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 today's code-package for side-by-side learning, visit:
https://globalpst.org/transforming-the-global-power-sector-open-data-and-tools-for-renewable-energy-integration/

Webinar Overview

Presenters

Karin Wadsack
Program Manager
National Renewable Energy Laboratory (NREL)

Galen Maclaurin
Senior Energy Researcher
National Renewable Energy Laboratory (NREL)

Kate Doubleday
Researcher
National Renewable Energy Laboratory (NREL)

Agenda – Day 1

1. Welcome and Housekeeping
2. Opening Remarks
3. Renewable Energy (RE) Data Explorer: High Quality Data for Decisions
4. Enabling Power Sector Transformation at Scale
5. Introduction to Production Cost Modeling (PCM)
6. Open-Source Tools for PCM Development
7. Overview of Sample Analysis and Training Materials

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

Opening Remarks

Karin Wadsack

National Renewable Energy Laboratory

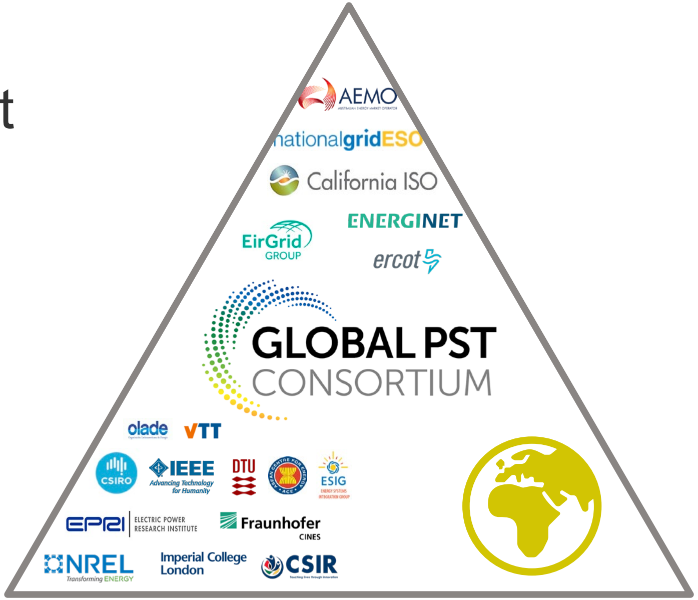
Global Power System Transformation (G-PST) Consortium

What?

A global **consortium** focused on support to **power system operators with advanced, low-emission solutions**

Who?

Founding System Operators (FSOs)



Core Team Technical Institutes

Developing Country System Operators

Indonesia, Ukraine, Vietnam, Thailand, India, South Africa, Pakistan, Morocco, Peru, Colombia, Panama, and others

Why?

To drive the development and transfer of the **technical and engineering knowledge** necessary for power system operators at the **speed and scale required** to support the global energy transition

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Advancing Action in Five Key Areas

1. System Operator Research & Peer Learning

Perform cutting edge applied research to create novel system operator solutions and globally disseminate and infuse new insights through peer learning

2. System Operator Technical Assistance

Provide implementation support to scale established best practice engineering and operational solutions

3. Foundational Workforce Development

Build the inclusive and diverse workforce of tomorrow through enhanced university curriculum and technical upskilling for utility and system operator staff

4. Localized Technology Adoption Support

Adapt modern power system technologies to individual country contexts through testing programs and standards development activities

5. Open Data and Tools

Support rigorous planning, operational analysis and enhanced real-time system monitoring through open data and tools

CORE TEAM – All Core Team members contribute to all activity pillars

REGIONAL LEADS – Coordinate regional peer learning networks and country-level technical assistance delivery efforts for Africa, Asia, and Latin America and the Caribbean

INTERIM SECRETARIAT – Work program coordination, partnerships and support, outreach, etc.

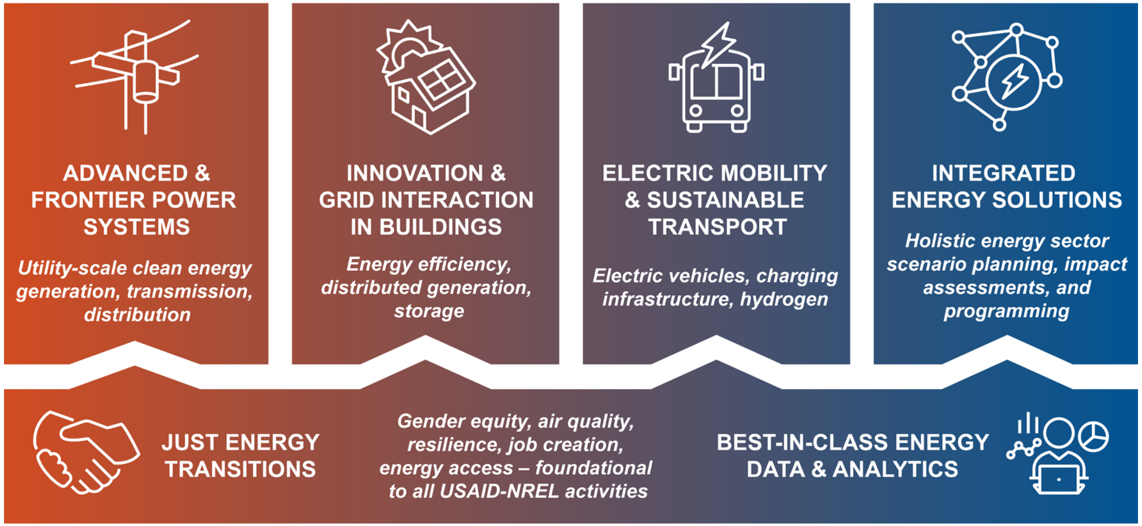
The USAID-NREL Partnership

www.nrel.gov/usaid-partnership

The U.S. Agency for International Development (USAID) and NREL partner with developing countries to decarbonize and transform energy systems around the world by addressing critical aspects of deploying advanced energy systems.

USAID-NREL PARTNERSHIP STRATEGIC PILLARS

Provision of demand-driven technical assistance through USAID Mission engagements, global knowledge platforms, and project implementation



USAID-NREL Global Knowledge Platforms

The USAID-NREL Partnership's global knowledge platforms provide free, state-of-the-art knowledge products, tools, and support on common and critical challenges to scaling up power, buildings, transport and integrated energy solutions

REexplorer MAPPING OUR ENERGY FUTURE — www.re-explorer.org

I-JEDI — www.i-jedi.org

Greening the Grid — www.greeningthegrid.org

Resilient Energy Platform — www.resilient-energy.org

Spotlight on Grid Integration Resources

REexplorer
MAPPING OUR ENERGY FUTURE

- High-quality renewable energy data for decisions
- Integrated geospatial visualization
- Free data downloads

Greening the Grid

- Grid integration toolkit
- Best practice frameworks, case studies, and technical resources
- Variable Renewable Energy (VRE) Guidebook for Practitioners

Public Data and Open-Source Tools: Transforming Energy

Catalyzing innovation

Accelerating deployment

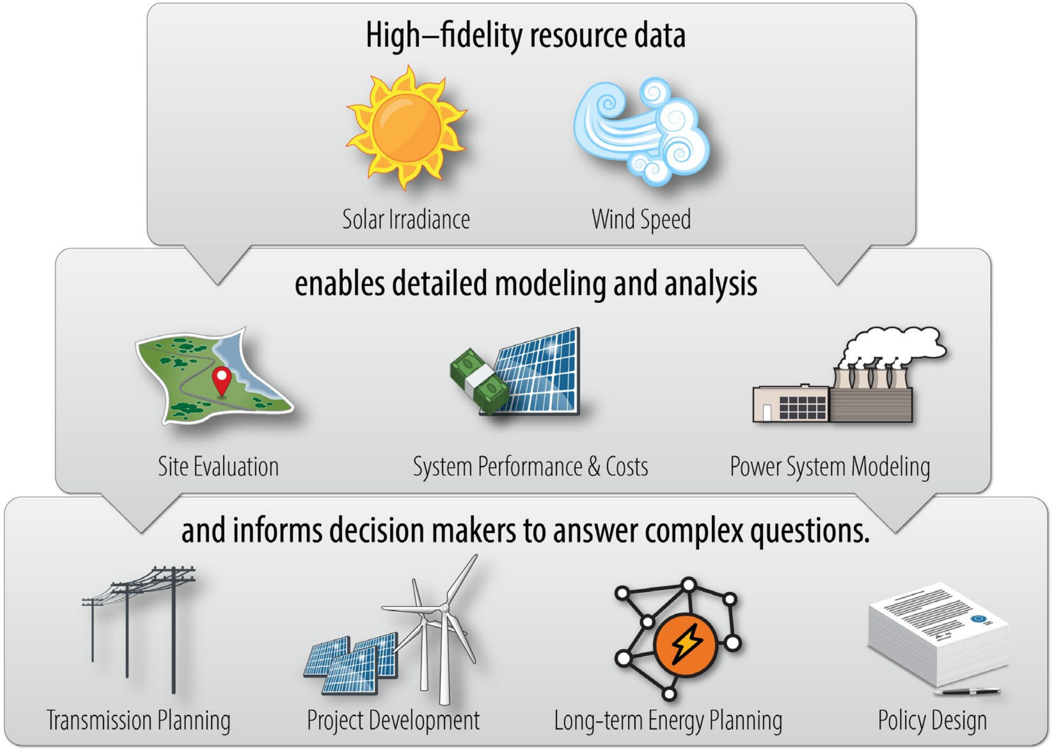
Empowering decision-makers

High Quality Data for Renewable Energy Decision-Making

Galen Maclaurin

National Renewable Energy Laboratory

High-Quality Data Accelerates Energy Transitions



Motivation and Objectives

DEMOCRATIZING DATA: Growing need for free timeseries wind and solar resource data across the globe to support:

- Project feasibility assessments
- Regional and national target setting
- Detailed power systems modeling
- Assessment of PV-Wind complementarity

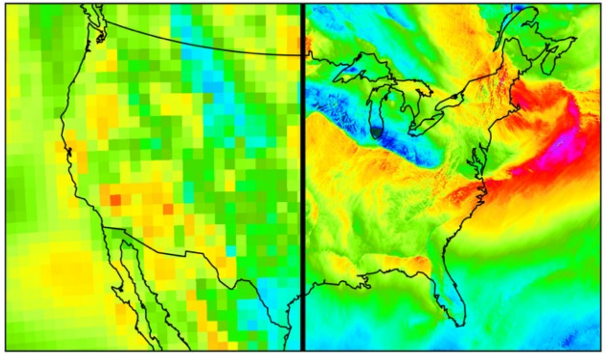
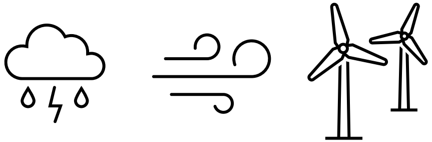


Figure Credit: Ryan King, NREL

OBJECTIVES: Provide high-quality, publicly available wind and solar resource data



VALUE PROPOSITION: Capture important atmospheric processes for the wind energy community:

- High-accuracy, meso-scale wind flow
- Sub-hourly to interannual resource variability
- Accurate vertical wind profile (wind shear)
- Ramping rates at fine temporal scales

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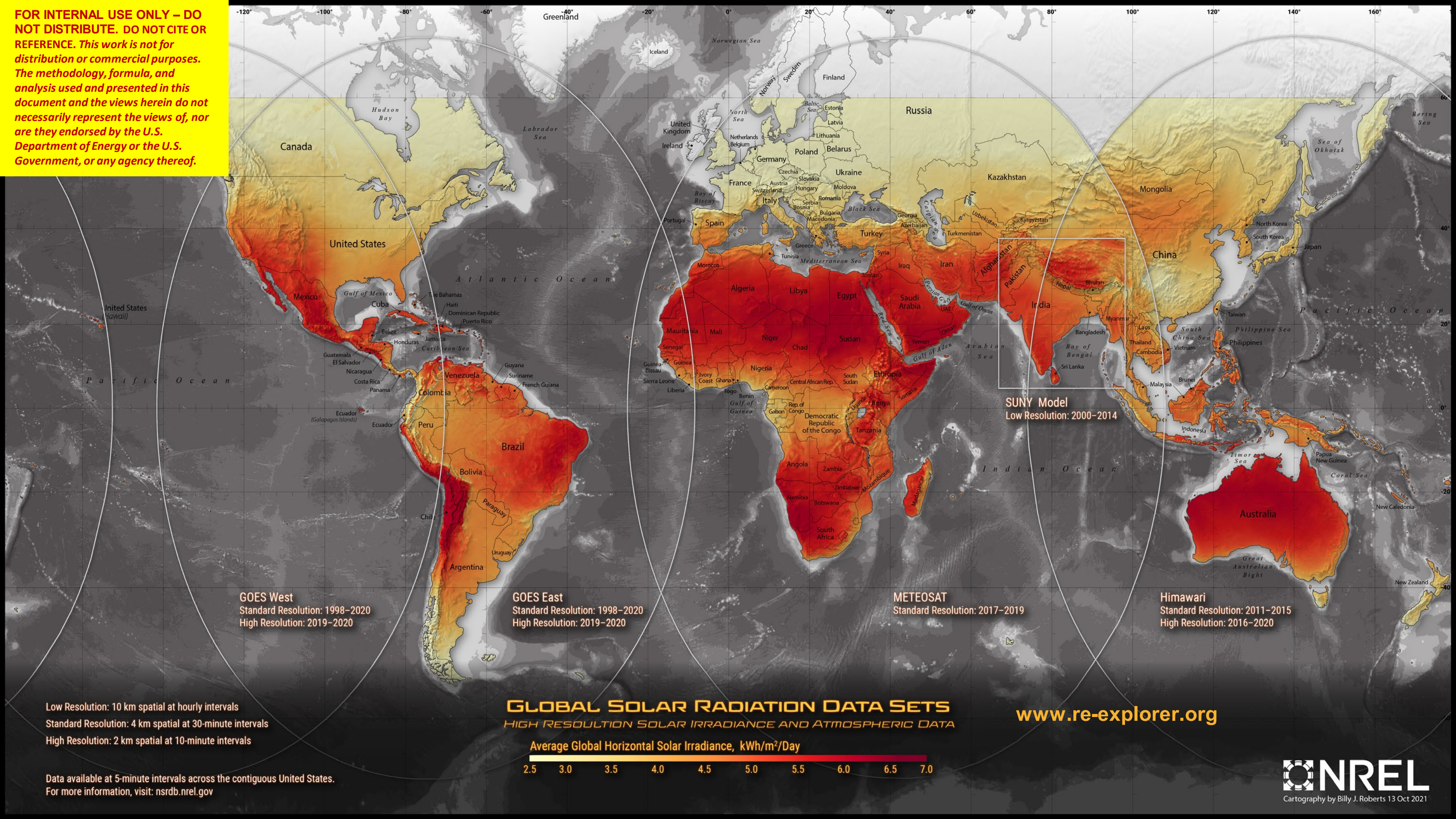


Solar Data Development Algorithm

NREL's Physical Solar Model (PSM)

- Characterizes absorption and scattering of solar radiation from clouds and aerosols
- Models the transfer of solar radiation through Earth's atmosphere
- Considers interactions with atmospheric constituents (e.g., CO_2, O_3, H_2O) and land surface
- Visit https://nsrdb.nrel.gov/ for more information.

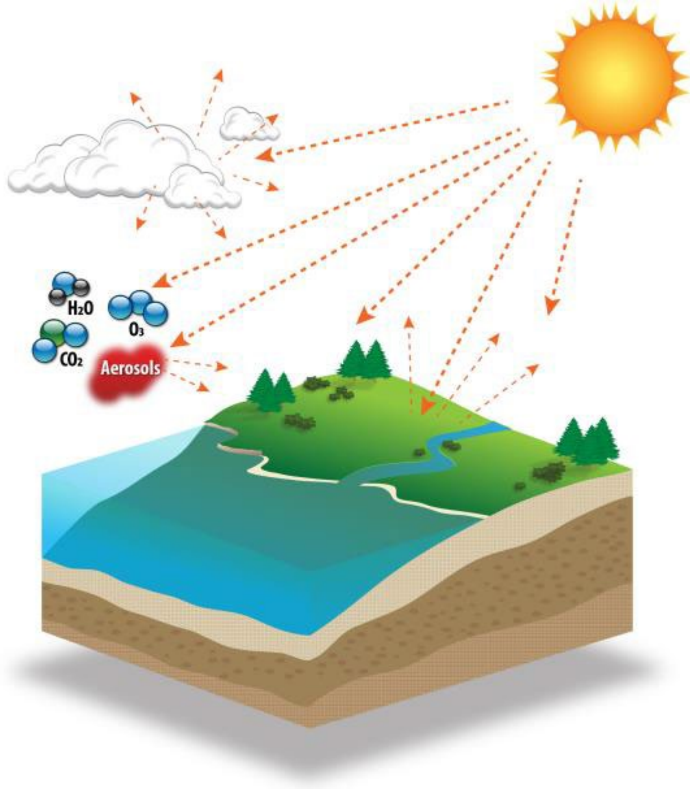
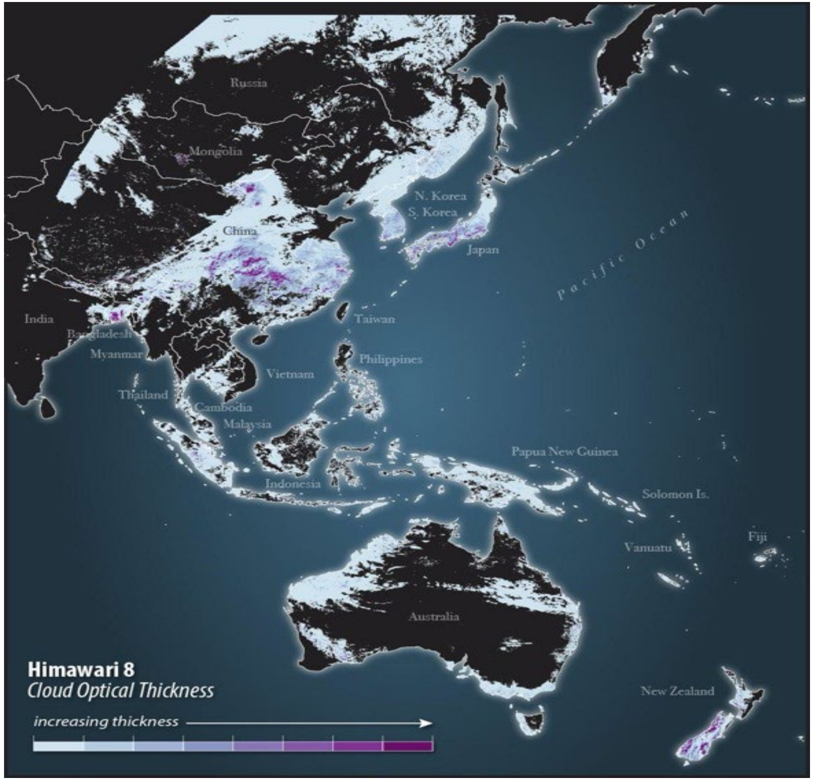


Illustration by Billy Roberts, NREL

Himawari Satellite Imagery

- Cloud characteristics are a key to estimate absorption and scattering of the incoming solar radiation
- Imagery from the Japanese Meteorological Agency's (JMA's) Himawari 7 and 8 satellites
- NREL partnered with the University of Wisconsin to model cloud type, optical thickness, and properties.

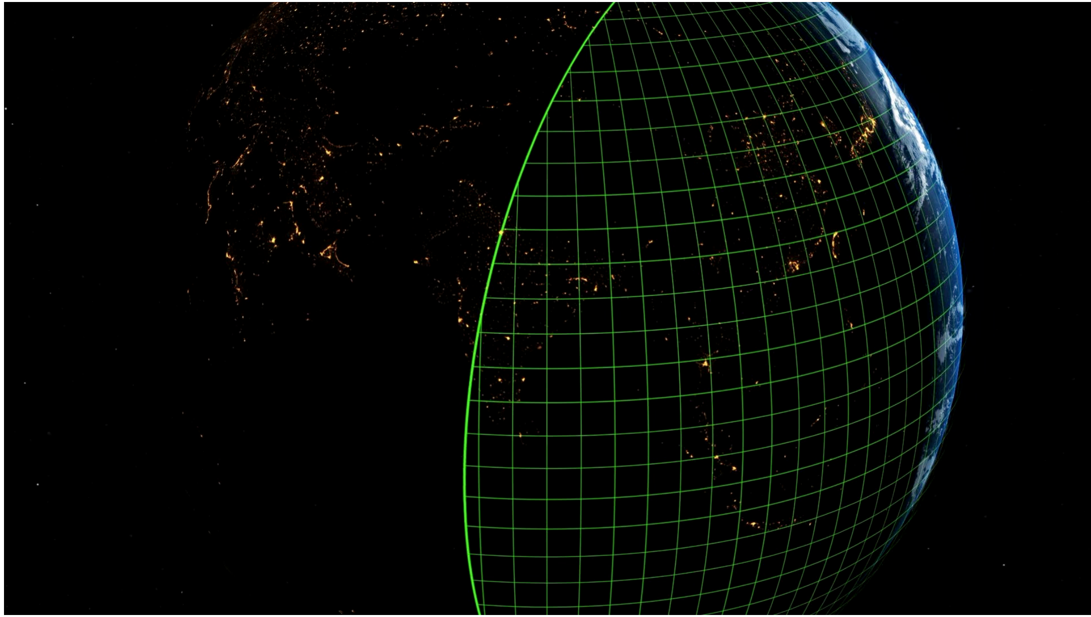


Cloud optical thickness shown for April 1, 2019. *Illustration by Billy Roberts, NREL*

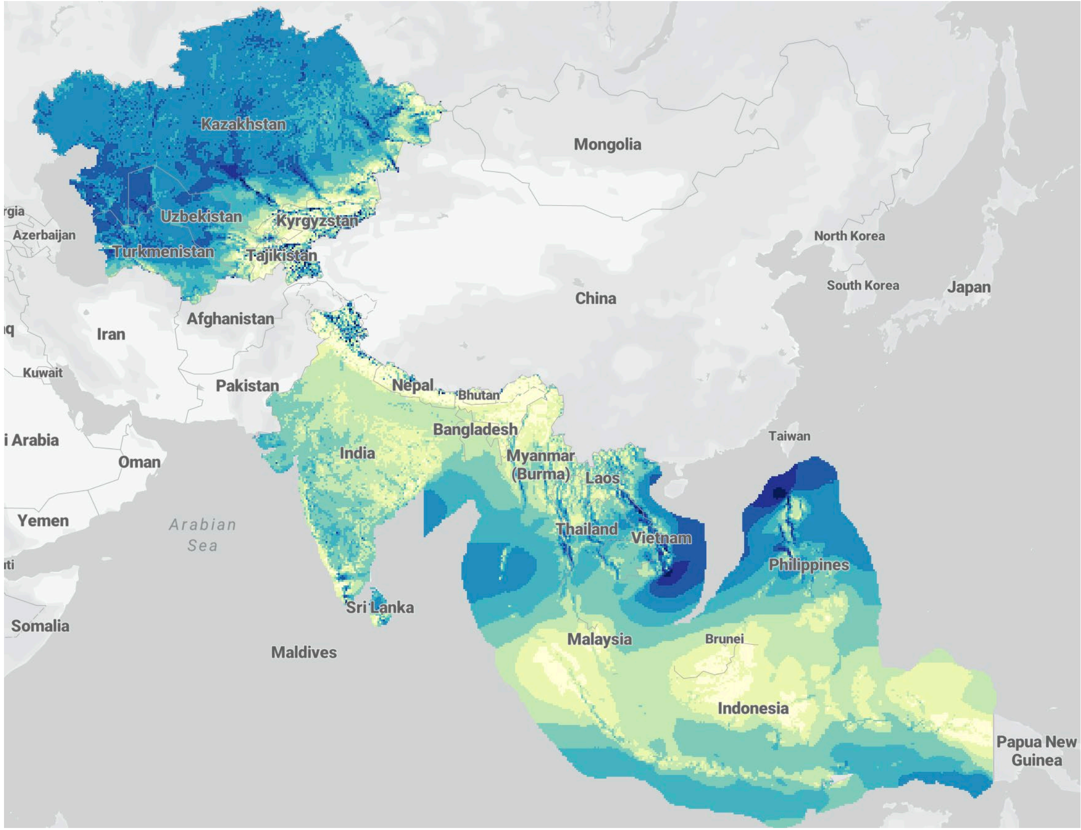
Southeast Asia Solar Resource Data

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.



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

A New Paradigm for Wind Resource Assessment

Combine cutting edge techniques in numerical weather prediction and machine learning

Weather Research and Forecasting (**WRF**) Model **+** Generative Adversarial Networks (**GANs**) **=** Meso-Scale Wind Resource Timeseries Data

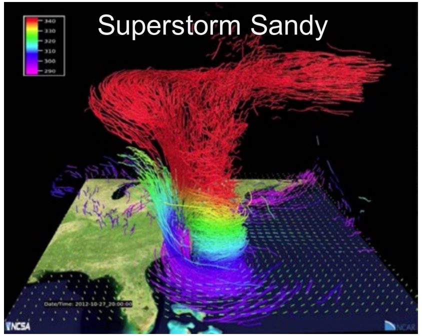


Figure Credit: Mel Shapiro, NCAR

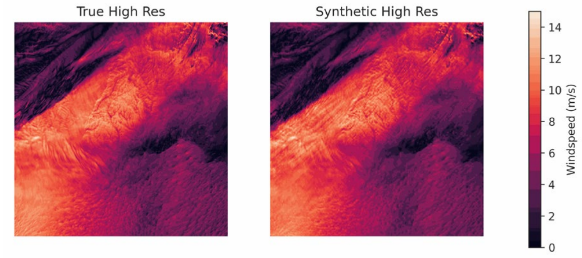


Figure Credit: Ryan King, NREL

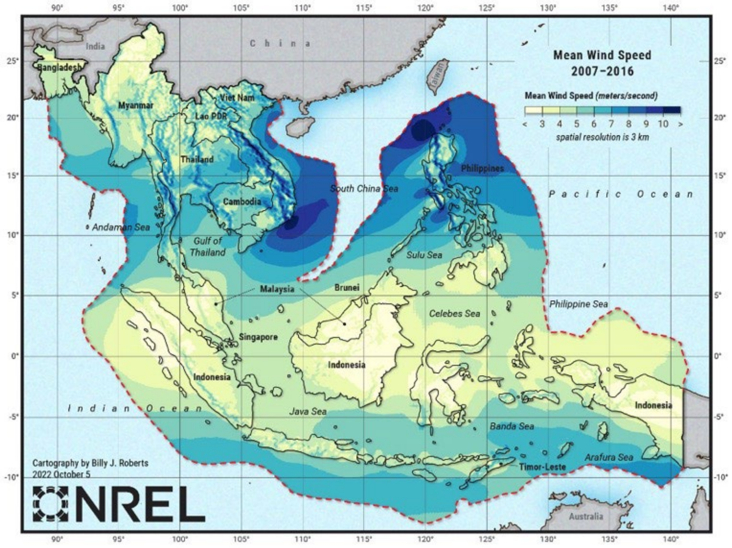


Figure Credit: Billy Roberts, NREL

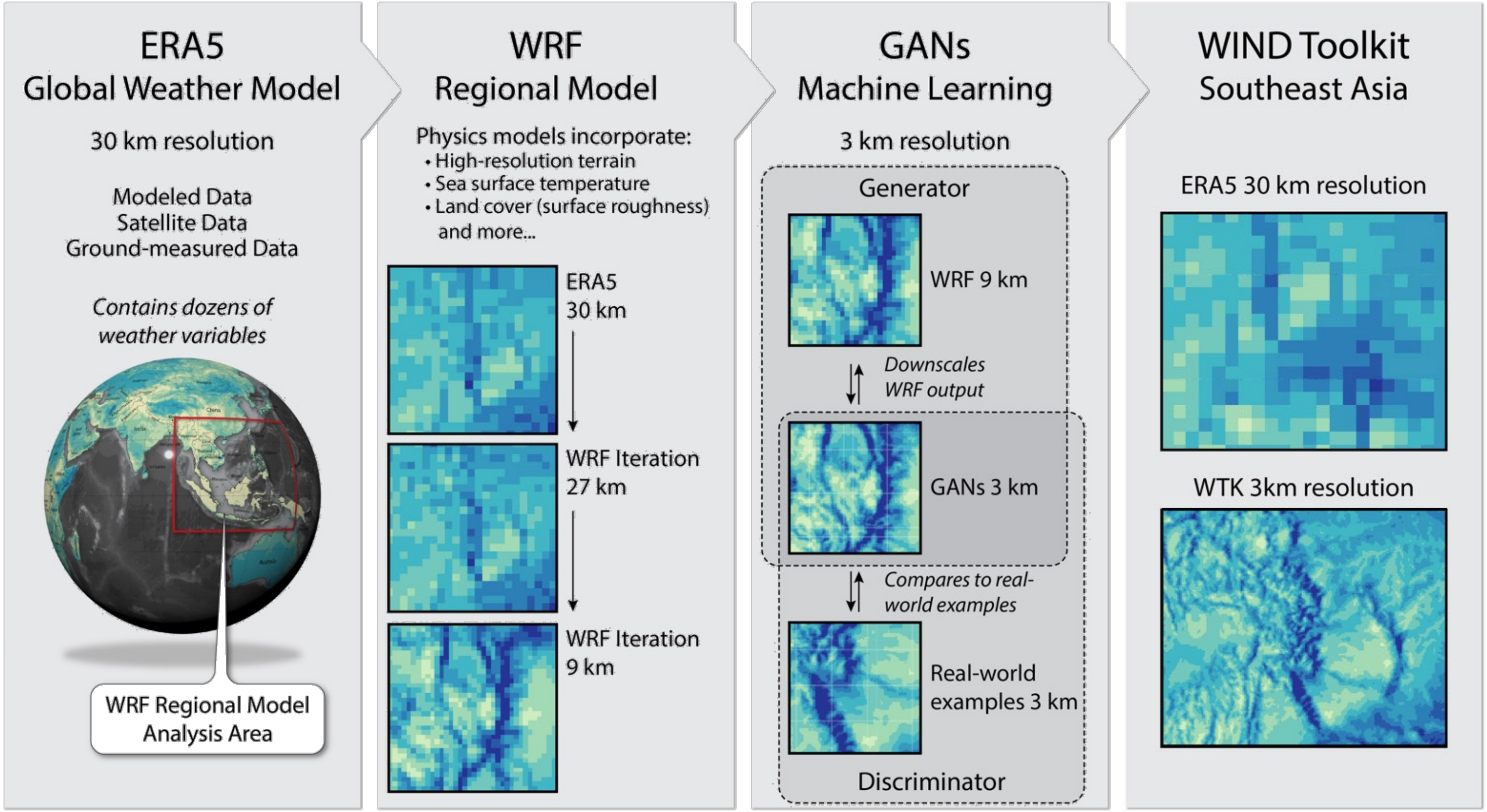
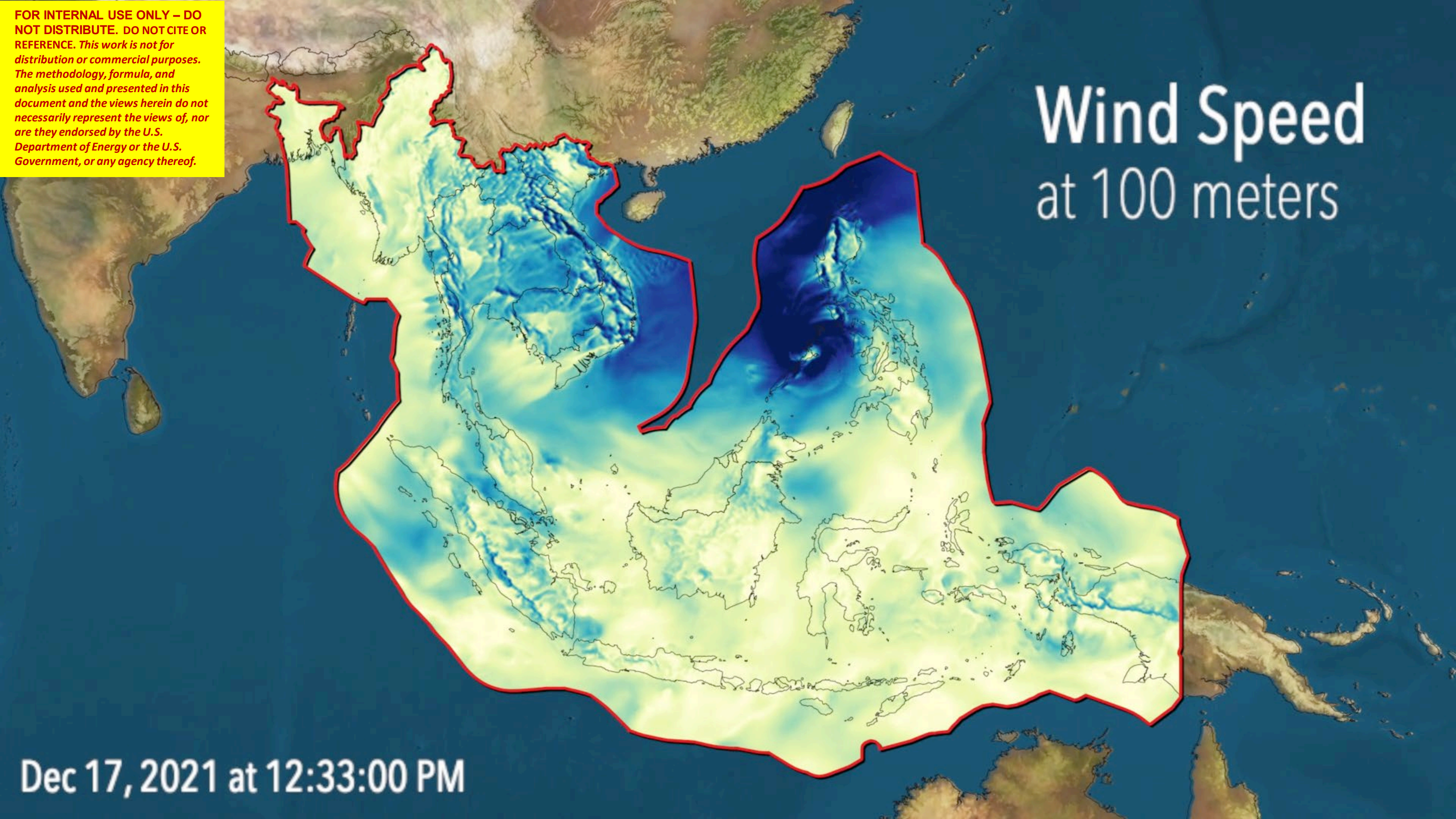
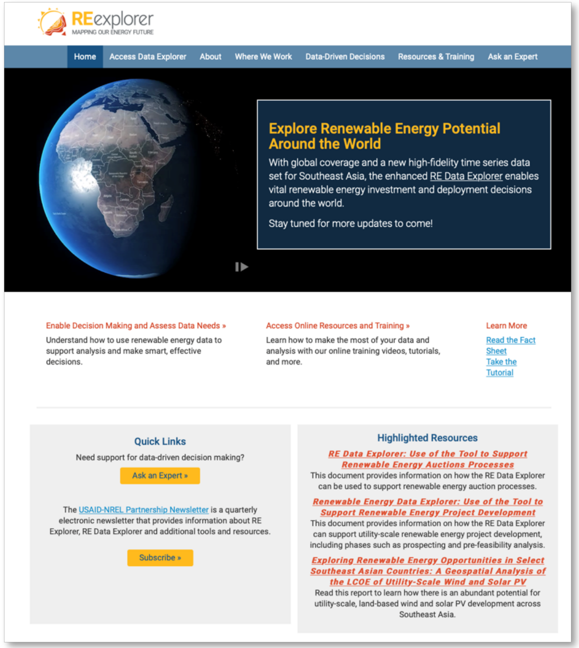


Figure Credit: Billy Robert, NREL


Wind Speed
at 100 meters
Dec 17, 2021 at 12:33:00 PM

Renewable Energy (RE) Data Explorer

- A **user-friendly geospatial visualization tool** for analyzing renewable energy potential and informing decisions.
- **Open data download repository** for high-quality renewable energy resource data.
- Support for **renewable energy decision-making**.

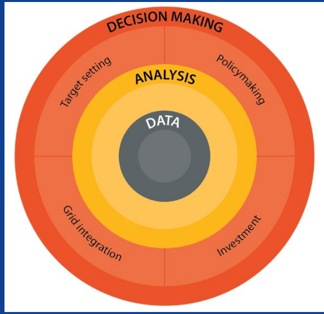


www.re-explorer.org

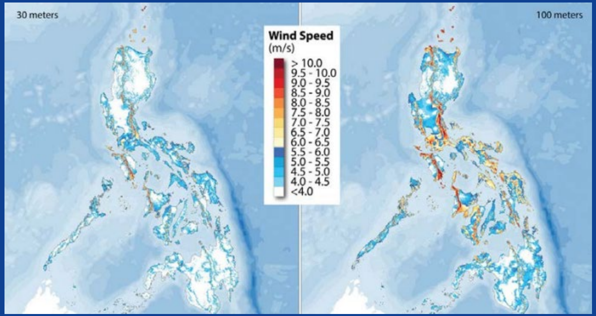
Additional Resources

RE Data Explorer was developed to support data-driven renewable energy analyses that can inform key renewable energy decisions globally.

Access the **RE Data Explorer Data-Driven Decisions webpage** to learn how renewable energy data can support informed renewable energy target setting, policy making, investment, and power sector planning



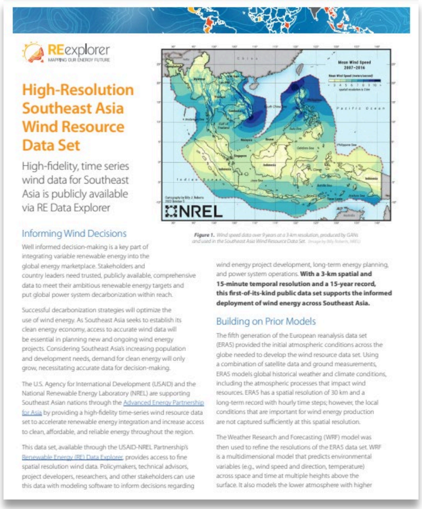
Leverage the **Renewable Energy Data, Analysis, and Decisions: A Guide for Practitioners** to enhance your capability to make informed and effective renewable energy decisions using high-quality renewable energy data.



Additional Resources

Learn more about renewable energy resource data developed for the Southeast Asia region.

[Developing Southeast Asia Solar Resource Data to Support the Clean Energy Transition in the Region]



[High-Resolution Southeast Asia Wind Resource Data Set]

Enabling Power Sector Transformation at Scale

Variable Renewable Energy Grid Integration

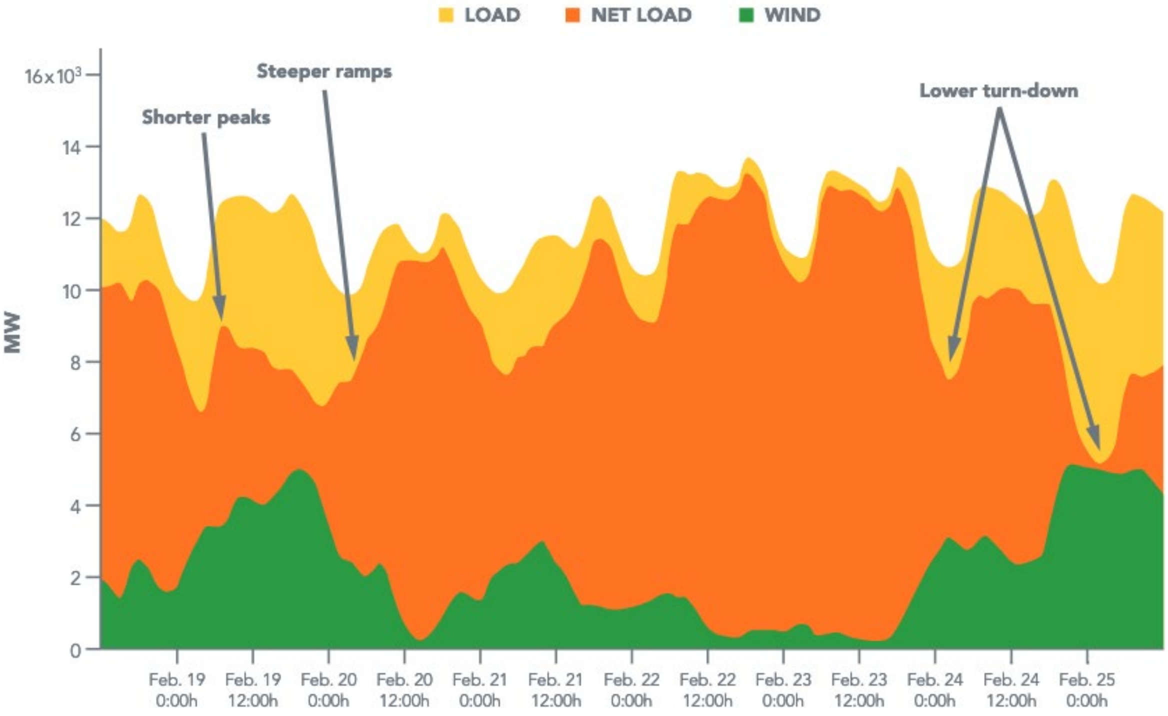
Kate Doubleday

National Renewable Energy Laboratory

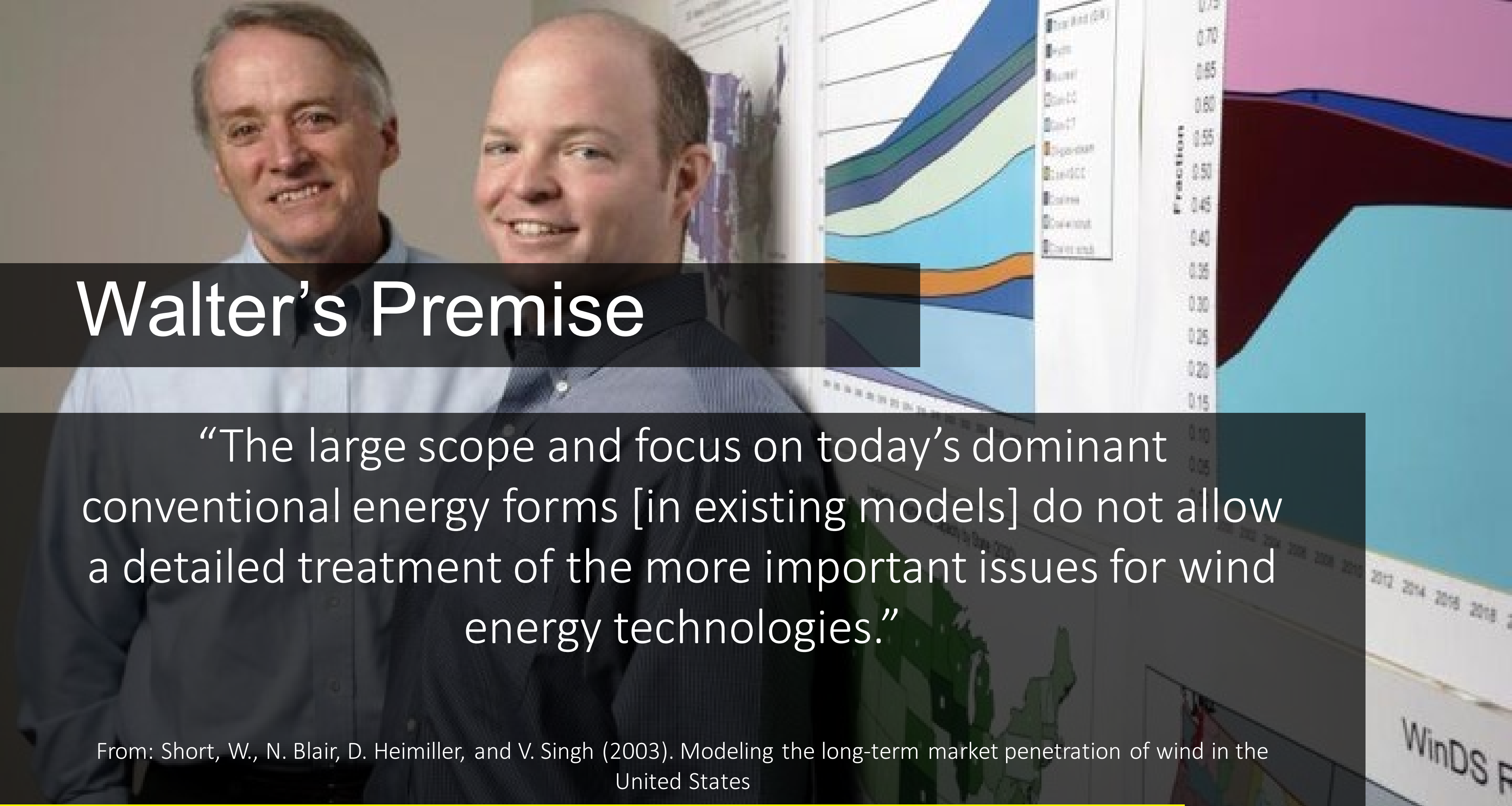
VRE Challenges

Variable renewable energy (VRE) resource challenges:

- Variable and uncertain
- Not “dispatchable”
- Does not provide inertia (without synthetic inertia controls)



Flexibility in 21st Century Power Systems



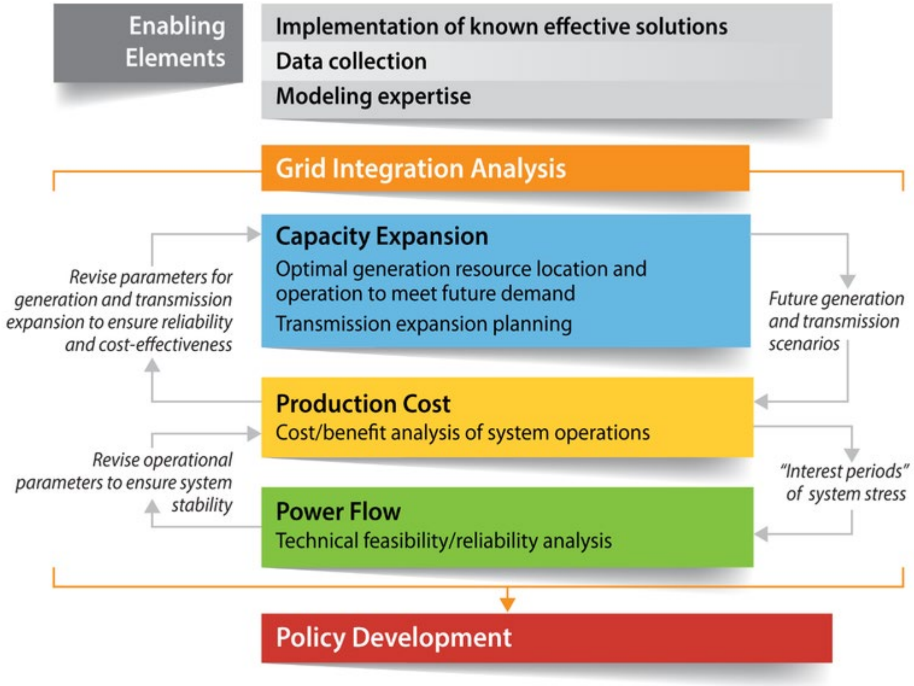
Walter's Premise

"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

What is grid integration?

Grid integration is the practice of power system planning, interconnection, and operation that enables efficient and cost-effective use of variable renewable energy (VRE) while maintaining the stability and reliability of the grid.



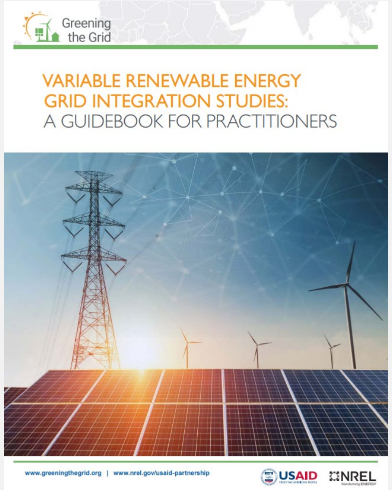
Types of grid integration analyses

[Integrating Variable Renewable Energy Into the Grid: Key Issues](#)
[The Evolution of Power System Planning with High Levels of Variable Renewable Generation](#)

Greening the Grid: An Expert-Curated Toolkit for VRE Integration

Access the **Grid Integration Toolkit** on **Greening the Grid** to unlock an extensive collection of expertly assembled and annotated resources that can facilitate your understanding of the key topics for integrating variable renewable energy into the grid

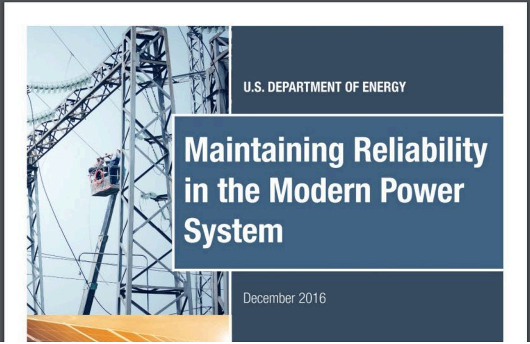
Grid Integration Toolkit

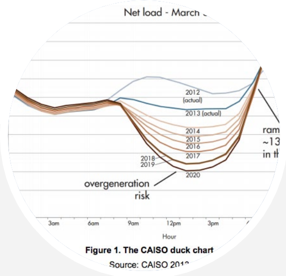


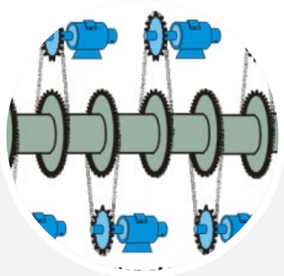
Check out the Variable Renewable Energy Grid Integration Guidebook for Practitioners to gain a comprehensive understanding of strategies and good practices for conducting a high-quality grid integration study

Greening the Grid

Four Pillars of Power System Reliability







Capacity

Power generation and transmission capacity must be sufficient to meet peak demand for electricity.

Flexibility

Power systems must have adequate flexibility to address variability and uncertainty in demand (load) and generation resources.

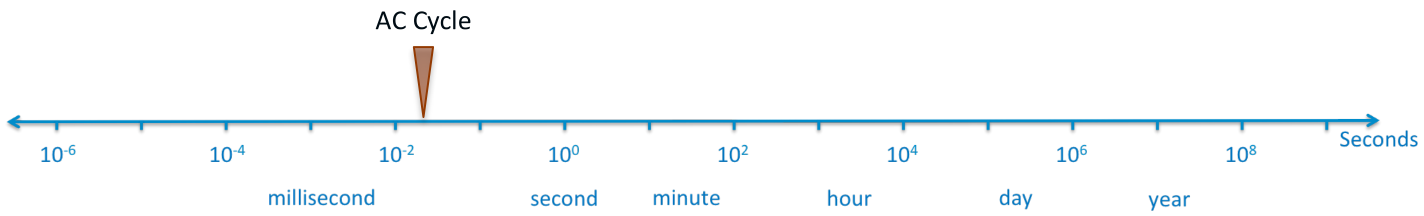
Frequency

Power systems must be able to maintain steady frequency.

Voltage

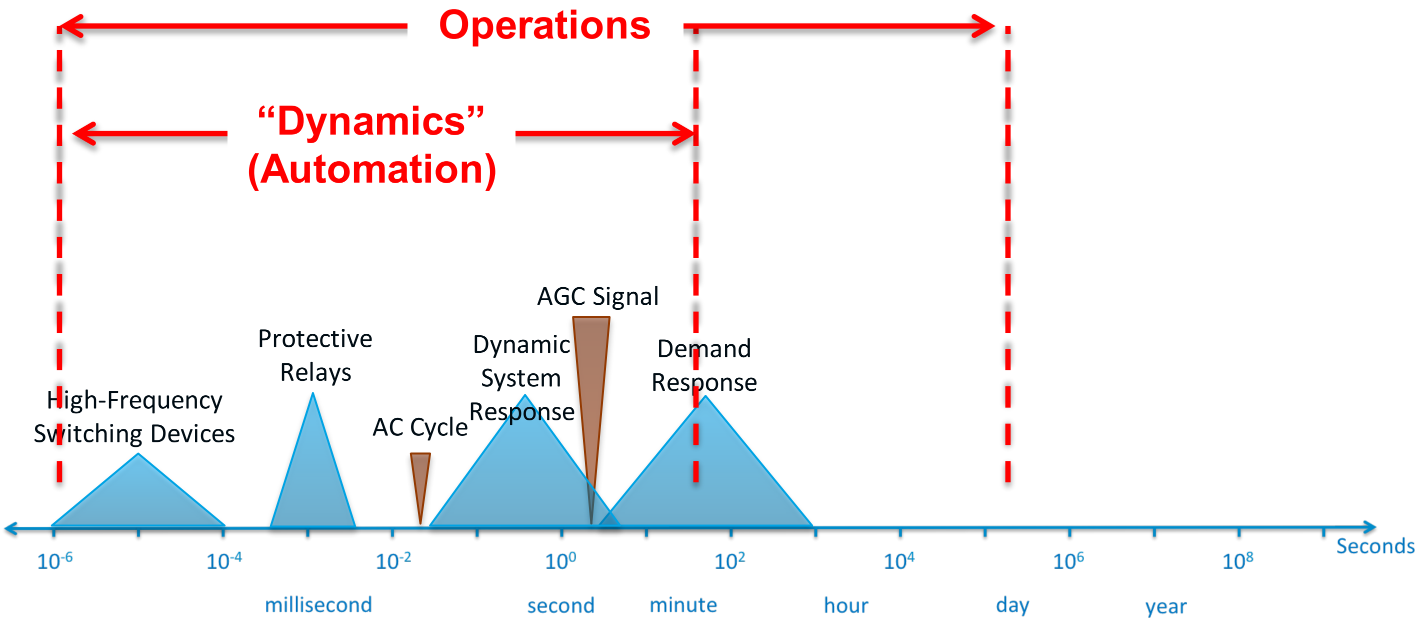
Power systems must be able to maintain voltage within an acceptable range.

Relevant grid decision timescales span 15 orders of magnitude



Adapted from A. Von Meier

Relevant grid decision timescales span 15 orders of magnitude



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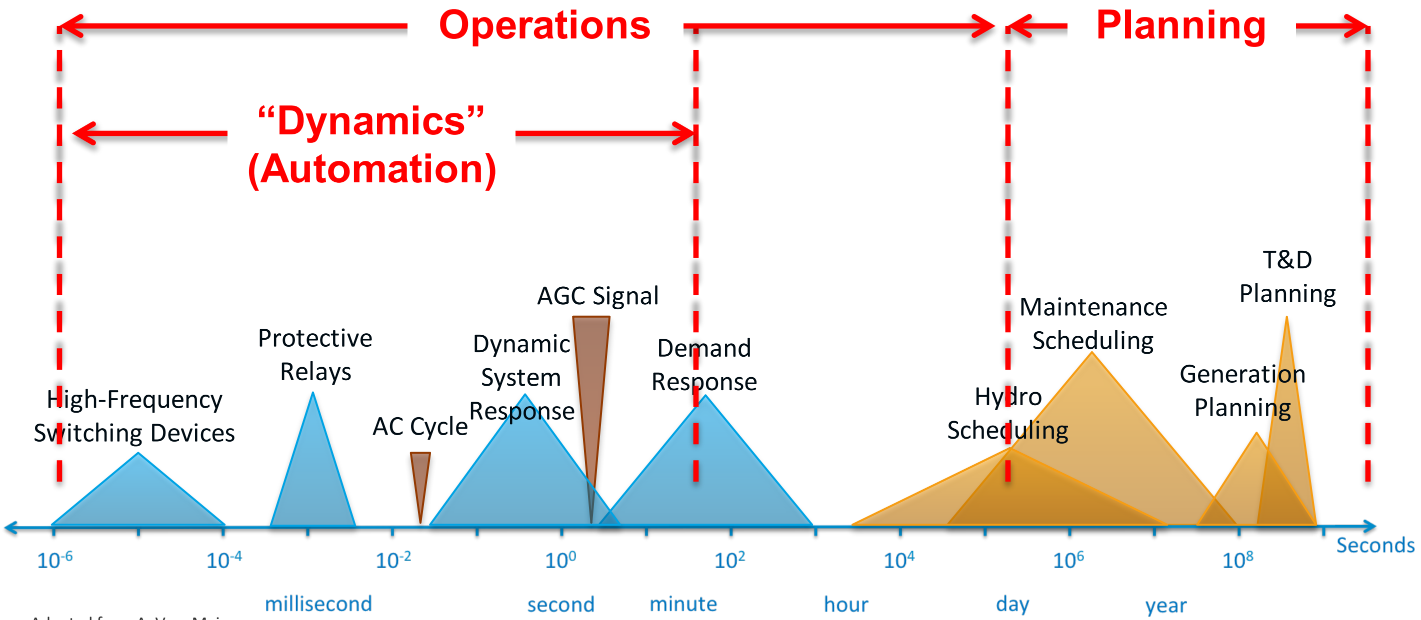

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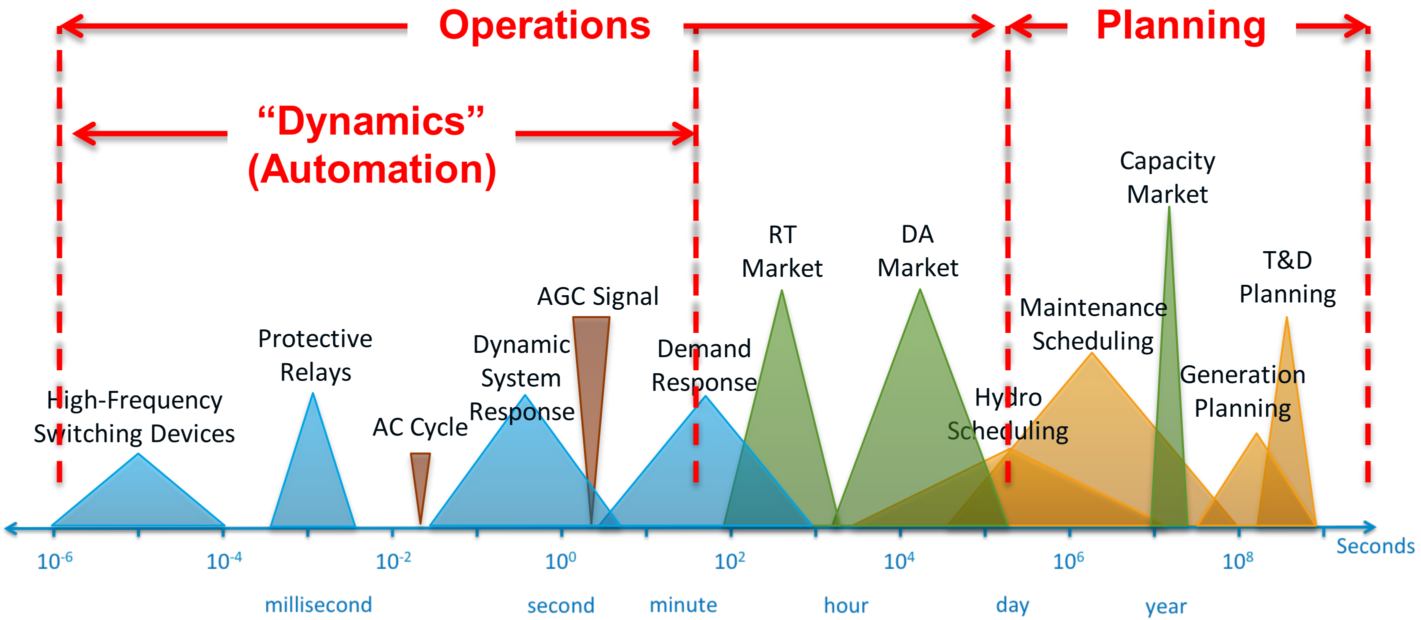

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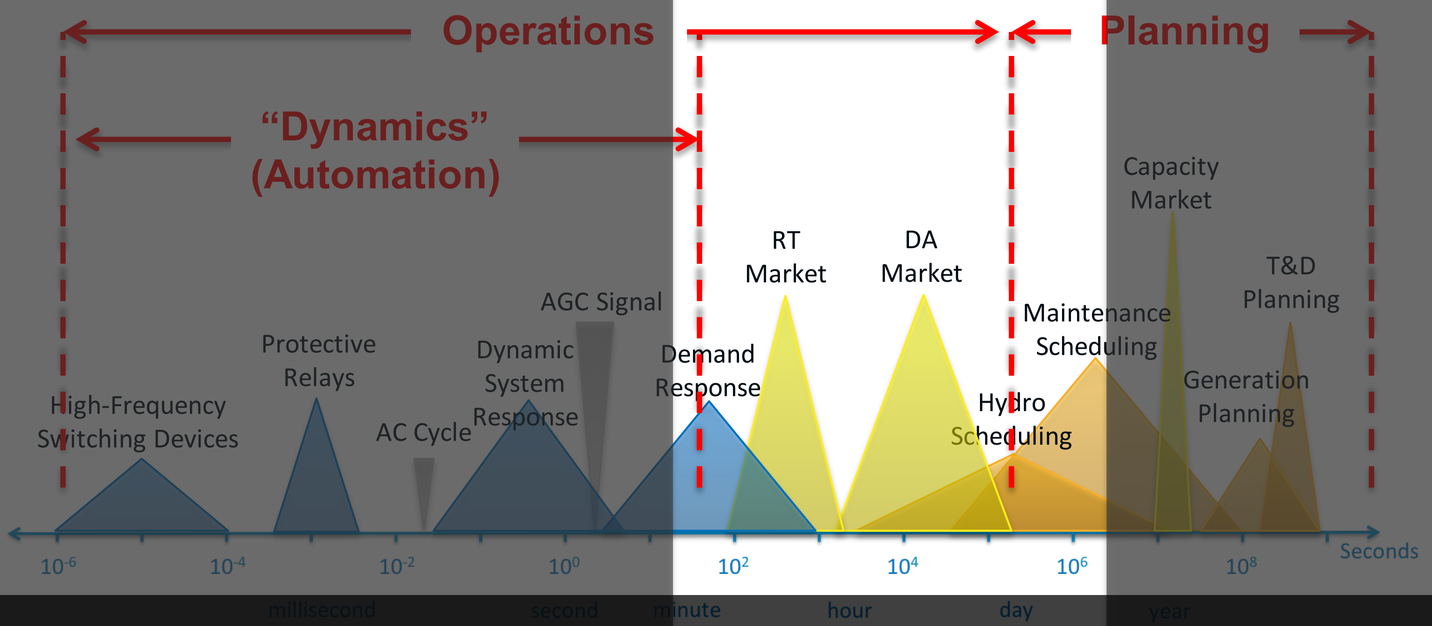
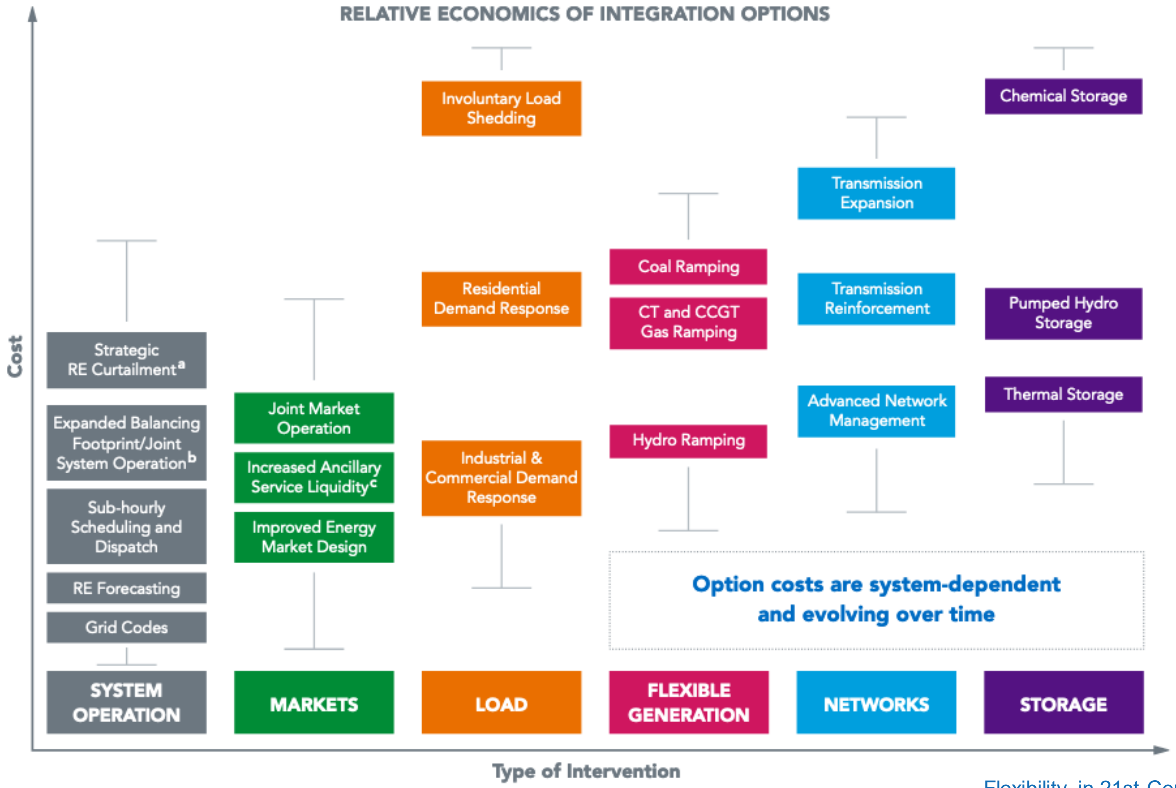


Production cost models (PCMs) simulate operations for planning

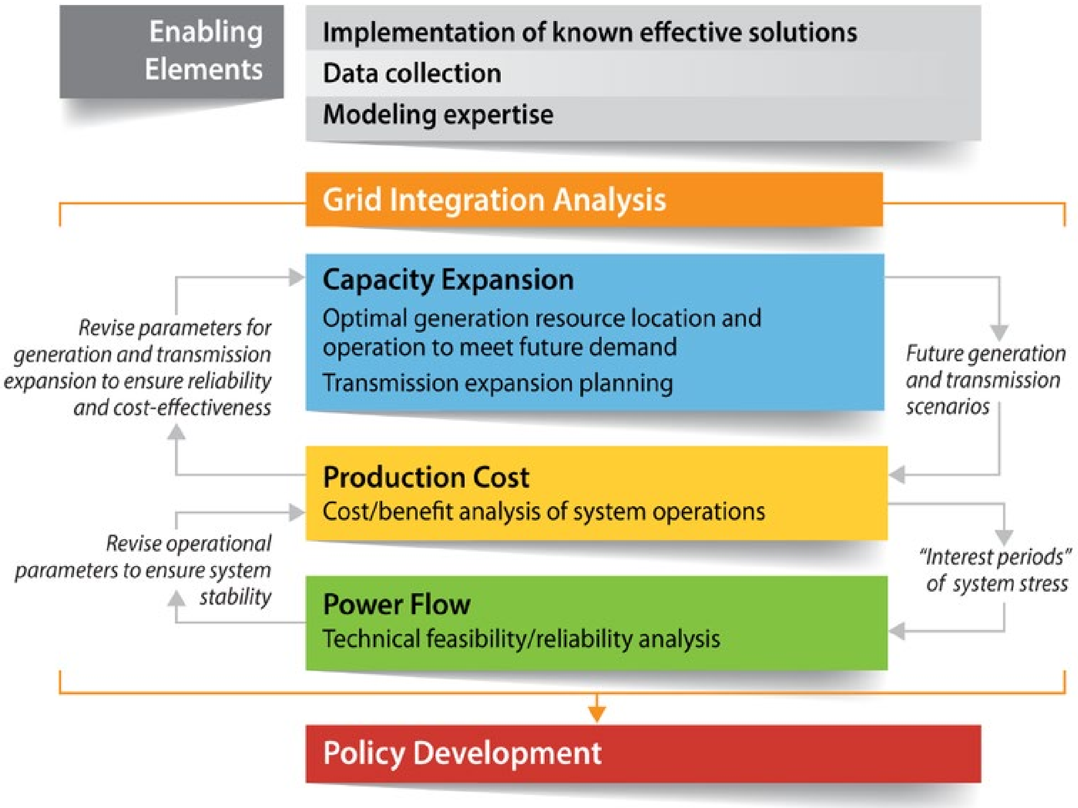
Sources of Flexibility



[Flexibility in 21st Century Power Systems](#)

Introduction to Production Cost Modeling (PCM)

PCM for System Planning



Example Outcomes: India Case Study

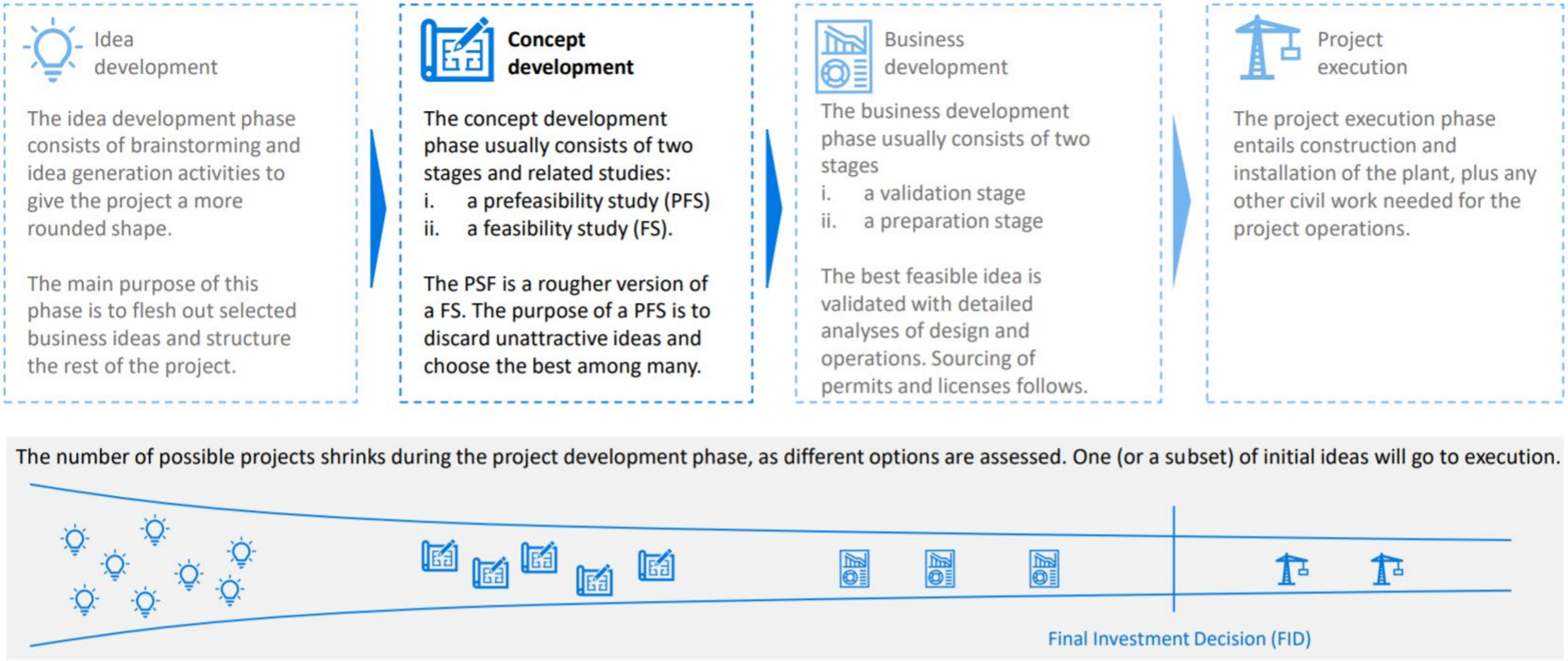
RE INTEGRATION STRATEGIES

100 GW SOLAR **60 GW WIND**

NORMAL OPERATIONS	COORDINATED SCHEDULING AND DISPATCH		COAL PLANT FLEXIBILITY		
STATE-LEVEL DISPATCH, 55% MINIMUM GENERATION	REGIONAL	NATIONAL	LOWER MINIMUM PLANT GENERATION (40% of capacity)	HIGHER MINIMUM PLANT GENERATION (70% of capacity)	LOWER MINIMUM PLANT GENERATION (40% of capacity) WITH REGIONAL BALANCING AREA COORDINATION
230,000 INR Crore Annual Production Cost	**2.8%** Savings annually	**3.5%** Savings annually	Negligible Savings annually	**0.90%** Increased cost annually	**3.3%** Savings annually
1.4% Renewable energy curtailment	**1.3%** Renewable energy curtailment	**0.89%** Renewable energy curtailment	**0.76%** Renewable energy curtailment	**3.5%** Renewable energy curtailment	**0.73%** Renewable energy curtailment

India Renewable Integration Study

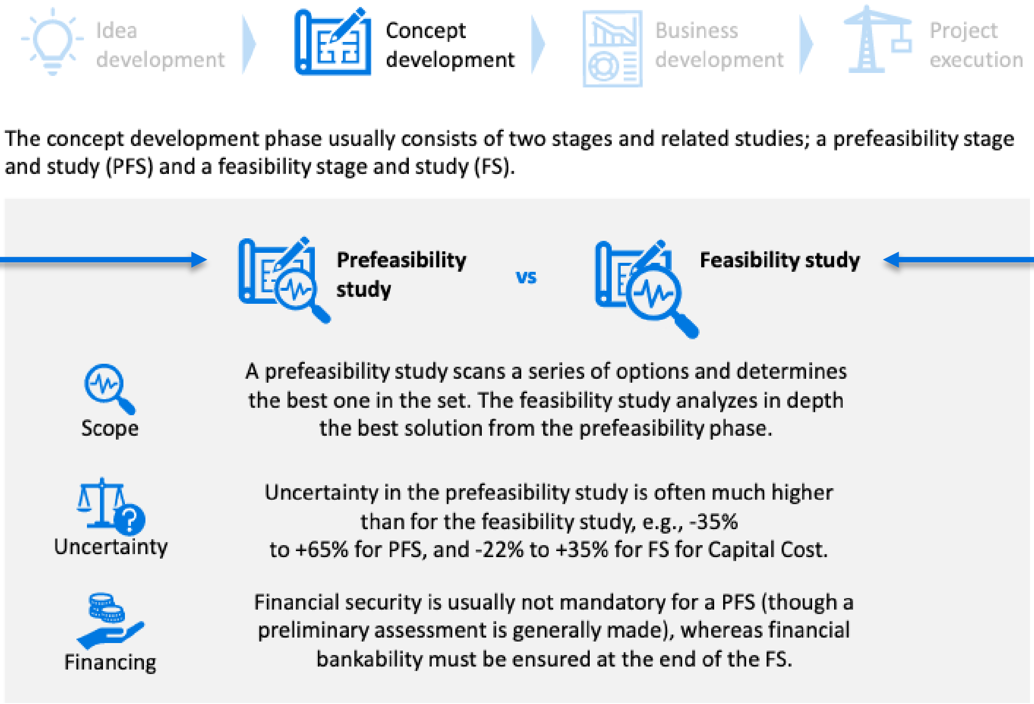
Developer Context: Project Development



Source(s): Danish Energy Agency Prefeasibility Study Guidelines

Developer Context: Project Development

RE Data Explorer can aide prefeasibility study & resource prospecting

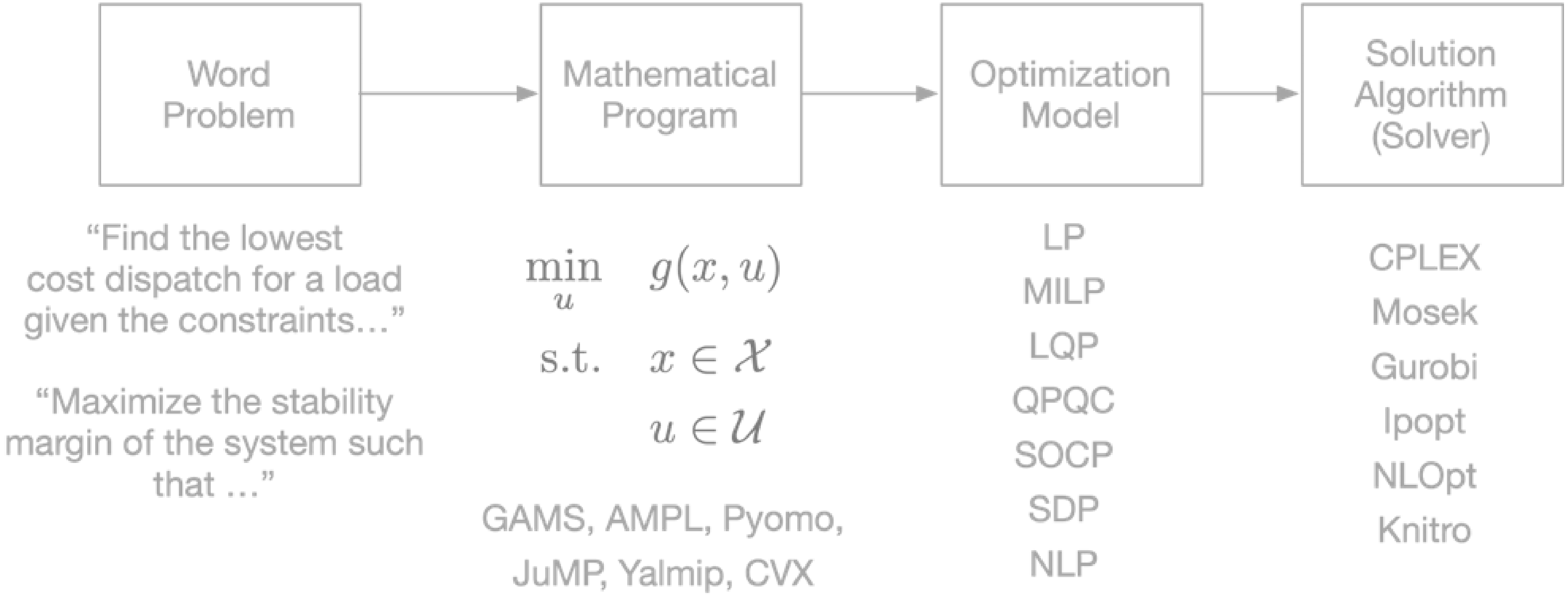


PCM can study impact of operations on project feasibility

- Bidding strategies
- Curtailment
- Local emissions displacement

Source(s): Danish Energy Agency Prefeasibility Study Guidelines

Structure of an Optimization Problem



Building PCM Problems

Cost Function: Linear, Polynomial, Piece-wise Linear.

Device and Branch Level Model: Generator Limits, Storage Capacity, Branch Power Flow.

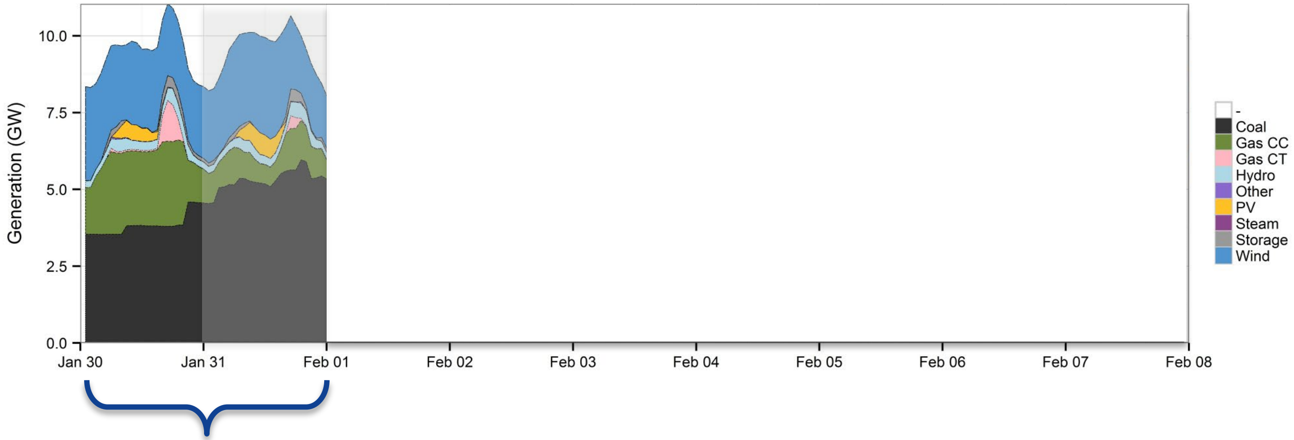
Network Model: Copper plate model or nodal flow balance.

Services Model: Reserves, Area Exchanges, Reactive Power Control Areas.

Feedforward Model: Reserves Commitments, Area Exchanges, Reactive Power Control Areas.

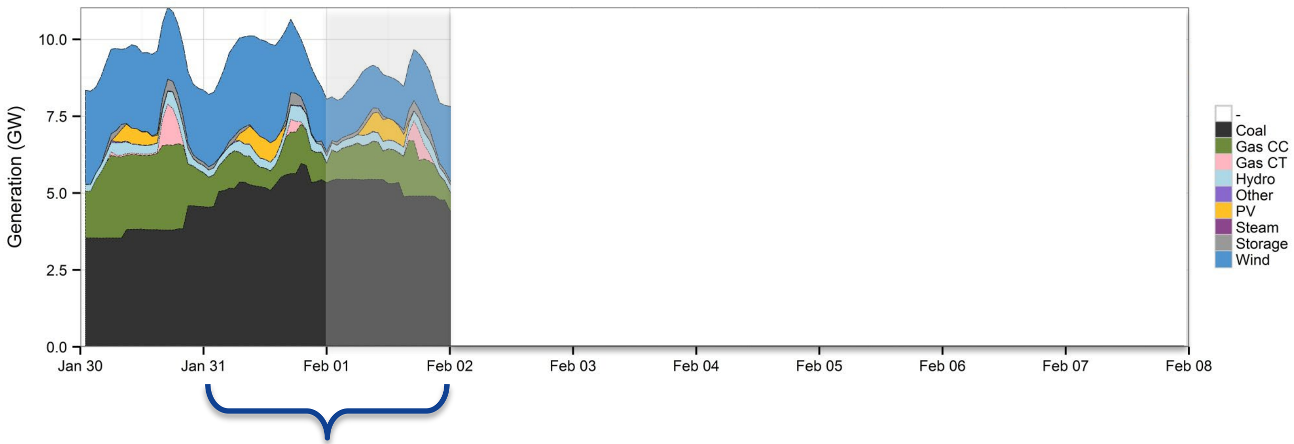
$$
\begin{aligned}
f^k(\cdot) = \min_{\vec{u}_t^k} \quad & C_{f_k}(\vec{u}_t^k) \\
\text{s.t.} \quad & H_{f_k}^D\left(\vec{u}_t, \vec{u}_{t-1}, \vec{x}_{t-1}, \vec{\rho}_t, \Phi^k | t\right) \leq 0 \\
& H_{f_k}^B\left(\vec{u}_t, \vec{u}_{t-1}, \vec{x}_{t-1}, \vec{\rho}_t, \Phi^k | t\right) \leq 0 \\
& H_{f_k}^N\left(\vec{u}_t, \vec{u}_{t-1}, \vec{x}_{t-1}, \vec{\rho}_t, \Phi^k | t\right) = 0 \\
& H_{f_k}^S\left(\vec{u}_t, \vec{u}_{t-1}, \vec{x}_{t-1}, \vec{\rho}_t, \Phi^k | t\right) \leq 0 \\
& H_{f_k}^F\left(\vec{u}_t, \vec{u}_{t-1}, \vec{x}_{t-1}, \vec{\rho}_t, \Phi^k | t\right) \leq 0
\end{aligned}
$$

Unit commitment and economic dispatch



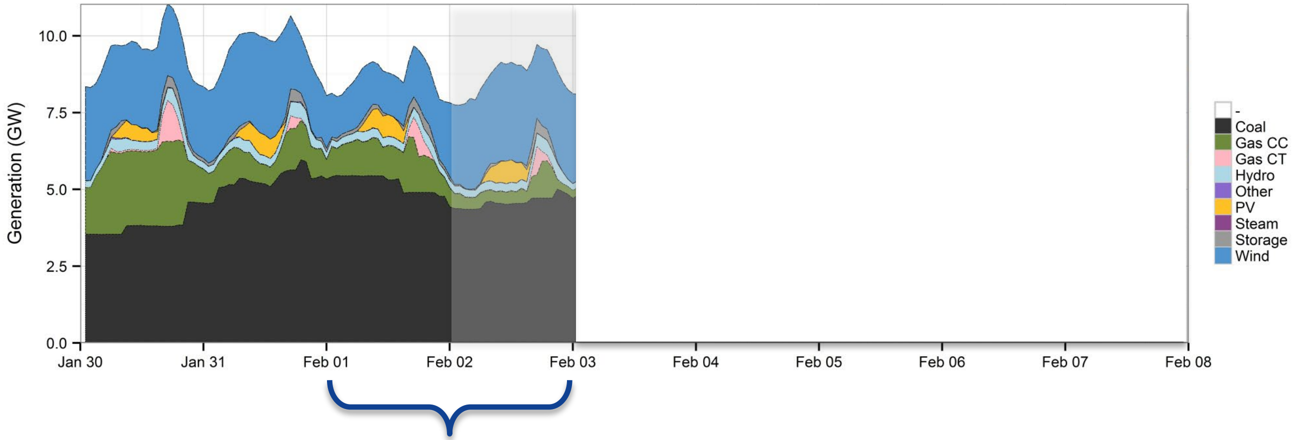
optimization horizon:
48 hours

Unit commitment and economic dispatch



rolling forward in
24 hour increments

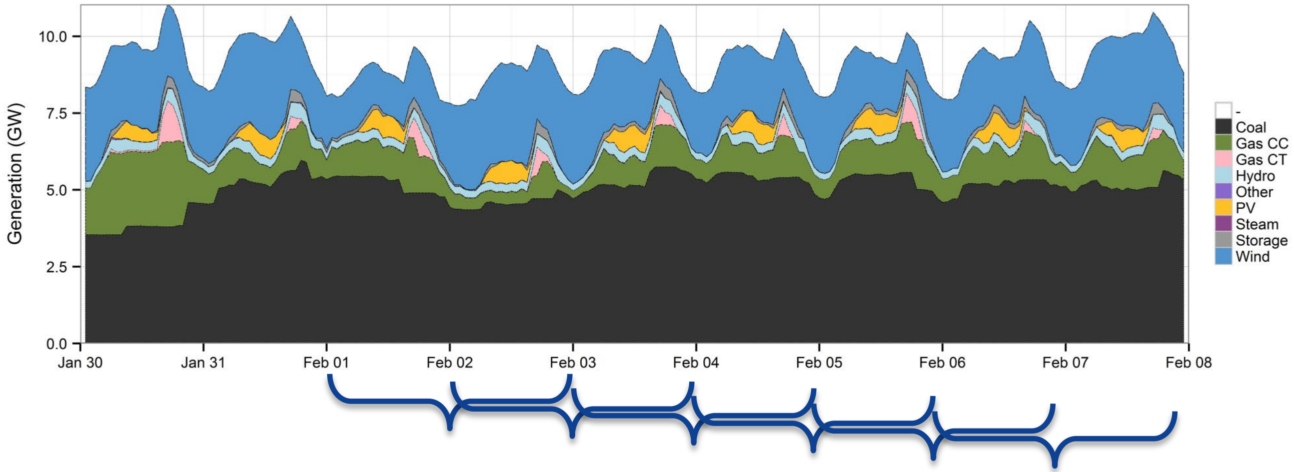
Unit commitment and economic dispatch



The state of the system at time t=0 is dependent on:

1. Generator commitment status: on/off
2. If "on": hours of continuous operation; current ramp rate
3. If "off": hours since last operation (minimum shut down duration)

Unit commitment and economic dispatch



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

Data Needs for PCM

See the VRE Guidebook for Practitioners (page 52) for a complete list of data requirements for PCM modeling.

Generator data:
- Bus location
- Minimum/maximum power levels
- Ramp limits
- Thermal plants:
  - Fuel type and heat rate curve
  - Minimum up time/down time
- Hydro plants:
  - Reservoir or river-flow data
- Storage plants:
  - Energy capacity
  - State-of-charge limits
- Eligible reserve categories
- Fuel cost data or market bids

System/operator data:
- Reserve categories and requirements

Transmission network data:
- Bus and branch topology
- Bus voltage level
- Line power flow limits
- Line reactance

Time-series data:
- Time-coincident load, wind, and solar time-series
  - Power data *or* resource data + a model
  - Hourly and/or sub-hourly resolution
  - Plant/bus, zonal, or area spatial resolution
- Require 2 time-series data sets to model forecast uncertainty using UC/ED:
  1. Forecast posted day-ahead, hour-ahead, 5-minute-ahead, etc.
  2. Realizations

Open-Source Data for PCM

Historical time-series data:

- RE Data Explorer Southeast Asia Wind data, Asia/Pacific Himawari and Puerto Rico Solar data
- National Solar Radiation Database (NSRDB)
- Wind Integration National Dataset Toolkit (North America)
- System operators often post historical hourly demand (for example, National Grid Corporation of the Philipines Operations Data)

Historical and real-time weather forecasts:

- European Centre for Medium-Range Weather Forecasts

Cost data:

- NREL Annual Technology Baseline (US)

Transmission network data:

- BetterGrids
- DR POWER
- openmod
- Texas A&M University synthetic networks

Plant operating characteristics:

- World Resources Institute Global Power Plant Database
- Industry and academic publications, such as IRENA's Flexibility in Conventional Power Plants brief
- US EPA National Electric Energy Data System (NEEDS)
- US EIA Form 923 and Form 923

Open-Source Tools for PCM Development

NREL System Advisor Model (SAM) and Sienna

Today's Workflow

REexplorer
MAPPING OUR ENERGY FUTURE

High-fidelity resource data
+
Plant Specifications
+
Plant Losses

System Advisor Model (SAM)

Electricity Production
+
Costs, Compensation, Financing, Incentives
=
Levelized Cost of Energy (LCOE), Net Present Value, Payback Period

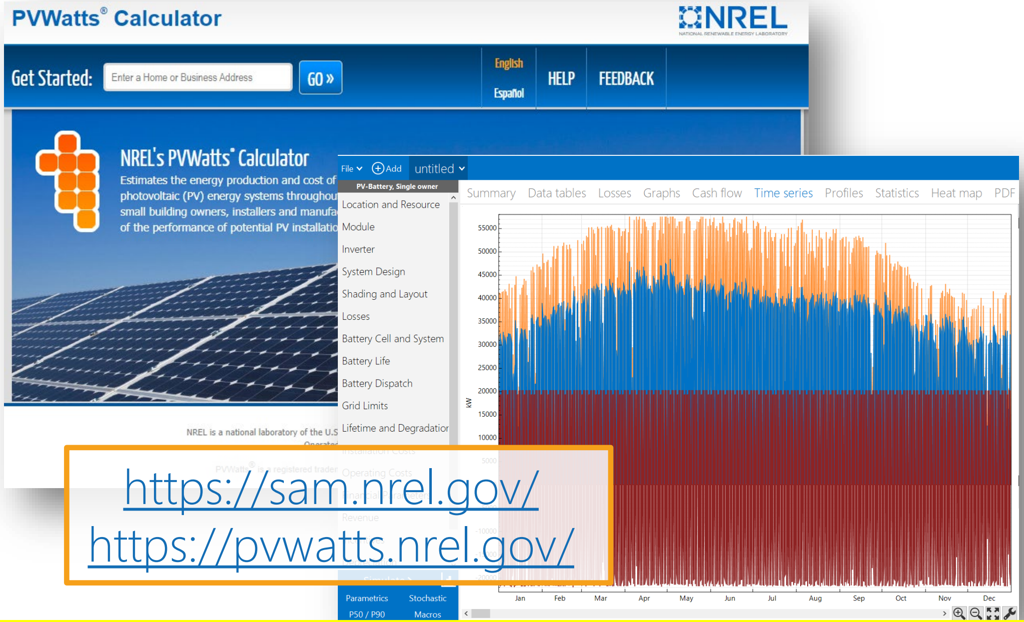
Thermal Generator Data
+
Transmission Constraints
+
Demand Time-Series

Sienna\Ops

Results
Hourly Locational Marginal Prices (LMPs), Transmission Line Flows Generator Set Points, RE curtailment

System Advisor Model (SAM)

Free software that enable detailed performance and financial analysis for renewable energy systems



- ✓ Open-source code
- ✓ Extensive documentation and user support
- ✓ Evaluate financial metrics for different markets
- ✓ Parametric and uncertainty analysis
- ✓ View and export key results

Overview of SAM Capabilities

Technologies

- Photovoltaics
- Battery Storage
- Wind power
- Concentrating solar power
- Marine energy and tidal systems
- Fuel cells
- Geothermal
- Biomass
- Solar water heating

Financial Models

- Behind-the-meter
  - Residential, Commercial
  - Third-party ownership
- Power purchase agreements
  - Single owner
  - Equity flips
  - Sale-leaseback
- Merchant plants
- Simple LCOE calculator

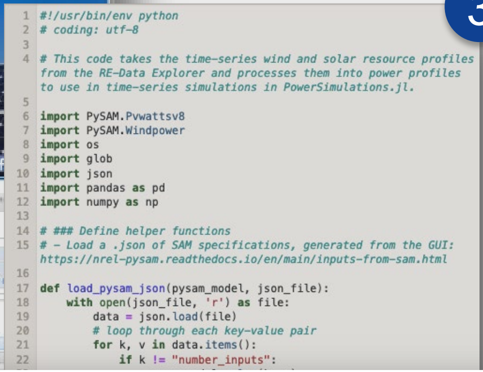
Accessing SAM

Online through the [PVWatts® Calculator]
- *For quick ballpark calculations*

1

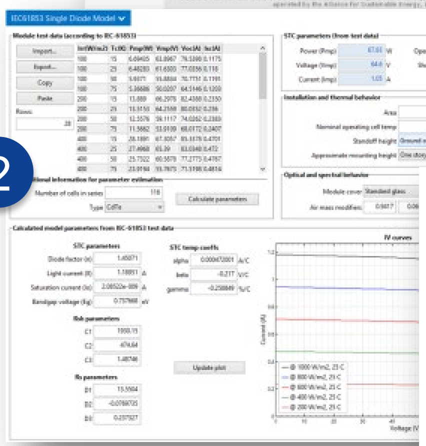
[Programmatically]
- *To develop your own application around SAM or run SAM through Python*

3



2

[Download the GUI]
- *For detailed modeling of individual plants*



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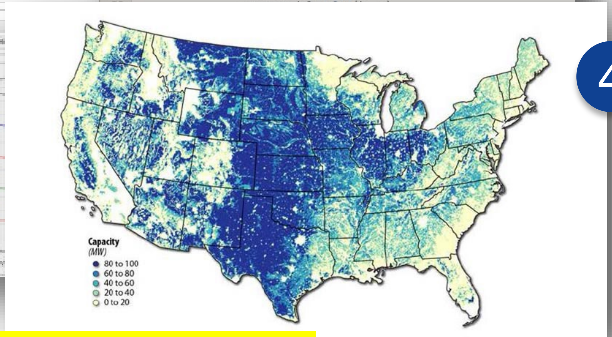
Through [reV, the Renewable Energy Potential Model]
- *For very large batch processing and scenario development*



Open-source ecosystem for power system modeling, simulation and optimization

Sienna\Data

Efficient intake and use of energy systems input data

Formerly known as SIIP

https://github.com/NREL-Sienna

Developed to support modeling with large shares of inverter-based sources

Sienna\Ops

Simulation of system scheduling, including sequential problems for production cost modeling

Sienna\Dyn

Simulation of power system dynamic response to disturbances and contingencies

Sienna in Julia

Sienna's three core applications use combinations of packages in the Julia Programming Language

Sienna\Data

Input data intake and handling

PowerSystems.jl
PowerSimulations.jl
PowerGraphics.jl
PowerNetworkMatrices.jl
PowerSystemsCaseBuilder.jl

Sienna\Ops

System scheduling simulations

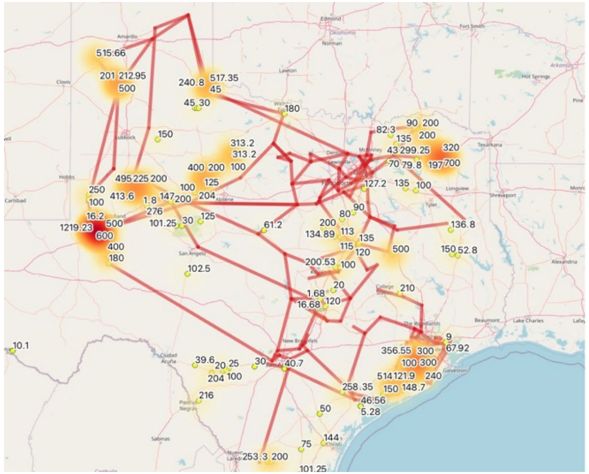
PowerSystems.jl
PowerSimulations.jl
PowerFlows.jl
PowerAnalytics.jl
PowerGraphics.jl

Sienna\Dyn

Dynamic response simulations

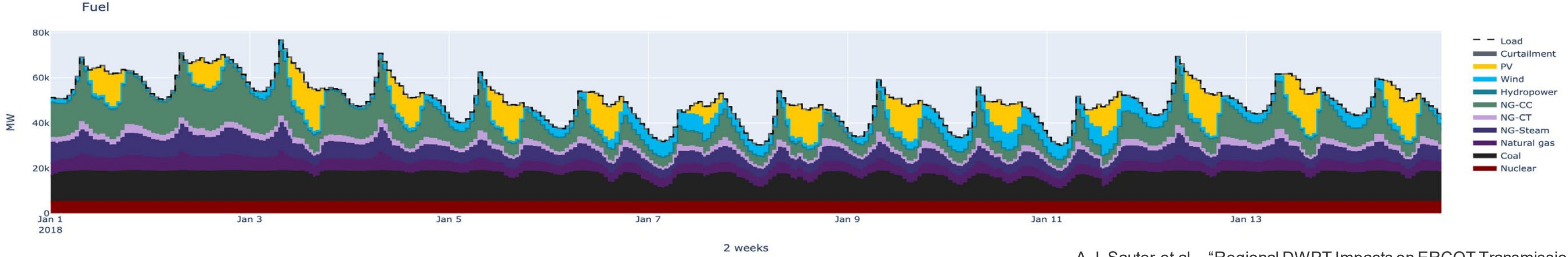
PowerSystems.jl
PowerSimulationsDynamics.jl
PowerGraphics.jl

Sienna\Ops: PCM for Large Systems



Generator Type	Installed Capacity Original System [MW]	Installed Capacity Modified System [MW]
PV	938.04	21,031.9
Gas Turbines	76,572.1	76,572.1
Steam Turbines	23,568.2	23,568.2
Hydro	1,326.72	15,81.22
Wind Power	15,089.0	14,755.4

The system achieves up to 45% instant penetration of solar power at certain hours of the day.

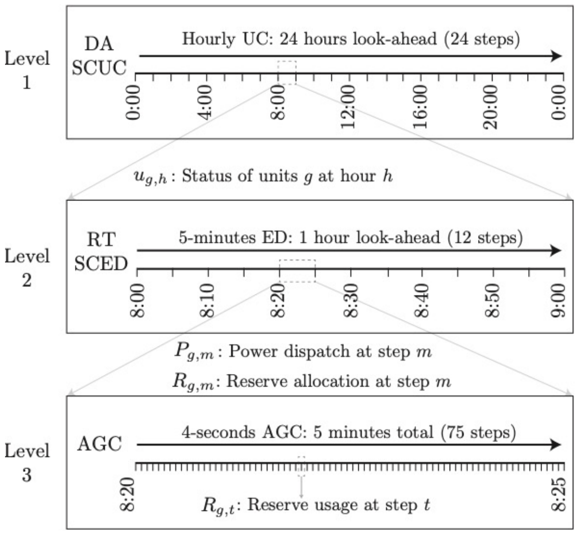


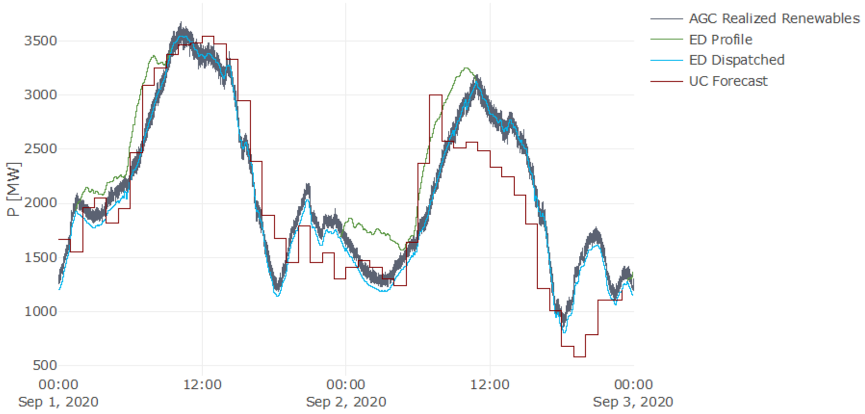
A.J. Sauter et.al. . "Regional DWPT Impacts on ERCOT Transmission System and Operation Cost." Submitted to Applied Energy

Automatic Generation Control

How effective are reserve requirements, market designs, and generator controls at handling wind, solar, load, and generator availability forecast errors to maintain supply/demand balance?

- Enables the assessment of system reliability
- Improves upon the scalability and PCM integration of existing state-of-the-art
- System performance evaluation capabilities
  - Reserve product adequacy
  - Ancillary service provision from emerging technologies
  - Forecasting techniques
  - Market design

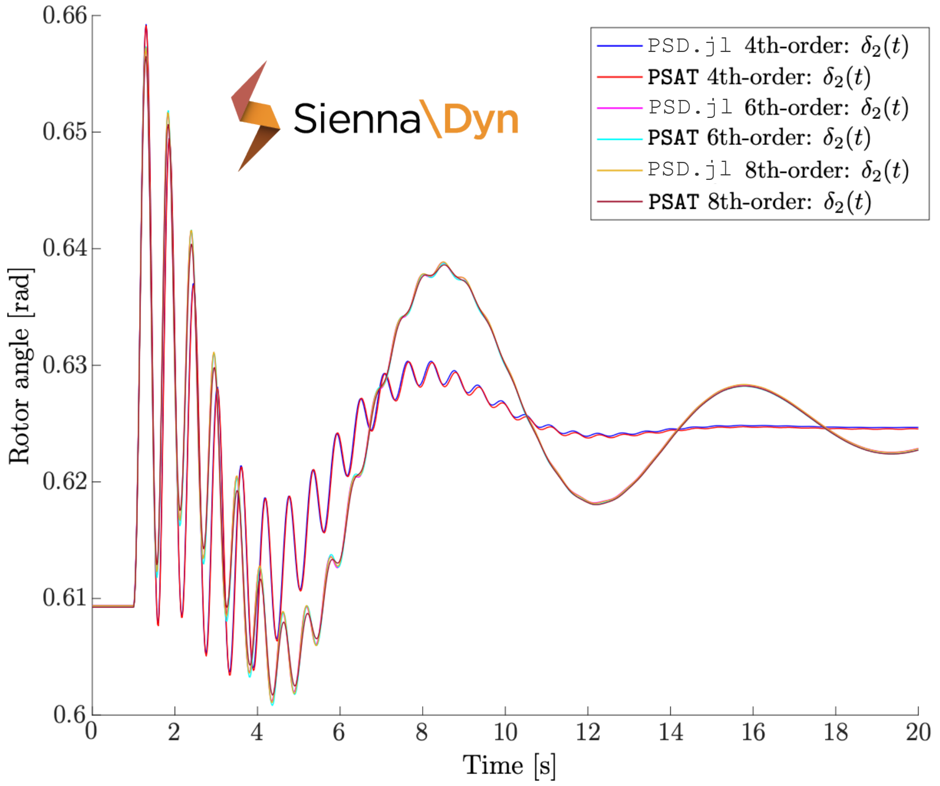




Transient Stability phasor EMT

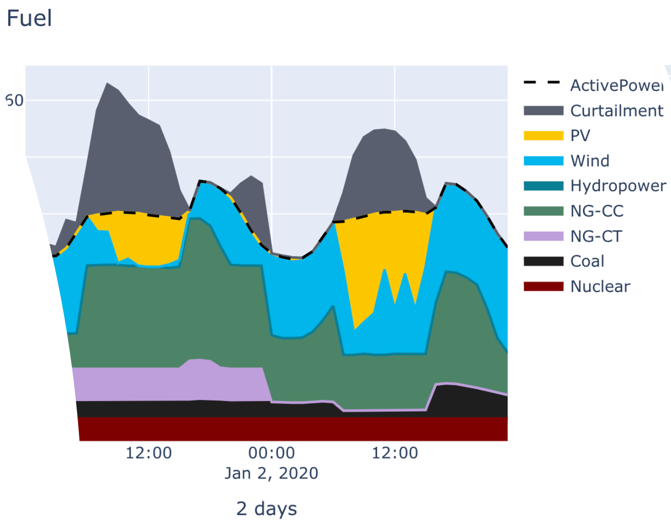
Is the system stable against perturbations from setpoint transitions, fluctuations in generator and demand injections, and contingencies?

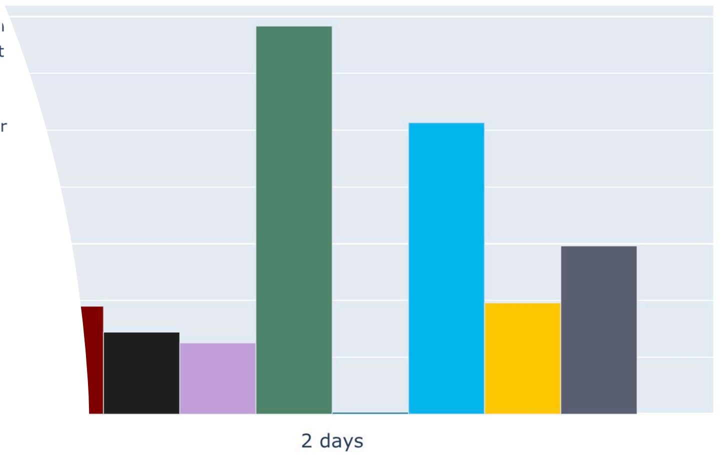
- Existing commercial tools can address these questions for select models and under a fix set of solution algorithms.
- Sienna\Dyn provides a scalable solution (open-source) to assess stability under evolving (low-inertia) grid conditions.

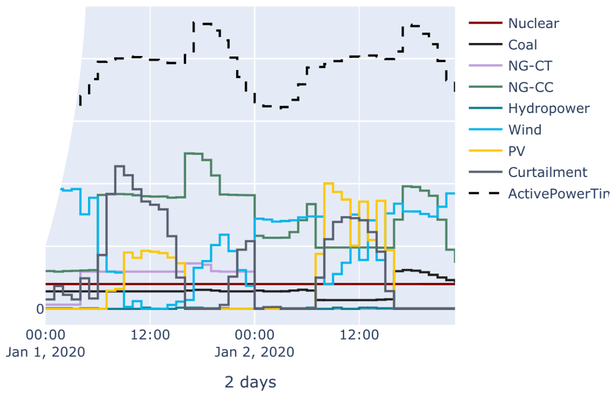


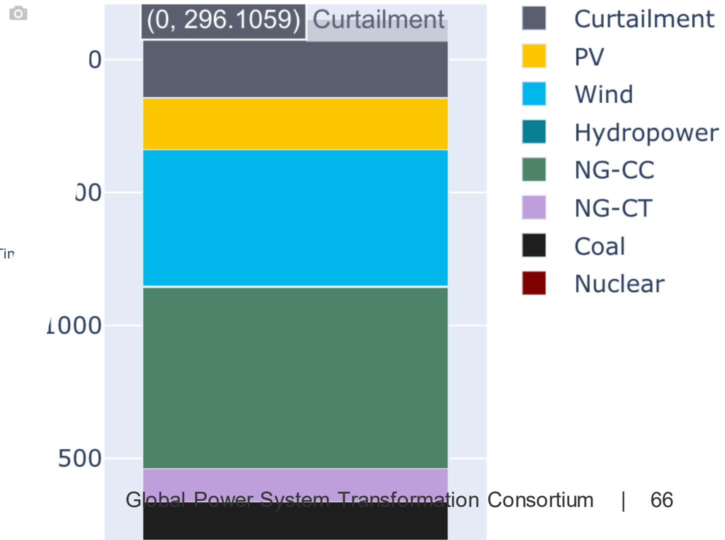
Visualizations with PowerGraphics.jl

- **Plot types:** bar, stack, line, (coming soon: networks)
- **Data:** System, Operations results, (coming soon: dynamics results)
- **Backends:** GR (static), PlotlyJS (basic interactivity)

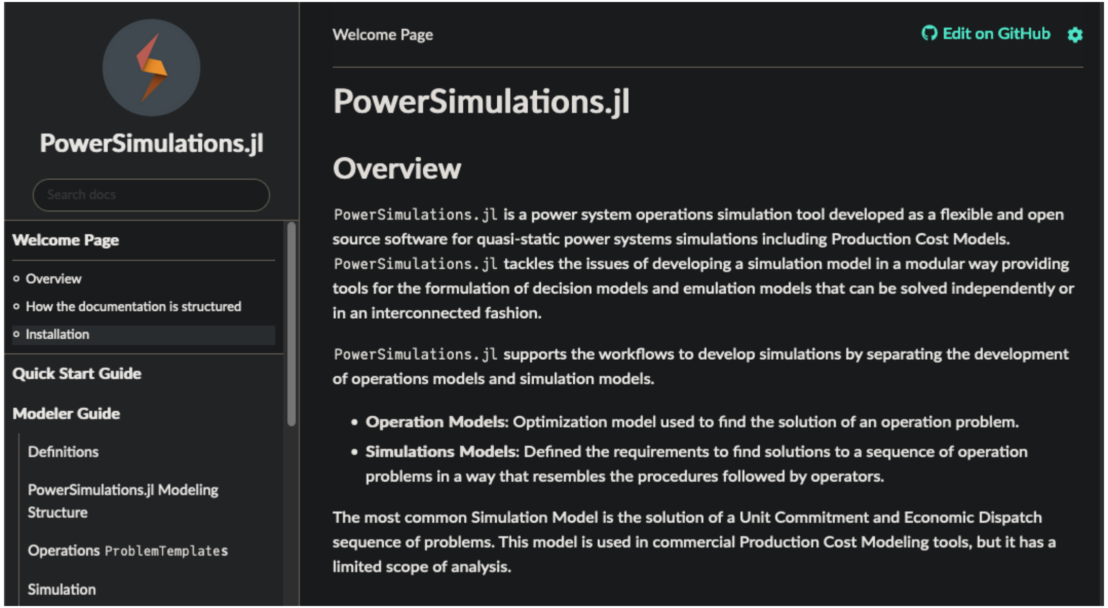








Sienna Resources



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

Other Open-Source Planning Tools

Production cost modeling:

- GridPath

Capacity Expansion:

- Caliope/Engage
- Switch
- GenX.jl
- ReOpt
- PyPSA

Load flow:

- MATPOWER
- PANDAPOWER
- PowerModels.jl

Dynamics:

- Sienna\Dyn (PowerSimulationsDynamics.jl)
- ANDES
- PowerDynamics.jl
- Dynawoo

Distribution scale:

- OpenDSS
- GridLab-D
- PowerModelsDistribution.jl

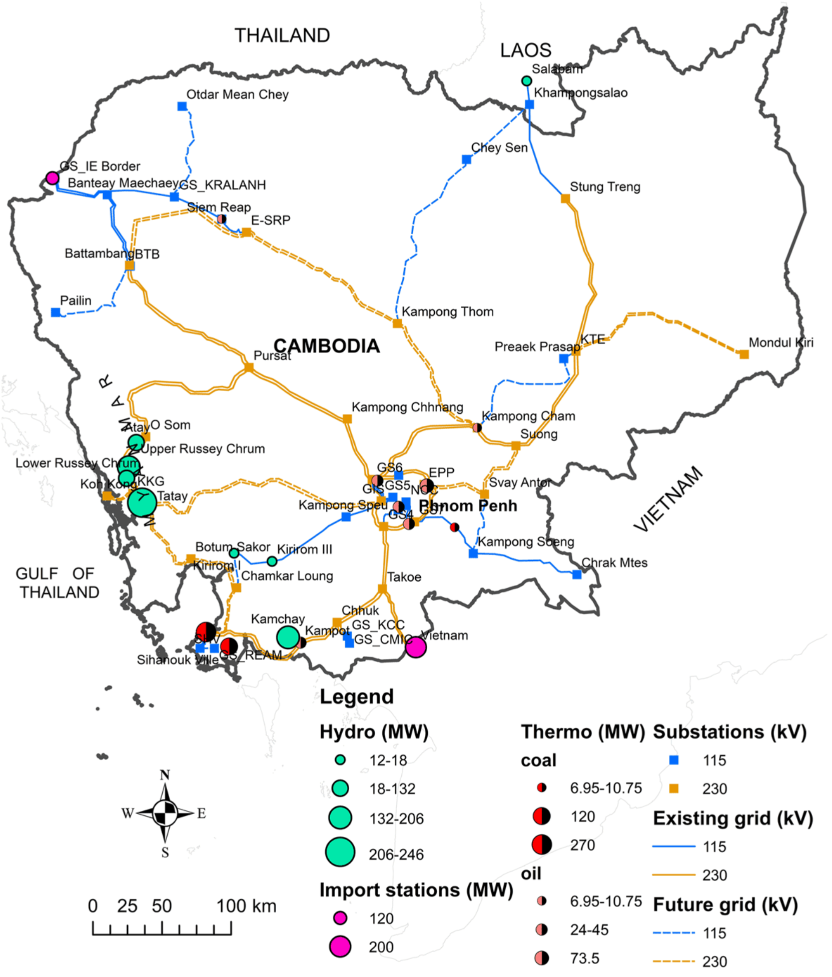
See https://g-pst.github.io/tools/

Synthesis and Wrap-Up

Key Takeaways

- 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

Case Study: Cambodia



PowNet (2021):

- Open-source, hourly-resolution operational model
- Includes transmission lines and generators
- https://github.com/Critical-Infrastructure-Systems-Lab/PowNet

Next Session

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

Preparing for Tomorrow's Session (Optional)

- The code for the case study production cost modeling demonstration is available on Github: https://github.com/NREL-Sienna/PSI-Cambodia
- An explanation of the demonstration is available in the PSI-Cambodia README, including some of the installation instructions below.
- **Instructions for installing software for the three open-source tools we will be using:**

1. RE-Data Explorer: Can be accessed online without any installation
2. System Advisor Model (SAM): We will run SAM in Python using the PySAM wrapper, as well as designing plant specifications in the SAM GUI:
   1. Download the SAM GUI
   2. Install Python
   3. Activate the environment as described in the PSI-Cambodia README (step 2.c in the README)
3. Sienna: Sienna is written in the Julia programming language
   1. Install Julia
   2. Activate the environment and run literate.jl as described in the PSI-Cambodia README (step 3 in the README)

- **For more information, visit Variable Renewable Energy Grid Integration Studies: A Guidebook for Practitioners.**

You can visit these resources at:

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

Q&A

Thank you!