

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

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September 22, 2022





Take home messages

GLIMPSE: <u>G</u>lobal Change Analysis Model <u>L</u>ong-term <u>I</u>nteractive <u>M</u>ulti-<u>P</u>ollutant <u>S</u>cenario <u>E</u>valuator

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





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



For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.



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



EPA United States Environmental Protection Agency Background: Energy-air-climate-water nexus

The Energy System



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-powerwater-use





- 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)

FPA United States Environmental Protection Agency 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

Human Earth Systems



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



Approach: Global Change Analysis Model



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



Approach: Global Change Analysis Model

Scenario assumptions



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:** CO₂, CH₄, N₂O, HFCs Air pollutants: NOx, SO₂, PM_{2.5}, VOCs, CO, NH₃ **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

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

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



Approach: EPA GCAM activities

Comparison with EPA 2016v2 modeling platform

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Dots: EPA projections; Black: Reference Case; Blue: Alternative Scenario

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



Approach: EPA GCAM activities

GLIMPSE: <u>G</u>CAM <u>L</u>ong-term <u>I</u>nteractive <u>M</u>ulti-<u>P</u>ollutant <u>S</u>cenario <u>E</u>valuator

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



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

GLIMPSE



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 O₃ 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 O₃ NAAQS as of Feb. 2022



EPA United States Environmental Protection Agency

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?



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

- Calibrations
- Policies
- Alternative assumptions



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We combine these to construct scenarios



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Creating a new Scenario Component...



New Scenario Component Creator



Component options include:

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



New Scenario Component Creator





New Scenario Component Creator





New Scenario Component Creator





New Scenario Component Creator

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New Scenario Component Creator





New Scenario Component Creator

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New Scenario Component Creator





New Scenario Component Creator





New Scenario Component Creator





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Saving the new component



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Saving the new component



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Illustrative application: Demonstration

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Specifying additional components



GLIMPSE Scenario Builder





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VE-HDV-Heavy-CT_90pct_by_2	045.csv		2022-09-12: 09:05		VE-HDV-Lig	ght-CT_90pct_	by_2035.csv	
VE-HDV-Medium-CT_90pct_by	_2045.csv		2022-09-12: 09:04		VE-LDV-CT	_90pct_by_203	35.csv	
VE-HDV-Light-CT_90pct_by_20	35.csv		2022-09-12: 09:02		VE-HDV-He	eavy-CT_90pct	_by_2035.csv	
VE-LDV-CT_90pct_by_2035.csv			2022-09-12: 09:01		CES_CT_90	oct_by_2035.cs	5V	~
VE-HDV-Heavy-CT_90pct_by_2	035.csv		2022-09-12: 09:00		<			
						Ð		
Scenario Library	Search:				→ [←]			
Scenario Name		Created	Completed	Si	tatus	ProbMkts		•
GCAM5p4-Ref-Orig		2022-07-19: 08:05	2022-07-19: 10:26	Su	lccess			
GLIMPSE-Reference		2022-08-23: 15:29	2022-08-23: 17:06	Su	lccess			



	GLIMPS	Creating Scenario	-		
	[Scenario name:	GLIMPSE-EEREVE		
GLIMPSE Scenario Builder		Database:	database_seminar4 (0 GB)		- 0 X
Component Library Search:		Final model year:	2050 🔻		PSE-EEREVE
Component Nam	ie	Create debug file?	СТ	•	e
EE-Buildings-CT_from_2025.csv VE-HDV-Heavy-CT 90pct by 2045.csv		✓ Use all available pro	ocessors?)45.csv
VE-HDV-Medium-CT_90pct_by_2045.csv		Save files in scenario fo	lder: (global setting)		
VE-HDV-Light-CT_90pct_by_2035.csv		✓ Main log	✓ Debug file		5.csv
VE-LDV-CT_90pct_by_2035.csv VE-HDV-Heavy-CT_90pct_by_2035.csv		Calibration log	Solver log		\rightarrow
Scenario Library Search:					
Scenario Name	Created				
GCAM5p4-Ref-Orig	2022-07-19: 08:0!				
GLIMPSE-Reference	2022-08-23: 15:2!				
					•
			OK Cancel		TC-



G	LIMPS	Creating Scenario	-		
		Scenario name:	GLIMPSE-EEREVE		
GLIMPSE Scenario Builder File Tools View Help		Database:	database_seminar4 (0 GB)		- 0 X
Component Library Search:	E	Final model year:	2050 -		PSE-EEREVE
Component Name		✓ Create debug file?	СТ	-	•
EE-Buildings-CT_from_2025.csv VE-HDV-Heavy-CT_90pct_by_2045.csv VE-HDV-Medium-CT_90pct_by_2045.csv		✓ Use all available pro Save files in scenario fo	ocessors? Ider: (global setting)		45.csv
VE-HDV-Light-CT_90pct_by_2035.csv VE-LDV-CT_90pct_by_2035.csv VE-HDV-Heavy-CT_90pct_by_2035.csv		Main log Calibration log Comments:	Debug file Solver log		.csv
Scenario Library Search:	Created	This is a demonstratio air pollutant impacs o in Connecticut.	on of using GLIMPSE to test the f hypothetical EE/RE/VE measure	es	Runtime
GCAM5p4-Ref-Orig	2022-07-19: 08:0!				3441.29 s
GLIMPSE-Reference	2022-08-23: 15:2:		O Cancel		5773.44 s



GLIMPSE Scenario Builder

GLIMPSE Scenario Builder						- 🗆 X	
File Tools View Help							
Component Library Search:		Create Scen	nario	GLIMPSE-EEREVE			
Component Name		Created 🔹			Componen	t Name	
EE-Buildings-CT_from_2025.csv	2	022-09-12: 09:08		VE-HDV-M	ledium-CT_90pct	_by_2045.csv	
VE-HDV-Heavy-CT_90pct_by_2045.csv	2	2022-09-12: 09:05			VE-HDV-Light-CT_90pct_by_2035.csv		
VE-HDV-Medium-CT_90pct_by_2045.csv	2	022-09-12: 09:04		VE-LDV-CT	_90pct_by_2035	CSV	
VE-HDV-Light-CT_90pct_by_2035.csv		022-09-12: 09:02		VE-HDV-H	eavy-CT_90pct_b	y_2035.csv	
VE-LDV-CT_90pct_by_2035.csv		022-09-12: 09:01		CES_CT_90	pct_by_2035.csv	~	
VE-HDV-Heavy-CT_90pct_by_2035.csv 2022-09-12: 09:00		022-09-12: 09:00		<		→ →	
<	ר	×			\oplus		
Scenario Library Search:				÷			
Scenario Name	Created	Completed	St	tatus	ProbMkts	Runtime	
GCAM5p4-Ref-Orig	2022-07-19: 08:05	2022-07-19: 10:26	Su	ICCESS		3441.29 s	
GLIMPSE-Reference	2022-08-23: 15:29	2022-08-23: 17:06	Su	ICCESS		5773.44 s	
GLIMPSE-EEREVE	2022-09-12: 10:04						
			• •				
			- /				

The new scenario is now in the Scenario Library



GLIMPSE Scenario Builder

GLIMPSE Scenario Builder					- 🗆 X	
File Tools View Help						
Component Library Search:		$B \times O$		Create Scenario	GLIMPSE-EEREVE	
Component Name		Created 🔻		Component Name		
EE-Buildings-CT_from_2025.csv	2022-09-12: 09:08			VE-HDV-Medium-CT_90pct_by_2045.csv		
VE-HDV-Heavy-CT_90pct_by_2045.csv	2	2022-09-12: 09:05		VE-HDV-Light-CT_90pct_by_2035.csv		
VE-HDV-Medium-CT_90pct_by_2045.csv	2	2022-09-12: 09:04		VE-LDV-CT_90pct_by_2035.csv		
VE-HDV-Light-CT_90pct_by_2035.csv	2	022-09-12: 09:02		VE-HDV-Heavy-CT_90pct_	by_2035.csv	
VE-LDV-CT_90pct_by_2035.csv	2	022-09-12: 09:01		CES_CT_90pct_by_2035.csv	v v	
VE-HDV-Heavy-CT_90pct_by_2035.csv	2	2022-09-12: 09:00				
	n					
Scenario Library Search:						
Scenario Name	Created	Complete	St	tatus ProbMkts	Runtime	
GCAM5p4-Ref-Orig	2022-07-19: 08:05	2022-07-19: 10:20			3441.29 s	
GLIMPSE-Reference	2022-08-23: 15:29	2022-08-23: 17:06			5773.44 s	
GLIMPSE-EEREVE	2022-09-12: 10:04					
L						

Running a scenario in GCAM-USA



GLIMPSE Scenario Builder

💽 GLIMPSE Scenario Builder — 🗆 🗙	
File Tools View Help	
Component Library Search: E:\Projects\GLIMPSE-5p4_v2\GCAM-Model\gcam-v5.4\exe\gcam.exe — [) ×
For further details, see: http://www.globalchange.umd.edu/models/gcam/	
Comport	
EE-Buildings-CT_from_2025.csv	
VE-HDV-Heavy-CT_90pct_by_20; Configuration_file: E:\Projects\GLIMPSE-5p4_v2\GLIMPSE-Data\GCAM-USA\ScenarioFolders\GLIMPSE-EEREVE\configuratio	n_GLIMP
VE-HDV-Medium-CT 90pct by SE-EEREVE.xml	
Parsing _/input/gramdata/yml/po_climate_model_yml_scenario_component	
VE-HDV-Light-CI_90pct_by_203r at Sing/input/gcamdata/xml/no_climate_model.xml scenario component.	
VE-LDV-CT_90pct_by_2035.csv Parsing/input/gcamdata/xml/resources.xml scenario compone t.	
VE-HDV-Heavy-CT_90pct_by_20 Parsing/input/gcamdata/xml/en_supply.xml scenario compone.	
Parsing/input/gcamdata/xml/en_transformation.xml scenario ().	
Parsing/input/gcamdata/xml/heat.xml scenario component.	
Parsing/input/gcamdata/xml/hydrogen.xml scenario componen	
Scenario Library	
Parsing/input/gcamdata/xml/industry.xml scenario component	
Scenario Name Parsing/input/gcamdata/xml/cement.xml scenario component.	
GCAMEnA Ref Orig	
Parsing/input/gcamdata/xml/en_Fert.xml scenario component.	
GLIMPSE-Reference Parsing/input/gcamdata/xml/HDDCDD_constdd_no_GCM.xml scenario component.	
GLIMPSE-EEREVE Parsing///Contrib/TechUpdates/transportation/transportation UCD CORE v2.xml scenario component.	
ParsingContrib\TechUpdates\transportation\transportation_UCD_CORE_onroad_lifetime_adjustment.xml scenar	io comp
onent.	
Parsing/input/gcamdata/xml/Ccoef.xml scenario component.	
Parsing/input/gcamdata/xml/cstorage.xml scenario component. Parsing ./input/gcamdata/xml/ag For Past bio base TRR MGMT xml scenario component	

This window provides status information about the run.



GLIMPSE Scenario Builder

SLIMPSE Scenario Builder				- 🗆 X			
File Tools View Help							
Component Library Search:		$P \bowtie \times O$	ſ	Create Scenario GLIMPSE-EEREVE			
Component Name		Created v		Component Name			
VE-TOV-LIGHT-CT_SOPEC_DY_2055.csv		2022-09-12: 09:01		VE-HDV-Medium-CT_90pct_by_2045.csv			
VE-EDV-CT_SOPEL_DY_2055.csv		2022-09-12: 09:00		VE-HDV-Light-CT_90pct_by_2035.csv			
CES CT 90pct by 2035.csv		2022-09-12: 08:47		VE-LDV-CT_90pct_by_2035.csv			
CO2_targets_NortheastUS.csv		2022-09-12: 07:42		VE-HDV-Heavy-CT_90pct_by_2035.csv			
Policy-CES_100x35_USA_acr.csv		2022-08-26: 22:16		<pre>CES_CI_90pct_by_2035.csv</pre>			
Onroad-OnlyEVandH2-from2030.csv		2022-08-26: 15:46 🗸					
		>	l				
Scenario Library Search:							
Scenario Name	Created	Completed		ProbMkts Runtime			
GCAM5p4-Ref-Orig	2022-07-19: 08:05	2022-07-19: 10:26	Su	3441.29 s			
GLIMPSE-Reference	2022-08-23: 15:29	2022-08-23: 17:06	Su	Jcces 5773.44 s			
GLIMPSE-EEREVE	2022-09-12: 10:04	2022-09-12: 11:44	Su	iccess 5968.08 s			

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



GLIMPSE Model Interface



Scenarios in the output database







GLIMPSE Model Interface

Scenario	Regions	Queries
LIMPSE-Reference 2022-9 US	A A	queries
IMPSE-EEREVE 2022-12- Afr	ica_Eastern	
Afr	ica_Northern	Primary and final energy
Afr	ica_Southern	Primary energy consumption by region (direct equivalent)
Afr	ica_Western	
Aus	stralia_NZ	
Bra	izil	
Car	nada	
Cer	ntral America and Caribbea	Electricity use by aggregate sector
Cer	ntral Asia	Coal use by aggregate sector
Chi	ina	-Table A Start
EU	-12	
EU·	-15	Hydrogen use by aggregate sector
Eur	ope_Eastern	🔁 🔄 Technologies
Eur	ope_Non_EU 🗸	Electricity generation by region (no cogen)(GCAM-USA)
	Turde Arrested	Run Ouery Diff Ouery Total Collapse Update Single Oueries Create Remove Ed

Queries available for extracting data from the output database



Scenario	Regions	Queries	
GLIMPSE-Reference 2022- GLIMPSE-EEREVE 2022-12	Africa_Eastern Africa_Southern Africa_Southern Africa_Western Australia_NZ Brazil Canada Central America and Caribbea Central Asia China EU-12 EU-15 Europe_Eastern Europe_Non_EU	Gutries GutMPSE Primary and final energy Final energy consumption by region Final energy consumption by aggregate sector Final energy consumption by aggregate sector and fuel Final energy consumption by sector and fuel Electricity use by aggregate sector Cola use by aggregate sector Refined liquids use by aggregate sector Refined liquids use by aggregate sector Technologies Electricity generation by region (no cogen)(GCAM-USA) Run Query Diff Query Total Collapse Update Single Queries Create Remove Edit	
			Query results pane





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File Edit Table Help										
		·								
Scenario	Regions		Evelet bu	ul comico outro	the bulk as h	Queries				
GLIMPSE-Reference 2022-9-91	Argentina A		Freight tru	ick service outpu	it by tech (no b	us)				\sim
GLIMPSE-EEREVE 2022-12-911	Colombia			ions by region						
	AL.		CO2 emiss	ions by region	te sector					
	AD		CO2 emiss	ions by aggrega	te sector					
	A7		CO2 by re	source productio	n					
	CA CA		CO2 emiss	ions by sector (r	n bio)					
	co		CO2 emiss	ions by tech	10 210)					
	CT		NOx.502.	PM2.5 by region						
	DC		NOx, 502,	PM2.5 by aggre	gate sector					
	DE		WOx, 502,	PM2.5 by sector	-					
	FL		WOx, SO2,	PM2.5 by tech						
	GA	-	📲 All emissio	ns by region						
	HI	-	📨 🖬 emissio	ns by aggregate	sector					
	IA		💴 🚄 All emissio	ns by sector						~
		Run Ouer	V Diff OL	ierv 🗌 Tota	Collapse	Update Sing	le Oueries	Create	Remove	Edit
			,			op and o party	- queries			
All emissions by region										
Filter Graph sma	at									
sconorio rel	2015	2020	202E	2020	2025	2040	204E	2050	Unite	
scenario re	2015	2020	2025	2030	2035	2040	2045	2050	Units	
GLIMPSE-EE CT	0.00300 0	.00281	0.00263	0.00243	0.00223	0.00214	0.00203	0.00205	Ig	^
GLIMPSE-EE CT		.21	7.05	6.01	4.34	3.88	3.52	3.30	MIC	
CLIMPSE-EE CT		00144	0.000135	0.000128	0.000122	0.000116	0.000110	0.000106	Ta	
CLIMPSE-EE CT		205	0.00241	0.00225	0.00196	0.0018/	0.00181	0.00177	Ta	
GLIMPSE-EE CT			0.0713	0.0702	0.0395	0.0390	0.0399	0.0701	Ta	
GLIMPSE-EE CT		2	0.00331	0.0277	0.0244	0.0233	0.0228	0.0222	Ta	
GLIMPSE-EE CT		2	0.00346	0.00663	0.00754	0.00475	0.00778	0.00774	Ta	
GLIMPSE-Re., CT		1	0.00268	0.00258	0.00254	0.00255	0.00254	0.00261	Ta	
GLIMPSE-Re CT			7.31	6.71	6.31	6.06	5.85	5.84	MTC	
GLIMPSE-Re CT			0.000139	0.000135	0.000129	0.000125	0.000119	0.000115	Ta	
GLIMPSE-Re CT	H3		0.00248	0.00243	0.00241	0.00242	0.00244	0.00247	Ta	
GLIMPSE-Re CT N	MVOC		0.0420	0.0415	0.0422	0.0434	0.0445	0.0447	Tq	
GLIMPSE-Re CT N	Ον	.418	0.0335	0.0285	0.0262	0.0254	0.0249	0.0247	To	×



GLIMPSE Model Interface

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File Edit Table Help			
Scenario	Regions	Oueries	
GLIMPSE-Reference 2022-9-9T	Argentina	Freight truck service output by tech (no bus)	^
GLIMPSE-EEREVE 2022-12-9T1	Colombia	Emissions	
	AK	CO2 emissions by region	
	AL	CO2 emissions by aggregate sector	
	AR	CO2 emissions by sector	
	AZ	CO2 by resource production	
	CA	CO2 emissions by sector (no bio)	
	со	CO2 emissions by tech	
	ст	NOx, SO2, PM2.5 by region	
	DC	NOX, SO2, PM2.5 by aggregate sector	
	DE	NOX, 502, MM2.5 Dy sector	
		All emissions by region	
	HT	All emissions by acquere sector	
	TD V		¥
< >>	< >	Run Query Diff Query Total Collapse Update Single Queries Create Remove	Edit
Filter Graph Forma sce reg GHG 2015 2 GLI CT CH4 0.00 0. GLI CT CO2 9.01 8. GLI CT N2O 0.00 0. GLI CT NH3 0.00 0. GLI CT NH4 0.008.0 0. GLI CT NMV 0.0588 0.	t 2020 2025 2030 2035 2030 2035 203 203 203 203 203 203 203 203 203 203	2040 2045 2050 Units 0.00 0.00 Tg 3.88 3.52 3.30 MTC 0.00 0.00 Tg 0.00 Tg B 0.00 Tg Tg 0.00	fresh
GLT. CT NOX 0.0503 0.	0418 0.0331 0.0277 0.0244 0	J.0233 U.0225 U.0222 IIg S 6	_
GLI CT SO2 0.0102.0			
GL., CT CH4 0.000	000.000.000.000	0.000.00000000	
GLI CT CO2 9.01 8.	21 7.31 6.71 6.31 6	5.06 5.85 5.84 MTC E 2	
GLI CT N2O 0.000	00 0.00 0.00 0.00 0	0.00 0.00 Tq	
GLI CT NH3 0.00 0.	00 0.00 0.00 0.00 0	0.00 0.00 Tg	
GLI CT NMV 0.0588 0.	0461 0.0420 0.0415 0.0422 0	0.0434 0.0445 0.0447 Tg	205
GLT CT NOV 0.0503.0	0418 0 0335 0 0285 0 0262 0		0 0
3			











GLIMPSE Model Interface

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File Edit Table Help		
File Edit Table Help Scenario GLIMPSE-Reference 2022-9-9T GLIMPSE-EEREVE 2022-12-9T GLIMPSE-EEREVE 2022-12-9T Colombia AK AL AR AZ CA CO CT DC DE	Queries Queries Emissions CO2 emissions by region CO2 emissions by aggregate sector CO2 emissions by sector NOx, SO2, PM2.5 by region NOx, SO2, PM2.5 by sector NOx, SO2, PM2.5 by sector	
FL GA HI IA X All emissions by region	Image: Nox, SO2, PM2.5 by tech Image: Nox, SO2, PM2.5 by tech	↓ Edit
sce reg GHG 2015 2020 2025 2030 203	15 2040 2045 2050 Units	resh
GLI CT CH4 0.00 0.00 0.00 0.00 0.00	CI C	1
GLI CT N2O 0.00 0.00 0.00 0.00 0.00 0.00		
GLI CT NH3 0.00 0.00 0.00 0.00 0.00) 0.00 0.00 Tg	
GLI CT NMV 0.0588 0.0461 0.0415 0.0402 0.03	195 0.0396 0.0399 0.0401 Tg	
GLI CT NOx 0.0503 0.0418 0.0331 0.0277 0.02	244 0.0233 0.0226 0.0222 Tg 6	
GLI CT PM2.5 0.0100 0.00 0.00 0.00 0.00	0 0.00 0.00 Tg	
GLI CT SO2 0.0102 0.00 0.00 0.00 0.00		
GLI CT N2O 0.00 0.00 0.00 0.00 0.00		
GLL. CT NH3 0.00. 0.00. 0.00 0.00 0.00		
GL., CT NMV., 0.0588 0.0461 0.0420 0.0415 0.04		202
GLI CT NOV 0.0503.0.0418.0.0335.0.0285.0.02	6 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	ñ 8



GLIMPSE Model Interface

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File Edit Table Help		
Scenario	Regions Oueries	_
GLIMPSE-Reference 2022-9-91	Argentina	^
GLIMPSE-EEREVE 2022-12-9T1	Colombia Emissions	
	AK CO2 emissions by region	
	AL CO2 emissions by aggregate sector	
	AR CO2 emissions by sector	
	AZ CO2 by resource production	
	CA CO2 emissions by sector (no bio)	
	CO CO emissions by tech	
	CT NOx,SO2,PM2.5 by region	
	DC NOX,502,PM2.5 by aggregate sector	
	UE NOX, SO2, PM2.5 By Sector	
	PL NOX, SOZ, PPLZ S UY LECH	
	GA All emissions by angrenate sector	
	TA An emissions by sector	
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All emissions by region	nat	
sce reg GHG 2015	2020 2025 2030 2035 2040 2045 2050 Units 🛛 Sum Across 🗘 LineChart 🗸 Same Scale Refresh	
GLI CT CH4 0.00	0.00 0.00 0.00 0.00 0.00 0.00 10.00 Tg	- 1
GLI CT CO2 9.01 8	8.21 7.05 6.01 4.34 3.88 3.52 3.30 MTC Statistics T region: CT	
GLI CT N2O 0.00	0.00 0.00 0.00 0.00 0.00 0.00 Tg	
GLI CT NH3 0.00 0	0.00 0.00 0.00 0.00 0.00 0.00 Tg	
GLI CT NMV 0.0588	0.0461 0.0415 0.0402 0.0395 0.0396 0.0399 0.0401 Tg	
GLI CT NOx 0.0503	0.0418 0.0331 0.0277 0.0244 0.0233 0.0226 0.0222 Tg	
GLI CT PM2.5 0.0100 0	0.00 0.00 0.00 0.00 0.00 0.00 Tg	
GLI CT 5O2 0.0102 0	0.00 0.00 0.00 0.00 0.00 0.00 Tg	
GLI CT CH4 0.00 0	3.000.000.000.000.000.00.0017g	
GLI CT CO2 9.01 8	5.21 /.31 0.71 0.31 0.00 5.85 5.84 MIC E 2	
GLT CT NMV 0.0599 /		
GLI CT NOX 0.0503 0	0,0418 0,0335 0,0285 0,0262 0,0254 0,0249 0,0247 Ta → 3 8 8	
7		







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File Edit Table Help							
Scenario Regions	Queries						
GLIMPSE-Reference 2022-9-97 GLIMPSE-EEREVE 2022-12-971 Argentina AK AL AR AZ CA CO CT DC DE FL	Freight truck service output by tech (no bus) Emissions CO2 emissions by region CO2 emissions by aggregate sector CO2 emissions by sector CO2 emissions by sector CO2 emissions by sector (no bio) CO2 emissions by tech NOx,SO2,PM2.5 by region NOx,SO2,PM2.5 by sector NOx,SO2,PM2.5 by tech	AutoSave Off R Book3 - Excel Se File Home Insert Page Layout Formulas	earch (Alt+Q) Data Review View Develop	Dan Loughlin 🎨 🗘 – 🗆 X ner Help Foxit PDF Power Pivot 🖵 🗗			
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While we answered the research questions, we did not address "Why?"

This is where GLIMPSE is particularly useful...



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?

Environmental Protection





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?



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 AppliedEnergy	vhiner rentil tre (*10) 405-443	Cleaner Engineering and Technology 1 (2020) 100017	Applied Energy 300 (2021) 117364	
Applied Energy FI SEVIER journal homepage: www.elsevier.com/locate/apenergy	Contents lists available at ScienceDirect Applied Energy FJ SFVTFR journal homepage: www.elsevier.com/locate/spenergy	Contents lists available at ScienceDirect Cleaner Engineering and Technology ELSEVIER journal homepage: www.journals.elsevier.com/cleaner-engineering-and-technology	Contents lists available at ScienceDirect Applied Energy Applied Energy ELSEVIER journal homepage: www.elsevier.com/locate/appnergy	
Projecting state-level air pollutant emissions using an integrated assessment model: GCAM-USA Wenjing Shi*i, Yang Our ³ , Steven J. Smith ^b , Catherine M. Ledna ^b , Christopher G. Nolte ^a , Daniel H. Loughlin ^{+,+} * Office of Bearch and Donkjouez, U.S. Boltomanial Protection Agency, Research Triagle Jvit, NC 2771, UKA * School Charge Research Testing, Park, Notherer Refer Mathematic Agency, Research Triagle Jvit, NC 2771, UKA * School Charge Research Testing, Park, Not Note: Refer Mathematic Agency, Research Triagle Jvit, NC 2771, UKA * School Charge Research Testing, Park, Not Note: Refer Mathematic Agency, Research Triagle Jvit, NC 2771, UKA * School Charge Research Testing, Park, Not Note: Refer Mathematic Agency, Research Testing, Park, NC 2771, UKA * School Charge Research Testing, Park, Not Note: Refer Mathematic Agency, Research Testing, Park, NC 2771, UKA * School Charge Research Testing, Park, Not Note: Refer Mathematic Agency, Research Testing, Park, NC 2771, UKA * School Charge Research Testing, Park, Note: Refer Mathematic Agency, Research Testing, Park, NC 2771, UKA * School Charge Research Testing, Park, Note: Refer Mathematic Agency, Research Testing, Park, NC 2771, UKA * School Charge Research Testing, Park, Note: Refer Mathematic Agency, Research Testing, Park, NC 2771, UKA * School Charge Research Testing, Park, Note: Refer Mathematic Agency, Research Testing, Park, NC 2771, UKA * School Charge Research Testing, Park, Note: Refer Mathematic Agency, Research Testing, Park, NC 2771, UKA * School Charge Research Testing, Park, Note: Refer Mathematic Agency, Research Testing, Park, NC 2771, UKA * School Charge Research Testing, Park, Note: Refer Mathematic Agency, Refer Mathematic Agency, Refer Mathematic Agency, Refer Mathemat	Estimating environmental co-benefits of U.S. low-carbon pathways using an integrated assessment model with state-level resolution Yang Out ^{3,b,1} , Wenjing Shi ^{1,1} , Steven J. Smith ⁵ , Catherine M. Ledna ⁵ , J. Jason West ⁵ , Christopher G. Nolte ⁵ , Daniel H. Loughlin ^{4,4} [*] Office of Baards and Dealgement, U.E. Brokensaud Powerk, Montana 4 Quel, K.K. Ishida Suas [*] Deprive of Handraman Stoke and Hangering Dealerly Mich Cathula 4 Caugh K.K. Chud Suas [*] Deprive of Handrama Stoke and Hangering Dealerly Mich Cathula 4 Caugh K.K. Chud Suas [*] Deprive of Handrama Stoke and Hangering Dealerly Mich Cathula 4 Caugh K.K. Chud Suas [*] Deprive of Handrama Stoke and Hangering Dealerly Mich Cathula 4 Caugh K.K. Chud Suas [*] Dealer of Handrama Stoke and Handrama Testand Handrama Code Caugh K.K. Under State A Caugh K.K. Chud Suas [*] Dealer of Handrama Stoke and Handrama Stoke and Handrama State A Caugh K.K. Chud State Caug	Incorporating upstream emissions into electric sector nitrogen oxide reduction targets Samaneh Babaee ^a , Daniel H. Loughlin ^b , P. Ozge Kaplan ^{b,*} [*] Od Right humas for Scince and Rhocater, U.S. Britmennend Preschender Dire, Research Trangle Fact, NC, 2771, United Bases ^b Od Right humas for Scince and Rhocater, U.S. Britmennend Preschender Dire, Research Trangle Fact, NC, 2771, United Bases ^b Od Right humas for Scince and Rhocater, U.S. Britmennend Preschender Dire, Research Trangle Fact, NC, 2771, United Bases ^b Od Right humas for Scince and Rhocater, Dire Research Trangle Fact, NC, 2771, United Bases ^b Od Right humas for Scince and Rhocater, Dire Research Trangle Fact, NC, 2771, United Bases ^b Od Right humas for Scince and Rhocater, Dire Research Trangle Fact, NC, 2771, United Bases ^b Od Right humas for Scince and Rhocater, Dire Research Trangle Fact, NC, 2771, United Bases ^b Od Right humas for Scince and Rhocater, Dire Research Trangle Fact, NC, 2771, United Bases ^b Od Right humas for Scince and Rhocater, Dire Research Trangle Fact, NC, 2771, United Bases ^b Od Right humas for Scince and Rhocater, Dire Research Trangle Fact, NC, 2771, United Bases ^b Od Right humas for Scince and Rhocater, Dire Research Trangle Fact, NC, 2771, United Bases ^b Od Right humas for Scince and Rhocater, Dire Research Trangle Fact, NC, 2771, United Bases ^b Od Right humas for Scince and Rhocater, Dire Research Trangle Fact, NC, 2771, United Bases ^b Od Right humas for Scince and Rhocater, Dire Research Trangle Fact, NC, 2771, United Bases ^b Od Right humas for Scince and Rhocater, Dire Research Trangle Fact, NC, 2771, United Bases ^b Od Right humas for Scince and Rhocater, Dire Research Trangle Fact, NC, 2771, United Bases ^b Od Right humas for Scince and Research Trangle Fact,	Evaluating long-term emission impacts of large-scale electric vehicle deployment in the US using a human-Earth systems model Yang Ou ^{3,4} , Noah Kitter ^{16,6} , Samaneh Babaee ^{4,4} , Steven J. Smith ³ , Christopher G. Nolte ⁴ , Daniel H. Loughlin ^{4,4} ¹ Noro Kald Charles Jandy, Nathar Distance (Annu Charles (Charles (C	
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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: Loughlin.Dan@epa.gov





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Acknowledgements:

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

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