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Introduction to GCAM-USA

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U.S. DEPARTMENT OF ENERGY BATTELLE

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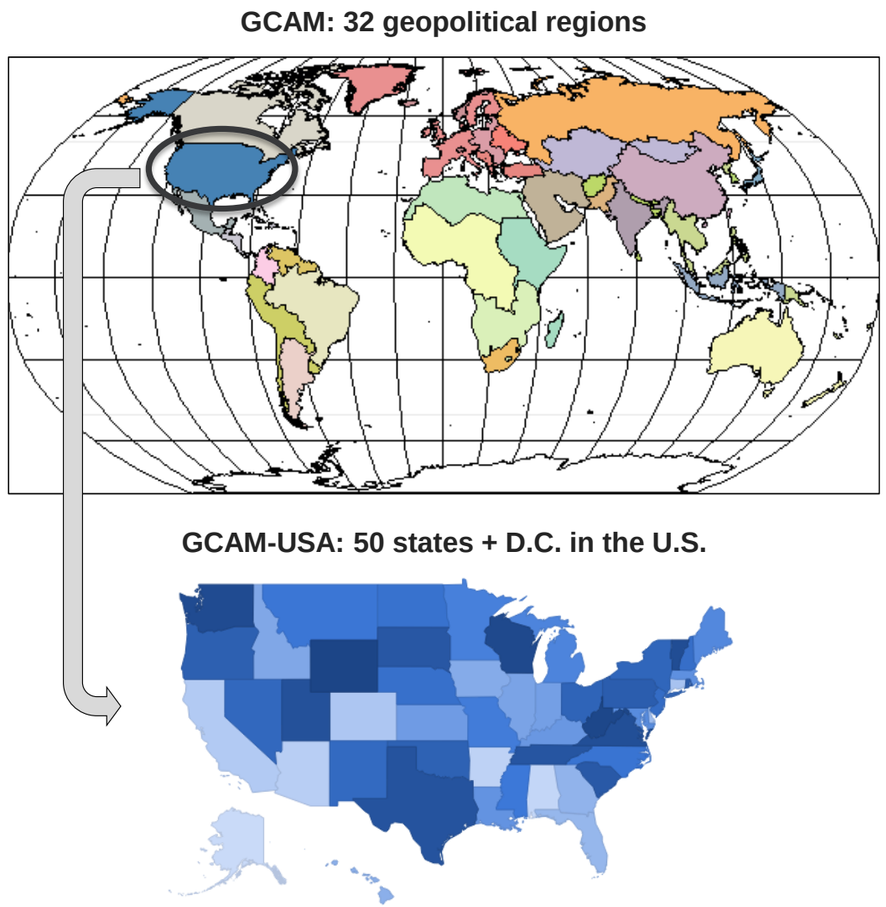
Session Agenda

- What is GCAM-USA?
- At what scale are energy, water, land, and emission activities represented in GCAM-USA? (spoiler – it depends)
- What are the key differences between GCAM-USA and GCAM-32?
- Other tips for using GCAM-USA

What is GCAM-USA?

- GCAM-USA is a version of GCAM with subnational detail in the United States
- GCAM-USA is embedded within the global version of GCAM
  - Conditions and markets in the U.S. states are consistent with international conditions
- GCAM-USA is part of the release version of GCAM
  - It is a community tool and is available for download from GitHub
  - Documentation available at http://jgcri.github.io/gcam-doc/gcam-usa.html



GCAM-USA Overview

Geographic scope	Energy Demands	Resources	Energy Transformation	Energy Prices	Land / Agriculture	Water	Non-CO_2 Emissions
State	• Buildings (residential and commercial) • Industry • Transportation (passenger and freight)						
Grid region							
River basin (HUC-2)							
National (USA)							

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River basin (HUC-2)							
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Grid region		• Carbon storage	Electricity supply and demand are balanced at the grid region level				
River basin (HUC-2)							
National (USA)		• Oil • Coal • Natural gas • Uranium	• Gas processing • Gas pipeline				

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Grid region		• Carbon storage	Electricity supply and demand are balanced at the grid region level	Region-specific prices for: • Refined liquids • Coal • Natural gas • Electricity • Hydrogen			
River basin (HUC-2)					• Land allocation • Agricultural production	Water supplies : • Runoff • Groundwater • Desalination Water demand drivers: • Irrigation	
National (USA)		• Oil • Coal • Natural gas • Uranium	• Gas processing • Gas pipeline	Same price in every state for: • Biomass	Food demand	Water demand drivers: • Primary energy (mining) • Livestock	

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Grid region		• Carbon storage	Electricity supply and demand are balanced at the grid region level	Region-specific prices for: • Refined liquids • Coal • Natural gas • Electricity • Hydrogen			• SF_6 emissions from electricity transmission
River basin (HUC-2)					• Land allocation • Agricultural production	Water supplies : • Runoff • Groundwater • Desalination Water demand drivers: • Irrigation	• GHG and non-GHG emissions from agriculture and land (*NOTE: this is still queried from the USA region, but is reported by basin)
National (USA)		• Oil • Coal • Natural gas • Uranium	• Gas processing • Gas pipeline	Same price in every state for: • Biomass	Food demand	Water demand drivers: • Primary energy (mining) • Livestock	• GHG and non-GHG emissions from resource production

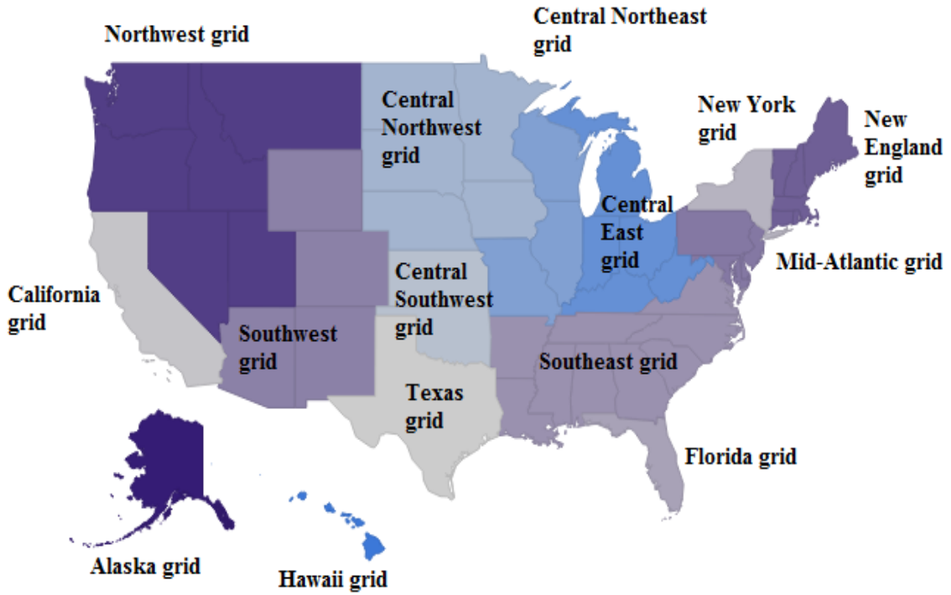
Differences between GCAM-USA and GCAM-32

Socioeconomic Drivers

- USA region population & GDP are updated to match the “sum-of-states”
- State-level population and economic growth assumptions are based on historical values through 2018.
- Future population growth assumptions are based on downscaled projections from the Shared Socioeconomic Pathways (SSP) database (Jiang et al. 2018; Jones and O’Neill 2016) for SSP2.
- Future economic growth assumptions based on per-capita GDP growth assumptions by US Census Division from the Annual Energy Outlook 2019 through 2050, with all states converging to the USA-region SSP2 labor productivity growth rate in 2100.
- The GCAM-USA Reference scenario assumes a growing U.S. economy and growing but gradually peaking population through the end of the century and, consequently, growing service demands in all end-use sectors.

Electricity Generation

- Electricity supply broken out into four sectors (load duration curve segments) to capture intra-annual variation of electricity demand
- GCAM-USA electricity sector uses nesting-subsector instead of pass-through-sector to represent generation technology and cooling technology competition
- Fuel mix
  - No new coal generation without CCS, consistent with Clean Air Act Section 111 (b) New Source Performance Standards
  - State-specific coal and nuclear power retirement pathways based on announced retirements and fleet age-structure
- Electricity trade in fifteen grid (NERC) regions



Grid regions are consistent with NERC regions

Energy Demand

- Buildings: GCAM-USA features additional building services and technological detail
  - In addition to space heating and cooling, both the residential and commercial building sectors include services such as lighting, water heating, and various appliances (refrigerator, dishwasher, oven / range, clothes washer, clothes dryer, etc.)
  - Technologies within each service sector include low and high-efficiency options that are powered by both secondary fuels (such as electricity) and primary fuels (such as gas and biomass).

- Industry
  - GCAM-USA does not include more detailed industry sectors introduced in GCAM v6.0 (e.g., Iron & Steel, Chemicals, Aluminum, Construction, Mining energy use, Agriculture energy use)
  - GCAM-USA does include vintaging of the aggregate industrial energy use sector, reflecting long-lived nature of industrial stock

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Tips for Using GCAM-USA

Mind Your Queries

- Structural differences between GCAM-USA and GCAM-32 mean that queries are not necessarily inter-operable
- Main_queries.xml contains a query section at the bottom with queries specific to GCAM-USA
- The electricity sector is particularly subject to query incompatibility, because of the nesting subsector structure
  - Adding a second forward slash between *[@type='subsector’] and [@type='technology’] indicates to the XPath query that it may need to look down multiple nests from the first subsector to find the technology nest

```
<emissionsQueryBuilder title="CO2 emissions by tech">
  <axis1 name="technology">technology</axis1>
  <axis2 name="Year">emissions</axis2>
  <xPath buildList="true" dataName="emissions" group="false" sumAll="false">*[@type = 'sector' ]/*[@type='subsector']//*[@type='technology']//
CO2/emissions/node()</xPath>
  <comments/>
</emissionsQueryBuilder>
```

- gcamdata: all chunks names start with zgcamusa_ and contain functions titled module_gcamusa_

Interpretation – Region Size

- Economic decisions in GCAM-USA use the same decision frameworks as GCAM-32, which was originally developed for more aggregate regions.
- Applying the same decision-making frameworks at finer spatial resolutions could produce results that require careful consideration.
- Smooth functions are used to retire existing capacity, and GCAM's logit-share equation is used to allocate technology investment in terms of energy produced rather than capacity installed.
- This could imply fractional retirements or investments for large capital like power plants.
- In reality, state-level decisions are discrete and often result in lumpy retirements and investments.
- **In the case of large capital (such as power plants), be mindful of these issues of scale.** Aggregating results to larger regions (such as grid-regions) may be appropriate when discussing investment / retirement outcomes.

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DISCUSSION

- GCAM-USA is available at: https://github.com/JGCRI/gcam-core
- GCAM-USA model documentation is available at: http://jgcri.github.io/gcam-doc/gcam-usa.html