A computational framework for supporting Environmental-Climate-Energy decision-making

Dan Loughlin and Chris Nolte
U.S. EPA Office of Research and Development

Wenjing Shi and Yang Ou
Oak Ridge Institute for Science and Education (ORISE) fellows

Steven J. Smith and Catherine Ledna
Joint Global Change Research Institute, Pacific Northwest National Laboratory

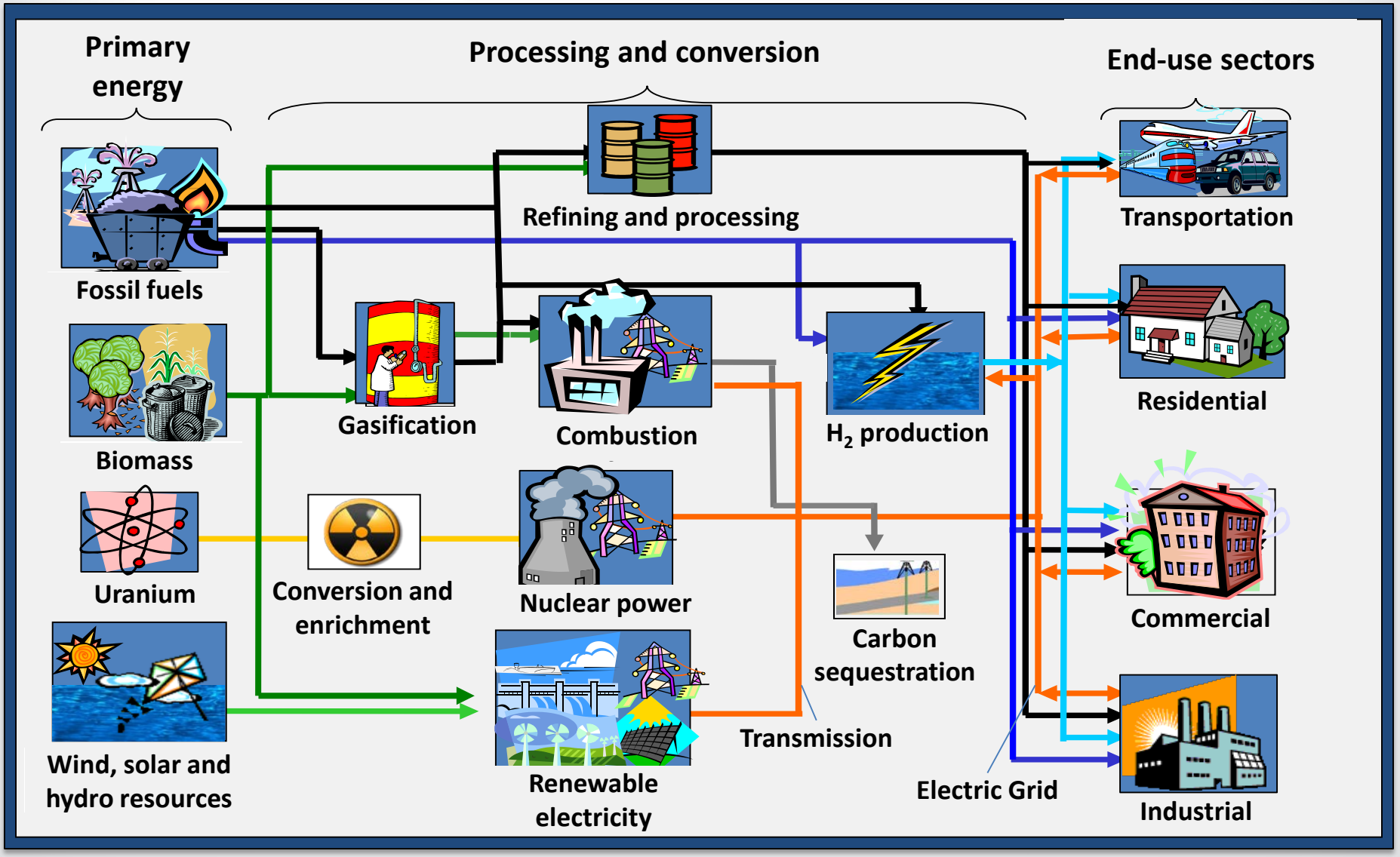
Research Triangle Park, N.C. 7/28/2016

Foreword

- **Objective**
  - Discuss an ongoing collaborative research project with linkages to air quality management in China
- **Intended audience**
  - Site visitors from the PowerChina Huadong Engineering Corp.
- **Additional contributors**
  - Samaneh Babaee, Colleen Baublitz, Raj Bhander, Barron Henderson, Daven Henze, Troy Hottle, Carol Lenox, Rob Pinder, Jason West
- **Disclaimer**
  - While this presentation has been cleared by the U.S. EPA Office of Research and Development, the material presented here reflects the views of the authors and does not necessarily reflect those of the U.S. EPA.

Energy and the environment

The energy system



Environmental impacts of energy

Energy system contributions to U.S. environmental concerns:

- **Air quality**
  - Photochemical smog: 92% of nitrogen oxide (NOx) emissions*
  - Acid rain: 86% of sulfur dioxide (SO_2) emissions*
  - Toxics: 87% of mercury (Hg) emissions*
- **Climate change**
  - Greenhouse gas emissions: 97% of carbon dioxide (CO_2) emissions*
  - Major source of short-lived climate pollutants (e.g., black carbon, methane)
- **Water**
  - Demands: electricity production accounts for 51% of fresh water withdrawals
  - Pollution:
    - wastewater from fuel extraction and processing, seepage from waste
    - eutrophication from N deposition, acidification from S deposition
- **Waste production**
  - Mine tailings, combustion residues, agricultural wastes

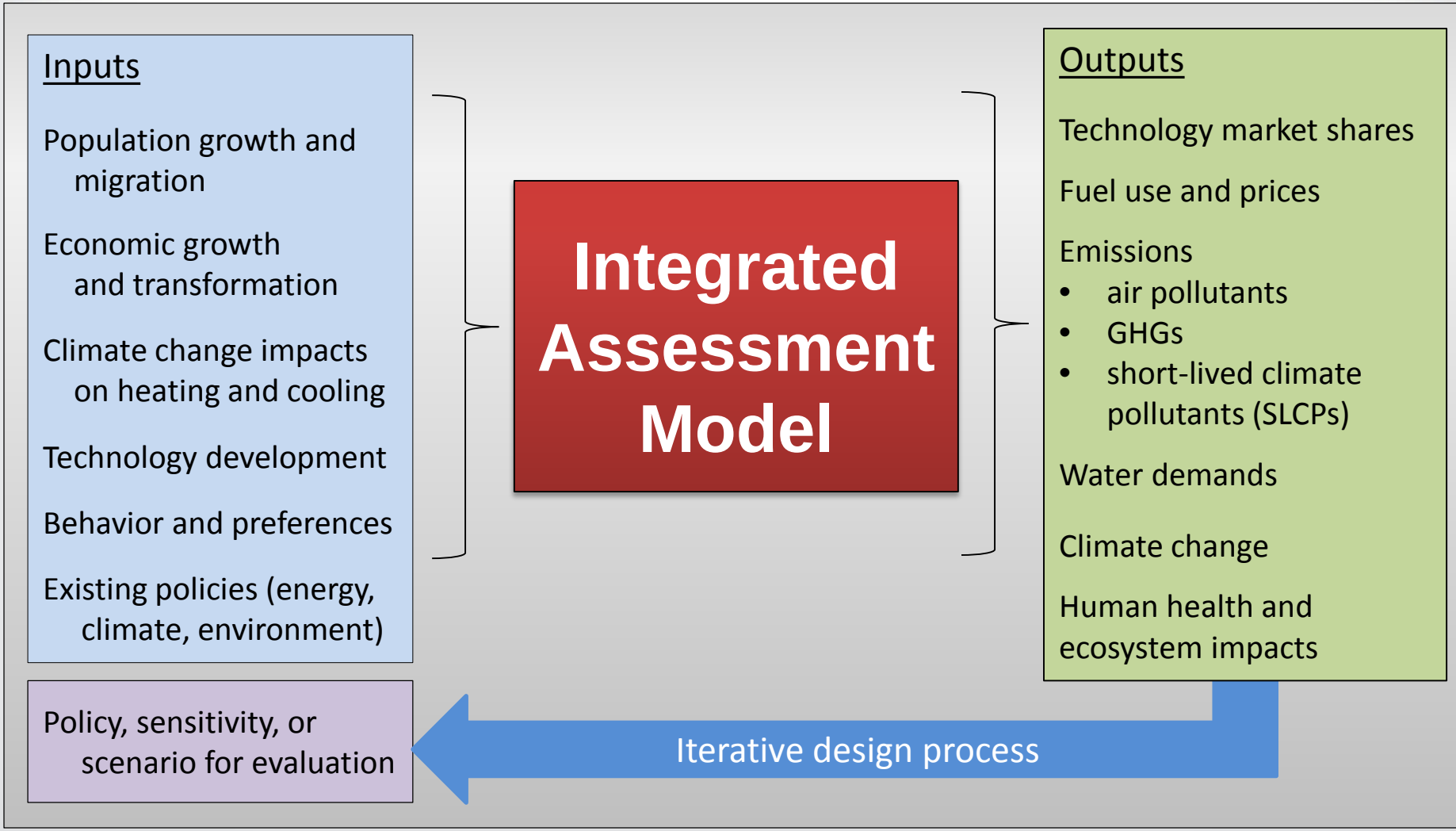
* Percentage of U.S. anthropogenic emissions due to the energy system

Science questions

- How can we simultaneously achieve environmental, climate change mitigation, and energy goals?
- What are the tradeoffs and synergies among these goals?
- Are there unintended consequences that may arise with various management strategies? Can we anticipate and prepare for these?
- What are the broader health, environmental and ecological impacts of different pathways for meeting society's energy needs?
  - Impacts under consideration include:
    - air quality and resulting human health effects,
    - damage to crops and timber, ecosystem impacts from N and S deposition,
    - water use by agricultural and energy sectors, and
    - resilience to drought and other climate change impacts.

The GLIMPSE project

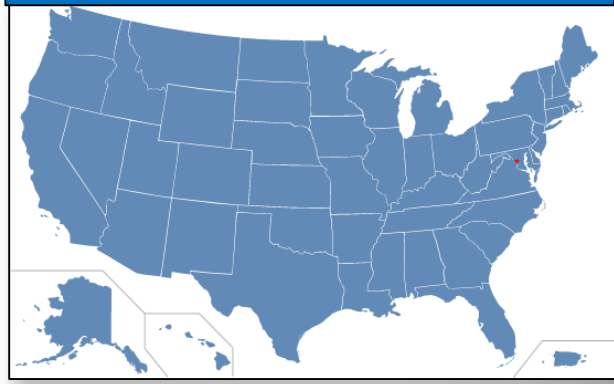
GLIMPSE: a modeling framework for exploring the answers to these questions



A component of GLIMPSE:
The Global Change Assessment Model (GCAM)

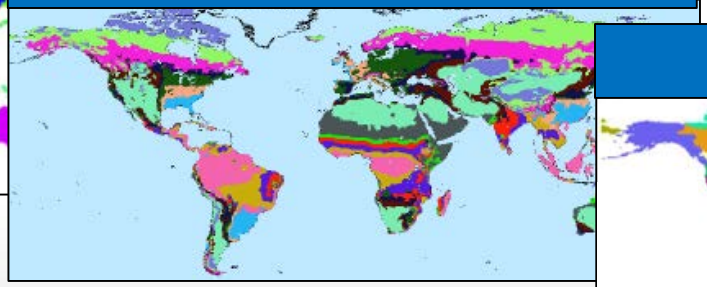
- Developed by Pacific Northwest National Laboratory
- Regions: 32 economic and energy; 283 agriculture and land use; 233 water basins
- 5-year time steps, extending from 2005 to 2100
- Technology-rich energy system detail
- Pollutant species
  - Climate forcers: CO_2, CH_4, SO_2, N_2O, BC, OC, HFCs
  - Air pollutants: NOx, SO_2, VOC, CO, NH_3, direct PM
- Open source and freely available, 1 hour runtime

GCAM-USA 50-state U.S. energy system



32 economic and energy regions

283 agriculture and land use regions

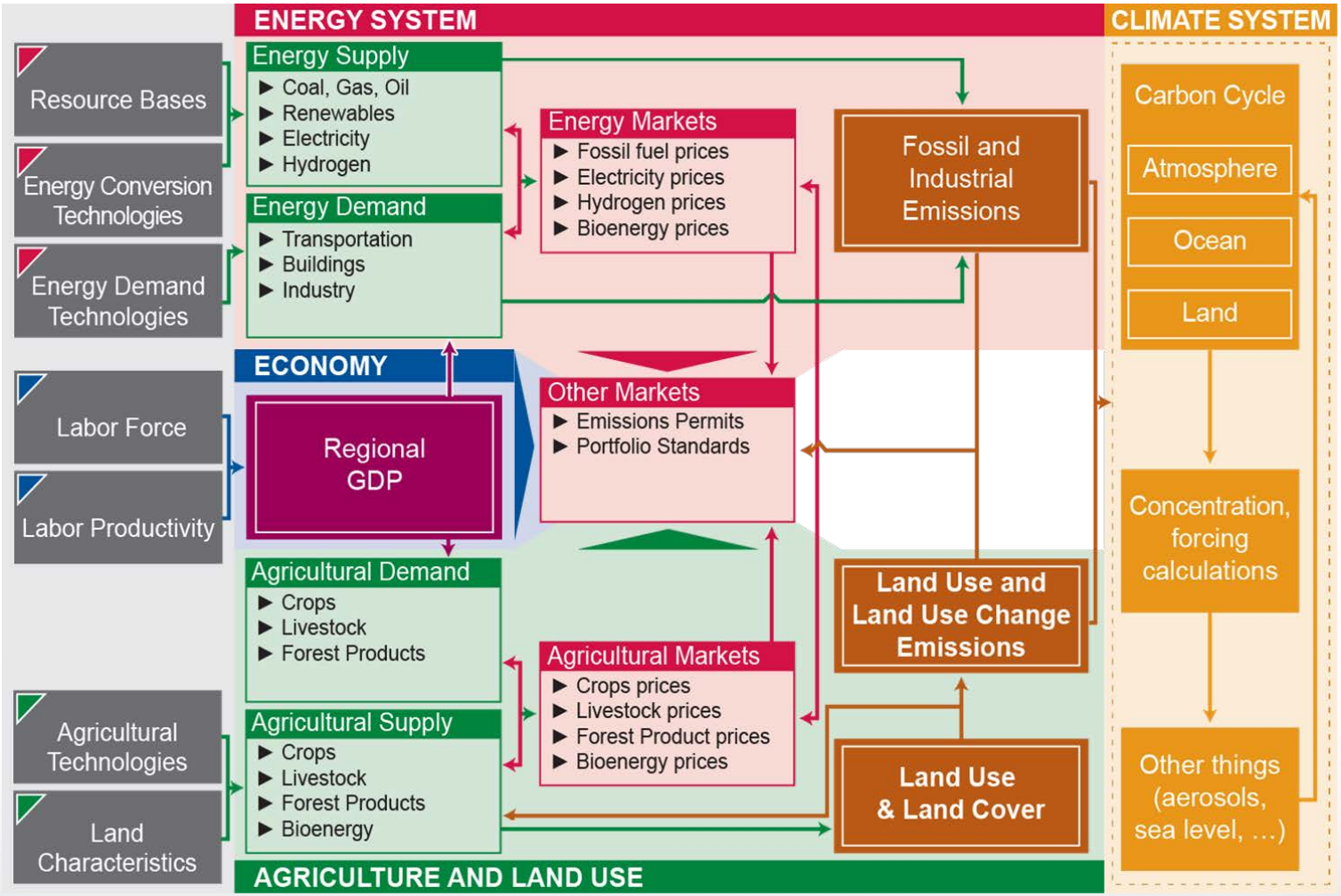


233 water basins

Source: JGCRI, PNNL

GCAM sectoral coverage

GCAM Components

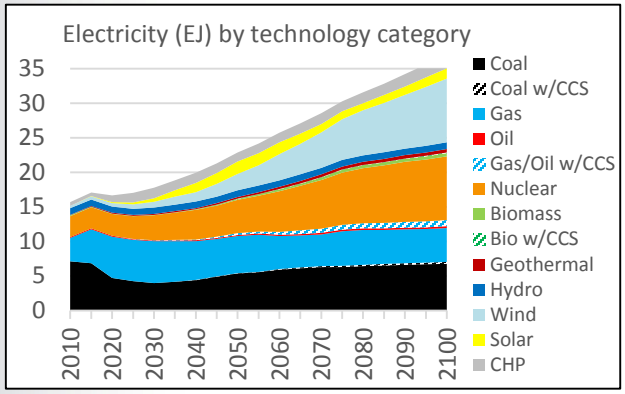


Source: JGCRI, PNNL

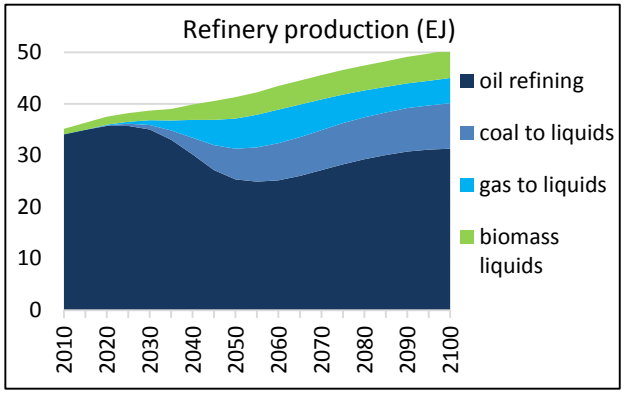
Example GCAM outputs

Example GCAM national-scale outputs for a hypothetical scenario

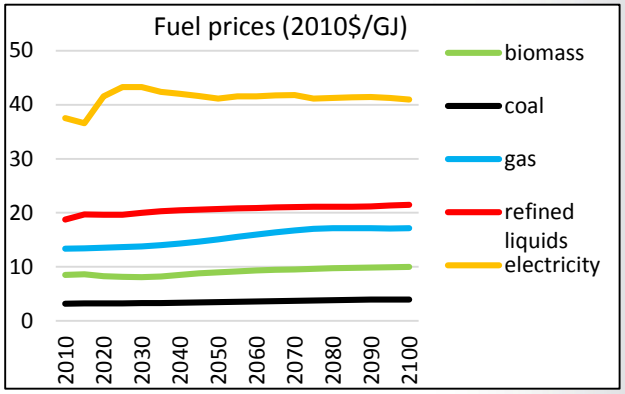
Technology market shares



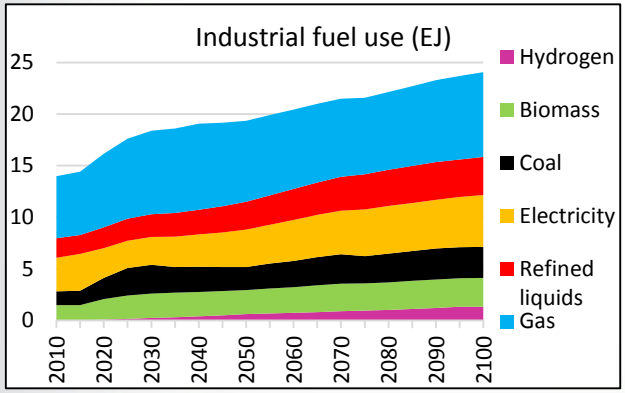
Fuel production



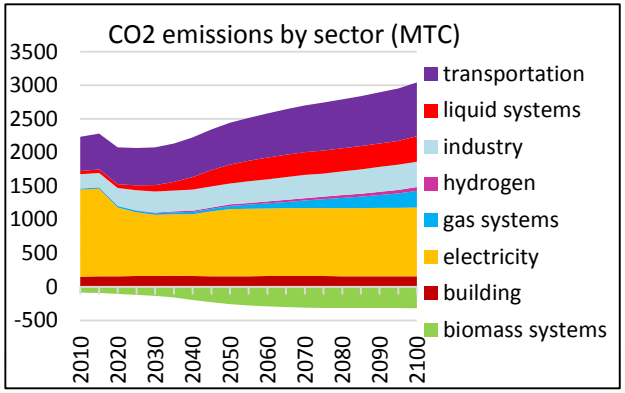
Fuel prices



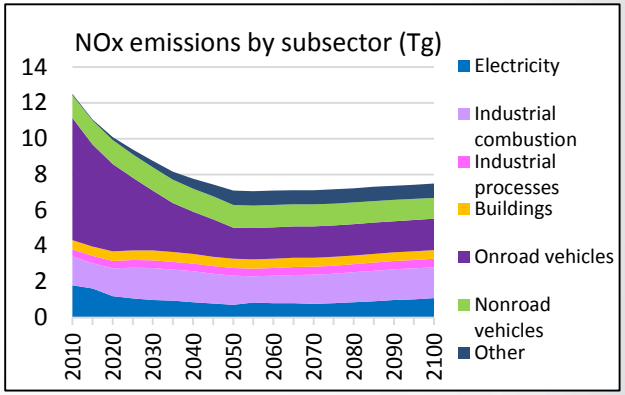
Sectoral fuel use



GHG emissions



Air pollutant emissions



Illustrative results

Additional GCAM outputs

- Primary energy consumption
- Final energy consumption
- Fuel use in electricity production
- Sectoral energy demand by service
- Sectoral fuel use and price by service
- Technology stock by service
- Industrial output (e.g., cement production)
- Land use by agro-ecological zone (AEZ)
- Agricultural production and prices
- Fertilizer use by crop
- Meat production and prices
- Feed production and prices
- Biomass production and consumption

- GHG emissions
- Air pollutant emissions
- CO_2 concentrations
- Climate forcing
- Global mean temperature
- Policy costs
- Regional CO_2 marginal abatement curve by period
- Energy-related water demands

Also, through ongoing work:

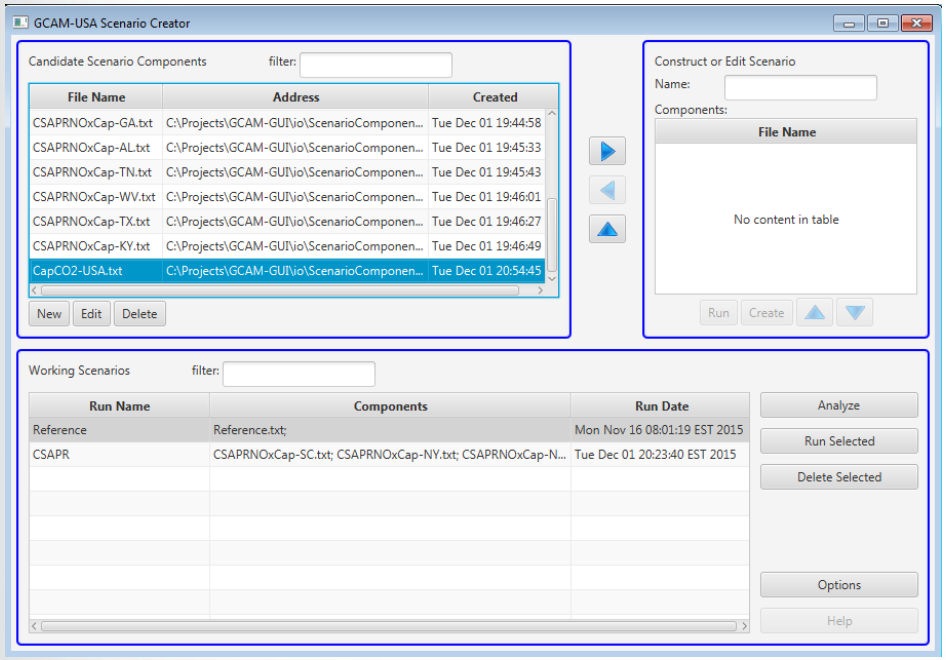
- PM mortality health benefits
- Ozone-related crop and timber impacts
- Deposition of N from NOx and NH_3
- Life cycle impacts

The GLIMPSE project

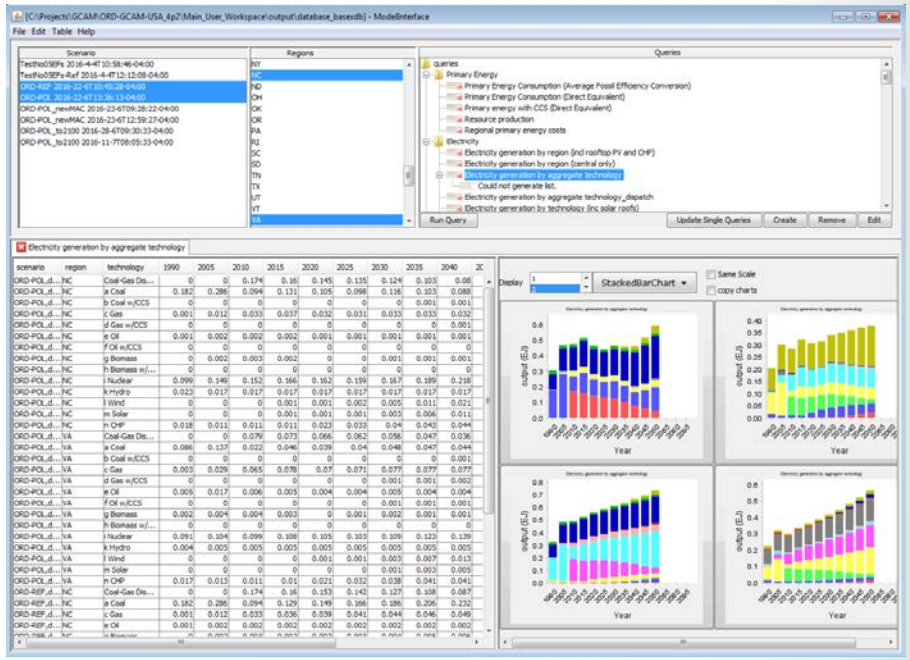
Tools for supporting decision making

We are developing a Scenario Builder to facilitate the construction of management strategies and running GCAM. We are also enhancing tools for exploring GCAM outputs.

Scenario Builder graphical interface



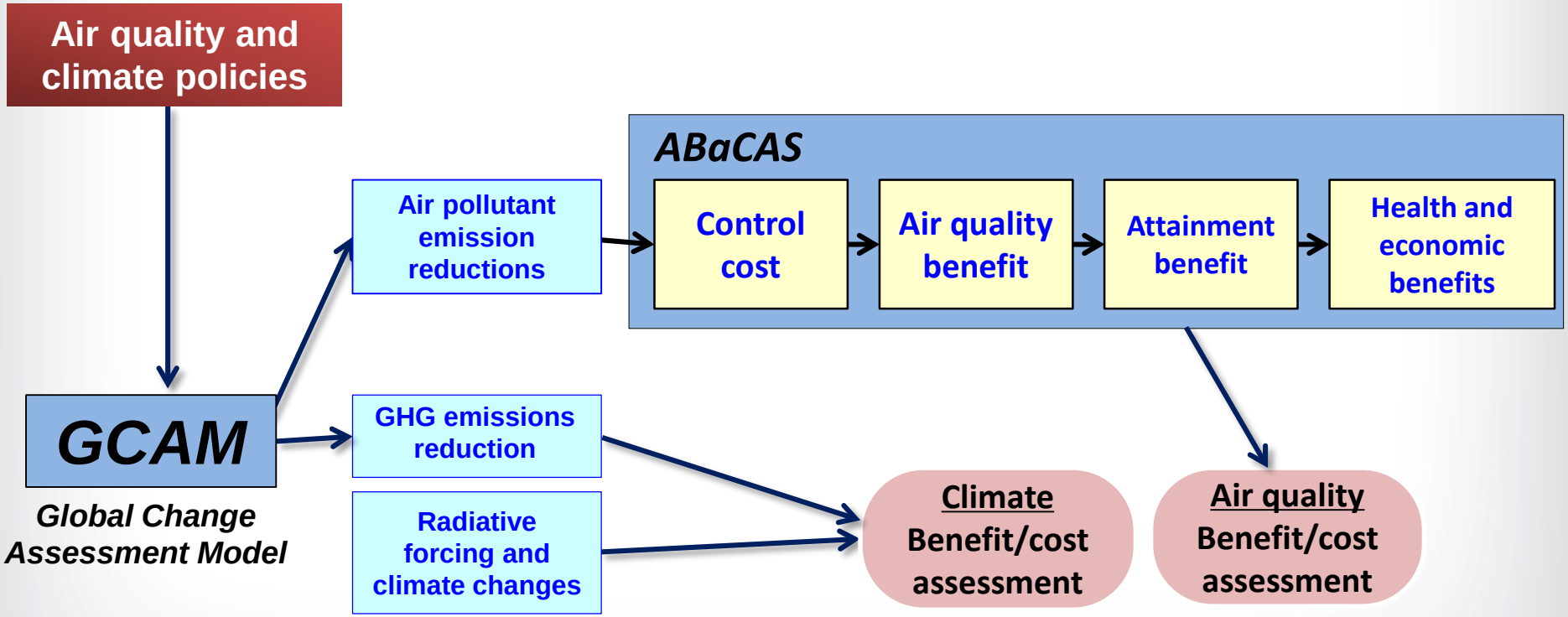
Exploratory data analysis tools



Illustrative results

GCAM-ABaCAS conceptual framework

GCAM can also be integrated with the Air Benefit and Cost Assessment System (ABaCAS).



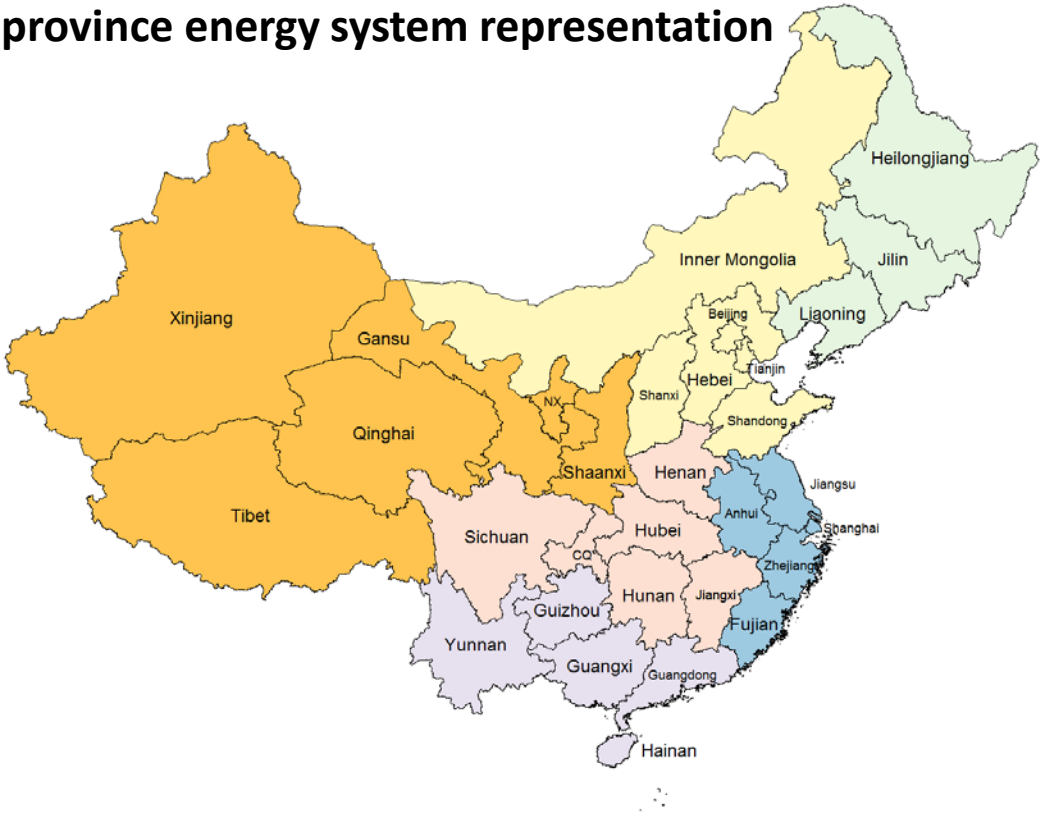
Source: Adapted from a graphic developed by Carey Jang, U.S. EPA

GCAM-China

GCAM-China is being developed in collaboration between researchers at Tsinghua University and PNNL (at the Joint Global Change Research Institute)

Potential applications of GCAM-China include analysis of national emission reduction targets, projection of air pollution emissions, and assessment of sectoral policies.

31-province energy system representation



Summary

- GLIMPSE has the potential to support long-term, coordinated environmental, climate and energy planning
- A component of GLIMPSE, the GCAM Integrated Assessment Model, is being customized to have additional country-level resolution
  - GCAM-USA: State-level for the U.S.
  - GCAM-China: Province-level for China

Questions? Comments?

Thank you! 谢谢！