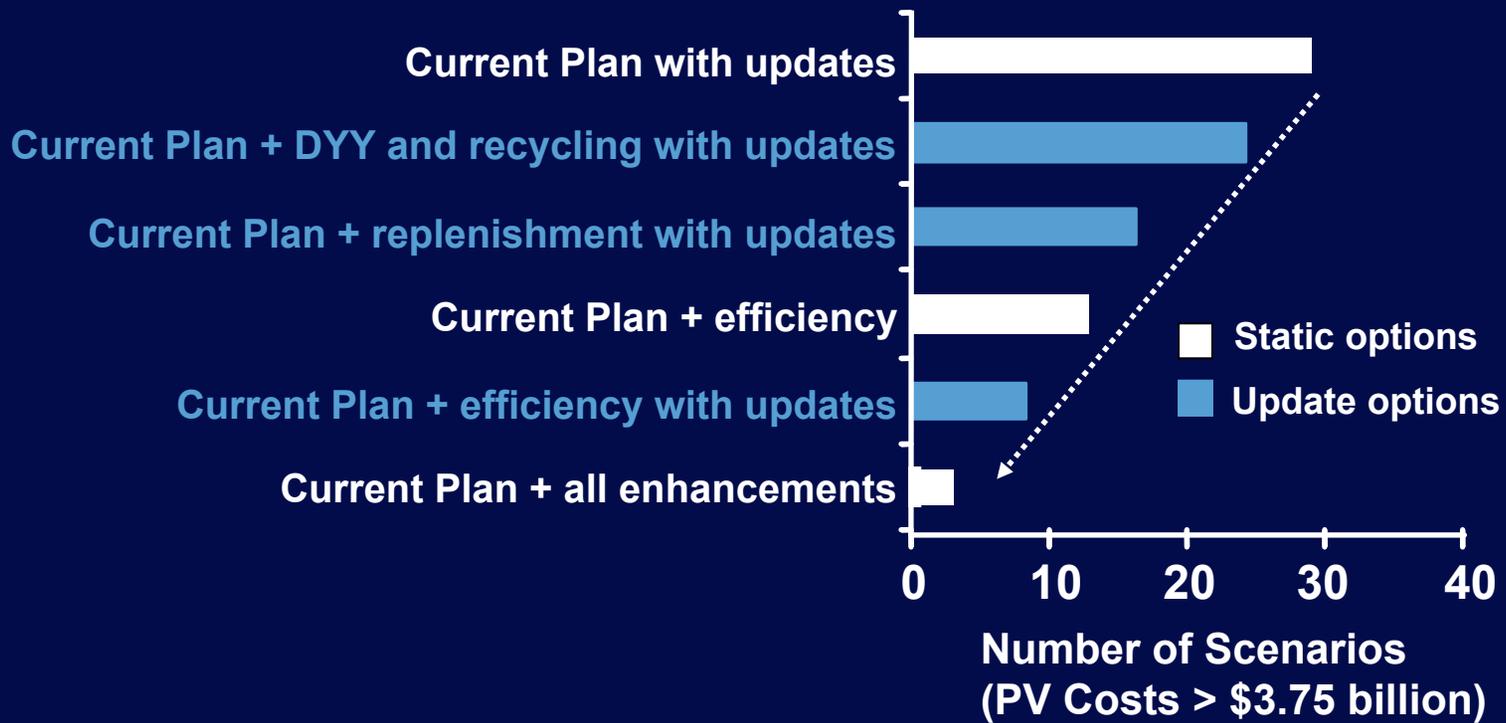
Compare Nine Strategies Over 200 Scenarios Reflecting Key Uncertainties



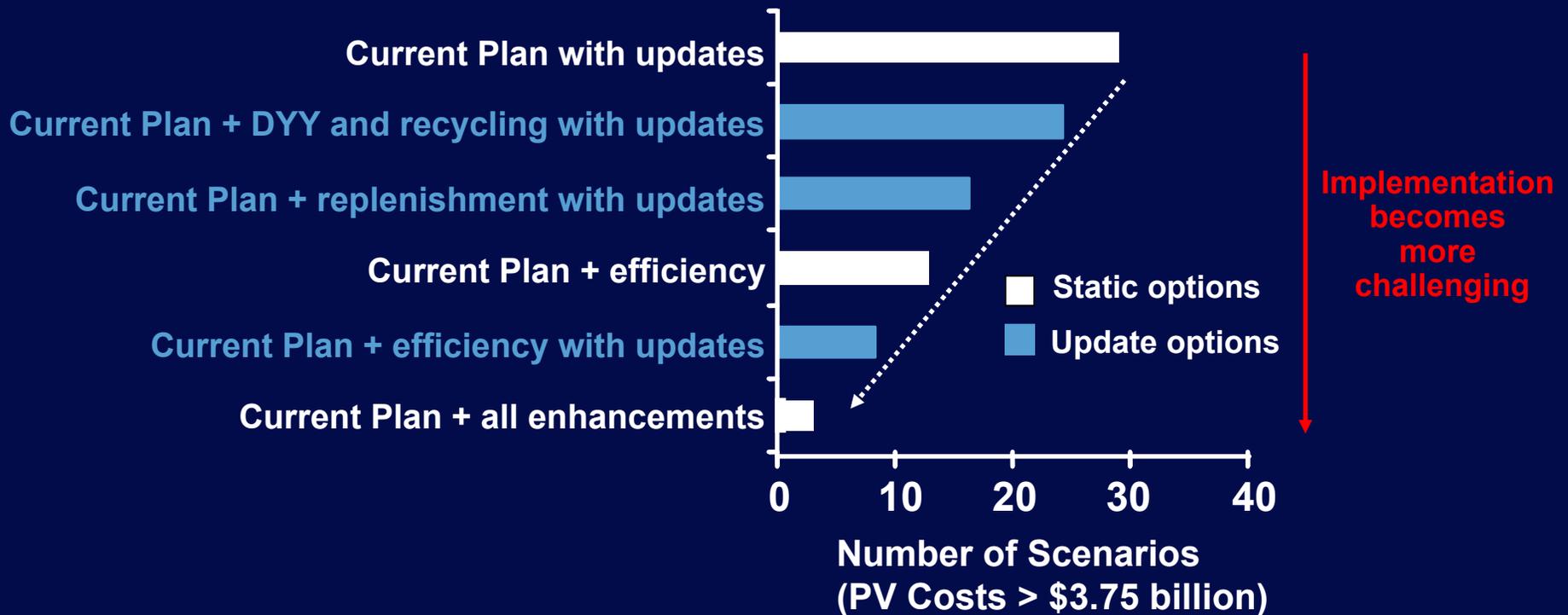
Just Allowing IEUA's Current Plan to Update Reduces Vulnerability Substantially



Acting Now Reduces Future Vulnerabilities Even More



Acting Now Reduces Future Vulnerabilities Even More



This analysis helped IEUA decide to make more near-term efficiency investments, and to monitor performance and adapt as needed down the road

Outline

- **Climate vulnerability and response option analysis for Inland Empire Utilities Agency (IEUA)**
- **Evaluating impacts of analysis on decision makers**

We Also Evaluated How This Analysis Affected Policy-Makers' Views

- **Four IEUA workshops presented modeling results to participants including:**
 - Agency professional managers and technical staff
 - Local elected officials
 - Community stakeholders

- **“Real-time” surveys measured participants’**
 - Understanding of concepts
 - Willingness to adjust policy choices based on information presented
 - Views on RDM

First Three Workshops Compared Alternative Approaches to Uncertainty

Compared three approaches

- Traditional qualitative scenarios
- Probabilistic forecasts
- RDM with Scenario discovery

Overall Presentation Structure for the RAND-IEUA Workshops

Workshop	Traditional Scenarios Without Probabilities	Long-Term Probabilistic Forecasts	Policy-Relevant Scenarios (Derived from RDM)
1	Presented	—	—
2	Reviewed	Presented	—
3	Reviewed	Reviewed	Presented

Workshop design approximates on-going laboratory experiments

RDM Scenarios More Useful, But More Difficult to Understand

Questionnaire item	Traditional Scenarios	Scenario Discovery
Provides results that can be used in planning	Agree somewhat	Agree strongly
Provides information on how to improve plan	Agree somewhat	Agree somewhat
Is easy to explain to decisionmakers	Agree somewhat	Disagree strongly

- **Traditional scenarios**
 - Gave IEUA much of the information they needed
 - Emphasized the importance of achieving goals in IEUA's plan
- **Scenario Discovery**
 - Provided more useful information
 - Sparked discussion of adaptive strategies

RDM Scenarios More Useful, But More Difficult to Understand

Questionnaire item	Traditional Scenarios	Scenario Discovery
Provides results that can be used in planning	Agree somewhat	Agree strongly
Provides information on how to improve plan	Agree somewhat	Agree somewhat
Is easy to explain to decisionmakers	Agree somewhat	Disagree strongly

- **Traditional scenarios**
 - Gave IEUA much of the information they needed
 - Emphasized the importance of achieving goals in IEUA's plan
- **Scenario Discovery**
 - Provided more useful information
 - **Sparked discussion of adaptive strategies**

Fourth (Adaptive Strategy) Workshop Compared Different Presentations of RDM

Participants reported:

- RDM helped support comparison of climate-related risks and choice among plans
- Preference for scatter plot over histogram scenario displays

After the workshop:

- 35% said consequences of bad climate change now appeared “more serious” than before
- 40% thought the likelihood of bad climate change outcomes for the IEUA was “greater” than before
- 75% though the ability of IEUA planners to plan for and manage effects was “greater” than before

Overall, analysis increased:

- Perceived likelihood of serious climate impacts
- Confidence that IEUA could take effective actions to reduce its vulnerability to climate change
- Support for near-term efficiency enhancements to current IEUA plan

Observations

- **Analysis suggests IEUA's current long-range plans:**
 - **Vulnerable to climate change**
 - **Can be made more resilient by near-term conservation, attention to storm intensity, and effective future monitoring and updating**
- **Measurements suggest**
 - **RDM analysis effectively shifted views on seriousness of climate challenges and appropriate responses, but requires more work to be easily understood by policy-makers**
 - **Importance of linking effective response options with presentation of climate uncertainty**
- **Currently using this approach to help several major water agencies include climate in their long-range plans**

More Information

David G. Groves, Robert J. Lempert, Debra Knopman, Sandra H. Berry: Preparing for an Uncertain Climate Future: Identifying Robust Water Management Strategies, RAND DB-550-NSF, 2008.

David G. Groves, Debra Knopman, Robert J. Lempert, Sandra H. Berry, and Lynne Wainfan, Presenting Uncertainty About Climate Change to Water Resource Managers, RAND TR-505-NSF, 2007.

David G Groves, David Yates, Claudia Tebaldi, “Developing and Applying Uncertain Global Climate Change Projections for Regional Water Management Planning,” submitted

David G. Groves and Robert J. Lempert, 2007: A new analytic method for finding policy-relevant scenarios, Global Environmental Change 17, 73-85.

Robert J. Lempert, Steven W. Popper, Steven C. Bankes, 2003: Shaping the Next One Hundred Years: New Methods for Quantitative, Long-Term Policy Analysis, RAND MR-1626-RPC, Aug.

www.rand.org/ise/projects/improvingdecisions/

Thank you!