Motivation for improved modeling: Large-scale studies and stakeholder input

US DOE / National Lab team
Presented by Greg Brinkman
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The North American Renewable Integration Study

State-of-the-art analysis of the U.S., Canada, and Mexico power systems, from planning through operations

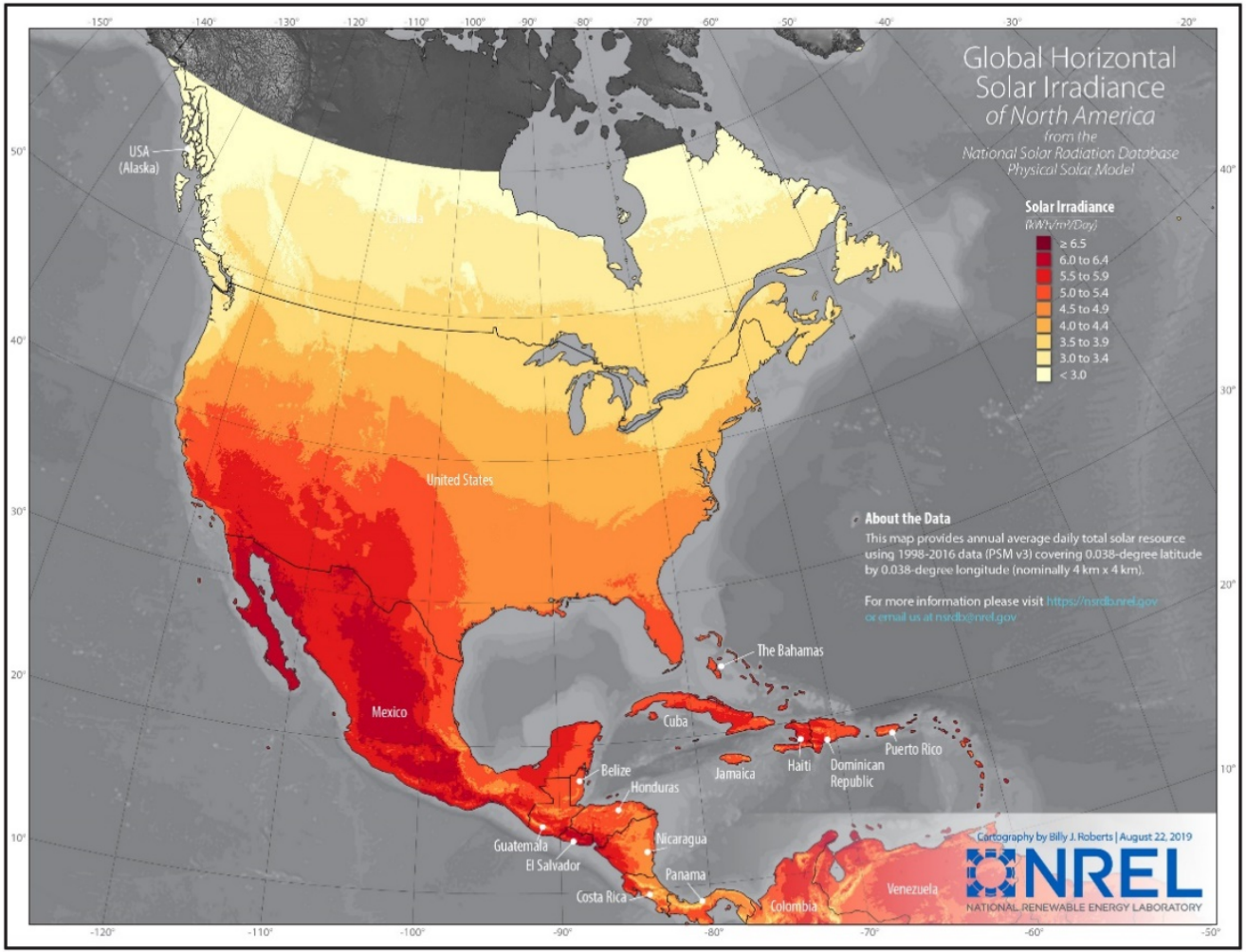
Natural Resources Canada | Ressources naturelles Canada

Canada

SENER
SECRETARÍA DE ENERGÍA

WHAT WE'RE STUDYING

- Long-term pathways to a modern power system in North America
- Operational feasibility of high-penetration scenarios
- Weather variability and uncertainty
- Value of enabling technologies: flexible hydro, thermal generation, transmission, storage
- Value of operating and planning practices: interchange, transmission expansion, local generation


Global Horizontal Solar Irradiance
of North America
from the National Solar Radiation Database Physical Solar Model
Solar Irradiance
(kWh/m²/Day)
≥ 6.5
6.0 to 6.4
5.5 to 5.9
5.0 to 5.4
4.5 to 4.9
4.0 to 4.4
3.5 to 3.9
3.0 to 3.4
< 3.0
About the Data
This map provides annual average daily total solar resource using 1998-2016 data (PSM v3) covering 0.038-degree latitude by 0.038-degree longitude (nominally 4 km x 4 km).
For more information please visit https://nsrdb.nrel.gov or email us at nsrdb@nrel.gov
USA (Alaska)
United States
Mexico
The Bahamas
Cuba
Jamaica
Haiti
Dominican Republic
Puerto Rico
Belize
Honduras
Guatemala
El Salvador
Nicaragua
Costa Rica
Panama
Colombia
Venezuela
Cartography by Billy J. Roberts | August 22, 2019
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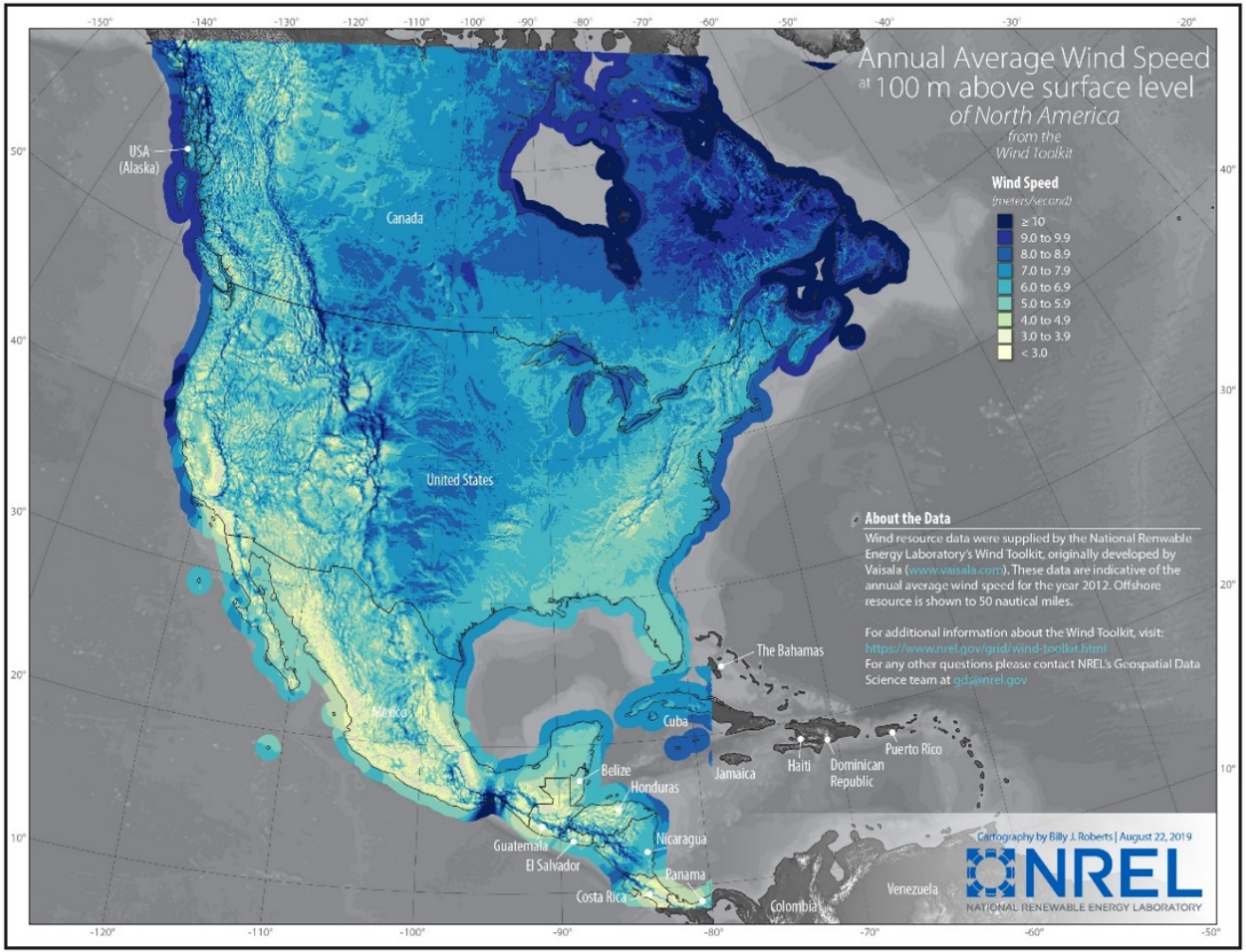
Annual Average Wind Speed
at 100 m above surface level
of North America
from the
Wind Toolkit
Wind Speed
(meters/second)
≥ 10
9.0 to 9.9
8.0 to 8.9
7.0 to 7.9
6.0 to 6.9
5.0 to 5.9
4.0 to 4.9
3.0 to 3.9
< 3.0
About the Data
Wind resource data were supplied by the National Renewable Energy Laboratory's Wind Toolkit, originally developed by Vaisala (www.vaisala.com). These data are indicative of the annual average wind speed for the year 2012. Offshore resource is shown to 50 nautical miles.
For additional information about the Wind Toolkit, visit:
https://www.nrel.gov/grid/wind-toolkit.html
For any other questions please contact NREL's Geospatial Data Science team at gds@nrel.gov
USA (Alaska)
Canada
United States
Mexico
The Bahamas
Cuba
Jamaica
Haiti
Dominican Republic
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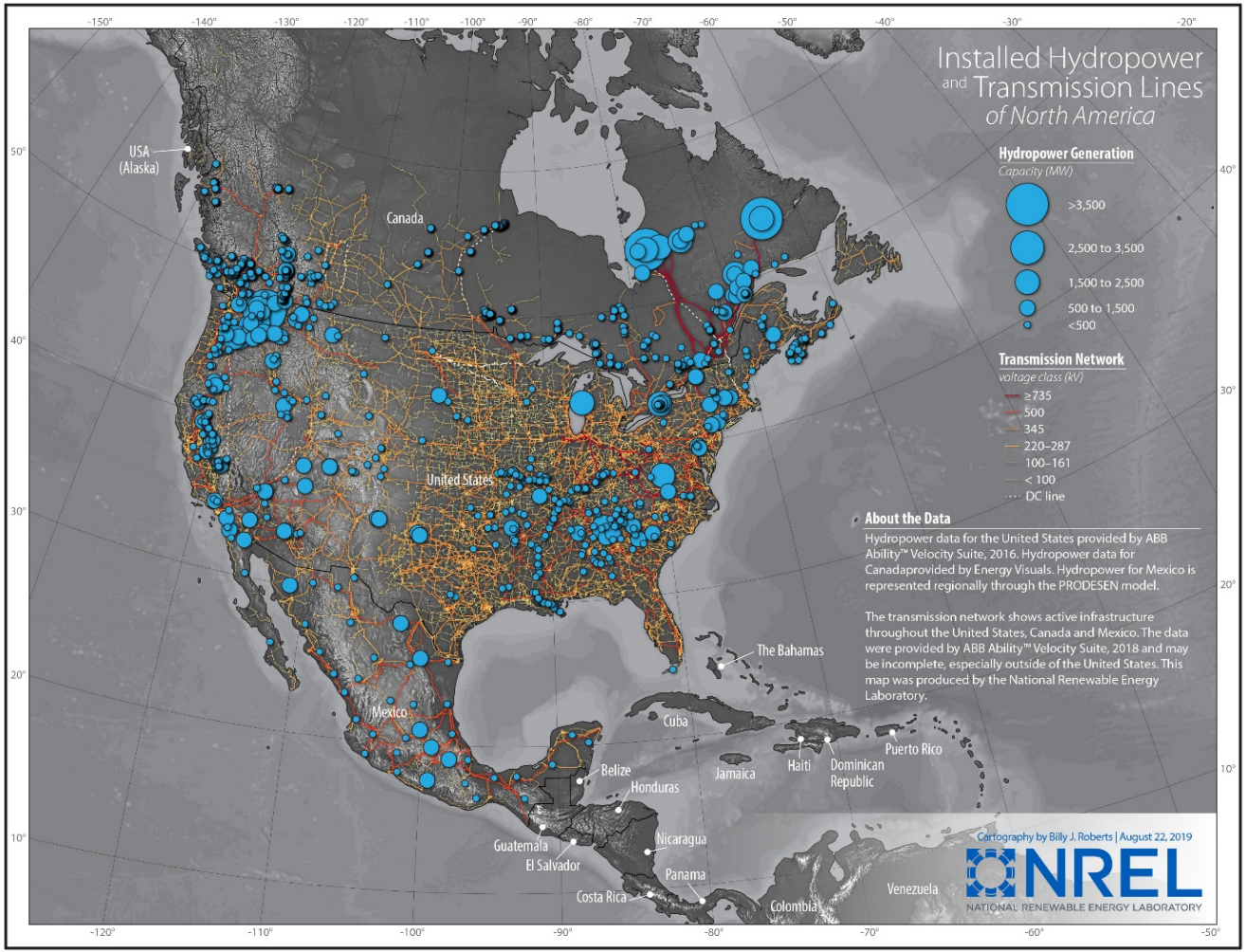
Installed Hydropower
and Transmission Lines
of North America
Hydropower Generation
Capacity (MW)
>3,500
2,500 to 3,500
1,500 to 2,500
500 to 1,500
<500
Transmission Network
voltage class (kV)
≥735
500
345
220–287
100–161
< 100
DC line
About the Data
Hydropower data for the United States provided by ABB Ability™ Velocity Suite, 2016. Hydropower data for Canadaprovided by Energy Visuals. Hydropower for Mexico is represented regionally through the PRODESEN model.
The transmission network shows active infrastructure throughout the United States, Canada and Mexico. The data were provided by ABB Ability™ Velocity Suite, 2018 and may be incomplete, especially outside of the United States. This map was produced by the National Renewable Energy Laboratory.
USA (Alaska)
Canada
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Mexico
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Jamaica
Haiti
Dominican Republic
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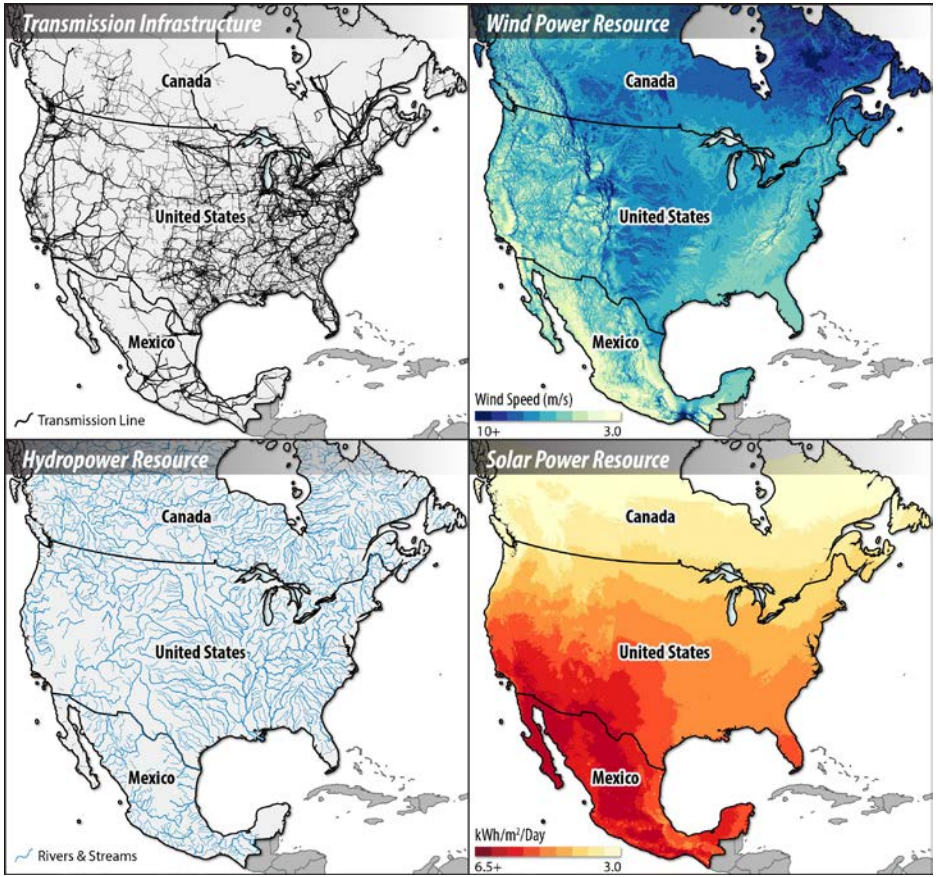
North America Is Very Diverse in Energy Resources and Load

The availability of natural resources varies widely across regions.

So does how and when energy is used on the grid.

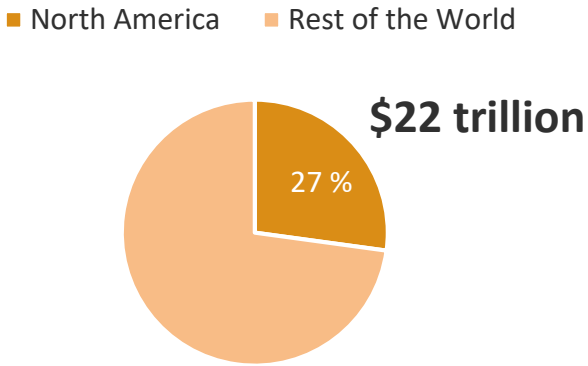
A modern power system can take advantage of this diversity to provide reliable, affordable, sustainable power.



How Big Is the North American Grid?

- Over **100,000 nodes** on the transmission grid
- Over **10,000 generators**
- Over **10,000 compute node-hours** required to run an operational simulation

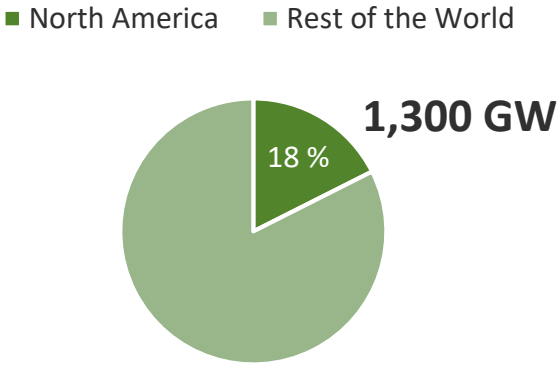
GROSS DOMESTIC PRODUCT



$22 trillion

Source: World Bank

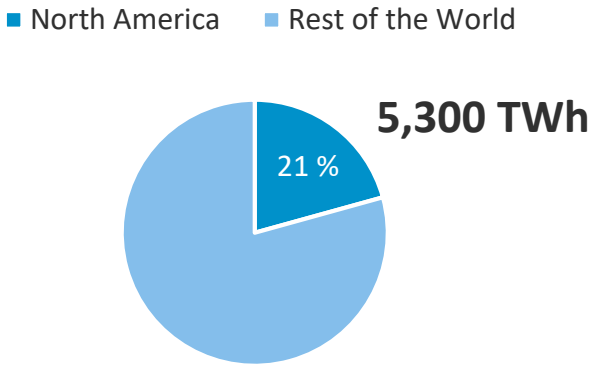
GENERATING CAPACITY



1,300 GW

Source: CIA

GENERATION



5,300 TWh

Source: BP Statistical Review

Accelerating Grid Modernization in North America

INFORMING

grid planners, operators, market participants, and regulators of challenges and opportunities for the grid

- How reliable and affordable is it?
- What operating practices and technologies help the most?
- Are the "solutions" robust?
- What is the benefit of inter-regional and cross-border cooperation?

ENABLING

stakeholders to deepen and extend their understanding of renewables and modern power systems

- Creating and disseminating new data
- Pioneering and deploying new methods and computational tools

CREATING

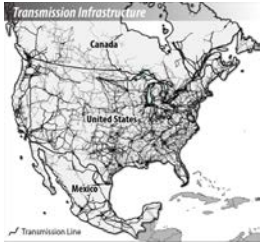
a framework for future analysis

- Stability (i.e., frequency, transient, voltage)
- Resilience to extreme events (e.g., weather)

Novel Need for Detail in Continental Modeling

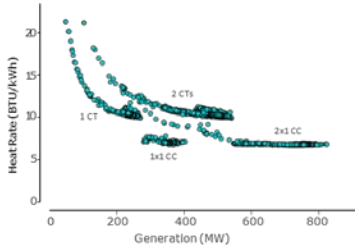
POWER FLOW CASE IMPORTS (GridDB)

100+ cases representing all U.S./Canada interconnections, 12-year span, load flow periods, automated import



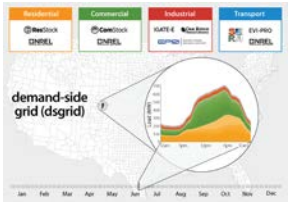
GENERATOR PARAMETERS

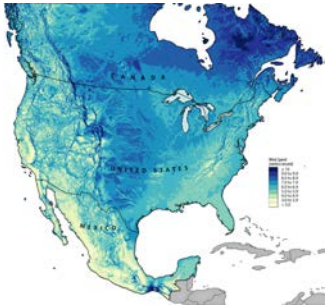
Detailed analysis of historical operating parameters, such as heat rate and minimum generation levels



LOAD

Detailed meteorologically consistent load data (adjustable to future conditions)





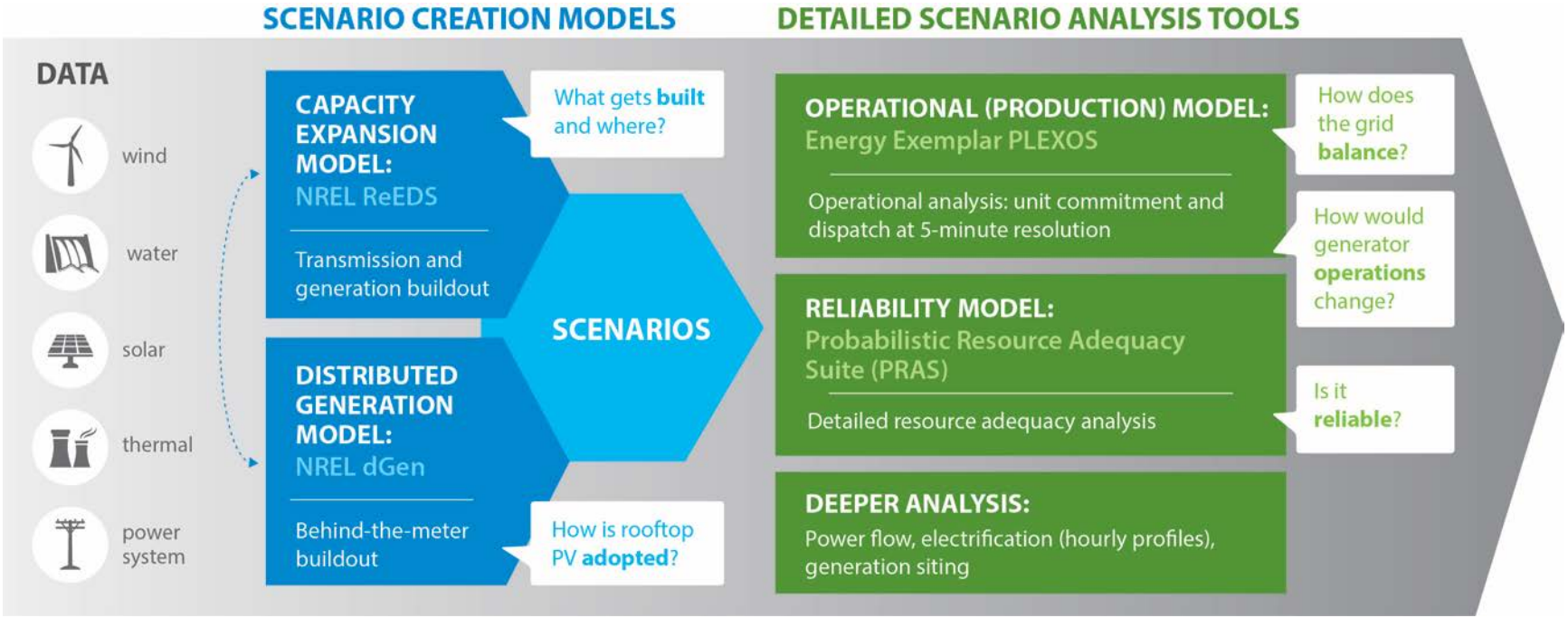
METEOROLOGY

7 years of 5-min time resolution data for wind and solar generators consistent with load

PARTNERSHIP AND TECHNICAL REVIEW

Ongoing review of all data, assumptions, and methods by system operators and others

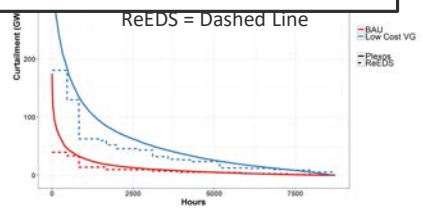
How it Works: Modeling Flow



Operational Simulation/ Production Cost (PLEXOS)

- Continental-scale model with detailed representation and realistic interregional interactions via geographic decomposition
- 5-minute time resolution, will model 7 years of meteorology (not done yet)
- Understand how grid operates, forecast error impacts, benefits from transmission, etc., in detail
- Comparisons with capacity expansion simplified dispatch, with feedback from learning

Hydropower flexibility sensitivities designed to understand the role of hydro in the future grid and the value of hydro flexibility. Wet/dry conditions will also be studied.



Key Hydro-Focused Analysis

- Value of hydropower flexibility
  - Based on a sensitivity with increased levels of flexibility from the standard assumptions and one with decreased levels of flexibility
- Analysis of wet and dry conditions
- Value of contribution toward resource adequacy
  - Hydropower plays a very key role in resource adequacy, especially in the high-wind/-solar scenarios
- Low-cost storage sensitivity
  - Informs what the grid could look like with increased storage, in the form of batteries and pumped hydro.

Hydropower Modeling Workshop discussion

(Emphasis in slides added by me for this meeting)

Representation of Hydropower in Production Cost Models

A PNNL and NREL sponsored workshop
2019, March 6-7 – Salt Lake City, UT

Pacific Northwest
NATIONAL LABORATORY

Modeling and valuing hydropower operations to enable grid reliability

https://www.pnnl.gov/events/hydropower-modeling-workshop

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Key takeaways and areas of agreement

- **Hydropower modeling objectives** (and thus modeling needs) **can be quite diverse**, depending on the question being asked, and specifically the time scale of interest (e.g., operations optimization vs. long-term investment planning). This also means that there are different needs and challenges for hydropower modeling, depending on which question we are addressing. Improvements in hydropower modeling will have to address these unique and differentiated needs.
- **Lack of publicly available data hinders** some (but not all) hydropower modeling activities. In many cases, publicly available data could suffice, but the major challenge is that this data is not accessible, organized, formatted, or readily usable. There are many ways in which the data challenge could be addressed without needing proprietary data.
- There is a need for improvements in **how we validate and characterize uncertainty from hydropower models**. There are no standards for evaluating the accuracy of models, or for attributing where sources of error are arising from. This could be beneficial to develop as a way to document improvements in hydropower modeling.
- Recognizing the complexity and difference in priorities of both hydropower systems and the power grid, new modeling frameworks are needed to capture this diversity. New modeling frameworks should be able to link the least-cost optimization decision-making of the power grid with the non-economic decision-making approaches of hydropower systems. These new frameworks could include linking existing models, developing co-optimization couplers to connect models, or creating entirely new models.
- As the grid is changing, **the role of hydropower is changing**. Production cost models and their representation of hydropower flexibility, markets, and local vs. global optimization of hydropower operations are inadequate to effectively represent hydropower dynamics. Further collaboration among energy system modelers and hydropower operators and modelers is needed to improve this representation.


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Questions?
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