



CEMM research to understand changing energy systems

Presentation to ACE BOSC Subcommittee

October 14, 2021

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Charge question and background

- Focus Area: Modeling the impacts of the Nation's transforming energy and transportation systems.
- Charge Question 3:
 - The Nation's energy and transportation systems are experiencing major transformations in response to economic drivers and to meet the Biden Administration's goal of net-zero carbon emissions by 2050.
 - O Understanding the dynamic changes in these complex, interconnected systems is important for understanding impacts of policies and technology changes on emissions of green house gases (GHGs), air pollutants, and other health and environmental impacts.
- While charge questions focused on modeling, energy, and transportation measurement work will be briefly discussed.



What do we know (and not know) about net-zero energy?

- What do we know?
 - Limited/targeted fossil fuels
 - Zero or negative-carbon electricity
 - Electrified end uses
 - Alternative fuels in hard to electrify/decarbonize sectors
 - Use less energy and materials
 - Integrated energy systems approaches
 - Use of carbon dioxide removal (CDR)

Adapted from Acevedo et al. (2021)

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Source: https://flowcharts.llnl.gov/

What do we know (and not know) about net-zero energy?

- What are the uncertainties?
 - Impact of regional differences/circumstances?
 - How much negative emissions?
 - Infrastructure needs?
 - Path dependence?
 - Any surprises?
 - Role of behavior?

Adapted from Acevedo et al. (2021)

Adding: net-zero at what scale and for whom? Are the costs and benefits of this transformation equitable?



Source: https://flowcharts.llnl.gov/



Why we need energy system modeling approaches?



Contributions to anthropogenic emissions:

GHGs:

- CO2 96%
- CH4 40%
- All GHGs 82% (93% less sinks)

Air pollutants:

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

The US energy system is also responsible for nearly as much freshwater withdrawals as agriculture.



Geographic scope of models & select applications



Since 2010, over 50 peer-reviewed papers (> 30 in-house) have been published using our modeling frameworks.

What do we do? CEMM's approach to energy systems

Developing

energy systems models

From resource extraction to power plants & refineries to all end-use sectors

Multi-pollutant, multi-media, & multisector

Forward-looking "What-if?" and "How can I?" scenarios

Environmental focus – particularly pollutant emissions, expanding to air quality and other endpoints (water)

Delivering

analyses, databases, and decision support tools for...

Anticipating future environmental challenges

Evaluating existing & proposed air, climate, & energy regulations

Identifying cost-effective strategies for achieving single & multi-pollutant emissions targets

Examining additional endpoints, such as air quality & health

Supporting

partners, collaborators, and users

EPA Program & Regional Offices

Universities & NGOs, including EPA grantees (STAR, CACES-CMU)

Other federal, state & local government agencies (DOE/NETL, LBNL, NESCAUM)

Energy Modeling Forum and other collaborations

Potential to feed into assessment work (EPA assessments, National Climate Assessment)



How and where is our energy systems modeling used?

Regions	ΟΤΑQ	ΟΑΡ	Other Federal
 (RARE) GLIMPSE in state-level multipollutant planning (R3) Climate-Energy-Water nexus (R10) incl. impact of dam closures and changing water availability 	 Emissions benefits of vehicle mass reduction EV market penetration scenarios OTAQ/CAMD/ORD project to evaluate electric sector impacts of EVs using GCAM, EV-load tool, IPM Emissions benefits of hydrogen use as fuel in transportation sector 	 Analysis of climate bills Scenario planning, multi-stage and robust decision-making EMF- Decarbonization Scenarios for North America NAAQS in Northeast Ozone Transport Region Role of industrial and commercial CHP in decarbonization scenarios 	 PNNL (GCAM support) Volpe (GLIMPSE training) DOE/NETL (EPAUS9r-TIMES user) MITRE (EPAUS9r-TIMES user) NESCAUM (NE TIMES development) LBNL (COMET collab. on buildings)
States and Local	OAQPS (AQAD/AQPD/HEID/SPPD)		External
 Emission reductions associated with NYC clean energy plan, EE/RE and electrification of transportation (R2) (RARE) Impact of state and regional climate and energy policies on ozone attainment (R1 and CT DEP) 	 Scenario methods Improvements to non-EGU emission projections using energy systems models Incorporating life-cycle considerations into policy design in the electric sector 	 EE/RE in SIPs and RIAs Linking energy systems models to reduced-form air quality models ADVANCE program 	 International Energy Agency's Energy Technology Systems Analysis Programme Starter Model Open Energy Outlook (NCSU) <u>EPAUS9r-TIMES</u>: UT-Austin, UT- SA, Carnegie Mellon, NCSU, West Virginia; <u>COMET</u>: CUNY, Rutgers, JHU <u>GLIMPSE</u>: Duke, Northeastern, UMD, Penn State



Energy and transportation measurement work

- CEMM has unique expertise and facilities for characterizing our combustion sources as technologies and fuels change over time
 - Emissions characterization of various **biomass** materials co-fired with **coal** and **natural gas** at a range of blend levels (up to 80%).
 - Emissions characterization for **waste-to-energy** and impacts on both GHG and air emissions, with implications for community waste management approaches.
 - Methods for emissions characterization of **residential wood combustion**, which continues to be a major PM concern in communities, especially arctic communities (e.g., AK).
- CEMM is also expanding our understanding of methane sources
 - Next Generation Emissions Measurement (NGEM) research for area source and fugitive emissions, such as oil and gas.
 - Methods/measurements for methane from reservoirs, including for **hydropower**, supporting GHG emissions inventory development.



Energy and transportation measurement work

- CEMM's mobile source emissions laboratory examines changes in pollutant emissions due to new vehicle and emissions control technologies and alternative/renewable fuels
 - Emissions characterization of NOx, VOC, SVOC, and PM emissions from both light and heavy-duty vehicles.
 - PM speciation results of brake and tire wear collected from on-road motor vehicles.
 - Testing of **non-road engines** like construction and agricultural equipment.





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Wrap up and take aways

- CEMM's unique capabilities enable a multi-sector (crossing silos!), multi-pollutant, and even multi-media approach to a transforming energy system as we look to netzero energy and deep decarbonization pathways.
- Modeling can assess these transformations at various levels of spatial and geographic resolution to answer science questions and meet the needs of different stakeholders and partners.
- **Measurements** can characterize GHG and air emissions for changing sources to inform emissions inventories and better understand exposures.
- Collaboration across ORD and with partners can explore the broader co-effects (e.g., benefits, impacts, unintended consequences) of these transformations via scenario development.
- Energy system changes are going to be transformative as we move to net-zero energy → this work is critical for the "E" in ACE!

