Observations and Recommendations on Model Comparisons and Uncertainty

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Snowmass Uncertainty Session

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Observations/Recommendations on Model Comparisons

- Be as clear as possible about purpose
  - Audience
  - Insights versus numbers
  - Policy information versus model diagnostics
- Be ecumenical towards disciplines&methods
- Consider a broad enough range of scenarios (especially on external drivers)
- Think carefully about what to standardize
  - Could be scenario variables or internal
  - How to handle policies

Observations/Recommendations on Model Comparisons (2)

- Consider the idea of multiple baselines
- Clearly specify definitions for inputs/outputs
  - Coverage
  - Level of aggregation
- Develop clear participation/access rules
- Avoid information overload
- Compare model projections with historical trends

Observations/Recommendations on Uncertainty Analyses

- Be as clear as possible about purpose
  - Audience
  - Insights versus numbers
  - Policy information versus model diagnostics
- Recognize large number of approaches
  - E.g. Monte Carlo versus SDMUU
- Consider a broad enough range of uncertainties

Observations/Recommendations on Uncertainty Analyses (2)

- Four interrelated parts to any uncertainty analysis
  - -Formulation
  - -Probability assessment
  - -Computation
  - - Interpretation
    Weakest link problem
- Beware of dynamic inconsistencies
  - Monte Carlo simulations and foresight?
  - Use mean preserving spreads?

Thank You

The Gorillas Standing in the Corner

- There is more than one decision maker.
- Don't really know who all the DMs are/will be.
- Policy uncertainties are very large.
- Disciplines differ in philosophy and methods.
- What to do about the unknowable unknowns.

Four Interdependent Elements of Any Uncertainty Analysis

- Formulation
  - Who knows what, when, and what can they do with that info.
  - Information structure, dynamics, and stochastics
- Probability Assessment
  - Statistical
  - Subjective
  - Combinations
- Computation
  - Software and hardware
  - Simulation and optimization
- Interpretation and communication of results
  - Many dimensions for inputs, policies and outputs
  - Need for focusing on needs of decision makers grows exponentially
- These elements need to be designed and implemented together

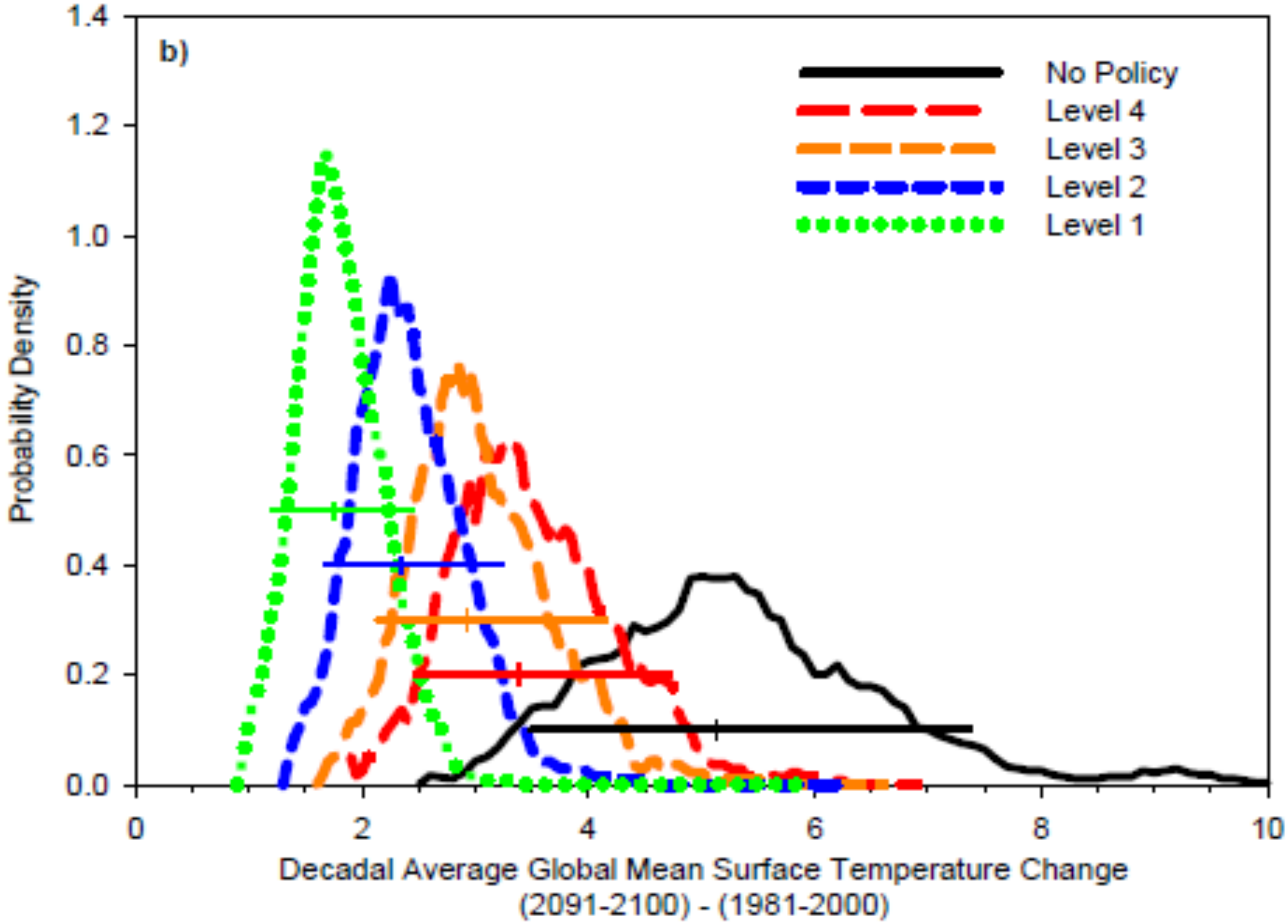
Outline

- Some Approaches to Uncertainty Analysis
- EMF Work on Uncertainty Analysis
- A Taxonomy of Approaches to Uncertainty
- Conceptual Issues in Information, Foresight and Uncertainty in Economic Modeling
- A Word About Stochastic Simulation
- Subjective Probability Assessments
- More Qualitative Frameworks

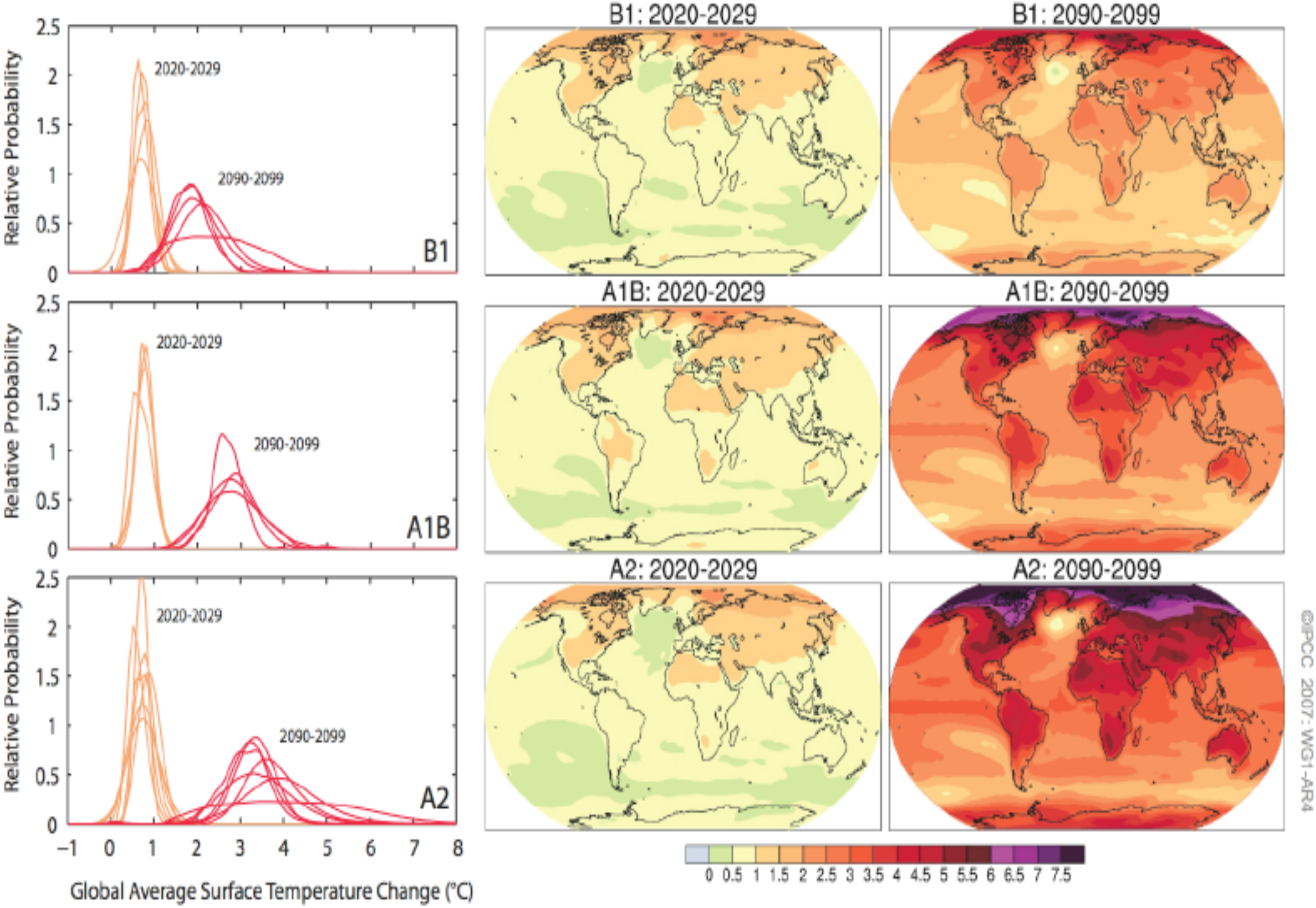
Some Approaches to Uncertainty Analysis

- Quantitative
  - Sensitivity Analysis
  - Scenario Analysis (Strategic Scenarios)
  - Stochastic Simulation
  - Decision Analysis
  - Stochastic Control
  - “Robust Planning”
  - Computational Statistics
- Qualitative
  - Story Lines
  - Strategic Planning Approaches

Stochastic Simulation Results From MIT IGSM



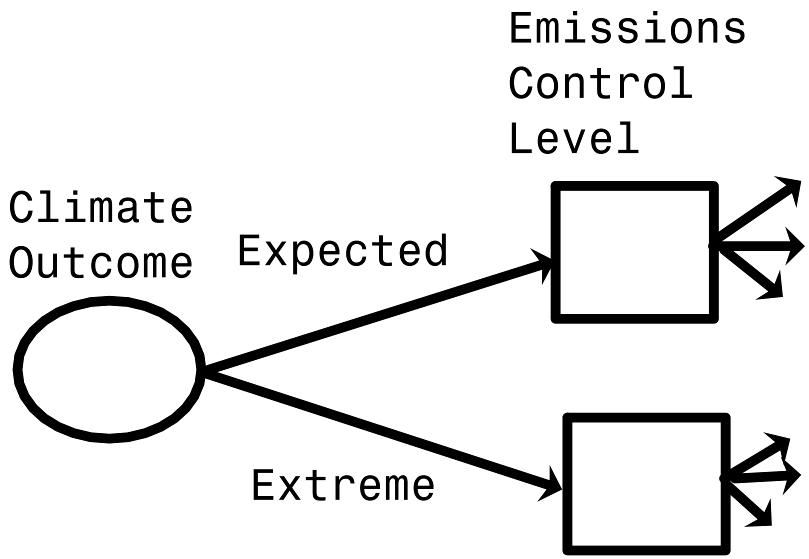
AOGCM Projections of Surface Temperatures



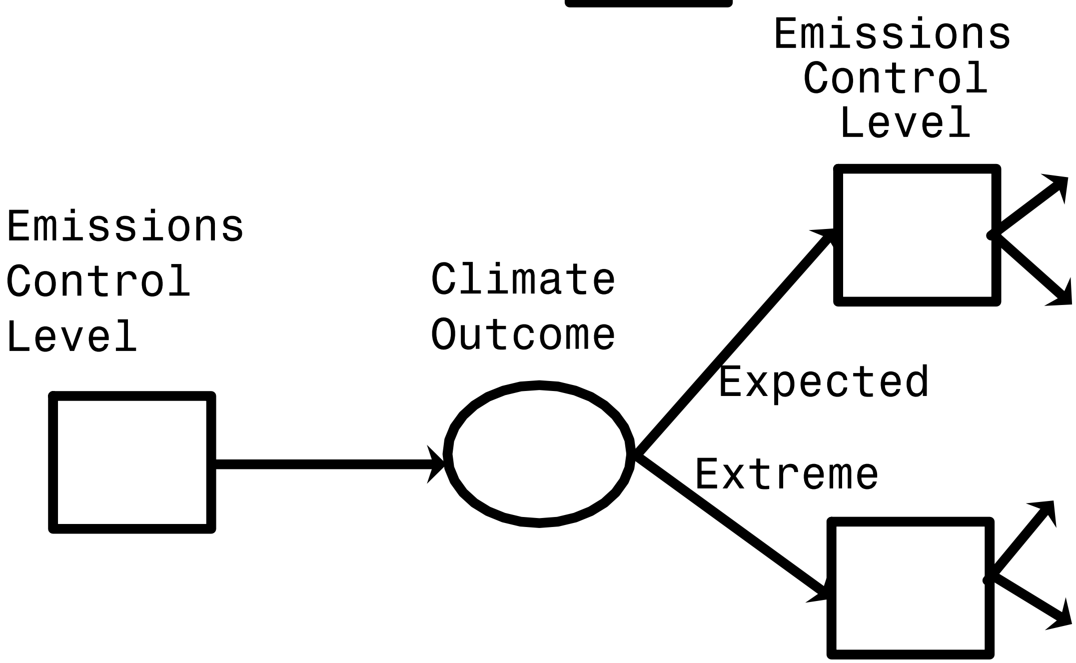
EMF Uncertainty Experiment: A Simple Example of Uncertainty Analysis in Optimization Models

Case	Climate Sensitivity (Per CO_2 Doubling)	Damage Function (Per 2 Degrees C Increase)
90% Prob.	2.5 Degrees C	2% of GDP
10% Prob.	4.8 Degrees C	15% of GDP

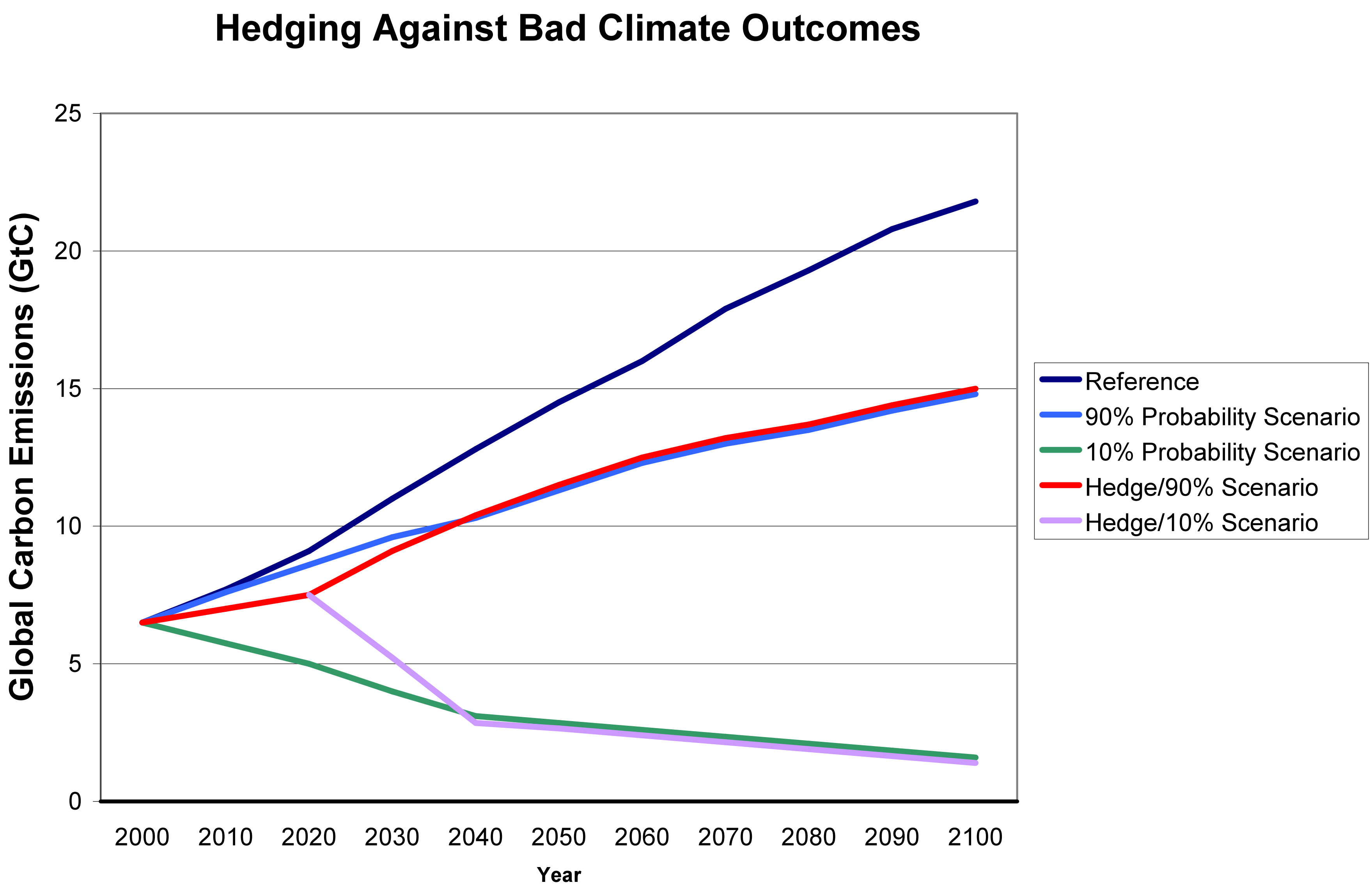
Adapted From A. Manne, 1998

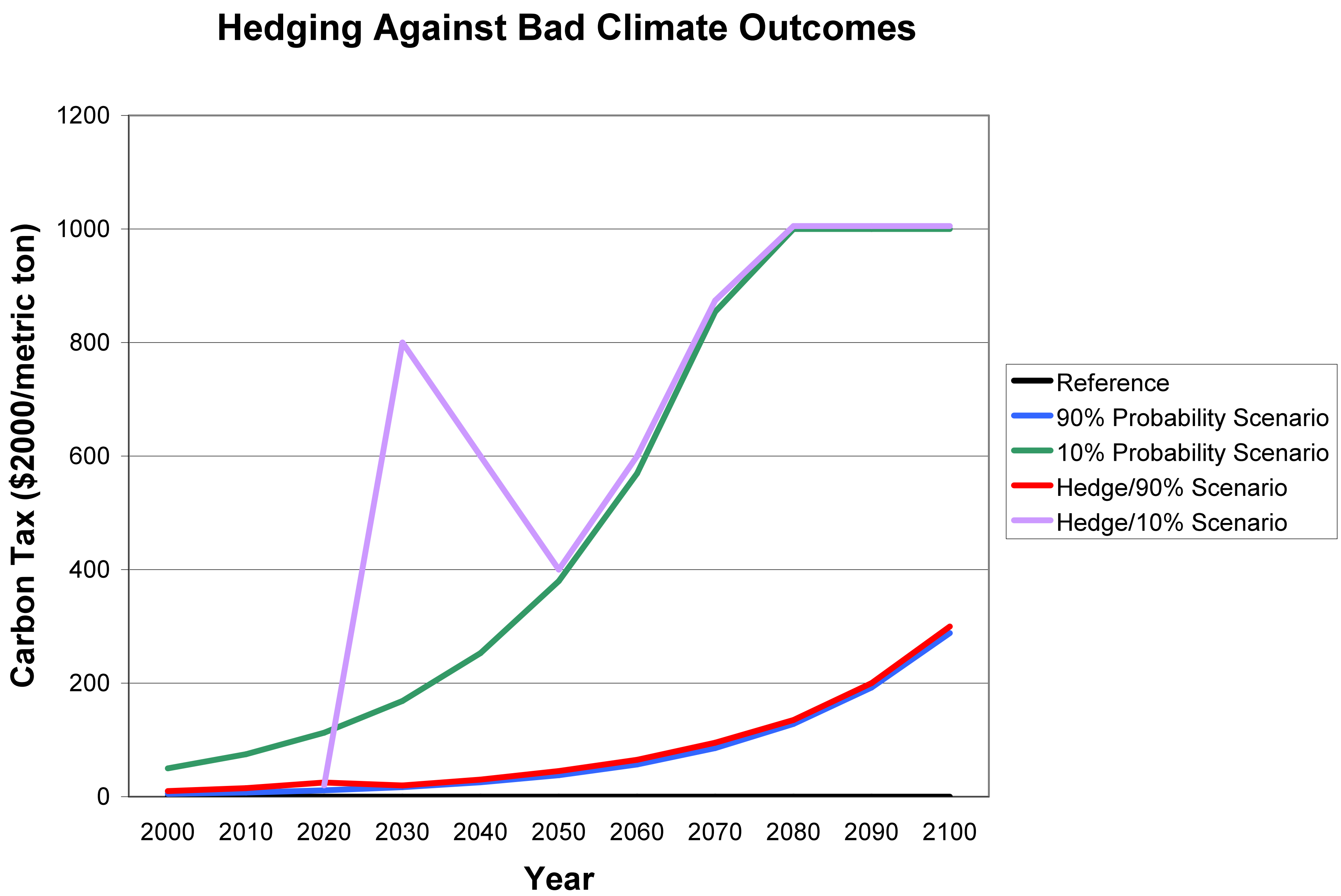


Clairvoyance



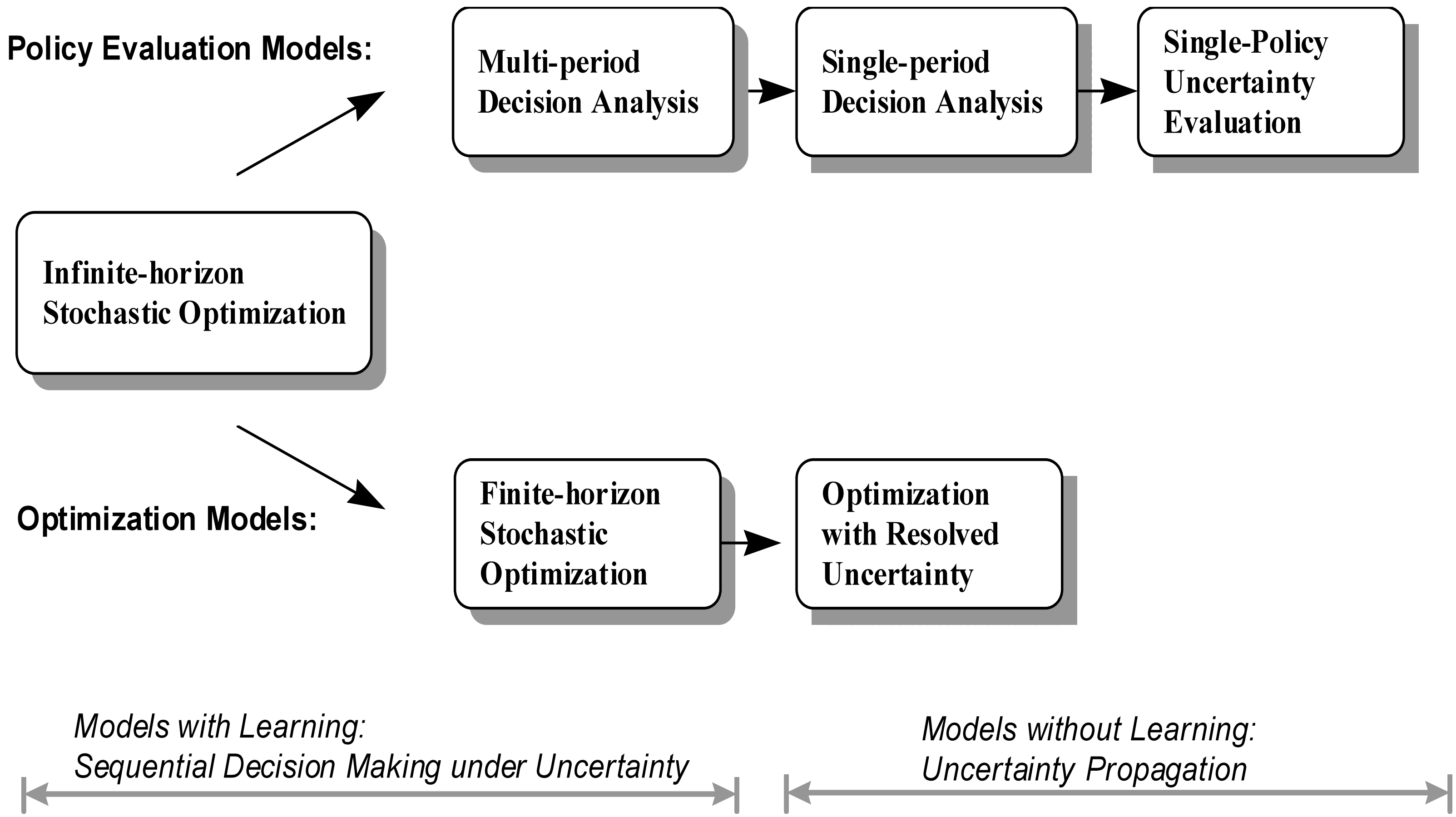
Sequential Decision-Making Under Uncertianty


Hedging Against Bad Climate Outcomes
Global Carbon Emissions (GtC)
0
5
10
15
20
25
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year
Reference
90% Probability Scenario
10% Probability Scenario
Hedge/90% Scenario
Hedge/10% Scenario



Hedging Against Bad Climate Outcomes
Carbon Tax ($2000/metric ton)
1200
1000
800
600
400
200
0
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year
Reference
90% Probability Scenario
10% Probability Scenario
Hedge/90% Scenario
Hedge/10% Scenario

Taxonomy of of Quantitative Approaches



Kann, Antje, and J.P. Weyant,
"A Comparison of Approaches for Performing Uncertainty Analysis in Integrated Assessment Models,"
<u>Journal of Environmental Management and Assessment,</u> Vol. 5, No.1, 1999, pp 29-46.

Overview of Quantitative Approaches to Uncertainty Analysis

Sequential Decision Making under Uncertainty

Uncertainty Propagation

Infinite-horizon Stochastic Optimization

$$\max_{\vec{C}_t} \sum_{t=0}^{\infty} \rho^t E(u(\vec{P}_t, \vec{I}_t, \vec{C}_t))$$

Optimization Models

Finite-horizon Stochastic Optimization

$$\max_{\vec{C}_{jt}} \sum_{j=1}^{J} E\left(\sum_{t=t_j}^{t_{j+1}-1} \rho^t u(\vec{P}_t, \vec{I}_{t_j}, \vec{C}_t) \right)$$

where t_j corresponds to times where the state of information is updated

Optimization with Resolved Uncertainty

$$E\left(\max_{\vec{C}_t} \sum_{t=0}^{T} \rho^t u(\vec{P}_t, \vec{C}_t) \right)$$

Policy Evaluation Models

Multi-period Decision Analysis

$$\max_{\{\vec{C}^i{}_j \in \{\vec{C}_j{}^1 \ldots \vec{C}_j{}^{N_j}\}\}_{j=1\ldots J}} \sum_{j=1}^{J} E\left(\sum_{t=t_j}^{t_{j+1}-1} \rho^t u(\vec{P}_t, \vec{I}_{t_j}, \vec{C}_t{}^i) \right)$$

where Nj corresponds to the number of discrete decision alternatives available at decision point j

Single-Period Decision Analysis

$$\max_{\vec{C}^i \in \{\vec{C}^1 \ldots \vec{C}^N\}} E\left(\sum_{t=0}^{T} \rho^t u(\vec{P}_t, \vec{C}^i{}_t) \right)$$

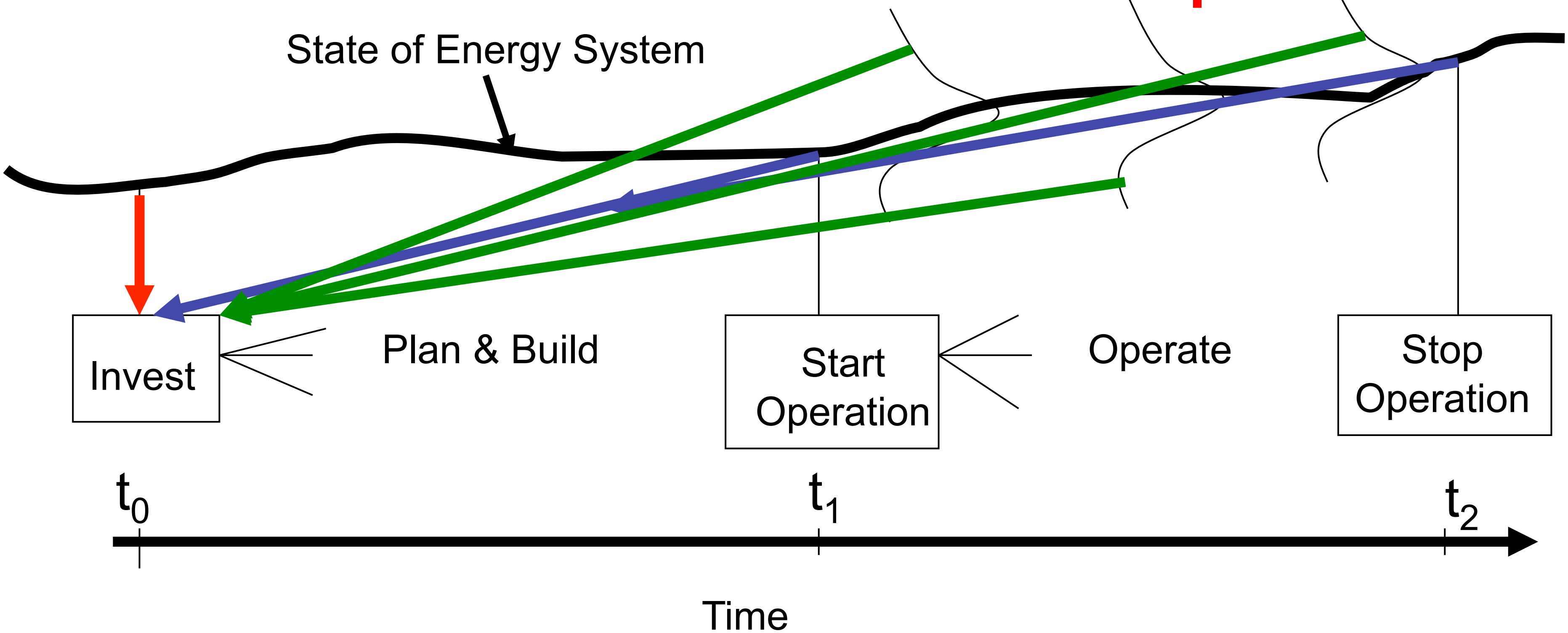
Single-Policy Uncertainty Evaluation

$$E\left(\sum_{t=0}^{T} \rho^t u(\vec{P}_t, \vec{C}_t) \right)$$

$\vec{P}_t$ = Physical state, $\vec{I}_t$ = Information state, $\vec{C}_t$ = Control variable, ρ = Discount rate, E = Expectation operator, u = Utility function

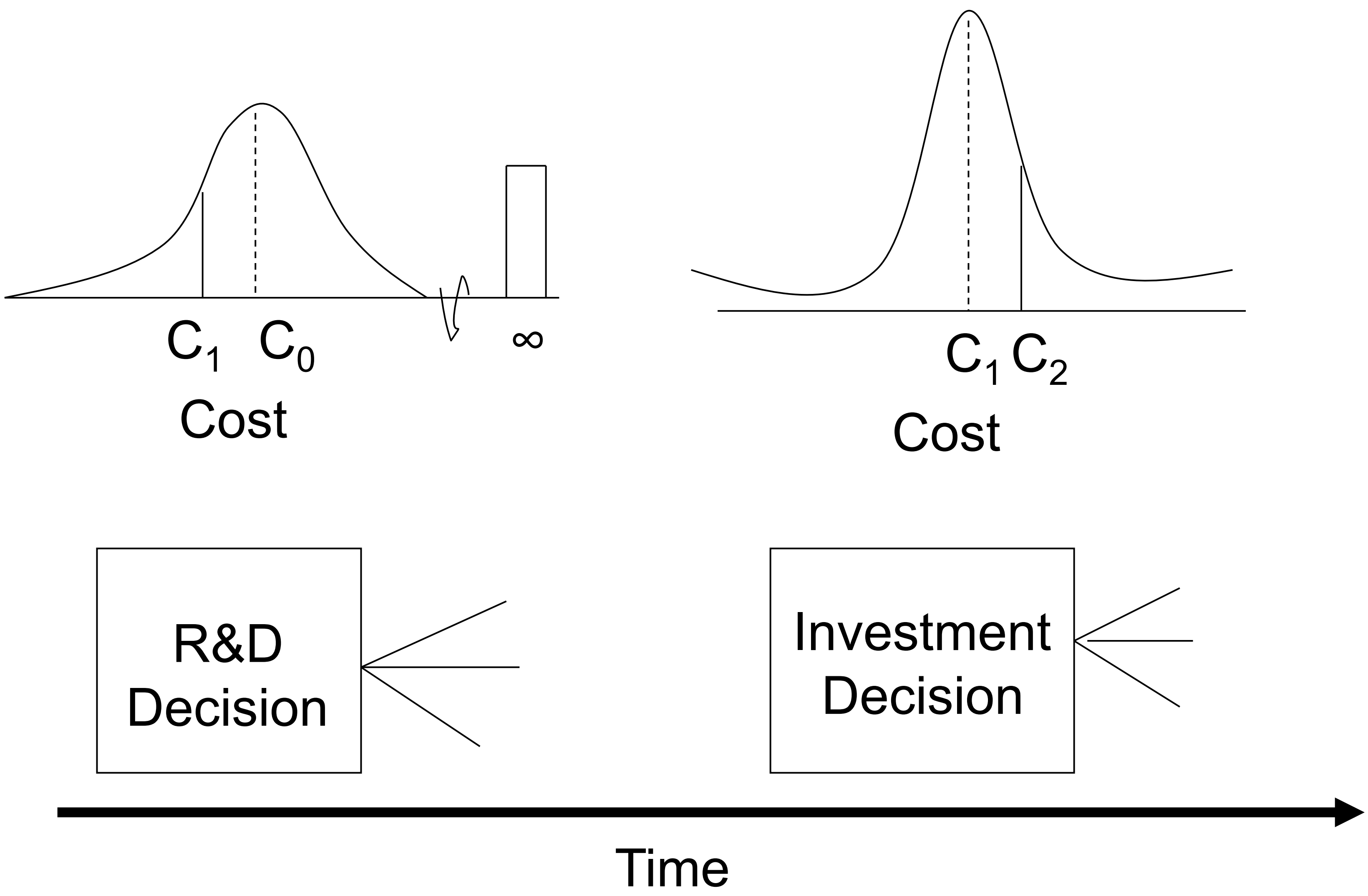
Incorporating Uncertainty

Information, Foresight & Uncertainty: Three Alternative Sets of Assumptions

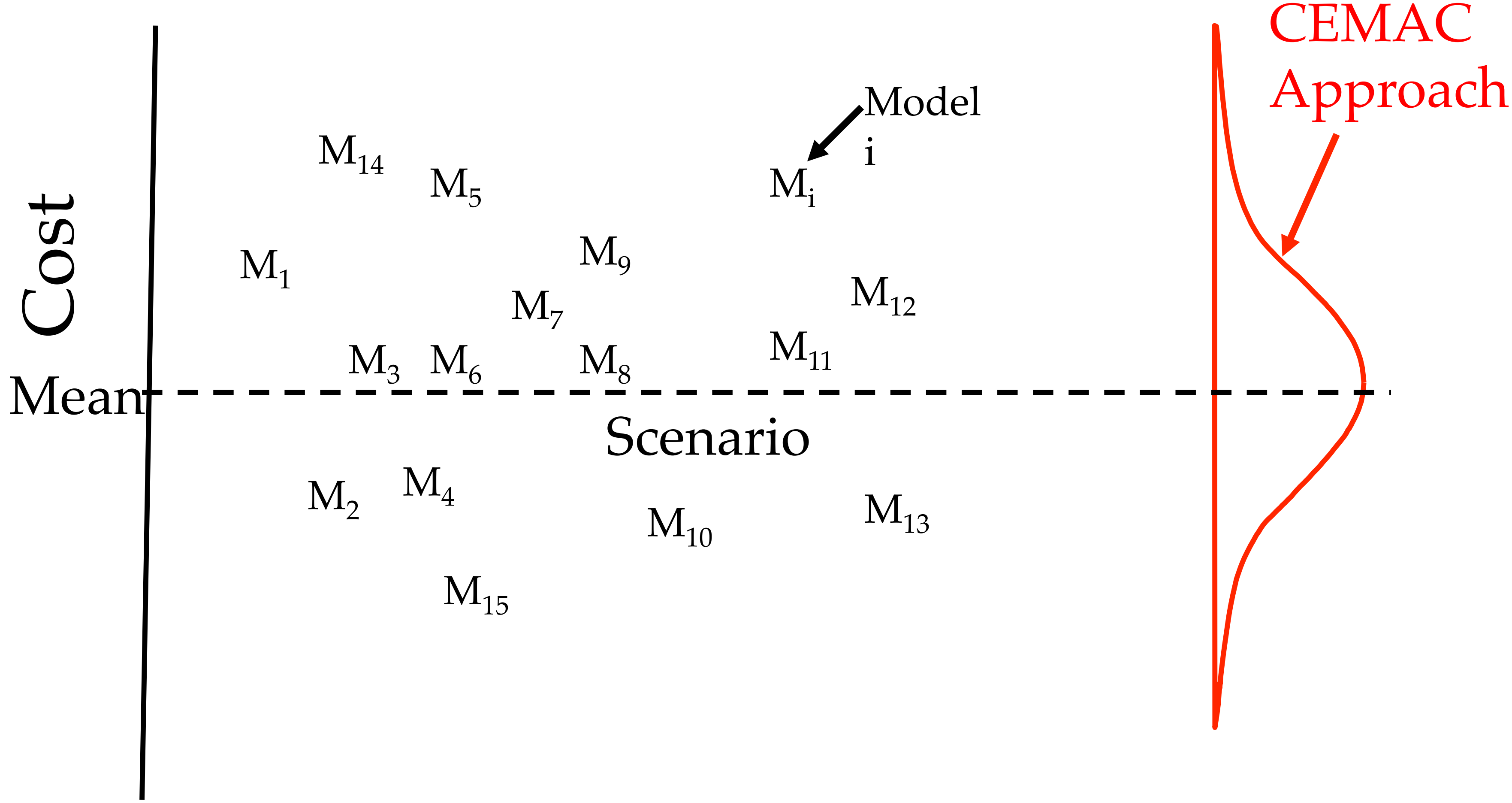


(1) Static, Myopic, or Recursive Dynamic
(2) Perfect Foresight (Rationale Expectations)
(3) Decision Making Under Uncertainty

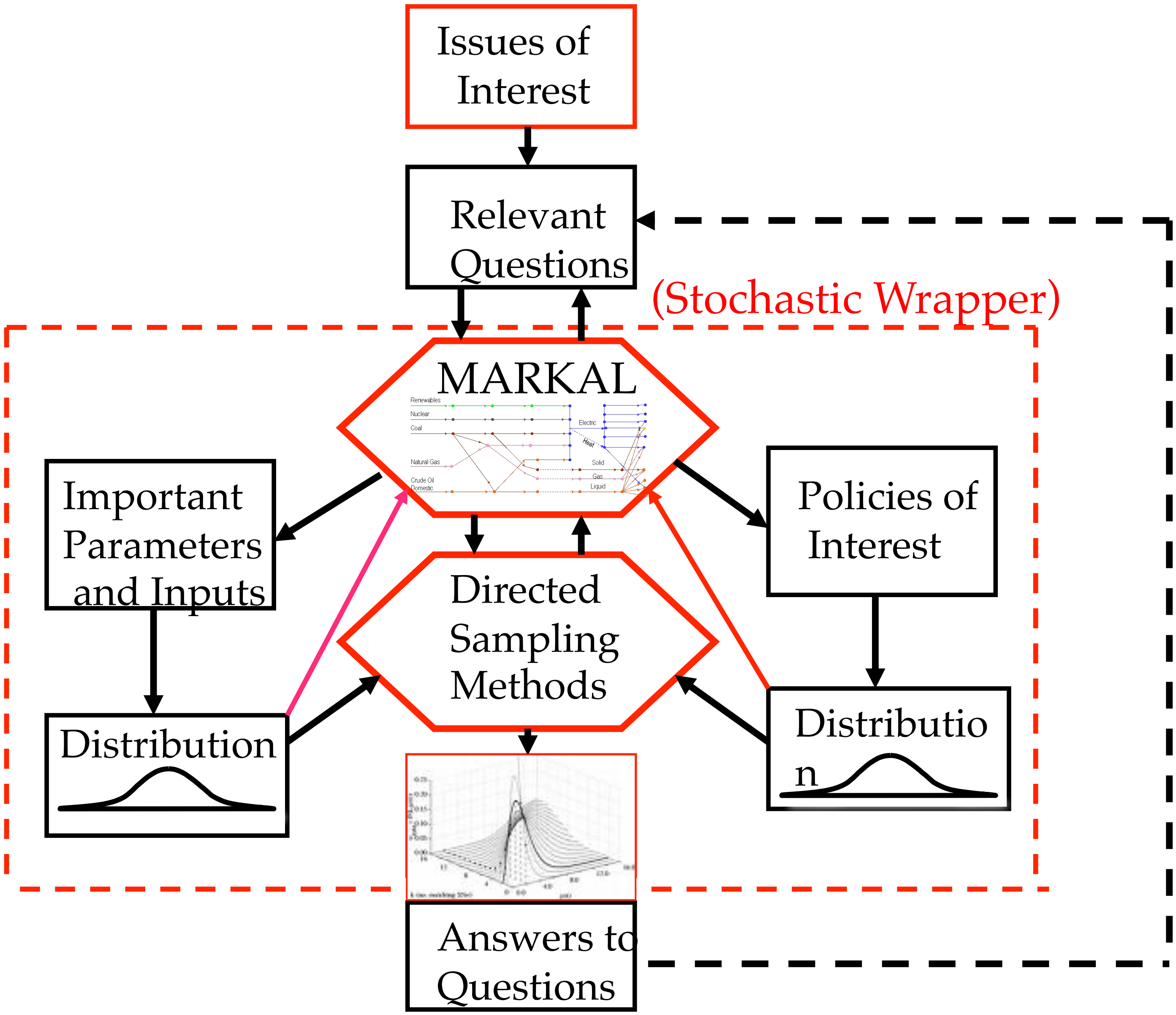
Interplay Between R&D and Investment Decisions



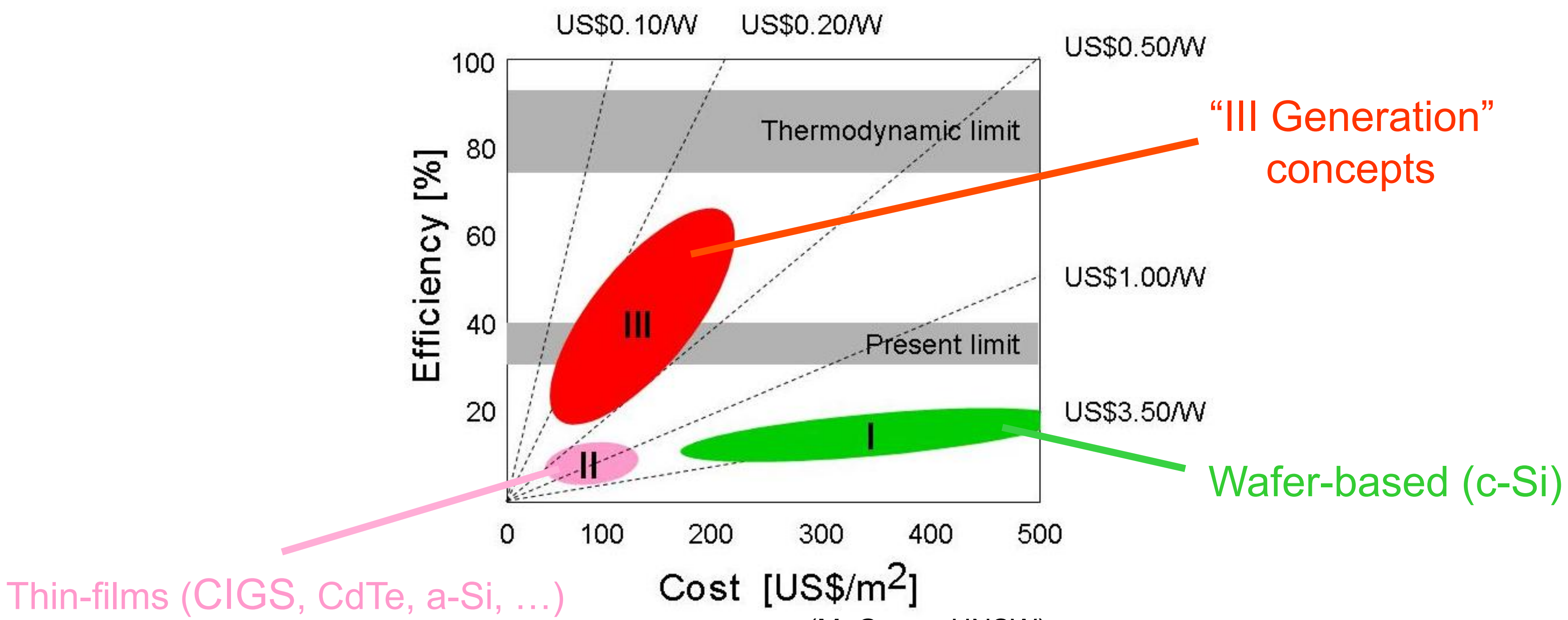
A Word On Stochastic Simulation: Typical Model Outputs and Alternative Approach



CEMAC Approach to Modeling & Analysis



Reducing Cost and Increasing Efficiency of Photovoltaic Systems



(M. Green, UNSW)

Cost ↓

- Cheaper Active Materials (abundant inorganic or organic)
- Lower Fabrication Costs (low-cost deposition / growth)
- Cheaper BOS Components (substrates, encapsulation, …)

Efficiency ↑

Reduce the Thermodynamic Losses at Each Step of the Photon-to-Electron Conversion Process

- Light Absorption
- Carrier Generation
- Carrier Transfer and Separation
- Carrier Transport

Solar Technology Assessment: Four Categories

Technology	Funding Trajectory	Definition of success (Efficiency, stability, cost)	Ex 1	Ex 2	Ex 3
Purely organic	\$10M 10yrs	15%; 30 yrs; \$50/m^2	.34	.04	.01
	\$80M 15yrs	31%; 15 yrs; \$50/m^2	.03	.08	.006
CIGS	\$15M 10yrs	15%; 30 yrs; \$50/m^2; no indium shortage	.04	0	.02
New inorganic	\$5M 10yrs	15%; 30 yrs; \$50/m^2	.64	.16	.001
	\$10M 10yrs	15%; 30 yrs; \$50/m^2	.85	.43	.013
	\$20M 10yrs	15%; 30 yrs; \$50/m^2	.85	.43	--
3rd Generation	\$15M 10yrs	36%; 30 yrs; \$100/m^2	.02	.02	.14

An Example of a Less Qualitative Approaches: The Simple Rules Strategy

"When the business environment was simple, companies could afford to have complex strategies. But now that business is so complex, they need to simplify. Smart companies have done just that with a new approach: a few straightforward, hard and fast rules that define direction without confining it."

Eisenhardt and Sull, Harvard Business Review, January 2001

Two Paradigms for Problem-Solving Under Uncertainty

	Conventional	Complex Adaptive
Defining ontology	Mechanistic	Complex
Social organization	Centralized/hierarchical	Decentralized/distributed
Competence/Knowledge	High, technocratic, explicit	Mixed, experiential, tacit
Scale of testing	Small number of large tests with high consequence of failure	Abundant small scale, safe-fail experimentation
Sources of legitimacy/ power	Policy communities, management elites	Civil society, democratic action, markets
Social location	Top	Bottom and middle
Goal	Optimization of expected utility (according to explicit, well-defined preferences)	Satisficing of multiple, often conflicting, and sometimes incommensurable values

Thomas Homer-Dixon, 2007

Recommendations on Uncertainty

- Deal With Uncertainty
- The Importance of Focus in Formulation
- The Importance of Flexibility in Analytics
- Relationship Between RA and RM
- The Importance of Flexibility in Policies
- Think Hard About What's Analyzed Versus What's Communicated

The End

Uses Of Integrated Assessment Models

Deterministic Models

Deterministic Policy Optimization Models

- Compute Optimal Carbon Taxes, Control Rates, etc.
- Calculate Costs of Meeting Emission/ Concentration/Climate/Impact Targets

Deterministic Policy Evaluation Models

- Insure Consistency in Assumptions
- Assess Interactions and Feedbacks
- Identify Critical Gaps in Research
- Project Specific Impacts

Decision Making Under Uncertainty Models

Stochastic Policy Optimization Models

- Assess Optimal Policies Under Uncertainty
- Compute Value of Information/Research

Stochastic Policy Evaluation Models

- Compute Probabilities of Cost/Benefits of Climate Policies
- Compute Probabilities of Meeting Targets

Cost/Benefit Modeling Approach:

Balancing the Costs of Controlling Carbon Emissions Against the Costs of the Climate impacts They Cause