Sustainability Research/Indicators via Integrated Assessment Modeling

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Where Do We Stand in Advancing the Scientific Foundation”

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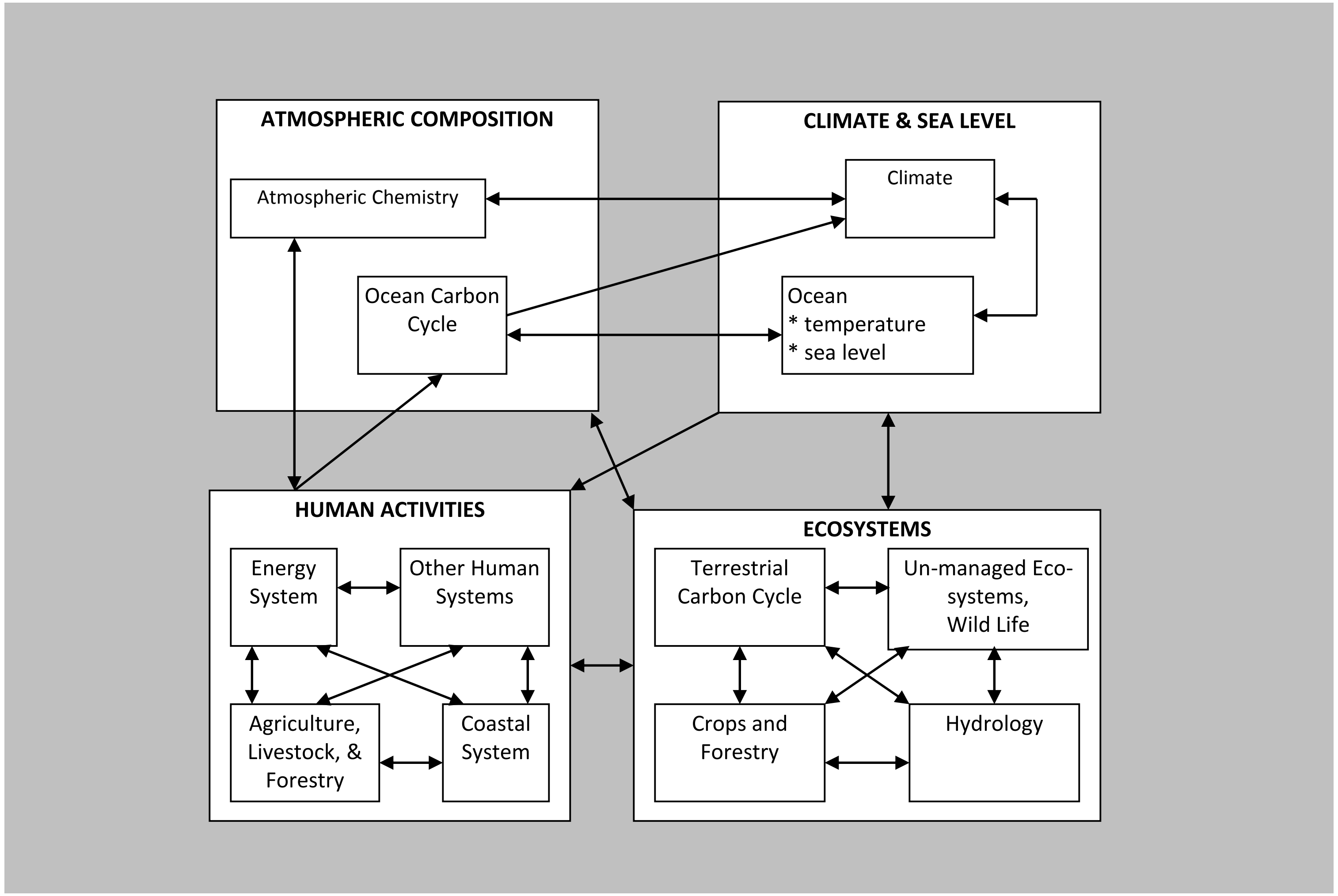
Outline

- State of the Art in Integrated Assessment Modeling in 2000
  - Poor understanding of many systems
  - Almost no understanding of critical linkages
  - Huge lack of critical data almost everywhere
  - Numbers meaningful only at very local level, concepts only at macro scale
- State of the Art In Integrated Assessment Modeling in 2015
  - Some models now more integrated with land, water and food capabilities
  - Development of Shared Socio-Economic Pathways along side RCP scenarios
  - Some key interactions identified and analyzed, but integrated climate feedbacks rare
  - Emergence of regional integrated assessment
- New Horizons/Directions for Future Research
  - Addition of climate feedbacks for selected scenarios
  - Integrated impacts assessment with linkages and trade and transfers
  - Much more work on extremes in climate and impacts
  - More sophisticated treatment of uncertainty

What is Integrated Assessment of Climate Change?

- Many definitions of IA for many purposes (climate change is just one application area)
- Could include any analysis involving two or more major earth system components including at least one natural and one human component
- Can be done with or without models
- Most “formal” IAMs cover as much of the global earth system as possible

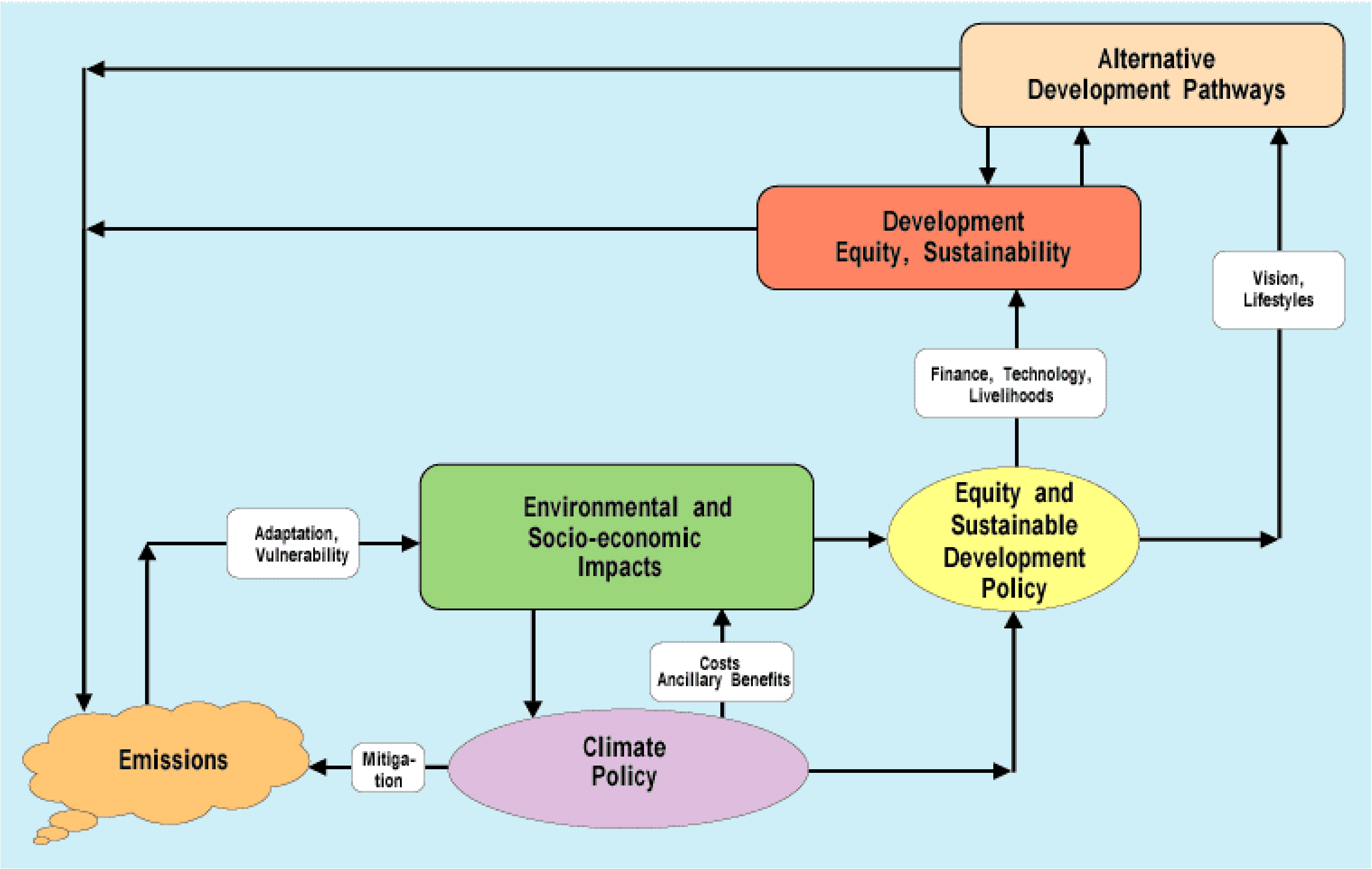
IPCC Second Assessment Report
Working Group 3 - Chapter 10
Integrated Assessment (1995)



Why Integrate?

- Understand complicated interactions and feedbacks among components
- Develop information and insights not available from individual disciplinary models
- Focus in on where and at what scale major interactions between components can occur

IPCC Third Assessment
Working Group 3 - Chapter 1
Sustainable Development and International Equity (2001)



Integrated Assessment Models (IAMs)

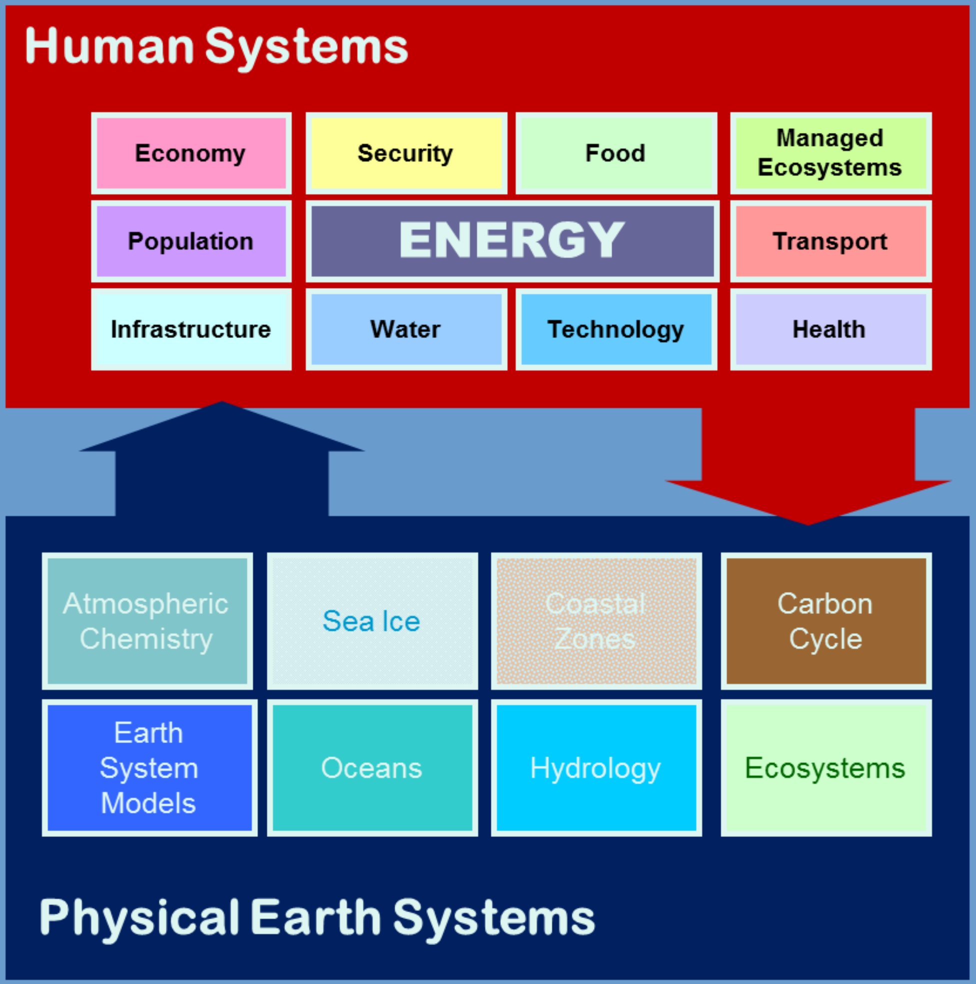
IAMs integrate human and natural Earth system climate science.

- IAMs capture interactions between complex and highly nonlinear systems. IAMs provide insights that would be otherwise unavailable from disciplinary research.
- IAMs provide physical science researchers with information about human systems such as GHG emissions, land use and land cover.

IAMs provide important, science-based decision support tools.

- IAMs support national, international, regional, and private-sector decisions.

From: Calvin, O'Neill and Sue Wing, DOE Climate-Energy Workshop October 24, 2014.



- Some integrated assessment models (e.g., DICE, PAGE, FUND) have focused on cost-benefit analysis. That is, weighing the costs of mitigation against the costs of inaction. Can call these Benefit-Cost (BC) IAMs.

- These models have very simple representations of the economy, but incorporate *all* potential feedbacks from the climate to the human system.

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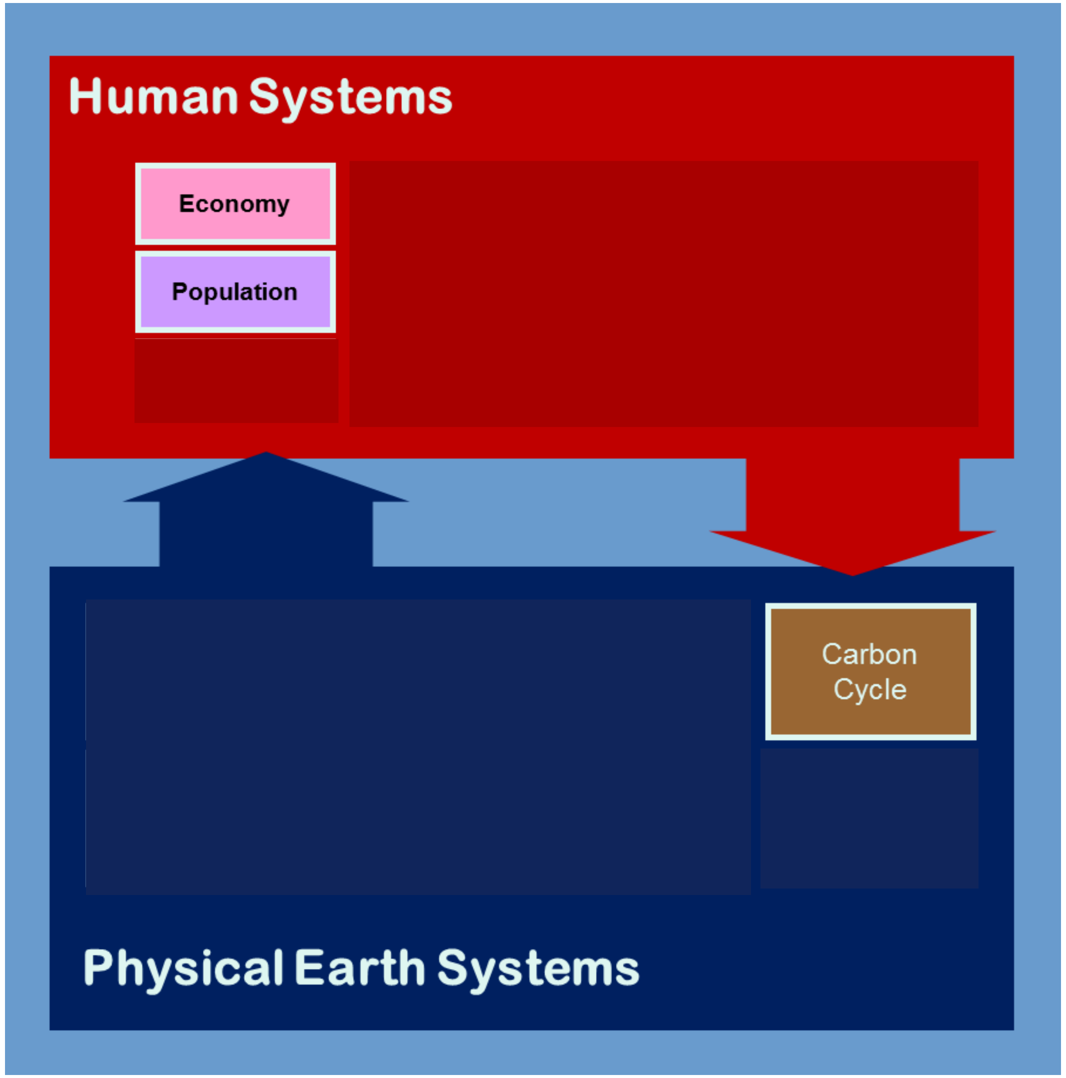
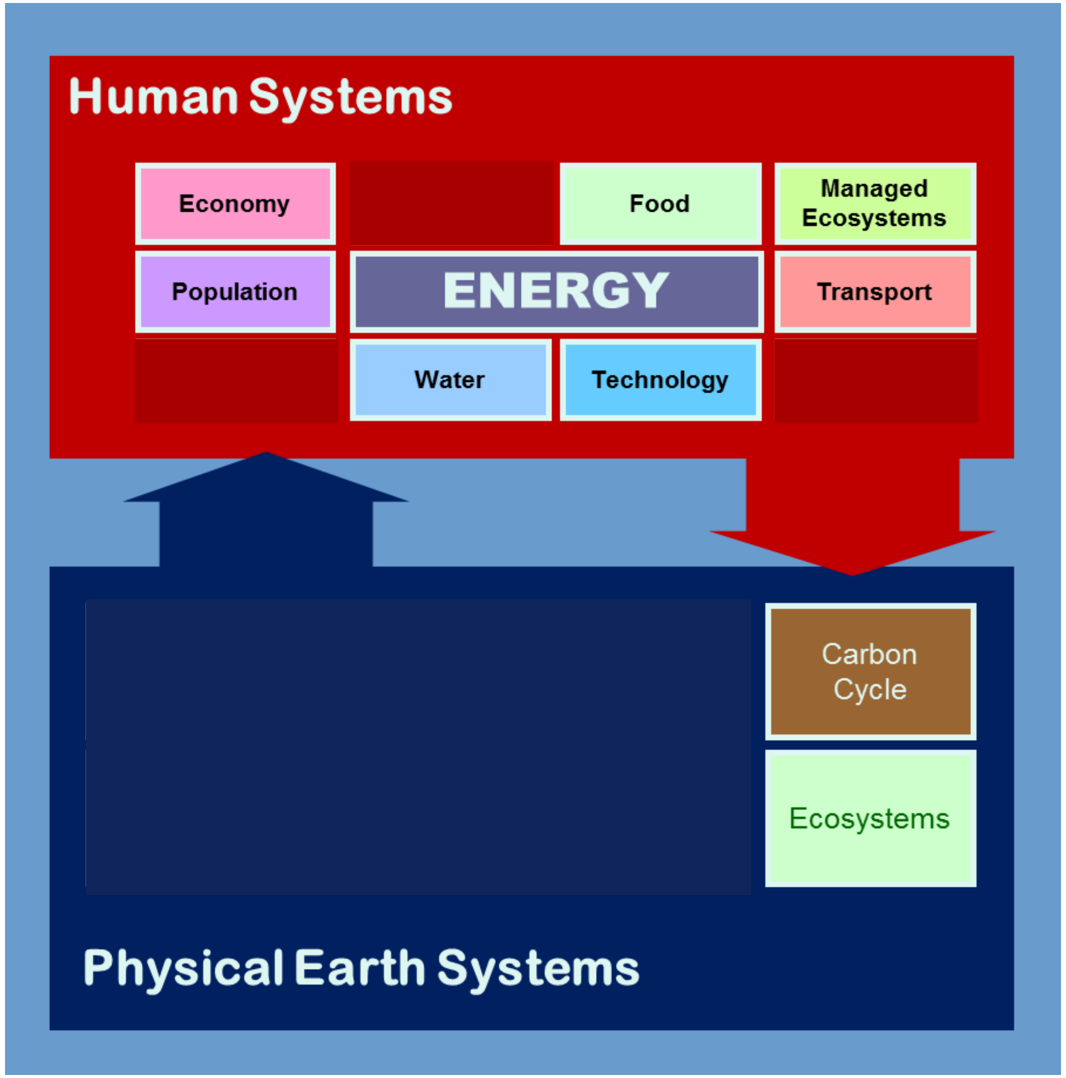


Some Sustainability Indicators from BC IAMs

- Aggregate economic output with some regional disaggregation in some models
- Aggregate economic damages attributable to climate change with some regional disaggregation in some models
- Global GHG concentrations and temperature change
- Some physical impacts of climate change with some regionalization in some models
- WARNING: Key drivers of many human capital and economic sustainability indicators are inputs to - not outputs from - these models. Social indicators often not considered at all.

- Other integrated assessment models (e.g., IGSM, GCAM, PIK, MESSAGE, IMAGE, MERGE) have focused on cost-effectiveness analysis, quantifying richer multi-sector transition pathways and tradefoffs and costs associated with stabilizing climate at a pre-defined levels. Can call these Detailed Process (DP) IAMs.

- These models have more complex representations of different components of the earth system (e.g., energy, land, water, agriculture, forests, eco-systems with different), but have largely excluded feedbacks from the earth systems to the human systems.



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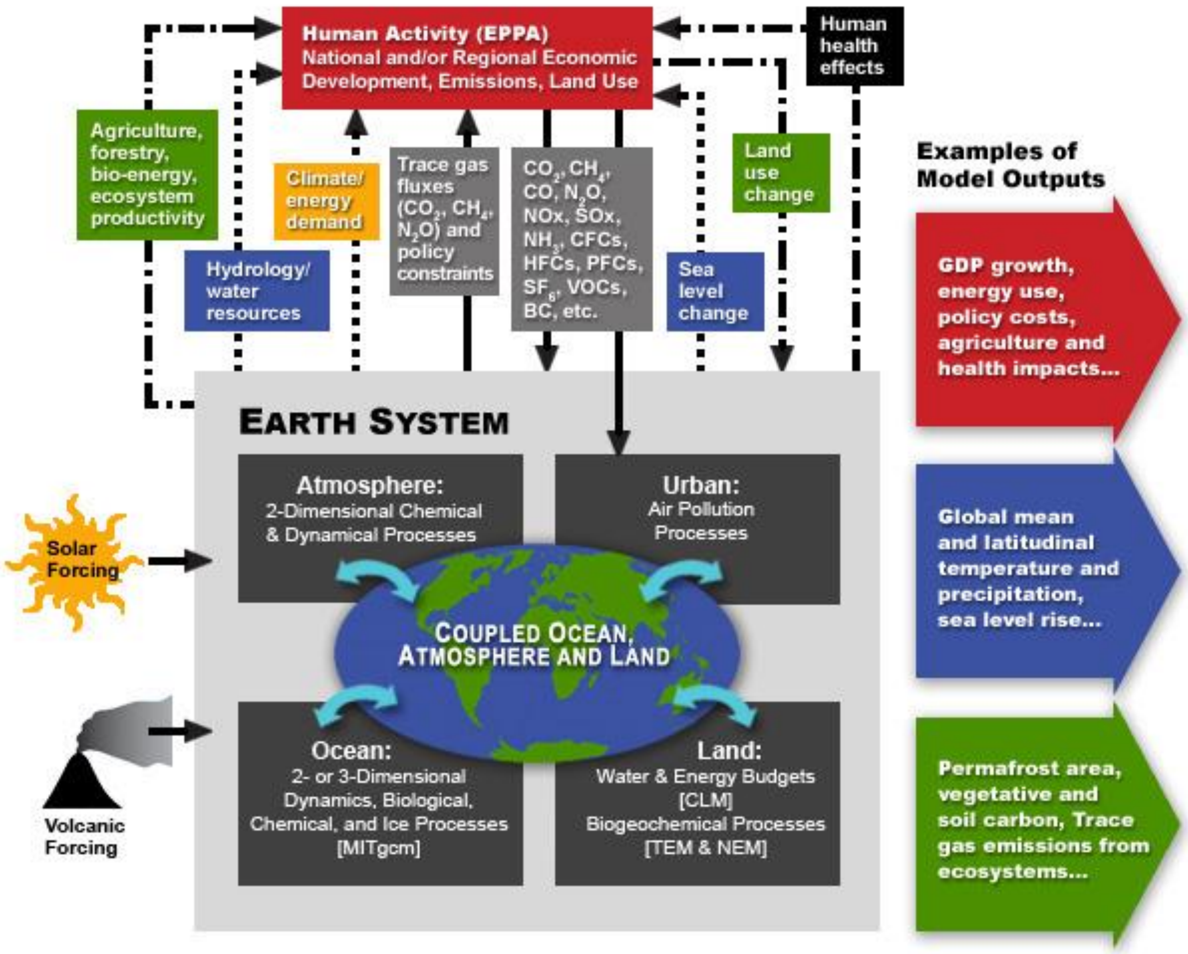
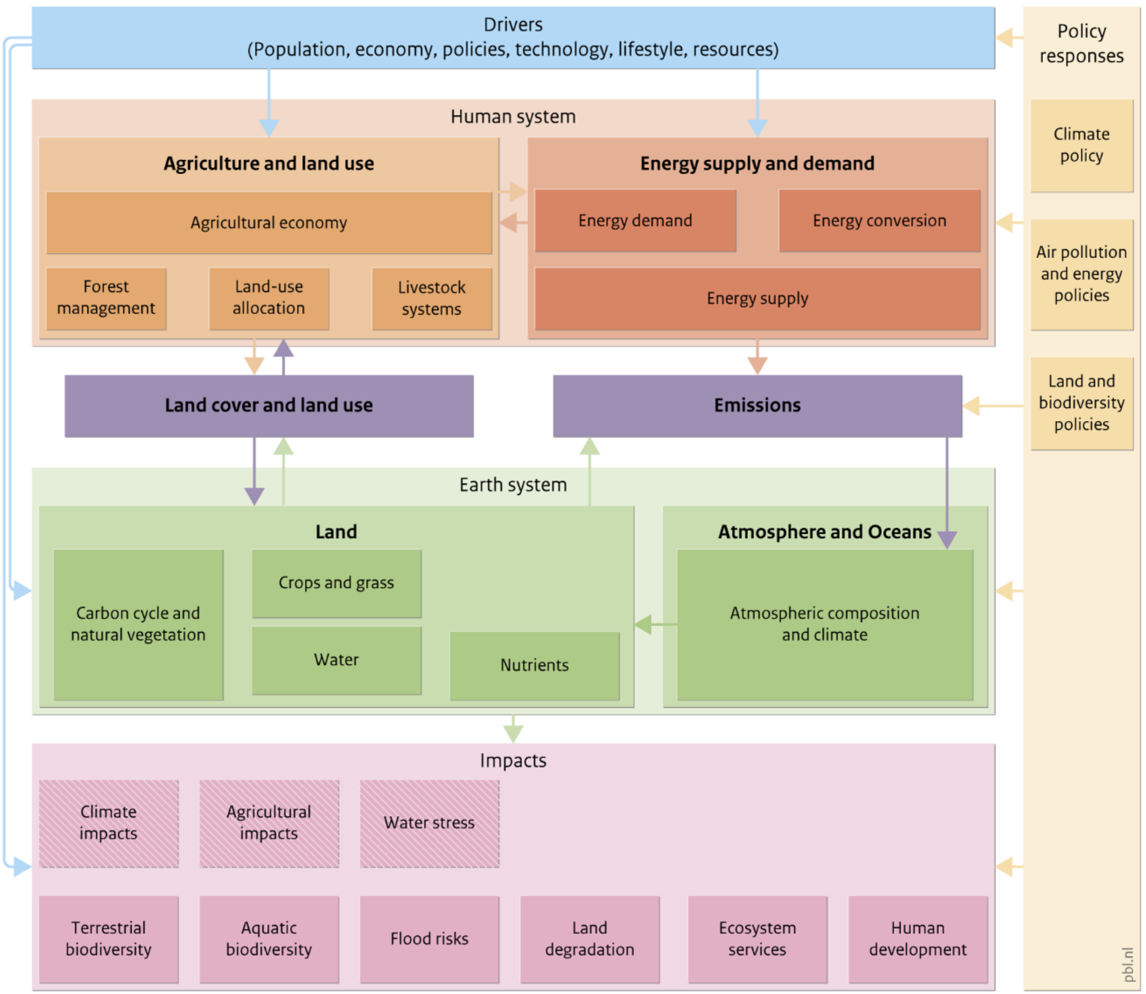
The MIT IGSM Model



The PBL IMAGE Model

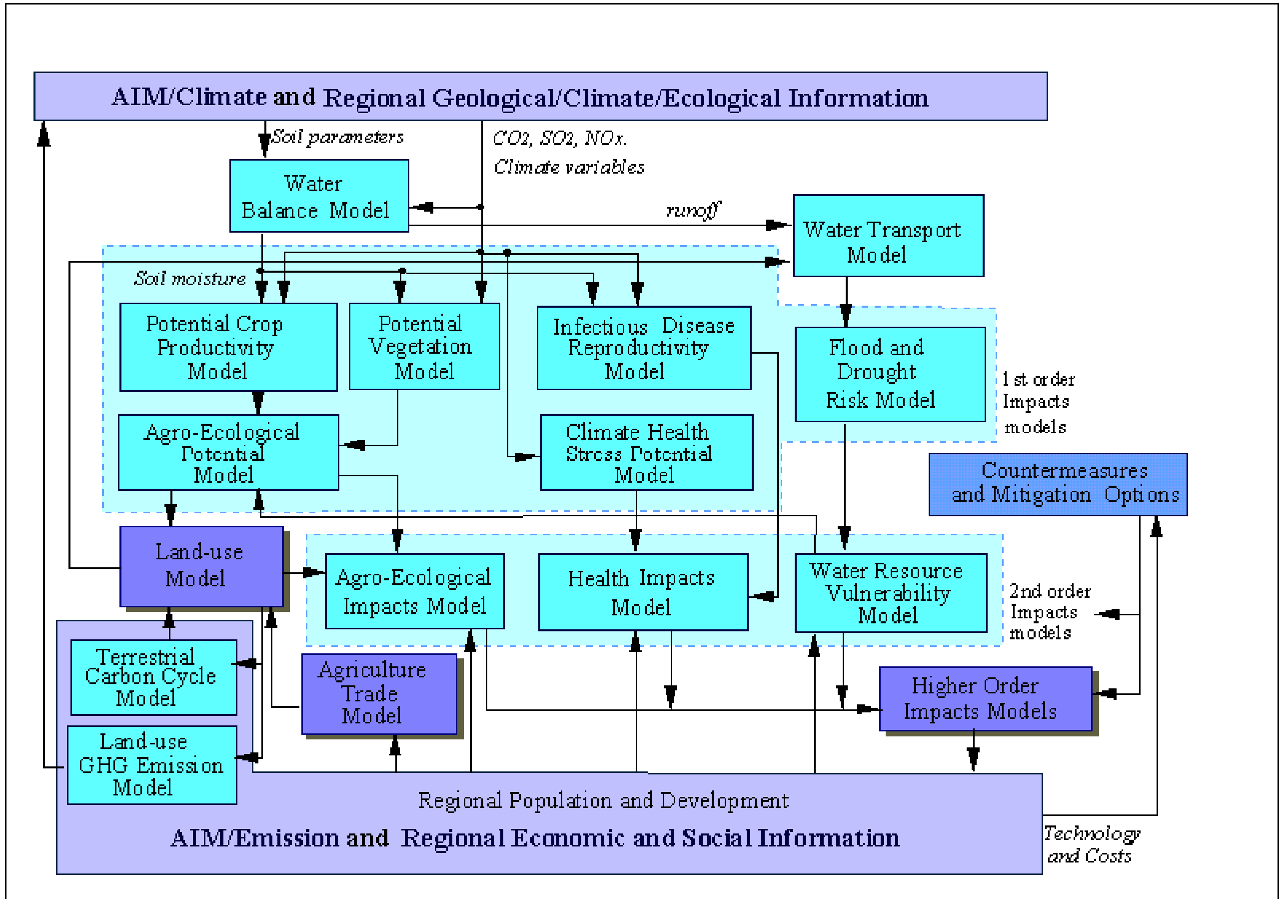
IMAGE 3.0 framework

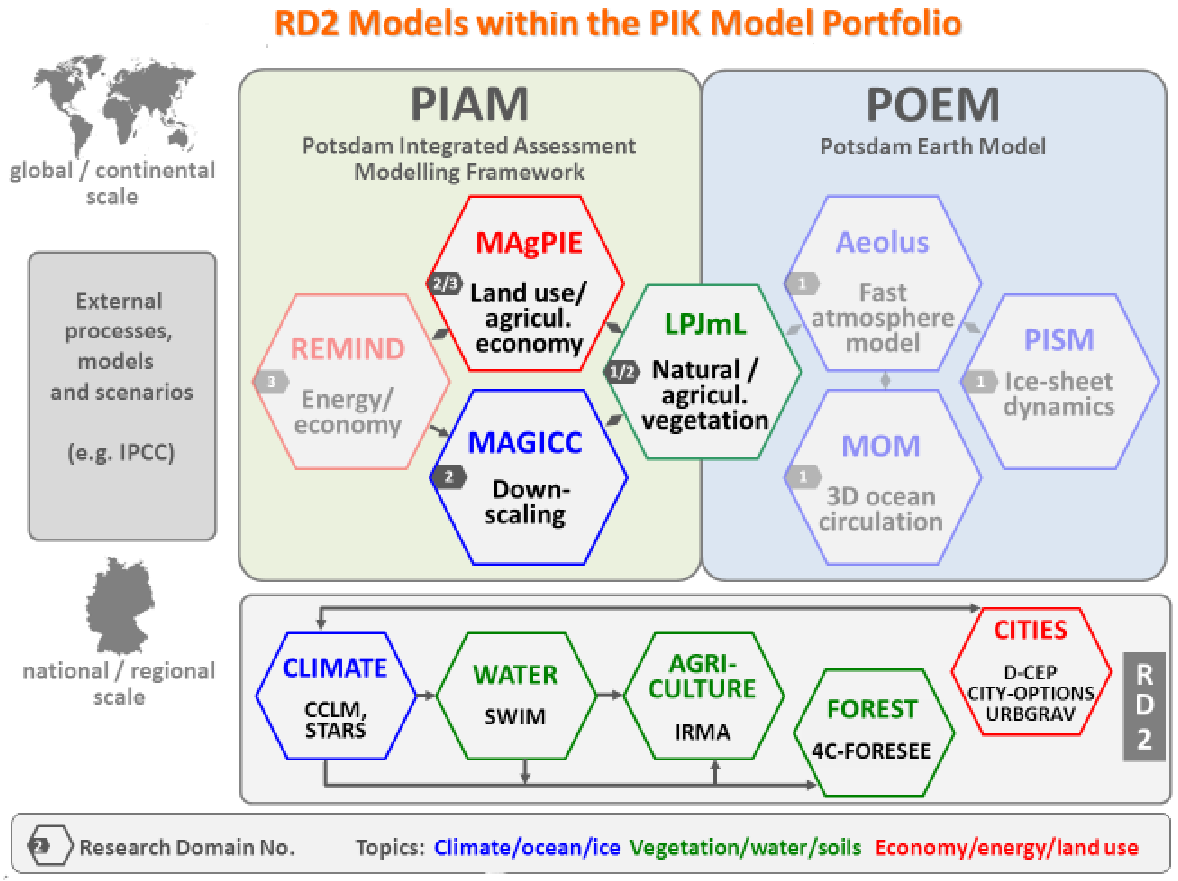


Source: PBL 2014

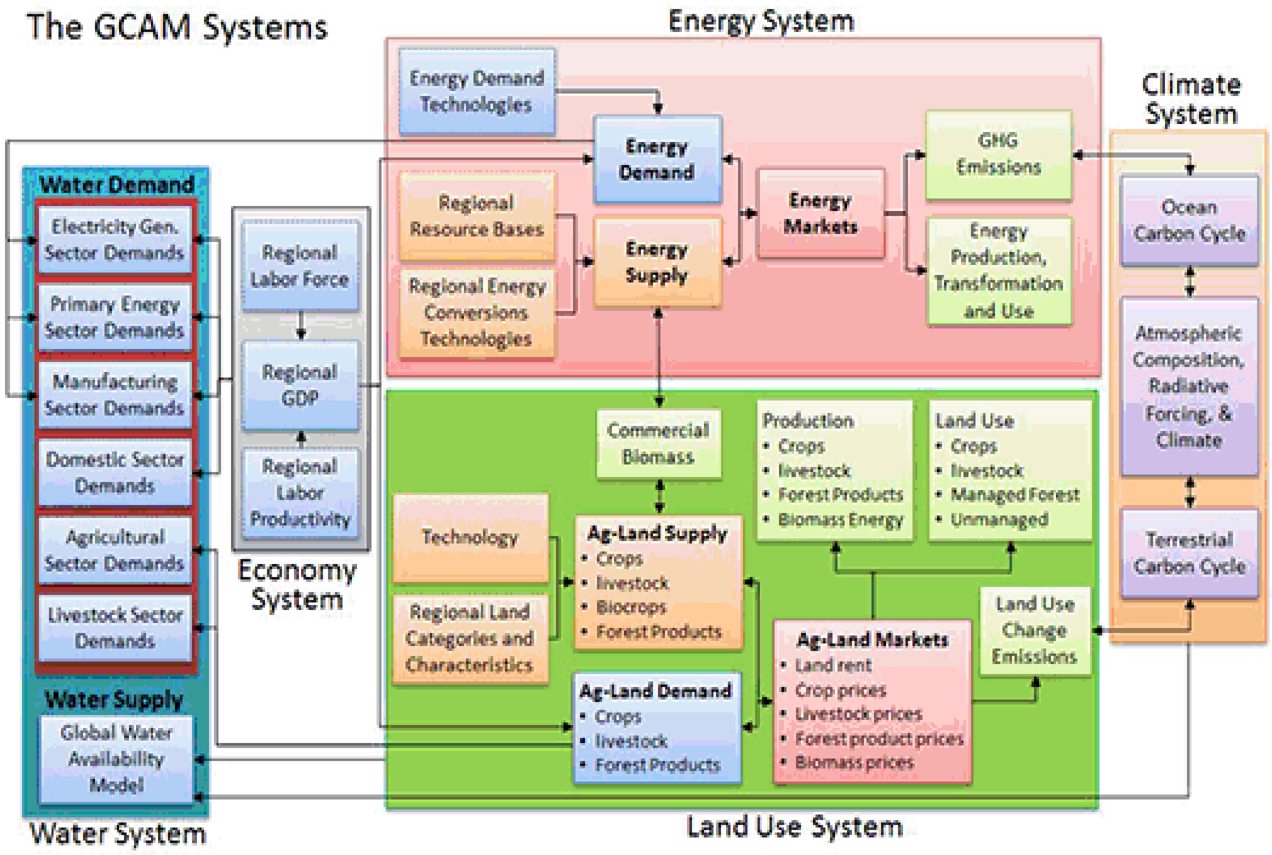
The Japan NIES Asian Integrated Assessment Model (AIM)

Potsdam Institute Integrated Assessment Framework

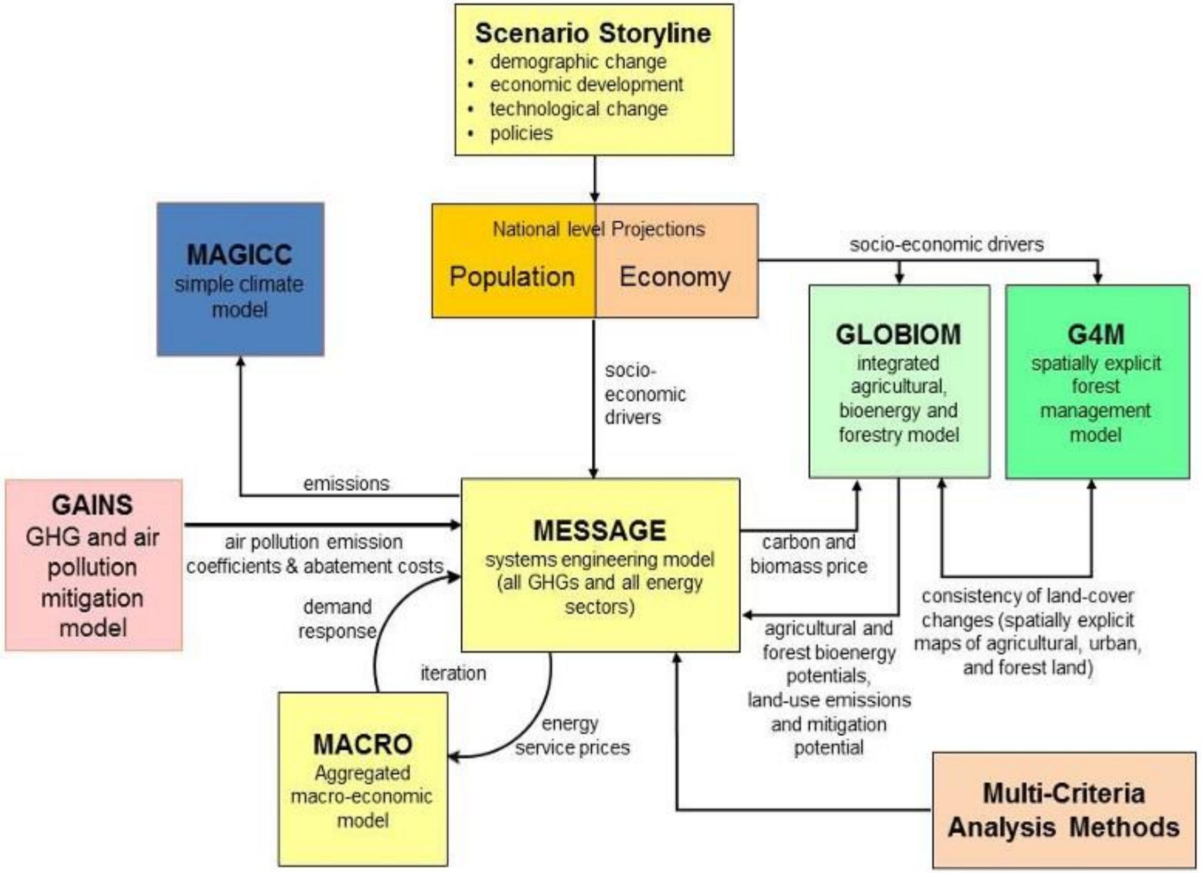




The GCAM Model



IIASA Integrated Assessment Framework



Some Sustainability Indicators from DP IAMs

- Land-Use/Land Cover
- Eco-systems (managed and un-managed)
  - NPP
  - Water & Heat Stress
- Agriculture
  - Crop productivity by crop and region
  - Including water availability, and ozone impacts
- Energy
  - Electricity generation and generation capacity
- Water
  - Rain, irrigation potential, natural and human configured storage
- Air Quality
  - Particle emissions and ozone levels most important according to GBD
- Sea Level/Coastal Zones
- WARNING: Key drivers of many human capital and economic sustainability indicators are inputs to - not outputs from - these models. Social indicators often not considered at all.

The EU CD-LINKS Project
Climate and Development Capabilities Assessment Survey

	Adaptation	Air pollution		Economy			Energy		Agriculture/Land/Nutrition			Health	Water			Other	
	Climate change adaptation	Air quality	Near term forcing	Economic development	Innovation	Employment	Energy poverty	Energy security	Land use and land degradation	Biodiversity	Food security	Health	Water Energy	Water Agriculture	Water Flooding	Global partnership	Other environmental impacts based on LCA data
AIM-CGE	Under Development	Under Development		Fully Operational		Fully Operational		Under Development	Fully Operational		Fully Operational	Fully Operational	Under Development				
CATSIM	Fully Operational			Fully Operational				Planned Development			Planned Development				Fully Operational		
China-TIMES		Under Development		Fully Operational				Fully Operational					Fully Operational				
DNE21+	Under Development	Under Development		Fully Operational	Under Development	Fully Operational	Planned Development	Under Development	Under Development		Under Development		Under Development	Under Development			
GAINS		Fully Operational	Fully Operational	Fully Operational						Fully Operational		Fully Operational					
GCAM		Fully Operational		Under Development	Fully Operational			Fully Operational	Fully Operational		Fully Operational		Fully Operational				
GEM-E3	Other: Please Specify	Planned Development		Fully Operational	Fully Operational	Fully Operational		Fully Operational			Fully Operational	Planned Development	Planned Development			Fully Operational	
IMAGE																	
India-MARKAL																	
India-CGE																	
IPAC																	
MESSAGE-Brazil	Fully Operational	Under Development			Fully Operational							Under Development	Under Development				
MESSAGE-GLOBIOM	Fully Operational	Fully Operational		Fully Operational	Fully Operational		Fully Operational	Fully Operational	Fully Operational	Fully Operational	Fully Operational	Under Development	Fully Operational	Under Development			
REMIND-MagPIE		Fully Operational		Fully Operational	Fully Operational			Fully Operational	Fully Operational	Fully Operational	Fully Operational		Fully Operational				Under Development
SLIMS																	
TIMES-Russia																	
WITCH	Fully Operational	Under Development		Fully Operational	Fully Operational			Fully Operational			Under Development		Under Development				

Some Big Needs in this Work

- Data and research on ocean acidification and its impacts
- Water information - irrigation potentials and aquifer net positions
- Black and organic aerosols emissions and composition
- Subsurface carbon sink assessments

Needed?: Integrated Assessment Perspective on Integrated Climate Impacts Analysis

- Multi-sector impacts may be significant (system boundaries)
  - Energy, land, water, food, climate, poverty, health, SLR, etc.
  - Could lead to significant competition, re-allocations, transfers of inputs
- Substitution of outputs could also be significant
  - General equilibrium effects (consumption, production, supply chains)
  - Transfers, inter-state commerce, international trade and aid, etc.
  - Can often ameliorate net impacts
  - But can also provide external shocks from outside regions
- Mitigation and impacts/adaptation interactions can be large
  - Land and water for biofuels squeeze agricultural/food markets
  - Climate change leads to energy supply and demand impacts
- Climate change feedbacks
  - Global earth system and back down
  - Regional
- Policy synergies
  - Land, agriculture, forest, energy, air quality, climate
  - Example includes climate change and air quality targeted policies.

Questions
Thanks You

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 economic growth

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

- Humans have:
  - 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