

# HUMAN-EARTH SYSTEMS DYNAMICS AND GLOBAL CHANGE: RISKS, RESPONSES, AND OPPORTUNITIES

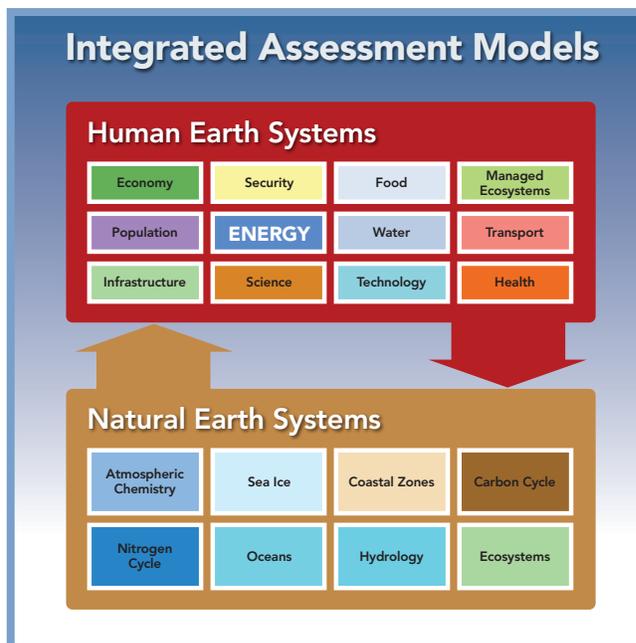
Research on the interactions of human and Earth systems has delivered tremendous value to date through the development and use of integrated assessment models (IAMs). The U.S. and governments around the world have compelling needs for scientific information on how global change, including climate change, might affect their economies, jobs, public health and safety, food and water availability, infrastructure, and natural resources. Built around risk and economic frameworks, IAMs are tools that link natural Earth system processes and human systems into a single model. One of the greatest strengths of IAMs is that they allow researchers and decision-makers the opportunity to explore a range of "what if" questions about global change impacts and responses.

In the past, IAMs have been used mainly to analyze the effects of different energy pathways, possible greenhouse gas mitigation options, and the role of technological advances in energy supply and demand, and influence on society and environmental systems. Today, these tools are being adapted to help provide scientific insights into decisions on natural resource management, infrastructure fragility, economic competitiveness, public health, land development, food production, coastal protection, and many more topics affected by global change. Within DOE, they are also being coupled with robust earth system models to form a new class of model: the integrated Earth System Model (IESM). These models—IESMs—are already providing valuable, deep insights into land use and the water, carbon, and nitrogen cycles. DOE has strategic partnerships with several agencies to study various aspects of this research.

## CHALLENGES

The emerging decision environment is driving human-earth system models toward shorter time-scales and regionally resolved spatial scales. Some of the challenging questions regarding IAMs and related modeling research include:

- How will human settlements change, how many people will live where, and what energy and other resources will they need that will influence and be influenced by climate change?
- How will climate change affect water resources, and what are the implications for energy and other infrastructure, competing water demands, land use, and adaptation strategies?
- How do coupled engineered systems, such as connected infrastructure, respond under global change and what are the apparent vulnerabilities and opportunities for improving resiliency?
- How will regional decision makers respond to multiple climate-induced challenges, accompanying vulnerabilities, and tradeoffs between mitigation and adaptation?
- What promises do science and technology hold for transformational solutions to both mitigation and adaptation?



*Elements and interactions of a DOE-sponsored integrated assessment model (IAM).*

- What are the costs and averted risks arising from climate decisions—for implementing mitigation actions and for preventing damage to human and natural systems?

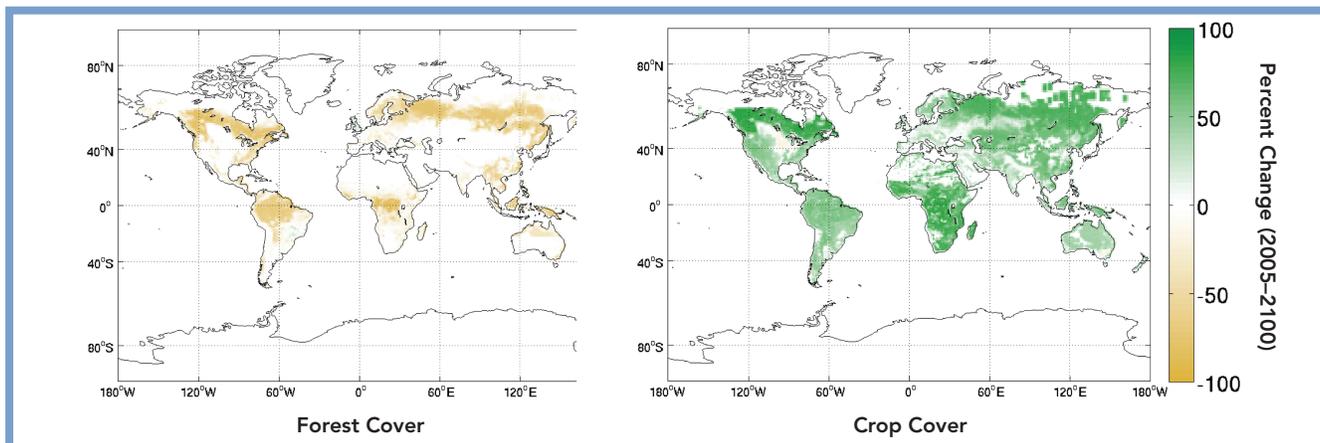
As DOE explores answers to these questions, with an eye toward understanding the central role of energy in this complex system, dynamic, crosscutting modeling challenges include: *risk and uncertainty estimation; process representations for impacted systems and responses; model interoperability; and data management and standardization.*

Additionally, a set of systems-level research themes have emerged. Three of these themes are listed below.

## EMERGING THEMES

### *Implications of energy strategies on land use and the climate system*

The energy system and the use of land for agricultural production are entangled in many ways. One important insight from this DOE program is that whether or not carbon on terrestrial landscapes has an explicit value is especially important for understanding land-use futures in regions around the world.



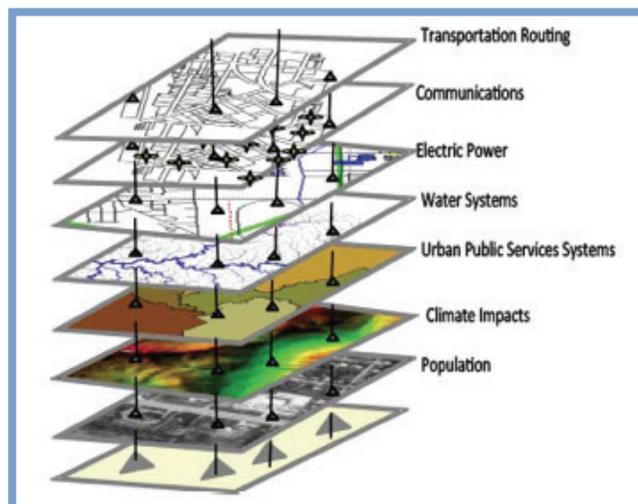
Potential land cover changes by the year 2100 under an energy scenario that does not value carbon on land. Results show significant decreases of forested area (left) and increases in agriculture area (right).<sup>1</sup>

### Regional interactions of water, energy, and land

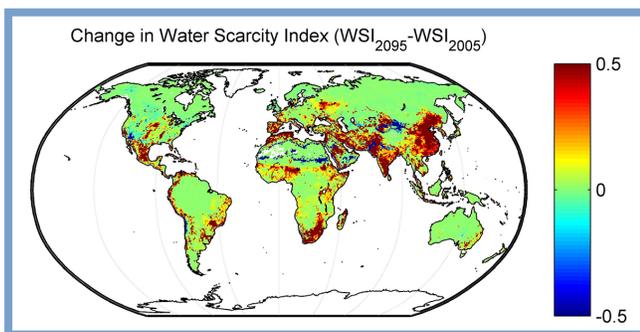
The energy sector is the second-largest source of withdrawals from water supplies, exceeded only by agriculture. Water is important not only for hydropower generation, but also for cooling thermoelectric and nuclear power plants. Therefore, it is crucial to understand how evolving energy technologies will impact water demand.

### Sensitivity of energy and connected infrastructure to climate impacts

U.S. infrastructure and the delivery of energy and other services are connected in complex and significant ways, thereby creating cascading vulnerabilities (and helpful redundancies in some cases) to climate-induced stressors. Working with other agencies in the federal community, DOE is laying the foundation for understanding these interdependencies and climate vulnerabilities in current and potential future configurations of infrastructure.



Infrastructure examined as a series of interconnected spatial layers of interacting systems.<sup>3</sup>



Change in water scarcity conditions between 2005–2095, calculated on the basis of future water availability and potential demand as reflected in a no-climate policy scenario and a single set of technology assumptions.<sup>2</sup>

## CONTACTS

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2. Hejazi et al. 2013. Pacific Northwest National Laboratory/Joint Global Change Research Institute, in preparation.  
3. Willbanks, Fernandez, et al. 2012. Climate Change and Infrastructure, Urban Systems, and Vulnerabilities. U.S. Department of Energy.

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