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What's New in GCAM 5.2

December 5, 2019

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GCAM v5.2

- Updated model is now available on GitHub: https://github.com/JGCRI/gcam-core/releases/tag/gcam-v5.2
- Updated documentation available: http://jgcri.github.io/gcam-doc/toc.html
  - Includes a developer guide: http://jgcri.github.io/gcam-doc/dev-guide.html

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Overview

- Regional ag markets
- Resources reserves
- Water markets
- GCAM-USA
- Bug Fixes
- Near-term emissions trends

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Regional Ag Markets

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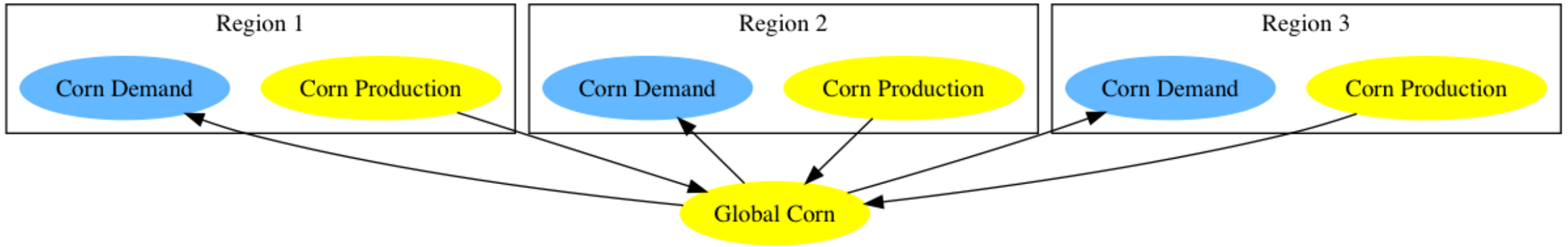
Regional Crop Market Differentiation: Motivation

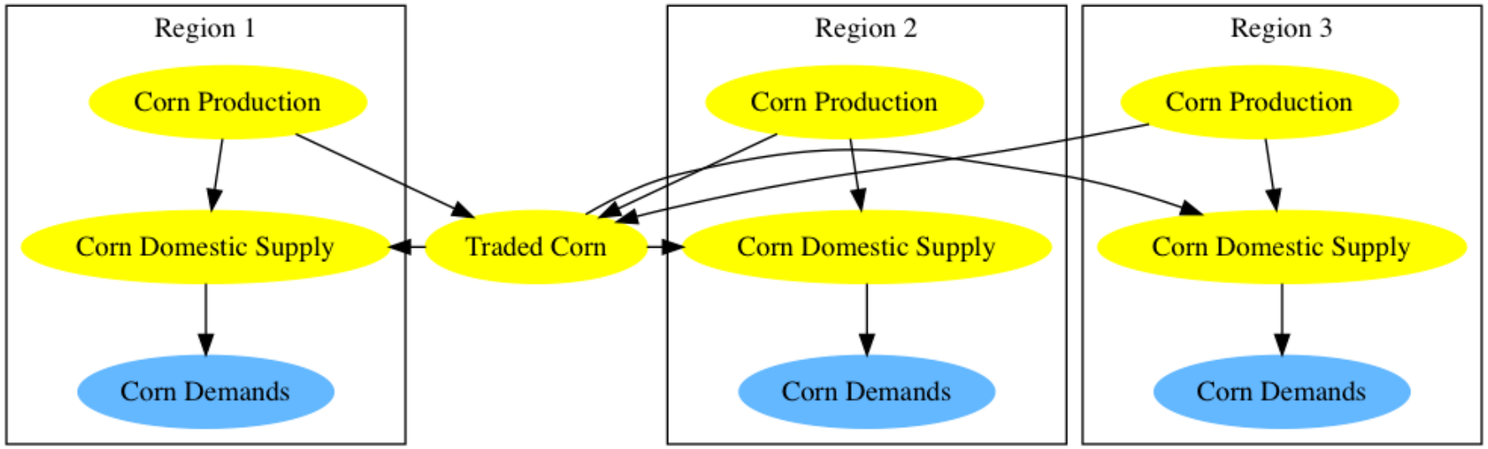
- For decades, the modeling approach of pure Global Markets has served our needs well for long-term analysis.
  - We are not dropping that useful capability.
- Several research questions arose that benefit from consideration of regional prices, inter-regional markets, and trading relationships and costs.
  - In general, many near-term analyses where trade is a factor.
  - Direct impact on domestic production of domestic demand growth.
  - Regional impacts on food demand, costs, and the ease of or difficulty of trade.
  - Impact of changing shipping costs, other trade scenario assumptions.
- Design considerations: maintaining flexibility and feasibility
  - Parametrically scope the space between pure Global and Regional Markets.
  - We did not want to lock in bilateral relationships.
  - Model equations still need to solve in a timely manner.

Global Markets (Hecksher-Ohlin): Pre-GCAM 5.2



- Example of Corn shown here.
- Each region supplies to a common global market.
- Each region demands from a common global market.
- Net imports/exports are the difference between demand and supply.
- Of course this is conceptual as much demand does come from domestic production – but it is at the global price.

Regionally-Differentiated Crop Markets with Global Trade: New for GCAM 5.2



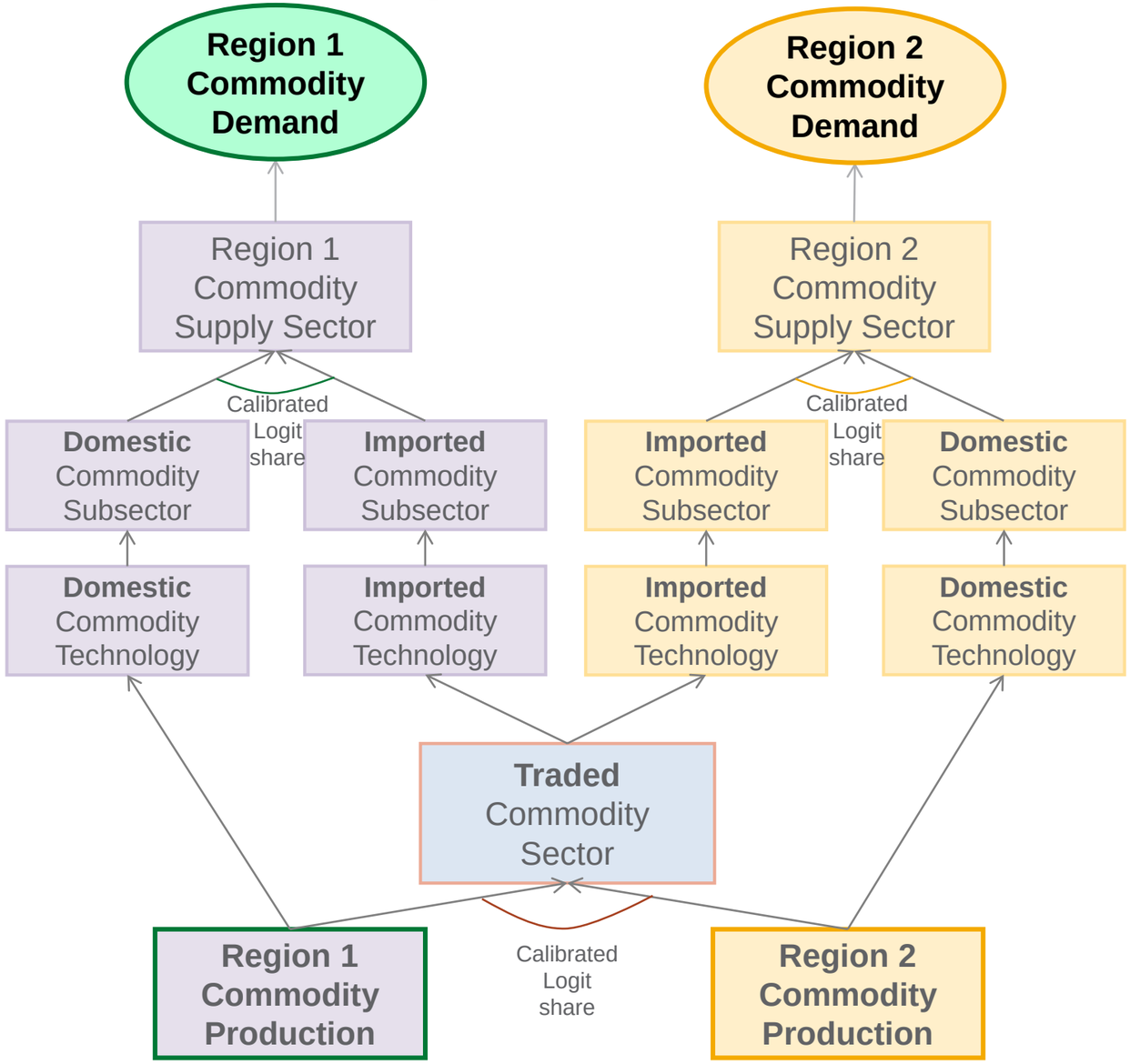
- Regional corn production is split between providing domestic supply and being sent to a global traded corn market.
- Correspondingly, regional demand is supplied by both own-regional production and imports from the global traded market.
  - An Armington-style distinction between domestic and imported goods.
- Gross trade is tracked as regions both import and export.

Summary of Main Trade Approaches in GCAM 5.2

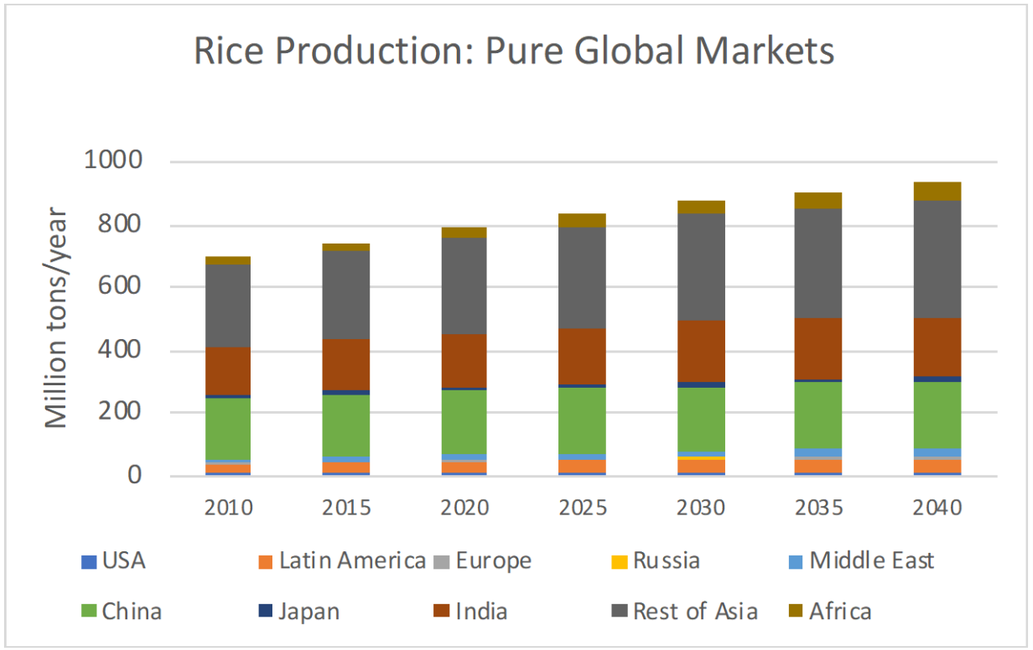
Approach	Trade	Market Prices	Market Equations	Calibration	Use in GCAM 5.2 Core
Global (Hecksher-Ohlin)	Dynamic Net Trade	Global	1 per Commodity	Regional Production & Demand	Fossil Fuels, Forest Products
Regional Markets with Global Trade	Dynamic Gross Trade	Regional	1 per Region per Commodity	Regional Production, Demand, Gross Imports and Gross Exports	Most Crops (*New for GCAM 5.2*)
Exogenous Trade	Static Net Trade	Regional	0 additional	Net Trade	Beef, Dairy, Pork, Poultry, Sheep/Goat

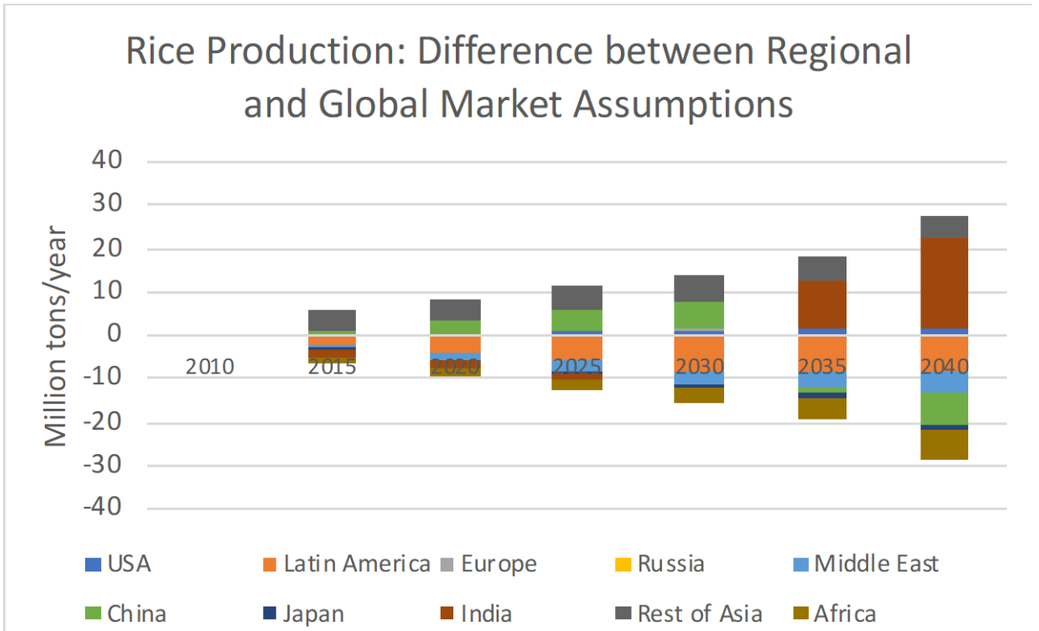
- (Note: There are some other trade approaches in GCAM 5.2)
  - E.g, nested logits for electricity trade in GCAM-USA.
  - Pure regional markets with no trade.

Regionally-Differentiated Crop Markets with Global Trade: Literal Implementation in Model Structure



Example GCAM Results: Regional Rice Production





- BAU, regional markets may not show a large change in regional production.
  - For analyses not focused on regional agriculture, these differences may not be critical.
  - Global markets with calibrated production approach is fairly stable.
- These marginal differences may be important for computing impact of regional demand growth, regional land use change, regional food prices.

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Resource Reserves

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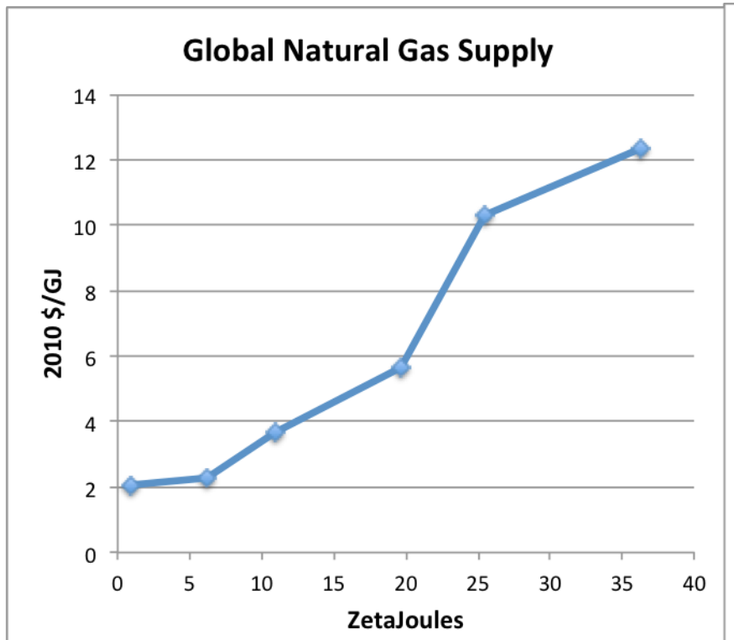
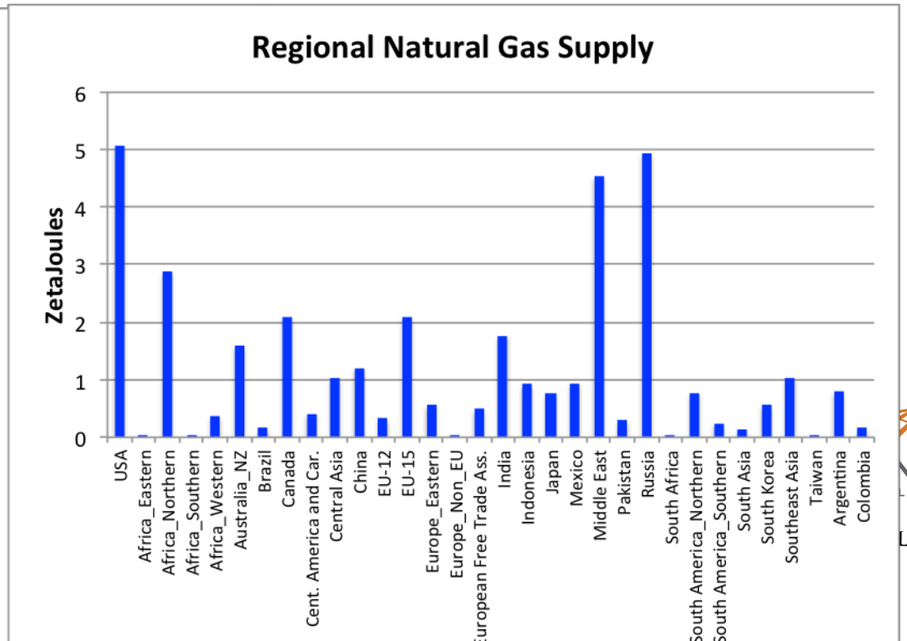
Fossil resource production in GCAM 5.1

- Long-term supply curves
- Global Markets

- Resource production can too easily shift from region to region
- Very sensitive near term “supply elasticity”





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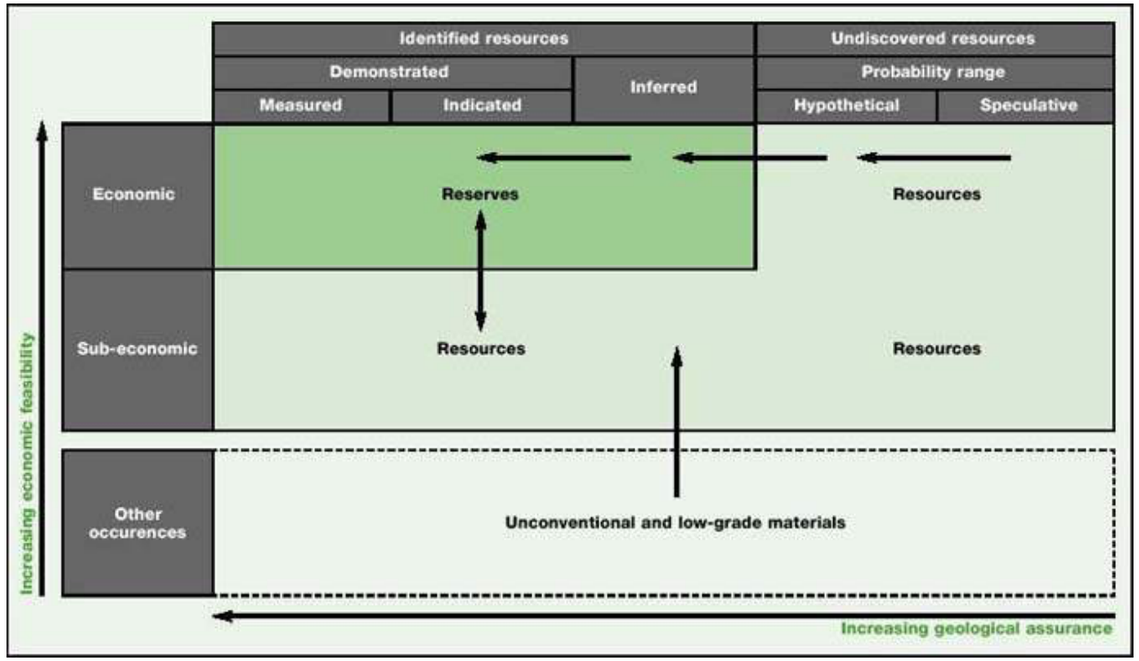
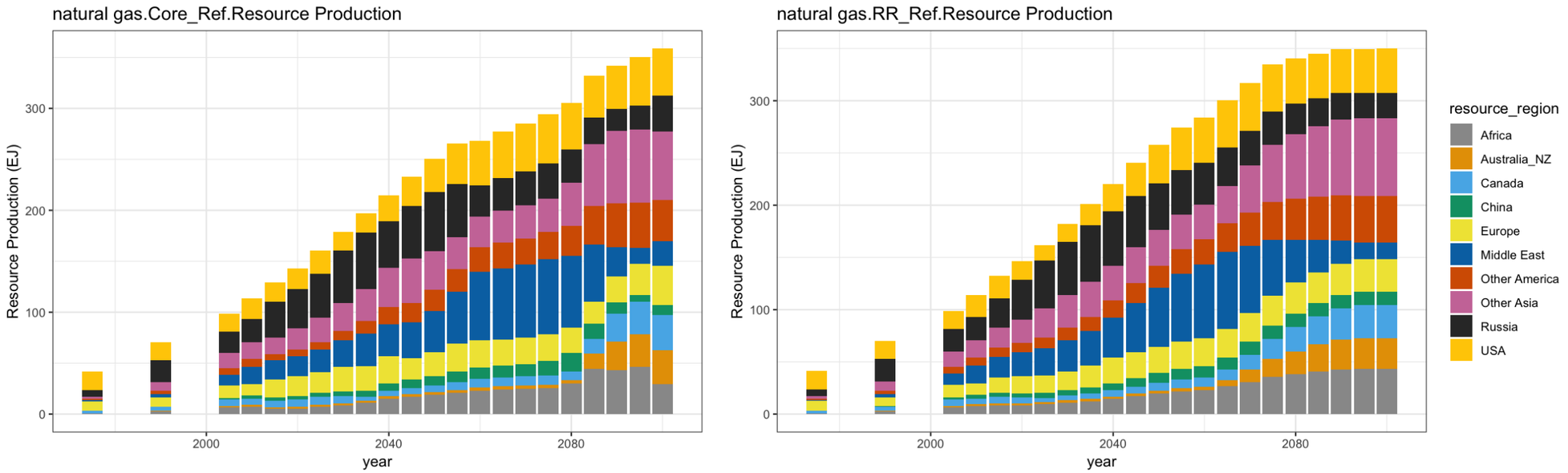
Add reserves to resource production in GCAM 5.2

- “New” investment still governed by the same long term supply curves
- The quantity from the supply curve (“reserve addition”) is now produced over a production lifetime of multiple periods
- Existing reserves (vintages) produce until it runs out
  - Assumed “decline” phase
  - Include a ”profit” shutdown



Resource/Reserve - Change in behavior

- Regional production is stable



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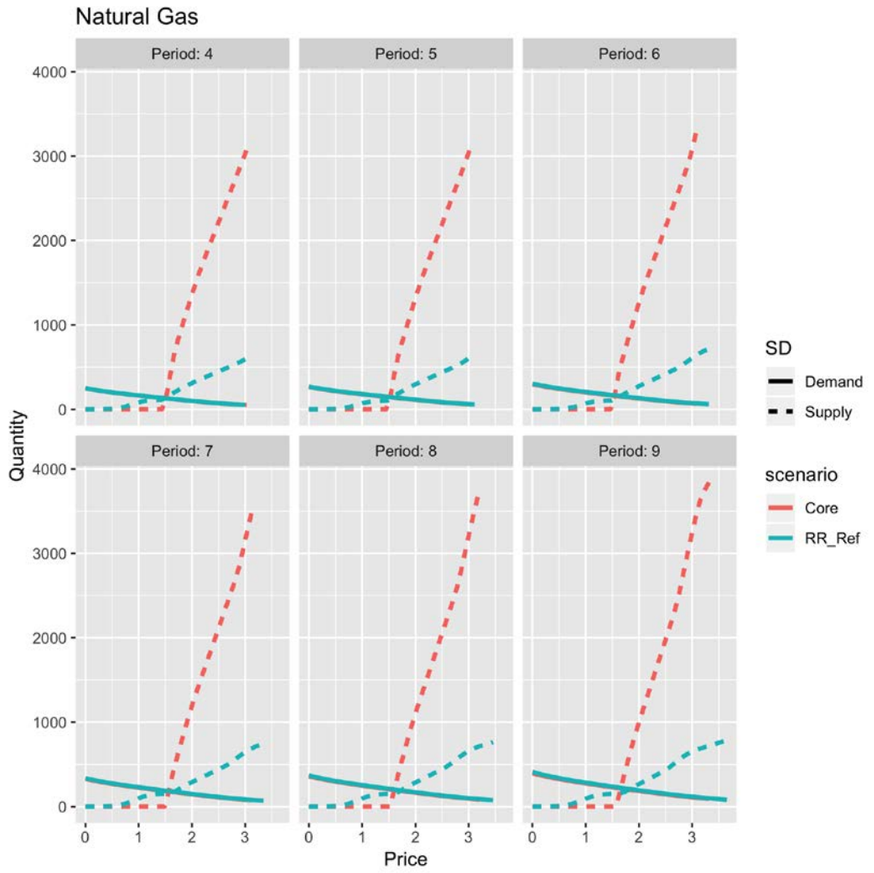
Resource/Reserve - Change in behavior

- Regional production is stable
- Resource expansion is more incremental



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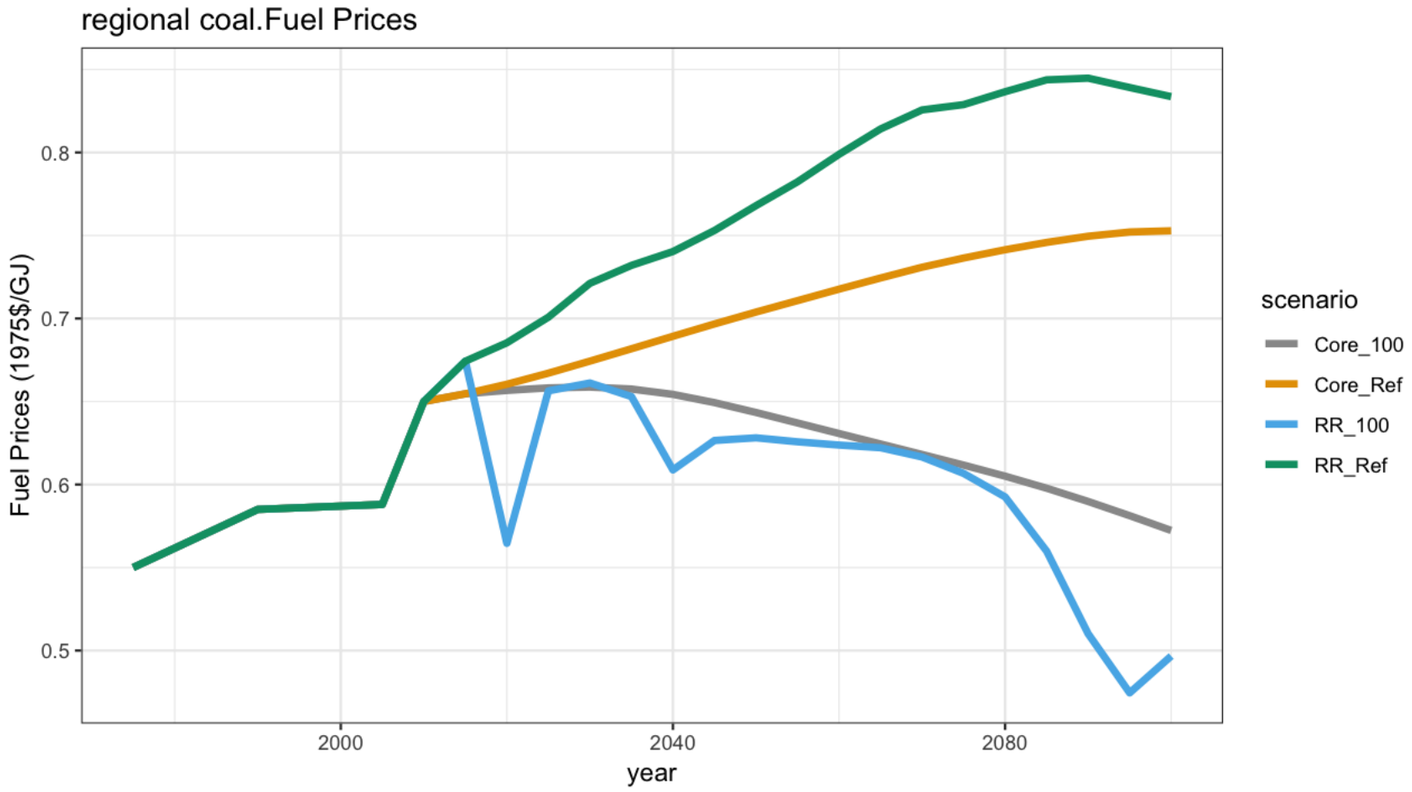
Resource/Reserve - Change in behavior

- Regional production is stable
- Resource expansion is more incremental
- Could *potentially* have price volatility



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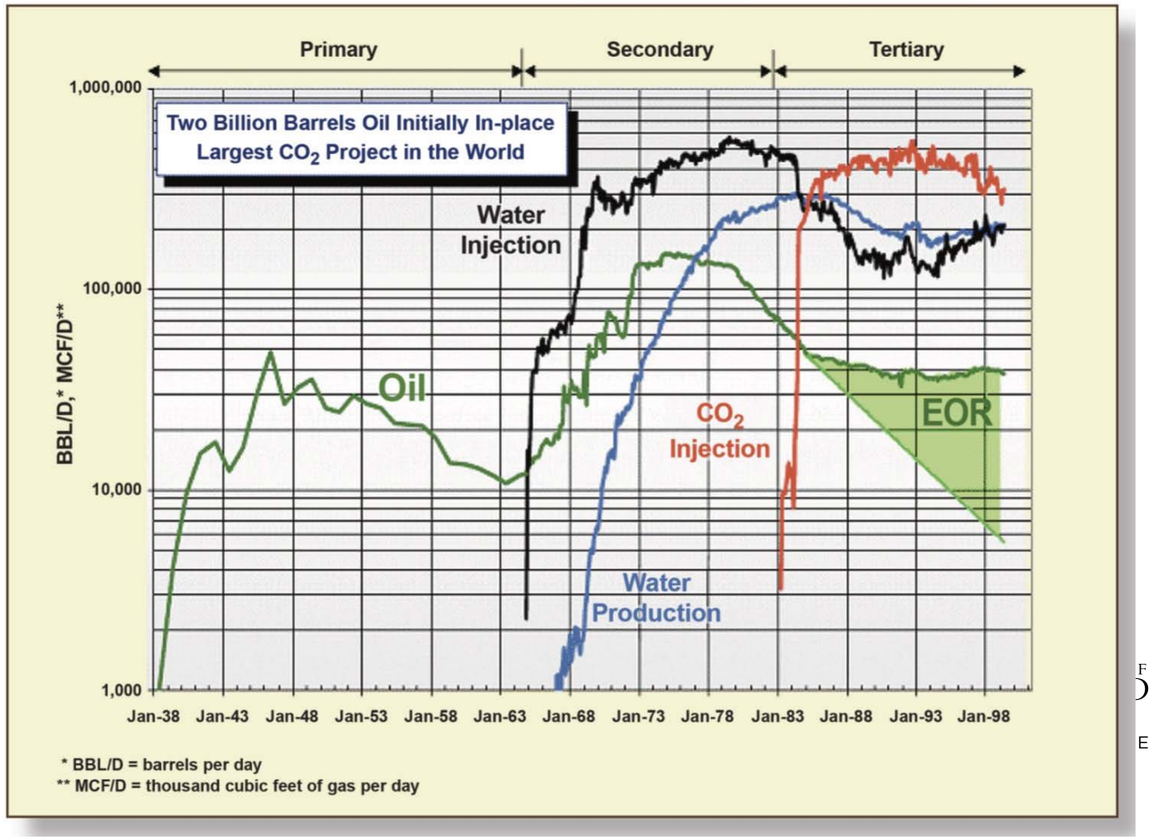
“Technology” explicitly included in the Resource

- More flexibility in modeling costs
- Add additional inputs to resource production
- Policies
- Non-CO2 parameters



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Water Markets

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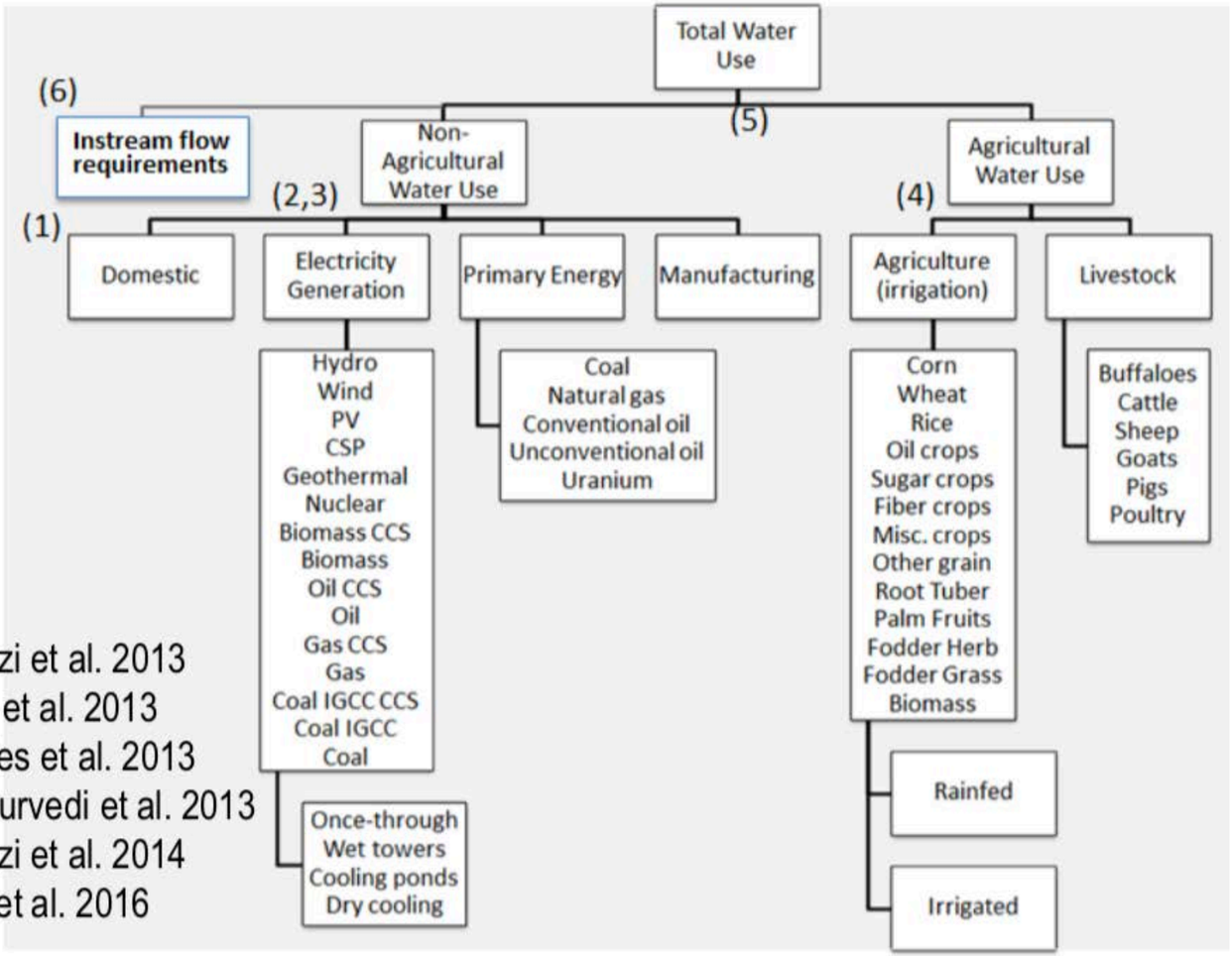
Water Demand Behavior (GCAM 5.1)

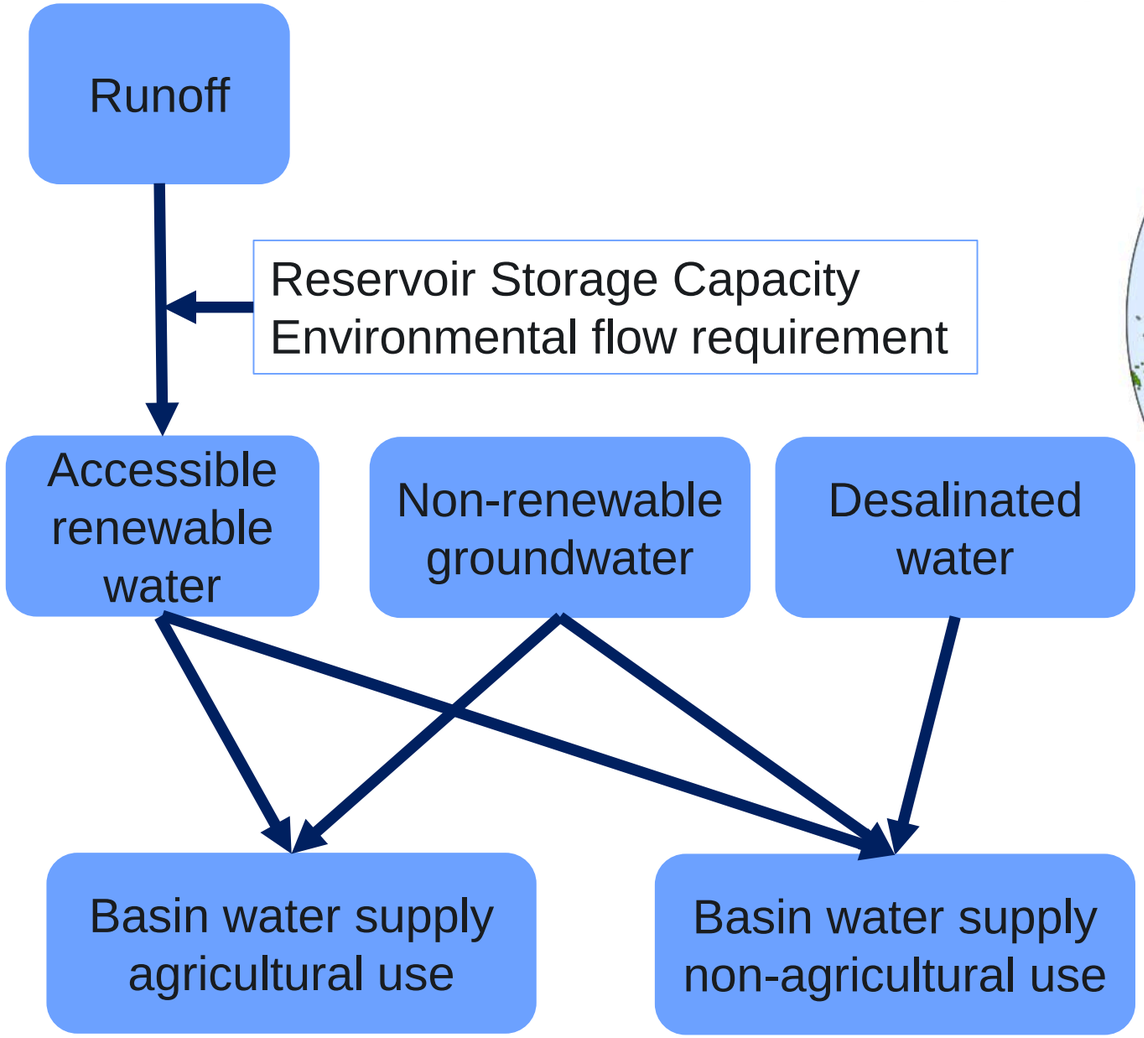
- Unconstrained water demand
  - Unlimited availability of water at zero cost
- Water demand sectors
  - Irrigated agriculture
  - Livestock
  - Municipal
  - Electricity
  - Primary energy
  - Industries

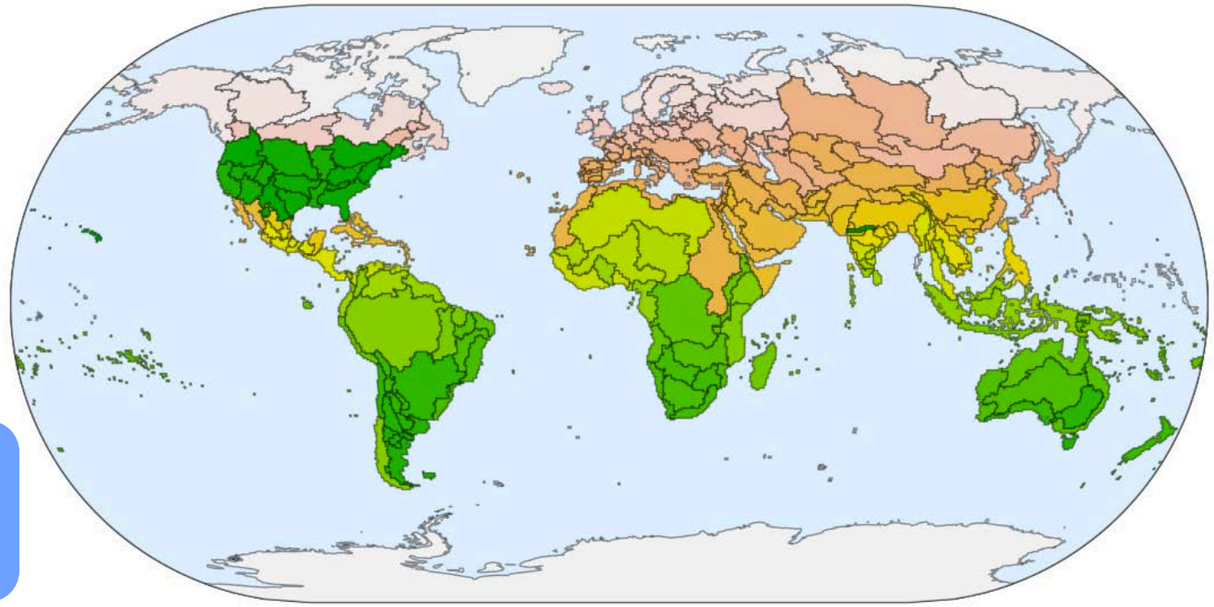


1) Hejazi et al. 2013
2) Kyle et al. 2013
3) Davies et al. 2013
4) Chaturvedi et al. 2013
5) Hejazi et al. 2014
6) Kim et al. 2016

Water Supply Resources (GCAM 5.2)

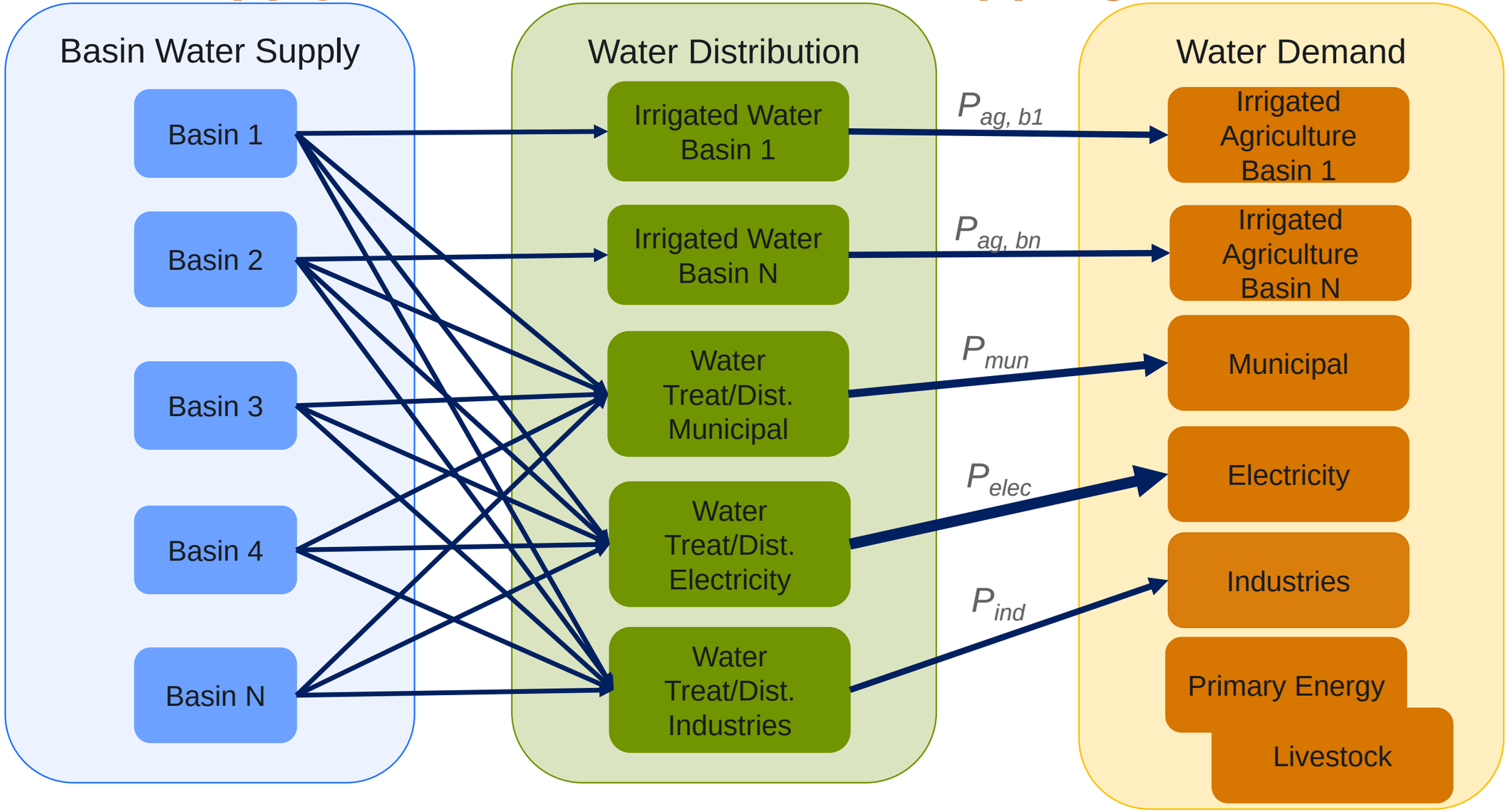
Global water supply by **235** major river basins





- Runoff - from Xanthos with global climate data (see Liu et al. 2019, Turner et al. 2019 and Vernon et al. 2019)
- Non-renewable groundwater – depletable resource curves from physics based model (Yonkofski et al. 2019)
- Desalinated water – energy & capital cost

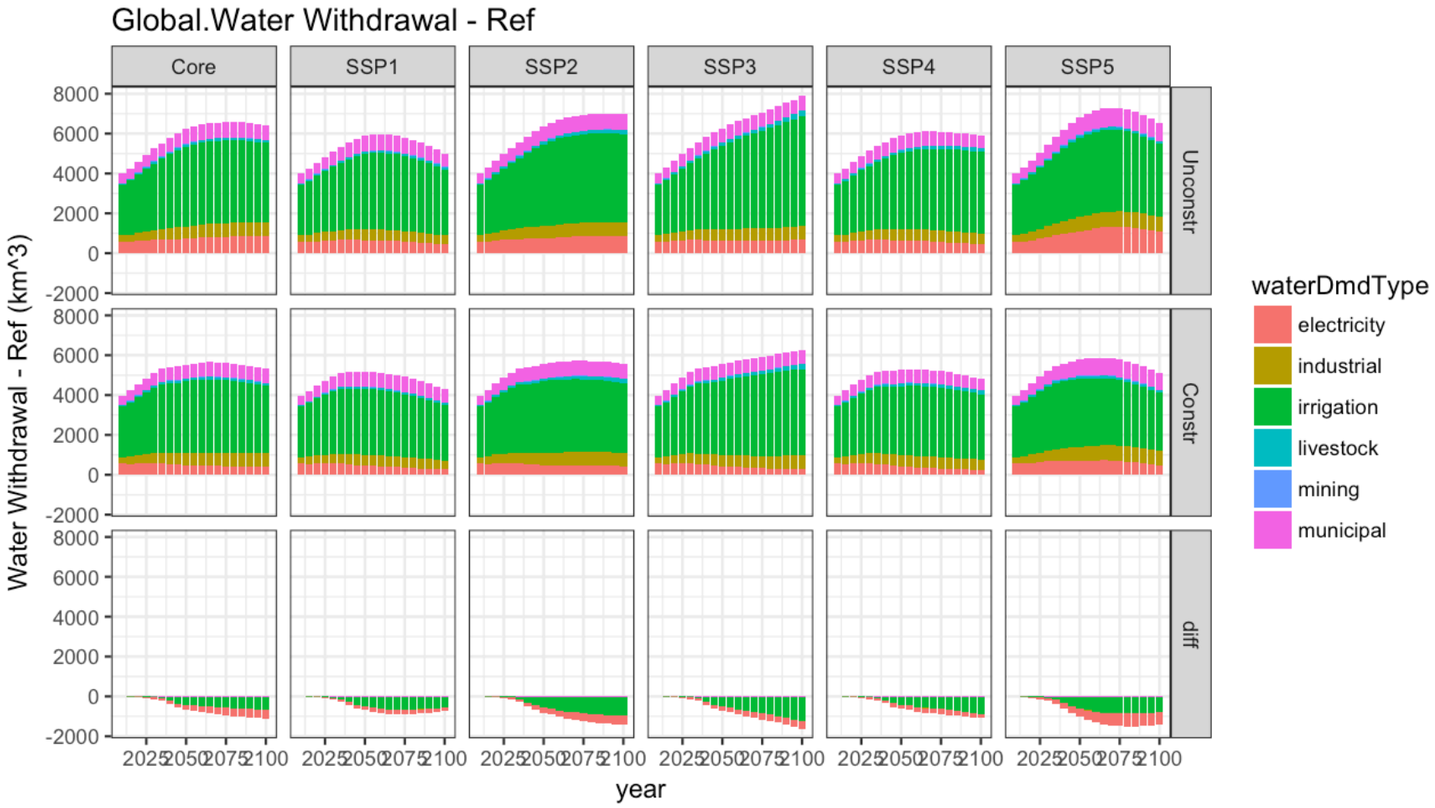
Water Supply and Demand Basin Mapping



(P_w includes losses, energy, capital, subsidy, & tax)

Water Constraints and Demand Responses (GCAM 5.2)

- Constrained water supply
  - Annual renewable basin supply fixed to historical volume
- 15% - 22% reduction in global water withdrawal volume by 2100
- Irrigated agriculture
  - 15% - 22% reduction in global withdrawal for irrigation
  - Largest reduction by volume
- Electricity cooling water
  - 38% - 55% reduction in global withdrawal for plant cooling
- Regional changes in water use may be larger



See Turner et al. 2019, Cui et al. 2019 and Graham et al. 2019 for more information on responses to water constraints.

Future GCAM Water Developments

1. Sub-annual dynamics
   - Improve reservoir services, operation and management
   - Explicitly account for recharge in groundwater
2. Expand natural water resource supplies
   - Include snowpack, glaciers, and lakes
   - Separate recharge groundwater and fossil groundwater
3. Improve water demands
   - Regional and sub-regional water use detail
   - Sub-annual profiles of water use
4. Adaptation options for water use
   - Improving conveyance and distribution losses
   - Efficient water use technologies
   - Gray water / water reuse
   - Inter-basin transfers
   - Virtual water trade

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GCAM-USA

Gokul Iyer and Matthew Binsted

(on behalf of rest of the team)

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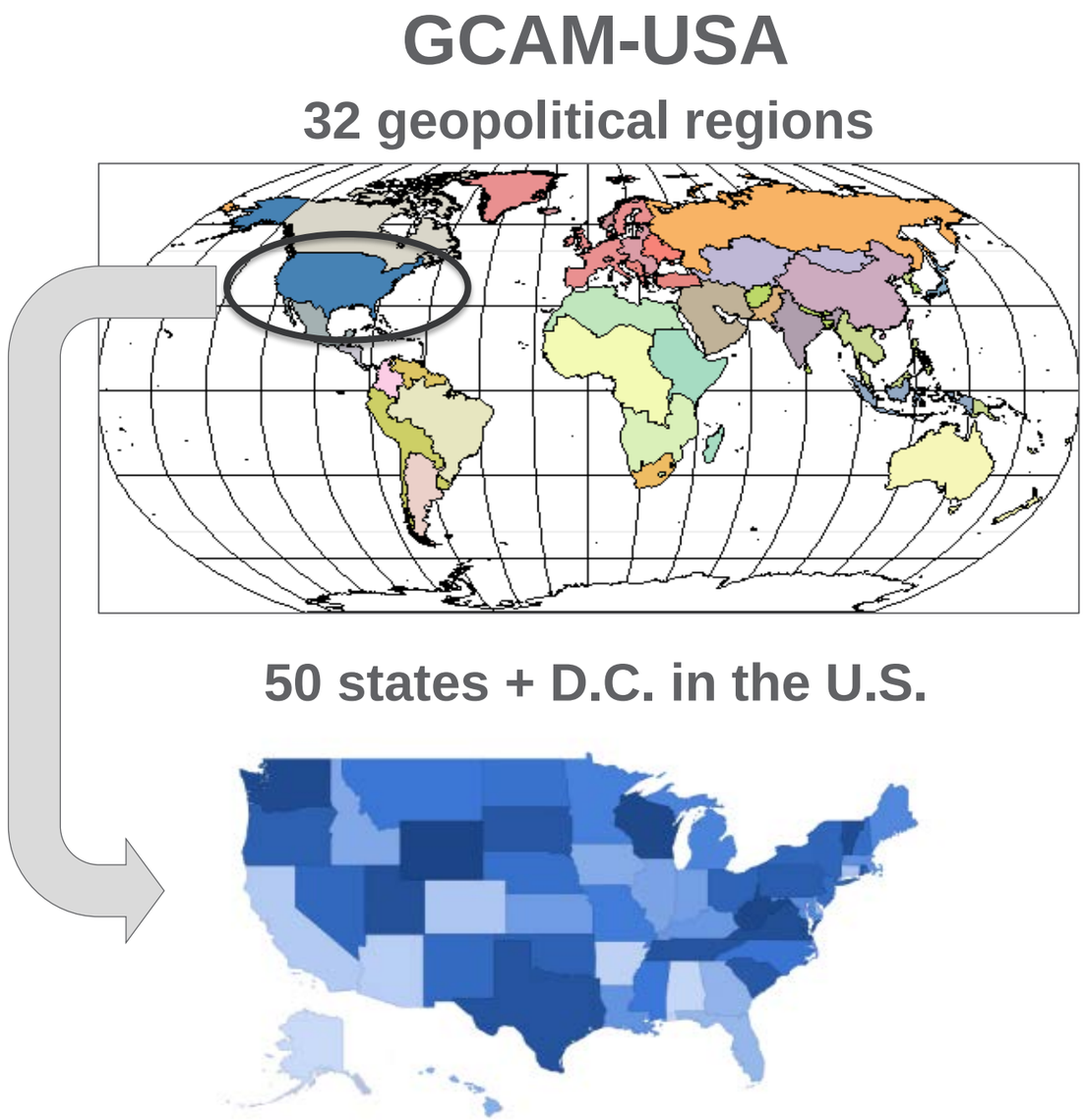
Overview of GCAM-USA

- GCAM-USA is a version of GCAM with state-level detail in the United States
- The 50-state version is embedded within the global version of GCAM
  - Conditions and markets in the U.S. are consistent with international conditions
- GCAM-USA is part of the release version of GCAM



Current level of detail in GCAM-USA

Socio-Economics	Energy Resources	Energy Transformation	Final Energy

• Population
• Labor Productivity (GDP)
	• Oil*
	• Coal*
	• Natural Gas*
	• Biomass
	• Solar
	• Wind
	• Geothermal
	• Carbon Storage
		• Refining
		• Gas Processing*
		• Hydrogen*
		• Electricity
			• Buildings
			  • Commercial
			  • Residential
			• Industry
			• Transportation
			  • Passenger
			  • Freight

**Represented at the national level. All other sectors are at the state-level*

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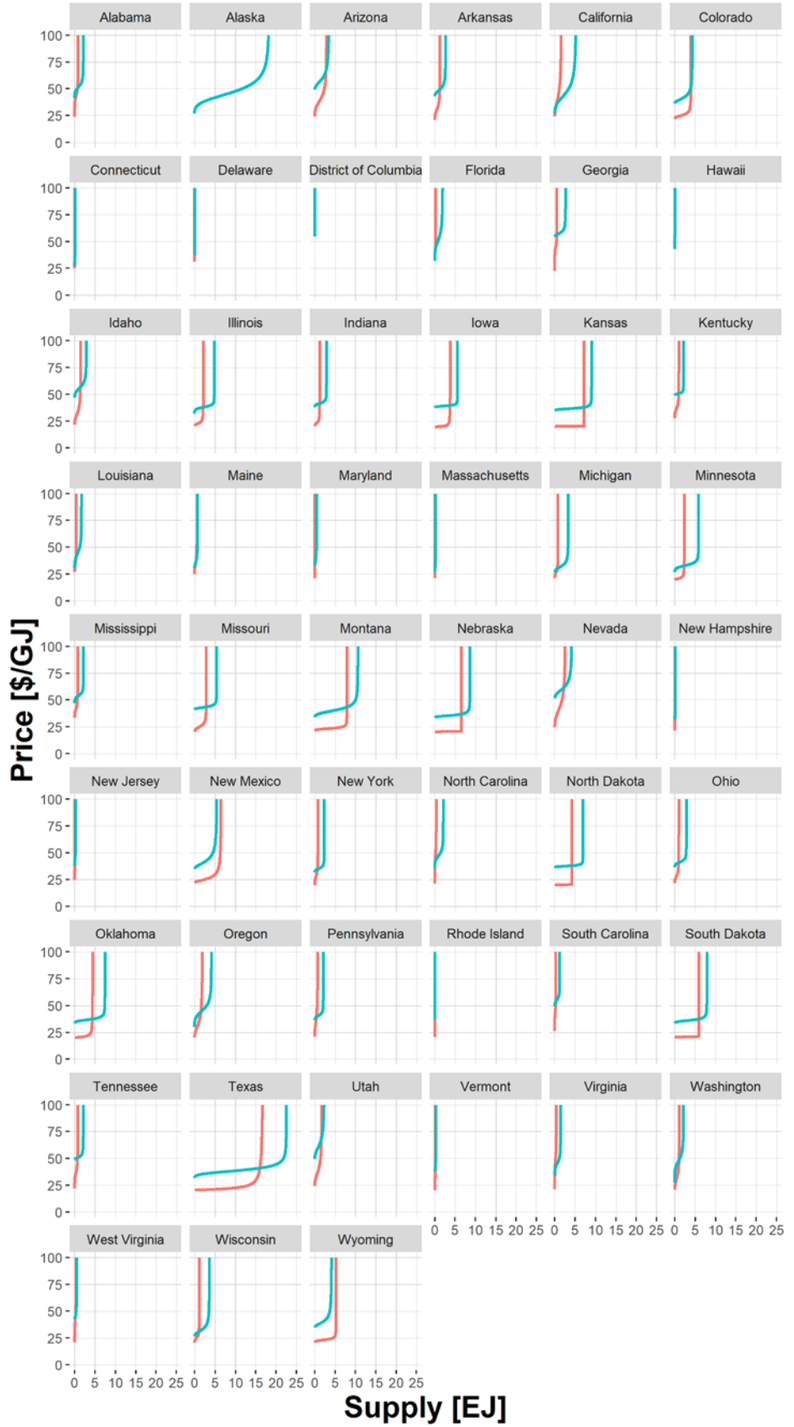
Socioeconomics and Resources

Socioeconomics:

- Updated state-level population and economic growth rate assumptions to match history (2015)
- Future population assumptions based on downscaled SSP2 projections
- Future economic growth rate assumptions vary by census region and are based on EIA's Annual Energy Outlook (AEO) through 2040 and then converge to GCAM-core assumptions in 2100

Resources:

- Updated state-level onshore wind resource curves
- State-level PV and CSP resource curves



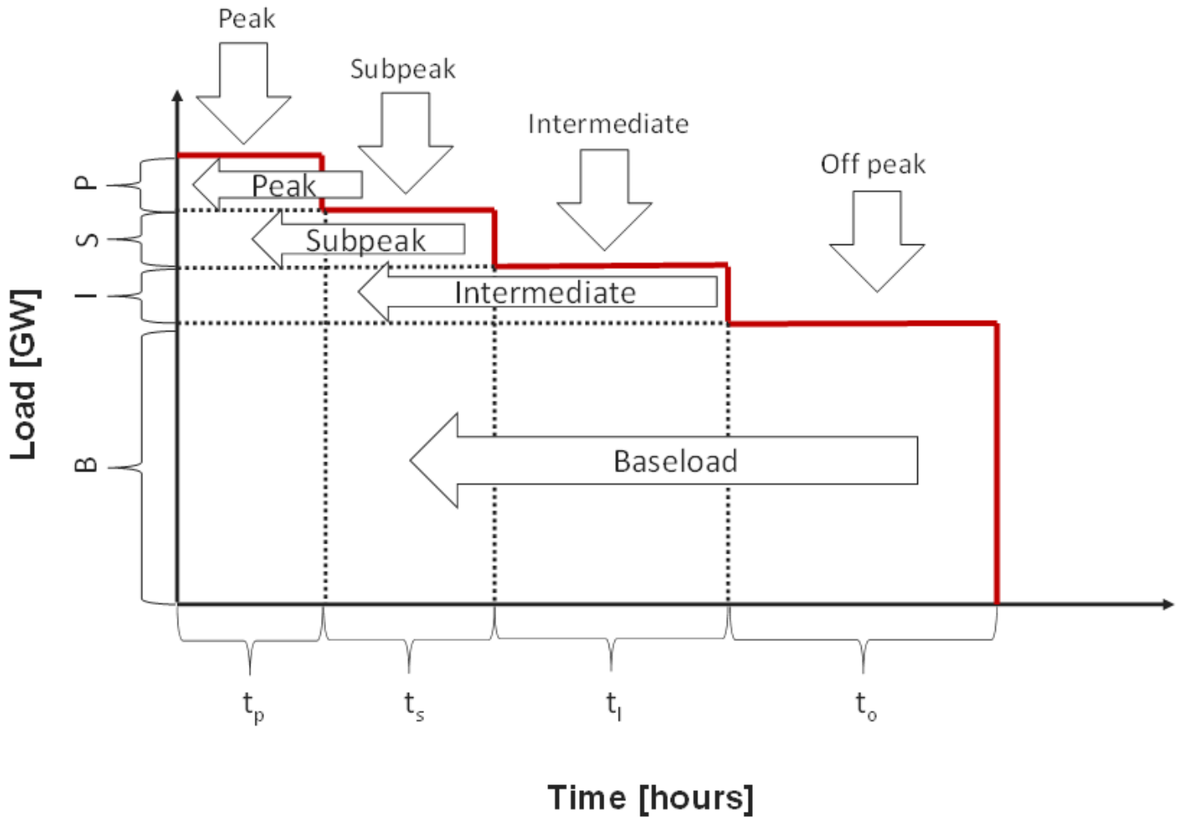
Improved Onshore wind resource curves from NREL

Power sector

Electricity:

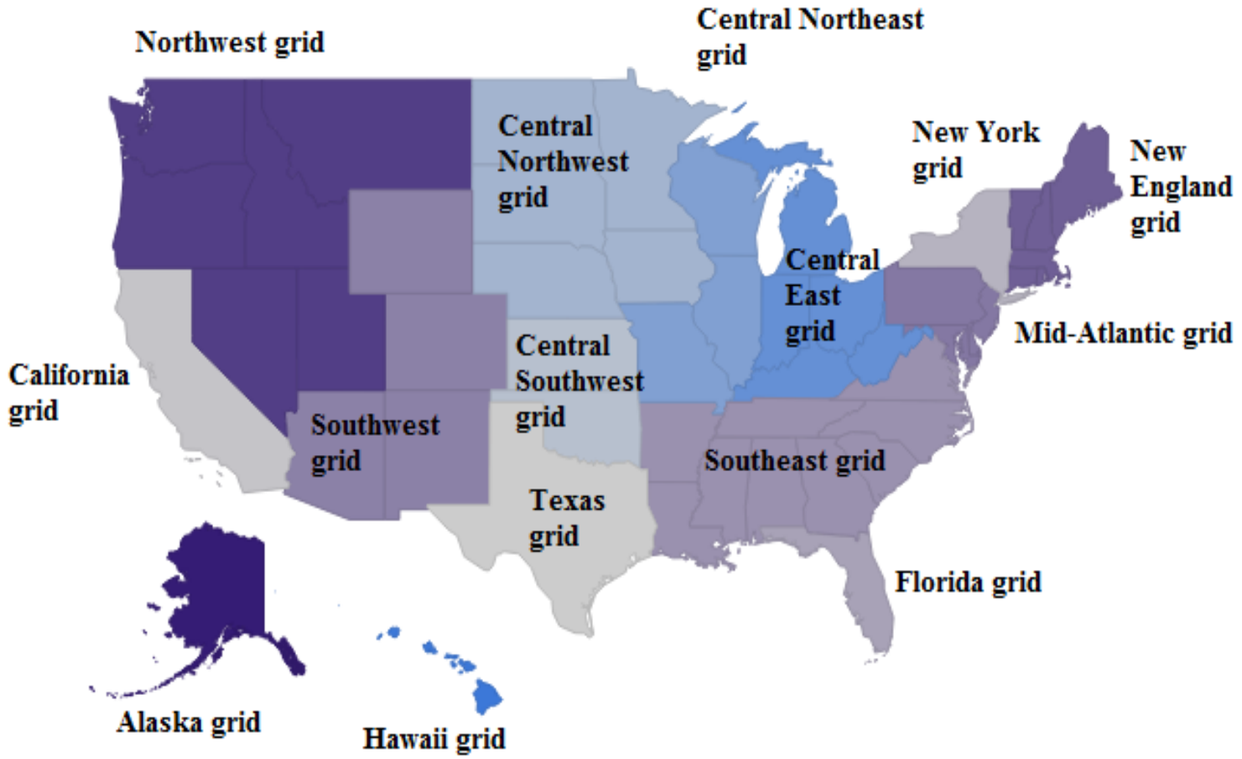
- Load duration curves in GCAM-USA capture supply-side dynamics of time-varying demand:
  - Power plants serving baseload also serve demand in all higher segments through the peak load.
  - Peaking capacity will operate only during the peak.
  - Storage can purchase off-peak to sell at peak.
- U.S. specific power sector technology cost assumptions
- State-specific coal and nuclear retirements based on plant/unit-level data-sets
- Updated exogenous hydropower assumptions to match AEO

Each grid region has a load-duration curve split into four segments



Electricity trade is represented in 15 grid regions

- Representation of electricity trade is important to reconcile supply and demand of electricity at a sub-national scale.
- Our representation focuses on net trade across grid regions as well as free trade among states within a grid region.

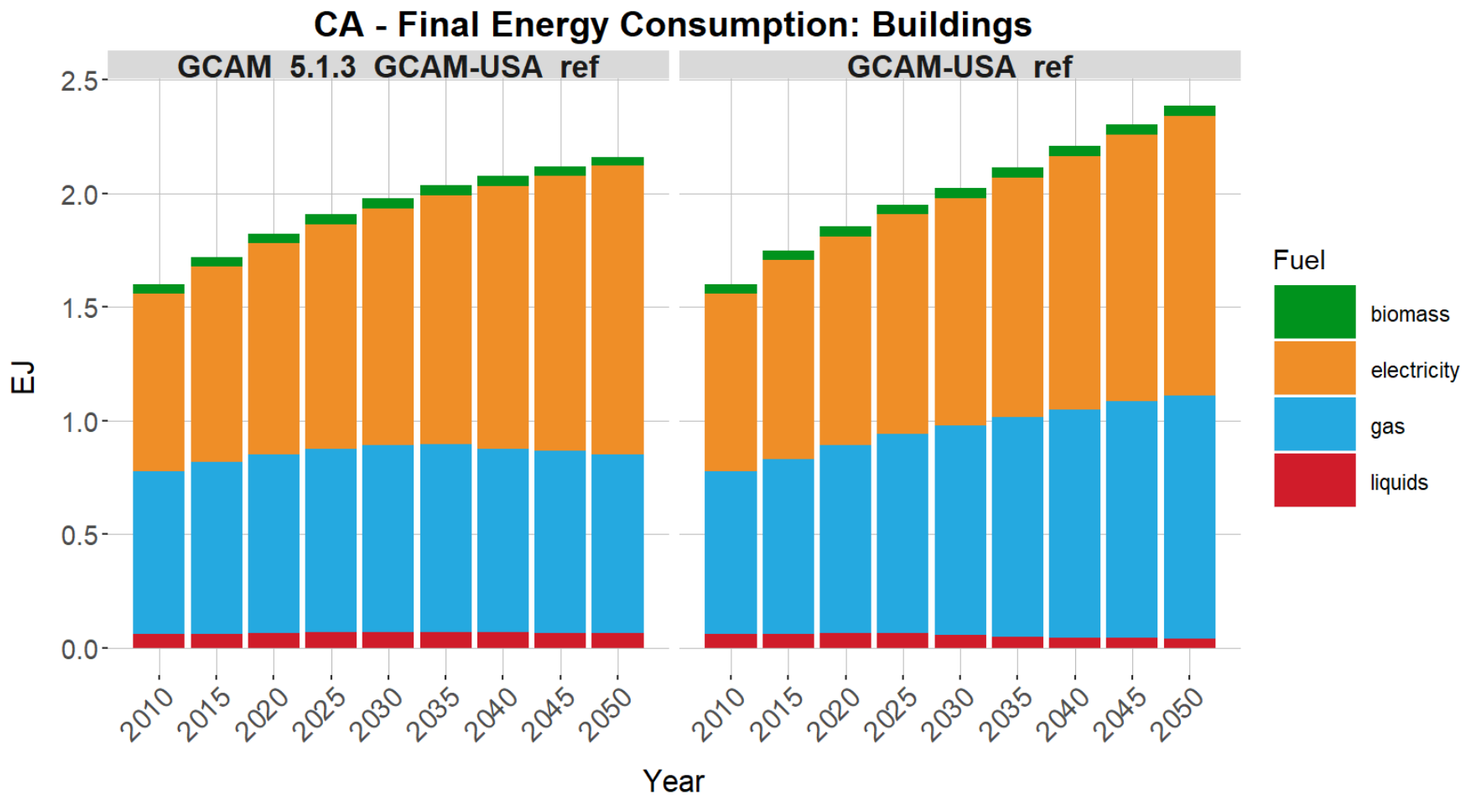


Grid regions are consistent with North American Reliability Corporation (NERC) regions

Buildings

Buildings

- More detailed building services
  - Heating, cooling, water heating, lighting, kitchen appliances, clothes appliances
- Increased technological detail for each building services
  - High-efficiency options
- Updated technology cost and efficiency assumptions



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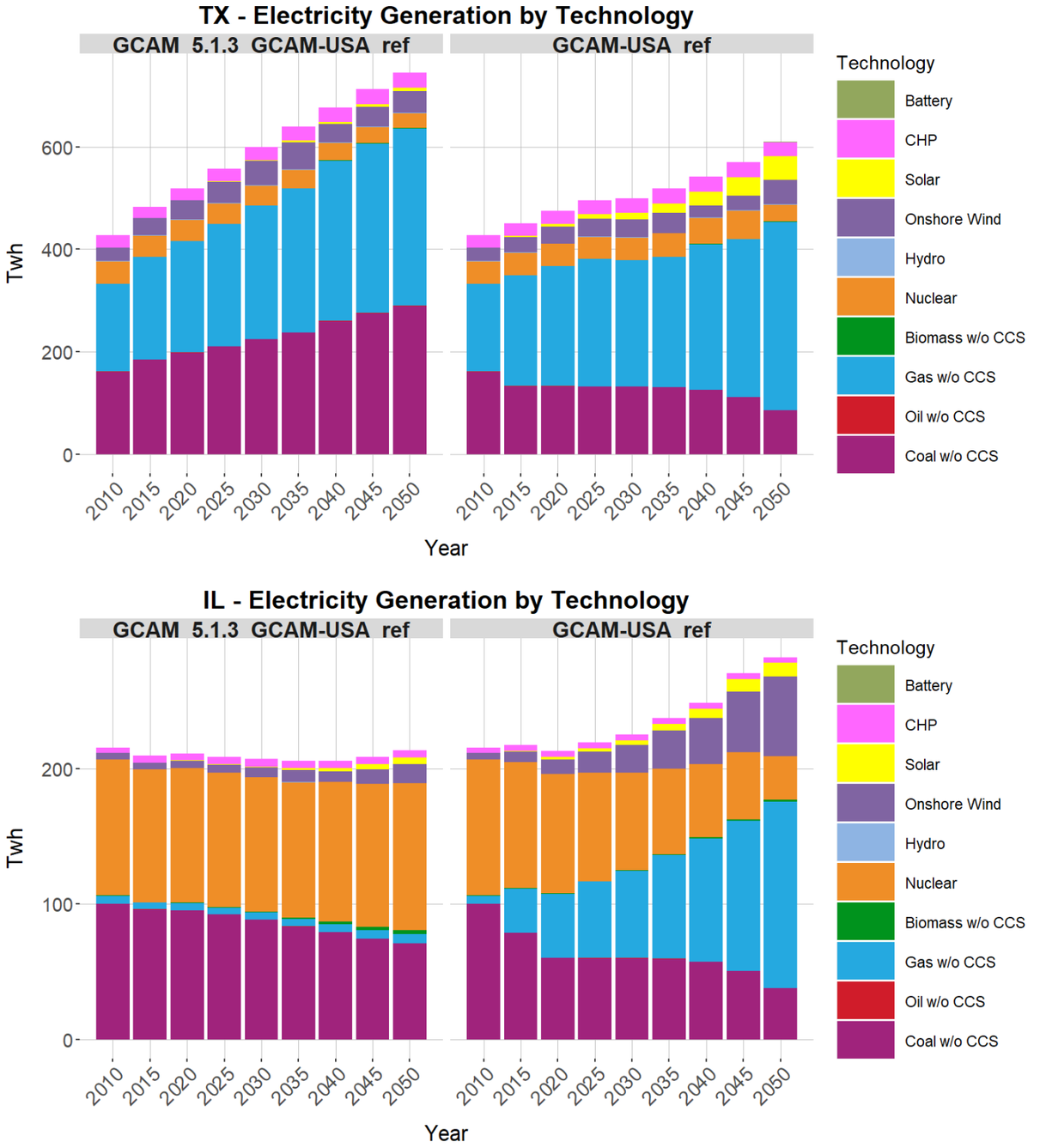
Improved State-level Reference Scenarios

- Collectively, our updates introduce state-level heterogeneity and up-to-date assumptions resulting in improved reference scenario results



Some ongoing developments

- Improved sub-annual dynamics in the power sector (e.g. separating investment and dispatch decisions)
- Non-CO2s
- Water

More details will be discussed during the GCAM-USA Break-out session at 1 pm (Room 1105)

https://www.jobs.ie/job-talk/wp-content/uploads/Late-to-work-768x576.jpg

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Bug fixes

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GCAM5.2 bug fix summary

- Resolves 9 JIRA or GitHub issues
  - Sets a consistent name for gcam executable
  - Updates queries to avoid double accounting RES policies
  - Adds 1st generation biofuels to primary energy queries
  - Addresses two GCAM fusion issues
  - Corrects the land use change emissions used in constraints
  - Corrects an issue in the solver configuration
  - Adds ability for policy cost calculator to sum multiple emissions
  - Fix Visual Studio project file to be consistent with documentation
- Other issues:
  - Removes “_” from crop names
  - Ensures 2010 radiative forcing across scenarios
  - Removes unused xml files
  - Fixes some issues with transportation queries

Sets a consistent name for gcam executable

- Older version of GCAM had three different names for the executable, depending on the platform.

Platform	Name
Linux / makefile	gcam.exe
Mac	objects
Windows / Visual Studio	Objects-MI.exe

- GCAM5.2 sets the name to **gcam.exe** on all platforms.

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Removes “_” from crop names

- GCAM uses the “_” to separate crop name, basin, irrigation, and management practice in agricultural production technologies. However, we had three crops that included “_” in their name, complicating some processing scripts. These names have been updated

Old Name	New Name
Root_Tuber	RootTuber
biomass_grass	biomassGrass
biomass_tree	biomassTree

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Removes unused xml files

- There were several xml files generated by the data system that were not used in any configuration file and as a result have not been tested or maintained. These have been removed:
  - Includes all transportation_agg_* files
  - Includes all trn_agg_* files

- In addition, there was one file interest_rate.xml that was read in to GCAM, but not used in any calculation. This file has been removed from the configuration and data system. Additionally, the error that would print if it wasn't read in has been removed.

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Near Term Emission Trends

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Near-term Emission Trends: Motivation

- The year 2020 is pretty close
- The world is no longer following a business-as-usual pathway : many countries have started to depart from a BAU emissions
- Nor is the world in a globally optimal 2.6 W/m2 pathway : there is no globally coordinated carbon price in place to reduce emissions
- We should make our assumptions consistent with this trend

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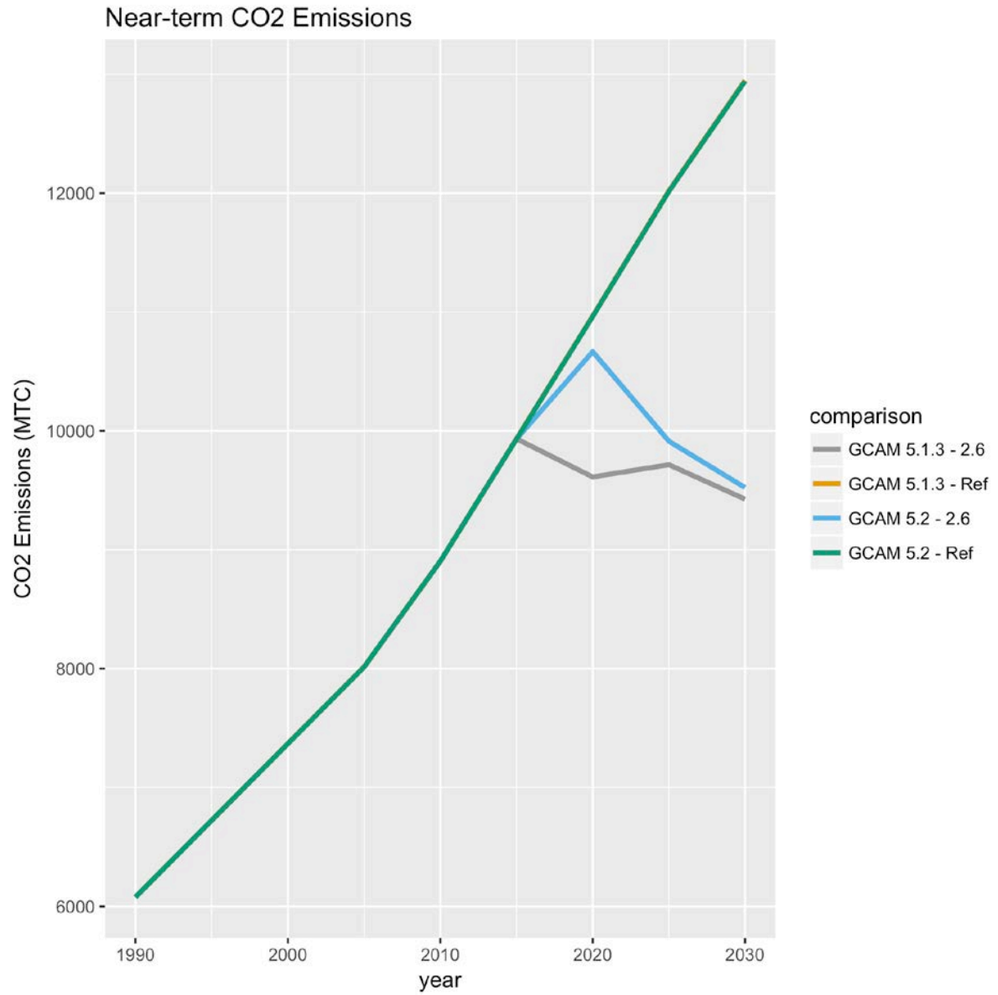
Use near-term / long-term carbon pricing approach

- Using the same assumptions as SSP 1 to implement
- Running target-finder becomes more complicated
  - Regionally varying near-term carbon pricing in 2020 “CO2_NearTerm”
  - Switch to a “Long Term Global” carbon pricing in 2025 and beyond “CO2_LTG”
  - Use a regional “Linked” market for CO2 to implement
  - Include a “configuration_policy.xml”

Near Term Emissions Update: Results



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Additional Features

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Land Constraints

- Add the ability to include a Tax / Subsidy directly into the land sharing for “unmanaged” types
- You can read a constraint on land and it will solve for the implied tax / subsidy required to meet that constraint

```
<scenario>
    <world>
        <region name="USA">
            <LandAllocatorRoot name="root">
                <LandNode name="AgroForestLand_GreatLakes">
                    <LandNode name="AgroForest_NonPasture_GreatLakes">
                        <LandNode name="AllForestLand_GreatLakes">
                            <UnmanagedLandLeaf name="UnmanagedForest_GreatLakes">
                                <land-constraint-policy>reduced_deforestation</land-constraint-policy>
                            </UnmanagedLandLeaf>
                        </LandNode>
                    </LandNode>
                </LandNode>
            </LandAllocatorRoot>
            <policy-portfolio-standard name="reduced_deforestation">
                <market>USA</market>
                <policyType>subsidy</policyType>
                <constraint year="2015">12</constraint>
                <constraint year="2020">12</constraint>
                <constraint year="2025">12</constraint>
```

Thank you