Integrated Assessment Modeling: An Overview

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CCI/IA Workshop
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Stephen H. Schneider-Champion of the World

I've paid my dues -
Time after time -
I've done my sentence
But committed no crime -
And bad mistakes
I've made a few
I've had my share of sand kicked in my face -
But I've come through

We are the champions - my friends
And we'll keep on fighting - till the end -
We are the champions -
We are the champions
No time for losers
'Cause we are the champions - of the world –

composed by Farrokh Bulsara

Two Schneider Like Quotes

Problem Statement

"Everbody knows people that who are good at disciplinary research often have neither the skills nor personalities to succeed in interdisciplinary research"

- Famous Snowmass Guy 2000

Response/Solution

"Thinks look bad from over here,
Too much confusion and no solution,
Everybody here knows your fear,
Your out of touch and you try too much,
Yesterday's glory won't help us today,
You gotta retire, GET OUT OF THE WAY!"

- Gabriel Mekler/John Kay 1968

Frequently Asked Questions About Snowmass (FAQs)

- Is it true my discipline is the chosen one?

    Are you out of your freekin mind?

- Are we now all true inter-disciplinarians?

    Are you kidding? We have a long way to go.

    Disciplinary standards are woefully insufficient

    We need our own interdisciplinary standards

    Need some kind of Schneider rule/scale

Outline

- Some background questions
- What is integrated assessment
- Where are we in IAM/ESM ing
- Complicated interdisciplinary stuff
- Five Examples (US based work with apologies)
- Directions for the future

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?
  - HIndcasting
  - Model assessment
- Who decides these things?
  - Disciplines, national academies, lawyers, us

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

A Central Question

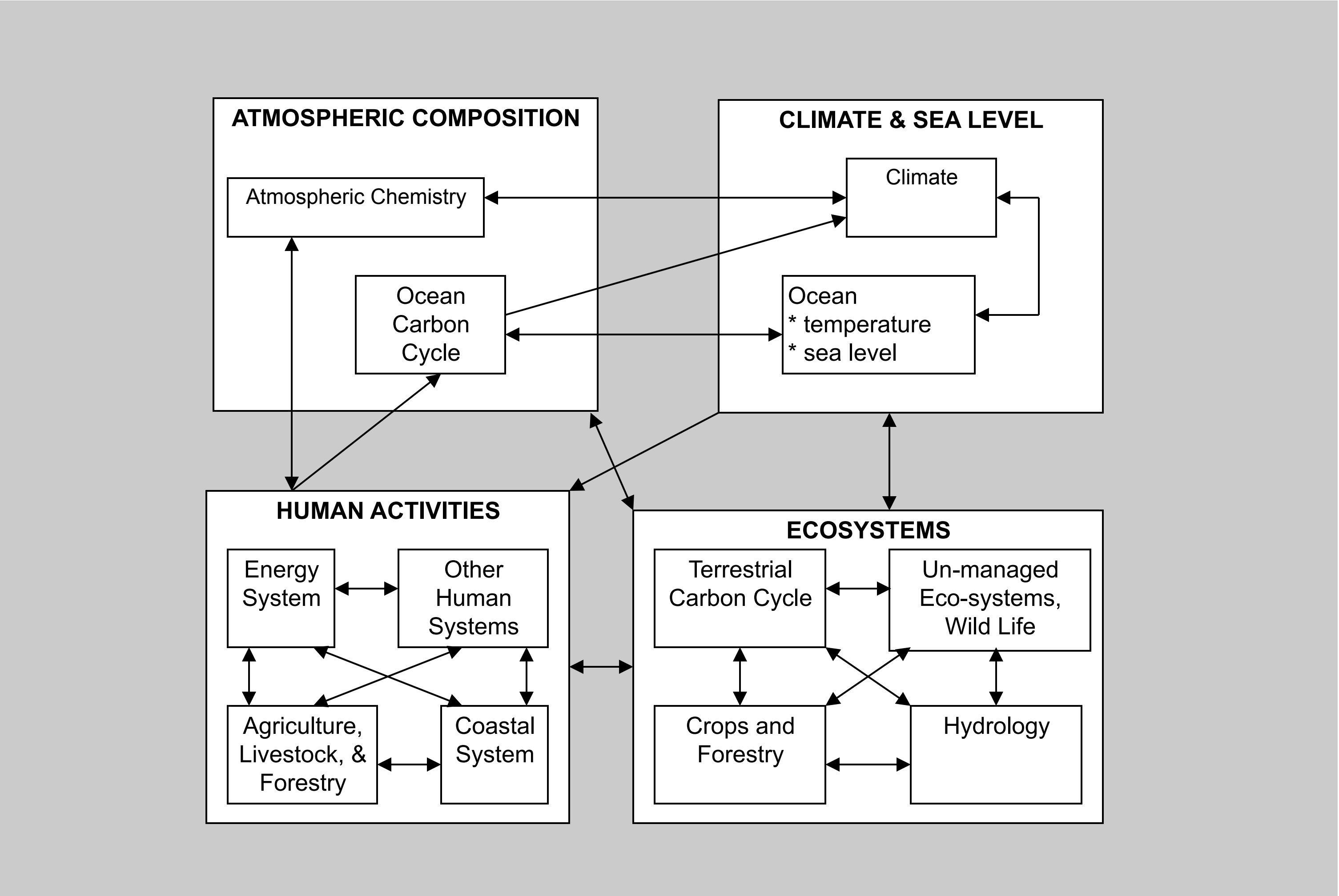
Question

What is a good model? scenario? way to deal with uncertainty? Approach to model assessment?

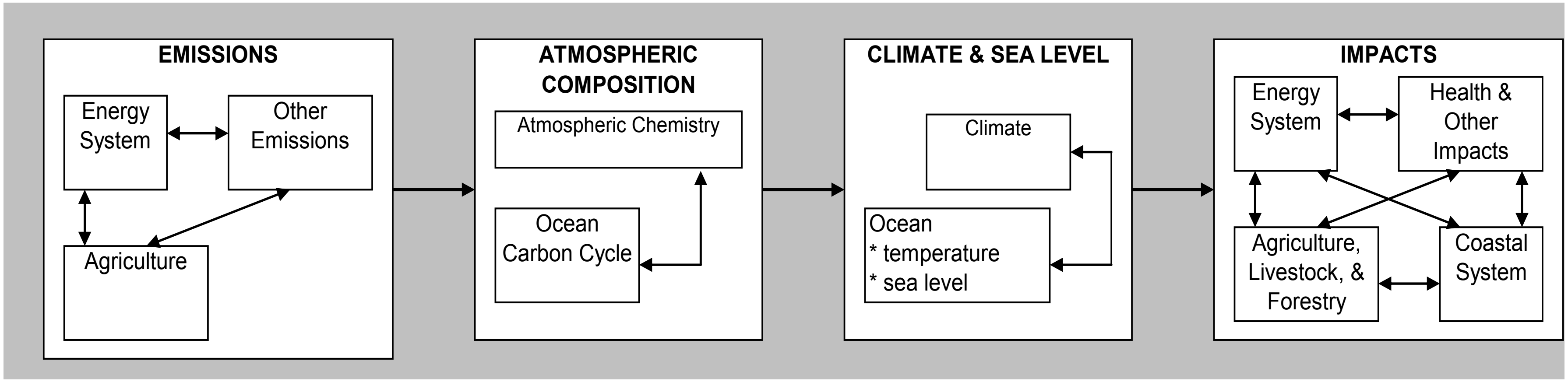
Answer

It depends on the question being asked.

Integrating The Sciences: Are We Integrated or…



...Still End-to-End ?



Do we need Integrated Earth Systems Models?
and if so, how do we construct them?

IAM Progress

- Carbon constraints
- Basic science integration (climate & carbon cycle)
- Ecosystems
- Burden Sharing
- Trade
- Multi-gases & chemistry
- Technology/technological change
- Land use
- Behavior
- Institutions

Basic Concepts of Integrated Assessment

- Ocean/Atmosphere/Atmospheric Chemistry
  - Conservation of momentum
  - Conservation of mass
  - Conservation of energy
  - Chemical Reactions
- Eco-systems
  - Photo-synthesis
  - Conservation of mass
  - Conservation of energy
  - Bio-Geo-Physical-Chemical Processes
- Socio-economic System
  - Birth and Death
  - Resource allocation, optimization and market equilibrium
  - Technology change and choice
  - Investment and Growth

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

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

Things One Would Like to Track in a Fully Integrated Assessment Model

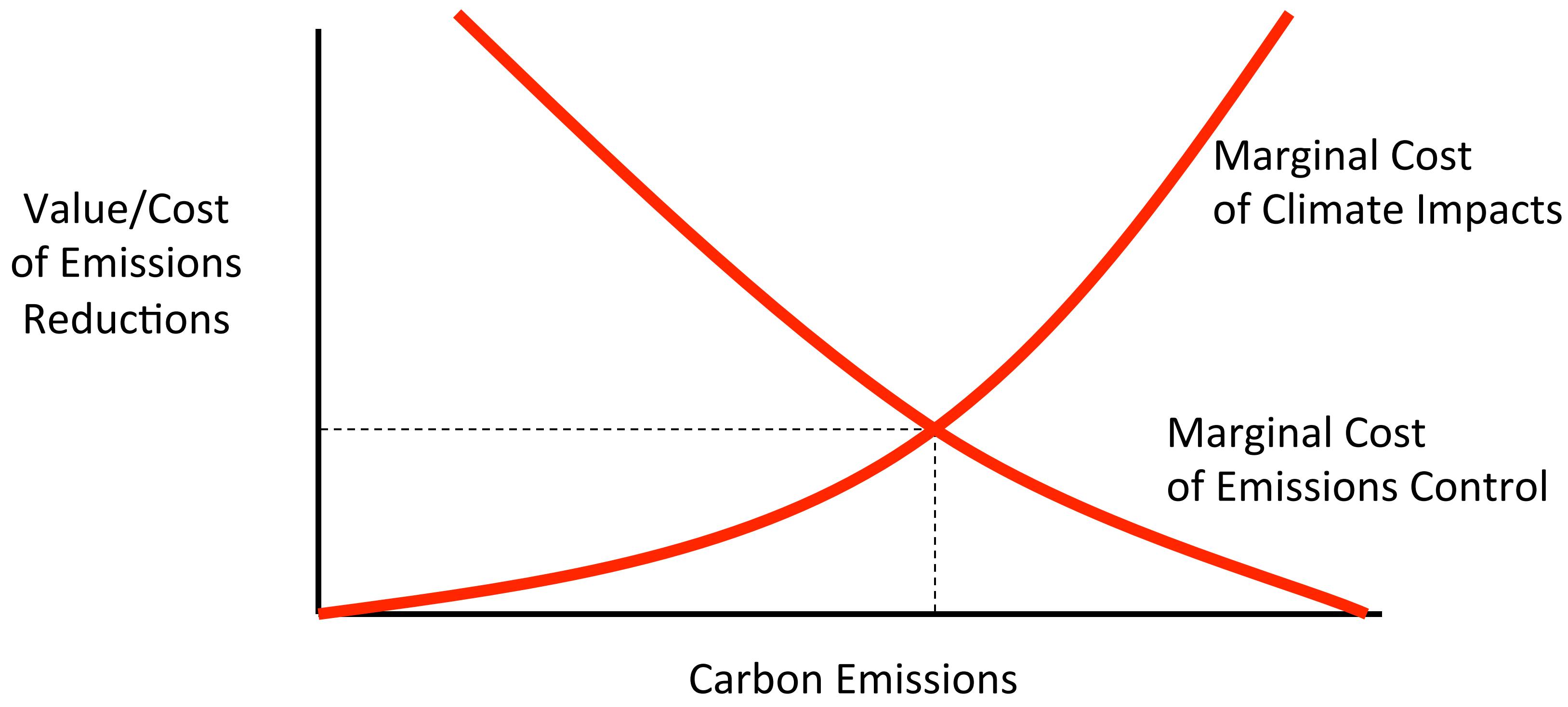
- Temperatures
- Pressures
- Carbon
- Methane
- N2O
- F-Gases
- Aerosols (Sulfur, Organic & Black carbon)
- VOCs
- Sox, Nox, Mercury, Aerosols, Ozone, PM, Concentrations
- Water
- Salt
- Nitrogen
- Land Use
- People
- Capital Stock (Infrastructure, Buildings, Equipment, Human Capital))
- Technologies
- Institutions
- Etc.

Complex IAM Interface Accounting

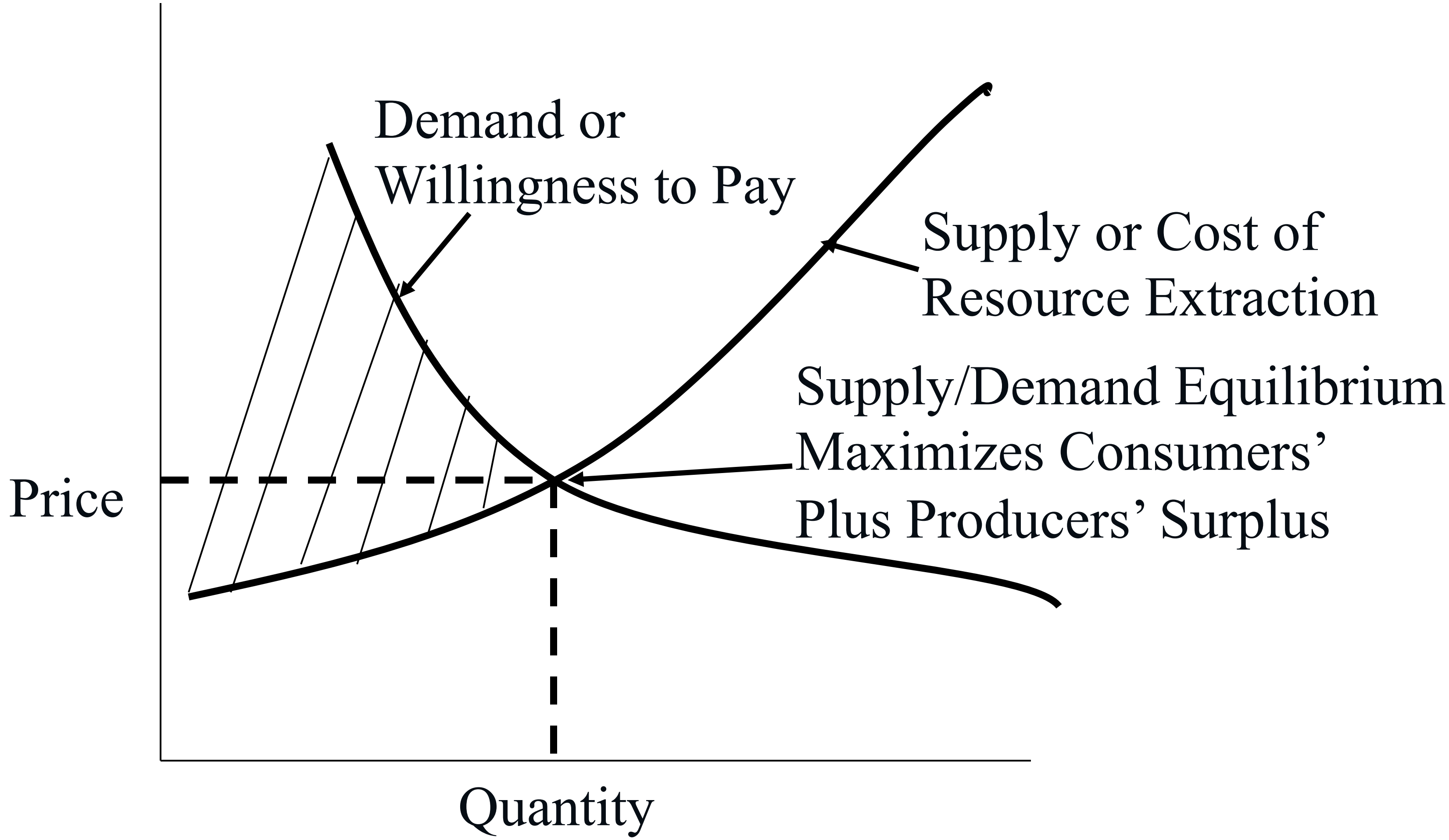
- Land Use
- Water
- Carbon
- Nitrogen
- Aerosols
- Methane

Example #1: DICE/RICE Cost/Benefit Modeling Approach

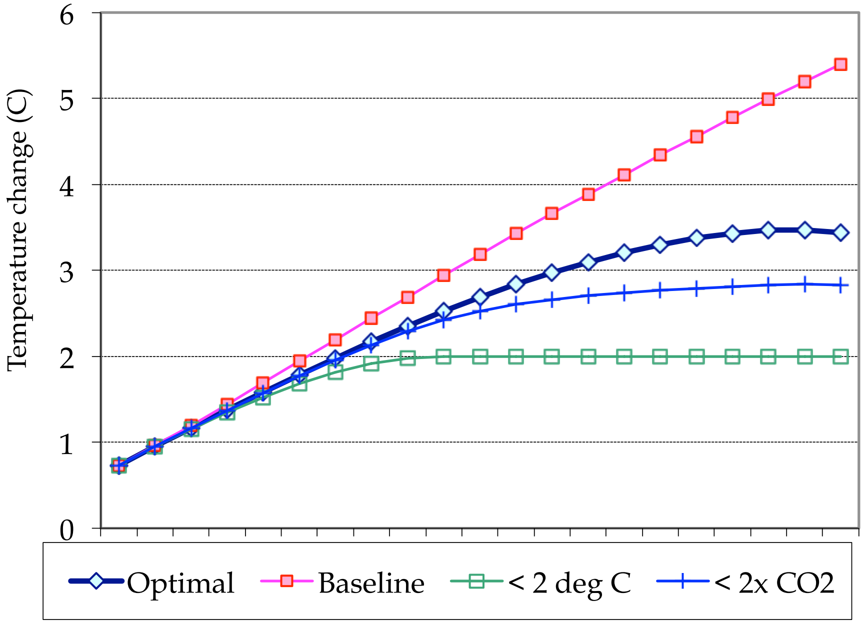
Balancing the Costs of Controlling Carbon Emissions Against the Costs of the Climate impacts They Cause

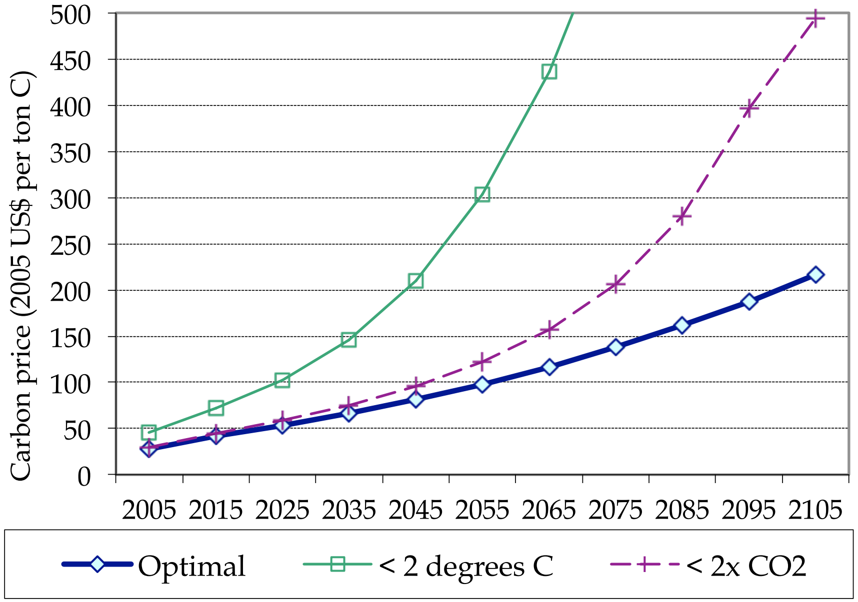


Supply/Demand Equilibrium



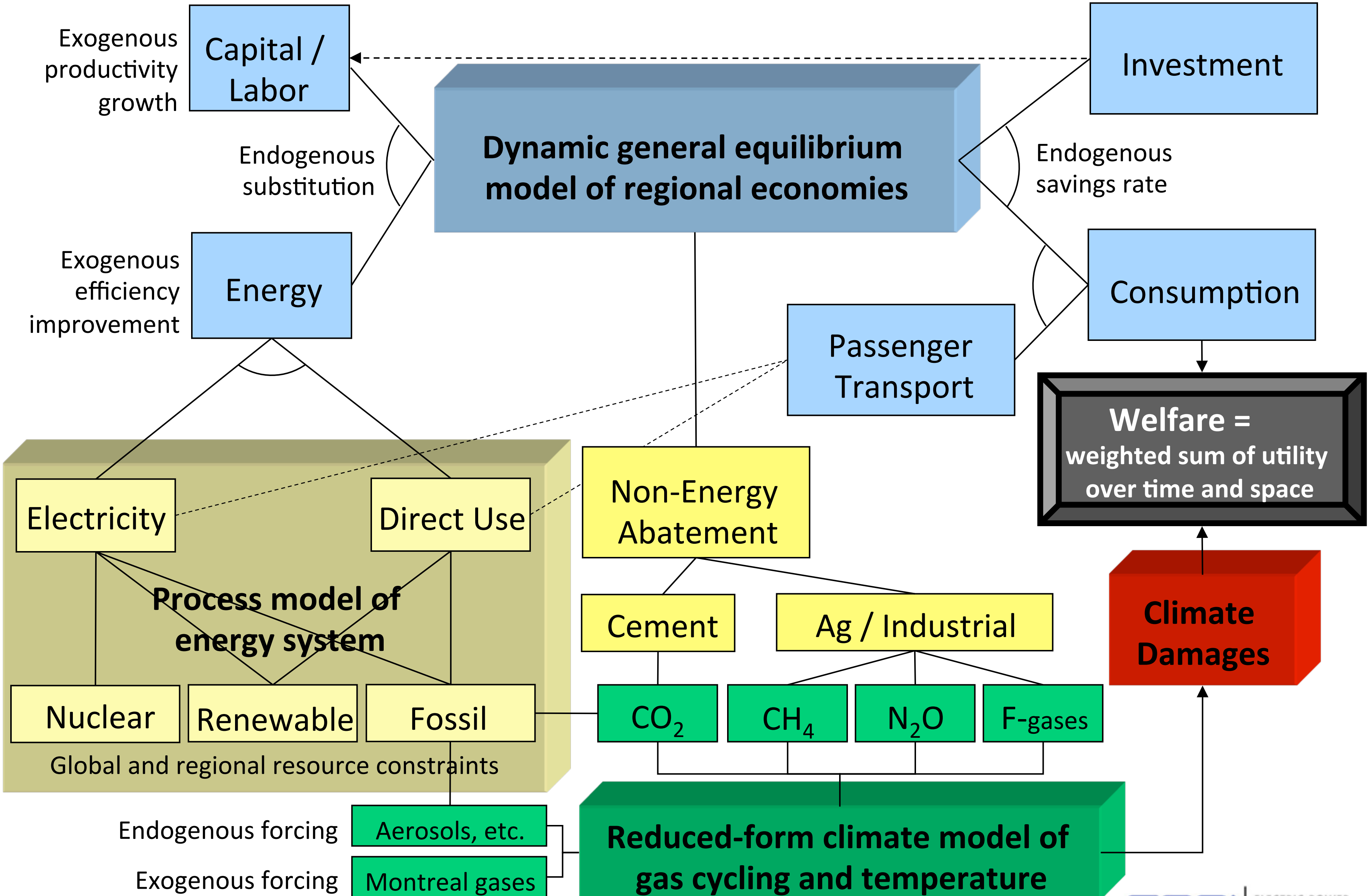
DICE/RICE RESULTS





Example #2: MERGE

A Model for Evaluating Regional and Global Effects of GHG Policies



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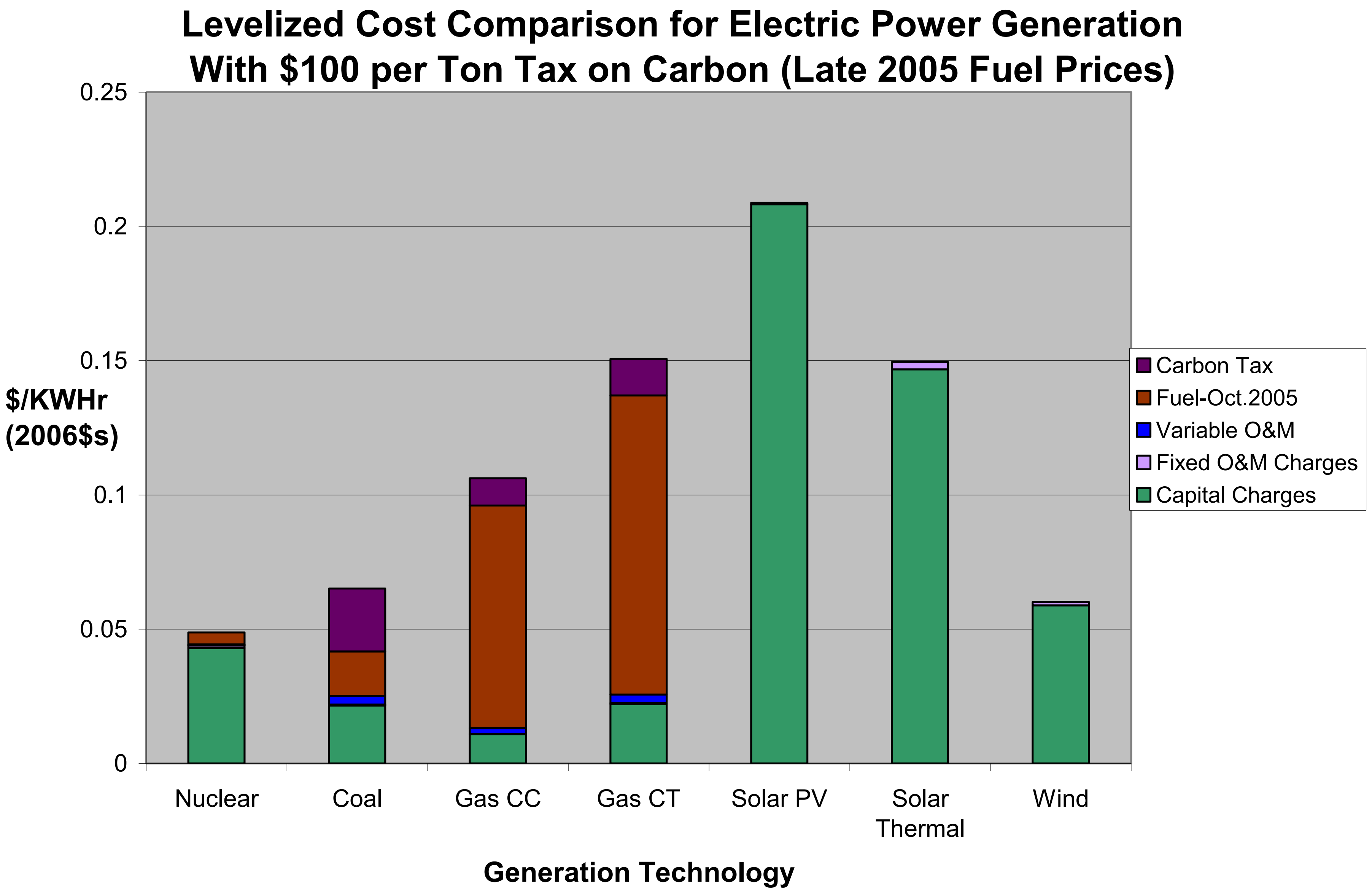
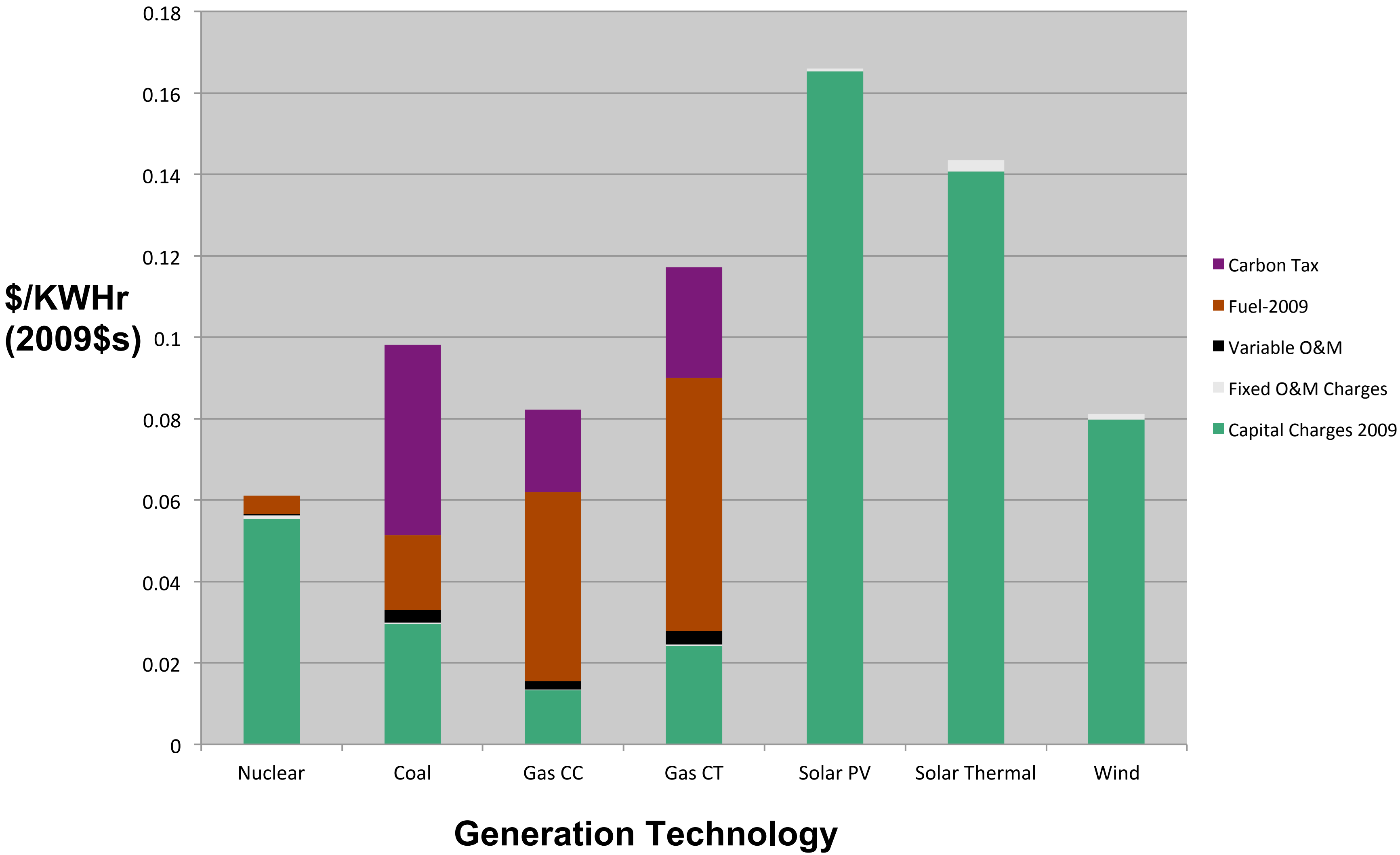
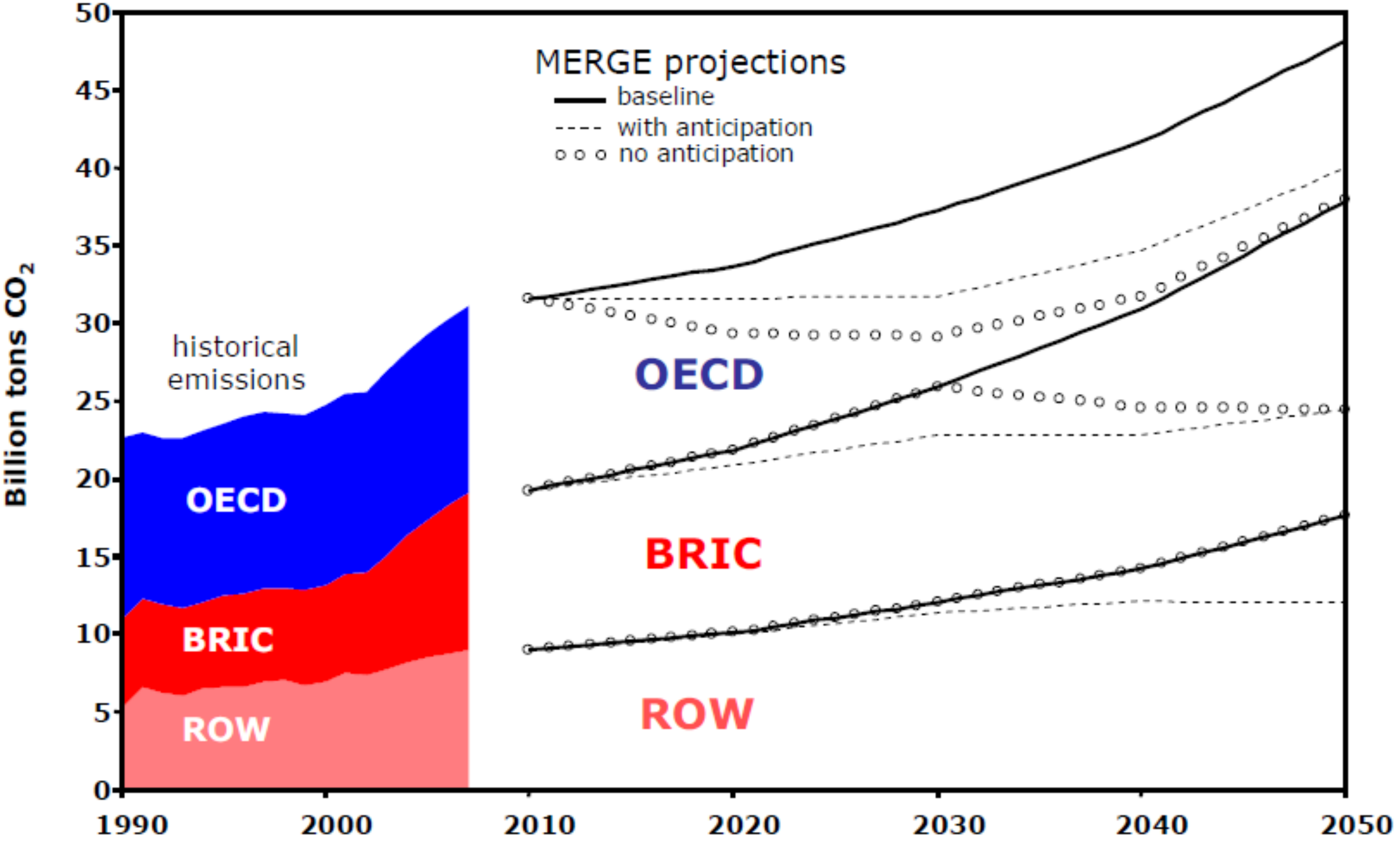
EPRI ELECTRIC POWER RESEARCH INSTITUTE


Levelized Cost Comparison for Electric Power Generation
With $100 per Ton Tax on Carbon (Late 2005 Fuel Prices)
0.25
0.2
0.15
0.1
0.05
0
$/KWHr
(2006$s)
Carbon Tax
Fuel-Oct.2005
Variable O&M
Fixed O&M Charges
Capital Charges
Nuclear
Coal
Gas CC
Gas CT
Solar PV
Solar Thermal
Wind
Generation Technology

Levelized Cost Comparison for Electric Power Generation With $200 per Ton Tax on Carbon (2009 Fuel Prices)



Expectations of future commitments leads to advanced energy planning and reduced cost

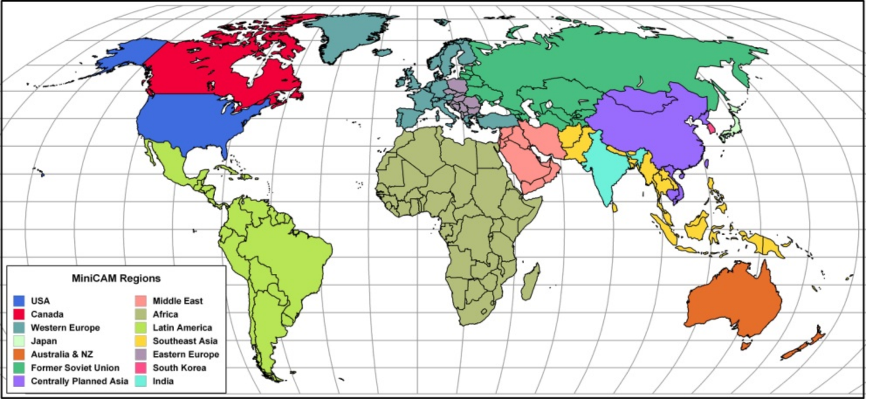


Expectations of future commitments leads to advanced energy planning and reduced cost

Table 1. Savings from Anticipation.

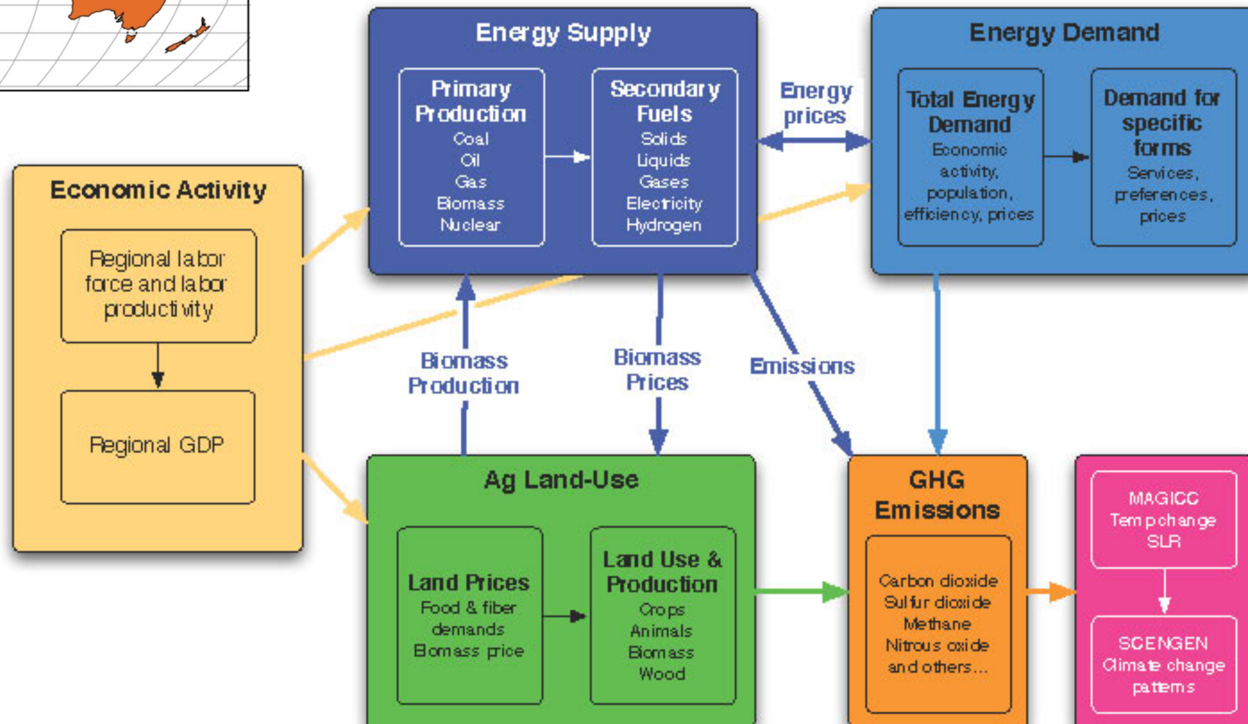
Reductions in the present value of GDP losses over the 21st century with anticipation of future targets by developing countries.

OECD	51%
BRIC	31%
ROW	44%
World	41%



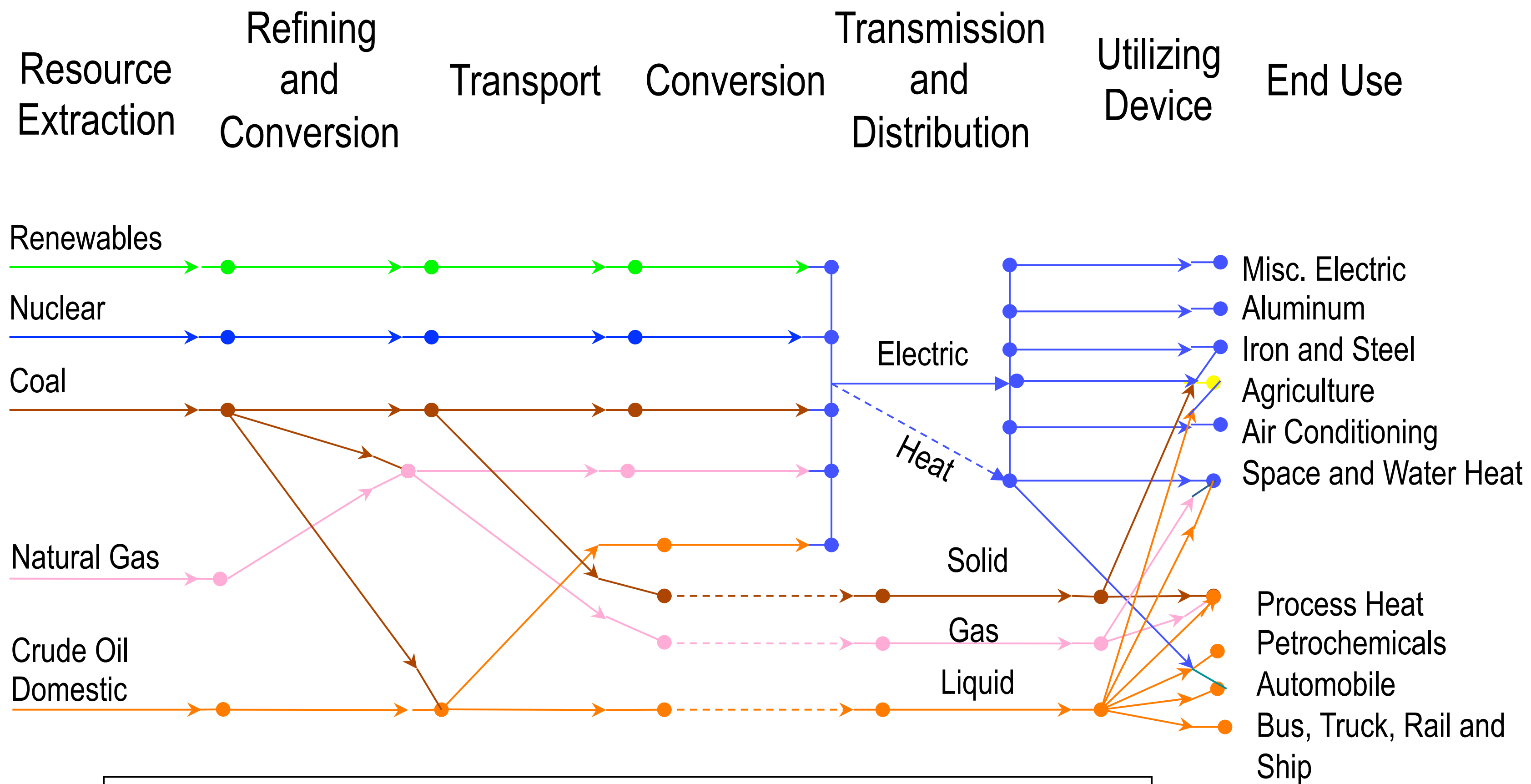
Example #3: GCAM

- Energy-Agriculture-Economy Market Equilibrium
- 14 Global Regions – Fully Integrated
- Explicit Energy Technologies – All Regions



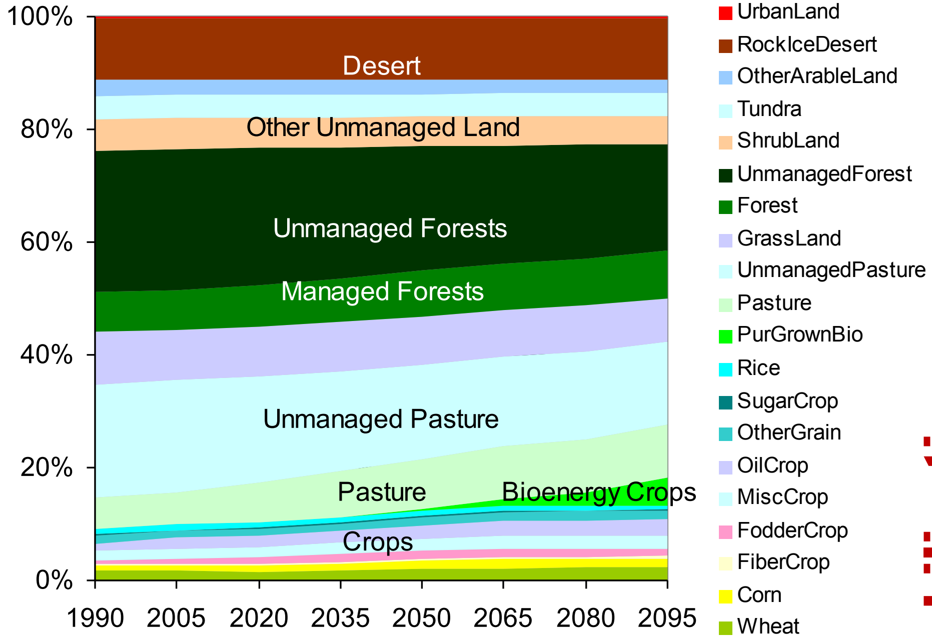
- Fully Integrated Agriculture and Land Use Model
    - 15 Greenhouse Gases and Short-lived Species
    - Typically Runs to 2100 in 15-year time steps

Simplified Reference Energy System



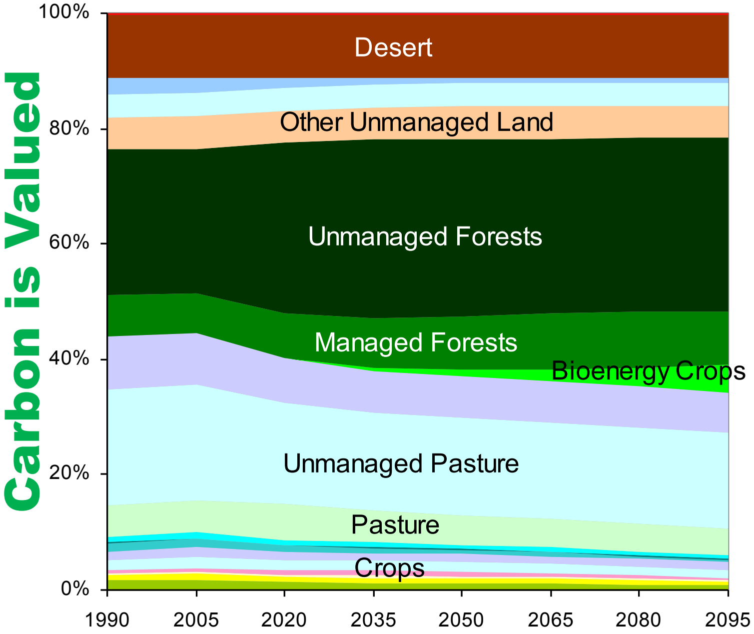
MARKAL
Objective: Minimize Energy System Costs
Constraints: Satisfy Energy Demands
Use Only Available Resources
Convert Energy Forms at Efficiencies of Available Technologies

The Land Use Implications of Stabilizing at 450 ppm When Terrestrial Carbon is Valued

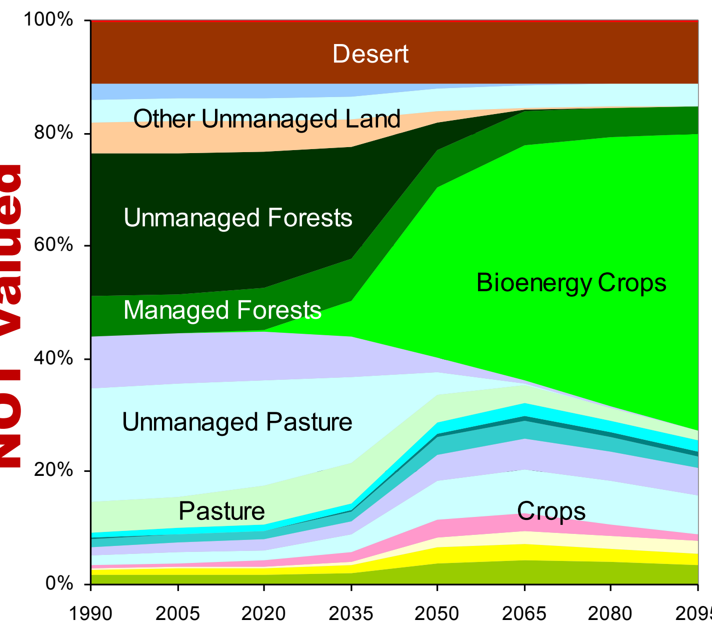


Reference Scenario

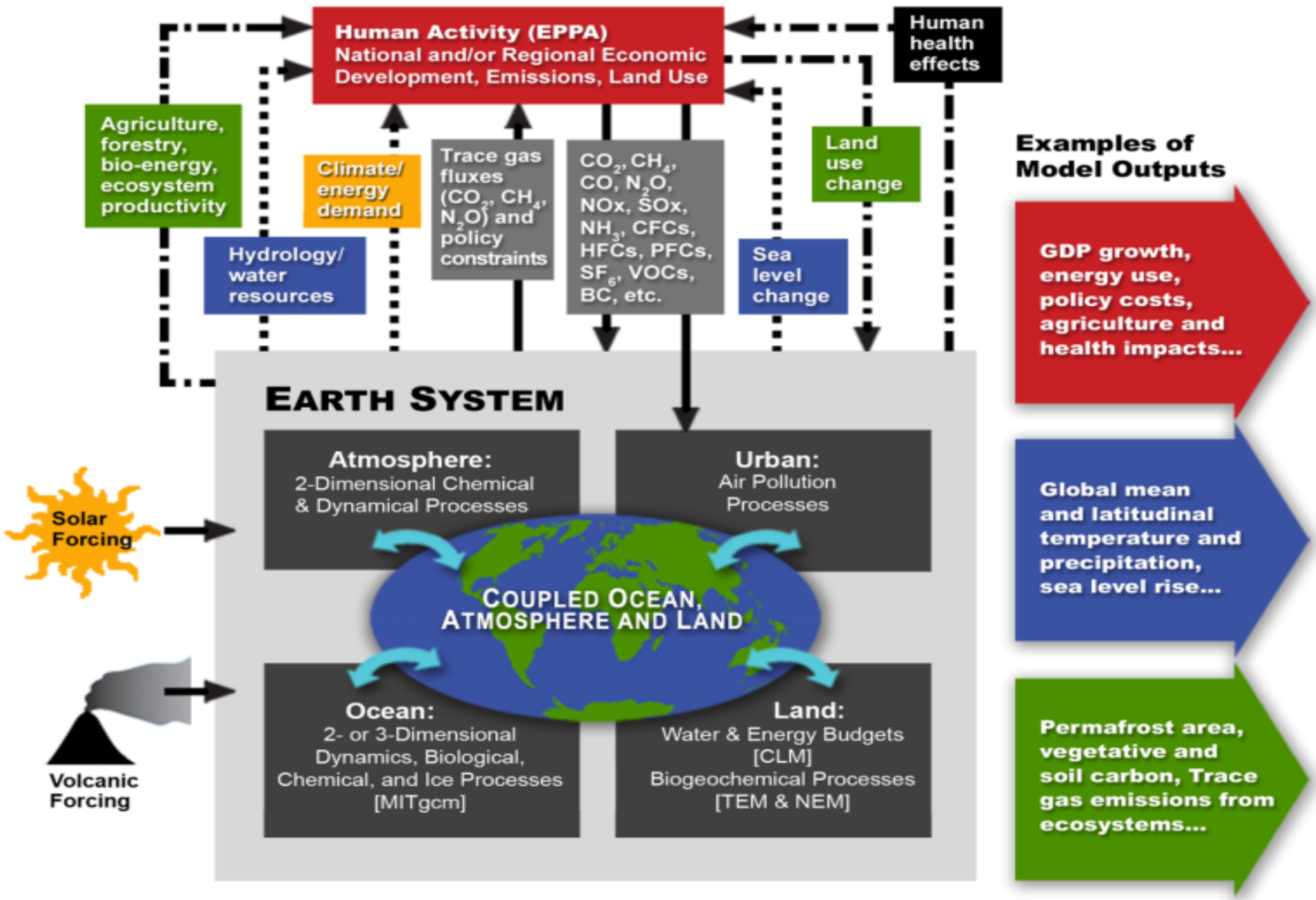
450 ppm Stabilization Scenario When ALL Carbon is Valued



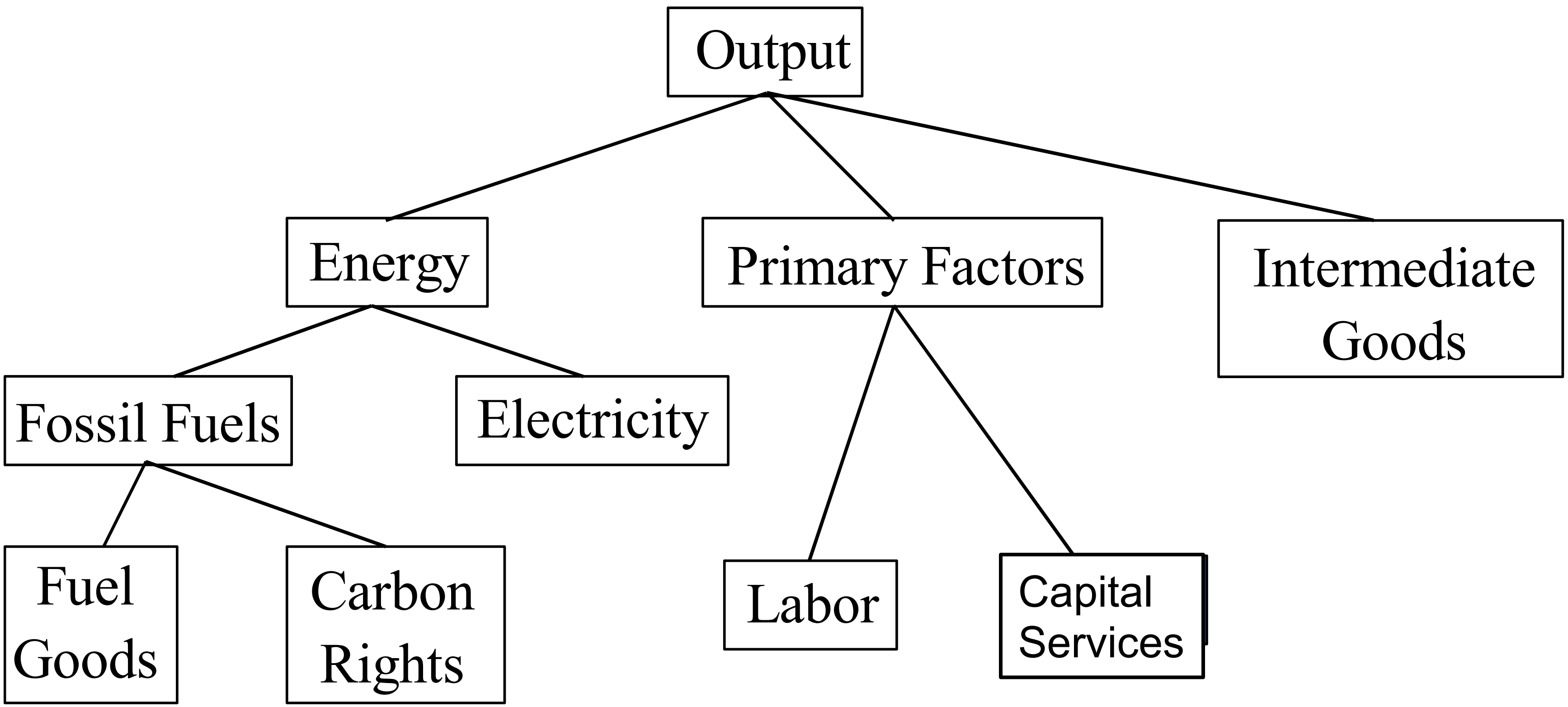
450 ppm Stabilization Scenario When Terrestrial Carbon is NOT Valued



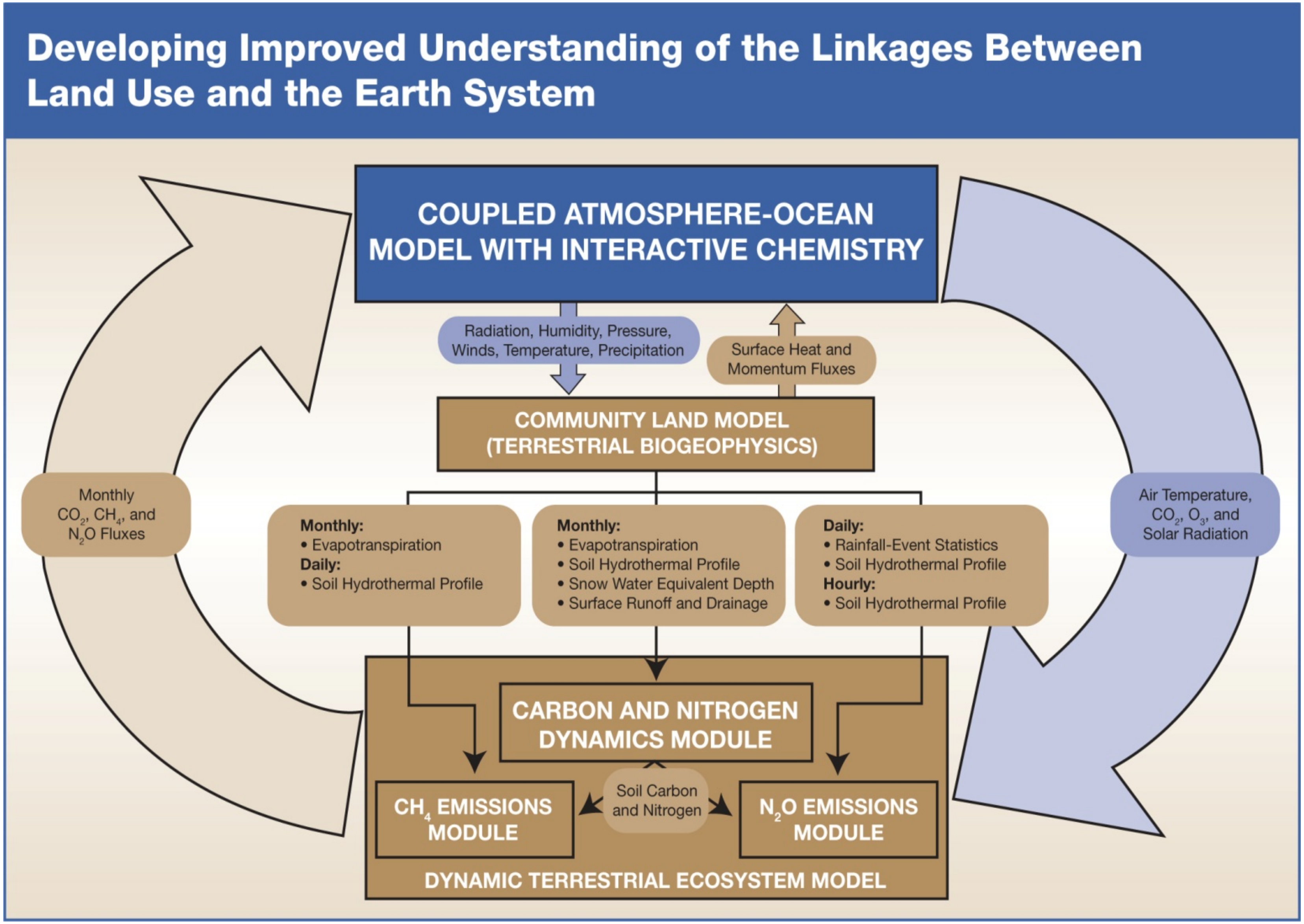
Example #4 & #5: MIT – IGSM/EPPA



Assessing Economy Wide Feedbacks: CGEs-Using Economy-Wide Production Functions



Example #4 MIT IGSM



Exploring the Regional Consequences of a Changing Climate on the Terrestrial Environment

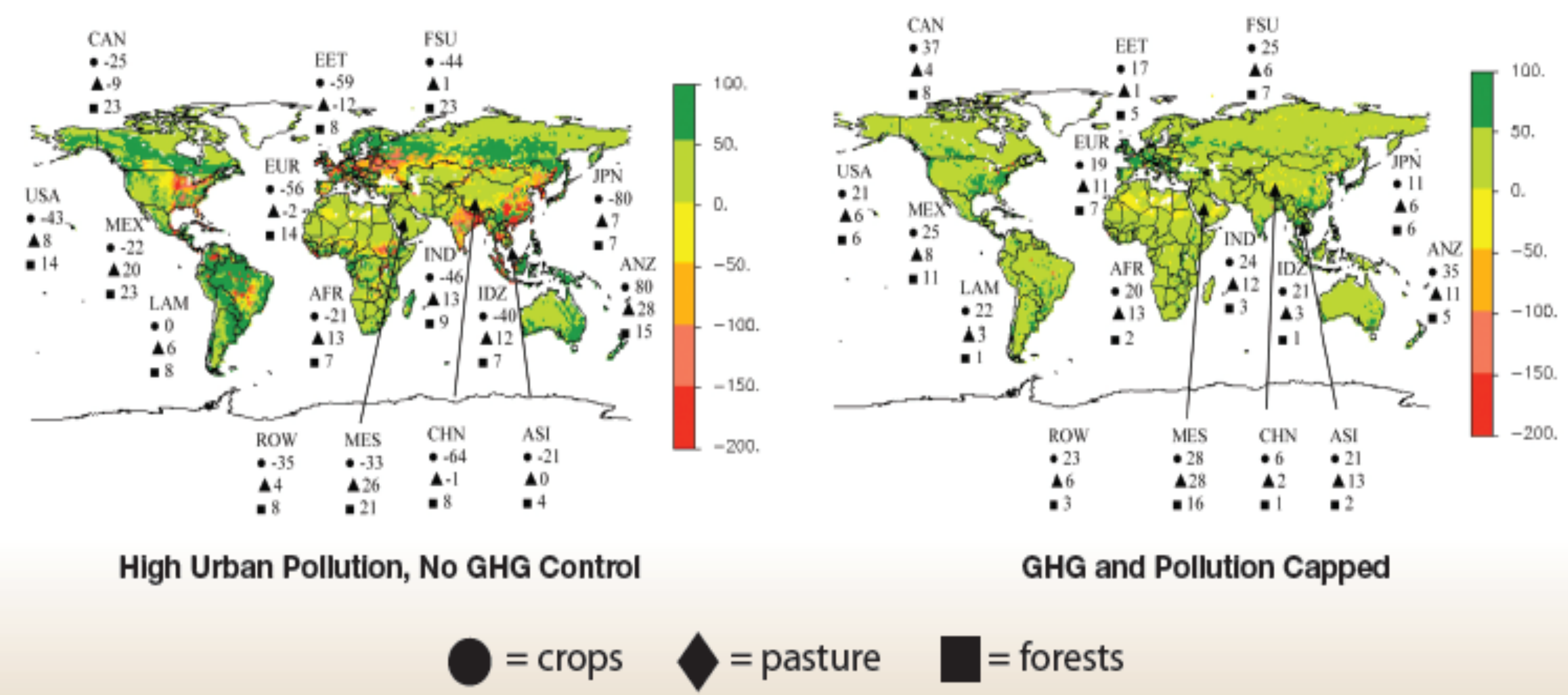
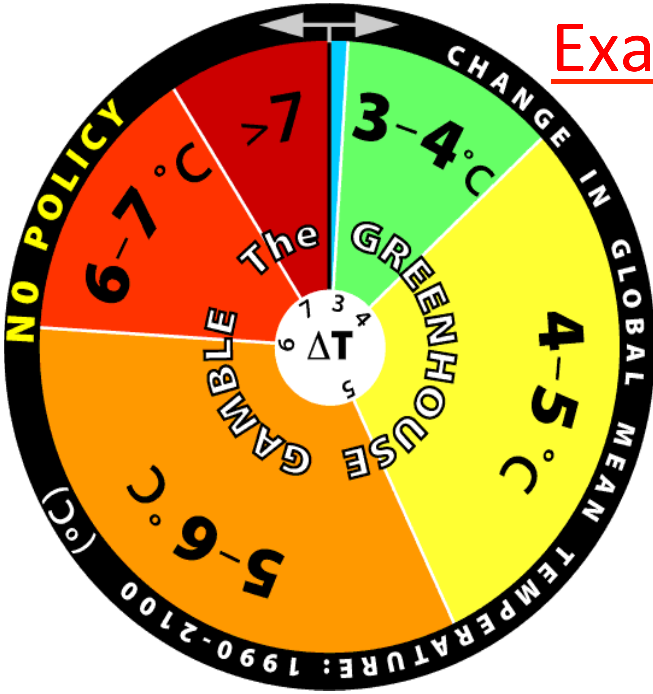


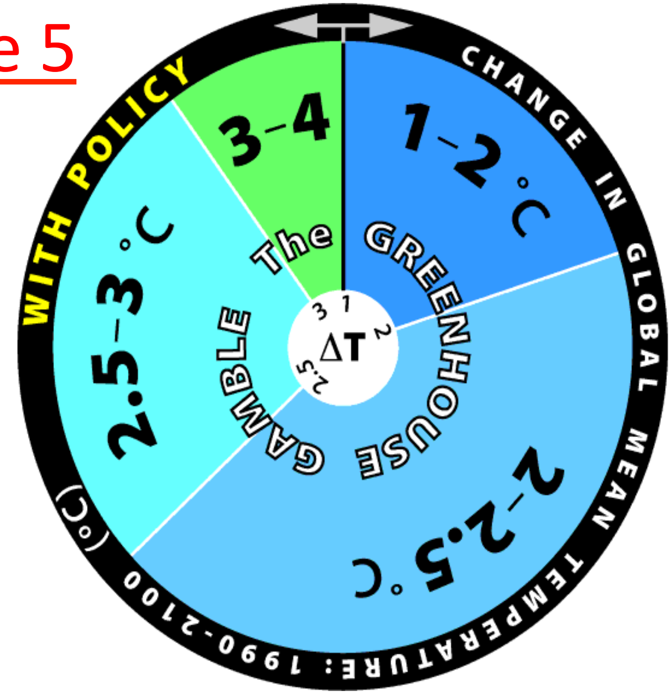
Fig. 3.9. Exploring the Regional Consequences of a Changing Climate on the Terrestrial Environment. Crop, pasture, and forest productivity are influenced significantly by climate change, CO_2 fertilization, and damage from ozone resulting from urban air pollution. For each of the economic regions in MIT's IGSM, the figures show the effects on yield (crops) and net primary productivity (pasture and forestry) between 2000 and 2100 ($gC/m^2/yr$).

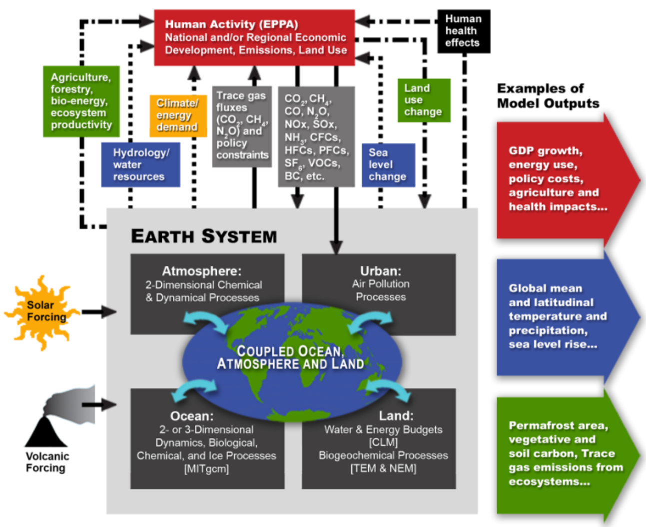
Without policy – emissions and climate response uncertain

With policy – fixed emissions (675 ppm CO2eq), climate response uncertain

Example 5







MIT IGSM

The MIT IGSM included uncertainty in both physical and social science/economics aspects, captured in formal uncertainty analysis to generate probabilistic outcomes, represented here as Greenhouse Gamble wheels.

U.S. DEPARTMENT OF **ENERGY** | Office of Science

SCIENCE CHALLENGES AND FUTURE DIRECTIONS:

Climate Change Integrated Assessment Research

Report from the U.S. Department of Energy
Office of Science
Office of Biological and Environmental Research
Workshop on Integrated Assessment, November 2008

JUNE 2009

Major Challenges
(from DOE State of IAM /Janetos, et al. Report)

- Strengthening Representation of Complex Interactions Among Energy, Environment, and Economics
- Incorporating Impacts, Adaptation, and Vulnerability
- Extending to Regional Scales and Shorter Times
- Quantifying Uncertainties in Models and Data
- Linking Climate Models and Communities – ESM's, IAM's, and IAV
- Advancing Community Model Approaches and Accessibility

Directions for the Future (2)

- Policy Driven Data, Model and Analysis Development
  - More "integrative science"
  - NAS ACC Advancing the Science report (Matson, Dietz, et al.)
  - Balance between "discovery" and "integrative science"?
- Need to get away from free societies=free markets=perfect markets=welfare maximization: Importance of institutions
- Demand, behavior, technology and incentives
- Sequential decision making under uncertainty
- Integrated technology assessment
  - e.g., climate
  - Need much better approach to inter-disciplinary research
- Better integration of data driven and structural models
- Put additional computational power to good use
  - Hardware, software, graphics/GIS

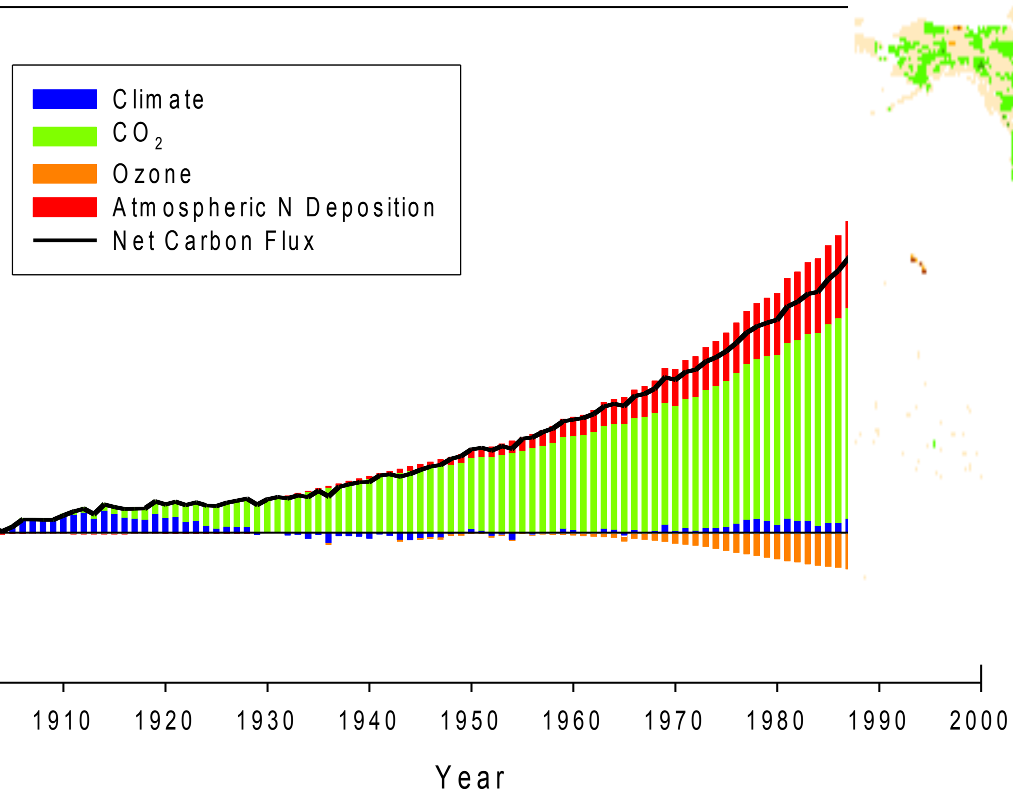
The End

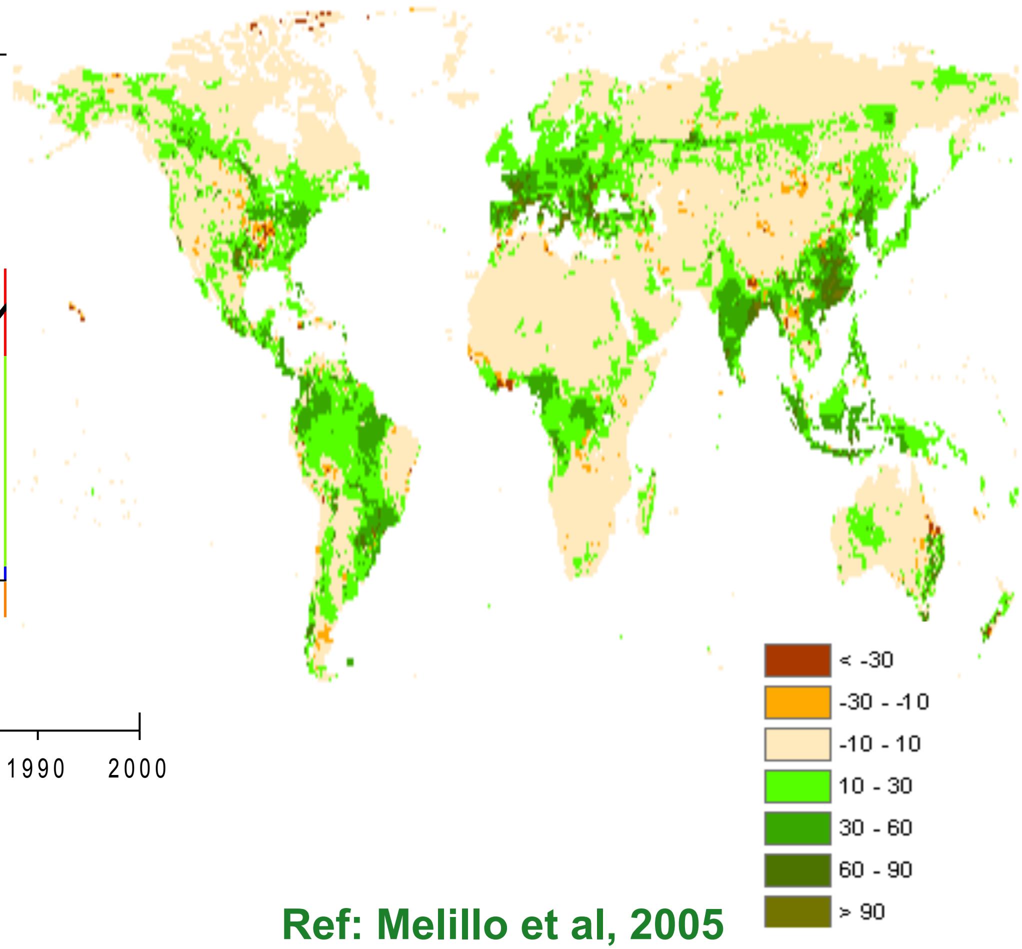
Model Development/Assessment Issues: Common Pitfalls in Policy Modeling

- 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

But the ozone that is a byproduct of certain human activities does become a problem at ground level and this is what we think of as 'bad' ozone. With increasing populations, more automobiles, and more industry, there's more ozone in the lower atmosphere. Since 1900 the amount of ozone near the earth's surface has more than doubled. Unlike most other air pollutants, ozone is not directly emitted from any one source. Tropospheric ozone is formed by the interaction of sunlight, particularly ultraviolet light, with hydrocarbons and nitrogen oxides, which are emitted by automobiles, gasoline vapors, fossil fuel power plants, refineries, and certain other industries.

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

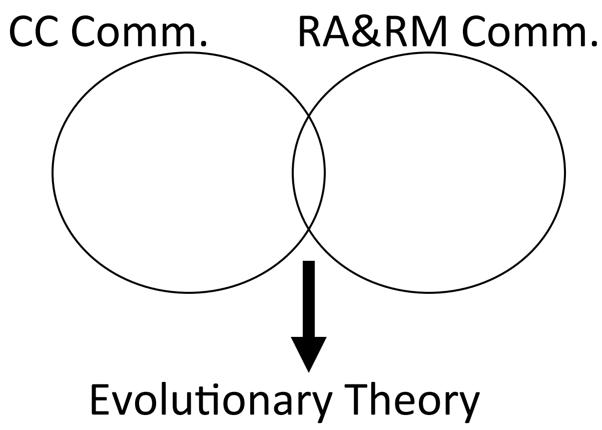




Ref: Melillo et al, 2005

Biggest Challenges Facing Integrated Earth Systems Assessment

- Integration (Strategic Cyclical Scaling)
- Uncertainty
- Abrupt Change
- Sustainable Development
- Technology
- Intertemporal Equity and Discounting
- And Jerks!



Schneider 1997 IAM Generations Paper

I. Premethodological (essentially unintegrated) assessments
- climatic determinism (naive association of regional climatic and social factors)
- case studies in which climatic variations at a region are associated with environmental or societal "responses" (e.g., 1846 potato blight in Europe or 1970s Sahelian drought and its suspected impacts)
- direct cause and effect links without feedbacks (e.g., value of coastal damage made equal to inundated property market values with no adaptation)

II. Second generation (some integration) climatic impact and policy assessments
- 2 × CO_2 equilibrium snapshots (or simple time varying CO_2) GCM scenarios
- no aerosols or other heterogeneous radiative forcings
- no realistic transient climate change scenarios
- simple (or no) landscape changes
- simple (or no) endogenous adaptation/technological change
- time and space variations in climate and impact sectors assumed substitutable
- no stochastic variability of weather, economy or technology variables
- simple (or no) representation of non-market impacts
- may be multi-sector, multi-biome and multi-regional, but limited subsets of species, sectors or regions
- conventional discounting applied equally to impacts and mitigation costs
- simple (or no) representation of uncertainty via probability distributions

III. Third generation (partly integrated) climatic impact and policy assessments
- includes more realistic transient scenarios of heterogeneous radiative forcings driving coupled Earth systems models
- stochastic variability explicitly included
- adaptation/technological change endogenized
- land use changes (including urbanization) endogenized
- individual species and communities may be simply represented
- alternative discounting assumptions explored
- subjective opinions from decision analytic surveys endogenized and uncertainties explicitly treated via probability distributions

IV. Fourth generation (more integrated) climatic impact and policy assessments
- synergism among habitat fragmentation, exotic species invasions, chemical releases and climatic changes explicitly treated
- biodiversity and ecosystem services (i.e., "non-market" nature) endogenously treated
- plausible biogeophysical surprises explicitly considered
- alternative demographic, political and macroeconomic processes endogenously considered (i.e., inclusion of changes in human behavior at various levels)

V. Fifth generation (largely integrated) climatic impact and policy assessments
- changing value systems explicitly considered
- surprises to social systems and values explored