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Analysis of energy-economy-climate issues: multiple modeling approaches

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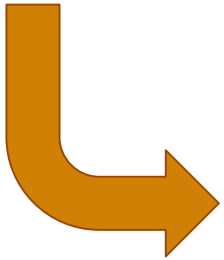
Outline

- Overview of types of models used for energy-economic-climate analysis
- Overview of the Global Change Assessment Model (GCAM)
- Examples of multi-model research projects
- Critical issues for designing effective multi-model research exercises

What is a model?

Inputs

Calibration data & assumptions

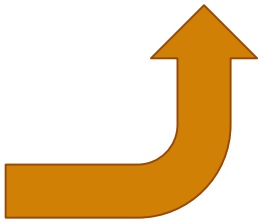


Model

Mathematical representation of behavior

Outputs

Projections of physical, economic, or social systems behavior



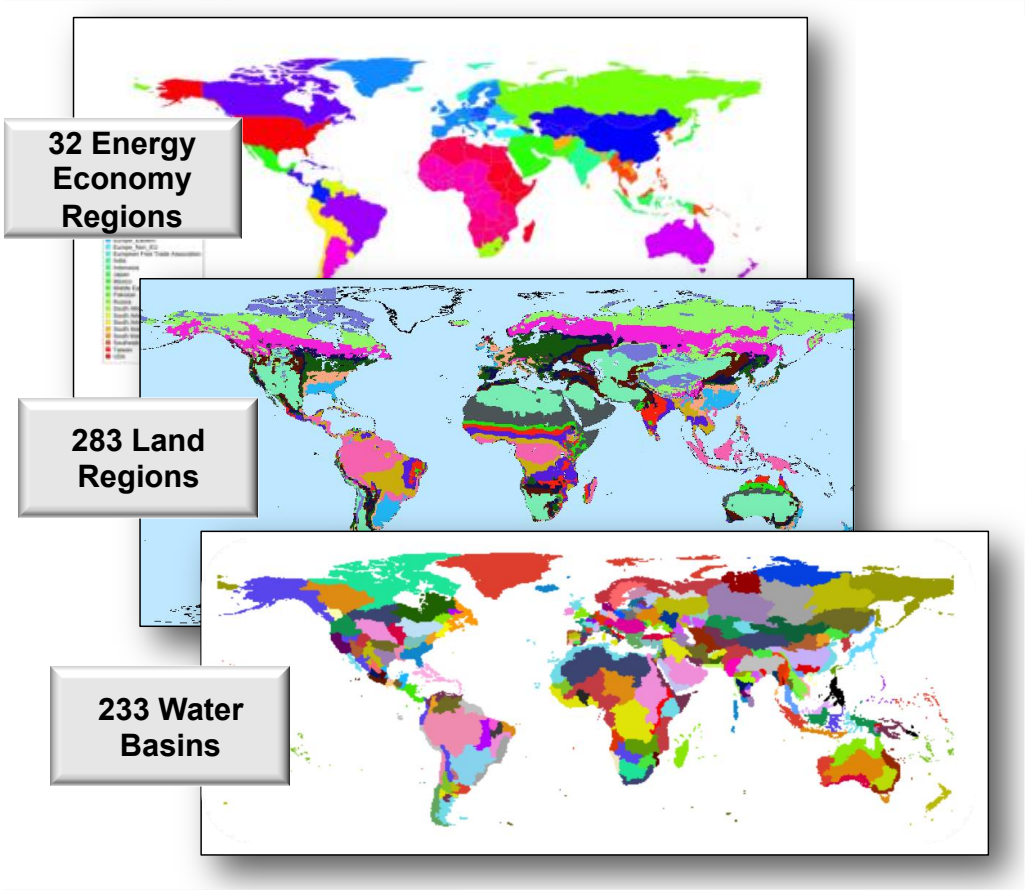
There are many types of models used in energy-economic-climate research

- Models designed for different purposes, vary in:
  - Spatial, temporal, sectoral, and technological scale and coverage
  - Structural design (GE, PE, process)

Broad classes of models

- Integrated Assessment (IA)
  - Global in coverage (spatial resolution varies), usually long-term (~2100)
  - Model economy, energy, and GHG emissions/climate systems, some include land/agriculture and water
  - May be general or partial equilibrium
- Computable General Equilibrium (GCE)
  - Economy-wide, all sectors
  - Economic, measured in currency (not physical quantities)
  - Domestic or global in coverage
  - Static or dynamic
- Partial Equilibrium (PE)
  - Single or multiple sector(s)
  - Domestic or global coverage
  - Generally physical quantities (check)
- Engineering or Process-based models (e.g., electric grid)
  - Single sector
  - Finer spatial and temporal scales

The Global Change Assessment Model



GCAM is a global integrated assessment model

- Links economic, energy, land use, water, and climate systems
- 32 geopolitical regions
- 283 land-use regions
- 233 water basins
- Runs through 2100 in 5-year time steps
- Emissions of 24 GHGs and short-lived species
- Used to analyze consequences of interdependencies between human and Earth systems
  - Energy, climate, and other policies
  - Socioeconomic development
  - Technology and resource changes
  - Climate impacts and adaptation
- Community model
- Developed and housed at the Joint Global Change Research Institute, collaboration with national and international researchers

Inputs and outputs in IAMs

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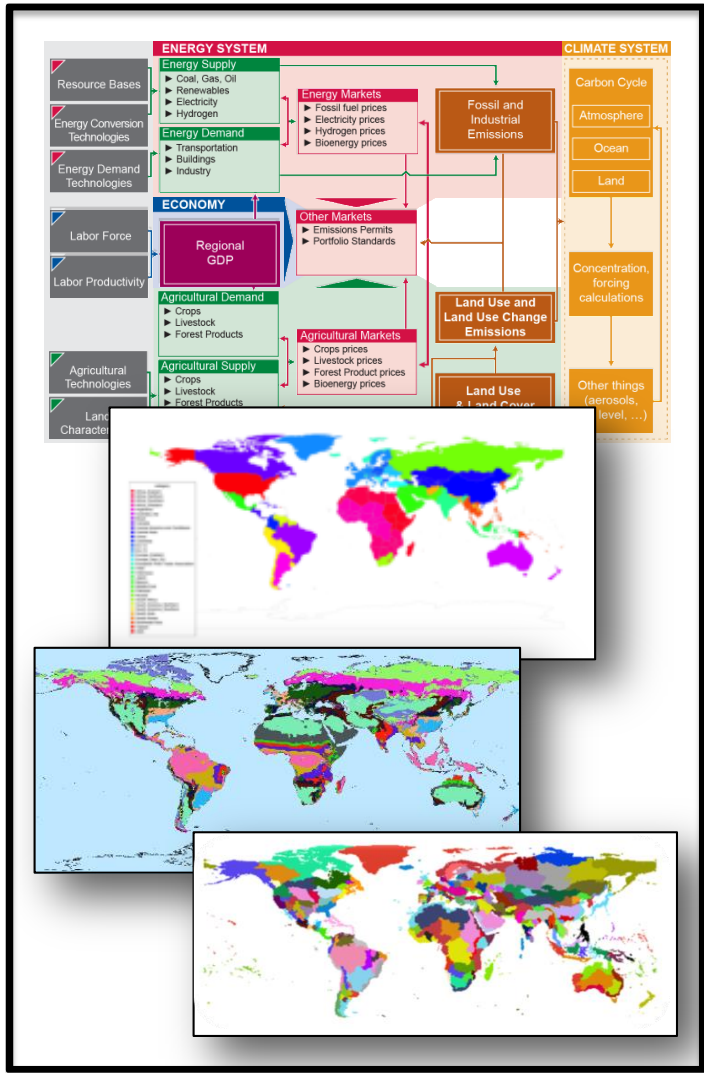
Scenario Assumptions

- Socioeconomic development
- Energy, land use, and water technologies
- Policies
- Resources



Scenario Outputs

- Prices, quantities
  - Energy production
  - Agricultural demand and production
- Land use
  - Crop (by type)
  - Pasture
  - Forest
  - Unmanaged
- Water demand
- Greenhouse gas emissions
- Economic indicators
  - Income transfer
  - Policy costs

Multi-model research

- Model intercomparison exercises cover diverse topics and organizers
  - Energy Modeling Forum (EMF)
    - EMF 33: Bioenergy and land use
    - EMF 32: US GHG and revenue recycling
    - EMF 29: Role of border carbon adjustment in unilateral climate policy
    - EMF 28: Effects of technology choices on EU climate policy
  - AME: Exploring the role of Asia in mitigating climate change
  - LAMP: Climate change impacts on agriculture, energy
  - PESETA I&II: Climate change impacts in Europe
- Using multiple models to explore a question can shed insight onto uncertainties, trends, and drivers
- Appropriate models/methods will vary depending on the specific questions/policies, data and output needs
  - Single model-type (RCPs & SSPs)
  - Multiple model types (LAMP, AME, EMF, PESETA)
- Different models can be used for different pieces of analysis
  - Outputs from one model may be inputs to others (trade, demand, prices)
  - Effects of policies, climate change, socioeconomic scenarios on different sectors or regions

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The role of Asia in mitigating climate change: Results from the Asia modeling exercise

Table 2
Participating models.

Model	Institution	Region	Regional scope	Asian regions	Time horizon	Time step	Corresponding paper in this volume
AIM-CGE	NIES	Japan	Global	Japan, Korea, China and Hong Kong, Rest of Asia-Pacific, Indonesia, Thailand, rest of Southeast Asia, India, rest of South Asia	2001–2100	10	Okagawa et al. (this issue)
AIM-Enduse	NIES	Japan	Global	Japan, China, India, Indonesia, Korea, Thailand, Malaysia, Viet Nam, other South-East Asia, other South Asia, other East Asia	2005–2050	1	Akashi et al. (this issue)
DNE21+	RITE	Japan	Global	Japan, China, India, Korea, Indonesia, Thailand, and Other Asia	2005–2050	5–10	Wada et al. (2012)
EPPA	MIT	USA	Global	China, India, Japan, high income Asia, rest of East Asia	2004–2100	5	Paltsev (2012)
GCAM	PNNL/JGCRI	USA	Global	China+, India, Japan, Korea, rest of South and East Asia	1990–2095	5	Eom et al. (this issue)
GCAM-IIM	IIM	India	India[a]	India	1990–2095	5	Shukla and Chaturvedi (2012)
GEM-E3	European Commission/ NTUA	EU	Global	China, India, Japan, rest of Asia	2004–2050	5	Saveyn et al. (this issue)
GRAPE	IAE	Japan	Global	China, Japan, Southeast Asia, India	2000–2100		Kurosawa (2012)
GTEM	ABARES	Australia	Global	China, India, Japan, Indonesia, other South East Asia	2005–2100	1	Mi et al. (this issue)
IMAGE	PBL	The Netherlands	Global	India, China+, Japan, Korea, Indonesia+, South East Asia, other South Asia	1970–2100	1	van Ruijven et al. (2012)
iPETS	NCAR	USA	Global	China, India	2004–2100	1	O'Neill et al. (2012)
KEI-Linkages	KEI	Korea	Global	Japan, Korea, China, India, Southeast Asia	2004–2050	1	Lim et al. (this issue)
MARIA-23	Tokyo U. of Science	Japan	Global	Japan, China, India, ASEAN + NIES, other Asian countries	1997–2107	10	Mori (this issue)
MERGE	EPRI	USA	Global	China, India, Japan, other Asia	2000–2100[b]	10	
MESSAGE	IIASA	Austria	Global	Centrally planned Asia and China, South Asia, other Pacific Asia	1990–2110	5–10	van Vliet et al. (2012)
Nepal-MARKAL	AIT	Nepal	Nepal	Nepal	2005–2100	5	Shrestha and Shakya (2012)
PECE	Renmin University	China	China	China	2005–2050	5	
Phoenix	PSU, BU	USA	Global	China and Taiwan, Japan, Korea, South Asia, Indonesia, India, Central and other Asia	2004–2070	5	Fisher-Vanden et al. (2012)
POLES-IPTS	IPTS	EU	Global	China, India, Japan, South Korea, rest of South Asia, rest of Southeast Asia	2000–2050	1	Dowling and Russ (2012)
ReMIND	PIK	Germany	Global	China, India, Japan, other Asia	2005–2150	5	Luderer et al. (2012 a,b)
TIAM-WORLD	Kanlo-KanORS	France	Global	China, India, Japan, Indonesia, South Korea, other developing Asia	2005–2100	10	Labriet et al. (this issue)
TIMES-VTT	VTT	Finland	Global	Japan + Korea, China, India, other developing Asia	2005–2100	10	Koljonen and Lehtila (this issue)
WITCH	FEEM	Italy	Global	China, India, South East Asia, and South Asia	2005–2150	5	Massetti et al. (this issue)

[a] GCAM-IIM is technically global in scope, but the authors only focus on the India region.
[b] MERGE computes economic variables through 2100 and climate variables through 2200.

Climatic Change
DOI 10.1007/s10584-014-1206-0

Overview of the special issue: a multi-model framework to achieve consistent evaluation of climate change impacts in the United States

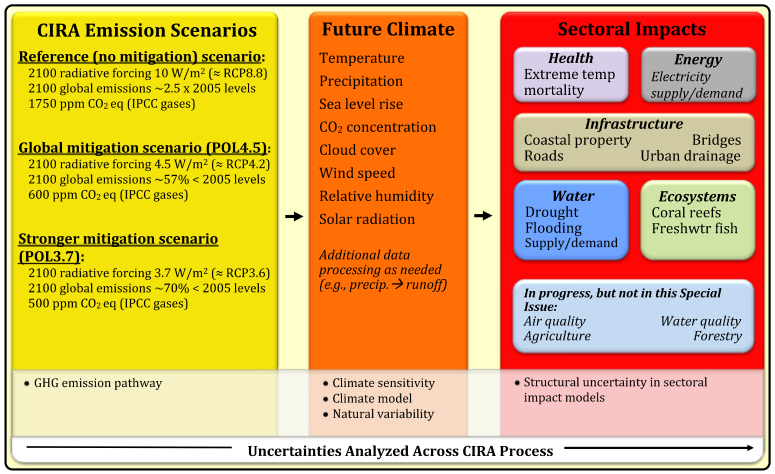

Fig. 1 The flow of inputs and outputs in the three main phases of the CIRA framework: emission and socioeconomic scenario development, climate projection, and impacts and benefits estimation

Impact Sector and Special Issue Paper Reference	Impact Estimated and Model Name (where applicable)	Description of Analysis
Water Resources (Strzepek et al. 2014)	Change in drought risk using several indices of drought.	Estimated for the 99 Assessment subregions of the Water Resource Regions of the contiguous US.
	Water supply and demand optimization and allocation	Spatial-equilibrium simulation of the water balance for each of the 99 Assessment subregions, with results aggregated to the Water Resource Regions of the contiguous US.
	Change in domestic water scarcity in the Global Change Assessment Model (GCAM)	Estimation of water scarcity index based on major water demand components for each of the Water Resource Regions of the contiguous US.
	Precipitation-based flooding damages	Inland damages calculated for the Water Resource Regions of the contiguous US.
Electric Power Sector (McFarland et al. in review)	Change in electricity demand and supply using the Integrated Planning Model (IPM), the state-level GCAM model (GCAM-USA), and the Regional Energy Deployment System (ReEDS)	Estimation of changes in electricity demand, supply mix, and system costs from ambient air temperature changes for the contiguous US with results aggregated to six regions.
Infrastructure (Neumann et al., 2014)	Property loss and property protection expenditures using the National Coastal Property Model (NCPM)	Sea level rise risks to coastal development, in terms of costs associated with lost property or protection measures, are estimated for the contiguous US.
	Vulnerable road infrastructure, with repair costs	Includes temperature and precipitation effects on paved (rutting & cracking damages) and unpaved (erosion) roads, and assumes that adaptation measures (e.g., resealing, regrading) will be implemented to maintain the current level of service.
	Bridges vulnerable to flooding, with retrofit costs (proactive and reactive to vulnerability)	Estimates change in maximum daily precipitation and peak flow for 100-yr flood. Results include both numbers of bridges affected in the contiguous US and the incremental climate-driven maintenance costs. Does not include damages due to storm surge.
	Urban storm water capacity exceedance and cost estimation of management response measures	Based on modeling in 19 major US cities of changes in the 10-year, 24-hour storm, consistent with the design criteria for most urban drainage infrastructure.
Human Health (Mills et al. 2014)	Extreme temperature mortality	Based on modeling of extreme heat and cold mortality in 33 US cities.
Ecosystems (Lane et al. 2014)	Change in coral reef cover using the Coral Mortality and Bleaching Output (COMBO) model, with recreation use valuation	Coral reefs in S. Florida, Puerto Rico, and Hawaii are analyzed.
	Change in suitable habitat for freshwater fish, with impacts to recreational fishing	Estimates thermal and precipitation based changes in suitable habitat for cold, warm, and rough fish species types. Economic estimates are based on freshwater recreational fishing days.
	Wildfire incidence and suppression costs using the MC1 Dynamic Global Vegetation Model	Estimated for the contiguous US at 0.5° × 0.5° resolution and aggregated to the USFS Geographic Area Coordination Center fire regions.
	Terrestrial carbon sequestration using the MC1 Dynamic Global Vegetation Model, with valuation using the social cost of carbon	Estimated for the contiguous US at 0.5° × 0.5° resolution and aggregated to the USFS Geographic Area Coordination Center fire regions.

Critical issues for designing multi-model exercises

- Designing effective multi-model research projects
  - Define the specific goal(s) of the exercise, e.g., policy questions, resource constraints, technology incentives, climate change impacts
  - Select models that are appropriate for the research question
  - Develop scenarios that will inform the policy questions – scenarios can be specified by their inputs or outputs, but not both
  - Create a supportive logistical framework, including project leadership and coordination, funding sponsors, host organizations
- Roles for sponsoring organization(s)
  - Framing of policy questions and information needs
  - Facilitation, create a forum for bringing together modeling teams (e.g., EMF)
  - Financial support for meeting space, travel, labor, data storage, and/or publication fees (e.g., EC JRC, US EPA, US DOE)