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Air pollutant emission projections for alternative scenarios using GLIMPSE/GCAM-USA 5.4

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Foreword

- Objectives of this presentation
  - We describe the GLIMPSE framework and demonstrate how it can be used to develop projections of air pollutant emissions for evaluation with the CMAQ air quality model.

- Acknowledgements
  - Other members of GLIMPSE Team
    - EPA: Fahim Sidi and Joyce Kim
    - Former team members: Carol Lenox, Wenjing Shi, Samaneh Babaee, Vicky Jia, Paelina DeStephano, Sara Simm, Farid Alborzi, and Catherine Ledna
  - Collaborators:
    - Partners across the Agency, including OAR and Regions 1, 3, and 4.
    - PNNL: Gokul Iyer and Matthew Binstead

- Disclaimers
  - Results are provided for illustrative purposes only. Do not cite.
  - The views expressed in this presentation are those of the authors and do not necessarily reflect the views or policies of the US EPA. Any mention of trade names, products, or services does not imply an endorsement by the US Government or EPA. EPA does not endorse any commercial products, services, or enterprises.

Abbreviations

- Models
  - CMAQ – Community Multi-Scale Air Quality model
  - DESID – Detailed Emission Scaling, Isolation, and Diagnostic module for CMAQ
  - GCAM – Global Change Analysis Model
  - GCAM-USA – GCAM version with state resolution for US
  - GLIMPSE – GCAM Long-term Interactive Multi-Pollutant Scenario Evaluator
- Sectors
  - ptegu – Point source electric generating unit (EGU)
  - ptnonipm – Point source other than EGUs
  - nonpt – Non-point sources
  - onroad – Onroad vehicles, including buses, cars, and trucks (passenger and heavy duty)
- Emissions
  - CH_4 - Methane
  - CO – Carbon monoxide
  - CO_2 – Carbon dioxide
  - GHG – Greenhouse gases
  - NOx – Nitrogen oxides
  - N_2O – Nitrous oxide
  - PM – Particulate Matter
  - $PM_{2.5}$ – PM of diameter less than 2.5 microns
  - SO_2 – Sulfur dioxide
  - NH_3 - Ammonia
- Units
  - EJ – Exajoules
  - MTC – Megatonnes Carbon
  - kT – Kilotonnes
  - t - tonnes
- Technologies and fuels
  - CCS – Carbon Capture and Sequestration
  - DAC – Direct Air Capture
  - EV – Electric Vehicle
  - BEV – Battery Electric Vehicle
  - CNG – Compressed Natural Gas
- Organizations
  - PNNL – Pacific Northwest National Laboratory
  - RGGI – Regional Greenhouse Gas Initiative
- Policies and measures
  - CES – Clean Energy Standard
  - EE – Energy efficiency
  - NAAQS – National Ambient Air Quality Standard
  - NSPS – New Source Performance Standard
  - RE – Renewable electricity
  - RGGI – Regional Greenhouse Gas Initiative
  - RPS – Renewable Portfolio Standard

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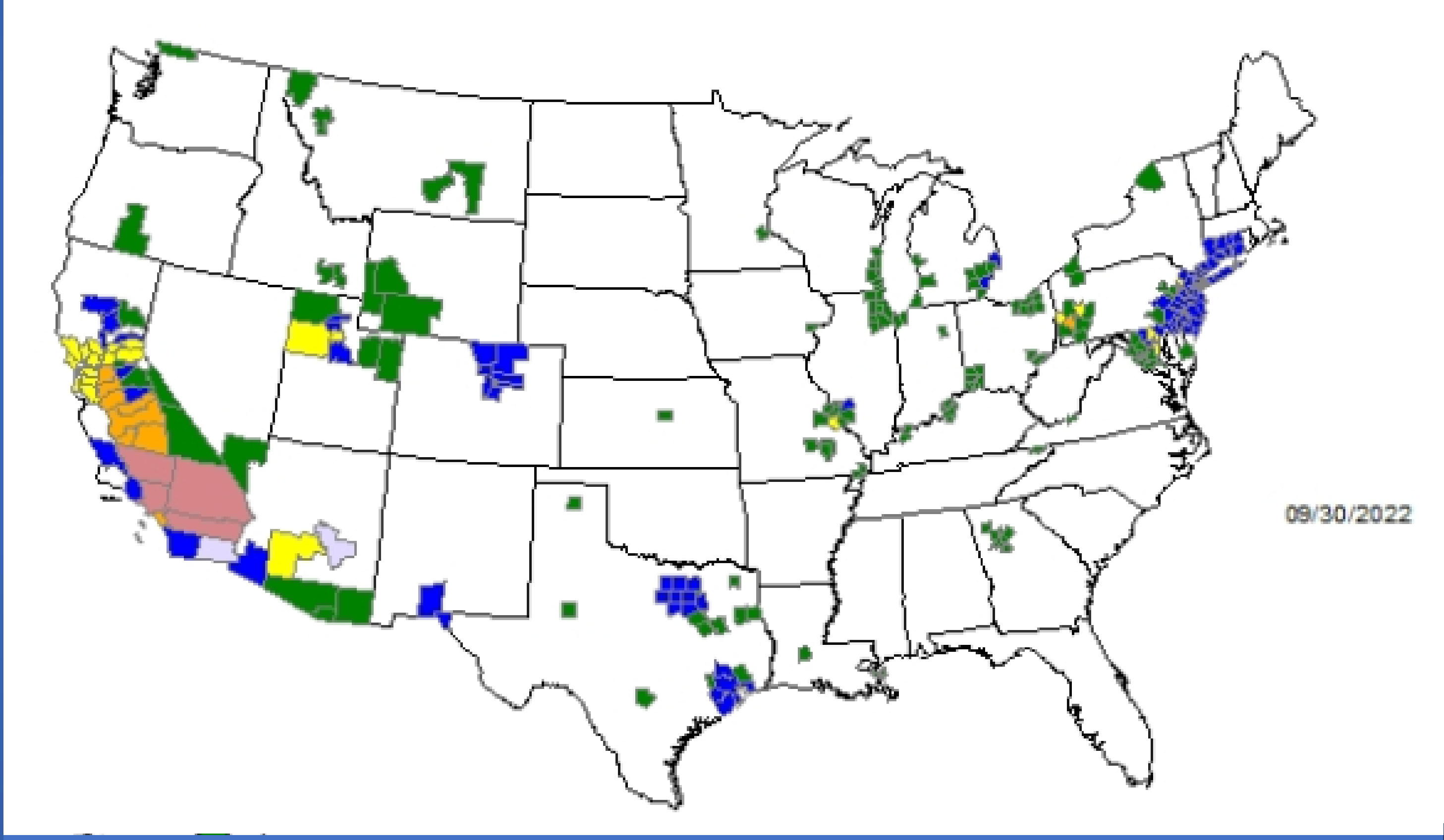
Outline

- Background
  - Linkages among air, climate, and energy
  - Premise: Decarbonization will result in air quality benefits
- Approach
  - Explore this premise using GLIMPSE and CMAQ-DESID
- Illustrative application
  - Simulate emission changes through 2050 for a Reference Case and a Deep Decarbonization scenario
  - Develop emission growth and control factors
- Considerations and next steps

Background: Remaining challenges

- The Clean Air Act and its amendments have been successful in reducing air pollutant emissions.
- These emission reductions have improved air quality across most of the US
- Nonetheless, nearly 140 million people live in counties that exceed one or more National Ambient Air Quality Standards (NAAQS)

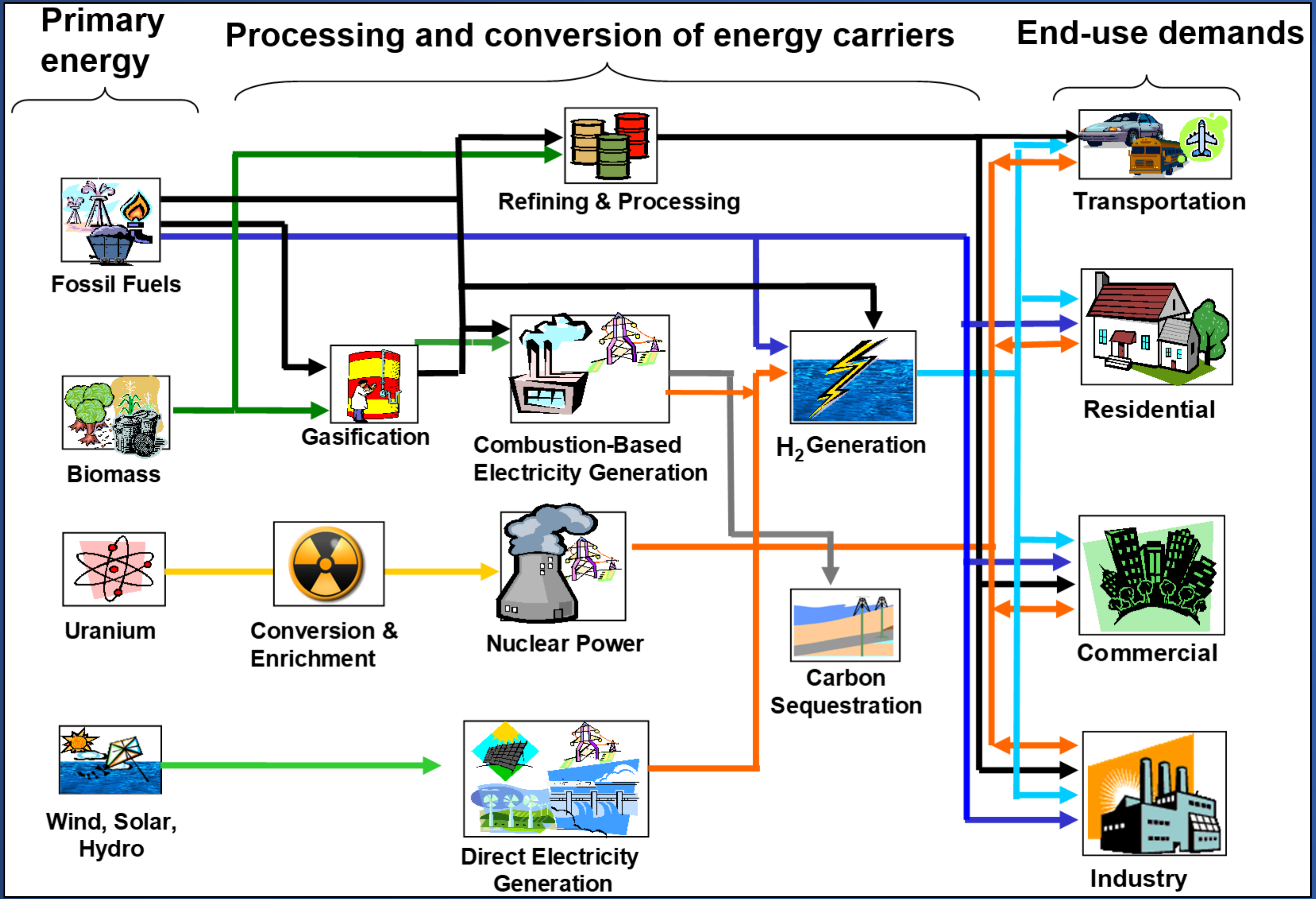
Counties designated in "Nonattainment"



Source: USEPA Greenbook
epa.gov/green-book

Background: Air, climate, and energy

The energy system



Energy system contributions to U.S. anthropogenic emissions:

Air pollutants:

- NOx – 91%
- SO_2 – 75%
- CO – 74%
- VOCs – 45%
- $PM_{2.5}$ – 22% (direct)

GHGs:

- CO_2 – 96%
- CH_4 – 40%

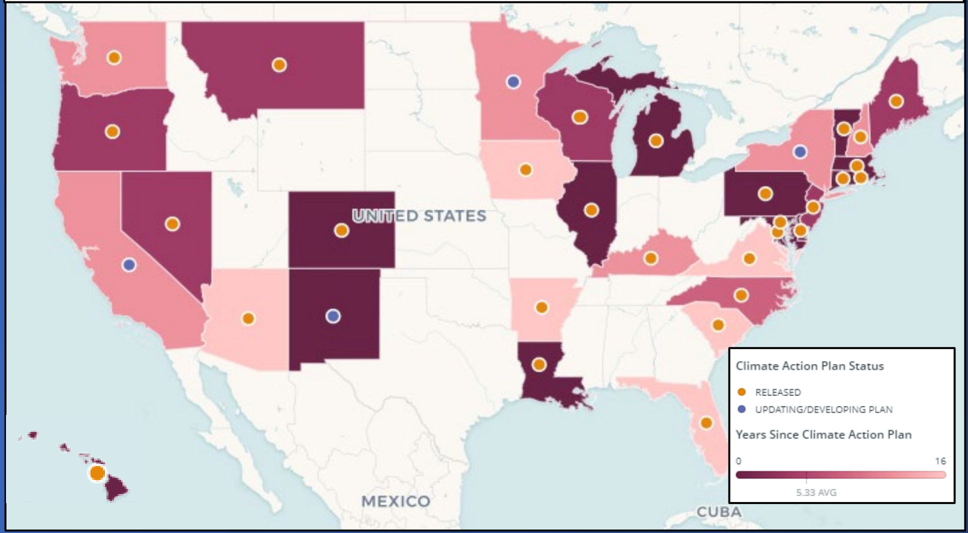
Sources: USEPA Emission Trends Report and EPA Report on Greenhouse Gas Sources and Sinks

Background: Climate change mitigation

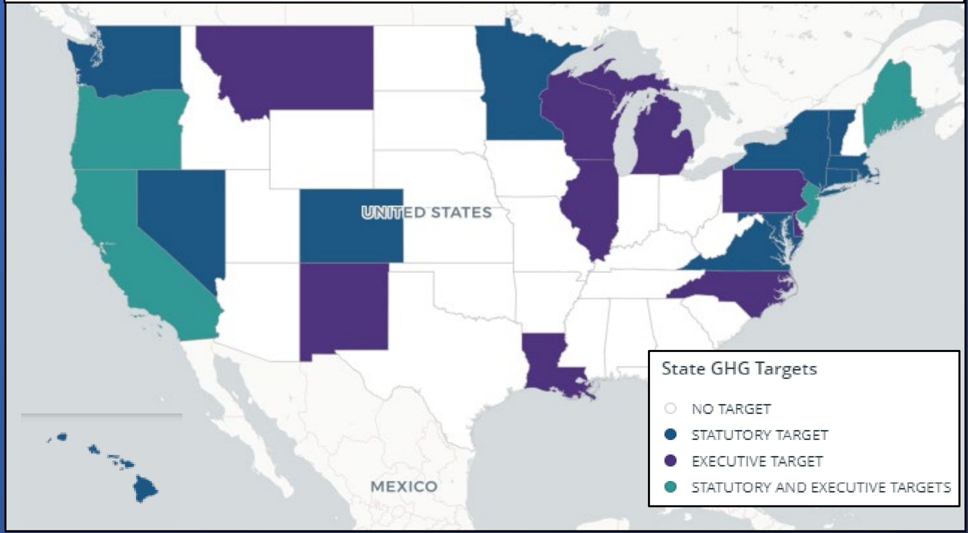
State actions include:

- Climate Action Plans
- GHG reduction targets
- Regional cap and trade policies
- Vehicle electrification targets
- Energy efficiency standards
- Building standards

33 states have or are creating Climate Action Plans



24 states + DC have specified GHG reduction targets



https://c2es.org

Background: Climate change mitigation

Federal actions include:

- Research and development
  - Advanced Research Projects Agency-Energy (ARPA-E)
  - Dept. of Energy programs
- Efficiency standards
  - Renewable fuel standards
  - Vehicle fuel economy
- Emissions standards
  - Oil and gas rule (proposed)
  - Emission standards for new fossil power plants
  - Vehicle GHG standards
- Financial incentives
  - Tax credits for electric vehicles, energy efficiency, and renewables
- Voluntary programs
  - Energy Star
- Inflation Reduction Act (e.g., tax incentives, Green Bank)

http://epa.gov/climate-change/climate-change-regulatory-actions-and-initiatives

Research questions

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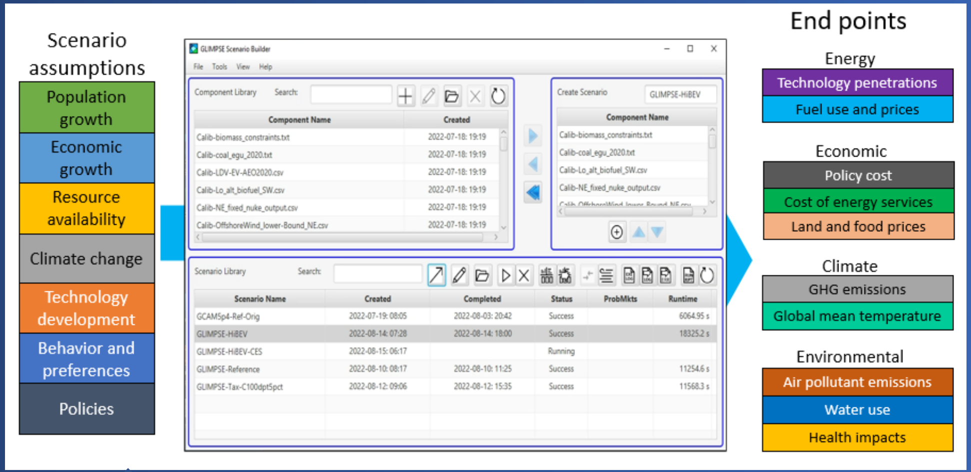
Conventional wisdom:

- Low- and zero-carbon technologies are also low in air pollutants
- Decarbonization will drive air quality improvements

- Is this conventional wisdom true?
- Under what conditions?
- What is the magnitude of co- or dis-benefits?
- Where do we expect these impacts to occur?
- Are there multiple pathways to achieve decarbonization goals?
- How do impacts differ by pathway?

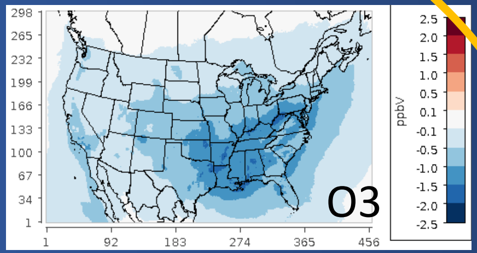
Overview:
Evaluating the air quality impacts of energy scenarios

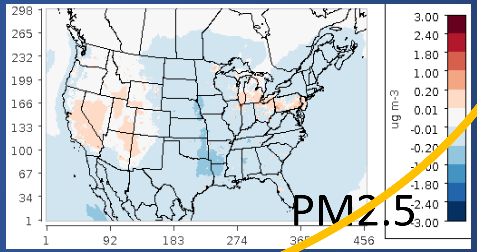
GLIMPSE / GCAM-USA



CMAQ

Air quality impacts





State-, pollutant-, sector-specific multiplicative emission growth factors

Scenario assumptions

This presentation

Dr. Uma Shankar's presentation

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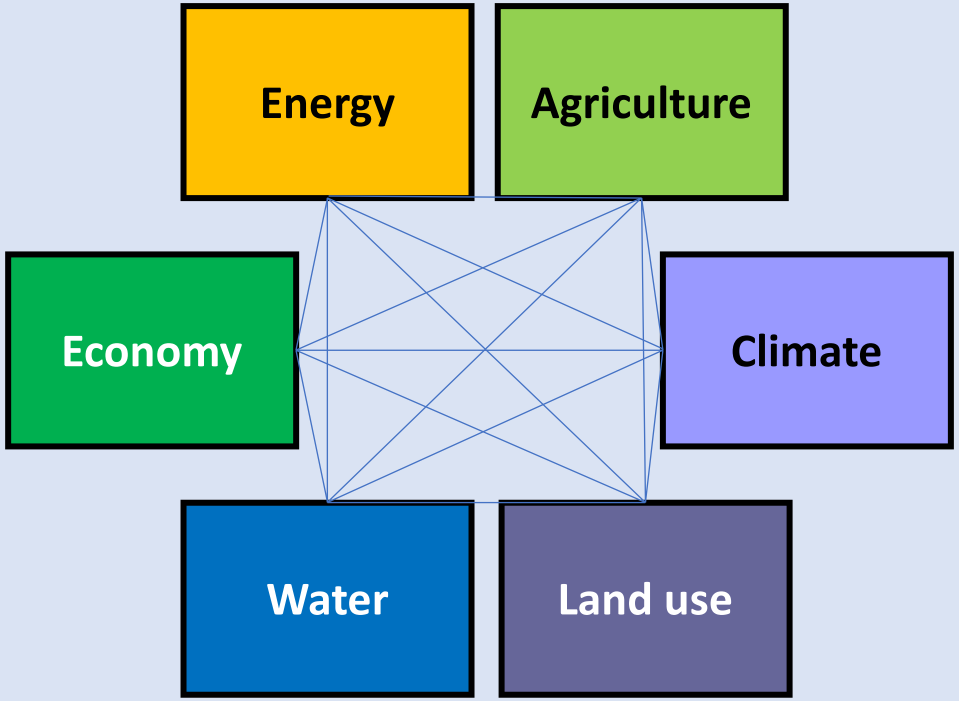
Method: GCAM model

Scenario assumptions

- Population growth
- Economic growth
- Resource availability
- Climate change
- Technology development
- Behavior and preferences
- Policies

GCAM Human-Earth Systems Model



Simulates the co-evolution of these systems through time

End points

Energy
- Technology penetrations
- Fuel use and prices

Economic
- Policy cost
- Cost of energy services
- Land and food prices

Climate
- GHG emissions
- Global mean temperature

Environmental
- Air pollutant emissions
- Water use
- Health impacts

Method: GCAM model

Scenario assumptions

- Population growth
- Economic growth
- Resource availability
- Climate change
- Technology development
- Behavior and preferences
- Policies

Global Change Analysis Model (GCAM)

Type: Technology-rich, energy-/land-/water-focused simulation model

Lead developer: Pacific Northwest National Lab

Time Horizon: 2010–2100, 5-yr increments

Spatial Resolution:

- **GCAM (core):** 32 global regions
- **GCAM-USA:** 31 global regions, 50 states + DC
- **GCAM-China:** 31 global regions, 23 provinces
- **GCAM-Canada, GCAM-Korea, GCAM-India** …

GHGs: CO_2, CH_4, N_2O

Air pollutants: NOx, SO_2, $PM_{2.5}$, VOCs, CO, NH_3

Runtime: 1 to 5 hours for EPA's GCAM-USA v5.4

Requirements: Desktop PC, Mac, Linux, or Cloud

Availability: Public domain, open source, free

End points

Energy
- Technology penetrations
- Fuel use and prices

Economic
- Policy cost
- Cost of energy services
- Land and food prices

Climate
- GHG emissions
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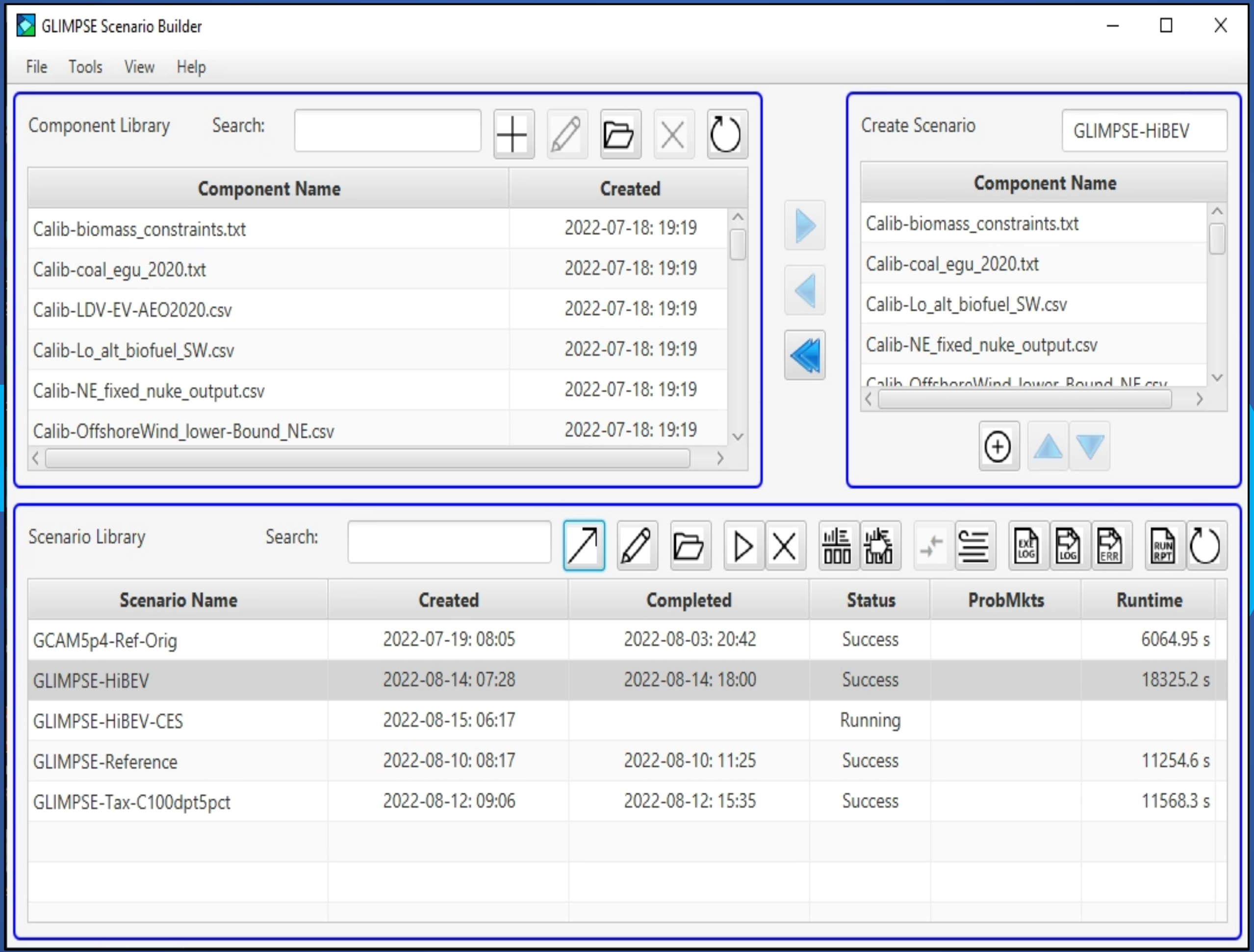
Environmental
- Air pollutant emissions
- Water use
- Health impacts

Method: GLIMPSE decision support tool

Scenario assumptions

- Population growth
- Economic growth
- Resource availability
- Climate change
- Technology development
- Behavior and preferences
- Policies



End points

Energy
- Technology penetrations
- Fuel use and prices

Economic
- Policy cost
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Climate
- GHG emissions
- Global mean temperature

Environmental
- Air pollutant emissions
- Water use
- Health impacts

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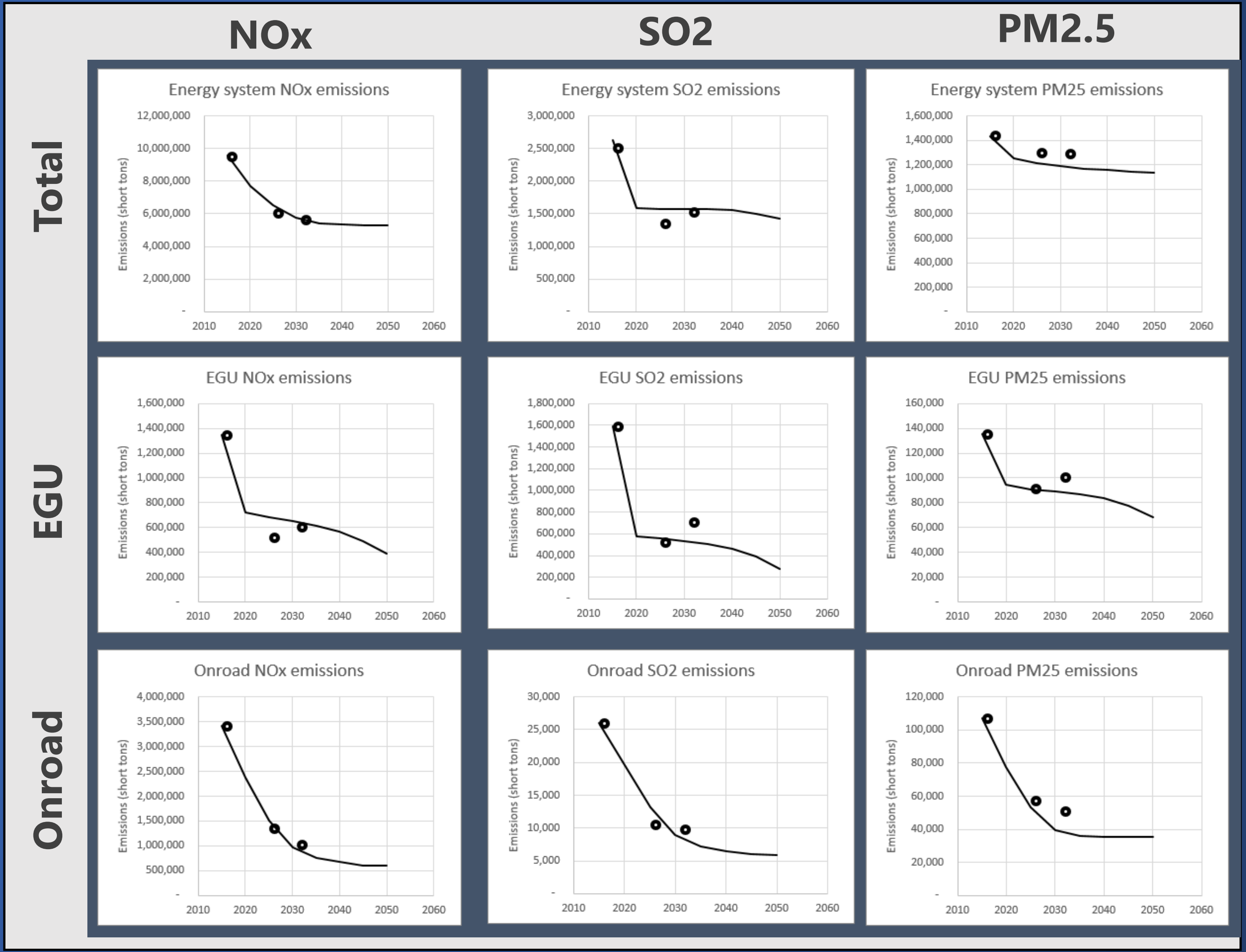
Method: EPA modifications to GCAM-USA

Updates

- Emission factors based on the National Emissions Inventory (NEI) and MOVES
- Scaling of sectoral emissions to the EPA 2016v2 emissions modeling platform
- Representation of key federal and state policies
- Technology cost updates
- Calibrations to reflect coal plant retirements through 2020

Comparison with EPA 2016v2 modeling platform



Dots: EPA projections; **Black: Reference Case**

Method: Experimental design

Reference Case (*Ref*)

Includes:

- Regional Greenhouse Gas Initiative (RGGI)
- Section 177 ZEV sales targets
- Light-duty near-term GHG rule
- Tier 3 standards for onroad sector
- Various NSPSs
- Investment and Production Tax Credits

Does not include:

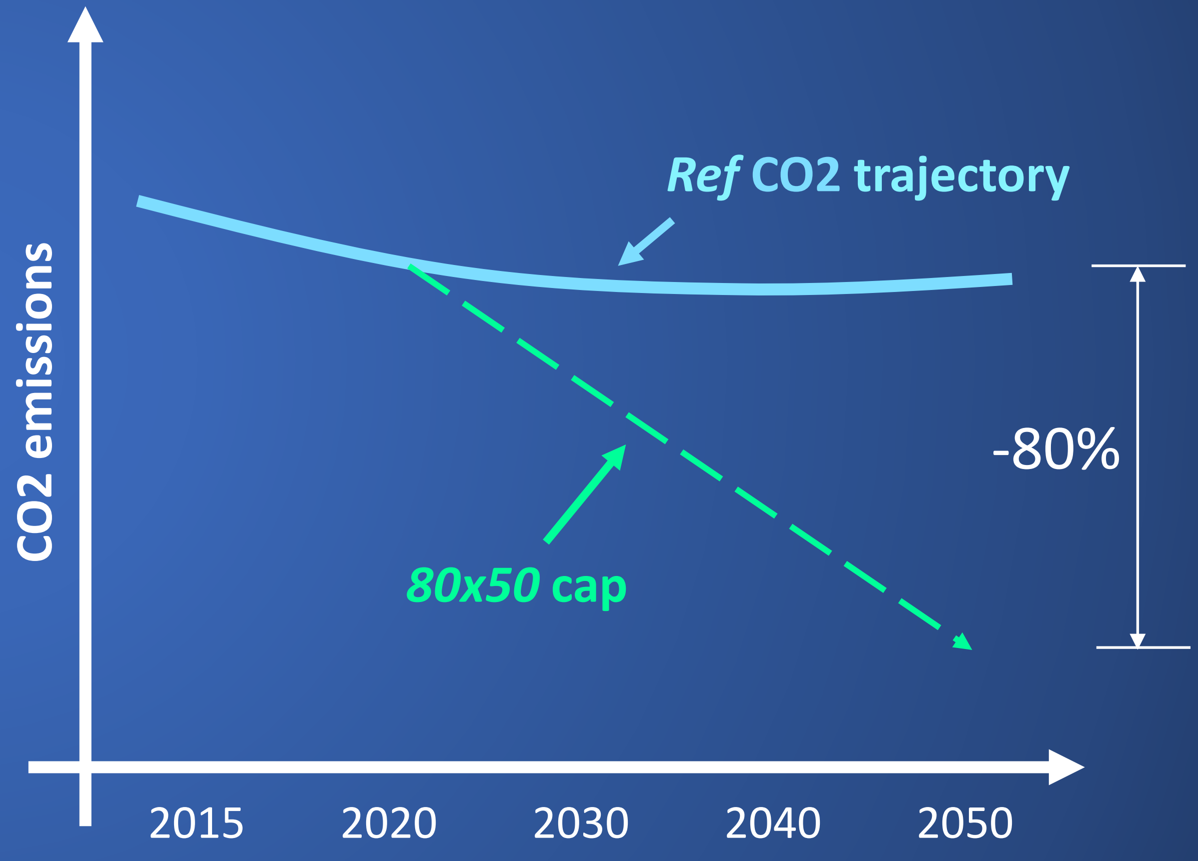
- Inflation Reduction Act (IRA)
- State CO2 reduction targets
- COVID-19 impacts on energy demands

Deep Decarbonization Case (*80x50*)

Layers on:

- **Linearly declining national CO2 cap: 2050 CO2 emissions are constrained to be 20% of 2020 levels**

U.S. energy system CO2 emissions



GCAM-USA simulates how to meet this trajectory

Method: Mapping GCAM-USA to CMAQ

GCAM Source Sector	CMAQ Emissions Stream
Electricity generation from all non-biomass fuels	ptegu
Electricity generation from biomass Industrial energy use and feedstocks Cement, fertilizer, and H_2 production	ptnonipm
Unconventional oil production, oil refining, gas pipelines Gasification, coal-to-liquids, and biomass-to-liquids	oilgas
All commercial and residential sectors except residential wood heating Regional biomass production for bioenergy and biofuels	nonpt
Residential wood heating	rwc
Onroad heavy-duty freight vehicle	onroad_diesel
Onroad light-duty vehicles and buses	onroad_gas
Domestic and international aviation	airports (no in-flight)
Nonroad passenger and freight rail transport	rail
Domestic shipping	pt_cmv_c1c2_12
International shipping	pt_cmv_c3_12

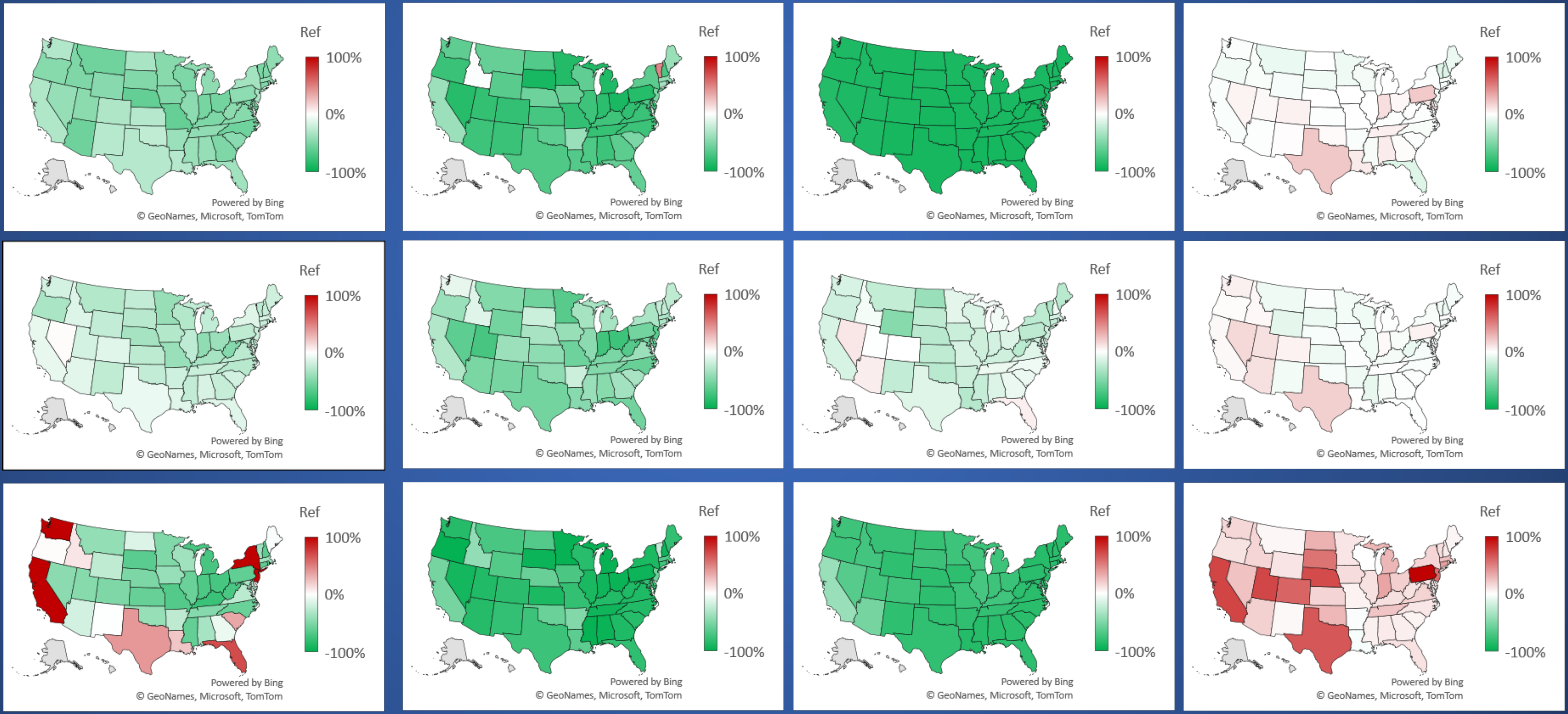
Method: Mapping GCAM-USA to CMAQ

- For each combination of state, pollutant, and category
  - Interpolate to obtain estimate of 2016 value
  - Divide GCAM-USA-projected 2050 value by 2016 value to calculate growth factor
- This vector of growth factors was then formatted for use with CMAQ's DESID module.

Results: Emissions change factors, *Ref*

2016->2050

	Overall	ptegu	onroad	ptnonipm
NOx				
PM2.5				
SO2				



Selected sectors

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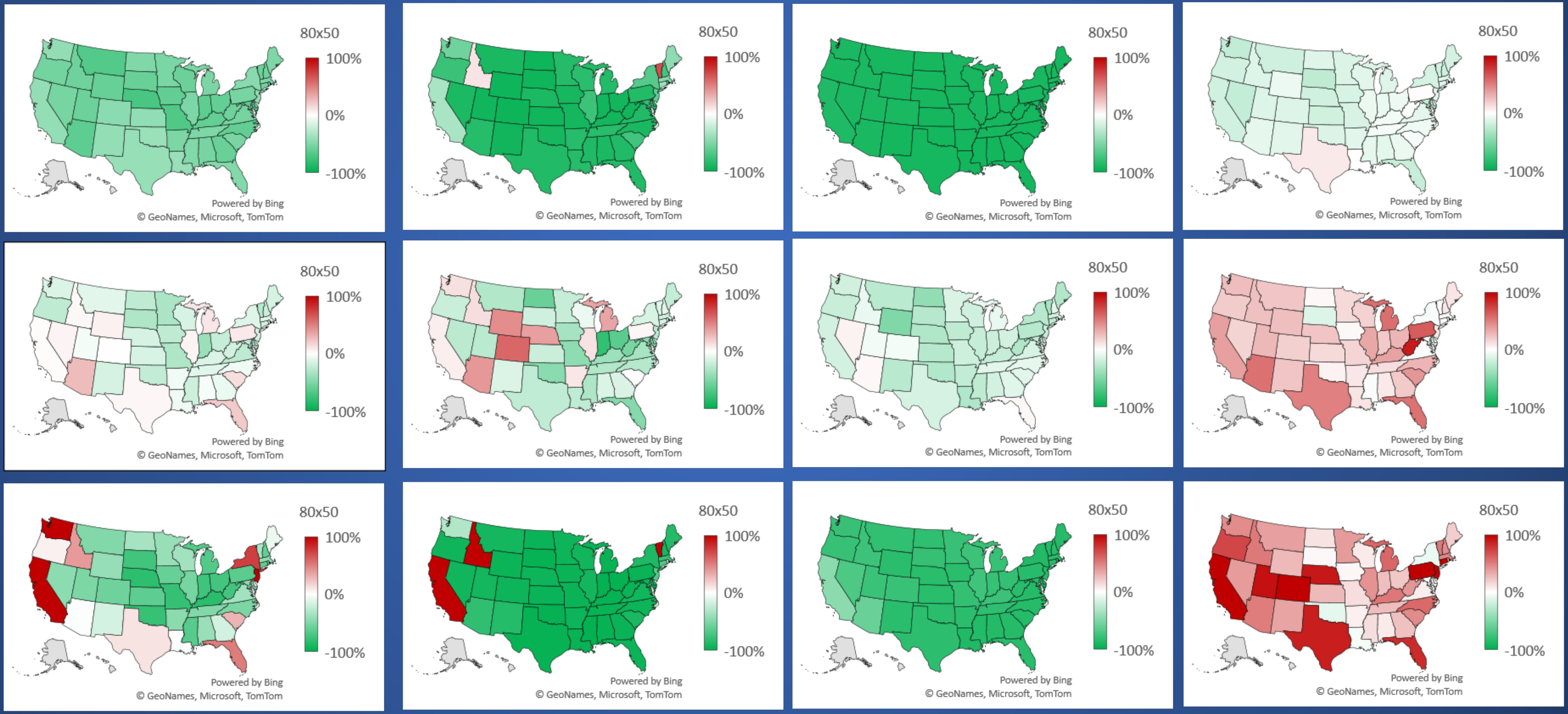
Results: Emissions change factors, *80x50*

2016->2050

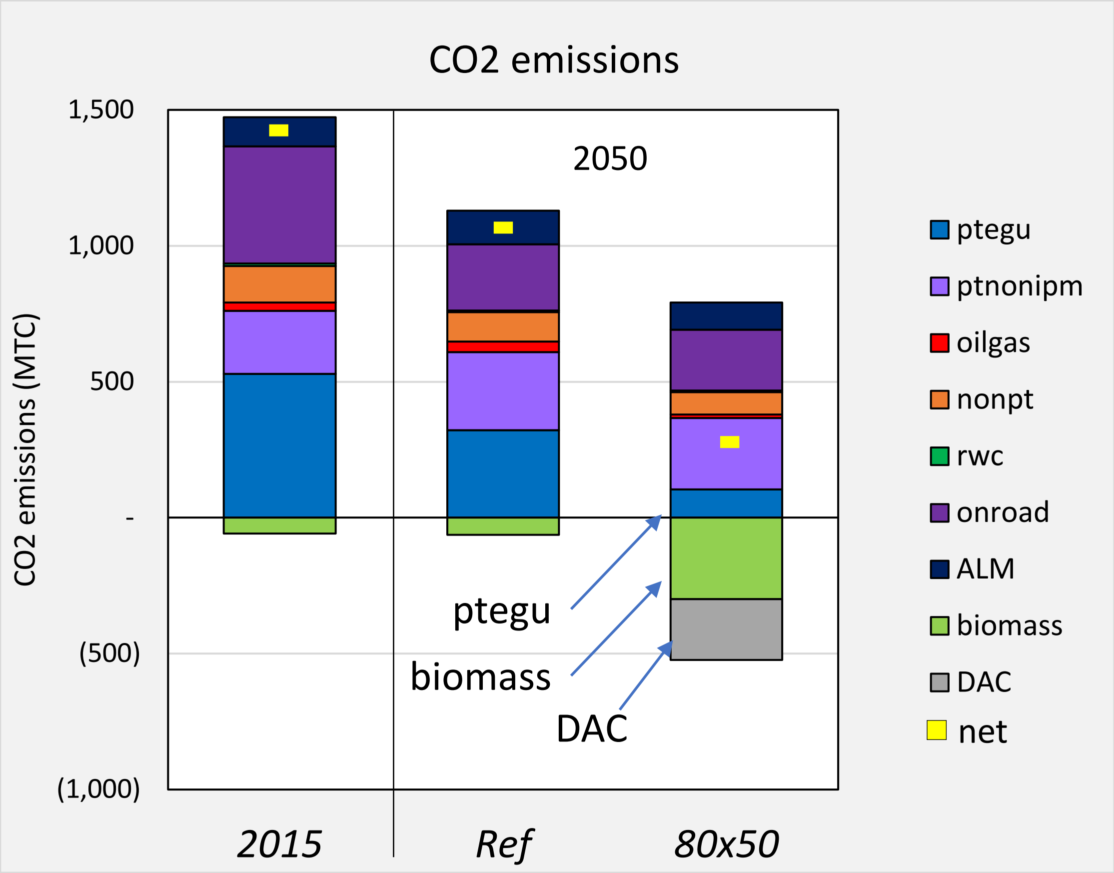
	Overall	ptegu	onroad	ptnonipm
NOx				
PM2.5				
SO2				



Selected sectors

Results: CO2 emissions

Q. How do CO2 emissions change by 2050 for our scenarios?

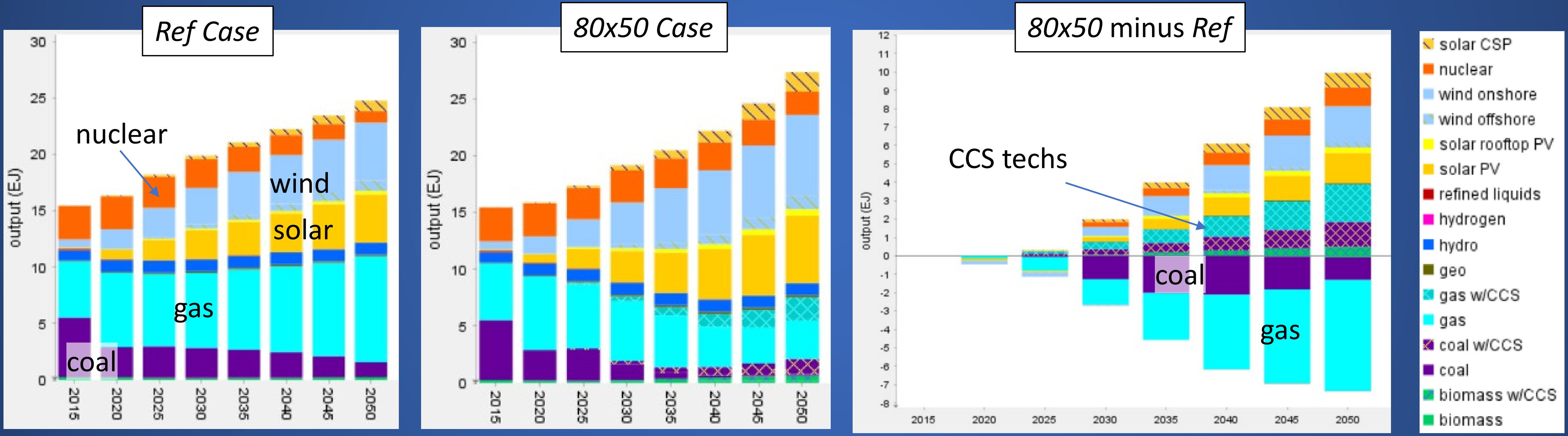


Observations:

- *Ref* CO_2 declines 25% (-400 MTC) by 2050:
  - Electric sector: -210 MTC (-39%)
  - Onroad transportation: -190 MTC (-44%)
- *80x50* declines 70% (-800 MTC) in 2050:
  - Biomass production: -240 MTC
  - Direct Air Capture (DAC): -220 MTC
  - Electric sector: -220 MTC
  - (All other sectors: -120 MTC)

Results: Electricity production by technology

Q. How does the 80x50 target impact the electric sector?

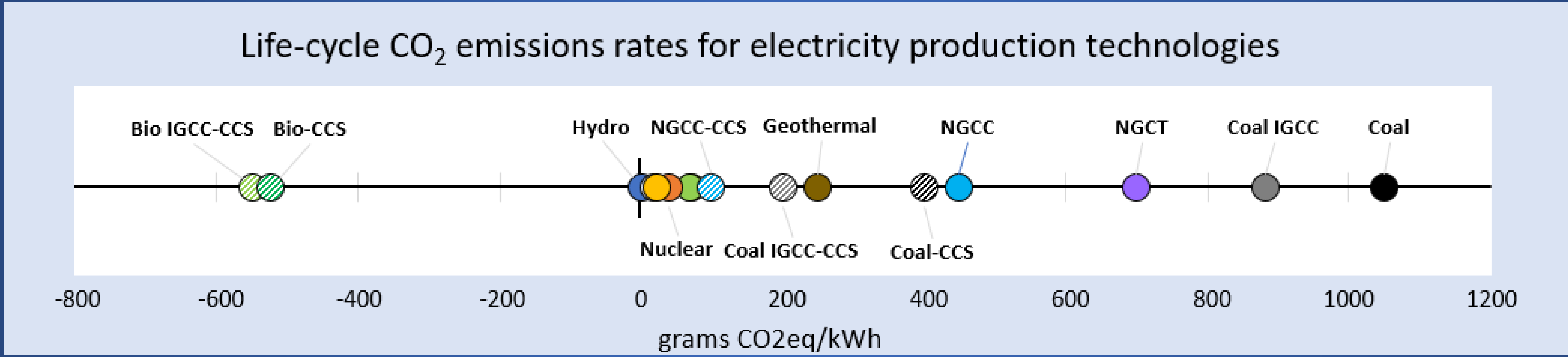


Coal with CCS is responsible for much of the increase in electric sector emissions

Biomass with CCS is responsible for much of the increase in industrial sector emissions

Results: Emission factors

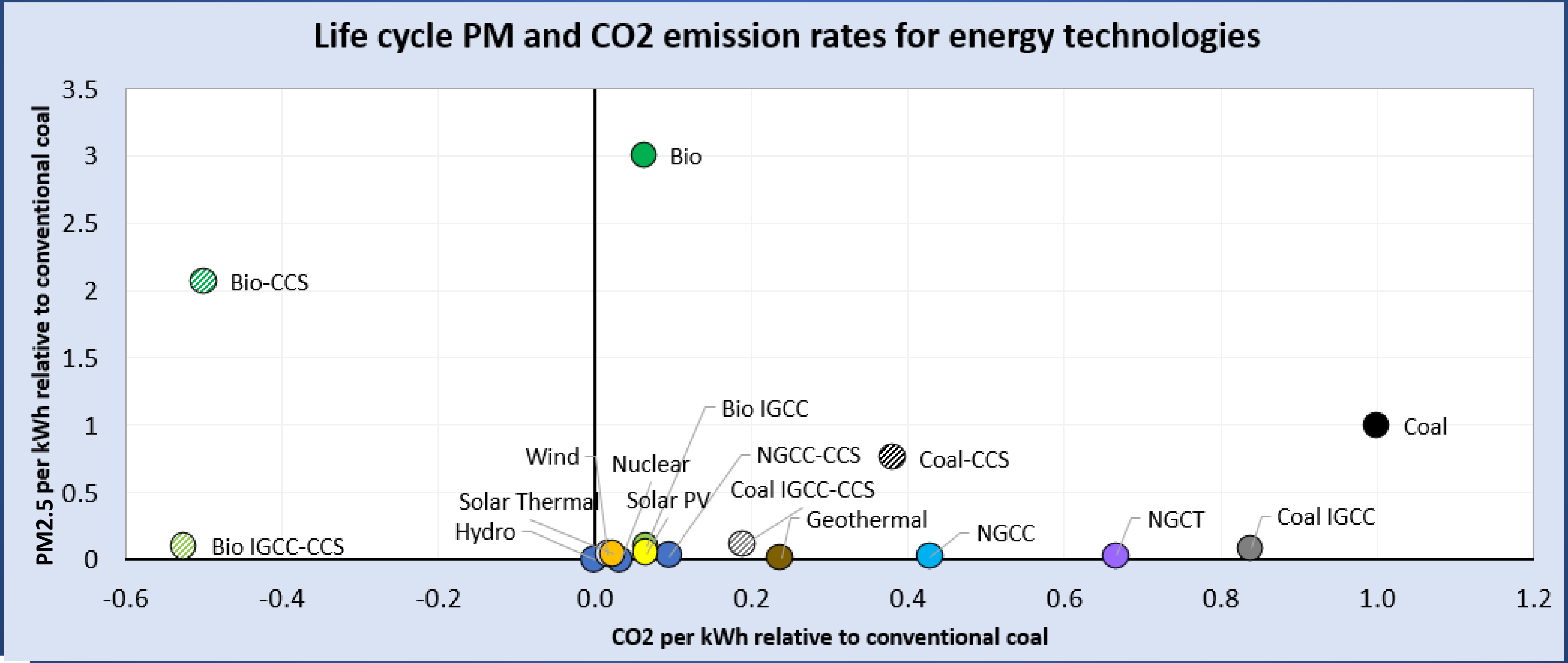
Q. How do emission factors for these technologies compare?



Emission factors from Babaee, Kaplan & Loughlin, *Cleaner Engineering and Technology*, 2020

Results: Emission factors, cont'd

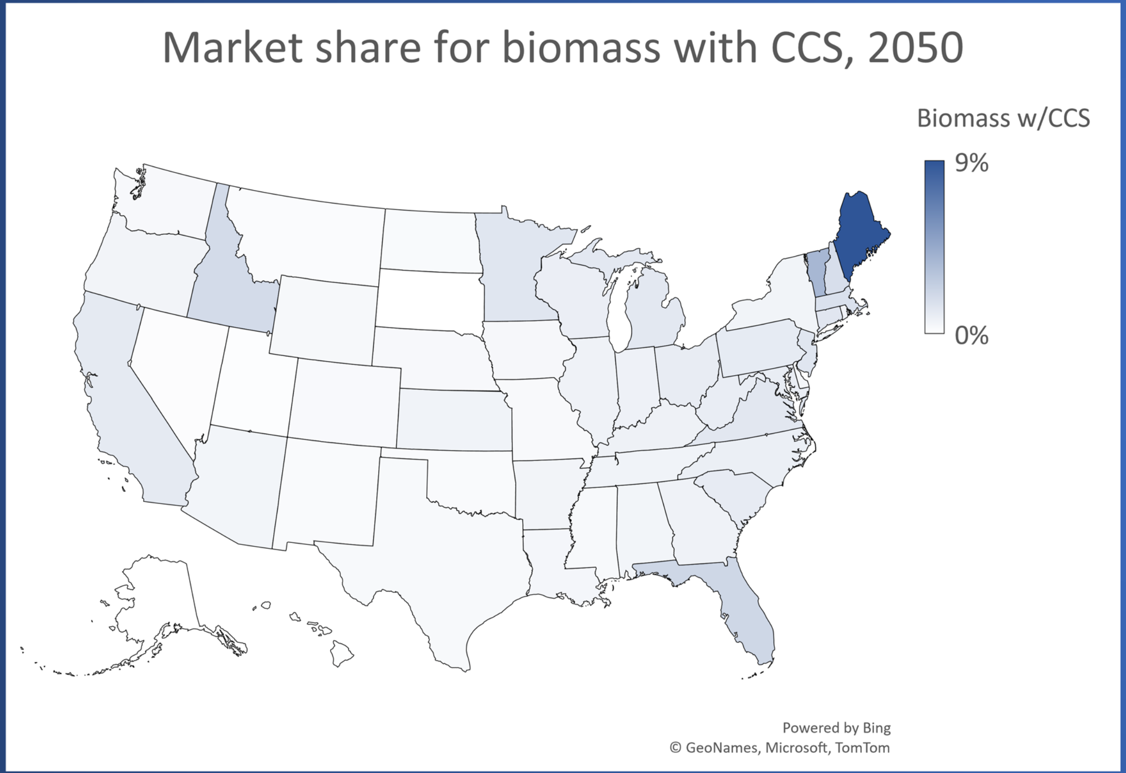
Q. How do emission factors for these technologies compare?

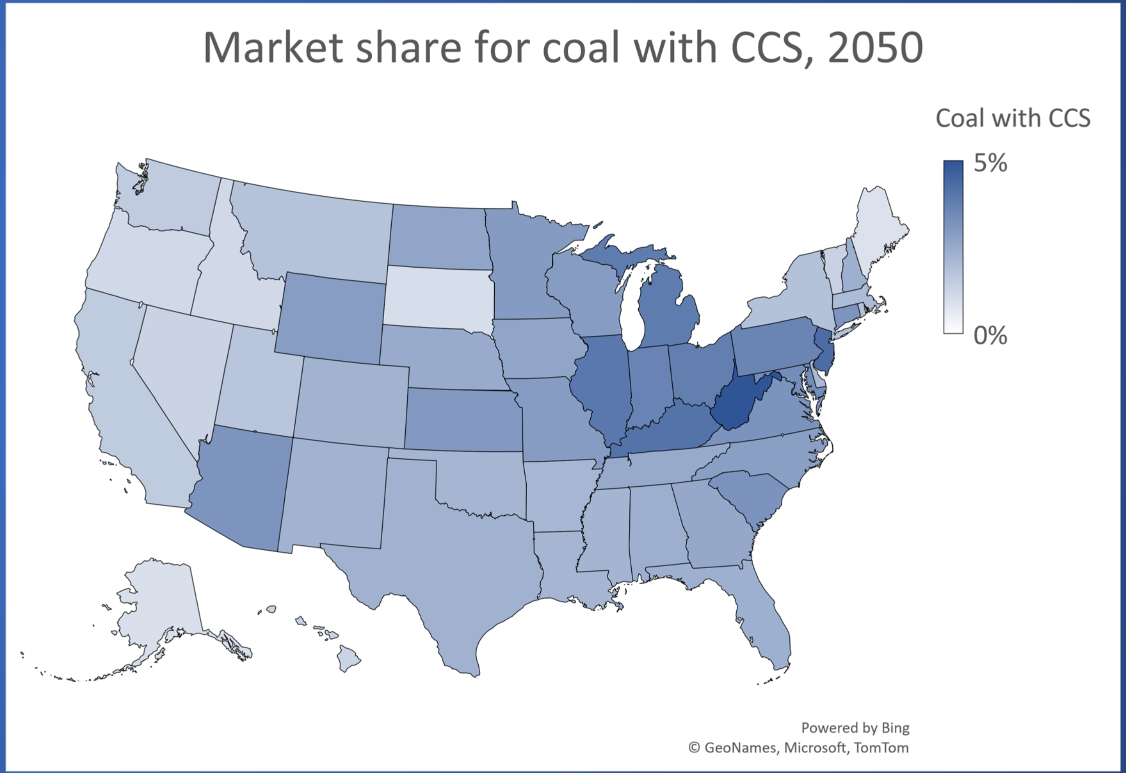


Emission factors from Babaee, Kaplan & Loughlin, *Cleaner Engineering and Technology*, 2020

Results: Spatial distribution of new capacity

Q. Where are these new coal and biomass with CCS plants being located?





For biomass and coal technologies, GCAM-USA places new capacity considering:

- State-level use of those fuels in 2015, the calibration year
- Cost-competitiveness with other technologies

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Revisiting our Research Quest

Conventional wisdom:

- Low- and zero-carbon tech
- Decarbonization wil

- Is this c
- H
- ts?
- to occur?
- to achieve decarbonization goals?
- by pathway?

Early answer:
It depends

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Discussion: Considerations

- Our 80x50 scenario yields SO2 and PM disbenefits
  - However, this is one of many possible mitigation pathways
- Emissions from coal- and biomass-with-CCS technologies are uncertain
  - Their emission factors are based upon pilot applications
  - It is possible that their emissions could be controlled further
- There may be barriers to the adoption of these technologies that are not yet represented in our scenario
  - Would a state with little or no coal adopt coal-with-CCS?

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Discussion: Considerations, continued

- Important assumptions driving scenario results:
  - Performance, availability, and competitiveness of new and emerging technologies
    - Electric and hydrogen vehicles
    - Advanced biofuels
    - Carbon capture and sequestration
    - Direct air capture
  - Rate of retirement of coal and nuclear plants
  - Which policies are included in the baseline, *Ref*

Discussion: Considerations, continued

- We did not include:
  - the Inflation Reduction Act
  - state GHG reduction targets
  - onroad electrification targets currently under consideration in many states
- These would impact technology adoption in *Ref* as well as the response to deep decarbonization targets
- We plan to explore additional scenarios in the future to explore many of these issues

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- Low- and zer
- Decarbonization will d

Support policy-making by exploring these topics

- Is this conventional wisdom true?
- Under what conditions?
- What is the magnitude of co- or dis-benefits?
- Where do we expect these impacts to occur?
- Are there multiple pathways to achieve decarbonization goals?
- How do impacts differ by pathway?

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Thank you for your time!

Questions?

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