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GCAM USA – A Tool For State-Level Energy and Emissions Projections

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2015 Emissions Inventory Conference
San Diego, CA

April 15, 2015

Outline

- Brief introduction to Integrated Assessment Models
- The Global Change Assessment Model (GCAM)
- Example Analyses
  - Bioenergy and CCS
  - Health Benefits of GHG Mitigation
- GCAM-USA
  - Overview
  - Transportation
  - Buildings
- Pilot Project: pollutant emissions
- Summary

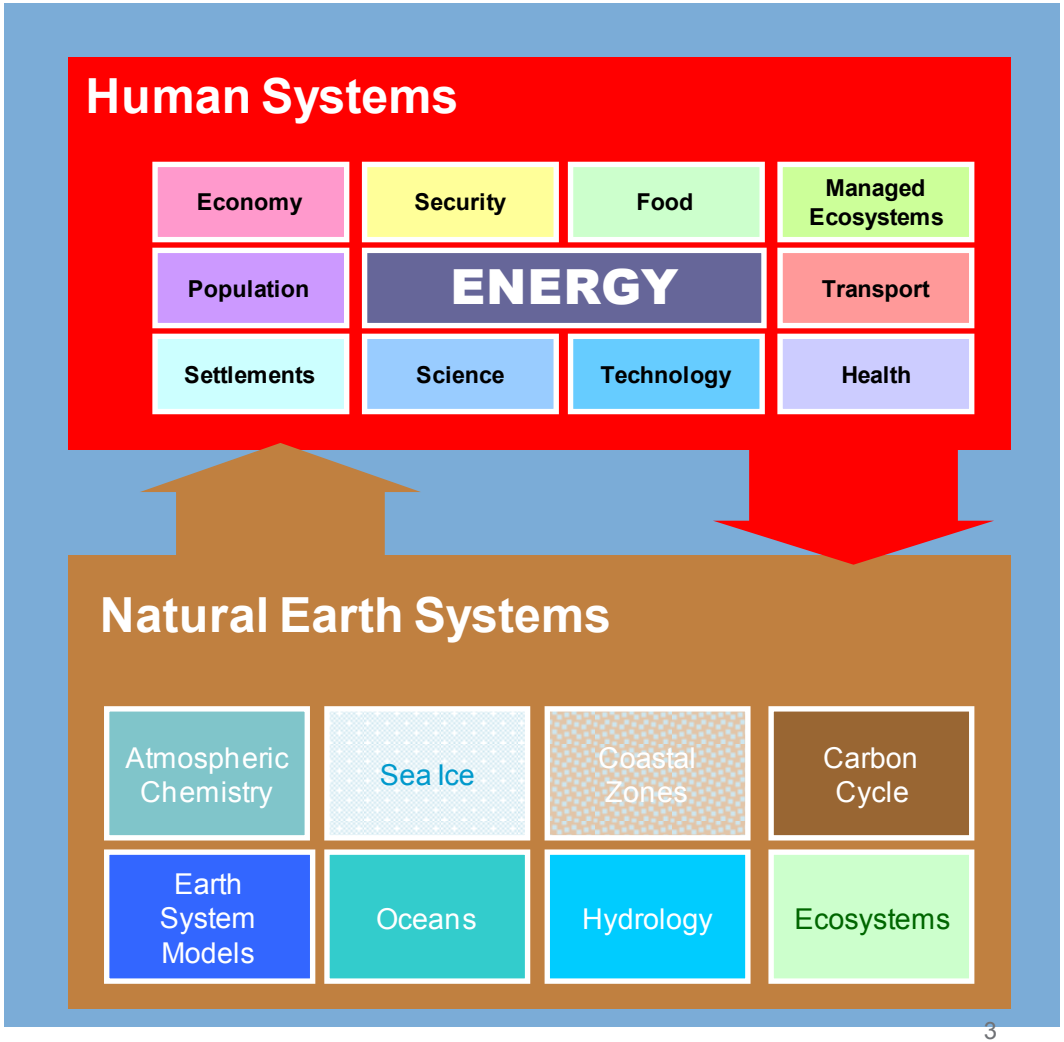
What is an Integrated Assessment Model (IAM)?

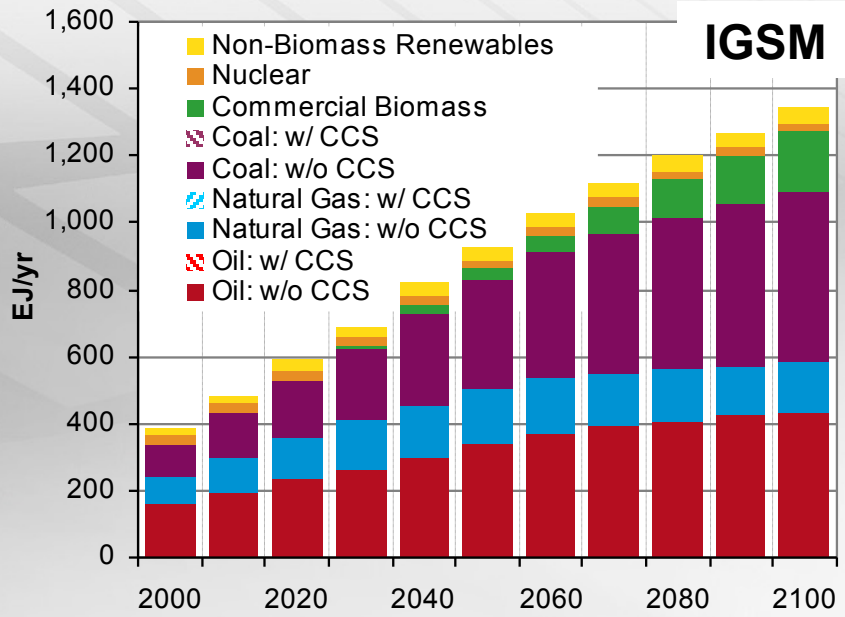
IAMs are research tools that integrate human and natural systems

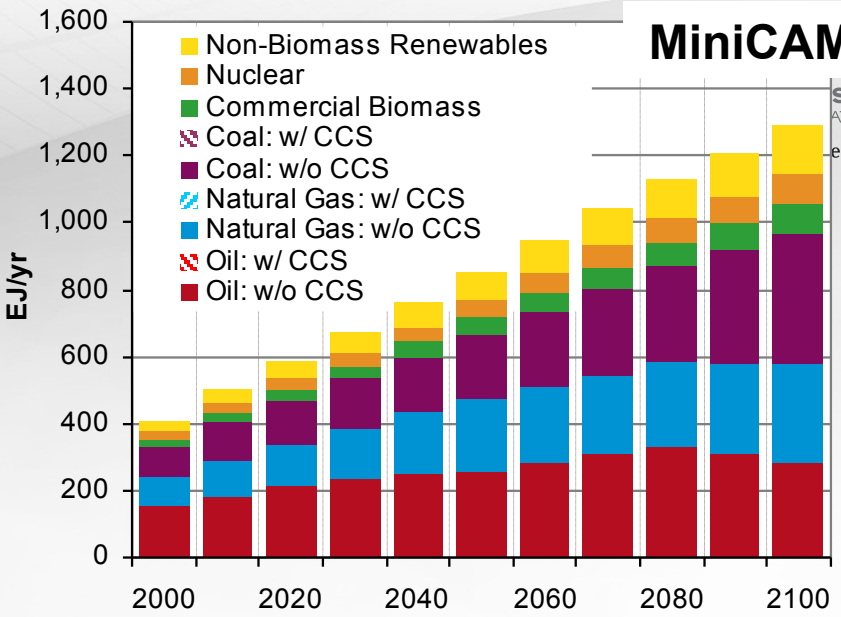
- IAMs provide insights that would be otherwise unavailable from disciplinary research
- IAMs focus on interactions between complex and nonlinear systems
- **IAMs are not substitutes for disciplinary research or more detailed modeling**

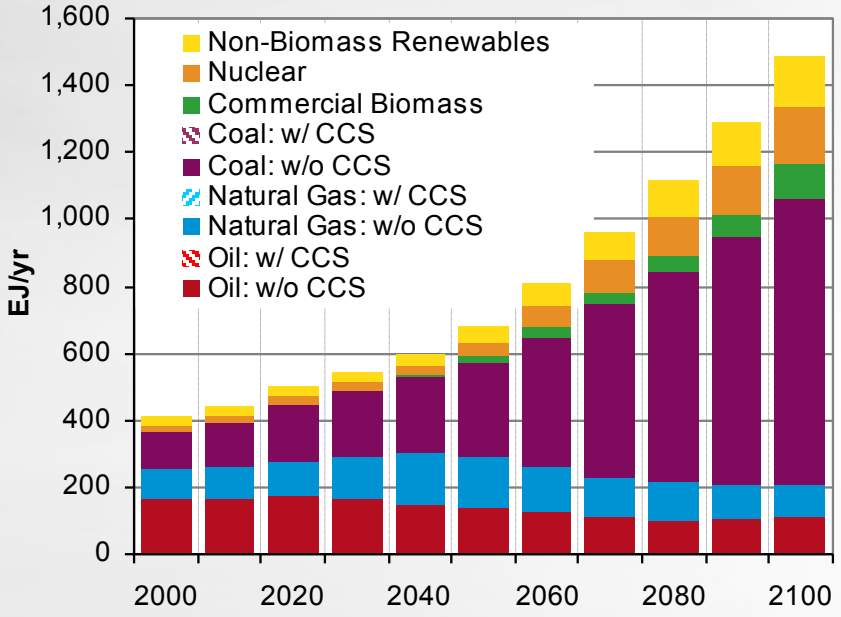
IAMs are also science-based decision support tools

- IAMs support national, international, regional, and private-sector decisions



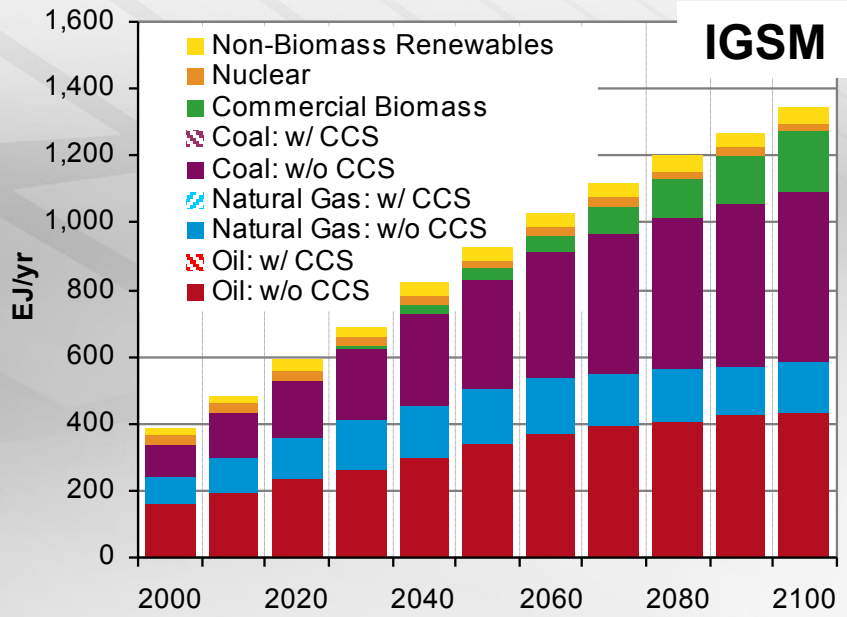


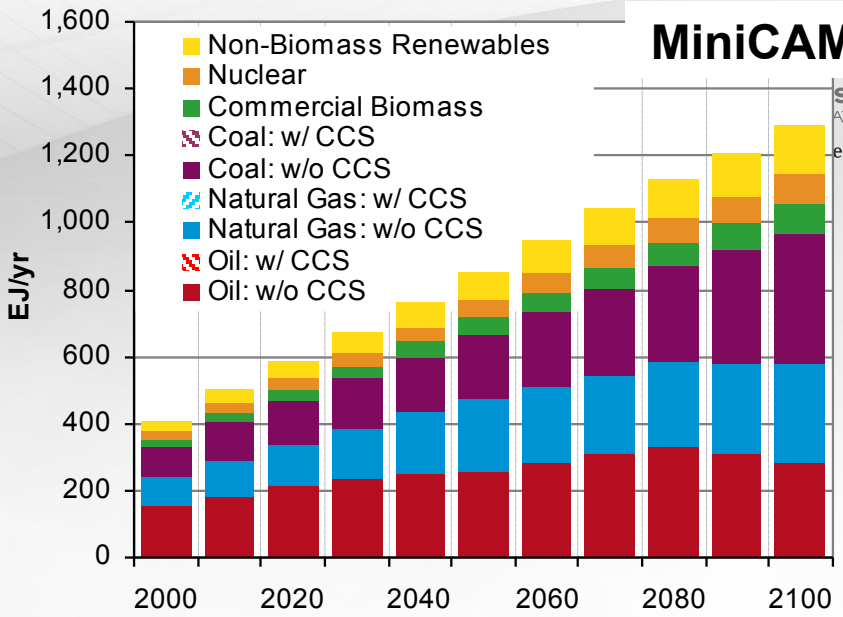


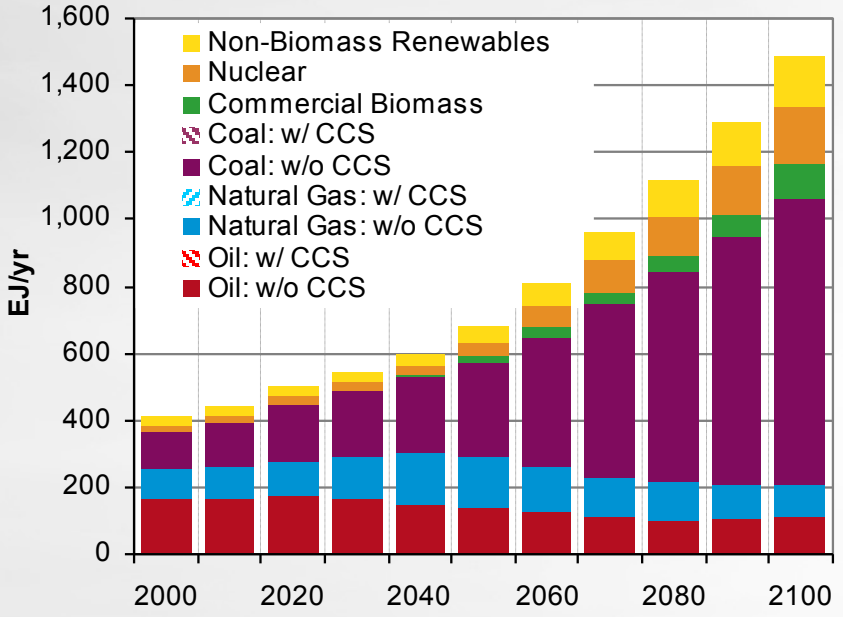


IAMs have been used extensively to support energy-related decision making at national and international scales.

From ***CCSP Product 2.1a: Scenarios of Emissions and Greenhouse Gas Concentrations***



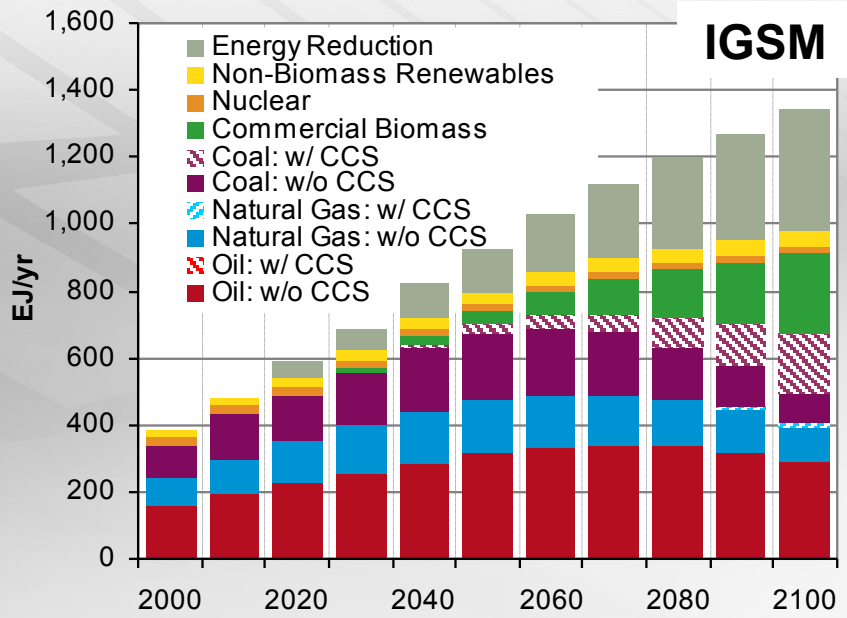


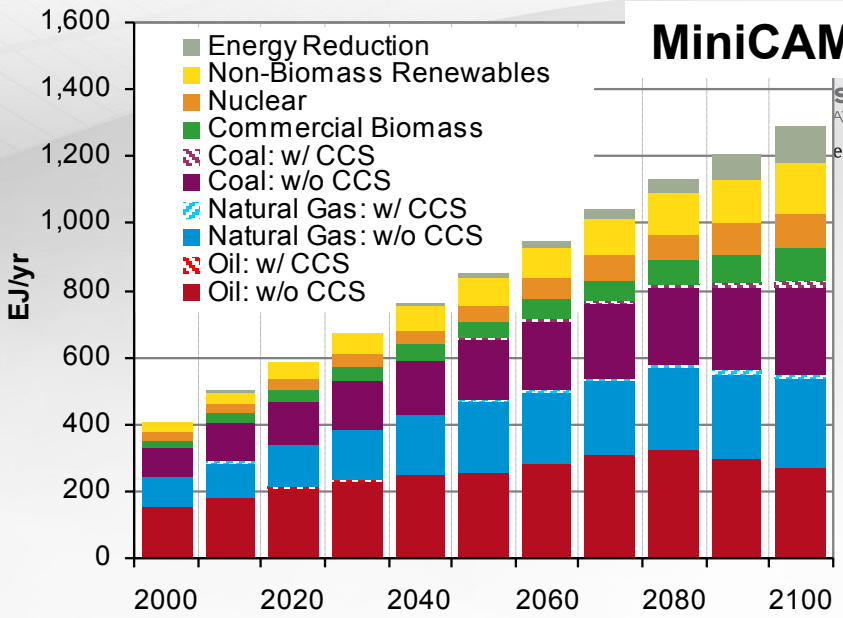


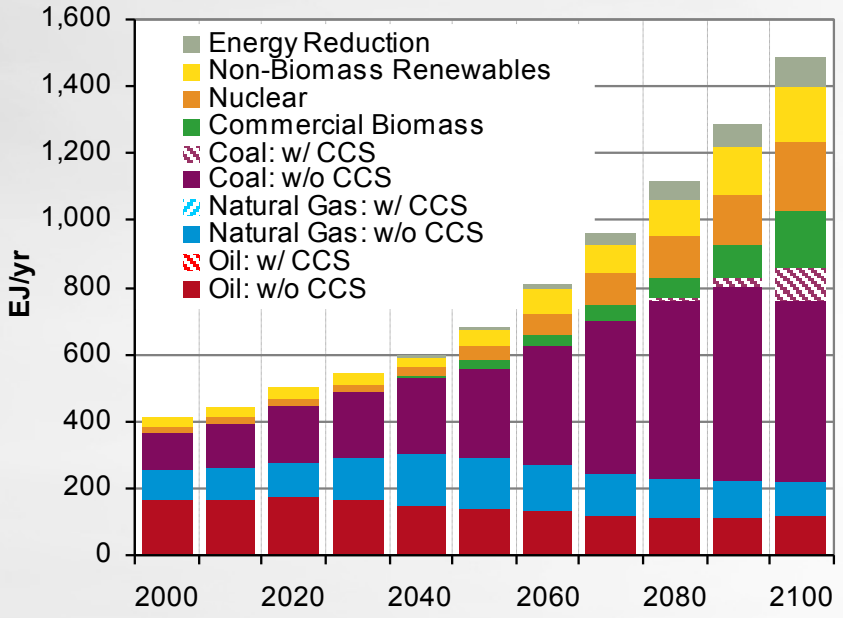
Primary Energy from the CCSP Scenarios

(Reference Scenario)

From ***CCSP Product 2.1a: Scenarios of Emissions and Greenhouse Gas Concentrations***



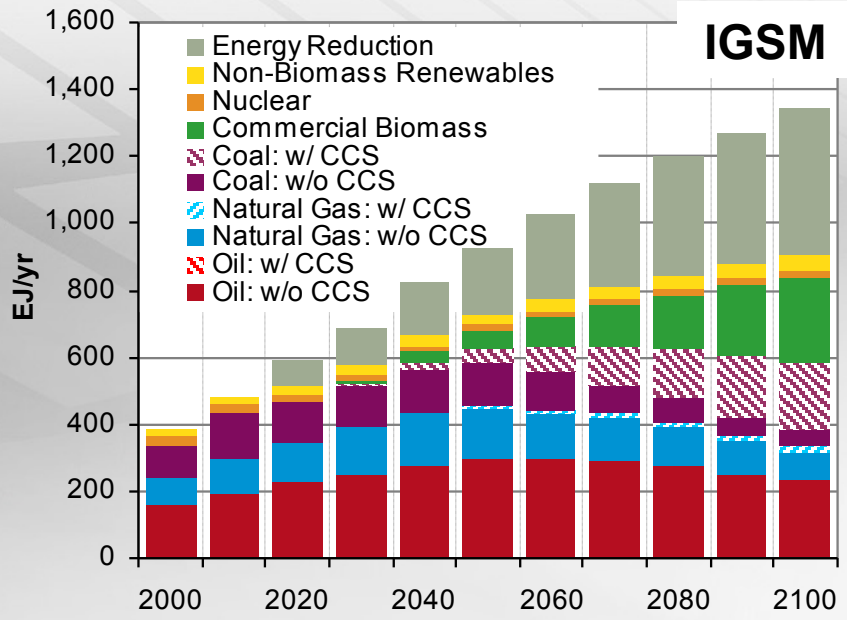


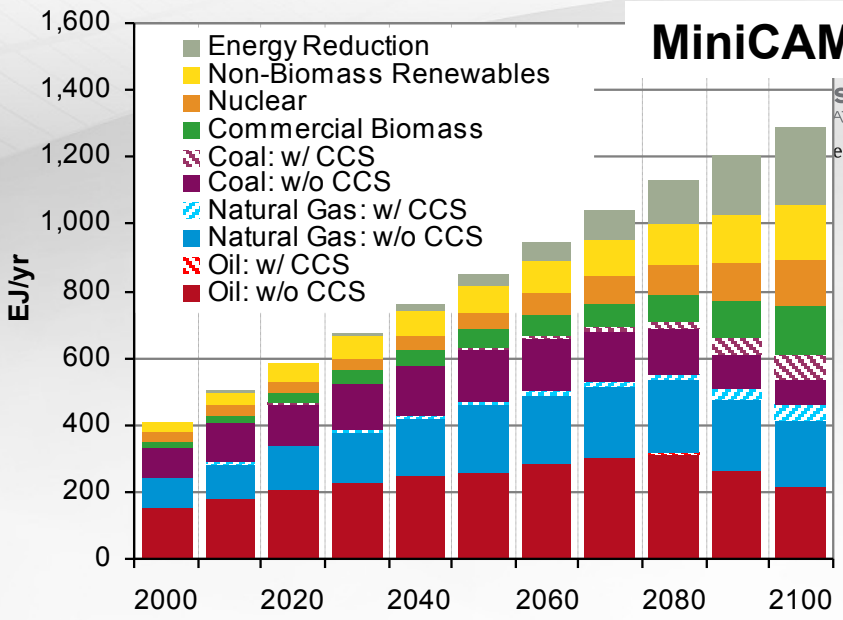


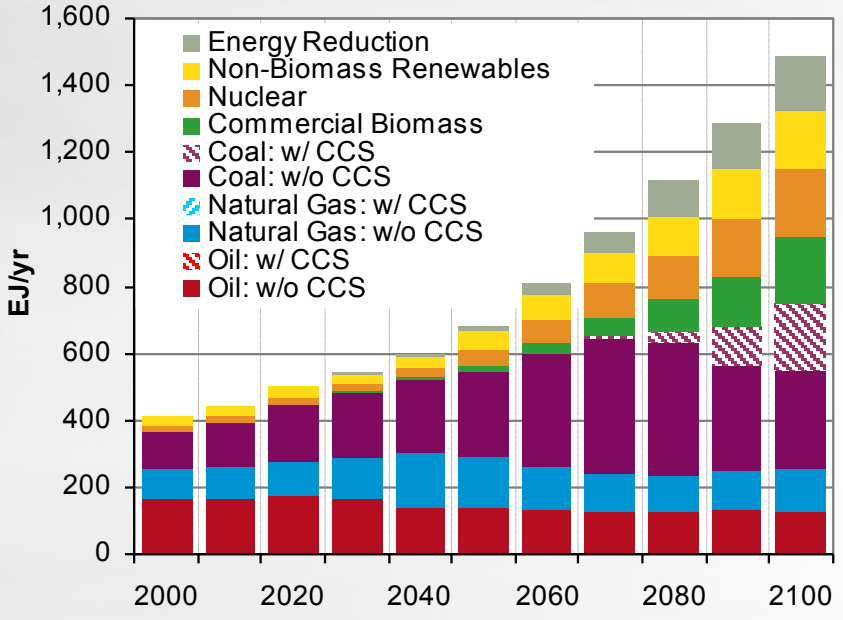
Primary Energy from the CCSP Scenarios

(≈ 750 ppmv CO_2)

From ***CCSP Product 2.1a: Scenarios of Emissions and Greenhouse Gas Concentrations***



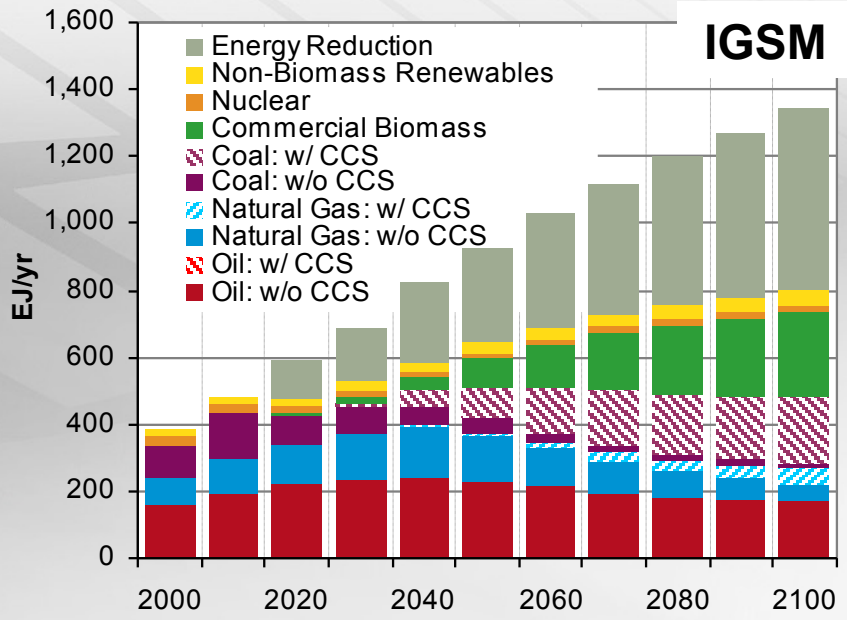


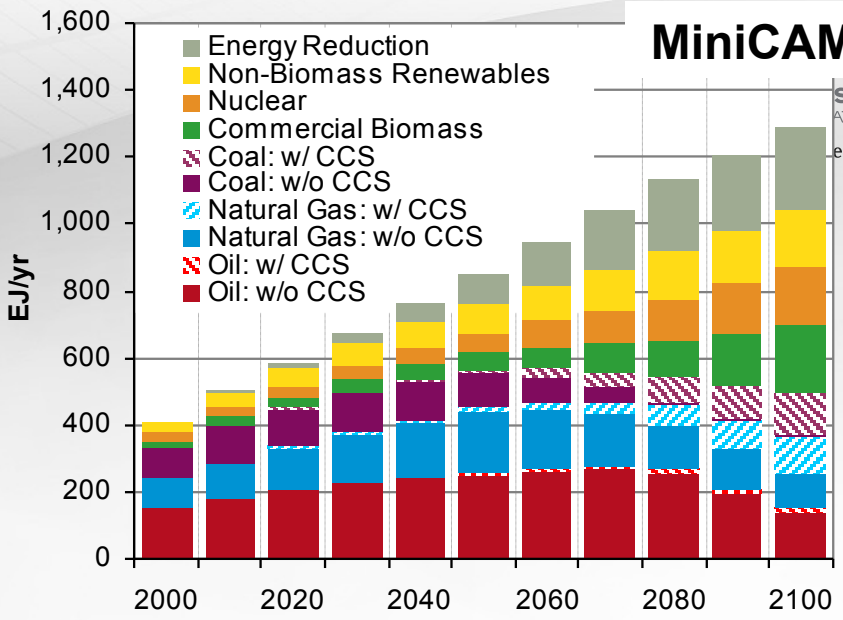


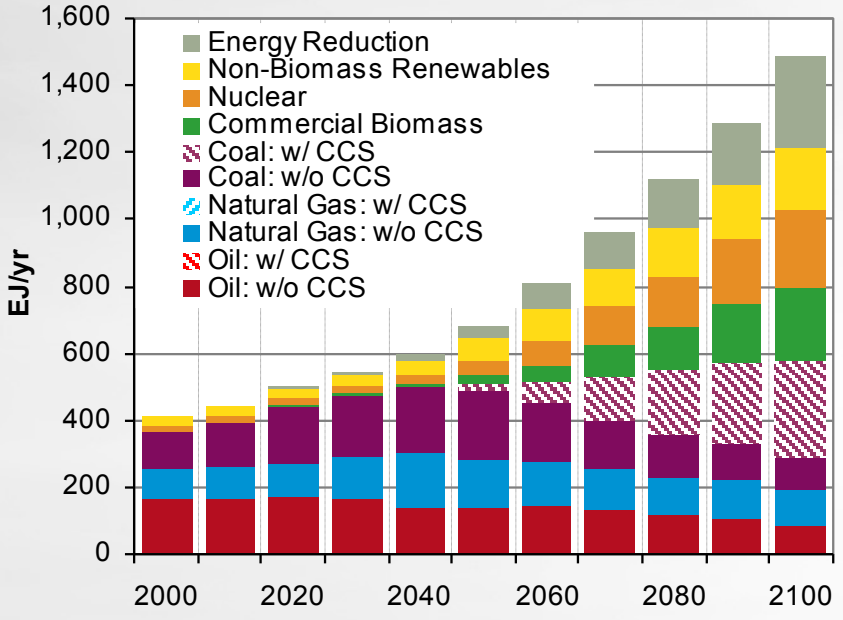
Primary Energy from the CCSP Scenarios

(≈ 650 ppmv CO_2)

From ***CCSP Product 2.1a: Scenarios of Emissions and Greenhouse Gas Concentrations***







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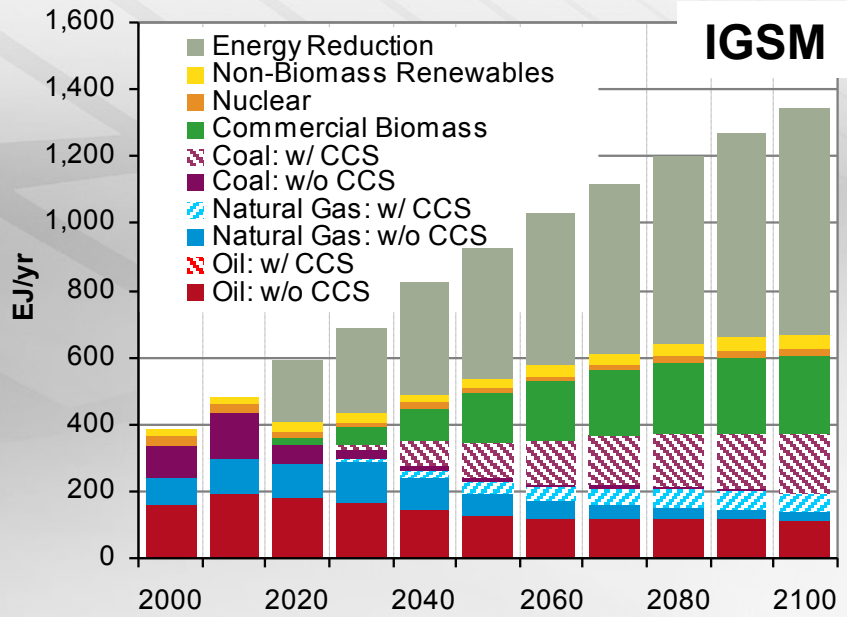

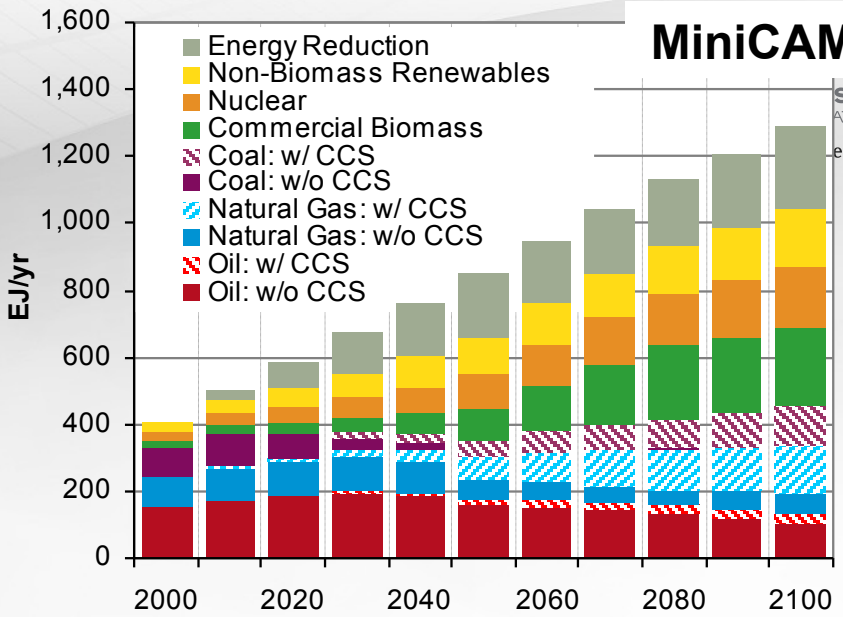

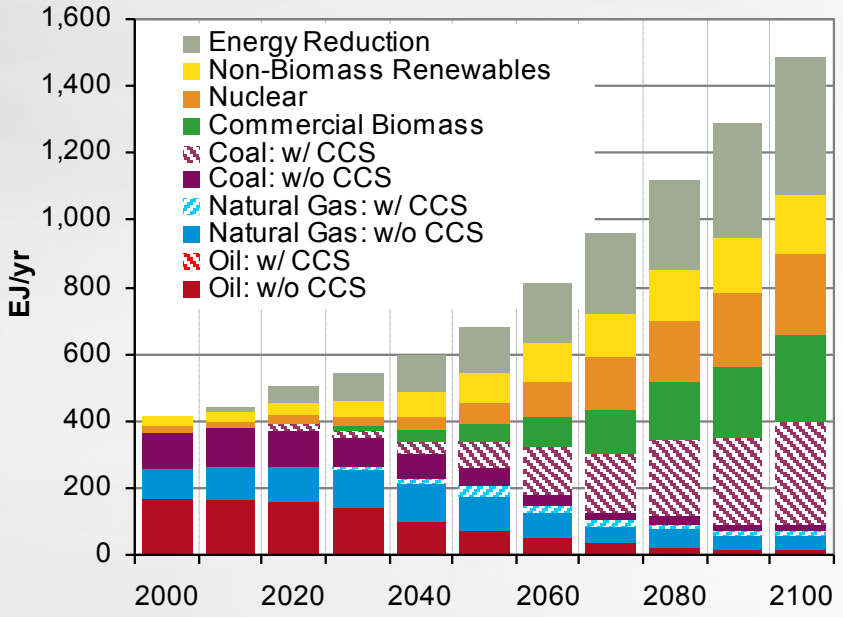

MERGE

Primary Energy from the CCSP Scenarios

(≈ 450 ppmv CO_2)

From ***CCSP Product 2.1a: Scenarios of Emissions and Greenhouse Gas Concentrations***

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The Global Change Assessment Model (GCAM)

The Global Change Assessment Model

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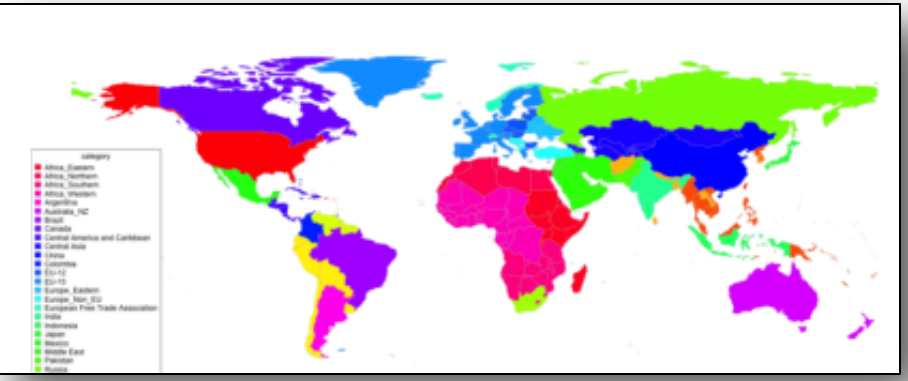
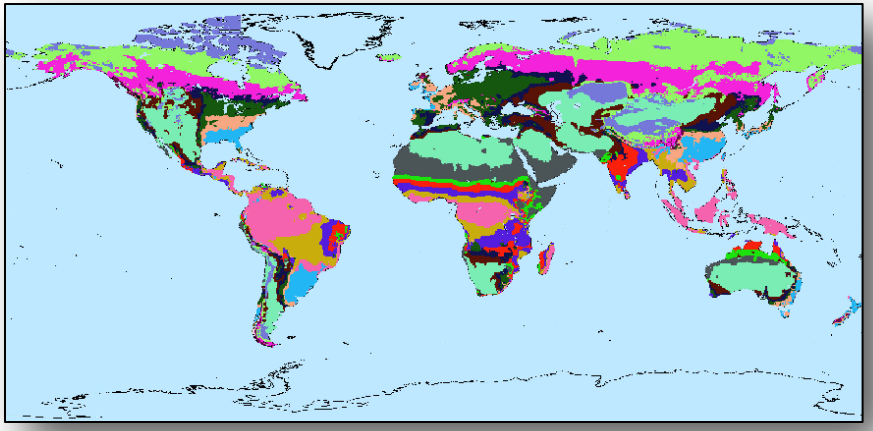
32 Region Energy/Economy Model



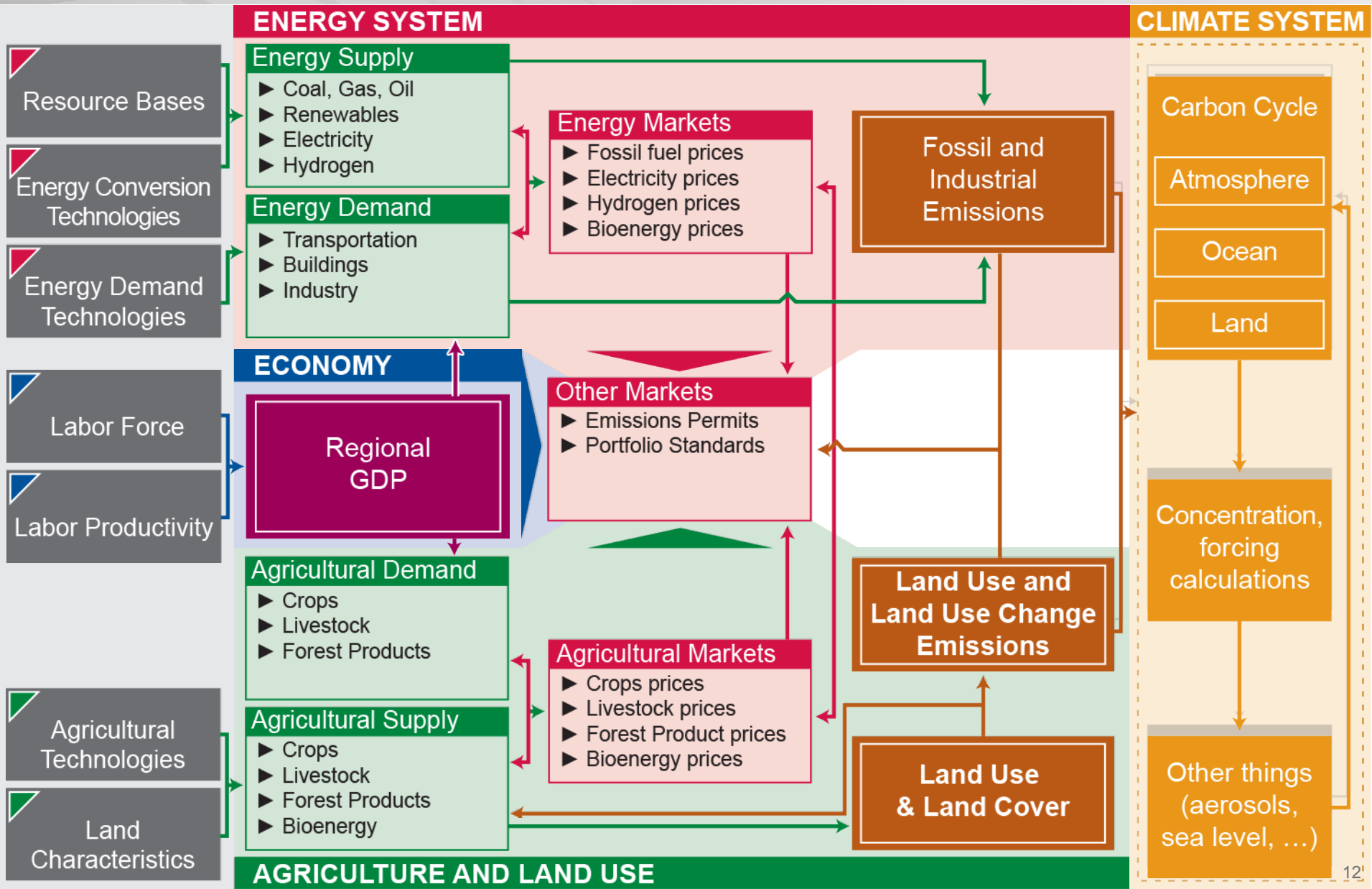
283 Agriculture and Land Use Regions



233 Water Basins

- GCAM is an open-source, global integrated assessment model
- GCAM links **Economic**, **Energy**, **Land-use**, and **Climate** systems (and now **Water**)
- Typically used to examine the effect of socioeconomic scenarios, technology, and policy on the economy, energy system, agriculture and land-use, and climate
- Technology-rich model (for an IAM)
- Emissions of 16 greenhouse gases and short-lived species: CO_2, CH_4, N_2O, halocarbons, carbonaceous aerosols, reactive gases, sulfur dioxide
- Runs through **2100** in **5-year time-steps**
- Documentation available at: **wiki.umd.edu/gcam**
- Also a GCAM Community Listserve

The Global Change Assessment Model



GCAM Studies:
Impact of Land-Use Policies on Climate Policy Costs

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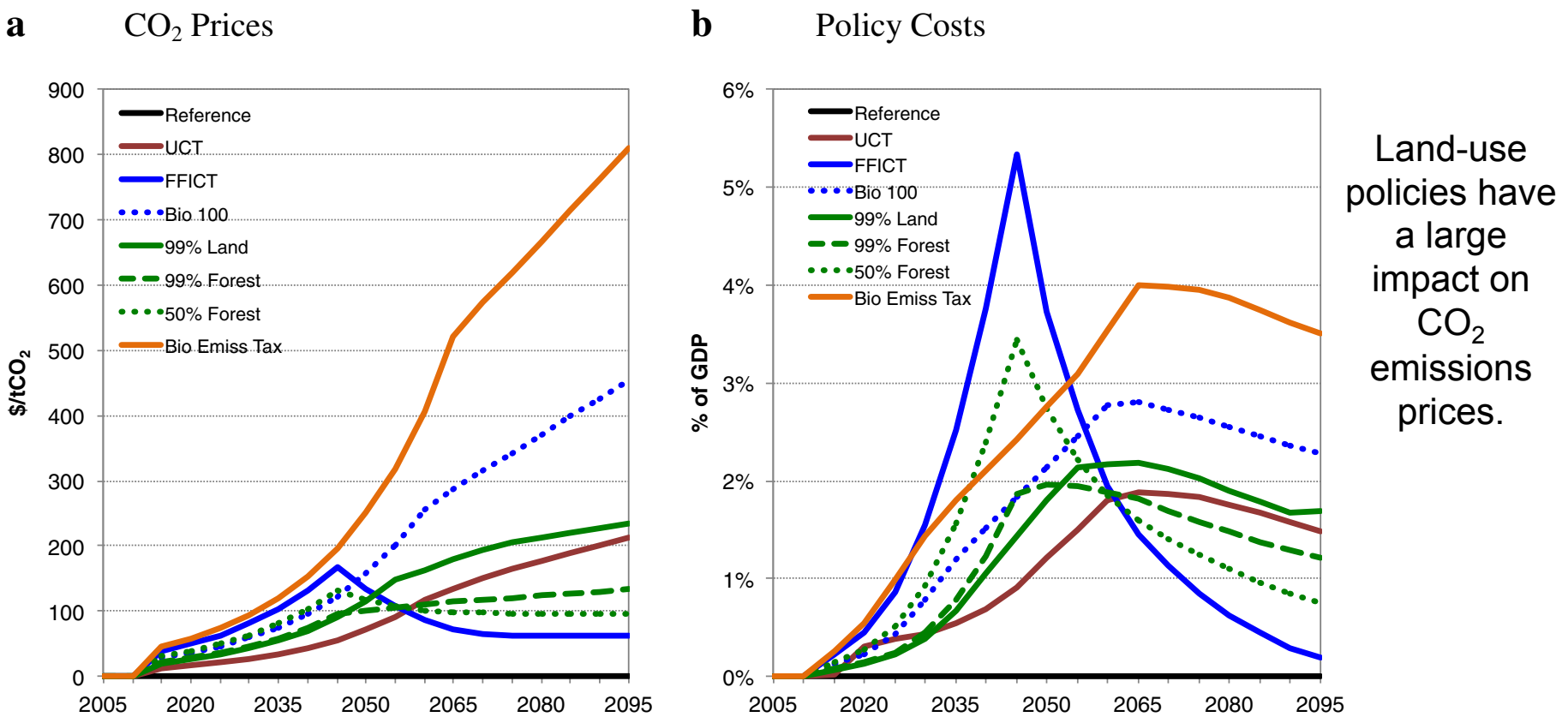
Cost of a global climate policy to limit total radiative forcing to 3.7 W/m²



Land-use policies have a large impact on CO_2 emissions prices.

Fig. 5 CO_2 prices and policy costs (Area under MAC curve) across bioenergy and land policy scenarios

Calvin, K., Wise, M., Kyle, P., Patel, P., Clarke, L. & Edmonds, J. 2013. Trade-offs of different land and bioenergy policies on the path to achieving climate targets. *Climatic Change,* 123, 691-704, 10.1007/s10584-013-0897-y

Study using GCAM data:
Health and Air-Quality Co-Benefits of GHG Mitigation

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Objective

- Quantify health and air quality co-benefit due to the pollutant emission reductions that occur from the implementation of a comprehensive climate policy over the 21st century.

Methods

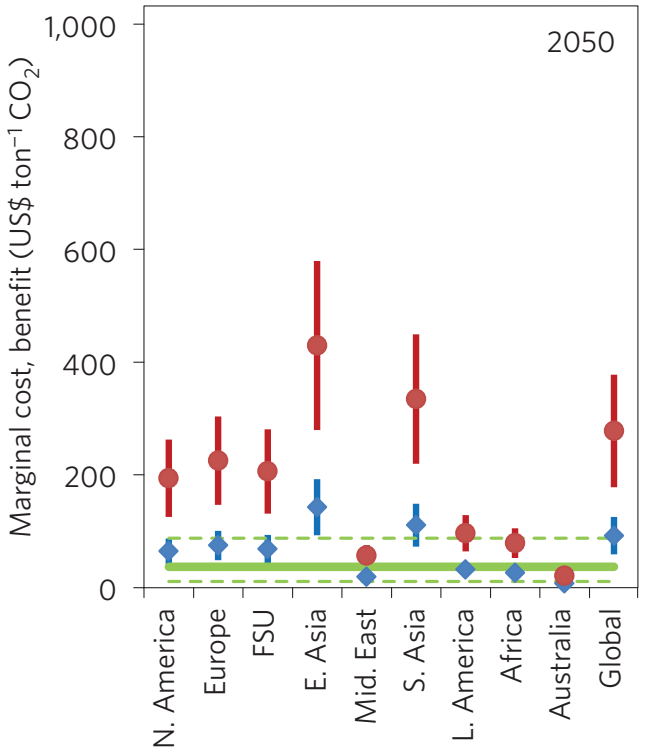
- Emissions of air pollutants decrease under a comprehensive climate policy. Examine the air quality implications of these reductions using the GCAM Reference and RCP4.5 scenarios, together with the MOZART-4 global chemical-transport model.

Findings

- Lower air pollution levels due to a climate policy scenario result in one million fewer deaths in 2050.
- The monetized value of the mortality reduction is generally larger than climate policy costs up until at least 2050.

Implications

- The air quality improvements that result from a comprehensive global climate policy are a substantial additional benefit of a global policy to reduce greenhouse gas emissions.



Monetized value of mortality reduction in 2050 due to pollutant emission reductions (low and high value of statistical life assumptions: blue and red bars) as compared to a range of climate policy costs.

West, J. J., Smith, S. J., Silva, R. A., Naik, V., Zhang, Y., Adelman, Z., Fry, M. M., Anenberg, S., Horowitz, L. W. & Lamarque, J.-F. 2013. Co-benefits of mitigating global greenhouse gas emissions for future air quality and human health. *Nature Clim. Change,* 3**,** 885-889, 10.1038/nclimate2009

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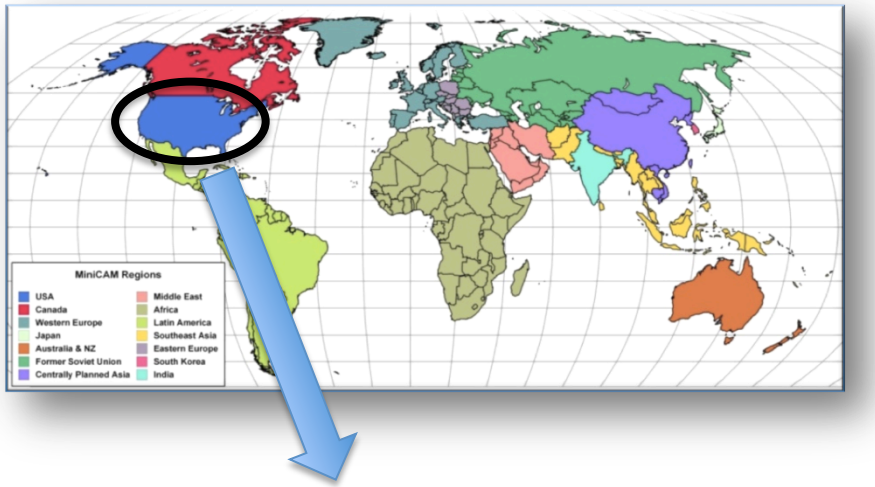
GCAM USA

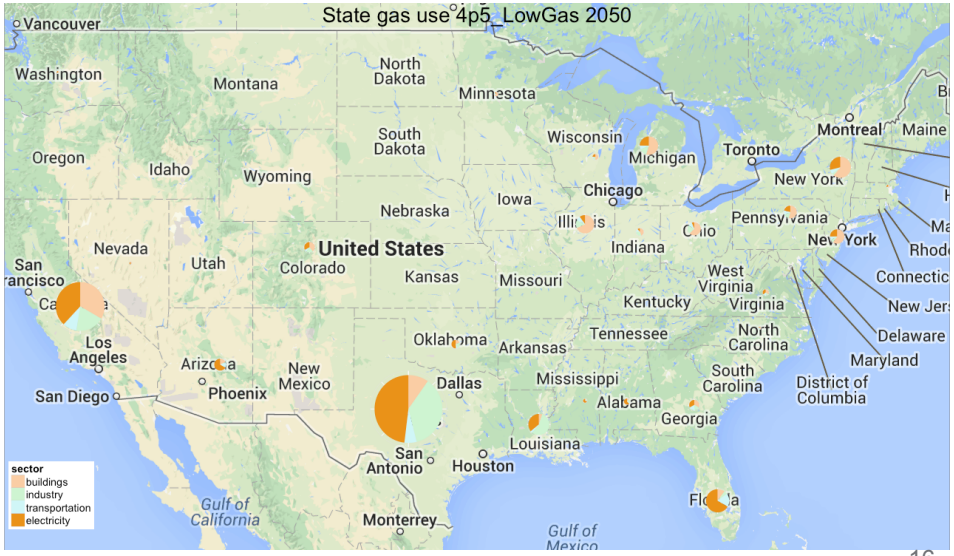
GCAM-USA: A Summary

- GCAM-USA is a version of GCAM with subregional detail in the United States.
- GCAM-USA is a full, global integrated assessment model (IAM).
- It is actively being used to explore energy-water-land interactions
- This is a new capability with many possible applications, **and many areas for further development**
- GCAM-USA development has been supported by PRIMA and the Integrated Assessment Research Program at the Office of Science.

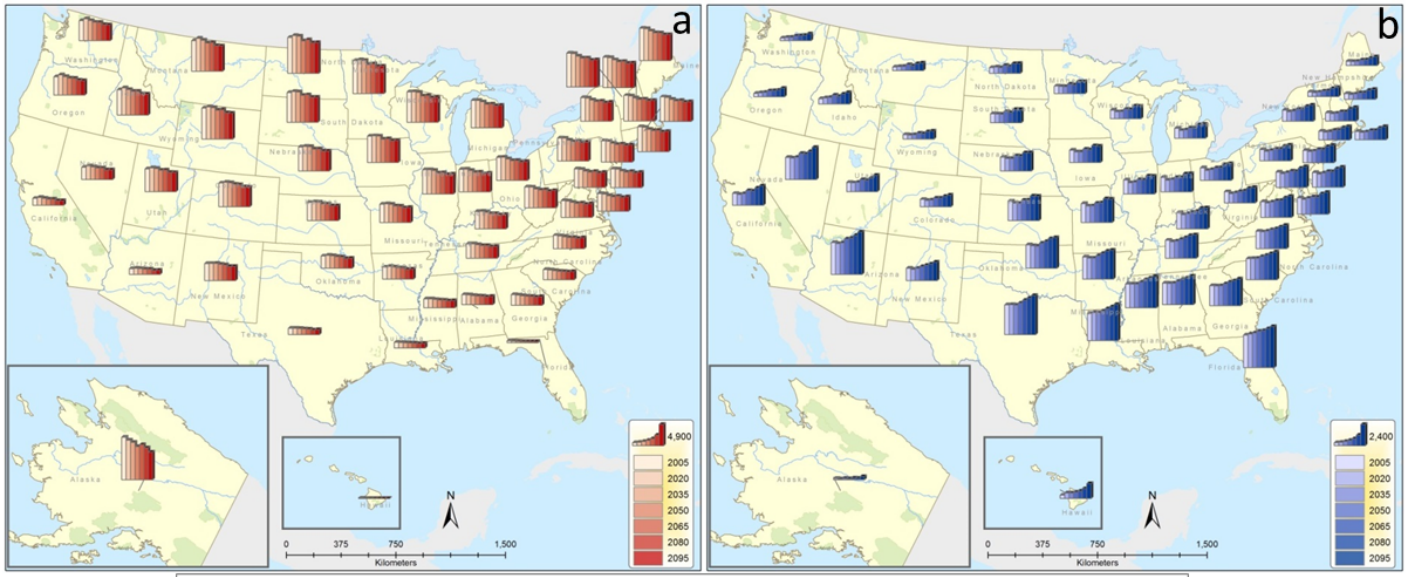
GCAM

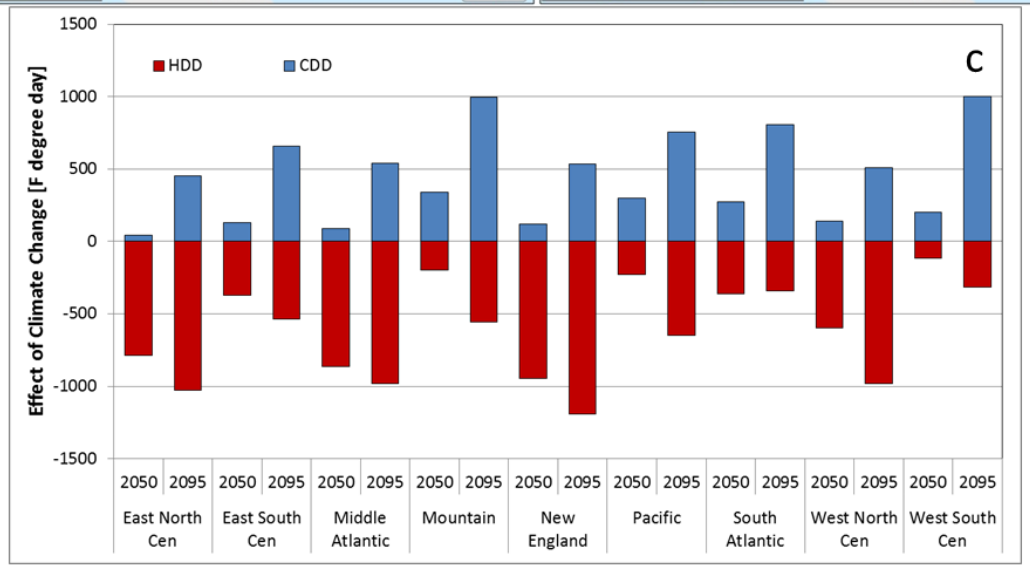


GCAM - USA



GCAM-USA





A more detailed representation of the U.S. at the 50 state level, embedded within the global model allows for improved modeling of issues such as the impact of changing climate on US building energy consumption.

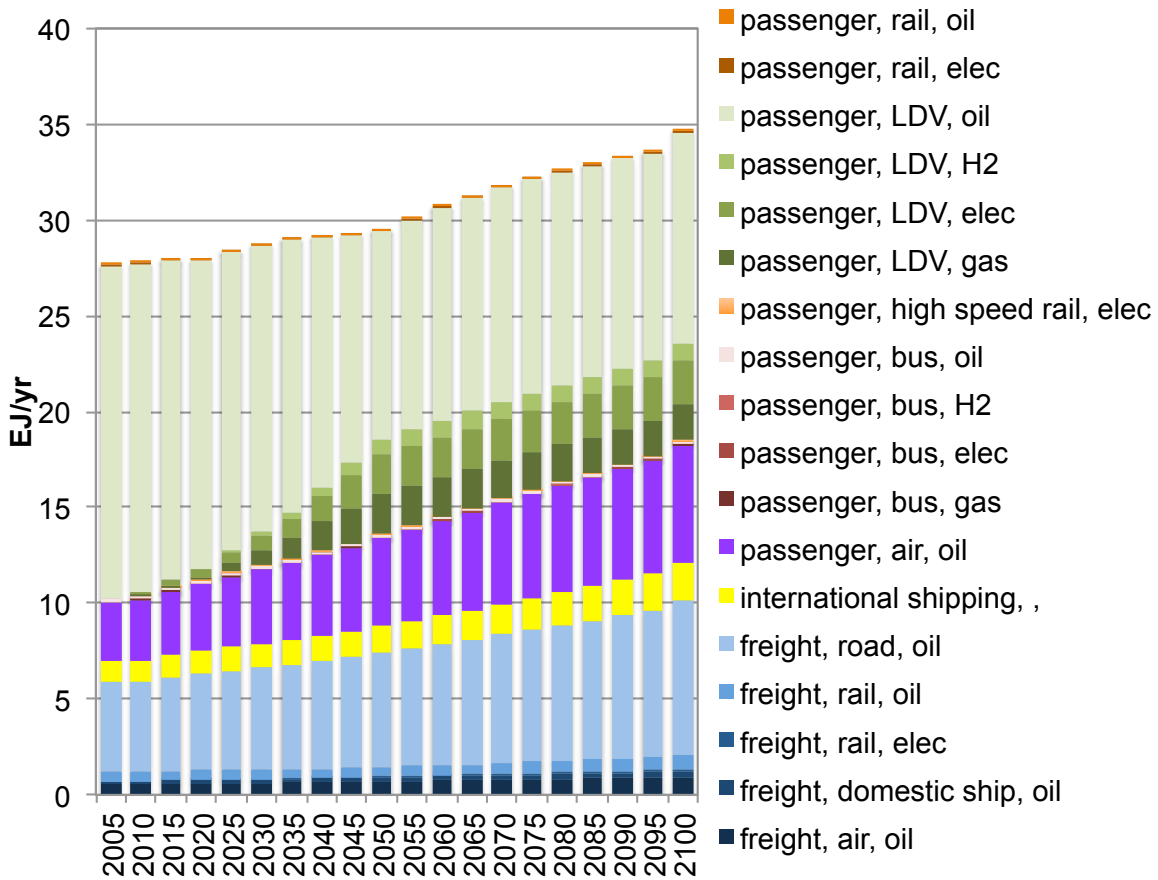
Zhou Y, et al. 2014. "Modeling the effect of climate change on U.S. state-level buildings energy demands in an integrated assessment framework." Applied Energy 113:1077-1088. doi:10.1016/j.apenergy.2013.08.034

Current GCAM-USA Detail

- Socioeconomics at state level
  - Population
  - GDP
- Energy transformation at state level
  - Electricity generation & Refining by state
  - Full electricity (and CO_2 storage) trade within modified NERC regions
- Renewable and carbon storage resources at state level
  - Wind, Solar (central and rooftop PV), geothermal
  - Carbon storage
- Energy final demands at state level
  - Buildings: representative commercial * residential building in each state
  - Transportation: passenger & freight with detailed technologies
  - Industry: aggregate energy demands (also have agr-USA process model)
- Not modeled at the state level
  - Fossil Resources
  - Agricultural demand (USA total) & supply (10 agro-economic zones AEZ)

The Energy System: Transportation

- We first determine passenger and freight demands by state
- Then track final energy by sector, mode, and fuel

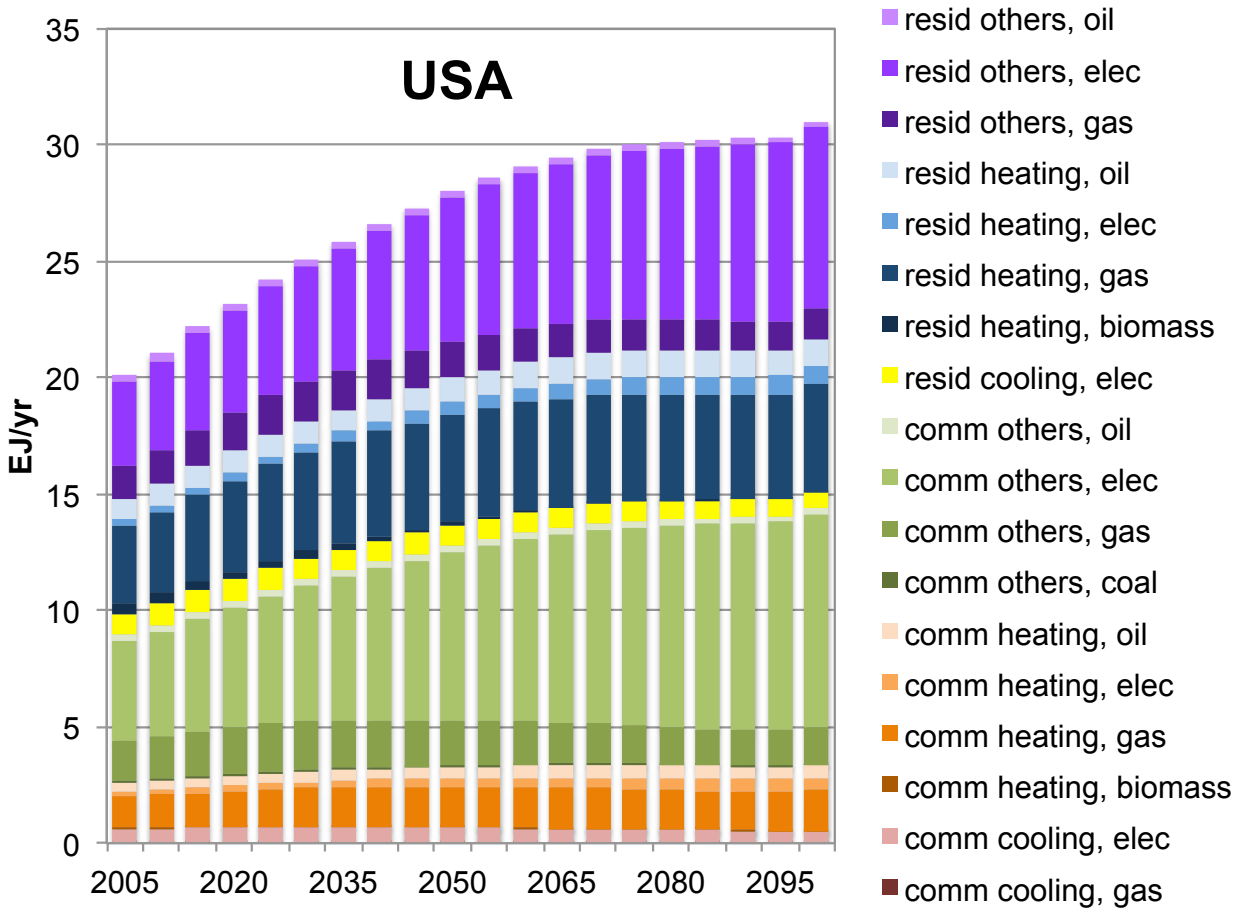


Many sub-sectors can be supplied by multiple technologies

- Electric or liquid LDVs
- Conventional or high speed rail

The Energy System: Buildings

- We first determine commercial & residential floorspace demands
- We then track final energy by sector (residential/commercial), service (heating, cooling, other), and fuel



Heating/Cooling depend on HDD/HDD, building shell thermal characteristics, & internal gains

Six residential building service demands.

Many services can be supplied by multiple technologies

- Heating: gas, oil, elec resistance, elec heat pump
- Lighting: incandescent, fluorescent, LED

Pilot Project:

Explore use of GCAM-USA to examine state-level emissions trajectories

State-level criteria pollutant emissions

We are starting a research project to explore how this modeling tool might be useful to examine the emissions implications of state-level air-, energy-, and climate-related actions.

> *For example: What is the potential for energy efficiency and renewable energy policies to reduce criteria air pollutants and GHG emissions?*

Over the next year we will enhance the GCAM-USA state model:

- Calibrate to NEI 2011 emissions at the state-level
- Incorporate impact of on-the books regulations, new source performance standards, MACT requirements, consent decrees, etc.
- Work with EPA to use GCAM emissions outputs to evaluate health & ecosystem impacts

Perform exploratory analysis to evaluate the potential usefulness of this tool for providing insights at the state level regarding pollutant emissions and impact of various policies.

Funding for this work provided by the US EPA Office of Research and Development.

Summary

- Integrated assessment models (IAMs) are moving to finer spatial and temporal scales in order to provide useful information and insights.
  - This project is an example of movement in this direction.
- **An IAM such as GCAM offers some potential advantages** for examining links between energy, land, policies, emissions, and impacts
  - Flexibility to examine a large number of scenarios over time: socio-economic drivers, technology options, and policies
  - Consistent representation across sectors and spatial scales. (Feedbacks between sectors, regional electricity markets, international trade, endogenous prices)
- **This does not replace the need for more detailed modeling**
  - Regulatory impact analysis requires more detailed tools that consider the system “as it is now” and might evolve in the near-term.