The Integrated Multisector, Multiscale Modeling (IM3) Scientific Focus Area (SFA) develops flexible and extensible coupled modeling capabilities that capture the dynamic, multiscale interactions among energy, water, land, urban, and other systems, at scales ranging from local (~1km) to the contiguous United States (CONUS).

IM3 couples high-resolution, physics- and process-based models to resolve key interactions and feedbacks not captured by lower-resolution modeling. IM3 uses these integrated modeling capabilities to study the system dynamics of the co-evolution of coupled human and natural system landscapes, including their responses to short-term shocks, long-term changes, or compound stressors (such as droughts and heat waves occurring together), and effects on vulnerability and resilience.

Launched in 2017, IM3’s initial research phase has included:

- Energy and water system dynamics modeling, coupling models and data at scales ranging from watersheds to major basins to simulate water availability and electricity system operations
- Modeling of the complex, multiscale linkages between land use and land cover change (LULCC), hydrology, and regional climate
- Development of high-resolution U.S. population projections sensitive to state-level demographic projections and climate-induced migration
- Scalable building energy demand modeling responsive to population, building technology, and weather
- Agent-based modeling to simulate emergent behavior in water management, crop planting, and urban-rural transition decisions
- City-specific and CONUS-scale studies of urban heat islands, microclimate feedbacks, and adaptation strategies
- Developing best practices for multi-model coupling, version control, and uncertainty characterization
- Founding a community of practice to support the MultiSector Dynamics research community

Funding and Participating Institutions
IM3 is sponsored by DOE’s Office of Science through its MultiSector Dynamics program area. As of FY20, the diverse research team includes five national laboratories and seven universities:

- Pacific Northwest National Laboratory (lead)
- Lawrence Berkeley National Laboratory
- National Renewable Energy Laboratory
- Oak Ridge National Laboratory
- Sandia National Laboratory
- Baylor University
- Boise State University
- Boston University
- Colorado School of Mines
- Cornell University
- Lehigh University
- University of Denver

CHALLENGES
The IM3 SFA focuses on the following scientific questions:

- What key factors and processes govern interactions among water resources, the electric grid, land use/land cover, and population dynamics at local to continental scales? What levels of spatial, temporal, and process resolution are needed to account for these interactions and feedbacks?

- How can short-term shocks and long-term trends—including technology shocks, weather extremes, climate scenarios, and human decision-making—interact to drive changes in the vulnerability and resilience of energy, water, land, other natural systems, and human infrastructures?
• What key design elements, technical innovations, and features (e.g., novel computational paradigms, coupling methods, interoperability approaches, representations of human decision-making, uncertainty characterization, etc.) are needed to underpin the development of flexible, extensible, and robust multisector modeling approaches capable of representing interactions among a wide range of human and earth system processes?

**IM3 RESEARCH AREAS**

**Energy-Water Dynamics Research:** The largest IM3 research thrust area explores the dynamics and resilience of energy and water systems on scales that range from individual watersheds to the contiguous United States. With the multiscale nature of energy-water interactions, research focuses on understanding how large-scale information (e.g., at the major basin or balancing authority scale) can be effectively used by high-resolution models, and how to better represent local-to-regional scale information.

**Land Use and Land Cover Change:** Strong, complex multiscale linkages between Land Use and Land Cover Change (LULCC) and other sectors make it an important sector to include in multisector modeling frameworks. This research is designed to systematically study downsampling approaches, the complex multiscale linkages between LULCC and other human and natural systems, such as population dynamics and surface hydrology, and the implications of LULCC for terrestrial hydrology and ecosystem services on local to continental scales.

**Population Dynamics:** Demographic dynamics—changes in total population, age structure, and spatial distribution—are key drivers of energy, water, and land use. Population distribution is also closely tied to infrastructure investments, exposure to extreme weather, and a host of other issues and systems. In this thrust area, IM3 is developing a new open-source modeling system for U.S. population dynamics that includes state-level demographic projections, a spatial downscaling model, and a representation of the influence of weather and climate on migration within the United States.

**FUTURE WORK**

IM3 has recently added a focus on urban systems to explore responses to drivers and stressors and subsequent interactions with the evolution of energy, water, and land systems over time. Future research is expected to continue studying the vulnerability and resilience of coupled human-natural systems to various drivers and stressors and adding additional sectors/systems.

**CONTACTS**

Bob Vallario  
DOE Program Manager  
MultiSector Dynamics  
bob.vallario@science.doe.gov

Jennie Rice  
Principal Investigator  
Pacific Northwest National Laboratory  
jennie.rice@pnnl.gov

**IM3 Website**

https://im3.pnnl.gov/