NREL's Publicly Available Energy and Economic Modeling Tools

Maxwell Brown

USAEE Webinar

September 9th, 2020

Overview

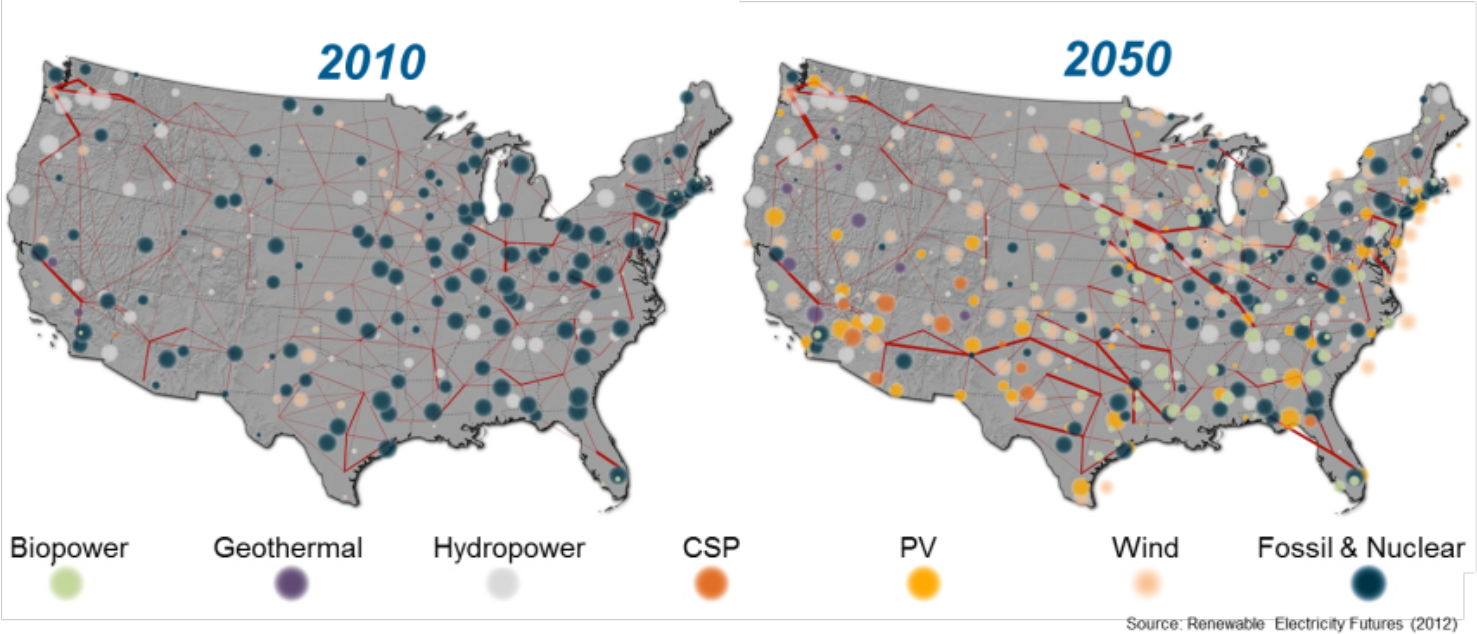
- Covering two models in more detail:
  - ReEDS – Electricity capacity expansion (20 minutes)
  - SLiDE – Computable general equilibrium (10 minutes)
- Several other NREL models covered briefly (10 minutes)
- Q&A (15-20 minutes)

- Note - Not *all* NREL's publicly available models

Regional Energy Deployment System (ReEDS)

ReEDS Team

What does ReEDS do?

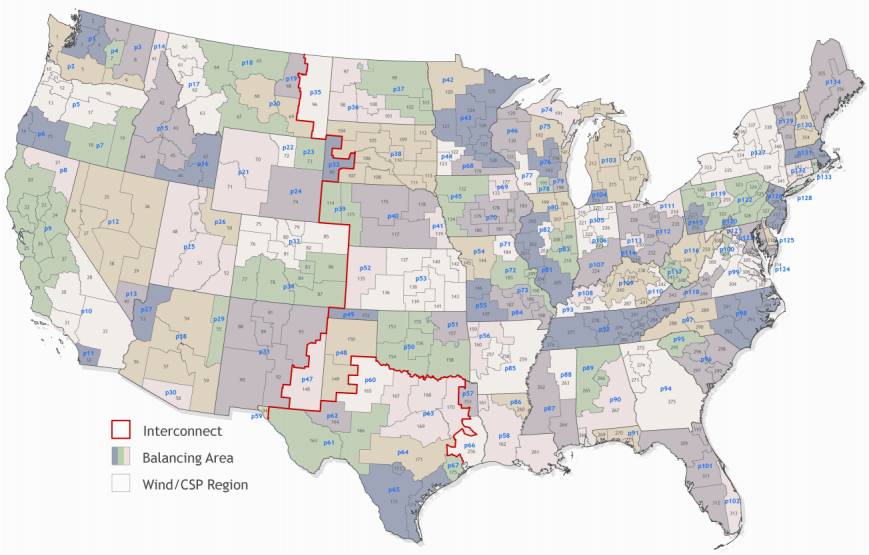


Given a set of input assumptions, ReEDS simulates the evolution and operation of US generation, storage, transmission, and end-use demand and associated technologies

Background

NREL's flagship electricity capacity expansion model

- Started as WiNDS in 2003, became ReEDS in 2009
- Objective to minimize costs of operation and investment
- Detailed characterization of variable renewable energy (VRE)
- High spatial resolution:
    - 205 balancing areas – 134 US, 20 Canada, 51 Mexico
    - 454 wind and CSP resource regions
- Major Constraints:
    - Energy supply and demand
    - Operating Reserves
    - Planning Reserve Margin
    - Federal and State Policies
    - Climate and Water
- Used in several seminal studies (Hydro/Wind Vision, Sunshot)
- Expansion to Canada (2013) and Mexico (2017)
- Link with USREP (2012-present)
- ReEDS India (2018-present)



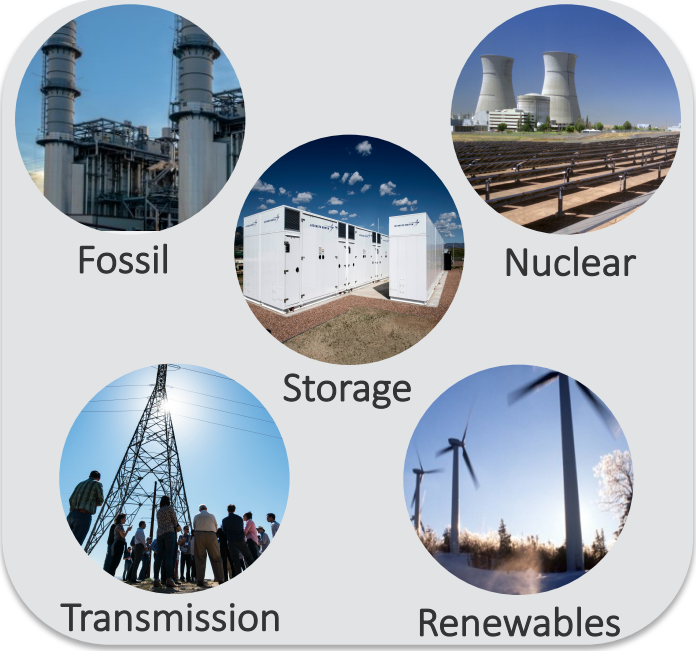
ReEDS 2.0 Enhancements

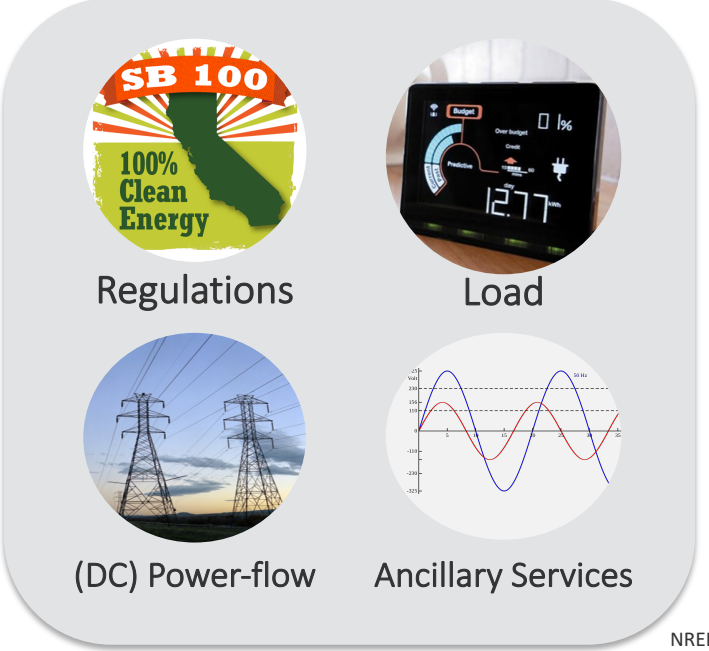
- User-specified years
- User-specified technology resolution (unit-level+)
- Explicit tracking of model plant vintages
- User-specified time horizons (solve time):
    - Sequential (~3 hours)
    - Sliding window (3-9 hours)
    - Intertemporal (1-3 days)
- Endogenous retirements and refurbishments
- Significantly shortened code length
- Iteration with detailed residential demand side*

Publicly Available: nrel.gov/analysis/reeds/

How does ReEDS work?

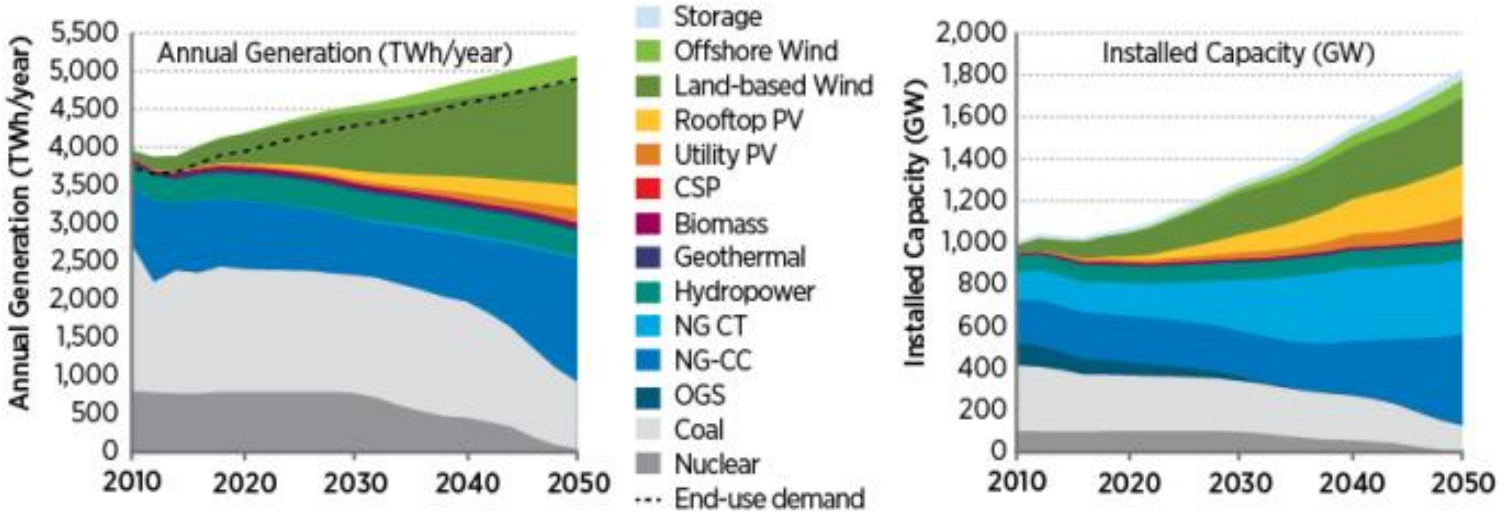
ReEDS uses a linear program that identifies the *least cost investment and operation* of resources (including storage) that simultaneously meets load, all other electricity service requirements (planning reserves, operating reserves), and physical and environmental constraints.





What are the key outputs?

Capacity and generation evolution of <u>all</u> generator types

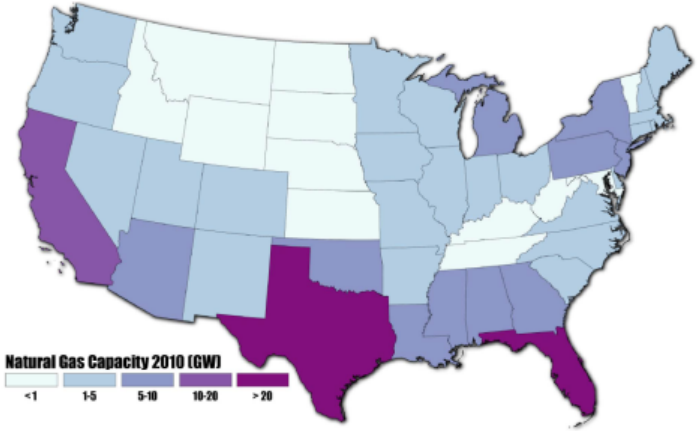


Wind Vision: A New Era for Wind Power (DOE 2015)

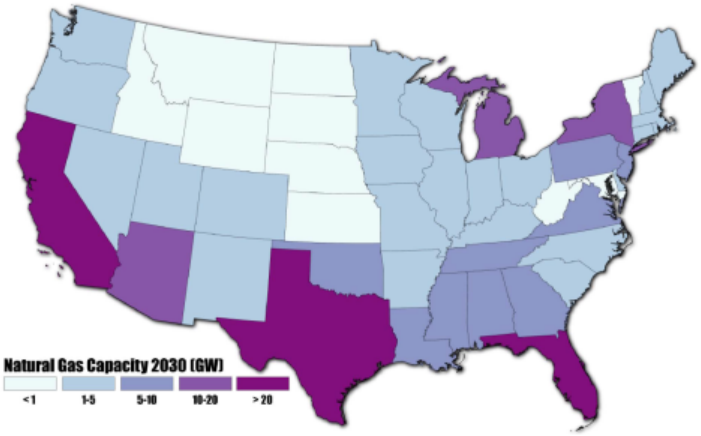
What are the key outputs?

Capacity and generation evolution by region at high geospatial resolution

2010

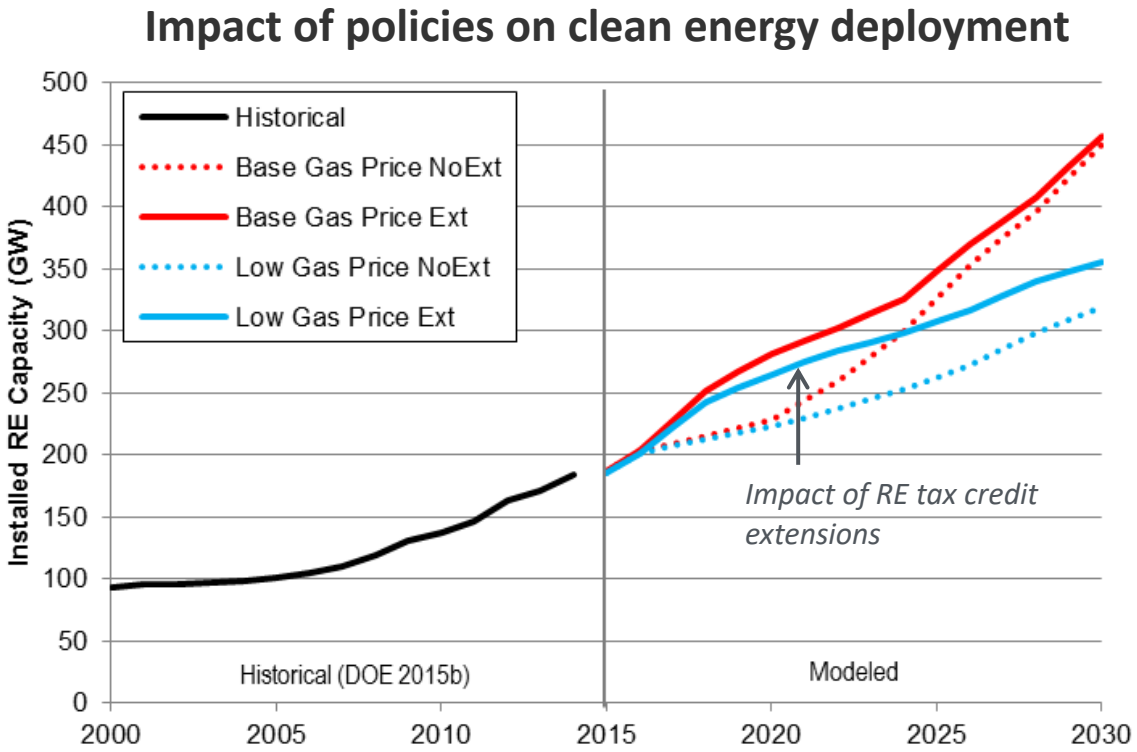


2030



U.S. Electric Power Futures: Preliminary Results (Presentation). (Lopez et al. 2012)

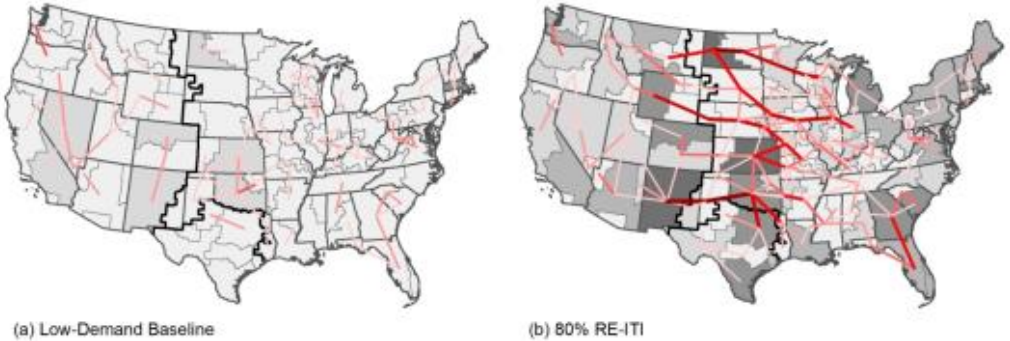
What are the key outputs?

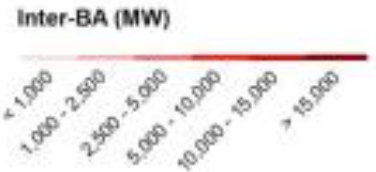


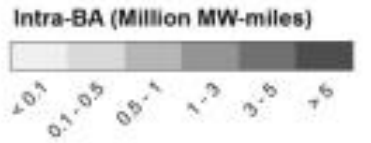
Impacts of Federal Tax Credit Extensions on Renewable Deployment and Power Sector Emissions (Mai et al. 2016)

What are the key outputs?

Transmission expansion



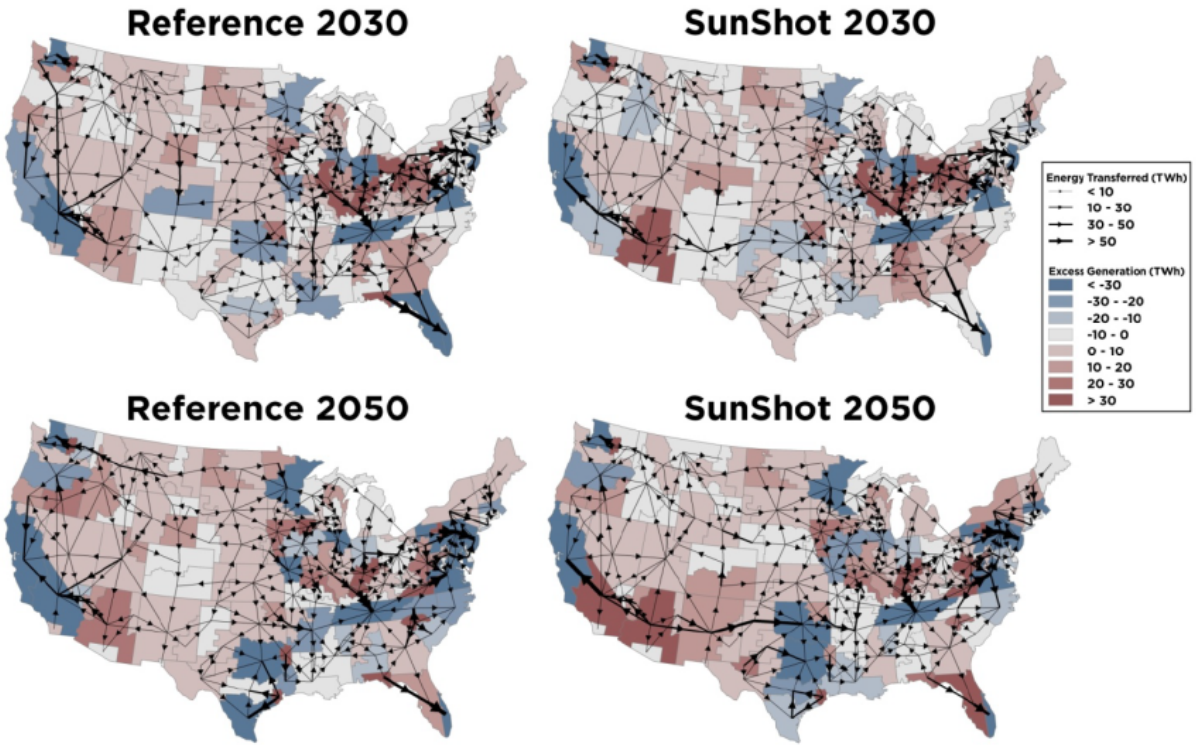




Envisioning a Renewable Electricity Future (Mai et al. 2014)

What are the key outputs?

Energy flows



SunShot Vision Study (DOE 2012)

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 outside the optimization to characterize variable renewables
- AC Power flow – Open Access ReEDS uses a pipeflow representation
- Plant-level decision making

What kinds of questions can the model answer?

- Quantifying the impacts of investment incentives on the generation and capacity
- Understanding how cost reductions (or performance improvements) for a technology impact the future US capacity mix

2020 Version Updates

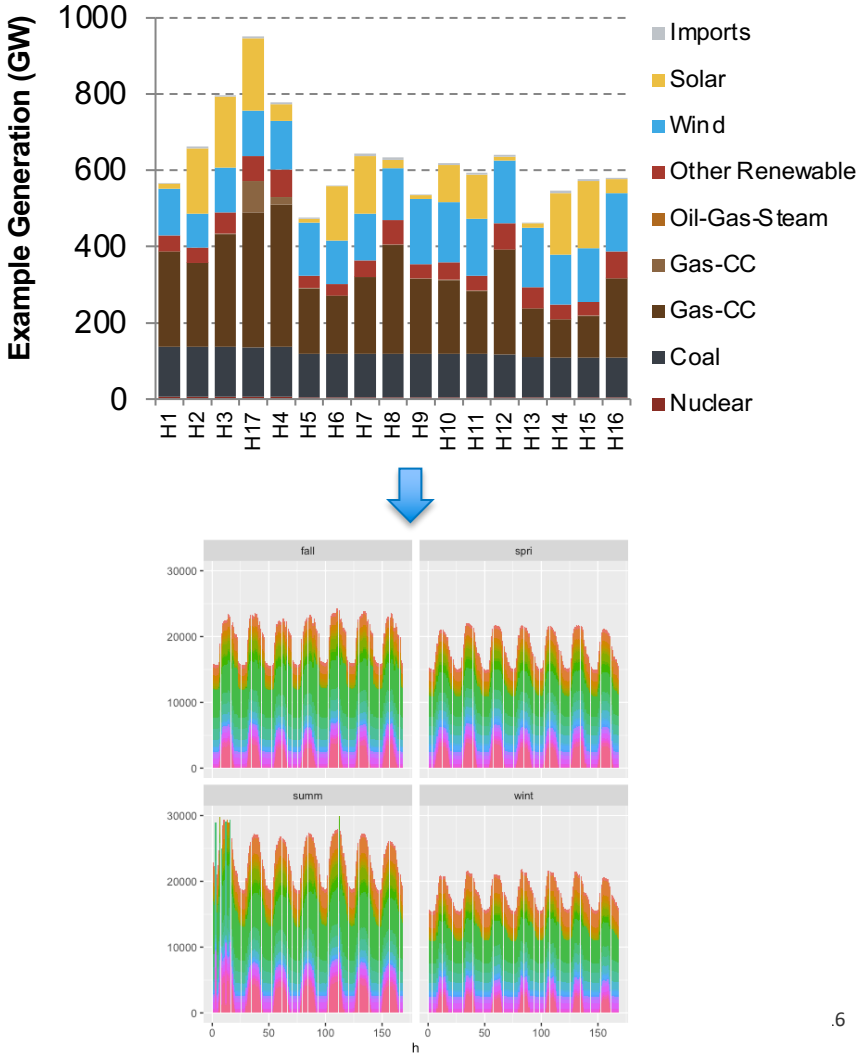
- Multiple storage durations
- Updated wind supply curves
- Augur module:
  - Simplified hourly dispatch for transmission flows, storage charge/discharge, and energy prices
  - Calculates curtailment and storage arbitrage value
  - Calculates capacity credit for VRE techs using 7 years of weather and load data
- EFS capabilities – load growth scenarios, load flexibility, gas response
- Cooling water capabilities

Temporal Flexibility

- Currently have 17 time-slices in ReEDS:

  4 hours per season (4x4) + 1 super-peak

- Adding in representation for average days/weeks/months as well as 8760, both for nation as a whole and focus regions



ReEDS Resources

- Request access to GitHub repository: nrel.gov/analysis/reeds/request-access.html
- Training video: https://youtu.be/Cdo27F18AZA
- Documentation: https://www.nrel.gov/docs/fy20osti/74111.pdf

Scalable Linked Dynamic Equilibrium (SLiDE) Model

with Caroline Hughes

Motivation

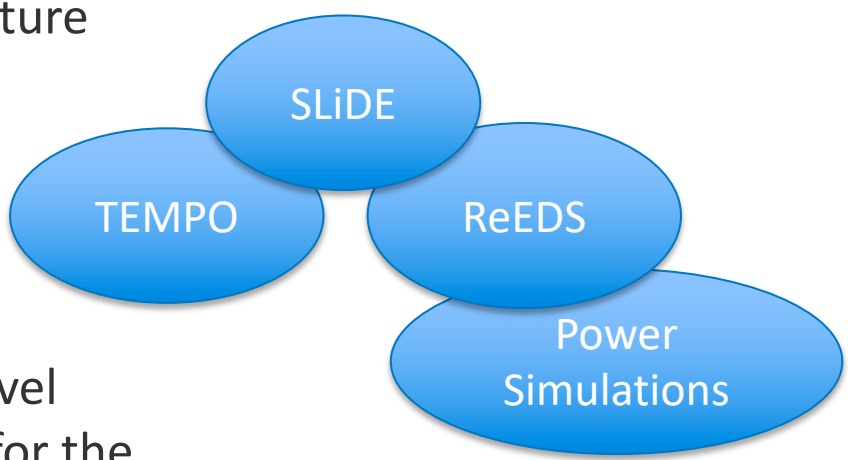
Although the economy and energy sectors are deeply intertwined, both are typically modeled in isolation

Very few publicly-available CGE models and datasets, especially when considering those linked with energy sector models

Perfect timing

Background

- Internally-funded project with development started in February 2020
- Built under the Scalable Integrated Infrastructure Planning (SIIP) platform
- Leveraging open-source blueNOTE dataset
- Written in Julia/JuMP



Goal: to communicate detailed, engineering-level results to the greater economy and vice versa for the analysis of employment, trade, and welfare implications of energy sector transformations

What's in a name?

- ***S***calable
  - Geographical: Counties -> Nations
  - Sectoral: Broad -> Specific
- ***Li***nked
  - … with ReEDS, Tempo, EMT, …
  - Comparable to ReEDS-USREP
- ***D***ynamic
  - Consideration of future market conditions
  - Myopic -> Intertemporal representations
- ***E***quilibrium

Wisconsin National Data Center

- Goal to provide publicly available datasets and companion models for evidence-based economic research on national and sub-national levels
- Primary product is the National Open-source Tools for Equilibrium analysis (blueNOTE) dataset
- Social Accounting Matrices for ***73 Sectors in 50 states***
- All input data publicly available
- Transparent data operations

windc.wisc.edu

Current Status & Next Steps

- Making repository publicly available this week, includes:
  - Data operations
  - Calibration exercises:
    - Raw data to balanced SAM
    - MPEC for calibration of factors of production, terms of trade, productivity
      *In progress – similar to Balistreri and Brown, 2020
  - Static and dynamic models

- Moving forward:
  - Linkages with bottom-up energy sector models
  - Analysis of NREL's critical objectives
  - Further model refinements:
    - Capital vintaging
    - Relaxing full employment
    - International representations
    - Household disaggregation

Other NREL Tools

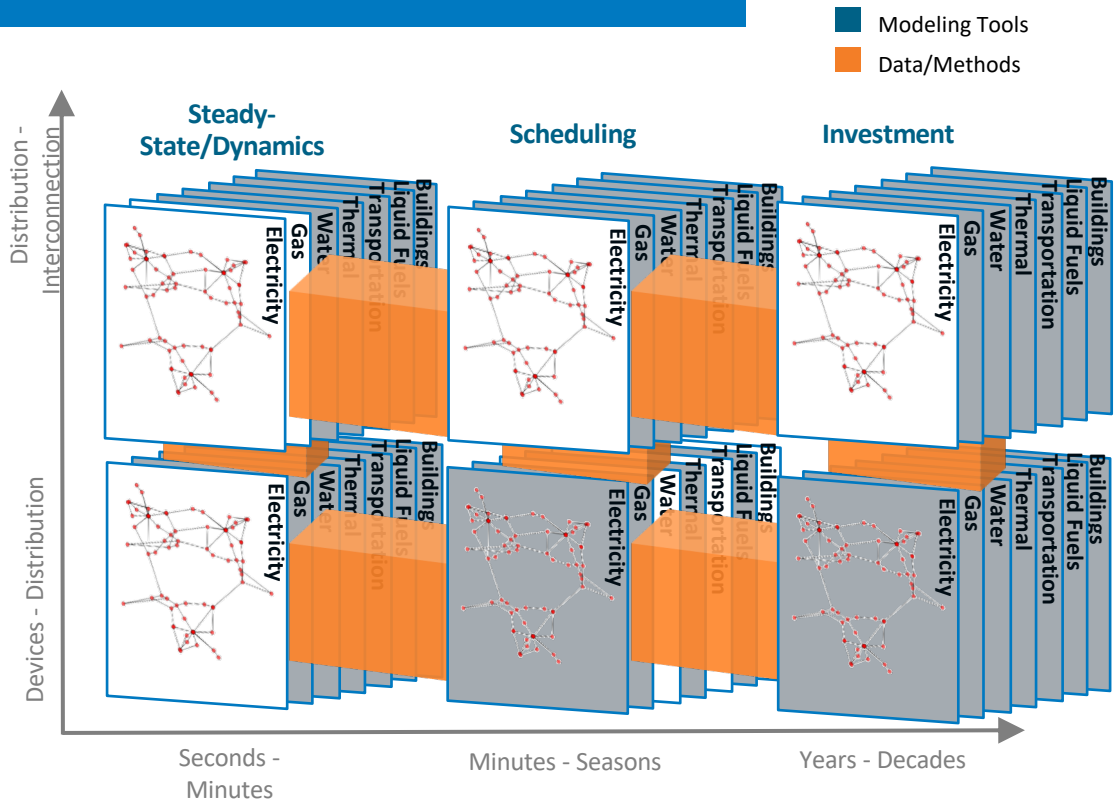
SIIP: An Integrated Modeling Vision

Framework Design Objectives

Modularity and Accessibility – flexible and transparent problem creation that is easily extensible

Integration – coherency between models representing distinct phenomena

Scalability – address scales that matter through efficient problem simulation and parallelism

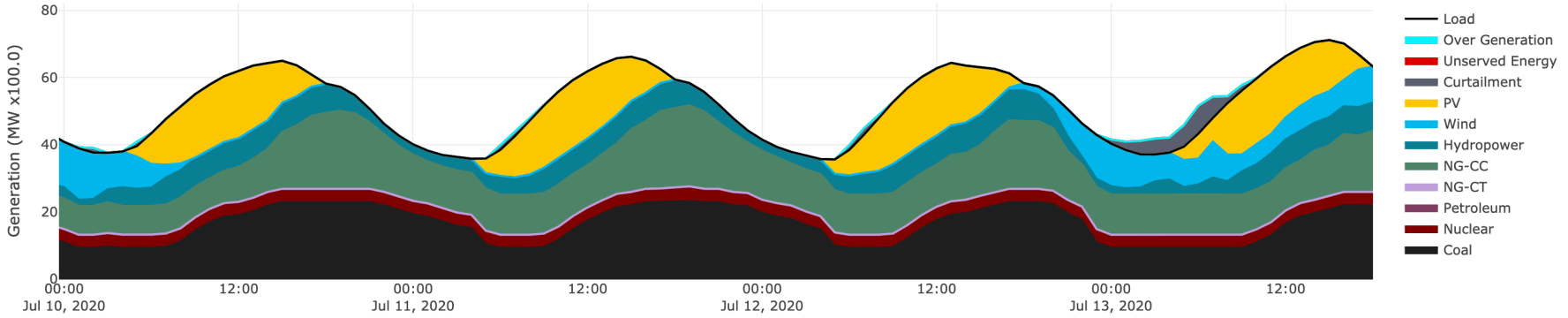


**Not representative of project deliverables*

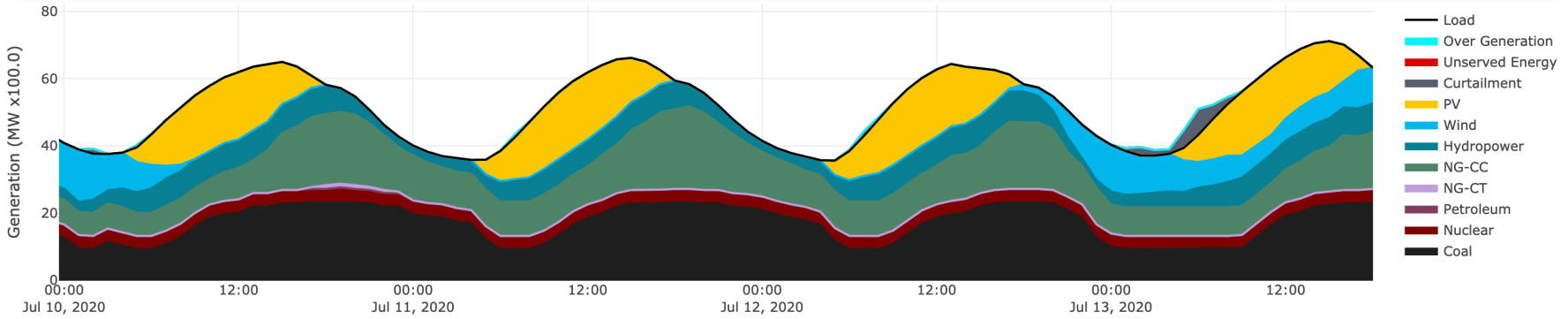
SIIP Performance: PCM Benchmarking

14 day RTS-GMLC sim	PLEXOS	PowerSimulations.jl
Xpress MIP GAP	0.1%	0.1%
Comp. Time	17:22.3	7:21.24

PowerSimulations.jl Stack

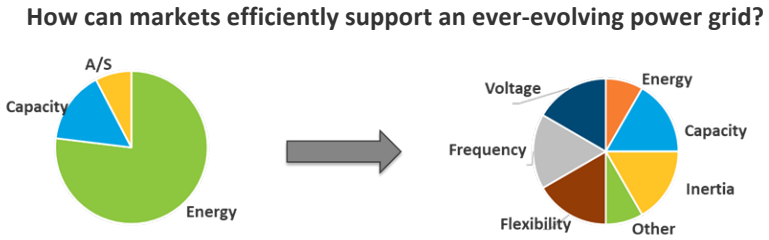


PLEXOS Stack



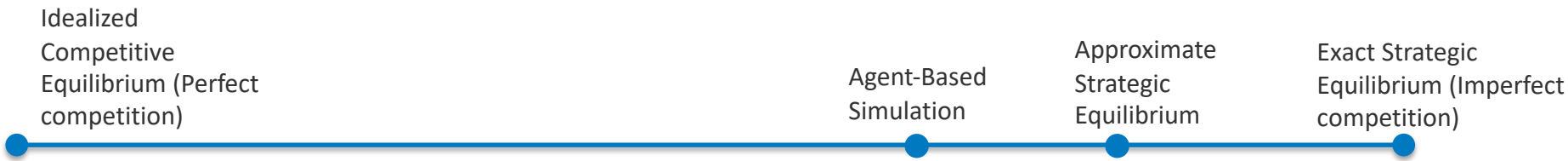
Next Steps in Capacity Expansion

- Develop a capacity expansion model for evaluating the impact of market design and investor heterogeneity on investment decisions and reliability: ***Electricity Markets and Investment Suite (EMIS)***
  - Represent individual investor firms with heterogenous beliefs about the future and risk representations
  - Explore how different market designs perform under uncertainty and imperfect information
  - Allow non-optimal investment (i.e., over- or under-investment) by firms with imperfect information
  - Leverage and integrate with the Scalable Integrated Infrastructure Planning (SIIP) modeling framework that include NREL's next generation of *integrated* modeling tools



EMIS Model Versions: 3 Tracks ("Tools")

1. **Idealized Competitive Equilibrium**
2. **Agent-Based Simulation**
3. **Approximate Strategic Equilibrium**



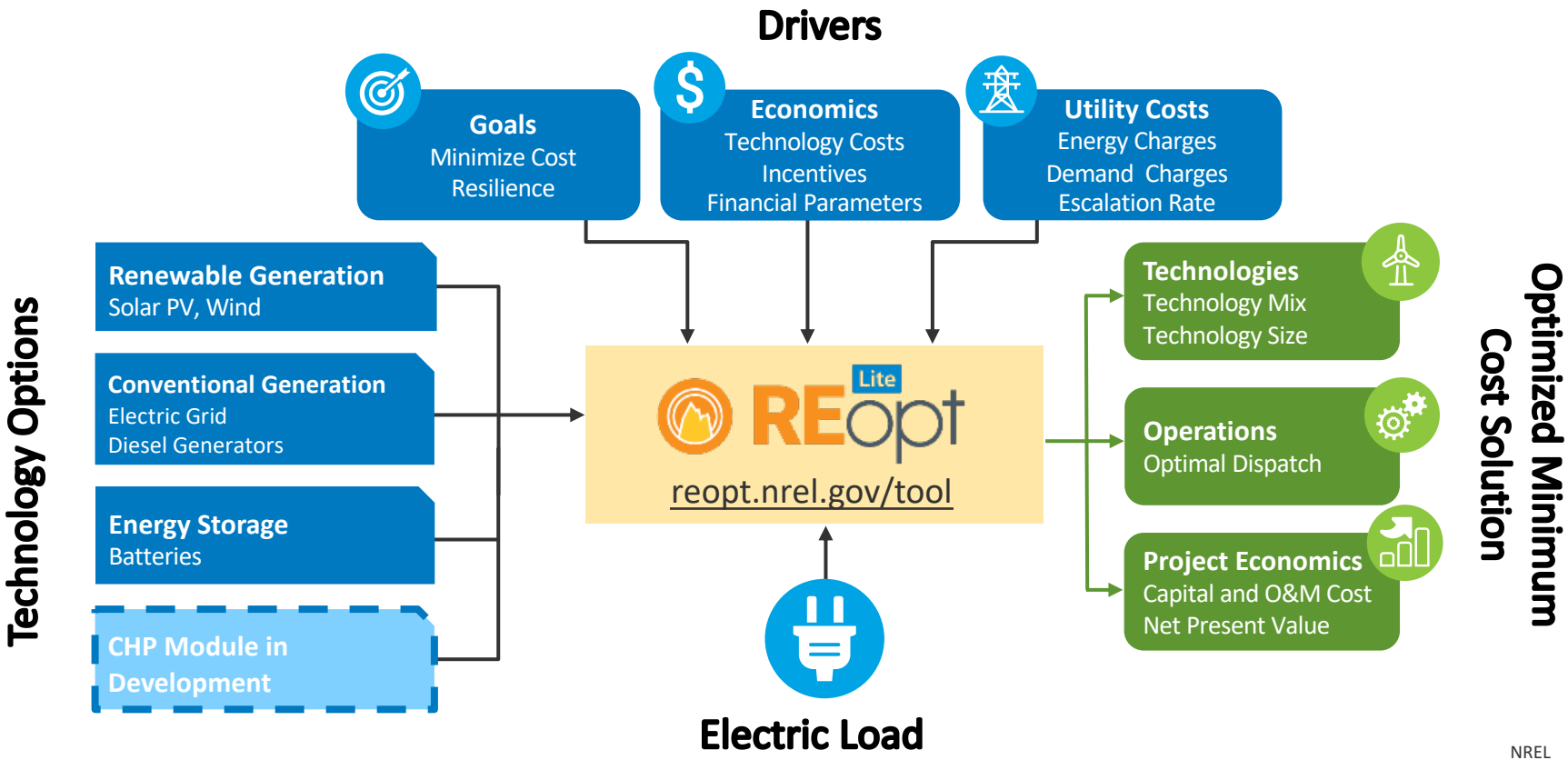
These tools cover the "spectrum" of market and behavior dynamics, with perfect competition on one end and imperfect competition (strategic behavior) on the other. We cannot have an exact strategic equilibrium, so our Approximate Strategic Equilibrium and Agent-Based Simulation tools are a means to approximate the desired heterogenous firm interactions.

REopt Lite Web Tool Transforms Complex Decisions Into Actionable Results

- The free, publicly available web tool guides investment in economic, resilient energy technologies;
- Based on decades of NREL decision-support expertise, REopt Lite™ transforms complex decisions into actionable results for building owners, utilities, and industry; and
- Open Source and API access to the tool enables analysis at scale.

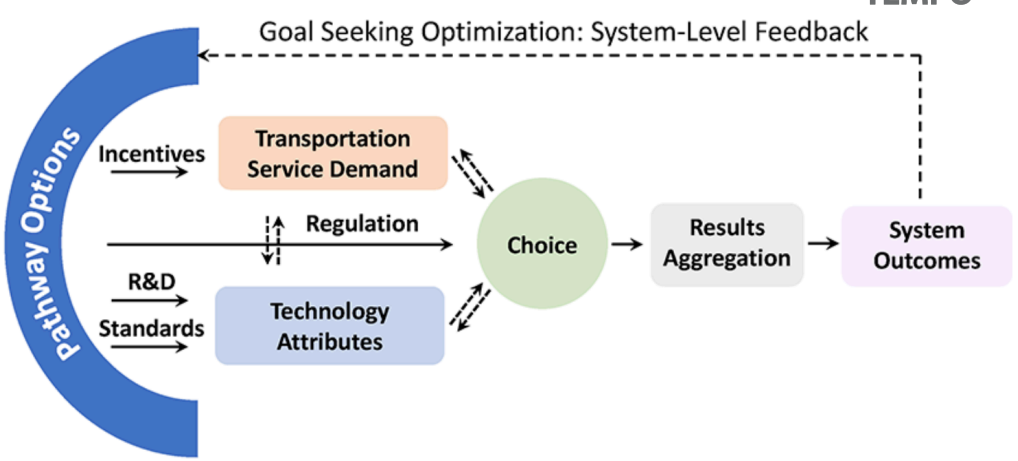
REopt Lite: Free Web Tool to Optimize Economic and Resilience Benefits of DERs

Formulated as a mixed integer linear program, REopt Lite provides an integrated cost-optimal energy solution.



Transportation Energy & Mobility Pathway Options (**TEMPO**)

TEMPO is a sector-wide transportation demand and choice model used to explore future pathways for transportation systems



CHALLENGE

- What is the potential for **radical transformations** of transportation and mobility demand and the energy supply and emissions implications?
- How might **interconnections** with other sectors and infrastructure evolve?
- Which fuels/technologies will be adopted and in which **market segments**?

FEATURES

- Model **household level** mobility demand and travel choice
- Endogenous **out-of-sample forecasting** to explore radical transformation
- Model **time-resolved energy use** for grid model linkages

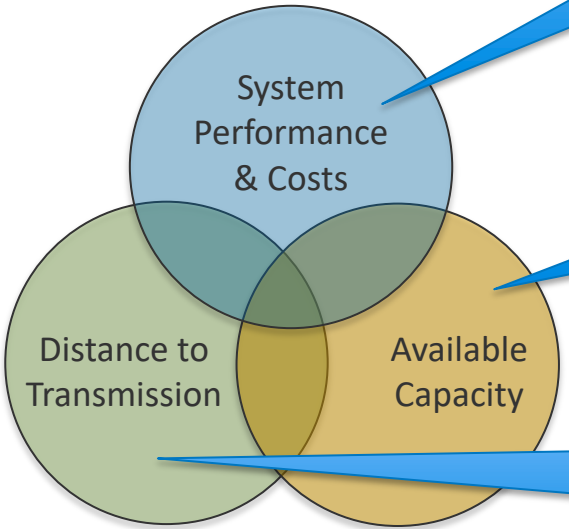
Significance & Impact

- Fill a research gap on sector-wide transportation modeling and properly represent alternative futures for mobility and technology use
- Generate long-term pathways to achieve system-level goals and assess integration opportunities between transportation and energy infrastructure and supply systems

Resources: https://www.nrel.gov/transportation/tempo-model.html

The Renewable Energy Potential (reV) Model

reV is a geospatial platform for assessing **system performance**, **available capacity**, **distance to transmission**, and **total costs** for potential solar and wind energy deployment at regional to continental scales.

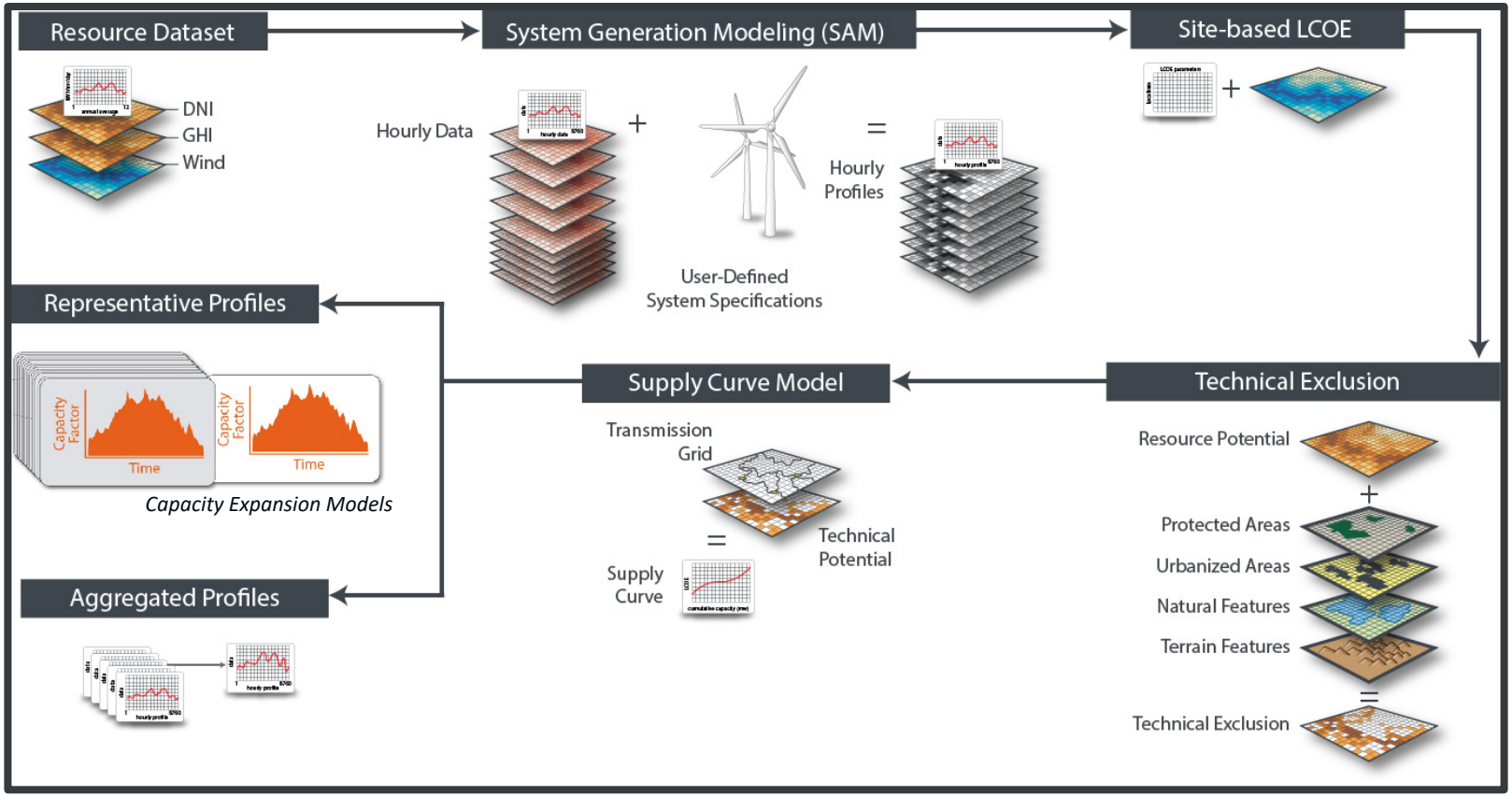


What does solar and wind resource look like across time and space, and how do specified systems respond in terms of electricity output?

How much land is available for deployment of solar and wind systems?

How far from existing transmission are potential solar and wind deployment sites?

reV Model Diagram



Thank you

Maxwell.Brown@nrel.gov

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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 US Department of Energy's Strategic Programs and Impacts Analysis 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.