



The Regional Energy Deployment System (ReEDS) Model

Wesley Cole, Maxwell Brown, Kelly Eurek,
Daniel Steinberg, and NREL ReEDS team

Webinar: October 31, 2019

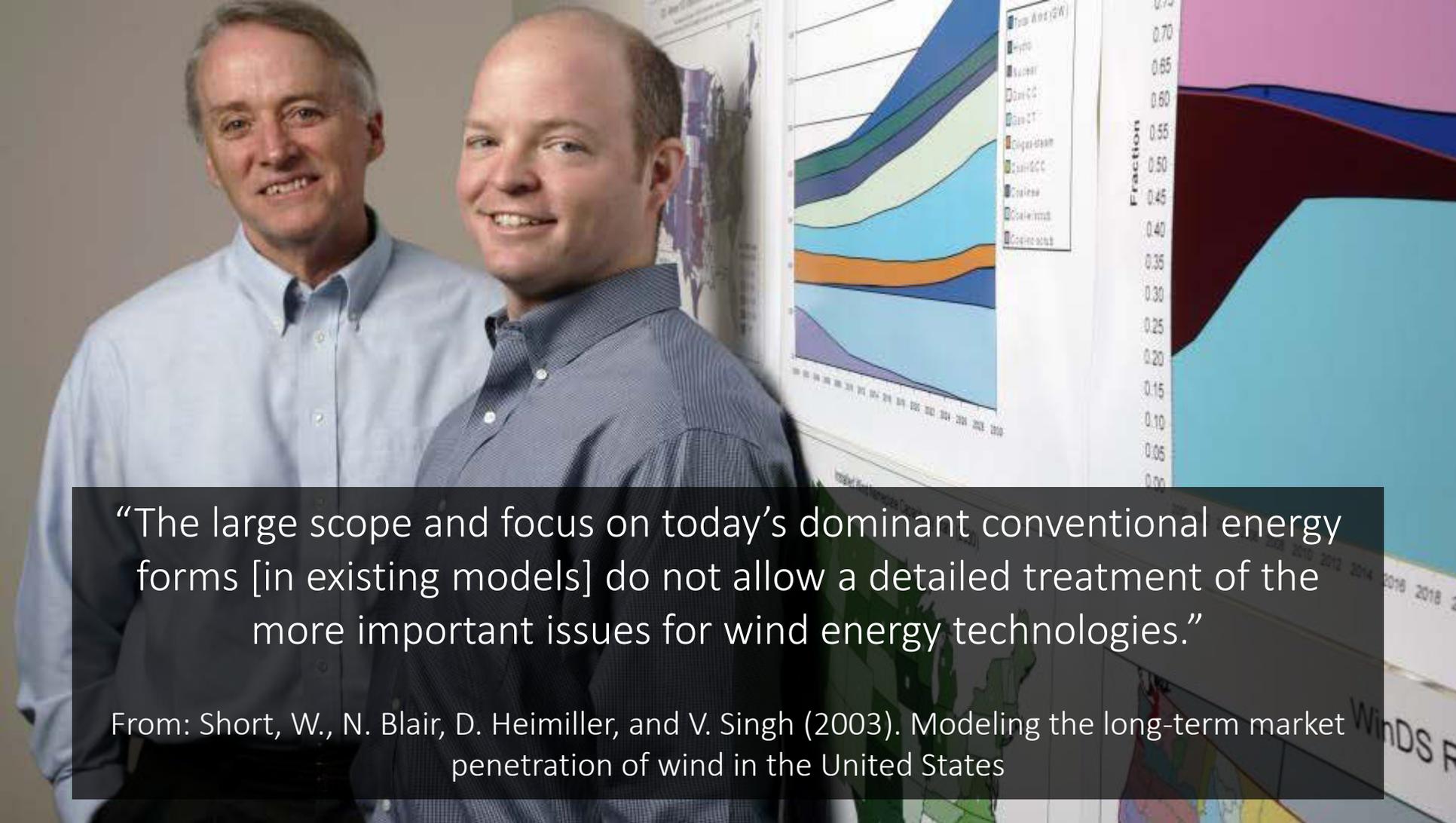


Who we are

Mechanical,
Electrical, and Civil
Engineers,
Economists,
Physicists,
Geophysicists,
Operations
Research Experts,
Policy Analysts, and
all Interdisciplinary
Analysts!

Agenda

- Preliminaries (5 minutes)
- History and Overview of ReEDS Model (20 minutes)
- Q&A on ReEDS Model Overview (5 minutes)
- Introduction to Using the ReEDS Model (20 minutes)
- Q&A on Using the ReEDS Model (10 minutes)

The image shows two men, one in a light blue shirt and one in a dark blue shirt, standing in front of a wall. The wall is covered with various charts and maps related to energy. On the right, there is a large area chart showing the 'Fraction' of energy from different sources over time (1980-2010). The legend includes 'Total Wind (2W)', 'Hydro', 'Nuclear', 'Coal', 'Gas', 'Oil', 'Natural Gas', 'Coal', 'Gasoline', 'Coal', 'Coal', and 'Coal'. The y-axis ranges from 0.00 to 0.70. Below this, there is another chart showing 'Wind' penetration from 2000 to 2018, with a y-axis from 0.00 to 0.70. A map of the United States is visible in the background, showing wind energy potential. A dark grey text box is overlaid on the bottom half of the image.

“The large scope and focus on today’s dominant conventional energy forms [in existing models] do not allow a detailed treatment of the more important issues for wind energy technologies.”

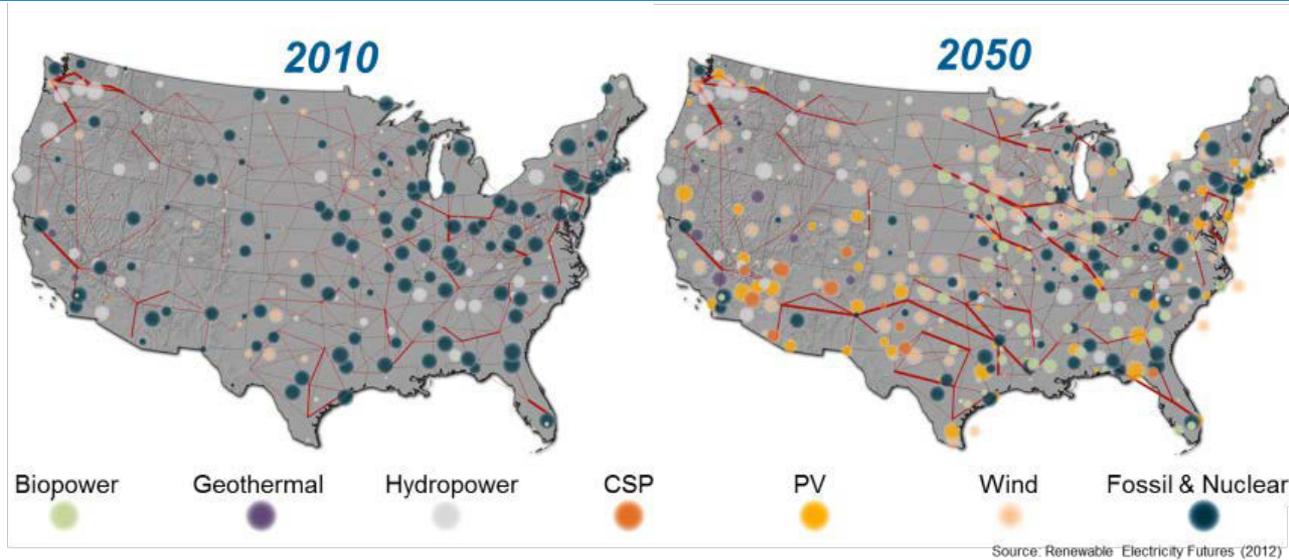
From: Short, W., N. Blair, D. Heimiller, and V. Singh (2003). Modeling the long-term market penetration of wind in the United States

WinDS → ReEDS → ReEDS 2.0

- 1999 – With support from a Strategic Initiative, Walter develops a spreadsheet model leveraging GIS data
- 2001 – Wind and Hydropower Technologies Program funds the development of an optimization model (WinDS)
- 2003 – WinDS Documentation and 1st analysis presented at AWEA
- 2004-2007 – Studies completed for AWEA, BLM, and others
- 2008 – **20% Wind Report**; Addition of CSP, Geothermal, Biomass, Storage, and release of the Regional Energy Deployment System (ReEDS)
- 2012 – **Renewable Electricity Futures Study, SunShot Vision**
- 2013 – Incorporation of water constraints
- 2014 – Incorporation of climate impacts; **PTC Extension analysis**
- 2015 – **Wind Vision, Standard Scenarios begins**
- 2016 – Incorporation of Canada and Mexico; **Hydropower Vision, Tax Extenders**
- 2017 – ReEDS 2.0 begins, **Electrification Futures Study, SunShot 2030**
- 2018 – **North American Renewable Integration Study, ReEDS 2.0 beta version completed**
- 2019 – **SunShot 2030 for CSP, Geothermal Vision, ReEDS 2.0 released**

Note: only a small sample of analyses and reports completed are shown here. Go [here](#) for a complete list.

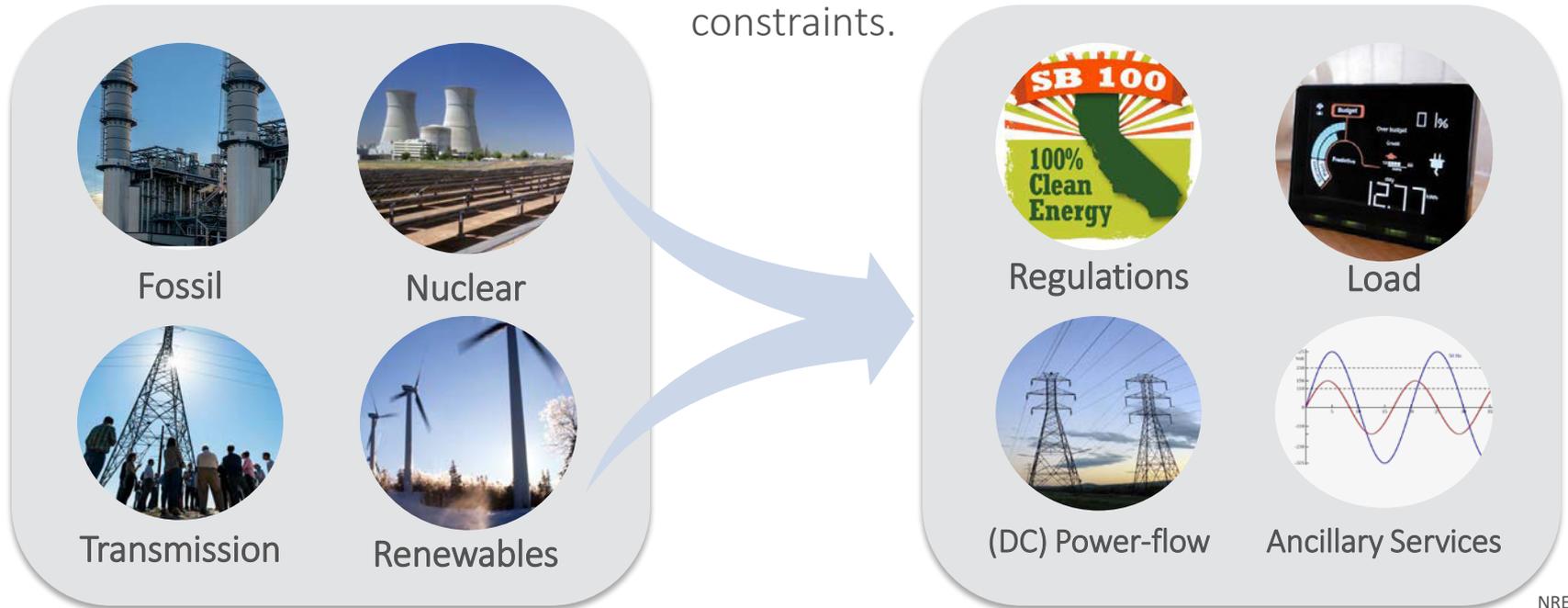
What does ReEDS do?



Given a set of input assumptions, ReEDS simulates the evolution and operation of US generation, storage, transmission, and end-use demand and associated technologies

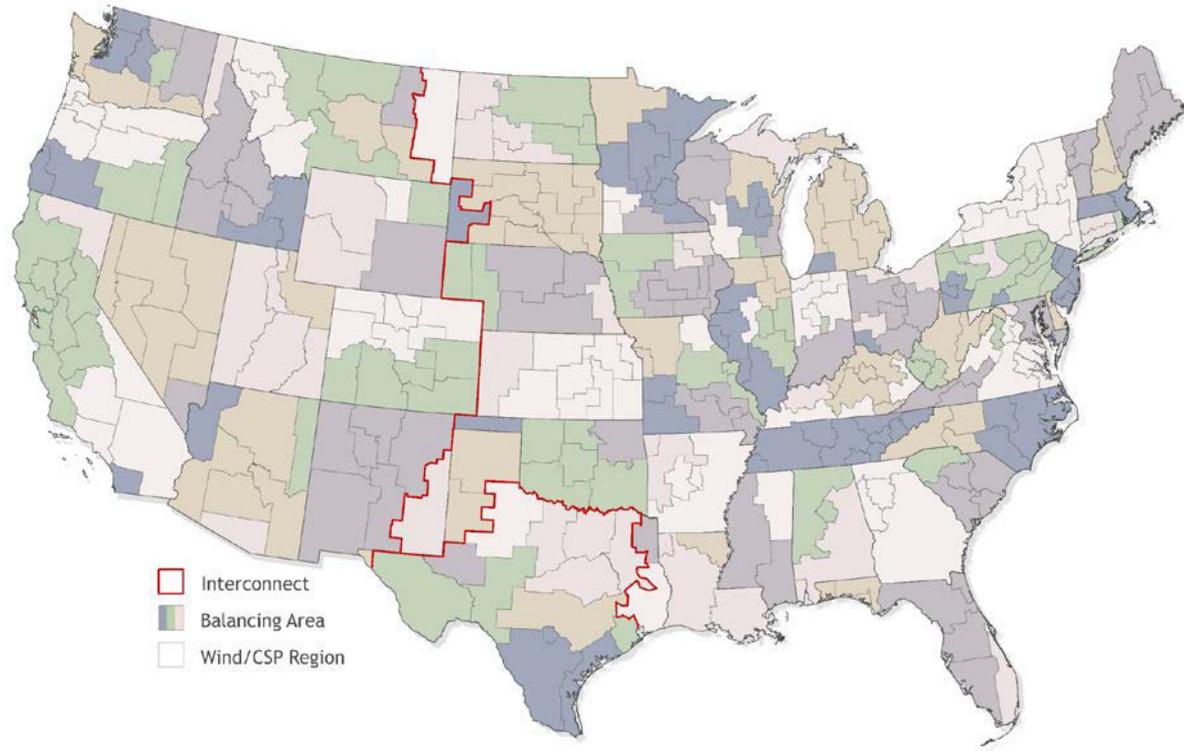
How does the supply-side really work?

The ReEDS supply-module identifies the *least cost mix and operation* of resources (including storage) that simultaneously meets load, all other electricity service requirements (planning reserves, operating reserves), and physical and environmental constraints.



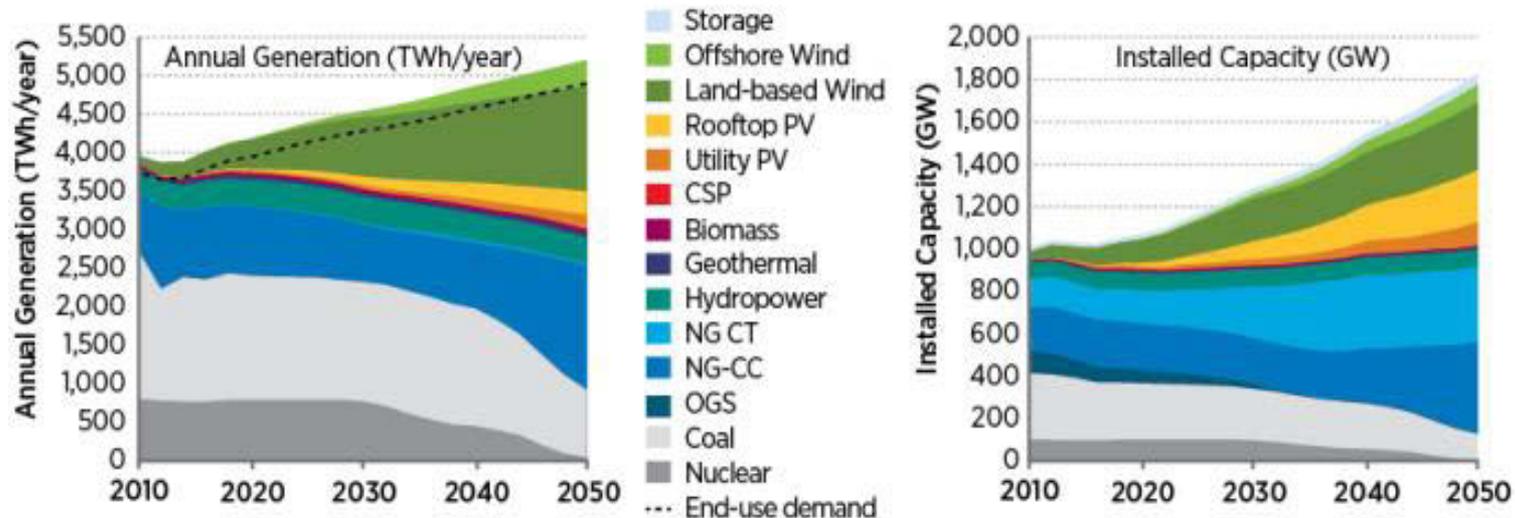
The Regional Energy Deployment System (ReEDS)

- 134 balancing areas;
356 RE resources
regions
- Reduced-form dispatch
 - 17 timeslices used to characterize demand in a typical day in each season as well as the “super-peak”
- Hourly representation of wind, PV, CSP, and load



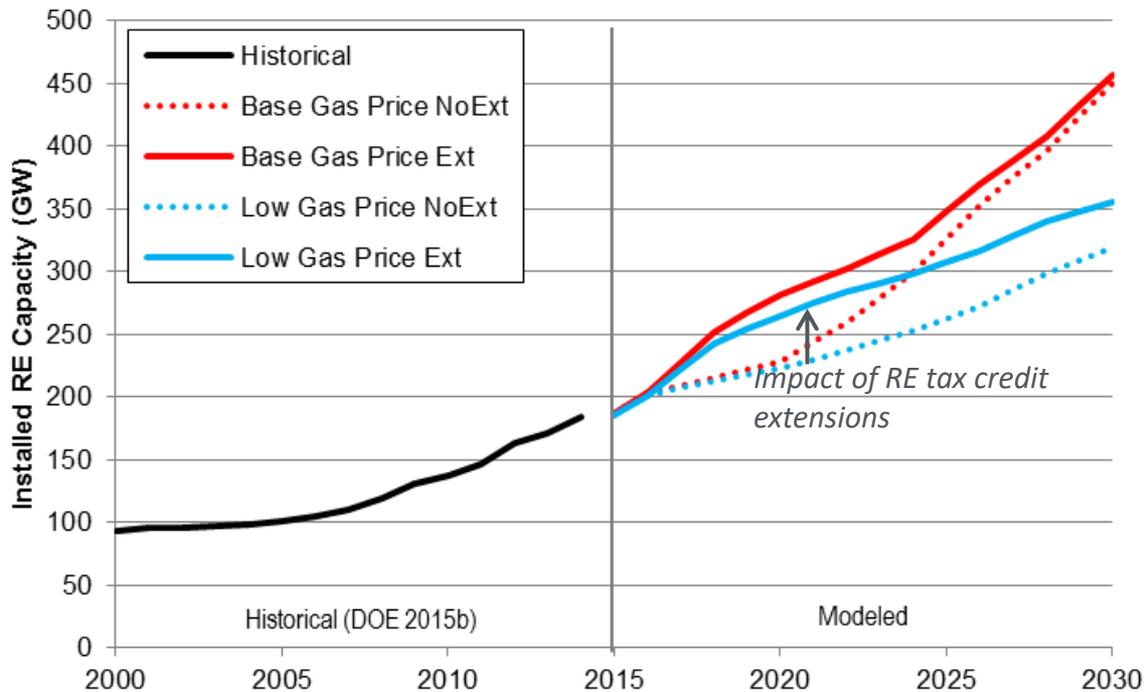
What are the key outputs?

Capacity and generation evolution of all generator types



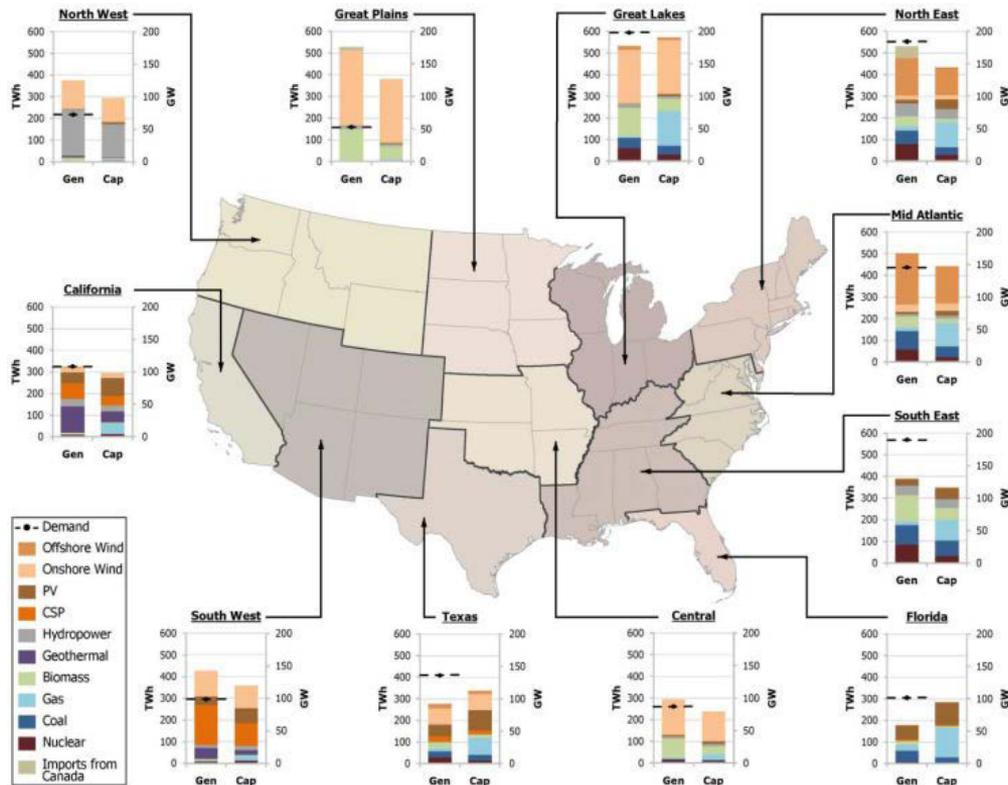
What are the key outputs?

Changes in model outcomes between scenarios



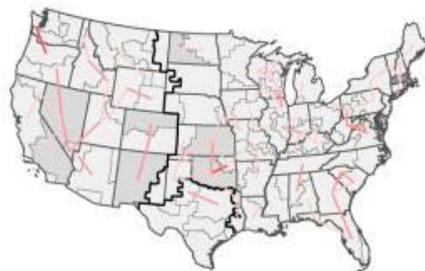
Impacts of Federal Tax Credit Extensions on Renewable Deployment and Power Sector Emissions (Mai et al. 2016)

What are the key outputs?

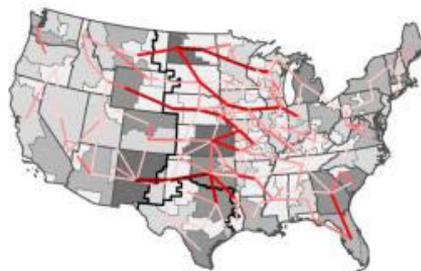


What are the key outputs?

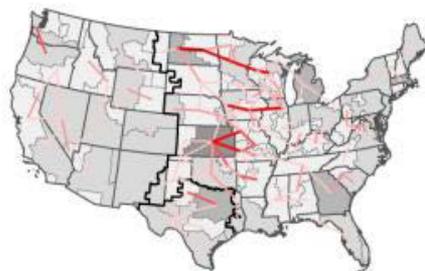
Transmission Expansion



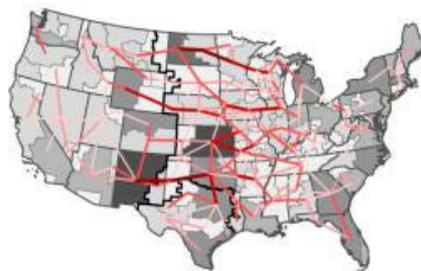
(a) Low-Demand Baseline



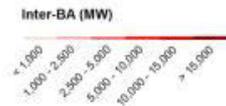
(b) 80% RE-ITI



(c) 80% RE-Constrained

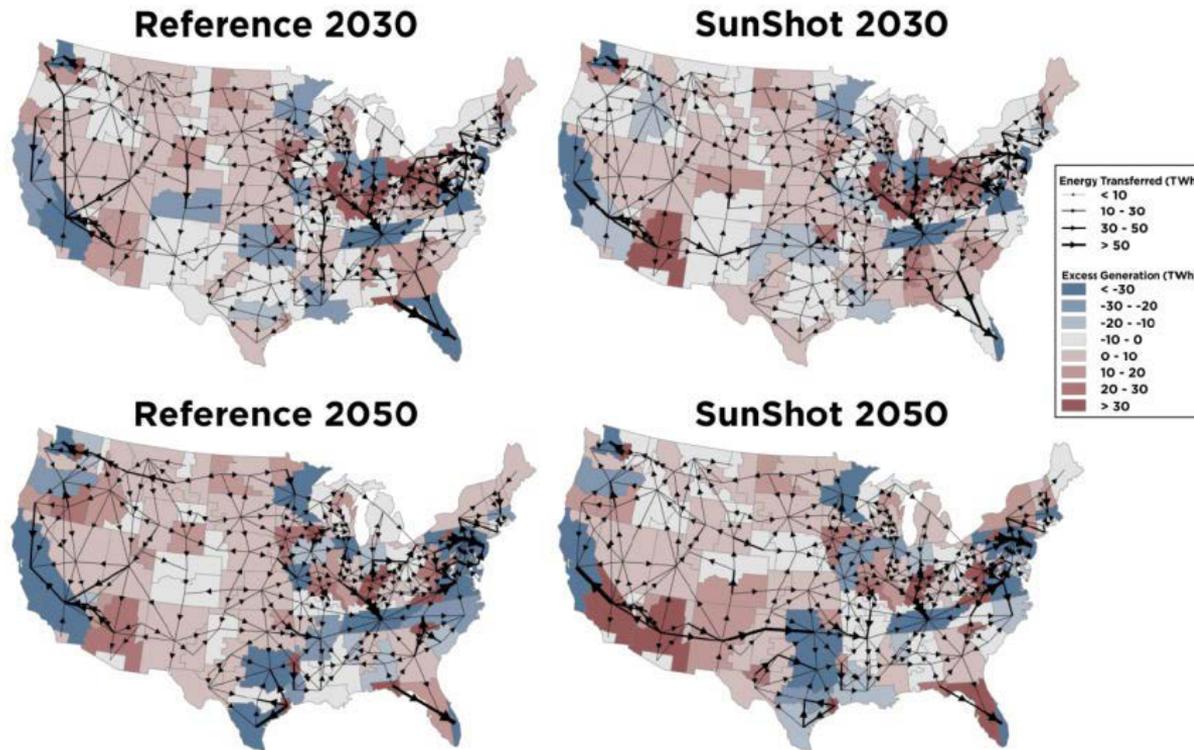


(d) High-Demand 80% RE



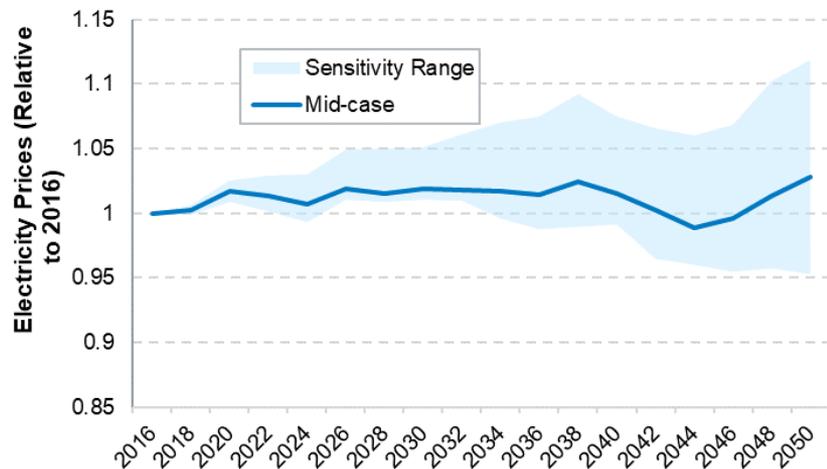
What are the key outputs?

Energy flows

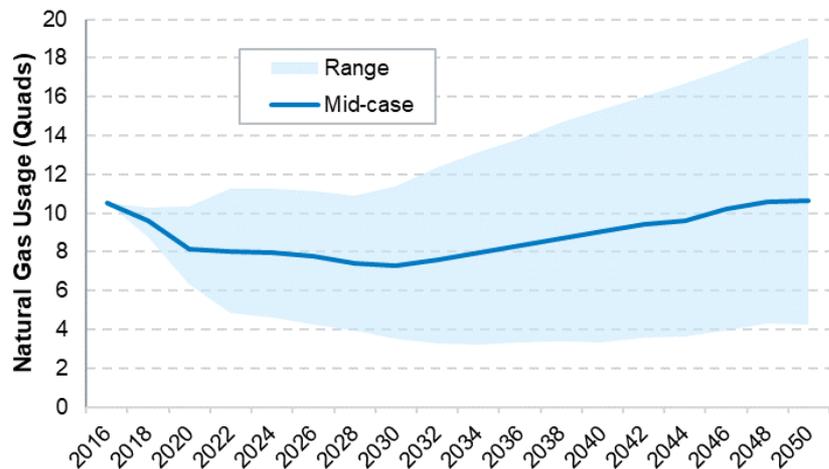


What are the key outputs?

Wholesale Electricity prices

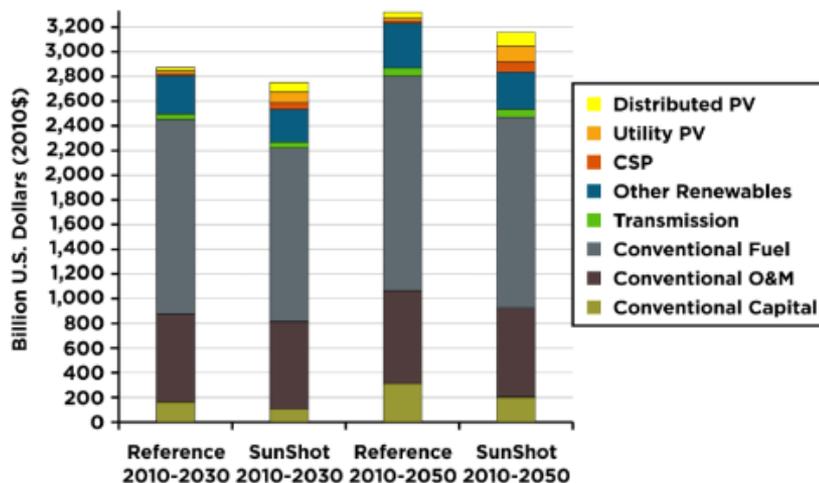


Fuel consumption and prices



What are the key outputs?

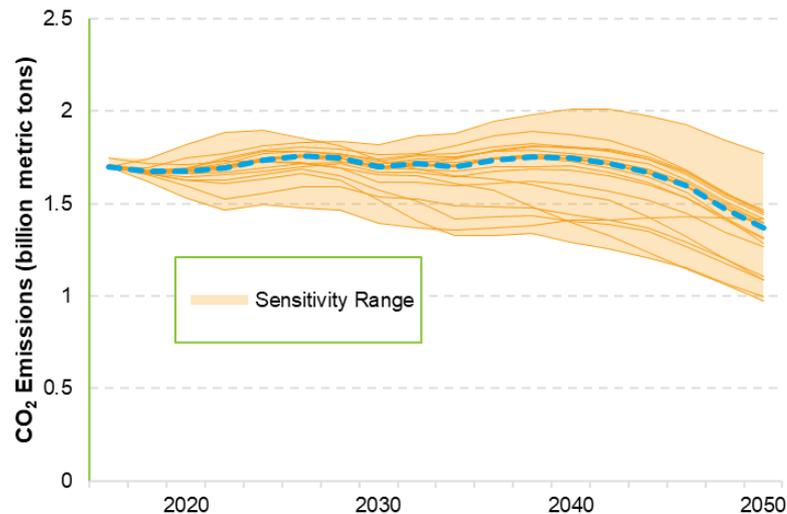
Electric infrastructure expenditures



SunShot Vision Study (DOE 2012)

CO₂*, SO₂, NO_x emissions

*combustion and life-cycle



NREL Standard Scenarios (2017)

What types of questions can be addressed with ReEDS

- **What does the model do particularly well?**
 - Examine the impacts of drivers of power sector change—policies, regulations, technology cost and performance, fuel prices—on the generation and capacity mix in the mid- to long-term
- **What doesn't the model do?**
 - Explicit unit commitment; full 8760 chronological dispatch – these are heuristically captured through analysis outside the optimization
 - AC Power flow
- **What kinds of questions can the model answer?**
 - What are the impacts of investment incentives on the evolution of generation and capacity?
 - How would reductions in the cost (or an improvement in the performance) of a technology impact the future US capacity mix?

Recent Examples of Analysis

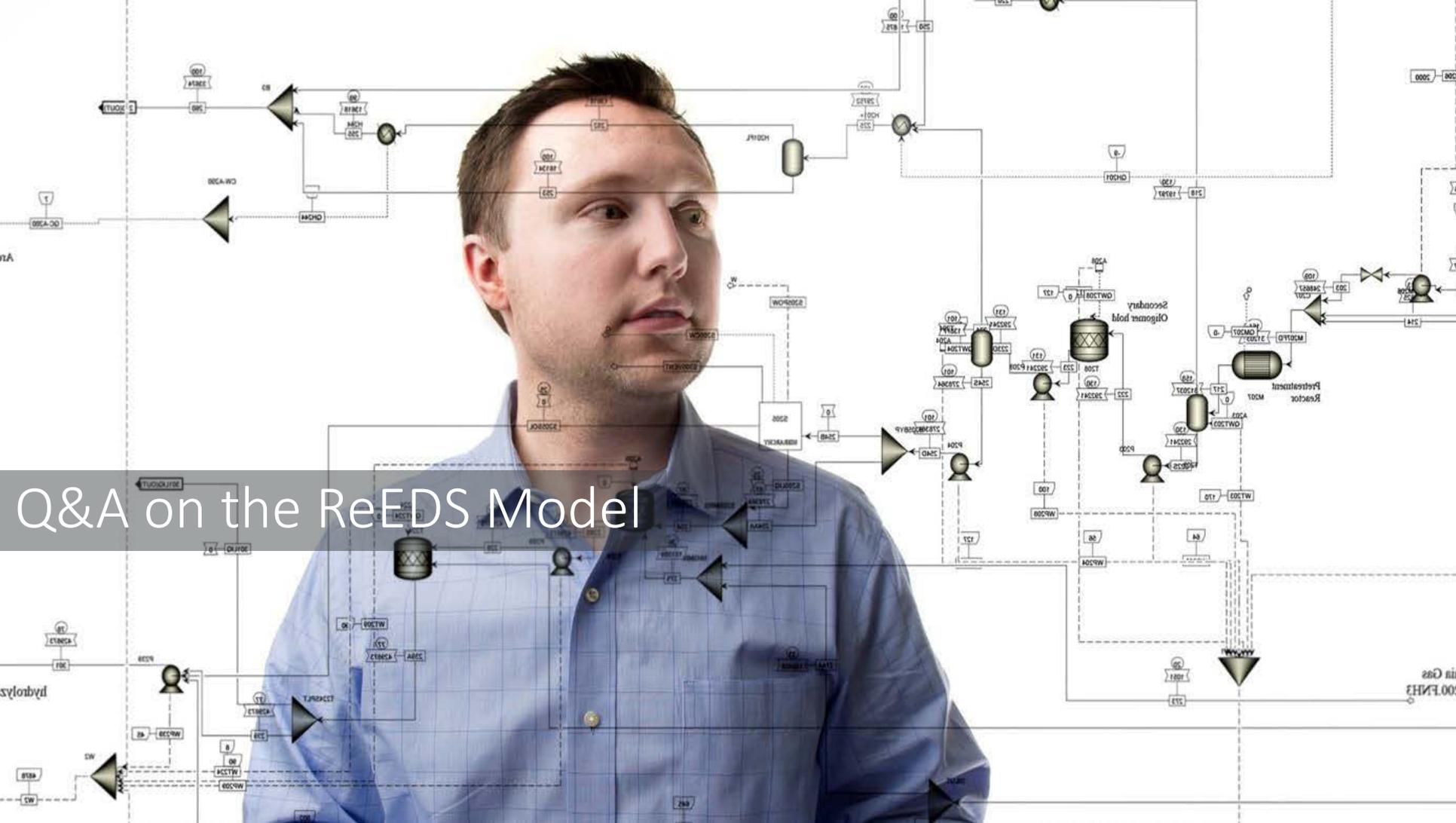
- **Wind and Solar PV Deployment after Tax Credits Expire: A View from the Standard Scenarios and the Annual Energy Outlook, *Electricity Journal***
- **Setting Cost Targets for Zero-Emission Electricity Generation Technologies, *Applied Energy***
- **The Impact of Planning Reserve Margins in Long-Term Planning Models of the Electricity Sector, *Energy Policy***
- **Exploring the Impacts of a National U.S. CO2 Tax and Revenue Recycling Options with a Coupled Electricity-Economy Model, *Climate Change Economics***
- **The Economic Impacts of High Wind Penetration Scenarios in the United States, *Energy Economics***
- **Impacts of Increasing Penetration of Renewable Energy on the Operation of the Power Sector, *Electricity Journal***
- **U.S. Energy Sector Impacts of Technology Innovation, Fuel Price, and Electric Sector CO2 Policy: Results from the EMF 32 Model Intercomparison Study, *Energy Economics***
- **Solar on the Rise: How Cost Declines and Grid Integration Shape Solar's Growth Potential in the United States, *MRS Energy & Sustainability***
- **The Role of Input Assumptions and Model Structures in Projections of Variable Renewable Energy: A Multi-Model Perspective of the U.S. Electricity System, *Energy Economics***
- **Comparing Power Flow Approximations for Electricity Infrastructure Capacity Expansion Models with High Spatial Resolution, *2018 IEEE/PES Transmission and Distribution Conference and Exposition (T&D)***
- **Valuing Variable Renewable Energy for Peak Demand Requirements, *Energy***

Where ReEDS is Going

- Examples of new capabilities that are under development:
 - Multiple battery storage durations
 - Enhanced energy value of storage capability
 - Addition of RE-storage hybrid technologies
 - Improved supply curves for RE resources
 - Retail rate module
 - Re-introduction of water and climate impacts
 - Addition of more weather years
 - Flexible spatial and temporal resolutions

Staying Engaged

- ReEDS mailing list
 - E-mail us at ReEDS.Inquiries@nrel.gov to get on the list
- ReEDS user group meeting
 - Likely summer 2020 in Golden, Colorado, or Washington D.C.
- “Watch” the repo to stay up-to-date on issues, patches, and new releases

A man with short brown hair, wearing a light blue button-down shirt, is shown from the chest up, looking slightly to his right with a thoughtful expression. He is positioned in the center of the frame. The background is a complex, detailed industrial process flow diagram (PFD) for a chemical plant. The diagram features numerous tanks, pumps, heat exchangers, and piping, with various labels and stream numbers. A semi-transparent grey banner is overlaid across the middle of the image, containing the text 'Q&A on the ReEDS Model'.

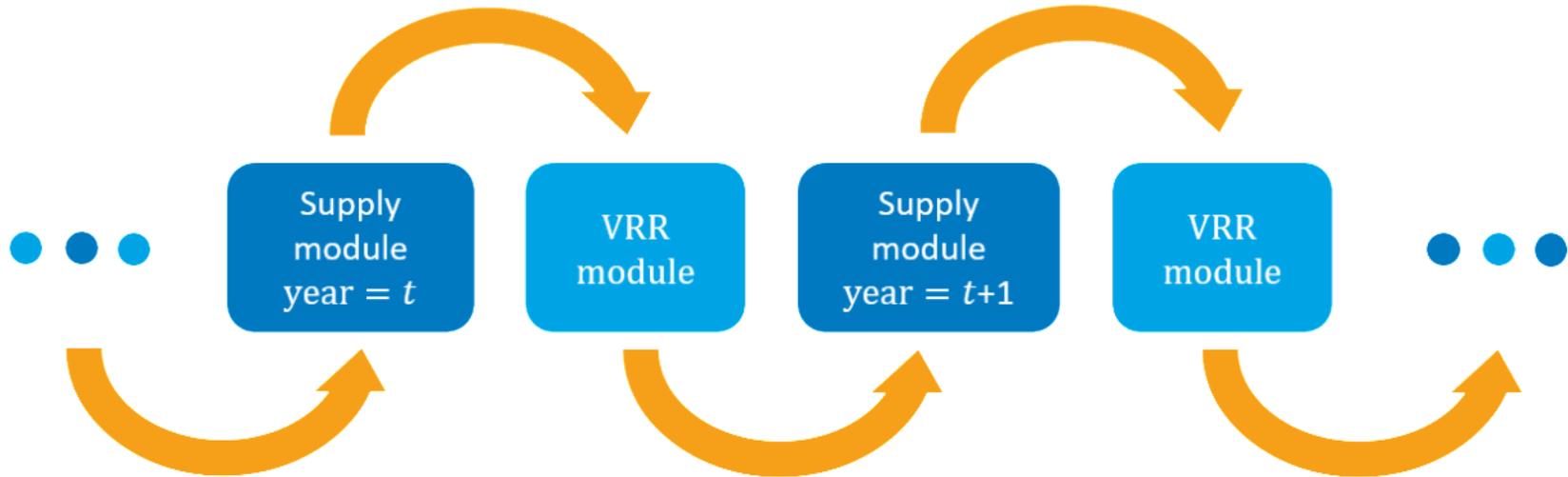
Q&A on the ReEDS Model

Using ReEDS Summary

- See the ReEDS User Guide: <https://www.nrel.gov/analysis/reeds/user-guide.html>
- Request access to the ReEDS GitHub repository
 - You need a GitHub.com account to be given access
- ReEDS requirements
 - GAMS and solver
 - Python and R
 - 2 cores and 15+ GB of memory

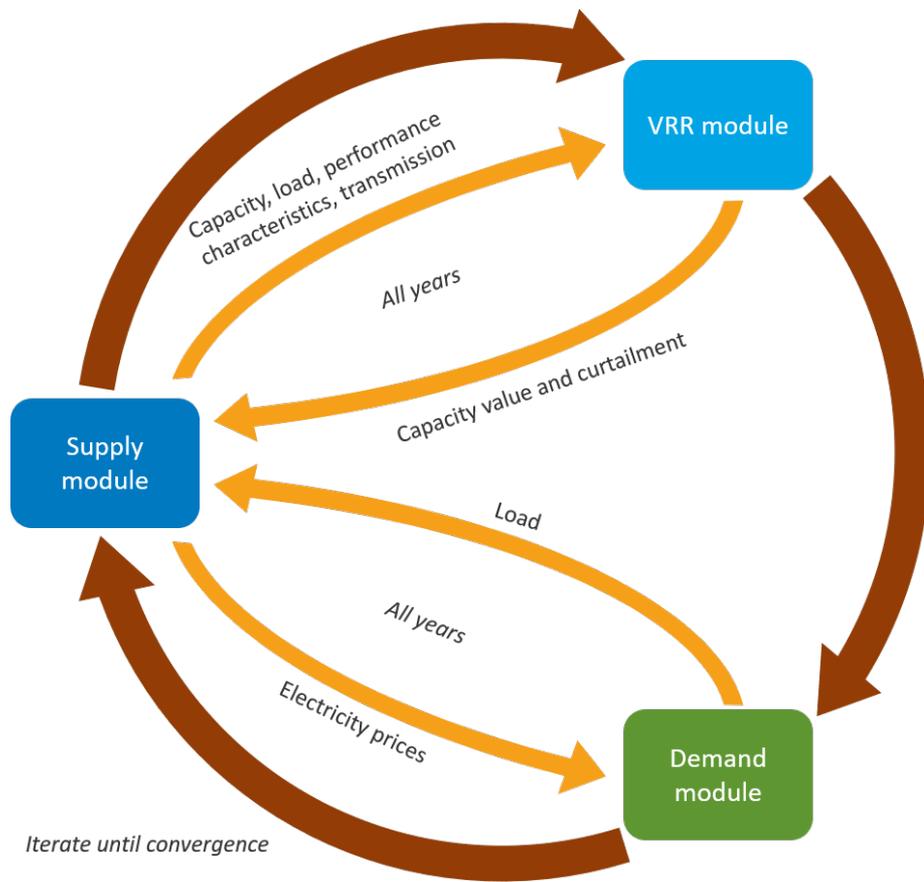
Sequential Solve

Capacity, load, performance
characteristics, transmission



Capacity value
and curtailment

Intertemporal Solve



ReEDS Demonstration

ReEDS.Inquiries@nrel.gov

www.nrel.gov/analysis/reeds

NREL/PR-6A20-75322

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the Solar Energy Technology Office, Office of Strategic Programs, and Wind Energy Technology Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

