



# Modeling U.S. air pollutant emissions and controls in GCAM-USA

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## Foreword

### **Objective of this presentation**

We describe extensions to the GCAM-USA modeling framework that facilitate exploration of the co-benefits, tradeoffs and synergies among strategies for addressing climate, air quality, and other environmental goals.

### **Intended audience**

The material presented here is intended for GCAM and other IAM modelers. For other audiences, please contact Dan Loughlin ([loughlin.dan@epa.gov](mailto:loughlin.dan@epa.gov)).

### **Disclaimers**

Modeling results are provided for illustrative purposes only.

While this presentation has been reviewed and cleared for publication by the U.S. Environmental Protection Agency, the views expressed here are those of the authors and do not necessarily represent the official views or policies of the Agency.

- 1. The GLIMPSE project**
- 2. Science questions being addressed in GLIMPSE project**
- 3. Why GCAM-USA?**
- 4. Modifications to GCAM-USA**
  - **U.S. emission factors (EFs), controls and policies**
  - **Scenario builder and analysis tools**
- 5. Effects of modifications**
- 6. Illustrative application**
- 7. Summary and next steps**

## I. The GLIMPSE project

- **GLIMPSE is a project being conducted by the U.S. EPA's Office of Research and Development.**
- **The primary goals of the project:**
  - **develop information and computational tools for**
    - **assessing strategies for meeting air, climate, and energy goals simultaneously, and,**
    - **supporting air-climate-energy planning at various levels (national, regional & state).**
- **GLIMPSE has focused on extending EPA's MARKAL modeling capabilities by adding air, climate and environmental impact factors.**
- **This presentation outlines ongoing work to integrate GCAM-USA into GLIMPSE.**

## 2. Science questions

- **How can we simultaneously (and cost-effectively and robustly) achieve air quality, climate change mitigation and energy goals?**
- **What are the tradeoffs and synergies among these goals?**
- **What are the implications of state-level energy efficiency and renewable energy measures on GHG and air pollutant emissions?**
- **How do these measures and end-of-pipe controls work together most effectively in a control strategy?**
- **What are the broader health, environmental and ecological impacts of different pathways for meeting society's energy needs?**
  - **Impacts under consideration include:** Air quality and resulting human health effects, agricultural damage to crops and timber, ecosystem impacts from N and S deposition, water use by agricultural and energy sectors, and resilience to drought and other climate change impacts

### **GCAM-USA is being integrated into GLIMPSE. Why?**

- **Model is open source and freely available.**
- **Runtime is <1 hr without specialized hardware or proprietary software.**
- **Input/output format is amenable to integration with a user interface.**
- **Includes air pollutants of interest to EPA**
  - **NO<sub>x</sub>, SO<sub>2</sub>, CO, PM<sub>2.5</sub>, PM<sub>10</sub>, VOC, NH<sub>3</sub>.**
- **Allows examination of national and state actions in global context.**
- **Expands current MARKAL-based GLIMPSE capabilities:**
  - **Spatial resolution: Census Div. -> State**
  - **Spatial bounds: U.S. -> Global**
  - **Temporal horizon: 2055 -> 2100**
  - **Sectoral coverage: Energy system -> Energy system plus economy, land use, agriculture, climate**



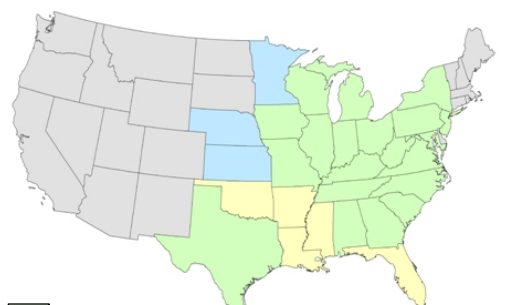
### 3. Why GCAM-USA?

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#### Importance of state-level resolution:

Emissions and energy policies are defined at the state-level, and renewable resources differ from state-to-state

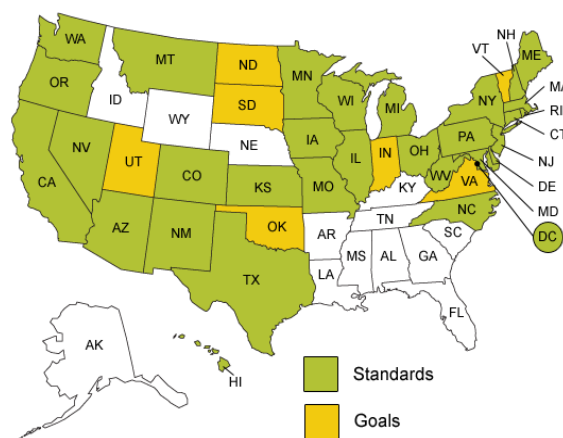
#### Cross-State Air Pollution Rule



- Annual SO<sub>2</sub> and NO<sub>x</sub>, ozone-season NO<sub>x</sub>
- Annual SO<sub>2</sub> and NO<sub>x</sub>
- Ozone-season NO<sub>x</sub>

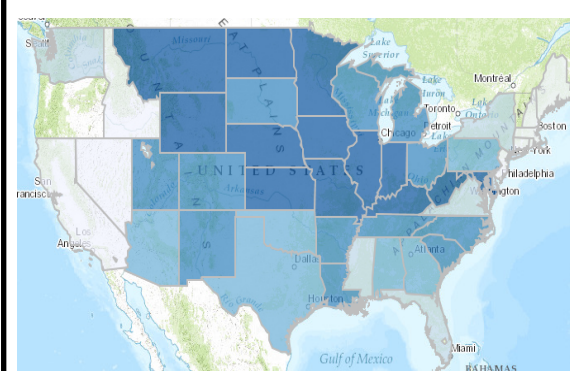
Source: U.S. EPA, <http://www3.epa.gov/crossstaterule/>

#### Renewable portfolio standards



Source: U.S. EIA, <https://www.eia.gov/todayinenergy/detail.cfm?id=4850#>

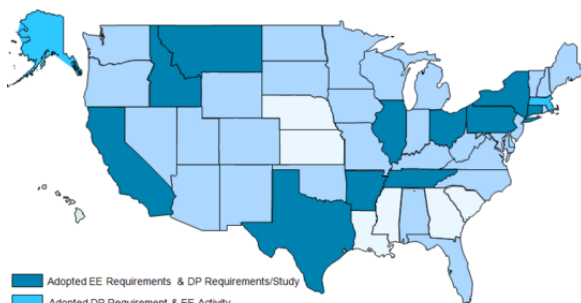
#### Clean Power Plan



#### Final emission rate limits

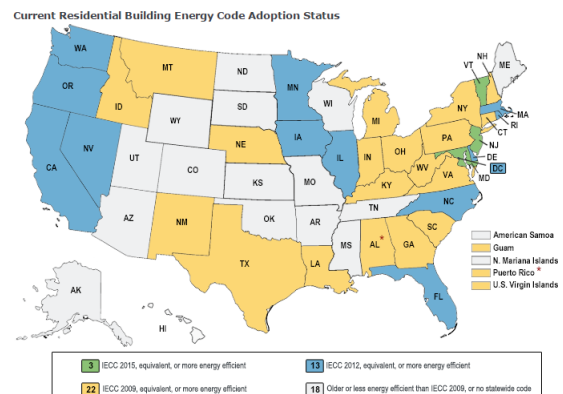
Source: U.S. EPA  
[www2.epa.gov/cleanpowerplan/clean-power-plan-final-rule-regulatory-impact-analysis](http://www2.epa.gov/cleanpowerplan/clean-power-plan-final-rule-regulatory-impact-analysis)

#### Demand response requirements



Source: U.S. EIA, <https://www.eia.gov/analysis/studies/electricity/>

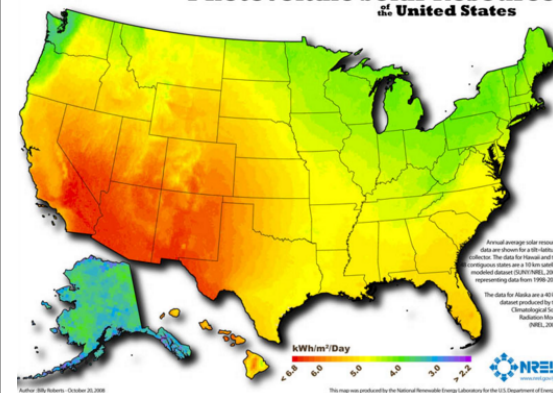
#### Residential and commercial building codes



Source: U.S. DOE, <https://www.energycodes.gov/status-state-energy-code-adoption>

#### Renewable resources

#### Photovoltaic Solar Resource of the United States

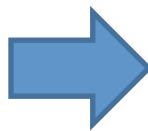


## 4. GCAM-USA modifications

### Limitations for our purposes

### How being addressed...

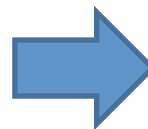
Air pollutant emission factors (EFs) decrease as a function of GDP growth, but do not explicitly reflect US regulations (e.g., Tier 3 and New Source Performance Standards).



Developed base-year and projected EFs using:

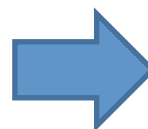
- Integrated Planning Model (IPM)
- Mobile Vehicle Simulator of Emissions (MOVES)
- WebFIRE EF database
- EPA Greenhouse Gas Inventory

Other regulations that cap state-level emissions are not currently included (e.g., Cross-State Air Pollution Rule, Clean Power Plan).



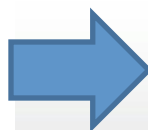
Added state-level pollutant caps derived from EPA Regulatory Impact Analyses.

Option to retrofit existing power plants with air pollutant controls is not implemented (e.g., Selective Catalytic Reduction for NO<sub>x</sub>)



Developed retrofit control characterizations based upon EPA's CUECost, CoST, and MARKAL modeling

Development and management of GCAM-USA inputs files currently is not user-friendly.

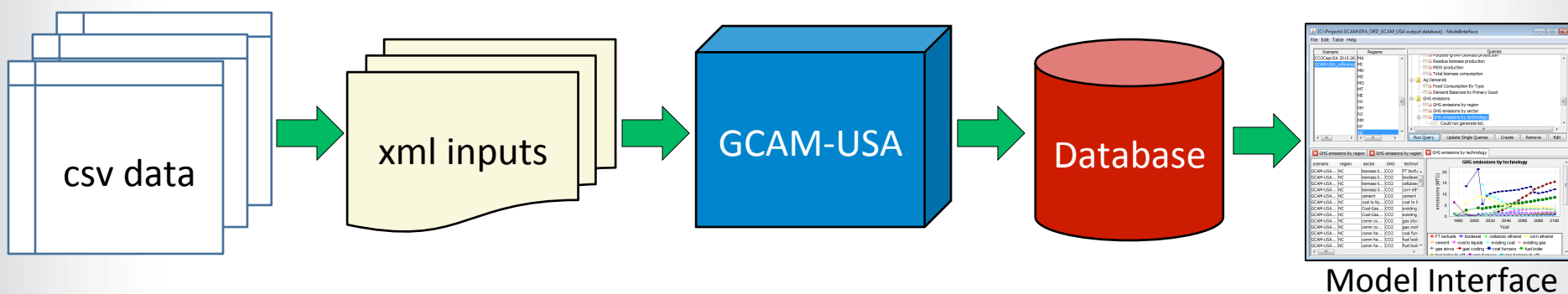


Developing a Scenario Builder and tools for analyzing and comparing results.

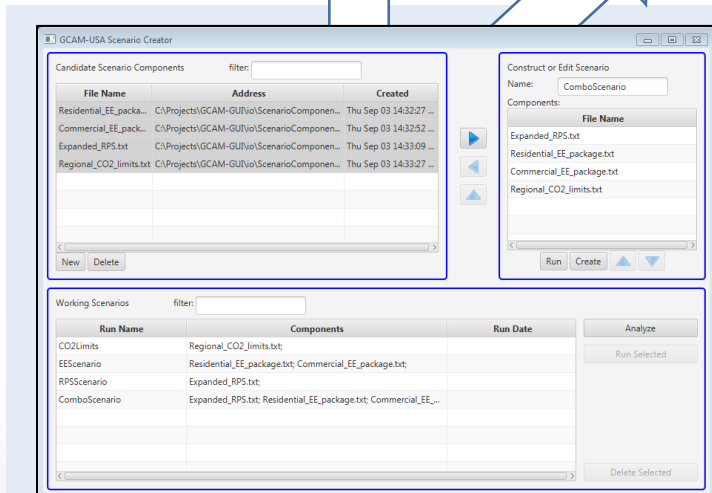
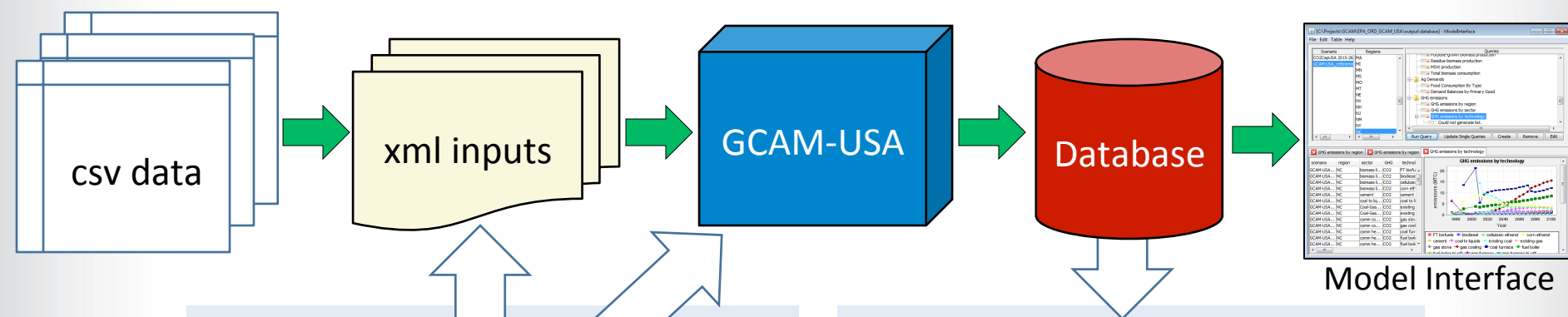


## 4. GCAM-USA modifications

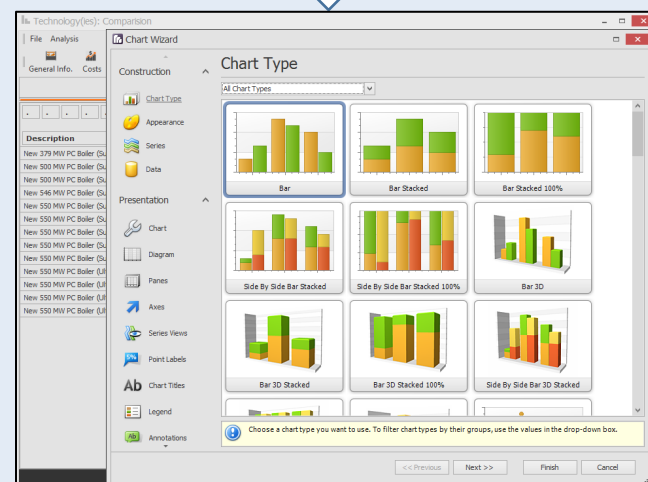
### GCAM-USA workflow:



## Scenario Builder and analysis tools:



**Front end:** Develop, manage and execute scenarios, set model options



**Back end:** View, analyze and compare scenario results



## 4. GCAM-USA modifications

### Scenario Builder: Creating scenario components

Scenario options

States and/or global regions to which to apply the changes

Tools for populating data table

Data table of values to use

Year	Value
2020	10.00
2025	12.76
2030	16.29
2035	20.79
2040	26.53
2045	33.86
2050	43.22
2055	55.16
2060	70.40
2065	89.85
2070	114.67

Applied to:

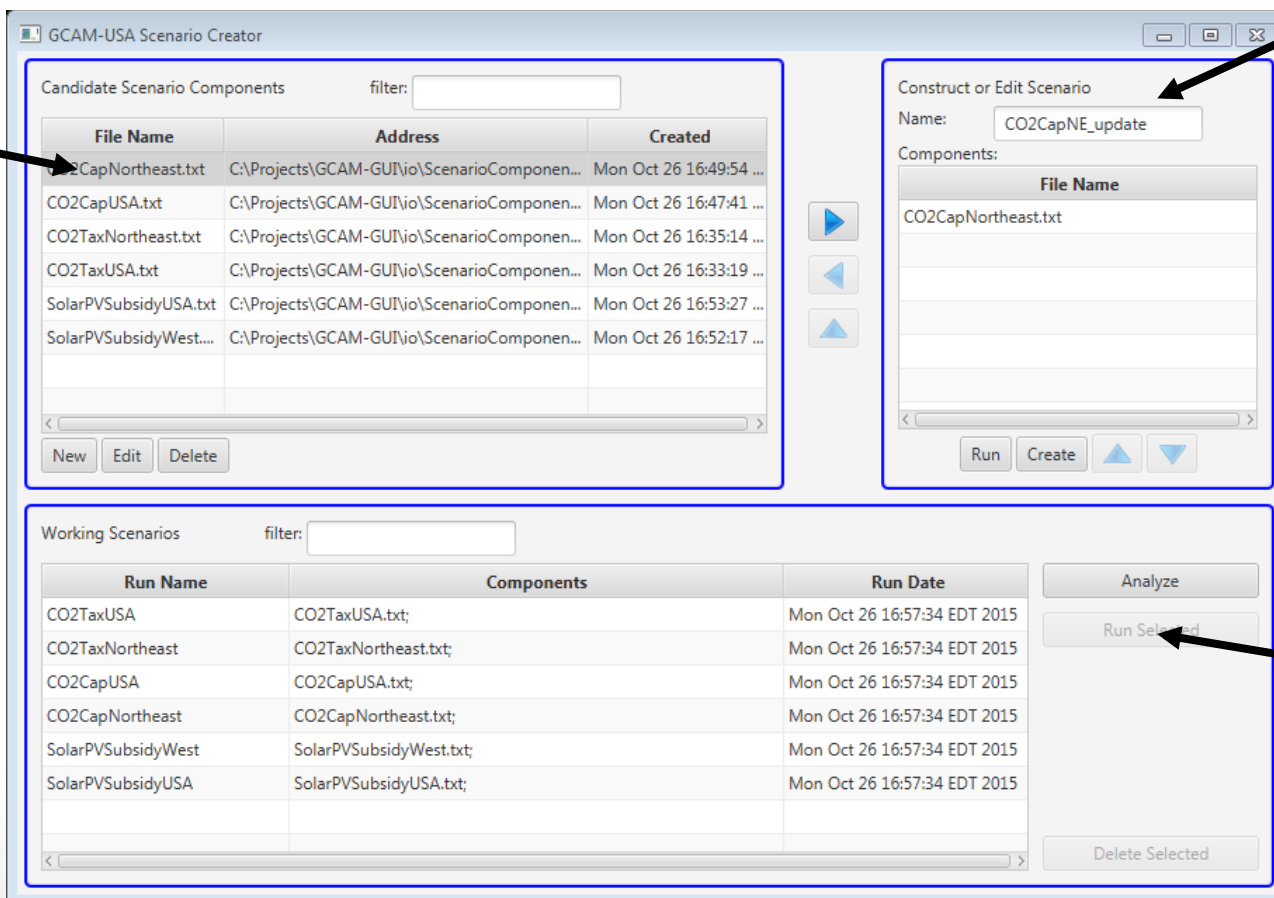
- world
  - USA
    - ☐ AL
    - ☐ AK
    - ☐ AZ
    - ☐ AR
    - ☒ CA
    - ☐ CO
    - ☐ CT
    - ☐ DE
    - ☐ DC
    - ☐ FL
    - ☐ GA
    - ☒ HI

## 4. GCAM-USA modifications

### Scenario Builder: Managing scenarios

Creating a new scenario from existing components

Library of scenario components



The screenshot displays the GCAM-USA Scenario Creator interface, which is divided into three main sections:

- Candidate Scenario Components:** A table listing available components for building scenarios. It includes columns for File Name, Address, and Created date.
- Construct or Edit Scenario:** A section for creating or editing a scenario. It includes a Name field (set to "CO2CapNE\_update"), a Components list (showing "CO2CapNortheast.txt"), and buttons for Run, Create, and navigation.
- Working Scenarios:** A table listing scenarios that are currently being worked on. It includes columns for Run Name, Components, and Run Date. Buttons for Analyze, Run Selected, and Delete Selected are also present.

Arrows from the surrounding text blocks point to specific elements in the interface:

- An arrow from "Library of scenario components" points to the "Candidate Scenario Components" table.
- An arrow from "Creating a new scenario from existing components" points to the "Construct or Edit Scenario" section.
- An arrow from "Management and execution of scenarios" points to the "Run Selected" button in the "Working Scenarios" section.

File Name	Address	Created
CO2CapNortheast.txt	C:\Projects\GCAM-GUI\io\ScenarioComponen...	Mon Oct 26 16:49:54 ...
CO2CapUSA.txt	C:\Projects\GCAM-GUI\io\ScenarioComponen...	Mon Oct 26 16:47:41 ...
CO2TaxNortheast.txt	C:\Projects\GCAM-GUI\io\ScenarioComponen...	Mon Oct 26 16:35:14 ...
CO2TaxUSA.txt	C:\Projects\GCAM-GUI\io\ScenarioComponen...	Mon Oct 26 16:33:19 ...
SolarPVSubsidyUSA.txt	C:\Projects\GCAM-GUI\io\ScenarioComponen...	Mon Oct 26 16:53:27 ...
SolarPVSubsidyWest....	C:\Projects\GCAM-GUI\io\ScenarioComponen...	Mon Oct 26 16:52:17 ...

Run Name	Components	Run Date
CO2TaxUSA	CO2TaxUSA.txt;	Mon Oct 26 16:57:34 EDT 2015
CO2TaxNortheast	CO2TaxNortheast.txt;	Mon Oct 26 16:57:34 EDT 2015
CO2CapUSA	CO2CapUSA.txt;	Mon Oct 26 16:57:34 EDT 2015
CO2CapNortheast	CO2CapNortheast.txt;	Mon Oct 26 16:57:34 EDT 2015
SolarPVSubsidyWest	SolarPVSubsidyWest.txt;	Mon Oct 26 16:57:34 EDT 2015
SolarPVSubsidyUSA	SolarPVSubsidyUSA.txt;	Mon Oct 26 16:57:34 EDT 2015

Management and execution of scenarios

## 5. Effects of modifications

### **Notes:**

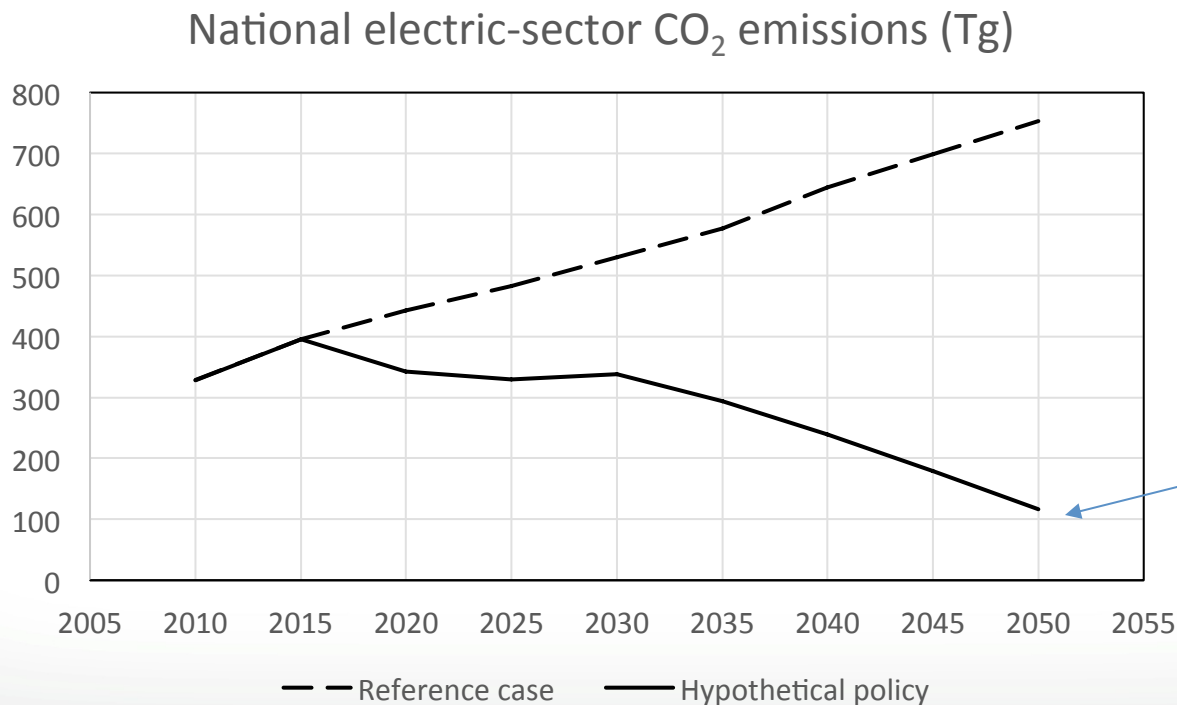
**Results shown in this presentation are created using the GCAM-USA model, using US-specific EFs provided by the EPA GLIMPSE team.**

**The application is a work in progress. Results are provided for illustrative purposes only.**

## 6. Example application

### Objective:

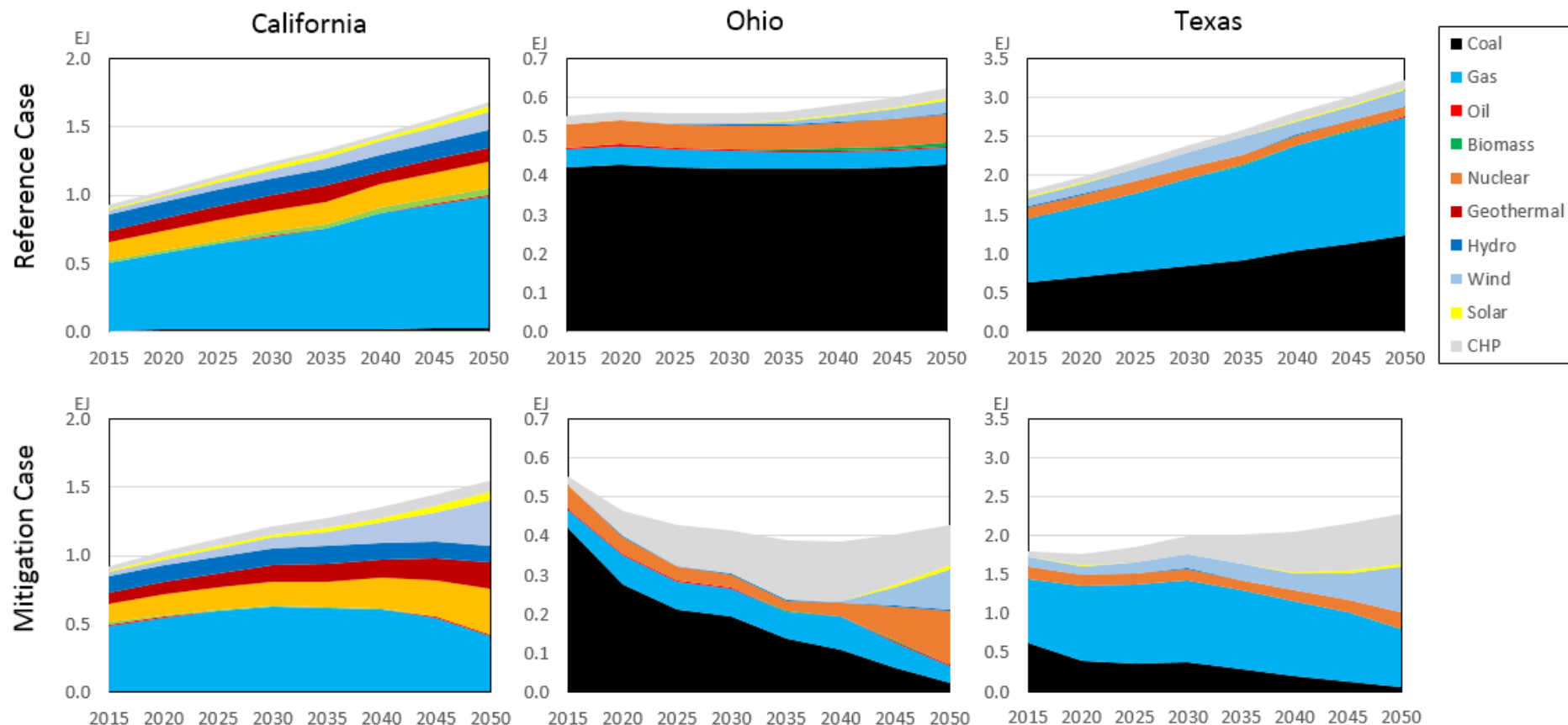
**Examine the air pollutant co-benefits associated with a hypothetical CO<sub>2</sub> mitigation pathway.**



80% reduction  
from 2010 level,  
implemented as  
national cap on  
*electric sector CO<sub>2</sub>*.

## 6. Example application

### Electricity production (EJ) by technology category



## 6. Example application

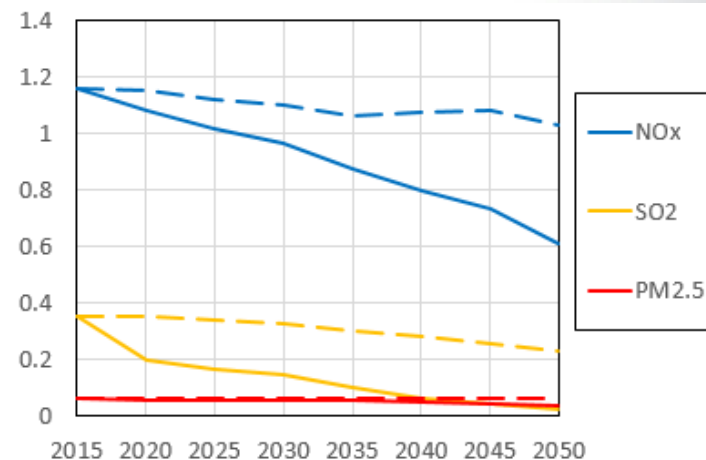
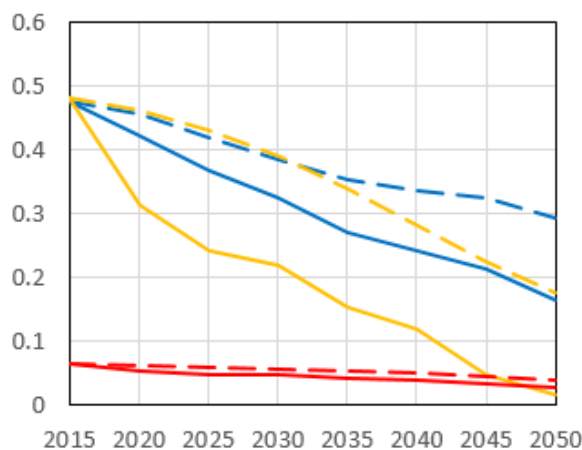
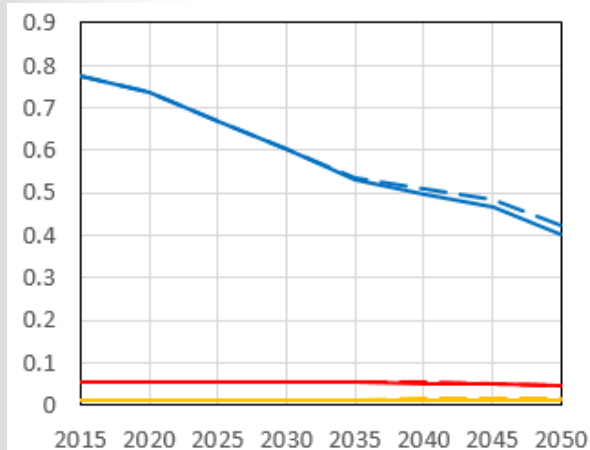
### Air pollutant emission reduction (Tg) co-benefits

Solid line represents CO<sub>2</sub> mitigation scenario results, dashed line is reference case

California

Ohio

Texas



Observation:

There are NO<sub>x</sub>, SO<sub>2</sub> and PM<sub>2.5</sub> co-benefits in each of these three states.



## 7. Summary and next steps

- **We have made great strides in modifying GCAM-USA to include air pollutant emissions, controls and regulations.**
- **The system has successfully been tested to evaluate the air pollutant implications of a GHG mitigation pathway.**
- **We have also made progress in developing a working Scenario Builder for use with GCAM-USA.**
- **Ongoing work includes:**
  - **testing our representation of air pollutant controls**
  - **adding industrial air pollutant control options**
  - **evaluating synergies and tradeoffs among air quality, climate and energy goals, and,**
  - **exploring the implications of energy technologies, fuels, and pathways on various environmental and health endpoints.**



# Questions?

Contact information:

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Steve Smith, JGCRI – [ssmith@pnnl.gov](mailto:ssmith@pnnl.gov)

For information on the GLIMPSE project:

Akhtar, F.H., Pinder, R.W., Loughlin, D.H., and Henze, D.K. (2013). GLIMPSE: a rapid decision framework for energy and environmental policy. *Environ Sci Technol*, 47(21), 12011-12019. doi: 10.1021/es402283j