EPA United States Environmental Protection Agency

EPA Tools & Resources Webinar: Supporting Air Quality and Climate Change Planning with GLIMPSE

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US EPA Office of Research and Development

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Take home messages

GLIMPSE: Global Change Analysis Model Long-term Interactive Multi-Pollutant Scenario Evaluator

GLIMPSE …

… is a tool for long-term air-climate-energy planning

… makes the powerful (and complex) GCAM-USA model accessible to a much broader audience

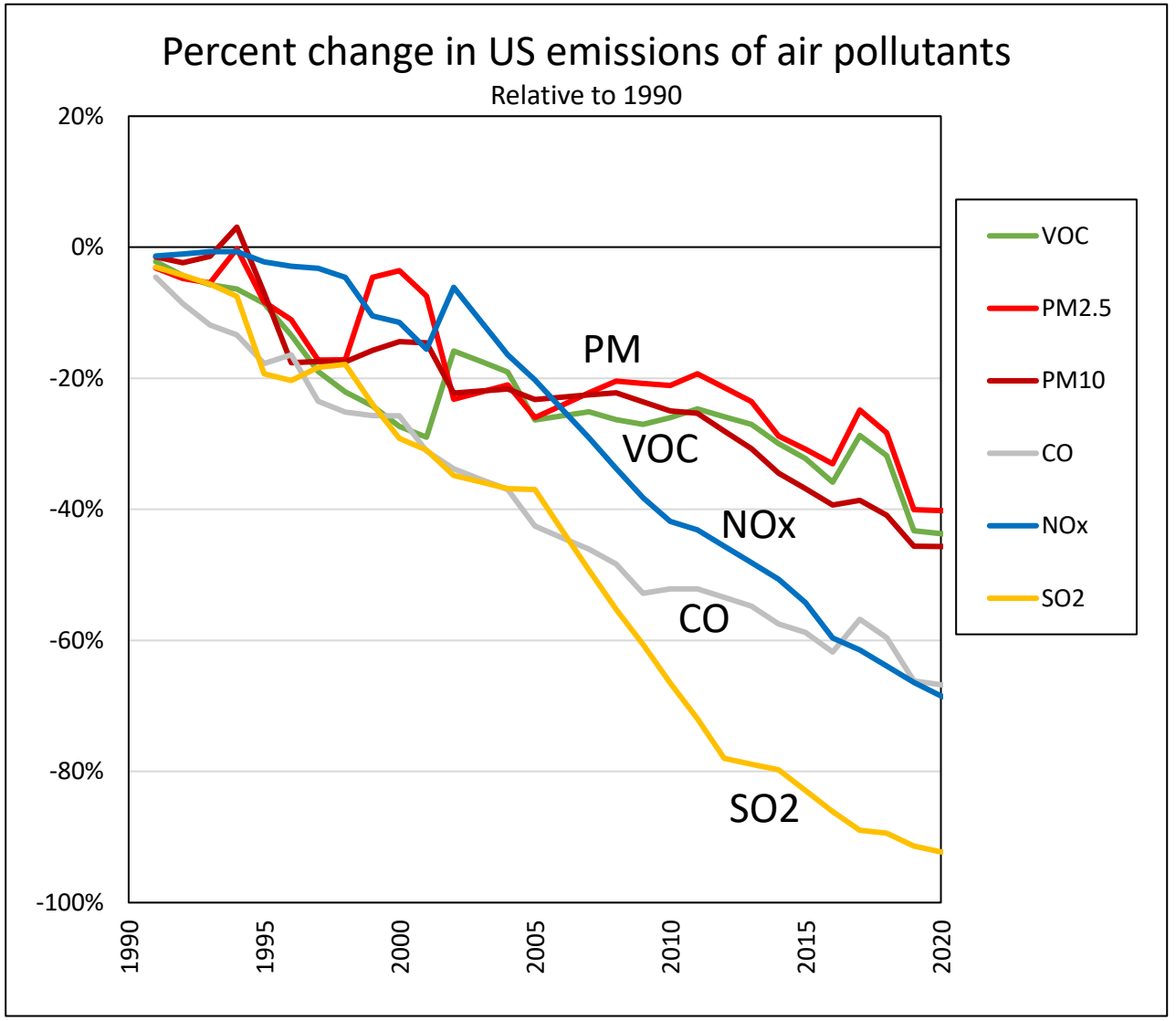
… has the potential to support state air quality planners develop strategies for meeting climate and air quality goals simultaneously

Presentation outline

- Background
  - Air quality and climate issues confronted by states
  - The interconnections among energy, air, climate, and water
- Objective of GILMPSE
  - Support development of strategies for addressing air and climate challenges simultaneously
- Approach
  - Global Change Analysis Model (GCAM)
  - GCAM Long-term Interactive Multi-Pollutant Scenario Evaluator (GLIMPSE)
- Example application
  - Emission impacts of state-level greenhouse gas (GHG) mitigation measures
- Impacts
- Next steps

Background: Air quality successes

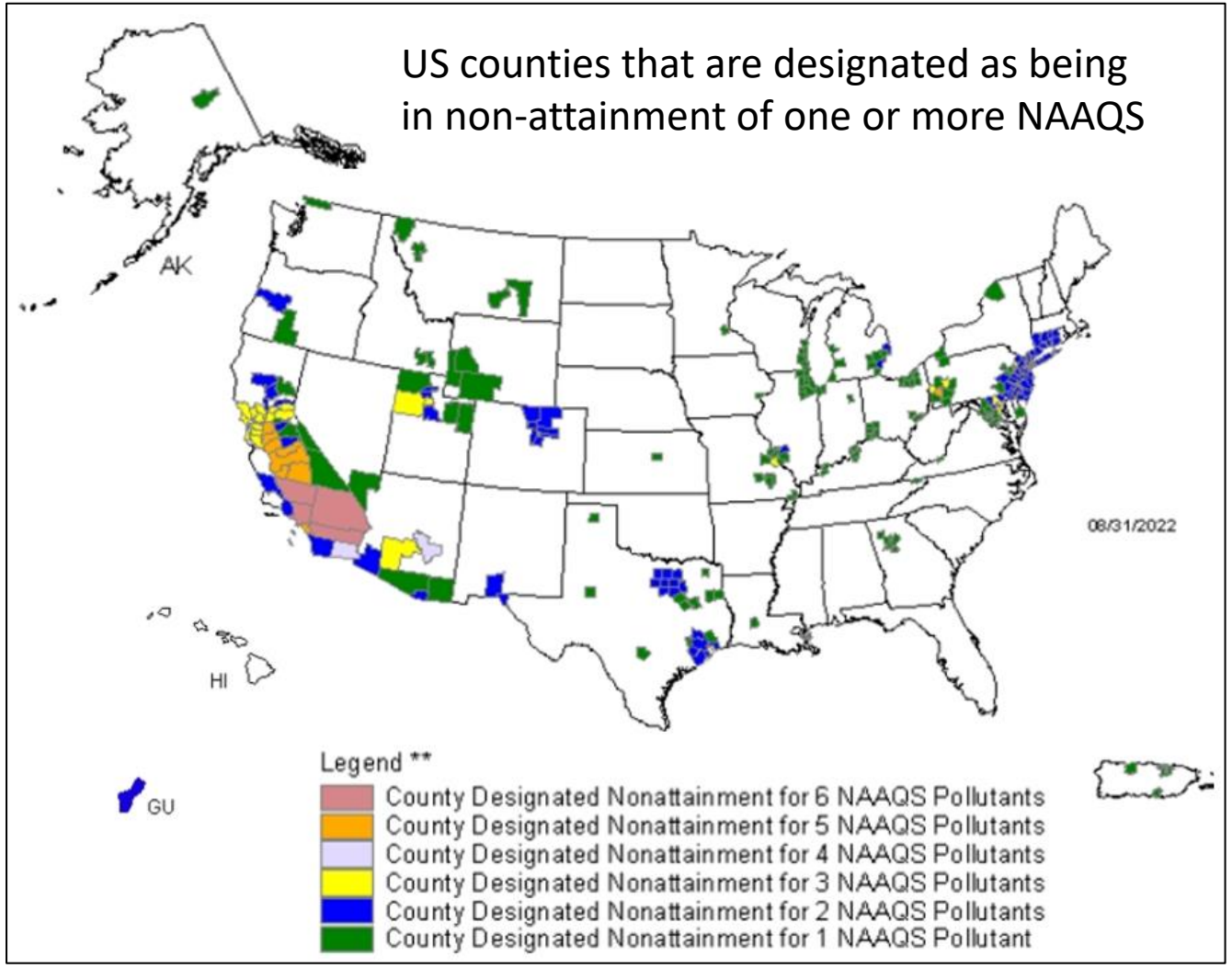
- The Clean Air Act and its Amendments have been successful in reducing air pollutant emissions
- Significant reductions in:
  - Nitrogen oxides (NOx)
  - Sulfur dioxide (SO2)
  - Carbon monoxide (CO)
  - Particulate matter (PM)
  - Volatile Organic Compounds (VOCs)



https://www.epa.gov/green-book

Background: Poor air quality persists

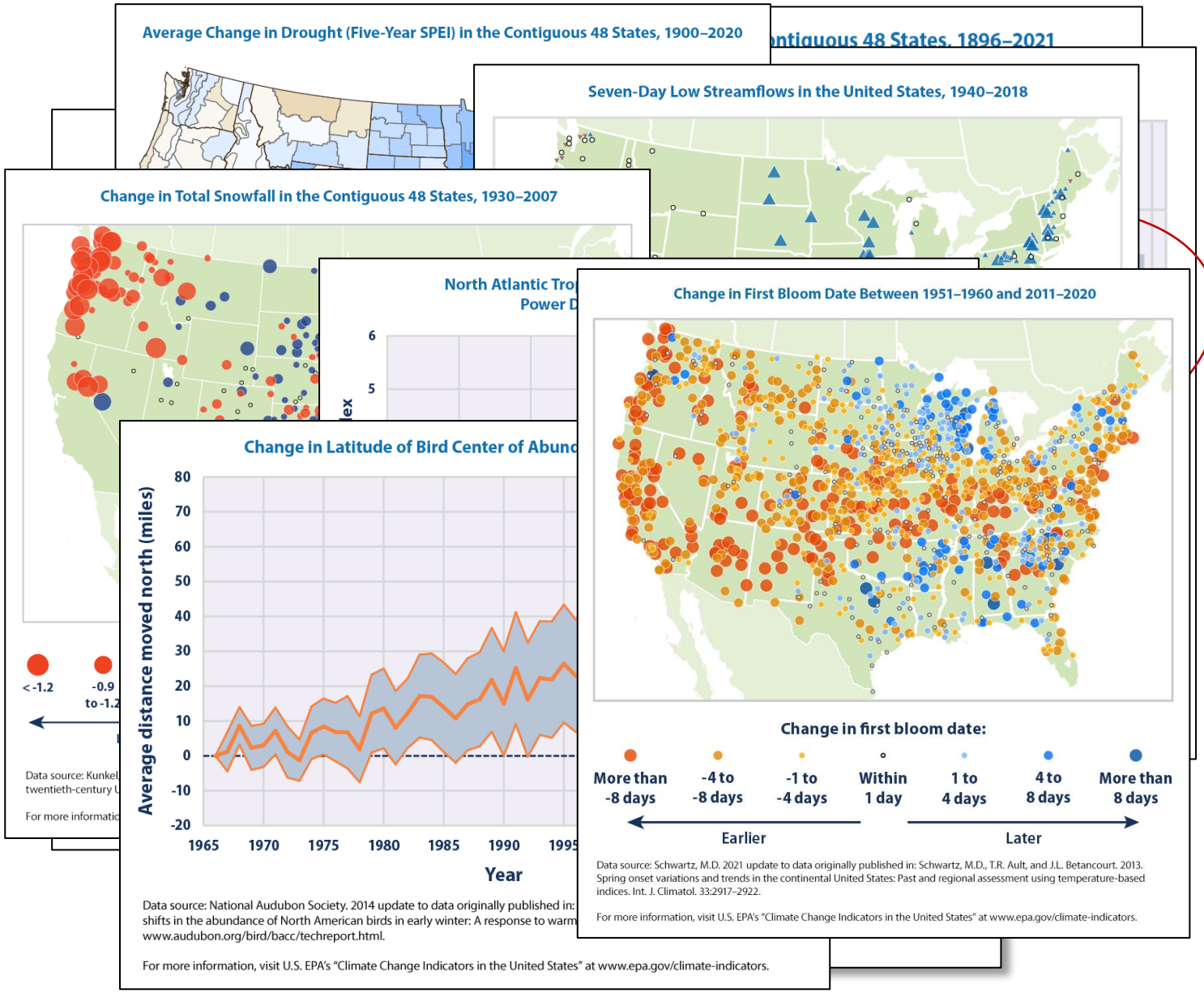
- Despite significant progress, more than 140 million Americans live in counties that exceed one or more National Ambient Air Quality Standards
- Persistent concerns
  - Tropospheric ozone
  - Fine particulate matter
  - Carbon monoxide
  - Lead



https://www.epa.gov/green-book

Background: Climate impacts

- Example indicators
  - Seasonal temperature
  - Heat waves
  - Wildfire extent
  - Heavy precipitation events
  - Drought
  - Stream flow and temperature
  - Changes in snowfall
  - Hurricane power
  - Bird migration patterns
  - Changes in bloom dates



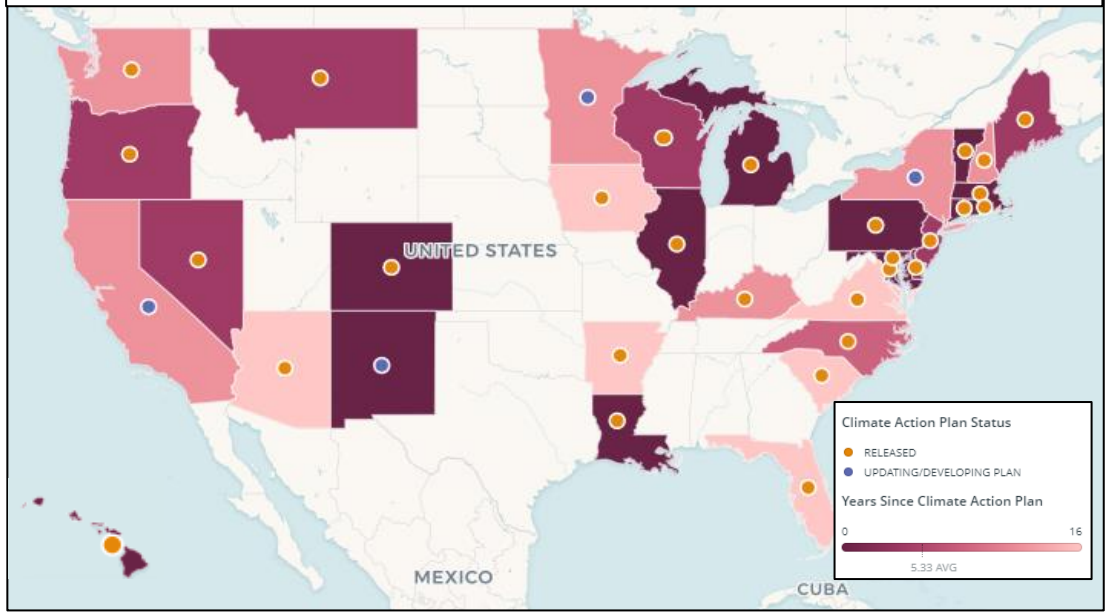
https://www.epa.gov/climate-indicators

EPA United States Environmental Protection Agency

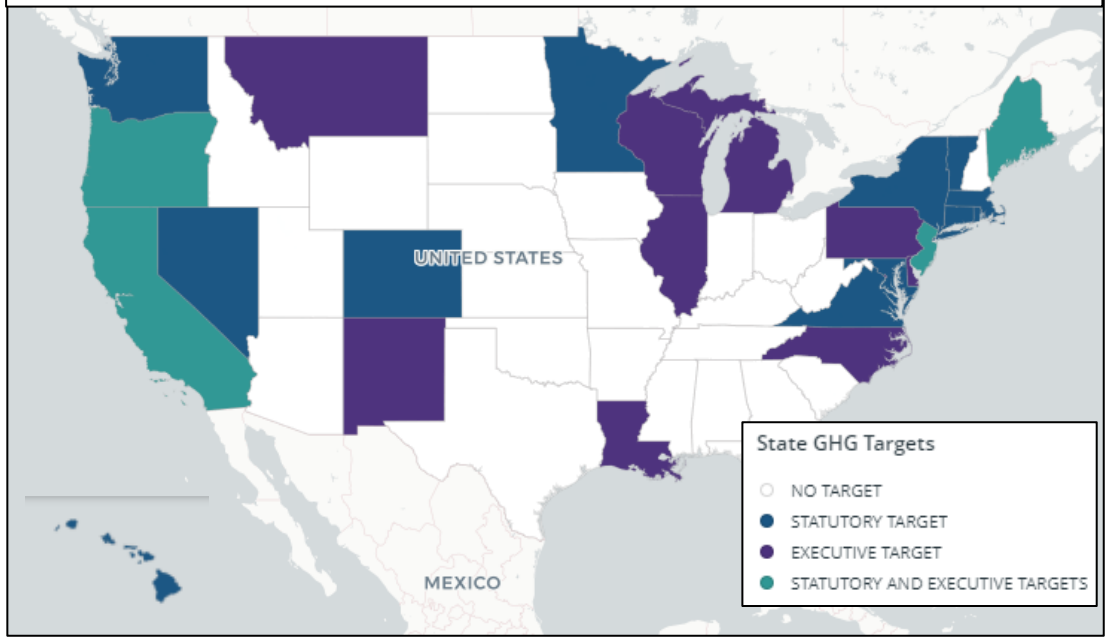
Background: State climate policies

- In response to climate challenges, many states have enacted:
  - 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

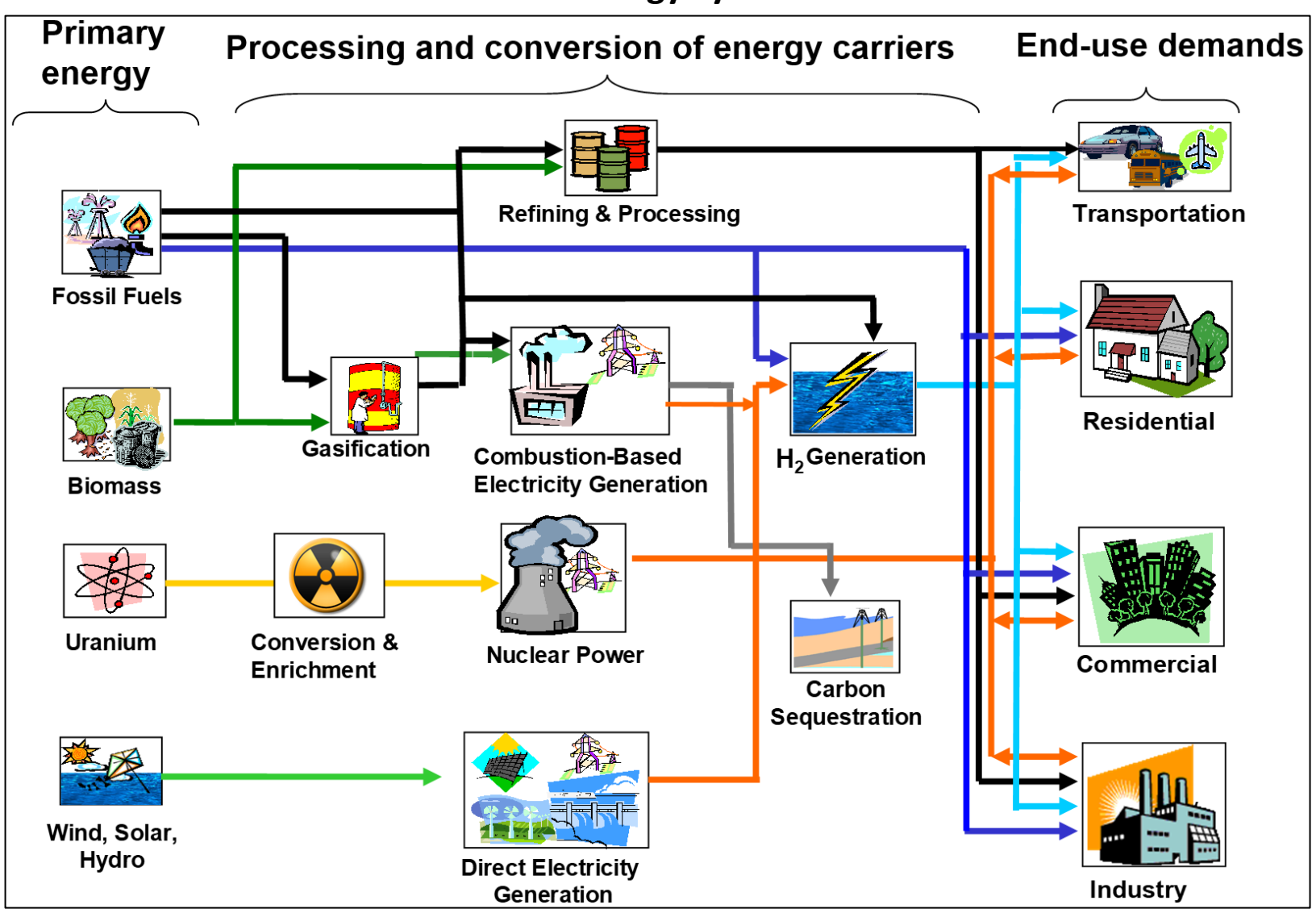


24 states + DC have specified GHG reduction targets



https://c2es.org

Background: Energy-air-climate-water nexus



Contributions to anthropogenic emissions:

GHGs:

- CO2 – 96%
- CH4 – 40%
- All GHGs – 82%

Air pollutants:

- NOx – 91%
- SO2 – 75%
- CO – 74%
- VOCs – 45%
- PM2.5 – 22% (direct)

In 2015, 41% US energy system freshwater withdrawals were for thermoelectric power plant cooling, nearly as much as for agriculture.

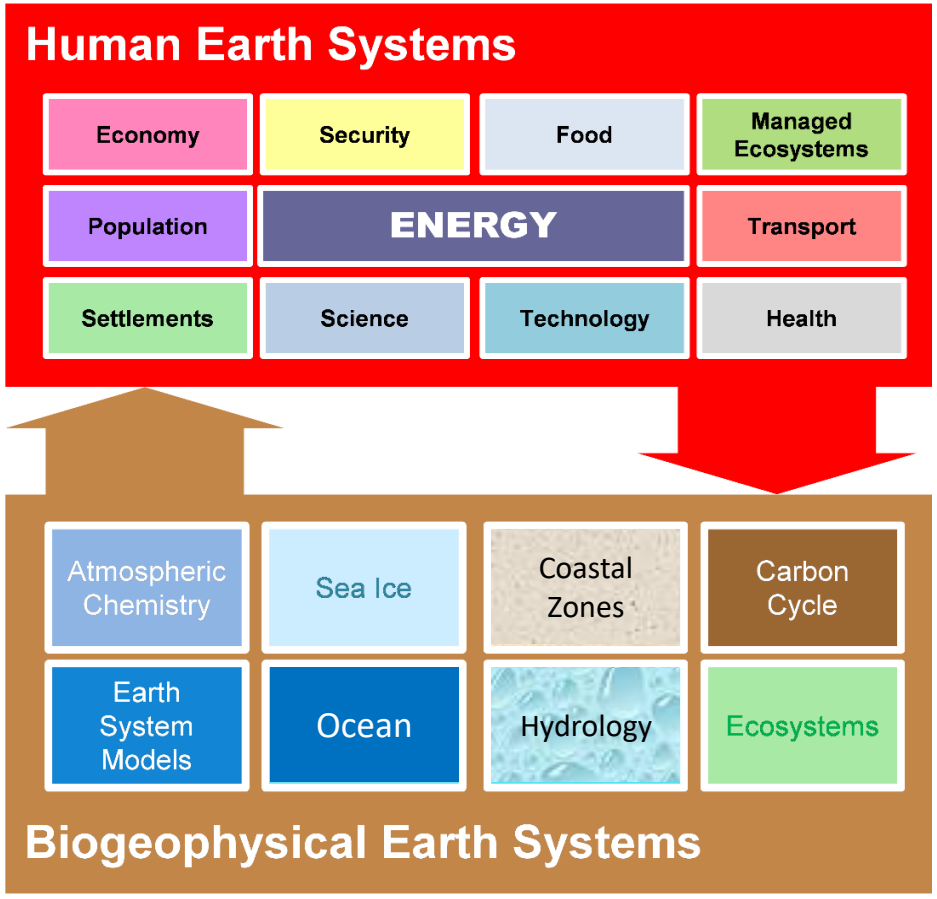
https://www.epa.gov/air-emissions-inventories/air-pollutant-emissions-trends-data
https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks
https://www.usgs.gov/mission-areas/water-resources/science/thermoelectric-power-water-use

Objective

- To address air quality and climate challenges simultaneously, states need planning tools that:
  - Focus on the entire energy system
  - Consider both GHGs and air pollutants
  - Capture cross-sector and cross-media dynamics
  - Support state-level inputs and outputs
  - Have temporal and spatial resolution suitable for decision-making:
    - air quality planning (often through 2030 or 2035)
    - climate planning (at least through 2030, but often through 2050 and beyond)

Approach: Integrated Assessment Models

- A rich set of models are already available (!)
- Integrated Assessment Models
  - 40 years of development
- Evolved to address the problem at hand:
  - 1980s - Projecting global CO2 emissions
  - 1990s - Projecting global GHG emissions
    - Developing global mitigation strategies
  - 2000s - Considering short-lived climate pollutants
    - Designing country mitigation strategies
  - 2010s - Understanding climate change impacts
    - Supporting state-level policies
  - 2015 and later…
    - Investigating the nexus of energy-air-climate-water-land-agriculture



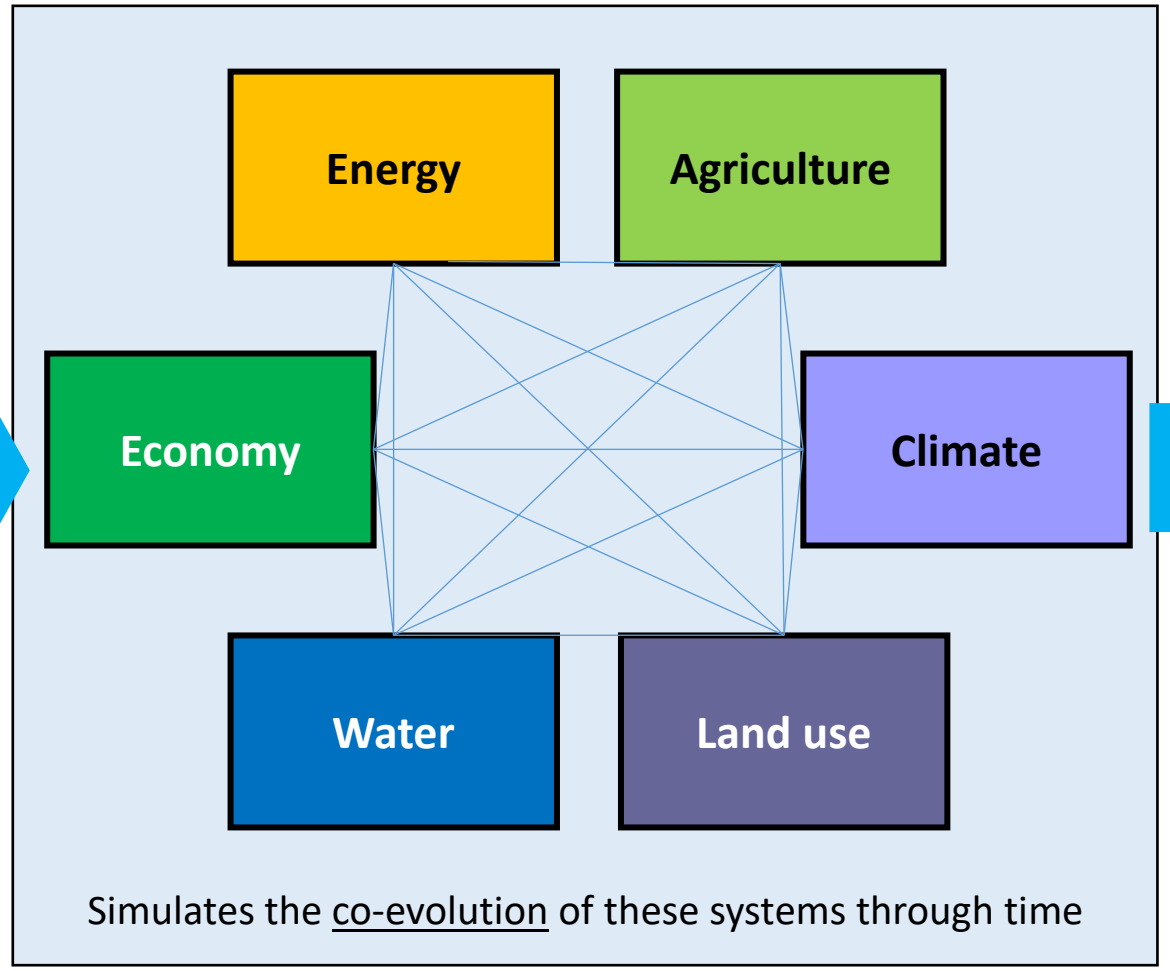
https://jgcri.github.io/gcam-doc/v4.3/overview.html

Approach: Global Change Analysis Model

Scenario assumptions

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

GCAM



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

GCAM documentation: http://jgcri.github.io/gcam-doc/

Approach: Global Change Analysis Model

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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, HFCs

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

GCAM documentation: http://jgcri.github.io/gcam-doc/

End points

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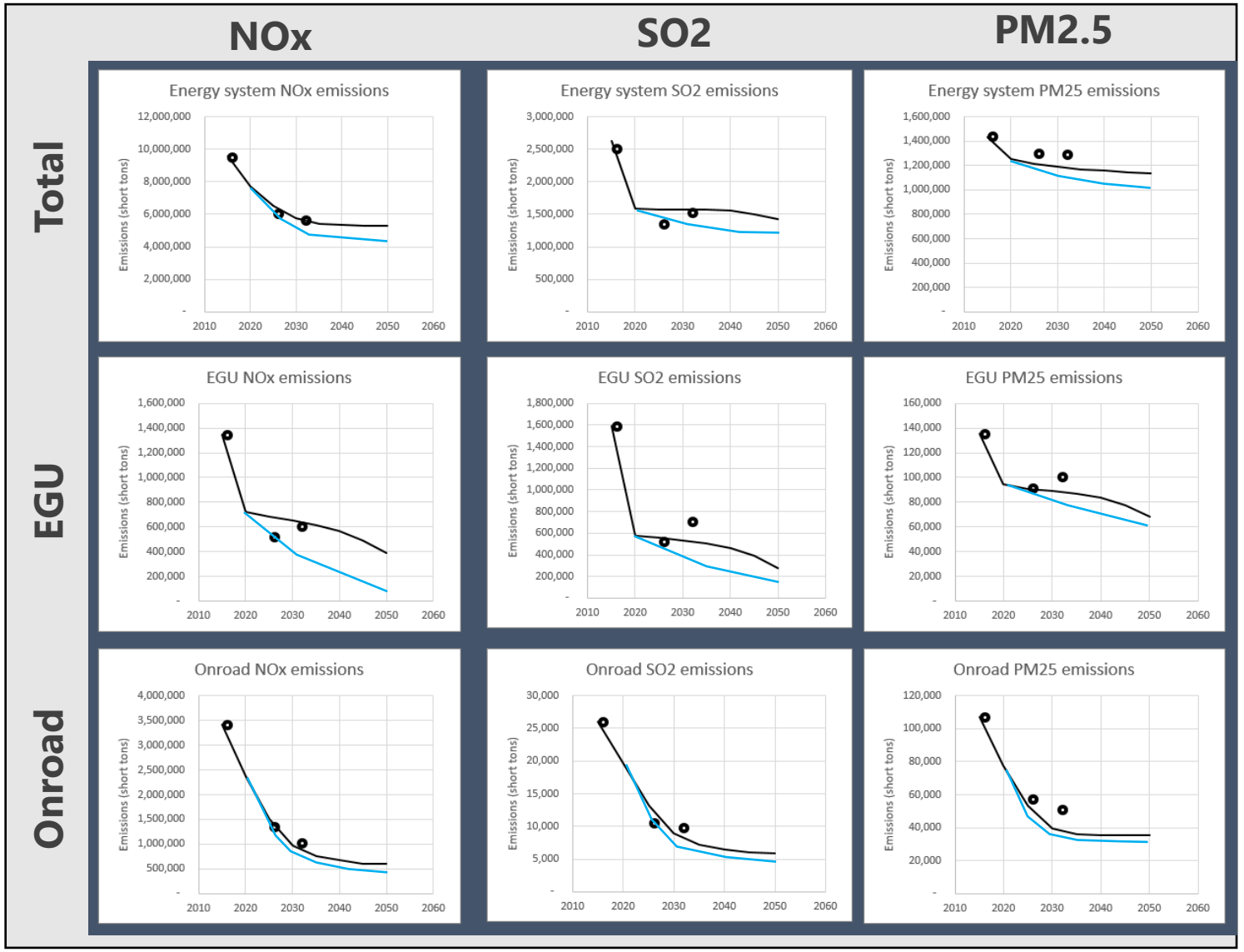
Environmental
- Air pollutant emissions
- Water use
- Health impacts

Approach: EPA GCAM activities

Updates

- Emission factors based on the National Emissions Inventory (NEI) and MOVES
- 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**; **Blue: Alternative Scenario**

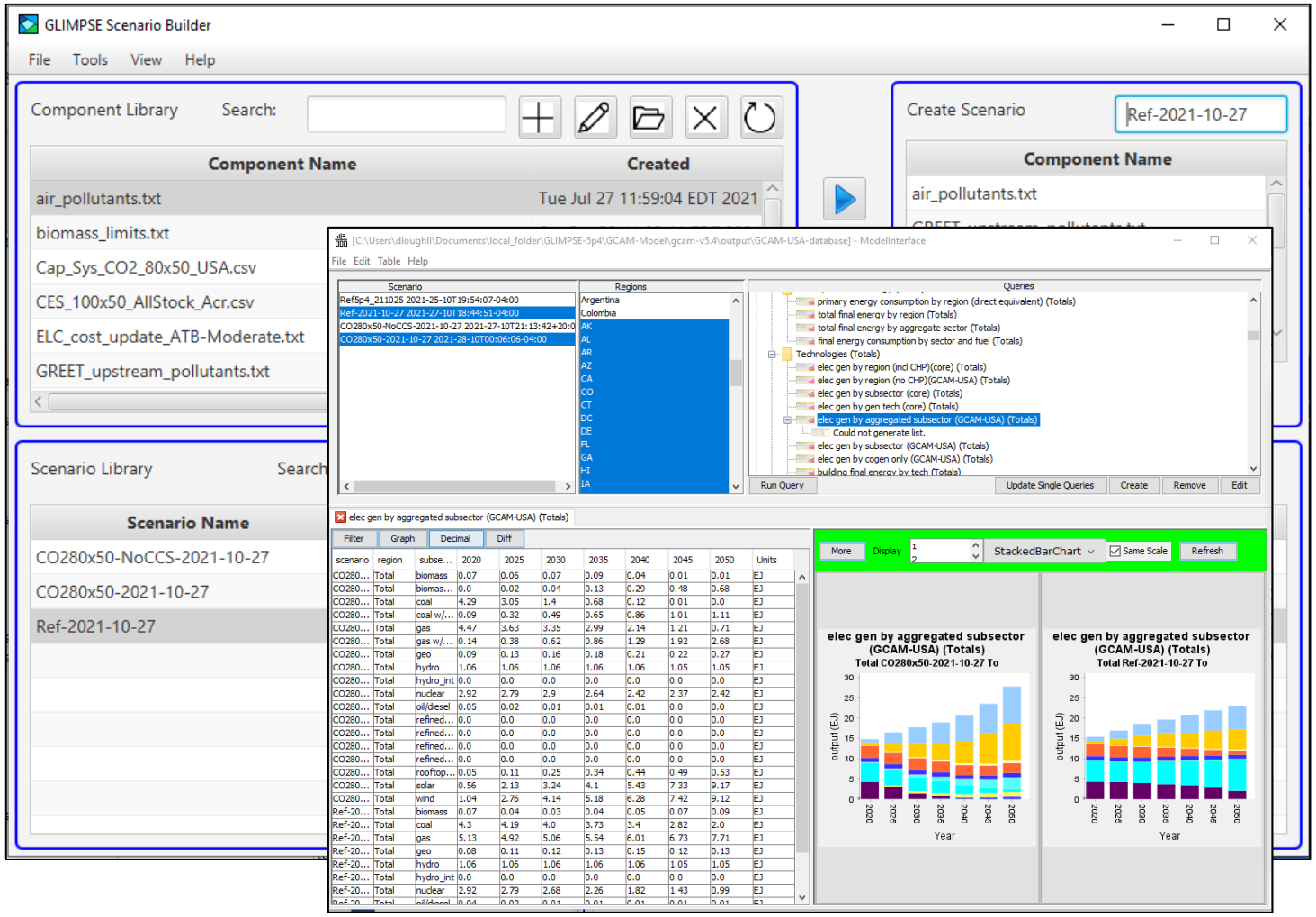
Approach: EPA GCAM activities

GLIMPSE: GCAM Long-term Interactive Multi-Pollutant Scenario Evaluator

Decision support system

- GLIMPSE graphical user interface for GCAM
- Supports exploratory analyses
  - Constructing scenarios
  - Managing GCAM execution
  - Visualizing results
- Facilitates policy evaluation
  - Technology market share targets
  - Technology and fuel subsidies or taxes
  - Pollutant taxes and caps
  - Technology availability

GLIMPSE



https://www.epa.gov/air-research/glimpse-computational-framework-supporting-state-level-environmental-and-energy

EPA United States Environmental Protection Agency

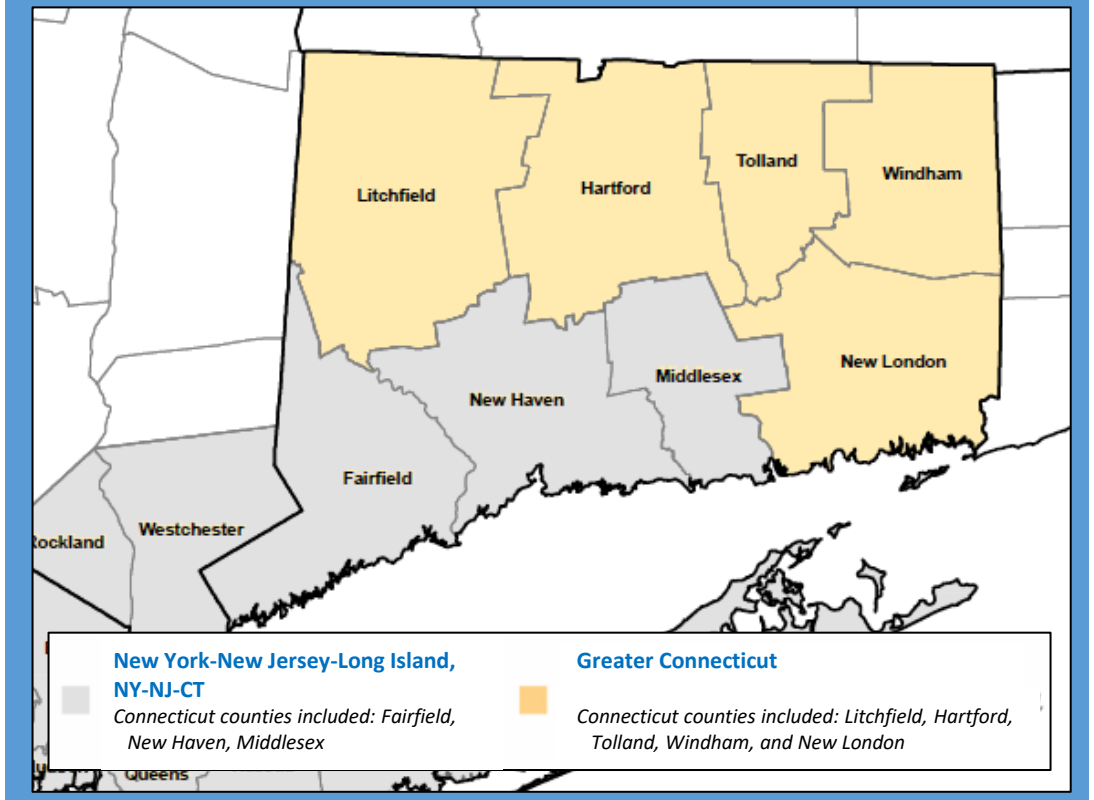
Illustrative Application

Exploring the emission reduction potential of energy efficiency, renewable electricity, and vehicle electrification in Connecticut (CT)

Illustrative application: Background

- All CT counties fall in one of two nonattainment areas that exceed the 2015 O_3 8-hr NAAQS
- CT and the surrounding states (DE,MA,MD,ME, NJ,NY,PA,RI, and VA) have adopted GHG reduction goals
  - CT: 80% reduction from 2001 levels by 2050
- How could GHG reduction measures such as energy efficiency, renewable energy, and vehicle electrification targets help CT reduce GHG and air pollutant emissions?

All CT counties designated in "nonattainment" of the 2015 O_3 NAAQS as of Feb. 2022



Illustrative application: 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

Hypothetical EE/RE/VE Case (*EE/RE/VE*)

Adds for Connecticut:

Energy efficiency (EE):

- From 2025, only high efficiency options are available for space heating, water heating, lighting, and cooking

Clean Energy Standard (RE):

- By 2035, 90% of in-state electricity production must be from "clean" sources

Vehicle electrification (VE):

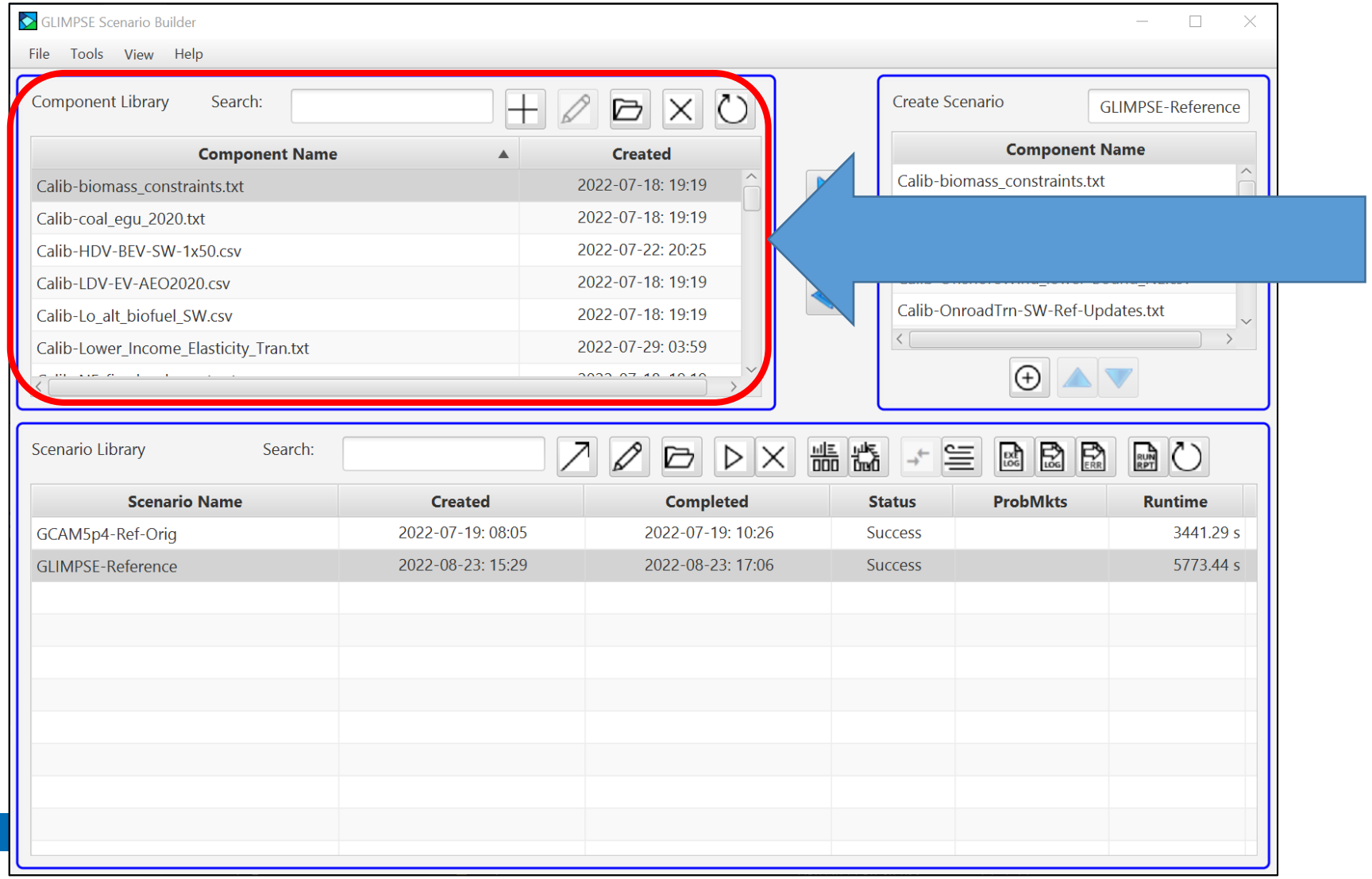
- By 2035, onroad passenger vehicle sales reach 90% electric
- By 2045, onroad freight vehicle sales reach 90% electric

Questions:

- What are the trends for GHG and air pollutant emissions under the *Ref* scenario?
- How do these trends change under the *EE/RE/VE* scenario?

Illustrative application: Demonstration

GLIMPSE Scenario Builder

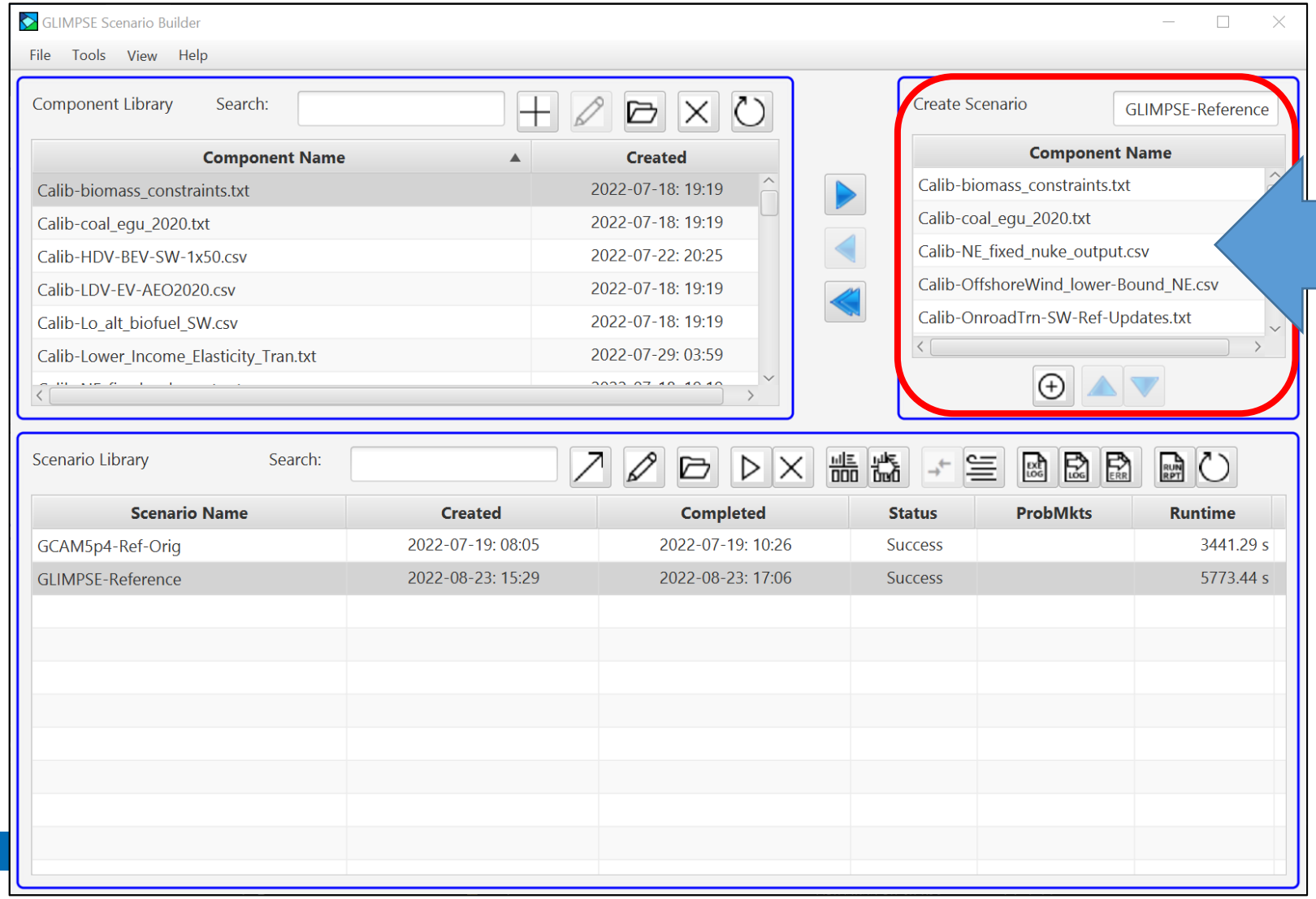


The Component Library Includes the "building blocks" of scenarios:

- **Calibrations**
- **Policies**
- **Alternative assumptions**

Illustrative application: Demonstration

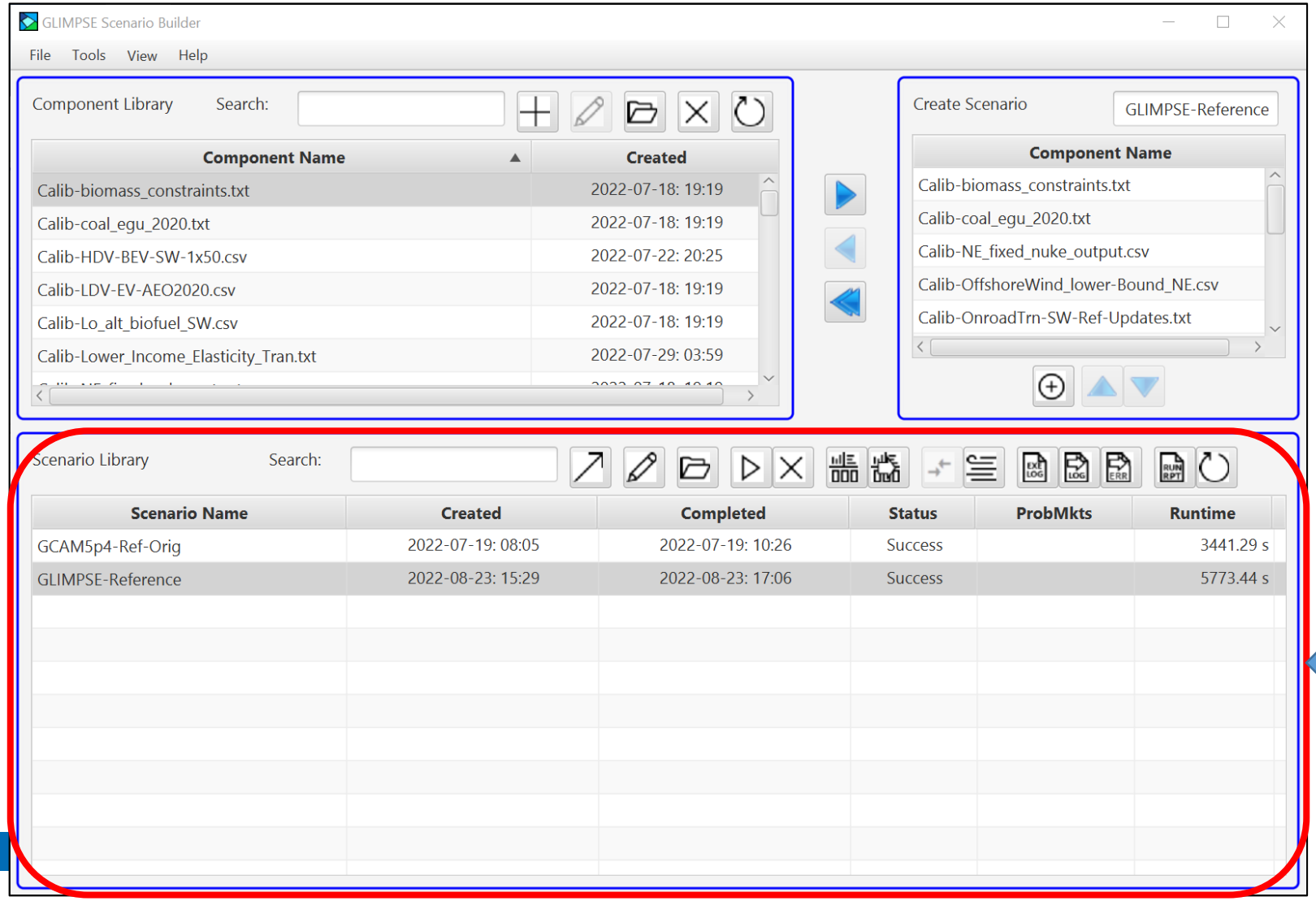
GLIMPSE Scenario Builder



We combine these to construct scenarios

Illustrative application: Demonstration

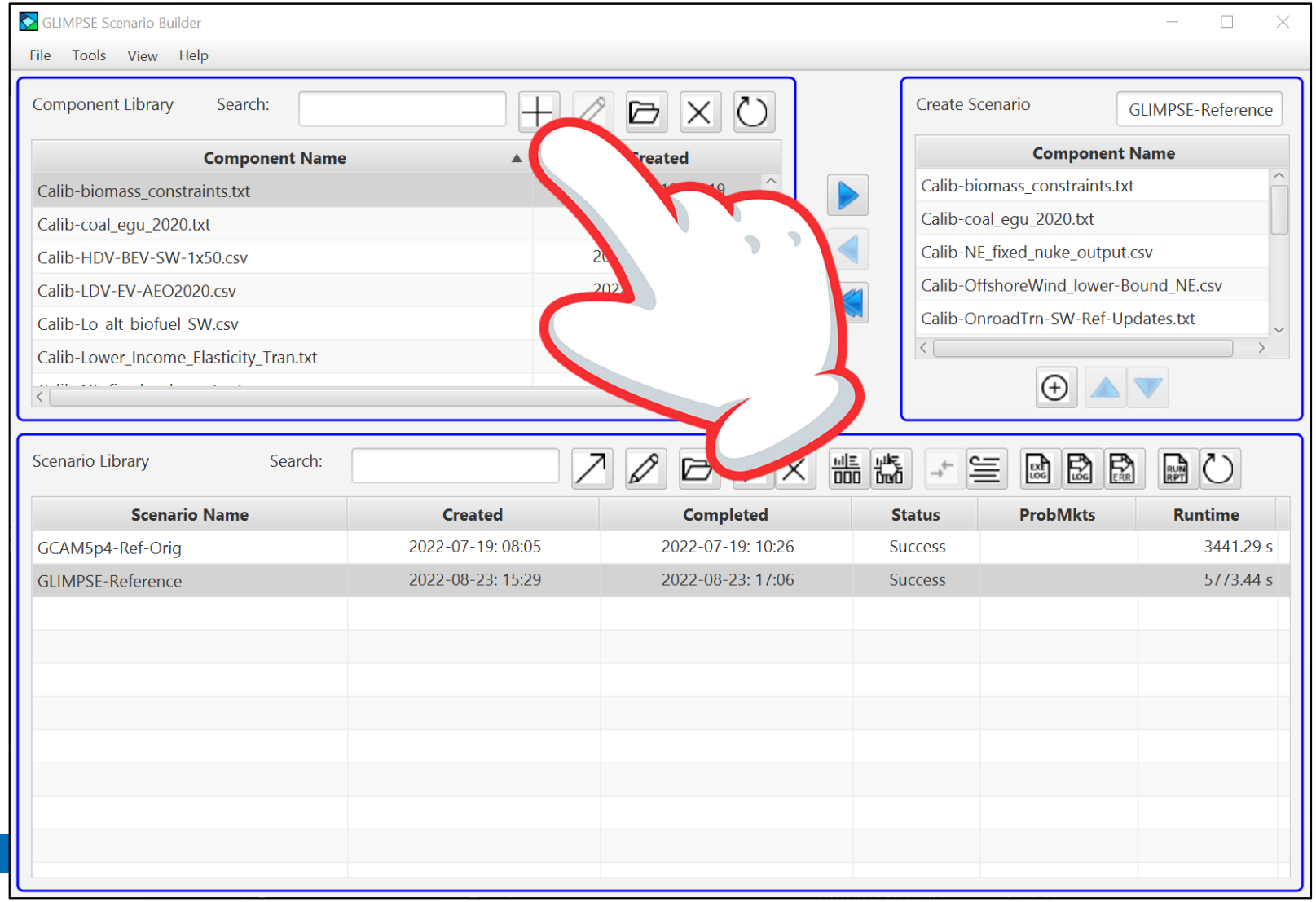
GLIMPSE Scenario Builder



Library of scenarios

Illustrative application: Demonstration

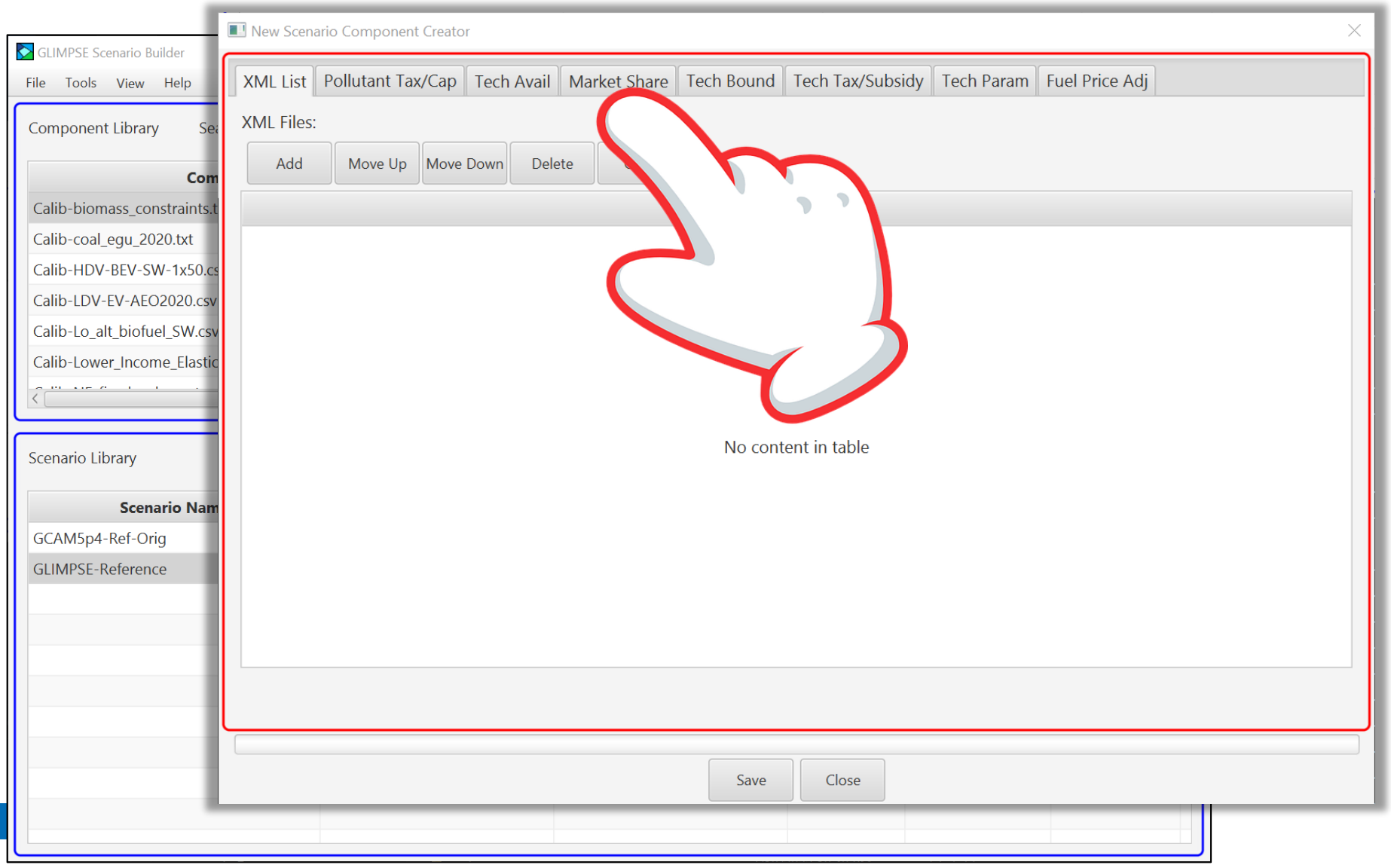
GLIMPSE Scenario Builder



Creating a new Scenario Component…

Illustrative application: Demonstration

New Scenario Component Creator

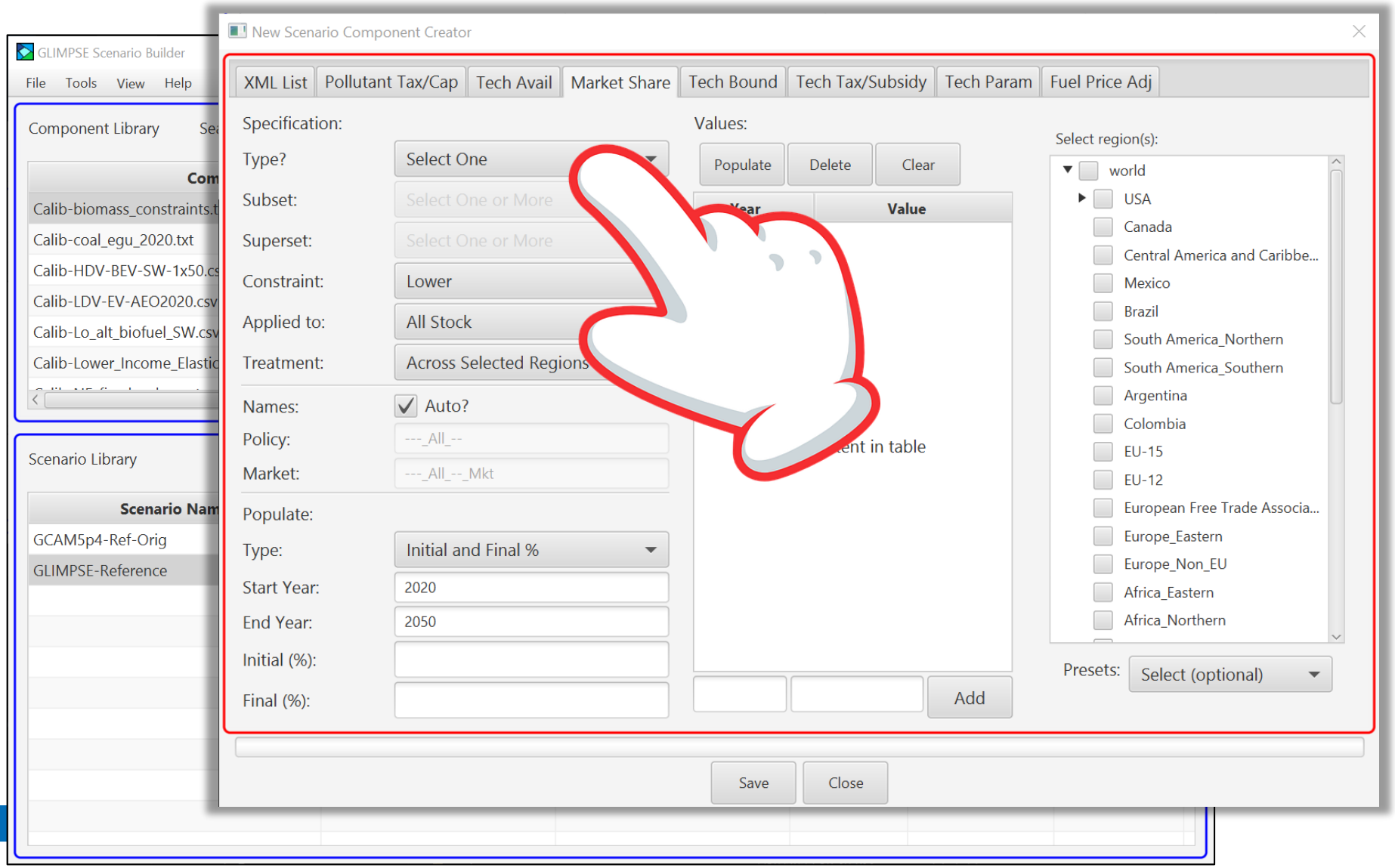


Component options include:

- Pollutant taxes and caps
- Technology availability
- Market share targets
- Technology taxes and subsidies
- Fuel price shocks…

Illustrative application: Demonstration

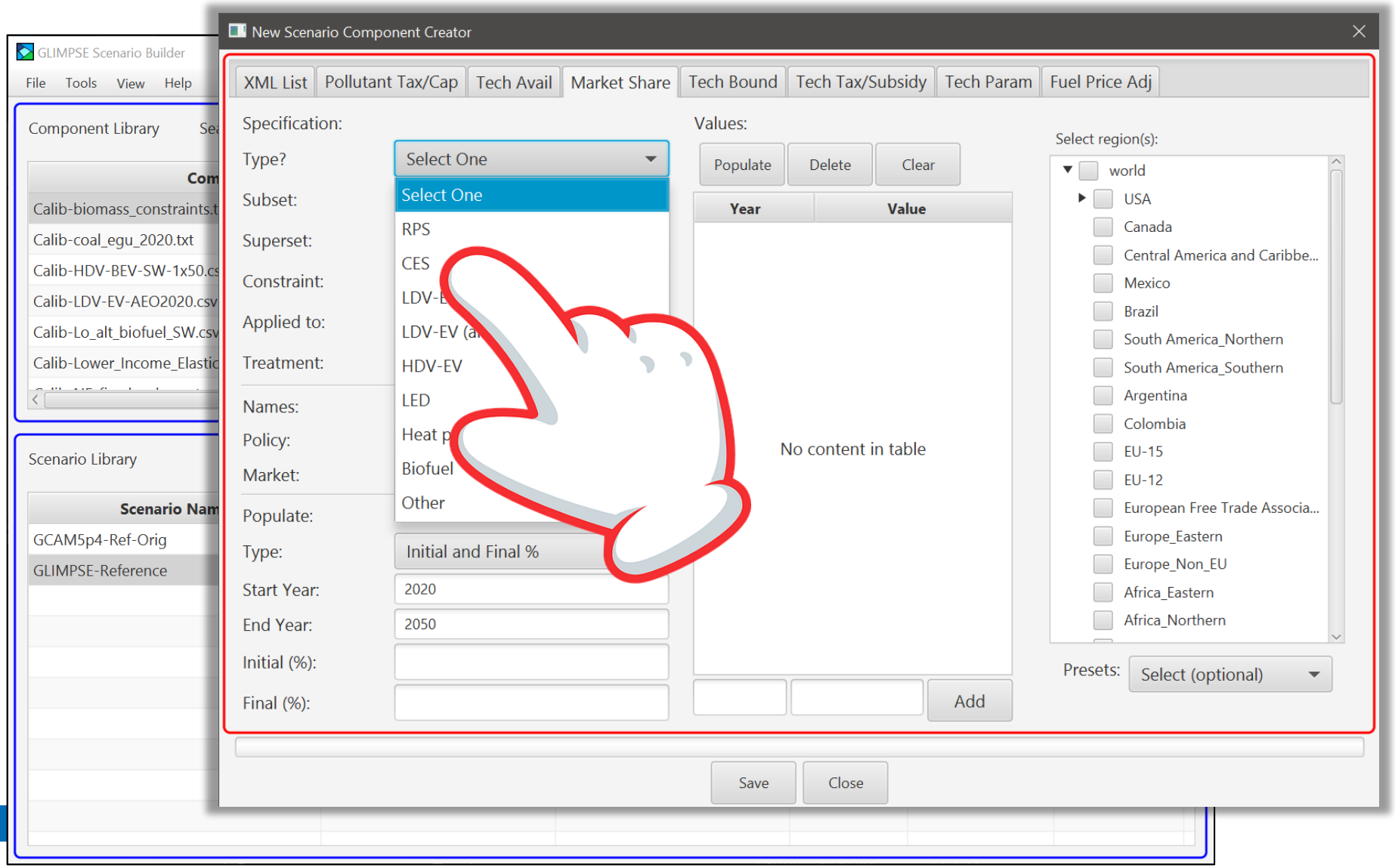
New Scenario Component Creator



Specifying a Clean Energy Standard (CES)

Illustrative application: Demonstration

New Scenario Component Creator



Specifying a Clean Energy Standard (CES)

Illustrative application: Demonstration

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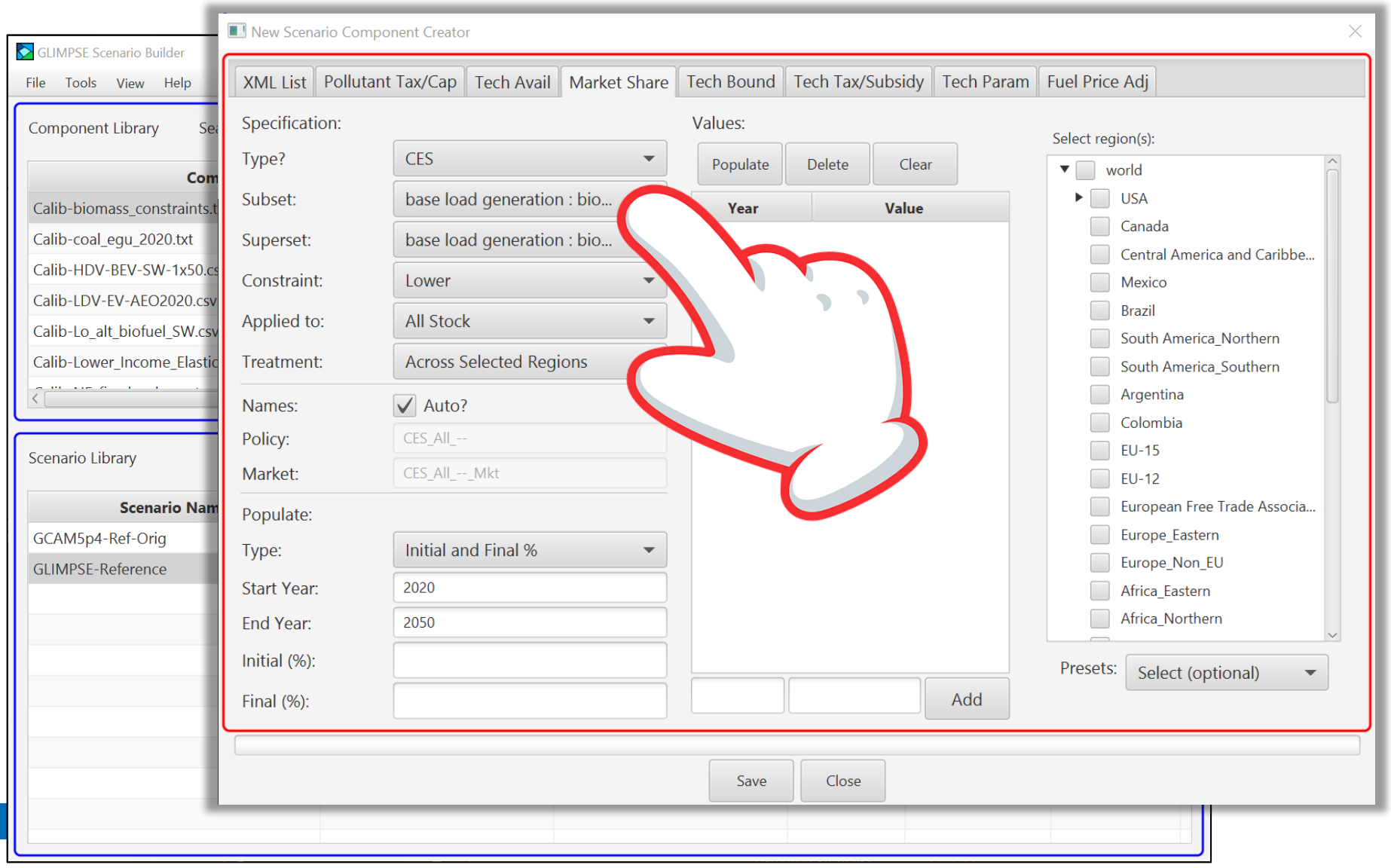

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Illustrative application: Demonstration

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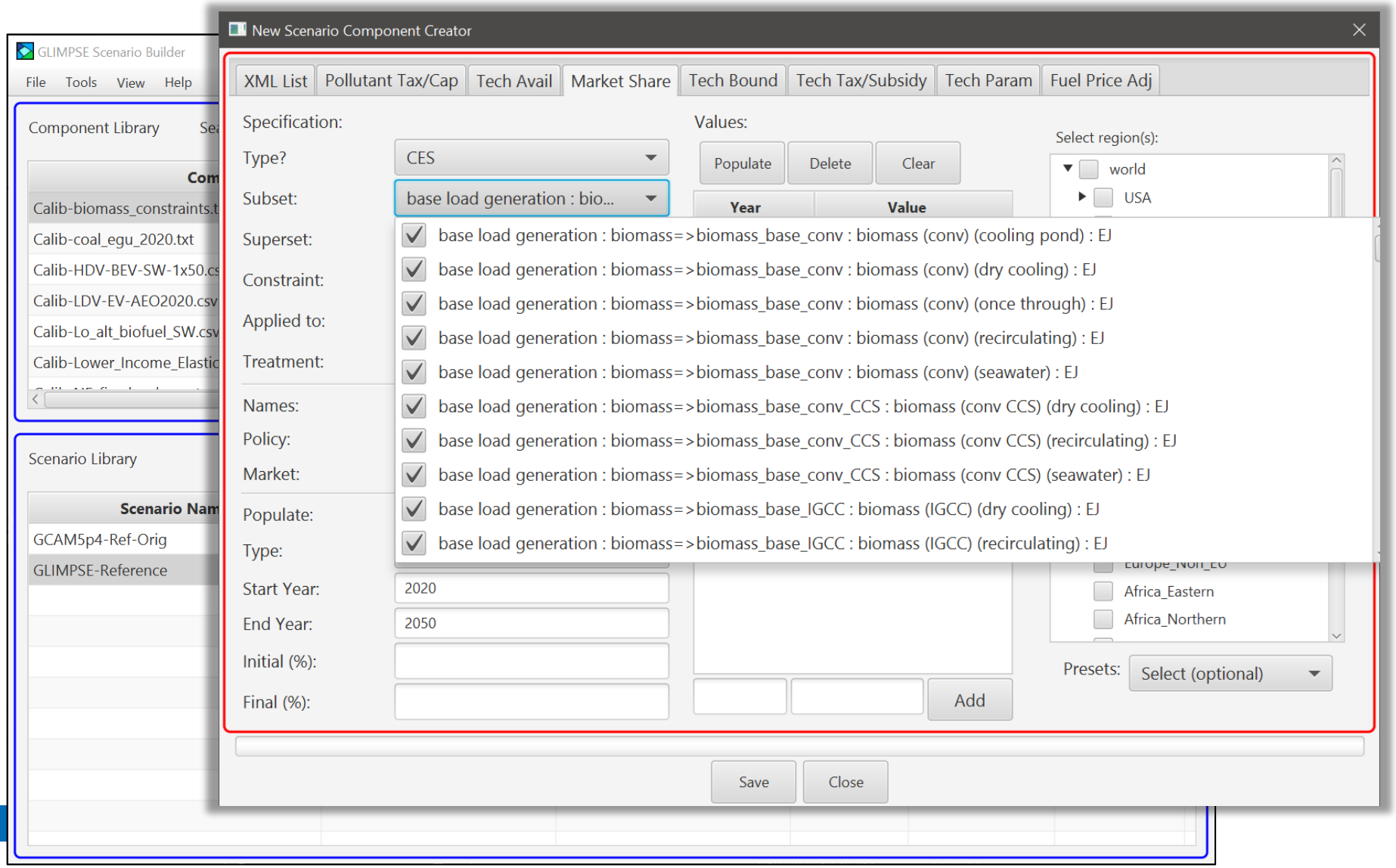

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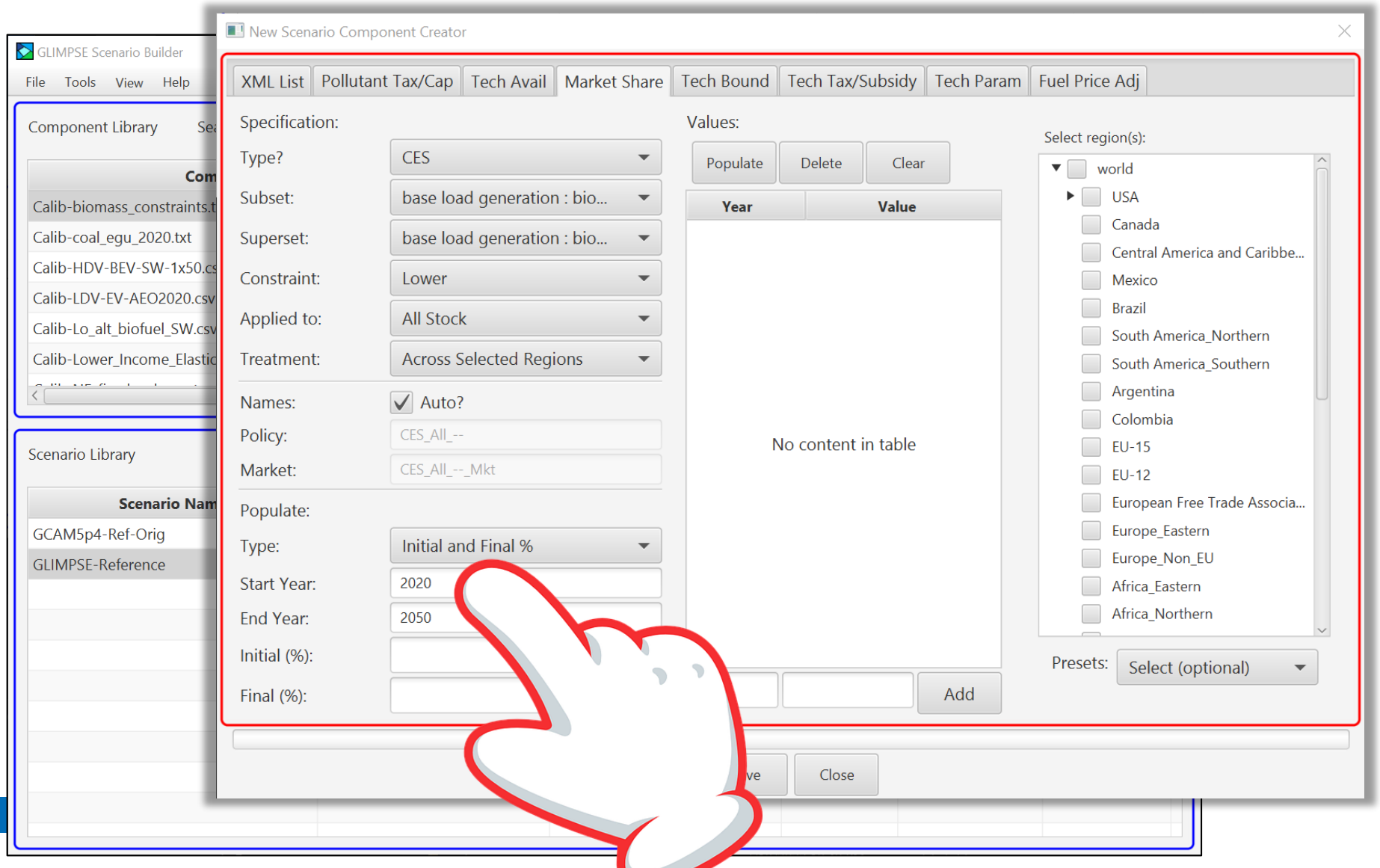

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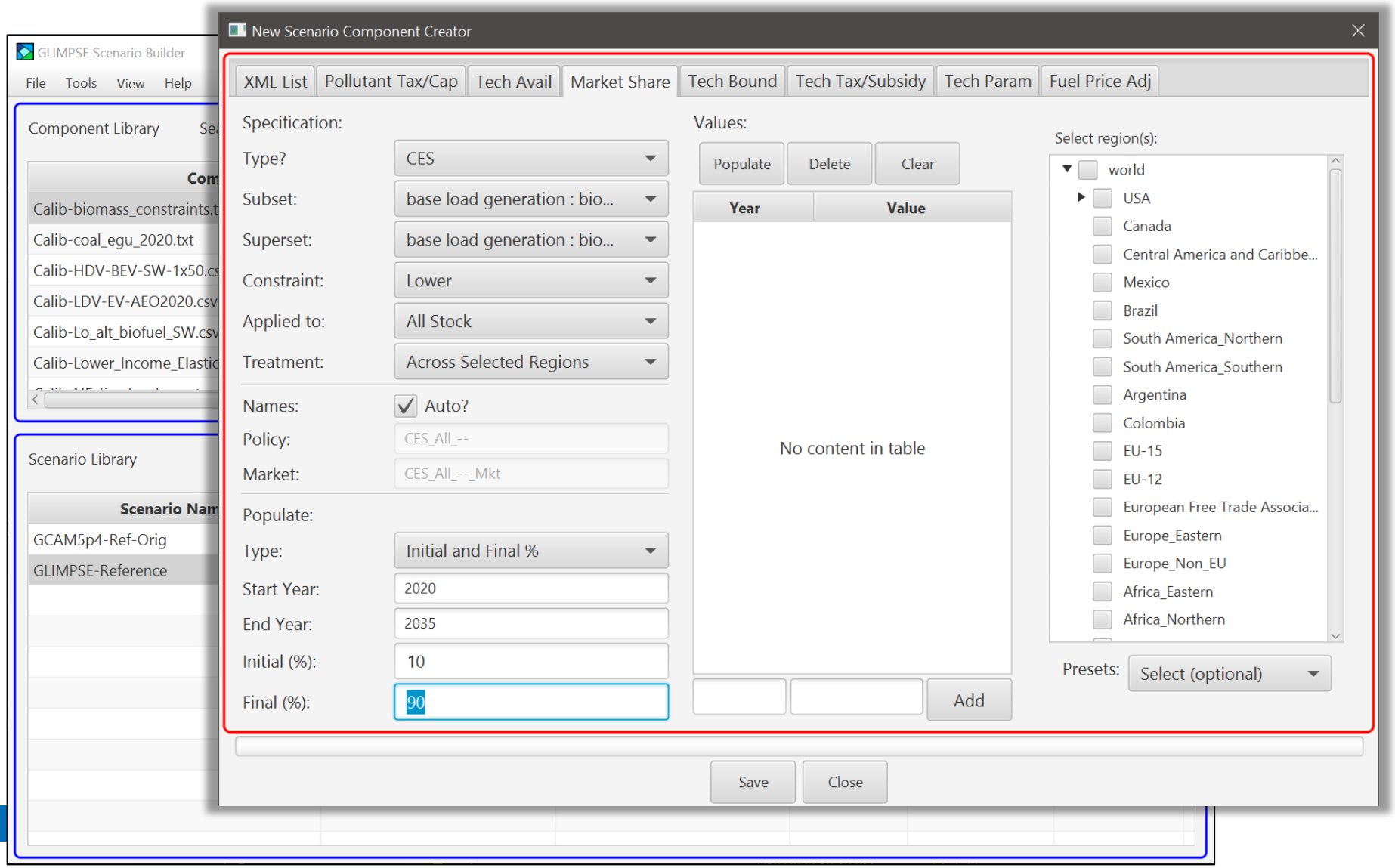

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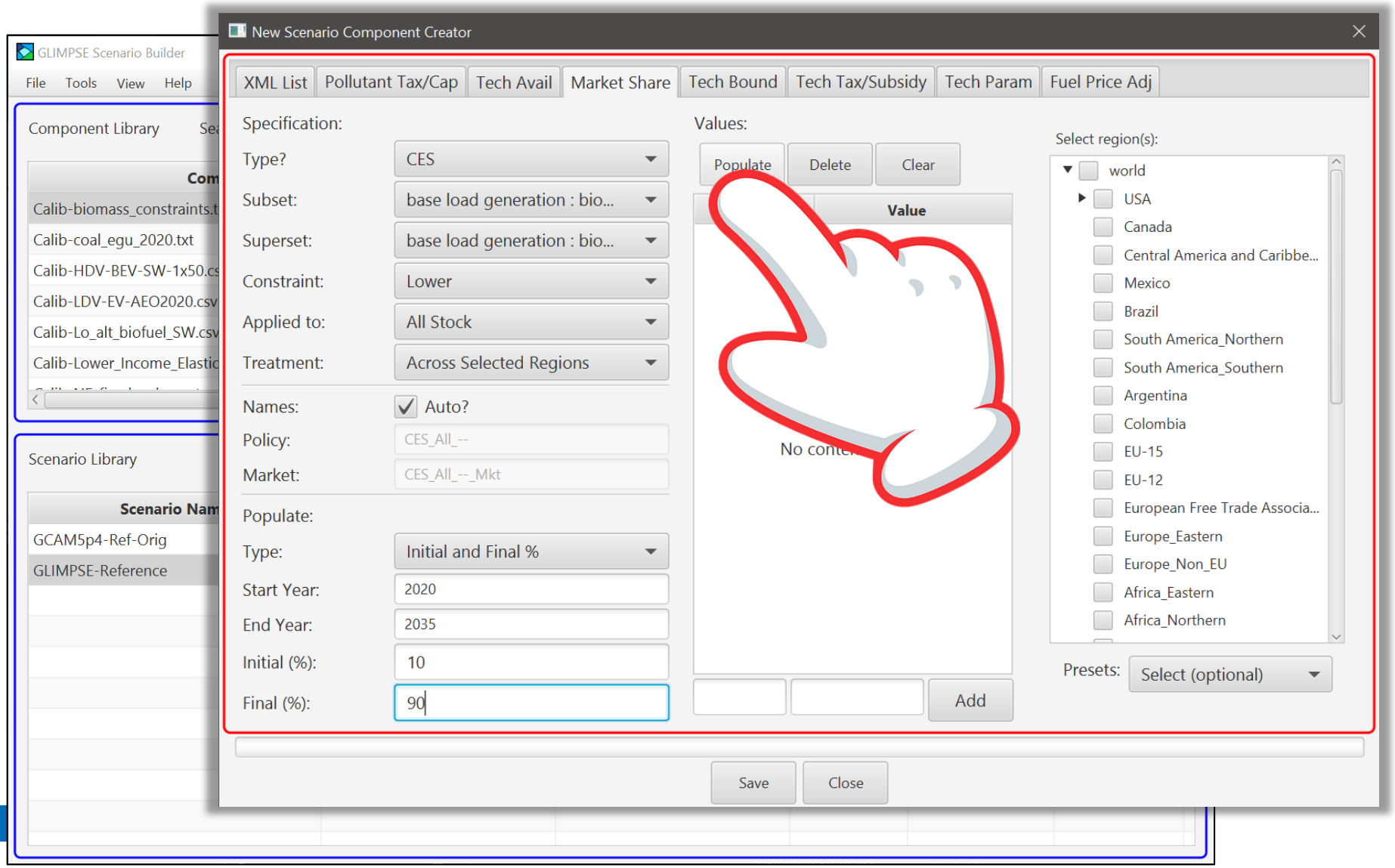

Specifying a Clean Energy Standard (CES)

Illustrative application: Demonstration

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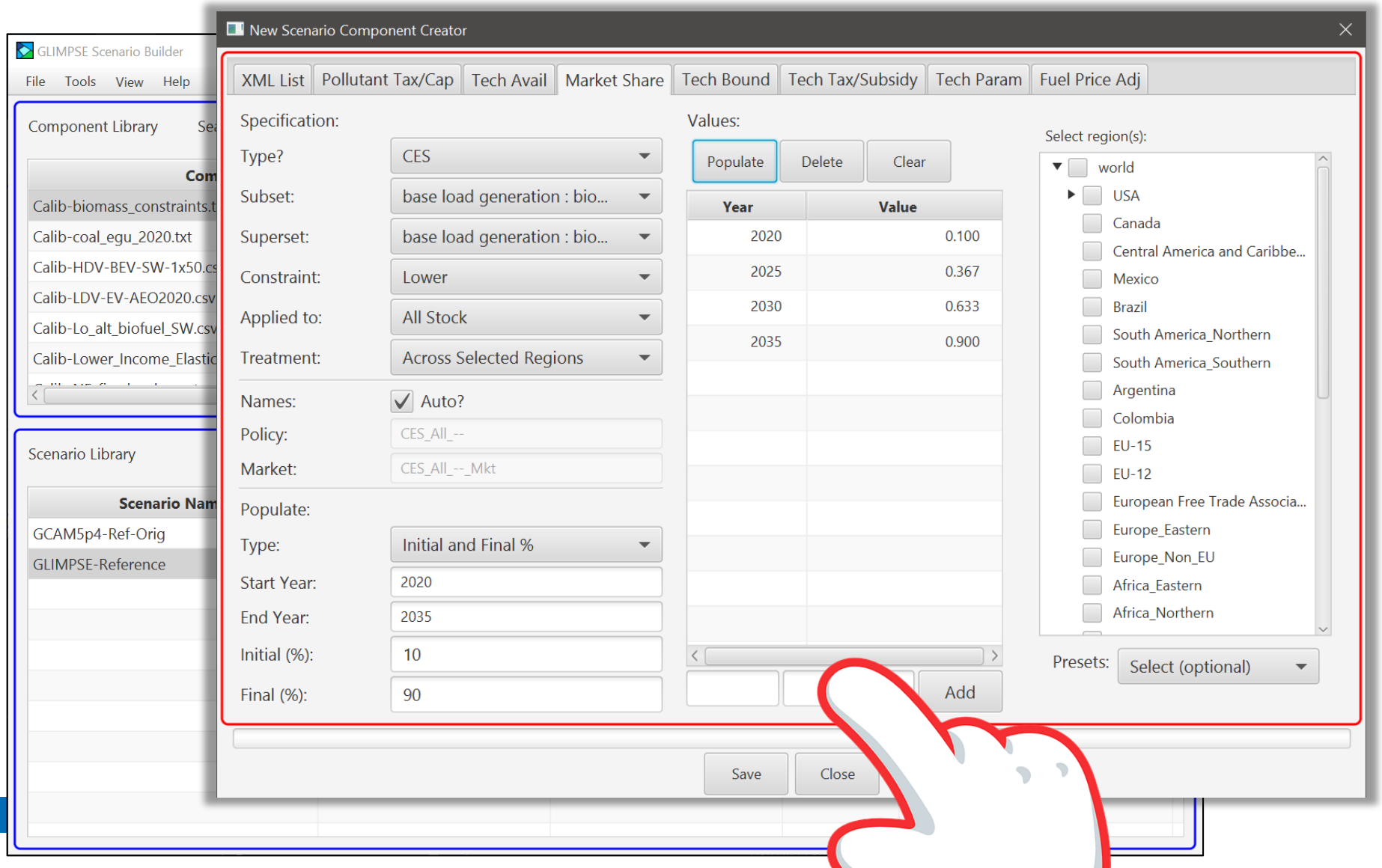

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Illustrative application: Demonstration

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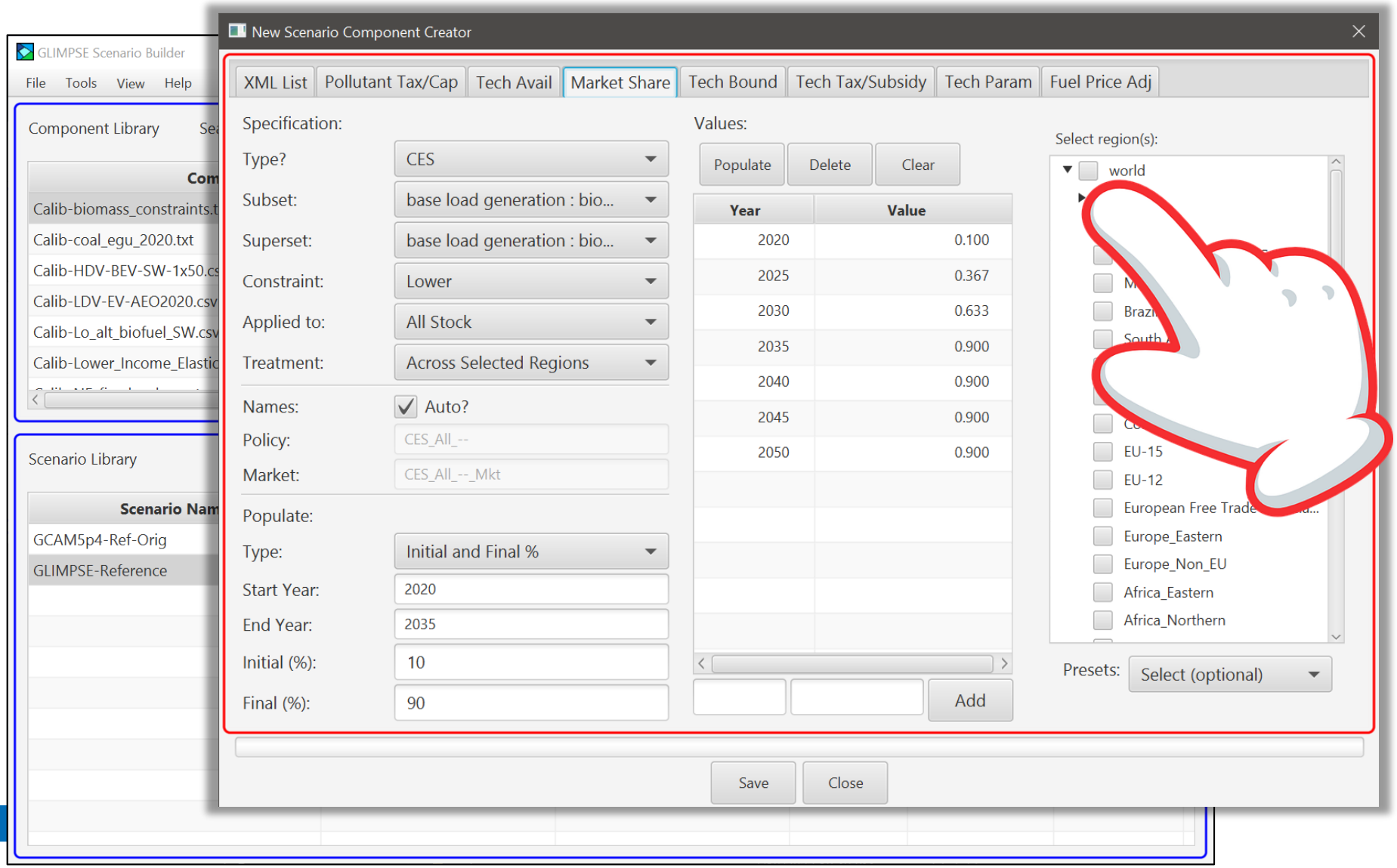

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Illustrative application: Demonstration

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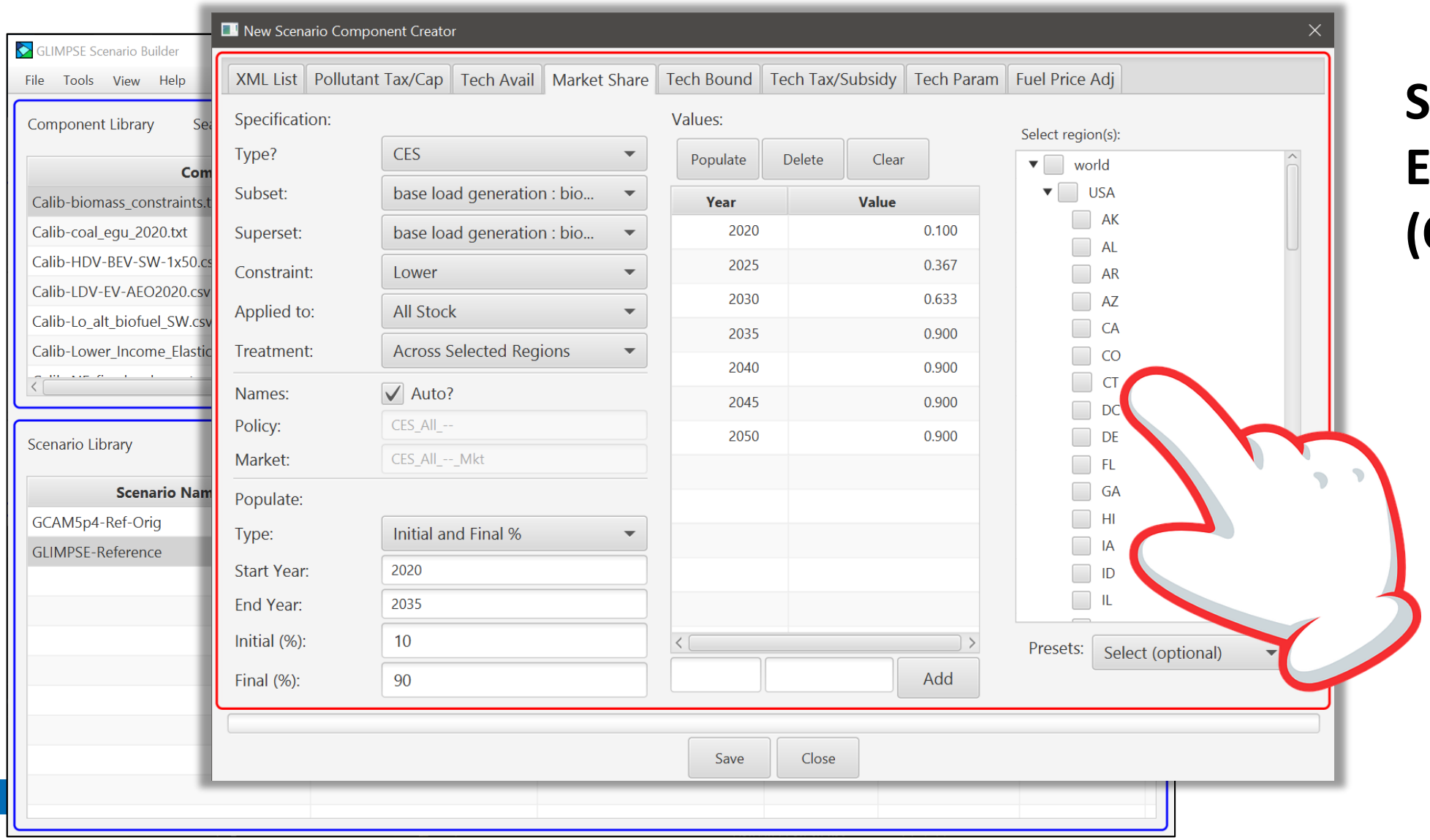

Specifying a Clean Energy Standard (CES)

Illustrative application: Demonstration

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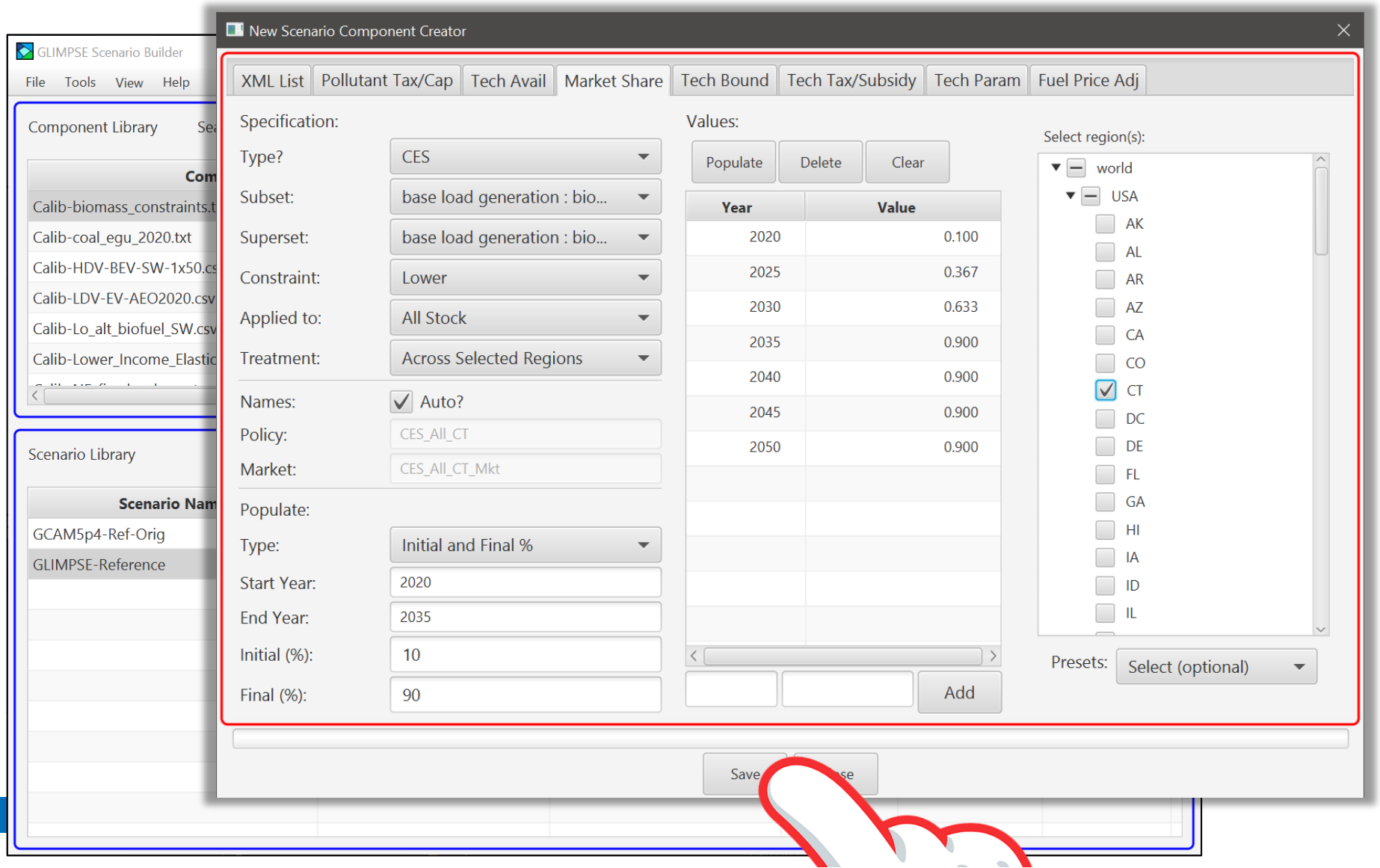
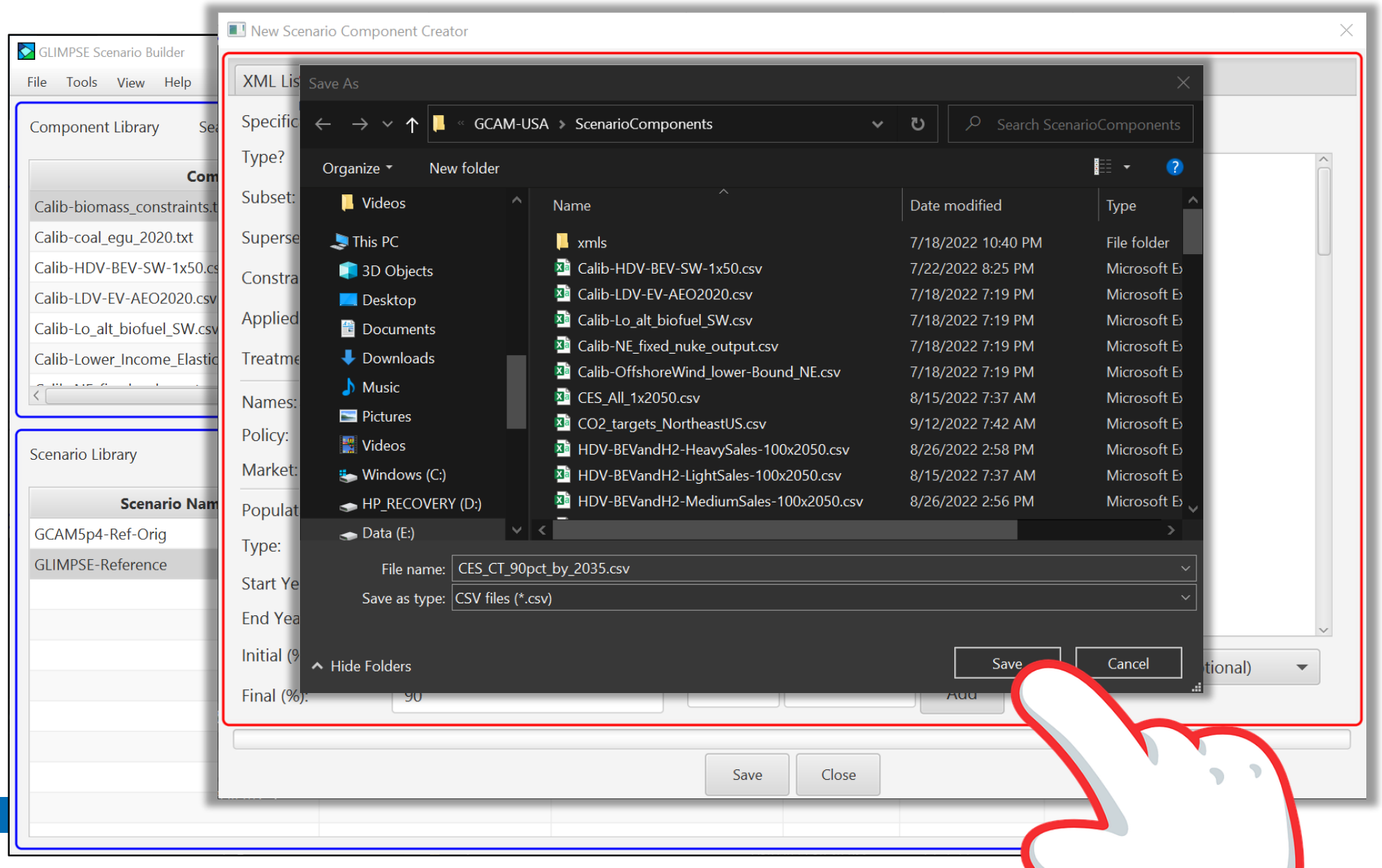


Saving the new component

Illustrative application: Demonstration

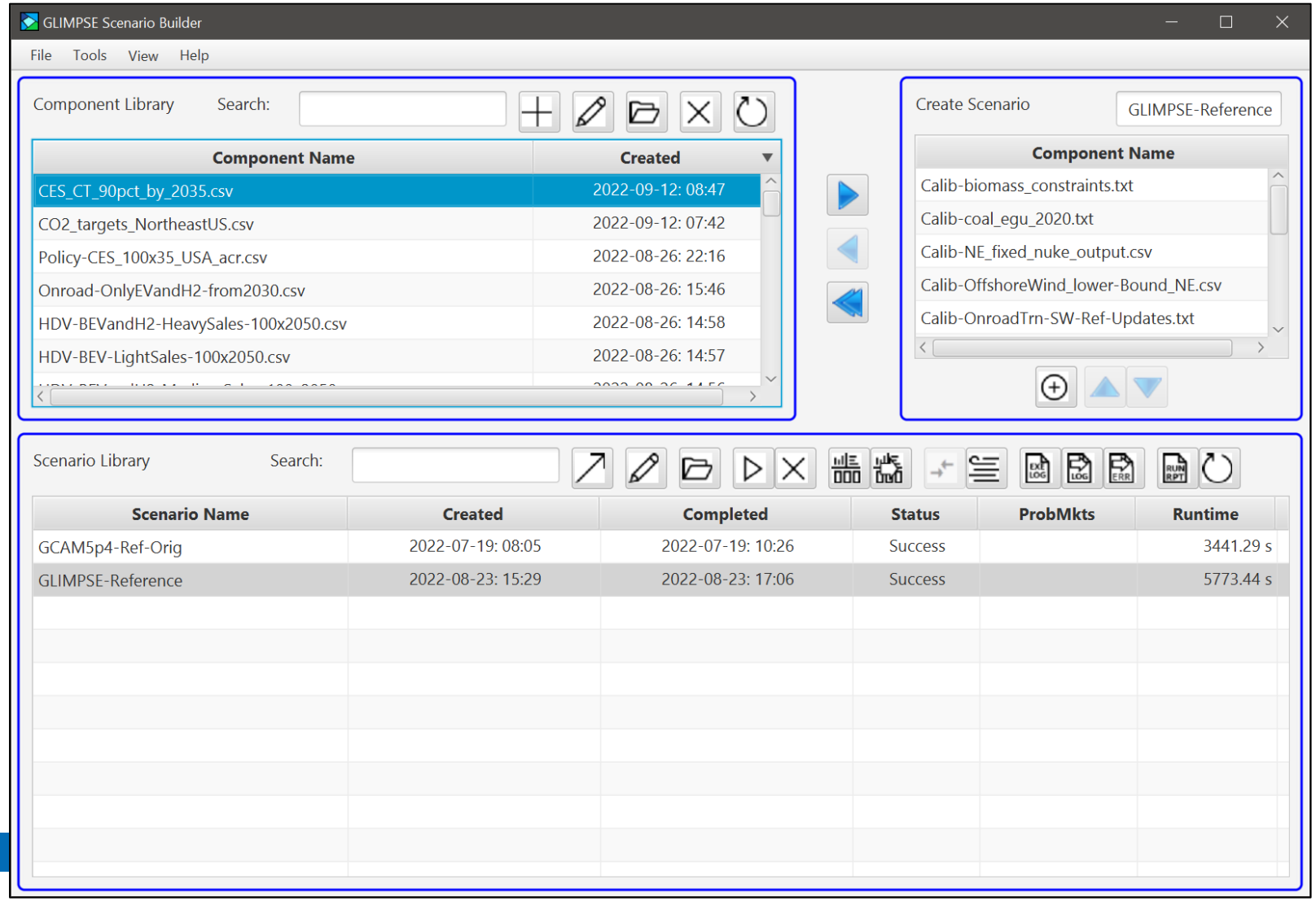
New Scenario Component Creator



Saving the new component

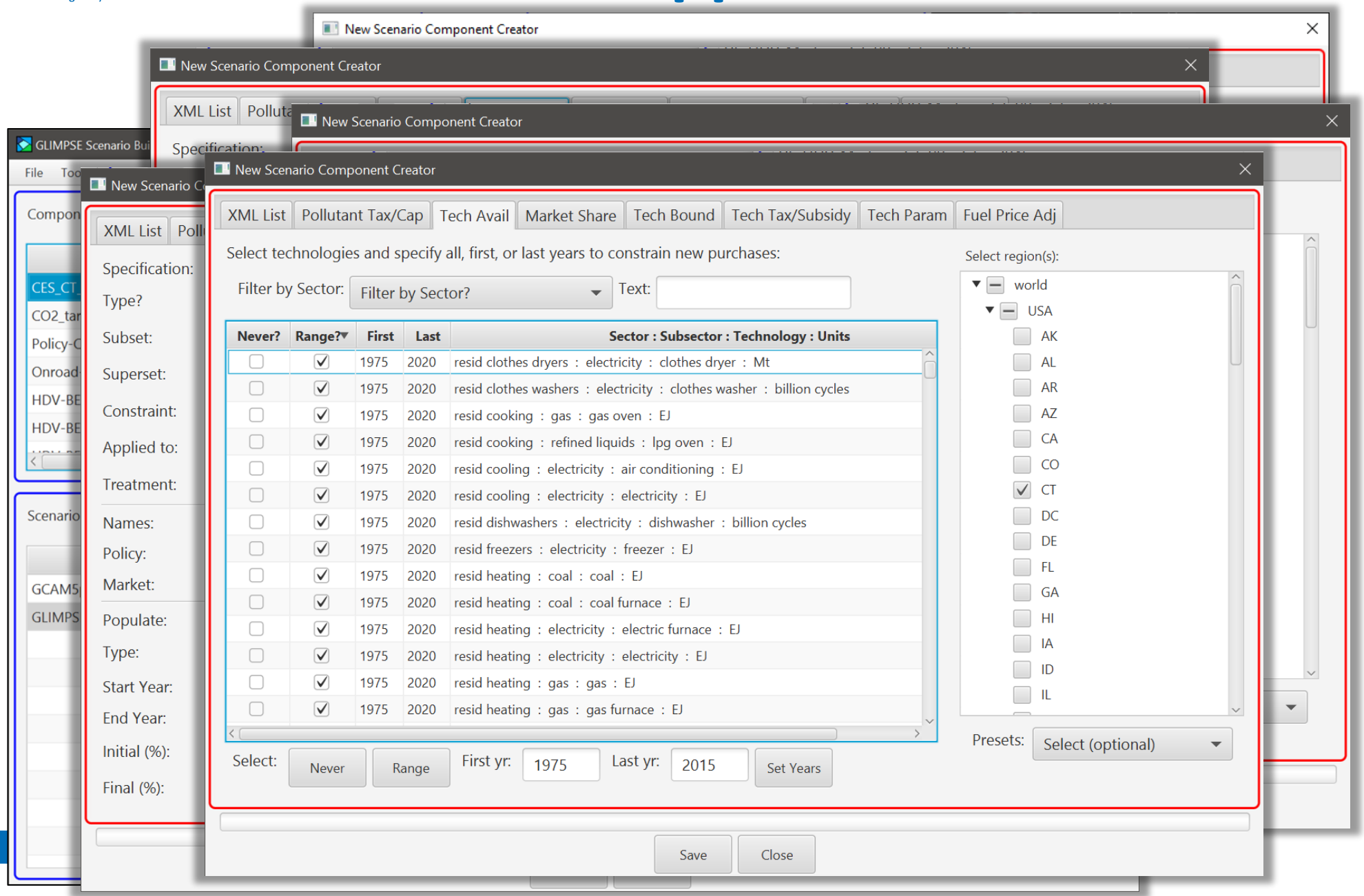
Illustrative application: Demonstration

GLIMPSE Scenario Builder



The new component is now in the library

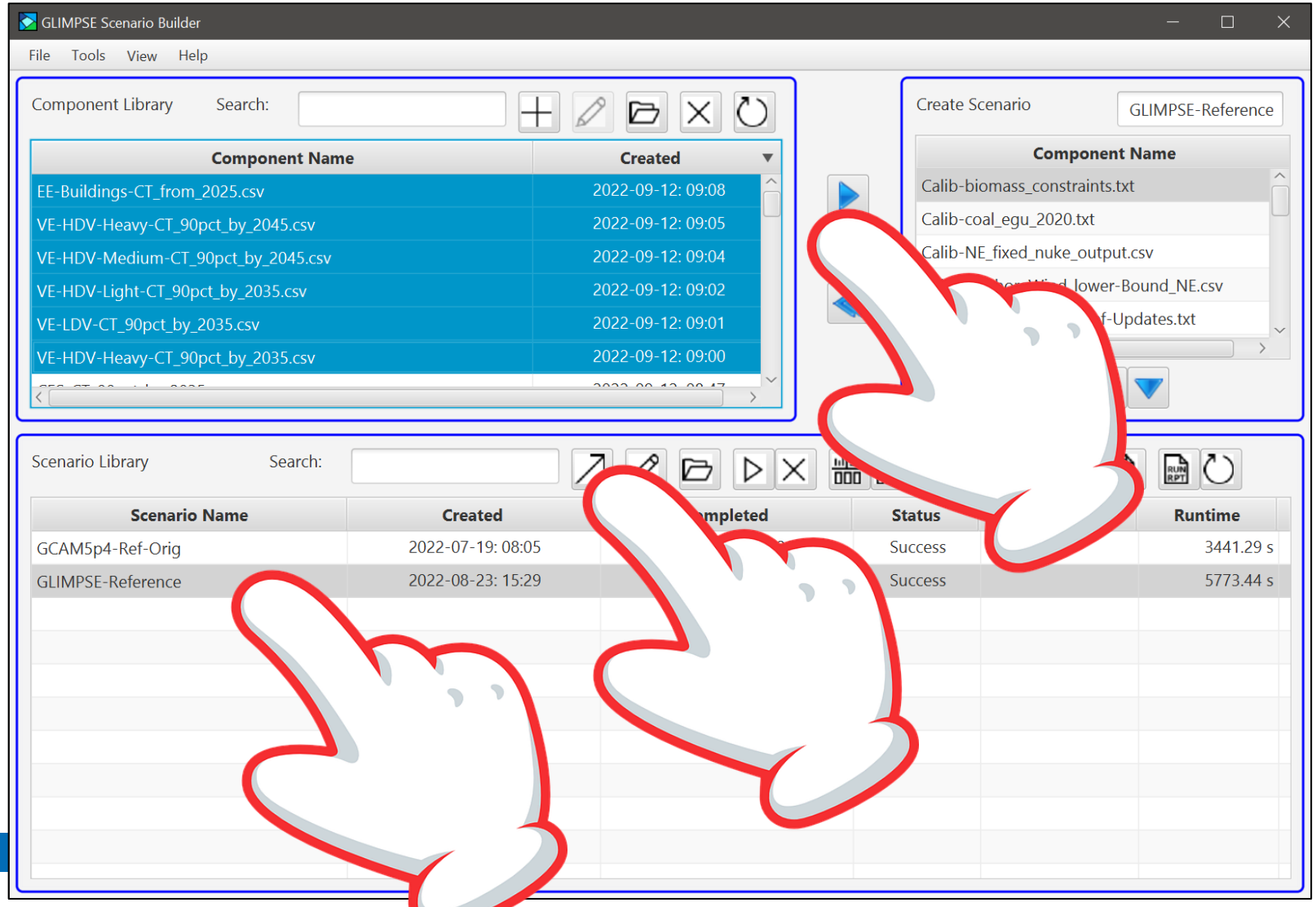
Illustrative application: Demonstration



Specifying additional components

Illustrative application: Demonstration

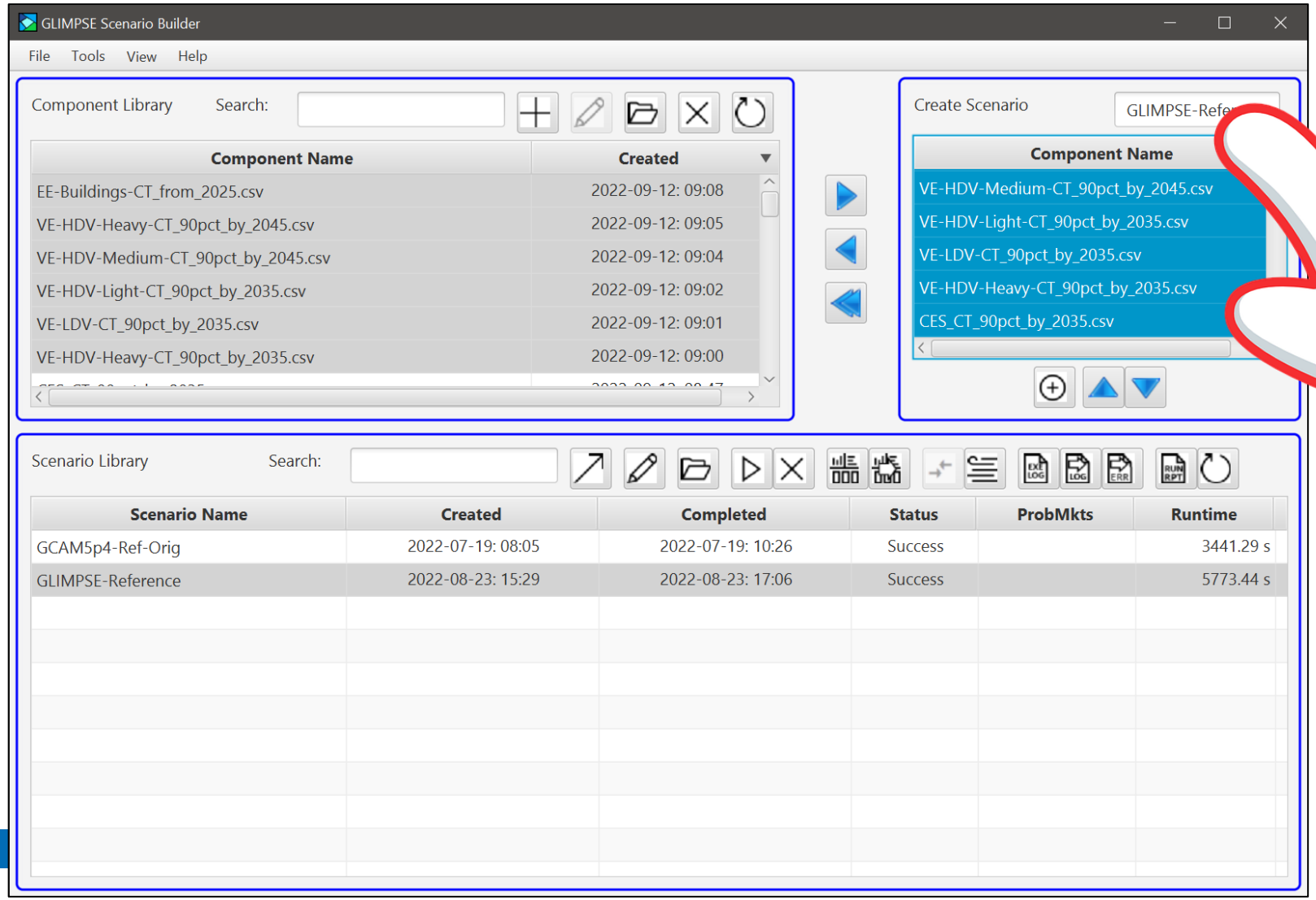
GLIMPSE Scenario Builder



Constructing a scenario

Illustrative application: Demonstration

GLIMPSE Scenario Builder



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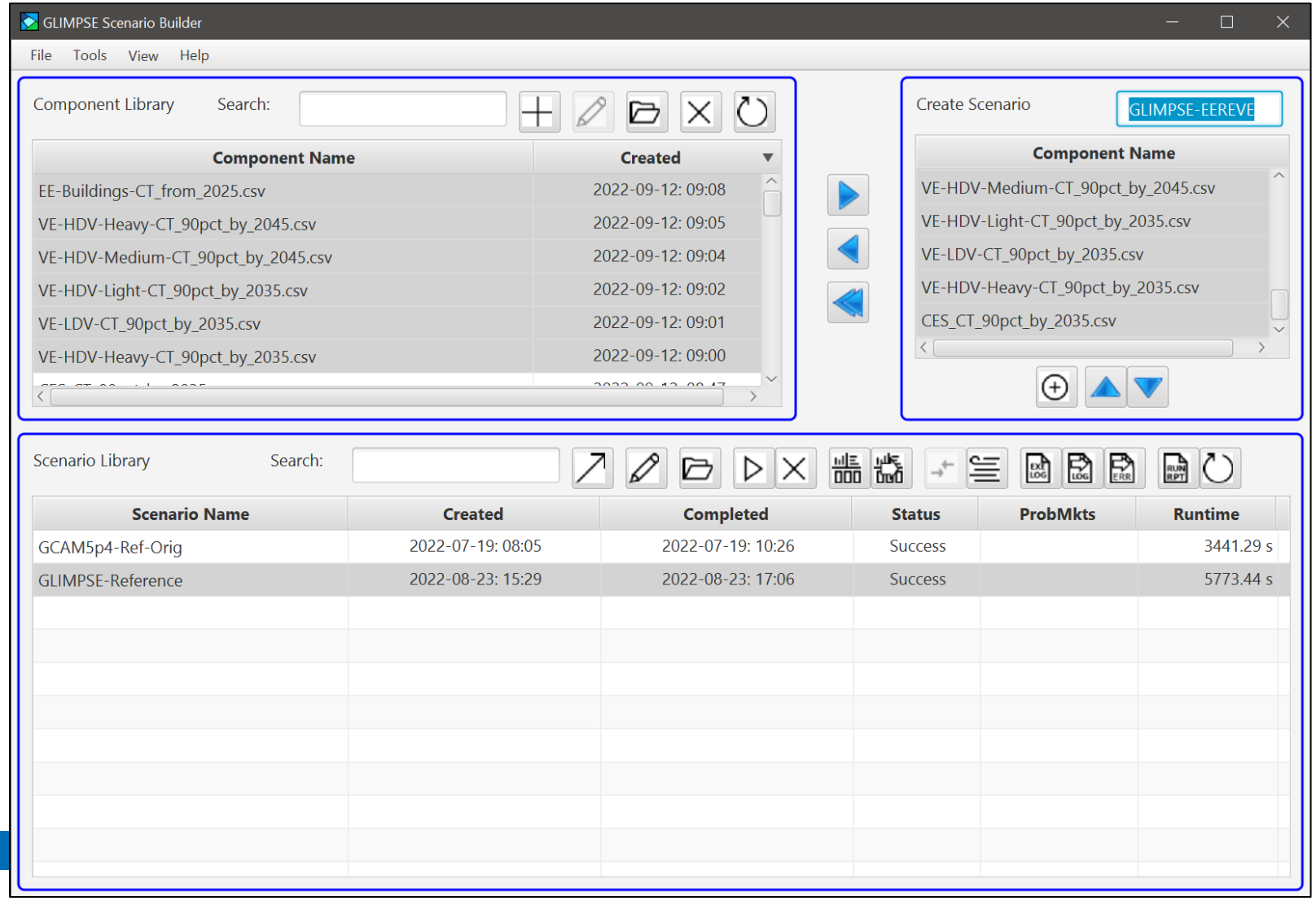

Constructing a scenario

Illustrative application: Demonstration

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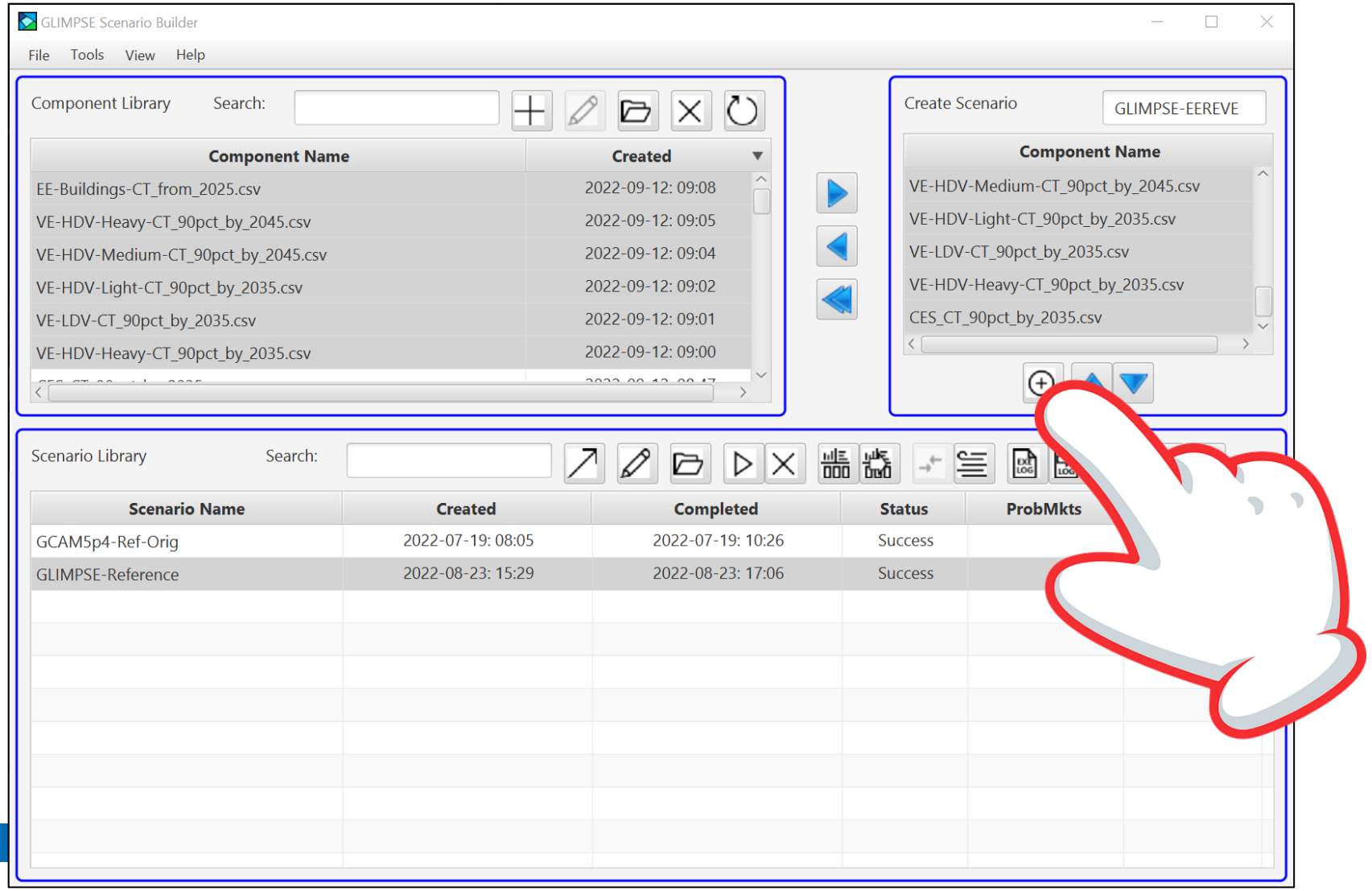

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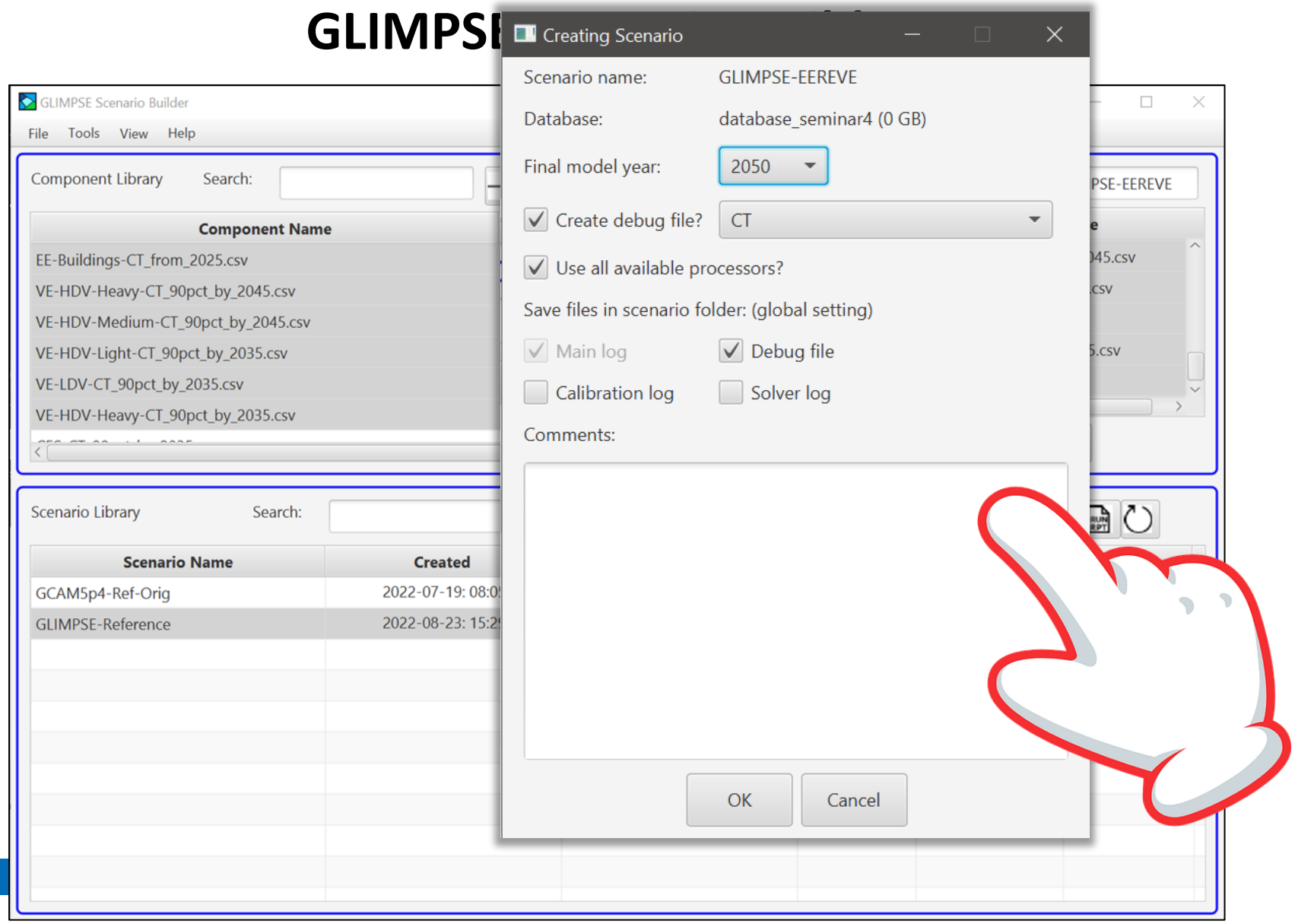

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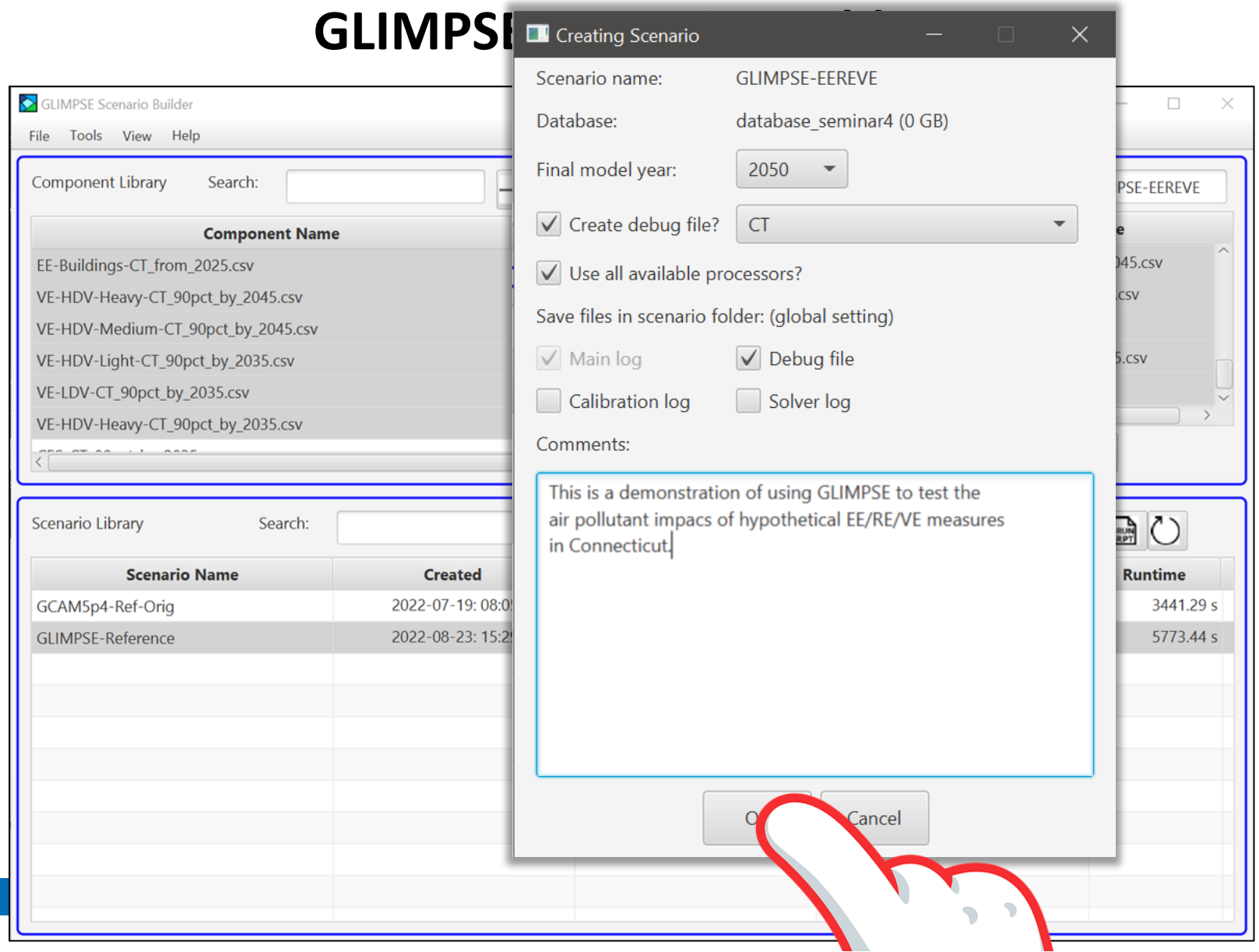

Constructing a scenario

Illustrative application: Demonstration

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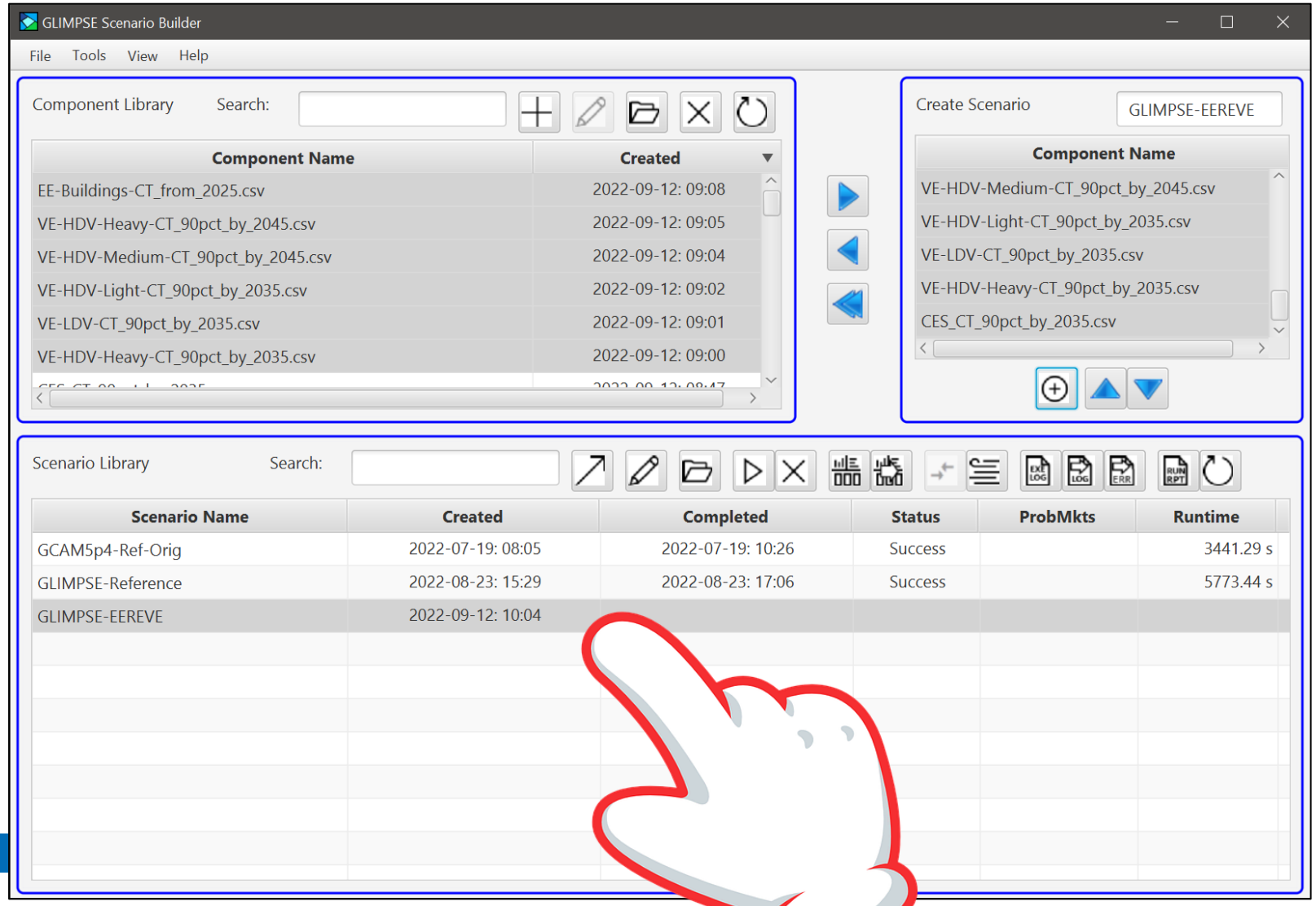
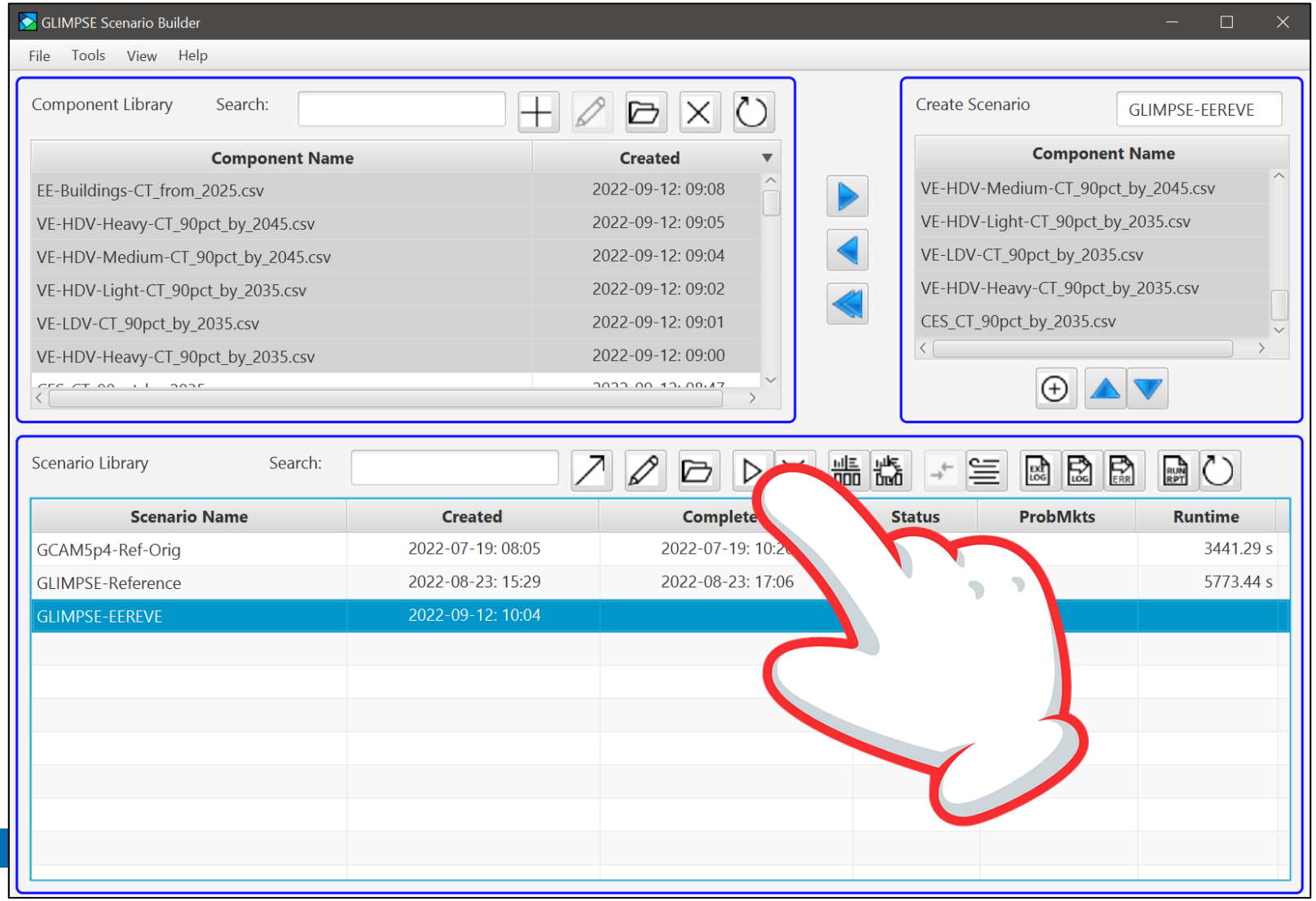


The new scenario is now in the Scenario Library

Illustrative application: Demonstration

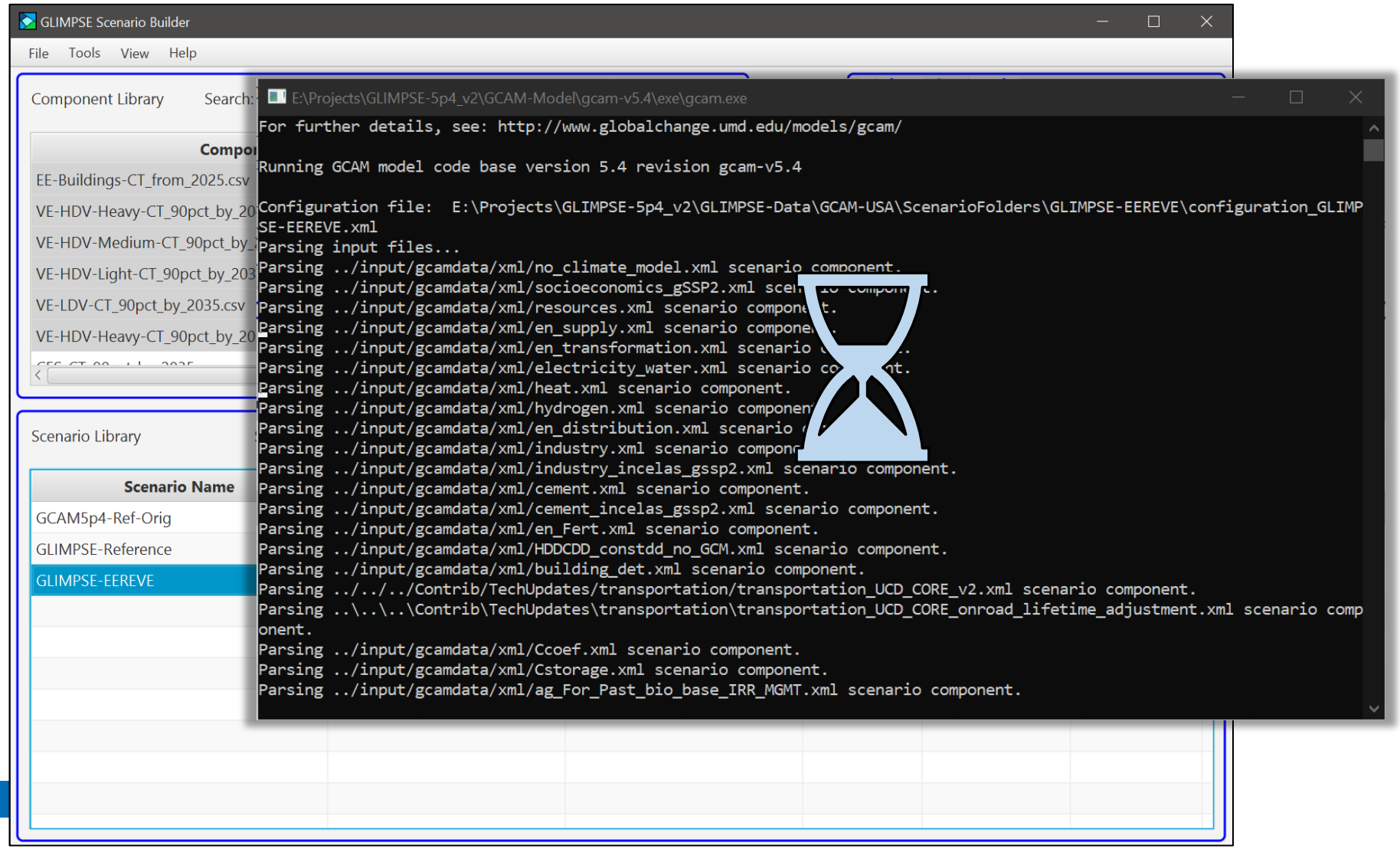
GLIMPSE Scenario Builder



Running a scenario in GCAM-USA

Illustrative application: Demonstration

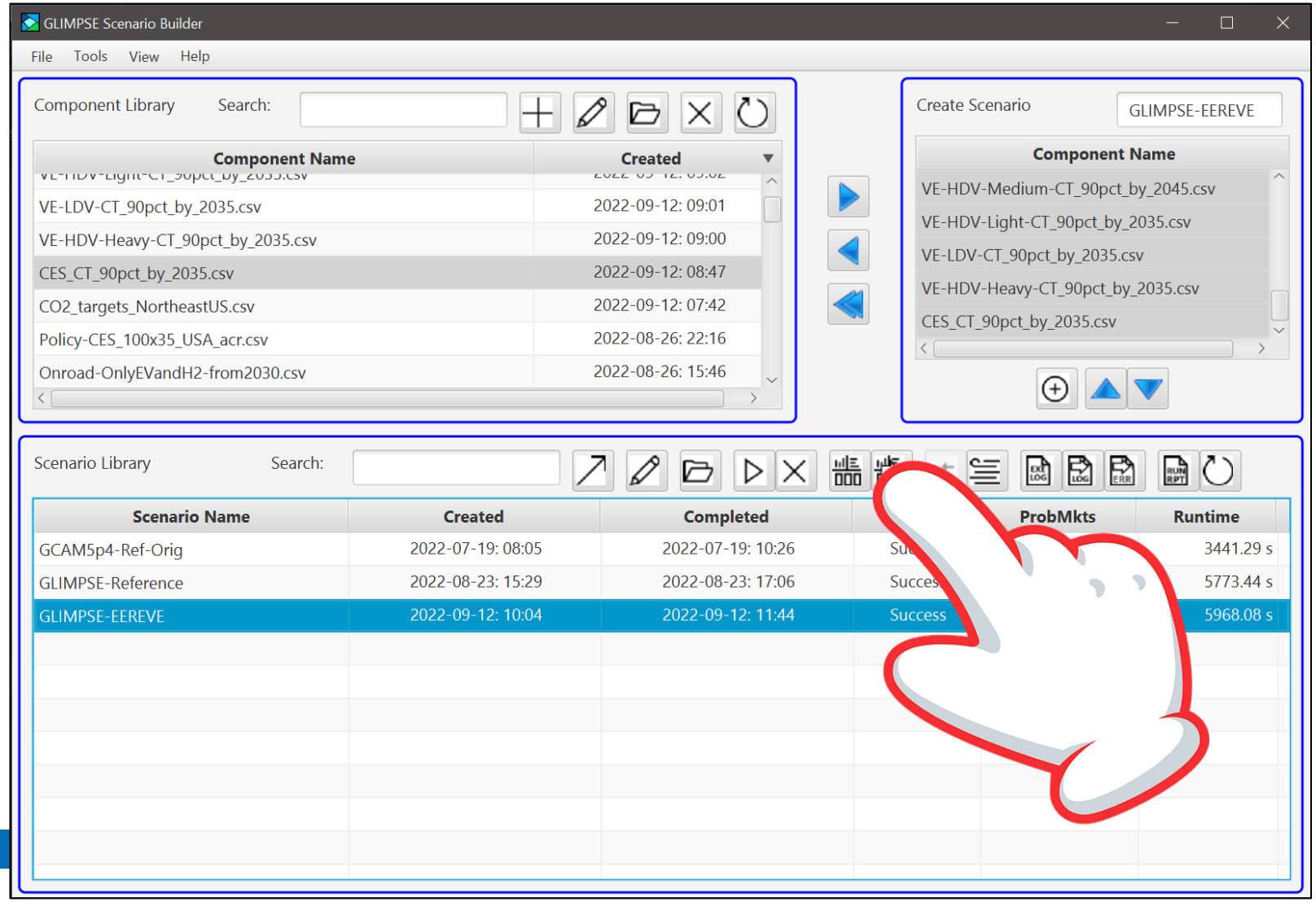
GLIMPSE Scenario Builder



This window provides status information about the run.

Illustrative application: Demonstration

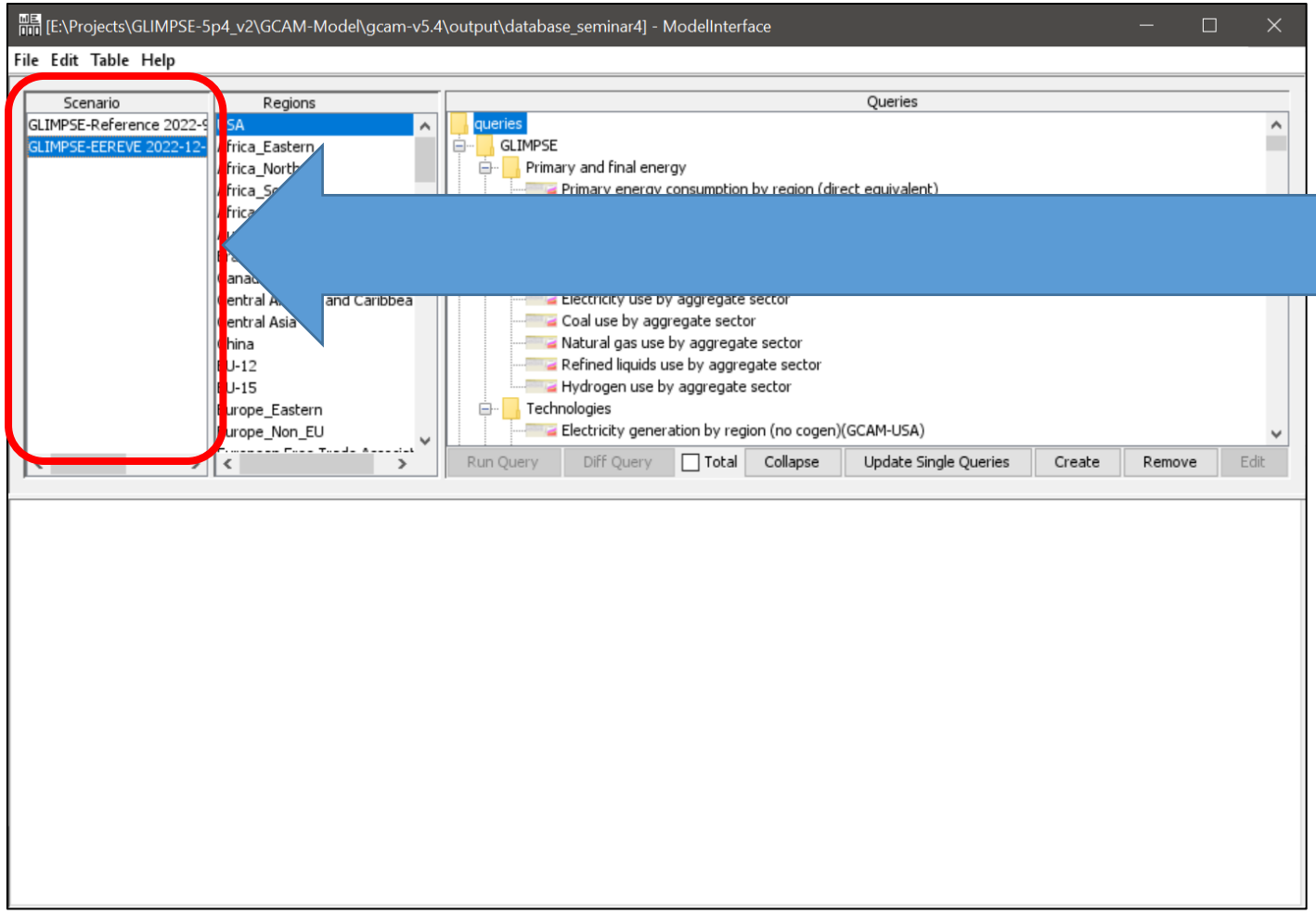
GLIMPSE Scenario Builder



The GCAM-USA run completed successfully and results are ready for analysis

Illustrative application: Demonstration

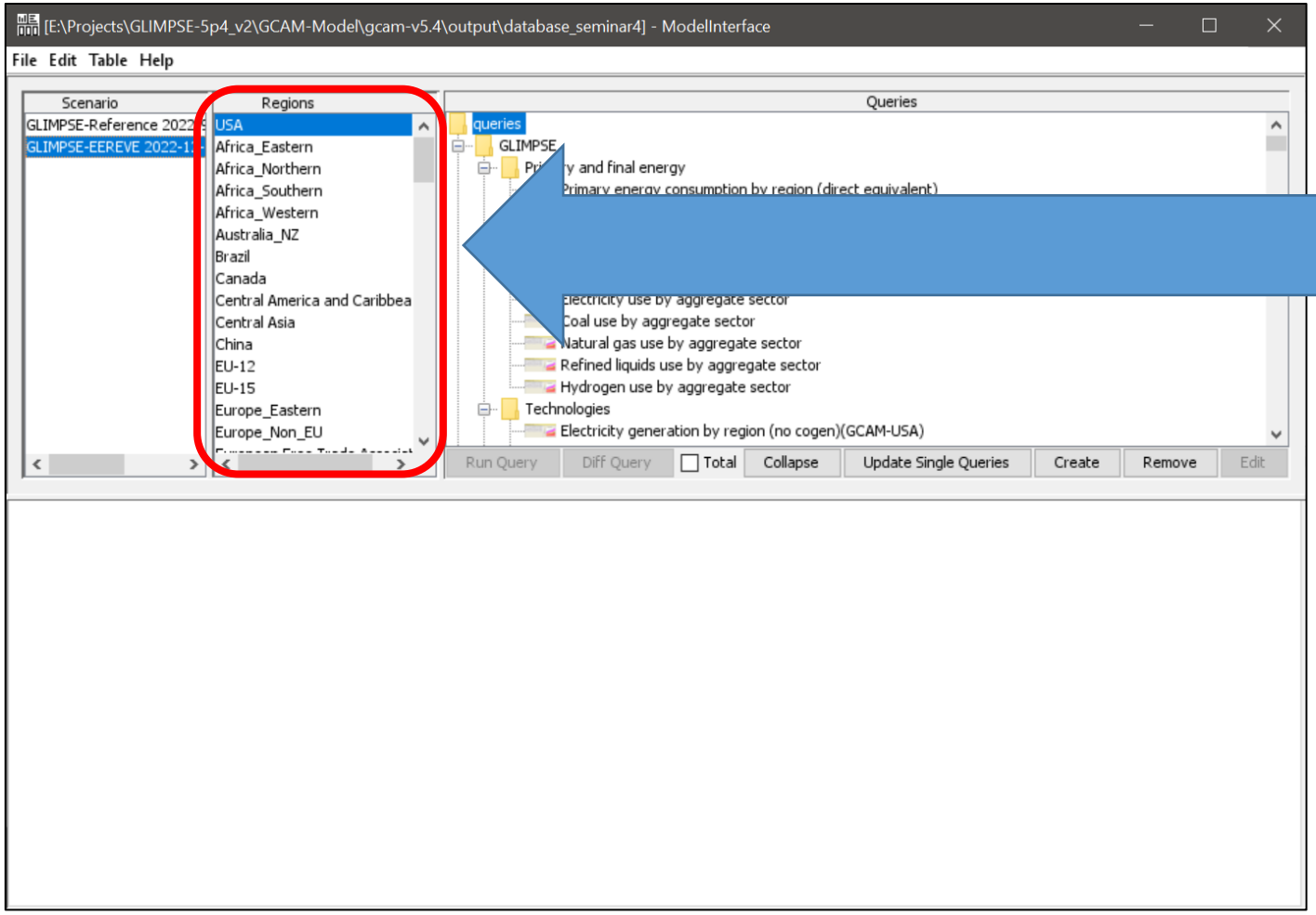
GLIMPSE Model Interface



Scenarios in the output database

Illustrative application: Demonstration

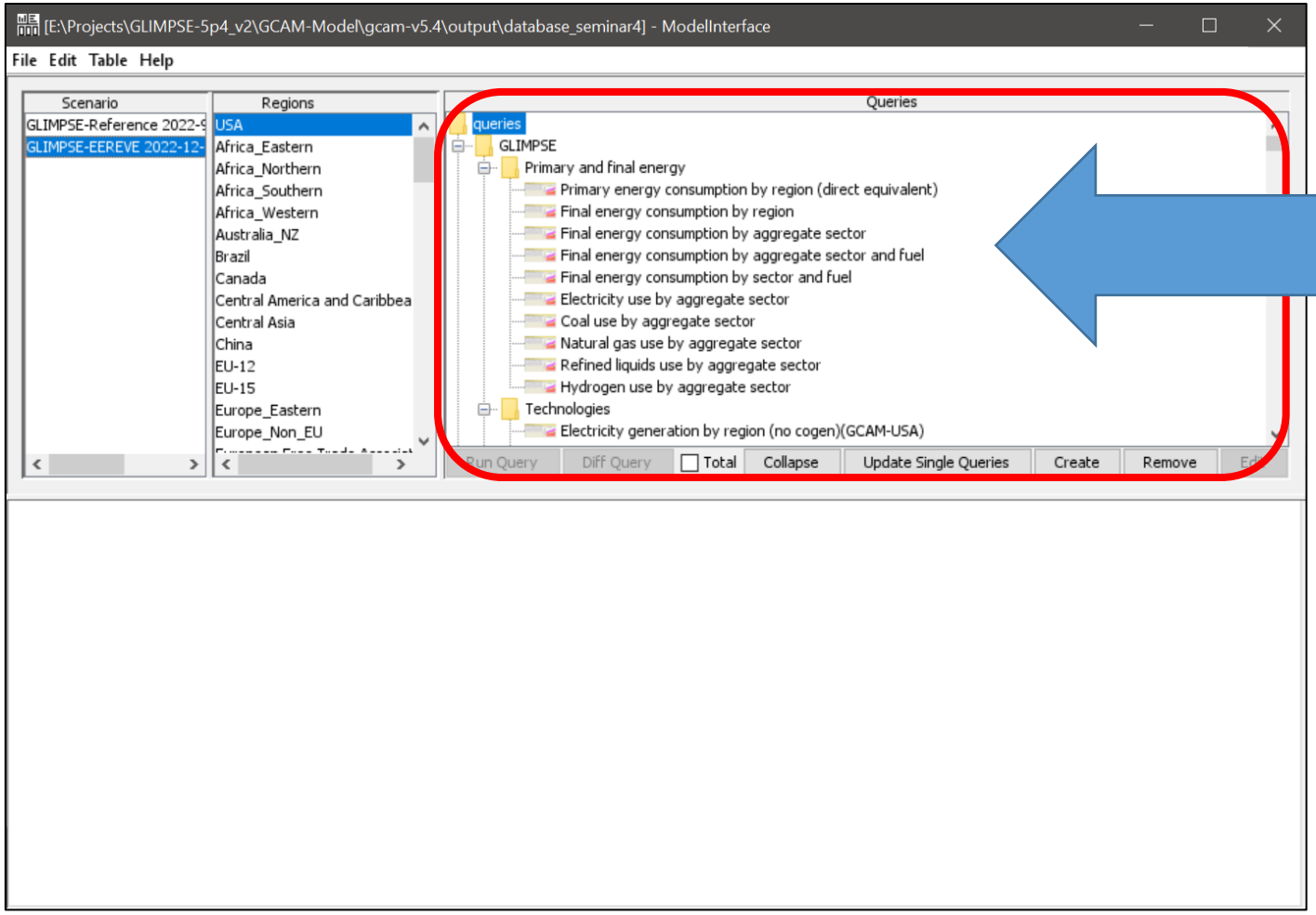
GLIMPSE Model Interface



Regions

Illustrative application: Demonstration

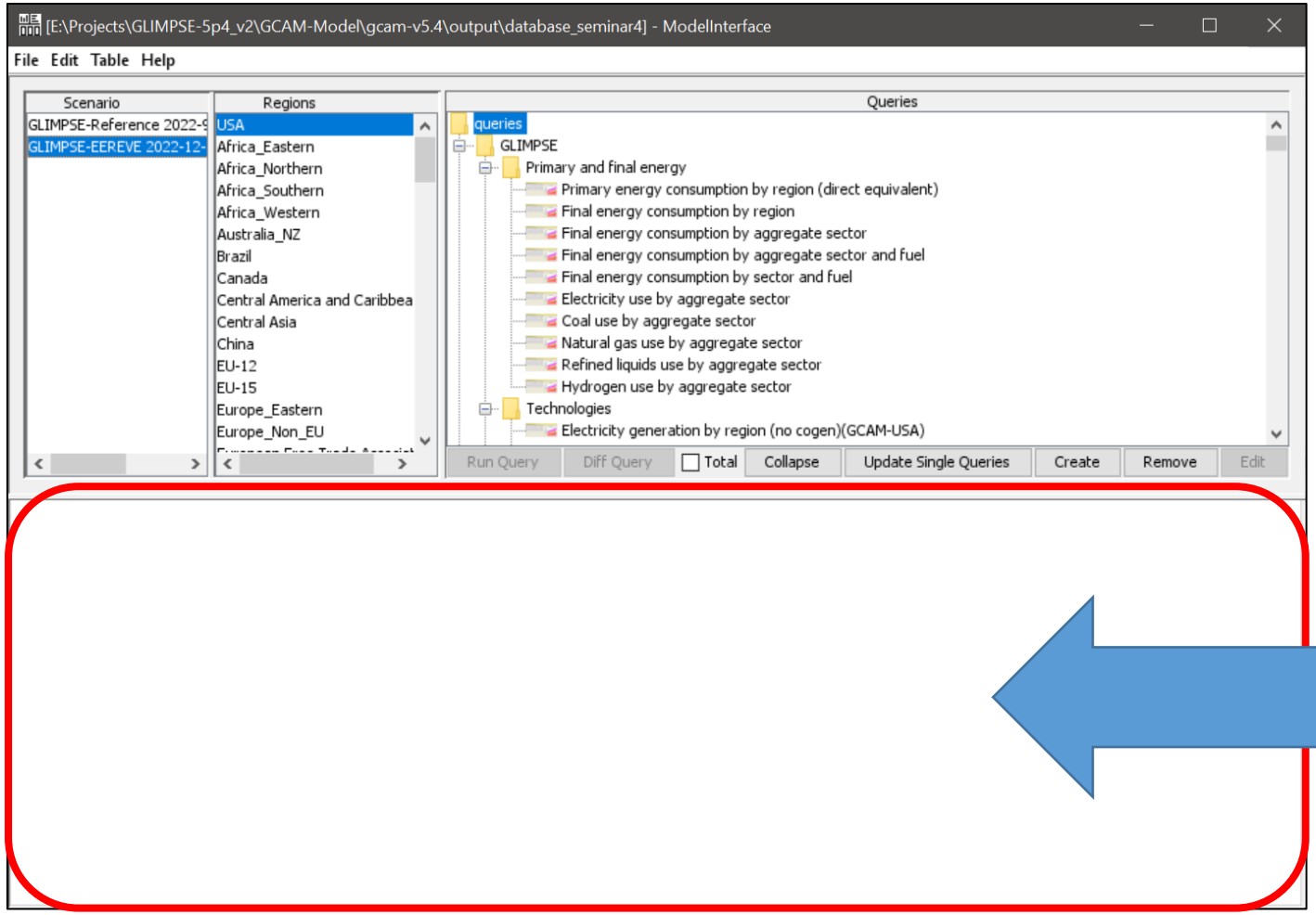
GLIMPSE Model Interface



Queries available for extracting data from the output database

Illustrative application: Demonstration

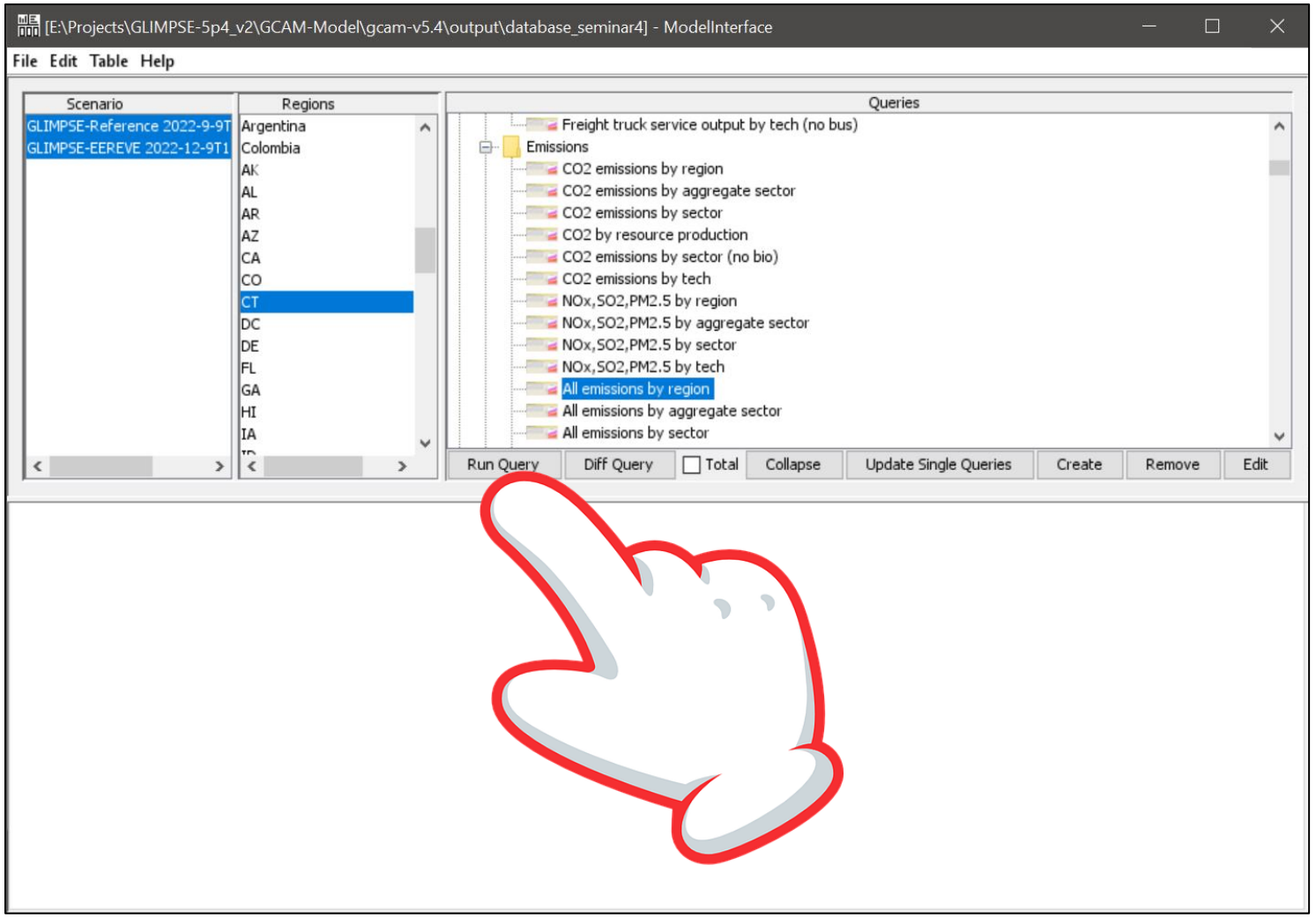
GLIMPSE Model Interface



Query results pane

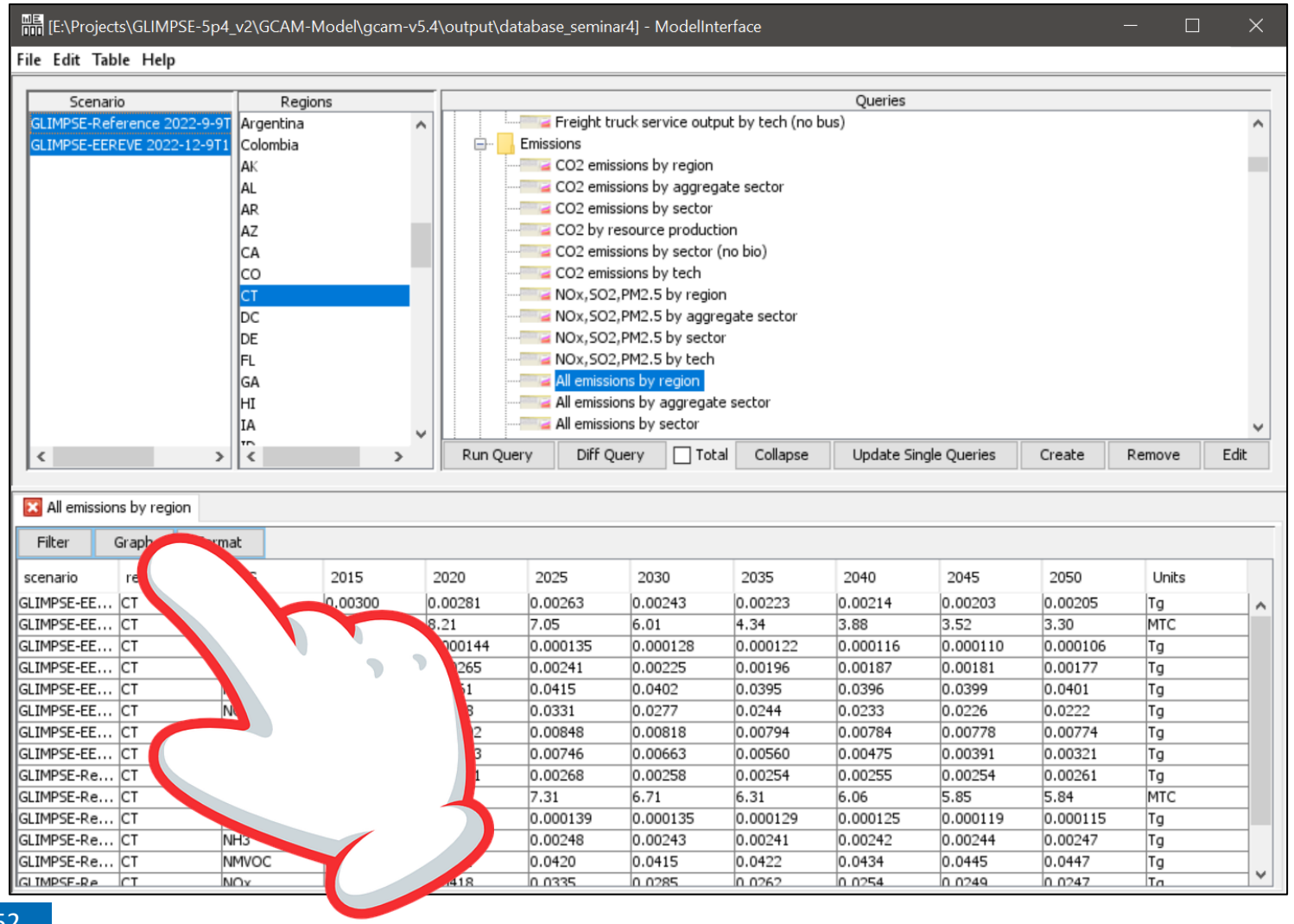
Illustrative application: Demonstration

GLIMPSE Model Interface



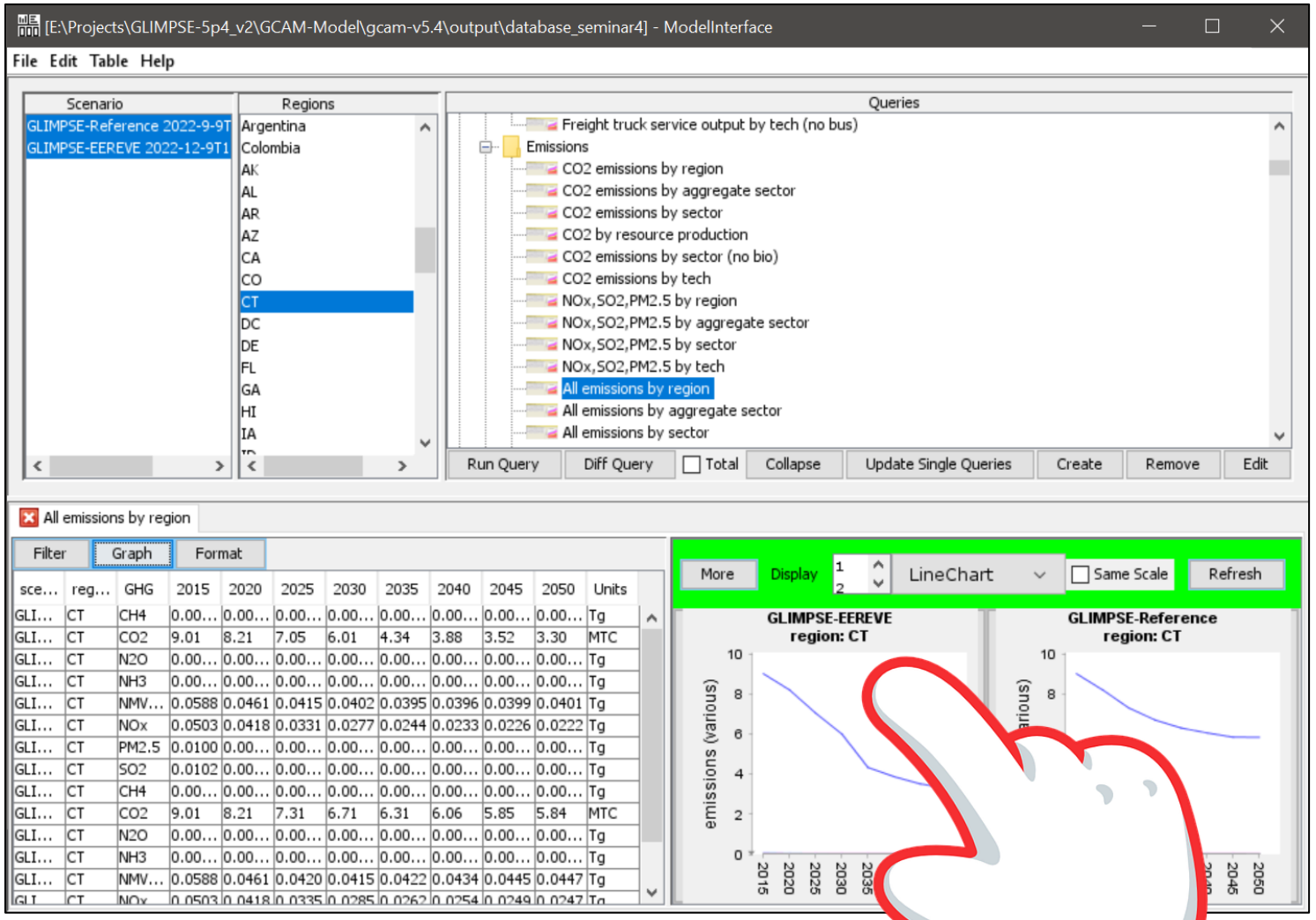
Illustrative application: Demonstration

GLIMPSE Model Interface

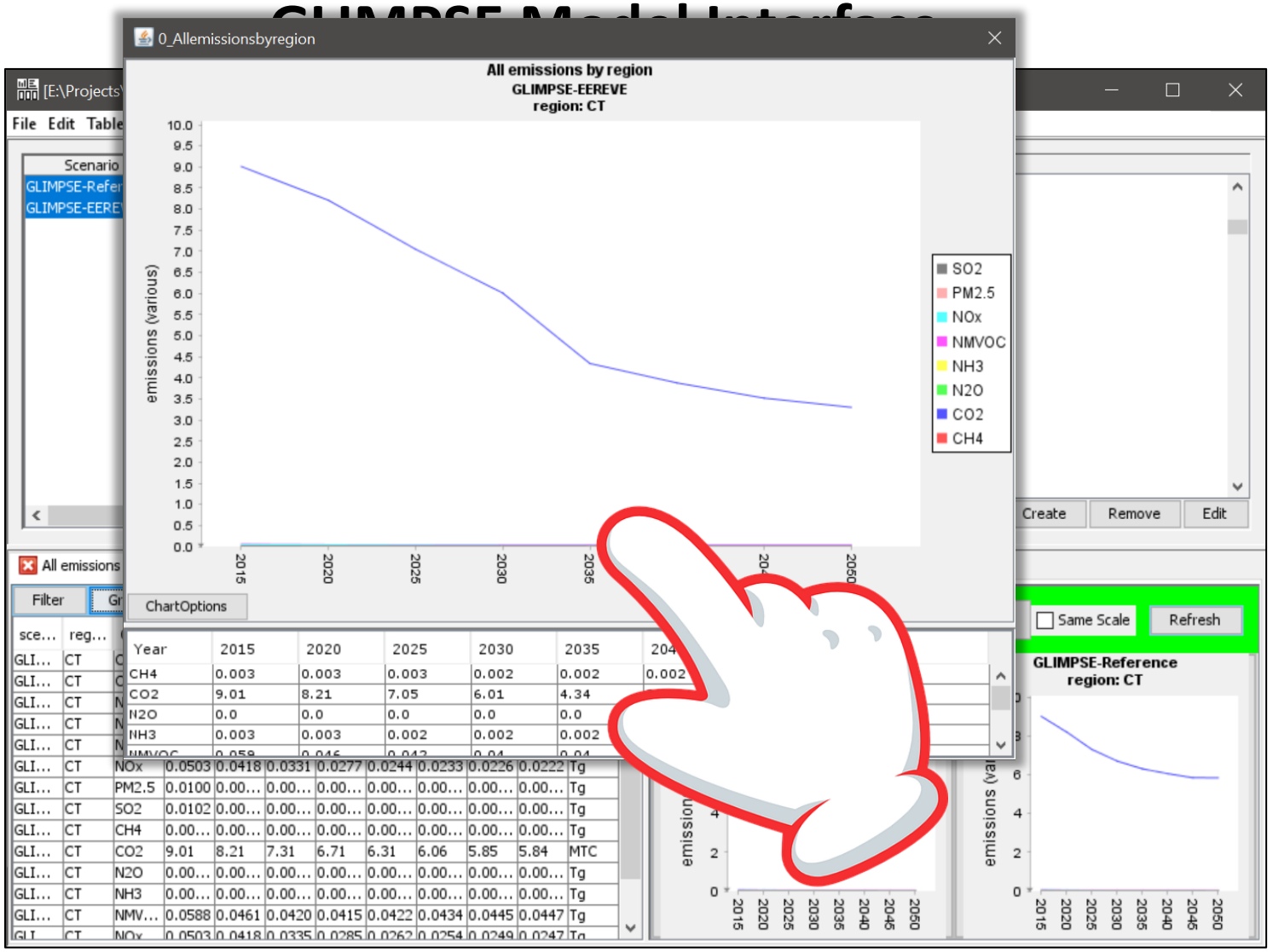


Illustrative application: Demonstration

GLIMPSE Model Interface

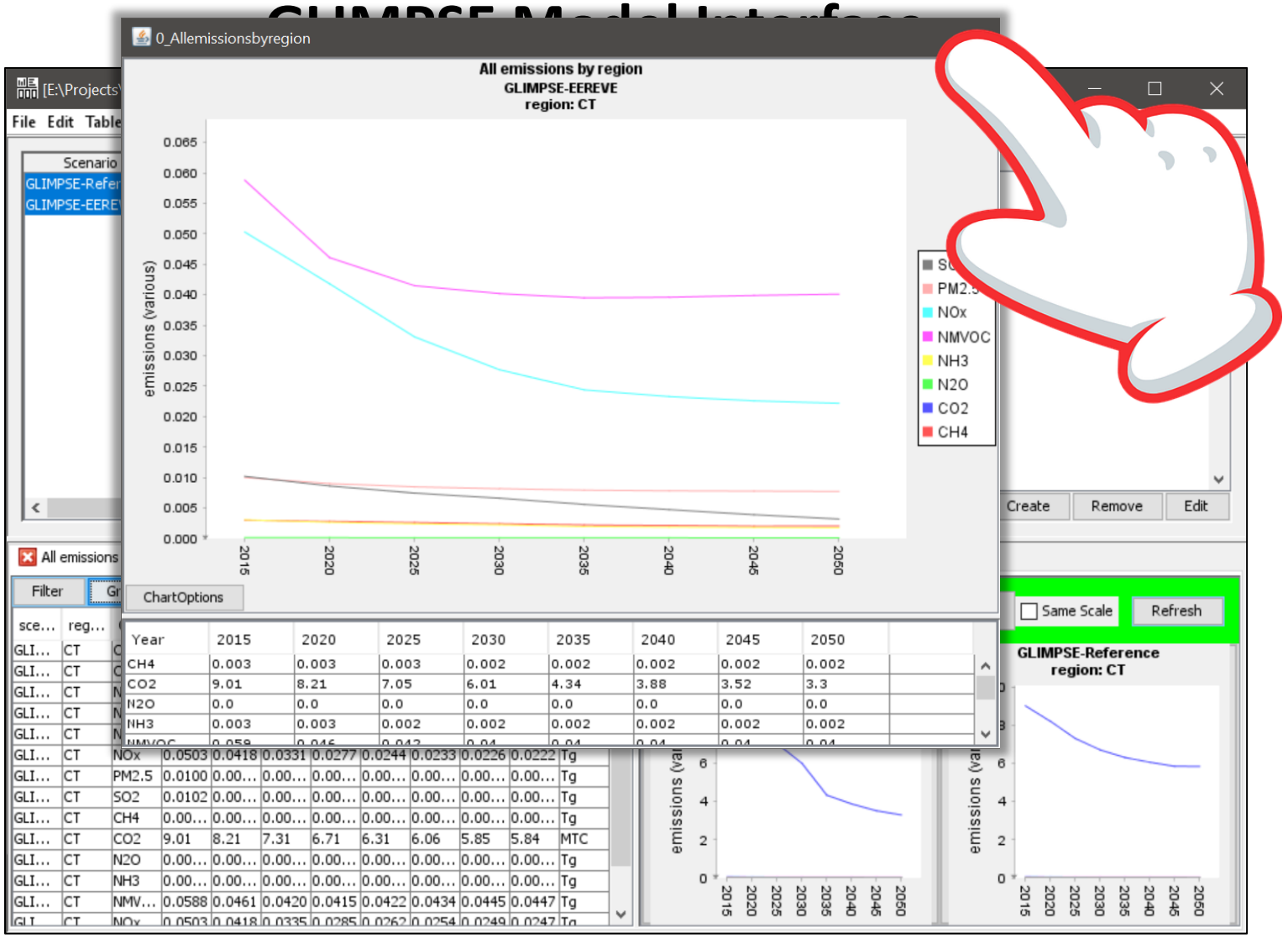


Illustrative application: Demonstration



Illustrative results

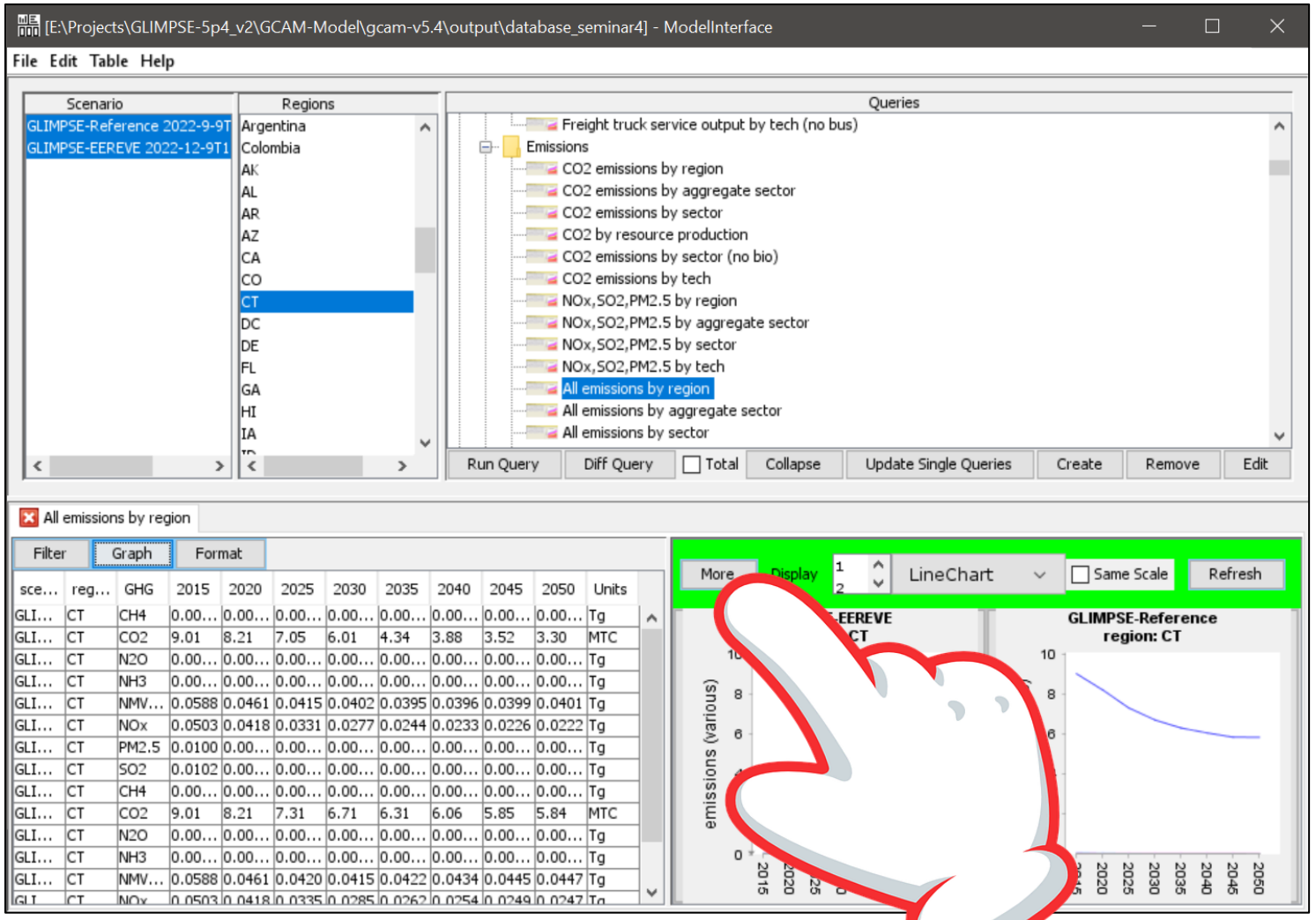
Illustrative application: Demonstration



Illustrative results

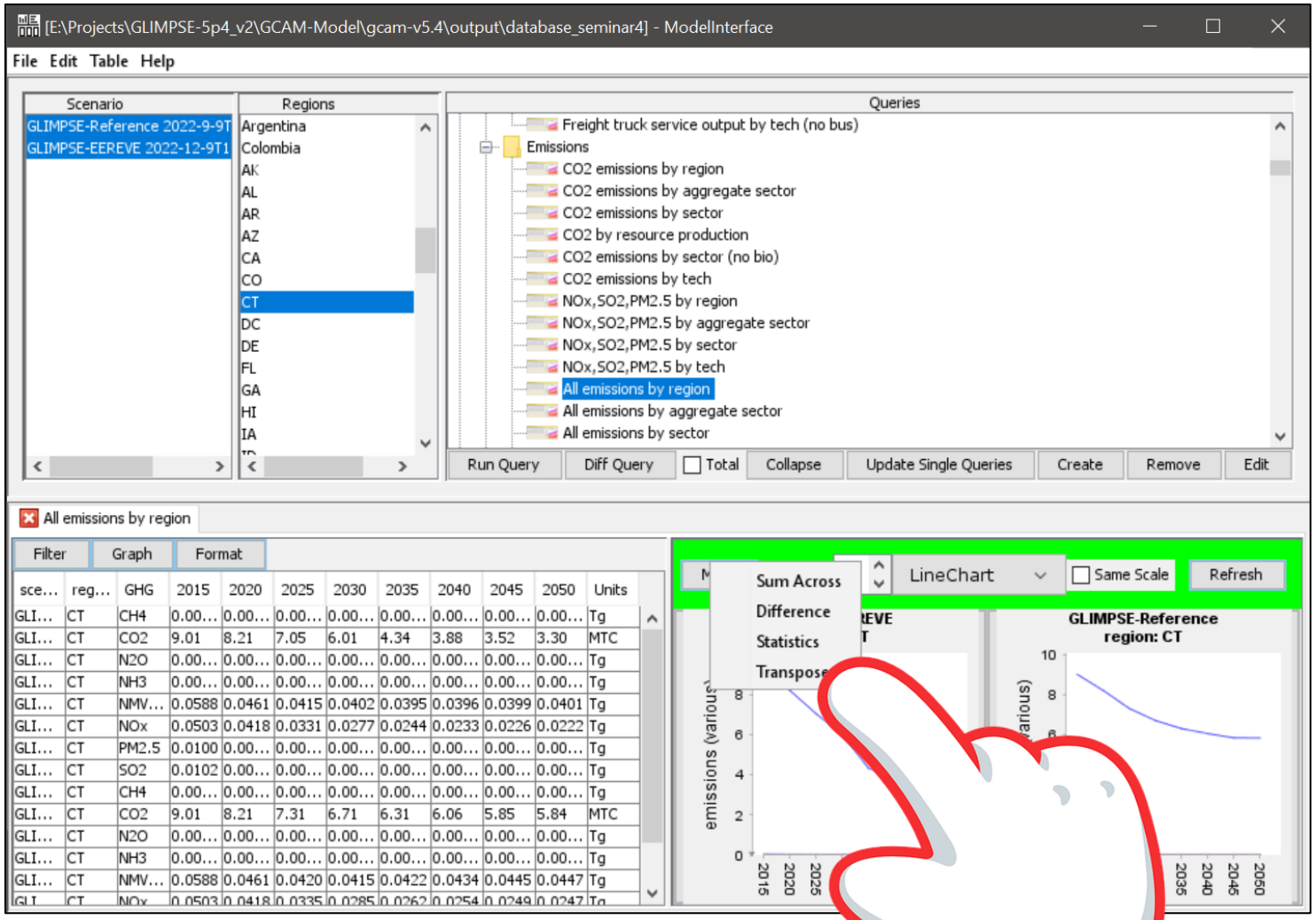
Illustrative application: Demonstration

GLIMPSE Model Interface



Illustrative application: Demonstration

GLIMPSE Model Interface



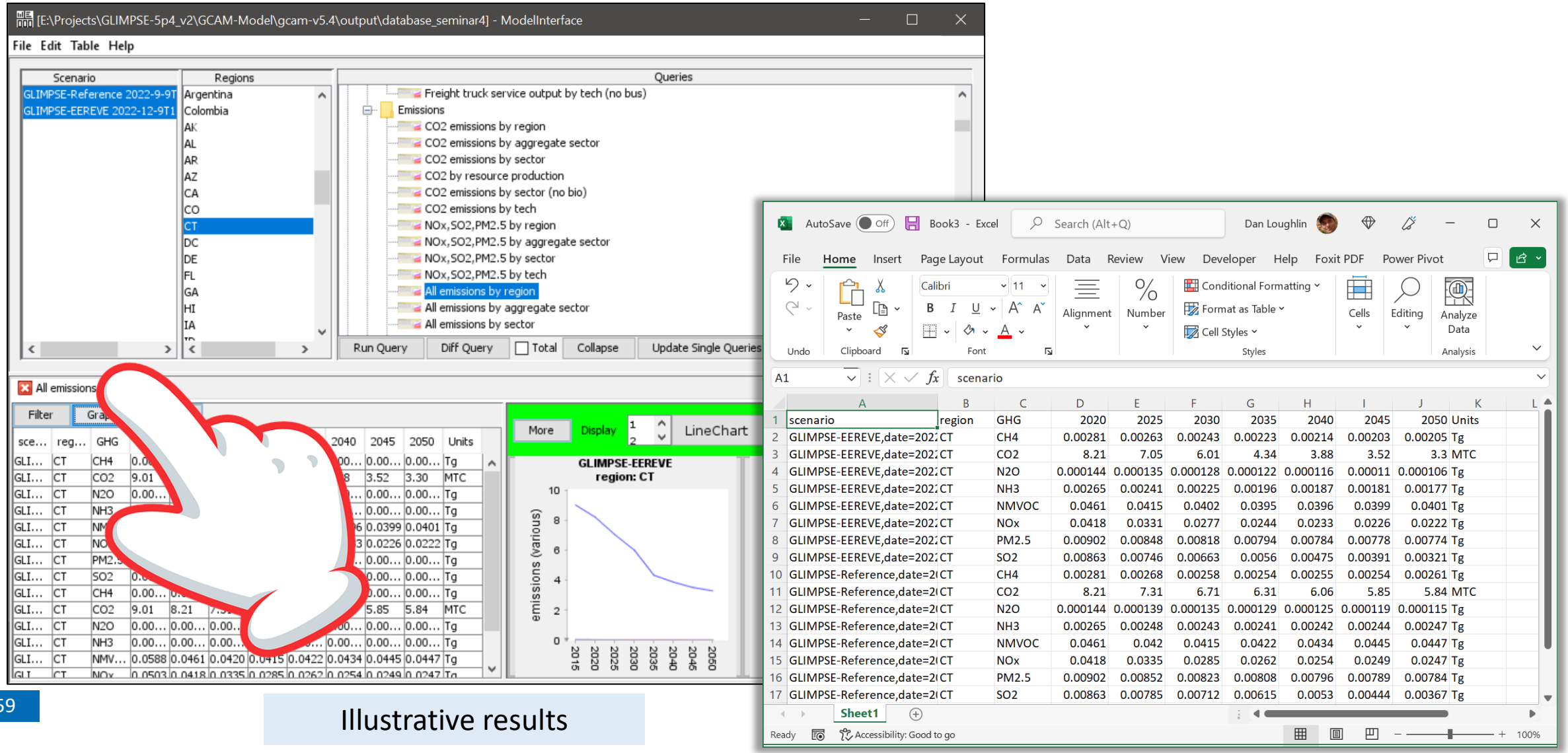
Illustrative application: Demonstration

Blue – *Ref*

Red – *EE/RE/VE*

Illustrative application: Demonstration

GLIMPSE Model Interface



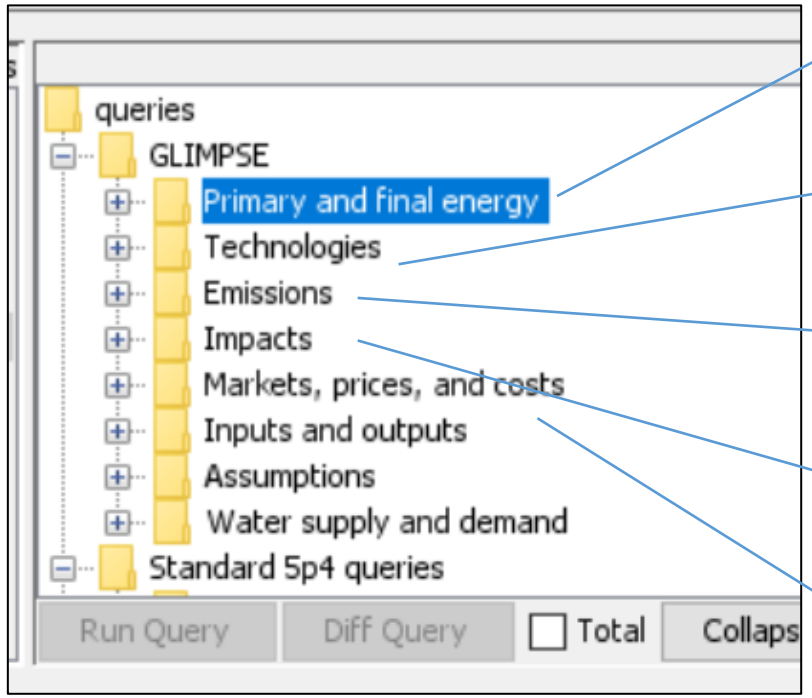
Illustrative results

Illustrative application: Demonstration

While we answered the research questions, we did not address "Why?"

<u>This</u> is where GLIMPSE is particularly useful…

GLIMPSE Queries



How much energy is being used?
For what purposes?

Which technologies have the greatest market shares?
How much fuel is being used by each?

How much GHGs and air pollutants are emitted?
Overall? By sector? By technology?

How does the scenario affect global climate?
What are the health impacts of emissions?

What are the prices of fuels and electricity?
What are the prices of energy services, such as passenger travel, space heating, and lighting?

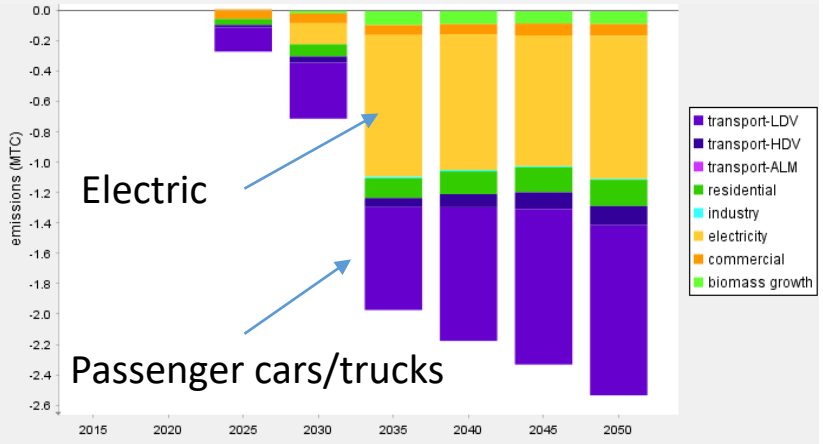
And how do these change under a policy or alternative scenario?

Illustrative application: Demonstration

Which sectors are reducing CO2?

Δ CO2 emissions by sector

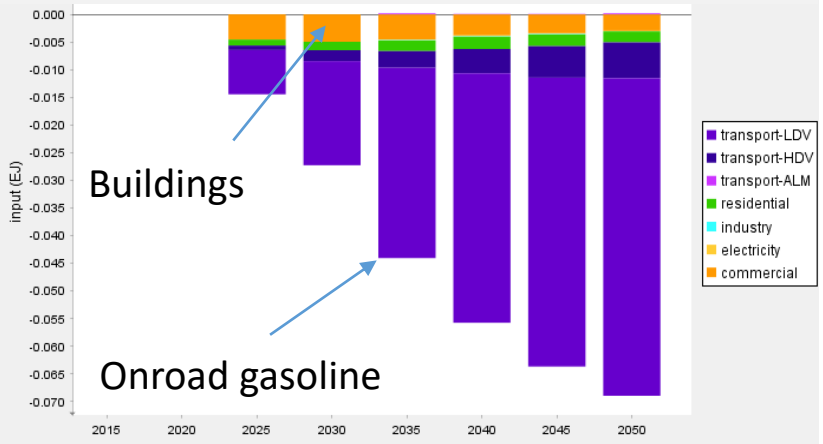
EE/RE/VE* minus *Ref



How is liquid fuel use changing?

Δ liquid fuel use by sector

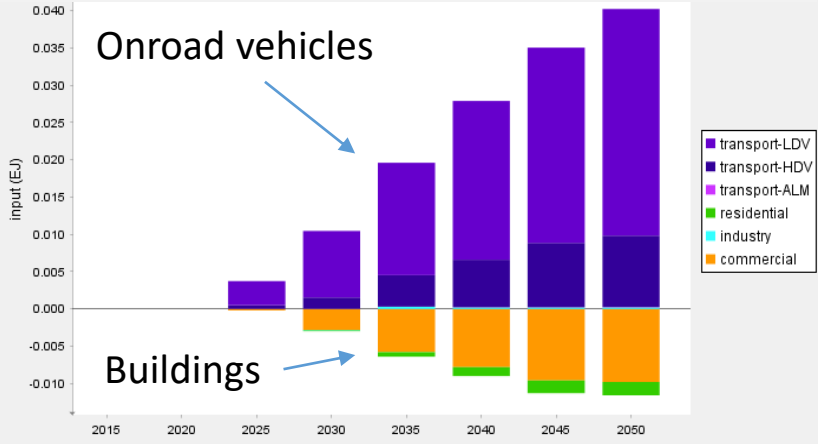
EE/RE/VE* minus *Ref



How is demand for electricity changing?

Δ electricity use by sector

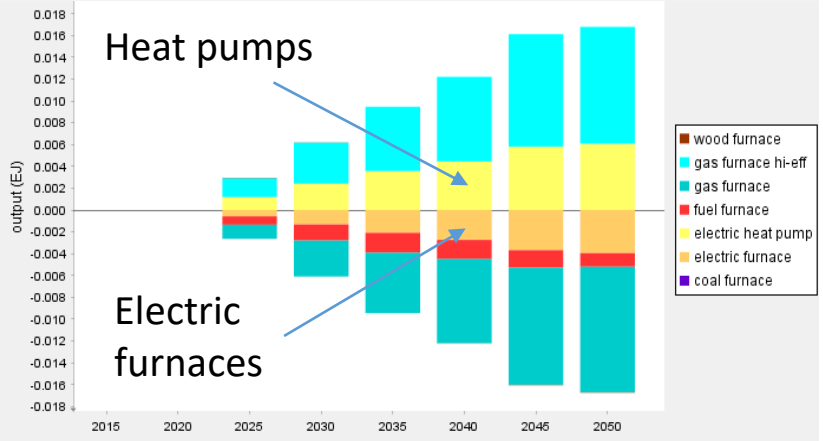
EE/RE/VE* minus *Ref



Why is commercial electricity decreasing?

Δ commercial heating by technology

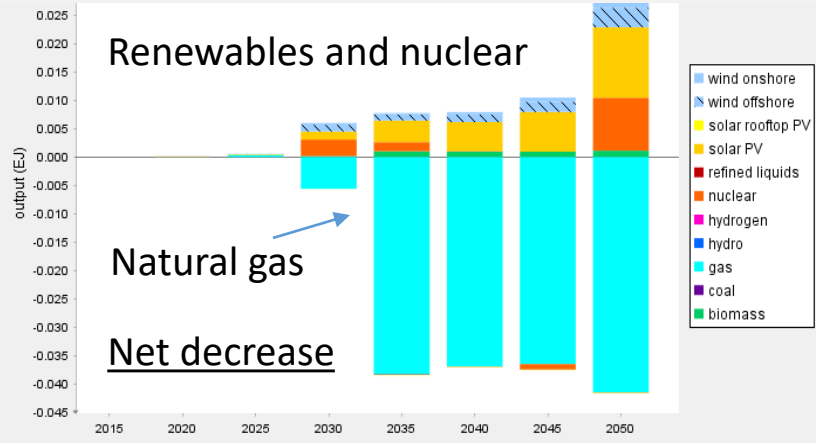
EE/RE/VE* minus *Ref



How does CT meet the CES?

Δ electricity production by technology

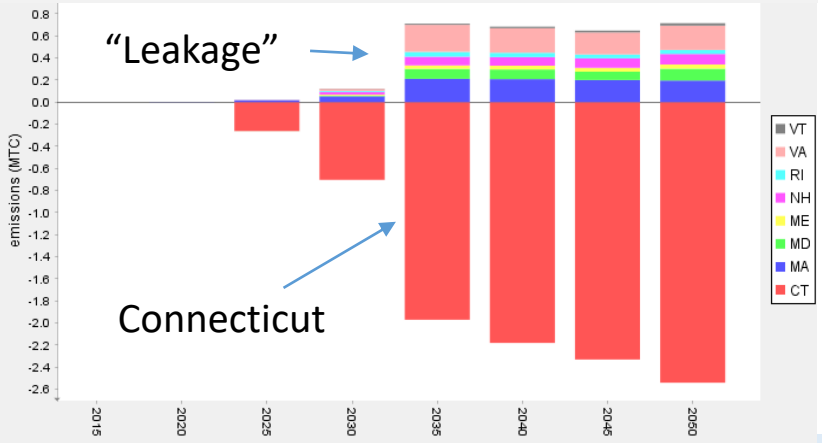
EE/RE/VE* minus *Ref



Is there "leakage" of CO2 to other states?

Δ CO2 emissions by state

EE/RE/VE* minus *Ref



Illustrative application: Demonstration

Additional directions for exploration

How do these results change if ...

… surrounding states adopt similar measures?
… RGGI constraints get tighter past 2030?
… state CO2 reduction targets are modeled?
… the Inflation Reduction Act is represented?

Illustrative application: Demonstration

This example represents the start of an iterative, exploratory modeling process where the GLIMPSE user learns more about the problem and potential solutions with each iteration

GLIMPSE is designed to support this type of exploratory process

Impacts

- GLIMPSE has the potential to help state planners use GCAM-USA, a complex integrated assessment model, to:
  - estimate air pollutant and GHG emissions into the future
  - identify emerging challenges to meeting goals
  - understand the impacts of energy efficiency and renewable electricity
  - explore the tradeoffs among energy-air-climate-water goals
  - test out potential policies in a virtual environment
  - identify win-win strategies for simultaneously meeting policy goals

Impacts

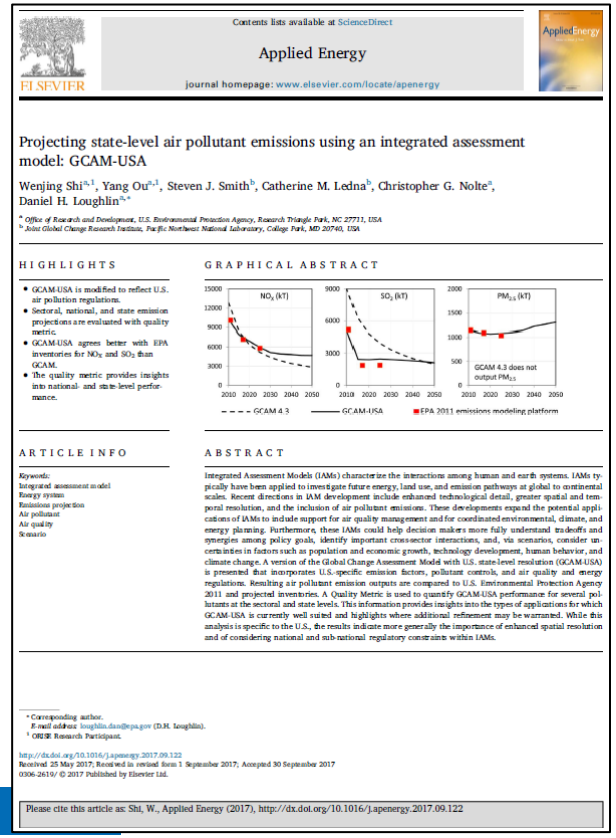
- GLIMPSE is supporting our research in our EPA Air-Climate-Energy program

Projecting air pollutant emissions

Estimating air pollutant co-benefits of GHG mitigation

Designing holistic policies

Evaluating the emission impacts of electric vehicles



Contents lists available at ScienceDirect

Applied Energy

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

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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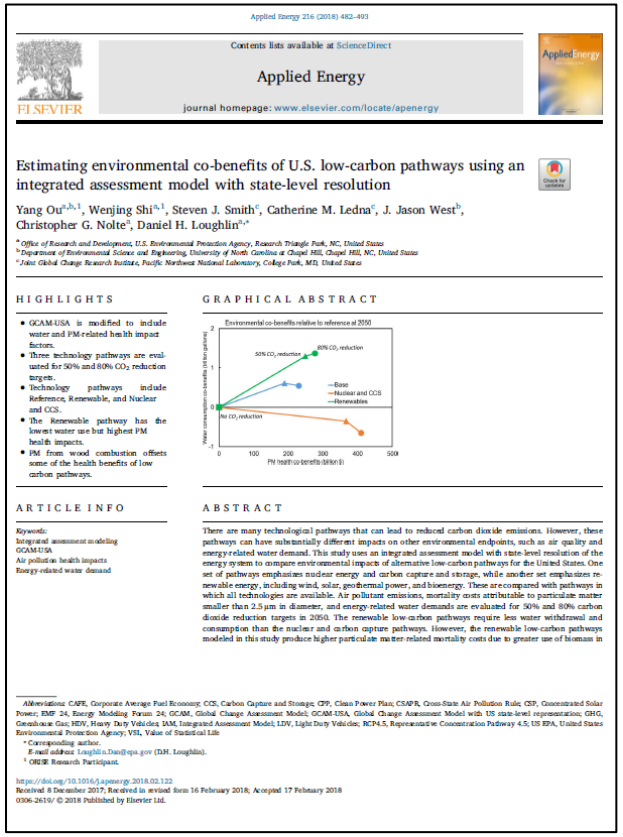

Applied Energy 216 (2018) 482–493

Contents lists available at ScienceDirect

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[c], Daniel H. Loughlin[a,*]

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[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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Cleaner Engineering and Technology

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Incorporating upstream emissions into electric sector nitrogen oxide reduction targets

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ARTICLE INFO

Keywords:
Life-cycle analysis (LCA)
Global change assessment model (GCAM)-USA
Power generation
Electricity production
Nitrogen oxide (NOx) emissions

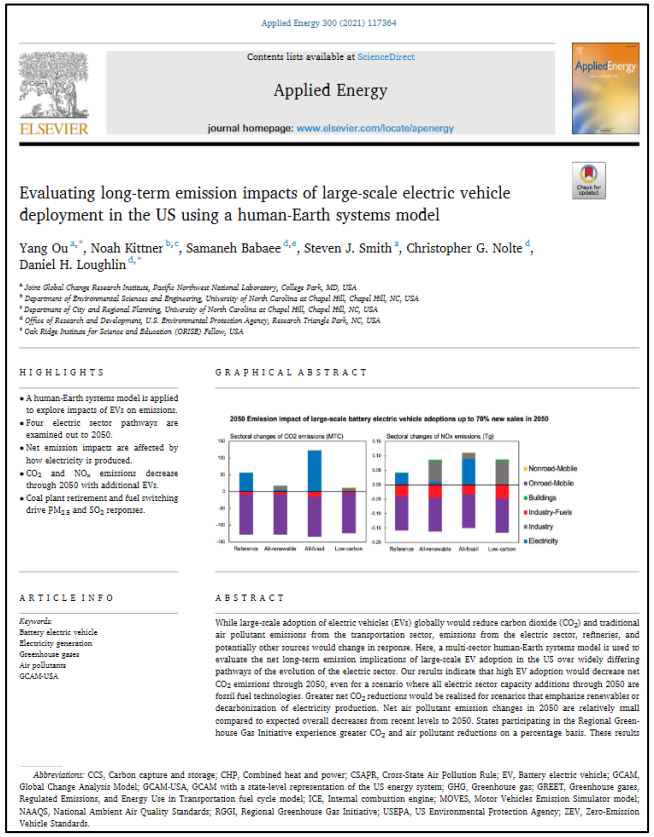
ABSTRACT

Electricity production is a major source of air pollutants in the U.S. Policies to reduce these emissions typically result in the power industry choosing to apply controls or switch to fuels with lower combustion emissions. However, the life-cycle emissions associated with various fuels can differ considerably, potentially impacting the effectiveness of fuel switching. Life-cycle emissions include emissions from extracting, processing, transporting, and distributing fuels, as well as manufacturing and constructing new generating capacity. The field of life-cycle analysis allows quantification of these emissions. While life-cycle emissions are often considered in greenhouse gas-mitigation targets, they generally have not been included in air quality policymaking. We demonstrate such an approach, examining a hypothetical electric sector emission reduction target for nitrogen oxides (NO_x) using the Global Change Assessment Model with U.S. state-level resolution. When only power plant emissions are considered in setting a NOx emission reduction target, fuel switching leads to an increase in upstream emissions that offsets 5% of the targeted reductions in 2050. When fuel extraction, processing, and transport emissions are included under the reduction target, accounting for 20% of overall NO_x reduction goal, the resulting control strategy meets the required reductions and does so at 35% lower cost by 2050. However, manufacturing and construction emissions increase and offset up to 7% of NO_x reductions in electric sector, indicating that it may be beneficial to consider these sources as well. Assuming no legal obstacles exist, life-cycle-based approaches could be implemented by allowing industry to earn reduction credits for reducing upstream emissions. We discuss some of the limitations of such an approach, including the difficulty in identifying the location of upstream emissions, which may occur across regulatory authorities or even outside of the U.S.

1. Introduction

Electricity production is a major source of air pollutants, including nitrogen oxides (NOx), sulfur dioxide (SO_2), and particulate matter (PM) emissions. These emissions can vary considerably based on how the electricity is generated and/or whether pollutant controls are applied. In the U.S., several federal regulations have been instituted to reduce emissions from the electric sector. These regulations reduce emissions at the power plant, typically by specifying emission rate limits or capping electric sector emissions. For example, new electric sector boilers are subject to New Source Performance Standards (NSPS), which are emission rate limits, for NOx, SO_2, and PM emissions (Federal Register 2012a). In contrast, the Cross-State Air Pollution Rule (CSAPR) is a cap-based regulation. CSAPR was instituted to limit the transport of pollutants into states with attainment challenges. Under CSAPR, electric sector emissions in 27 states are capped for NOx, SO_2, or both (Federal Register 2011). Many states have also passed legislation limiting power plant emissions, such as North Carolina and Maryland (CSA 2002; HAA 2009).

One approach for complying with these regulations is to apply emission controls at the power plant that either modify the combustion process or that strip pollutants from the exhaust gas. While uncontrolled coal-fired power plants are among the highest emitters of many air pollutants, devices such as selective catalytic reduction, flue gas desulfurization, and electrostatic precipitators can reduce NOx, SO_2, and PM emissions from coal combustion by 90%, 95–99%, and 99–99.9%, respectively (EPA 2005). Another option is switching to fuels with lower combustion emissions. Natural gas combustion in combined-cycle turbines produces lower emissions than controlled coal, further reducing per-kWh totals of NOx, SO_2, and PM by 82%, 99.8%, and 75% (Massetti



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Applied Energy

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Evaluating long-term emission impacts of large-scale electric vehicle deployment in the US using a human-Earth systems model

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[b] Department of Environmental Sciences and Engineering, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA
[c] Department of City and Regional Planning, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA
[d] Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, NC, USA
[e] Oak Ridge Institute for Science and Education (ORISE) Fellow, USA

HIGHLIGHTS

- A human-Earth systems model is applied to explore impacts of EVs on emissions.
- Four electric sector pathways are examined out to 2050.
- Net emission impacts are affected by how electricity is produced.
- CO_2 and NO_x emissions decrease through 2050 with additional EVs.
- Coal plant retirement and fuel switching drive $PM_{2.5}$ and SO_2 responses.

GRAPHICAL ABSTRACT

ARTICLE INFO

Keywords:
Battery electric vehicle
Electricity generation
Greenhouse gases
Air pollutants
GCAM-USA

ABSTRACT

While large-scale adoption of electric vehicles (EVs) globally would reduce carbon dioxide (CO_2) and traditional air pollutant emissions from the transportation sector, emissions from the electric sector, refineries, and potentially other sources would change in response. Here, a multi-sector human-Earth systems model is used to evaluate the net long-term emission implications of large-scale EV adoption in the US over widely differing pathways of the evolution of the electric sector. Our results indicate that high EV adoption would decrease net CO_2 emissions through 2050, even for a scenario where all electric sector capacity additions through 2050 are fossil fuel technologies. Greater net CO_2 reductions would be realized for scenarios that emphasize renewables or decarbonization of electricity production. Net air pollutant emission changes in 2050 are relatively small compared to expected overall decreases from recent levels to 2050. States participating in the Regional Greenhouse Gas Initiative experience greater CO_2 and air pollutant reductions on a percentage basis. These results

Abbreviations: CCS, Carbon capture and storage; CHP, Combined heat and power; CSAPR, Cross-State Air Pollution Rule; EV, Battery electric vehicle; GCAM, Global Change Analysis Model; GCAM-USA, GCAM with a state-level representation of the US energy system; GHG, Greenhouse gas; GREET, Greenhouse gases, Regulated Emissions, and Energy Use in Transportation fuel cycle model; ICE, Internal combustion engine; MOVES, Motor Vehicles Emission Simulator model; NAAQS, National Ambient Air Quality Standards; RGGI, Regional Greenhouse Gas Initiative; USEPA, US Environmental Protection Agency; ZEV, Zero-Emission Vehicle Standards.

Impacts

- GLIMPSE is being developed with input from users
  - Our EPA colleagues
  - Conversations with state air quality modeling staff
- GLIMPSE is being beta-tested currently
  - 3 years in a graduate course on Integrated Assessment Modeling at Duke Univ.
  - Pilot project with CT to explore air quality topics and build capacity to run GLIMPSE
- GLIMPSE is being used by students in projects and theses to evaluate:
  - the Transportation and Climate Initiative (Duke)
  - NC's Clean Transportation Plan (Duke)
  - Clean energy options in Massachusetts (Northeastern)
  - Clean energy scenarios in Georgia (Fort Valley St., Morehouse, and Emory)
  - State-level strategies for improving air quality (UNC-CH)

Interested?

- This fall, we plan to kick off a beta-test / peer-review prior to public release:
  - Participants will represent different types of users
    - Integrated Assessment Modelers
    - University researchers / lecturers
    - State modelers/policy analysts

We have the capacity to include several additional beta testers

Please contact me to learn more:
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Contact

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GLIMPSE Team
EPA: Dan Loughlin and Chris Nolte (co-leads), Joyce Kim, Fahim Sidi, Uma Shankar, Carol Lenox
Pacific Northwest National Laboratory: Steve Smith, Yang Ou, Maridee Weber
Former team members: Wenjing Shi, Samaneh Babaee, Vicky Jia, Paelina DeStephano, Sara Simm, Fahim Albourzi, Catherine Ledna

Collaborators:
Partners across the Agency, including across the EPA Office of Air and Radiation and in EPA Regions 1, 3, and 4
CT DEEP, including Paula Gomez