Project BlueSky: Building EIA's Next Generation Energy Model

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EIA and Long-Term Modeling

- The U.S. Energy Information Administration (EIA) is the statistical and analytical agency within the U.S. Department of Energy.
- EIA is the nation's premier source of energy information.
- By law, our data, analyses, and forecasts are independent of approval by any other officer or employee of the U.S. government.
- Our *Annual Energy Outlook* explores long-term energy trends in the United States and the *International Energy Outlook* explores long-term energy trends across the globe, both with projections to 2050.

Project BlueSky

- *Project BlueSky* is a cross-team collaborative effort to consider EIA's future long-term modeling program.
- The goal is to build a next generation energy model that would be used to produce our long-term projections.
- *Project BlueSky* is NOT related to the updates we are making to NEMS for AEO2025; those are short-term updates while this is a parallel long-term effort.

Goals of the presentation

- Give an overview of Project BlueSky
- Provide an overview of desired model capabilities
- Clarify the timeline for this effort and next steps
- We would like to receive your feedback on the following:
  - As an EIA stakeholder, does this effort align with your needs?
  - From your perspective, which issues are most important?
  - How can we ensure an inclusive development process?
  - Who else should we speak with?
  - What are we missing?

Why rethink our approach to long-term modeling?

- The global energy system is changing rapidly
  - Technologies enter (and leave) the system at a fast pace
  - Low carbon and net-zero pathways of increasing interest
  - Risks to security, reliability, and resilience are evolving
  - Uncertainty is heightened
- Impacts on people becoming more relevant and important
  - Industrial policy has driven incentives for energy communities and local economies
  - Infrastructure changes have material impacts at the regional, community, and household levels
- The world is increasingly interconnected
  - Electrification has increased interconnection between sectors
  - Global growth in renewables and batteries draw on same material supply chains
  - Macroeconomic and international trade represent system important feedbacks

Need to think beyond our existing long-term models

- EIA has been using the National Energy Modeling System (NEMS) to produce the Annual Energy Outlook since 1994
- Code base has become unwieldy and hard to maintain
- Broad recognition that we need to develop a new modeling framework

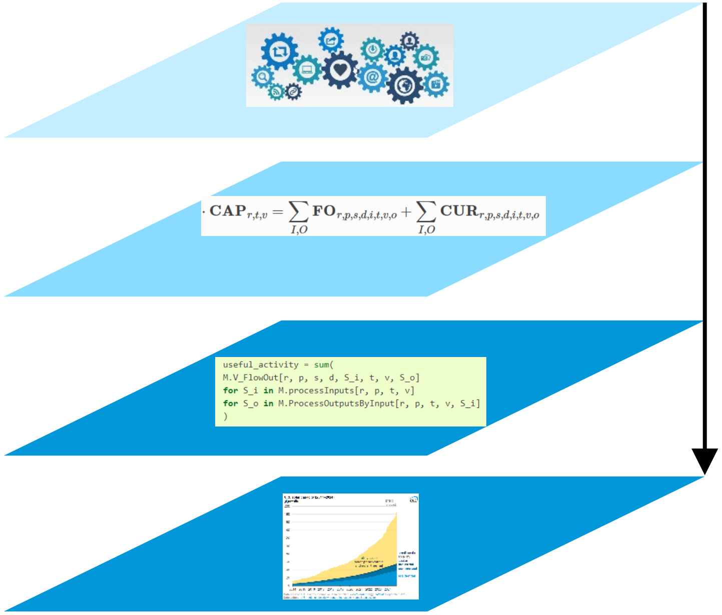
(14) striving to migrate toward a single, consistent, and open-source modeling platform, and increasing open access to model systems, data, and outcomes, for—

Excerpt from Infrastructure Investment and Jobs Act

Project BlueSky to Develop the Next-Generation Energy Model at EIA

Modeling Layers

Energy models can be conceptualized as four representative layers:



Governing dynamics: methods used to drive systems change over time

Mathematical representation: equations used to represent the governing dynamics

Code implementation: code used to represent the mathematical formulation

Output: Visualizing output and explaining the assumptions, context, and insights

***Project BlueSky* focuses on re-evaluating all four layers.**

Our goals for the next-generation model

- The global energy system is in a period of rapid change.
- Impacts on people becoming more relevant and important.
- The world is increasingly interconnected.

- **Open and accessible:** source code and input data available under open source licenses
- **Nimble, flexible, modular:** update or change quickly, handle diverse modeling needs, adjust model complexity to suit the question, separate code and data; system representation
- **Robust and granular analysis:** Rigorous consideration of uncertainty to quantify resilience, reliability, and community impacts

Why open and accessible?

- Promote transparency in our work
- Enable model introspection and clear misconceptions
- Validate and receive feedback on approaches
- Allow replication and expansion of our model-based analyses
- Collaborate on model development

Using modern software tools and programming languages

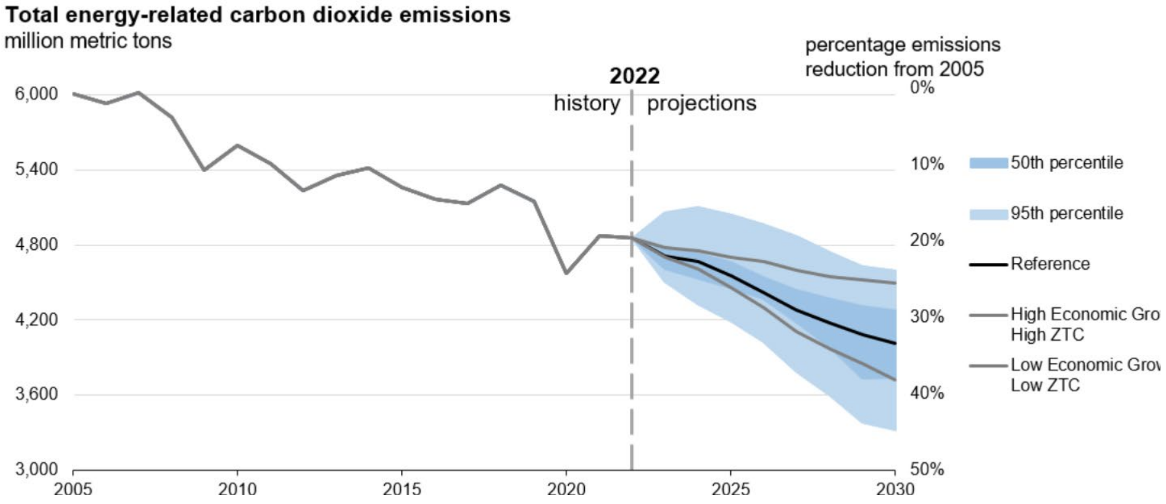
- Modern, open-source software is free with a large community of users and amenable to future needs (*e.g.*, cloud).
- Able to handle new types of math formulations for emerging issues
- Able to communicate with different modeling languages to automate processes
- Handle large data needs of pre-processing, organizing, analyzing, and validating
- Access to an external talent pool and internal experience

Why nimble, flexible, and modular?

- Technology innovation is rapid
- Ongoing shift to renewables requires a high degree of spatio-temporal detail
- Policy environment is evolving; recent focus on targeted incentives
- Rapid energy system changes impact people in new ways
- This environment heightens uncertainty in decision making
- Addressing this complexity requires a model that is:
  - Nimble: update or change quickly
  - Flexible: handle diverse modeling needs
  - Modular: swap model components

Why **robust** and granular analysis?

- Energy advancements are moving at a faster rate than available data.
- Quantifying uncertainty must be foundational to the assessment of energy futures.
- Uncertainty analysis allows us to more accurately reflect what we know about the future. (Example from AEO2023 below)



National Research Council (1992)*:

"Uncertainty is inherent in the nature of models and cannot be eliminated. Nor should it be ignored."

"NEMS should be designed to represent and analyze the effects of uncertainty explicitly."

** National Research Council 1992. The National Energy Modeling System. Washington, DC: The National Academies Press. https://doi.org/10.17226/1997.*

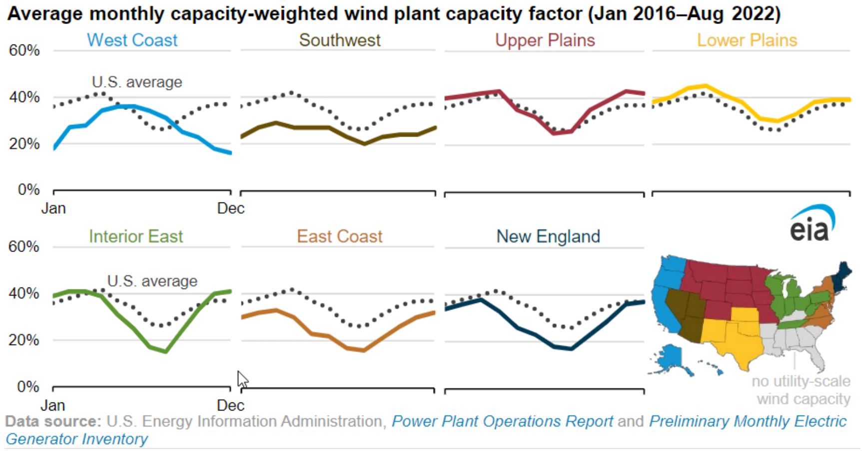
Why robust and **granular** analysis?

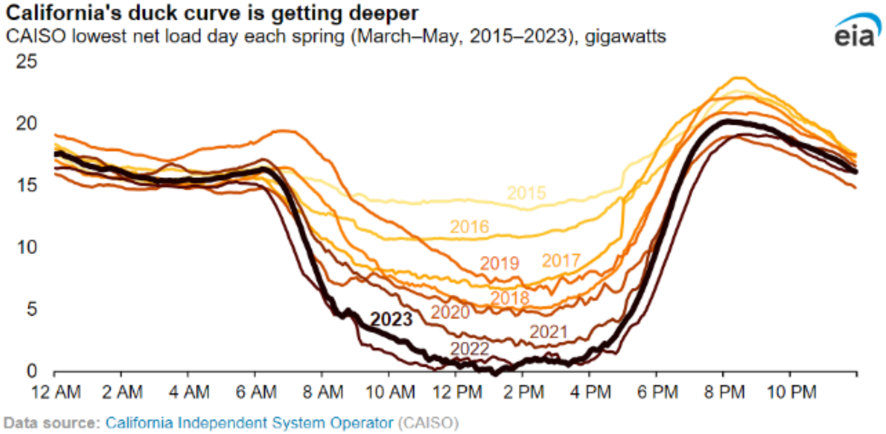
Wind and solar growing at a rapid rate

- Need to characterize resource variability at finer spatial and temporal scales
- Hourly electricity dispatch affects long-term capacity deployment

People affected by changing infrastructure

- Local changes to physical infrastructure
- Availability of new consumer technology
- Prices affect energy burdens
- Shifts in energy-related jobs



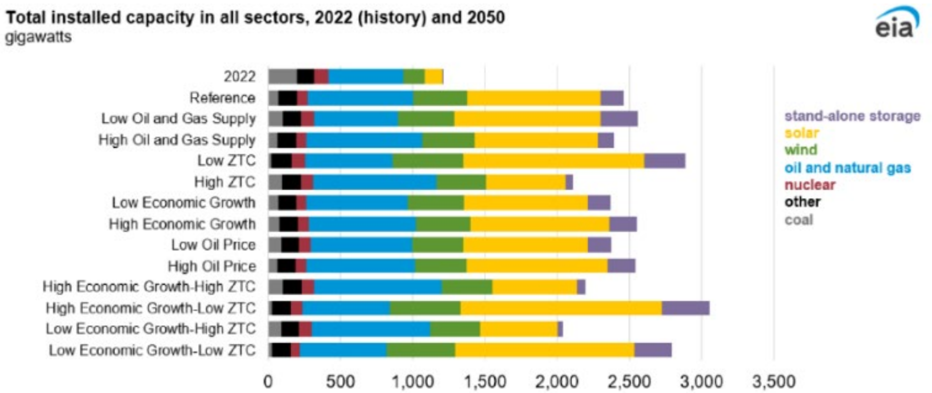


Expanding Model Boundaries

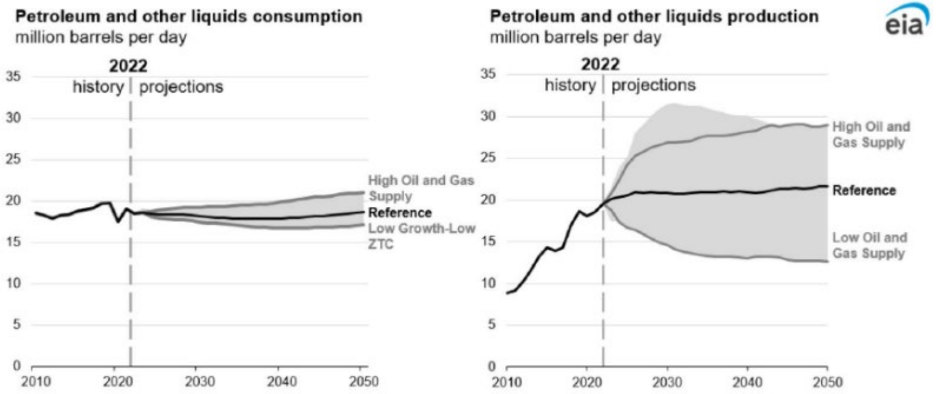
AEO2023 Illustrative Outputs

For a limited number of cases:

- capacity builds
- energy production and consumption
- emissions
- some price information



Data source: U.S. Energy Information Administration, *Annual Energy Outlook 2023* (AEO2023)
Note: ZTC=Zero-Carbon Technology Cost; other=geothermal, biomass, municipal waste, fuel cells, hydroelectric, pumped hydro storage.

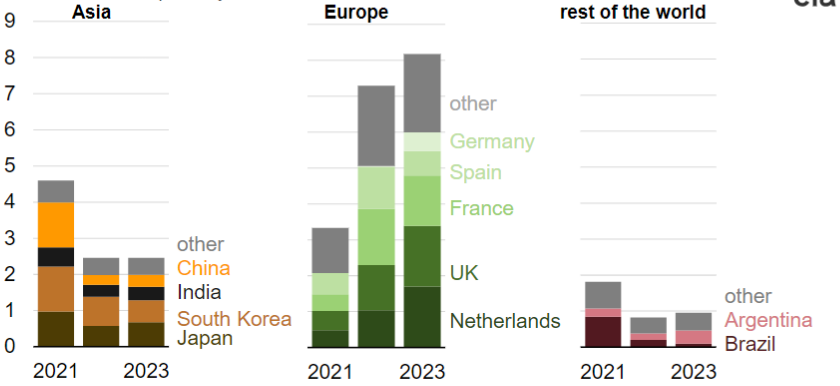


Data source: U.S. Energy Information Administration, *Annual Energy Outlook 2023* (AEO2023)
Note: Biofuels are not included in *petroleum and other liquids* production or consumption. Shaded regions represent maximum and minimum values for each projection year across the AEO2023 Reference case and side cases. ZTC=Zero-Carbon Technology Cost.

Next Gen: Fuel and material risks affect security, reliability, and resiliency

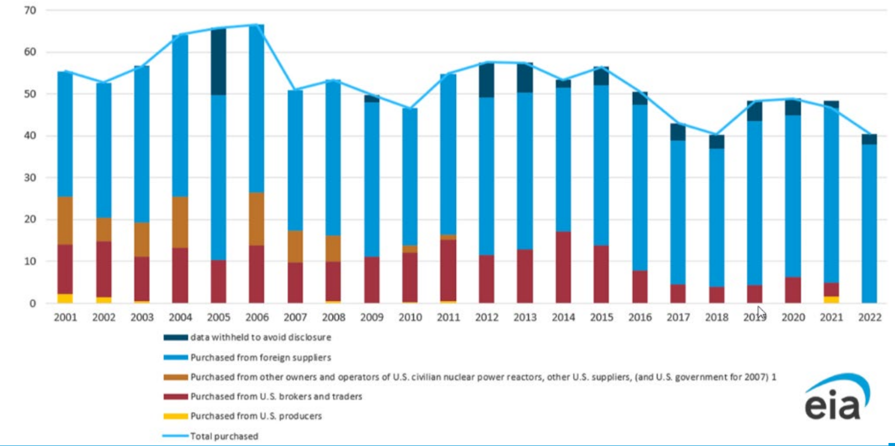
- Changing trade patterns associated with conventional fuels
- Geopolitical risks are complex
- Desire to model a wider range of cases, such as shocks

U.S. liquefied natural gas exports by destination country (Jan 2021–Jun 2023)
billion cubic feet per day



Data source: U.S. Department of Energy, LNG Reports
Note: Data are annual averages for 2021 and 2022 and the six-month (Jan–Jun) average for 2023.

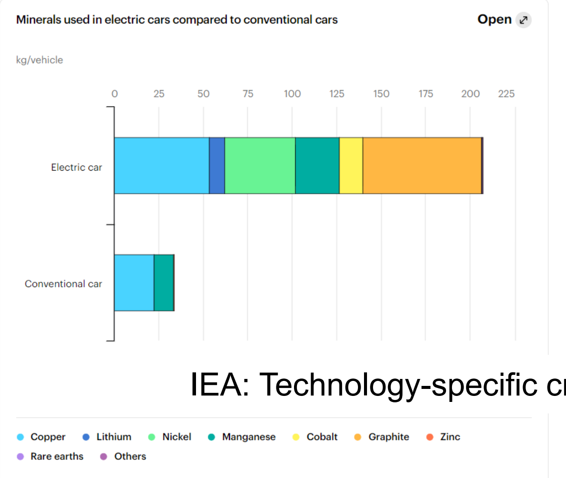
Figure S1. Uranium purchased by owners and operators of U.S. civilian nuclear power reactors, 2001-2022 deliveries
million pounds U_3O_8 equivalent

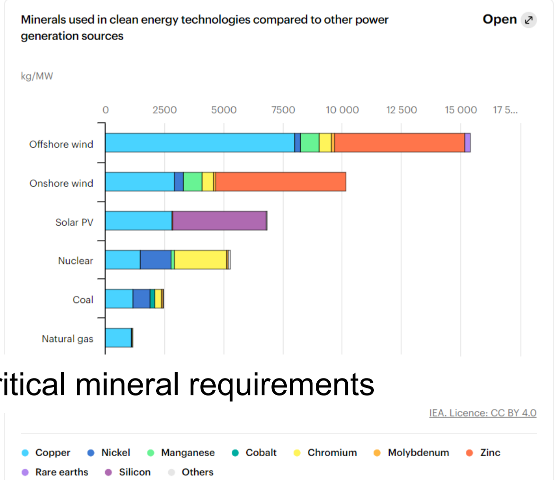


Next Gen: Fuel and material risks affect security, reliability, and resiliency

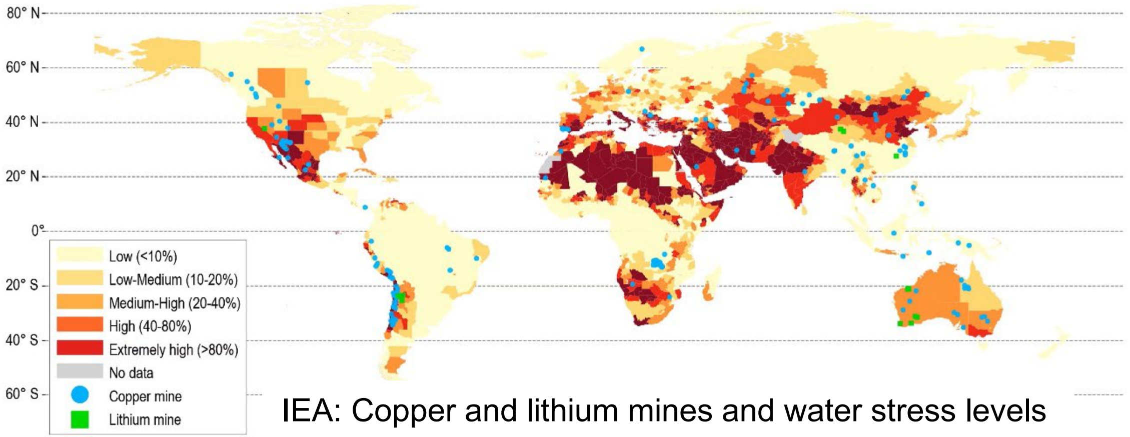
- Critical minerals present a new and evolving supply chain risks
- Batteries and renewables growing quickly; rely on several critical minerals
- Recent policy incentivizes domestic production

https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/reliable-supply-of-minerals





IEA: Technology-specific critical mineral requirements

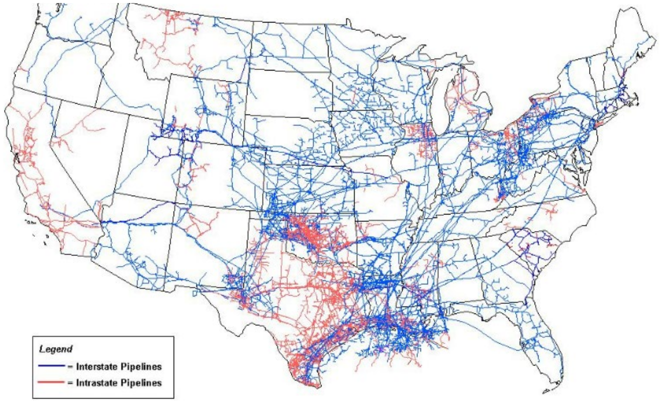


IEA: Copper and lithium mines and water stress levels

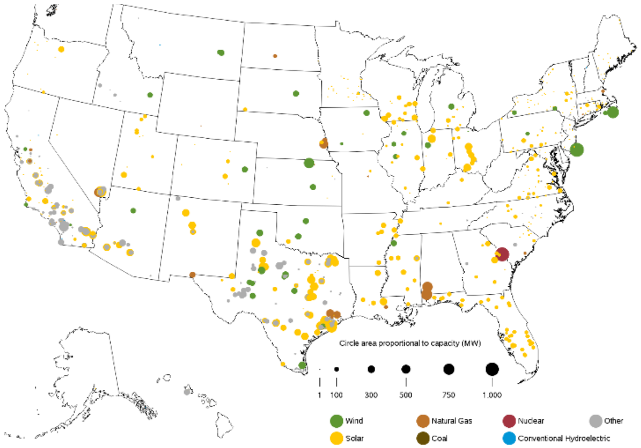
Next Gen: Infrastructure development

- Project locations or areas where new energy infrastructure likely to be built
- Better characterize effects of federal, regional, and state policy
- Changes in infrastructure:
  - affect community well-being
  - indicate locational shifts in energy jobs
  - inform regional assessments of security, reliability, and resilience

U.S. natural gas pipeline network

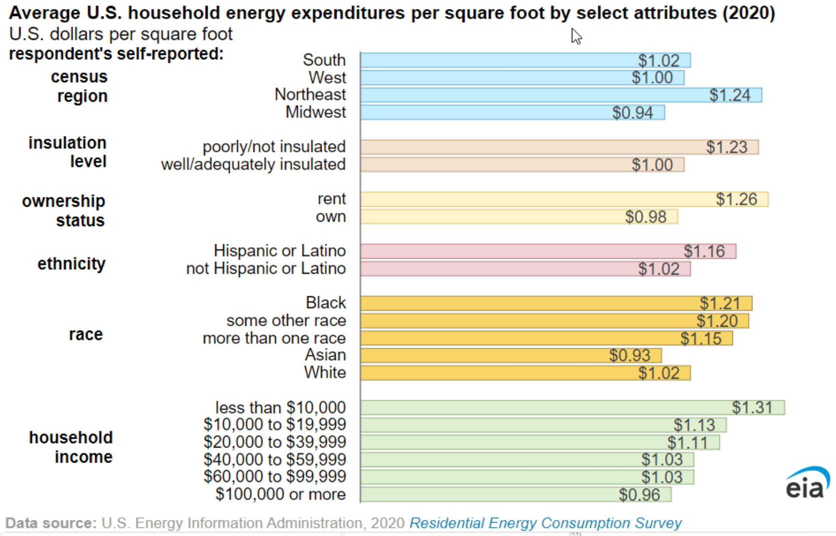


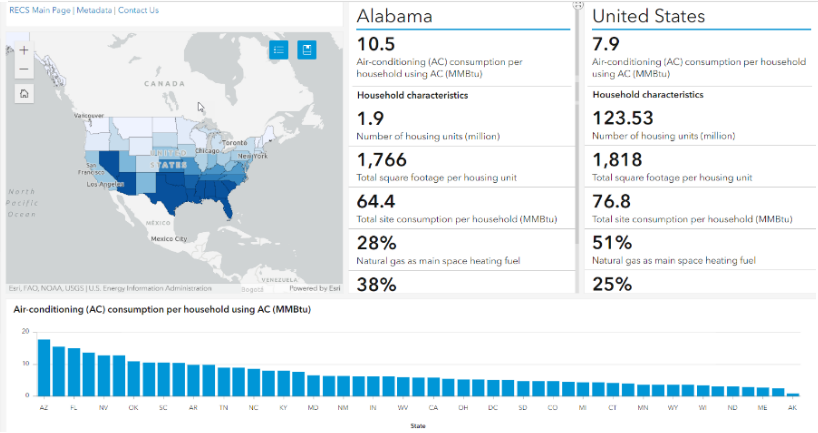
U.S. electric sector planned capacity additions



Next Gen: Impacts on people

- RECS data provides detailed demographic snapshot of household energy expenditures
- Apply statistical methods to project into future
- Provide more clarity on effects of policy targeting specific communities or households
- Determine who benefits from new consumer technologies
- Evaluate household energy burdens
- Identify evolving vulnerabilities by household type





What’s Next?

Next Steps and Timeline

- Continuous outreach and feedback with diverse stakeholders via individual conversations, focus groups, webinars, and conferences.
- Next year will be spent building a basic prototype and testing capabilities.
- Goal is to release a prototype publicly via Github and an open-source license by this time next year.
- Depending on what we learn from the prototype and how feedback goes, another two years after that will be dedicated to further model development.
- Eventually use the next-generation model to produce the Annual Energy Outlook and International Energy Outlook.

Concluding Thoughts

- Rapid changes across the energy system require us to continually adapt our modeling approaches
- Need to make our work more collaborative and accessible
- Need to leverage and build on the existing work and open-source ecosystem

- We would like to receive your feedback on:
  - As an EIA stakeholder, does this effort align with your needs?
  - From your perspective, which issues are most important?
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Independent Statistics and Analysis

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