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

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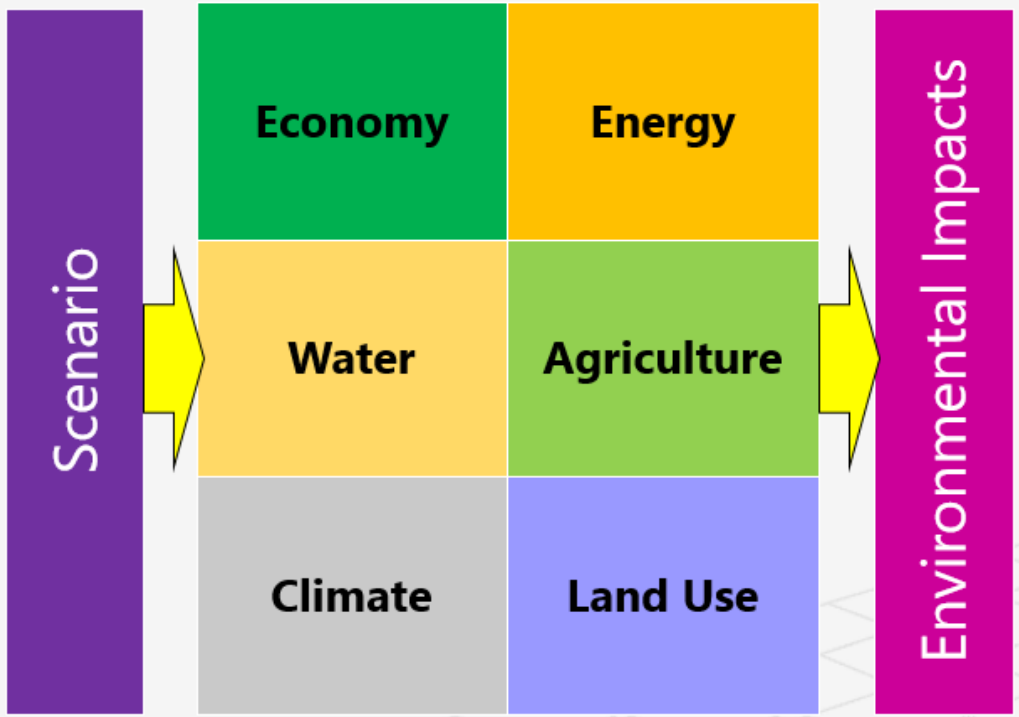


Underlining denotes 50% time or more
See the extra slides for definition of abbreviations

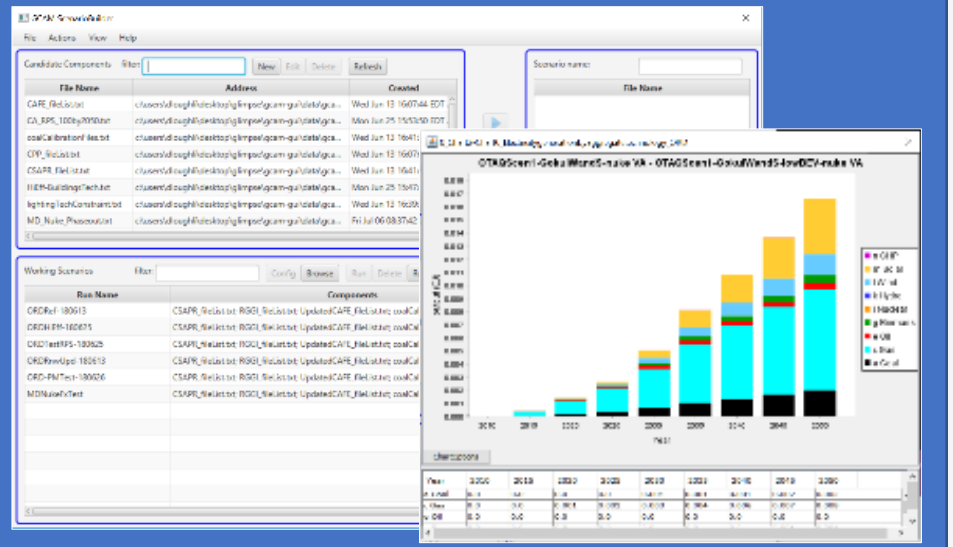
Overview

- Energy choices affect the objectives of:
  - addressing climate change
  - protecting the environment, including air & water quality
  - meeting energy & water needs
- Approaches are needed to:
  - examine tradeoffs & find holistic solutions
  - assess new & emerging energy technologies
- The GCAM human-Earth systems model supports these purposes
- GCAM's complexity has limited its use to "hard core" modelers
- ORD's GLIMPSE tool makes GCAM accessible to a wide range of analysts & decision makers by facilitating:
  - representing policies
  - constructing & executing scenarios
  - visualizing & analyzing results
  - identifying cost-effective management strategies

Global Change Analysis Model (GCAM-USA)

Type: Technology-rich integrated assessment model
Spatial: 32 global regions with state-level resolution
Temporal: 2010-2100 in 5-yr increments
Components: energy (transportation, industry, buildings), agriculture, land use, water, & climate systems
Endpoints: CO_2, CH_4 & other GHGs; air pollutants; water demands; PM mortality costs; & global mean temperature
Lead developer: Pacific Northwest National Laboratory
Availability: public domain, open source, runs on desktop computer in several hours

GLIMPSE



Examples of impacts

Scientific

- ***Electric vehicle analysis***: Identified critical factors affecting net emissions, e.g., lifetime extensions decisions for coal plants, refinery operations, potential for price-induced fuel switching in other sectors, importance of regional policies (e.g., RGGI)
- ***Health outcome-based control strategy design***: Demonstrated how GCAM can be used to identify cost-effective multi-pollutant, multi-sector strategies for reducing the health burden of air pollution
- ***Holistic policy design***: Identified cost savings, but also potential unintended consequences, of allowing the electric sector to receive credit for upstream NOx reductions in meeting powerplant NOx reduction targets
- ***Control strategy design***: At the state level, characterized the cost-effectiveness of energy efficiency, renewable electricity, & end-use electrification in reducing air pollutant emissions (to be completed in 2022)

Program Office Support

- With OAP & OTAQ: Linking GCAM-USA & a detailed electric sector model
- With OAP: Building capacity to evaluate climate mitigation proposals with GCAM-USA
- With OAQPS: Exploring EE/RE in State Implementation Plans

Educational

- Project-based graduate-level course on Integrated Assessment Modeling (using GLIMPSE)
  - Duke University ('20,'21,'22), Penn St. ('22), Univ. of MD ('22)
- Theses & dissertations: PhD & MS students at Duke Univ., UNC, Northeastern, & Penn St.

GLIMPSE is helping the program office bring GCAM's capabilities in-house

Students can conduct important analyses without first spending months coding policies in complex formats, learning R, etc.

Once GLIMPSE is released, the broader domestic and international GCAM communities will be able to benefit as well.

Next steps

Public release of GLIMPSE

- Expected this winter and will involve a webinar, trainings, & support (amount depends on resources)
- Future updates include new & updated policy representations, reporting & visualization improvements, & integration of new versions of GCAM

State applications

- Ongoing RARE application with EPA Region 1 & Connecticut's Dept. of Energy and Environmental Protection
  - All CT's counties exceed the 2008 Ozone NAAQS
  - CT & surrounding states have instituted a number climate change mitigation measures that are also expected to reduce air pollutant emissions
  - Research question: How will these actions affect CT's attainment status and plans?
  - Approach: Working with CT staff to assess these impacts with GLIMPSE
- Discussing similar applications through EPA's Advance program

Potential new direction in StRAP 4

- Beyond energy - Exploring environmental impacts of energy system transformations
  - Quantifying challenges related to abandoned infrastructure (e.g., underground storage tanks); increased manufacturing of solar panels, batteries, & carbon fiber; fate of end-of-use batteries, wind turbines, and solar panels; mining rare earth metals

Extra Slides

GLIMPSE Publications

Ou, Y., Kittner, N., Smith, S.J., Babaee, S., Nolte, C.G., and D.H. Loughlin (2021). Evaluating long-term emission impacts of large-scale electric vehicle deployment in the US using a human-earth systems model. *Applied Energy*, 300(2021), 117364. https://doi.org/10.1016/j.apenergy.2021.117364

Babaee, S., Loughlin, D.H., and P.O. Kaplan (2020). Incorporating upstream emissions into electric sector nitrogen oxide reduction targets. *Cleaner Engineering and Technology*, https://doi.org/10.1016/j.clet.2020.100017

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

Ou, Y., Smith, S.J., West, J.J., Nolte, C.G., and D.H. Loughlin (2019). State-level drivers of future fine particulate matter mortality for the United States. *Environmental Research Letters*,14(2019) 124071, https://doi.org/10.1088/1748-9326/ab59cb

Ou, Y., Shi, W., Smith, S.J., Ledna, C.M., West, J.J., Nolte, C.G., and D.H. Loughlin (2018). Estimating environmental co-benefits of U.S. GHG reduction pathways using the GCAM-USA Integrated Assessment Model. *Applied Energy*, 216C(2018) pp. 482-493. https://doi.org/10.1016/j.apenergy.2018:02.122

Shi, W., Ou, Y., Smith, S.J., Ledna, C., Nolte, C.G., and D.H. Loughlin (2017). Projecting state-level air pollutant emissions using an integrated assessment model: GCAM-USA. *Applied Energy*, 208(2017), pp 511-521. https://doi.org/10.1016/j.apenergy.2017.09.122

Abbreviations

Models and Tools:
CMAQ - Community Multi-Scale Air Quality Model
DESID - Detailed Emissions Scaling Isolation and Diagnostic module
FAST-CE - Flexible Air quality Scenario Tool – Community Edition
GCAM - Global Change Analysis Model
GCAM-USA - A GCAM variant with state-level resolution for the US region
GLIMPSE - GCAM Long-term Interactive Multi-Pollutant Scenario Evaluator
IPM - Integrated Planning Model
MOVES - MOtor Vehicle Emission Simulator
SMOKE - Sparse Matrix Operator Kernel Emissions

EPA Organization:
AO - Administrator's Office
NCEE - National Center for Environmental Economics
OAP - Office of Atmospheric Programs
OAQPS - Office of Air Quality Policies and Standards
OAR - Office of Air and Radiation
ORD - Office of Research and Development
OTAQ - Office of Transportation and Air Quality

Other Organizations:
ORISE - Oak Ridge Institute for Science and Education
PNNL - Pacific Northwest National Laboratory

Pollutants and air pollution:
CH_4 - Methane
CO_2 - Carbon dioxide
GHGs - Greenhouse Gases
NAAQS - National Ambient Air Quality Standards
NH_3 - Ammonia
N_2O – Nitrous Oxide
NOx - Nitrogen Oxides
O_3 - Ozone
PM - Particulate Matter
$PM_{2.5}$ – PM with a diameter of 2.5 microns or less
SO_2 - Sulfur Dioxide

Other:
CT - Connecticut
EE - Energy Efficiency
EV - Electric Vehicles
GUI - Graphical User Interface
IAM - Integrated Assessment Model
RARE - Regional Applied Research Effort
RE - Renewable Electricity
RPS – Renewable Portfolio Standard

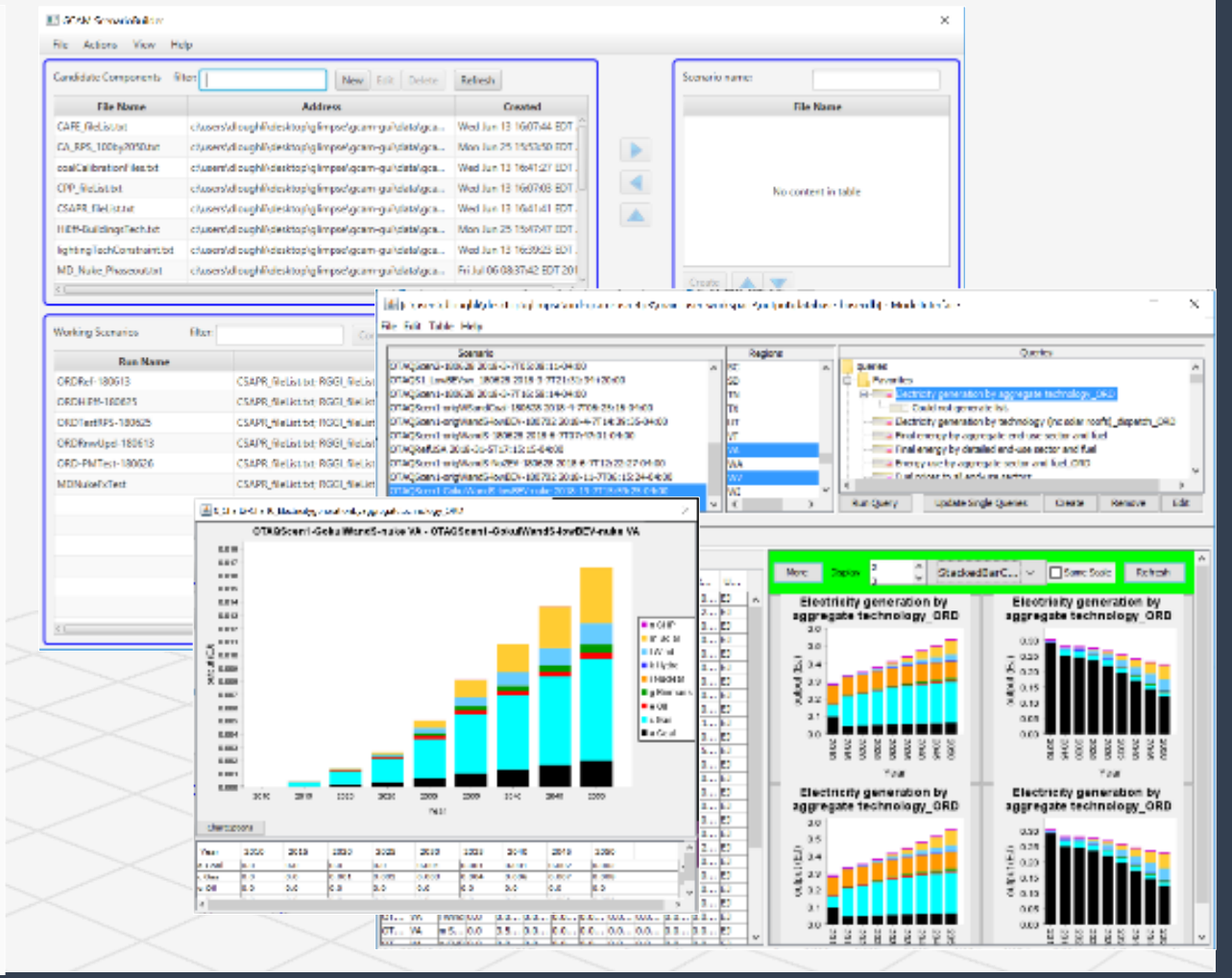
What is GLIMPSE?

GCAM Long-term Interactive Multi-Pollutant Scenario Evaluator

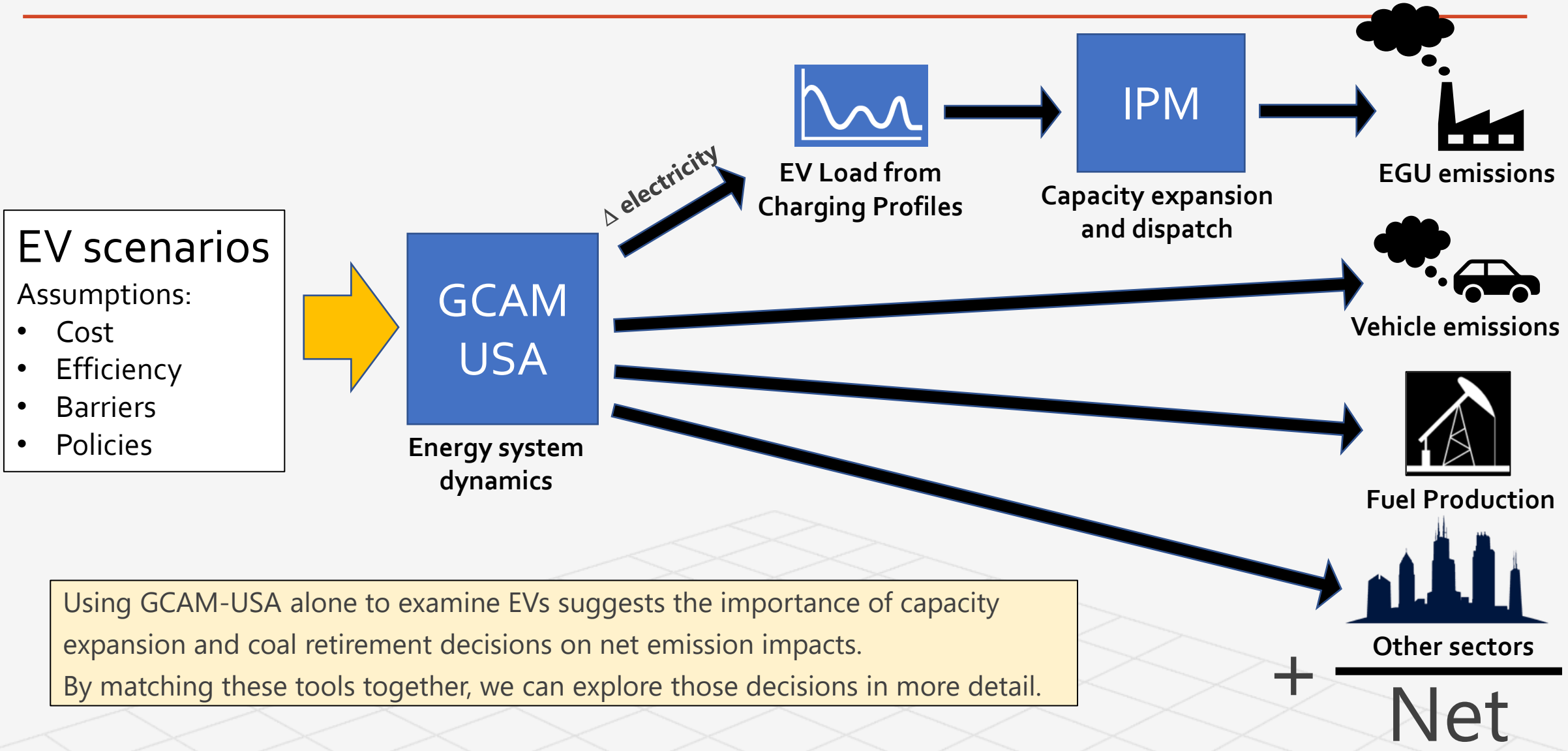
GLIMPSE

GCAM-USA improvements to support environmental decision-making

- User-friendly GUI for GLIMPSE
- Includes “levers” for easily setting up policies
  - *Pollutant taxes and caps*
  - *Technology subsidies*
  - *Market share constraints*
- Visualization tools support exploratory analysis
- Current users
  - *ORD*
  - *OTAQ/TCD*
  - *OAP/CCD*
  - *Duke IAM course (Loughlin/Shindell)*
  - *Northeastern Univ., Penn State*
- Training this past summer
  - *OAQPS, NCEE, Regions 1, 4*
  - *CT DEEP, Volpe, NC State, others*



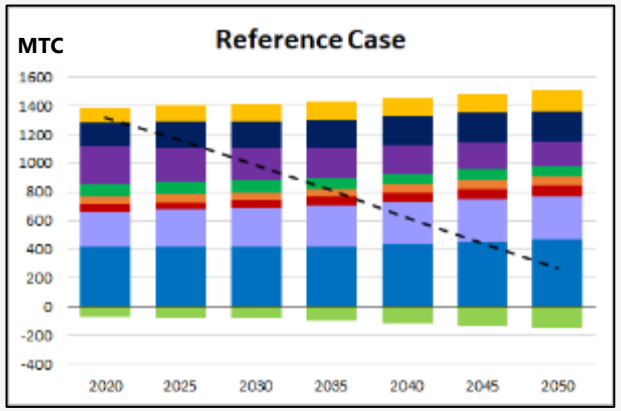
GCAM: Technology assessment – EV adoption (with OTAQ & OAP)

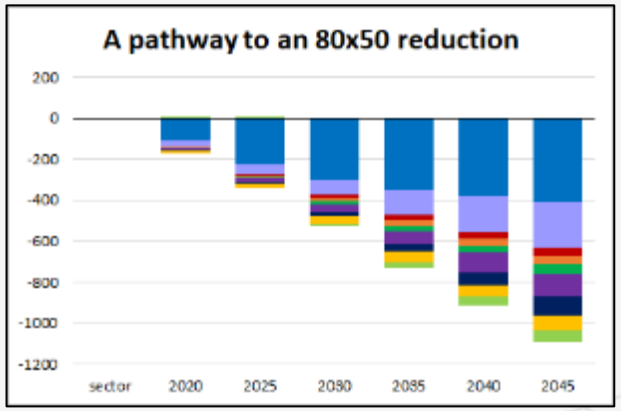


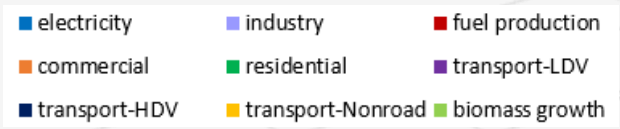
Using GCAM-USA alone to examine EVs suggests the importance of capacity expansion and coal retirement decisions on net emission impacts.
By matching these tools together, we can explore those decisions in more detail.

GCAM: Achieving economy-wide emission targets (with OAP/CCD)

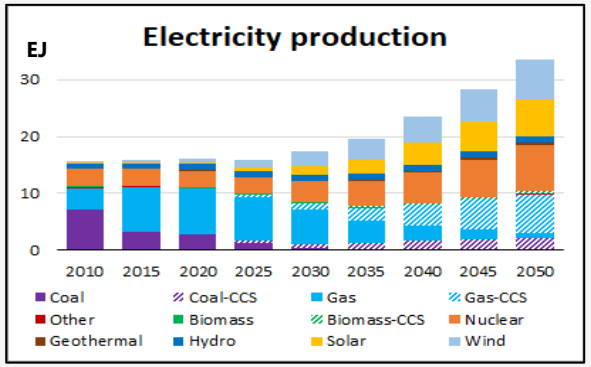
Finding a low-cost mitigation pathway

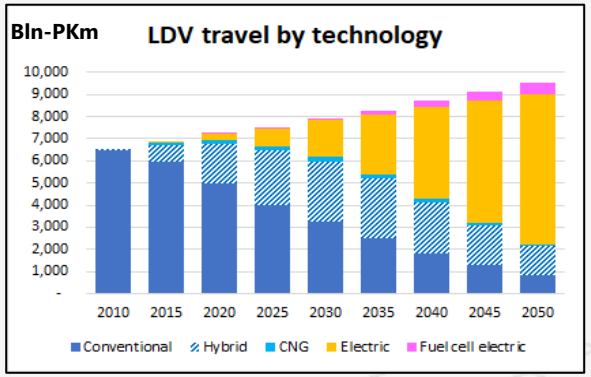


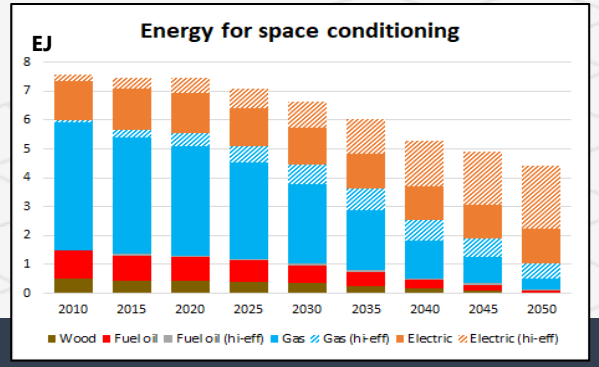




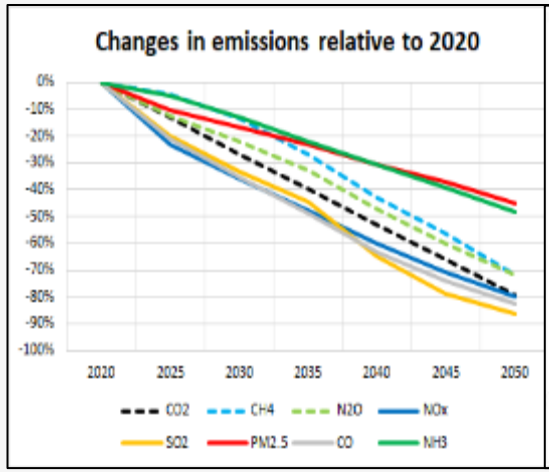
Resulting sector-specific strategies

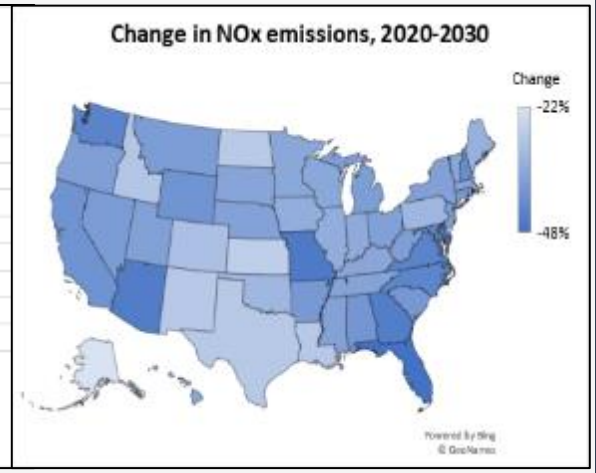






Emission impacts





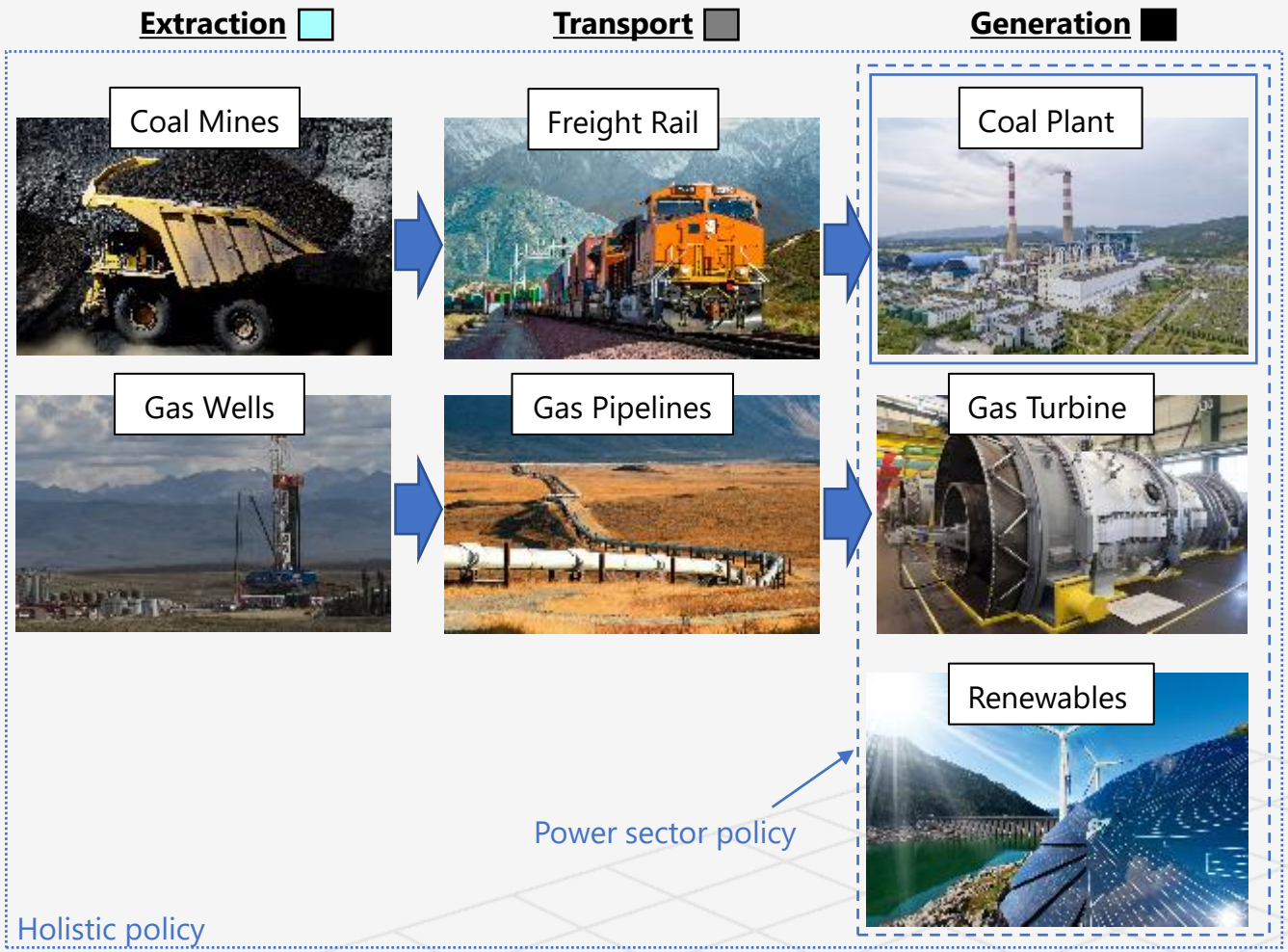
Research questions:

Are there pathways to meet the 80x50 target that achieve greater air pollution co-benefits?

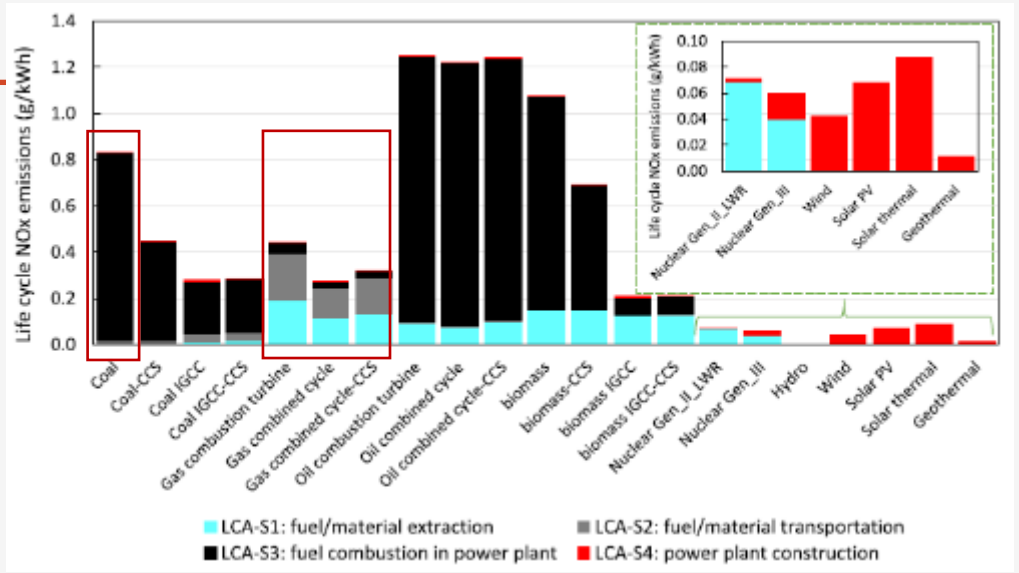
What is the relative cost-effectiveness of individual measures? (e.g., EE, EV targets, RPSs,…)

How does consideration of near-term air quality benefits impact our GHG mitigation strategy?

GCAM: Holistic policy design



NOx emissions per kWh (combustion & life cycle)



Overview:

- Simulated a holistic policy that requires specific NOx emission reductions across the life cycle
- Giving "credit" for upstream emission reductions resulted in some disbenefits (e.g., via reduced coal retirement), including small increases direct PM, SO2, & GHG increases
- Insights such as this could be useful in policy development
- Approach could be applied to GHGs

Babaee, S., Loughlin, D.H., and P.O. Kaplan (2020). Life cycle analysis of U.S. energy scenarios using a state-level integrated assessment model: GCAM-USA. *Cleaner Engineering and Technology*, https://doi.org/10.1016/j.clet.2020.100017.

Energy models to air quality impacts (with OAQPS)

Emission changes from TIMES, GCAM, or COMET

Change in emissions (t)

Difference	2015	2020	2030
Area source carbon	-	-	-
Mobile source carbon	-	(0)	0
EGU and non-EGU carbon	-	(103)	(160)
Area source SO2	(0)	(44)	(52)
EGU SO2	-	(551)	(312)
Non-EGU SO2	0	(1,019)	(1,547)
VOC	-	-	-
Area source NH3	-	(8)	(8)
Mobile source NH3	-	(1)	(3)
EGU NOx	0	(432)	(280)
Non-EGU NOx	-	(569)	(828)
Mobile source NOx	-	(211)	(243)