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The GLIMPSE Project:

A decision support tool for air quality management

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United States Environmental Protection Agency

Foreword

- Intended audience
  - Research community, emissions and air quality modelers, and state air quality managers and staff
- Objectives of this presentation
  - Introduce GLIMPSE and the underlying model, GCAM-USA
  - Discuss stakeholder engagement activities
  - Present ongoing applications
  - Highlight public release and training next summer
- Acknowledgments

  - ORISE participants are supported through an Interagency Agreement (IA) with DOE and Oak Ridge National Laboratory. PNNL participants are supported through an IA with DOE and Pacific Northwest National Laboratory.
  - Funding was provided through the EPA Regional Applied Research Effort (RARE) and Air-Energy (A-E) programs.

Abbreviations

- Models
  - GCAM – Global Change Assessment Model
  - GCAM-USA – GCAM version with state resolution for US
  - GLIMPSE – GCAM Long-term Interactive Multi-Pollutant Scenario Evaluator
- Emissions
  - CO – Carbon monoxide
  - CO_2 – Carbon dioxide
  - GHG – Greenhouse gases
  - NOx – Nitrogen oxides
  - PM – Particulate Matter
  - $PM_{2.5}$ – PM of diameter less than 2.5 microns
  - SO_2 – Sulfur dioxide
- Units
  - EJ – Exajoules
  - MTC – Megatonnes Carbon
  - kT – Kilotonnes
  - t - tonnes
- Technologies and fuels
  - CCS – Carbon Capture and Sequestration
  - CHP – Combined Heat and Power
  - EV – Electric Vehicle
  - CNG – Compressed Natural Gas
- Organizations
  - ORISE – Oak Ridge Institute for Science and Education
  - PNNL – Pacific Northwest National Laboratory
  - RGGI – Regional Greenhouse Gas Initiative
  - U.S. EPA – United States Environmental Protection Agency
- Policies and measures
  - CES – Clean Energy Standard
  - EE – Energy efficiency
  - RGGI – Regional Greenhouse Gas Initiative
  - RPS – Renewable Portfolio Standard
  - TCI – Transportation and Climate Initiative

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Premise:

States have long-term planning needs for which model-based decision support tools would be helpful

Air quality:

What issues could challenge air quality management in my state?

Population growth? Economic growth? Climate change? Electric vehicles?

How well do existing state and regional policies address these challenges?

What additional measures may be necessary?

Management:

How could state and regional climate policies (e.g., RGGI, RPS, EE/RE, ZEV mandate …) affect air quality?

Conversely, how do state and regional air quality policies affect GHG mitigation goals?

Are there cost-effective strategies for meeting my air quality and climate goals simultaneously?

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Topics that arise:

How could the following affect my state?

Expansion of RGGI?

Introduction of the TCI transportation sector cap-and-invest program?

More states adopt ZEV mandates?

ZEV targets become more stringent?

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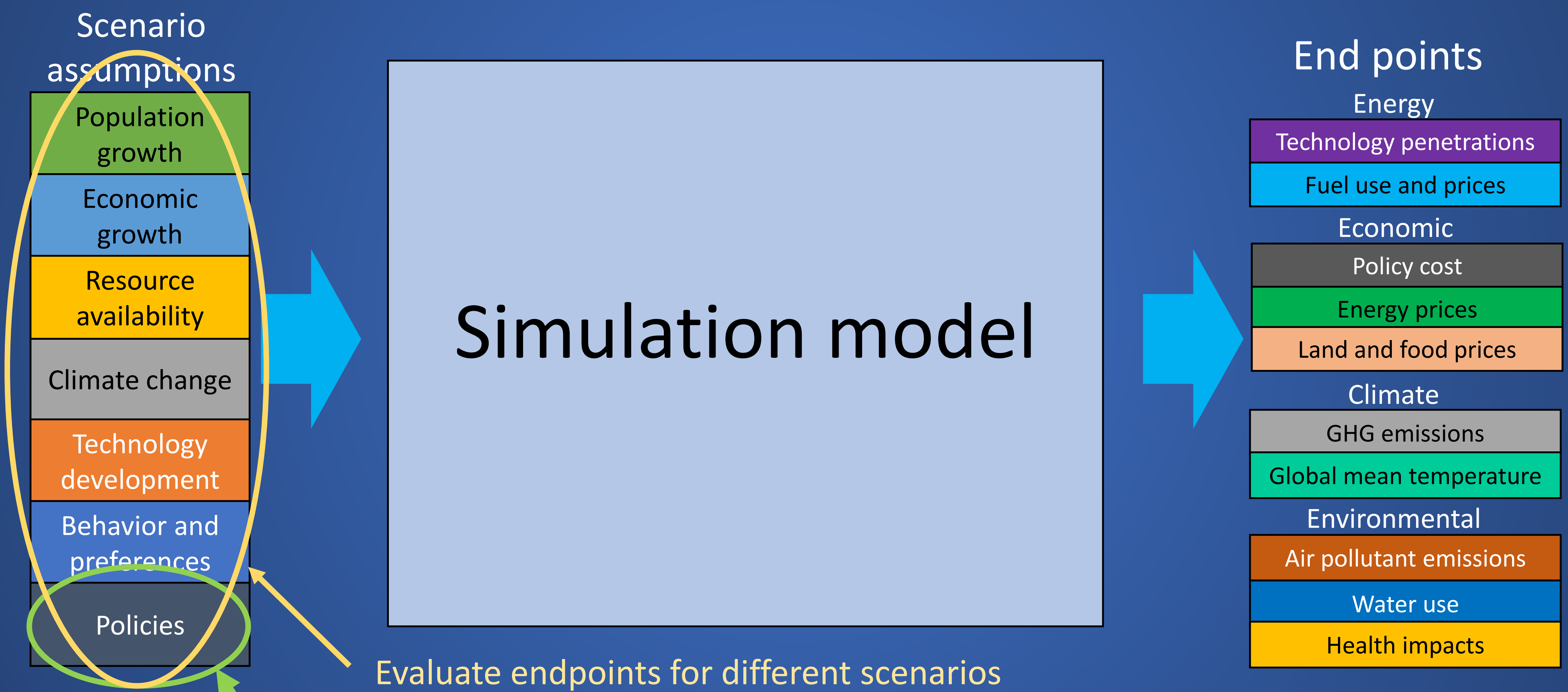
GLIMPSE Objective:

Develop tools to assist in exploring answers to questions such as these

What is GLIMPSE?

GCAM Long-term Interactive Multi-Pollutant Scenario Evaluator



Evaluate endpoints for different scenarios

Test the efficacy of existing policies for various scenarios

Evaluate the cost-effectiveness of proposed policies

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What is GLIMPSE?

GCAM Long-term Interactive Multi-Pollutant Scenario Evaluator

Scenario assumptions

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

Global Change Assessment Model (GCAM)

- Energy
- Agriculture
- Economy
- Land Use
- Water
- Buildings

Simulates the co-evolution of these systems through time

End points

Energy

- Technology penetrations
- Fuel use and prices

Economic

- Policy cost
- Energy prices
- Land and food prices

Climate

- GHG emissions
- Global mean temperature

Environmental

- Air pollutant emissions
- Water use
- Health impacts

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Global Change Assessment Model (GCAM)

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

Lead developer: Pacific Northwest National Lab

Time Horizon: 2010–2100, typically in 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** …

Runtime: 2 to 5 hours for EPA's GCAM-USA v4.3

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
- Energy prices
- Land and food prices

Climate

- GHG emissions
- Global mean temperature

Environmental

- Air pollutant emissions
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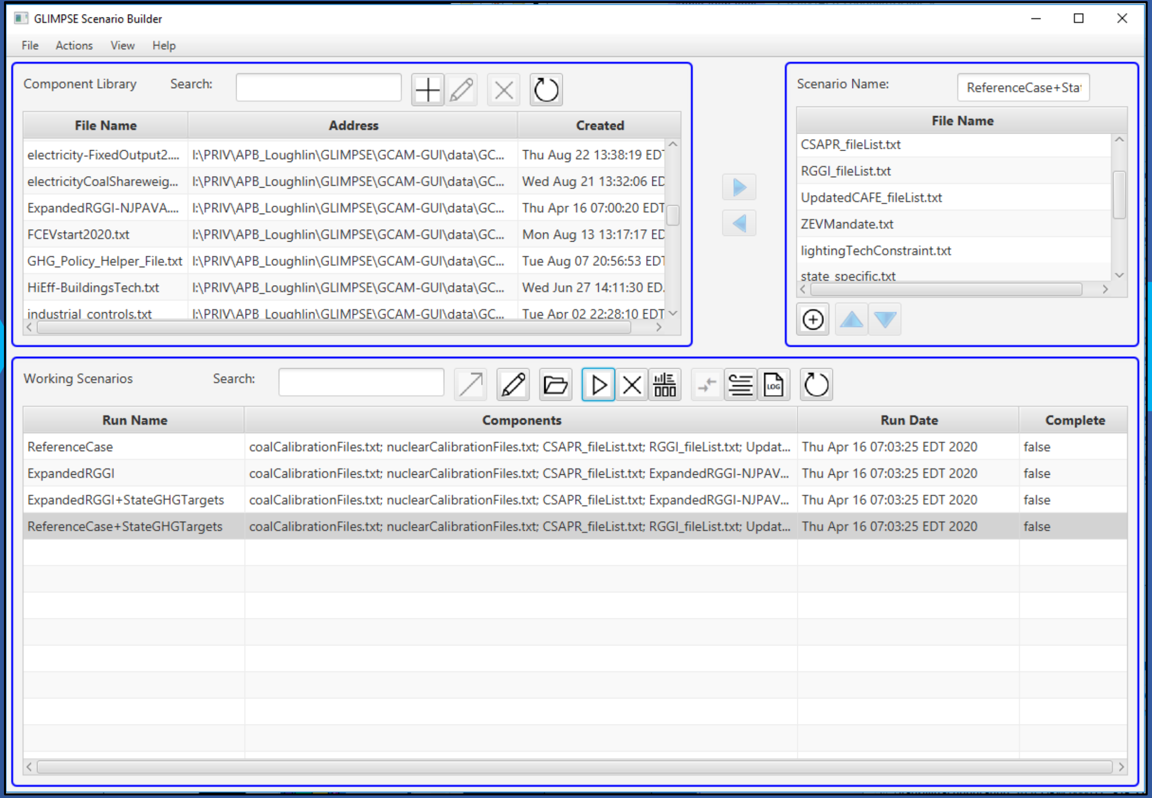
- Policies

GLIMPSE Scenario Builder



End points

Energy

- Technology penetrations
- Fuel use and prices

Economic

- Policy cost
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- Land and food prices

Climate

- GHG emissions
- Global mean temperature

Environmental

- Air pollutant emissions
- Water use
- Health impacts

Setup scenarios and manage execution

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What is GLIMPSE?

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Scenario assumptions

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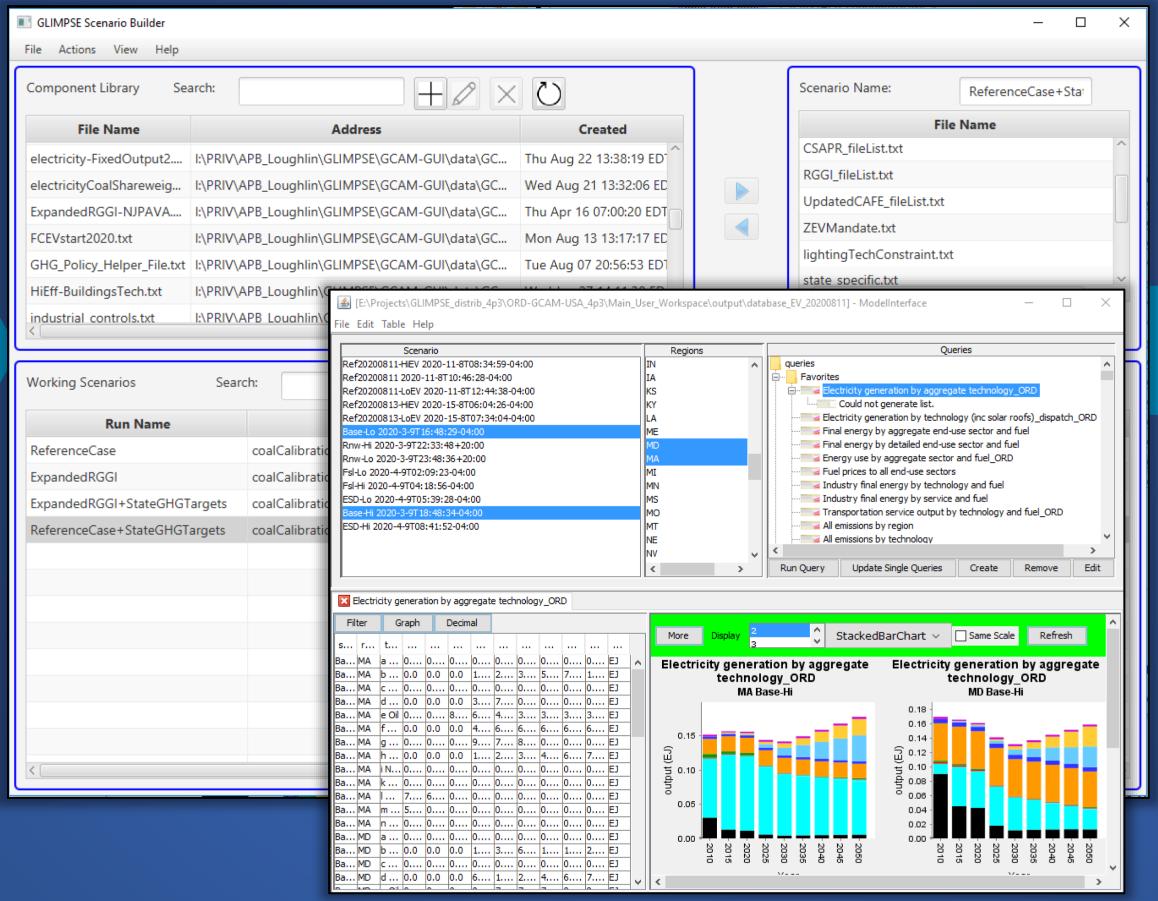
GLIMPSE Model Interface



Visualize results

End points

Energy
- Technology penetrations
- Fuel use and prices

Economic
- Policy cost
- Energy prices
- Land and food prices

Climate
- GHG emissions
- Global mean temperature

Environmental
- Air pollutant emissions
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What is GLIMPSE?

GCAM Long-term Interactive Multi-Pollutant Scenario Evaluator

Scenario assumptions

- Population growth
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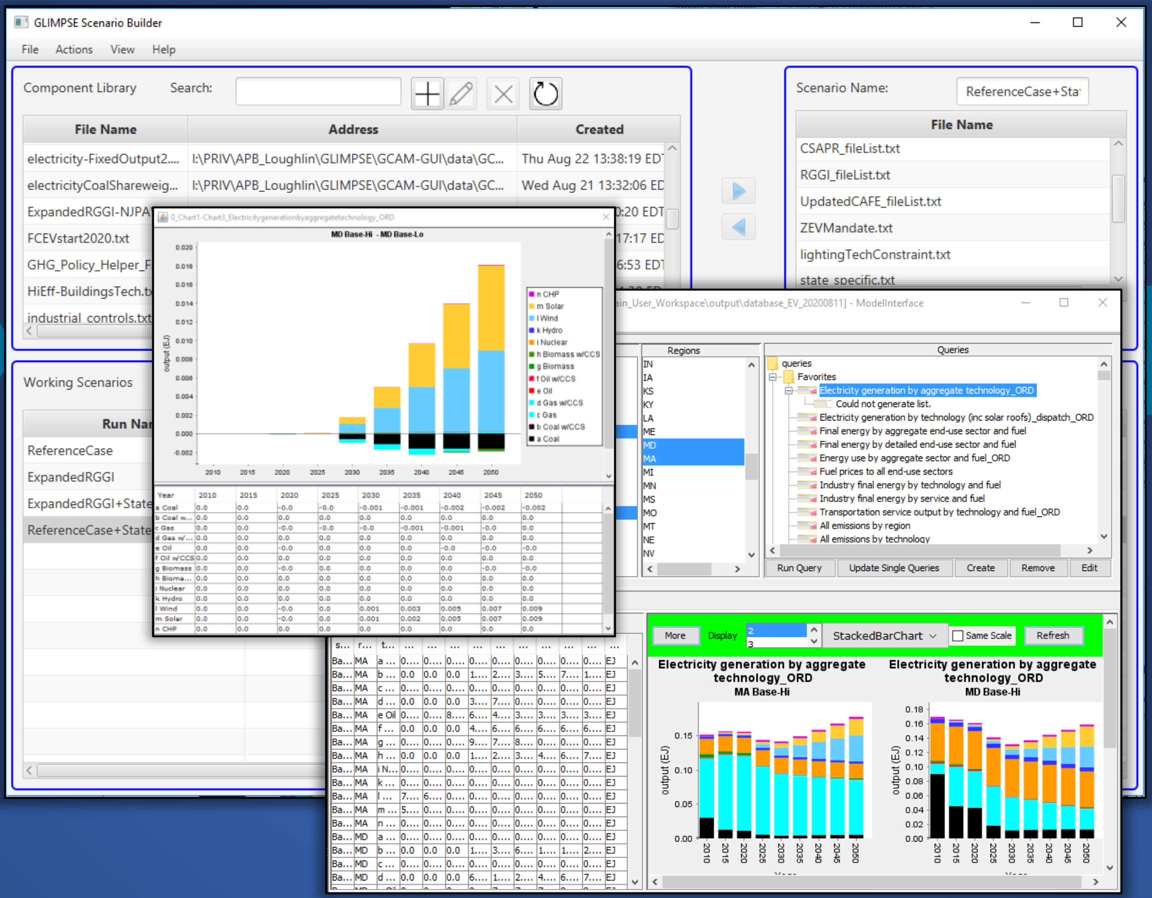
- Policies

GLIMPSE Model Interface



End points

Energy

- Technology penetrations
- Fuel use and prices

Economic

- Policy cost
- Energy prices
- Land and food prices

Climate

- GHG emissions
- Global mean temperature

Environmental

- Air pollutant emissions
- Water use
- Health impacts

Identify changes from one scenario to another

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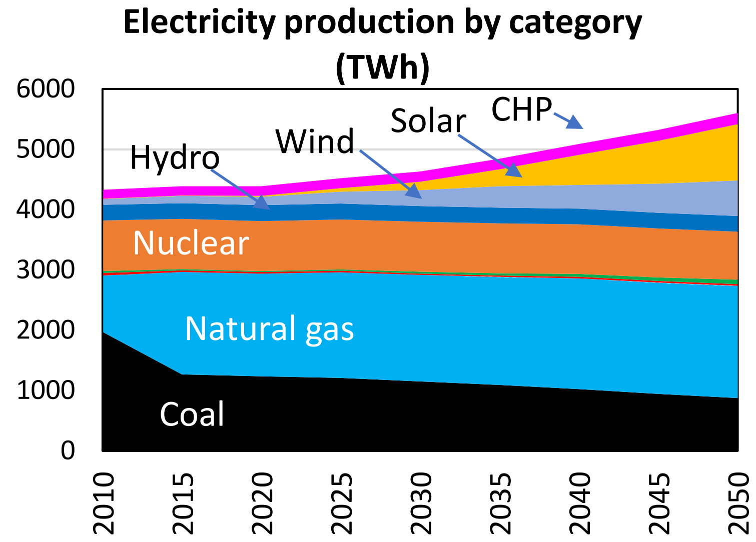
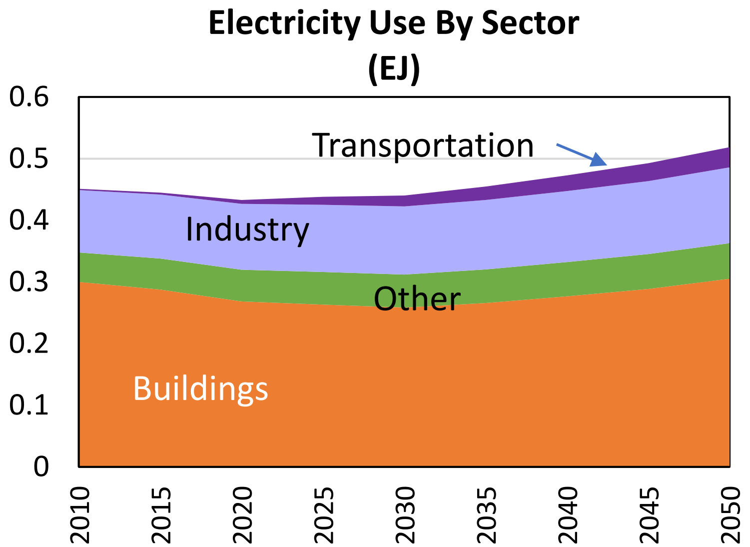
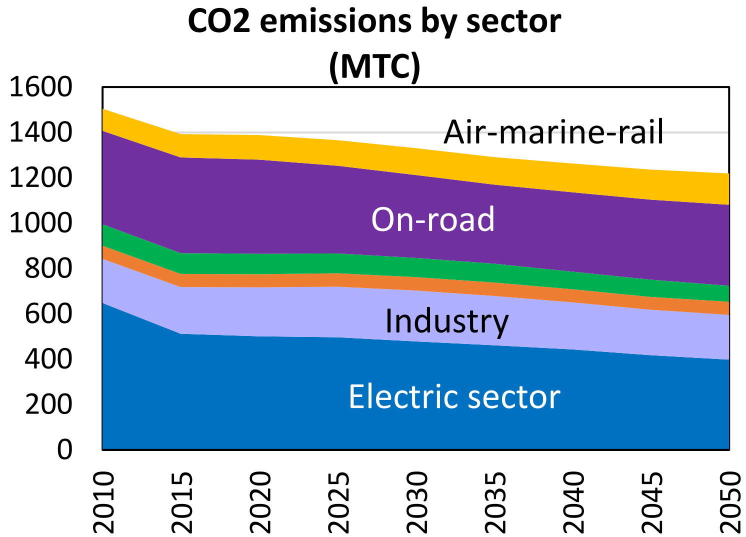
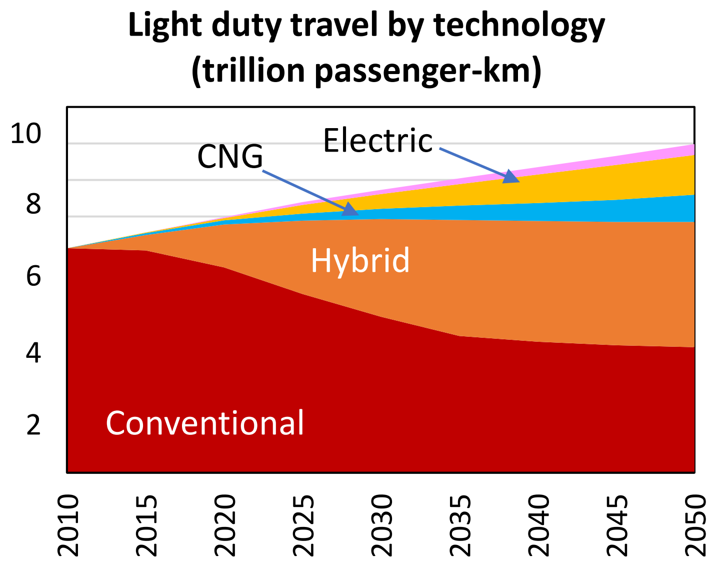
Example outputs (national, regional, or state level)

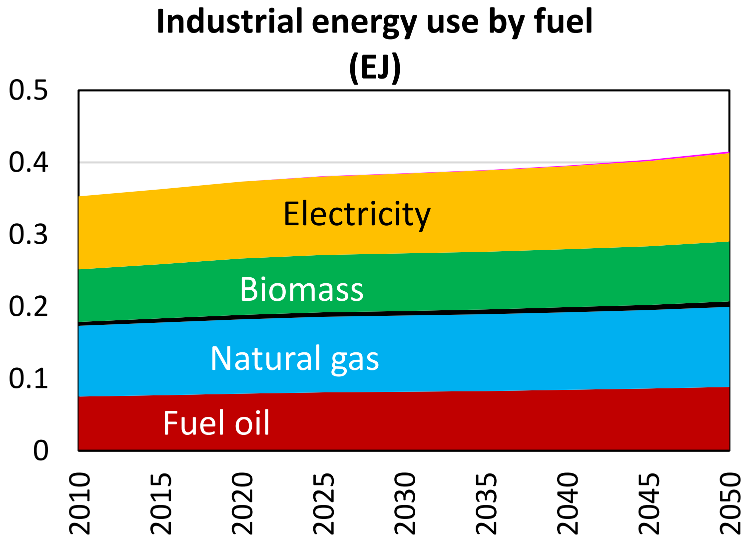
Illustrative results

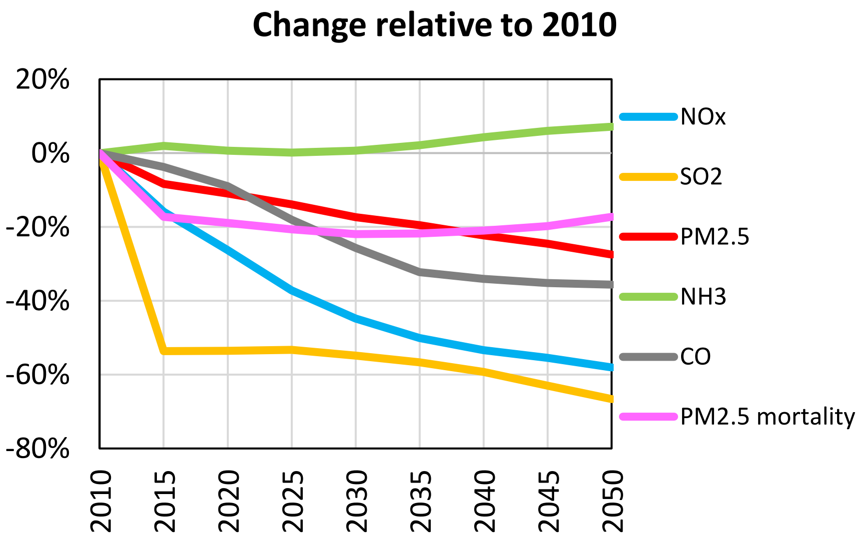












FY20: Stakeholder engagement

What planning tools are already available?

What needs are currently unmet?

How could GLIMPSE support state planning?

Who would use GLIMPSE and how?

What features are needed?

What skills would users need to have?

What training and support are required?

Stakeholder engagement

- Presentations, discussions, trainings, and testing
  - MARAMA State Air Directors meeting, Sept 2019
  - EPA Region 3 AVERT/COBRA training, Nov 2019
  - MARAMA Training Webinar, April 2020
  - Discussions with state air quality managers and staff:
    - CO, MD, NC, PA, VA, and OR
    - Represented a mix between air quality and climate programs
  - Beta-testing
    - EPA Skills Marketplace Team
    - Duke graduate students in Integrated Assessment course

MARAMA Training Webinar

- 88 attendees (~50% from MARAMA states)
- Solicited rankings and ideas for applications of GLIMPSE
- Several attendees indicated their interest in participating in applications
- Follow-up discussions with state air quality managers and staff:
  - CO, MD, NC, PA, VA, and OR
  - Represented a mix between air quality and climate programs

Follow-up discussions with states

Organized and led by Paelina DeStephano

- Lessons learned
  - Some tools are already available
    - Many are expensive
    - Some are generalized and cannot capture state-specific information
    - Some are customizable but data requirements are significant
    - Typically do not represent system dynamics
    - Rarely examine air quality and climate together
  - Saw value in tools like GLIMPSE, including its dual capability:
    - Evaluating specific policies
    - Identifying optimal strategies
  - The need is now (or yesterday!)
    - Analyses needed for legislative proposals in process or going forward soon
    - Topics: energy efficiency, vehicle electrification, RGGI, RPS, …
  - States have differing levels of modeling ability
    - Many outsource to regional planning organizations, universities, consultants

Identification of applications

We identified three applications to pursue:

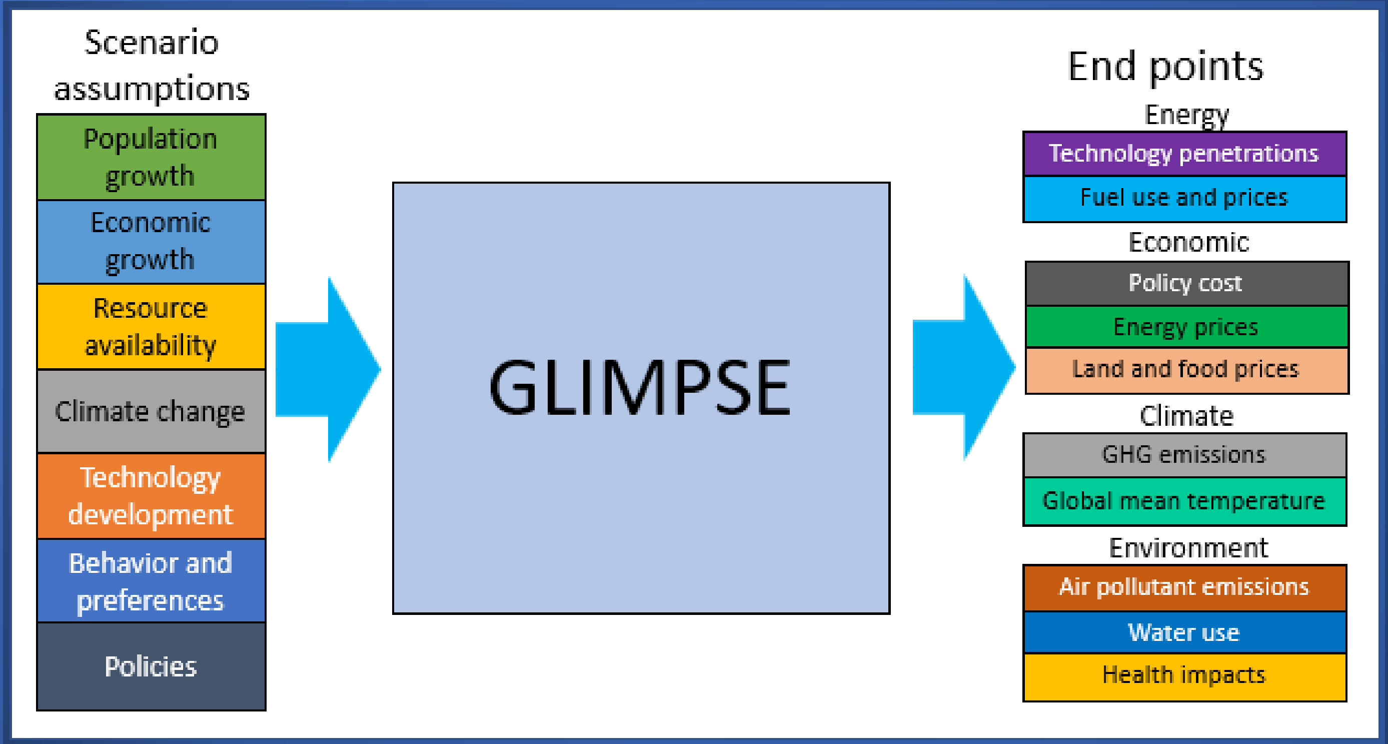
1. Emerging challenges for air quality management
2. Multi-pollutant control strategies incorporating EE/RE
3. Air pollutant co-benefits of state GHG reduction targets

Application 1.
Emerging challenges for air quality management

Which of the scenario assumptions could pose challenges to meeting state air pollutant and GHG targets?

Approach:

- Identify of high-medium-low projections for key scenario assumptions
- Examine state-level emission responses to individual and combined changes
- Evaluate robustness of current and potential policies



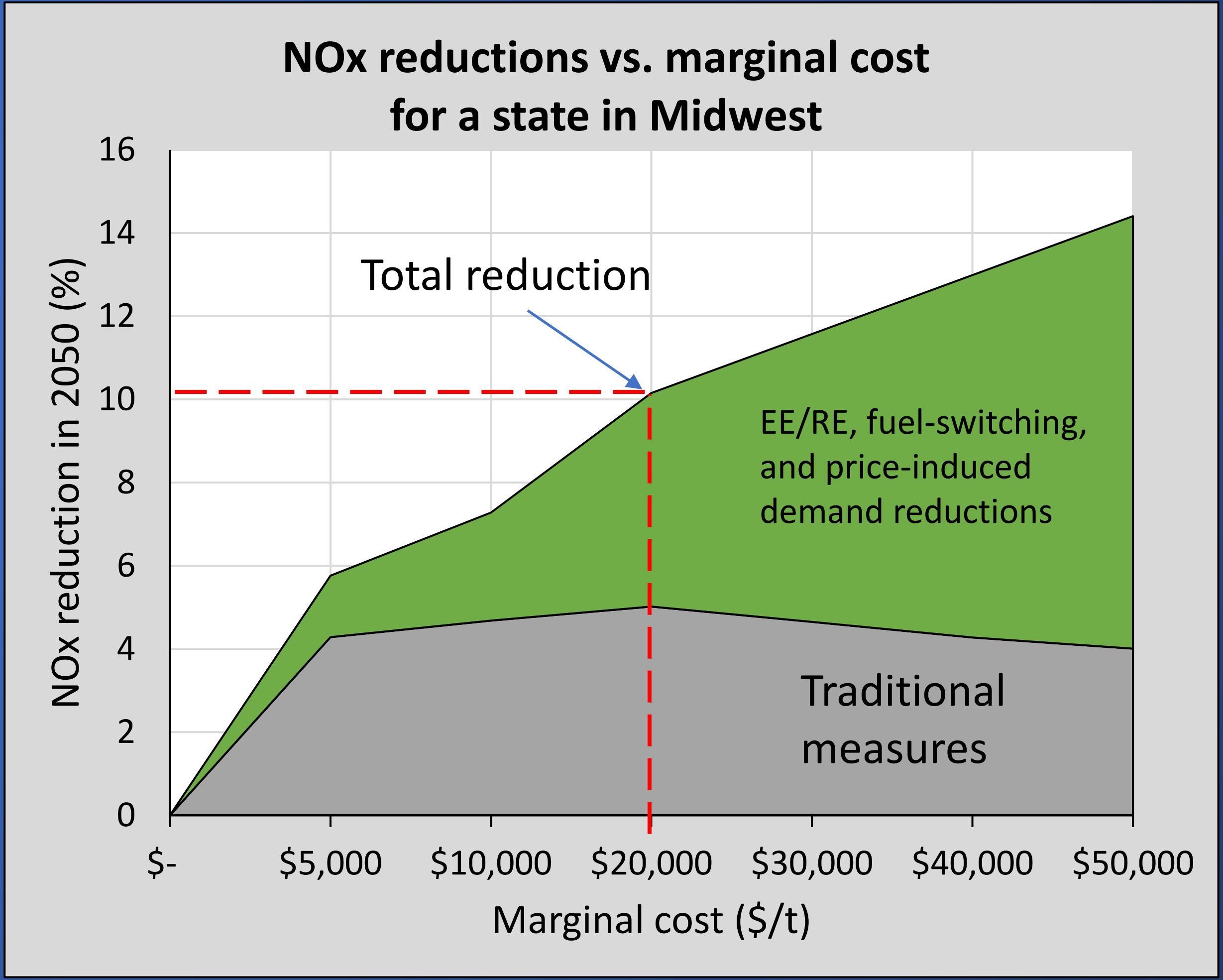
Application 2.

Multi-pollutant control strategies incorporating EE/RE

Are non-traditional measures cost-competitive for reducing air pollutant emissions?

Approach:

- identify optimal levels of controls and EE/RE to meet emission reduction targets
- expand methodology to consider multi-pollutant targets simultaneously



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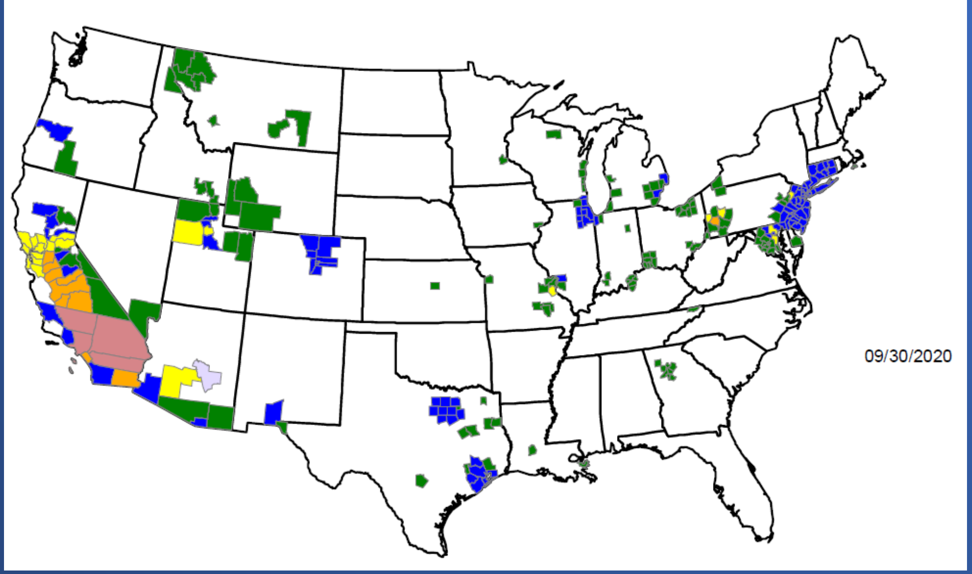
Application 3.
Air quality co-benefits of state GHG reduction measures

Criteria pollutant nonattainment areas are shown below; 29 states and DC have instituted GHG actions that likely will result in air pollutant co-benefits

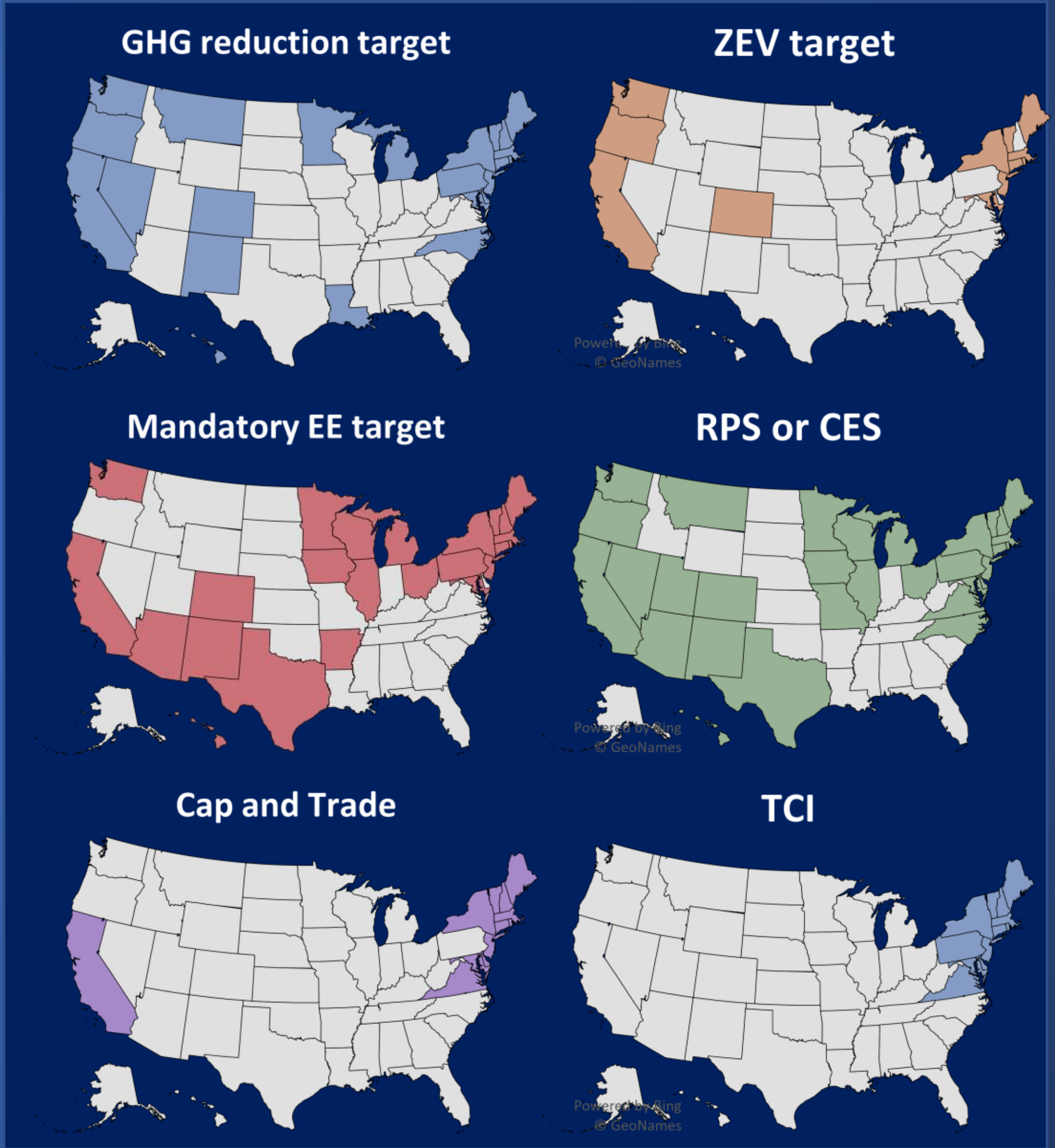
Approach: Use GLIMPSE to characterize air pollutant co-benefits of state-level GHG actions.

Initial focus: (1) State GHG reduction targets for states in the Northeast and Mid-Atlantic, (2) deeper exploration of MD

Nonattainment areas for criteria pollutants



State GHG policies



Next steps

- Iteratively work with stakeholders to complete applications
- Develop a policy library and add “levers” to GLIMPSE
- Integrate and test improvements to GCAM-USA
  - New industrial
    - Adds technological detail (boilers, process heaters, engines)
  - Updated electric sector
    - Incorporates load segmentation and dispatch
- RARE project to examine ozone attainment in Connecticut
- This coming summer:
  - Public release to interested parties
  - Trainings

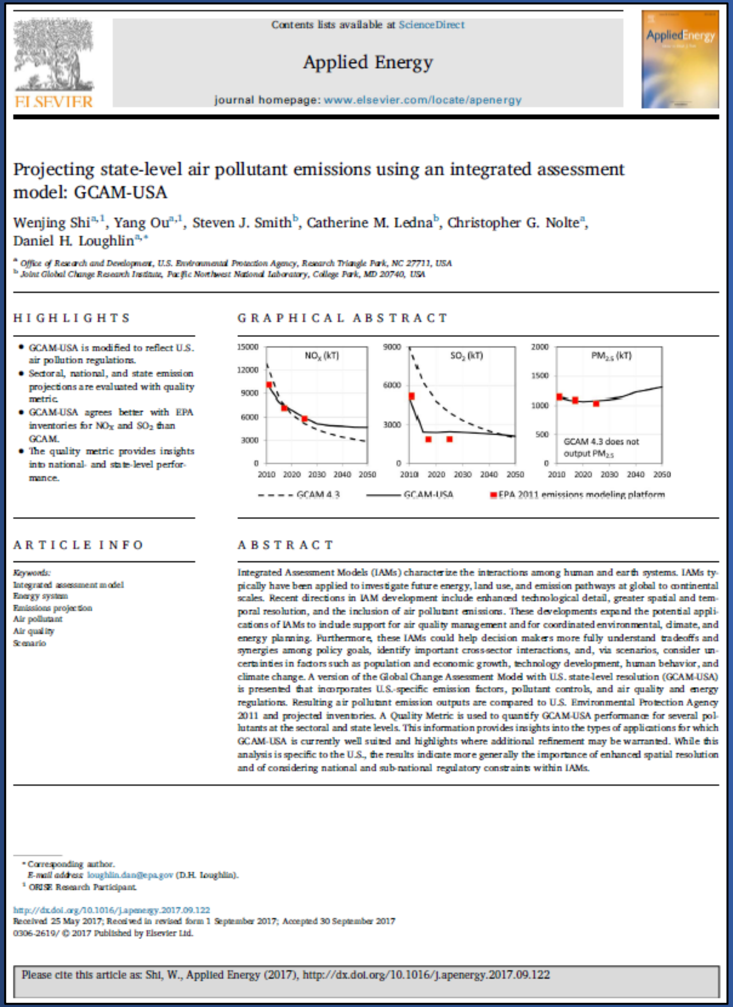
For more information

- GCAM documentation
  - http://jgcri.github.io/gcam-doc/index.html
- GLIMPSE website
  - https://www.epa.gov/air-research/glimpse-computational-framework-supporting-state-level-environmental-and-energy
- Are you interested in using GLIMPSE?
  - Email Loughlin.Dan@epa.gov

Extra slides

GLIMPSE applications in the literature?

Projecting pollutant emissions



Contents lists available at ScienceDirect

Applied Energy

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ELSEVIER

Projecting state-level air pollutant emissions using an integrated assessment model: GCAM-USA

Wenjing Shi[a,1], Yang Ou[a,1], Steven J. Smith[b], Catherine M. Ledna[b], Christopher G. Nolte[a], Daniel H. Loughlin[a,*]

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[b] Joint Global Change Research Institute, Pacific Northwest National Laboratory, College Park, MD 20740, USA

HIGHLIGHTS

- GCAM-USA is modified to reflect U.S. air pollution regulations.
- Sectoral, national, and state emission projections are evaluated with quality metric.
- GCAM-USA agrees better with EPA inventories for NO_X and SO_2 than GCAM.
- The quality metric provides insights into national- and state-level performance.

GRAPHICAL ABSTRACT

ARTICLE INFO

Keywords:
Integrated assessment model
Energy system
Emissions projection
Air pollutant
Air quality
Scenario

ABSTRACT

Integrated Assessment Models (IAMs) characterize the interactions among human and earth systems. IAMs typically have been applied to investigate future energy, land use, and emission pathways at global to continental scales. Recent directions in IAM development include enhanced technological detail, greater spatial and temporal resolution, and the inclusion of air pollutant emissions. These developments expand the potential applications of IAMs to include support for air quality management and for coordinated environmental, climate, and energy planning. Furthermore, these IAMs could help decision makers more fully understand tradeoffs and synergies among policy goals, identify important cross-sector interactions, and, via scenarios, consider uncertainties in factors such as population and economic growth, technology development, human behavior, and climate change. A version of the Global Change Assessment Model with U.S. state-level resolution (GCAM-USA) is presented that incorporates U.S.-specific emission factors, pollutant controls, and air quality and energy regulations. Resulting air pollutant emission outputs are compared to U.S. Environmental Protection Agency 2011 and projected inventories. A Quality Metric is used to quantify GCAM-USA performance for several pollutants at the sectoral and state levels. This information provides insights into the types of applications for which GCAM-USA is currently well suited and highlights where additional refinement may be warranted. While this analysis is specific to the U.S., the results indicate more generally the importance of enhanced spatial resolution and of considering national and sub-national regulatory constraints within IAMs.

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0306-2619/ © 2017 Published by Elsevier Ltd.

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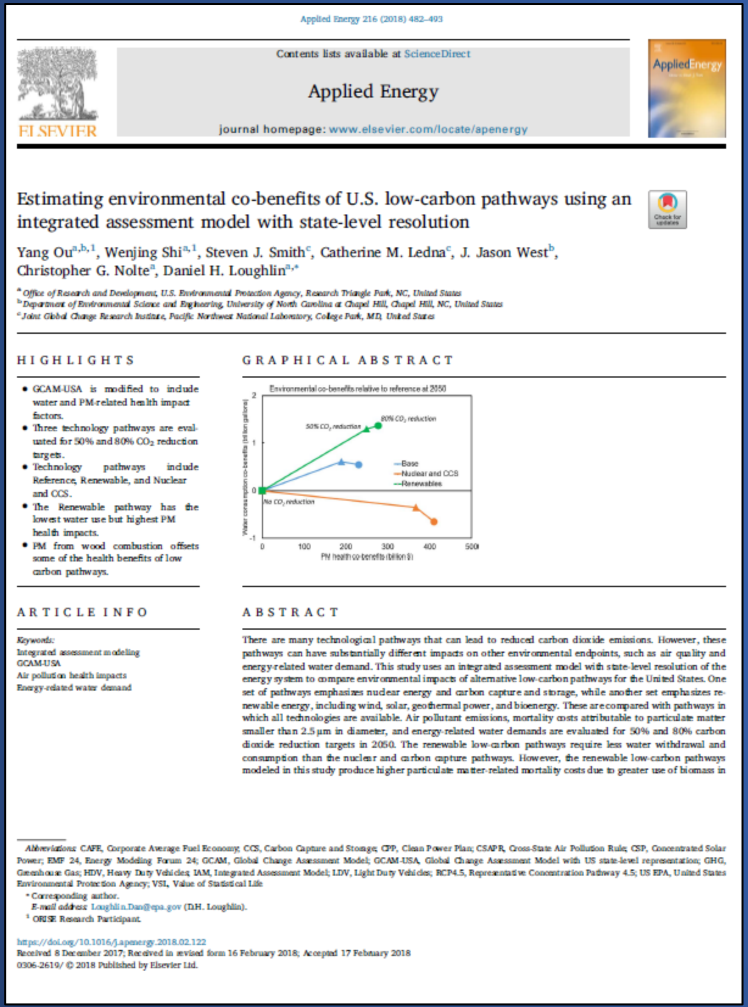
Key messages:

- GCAM-USA can be used to project air pollutant emissions through 2050
- For a reference case, NOx, SO_2, and PM emissions match well with EPA inventory projections

Ou Y., West, J.J., Smith, S.J., Nolte, C.G., and D.H. Loughlin (2020). Air pollution control strategies directly limiting national health damages in the US. *Nature Communications*, (2020)11:957, DOI: https://doi.org/10.1038/s41467-020-14783-2

GLIMPSE applications in the literature?

Estimating co-benefits of GHG mitigation pathways



Applied Energy 216 (2018) 482–493

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Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

Estimating environmental co-benefits of U.S. low-carbon pathways using an integrated assessment model with state-level resolution

Yang Ou[a,b,1], Wenjing Shi[a,1], Steven J. Smith[c], Catherine M. Ledna[c], J. Jason West[b], Christopher G. Nolte[a], Daniel H. Loughlin[a,*]

[a] Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, NC, United States
[b] Department of Environmental Science and Engineering, University of North Carolina at Chapel Hill, Chapel Hill, NC, United States
[c] Joint Global Change Research Institute, Pacific Northwest National Laboratory, College Park, MD, United States

HIGHLIGHTS

- GCAM-USA is modified to include water and PM-related health impact factors.
- Three technology pathways are evaluated for 50% and 80% CO_2 reduction targets.
- Technology pathways include Reference, Renewable, and Nuclear and CCS.
- The Renewable pathway has the lowest water use but highest PM health impacts.
- PM from wood combustion offsets some of the health benefits of low carbon pathways.

GRAPHICAL ABSTRACT

ARTICLE INFO

Keywords:
Integrated assessment modeling
GCAM-USA
Air pollution health impacts
Energy-related water demand

ABSTRACT

There are many technological pathways that can lead to reduced carbon dioxide emissions. However, these pathways can have substantially different impacts on other environmental endpoints, such as air quality and energy-related water demand. This study uses an integrated assessment model with state-level resolution of the energy system to compare environmental impacts of alternative low-carbon pathways for the United States. One set of pathways emphasizes nuclear energy and carbon capture and storage, while another set emphasizes renewable energy, including wind, solar, geothermal power, and bioenergy. These are compared with pathways in which all technologies are available. Air pollutant emissions, mortality costs attributable to particulate matter smaller than 2.5 µm in diameter, and energy-related water demands are evaluated for 50% and 80% carbon dioxide reduction targets in 2050. The renewable low-carbon pathways require less water withdrawal and consumption than the nuclear and carbon capture pathways. However, the renewable low-carbon pathways modeled in this study produce higher particulate matter-related mortality costs due to greater use of biomass in

Abbreviations: CAFE, Corporate Average Fuel Economy; CCS, Carbon Capture and Storage; CPP, Clean Power Plan; CSAPR, Cross-State Air Pollution Rule; CSP, Concentrated Solar Power; EMF 24, Energy Modeling Forum 24; GCAM, Global Change Assessment Model; GCAM-USA, Global Change Assessment Model with US state-level representation; GHG, Greenhouse Gas; HDV, Heavy Duty Vehicles; IAM, Integrated Assessment Model; LDV, Light Duty Vehicles; RCP4.5, Representative Concentration Pathway 4.5; US EPA, United States Environmental Protection Agency; VSL, Value of Statistical Life

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https://doi.org/10.1016/j.apenergy.2018.02.122
Received 8 December 2017; Received in revised form 16 February 2018; Accepted 17 February 2018

Key messages:

- Different GHG mitigation pathways can have very different environmental impacts
- A stylized renewable pathway had less dependence on water withdrawals and thus could be more drought resistant
- For states with high residential biomass use, the renewable pathway had health disbenefits relative to a nuclear and CCS pathway

Ou, Y, Smith, SJ, West, JJ, Nolte, CG, and DH Loughlin (2019). State-level drivers of future fine particulate matter mortality for the United States. *Environmental Research Letters*,14(2019) 124071, DOI: https://doi.org/10.1088/1748-9326/ab59cb

GLIMPSE applications in the literature?

Projection of state-level PM mortality

IOP Publishing   *Environ. Res. Lett.* 14 (2019) 124071   https://doi.org/10.1088/1748-9326/ab59cb

Environmental Research Letters

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LETTER

State-level drivers of future fine particulate matter mortality in the United States

Yang Ou[1,2,3], Steven J Smith[4], J Jason West[3], Christopher G Nolte[2] and Daniel H Loughlin[2,5]

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2 Center for Environmental Measurement and Modeling, US Environmental Protection Agency, RTP, NC, United States of America
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4 Joint Global Change Research Institute, Pacific Northwest National Laboratory, College Park, MD, United States of America
5 Author to whom any correspondence should be addressed.

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Keywords: energy, air quality management, health impacts, human-earth system model, air pollution, emission projection

Supplementary material for this article is available online

Abstract

Future fine particulate matter ($PM_{2.5}$) concentrations and resulting health impacts will be largely determined by factors such as energy use, fuel choices, emission controls, state and national policies, and demographics. In this study, a human-earth system model is used to estimate $PM_{2.5}$ mortality costs (PMMC) due to air pollutant emissions from each US state over the period 2015 to 2050, considering current major air quality and energy regulations. Contributions of various socioeconomic and energy factors to PMMC are quantified using the Logarithmic Mean Divisia Index. National PMMC are estimated to decrease 25% from 2015 to 2050, driven by decreases in energy intensity and PMMC per unit consumption of electric sector coal and transportation liquids. These factors together contribute 68% of the decrease, primarily from technology improvements and air quality regulations. States with greater population and economic growth, but with fewer clean energy resources, are more likely to face significant challenges in reducing future PMMC from their emissions. In contrast, states with larger projected decreases in PMMC have smaller increases in population and per capita GDP, and greater decreases in electric sector coal share and PMMC per unit fuel consumption.

Introduction and objectives

Long term trends in air quality and health burdens will be driven by pollutant emissions and underlying socioeconomic factors. Emissions sources such as factories, motor vehicles, and electric utilities contribute to total concentrations of $PM_{2.5}$ by emitting $PM_{2.5}$ and its precursors, including nitrogen oxides (NO_x), sulfur dioxide (SO_2), and ammonia (NH_3). Over recent decades, regulatory efforts targeting these major emission sources have substantially reduced the US public health burden from air pollution (Butt *et al* 2017, Fann *et al* 2018, Shapiro and Walker 2018, Zhang *et al* 2018). Previous studies have applied chemical transport models (CTMs) to attribute total $PM_{2.5}$ health impacts to specific emission sources and locations (Fann *et al* 2012, Caiazzo *et al* 2013, Dedoussi and Barrett 2014, Turner *et al* 2015, Penn *et al* 2017). These studies generally found that $PM_{2.5}$ health impacts arise from many different emission sources (Turner *et al* 2015) that affect public health by their proximity to population exposed (Fann *et al* 2009). For example, most electric sector $PM_{2.5}$ health impacts are attributable to emissions from states that have considerable coal-fired electricity production and large downwind population, while health impacts of the residential sector are mainly attributed to states with large population and significant residential wood combustion (Penn *et al* 2017).

A variety of socioeconomic factors also affect future changes in $PM_{2.5}$ health impacts. First, socioeconomic development increases service and energy demands (Riahi *et al* 2017), potentially resulting in greater fuel combustion. Second, population growth not only boosts energy demand but also typically increases population exposure to air pollution. Third,

Key messages:

- $PM_{2.5}$ mortality costs are expected to decrease nationally by 25% from 2010 to 2050
- Decreasing energy intensity is the largest factor that drives this trend
- However, some states have increasing PM mortality costs, driven by population growth, economic growth, and a reliance on fuels and technologies with higher PM emissions intensity

Ou, Y, Shi, W, Smith, SJ, Ledna, CM, West, JJ, Nolte, CG, & DH Loughlin (2018). Estimating environmental co-benefits of U.S. GHG reduction pathways using the GCAM-USA Integrated Assessment Model. *Applied Energy*, 216C(2018) pp. 482-493. DOI: https://doi.org/10.1016/j.apenergy.2018:02.122

GLIMPSE applications in the literature?

Strategies for reducing PM mortality


nature COMMUNICATIONS

ARTICLE

Check for updates

https://doi.org/10.1038/s41467-020-14783-2 OPEN

Air pollution control strategies directly limiting national health damages in the US

Yang Ou[1,2,5], J. Jason West[1], Steven J. Smith[3], Christopher G. Nolte[4] & Daniel H. Loughlin[4]

Exposure to fine particulate matter ($PM_{2.5}$) from fuel combustion significantly contributes to global and US mortality. Traditional control strategies typically reduce emissions for specific air pollutants and sectors to maintain pollutant concentrations below standards. Here we directly set national $PM_{2.5}$ mortality cost reduction targets within a global human-earth system model with US state-level energy systems, in scenarios to 2050, to identify endogenously the control actions, sectors, and locations that most cost-effectively reduce $PM_{2.5}$ mortality. We show that substantial health benefits can be cost-effectively achieved by electrifying sources with high primary $PM_{2.5}$ emission intensities, including industrial coal, building biomass, and industrial liquids. More stringent $PM_{2.5}$ reduction targets expedite the phaseout of high emission intensity sources, leading to larger declines in major pollutant emissions, but very limited co-benefits in reducing CO_2 emissions. Control strategies limiting health damages achieve the greatest emission reductions in the East North Central and Middle Atlantic states.

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Key messages:

- GCAM-USA is used to identify cost-effective strategies for reducing PM health costs nationally
- Approach considers end-of-pipe controls, energy efficiency, renewable energy, and fuel-switching simultaneously
- Also, considers health damages specific to PM precursors and source sectors
- Focusing on high impact locations and source categories results in benefits that far outweigh control costs

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