GLOBAL PST CONSORTIUM

USAID FROM THE AMERICAN PEOPLE

NREL Transforming ENERGY

REexplorer MAPPING OUR ENERGY FUTURE

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:

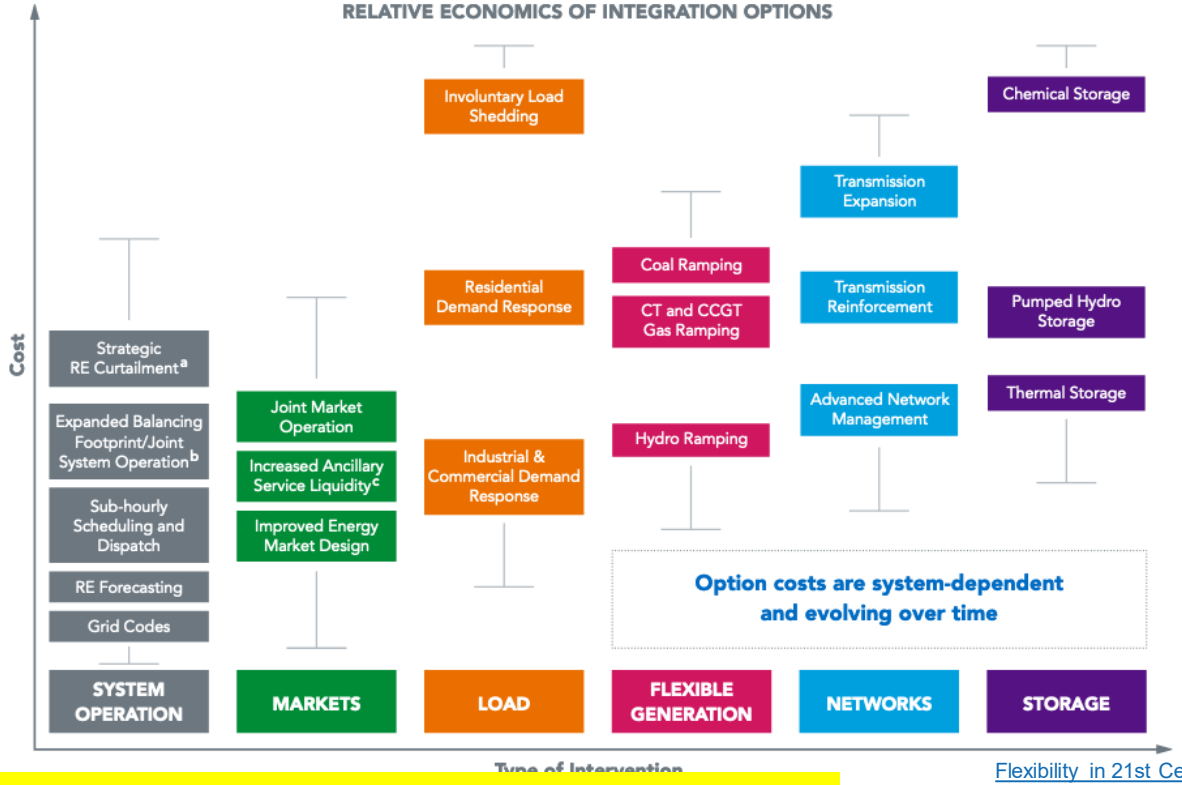
- This webinar is **being recorded** and will be shared with attendees.
- You will be **automatically muted** upon joining and throughout the webinar.
- Please use the **Q&A function** to ask questions to be addressed during the Q&A portions. You can find this function in your toolbar.
- Please use the **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/

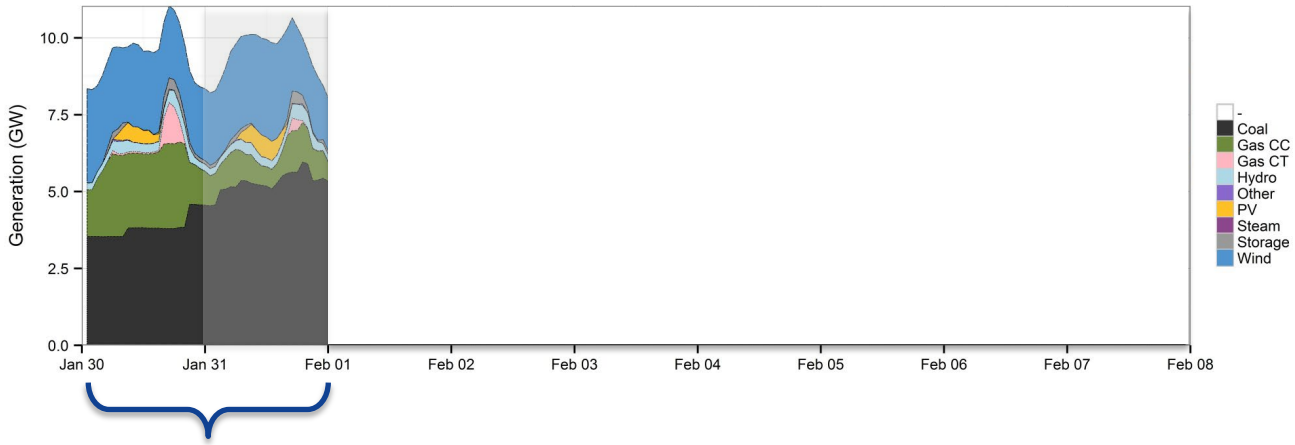
Agenda – Day 2

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

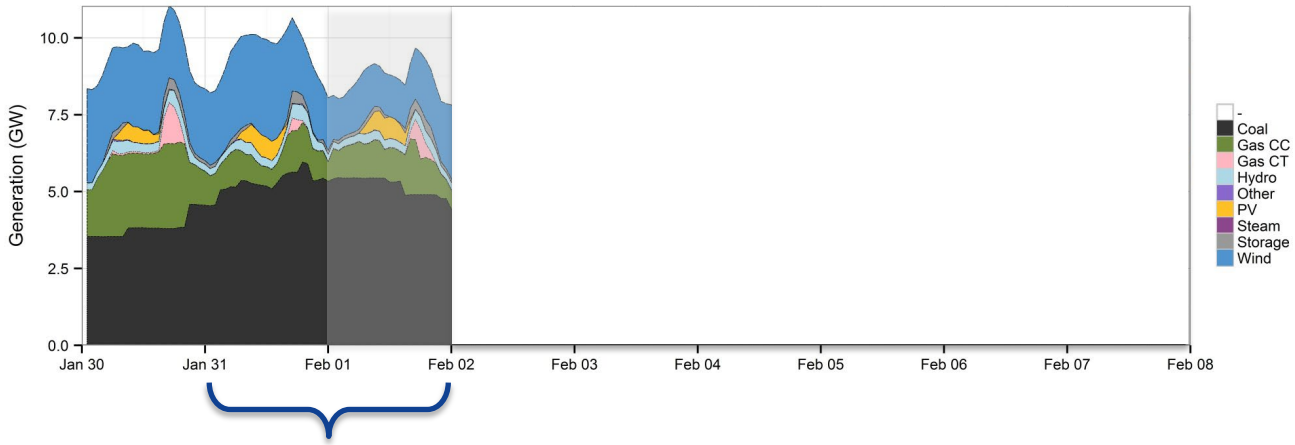


Unit commitment and economic dispatch



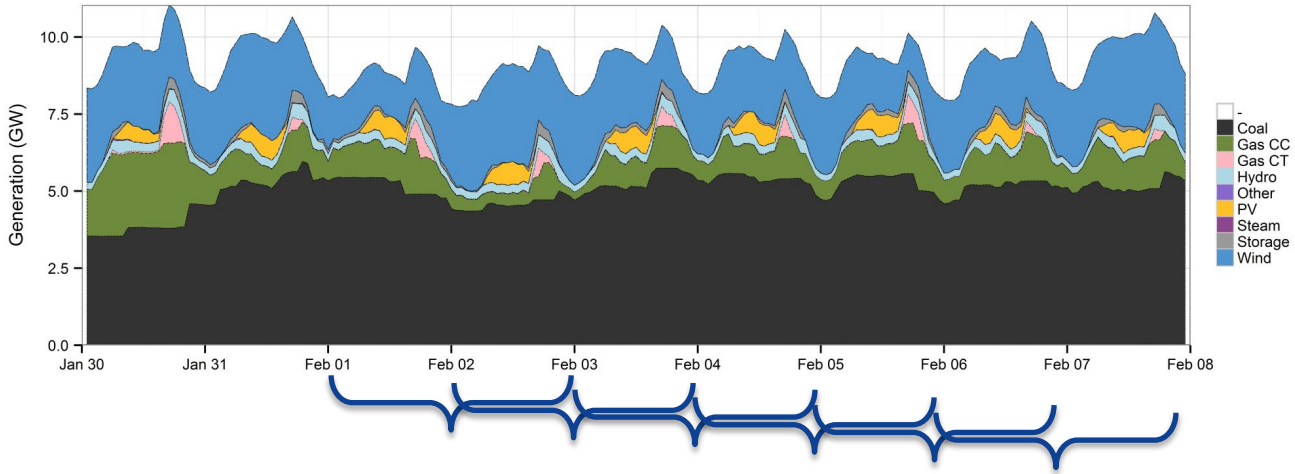
optimization horizon:
48 hours

Unit commitment and economic dispatch



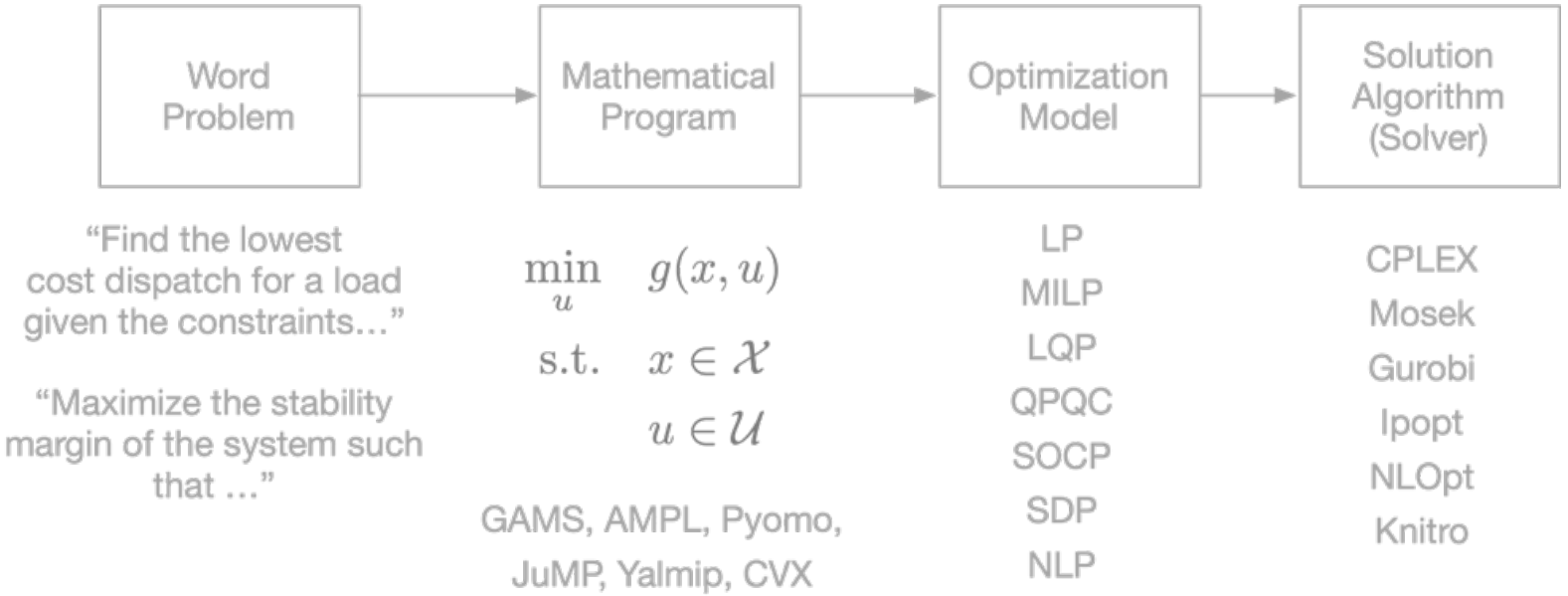
rolling forward in
24 hour increments

Unit commitment and economic dispatch

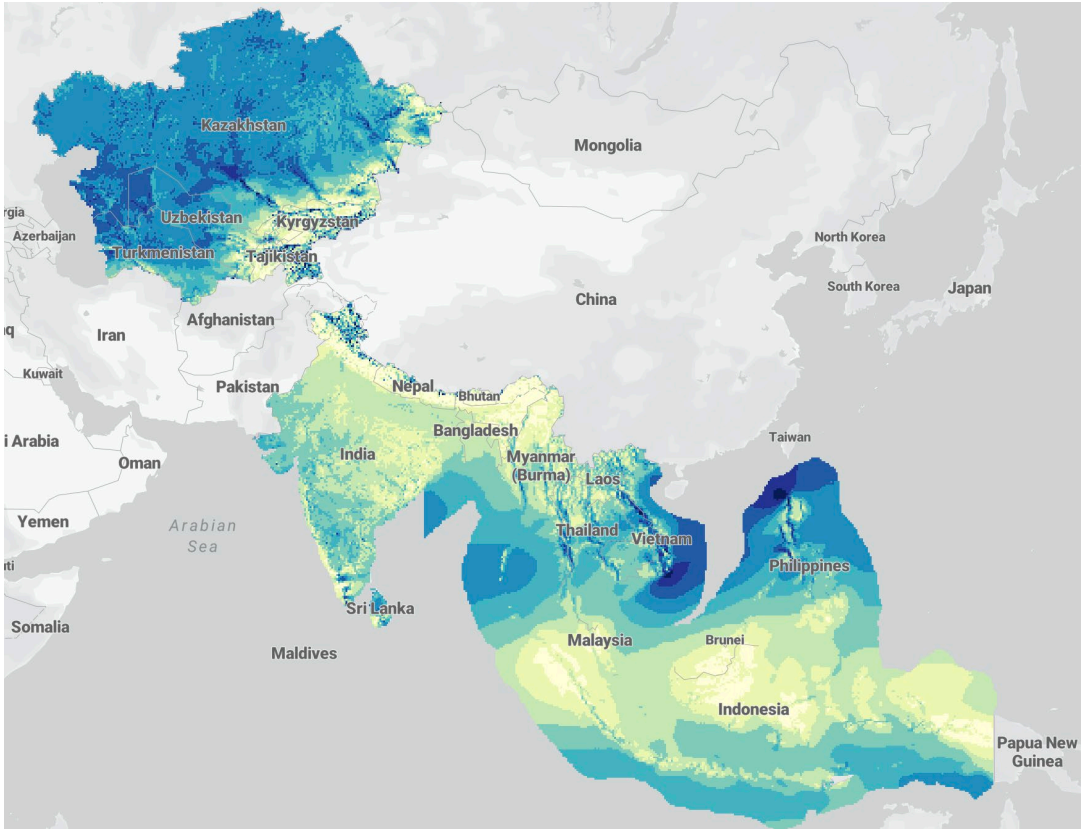


- **Intertemporal Unit-Commitment & Economic Dispatch (UC/ED)**
  Mixed Integer Programming problem (MIP)
- **Sequential UC/ED Steps**

Structure of an Optimization Problem



NREL Wind Resource Data



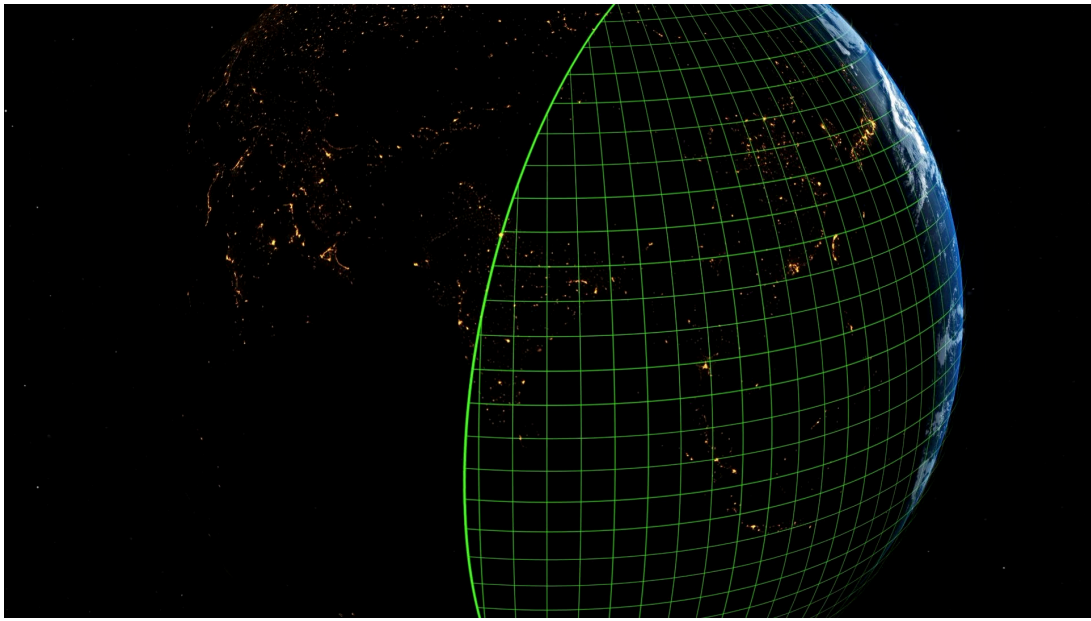
NREL Wind Data - Asia

- 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

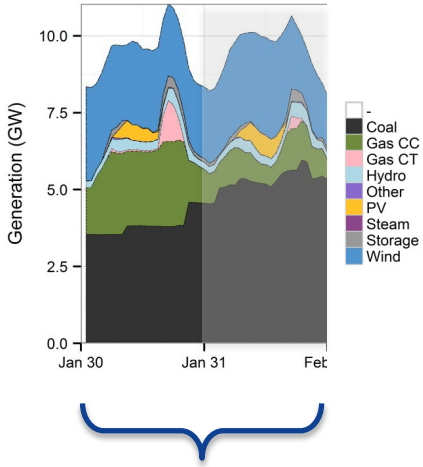
Released in February 2021:

- 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

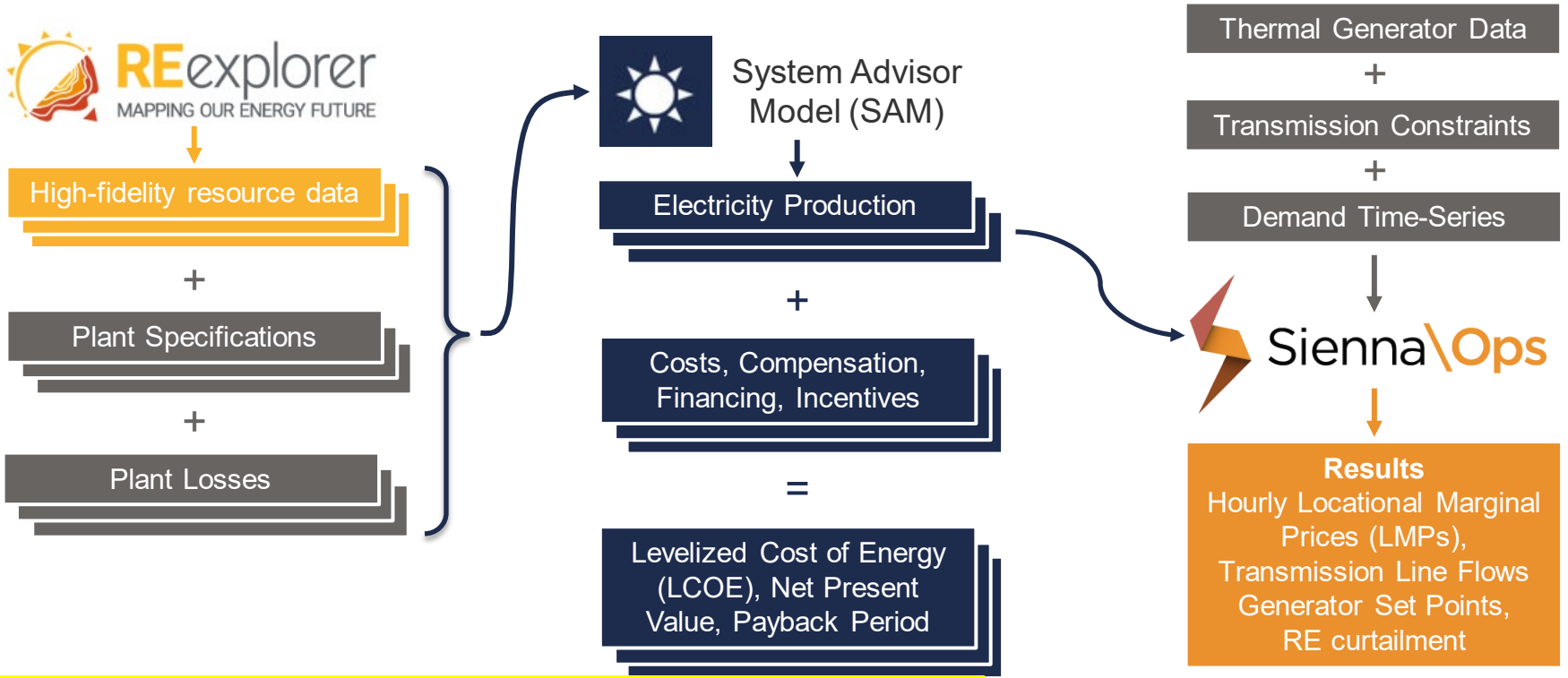
- Power system *flexibility* is key for integrating VRE
- Time-series production cost modeling can quantify the benefits of many sources of operational flexibility
- For system operators, PCM is key to operations and planning:
  - Minimize operating & reserve costs on a daily, hourly, subhourly basis
  - 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

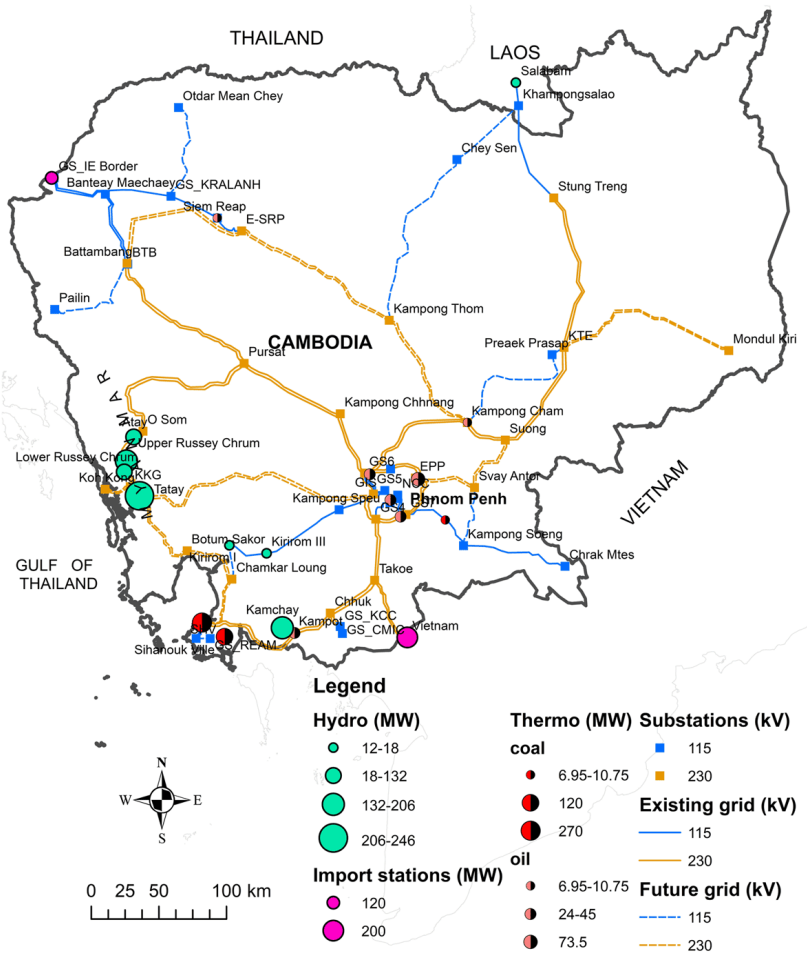
Overview of PCM Workflow



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

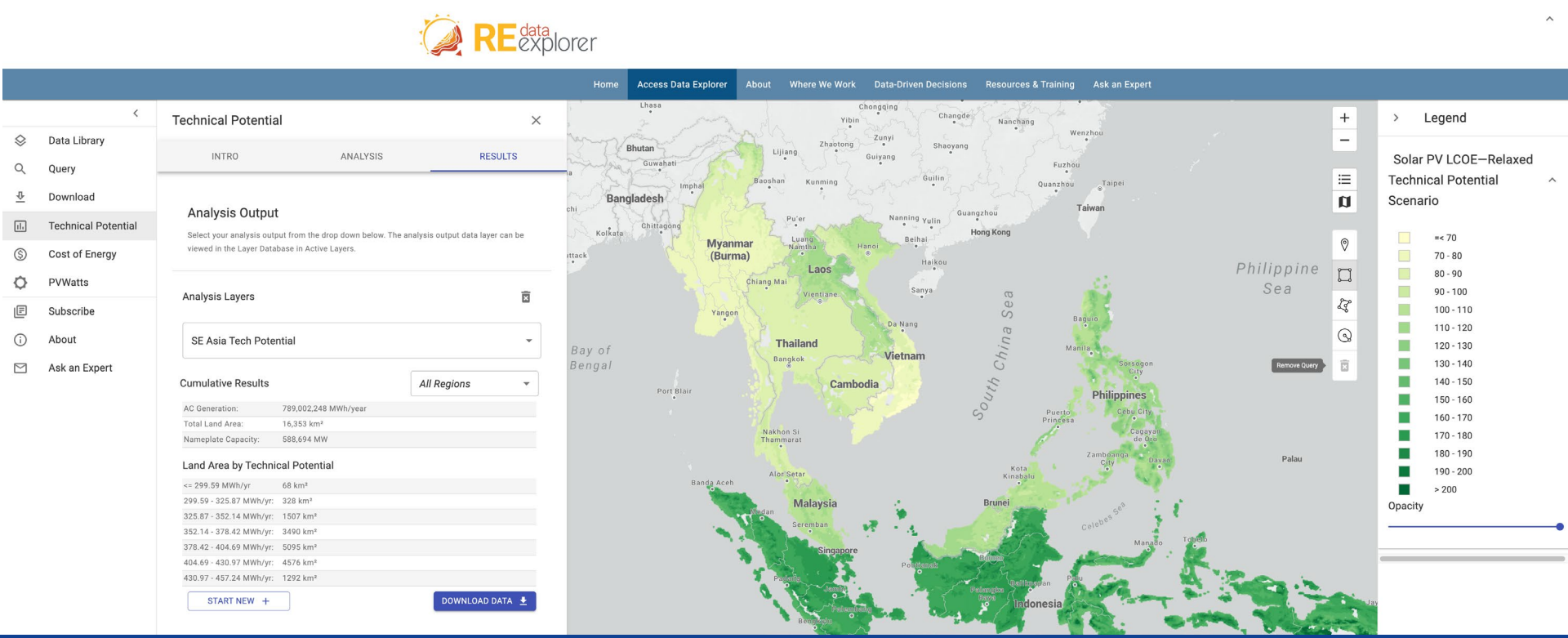
Renewable Energy (RE) Data Explorer

REexplorer
MAPPING OUR ENERGY FUTURE

- 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.



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

RE Data Explorer: Technical Potential

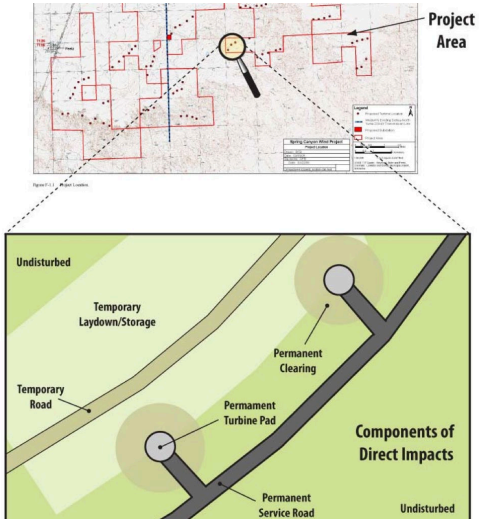
Annual Technical Potential=

Available area (km^2) * **Power Density (MW/km^2)** * Mean Capacity Factor * 8760 hours

PV Plant

28-36 MW/km^2 Fixed-Tilt PV

Wind Plant



3-5 MW/km^2 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})

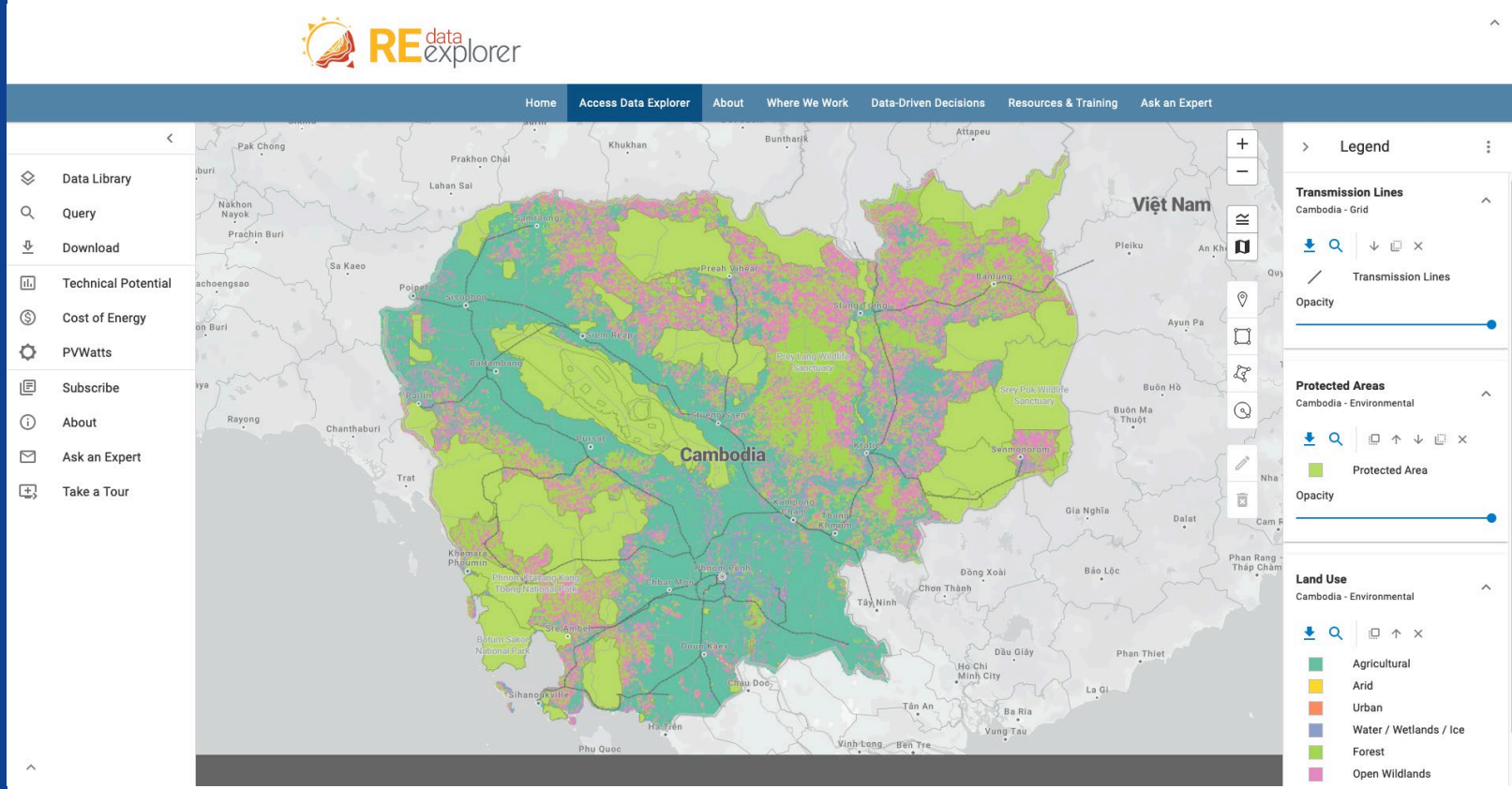
* Corriente Alterna (CA); Corriente Continua (CC)

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

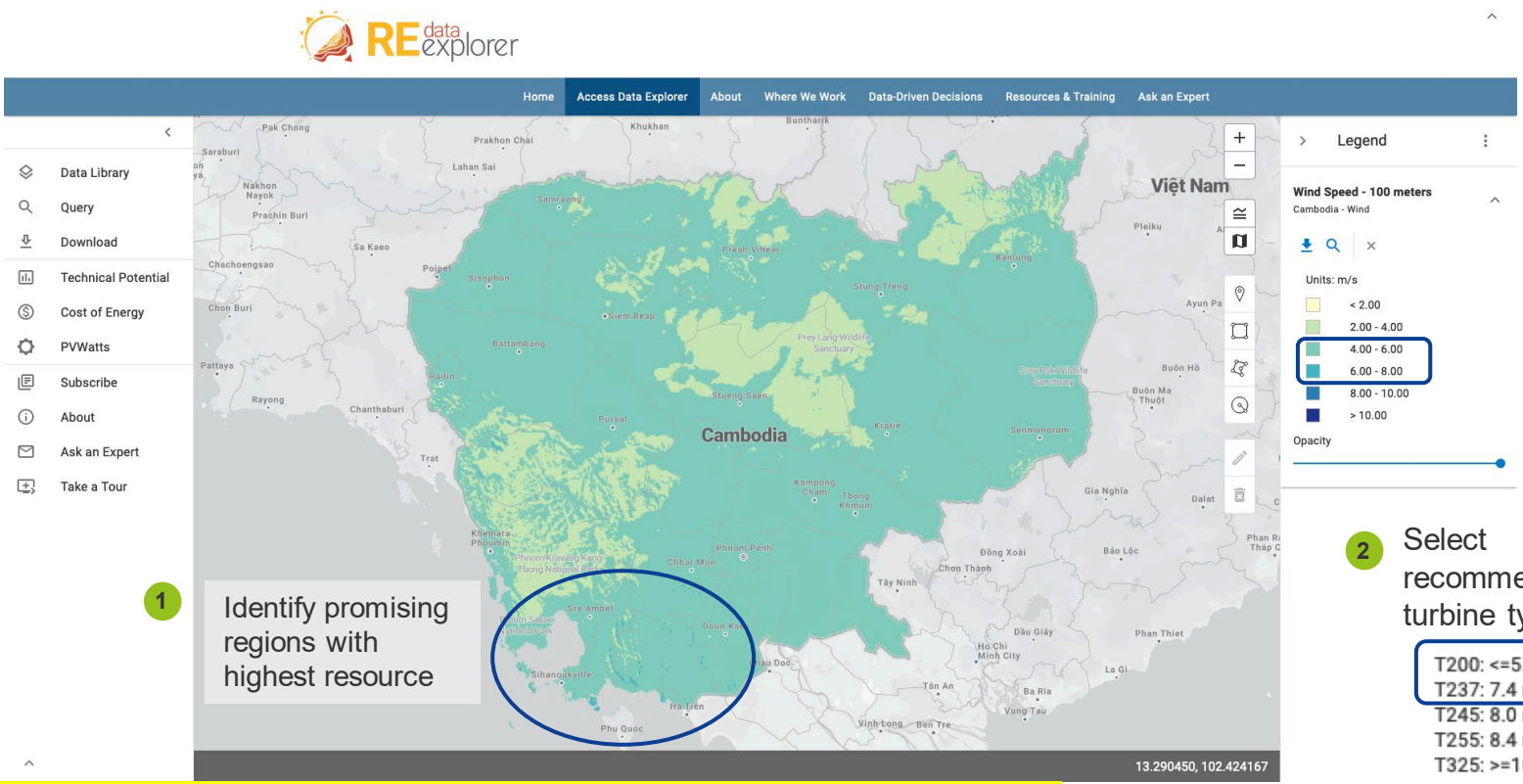
RE Data Explorer Demonstration

Land Use Review



Land Use

Wind Resource Review

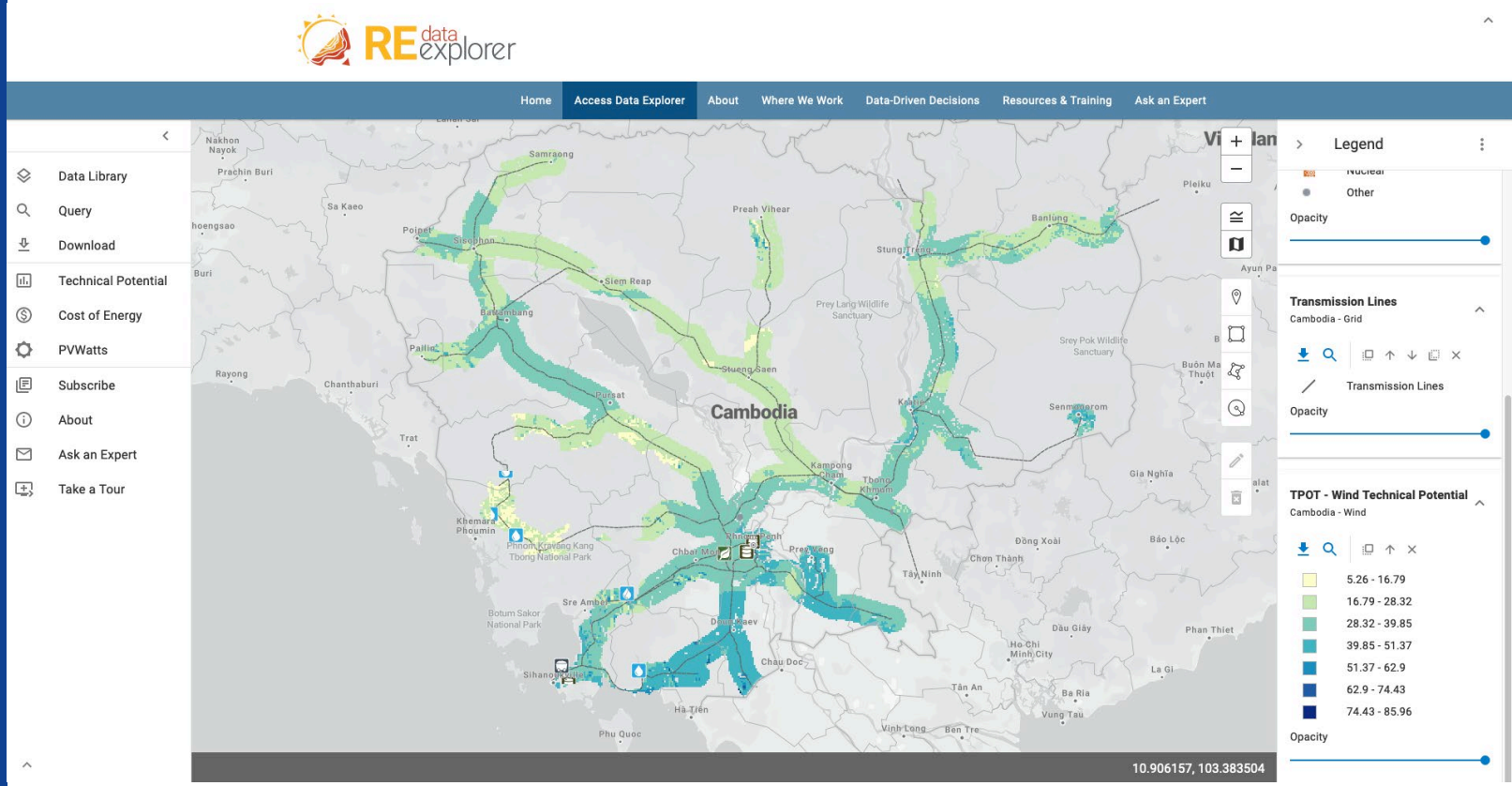


1 Identify promising regions with highest resource

2 Select recommended turbine types:

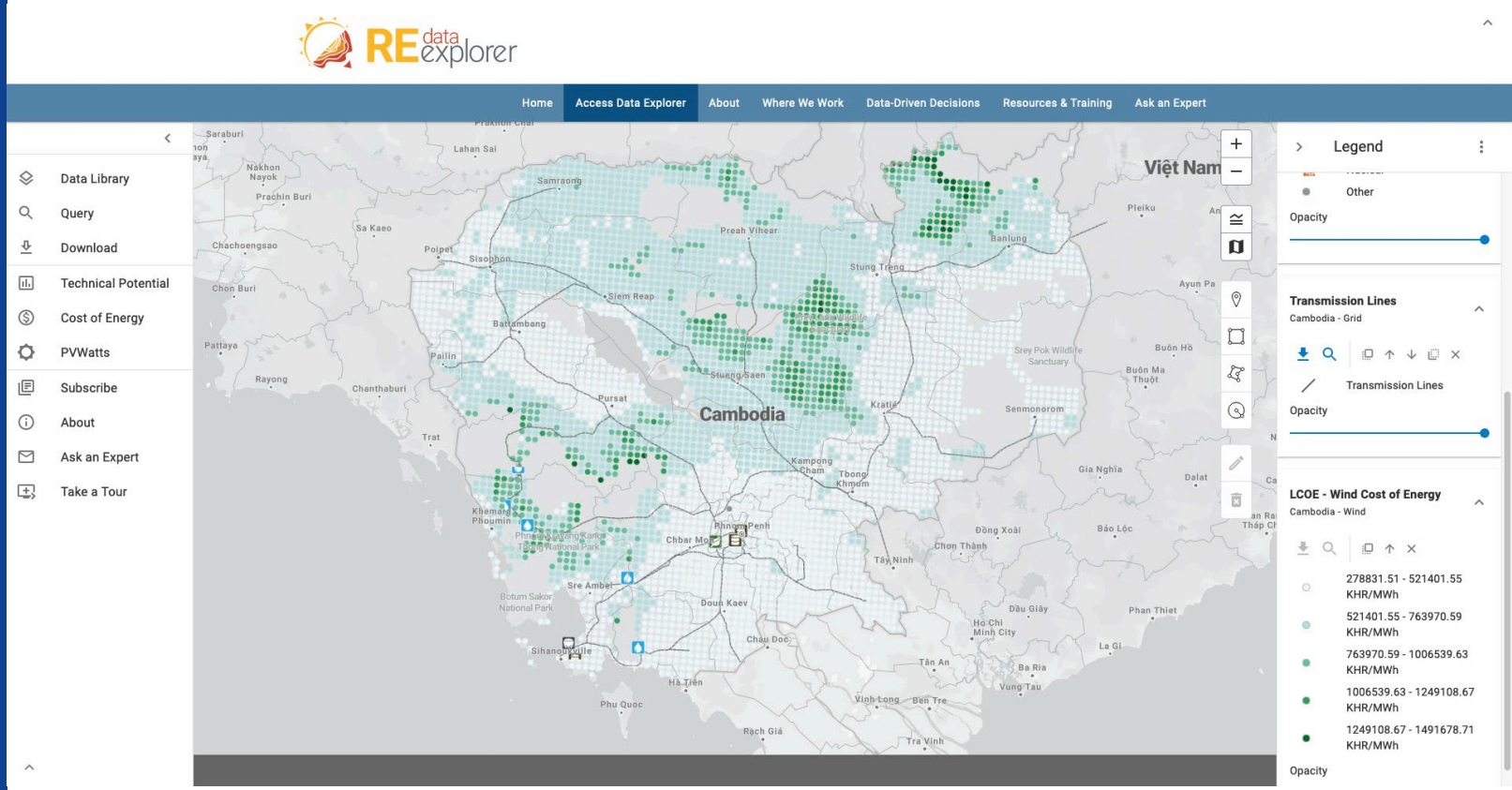
T200: <=5.5 m/s
T237: 7.4 m/s
T245: 8.0 m/s
T255: 8.4 m/s
T325: >=10.0 m/s

Wind Technical Potential Analysis



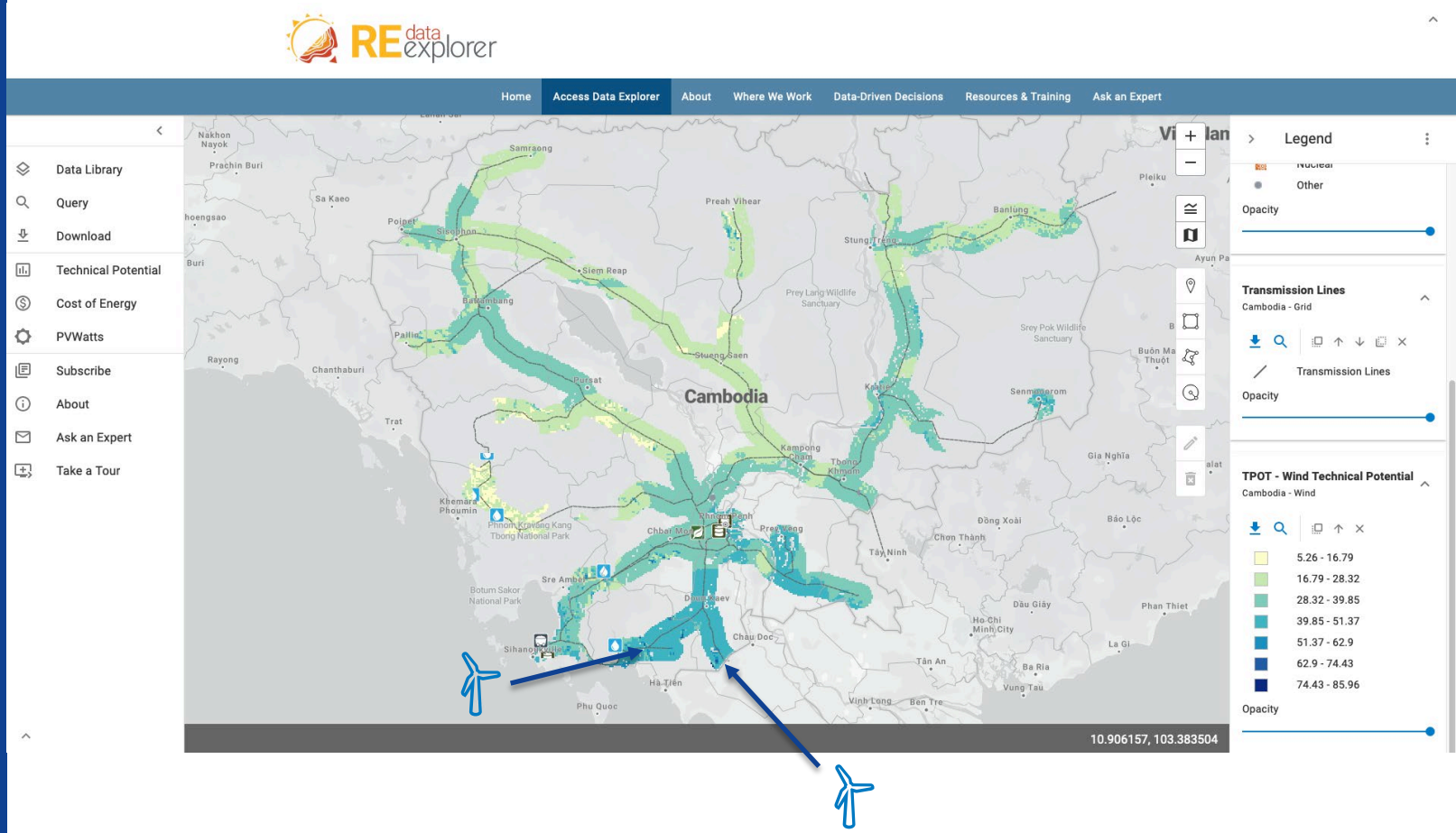
- Restricted to within 10 km of transmission lines
- Excluding urban areas and water/wetlands

Wind Cost of Energy Analysis



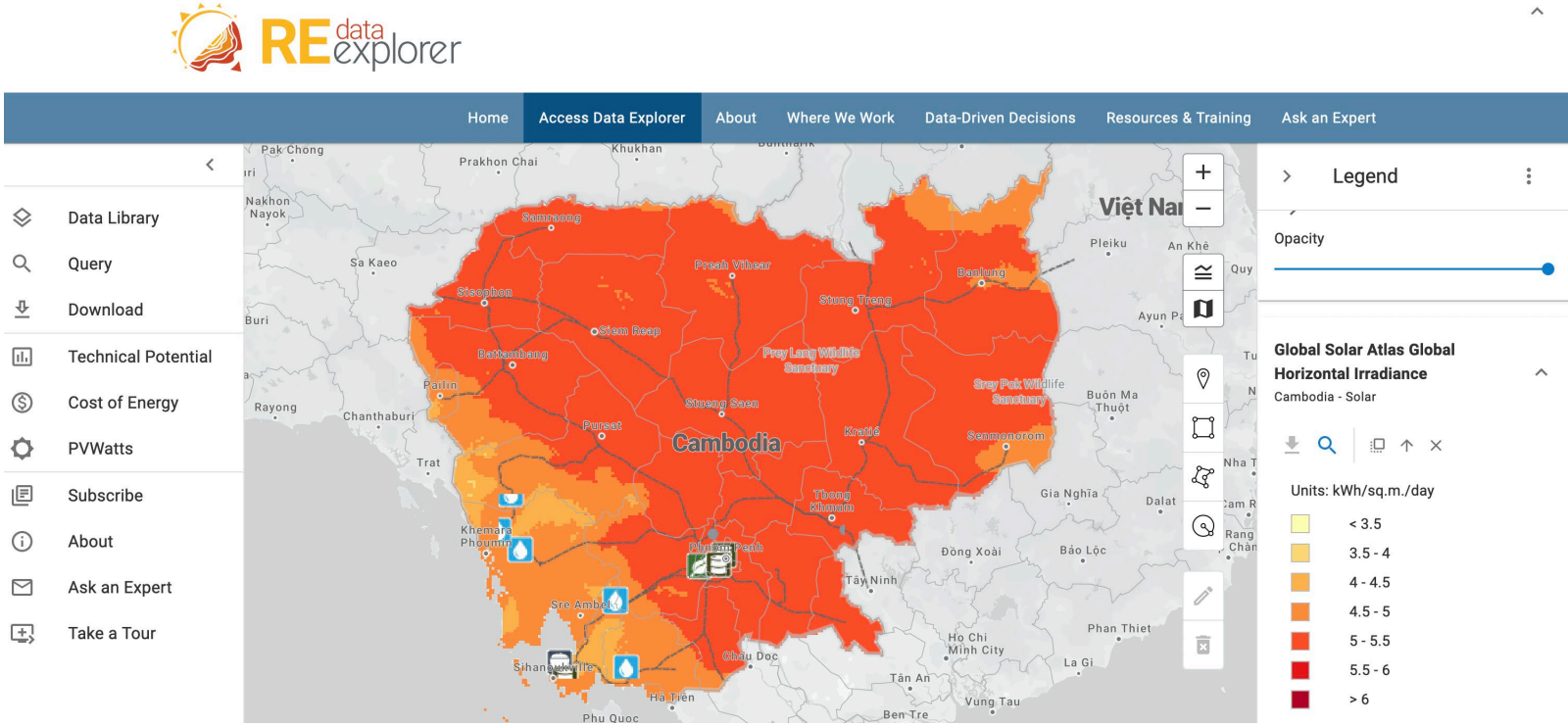
- Relaxed Scenario
- Excluding urban areas and water/wetlands

Hypothetical Wind Plants

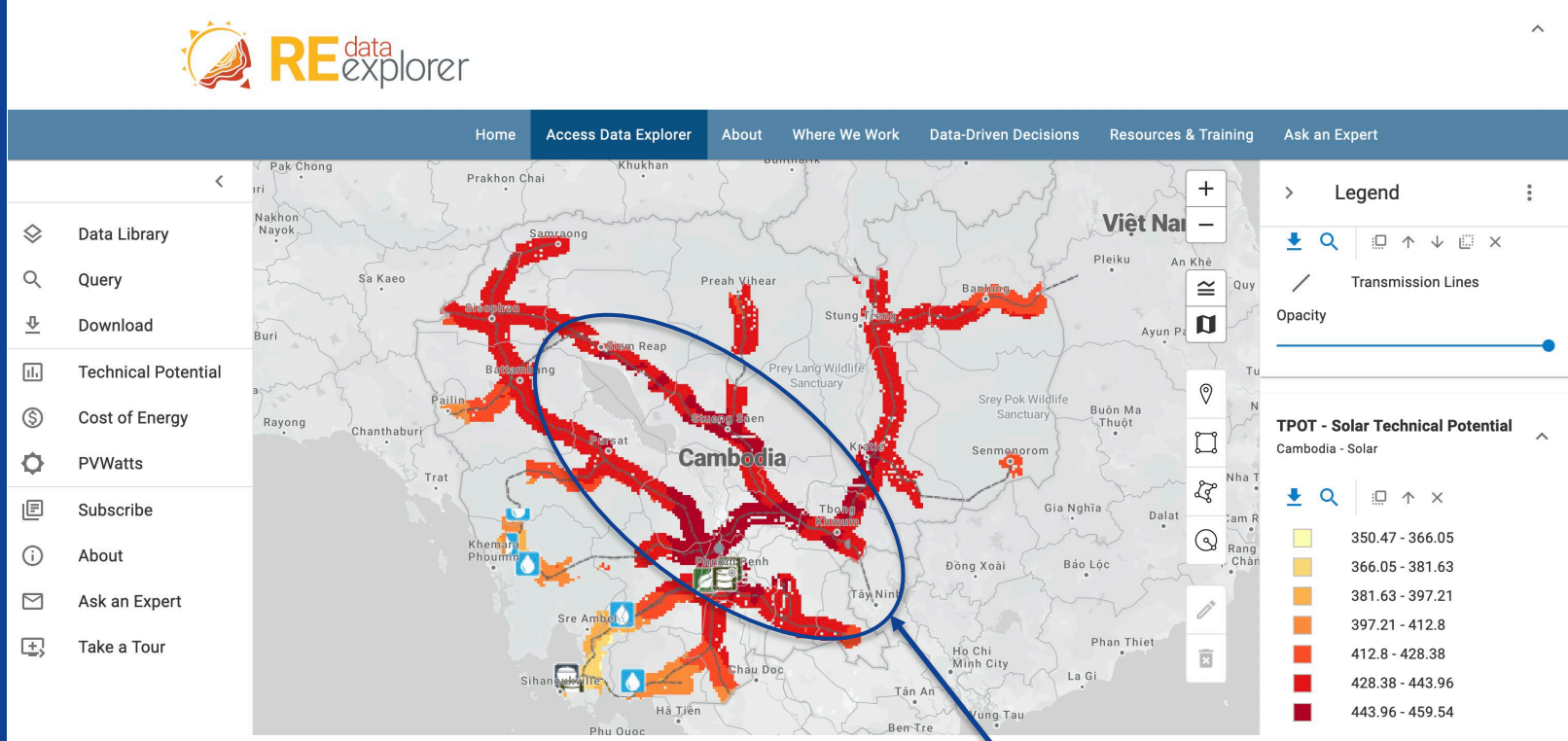


- For demonstration purposes: Select two high-technical-potential and low-LCOE locations near existing transmission nodes

Solar Resource Review



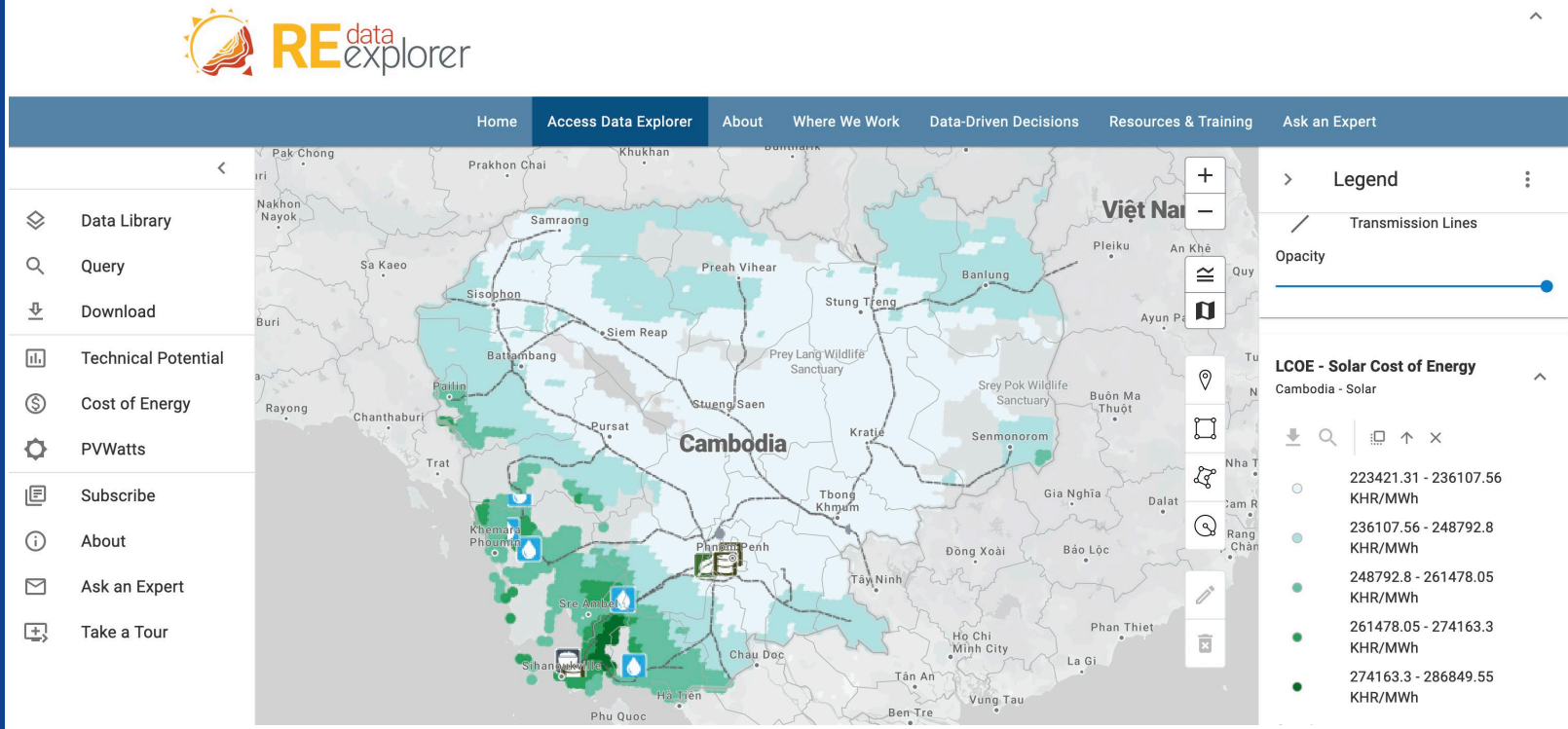
Solar Technical Potential Analysis



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

Promising areas to investigate further

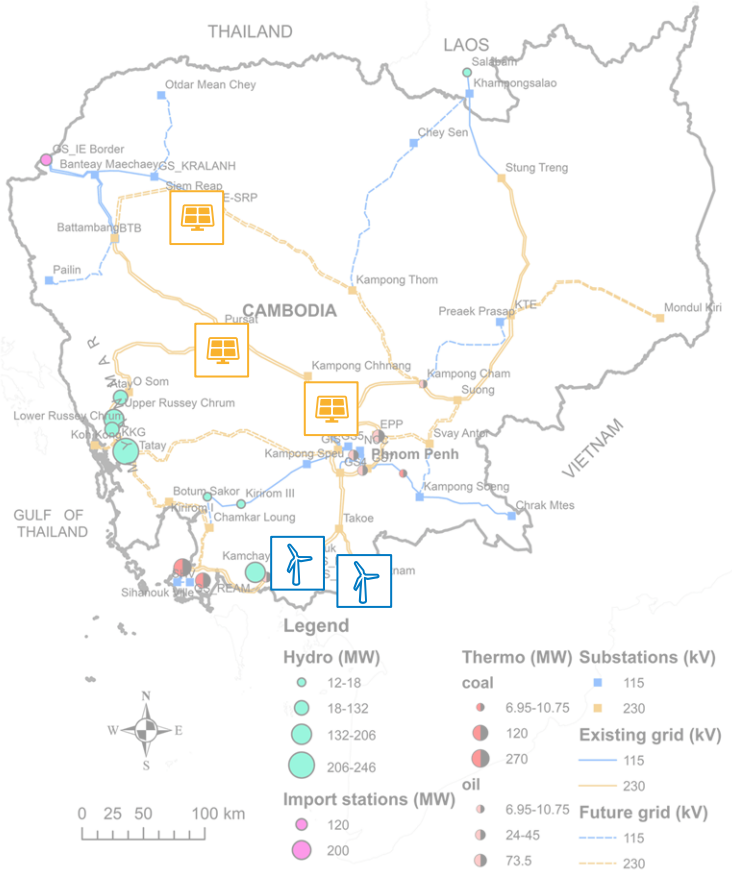
Solar Levelized Cost of Energy Analysis



- Relaxed Scenario
- Excluding urban areas and water/wetlands

New Renewable Energy Plants

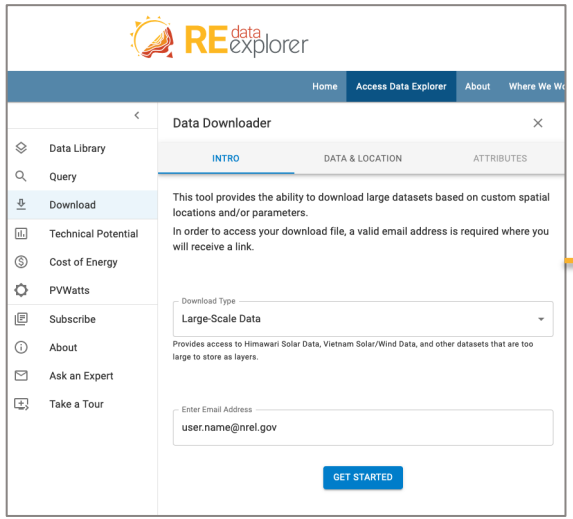
- Repeat same prospecting process with Himawari solar data
- Select 2 wind locations and 3 solar locations for hypothetical plants
- Add to existing buses in the PowNet transmission model

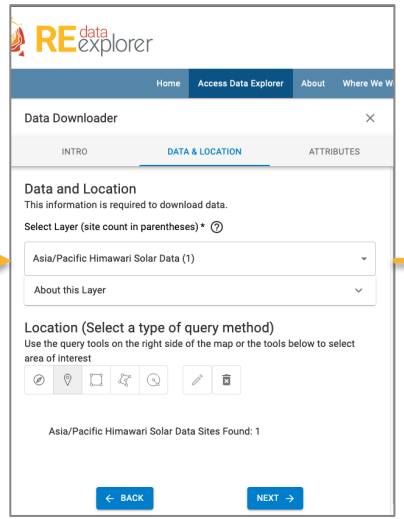


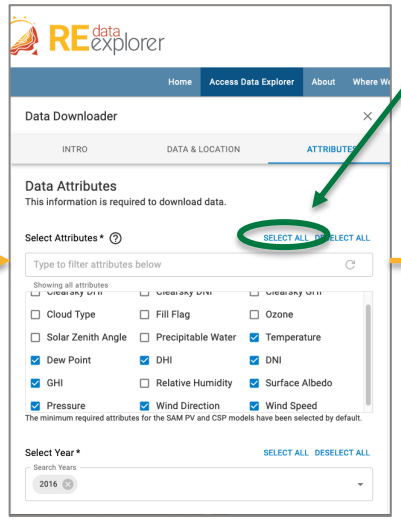
Modified from Chowdhury et al. 2020

Download High Resolution Weather Data

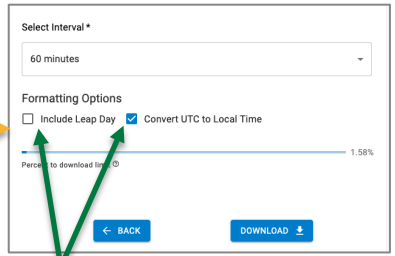
- For this example, we download hourly 2016 weather datasets for consistency with PowNet's 2016 demand:
  - Southeast Asia Wind Data
  - Asia/Pacific Himawari Solar Data







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



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

PCM Demonstration in Sienna\Ops

Part 2: Results after VRE Integration

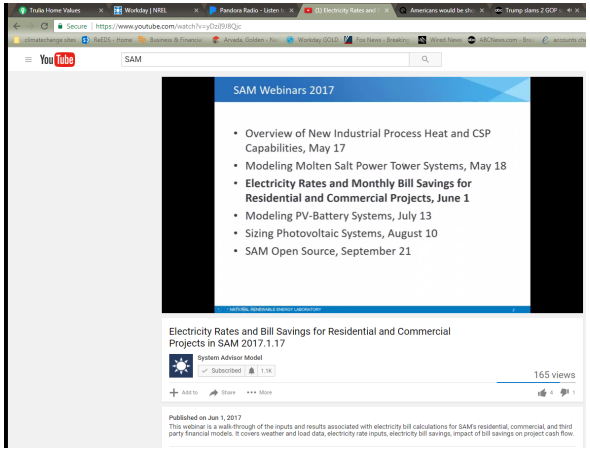
Synthesis and Wrap-Up

Key Takeaways

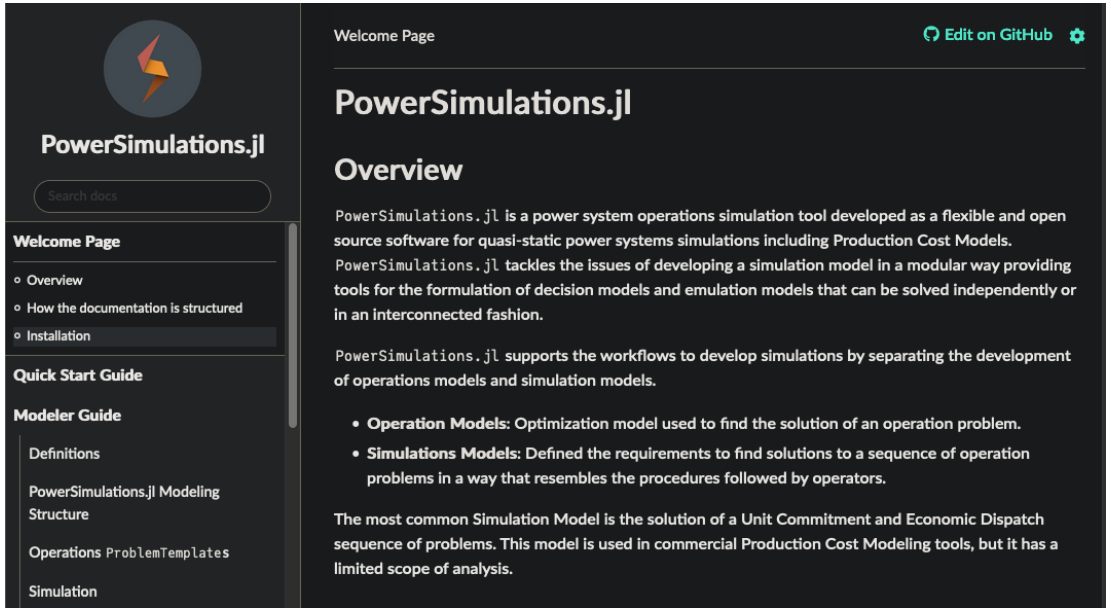
- RE Data Explorer's new Southeast Asia wind dataset provides high-resolution, open-source data for site prefeasibility and feasibility studies. High-resolution solar data is also available for this region and others.
- Open-source data and tools enable system operators and developers to conduct planning 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



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