Independent Statistics and Analysis
U.S. Energy Information Administration

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MEMORANDUM FOR: Angelina LaRose

Assistant Administrator for Energy Analysis

FROM: Jim Diefenderfer

Director, Office of Long-Term Energy Modeling

SUBJECT: Summary of Electricity Modeling for Deep Decarbonization Workshop held on January 30, 2024, in partnership with Resources for the Future (RFF).

The workshop facilitated discussion on the challenges and barriers to modeling economy-wide and electric power sector deep decarbonization scenarios across several different models. The workshop was conducted under Chatham House Rule, and the presentation materials and list of attendees is not available for public release. Participants included modelers from government, industry, and academia who develop, maintain, and use long-term capacity expansion and electricity market models, especially those focused on the U.S. market.

Overview

The workshop included presentations from a number of modeling groups that use either the National Energy Modeling System (NEMS) model or their own capacity planning model framework to address the three main deep decarbonization topics of the workshop. These three main topics and respective sessions were *Operationalizing a Zero Carbon Grid*, *Demand-Side Feedback to the Power Sector*, and *Energy Storage and Emerging Technologies*.

The session titled *Operationalizing a Zero Carbon Grid* addressed barriers and challenges to modeling a zero-carbon electric power sector and possible methods to help overcome transmission constraints and reliability issues in capacity planning models.

The session titled *Demand-Side Feedback to the Power Sector* focused on scenarios with high electric-vehicle penetration and the impact on the electric power sector. In particular, we focused on demand resulting from different patterns of charging behavior. The session also included a presentation and discussion on modeling flexible demand strategies for storage technologies.

The third and final session, titled *Energy Storage and Emerging Technologies,* provided insights and discussion on modeling longer-term (for example, seasonal) storage, the capacity contributions of storage resources, and modeling emerging technologies.

In addition to the three main sessions, the Electric Power Research Institute (EPRI) hosted a lunchtime presentation and discussion on results from an inter-model comparison of electric power sector deep decarbonization scenarios.

The workshop concluded with a discussion on the three sessions and suggestions for how EIA can best apply the topics discussed during the workshop in NEMS's electric power sector modeling efforts for AEO2025 and beyond.

Summary of Presentations

OnLocation, Inc., set the stage for the discussion with their presentation, *Modeling Market Structures for the Energy Transition*. The presentation discussed the challenges of operating a grid with zero marginal costs and discussed the role of regulatory entities in defining the rules for how such a grid would operate and how that would translate into the structures used in modeling. It also talked about the limitations of those structures. The presentation included suggestions for how prices could be set to support costs in the future, including representing cost of service, or pricing to recover costs (for example, energy markets, energy plus explicit capacity markets, or demand-side price response).

EIA followed with *Limitations with NEMS on Representing a Fully Decarbonized Power Sector*. The presentation covered the history of variable renewable generation limits and our work to improve EIA's ability in updating those modeling assumptions and in modeling deep decarbonization scenarios. Recent work conducted included validating NEMS with production cost model comparisons, representing seasonal storage, improving transmission capabilities, as well as other features.

NREL's presentation was called *Resource Adequacy Planning for a Low-Carbon Grid: A "Stress Period" Formulation*. NREL explained that marginal electricity costs increase non-linearly as you approach high reductions of CO_2 emissions mostly because of meeting resource adequacy needs. They discussed the challenges of modeling with capacity credits and presented preliminary results on integrating their resource adequacy model, PRAS, with their capacity expansion model, ReEDS.

The first session concluded with a presentation from Resources for the Future (RFF) called *Comments for EIA about Electricity Modeling for Deep Decarbonization*. RFF highlighted work related to the E4ST model and discussed the importance of high spatial resolution and transmission representation for electric power sector modeling of deep decarbonization in a linear framework. The presentation included several recommendations for us to consider and additional topics for future discussion and collaboration opportunities.

A lunchtime presentation and discussion occurred after the first session. EPRI presented *Overview of Multi-Model Studies Looking at Zero-Emitting Grids*. This presentation summarized recent modeling efforts on decarbonization and the role of the electric power sector. The presentation showed model consensus on electrification as a key contributor of economy-wide deep decarbonization, given that the electricity sector is seen as the initial driver of net CO_2 reductions. Model comparisons also showed a mix of resources deployed to meet deep decarbonization scenarios, and wind and solar accounted for the largest contributions of new capacity additions in future projections.

The second session of the workshop was called *Demand-Side Feedback to the Power Sector*. The first presentation of the session was from OnLocation, Inc., and was called *Impact of EV Load Shapes*. The presentation discussed how load shapes are used within the NEMS modeling framework and how the timing of demand affects the deployment and operation of different generating technologies. The presentation also included preliminary results of model testing under different load shapes for EVs and provided recommendations on updates for us to consider. For example, OnLocation, Inc., recommended changing EV load shapes to spread charging profiles across more hours and to be less concentrated during night-time hours or to include multiple load shapes for different vehicle types.

EIA followed with a presentation called *Integrating EVs into the Grid*. Our presentation covered modeling considerations regarding current and future adoption of EVs and how the uncertainty in the charging infrastructure could limit the high deployment of EVs in the transportation sector.

The last presentation of the second session came from EPRI, on *Modeling Flexible Demand and Strategies for Modeling Storage*. EPRI discussed work related to their REGEN model. They highlighted that in economy-wide deep decarbonization scenarios, EVs and heating and cooling demand make up a large portion of electricity demand, and both could be flexible demand resources. They presented model results of coordinated charging of EVs by co-optimizing demand with electricity dispatch, which resulted in some shifting of residential EV owners from night-time charging to daytime charging patterns.

The third session of the workshop was called *Energy Storage and Emerging Technologies*. NREL opened the session with a presentation called *Insights from Energy Storage Modeling and Analysis*. The presentation highlighted the value storage provides to the grid, especially under deep decarbonization scenarios, both in terms of its ability to meet resource adequacy needs and in its synergistic relationship with solar generation. The presentation also covered modeling beyond diurnal storage, considering multiday and seasonal storage representation.

Princeton University's Zero-carbon Energy systems Research and Optimization Laboratory (ZERO Lab) followed with a presentation titled *Representing the Capacity Contributions from Storage Resources*. They discussed how properly accounting for capacity contribution from storage across all representative hours allows more precision modeling of charge and discharge decisions in their GenX model, which is necessary when modeling decarbonization scenarios with long-duration energy storage.

Our next presentation was titled *Modeling Diurnal-Term vs. Seasonal Storage*. The presentation included preliminary results using a simplified model to test if our models are seeing a decoupling of recharge and discharge capacity in addition to decoupling of energy and power capacity. It also sought to determine how best to reconcile the cost trade-offs between duration types. The presentation concluded with two questions posed to the attendees: What is the best data source for energy storage technology costs and what are your views on various energy storage duration options?

Evolved Energy Research presented last with a presentation called *Emerging Technologies* about their EnergyPATHWAYS modeling tools and results from a recent study they conducted using the model. The presentation included insights on how to better model a wide array of scenarios, including deep decarbonization scenarios. The suggestions for us included incorporating an agile and flexible model structure where data structures are flexible and the same model components can be used to represent multiple technologies.

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The workshop concluded with a discussion of the presentations and suggestions for what participants would like to see incorporated into our modeling efforts for the *Annual Energy Outlook 2025* (AEO2025).

Discussion

During the discussion period for the first session, a participant asked how we select the load duration curves, specifically how the hours are selected. We said that the load curves for dispatch are selected based on 24 day-types (one weekday and one weekend day per month) and for capacity expansion are selected based on nine time-segments based on demand levels and seasons.

A participate asked how we handle our fuel price projections, particularly why we don't use natural gas futures prices for long-term modeling of prices. We explained how the AEO Reference case is supplemented with the High Oil and Gas Supply case and the Low Oil and Gas Supply case. The recovery per well is assumed 50% higher in the high case and 50% lower in the low case, which provides a more stable comparison than using futures prices that may have other market factors considered in the price.

A participant asked how different models represent model retirement decisions if a unit cannot recover their costs during dispatch. How much of your fixed costs must be recovered to keep the unit operating? We responded that units that cannot recover their costs are retired unless the unit is needed to meet the reserve margin.

A participant asked how to evaluate the tradeoffs between additionality and solvability. Is more always better? Several attendees responded that the additionality depends on the questions that the model is trying to answer. This tradeoff is particularly challenging for us to address given the broad applicability of our model. Some models can be tailored to meet the question at hand, but our mission results in a model that attempts to answer all the questions at once.

A participant asked the NREL presenter if the concept NREL is creating a smarter resource adequacy formulation by using PRAS and, if so, is that why you are building less and valuing capacity from other sources more? The NREL presenter agreed with this statement, based on initial testing.

A participant asked the EPRI lunchtime speaker what would be the model the speaker would create today if having to start from scratch? The speaker responded that the model would be one that contained ultimate flexibility in terms of both model and data structure.

Modelers discussed whether accounting for residential EV charging should be seen as a residential end use or a transportation end use. In addition, they discussed charging infrastructure and whether and how charging infrastructure expansion should be accounted for within electric power sector transmission and distribution expansion costs.

We received recommendations for our research project on long-duration storage. Participants suggested resolving the optimization problem by setting storage capacity and energy costs and solving for the size of capacity and storage that right sizes the need of the test problem. Participants pointed out that the capacity-in costs, capacity-out costs, and storage costs can all be differently valued and sized, leading to more degrees of freedom in modeling.

Attendees

We hosted the working group meeting both online and in-person, and 63 people attended, including EIA staff and external participants. Attendees represented several organizations, including Resources for the Future (RFF); the U.S. Energy Information Administration (EIA); the U.S. Environmental Protection Agency (EPA); the National Renewable Energy Laboratory (NREL); OnLocation, Inc.; the Electric Power Research Institute (EPRI); Evolved Energy Research; Rhodium; Princeton University; Penn State University; and the University of California, Davis.