Sustainability Research/Indicators via Integrated Assessment Modeling

John P. Weyant
Stanford University

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“Transition toward Sustainability after 15 Years: 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.

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

From: Calvin, O’Neill and Sue Wing, DOE Climate-Energy Workshop October 24, 2014.
The MIT IGSM Model

The PBL IMAGE Model
The Japan NIES Asian Integrated Assessment Model (AIM)

AIM/Climate and Regional Geological/Climate/Ecological Information
- Soil parameters
- CO₂, SO₂, H₂O, Climate variables
  - Water Balance Model
  - Water Transport Model
- Greening
  - Potential Crop Productivity Model
  - Potential Vegetation Model
  - Infectious Disease Reproductive Model
  - Food and Drought Risk Model
  - Climate Health Service Potential Model
- Countermeasures and Mitigation Options
- Land-use Model
  - Agro-Ecological Potential Model
  - Agro-Ecological Impacts Model
- Agriculture Trade Model
- Health Impacts Model
- Water Resource Vulnerability Model
- Higher Order Impacts Models

Regional Population and Development
AIM/Emission and Regional Economic and Social Information

Potsdam Institute Integrated Assessment Framework

RD2 Models within the PIK Model Portfolio
- PIAM
  - Potsdam Integrated Assessment Modelling Framework
    - MAgPIE
    - Land use/agricultural economy
  - Downscaling
    - MAGICC
    - Natural/agricultural vegetation
- POEM
  - Potsdam Earth Model
    - Aeolus
    - Fast atmosphere model
    - REMIND
    - Energy/economy
    - LPJmL
    - Natural/agricultural vegetation
  - 3D ocean circulation
  - MOM
    - PISM
    - Ice-sheet dynamics
  - CITIES
    - CLIMATE
      - CCLM, STARS
    - WATER
      - SWIM
    - AGRICULTURE
      - IRMA
    - FOREST
      - 4C-FORESEE

Research Domain No.
Topics: Climate/ocean/ice Vegetation/water/soils Economy/energy/land use
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

<table>
<thead>
<tr>
<th>Adaptation</th>
<th>Air pollution</th>
<th>Economy</th>
<th>Energy</th>
<th>Agriculture/Land/Nutrition</th>
<th>Health</th>
<th>Water</th>
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<td>Air quality</td>
<td>Near term forcing</td>
<td>Economic development</td>
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<td>Employment</td>
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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