Overview of Integrated Assessment

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Outline

- What is Integrated Assessment
- Some Background Questions
- Why Do Integrated Assessment
- Differences in Natural and Social Science Perspectives
- Different Types of Integrated Assessment Models
- Contributions of Integrated Assessment
  - Internal Consistency Checks
  - Insights Like The Four Flexibilities
  - Rough Numbers To Guide Policy Development
  - Research Prioritization
- Examples of Integrated Assessment
- Frontiers in Integrated Assessment
  - Coping With Complexity
  - Incorporating Uncertainty
  - Embracing Technological Change
  - Integrating the Sciences
  - Synthesizing the Impacts
  - Promoting Development
- Assessing Assessments
  - Peer Reviewed Proposals/Literature
  - Forum Analysis
  - Model Assessment Projects
  - PCMDI-Like Institution

What is Integrated Assessment of Climate Change Policy?

- Many definitions of IA for many purposes
- Here we call integrated assessment of climate change policy any attempt to bring together the costs and benefits of climate change policies in a systematic manner

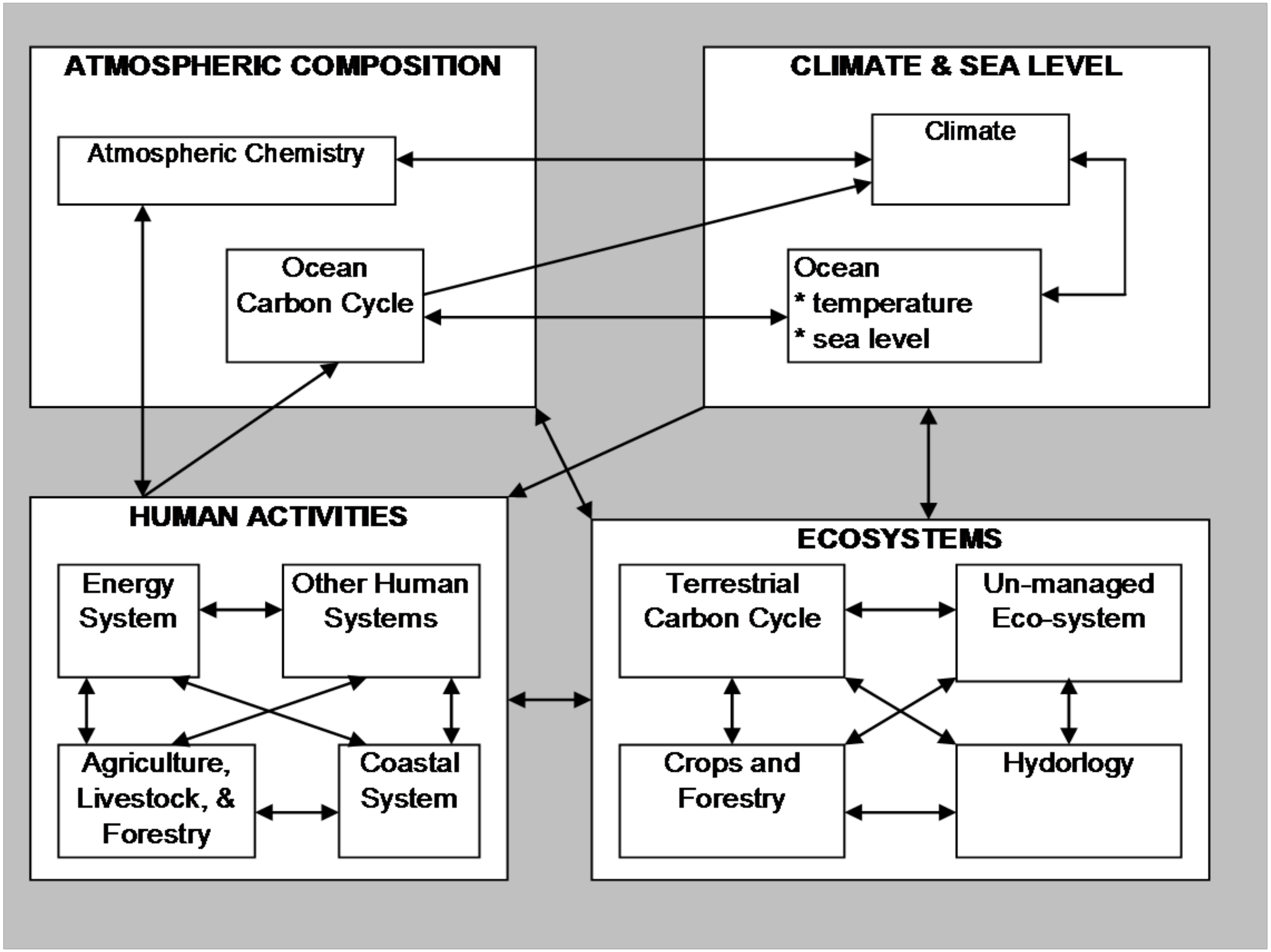
Background Questions

- Why assess?
  - Need insights and numbers for policy development
- Why model?
  - Consistency
  - Insights
  - Learning
  - Rough numbers +sensitivities
- What principles to use?
  - Disciplinary differences
  - What is empirical evidence?
- How should models be evaluated?
  - Backcasting
  - Model assessment
- Who decides these things?
  - Disciplines, national academies, lawyers, us

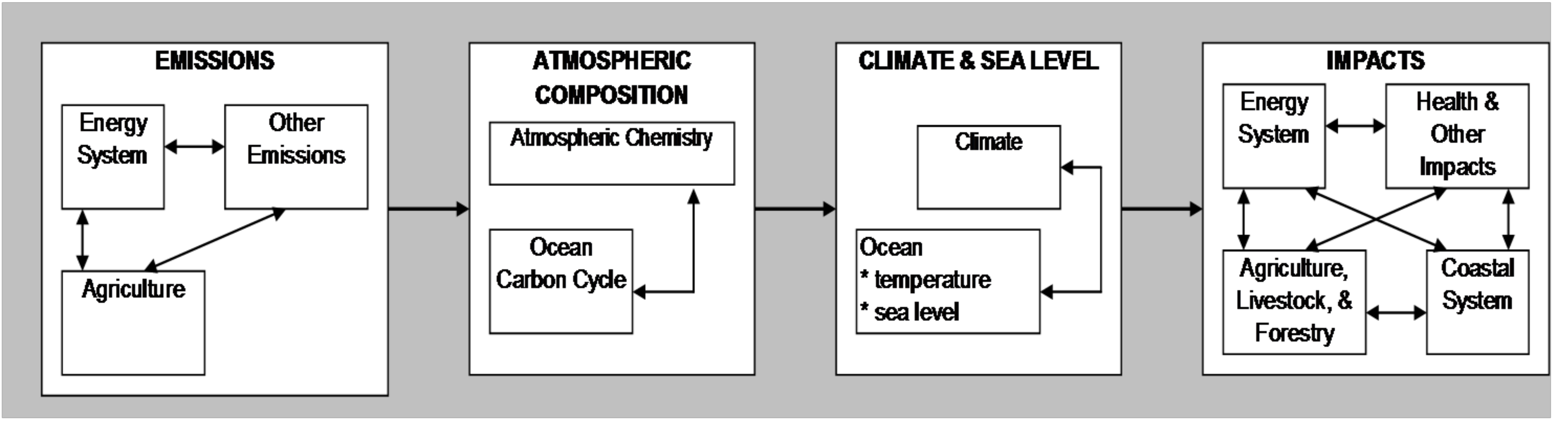
Some Things We Find in Economics, But Not in Physics or Biology

- Preferences (possibly changing over time)
- Expectations (certainly changing over time)
- The ability to make contingent decisions
- These characteristics may lead to differences in:
  - Framing questions
  - Modeling systems
  - Integrating models
  - Assessing models

Fully Integrated Approach to Integrated Assessment



End to End Approach to Integrated Assessment



Two Kinds of Integrated Assessment Models

- Policy Optimization Models
  - Focused on Finding Optimal Level of Emissions
  - Usually Include Impacts at the Aggregate Level
- Policy Evaluation Models
  - Focused on Simulating Effects of Policies
  - Usually More Detailed Impacts
  - Can be Run Backwards - Tolerable Windows Approach

Types of
Integrated Assessment Models

Deterministic Models

Deterministic Policy Optimization Models	Deterministic Policy Evaluation Models

Decision Making Under Uncertainty Models

Stochastic Policy Optimization Models	Stochastic Policy Evaluation Models

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

Decision Making Under Uncertainty Models

Stochastic Policy Optimization Models

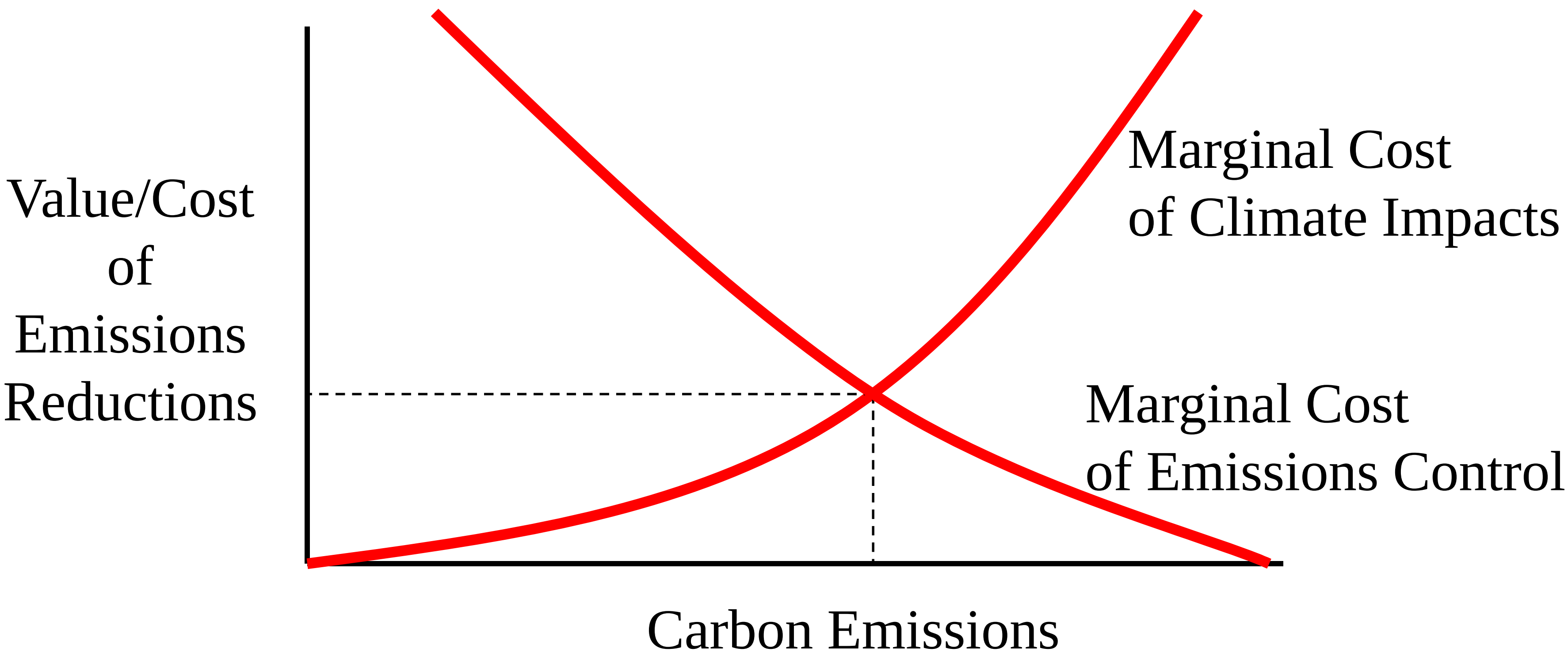
- Assess Optimal Policies Under Uncertainty
- Compute Value of Information/Research

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



Example#1: C/B Results From Nordhaus "A Question of Balance" Book 7/2008

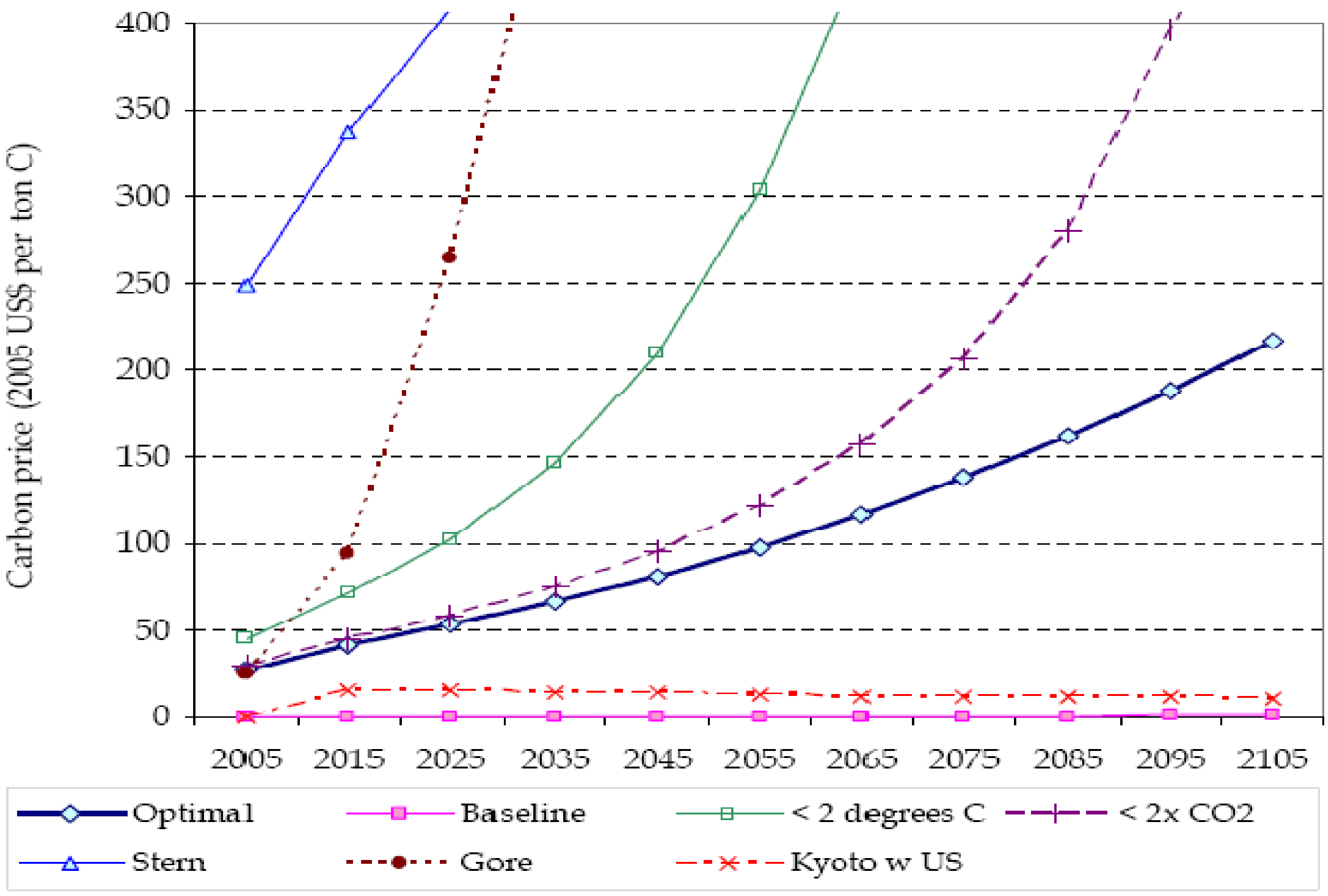


Figure V-4. Carbon prices for different strategies

Example#1: C/B Results From Nordhaus "A Question of Balance" Book 7/2008

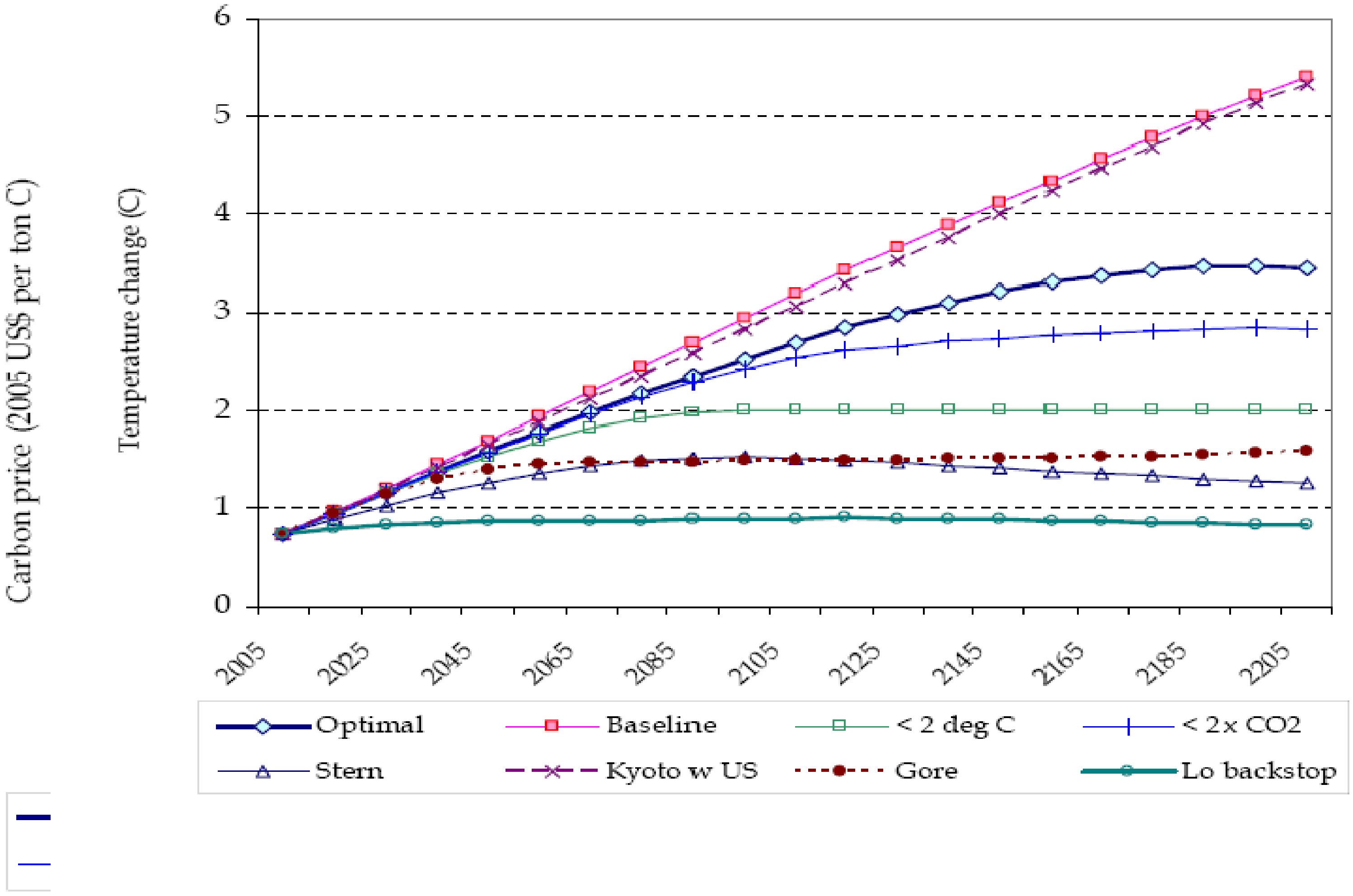


Figure V-8. Projected global mean temperature change by policy

Figure V-4. Carbon prices for different strategies

Components of Mitigation Costs

- Direct resource costs
- Indirect opportunity costs
  - Less of one commodity, but perhaps more of another
  - Can include shifts in industry structure
  - Can include trade impacts
- Economic growth impacts
  - Tied into capital accumulation
  - Also depends heavily on technological change
- Dis-eqilibrium impacts

And Then We Have The Bottom-Up Engineering Models: IPCC AR4 Global Mitigation Cost Estimates

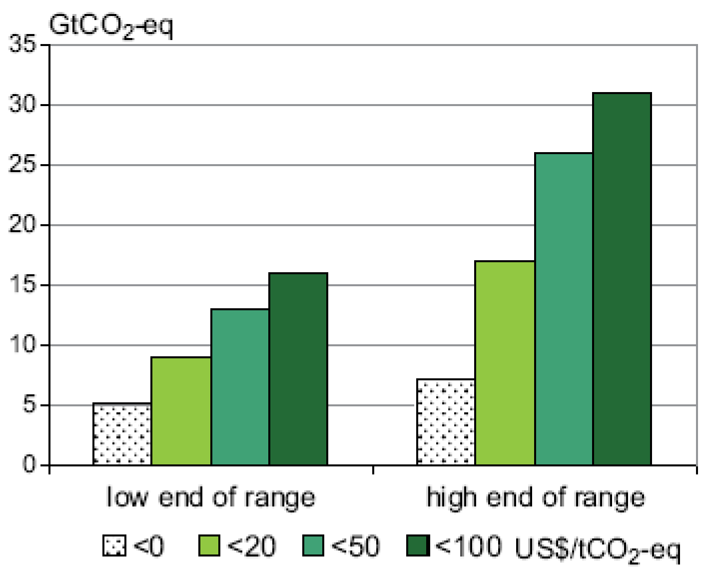


Figure SPM.5A: *Global economic mitigation potential in 2030 estimated from bottom-up studies (data from Table SPM.1)*

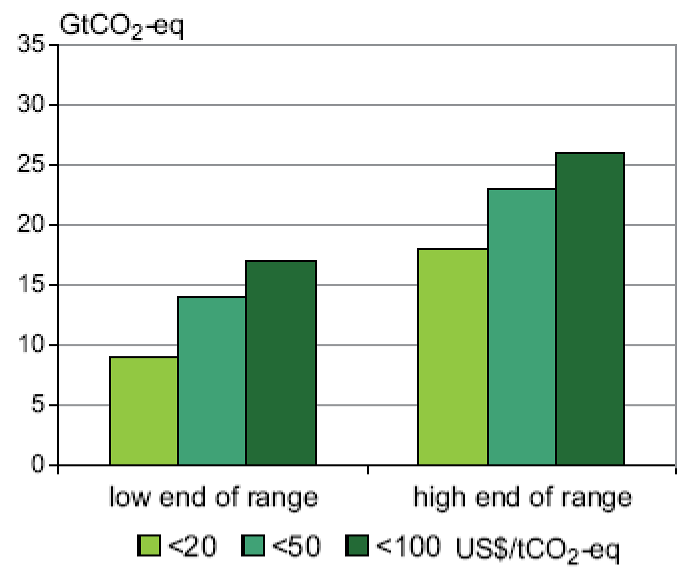


Figure SPM.5B: *Global economic mitigation potential in 2030 estimated from top-down studies (data from Table SPM.2)*

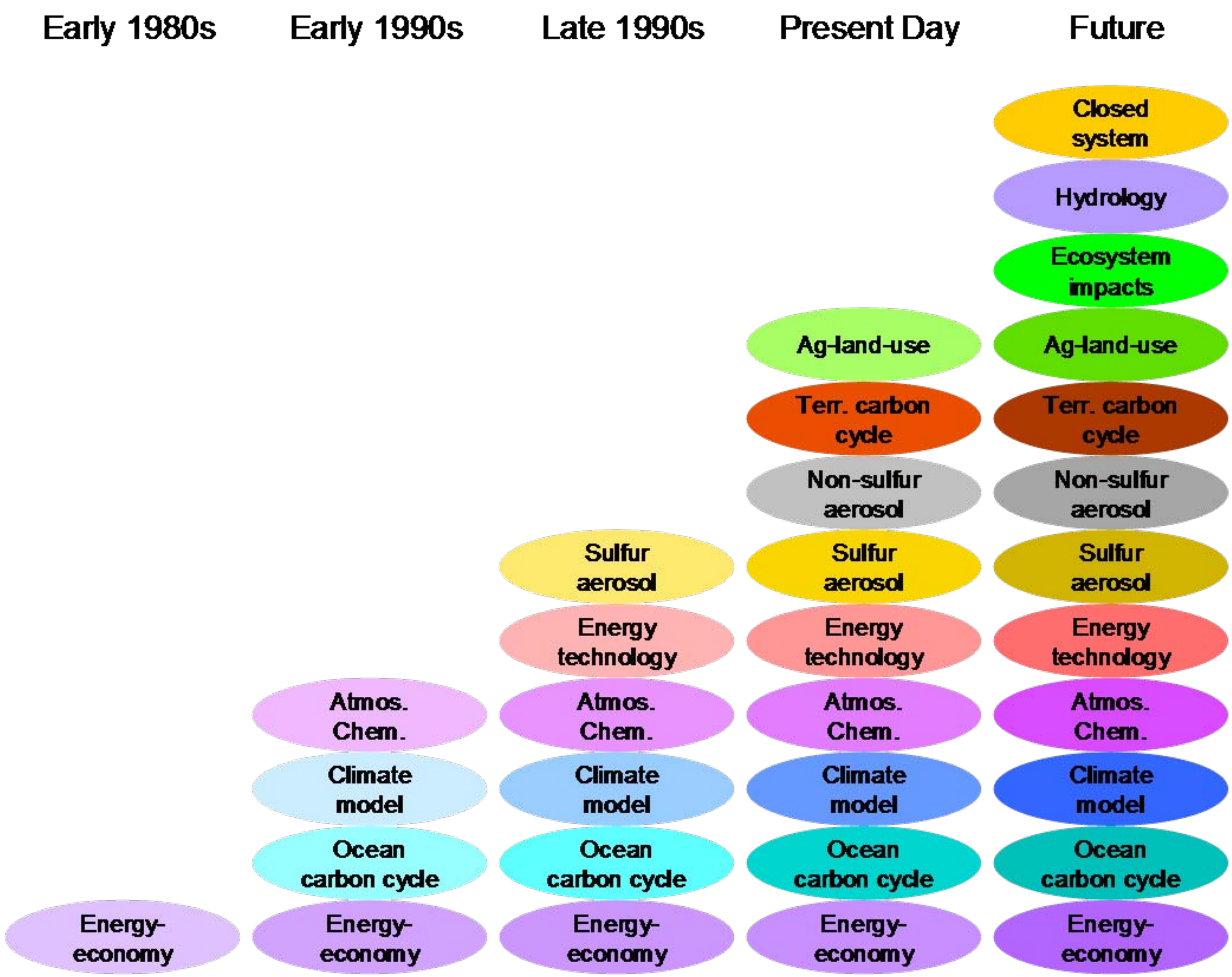
A Range of Approaches to Projecting Mitigation Costs

Table 3.12: *Top-down models assessed for mitigation opportunities in 2030*

Model	Model type	Solution concept	Time horizon	Modelling team and reference
AIM (Asian-Pacific Integrated Model)	Multi-Sector General Equilibrium	Recursive Dynamic	Beyond 2050	NIES/Kyoto Univ., Japan Fujino *et al.*, 2006.
GRAPE (Global Relationship Assessment to Protect the Environment)	Aggregate General Equilibrium	Inter-temporal Optimization	Inter-temporal Optimization	Institute for Applied Energy, Japan Kurosawa, 2006.
IMAGE (Integrated Model to Assess The Global Environment)	Market Equilibrium	Recursive Dynamic	Beyond 2050	Netherlands Env. Assessment Agency Van Vuuren *et al.*, Energy Journal, 2006a. (IMAGE 2.2) Van Vuuren *et al.*, Climatic Change, 2007. (IMAGE 2.3)
IPAC (Integrated Projection Assessments for China)	Multi-Sector General Equilibrium	Recursive Dynamic	Beyond 2050	Energy Research Institute, China Jiang *et al.*, 2006.
MERGE (Model for Evaluating Regional and Global Effects of GHG Reduction Policies)	Aggregate General Equilibrium	Inter-temporal Optimization	Beyond 2050	EPRI & PNNL/Univ. Maryland, U.S. USCCSP, 2006.
MESSAGE-MACRO (Model for Energy Supply Strategy Alternatives and Their General Environmental Impact)	Hybrid: Systems Engineering & Market Equilibrium	Inter-temporal Optimization	Beyond 2050	International Institute for Applied Systems Analysis, Austria Rao and Riahi, 2006.
MiniCam (Mini-Climate Assessment Model)	Market Equilibrium	Recursive Dynamic	Beyond 2050	PNNL/Univ. Maryland, U.S. Smith and Wigley, 2006.
SGM (Second Generation Model)	Multi-Sector General Equilibrium	Recursive Dynamic	Up to 2050	PNNL/Univ. Maryland and EPA, U.S. Fawcett and Sands, 2006.
POLES (Prospective Outlook on Long-Term Energy Systems)	Market Equilibrium	Recursive Dynamic	Up to 2050	LEPII-EPE & ENERDATA, France Criqui et al., 2006.
WIAGEM (World Integrated Applied General Equilibrium Model)	Multi-Sector General Equilibrium	Inter-temporal Optimization	Beyond 2050	Humboldt University and DIW Berlin, Germany Kemfert *et al.*, 2006.

Source: Weyant et al., 2006.

Evolution of IA Modeling



Source: J. Edmonds - JGCRI

RCP Candidates: Published Scenarios With All Gases

Table 2. RCP candidates. Asterisks indicate that at least one scenario is available, although there may be more than one.

IAM (affiliation)[1]	RCP8.5	RCP6	RCP4.5	RCP3-PD	Reference(s)
AIM (NIES)		*[2]	*	*[2]	Fujino et al. (2006)ć Hijioka et al. (2008)
GRAPE (IAE)			*		Kurosawa (2006)
IGSM (MIT)	*	*	*		Reilly et al. (2006)ć Clarke et al. (2007)
IMAGE (MNP)	*	*	*	*	van Vuuren et al. (2006ć2007)
IPAC (ERI)		*[2]	*		Jiang et al. (2006)
MESSAGE (IIASA)	*	*	*	*	Rao and Riahi (2006)ć Riahi et al. (2007)
MiniCAM (PNNL)		*	*		Smith and Wigley (2006)ć Clarke et al. (2007)

Notes:

[1] AIM = Asia-Pacific Integrated ModelćNIES = National Institute for Environmental StudiesćGRAPE = Global Relationship to Protect the EnvironmentćIAE = Institute of Applied EnergyćIGSM = Integrated Global System ModelćMIT = Massachusetts Institute of TechnologyćIMAGE = Integrated Model to Assess the Global EnvironmentćMNP = Netherlands Environmental Assessment AgencyćIPAC = Integrated Policy Assessment Model for ChinaćERI = Energy Resource InstitutećMESSAGE = Model for Energy Supply Strategy Alternatives and their General Environmental ImpactćMiniCAM = Mini-Climate Assessment ModelćPNNL = Pacific Northwest National Laboratory.

[2] These scenarios are availablećbut would require revisions to meet the RCP forcing criteria.

Areas Where Climate Change Impacts Are Anticipated

MARKET

- Agriculture
- Forestry
- Sea Level Rise
- Water Supply
- Energy Consumption
- Fisheries
- Extreme Events/Insurance

NON-MARKET

- Unmanaged Eco-Systems
  - Terrestrial
  - Marine
- Human Health*
- Bio-Diversity*
- Wildlife
- Recreation*
- Amenities

*Some Market Components

Approaches to Integration of Costs & Benefits

- Do Informally Through Careful Choice of Target and Then Minimize Costs to Achieve
- Iterate Between Tolerable Windows and Optimization Approaches
- Formal Cost/Benefit Analysis

Contributions of Integrated Assessment

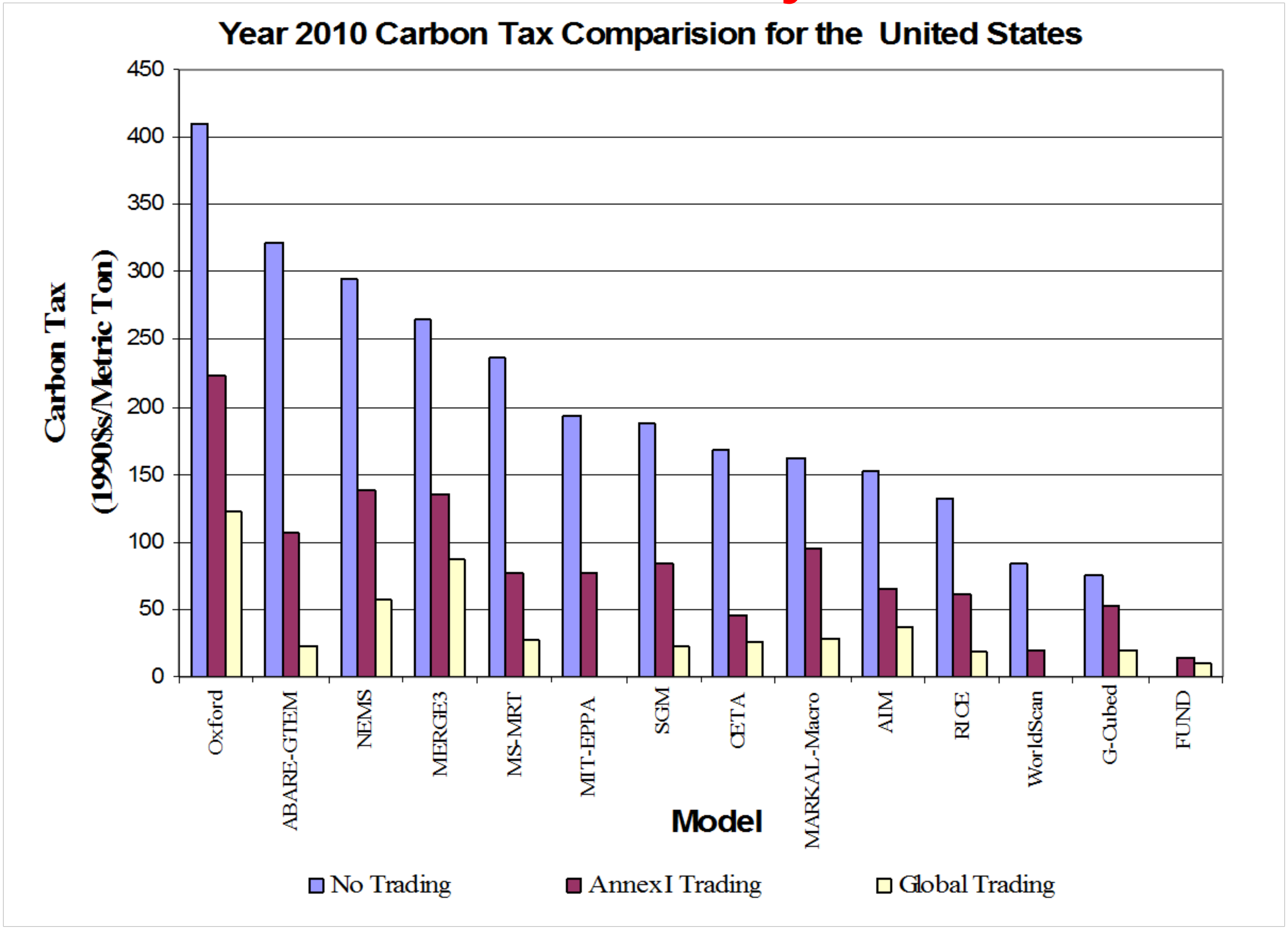
- Internal Consistency Checks
- Insights Like The Four Flexibilities
- Rough Numbers To Guide Policy Development
- Research Prioritization

Four Kinds of
Mitigation Policy Flexibilities

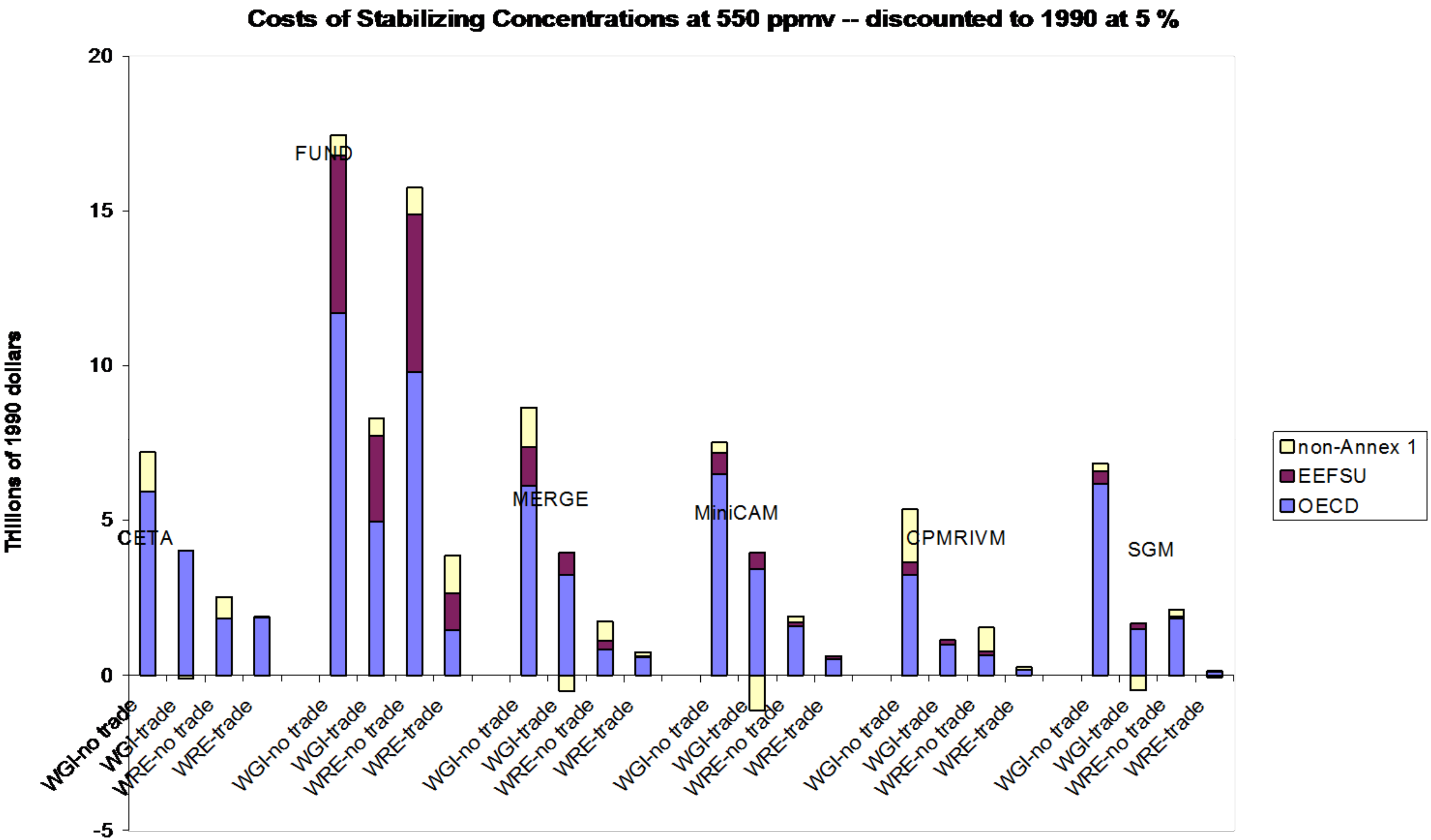
1. Where Flexibility
2. When Flexibility
3. How Flexibility
4. What Flexibility

1. Where Flexibility

The Cost of Kyoto



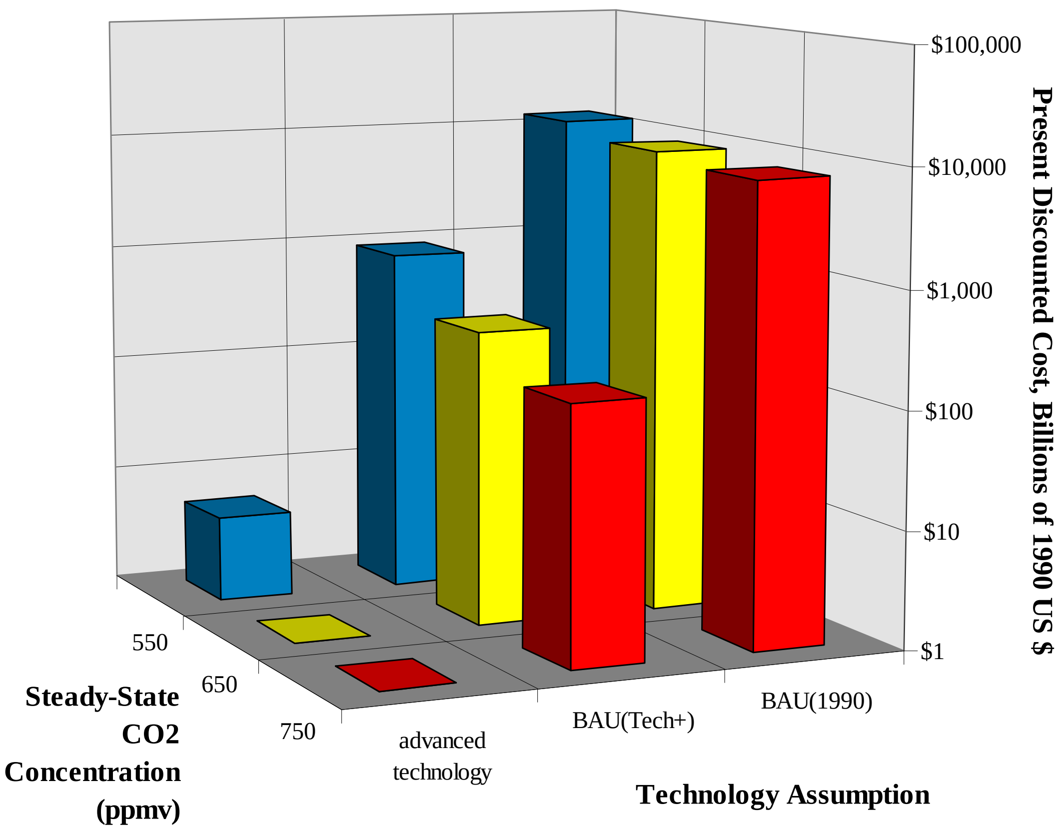
2. Where and When Flexibility



3. How Flexibility

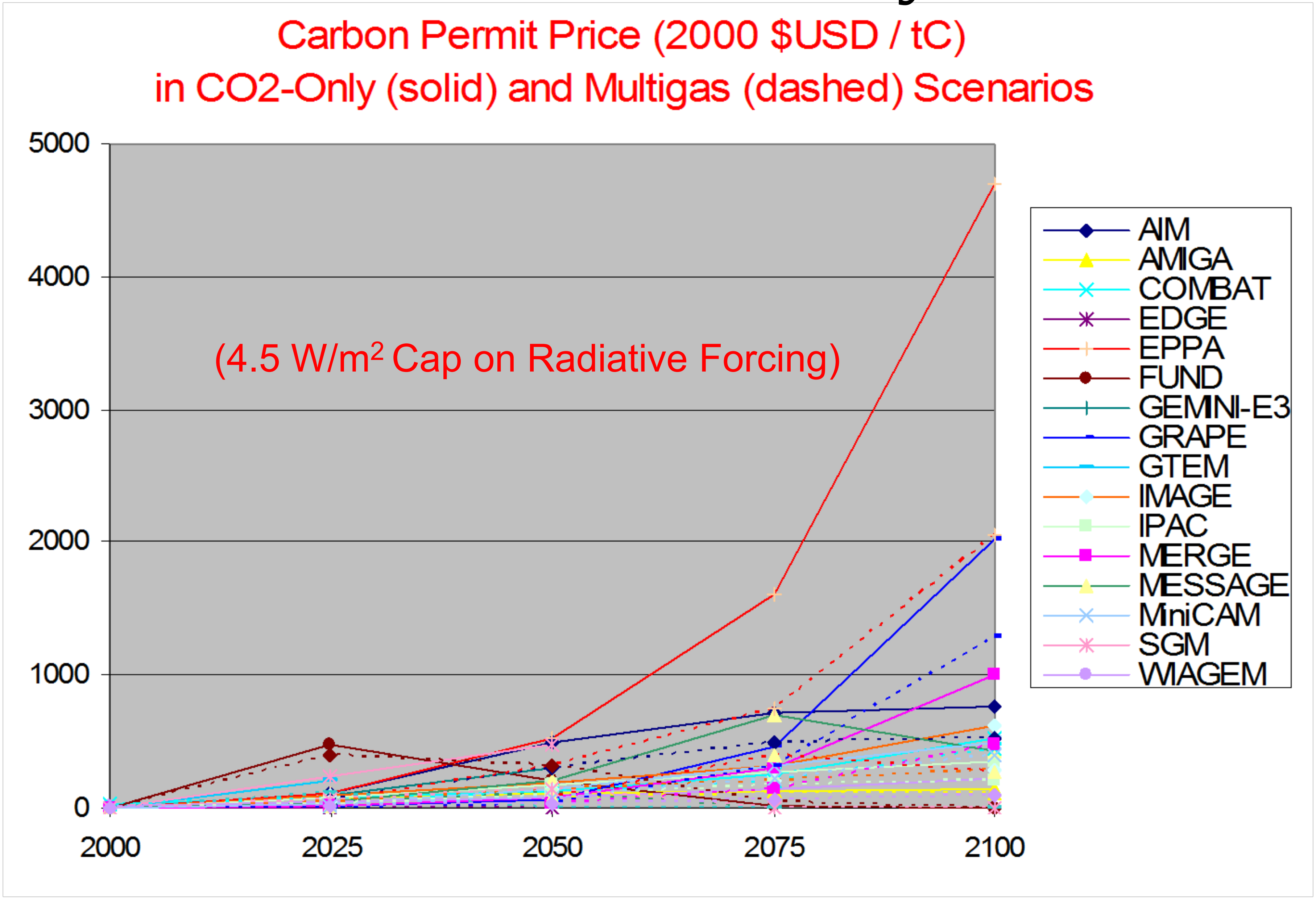
The VALUE OF DEVELOPING NEW ENERGY TECHNOLOGY

(Present Discounted Costs to Stabilize the Atmosphere)



Minimum Cost Based on Perfect Where & When Flexibility Assumption. Actual Cost Could be An Order of Magnitude Larger.

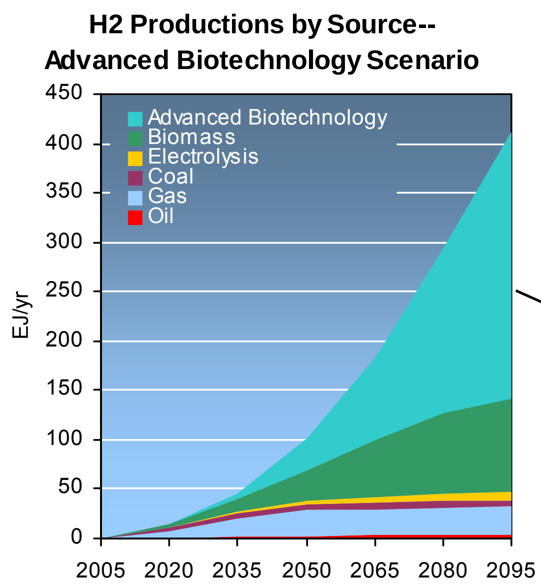
4. What Flexibility

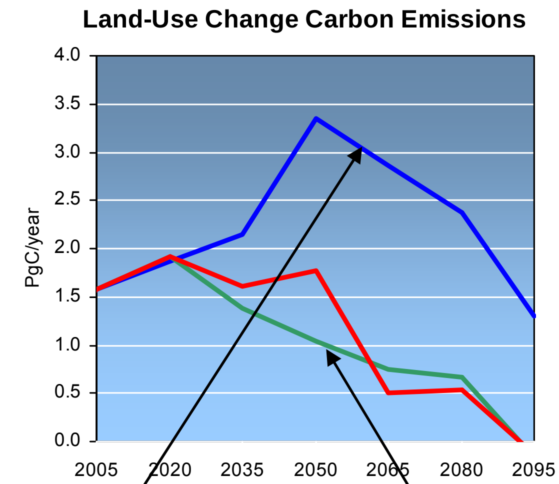


Some Areas Where Some Integration Has Proven Useful

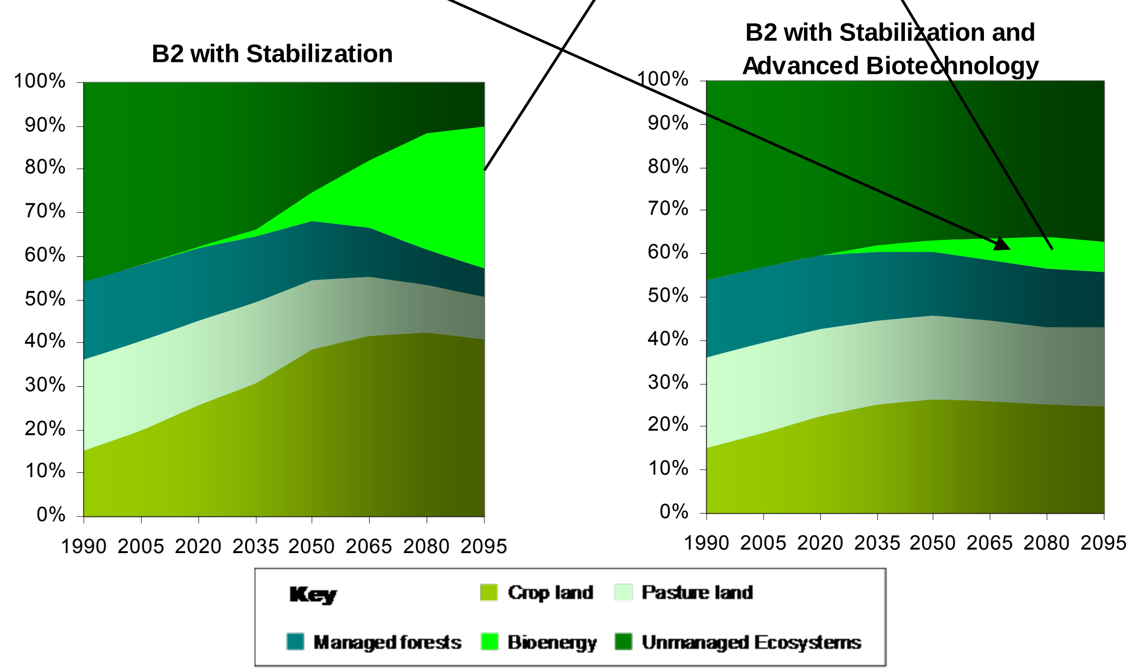
- Biological Sinks
- CO_2 Fertilization
- Sulfate Aerosols
- Biofuels Assessments
- Health Impact Assessments

Example Application #2: Breakthroughs in Biological Science



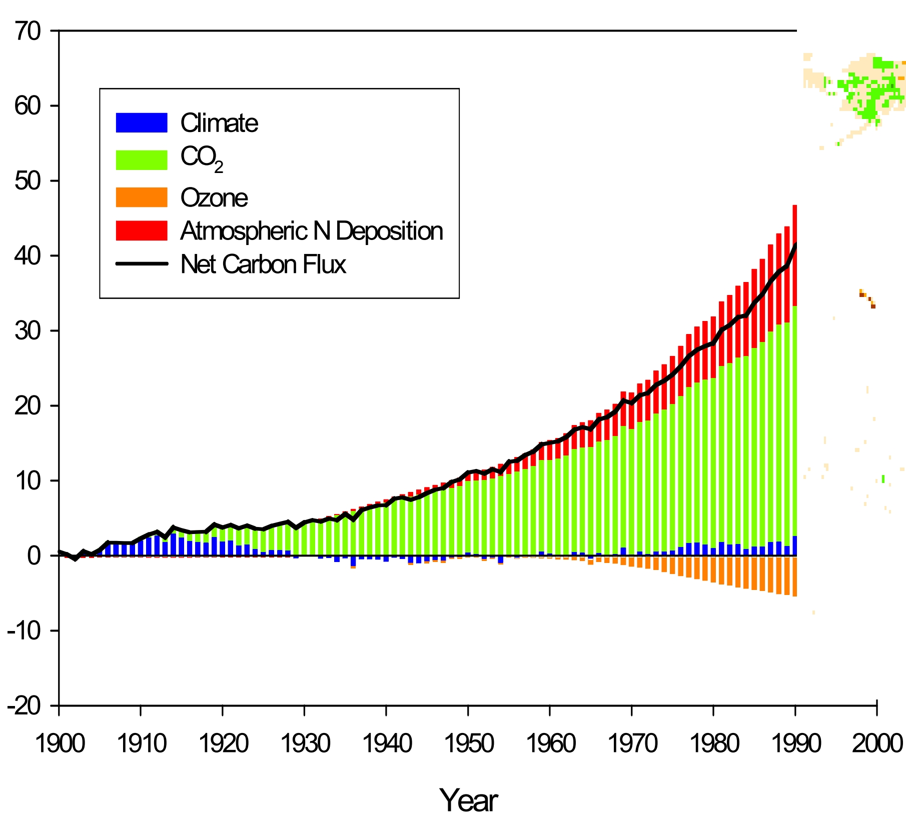


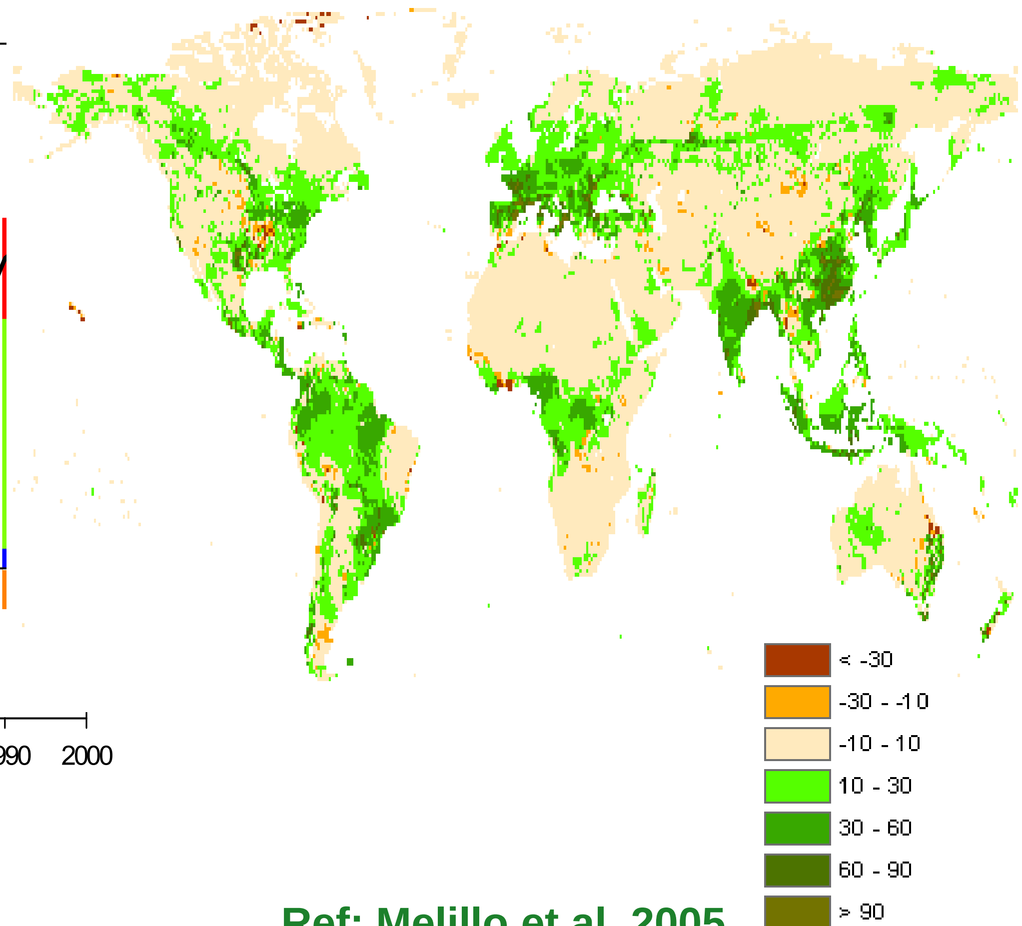
Against a background of limiting GMST to 2ºC, what if agricultural and biomass crop productivities could be enhanced and a biological source of H_2 that is cost-competitive with CH_4 was developed?



Source: J. Edmonds, JGCRI

Example #3: Terrestrial Ecosystem Model addresses impacts of Climate Change & Air Pollution on Carbon Cycle





Ref: Melillo et al, 2005

Frontiers in Integrated Assessment

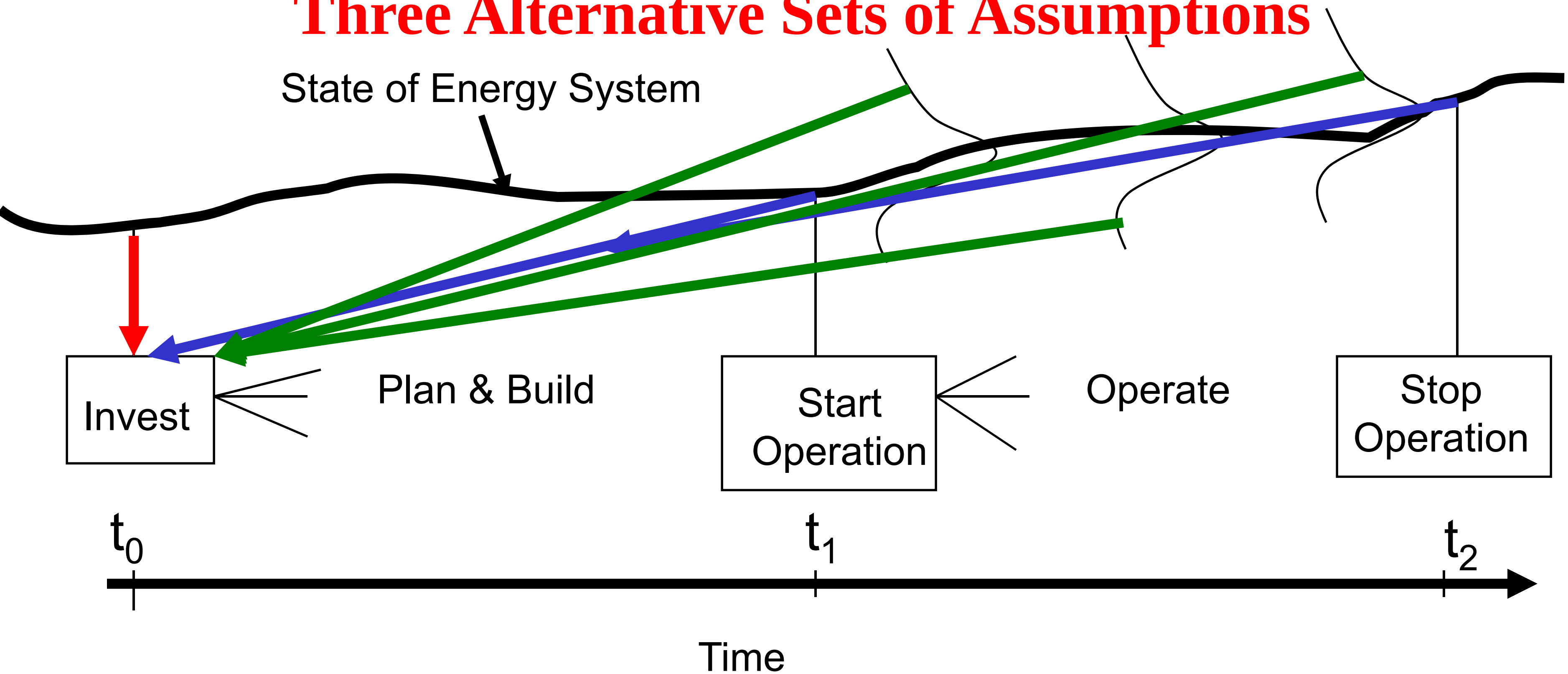
- Coping with complexity
- Incorporating uncertainty
- Embracing technological change
- Integrating the sciences
- Synthesizing the impacts
- Promoting development

I. Coping With Complexity

- Need to Maintain Problem Focus
- Proliferation of Data, Modules, Interactions
- Need Strategic Approach to Formulation/Implementation
- Lessons From Complexity Theory?
- Operationalize Multi-Level Cyclical Scaling?

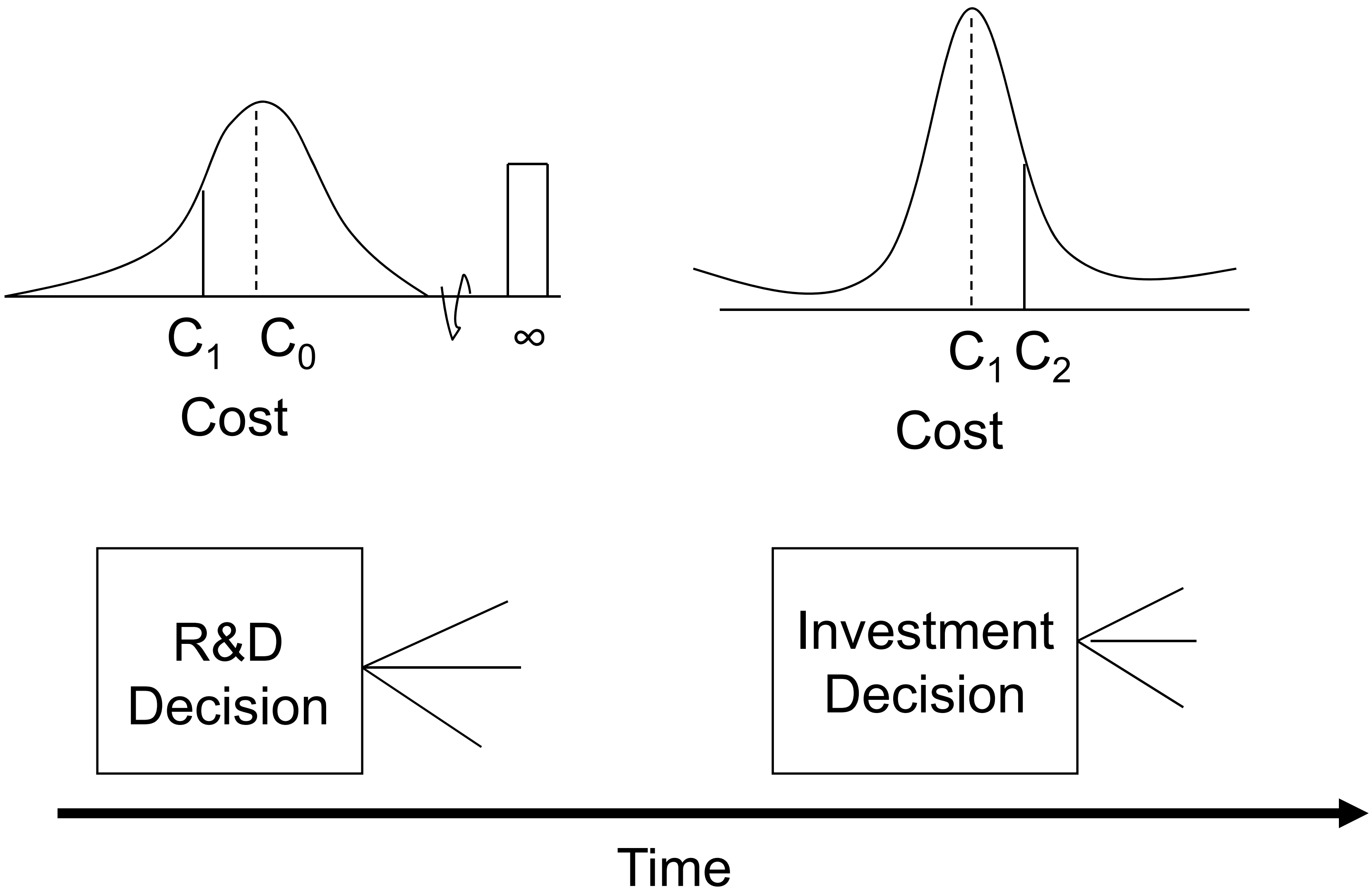
II. Incorporating Uncertainty

Information, Foresight & Uncertainty: Three Alternative Sets of Assumptions



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

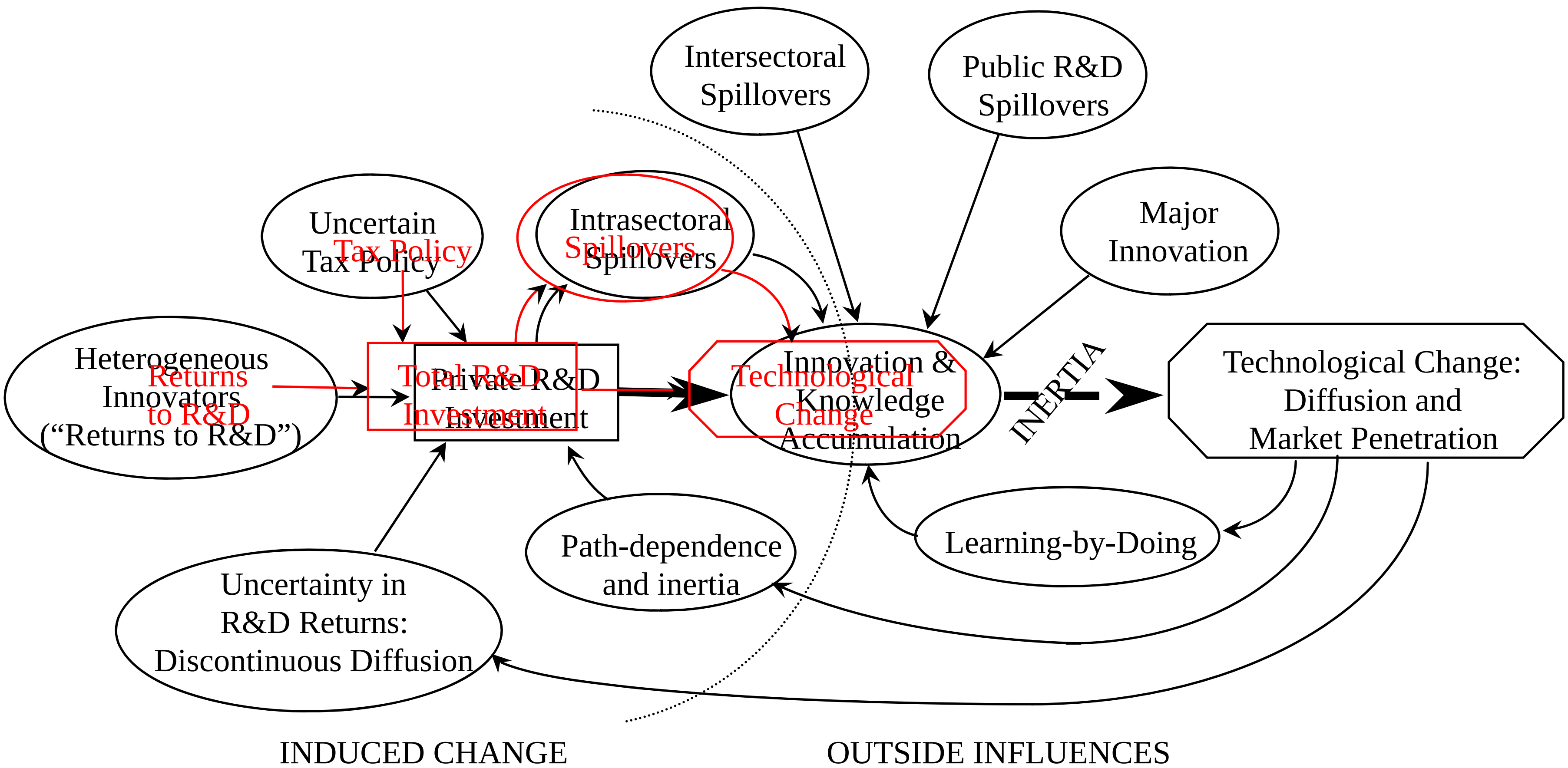
Interplay Between R&D and Investment Decisions



III. Embracing Technological Change

Limitations and Possible Extensions to Current Methods for Modeling ITS

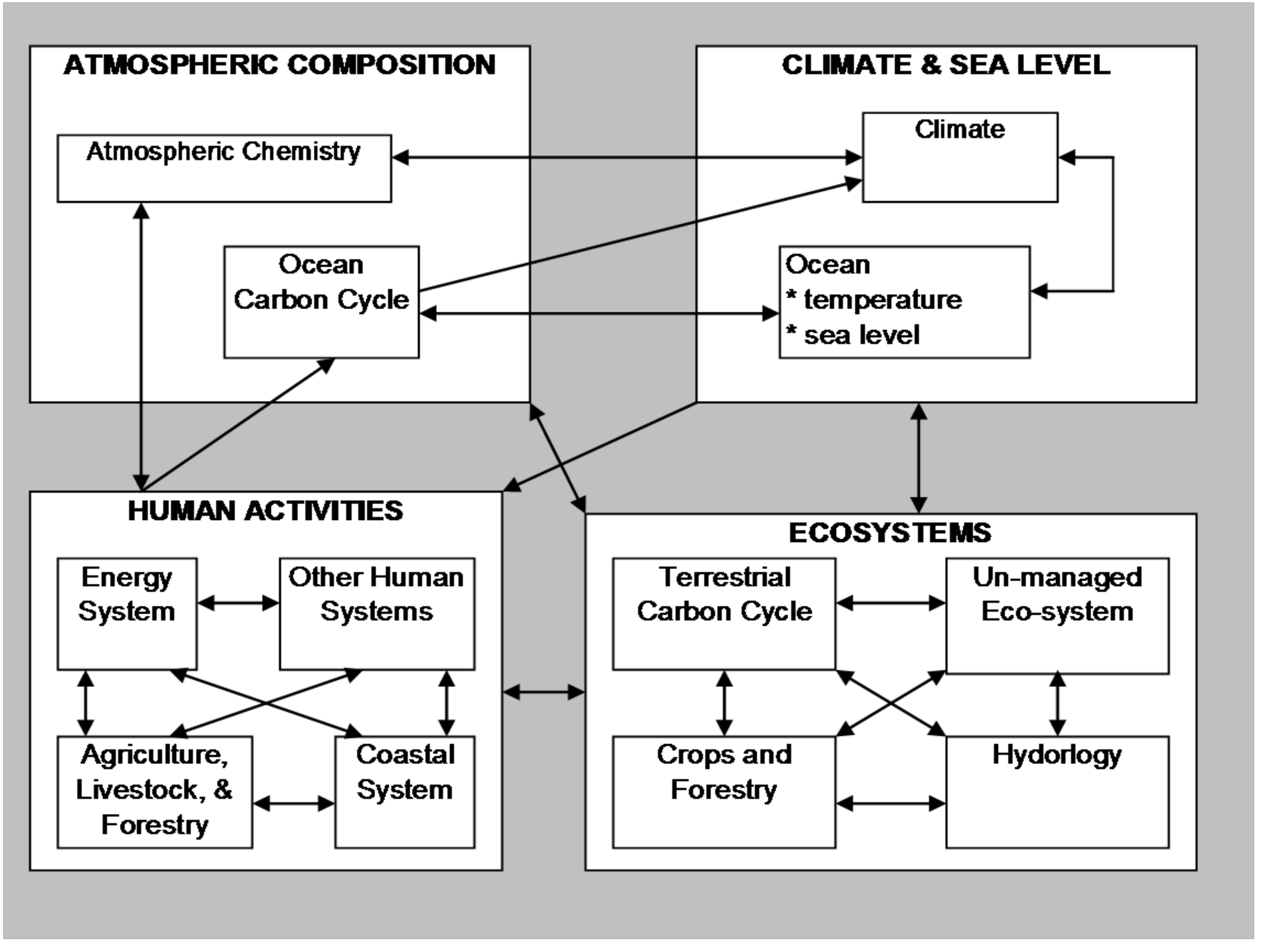
Current approaches omit important dynamics of technological change. A broader framework for analyzing ITC is needed.



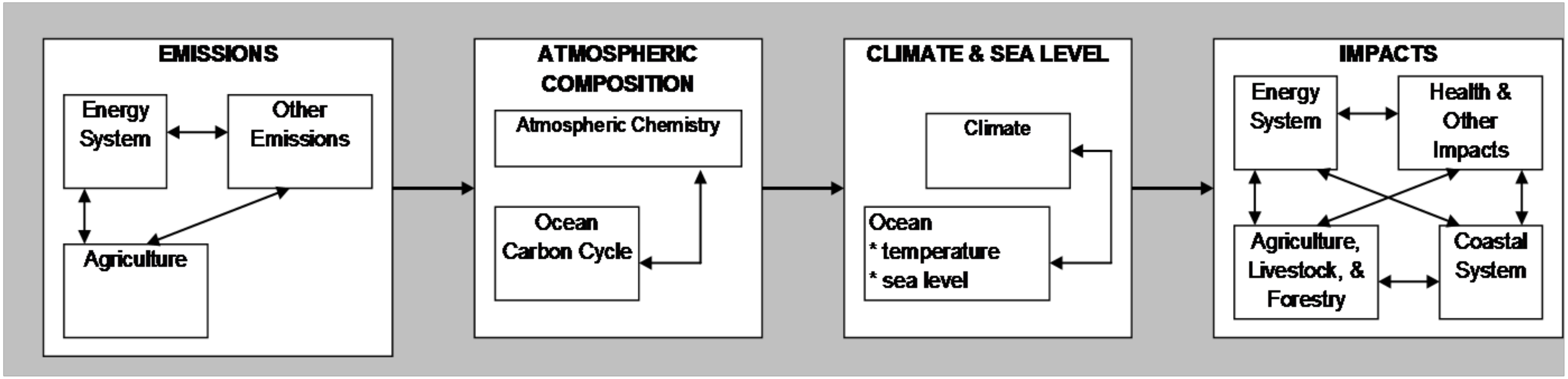
Observations Regarding Current Approaches to Modeling ITC

- Current approaches to ITC provide a good foundation:
  - spillovers
  - innovation incentives and knowledge capital
  - heterogeneous firms and technologies
- Current approaches suggest weak or ambiguous effect of ITC, but underestimate importance:
  - Focus only on R&D-based technological change
    - » learning-by-doing
    - » diffusion or imitation by existing technology
  - Assume continuous, known returns to R&D function (no surprises or discontinuities)
    - » No provision for major innovations
    - » Model only one dimension of technological change (cost)
  - Neglect path-dependence and inertia in changing technology dynamics
- Modeling challenge will be to incorporate enough complexity to realistically capture technology dynamics in a meaningful way.
- Policy challenge will be to use insights from models, but qualify findings with a more complete understanding of technological evolution.

IV. Integrating The Sciences
Are We Integrated or…



…Still End-to-End ?



Do we need Integrated Earth Systems Models?

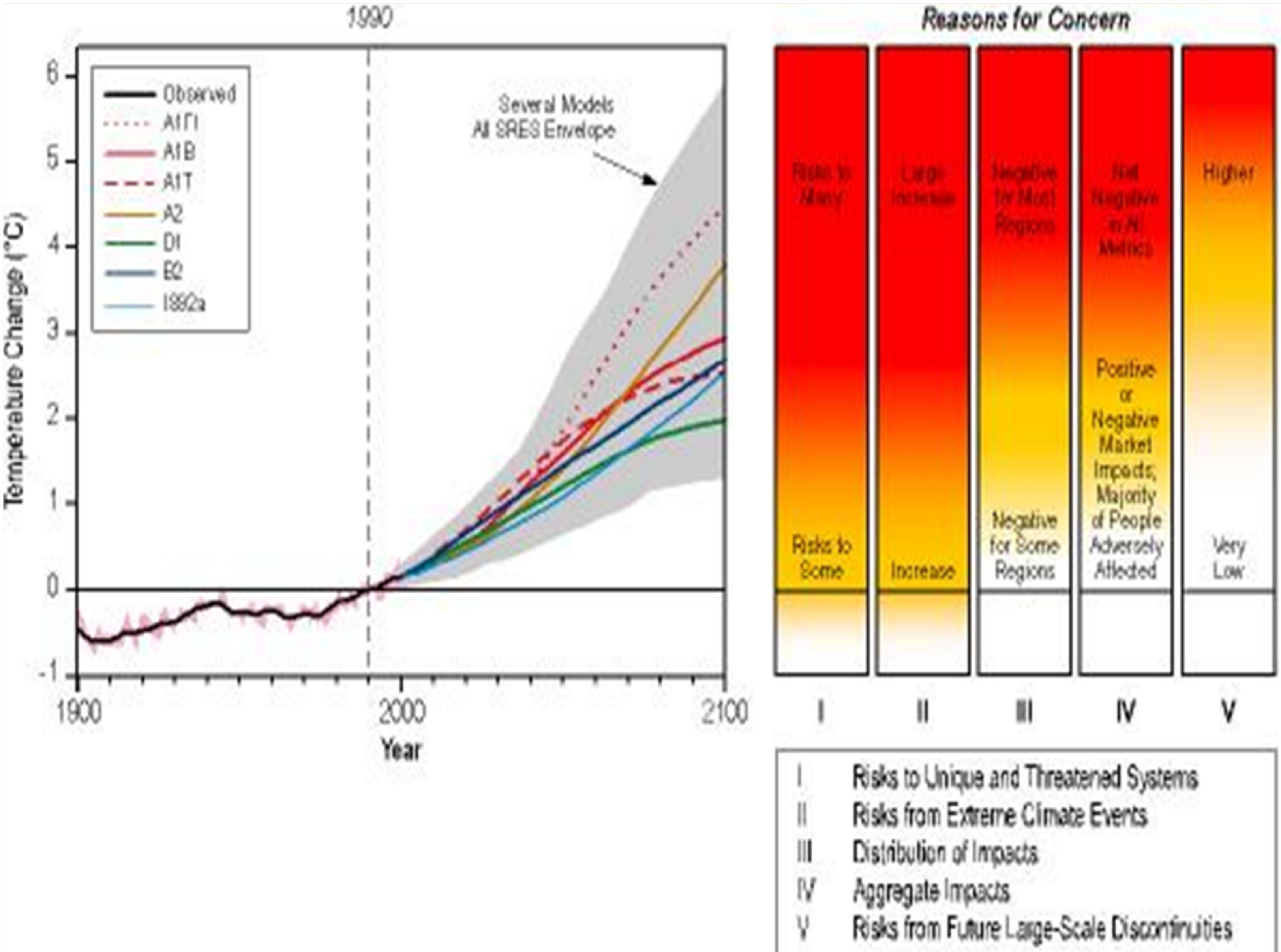
V. Synthesizing The Impacts:
Where We Are In Impacts/Adaptation Analyses

- Reasonable economics estimates in a few sectors
  - Agriculture
  - Forestry
  - Sea level rise
- Preliminary physical impacts representations in others
  - Health
  - Wildlife
  - Water supply
- First order causal mechanisms in others
  - Unmanaged eco-systems
  - Biodiversity
  - Extreme events – both changes in variability and abrupt changes
- How to weigh what we know and don't know and what we can measure or not measure and what we can value and not value is a big challenge

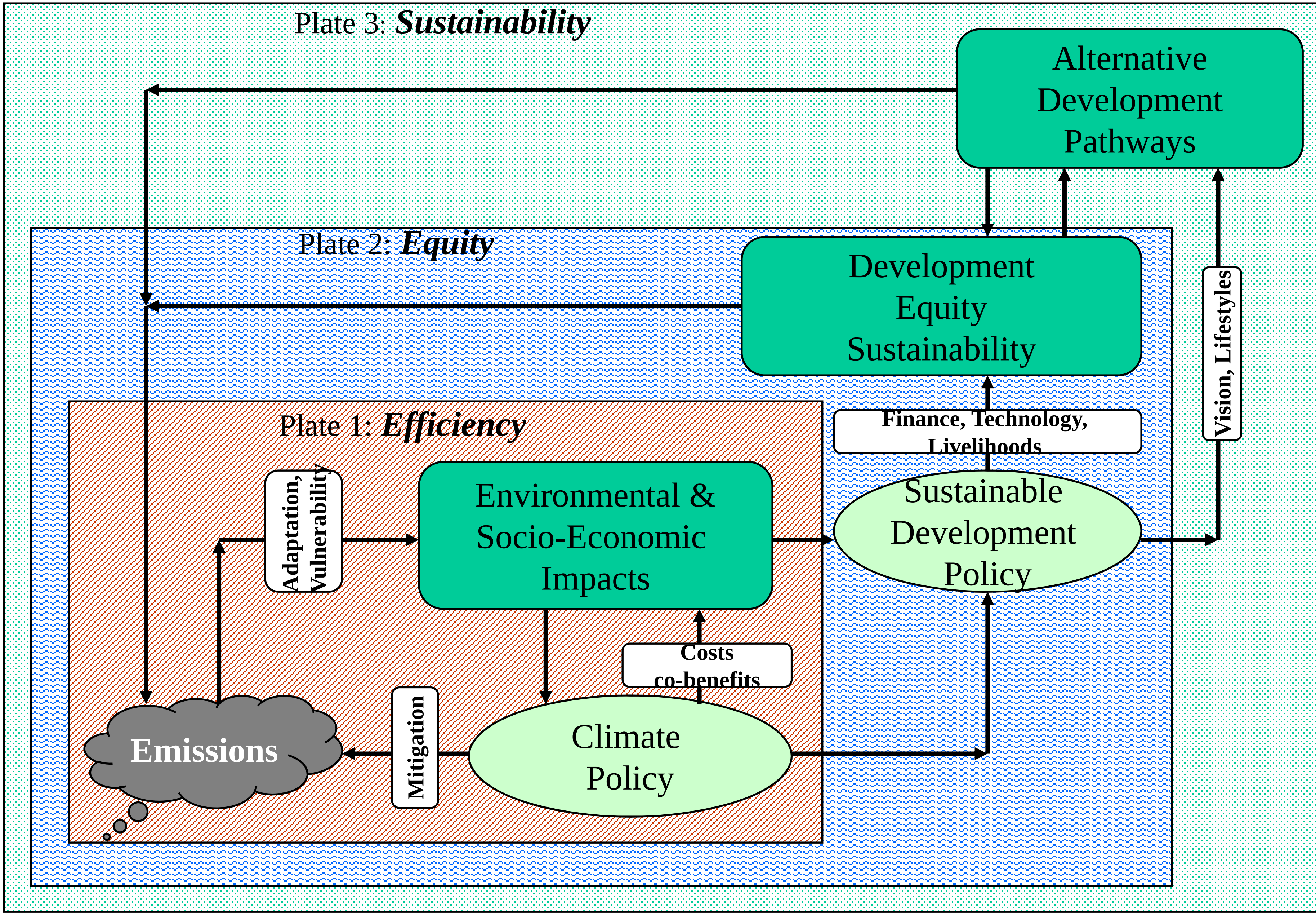
Key Challenges Faced in Projecting Impacts

- Projecting Regional Climate
  - Temperature
  - Precipitation
  - Variability
- Projecting Baseline Conditions
- Transient Versus Equilibrium Impacts
- Factoring In Adaptation
- Valuing Non-Market Impacts

Beyond Flaming Embers ?



VI. Promoting Development



Whither the Poor and Defenseless? A Revealed Preference Study of Climate Change Policy Analyses

<u>Class of World Citizen</u>	<u>Typical OECD (AEA Member?) Analysis</u>	<u>ROW Analysis</u>
2 Billion People Without Markets	What 2 Billion People?	High Priority: Reduce Their Vulnerability
2 Billion In or Near Poverty with Fragile Markets	They Don't Count for Much!	High Priority: Reduce Their Vulnerability
2 Billion Potential Decaf Latté Drinkers	Half Are Stuck In Transition, But the Rest We Can Help	They Can Take Care of Themselves

Potential Areas of Model Refinement (I)

1. Technology/Technology Change
   - Invention
   - Innovation
   - Diffusion
2. Spatial/Temporal Disaggregation
3. Uncertainty
   - In the World, aka Scenario Uncertainty
   - How it Impacts Behavior of Modeled Agents
   - Related to Degree of Foresight Assumed
4. Data
   - Technology, Energy End Uses, Resources
   - Institutions
   - Economic Output, I/O, Fuel Markets, Trade

Potential Areas of Model Refinement (II)

5. Representation of Market Imperfections
6. Representation of "Non-Rational" Behavior
7. Ability to Analyze "Plausible" Policies
   - Standards
   - Sectoral Caps
   - Remedies for Market Imperfections
8. Macro/Microeconomic Integration
9. Public Finance/Financial Market Integration
10. Marrying Conceptual Structures With Data

Integrated Assessment of Integrated Assessments?

- – Peer Reviewed Proposals
- – Peer Reviewed Literature
- – Forum Analysis
- – Model Assessment Projects
- – PCMDI-Like Institution
- – Other

Thank You!

Basic Strategies for Developing Models

- Identify All Potential Questions First, Then Design the Model to Help Address Them
- Develop a Flexible Modeling Architecture That Can Be Easily Adapted to New Problems
- Do Both!

Model Development/Assessment Issues: Common Pitfalls in Policy Modeling

- Lack of Focus
  - Pick a basic model structure without a set of applications firmly in mind
  - Not modifying model in response to new problems
- Mistaking the Model for Reality
  - If its not in the model it probably doesn’t exist
  - Test alternative assumptions only against the model
  - Methodological limitations imply real world restrictions
- Poor Communication of Results
  - Overstating strength of results
  - Omitting key relevant assumptions/qualifications

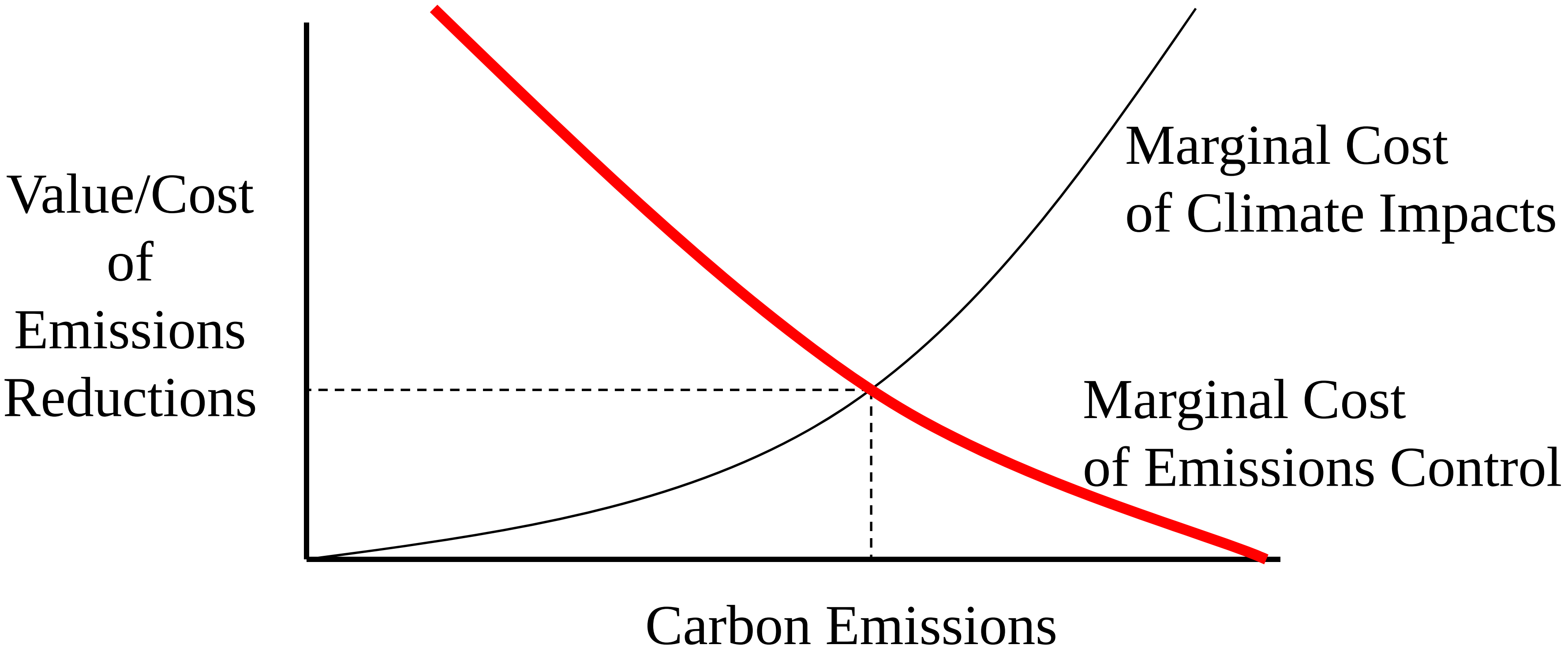
Technology is King

Table 1: Technology Assumptions

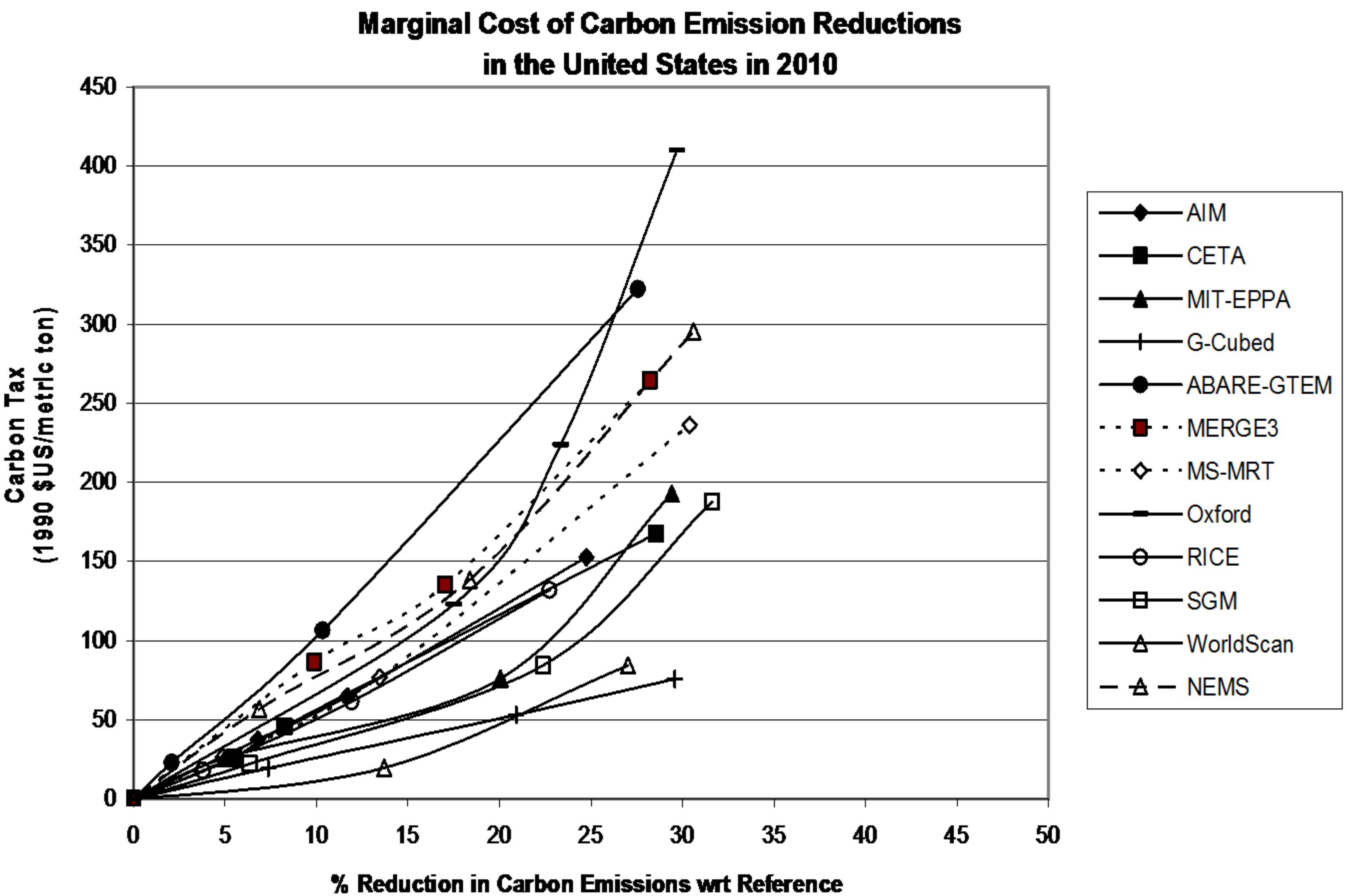
Technology	units	1990 Base	Year 2100 MiniCAM B2	Year 2100 MiniCAM B2 AT
US Automobiles	mpg	18	60	100
Land-based Solar Electricity	1990 c/kWh	61	5.0	5.0
Nuclear Power	1990 c/kWh	5.8	5.7	5.7
Biomass Energy	1990$/gj	$7.70	$6.30	$4.00
Hydrogen Production (CH_4 feedstock)	1990$/gj	$6.00	$6.00	$4.00
Fuel Cell	mpg (equiv)	43	60	98
Fossil Fuel Power Plant Efficiency (Coal/Gas)	%	33	42/52	60/70
Capture Efficiency	%	90	90	90
Carbon Capture Power Penalty (Coal)	%	25	15	5
Carbon Capture Power Penalty (Gas)	%	13	10	3
Carbon Capture Capital Cost (Coal)	%	88	63	5
Carbon Capture Capital Cost (Gas)	%	89	72	3
Geologic Disposal (CO_2)	$/tC	37.0	37.0	23.0

Cost/Benefit Modeling Approach:

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



The Substitution in the Models



The Energy Resource Mix