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GLIMPSE:

A GCAM-USA-based tool for supporting coordinated energy and environmental planning

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Office of Research and Development
U.S. Environmental Protection Agency, Research Triangle Park, NC

Foreword

- Objective of this presentation
  - Introduce the GLIMPSE project and demonstrate its use
- Intended audience
  - Modelers within the GCAM community and policy analysts interested in tools for evaluating the air quality impacts of scenarios of the future
- Disclaimers
  - While this material has been cleared for presentation, it does not necessarily reflect the views or policy of the U.S. EPA
  - Results are provided for illustrative purposes only. There are many underlying caveats and assumptions not discussed fully here. Please do not cite results.

Abbreviations

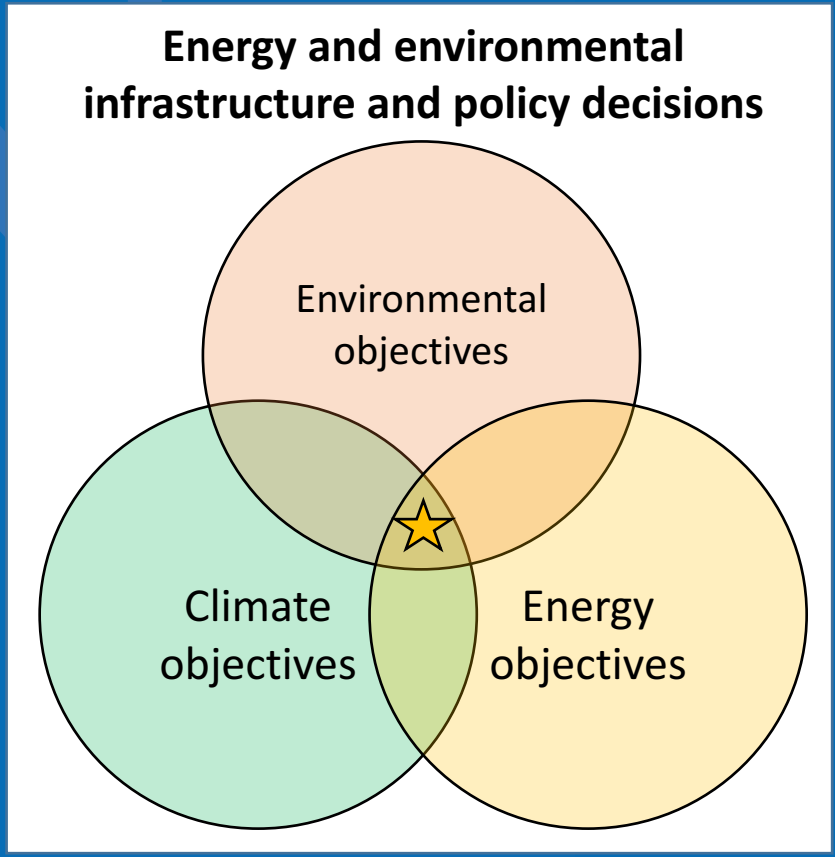
- Greenhouse gases
  - CH_4 – methane
  - CO_2 – carbon dioxide
- Traditional air pollutants
  - CO – carbon monoxide
  - NH_3 - ammonia
  - N - nitrogen
  - NOx – nitrogen oxides
  - O_3 – ozone
  - PM – particulate matter
  - $PM_{2.5}$ – PM with a diameter less than 2.5 microns
  - SO_2 – sulfur dioxide
  - NEI – National Emissions Inventory
- Policies and regulations
  - CAFE – Corporate Vehicle Efficiency Standard
  - CSAPR – Cross-State Air Pollution Rule
  - RES – Renewable Electricity Standard
  - RGGI – Regional Greenhouse Gas Initiative
- Economics
  - GDP – Gross Domestic Product
- Modeling
  - CoST – Control Strategy Tool
  - GCAM – Global Change Assessment Model
  - GREET – Greenhouse Gas, Regulated Emissions and Energy Use in Transportation model
  - IAM – Integrated Assessment Model
  - IPM – Integrated Planning Model
  - MOVES – MObile Vehicle Emissions Simulator
  - NONROAD – Nonroad mobile source model
  - SMOKE – Sparse Matrix Operator Kernel Emissions modeling system
- Energy and technologies
  - BEV – battery electric vehicle
  - CCS – Carbon capture and sequestration
  - CHP – Combined heat and power
  - EGU – Electricity generating unit
  - FCEV – fuel cell electric vehicle
  - NG – natural gas
  - PV – photovoltaic

Outline

- GLIMPSE project objectives
- Background: GCAM and GCAM-USA
- GLIMPSE activities
- Validating GCAM-USA emission projections
- Example applications
  - Developing growth and control factors
  - Examining environmental co-benefits of a regional policy
- The GLIMPSE graphical user interface
- Next steps

GLIMPSE project objectives

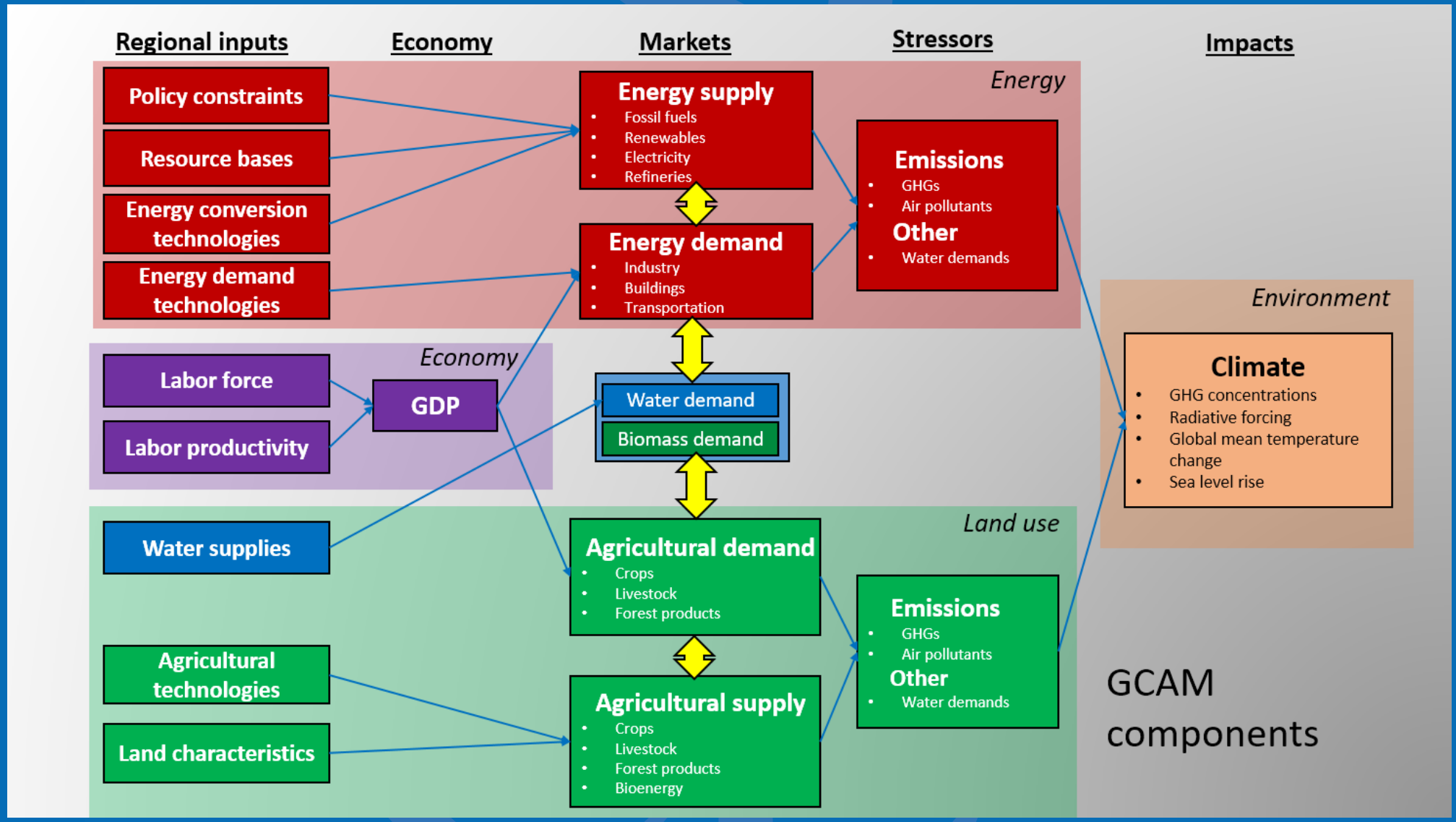
- Develop model-based tools for long-term environmental and energy planning
  - Evaluate scenarios (exploring assumptions: technology, policy, socio-economic, …)
  - Understand tradeoffs among policy options
  - Identify cost-effective, robust management strategies
- Support decisions at various geo-political scales
  - National
  - Regional
  - State
- Desired attributes
  - Low-cost or free, open source
  - Easy to use
  - Executes on desktop computer
  - Relatively quick



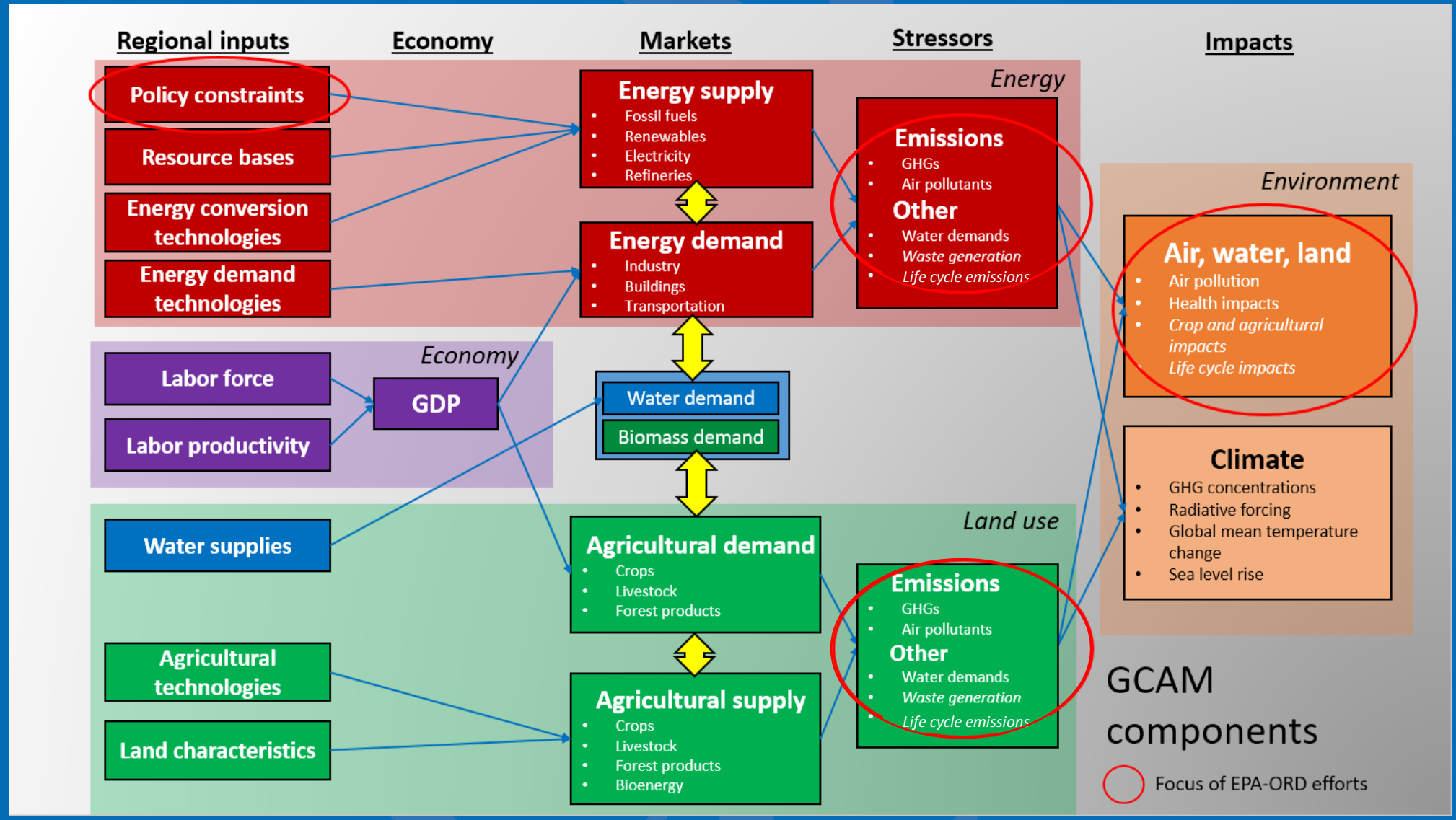
Background: GCAM and GCAM-USA

- The computational “engine” underlying GLIMPSE is GCAM-USA
- GCAM:
  - A technology-rich Integrated Assessment Model (IAM)
  - IAMs simulate interactions among human and earth systems
  - 30 years of applications, predominantly related to climate change mitigation
  - Estimates greenhouse gas (GHG) emissions, but also NOx, SO_2, CO, PM, NH_3 and other air pollutants
  - Global coverage, 32 regions; Time horizon of 2010-2100 in 5 yr steps
  - Public domain, open source, requires no proprietary software, free
  - Runtime of <<1 hour on a typical desktop computer
- GCAM-USA:
  - Shares the same code as GCAM
  - Energy system represented at the state level

Background: GCAM components



Background: GCAM components



GLIMPSE activities

GCAM-USA

Improvements to model

Regulatory representations
- CSAPR
- CAFE
- State-level RES
- RGGI

Emission factors from MOVES, IPM, NONROAD, GREET

Partnering with others

EPA program office testers of graphical interface and model

Collaborating with EPA Region 1 to explore regional applications:
- pathways for meeting state-level air quality, energy and climate targets

University and state-level partners

Graphical interface

Developed "Scenario Builder" to facilitate running the model and managing results

Modifying existing output tools for visualizing and analyzing results

Applications

Effects of alternative population growth and migration patterns on energy and emissions

Health effects of alternative energy pathways

Technology assessment

Other activities

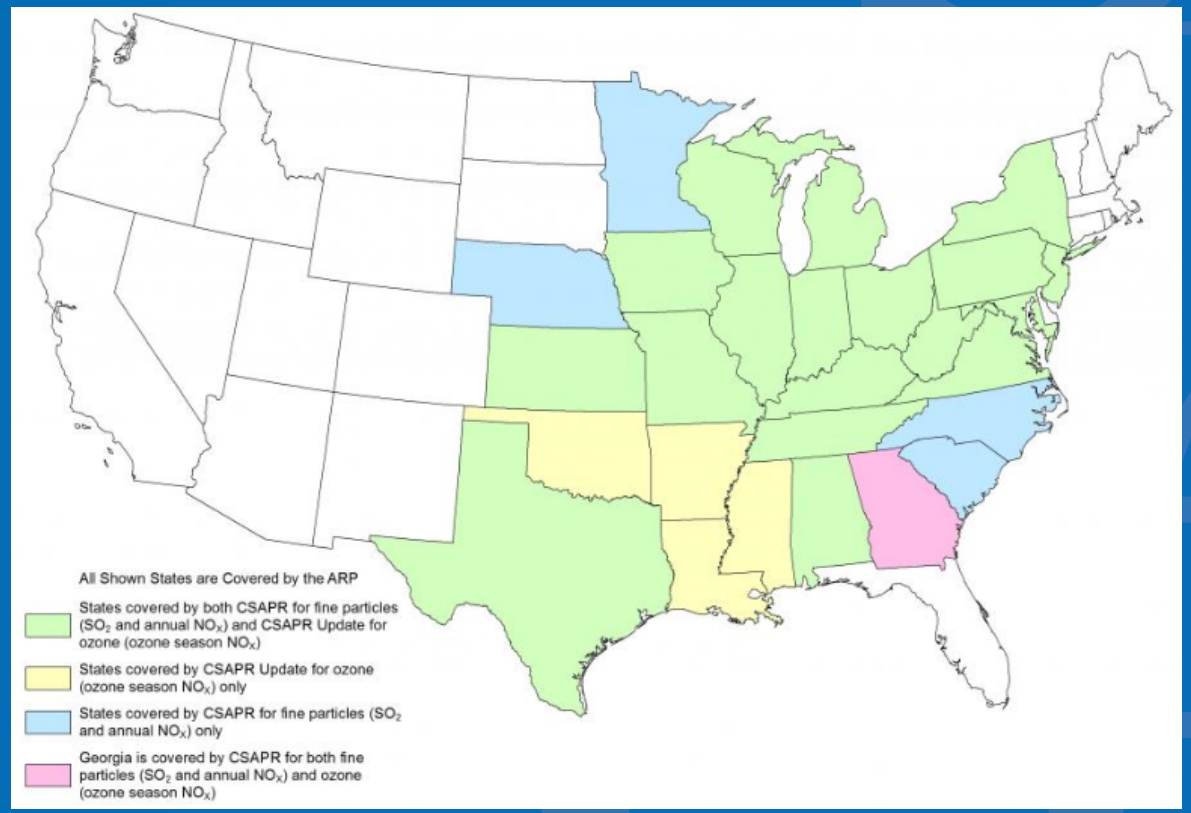
Emissions validation: Comparing national-, state-, and sector-level emission outputs with the NEI and EPA projections

Adding impact factors: PM mortality costs, O_3 damage to timber and crops, N deposition

State-level constraints

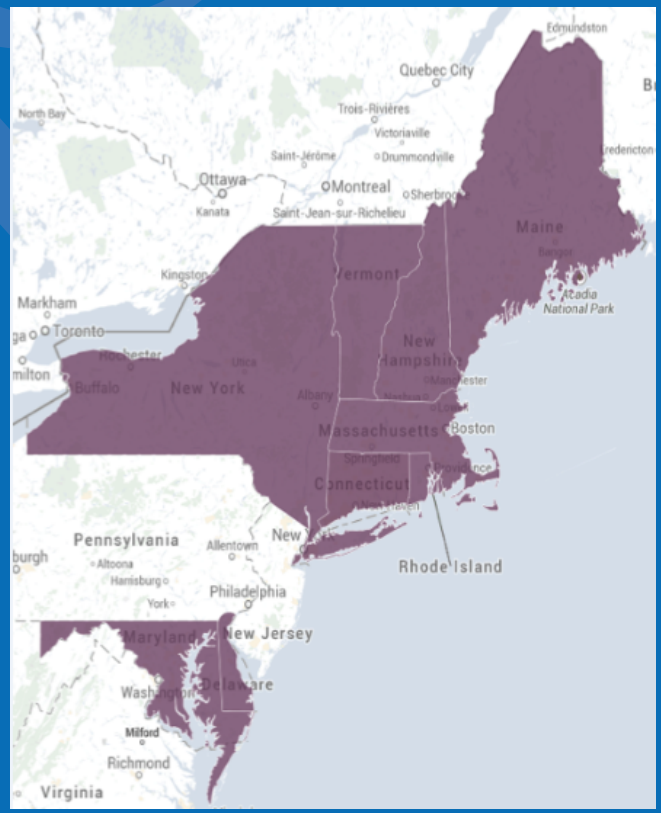
CSAPR region

State-level constraints on electric sector NOx and SO_2



RGGI region

Regional electric sector CO2 constraints



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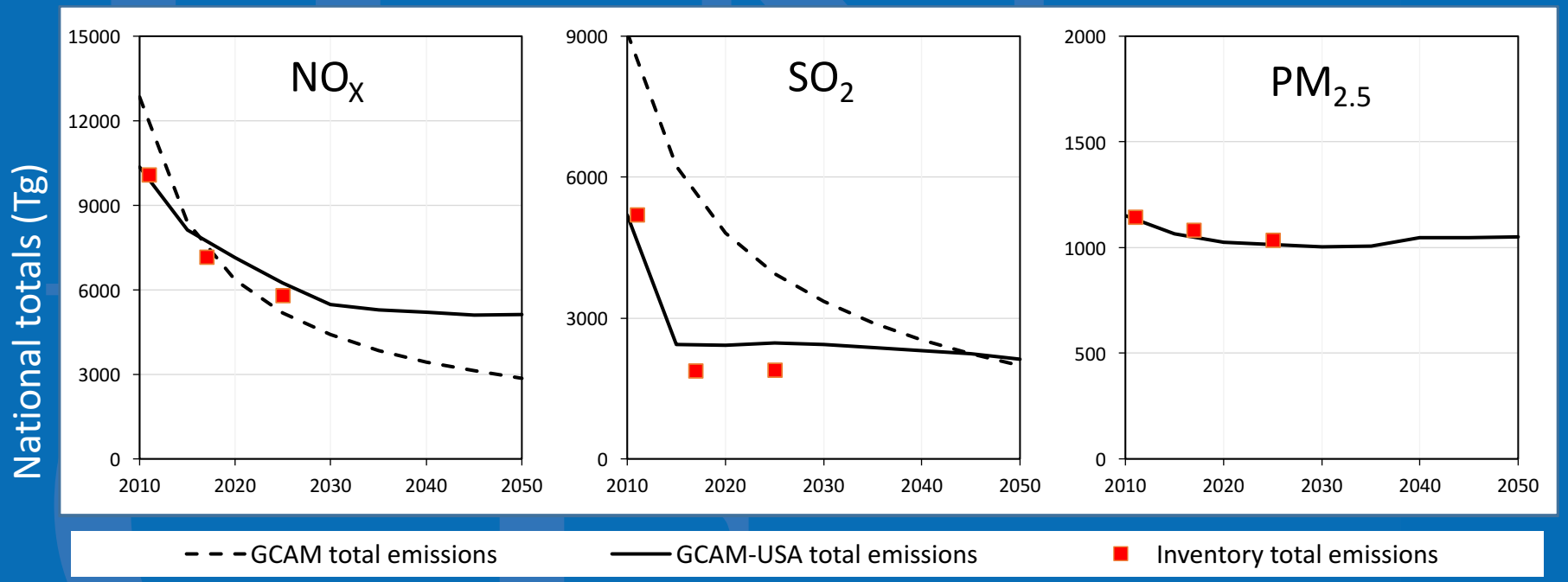
Validation

Wenjing Shi, Yang Ou, Steven J. Smith, Catherine M. Ledna, Christopher G. Nolte, Daniel H. Loughlin, Projecting state-level air pollutant emissions using an integrated assessment model: GCAM-USA, In Applied Energy, 2017, ISSN 0306-2619, https://doi.org/10.1016/j.apenergy.2017.09.122.

Validation

Comparison of GCAM-USA emission outputs and EPA inventories

National totals by pollutant

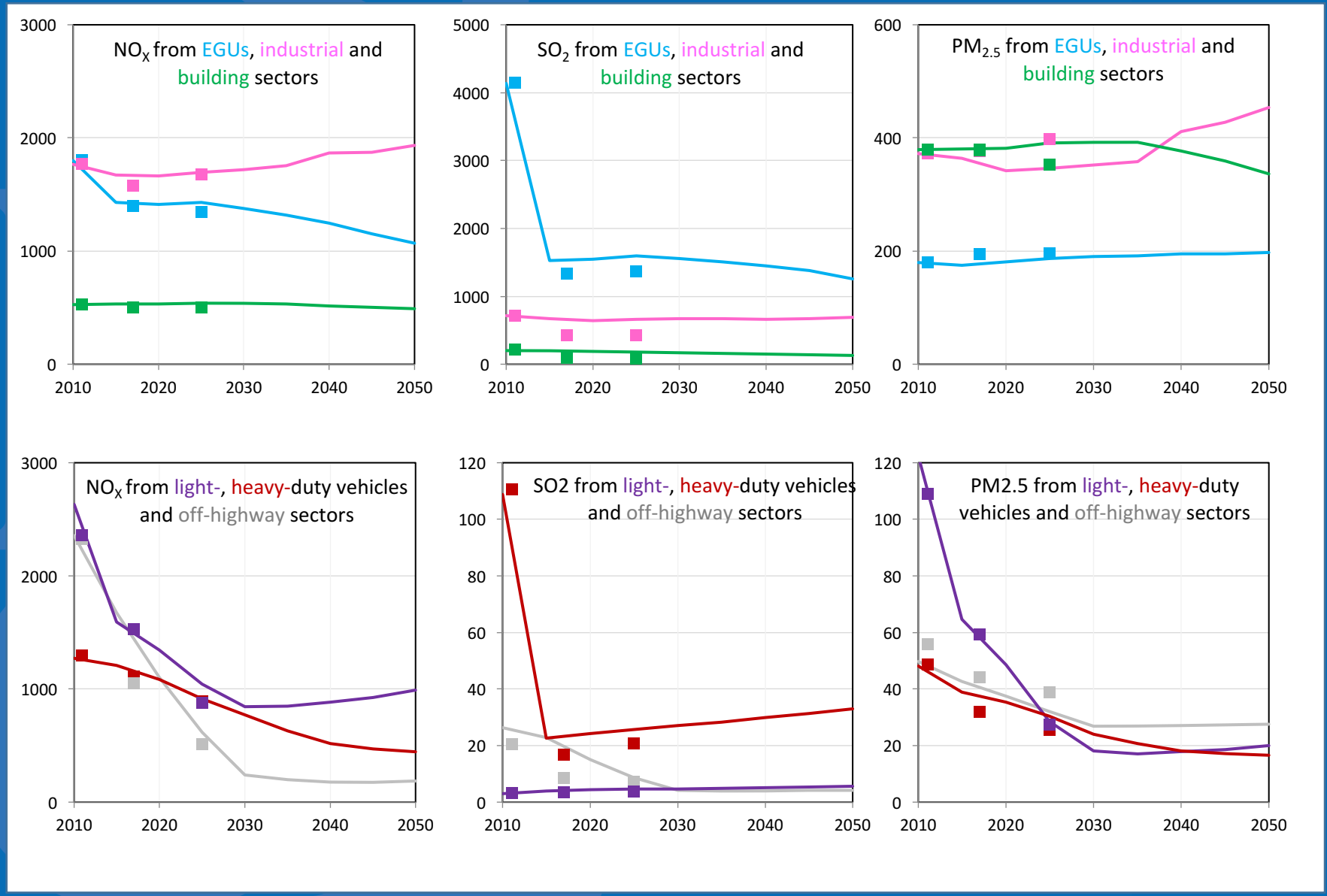


Validation

National emission totals by pollutant and sector

Comparison of GCAM-USA emission outputs and EPA inventories

GCAM-USA: Solid lines
EPA inventories: Dots



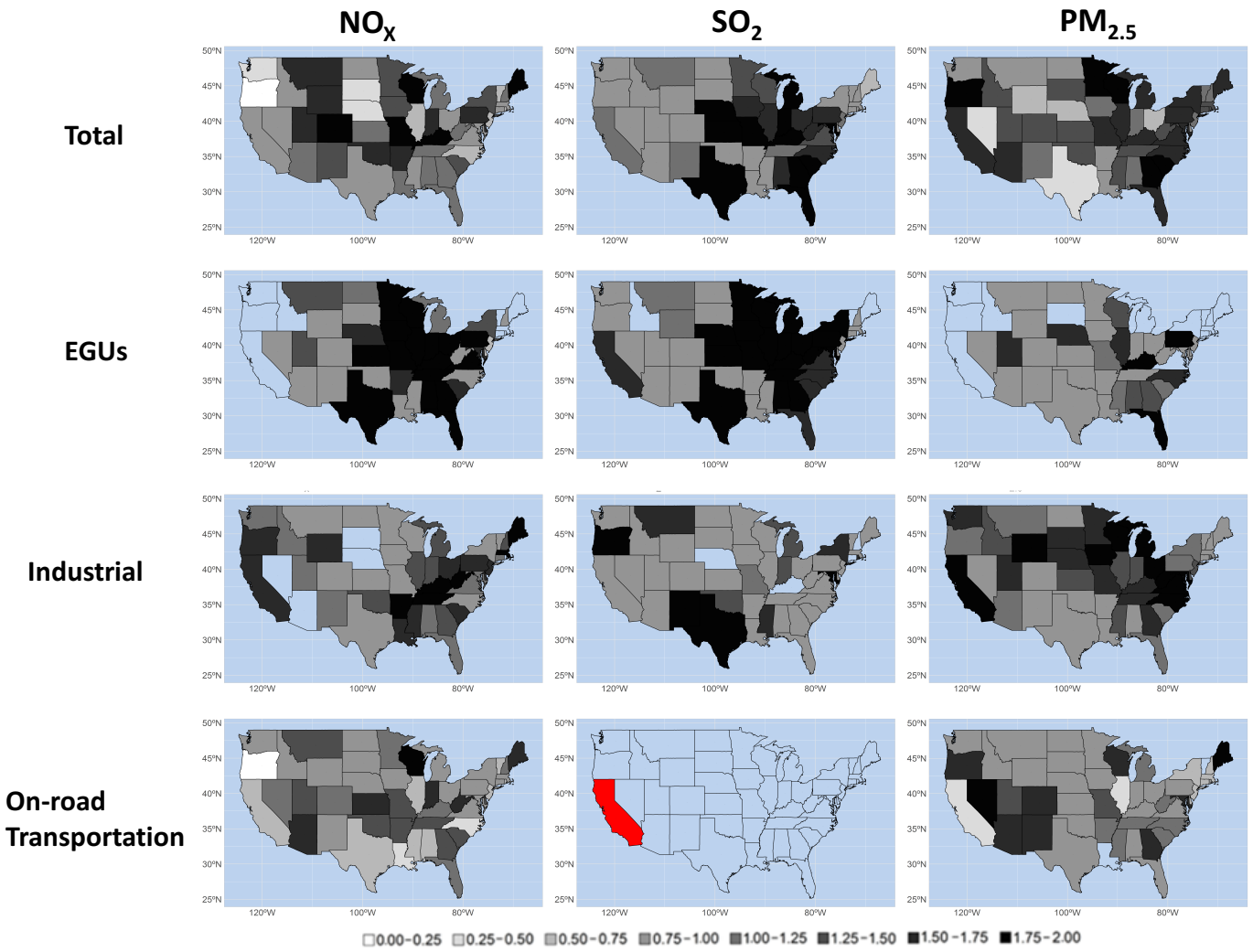
Validation

A Quality Metric (QM) is developed to quantify GCAM-USA performance for each pollutant.

	Percent of Inventory	Difference between GCAM-USA and the Inventory		GCAM-USA Quality Metric	GCAM Quality Metric
		2010	2010/2011-2025 Slope		
	%	%	%		
NOx Total	**100%**	**3%**	**3%**	**1.6**	**0.0**
EGUs	18%	0%	5%	**1.7**	**0.0**
Industrial	18%	0%	1%	**1.9**	**0.0**
Residential&commercial	5%	0%	8%	**1.6**	**0.0**
Light duty vehicles	23%	1%	4%	**1.7**	**0.0**
Heavy duty vehicles	23%	11%	2%	**0.9**	**0.0**
Air, marine and rail	13%	-2%	3%	**1.7**	**0.0**
SO_2 Total	**100%**	**0%**	**11%**	**1.4**	**0.0**
EGUs	80%	0%	6%	**1.7**	**0.0**
Industrial	14%	0%	33%	**1.0**	**0.0**
Residential&commercial	4%	-3%	55%		
Light duty vehicles	0%	29%	-3%		
Heavy duty vehicles	0%	-8%	43%		
Air, marine and rail	2%	-2%	5%		

- GCAM-USA has higher QM than GCAM.
- Agreement in absolute magnitude is better than agreement in slopes.
- Industrial SO_2 slope difference is as high as 33%, due to the lack of technology-specific industrial emission factors in GCAM-USA.

Validation



Source: Shi et al. (in press)

- Black: High quality fit
- White: Lower quality fit, but within tolerances
- Red: outside tolerances
- Transparent: not measured since category < 5% of inventory

- Higher QMs for total emissions and electric sector emissions;
- Higher electric sector QMs in CSAPR states;
- Relative low industrial sector and on-road transportation sector QMs

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Application: Emission projection

Application: Projecting emissions

2010 to 2050 emissions growth and control factors for NOx

GCAM-USA results can be processed to produce internally consistent state-, pollutant-, source-category specific growth factors suitable for air quality modeling.

Here, we compare Reference Case factors with those of an alternative energy scenario.

		Reference Case			Alternative scenario		
Sector	Fuel	CA	OH	TX	CA	OH	TX
Electric	Biomass	0.53	2.07	0.48	0.60	2.36	0.52
	Coal	0.93	0.49	1.01	0.92	0.51	1.00
	Gas	1.79	0.46	0.55	1.95	0.47	0.58
	Oil	1.28	0.93	0.02	1.41	1.01	0.83
Industrial	Coal	1.22	0.89	1.72	1.22	0.89	1.72
	Gas	1.19	0.85	1.53	1.19	0.85	1.53
	Oil	0.95	0.63	1.24	0.95	0.63	1.24
	Refineries	0.73	0.73	0.73	0.55	0.55	0.55
Commercial	Biomass	1.46	0.84	1.70	1.46	0.84	1.70
	Gas	1.37	0.66	1.32	1.37	0.66	1.31
	Oil	1.16	0.62	1.34	1.16	0.62	1.34
Residential	Gas	1.29	0.76	1.20	1.29	0.76	1.20
	Oil	1.55	0.83	1.54	1.55	0.83	1.54
	Wood	1.40	1.07	1.70	1.41	1.07	1.71
Mobile	LDV	0.09	0.06	0.09	0.00	0.00	0.00
	HDV	0.28	0.27	0.44	0.28	0.27	0.44
	Aircraft	1.33	0.65	1.40	1.37	0.67	1.45
	Marine & rail	0.72	0.22	0.55	0.72	0.22	0.55

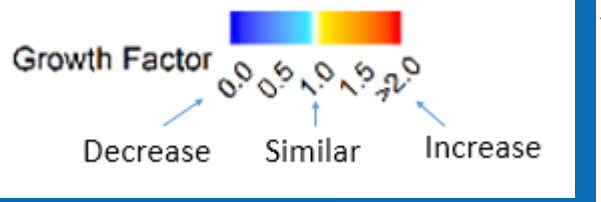
Illustrative results

Application: Projecting emissions

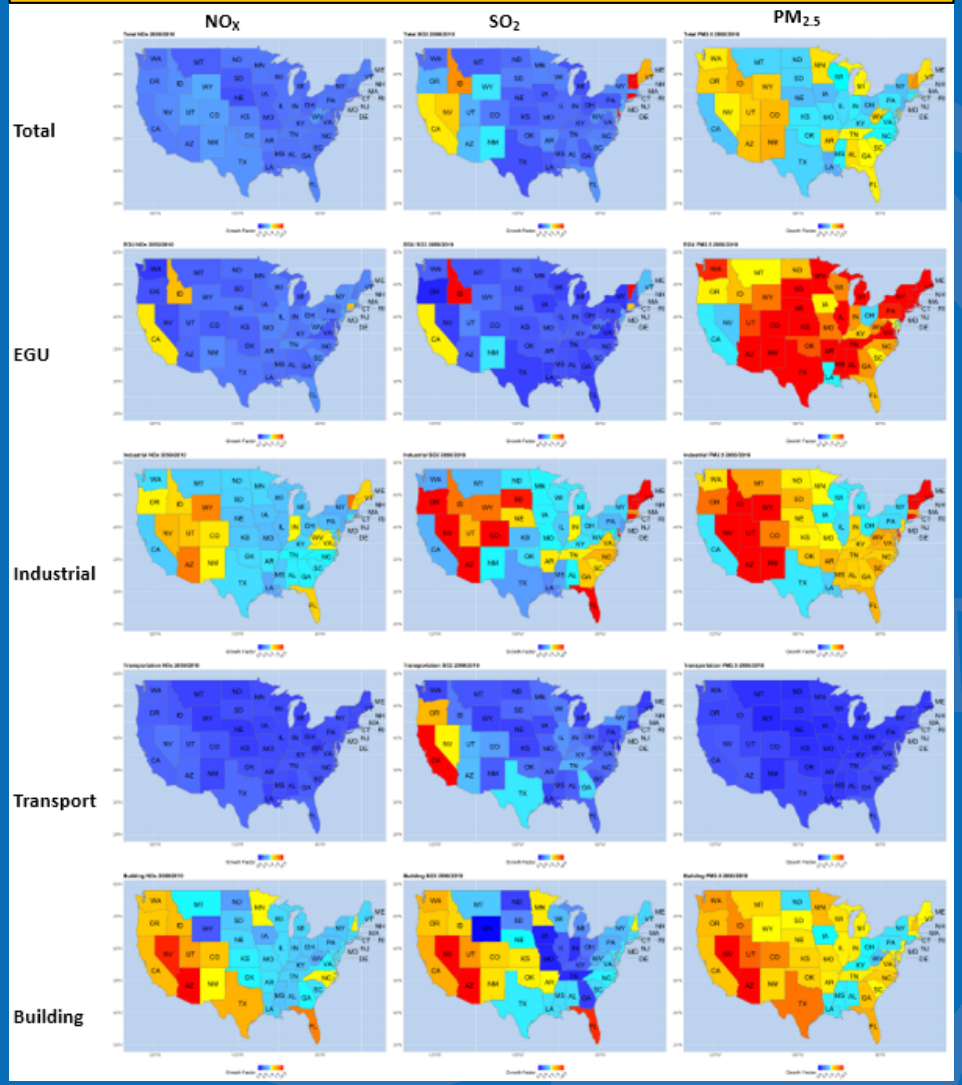
State-level 2010 to 2050 growth and control factors

Examining growth and control factors geographically provides some insights into state and regional trends.

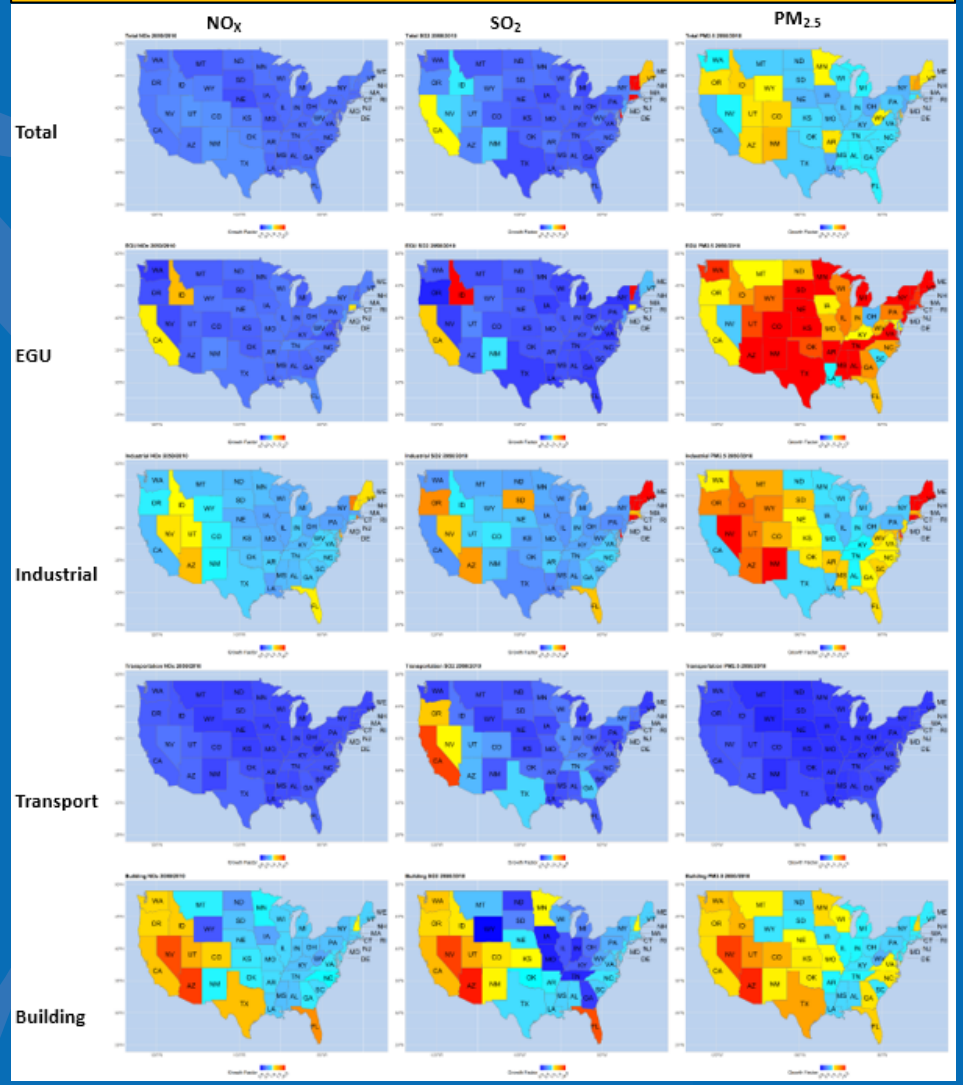
We are evaluating the use of exploratory data visualization and statistics to understand more fully what drives state-level differences.



Reference case



Alternative scenario



Illustrative results

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Application: Policy analysis

Application: Co-benefits assessment

Goal: Estimate air pollutant emission changes and reduction in PM2.5 mortality costs of current and proposed Regional Greenhouse Gas Initiative (RGGI) targets

Region-wide electric sector CO_2 caps

2015	-	89 x 10^6 tons
2020	-	78 x 10^6 tons
2025	-	66 x 10^6 tons
2030	-	55 x 10^6 tons

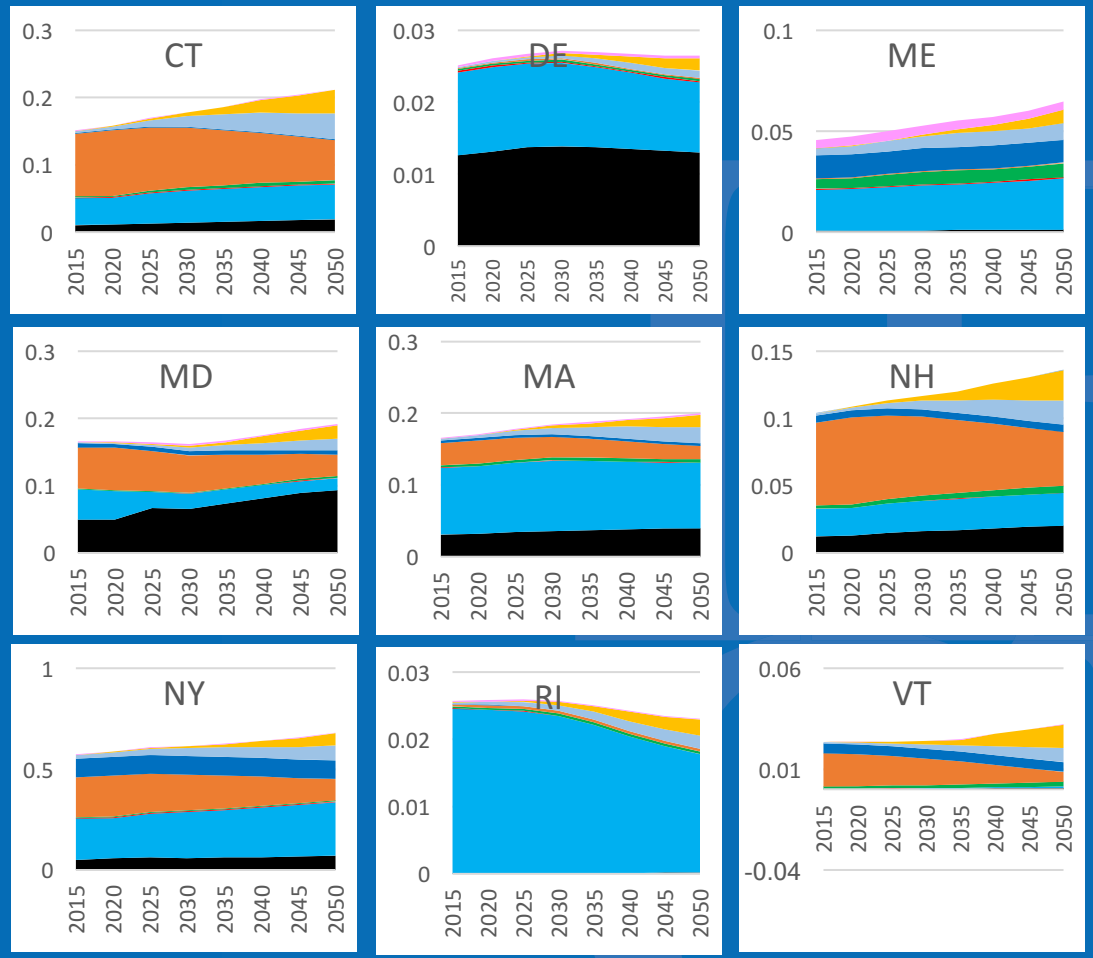
Recently proposed

RGGI region: CT, DE, ME, MD, MA, NH, NY, RI, VT

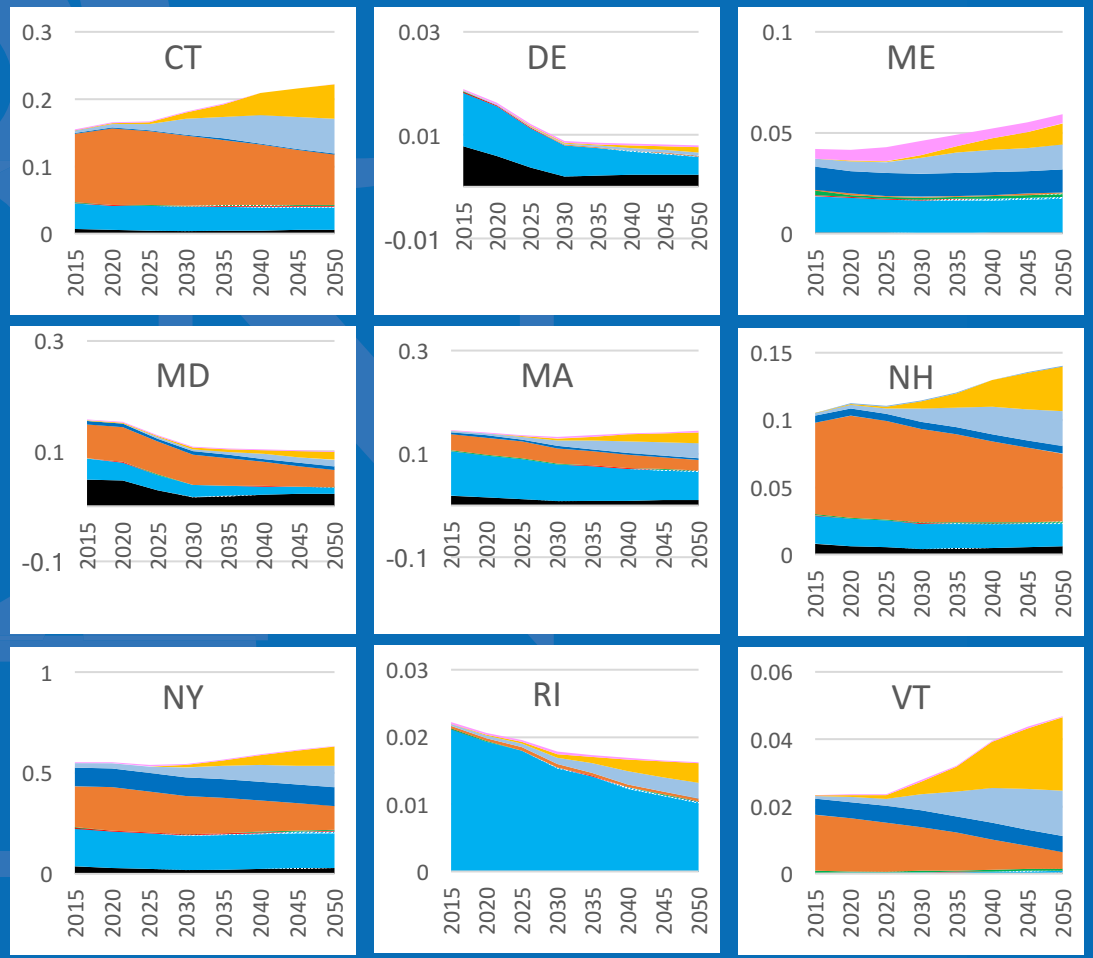
Application: Co-benefits assessment

Illustrative results

Electricity production (EJ) without RGGI



Electricity production (EJ) with RGGI

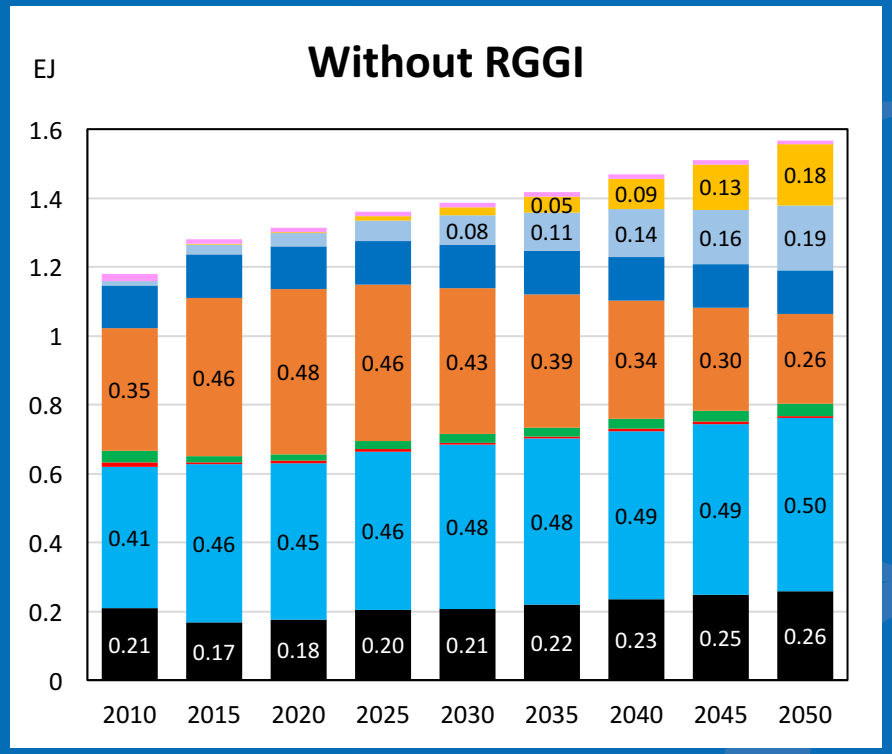


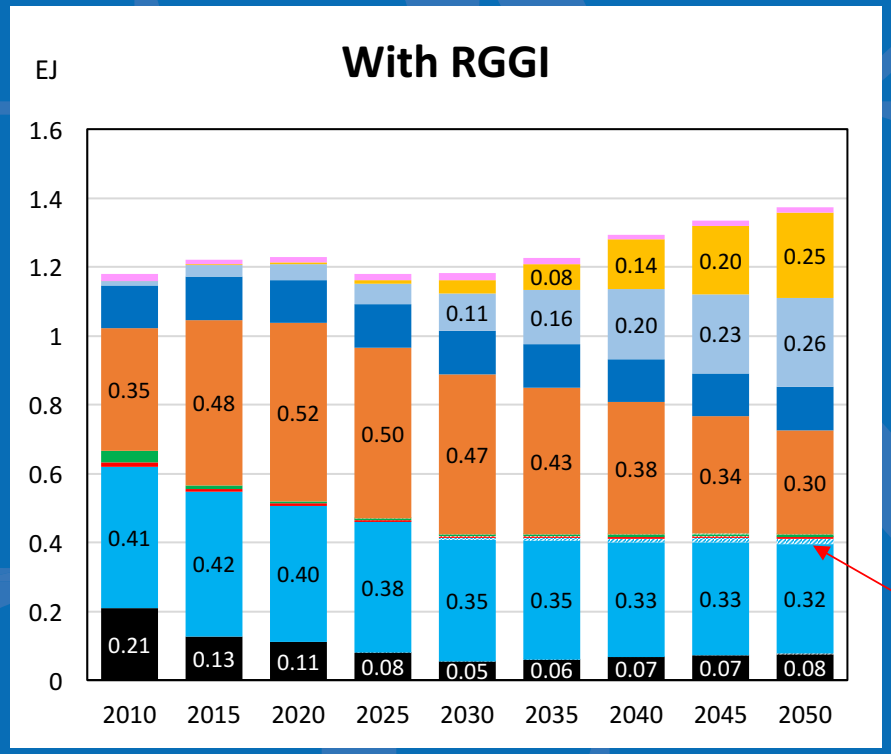
Coal | Gas | Biomass | Nuclear | Geothermal | Hydro | Wind | Solar | CHP

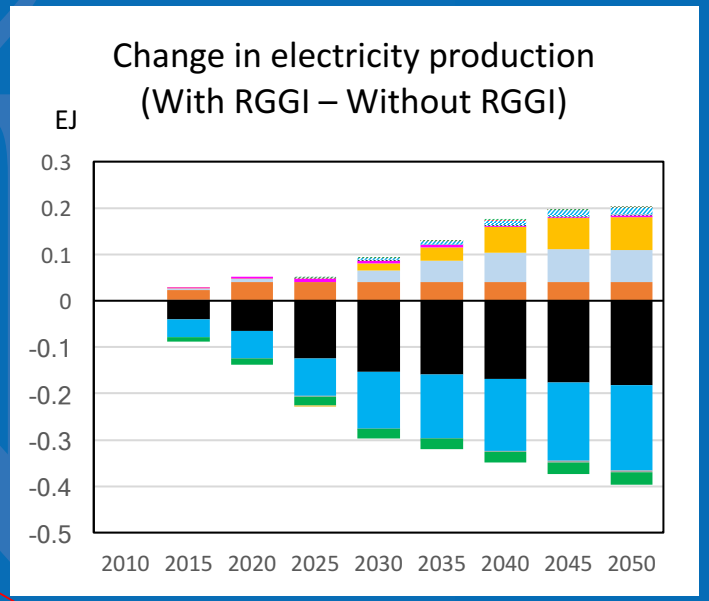
Application: Co-benefits assessment

Illustrative results

Electricity production by aggregated technology category in the RGGI region







Coal | Gas | Biomass | Nuclear | Geothermal | Hydro | Wind | Solar | CHP

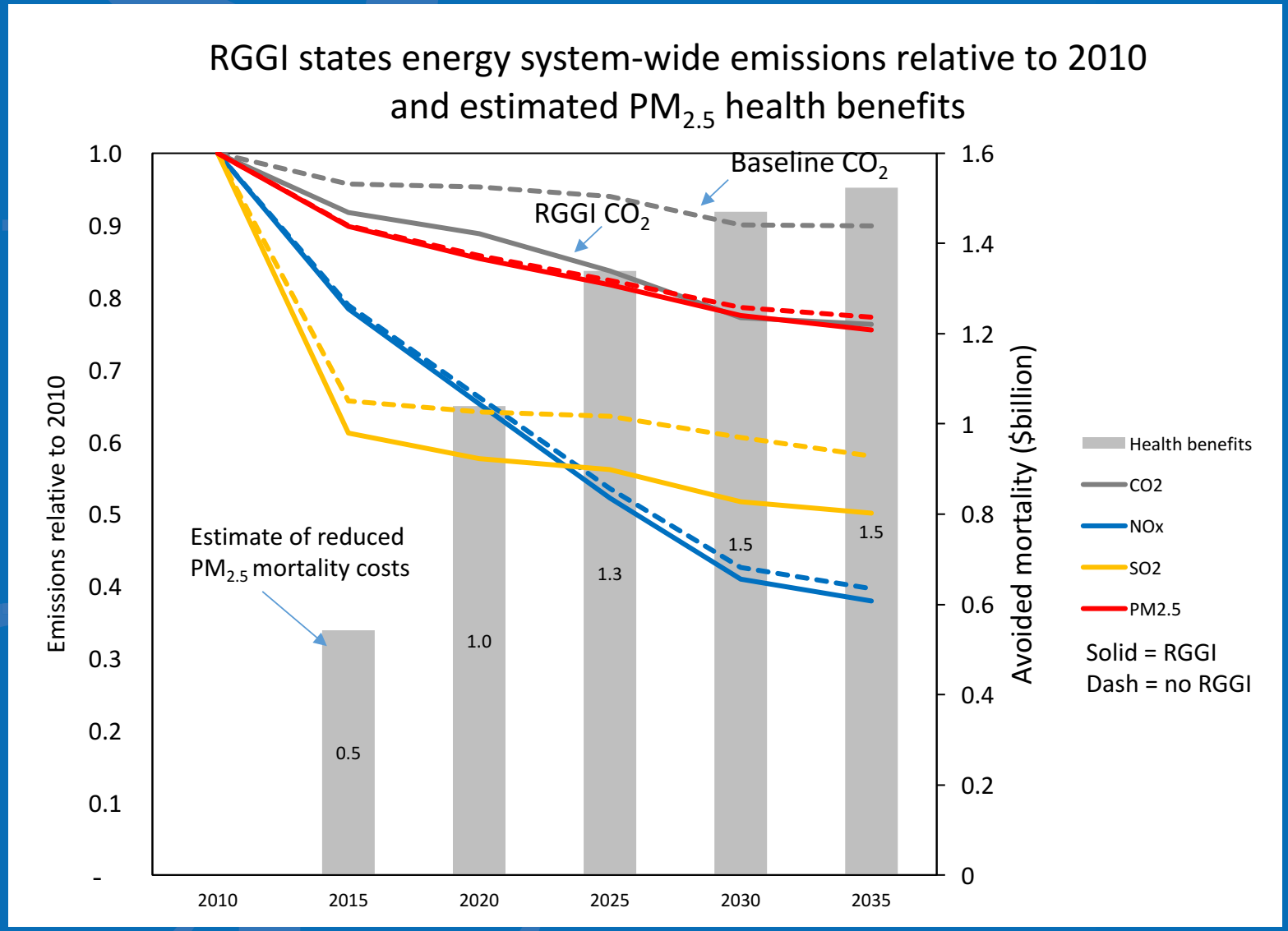
RGGI region: CT, DE, ME, MD, MA, NH, NY, RI, VT

Application: Co-benefits assessment

Comparison of emission trajectories for CO_2, NO_x, SO_2, and $PM_{2.5}$ in the RGGI region states with and without the proposed regional targets.

Bars show annual estimates of avoided $PM_{2.5}$ mortality costs from RGGI.

Source- and pollutant-specific PM2.5 mortality impact factors obtained from OAQPS report: "Estimating the benefit per ton of reducing PM2.5 precursors from 17 sectors." National average values used.

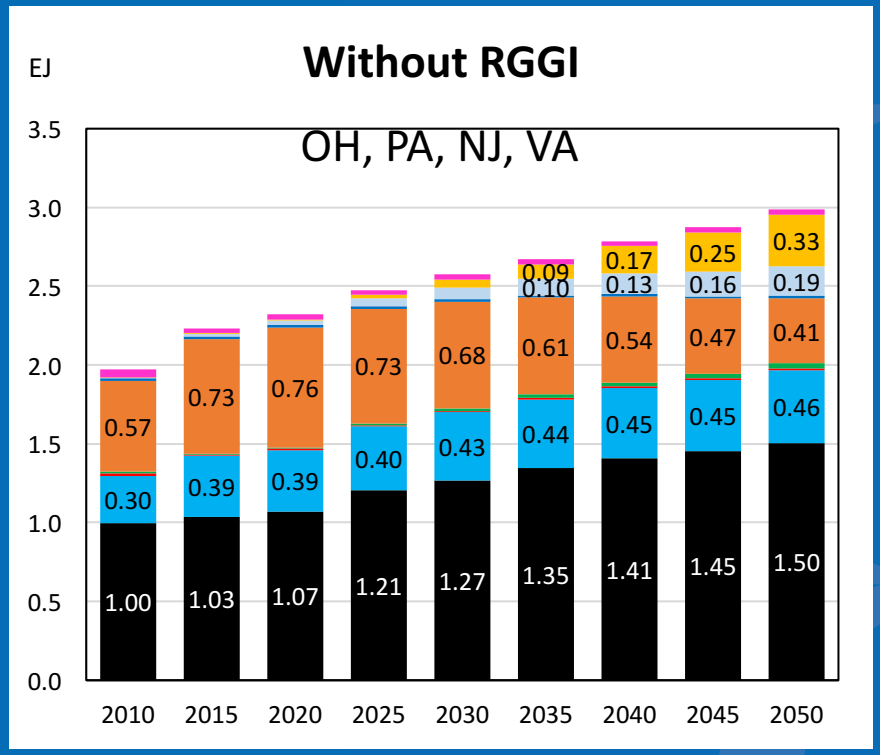


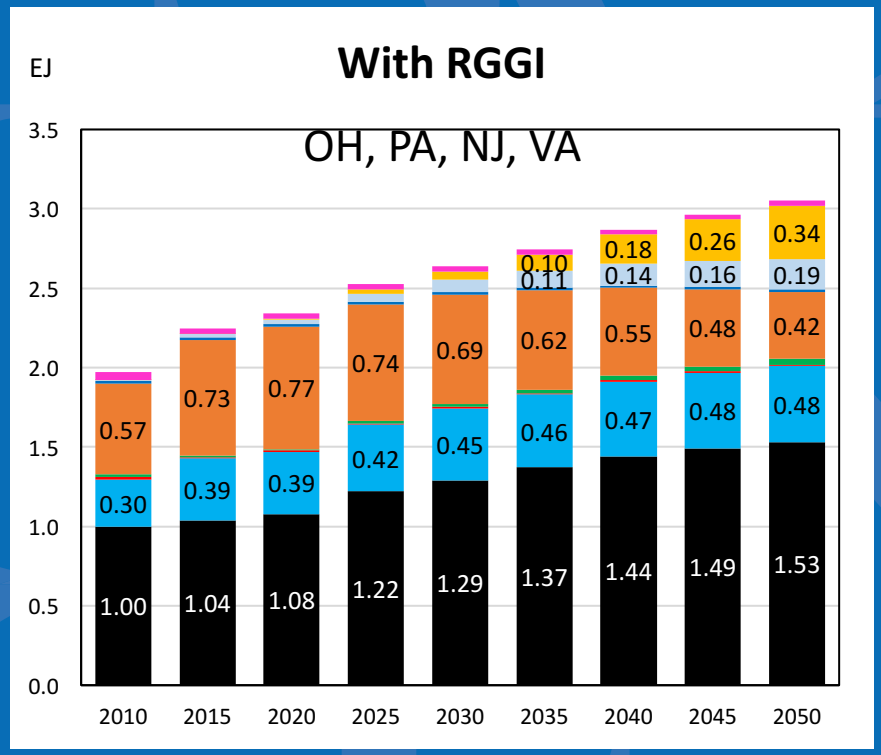
Illustrative results

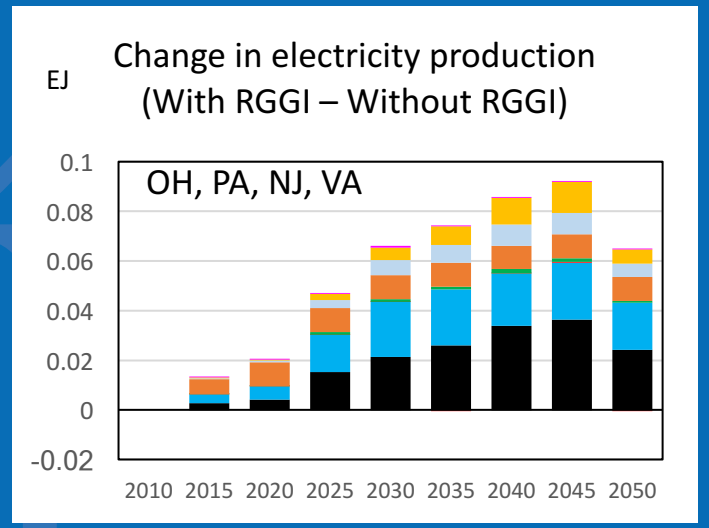
Application: Co-benefits assessment

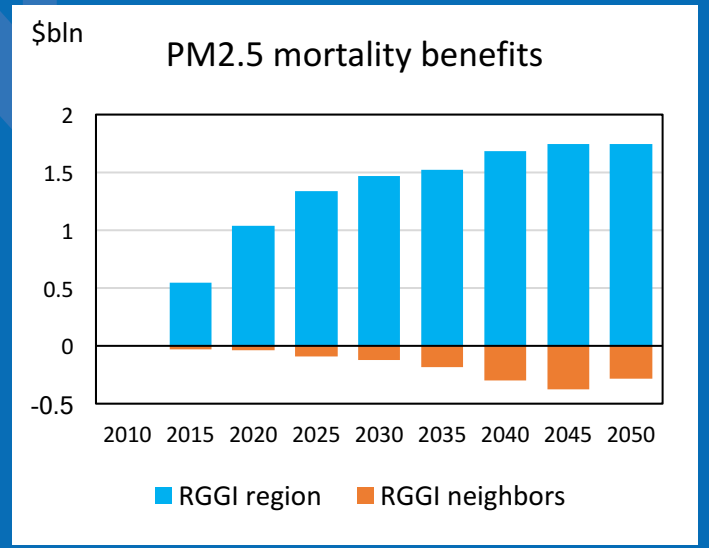
Illustrative results

What is the impact of RGGI on surrounding states?









RGGI neighbors: OH, PA, NJ, VA

RGGI region: CT, DE, ME, MD, MA, NH, NY, RI, VT

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GLIMPSE graphical user interface

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GLIMPSE Scenario Builder

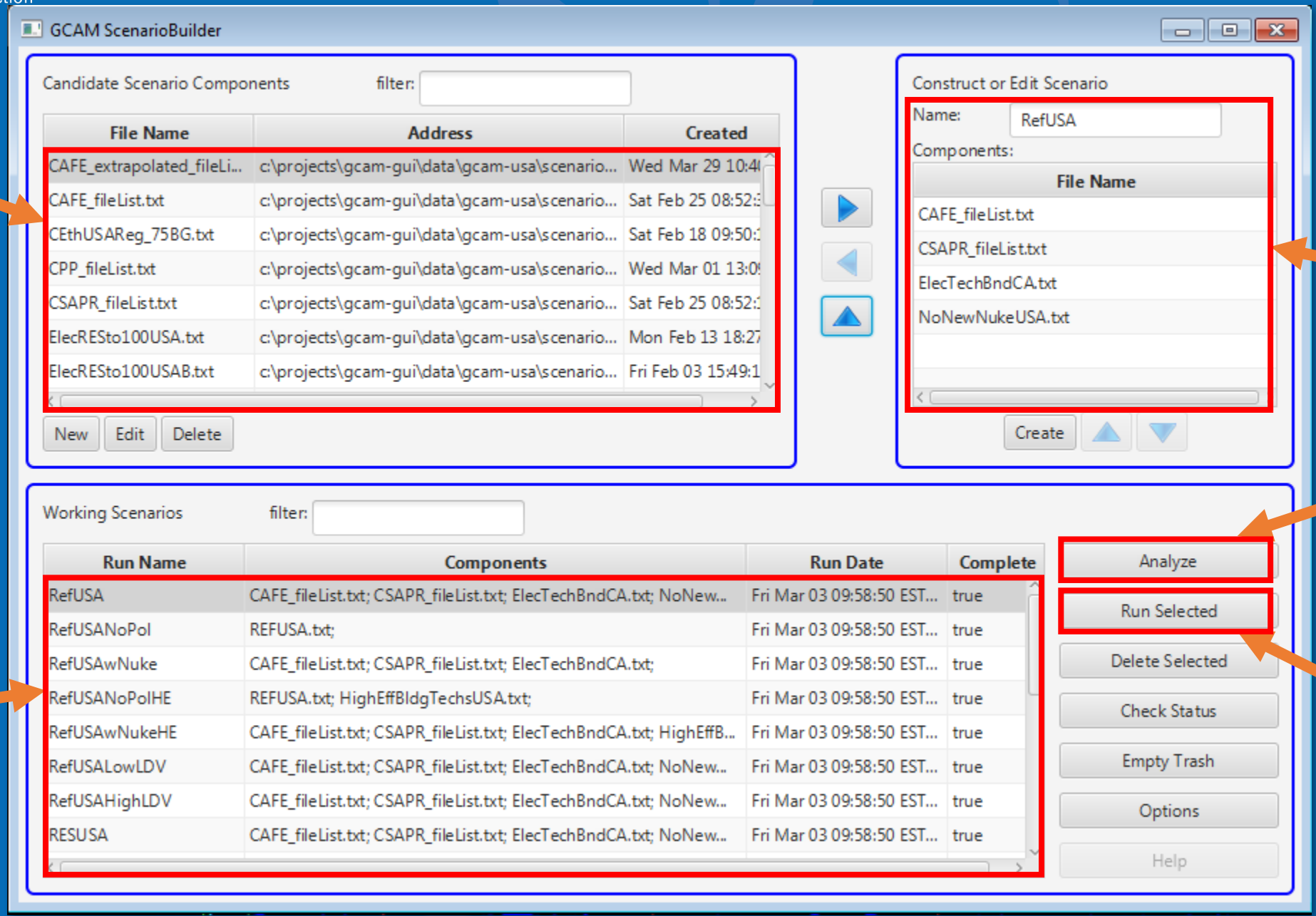
Scenario building blocks

Creating a scenario

Analysis of results

Library of scenarios

One-click scenario execution



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GLIMPSE Enhanced ModelInterface

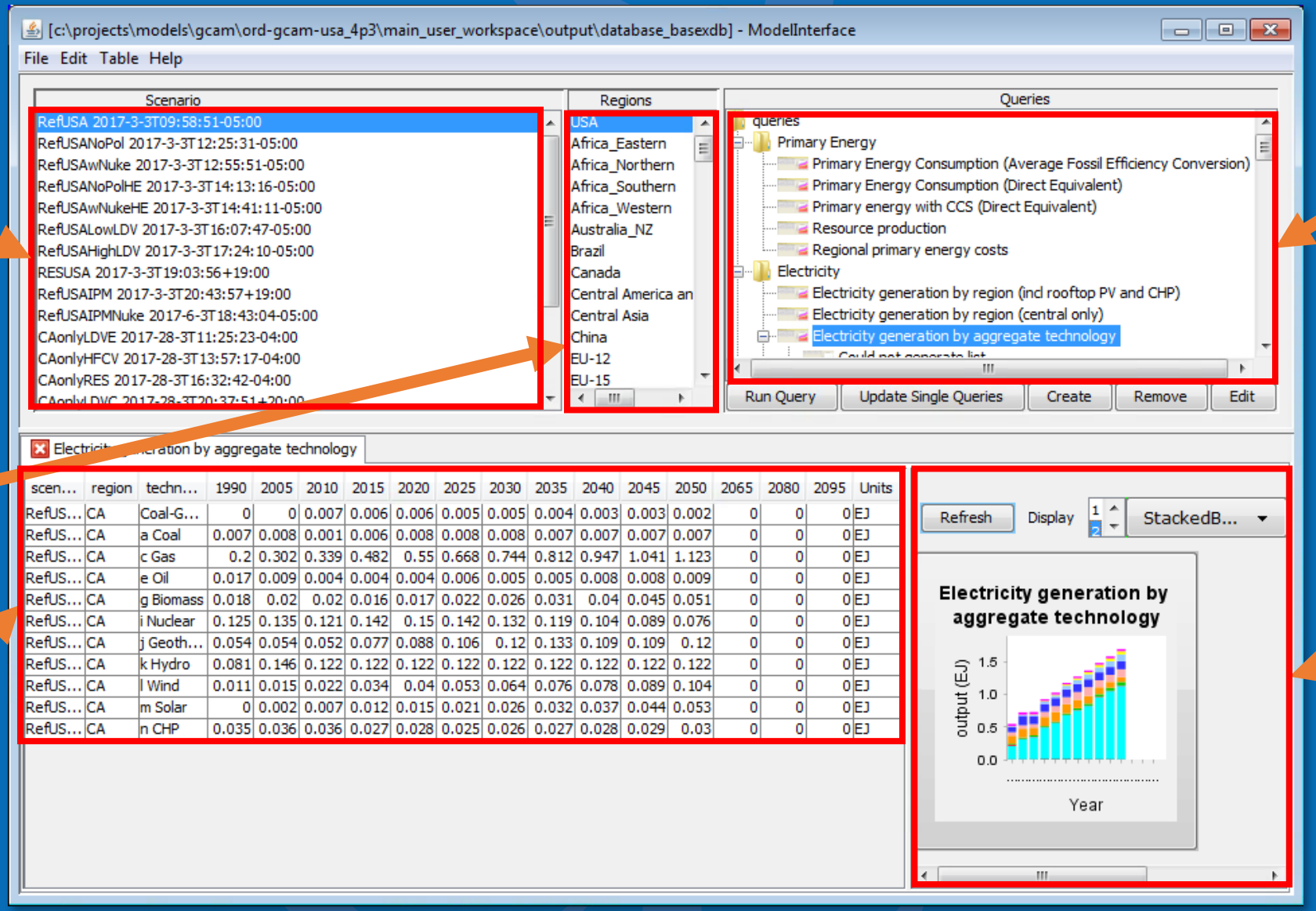
Scenarios in results database

Modeled regions

Query results

List of scenario outputs that can be queried

Query visualization



scen...	region	techn...	1990	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2065	2080	2095	Units
RefUS...	CA	Coal-G...	0	0	0.007	0.006	0.006	0.005	0.005	0.004	0.003	0.003	0.002	0	0	0	EJ
RefUS...	CA	a Coal	0.007	0.008	0.001	0.006	0.008	0.008	0.008	0.007	0.007	0.007	0.007	0	0	0	EJ
RefUS...	CA	c Gas	0.2	0.302	0.339	0.482	0.55	0.668	0.744	0.812	0.947	1.041	1.123	0	0	0	EJ
RefUS...	CA	e Oil	0.017	0.009	0.004	0.004	0.004	0.006	0.005	0.005	0.008	0.008	0.009	0	0	0	EJ
RefUS...	CA	g Biomass	0.018	0.02	0.02	0.016	0.017	0.022	0.026	0.031	0.04	0.045	0.051	0	0	0	EJ
RefUS...	CA	i Nuclear	0.125	0.135	0.121	0.142	0.15	0.142	0.132	0.119	0.104	0.089	0.076	0	0	0	EJ
RefUS...	CA	j Geoth...	0.054	0.054	0.052	0.077	0.088	0.106	0.12	0.133	0.109	0.109	0.12	0	0	0	EJ
RefUS...	CA	k Hydro	0.081	0.146	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0	0	0	EJ
RefUS...	CA	l Wind	0.011	0.015	0.022	0.034	0.04	0.053	0.064	0.076	0.078	0.089	0.104	0	0	0	EJ
RefUS...	CA	m Solar	0	0.002	0.007	0.012	0.015	0.021	0.026	0.032	0.037	0.044	0.053	0	0	0	EJ
RefUS...	CA	n CHP	0.035	0.036	0.036	0.027	0.028	0.025	0.026	0.027	0.028	0.029	0.03	0	0	0	EJ

An extension of PNNL's ModelInterface

Next steps

- Continue to foster existing partner relationships
  - EPA Program Offices, EPA Region 1, State of MD, NESCAUM
- Explore other uses
  - classroom setting, university research projects?
- Applications
  - emission projections, technology assessment, population growth and migration patterns…?
- Leverage new and emerging GCAM-USA features
  - PNNL:
    - industrial sector improvements, time slices (seasonal day and night), water supplies
    - shift of calibration year to 2015
  - ORD:
    - air pollutant controls from CoST

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Questions?

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