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Transforming the Global Power Sector

Open Tools and Data for Renewable Energy Integration

June 2023

Welcome!

Welcome to our webinar! Here are a few notes about using Zoom:

- This webinar is **being recorded** and will be shared with attendees.
- You will be **automatically muted** upon joining and throughout the webinar.
- Please use the **Q&A function** to ask questions to be addressed during the Q&A portions. You can find this function in your toolbar.
- Please use the **chat feature** to add comments and share input.
- If you have **technical issues**, please use the chat feature to message **Isabel McCan** or **Holly Darrow**.
- You can adjust your audio through the **audio settings**. If you are having issues, you can also dial-in and listen by phone, which can be found in your registration confirmation email.

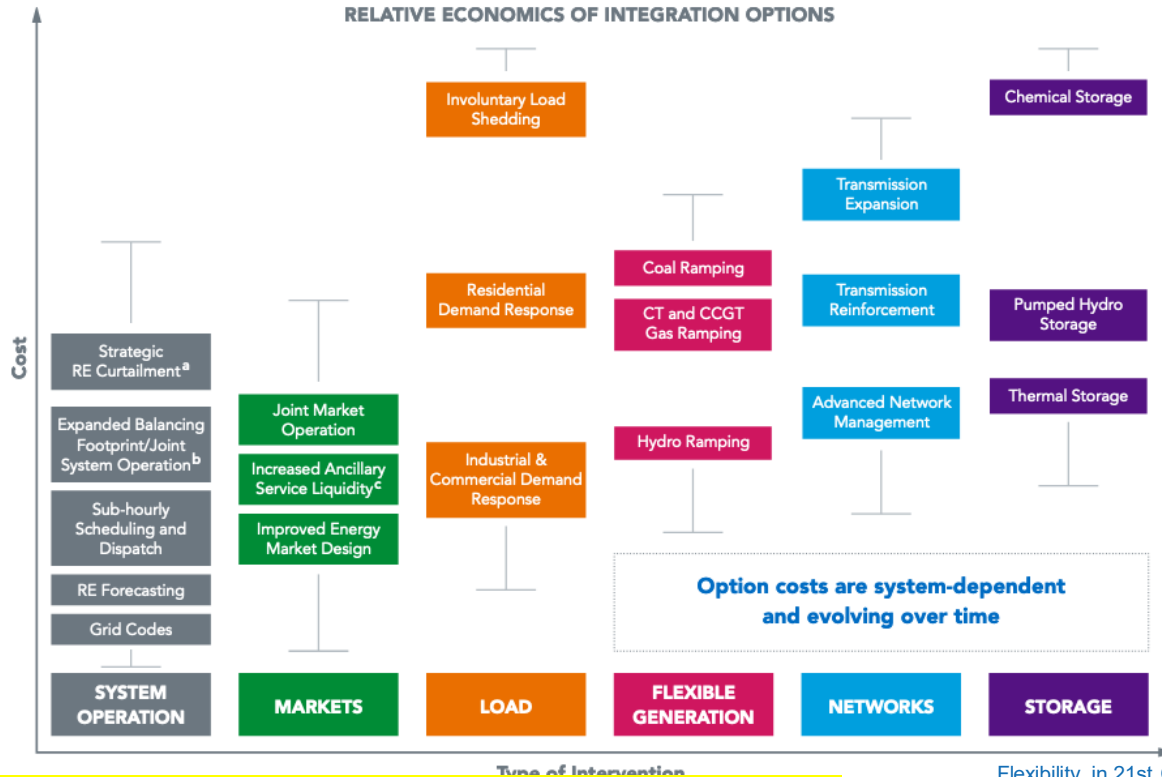
To view the recordings and resources from yesterday's session, please visit:

<https://globalpst.org/transforming-the-global-power-sector-open-data-and-tools-for-renewable-energy-integration/>

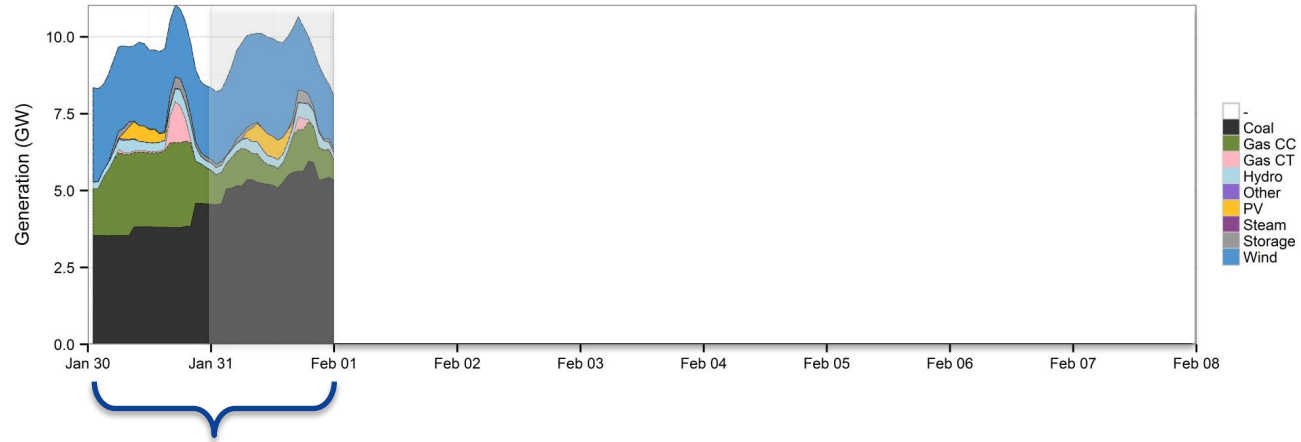
Agenda – Day 2

- 1 Recap of Day 1
- 2 Overview of PCM Workflow and Sample Analysis
- 3 Resource Visualization and Site Screening in RE Data Explorer
- 4 PCM Demonstration in Sienna\Ops
- 5 Open-Source Training Resources
- 6 Audience Q&A
- 7 Wrap Up

Sources of Flexibility

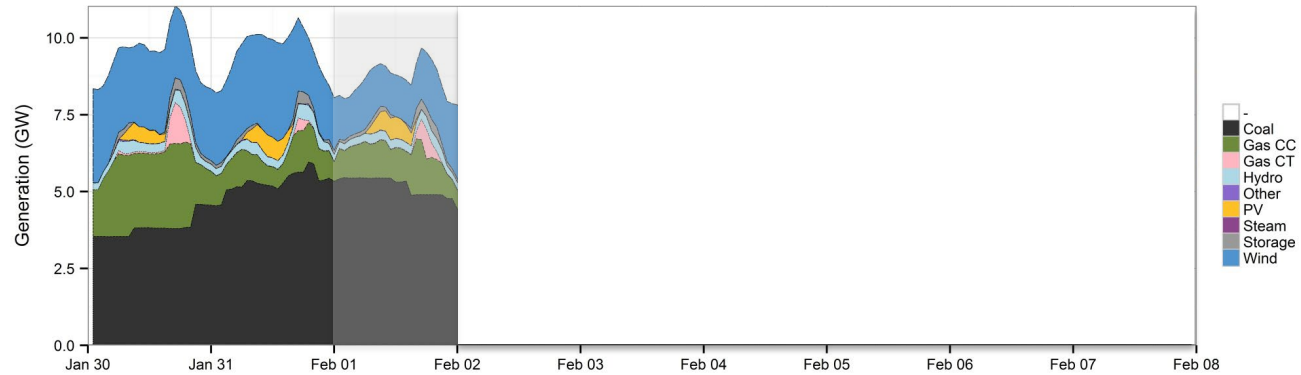


Unit commitment and economic dispatch



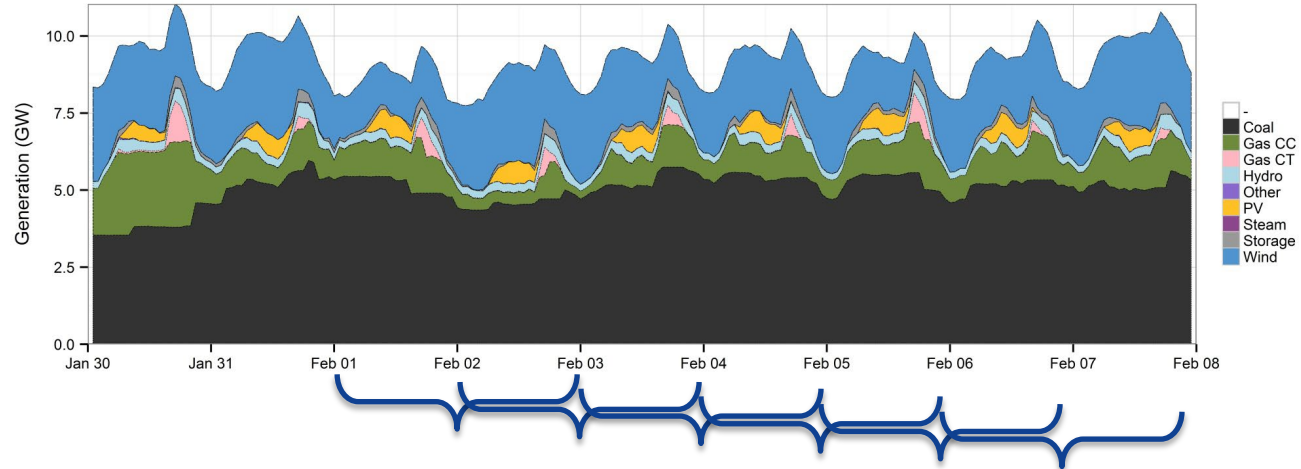
optimization horizon:
48 hours

Unit commitment and economic dispatch



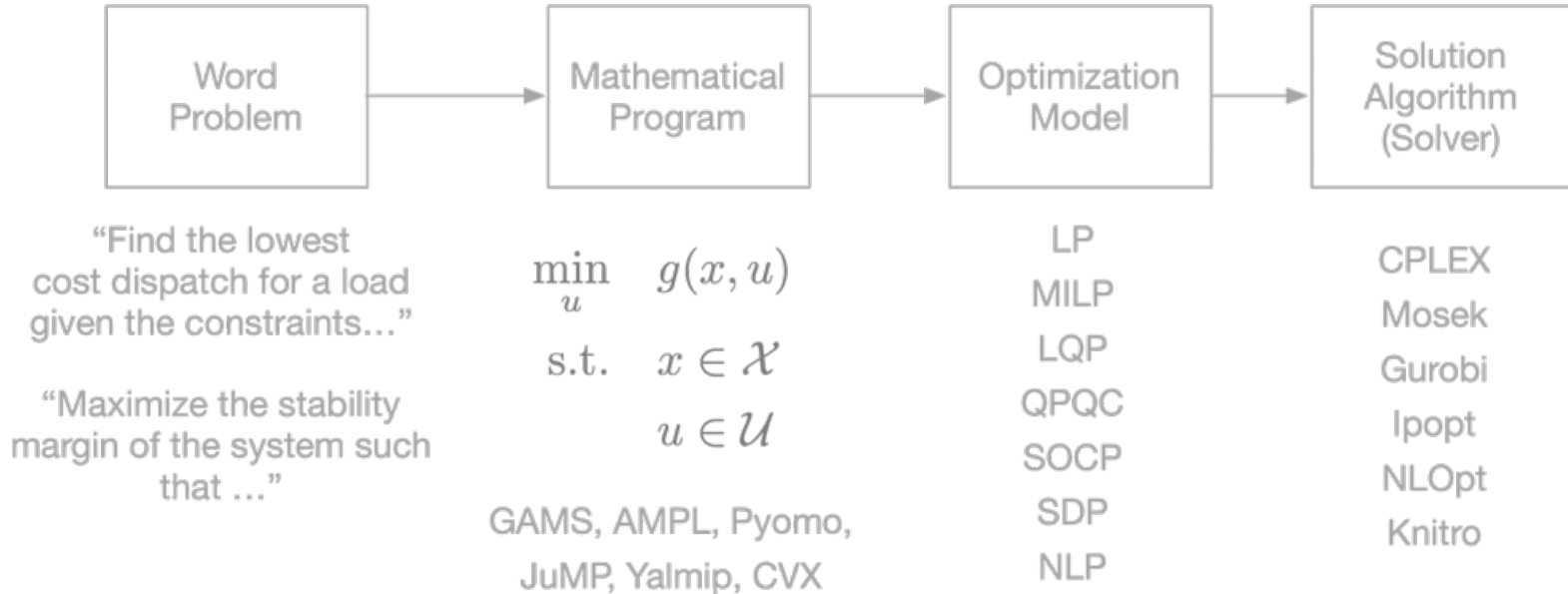
rolling forward in
24 hour increments

Unit commitment and economic dispatch

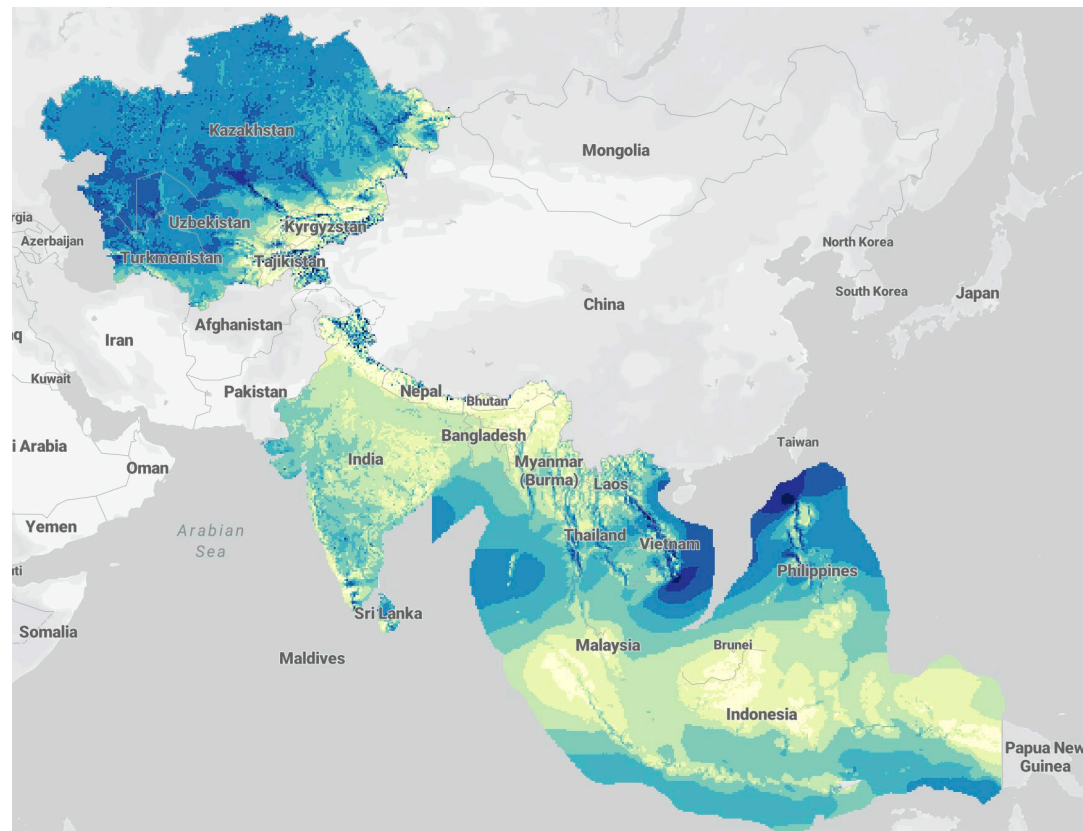


- **Intertemporal Unit-Commitment & Economic Dispatch (UC/ED)**
Mixed Integer Programming problem (MIP)
- **Sequential UC/ED Steps**

Structure of an Optimization Problem



NREL Wind Resource Data



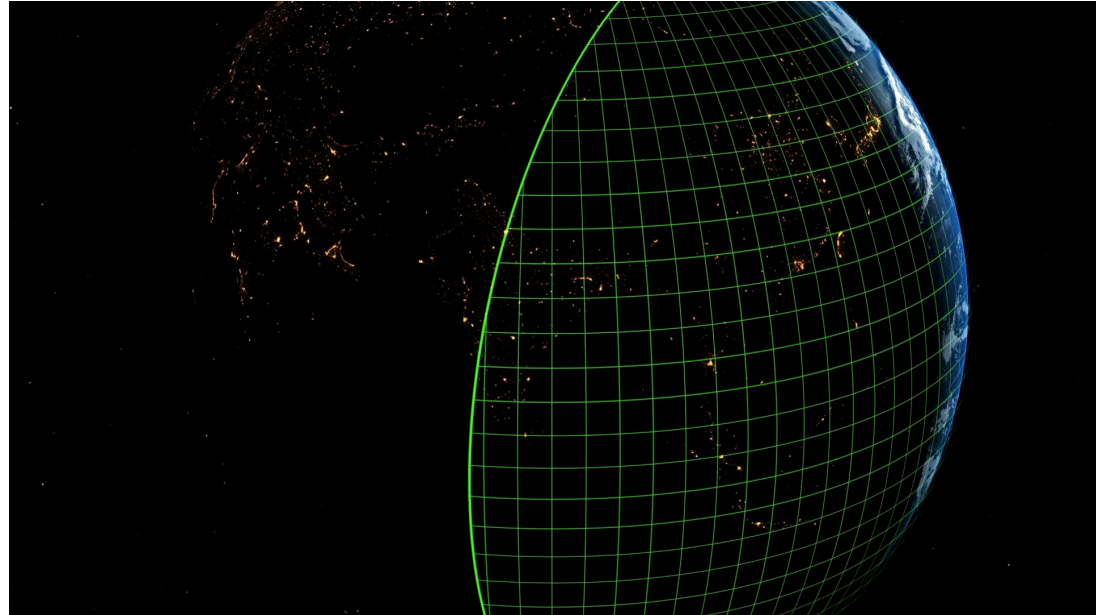
NREL Wind Data - Asia

- Central Asia – 2015
 - 2km, 15 minute - Kazakhstan
 - 9km, 15 minute - other countries
- South Asia – 2017
 - 3km, 5 minute
 - India, Sri Lanka, Nepal, Bhutan
- Southeast Asia 2007-2021
 - 3km, 15 minute
 - Association of Southeast Asian Nation (ASEAN) countries and Bangladesh

Southeast Asia Solar Resource Data

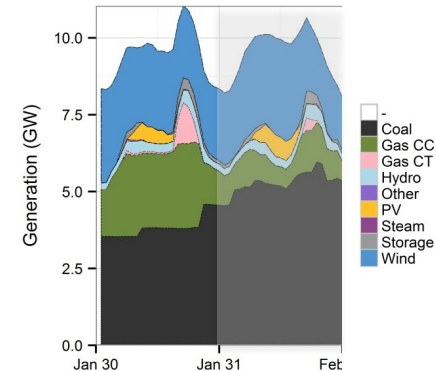
Released in February 2021:

- High fidelity solar radiation data covering SE Asia and much of the Indo-Pacific region.
- 10-years of high spatial and temporal resolution data and a Typical Meteorological Year (TMY) data set.
- Easily accessible, free, and open data.



Recap of Key Takeaways from Day 1

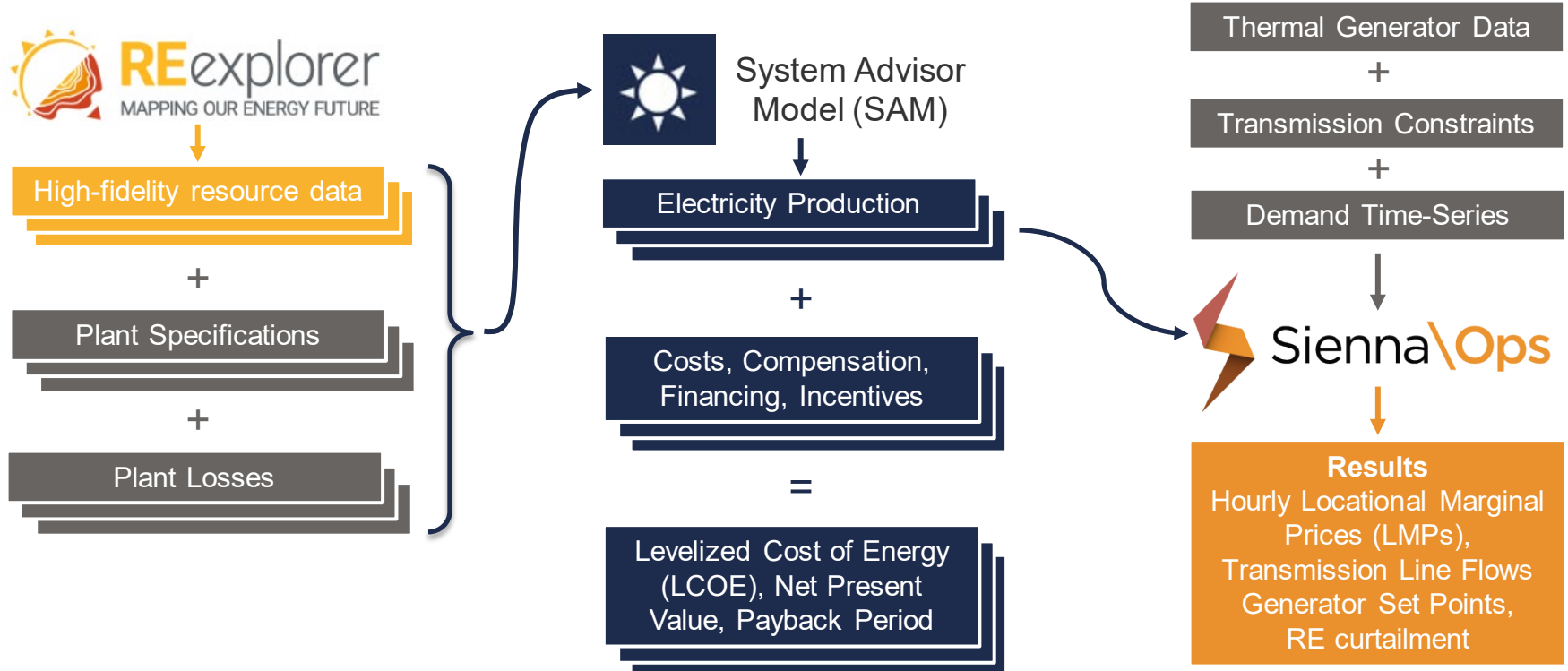
- Power system *flexibility* is key for integrating VRE
- Time-series production cost modeling can quantify the benefits of many sources of operational flexibility
- For system operators, PCM is key to operations and planning:
 - Minimize operating & reserve costs on a daily, hourly, subhourly basis
 - Study & anticipate impacts of VRE scenarios on operations
- For developers, PCM can help determine site feasibility:
 - Transmission-constrained curtailment, market bidding strategies (hybrid/storage), locational cost and emissions impacts
- Open-source data and models reduce cost and difficulty of site prefeasibility and feasibility studies



optimization horizon:
48 hours

Overview of PCM Workflow with Sienna\Ops

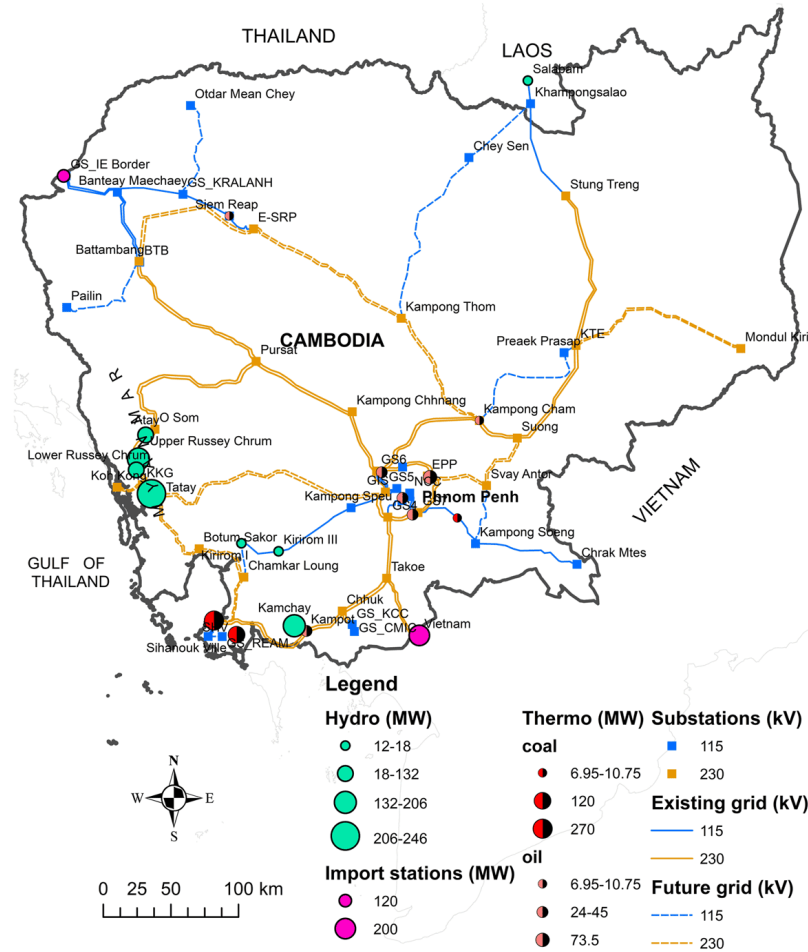
Overview of PCM Workflow



Sample Analysis: Cambodia

PowNet (2021):

- Open-source, hourly-resolution operational model
- Includes transmission lines and generators
- Includes time-series load and hydro data based on 2016
- No wind or solar generators included yet



Modified from
Chowdhury et al. 2020

Case Study Code

<https://github.com/NREL-Sienna/PSI-Cambodia>

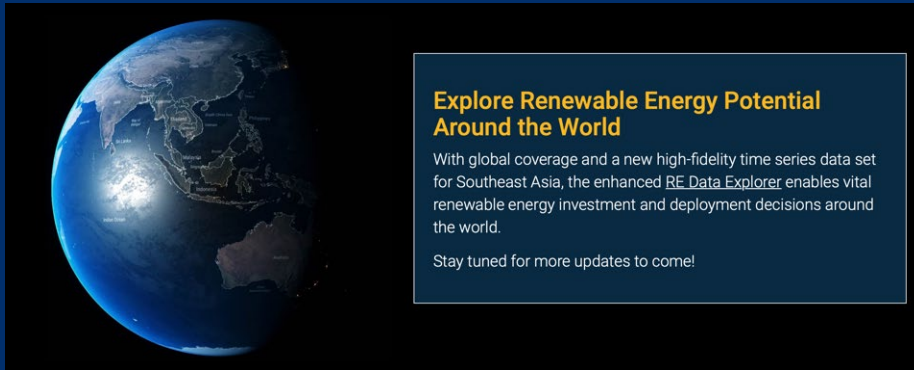
Disclaimer

- *Case study is for illustrative purposes only*
- No endorsement of specific technologies/brands or developing specific renewable resource locations
- After demonstrating initial resource prospecting in RE Data Explorer, we did not include practical due diligence about renewable energy siting
- We did not consult or get endorsements from local experts and authorities

Resource Visualization and Site Screening

Utility-Scale Wind and Solar Prospecting

- A user-friendly geospatial analysis tool for analyzing renewable energy potential and informing decisions.



www.re-explorer.org

- Performs visualization and analysis of renewable energy potential that can be customized for different scenarios.
- Repository for download of high-quality data and integration with other analytic tools.
- Supports prospecting, integrated planning, policymaking, and other decision-making activities to accelerate renewable energy deployment.

Technical Potential

INTRO ANALYSIS RESULTS

Analysis Output

Select your analysis output from the drop down below. The analysis output data layer can be viewed in the Layer Database in Active Layers.

Analysis Layers: SE Asia Tech Potential

Cumulative Results: All Regions

AC Generation:	
789,002,248 MWh/year	
Total Land Area:	
16,353 km ²	
Nameplate Capacity:	
588,694 MW	

Land Area by Technical Potential

<= 299.59 MWh/yr	68 km ²
299.59 - 325.87 MWh/yr	328 km ²
325.87 - 352.14 MWh/yr	1507 km ²
352.14 - 378.42 MWh/yr	3490 km ²
378.42 - 404.69 MWh/yr	5095 km ²
404.69 - 430.97 MWh/yr	4576 km ²
430.97 - 457.24 MWh/yr	1292 km ²

START NEW + DOWNLOAD DATA



Legend

Solar PV LCOE—Relaxed Scenario

Lightest Yellow	<= 70
Light Yellow	70 - 80
Yellow-Green	80 - 90
Light Green	90 - 100
Green	100 - 110
Medium Green	110 - 120
Dark Green	120 - 130
Very Dark Green	130 - 140
Dark Green	140 - 150
Very Dark Green	150 - 160
Dark Green	160 - 170
Very Dark Green	170 - 180
Dark Green	180 - 190
Very Dark Green	190 - 200
Dark Green	> 200

Opacity:

Supports Evaluation of RE Resources, Technical Potential and Cost of Energy across Southeast Asia

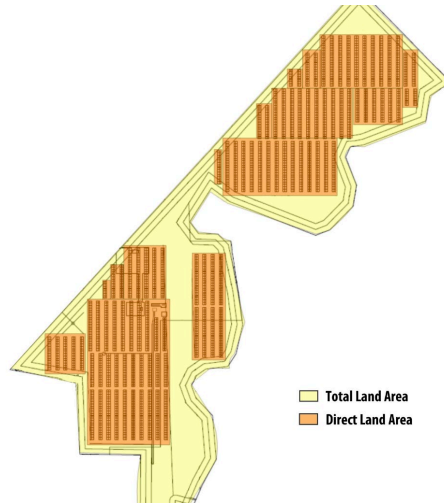
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RE Data Explorer: Technical Potential

Annual Technical Potential=

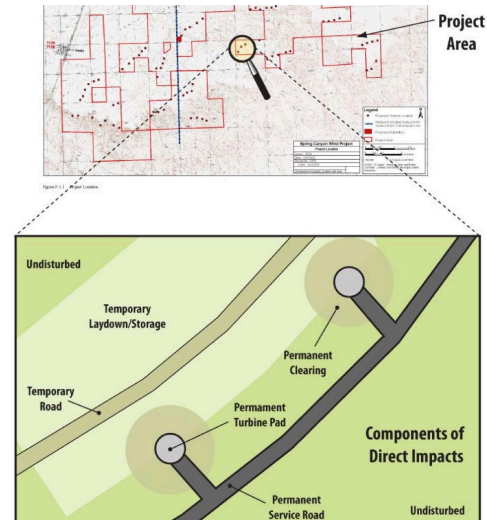
Available area (km²) * **Power Density (MW/km²)** * Mean Capacity Factor * 8760 hours

PV Plant



28-36 MW/km² Fixed-Tilt PV

Wind Plant



3-5 MW/km² Wind Plant

Levelized Cost of Energy (LCOE)

- LCOE is a standard metric used to compare different generation technologies.
- Captures the relationship between energy production and costs.
- Simple metric for representing the cost of energy that requires few inputs.

$$LCOE (\$/MWh) = \frac{(CapEx \times FCR) + OpEx}{AEP_{net}} \times 1000$$

- LCOE is typically in \$/kWh or \$/MWh
- Typical ranges for competitive technologies is \$0.02-0.1/kWh or \$20-100/MWh
- Capital Expenditures (CapEx) - The total cost to develop and build a plant, including system components, transportation, labor, balance of station.
- Operating Expenditures (OpEx) – Costs to operate and maintain the plant per year across the lifetime of the project.
- CapEx and OpEx typically in \$/W or \$/kW
- Fixed Charge Rate (FCR) represents the percentage of annual revenue required to finance the project (typically 6-12%).
- Net Annual Energy Production (AEP_{net})

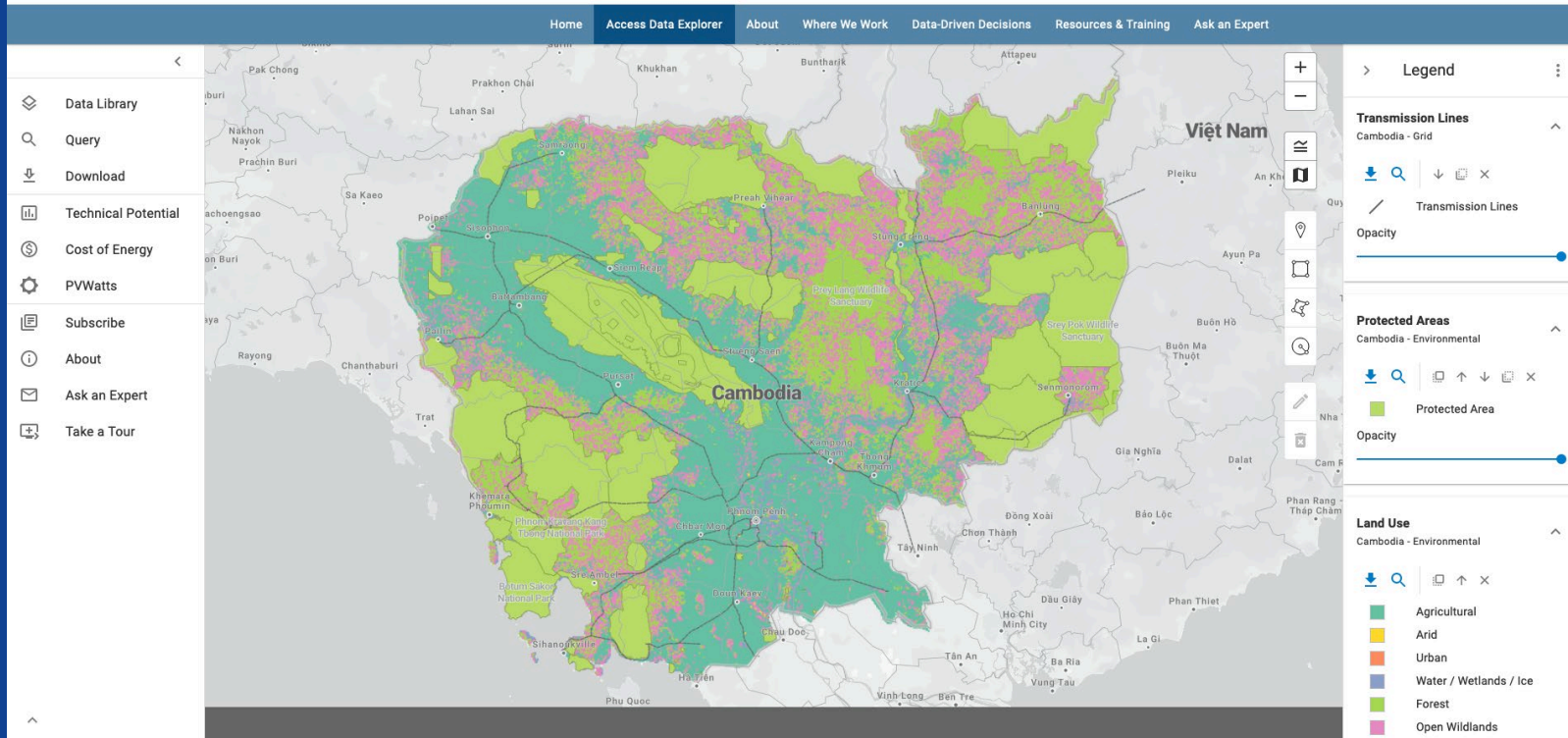
* Corriente Alterna (CA); Corriente Continua (CC)

Time-Series Data Selection for PCM

- PCM uses *time-coincident* modeling to accurately assess the weather impact on the power system
 - Demand, solar, wind (and hydro) data must be time-aligned
- Typical Meteorological Year (TMY) weather data is popular for calculating average or expected performance of a solar plant
 - “Typical” weather is assessed on a location-by-location basis
 - TMY weather is appropriate to use when considering a single RE plant in isolation
 - TMY data is not appropriate for system-level studies, because it is not guaranteed to be time-coincident across locations
- Recommendations for PCM time-series data:
 - Base studies on historical Actual Meteorological Year (AMY) weather
 - Could include consistently-applied climate change adjustments
 - If modeling forecasts, use a consistent input source (e.g., a [Numerical Weather Prediction model](#))
- Since PowNet uses 2016 demand data, we will use 2016 AMY solar and wind data from RE Data Explorer

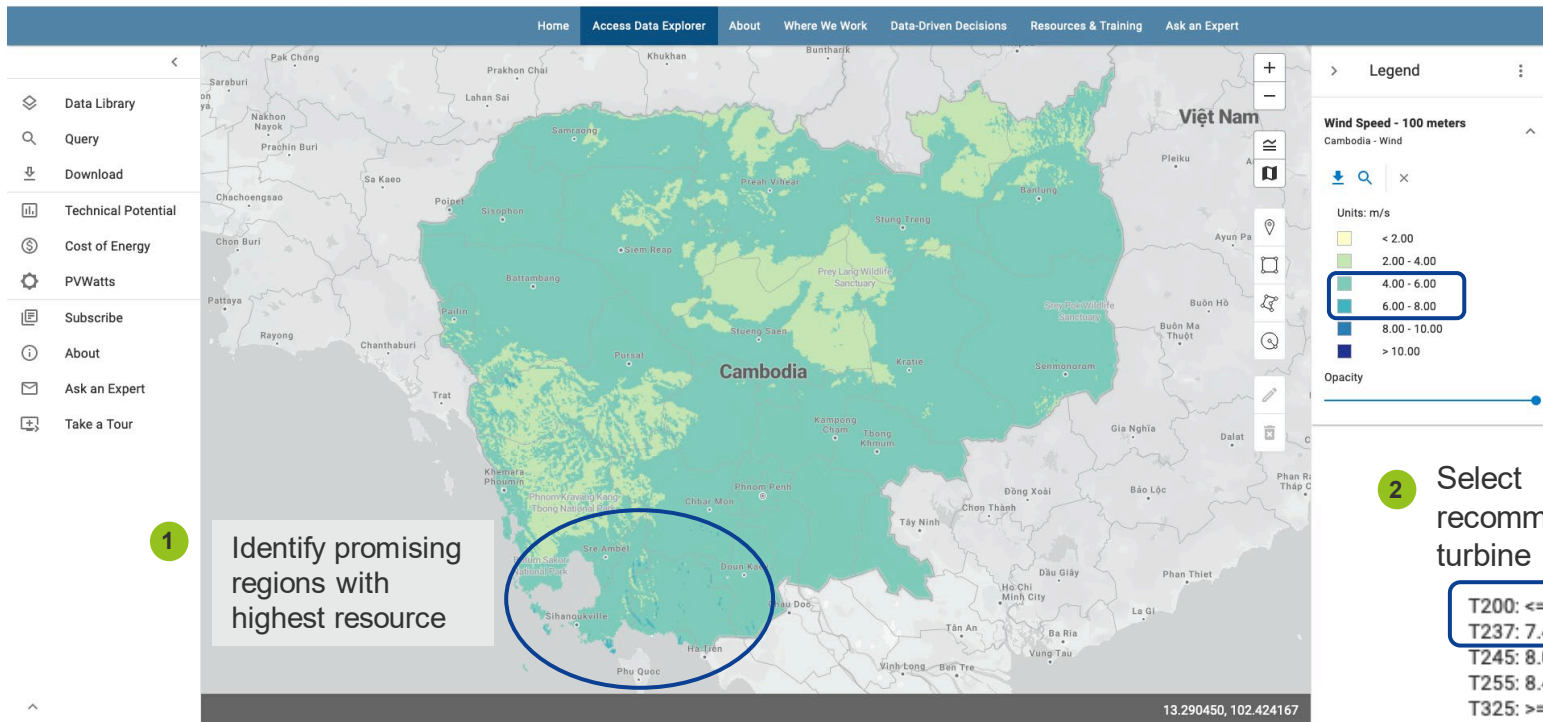
RE Data Explorer Demonstration

Land Use Review

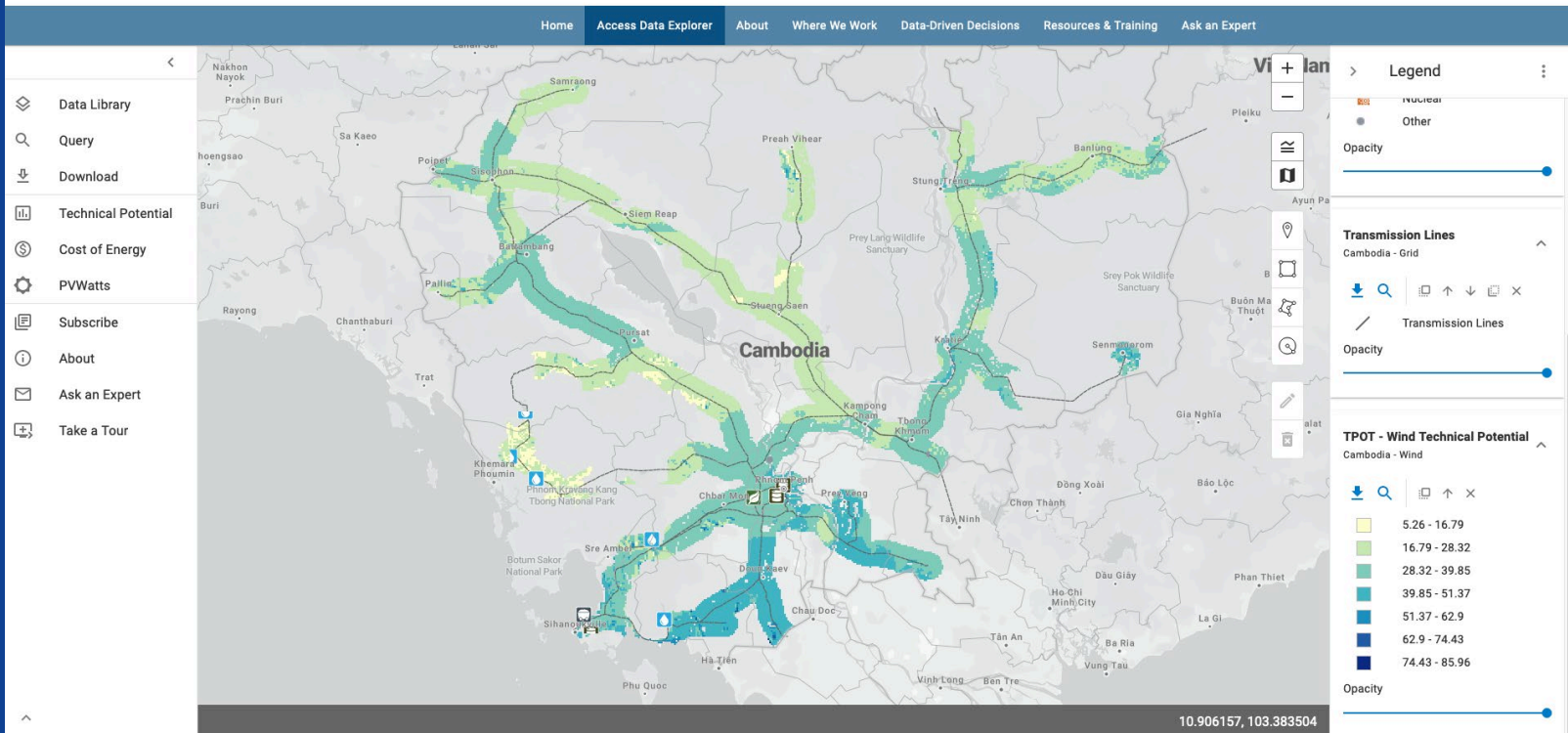


Land Use

Wind Resource Review

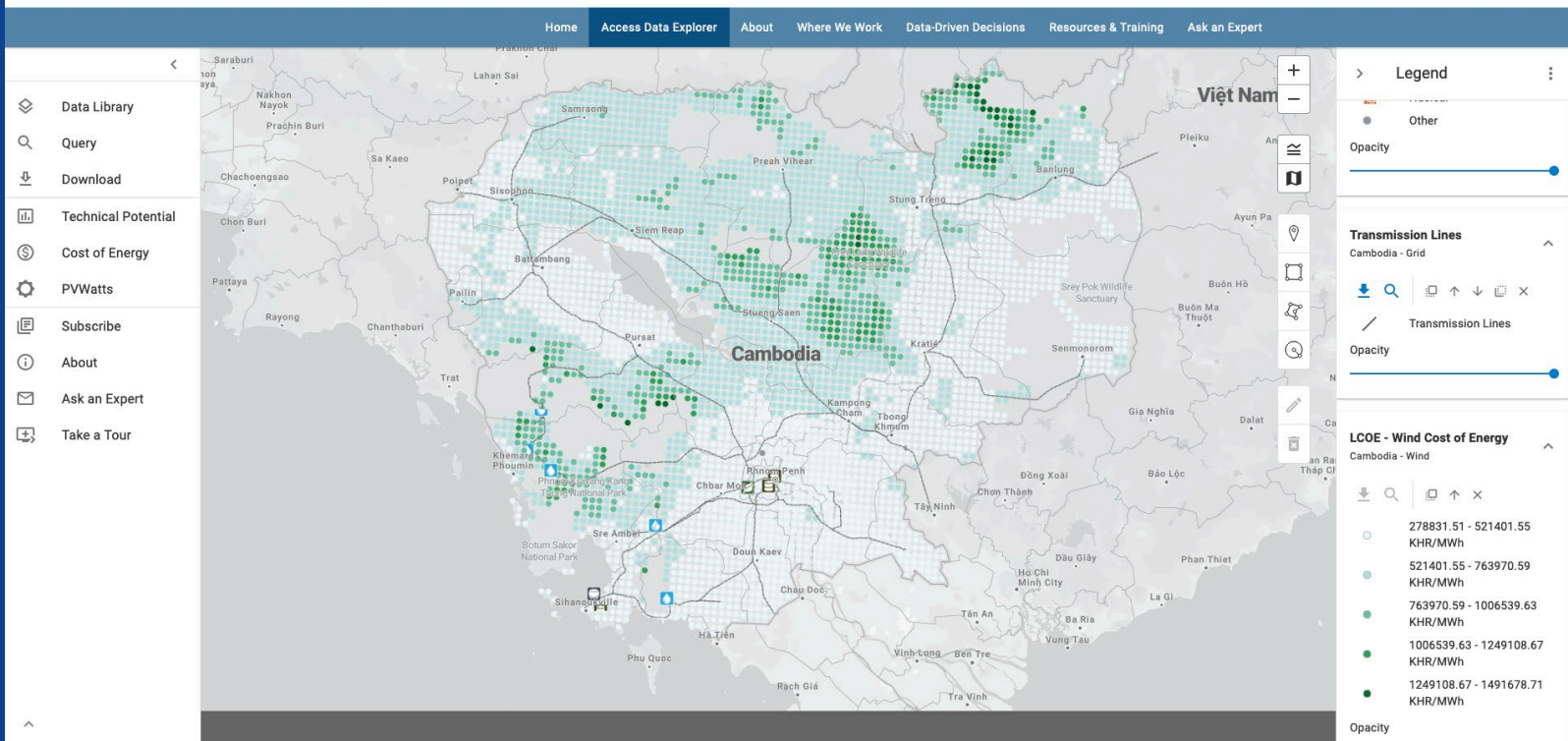


Wind Technical Potential Analysis



- Restricted to within 10 km of transmission lines
- Excluding urban areas and water/wetlands

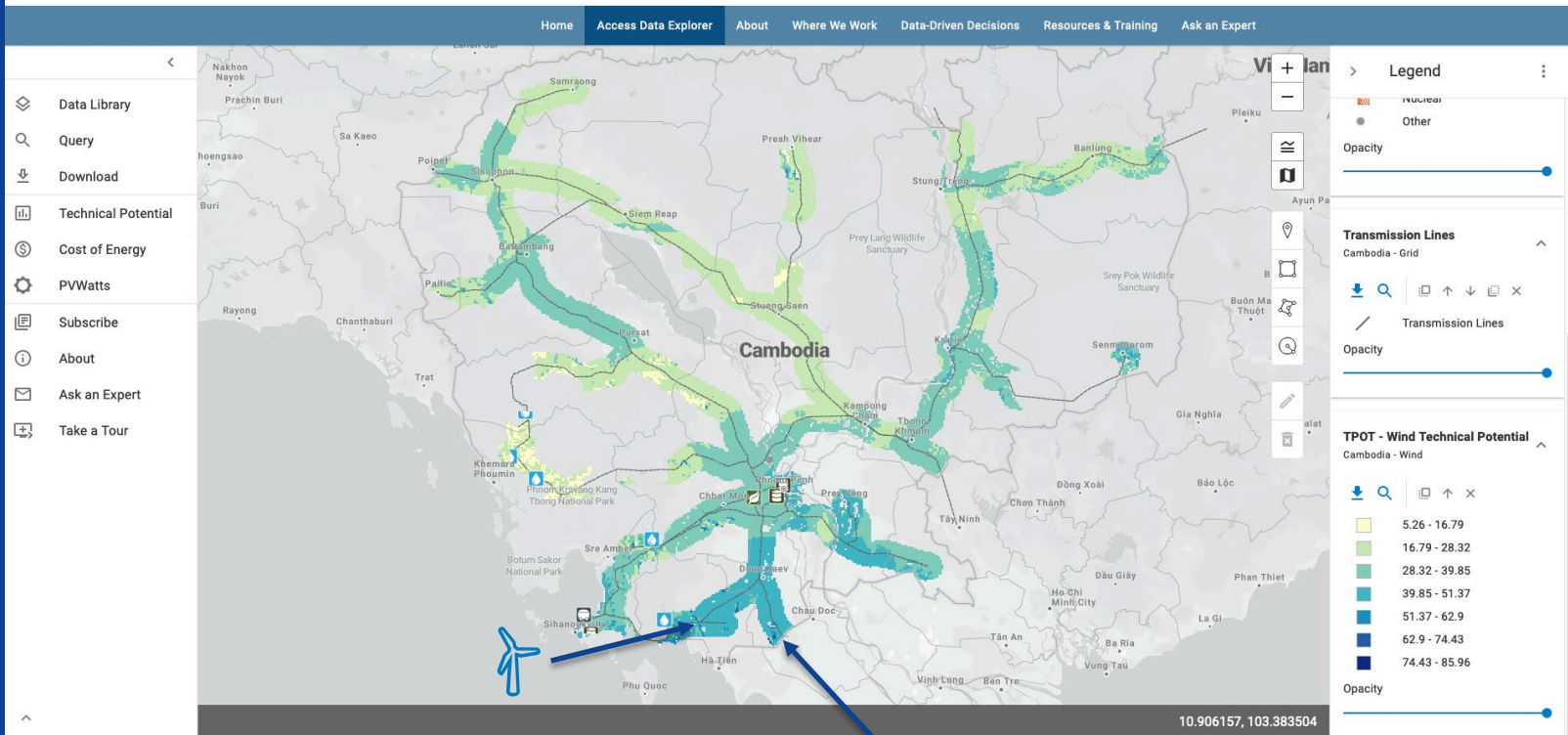
Wind Cost of Energy Analysis



- Relaxed Scenario
- Excluding urban areas and water/wetlands

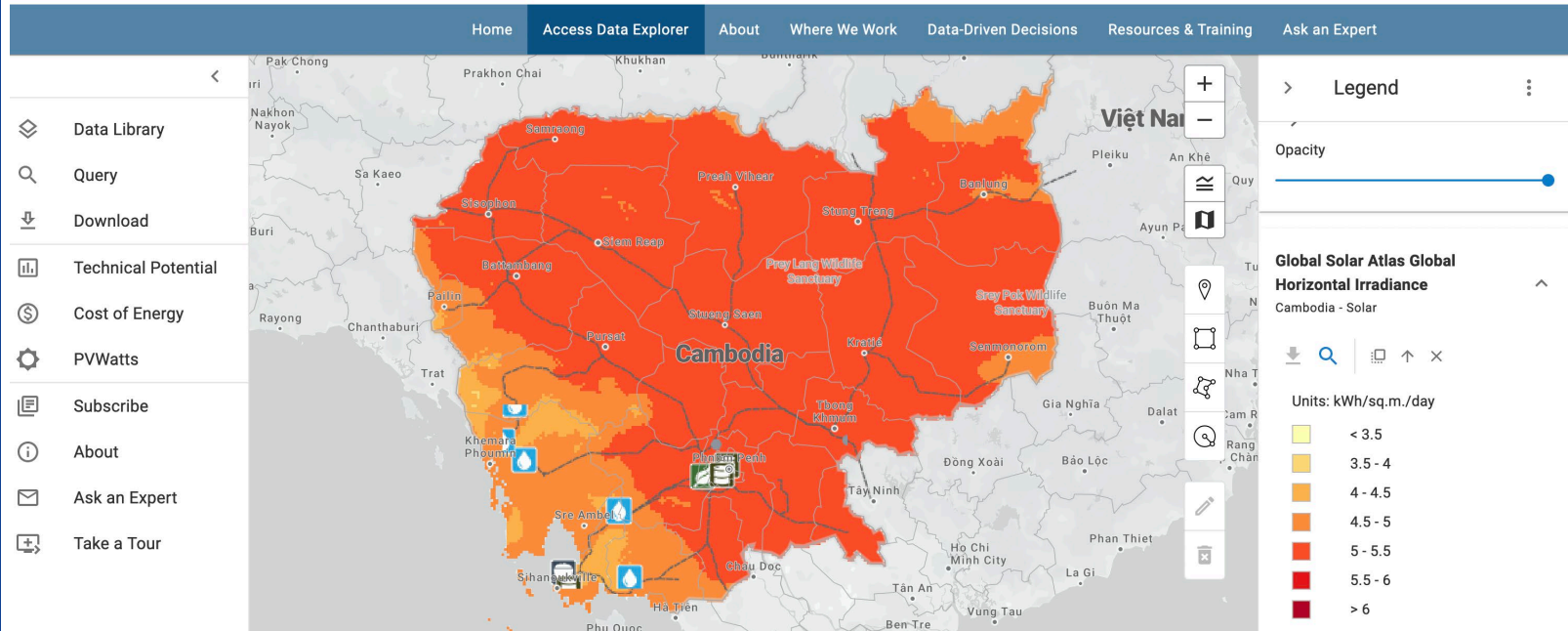
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Hypothetical Wind Plants



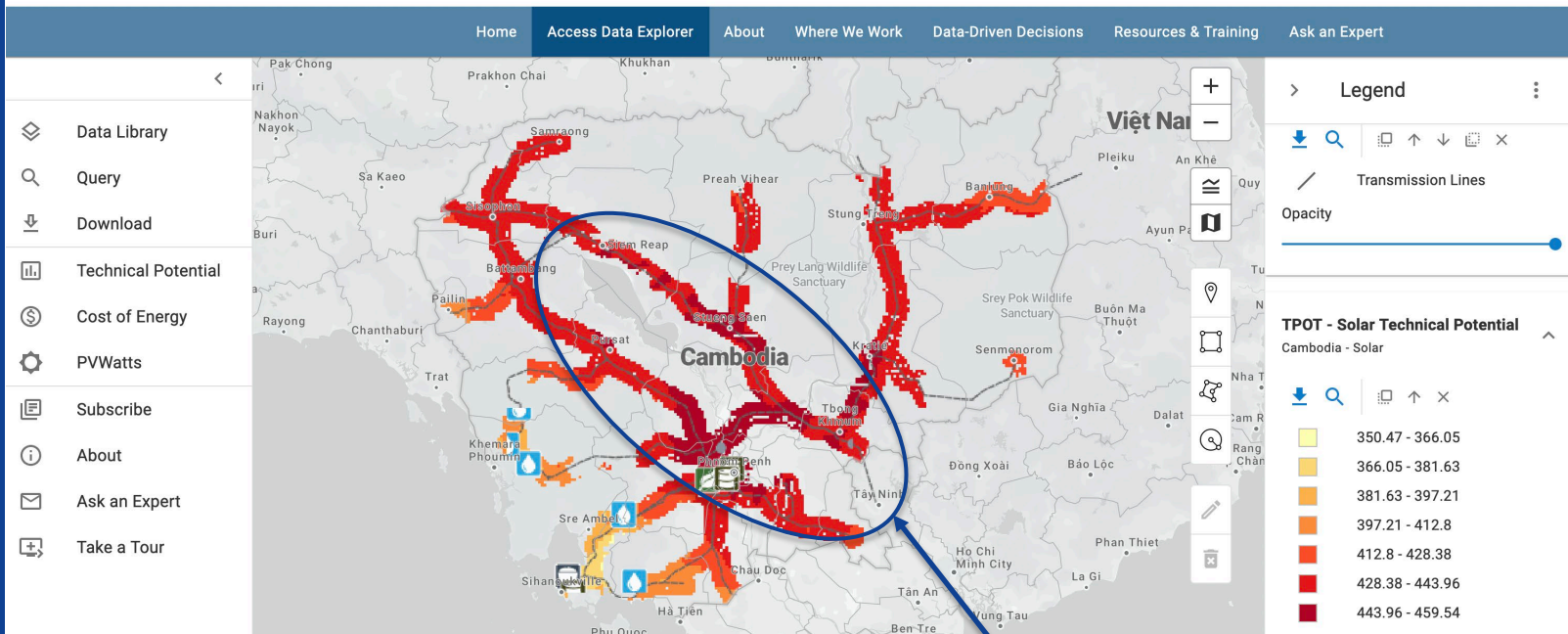
- For demonstration purposes: Select two high-technical-potential and low-LCOE locations near existing transmission nodes

Solar Resource Review



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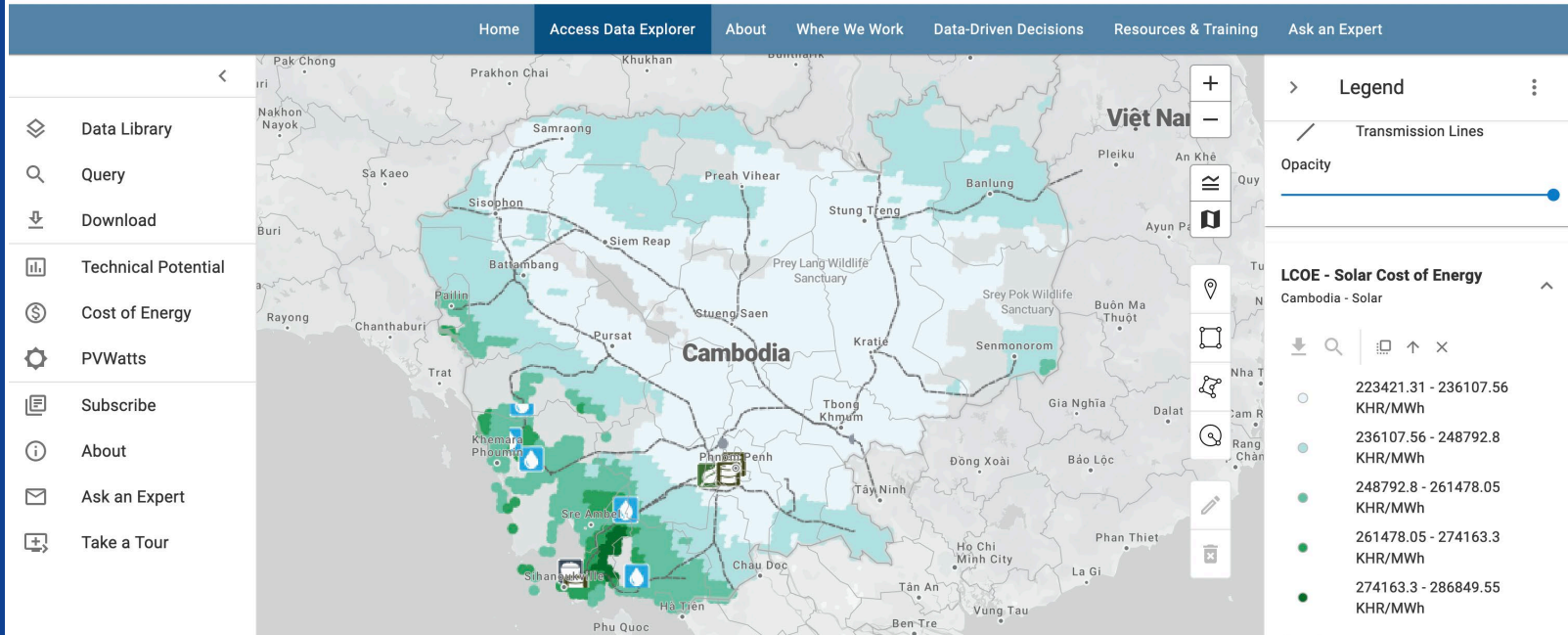
Solar Technical Potential Analysis



- Fixed tilt systems
- Excluding urban areas and water/wetlands
- Restricted to within 10 km of transmission lines

Promising areas to investigate further

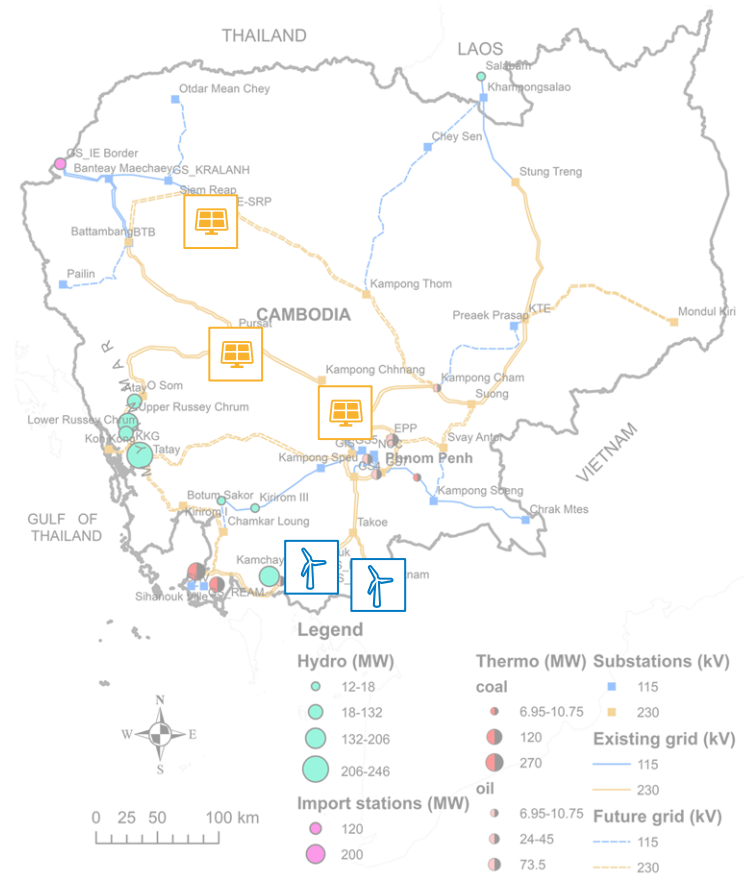
Solar Levelized Cost of Energy Analysis



- Relaxed Scenario
- Excluding urban areas and water/wetlands

New Renewable Energy Plants

- Repeat same prospecting process with Himawari solar data
- Select 2 wind locations and 3 solar locations for hypothetical plants
- Add to existing buses in the PowNet transmission model



Modified from
Chowdhury et al. 2020

Download High Resolution Weather Data

- For this example, we download hourly 2016 weather datasets for consistency with PowNet's 2016 demand:
 - Southeast Asia Wind Data
 - Asia/Pacific Himawari Solar Data

The screenshot shows the 'Data Downloader' interface with the 'INTRO' tab selected. The left sidebar contains navigation options: Data Library, Query, Download, Technical Potential, Cost of Energy, PVWatts, Subscribe, About, Ask an Expert, and Take a Tour. The main content area explains that the tool provides the ability to download large datasets based on custom spatial locations and/or parameters, and that a valid email address is required to receive a link. A 'Download Type' dropdown is set to 'Large-Scale Data'. An 'Enter Email Address' field contains 'user.name@nrel.gov'. A 'GET STARTED' button is at the bottom.

The screenshot shows the 'Data Downloader' interface with the 'DATA & LOCATION' tab selected. The 'Data and Location' section is active, showing 'Asia/Pacific Himawari Solar Data (1)' in the location dropdown. Below, there are tools for selecting an area of interest on a map. A 'Location (Select a type of query method)' section is visible. At the bottom, it says 'Asia/Pacific Himawari Solar Data Sites Found: 1'. 'BACK' and 'NEXT' buttons are at the bottom.

The screenshot shows the 'Data Downloader' interface with the 'ATTRIBUTES' tab selected. The 'Data Attributes' section is active, showing a list of attributes to be selected for download. A green circle highlights the 'SELECT ALL' button. The 'Select Attributes' section includes checkboxes for various weather parameters like Cloud Type, Solar Zenith Angle, Dew Point, GHI, Pressure, etc. At the bottom, there is a 'Select Year' dropdown set to '2016'. 'SELECT ALL' and 'Deselect All' buttons are visible.

SAM uses some but not all available time-series inputs; "Select All" makes it easy

The screenshot shows the 'Formatting Options' dialog box. It has a 'Select Interval' dropdown set to '60 minutes'. Under 'Formatting Options', there are checkboxes for 'Include Leap Day' (unchecked) and 'Convert UTC to Local Time' (checked). A progress bar shows 'Percent to download in' at 1.58%. 'BACK' and 'DOWNLOAD' buttons are at the bottom.

Always ensure time-zone and time-stamp consistency among time-series data sets

PCM Demonstration in Sienna\Ops

Part 2: Results after VRE Integration

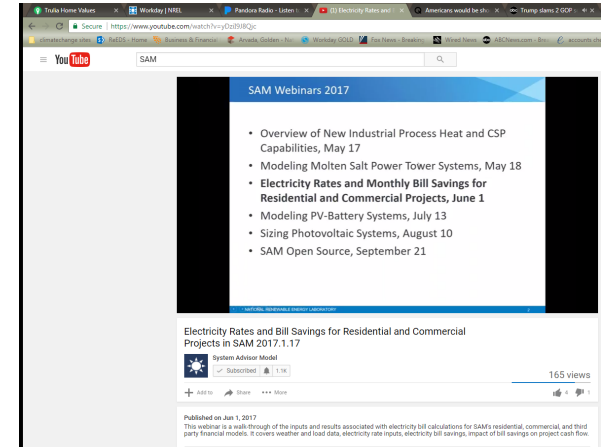
Synthesis and Wrap-Up

Key Takeaways

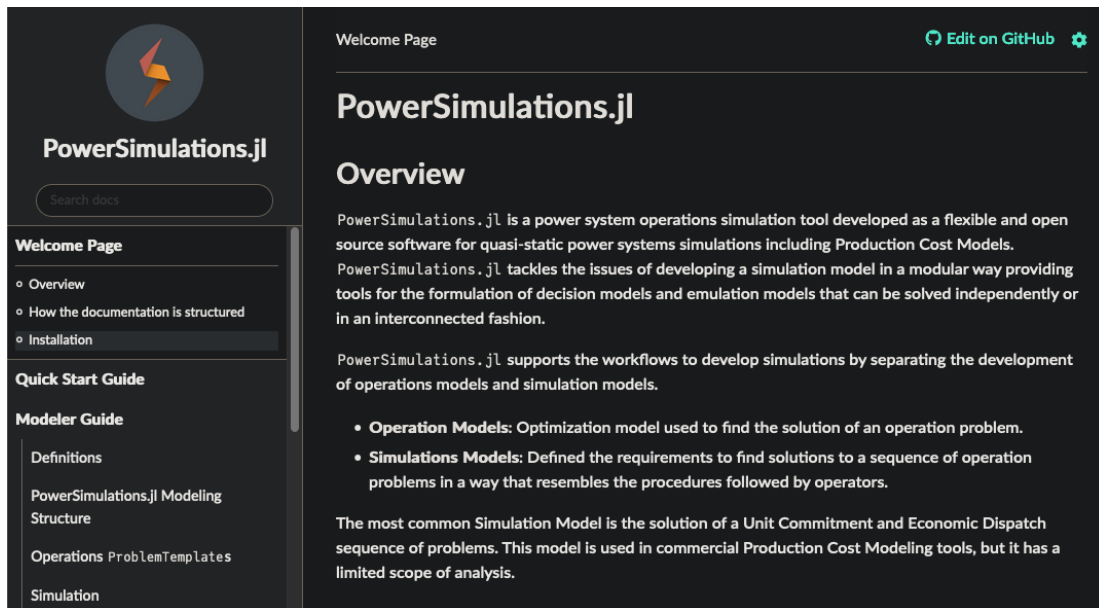
- RE Data Explorer's new Southeast Asia wind dataset provides high-resolution, open-source data for site prefeasibility and feasibility studies. High-resolution solar data is also available for this region and others.
- Open-source data and tools enable system operators and developers to conduct planning and feasibility studies
- PCM can be used to understand how operational impacts of a power plant and power system on each other
- Understanding and increasing operational *flexibility* is key to grid integration of VRE


SAM Resources

- Website – <http://sam.nrel.gov>
 - [Support Forum](#) – Ask your question!
 - General info/ online help file / contact info
- YouTube Channel
 - <https://www.youtube.com/user/SAMDemoVideos>
 - All prior webinars and seminars
- Bi-Monthly Round Table sessions
 - SAM team asks questions live and interactively
- Email Support
 - SAM support can provide email support if question/bug is involved



Sienna Resources



Welcome Page [Edit on GitHub](#) 

PowerSimulations.jl

Search docs

- Welcome Page
 - Overview
 - How the documentation is structured
 - Installation
- Quick Start Guide
- Modeler Guide
 - Definitions
 - PowerSimulations.jl Modeling Structure
 - Operations ProblemTemplates
 - Simulation

Overview

PowerSimulations.jl is a power system operations simulation tool developed as a flexible and open source software for quasi-static power systems simulations including Production Cost Models. PowerSimulations.jl tackles the issues of developing a simulation model in a modular way providing tools for the formulation of decision models and emulation models that can be solved independently or in an interconnected fashion.

PowerSimulations.jl supports the workflows to develop simulations by separating the development of operations models and simulation models.

- Operation Models:** Optimization model used to find the solution of an operation problem.
- Simulations Models:** Defined the requirements to find solutions to a sequence of operation problems in a way that resembles the procedures followed by operators.

The most common Simulation Model is the solution of a Unit Commitment and Economic Dispatch sequence of problems. This model is used in commercial Production Cost Modeling tools, but it has a limited scope of analysis.

Package documentation includes Quick Start Guides and Tutorials:

- [PowerSystems.jl](#)
- [PowerSimulations.jl](#)
- [PowerSimulationsDynamics.jl](#)
- [PowerGraphics.jl](#)

NREL Team: sienna@nrel.gov

Slack: <https://nrel-sienna.slack.com>

Q&A

Thank you for joining us!

For more information on the **USAID-NREL Partnership**, visit nrel.gov/usaid-partnership or reach out to USAID.NREL@nrel.gov

For more information on the **Global Power System Transformation Consortium (G-PST)**, visit globalpst.org or reach out to globalpst@nrel.gov

References

Chowdhury, A. F. M. Kamal, Jordan Kern, Thanh Duc Dang, and Stefano Galelli. 2020. “PowNet: A Network-constrained Unit Commitment/economic Dispatch Model for Large-scale Power Systems Analysis”. *Journal of Open Research Software* 8 (1): 5. DOI: <https://doi.org/10.5334/jors.302>

PowNet v1.3. 2021. “PowNet: Network-constrained Unit Commitment / Economic Dispatch model in Python.” <https://github.com/kamal0013/PowNet>