21st Century POWER PARTNERSHIP
Accelerating the transformation of power systems

MODELING THE GRID INTEGRATION OF VARIABLE RENEWABLE ENERGY (VRE) RESOURCES

23 November 2018

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National Renewable Energy Laboratory (NREL)

NREL/PR-6A20-72957

CLEAN ENERGY MINISTERIAL
Accelerating the Transition to Clean Energy Technologies

NREL at a Glance

1,800

Employees,
plus more than
400
early-career researchers and visiting scientists

World-class
facilities, renowned technology experts

nearly 750

Partnerships
with industry, academia, and government

Campus
operates as a living laboratory

$872M annually

National economic impact

OUTLINE

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TRADITIONAL (~30 min)

- Overview of modeling tools, methods, and datasets that we traditionally/currently use

FORWARD-LOOKING (~40 min)

- What are we working on now?
- Where are we heading?

OVERVIEW OF MODELING TOOLS, METHODS, AND DATASETS THAT WE TRADITIONALLY/CURRENTLY USE

Some NREL Tools

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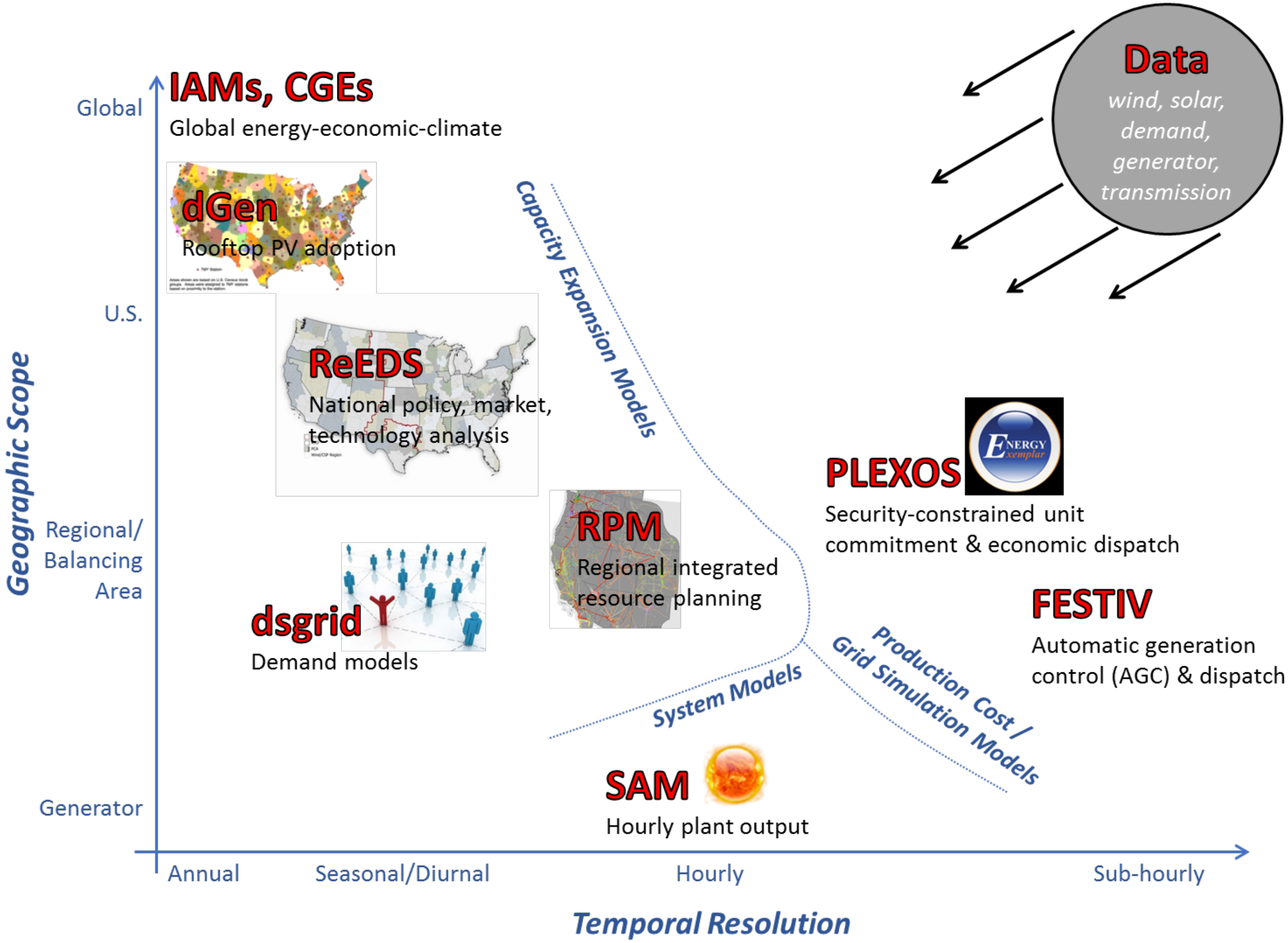
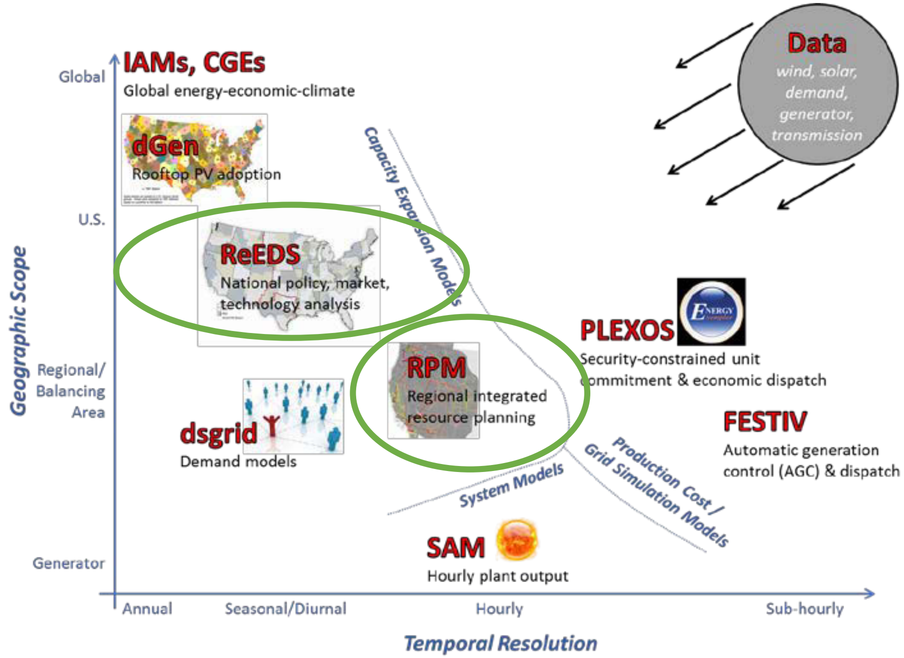


Capacity Expansion Models

- Regional Energy Deployment System (ReEDS)
- Resource Planning Model (RPM)



Regional Energy Deployment System (ReEDS)

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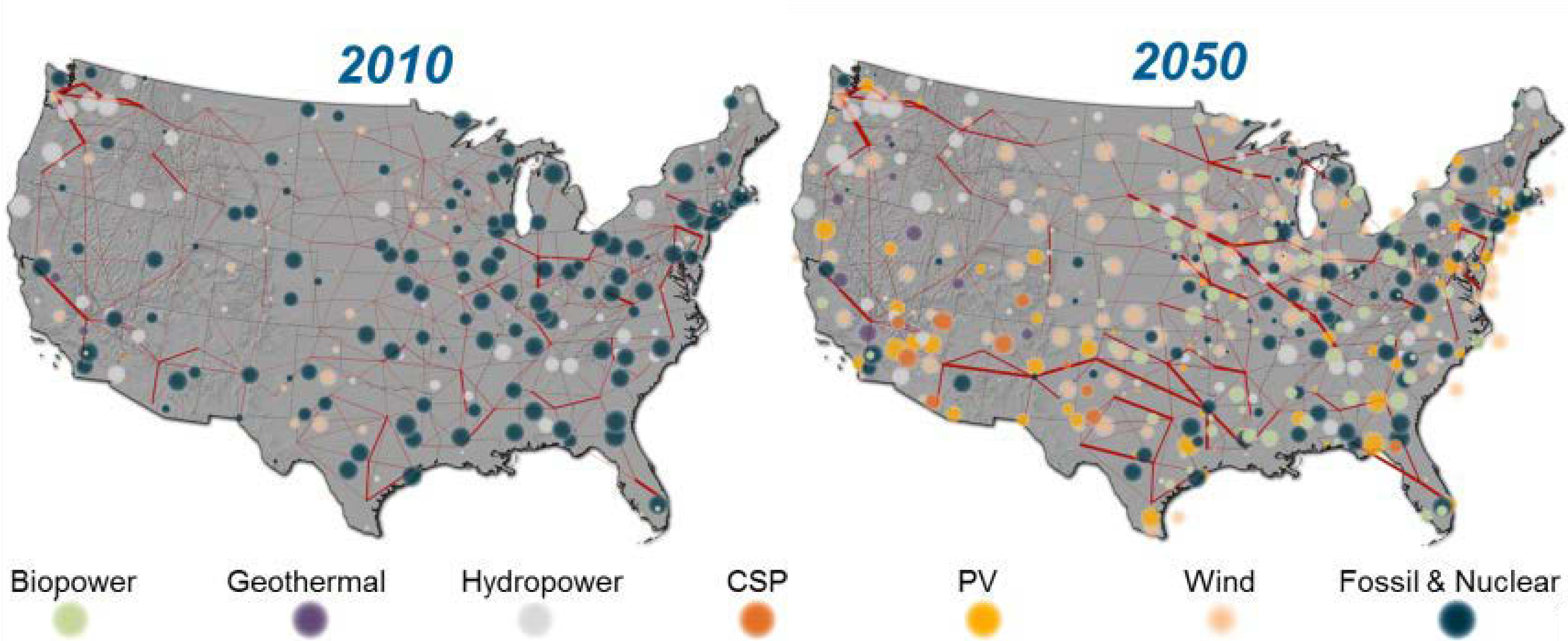

Source: Renewable Electricity Futures (2012)

Simulates the expansion and operation of the *North American* generation and transmission system given projections of load, fuel prices, technology costs and performance, and policies/regulations
https://www.nrel.gov/analysis/reeds

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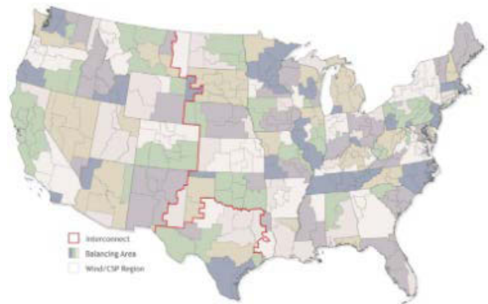
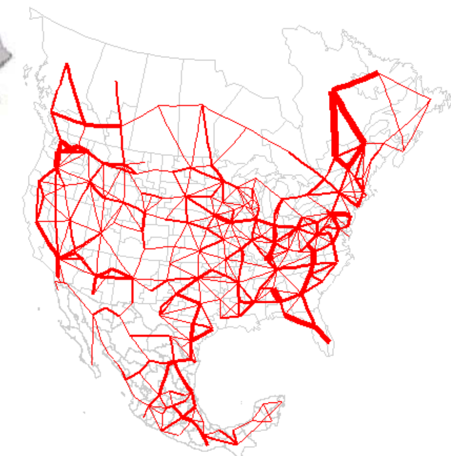
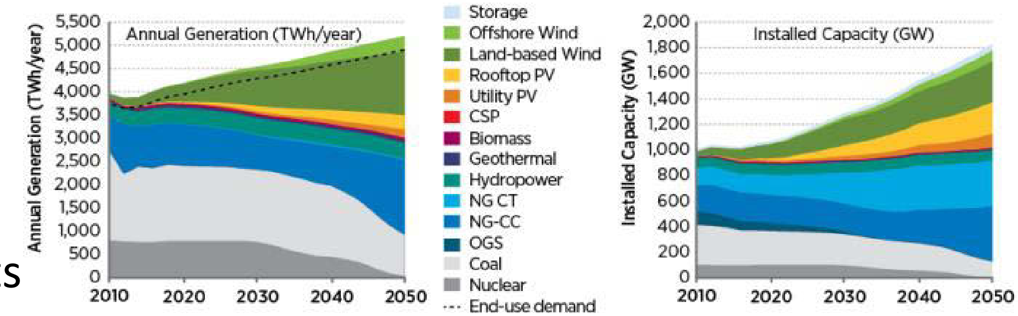
ReEDS Key Attributes

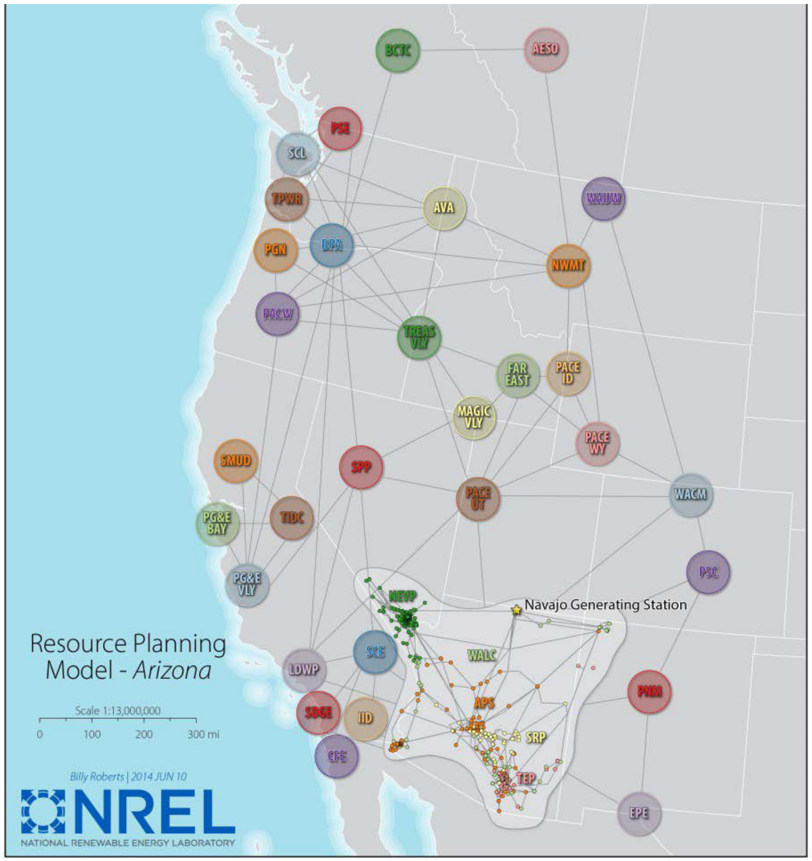
- **High spatial resolution** to represent transmission, RE resources and load:
  - 134 Balancing Areas (BAs), 356 renewable resource regions
- **High temporal resolution** to represent seasonal and diurnal variations in load and resources:
  - 17 time-slices for each year
- Detailed representation of challenges associated with **integration of variable resource renewables**:
  - curtailment and capacity value
- **Key outputs**: annual generator and transmission capacity builds/retirements dispatch, emissions, fuel consumption, electricity prices

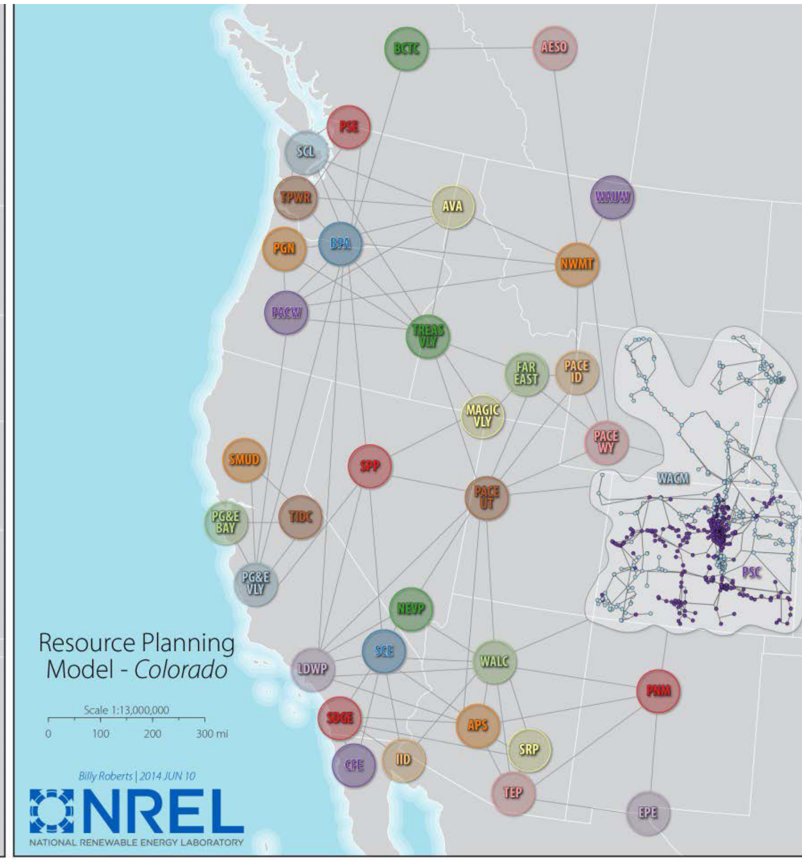






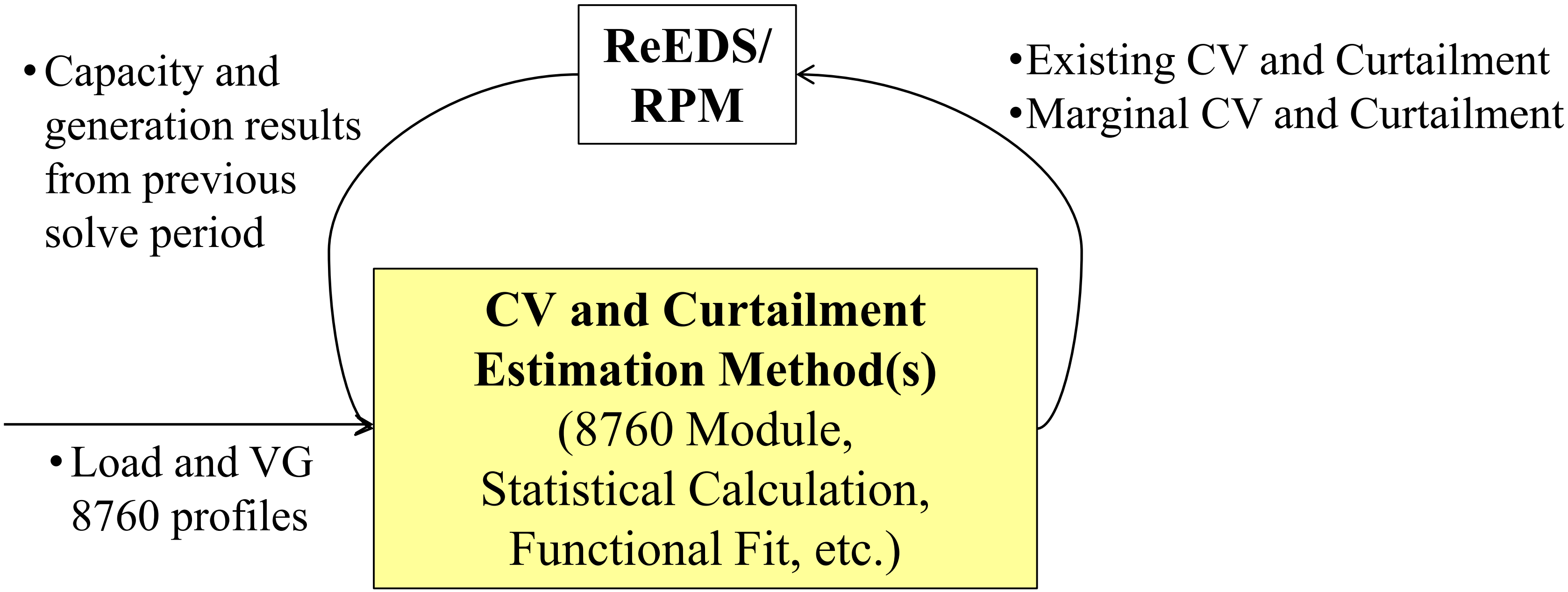
Resource Planning Model (RPM): mixed nodal/zonal model





http://www.nrel.gov/analysis/models_rpm.html

Capacity value (CV) and Curtailment



Distributed Resources and Demand-Side Tools

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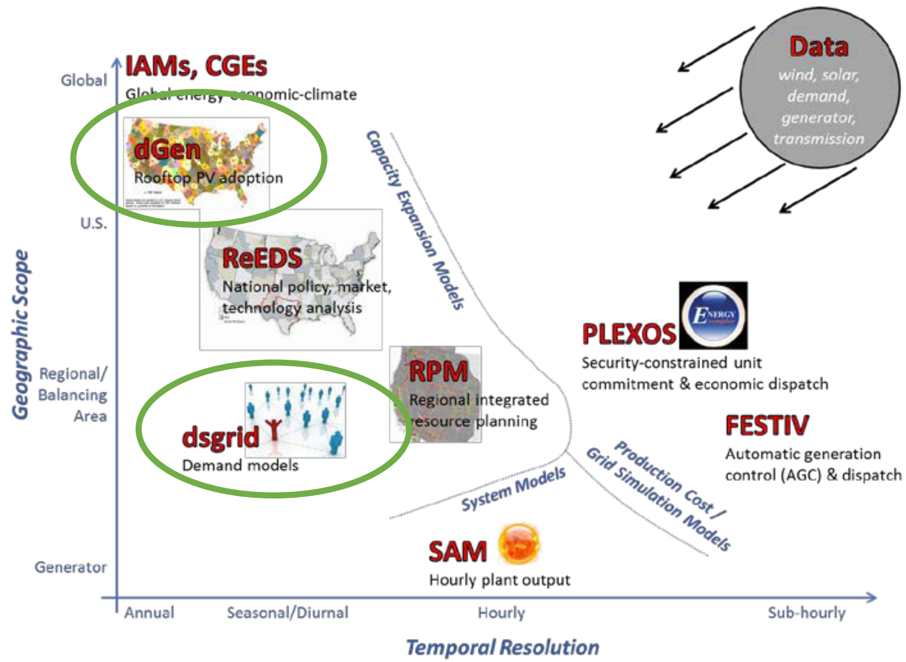
- dGen
  - NREL Point of Contact (POC): Ben Sigrin
- Demand-side grid (dsgrid)
  - NREL POC: Elaine Hale



THE DEMAND-SIDE GRID (DSGRID) MODEL CREATES HIGHLY RESOLVED TIME-SYNCHRONOUS LOAD DATA BY LEVERAGING SECTOR-SPECIFIC MODELING EXPERTISE

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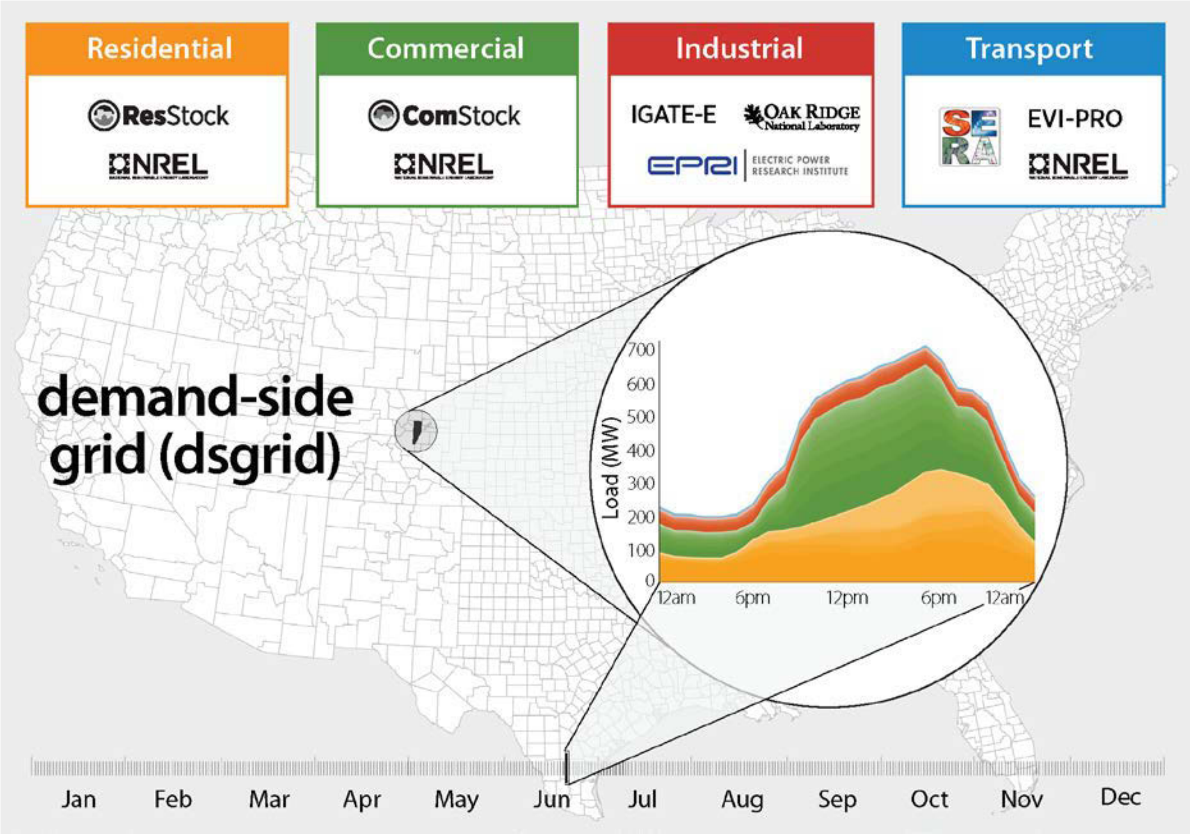
Bottom-up modeling of buildings, industry, and electric vehicles to enable:

- Future projections and what-if scenarios **for load shape** in addition to magnitude
- Realistic estimates of potential **load flexibility** (i.e., demand response)
- Understand **interactions** between energy efficiency and demand response potential (also renewables and DERs)



https://www.nrel.gov/docs/fy18osti/71492.pdf

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Distributed Technology Diffusion (dGen)

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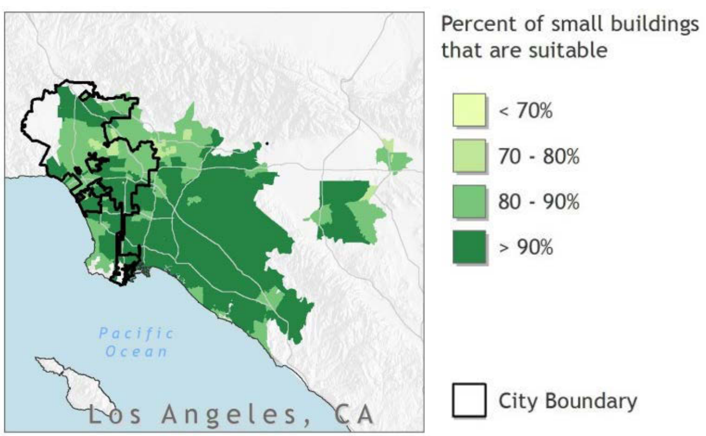
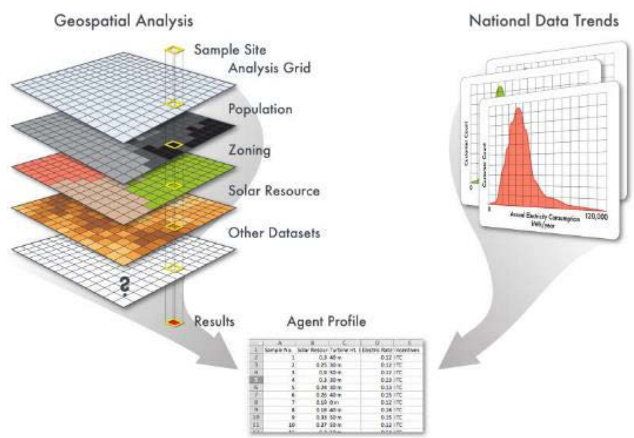
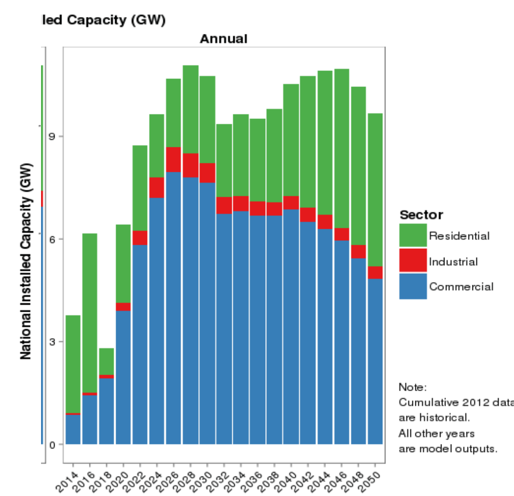
ReEDS and RPM do not estimate DG adoption. A separate model (dGen) is used.

- Forecasts customer adoption of distributed generation technologies (solar, storage, wind, geothermal) for residential, commercial, and industrial entities, given assumptions about future electricity costs, technology cost and performance, policy and regulation, and customer behavior
- High geographic resolution enables state, utility, or city-specific analysis with overlay of multiple spatial layers







https://www.nrel.gov/analysis/dgen/

REEDS (OR RPM)-DGEN LINKAGES

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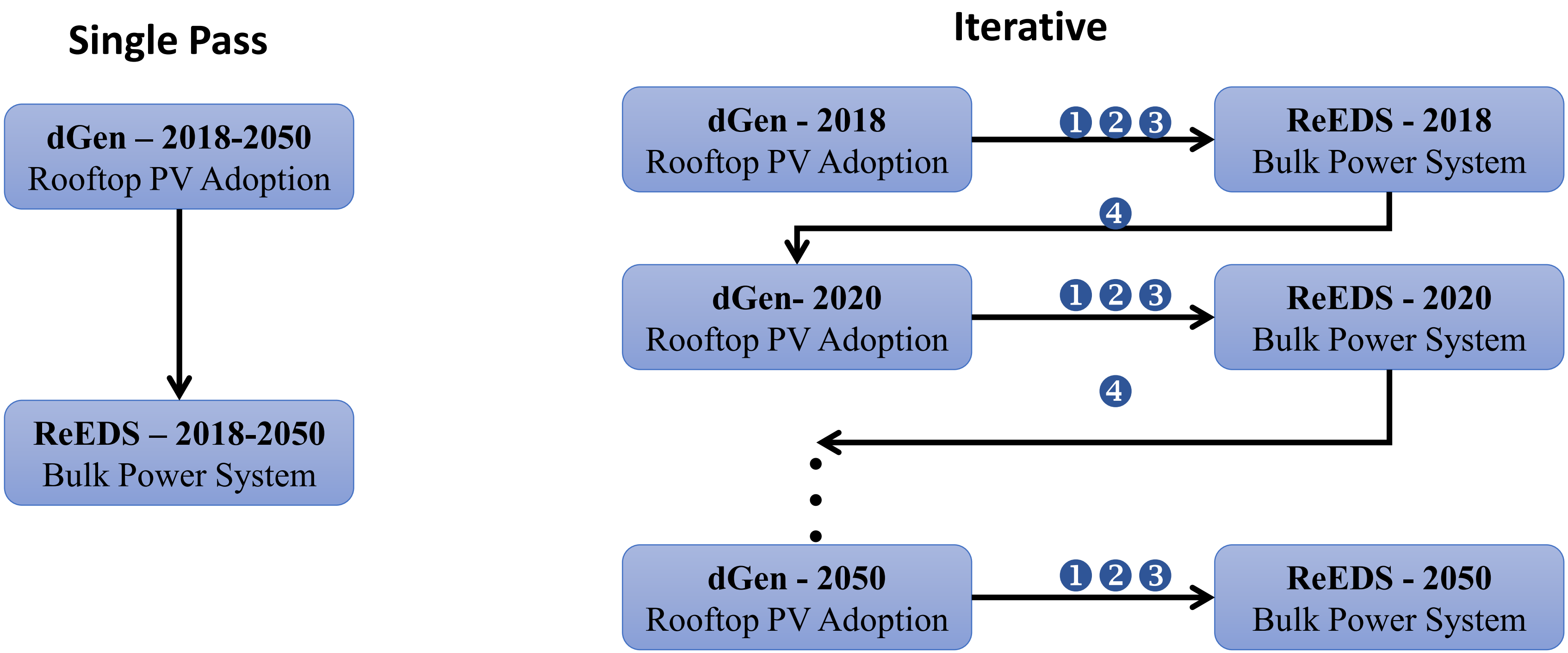
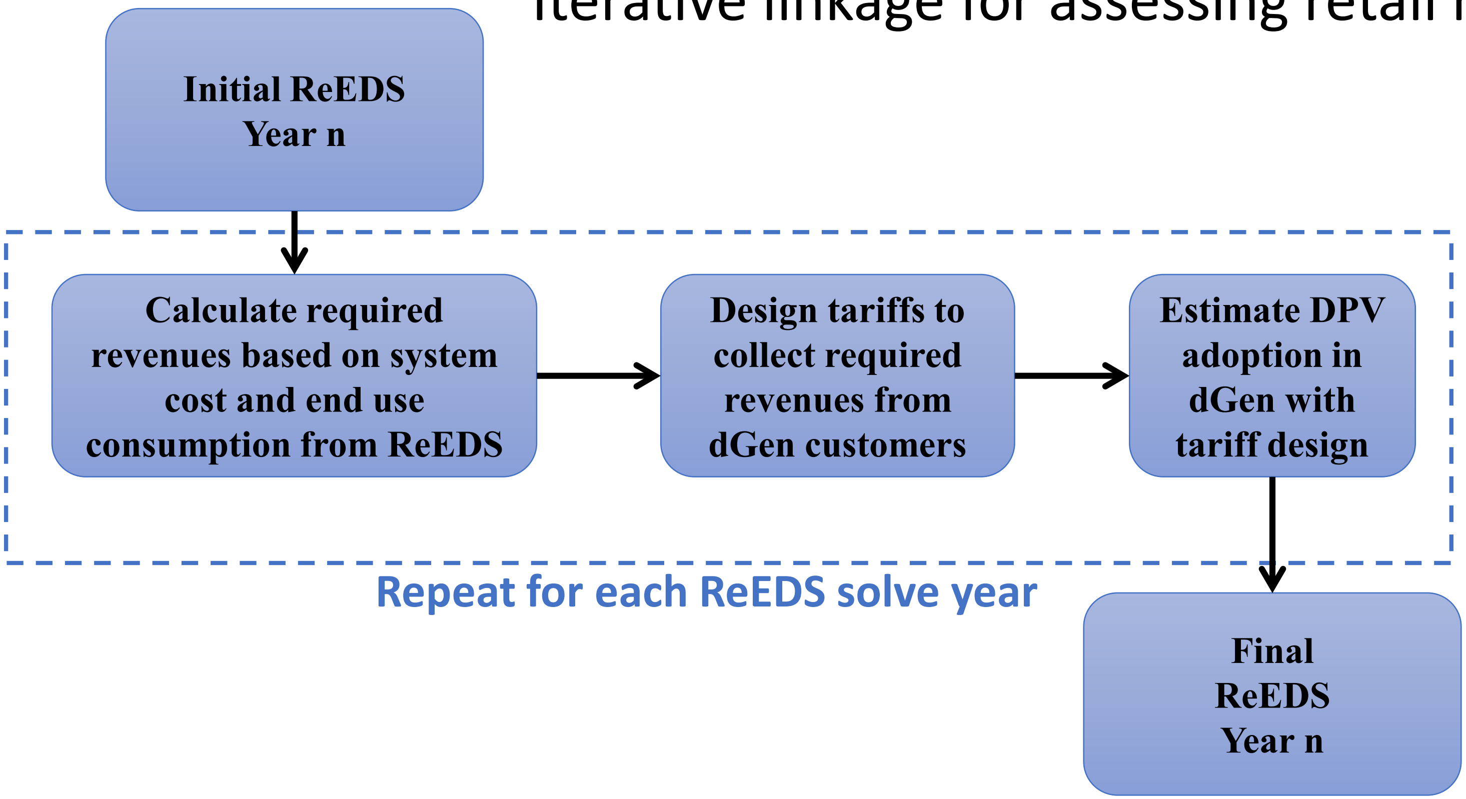


❶ Rooftop PV capacity by region
❷ Capacity factor by time slice
❸ Retail electricity prices of adopters
❹ Rooftop PV marginal curtailment rate

https://doi.org/10.1016/j.apenergy.2016.02.004

ReEDS (or RPM)-dGen Linkages

Iterative linkage for assessing retail rate impact



https://doi.org/10.1016/j.tej.2017.10.003

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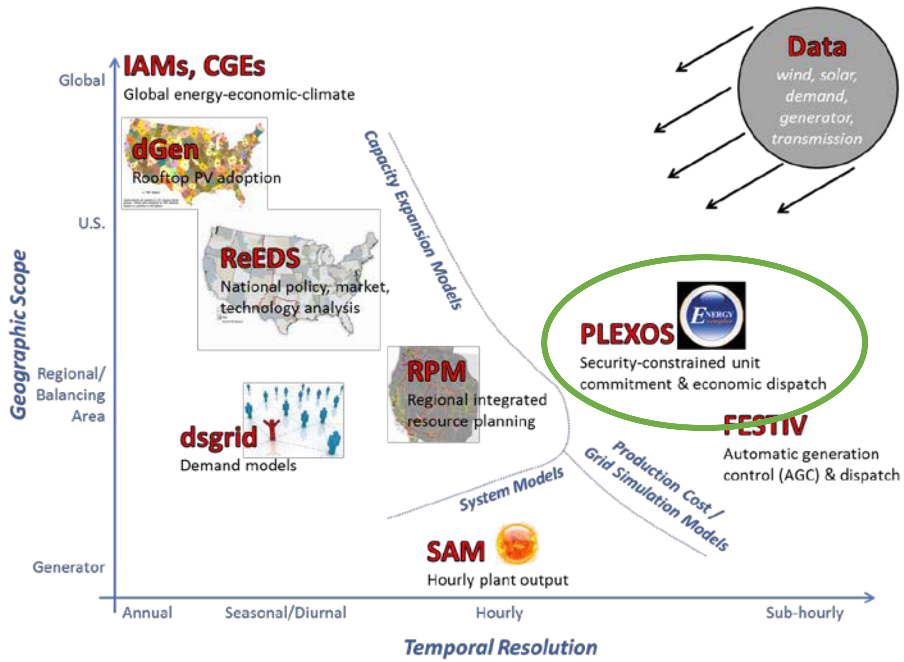
PLEXOS

NREL POC: Greg Brinkman



PLEXOS Production Cost Model

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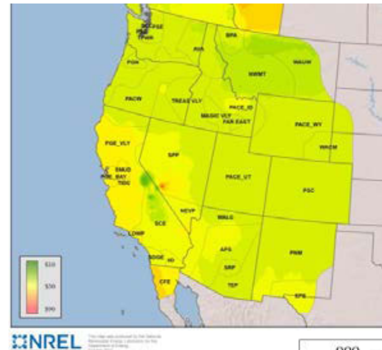
Hourly or subhourly chronological

Commits and dispatches generating units based on:

- Electricity demand
- Operating parameters of generators
- Transmission grid parameters

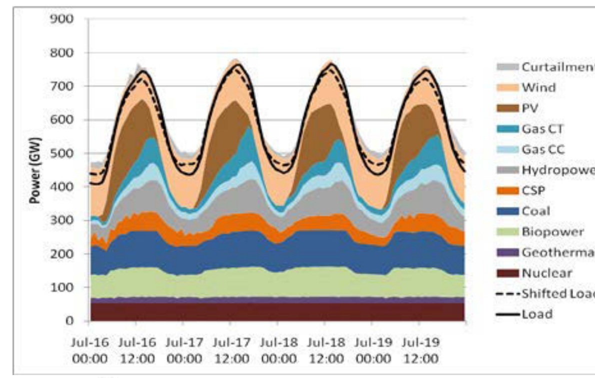
Used for system generation and transmission planning

- Increasingly used for real-time operation



Locational prices, production cost

Dispatch information, curtailment, fuel usage



Transmission congestion

MODEL LINKAGES: REEDS-TO-PLEXOS

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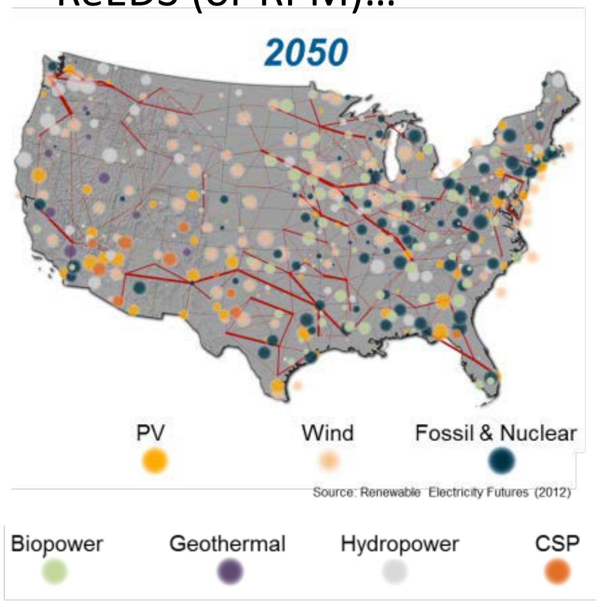
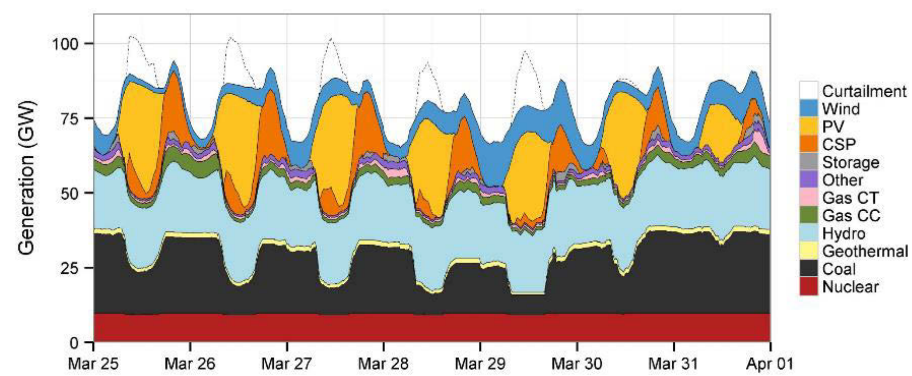
Take buildout from ReEDS (or RPM)…

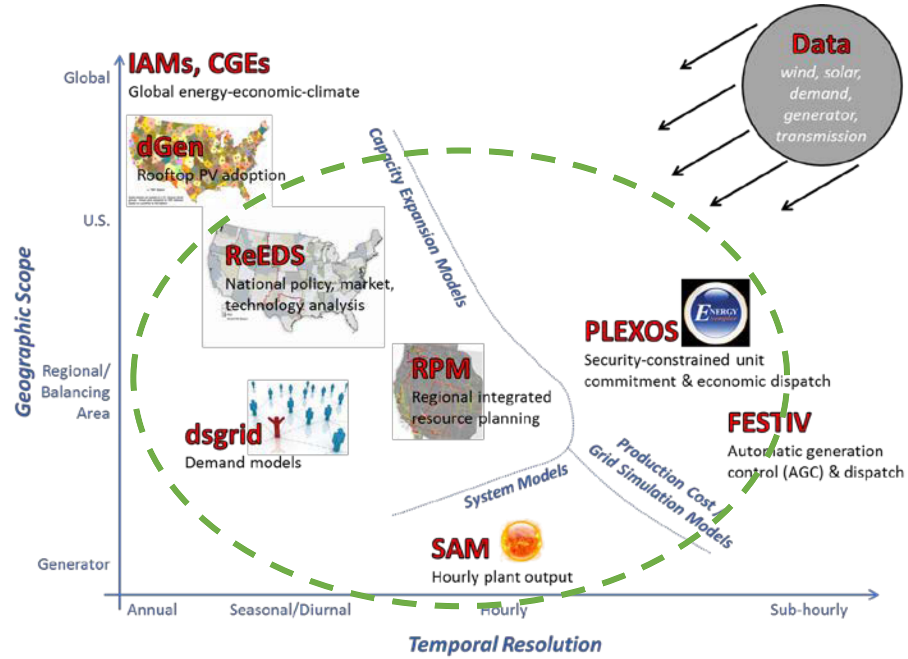


…and translate into operational database for PLEXOS



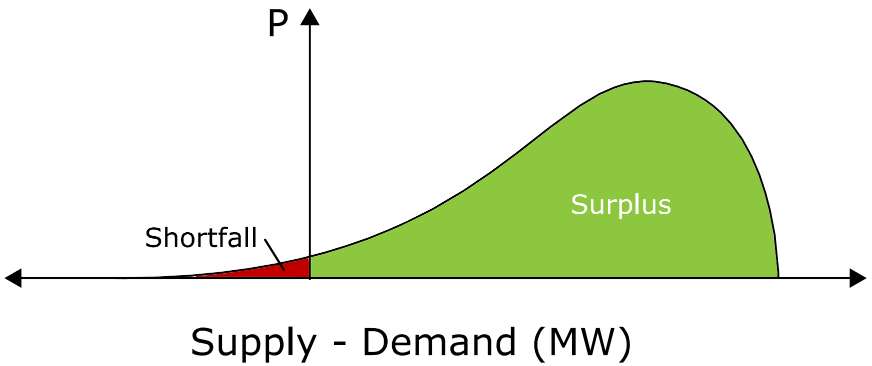
Resource Adequacy Assessment Tool

- Probabilistic Resource Adequacy Suite (**PRAS**)
  - Recently extended to include transmission network outages
  - Currently developing capability to capture energy-limited resources, such as storage and responsive demand
  - NREL POC: Gord Stephen



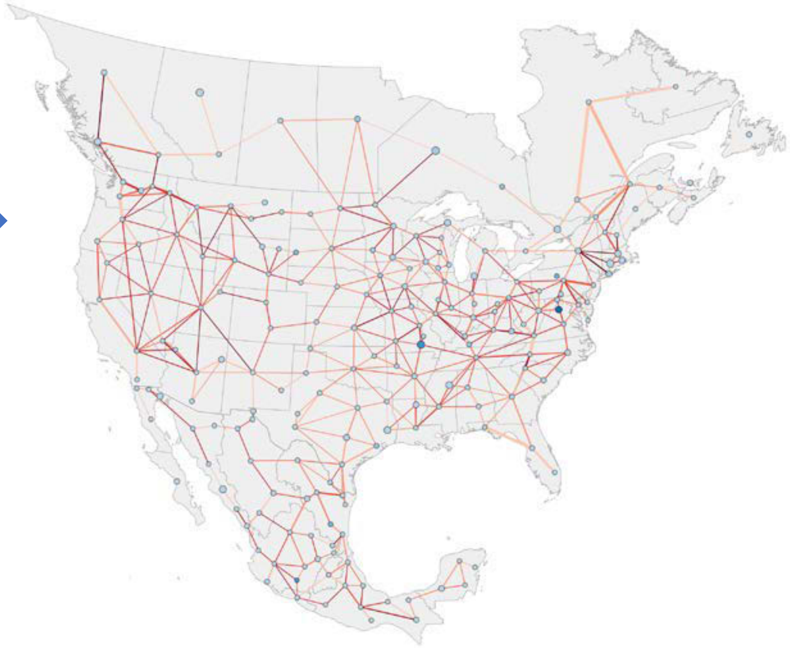
PRAS

Simple single-region, single-period analysis



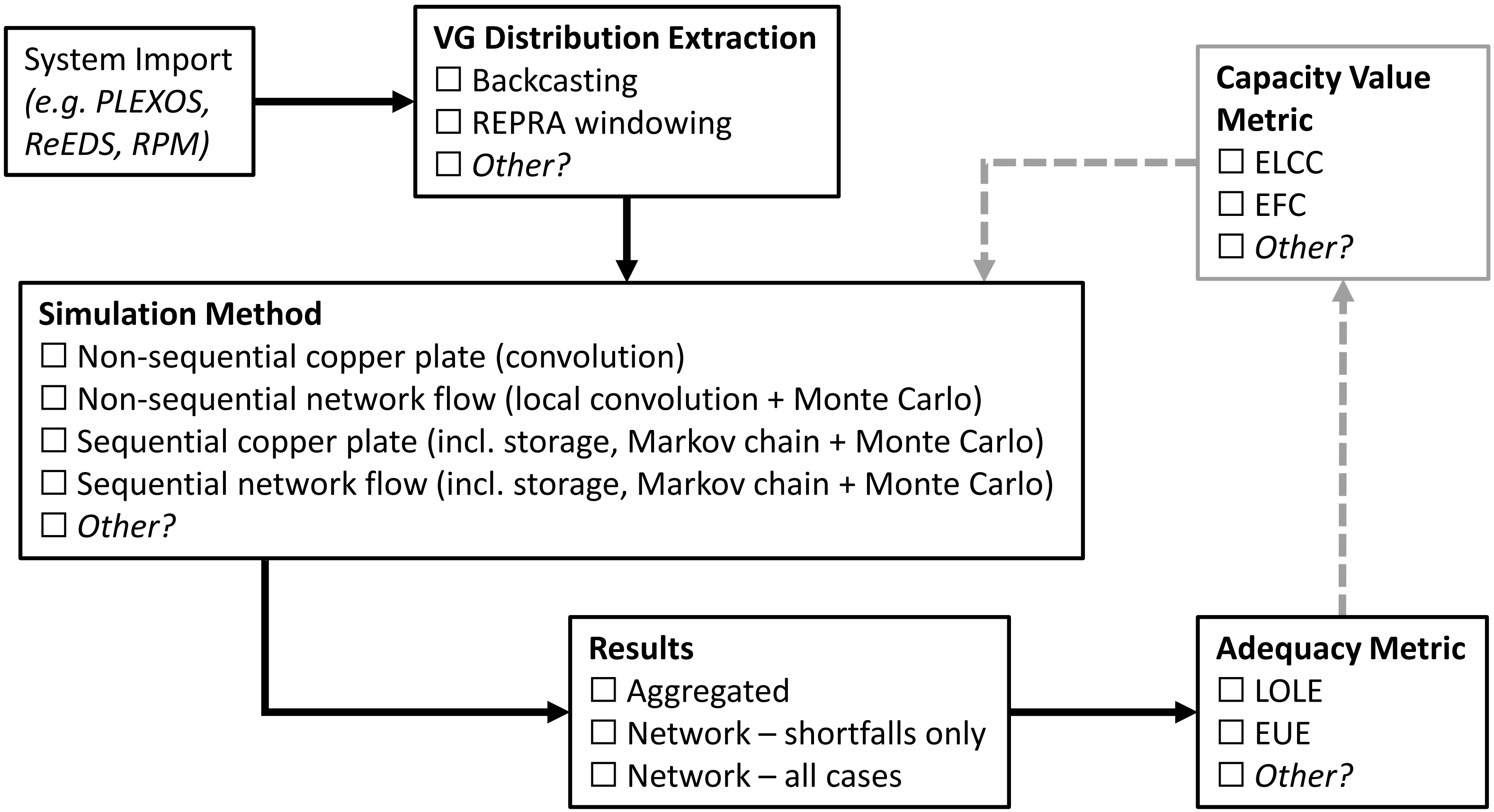
Shortfall probability = LOLP
Probability-weighted average shortfall magnitude = EUE

Large-scale, multi-region analysis



PRAS – Choose Your Own Adventure

PRAS provides a modular collection of data processing and system simulation tools

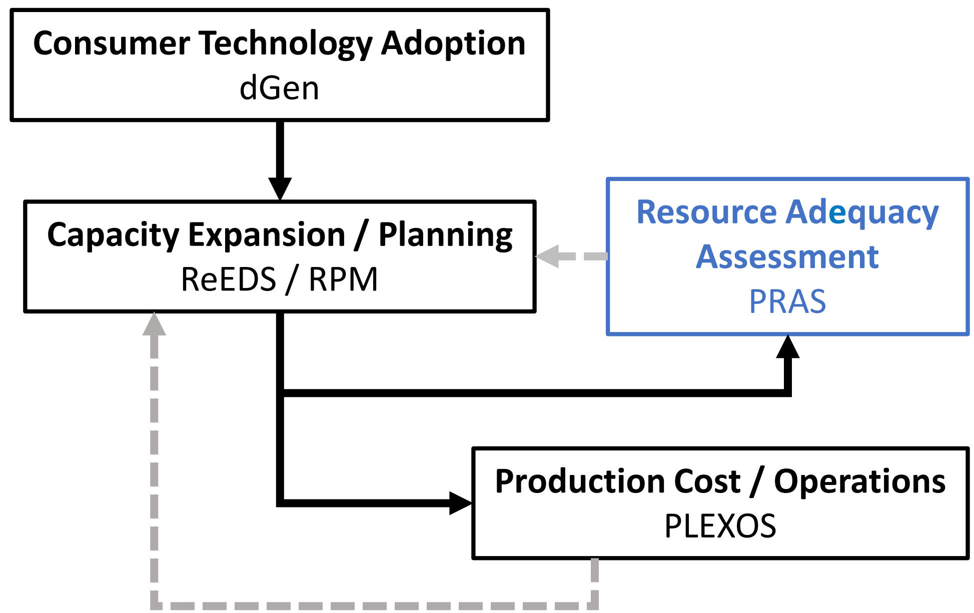


PRAS IN NREL GRID INTEGRATION STUDIES

- Evaluates / validates resource adequacy of grid buildout scenarios from capacity expansion models

- Informs adjustments to internal resource adequacy heuristics in those models

- Calculates capacity value (e.g. EFC, ELCC) of individual resources (e.g. wind, solar, transmission) under different scenarios



SHORTER TIMESCALE TOOLS

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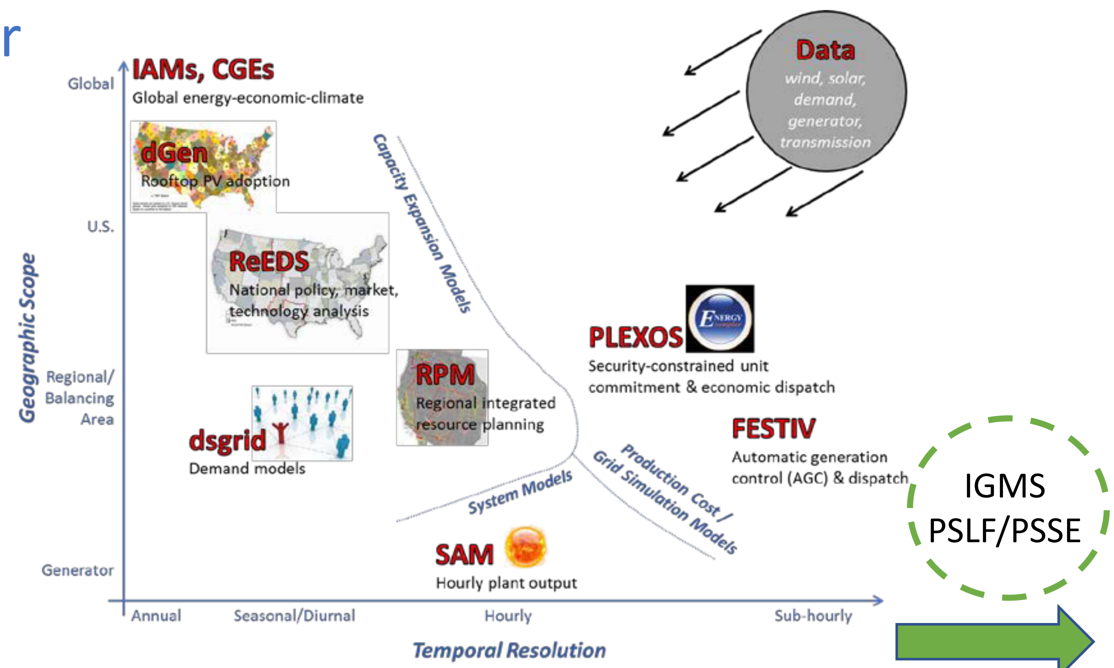
- Transmission and stability analysis; Transmission + Distribution → other parts of NREL
- NREL POCs: Himanshu Jain, Yingchen (YC) Zhang, Bryan Palmintier



DATASETS

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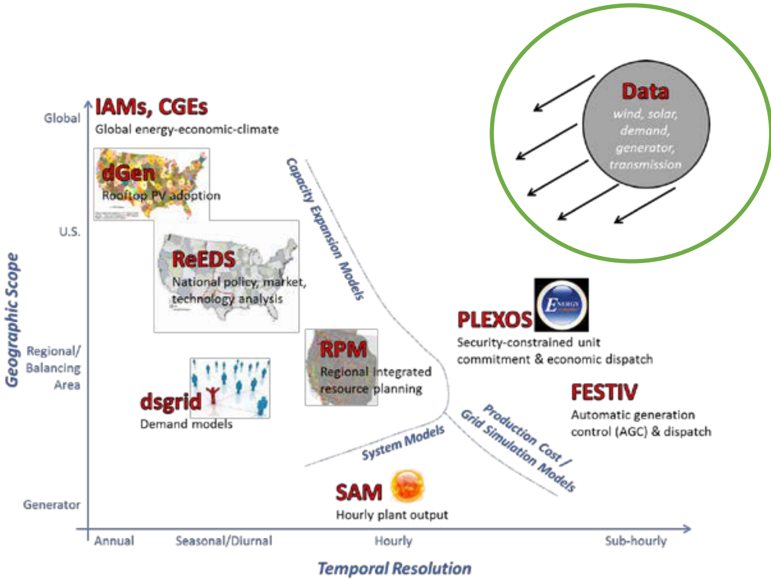
- VRE profiles
  - NSRDB (National Solar Radiation Database)
  - Wind Toolkit
  - reV for enhanced user interface/data coordination
  - SAM
- Load profiles
- Generator properties
  - heat rate curves, emissions, costs, ramping, etc.
  - Network connection/mapping
  - Outages and repair times
- Hydropower data



NREL Resource Data: The Americas

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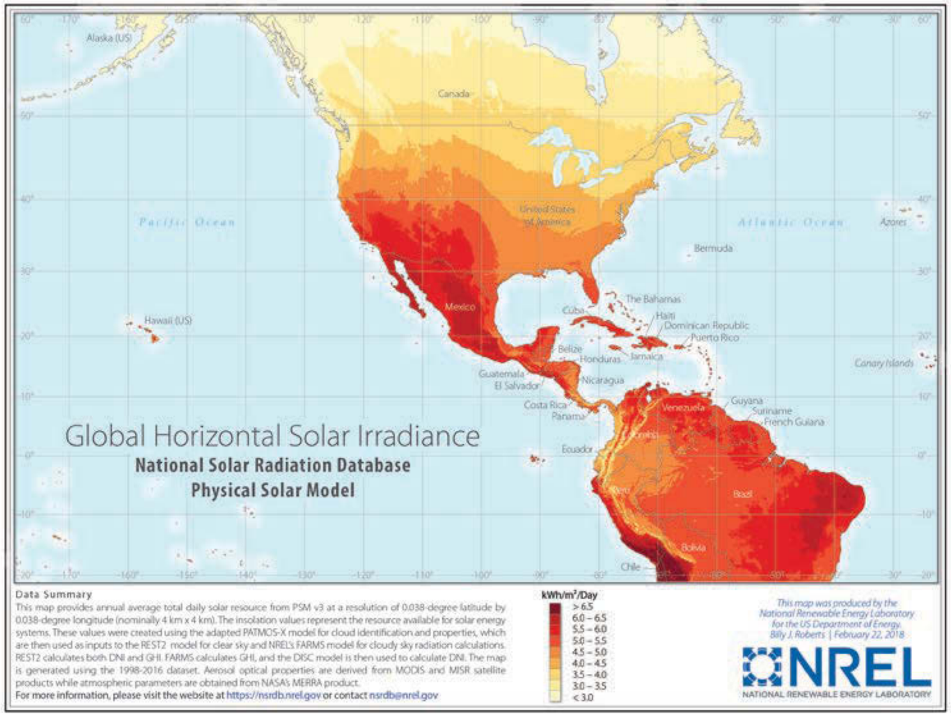
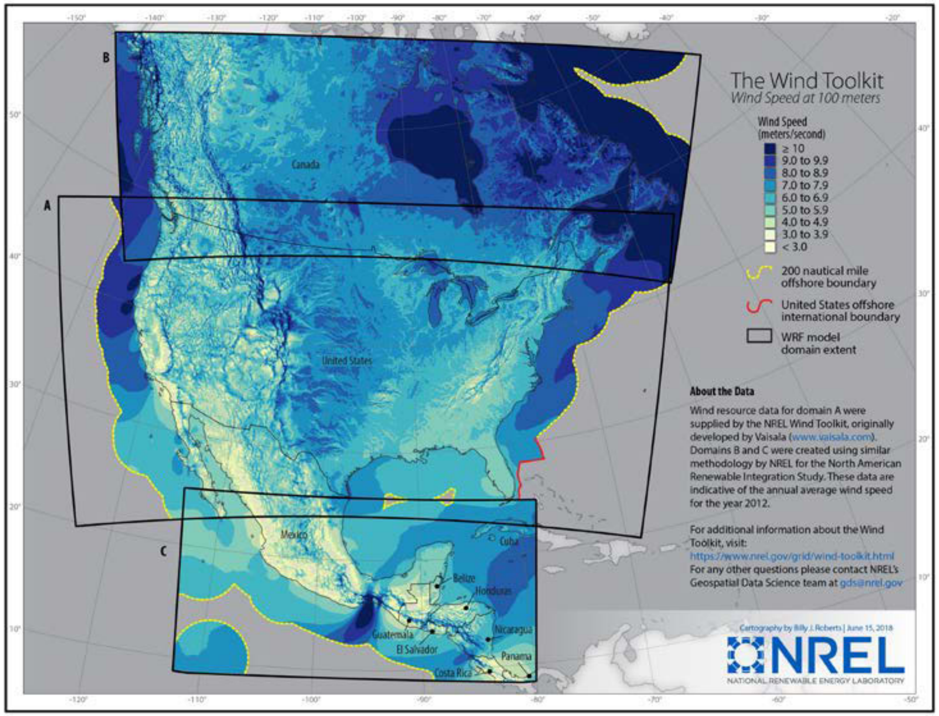




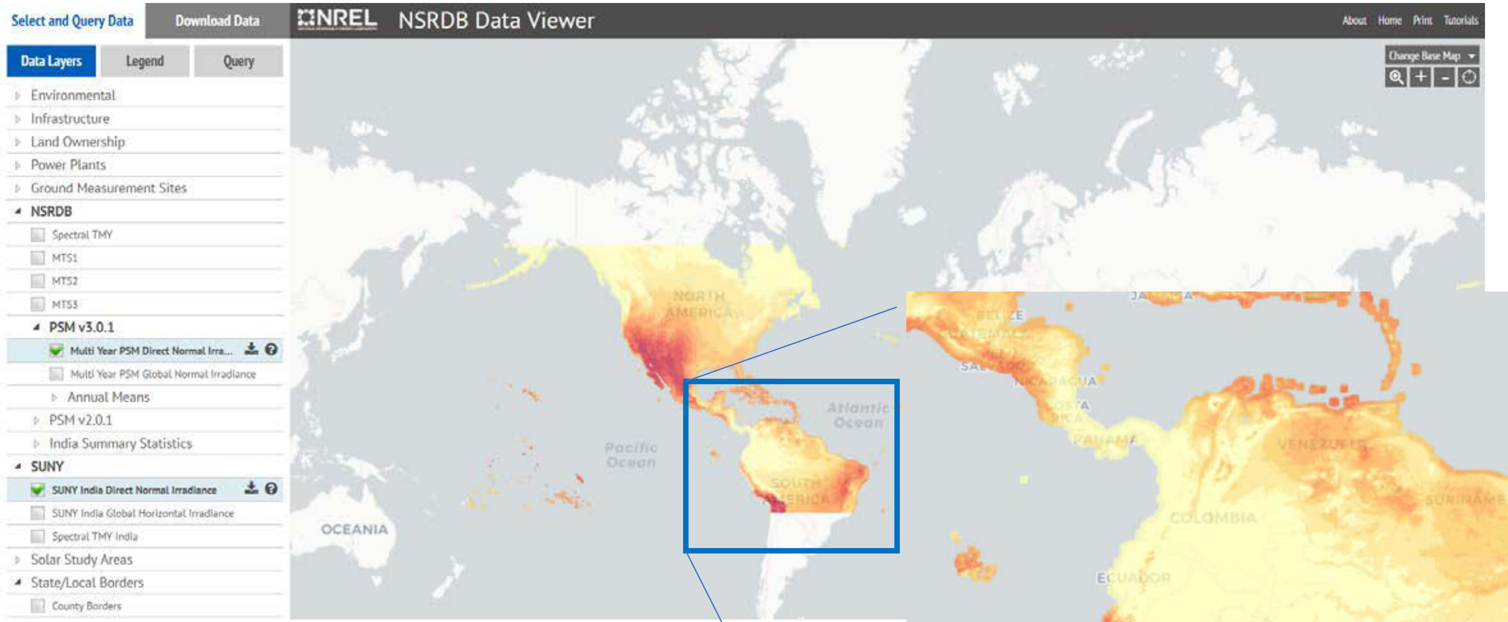
National Solar Radiation Database (NSRDB)

- **Temporal Range: 1998-2016**
- **Temporal Interval: 30-minute**
- **Spatial Resolution: nominal 4 km**
- **Spatial Extent: Most of Western Hemisphere**

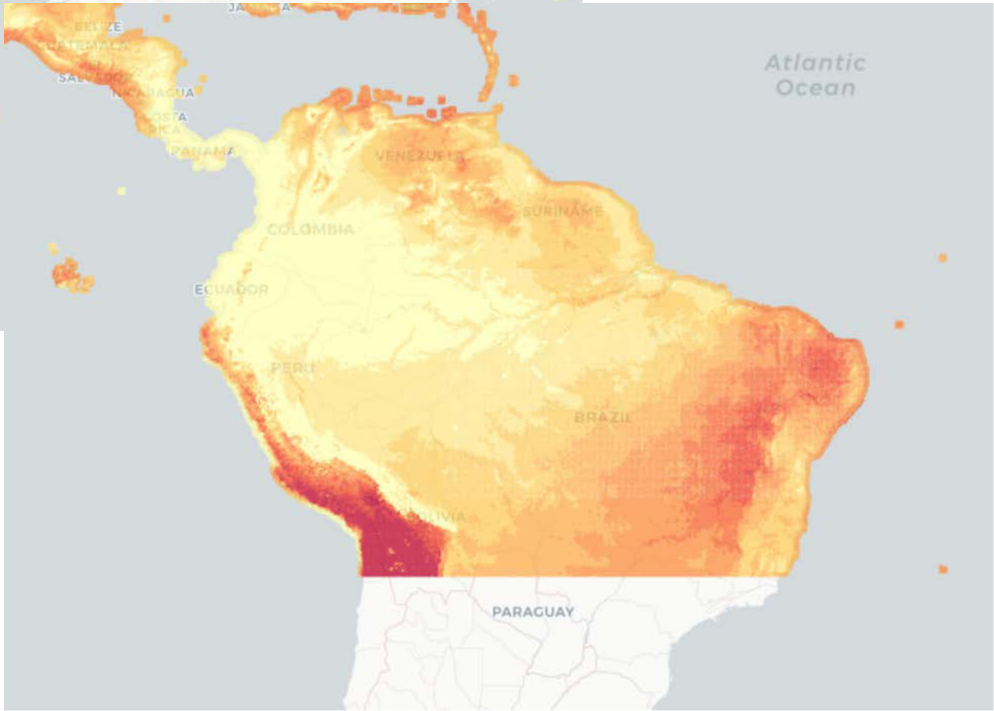
WIND Toolkit

- **Temporal Range: 2007-2013**
- **Temporal Interval: 5-minute**
- **Spatial Resolution: nominal 2 km**
- **Spatial Extent: North America**

NSRDB in South America

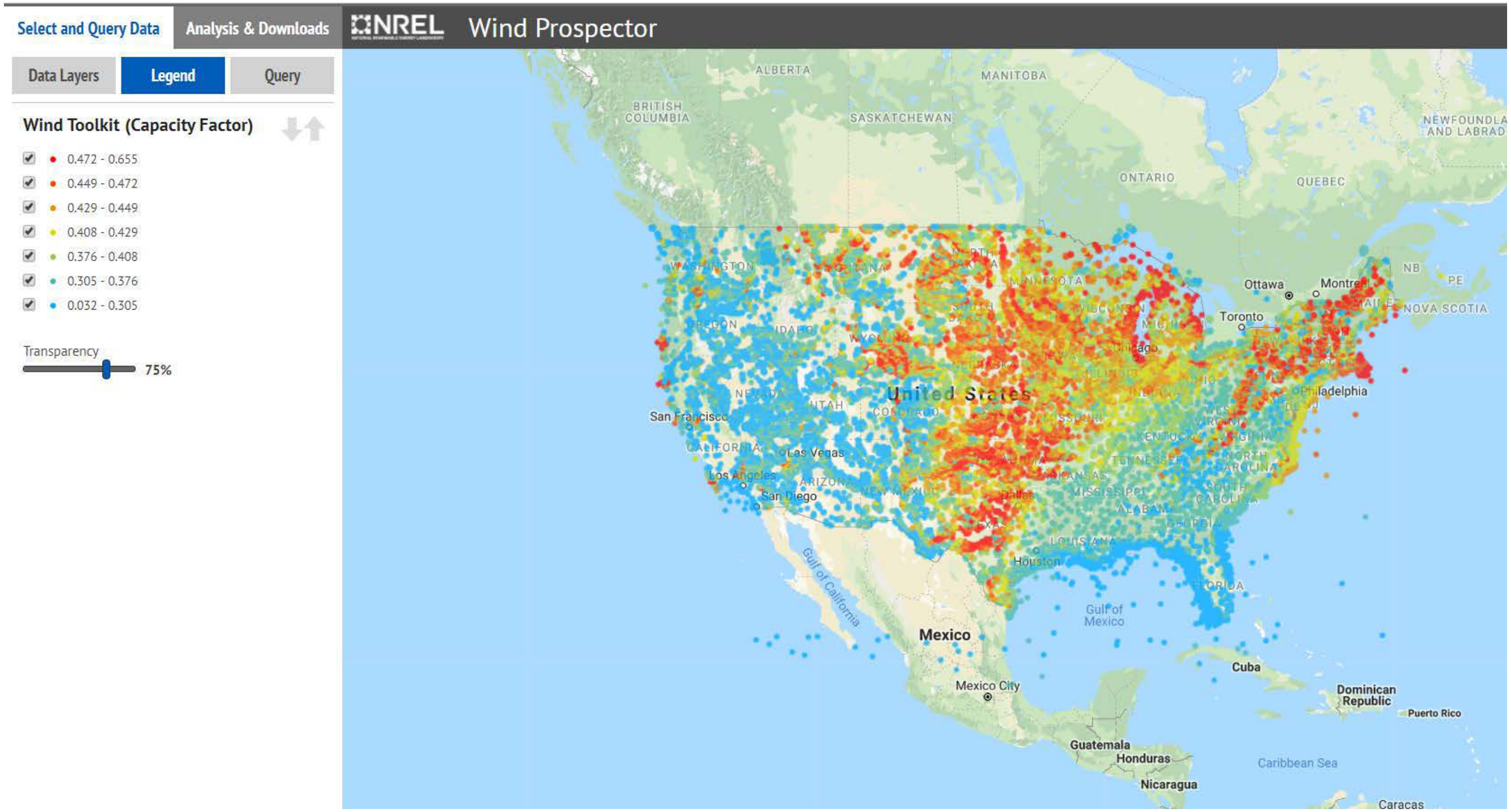


https://nsrdb.nrel.gov/nsrdb-viewer



Brazil | China | India (co-lead) | Denmark | Finland | Mexico (co-lead) | South Africa | Spain | United States (co-lead, under review)

Wind Toolkit



https://maps.nrel.gov/wind-prospector/

https://www.nrel.gov/docs/fy15osti/61740.pdf

NREL's EXPANDING PORTFOLIO OF INTERNATIONAL WIND RESOURCE DATA

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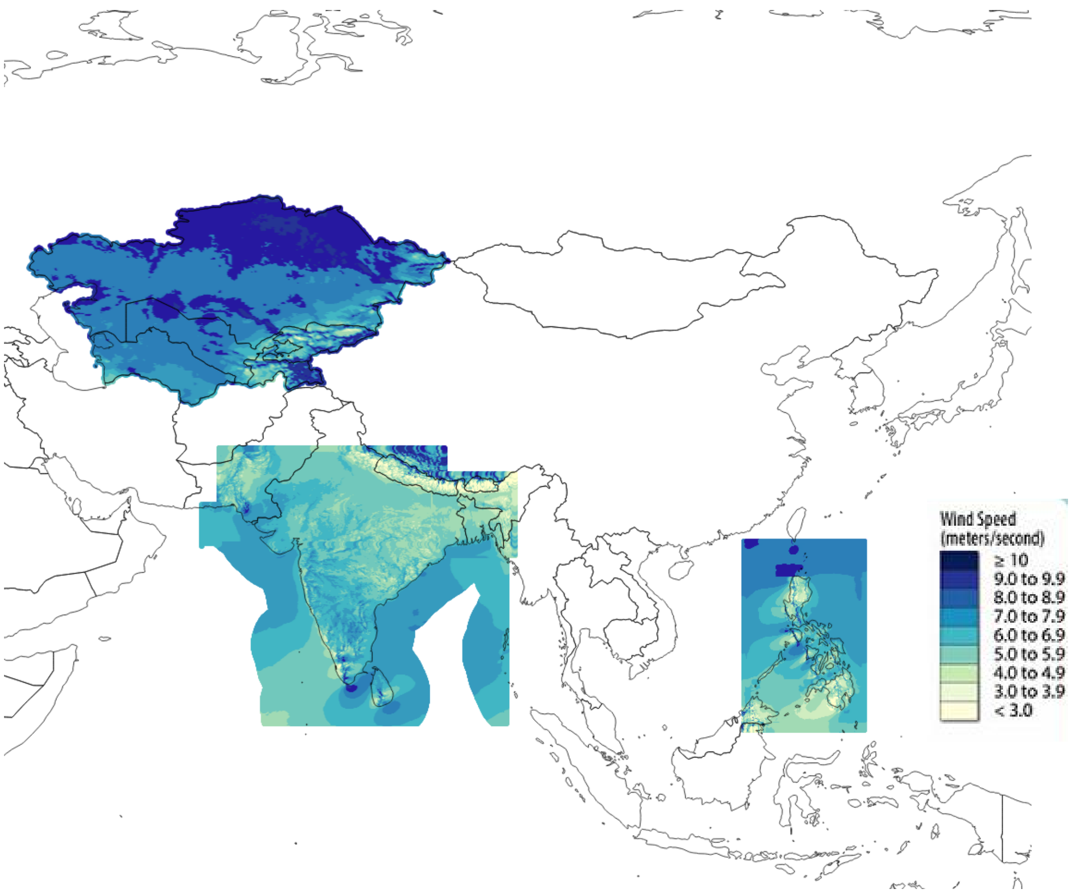

India:
- 2014
- 5 min, 3 km resolution

Kazakhstan:
- 2015
- 15 min, 3 km resolution

Greater Kazakhstan Area:
- 2015
- 15 min, 9 km resolution

Bangladesh:
- 2014-06 to 2017-12
- 1 hr, 3 km resolution

Philippines:
- TMY

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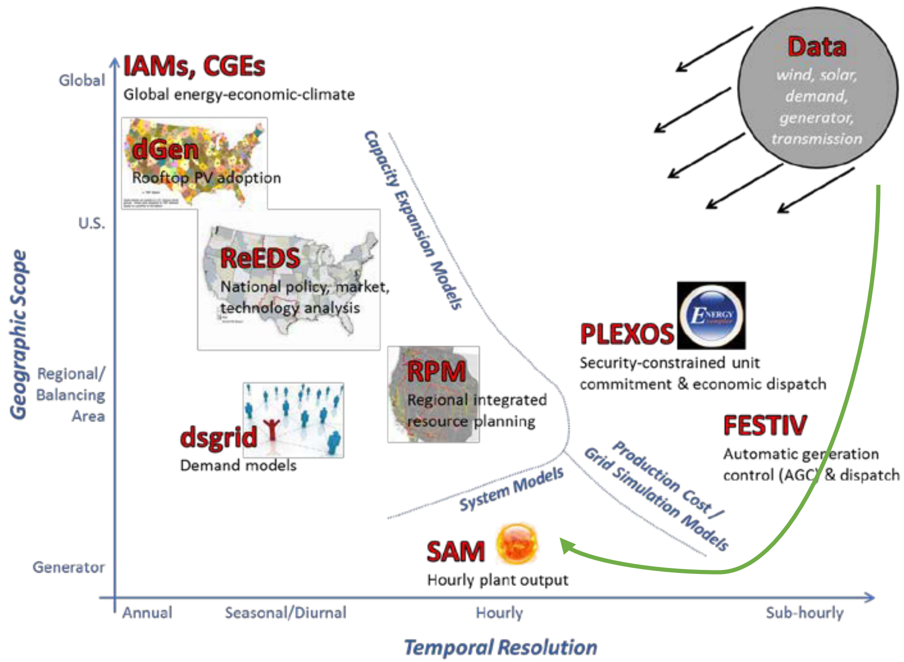
SYSTEM ADVISOR MODEL (SAM)

NREL POC: Janine Freeman



SAM

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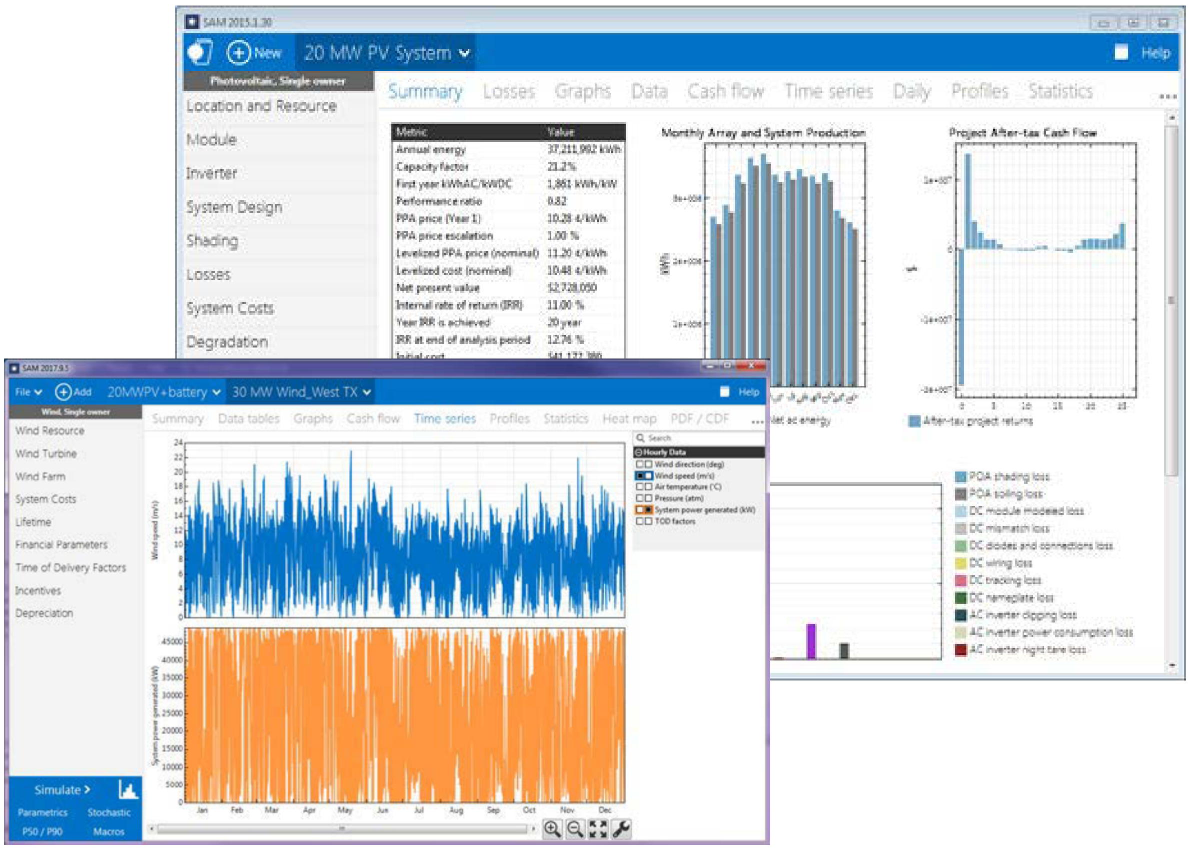
SAM is **free** software for modeling the performance and economics of renewable energy projects.



Technologies

Photovoltaics
Wind
Concentrating solar power
Geothermal
Biomass
Solar water heating

Financial Models

- Behind-the-meter
  - residential
  - commercial
  - third-party ownership
- Power purchase agreements
  - single owner
  - equity flips
  - sale-leaseback
- Simple LCOE calculator

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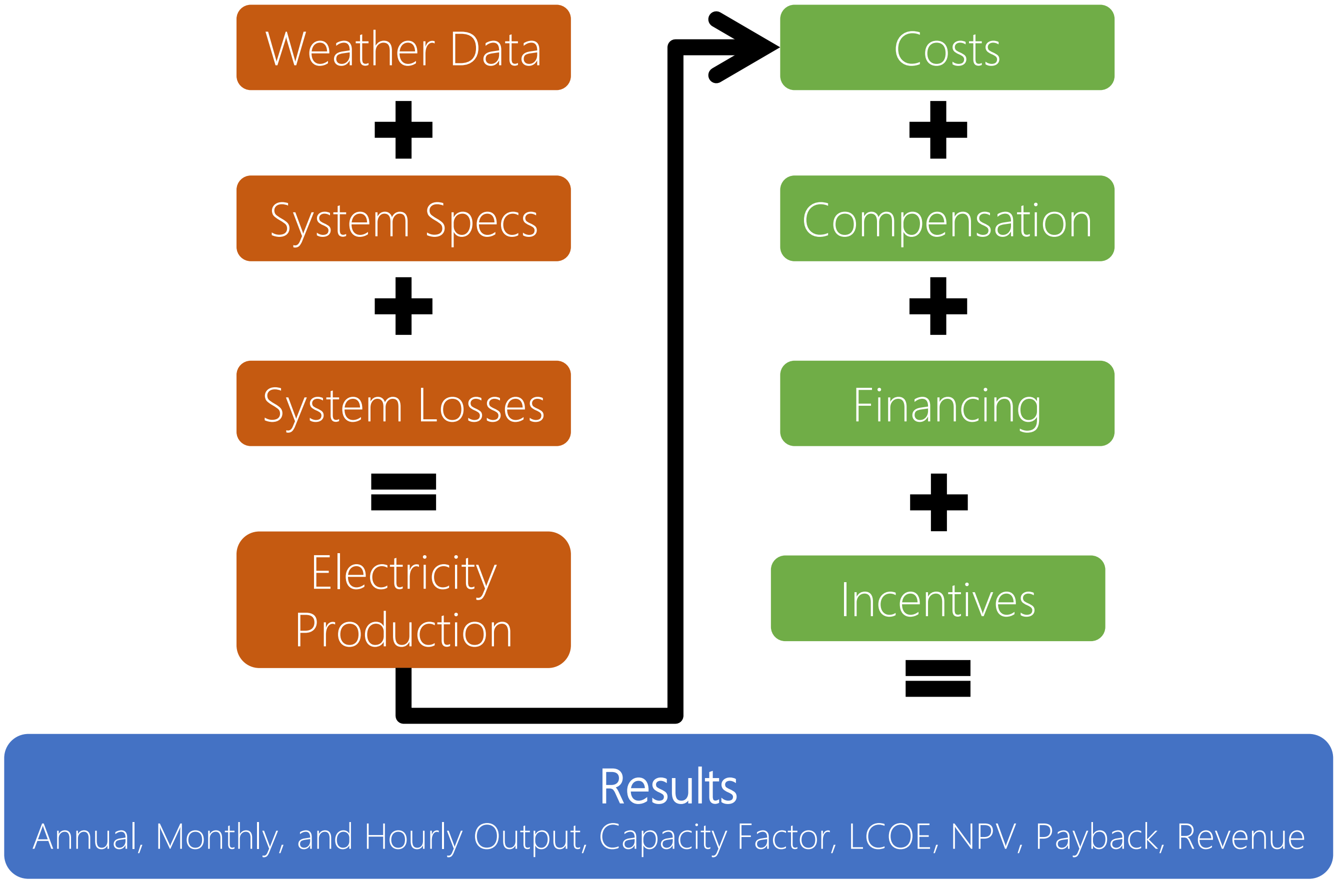
Steps to Modeling Renewable Energy in SAM



Enhanced Coordination of data using Renewable Energy Potential Model (reV)

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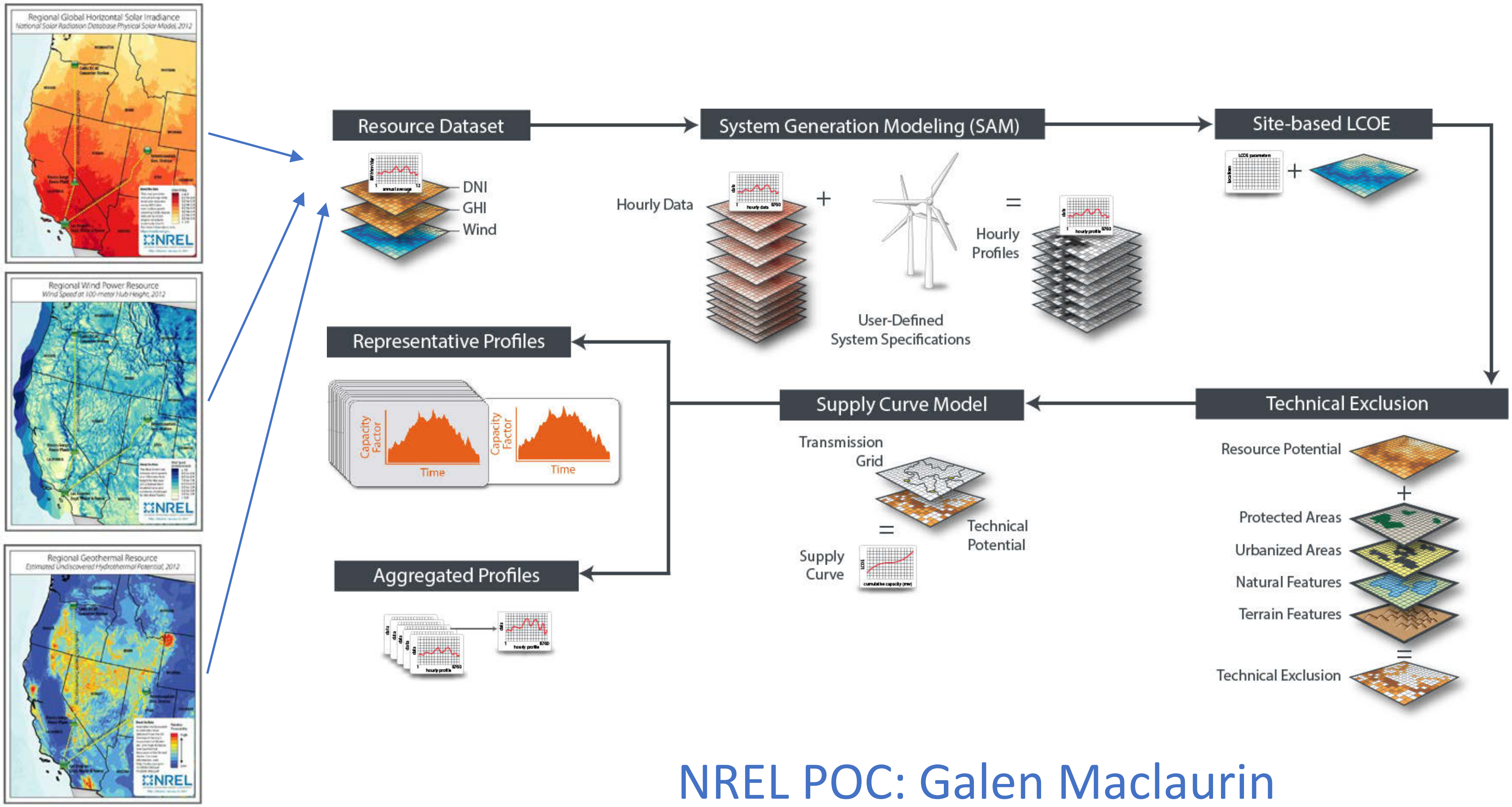

NREL POC: Galen Maclaurin

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Energy-Water Nexus: Hydropower Data for our Models

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- Characterize hydropower resources
  - Existing dams, expand/upgrade existing resources, power non-powered dams, and new stream reaches
  - Separate into dispatchable and non-dispatchable
  - Pumped storage hydropower
- Seasonal water availability as a long-term average, no interannual variability
  - Seasonal capacity variations are represented for the existing fleet
  - Implemented in ReEDS at time-slice level
- PLEXOS does monthly energy limits and hourly/sub-hourly UC and dispatch (RT dispatch is typically fixed from DA)

NREL POCs: Stuart Cohen and Jordan Macknick

Hydropower modeling: https://www.nrel.gov/docs/fy17osti/68231.pdf
https://www.energy.gov/eere/water/articles/hydropower-vision-new-chapter-america-s-1st-renewable-electricity-source

Energy-Water Nexus: Thermal Cooling in ReEDS

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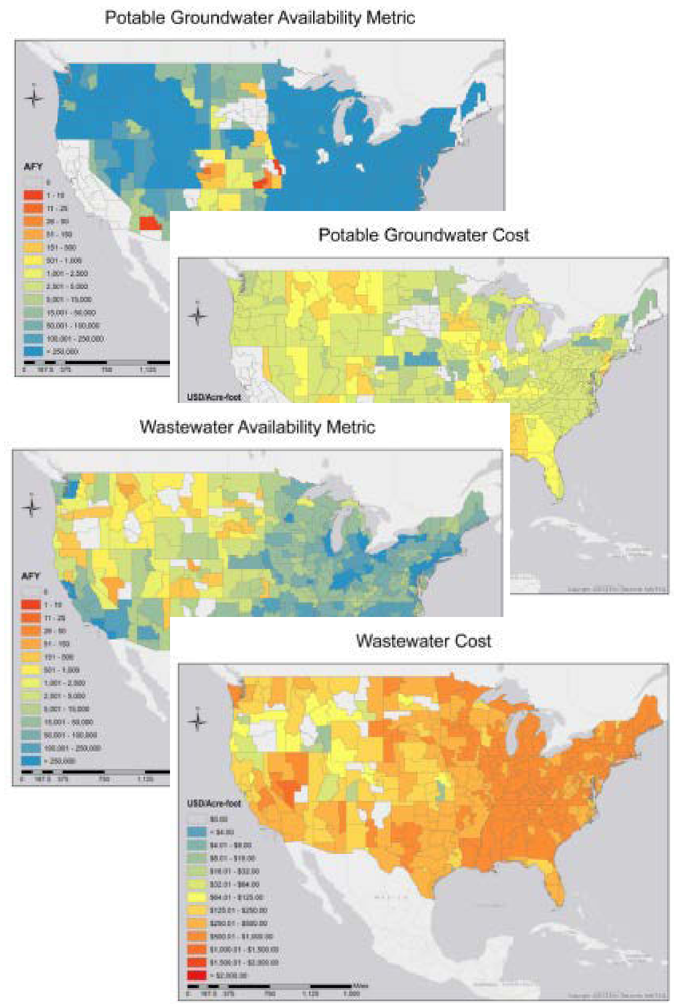
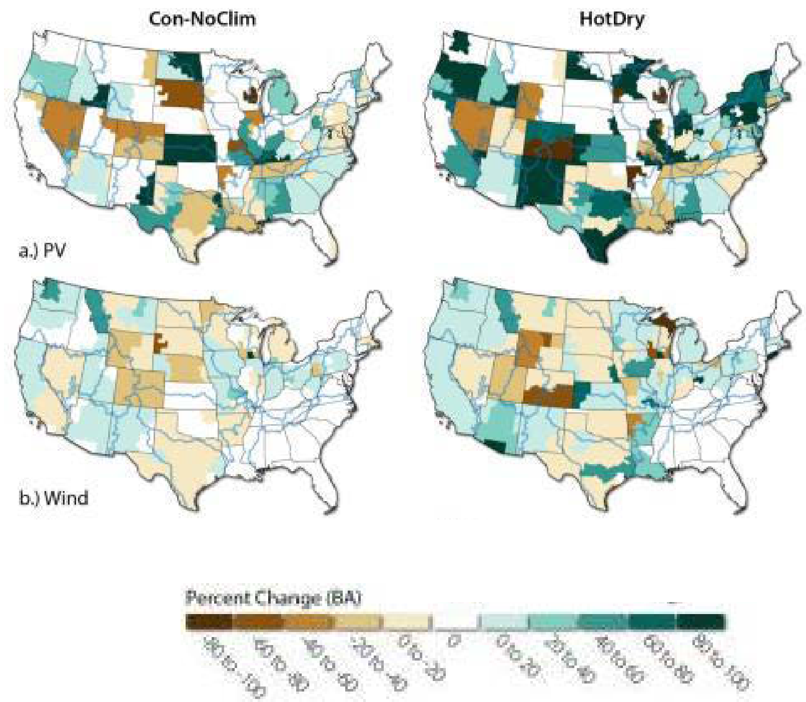
- Characterize thermal cooling water supply and demand
- Water access supply curves, including regional availability and cost of multiple water classes
- Thermal generators have cooling technology mapping, each of which is characterized by seasonal water withdrawal and consumption rates (constrained by balancing area) and various operational constraints/costs



Energy-Water Nexus: Link ReEDS with Climate Models

- Assess impact of climate change on electricity system
  - Load changes by season and region
  - Thermal power plant performance changes due to air temperature-efficiency relationships
  - Transmission line capacity is reduced at high temperatures
  - Surface water availability/temperature for thermal cooling/hydropower changes with precipitation-runoff trends



https://www.globalchange.gov/content/nca4-planning

Central Data Set: Annual Technology Baseline

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Updated each year and released with suite of "Standard Scenarios"

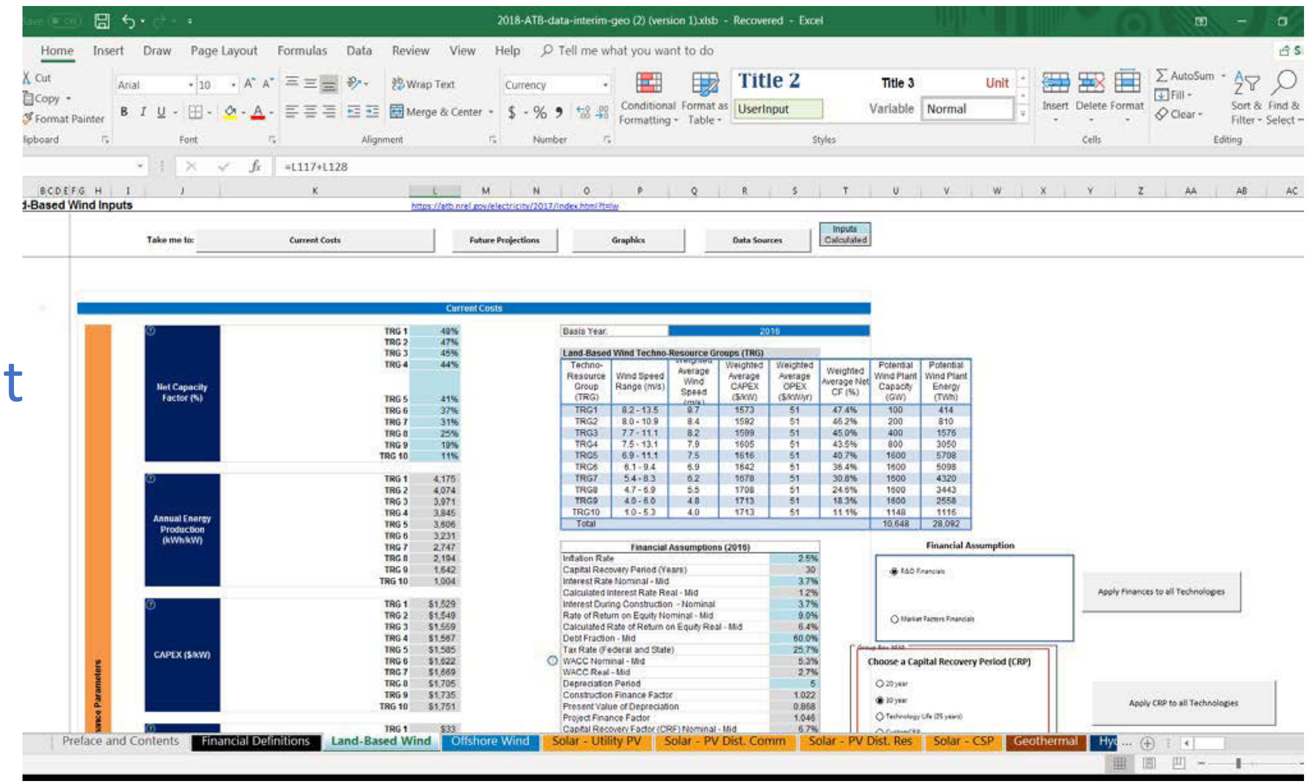
https://www.nrel.gov/analysis/data-tech-baseline.html

https://atb.nrel.gov/

NREL POCs:

Laura Vimmerstedt

and Wesley Cole



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(co-lead)

Denmark

Finland

Mexico
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South Africa

Spain

United States
(co-lead, under review)

Model Outputs

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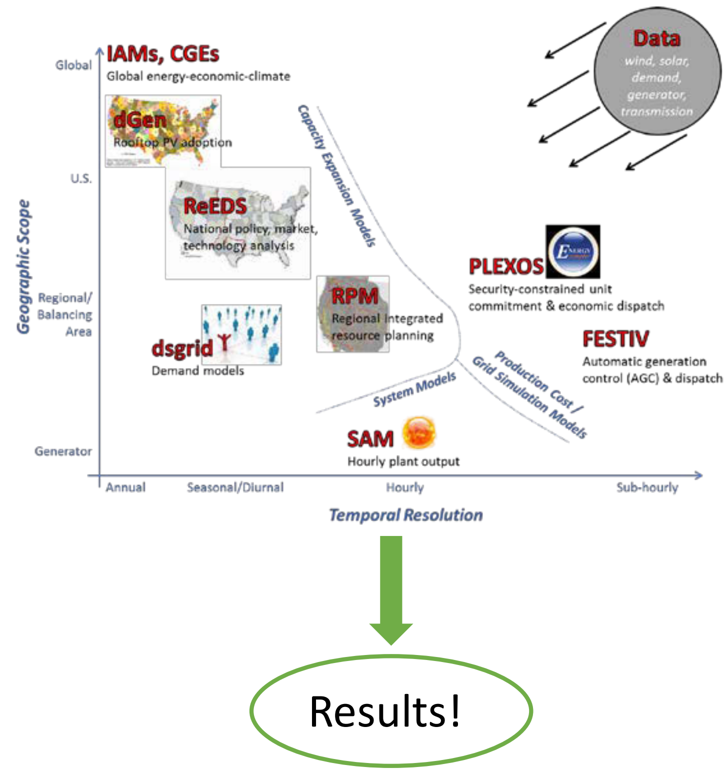
- Standard output reports to visualize results and diagnose problems



REEDS OUTPUTS

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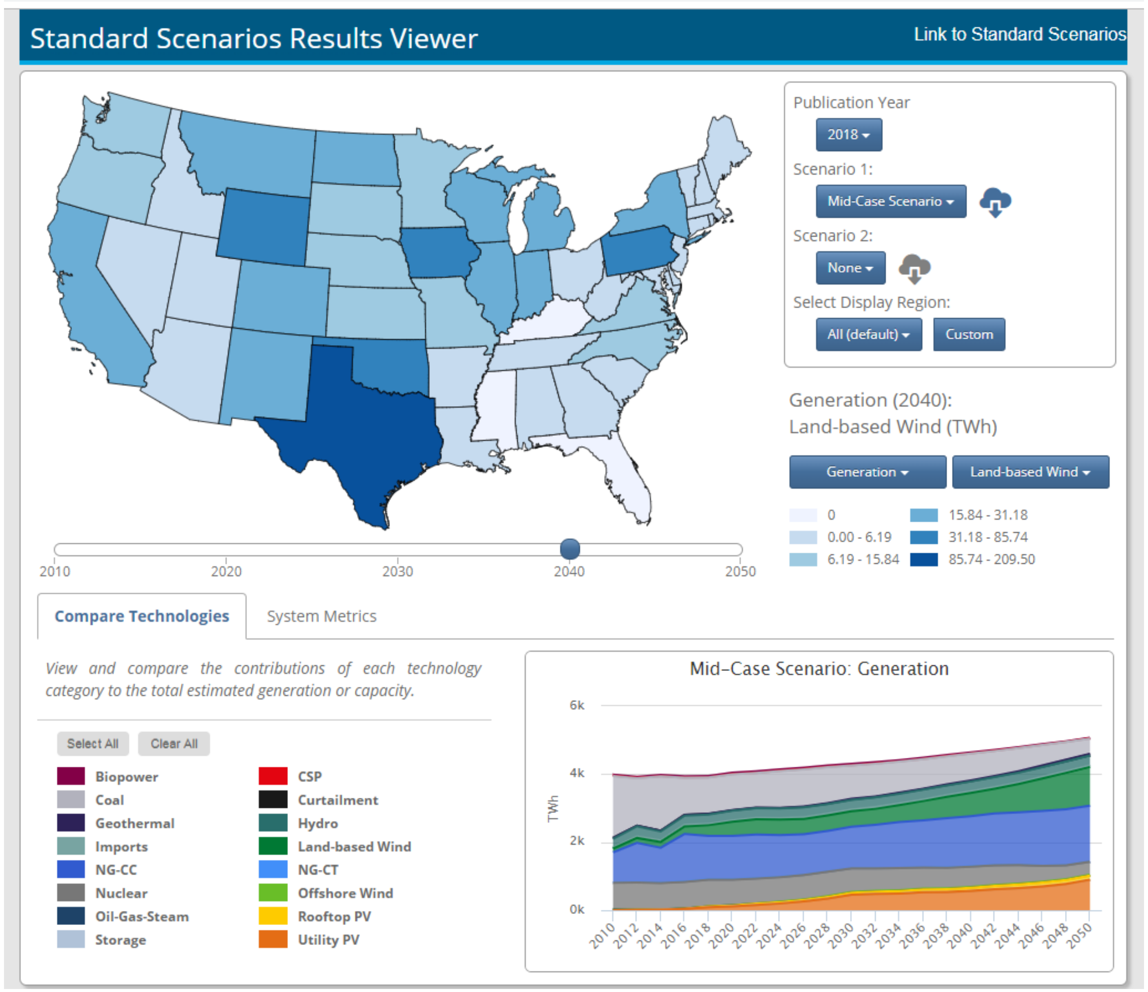
Standard html reports plus interactive data viewer (example here for Standard Scenarios):



https://openei.org/apps/reeds/#

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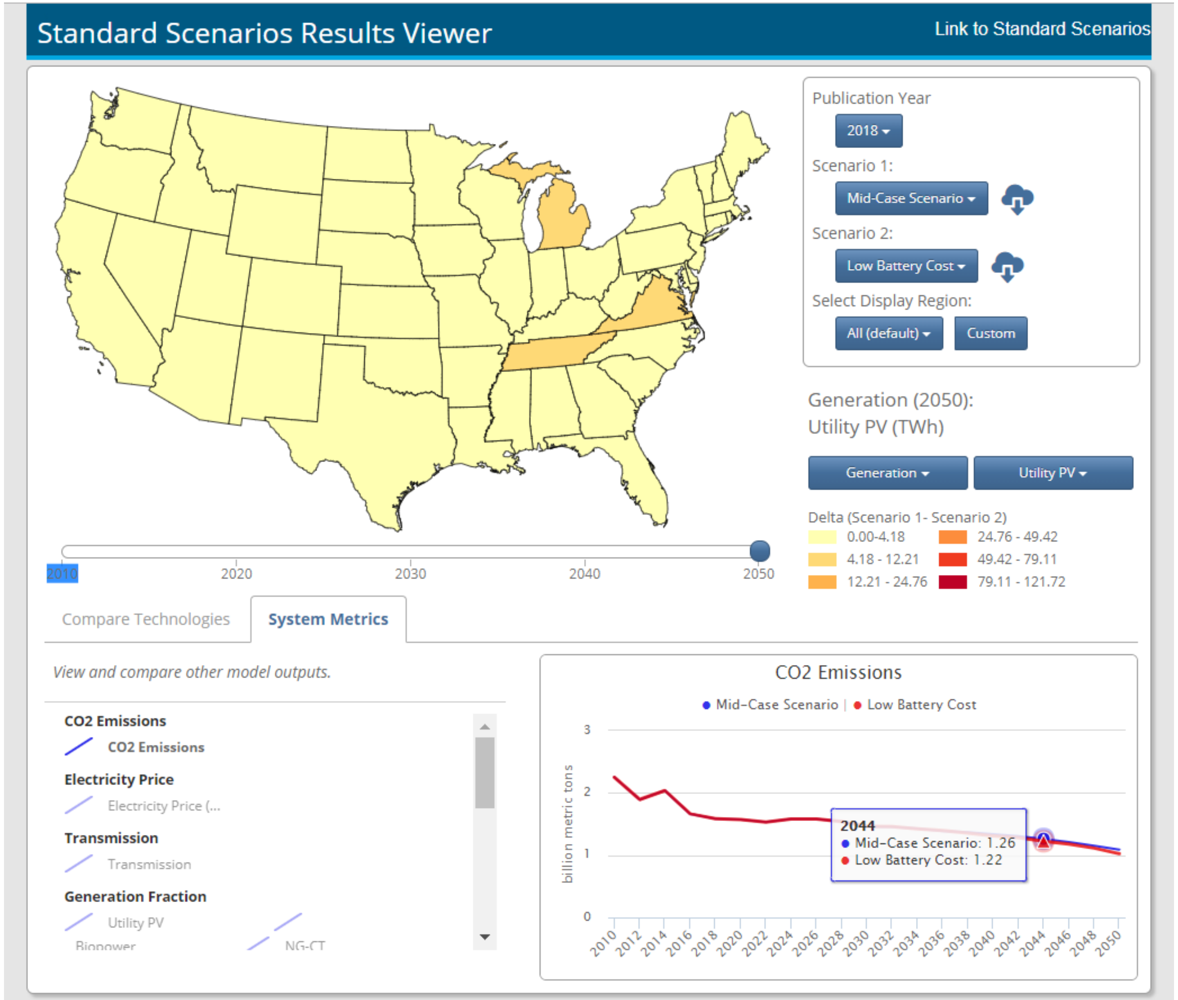
Standard Scenarios Results Viewer
Link to Standard Scenarios
Publication Year
2018
Scenario 1:
Mid-Case Scenario
Scenario 2:
Low Battery Cost
Select Display Region:
All (default)
Custom
Generation (2050):
Utility PV (TWh)
Generation
Utility PV
Delta (Scenario 1- Scenario 2)
0.00-4.18
4.18 - 12.21
12.21 - 24.76
24.76 - 49.42
49.42 - 79.11
79.11 - 121.72
2010
2020
2030
2040
2050
Compare Technologies
System Metrics
View and compare other model outputs.
CO2 Emissions
CO2 Emissions
Electricity Price
Electricity Price (...
Transmission
Transmission
Generation Fraction
Utility PV
Biopower
NG-CT
CO2 Emissions
Mid-Case Scenario | Low Battery Cost
billion metric tons
2044
Mid-Case Scenario: 1.26
Low Battery Cost: 1.22

PLEXOS Outputs: "MAGMA"

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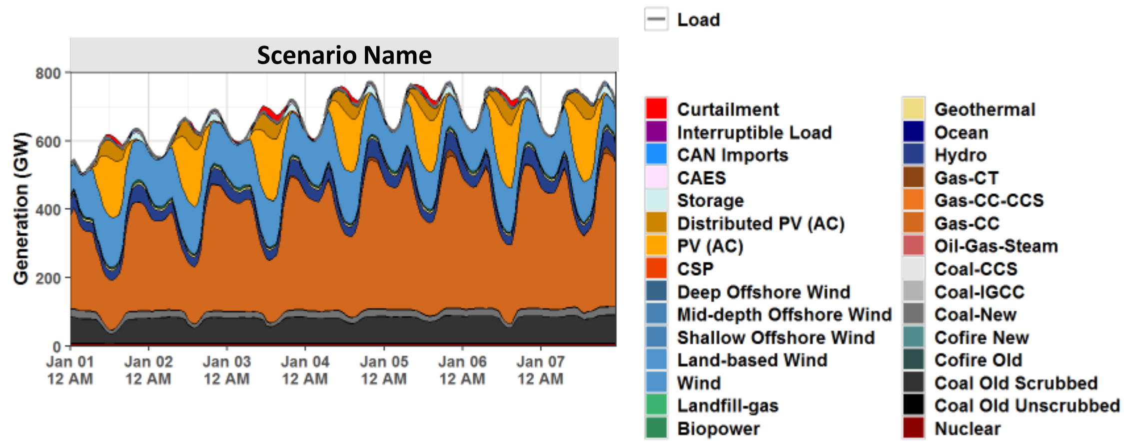
https://github.com/NREL/MAGMA

- 1. Total Generation
- 1.1. Generation Differences
- 2. Zonal Generation
- 2.1. Zonal Generation Differences
- 3. Regional Generation
- 3.1. Regional Generation Differences
- 4. Individual Regions
- 5-7. Specified Period Dispatch Stacks
    - 5. Total
    - January
    - 6. Zones
    - January : AZNM
    - January : BPA
    - January : CAISO
    - January : ERCOT
    - January : FRCC
    - January : ISO-NE
    - January : MISO-E
    - January : MISO-S
    - January : MISO-W
    - January : NWPP
    - January : NYISO
    - January : PJM-E
    - January : PJM-W
    - January : RMPP
    - January : SE

5-7. Specified Period Dispatch Stacks

5. Total

January



CLEAN ENERGY MINISTERIAL
Accelerating the Transition to Clean Energy Technologies

Brazil | China | India (co-lead) | Denmark | Finland | Mexico (co-lead) | South Africa | Spain | United States (co-lead, under review)

Enhanced Visualizations: Kaleidoscope

(https://github.com/NREL/kaleidoscope)

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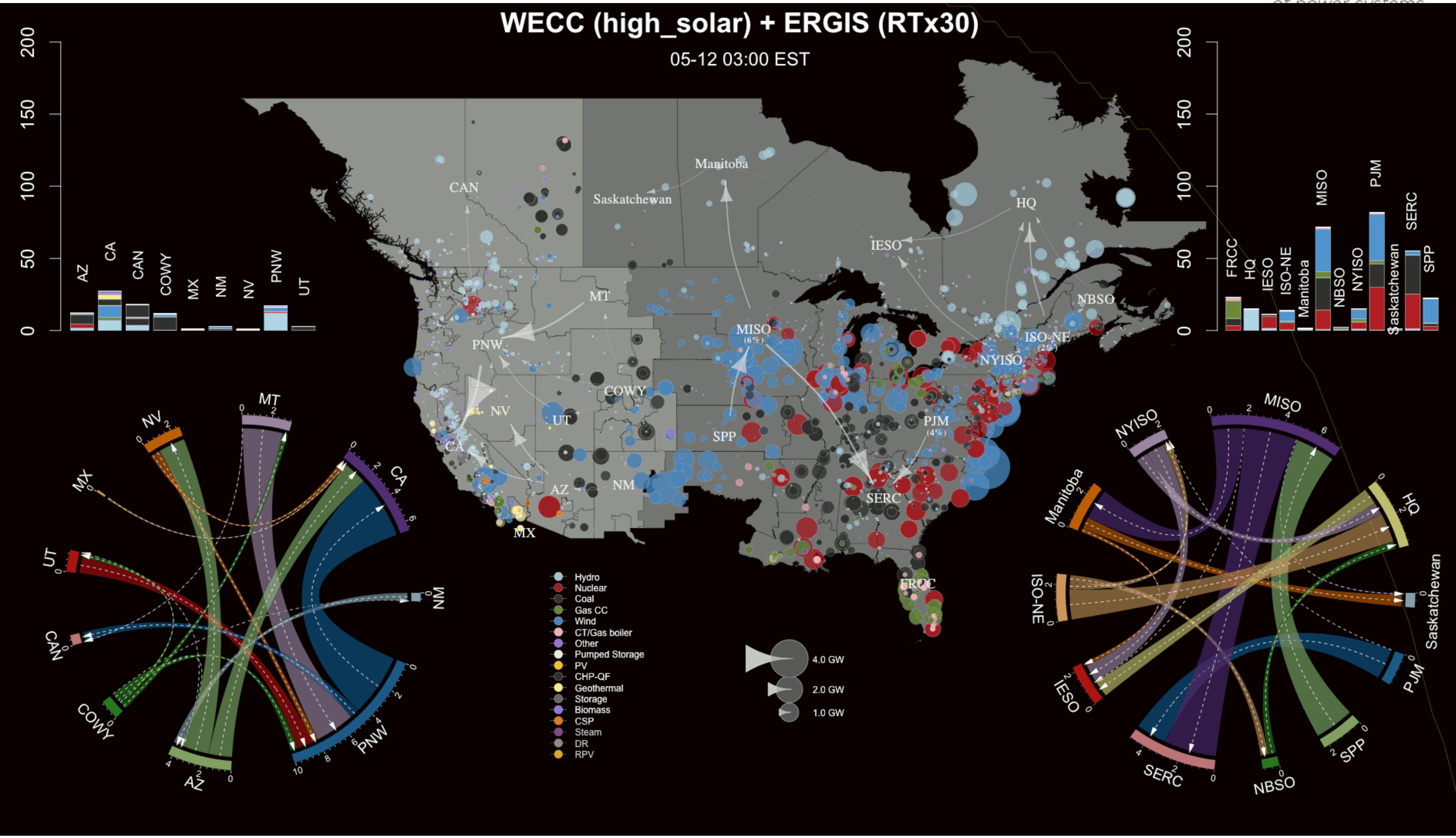

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OUTLINE

TRADITIONAL (~30 min)

- Overview of modeling tools, methods, and datasets that we traditionally/currently use

FORWARD-LOOKING (~40 min)

- What are we working on now?
- Where are we heading?

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Accelerating the transformation of power systems

WHAT ARE WE WORKING ON NOW?

Greater Interoperability Between Modeling Tools and Data Sets

- Energy systems integration
  - Developing capabilities to model differing loads, electrification, integration of various energy systems
  - Greater emphasis on cross-sector, multi-timescale tools (and analysis)
  - Better understanding of system interactions
- Ultra-high VRE penetration studies
- Continental grid integration studies
- Advanced solving techniques utilizing HPC (high performance computing) facility
- Greater focus on flexibility
  - Flexibility Inventory tool

Power System – Natural Gas Modeling

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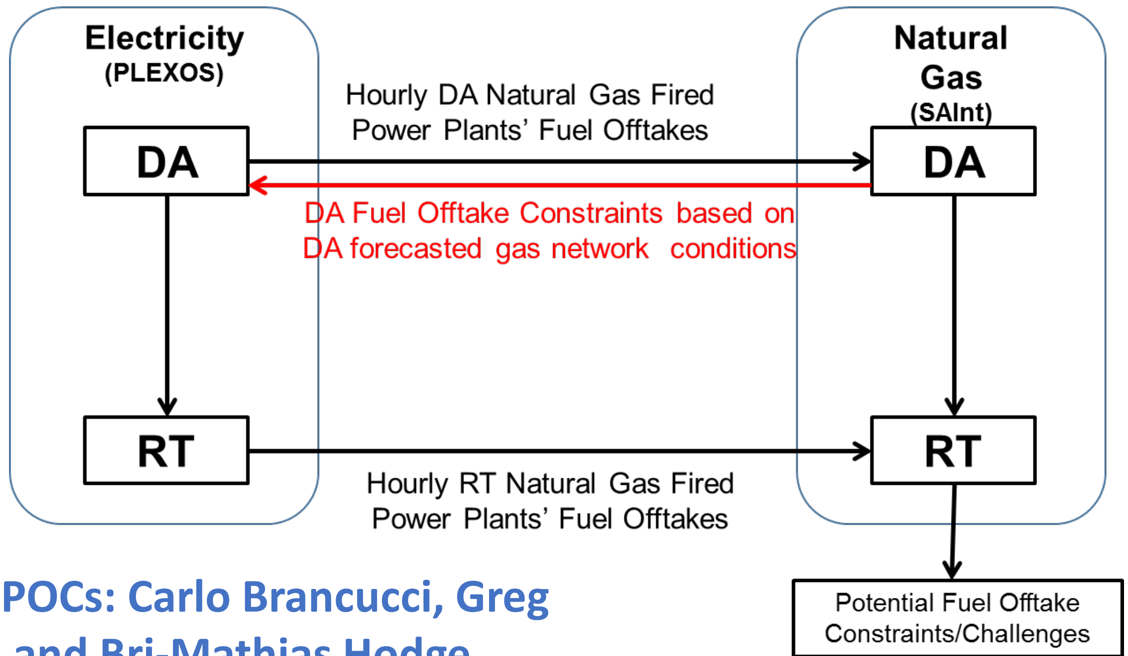
- Natural gas-fired generation is increasing, and increases in VRE penetration levels impact how gas fired power plants interact with the **power system**, as well as how they interact with the **gas network**
- Objective: co-simulate power and natural gas network operations



Compare Business as Usual versus DA Coordination

Assess economic and reliability impacts

NREL POCs: Carlo Brancucci, Greg Stark, and Bri-Mathias Hodge

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Electrification Futures Study (EFS):
How do changes to annual electricity demand impact capacity expansion results?

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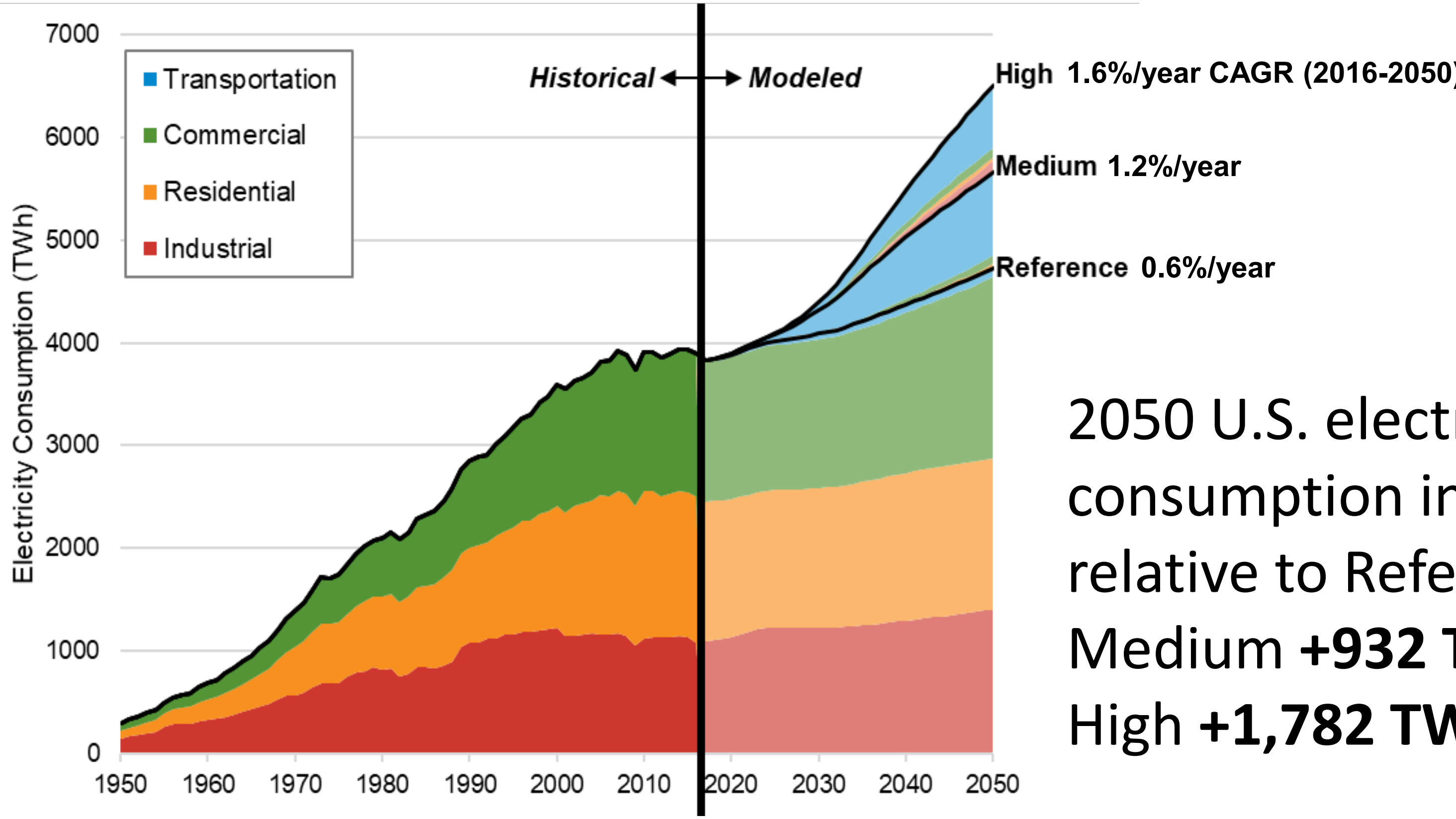

2050 U.S. electricity consumption increases relative to Reference
Medium **+932 TWh (20%)**
High **+1,782 TWh (38%)**

NREL POCs: Trieu Mai and Caitlin Murphy
https://www.nrel.gov/docs/fy18osti/71500.pdf

www.nrel.gov/efs

EFS: How do changes to the timing and magnitude of peak demand impact capacity expansion results?

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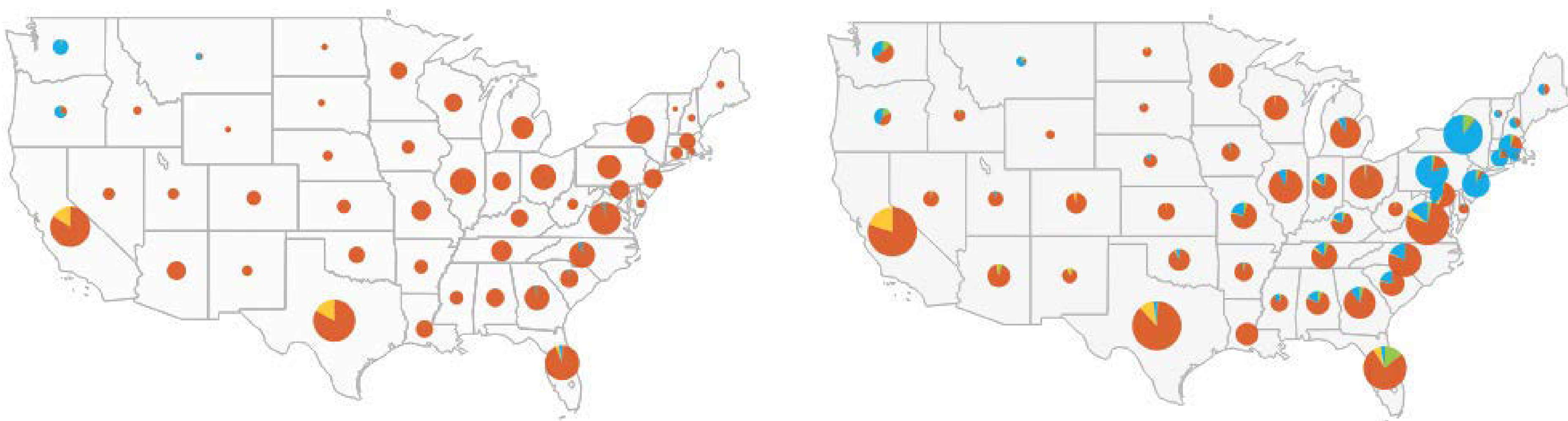
2015 **2050**



Season
Spring
Summer
Fall
Winter

Peak Load (GWh)
1
20
40
60
80
≥ 100

Summer = June-August,
Fall = September-November,
Winter = December-February,
Spring = March-May

- **EFS added a winter peaking timeslice to capture interactions during this key period**
- **Demand side flexibility is modeled endogenously**

https://www.nrel.gov/docs/fy18osti/71500.pdf

Better Understanding of Increasingly Complex System Interactions

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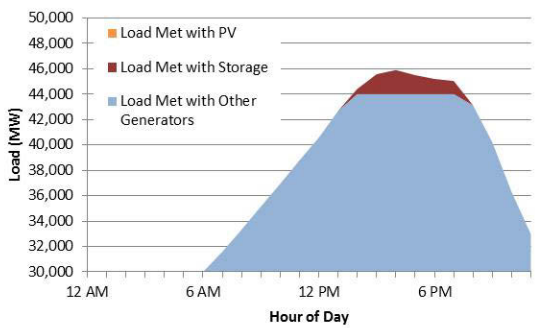
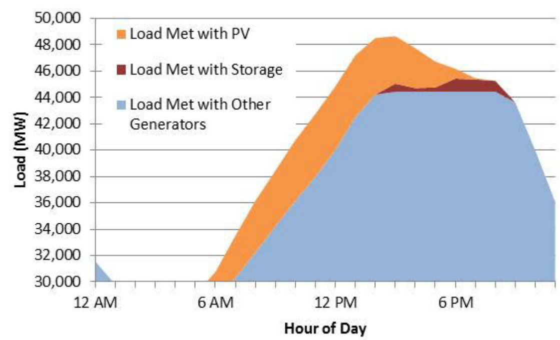
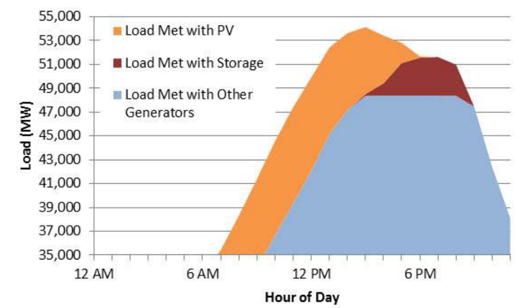
Synergistic relationship between VRE deployment and storage as a peaking resource



Zero PV



5% PV



10% PV

With increased PV penetration, the capacity credit of PV decreases while the capacity credit of storage (generally…) increases

Source: Denholm 2018: https://www.nrel.gov/docs/fy18osti/70905.pdf
See application in ReEDS: https://www.nrel.gov/docs/fy18osti/71462.pdf

LA 100% Renewable Energy Study

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Use a suite of *coordinated* modeling and simulation tools to determine what investments could be made to achieve a *reliable* 100% renewable energy portfolio

Key considerations:

- Load (including flexible portions), resource, and network data at adequate spatial and temporal resolution to characterize system → projected to future and capturing price responsiveness of flexible loads and DR
- Distribution system hosting capacity and update costs

NREL POC: Paul Denholm

The North American Renewable Integration Study (NARIS)

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

WHAT WE'RE STUDYING

- Long-term pathways to a modern power system in North America
- Operational feasibility of very high-penetration scenarios
- Weather variability and uncertainty
- Value of enabling technologies: flexible hydropower, thermal generation, demand response, storage, transmission
- Value of operating practices: interchange, enhanced scheduling, local generation, reserve provisions

Natural Resources Canada | Ressources naturelles Canada
Canada
SENER SECRETARÍA DE ENERGÍA

Preliminary Findings, Not for Quotation or Distribution

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NARIS Modeling Flow

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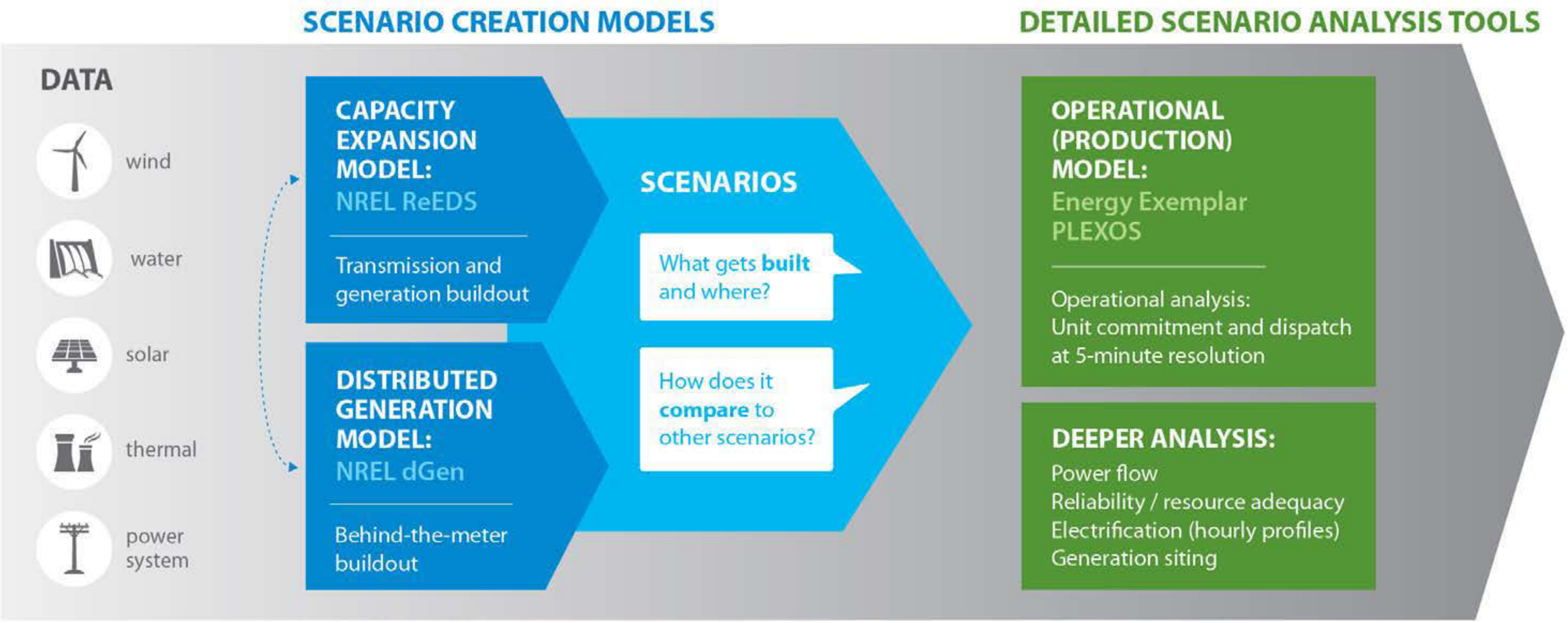

Preliminary Findings, Not for Quotation or Distribution

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Decomposition techniques with parallel computing

Some NREL POCs: Devon Sigler, Josh Novacheck, Clayton Barrows

Example: Domain Decomposition

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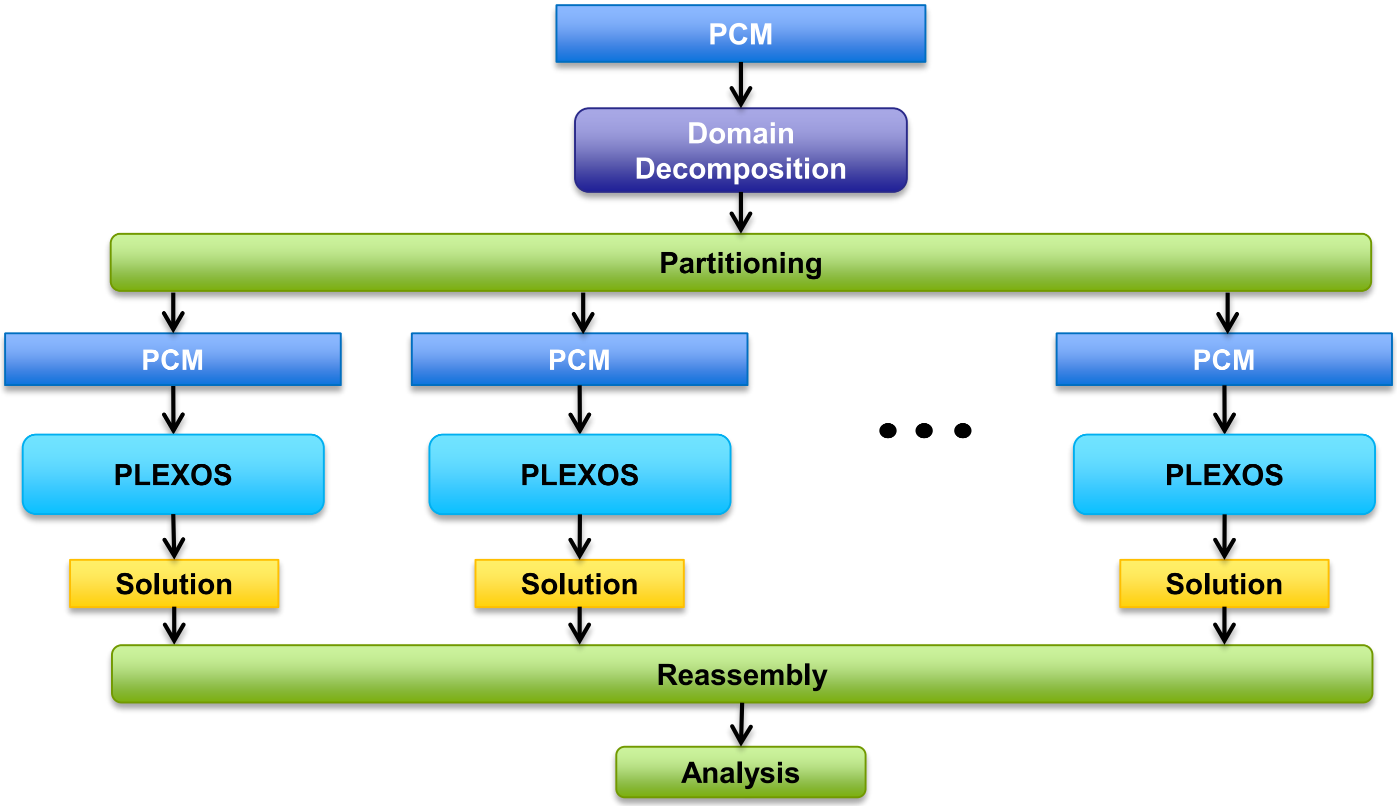
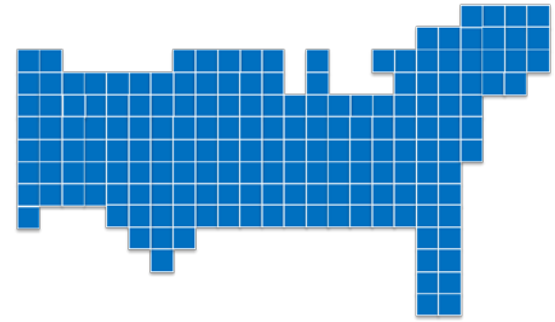
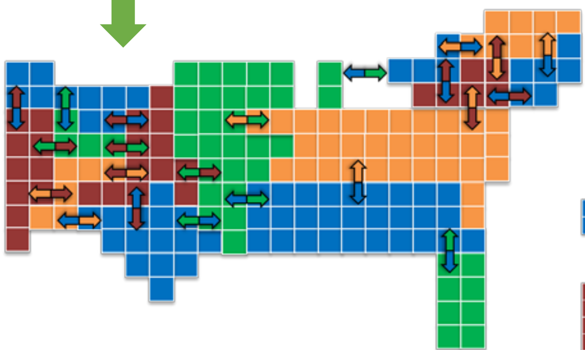


Example: Geographic Decomposition

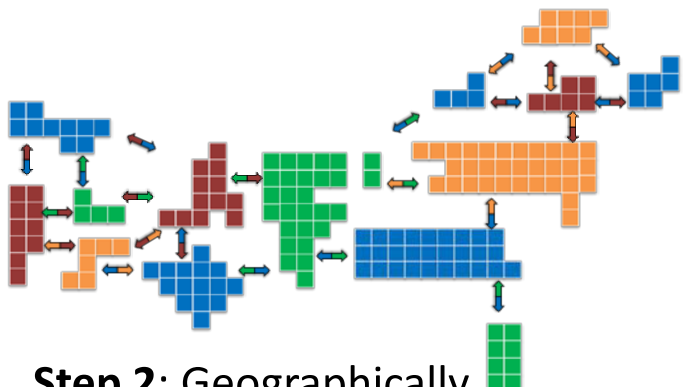
New approach uses decomposition to reduce solve time

Traditionally, one optimization for the entire system

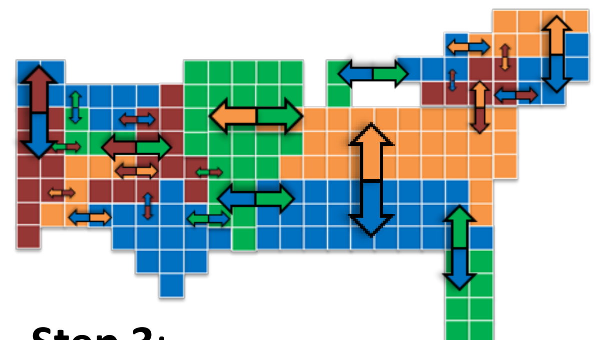




Step 1: Interchange Forecast (run DA as LP)



Step 2: Geographically Decompose UC (solve each "focus region" with outputs from #1 in rest-of-system)



Step 3: Power Flow Reconciliation (full system using each region from Step 2)

Flexibility Inventory: Quantification of Flexibility

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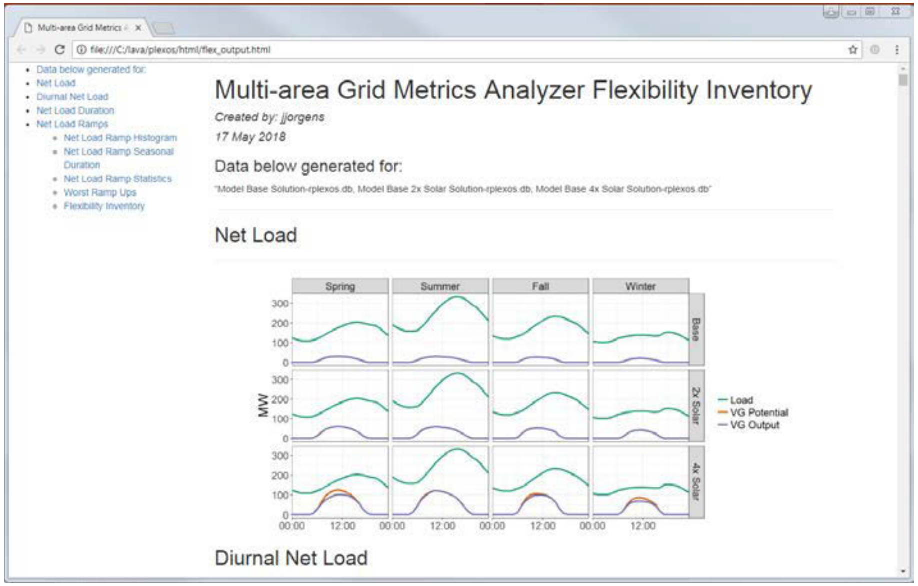
- Logistics: Current flexibility inventory can process the results of PLEXOS runs
- Requires both input and output
- Takes additional inputs, such as:
  - Flexibility inventory timeframes
  - Information about reserves
- Flexibility inventory results are produced as an html file, and plots in png format
- Publicly available in the “flexibility-inventory” branch of the MAGMA repository: https://github.com/NREL/MAGMA
- Report coming soon: Jorgenson, J. et al, "Power System Flexibility Requirement and Supply in High Solar PV Scenarios in the Western U.S." NREL/TP-6A20-72471



- **NREL POC: Jennie Jorgenson**

STEP 1: QUANTIFY FLEXIBILITY NEEDS

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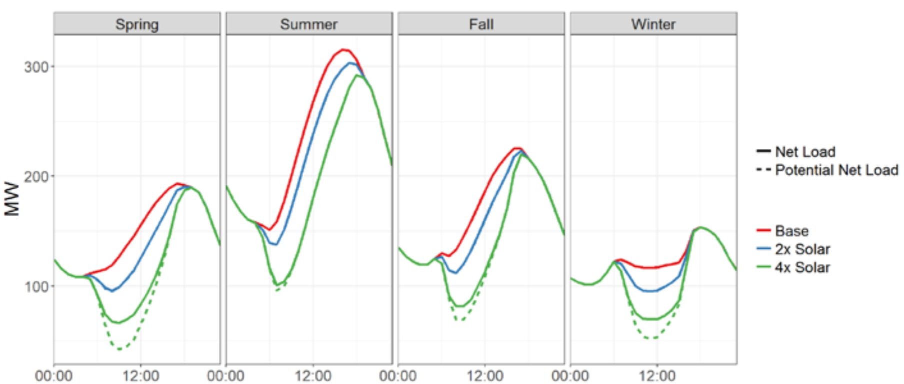
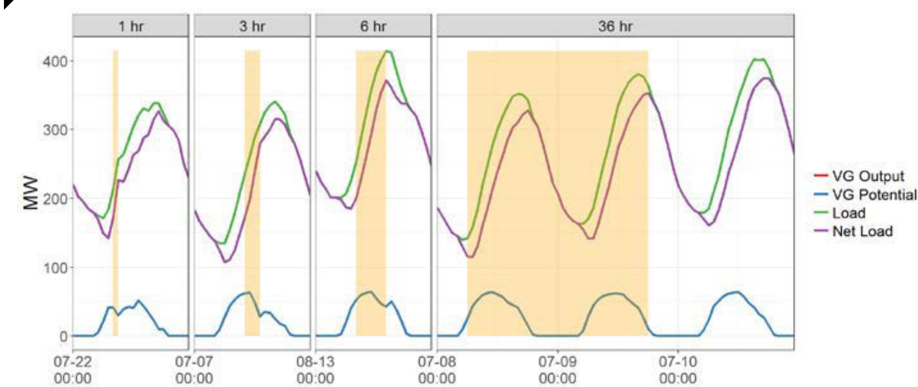
Net Load Analysis



Ramping Needs

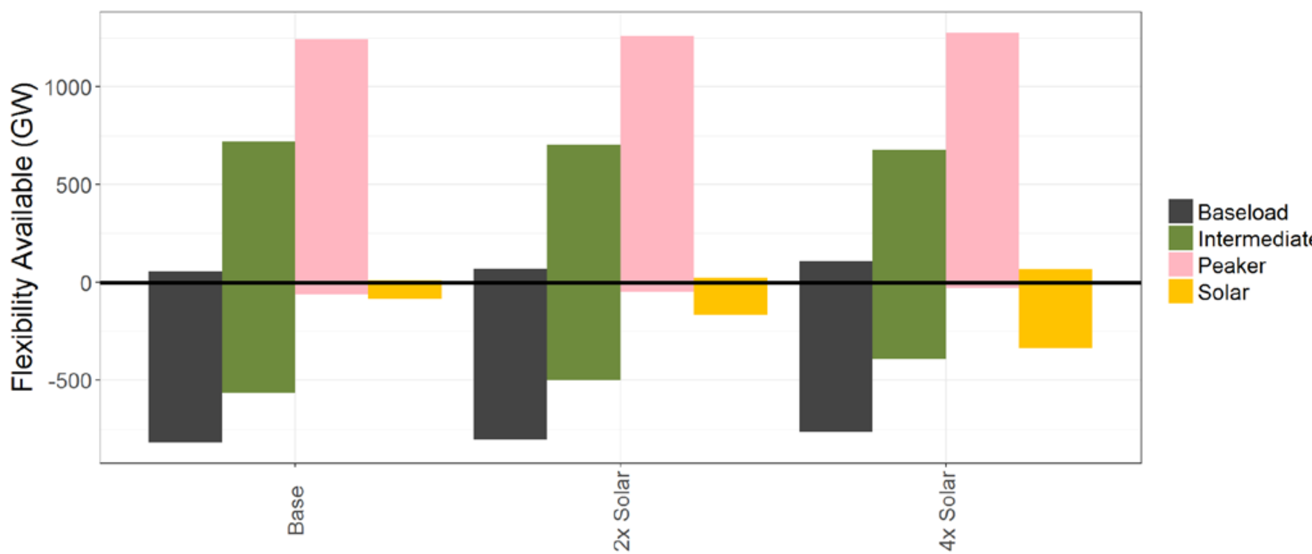


Largest ramps over various timescales

STEP 2: QUANTIFY FLEXIBILITY SUPPLY

Analyze commitment and dispatch of the generator fleet, and determine upward and downward flexibility, incorporating:

- Ramp rate
- Max Capacity
- Min Gen level
- Min up time
- Min down time
- Reserve provision



STEP 3: IDENTIFY POTENTIAL SHORTAGES

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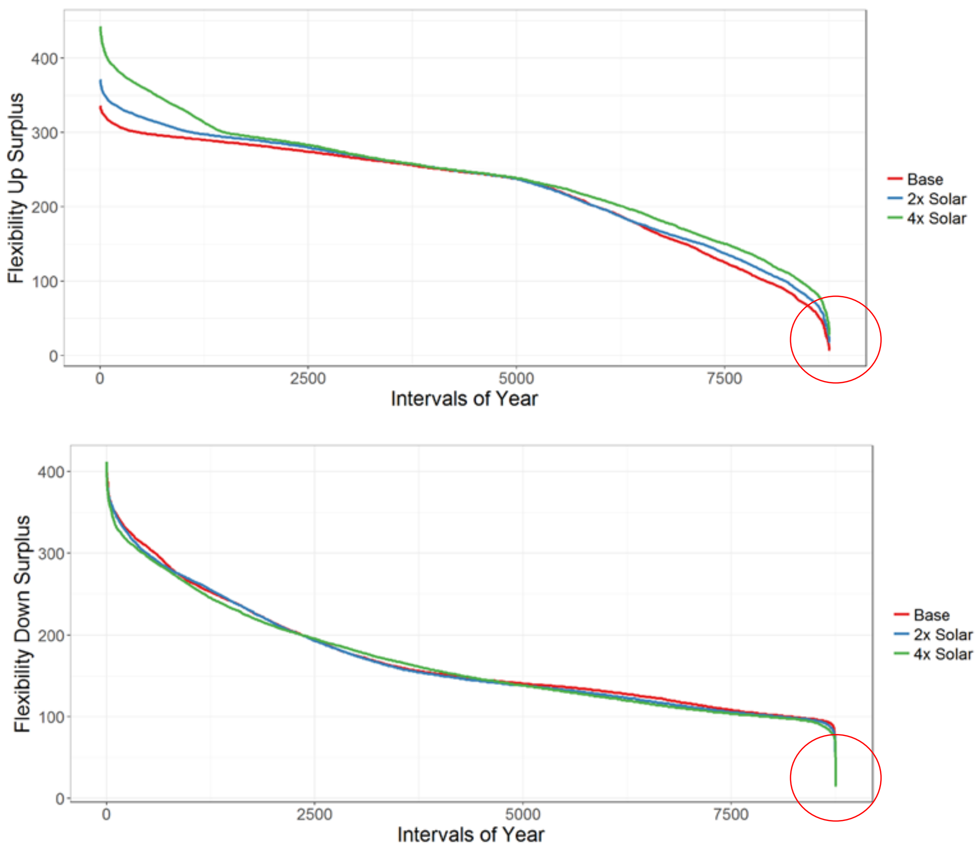

- Determine inventory at “low” levels
- Determine date and time
- Look for systematic reoccurrences of low inventory levels (i.e., time of day, season)
- Identify available resources during these periods

Where are we heading?

A VISION FOR NEXT-GENERATION OF MODELING TOOLS

- Improved versions of ReEDS
- Greater emphasis on reliability and resiliency
- Open source!
  - PRAS
  - ReEDS 2.0
  - ReEDS India → flexible "abstractions" enable adaptation to other countries/systems
- Enhanced visualizations
- Flexible framework for coordinated suite of modeling tools
  - Integrated, flexible framework with consistent structure and database across multiple timescales

IMPROVED REEDS: "REEDS 2.0"

- **Demand-side module**: developed a representation of consumer decision-making around energy service consumption, device adoption, and electricity consumption
- **Dynamic foresight and solve-year flexibility**: developed the capability to solve using one of three different types of foresight into future years: sequential (myopic), intertemporal (perfect foresight), and sliding-window (perfect foresight over a user specified interval)
- **Modular structure and iteration**: to address non-linearities introduced by the demand-side module and intertemporal optimization capability, ReEDS 2.0 was restructured to consist of three stand-alone modules (supply, demand, & VRR); solutions are obtained through an iterative process

NREL POC: Daniel Steinberg

ReEDS 2.0 Structure

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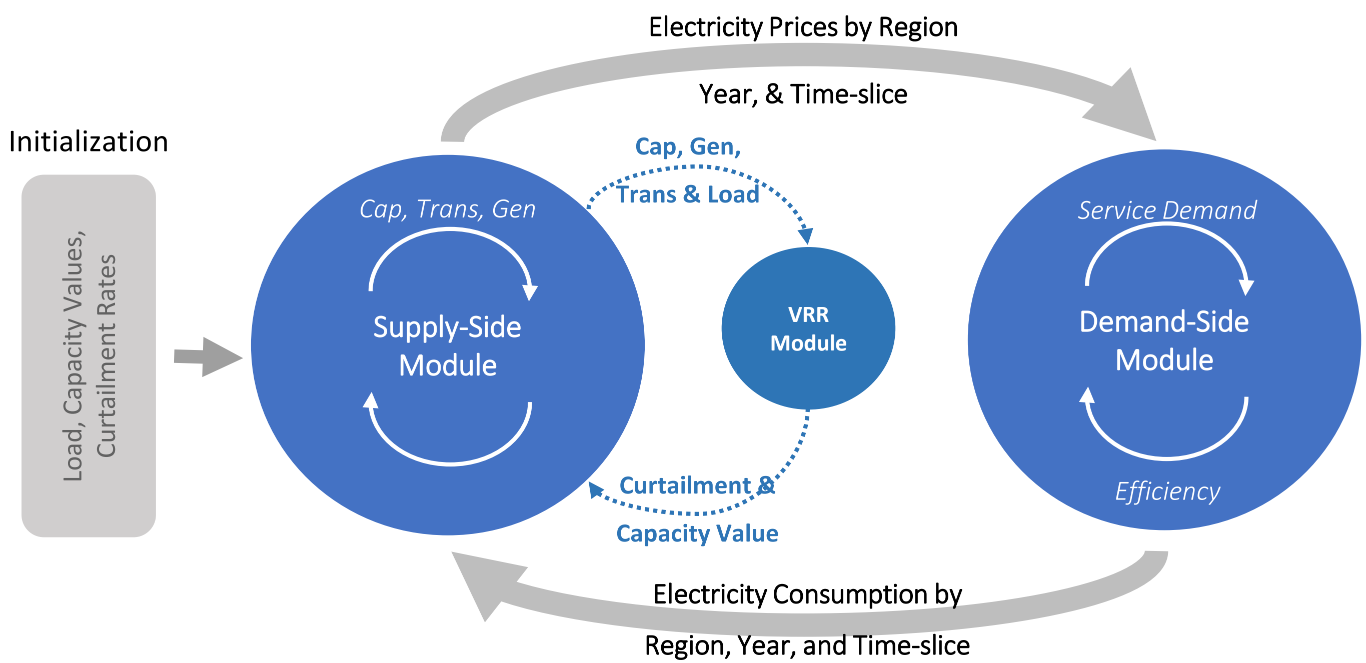
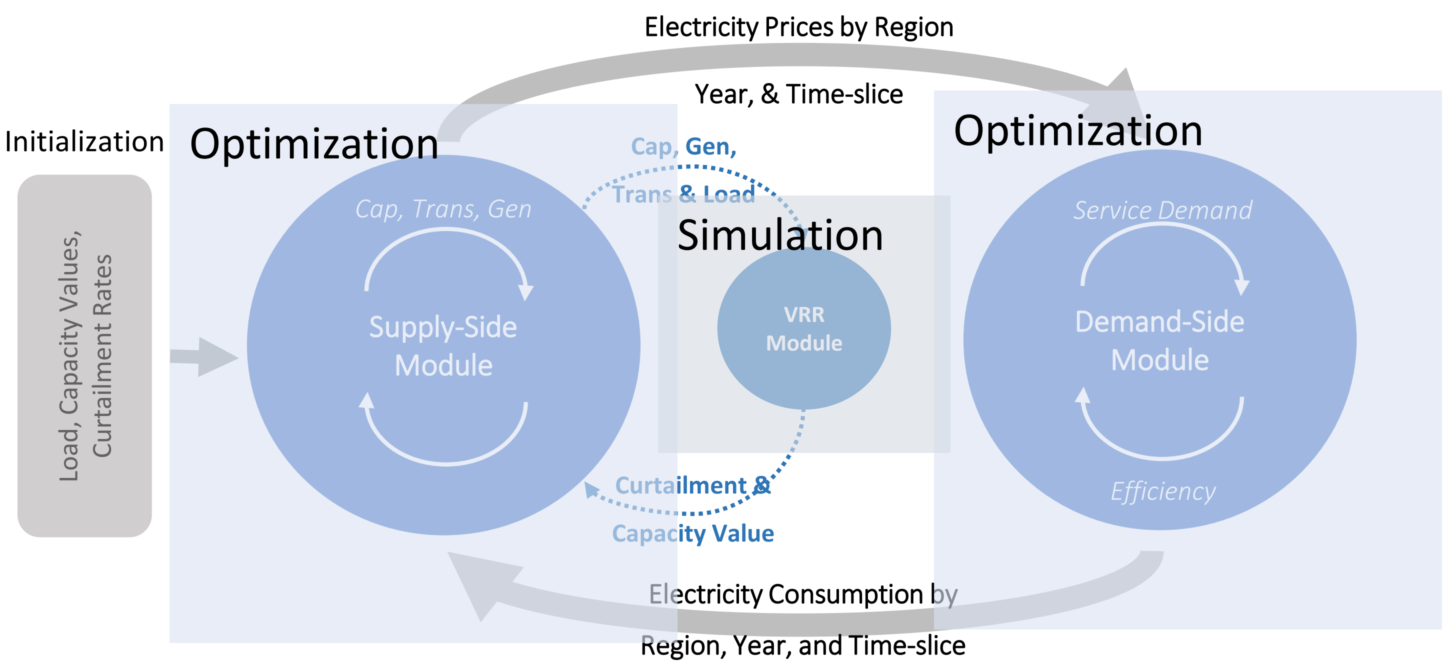


Converges on Electricity Consumption

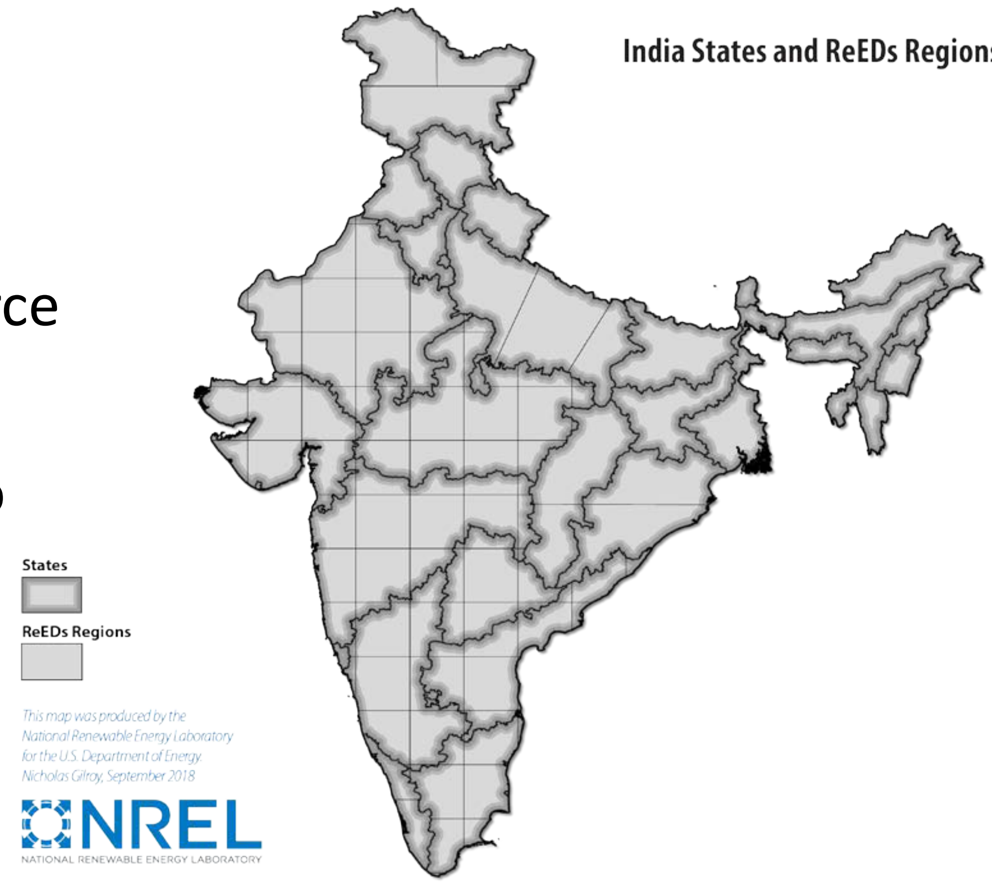
ReEDS 2.0 Structure



Converges on Electricity Consumption

IMPROVED REEDS: "REEDS-INDIA"

- Adapt ReEDS to the Indian power system
  - First application of ReEDS outside of North America
  - Target audience is Central Electricity Authority (CEA)
- 34 balancing areas, 146 resource regions, 35 time slices
- Emphasis on making model structure generic/adaptable to any country or region
- Will be open sourced, including user-friendly interactive results viewer
- NREL POC: Amy Rose

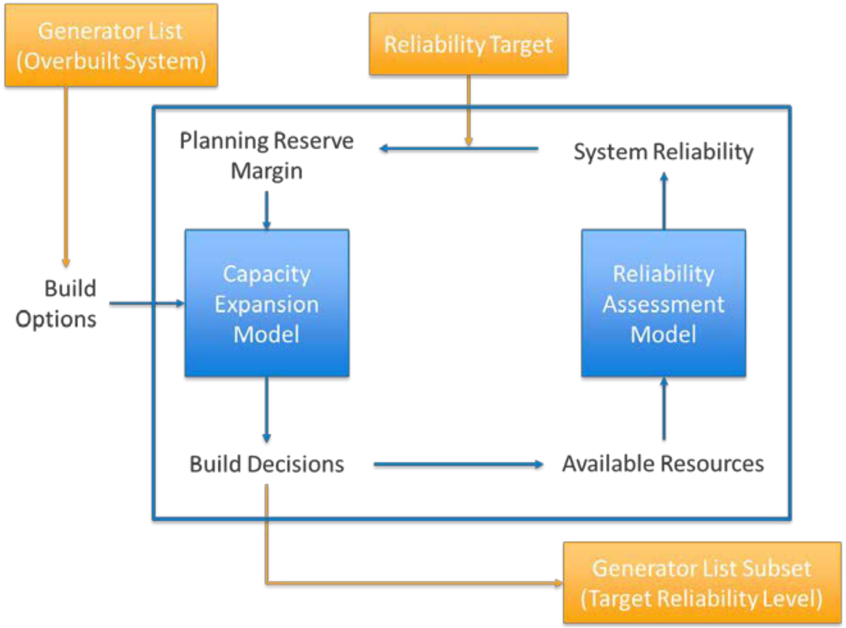


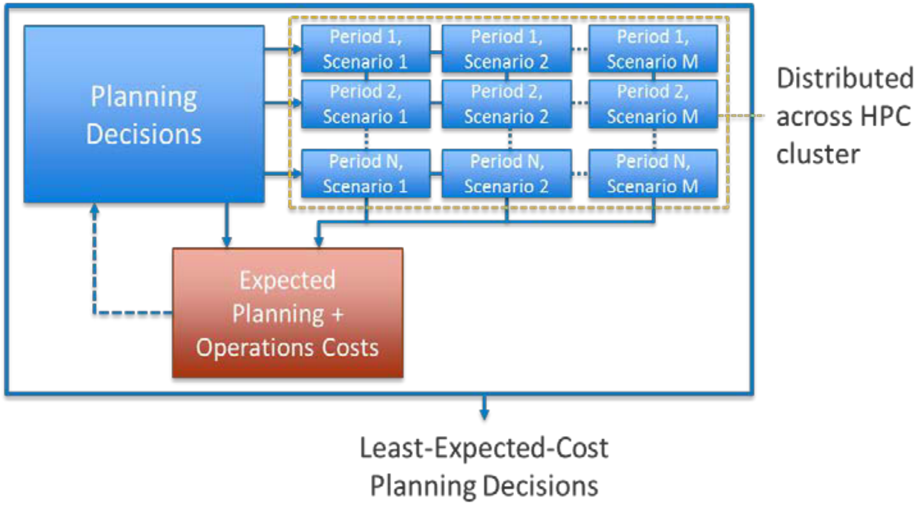
Key considerations for adapting a Capacity Expansion Model to a different system

1. What type of data are available?
2. Do the current capabilities capture all the relevant features of the power system?
   - May require different structures for certain parameters based on available data
   - Also could require modified or additional constraints

These two considerations make adapting a model for any new power system a challenge

Resource Adequacy-Aware Capacity Expansion Model



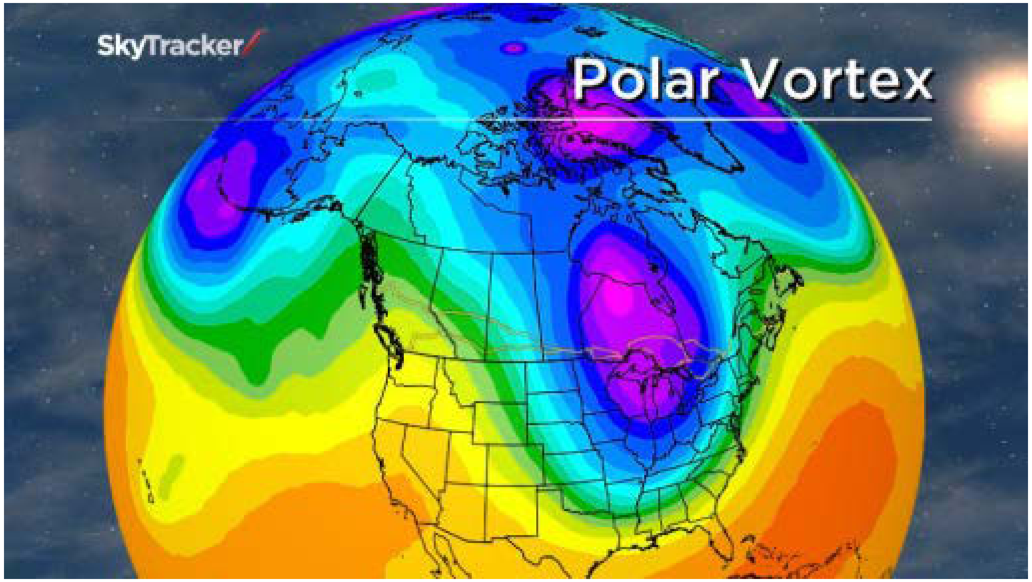


Iterative linking of resource adequacy assessment with capacity expansion model

Directly embed resource adequacy assessment scenarios into capacity expansion model; eliminate use of PRM and CV

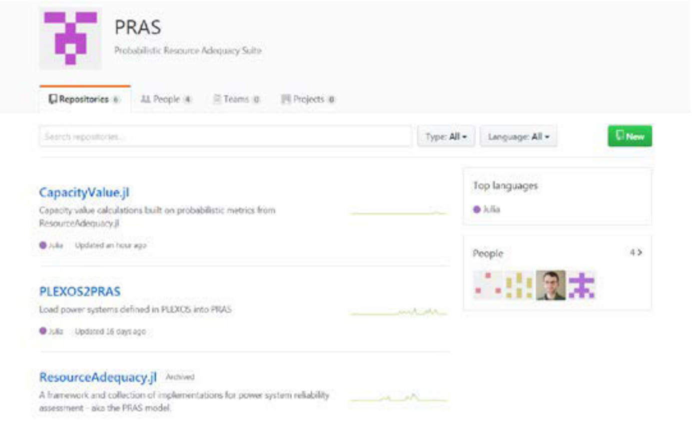
Modeling Resiliency

- Joint probabilities for common-mode outages
- Capture corelated, extreme events
- New metrics?



Open Source!

- PRAS: https://github.nrel.gov/PRAS
  - Coming in 2019 (hopefully)
- dGen
  - Coming in Sept 2020
- ReEDS 2.0
  - Coming in late 2019
- ReEDS India
  - Coming spring 2019
- and many more!



Enhanced Visualizations

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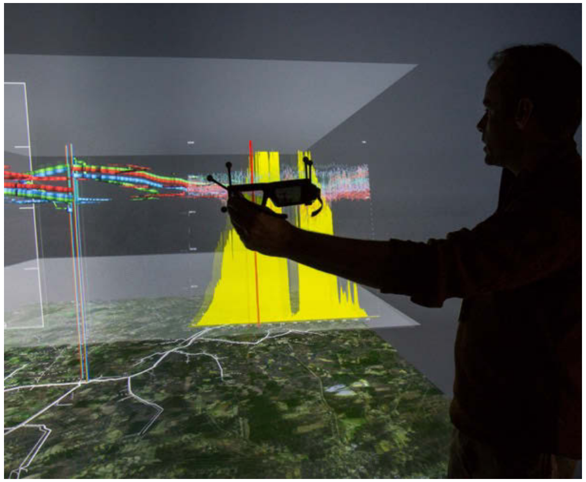
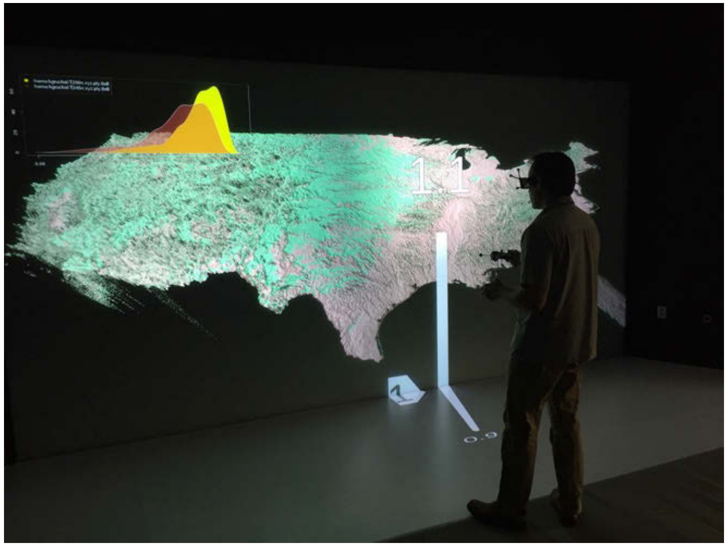
Aids in diagnostic, validation, and analysis efforts

- Kaleidoscope
- Various online data "viewers"
- 3D visualization room





An Integrated Modeling Vision

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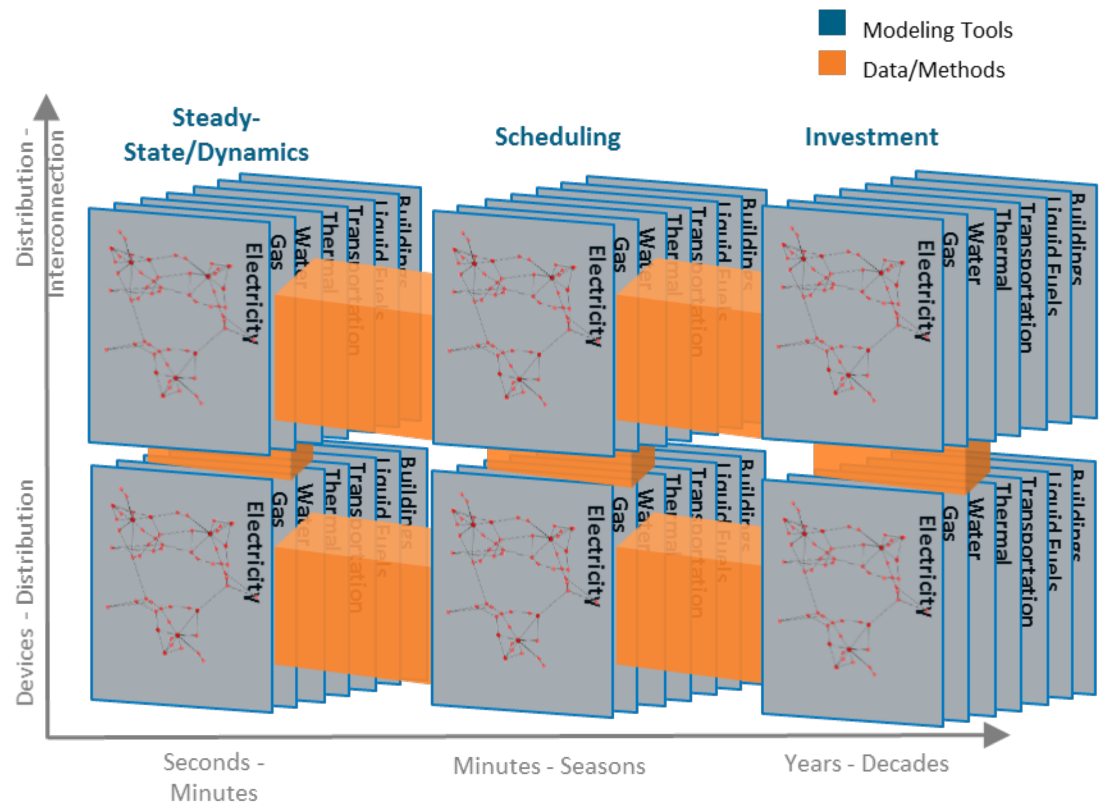
Objectives

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



Scalable Integrated Infrastructure Planning (SIIP) Toolkit

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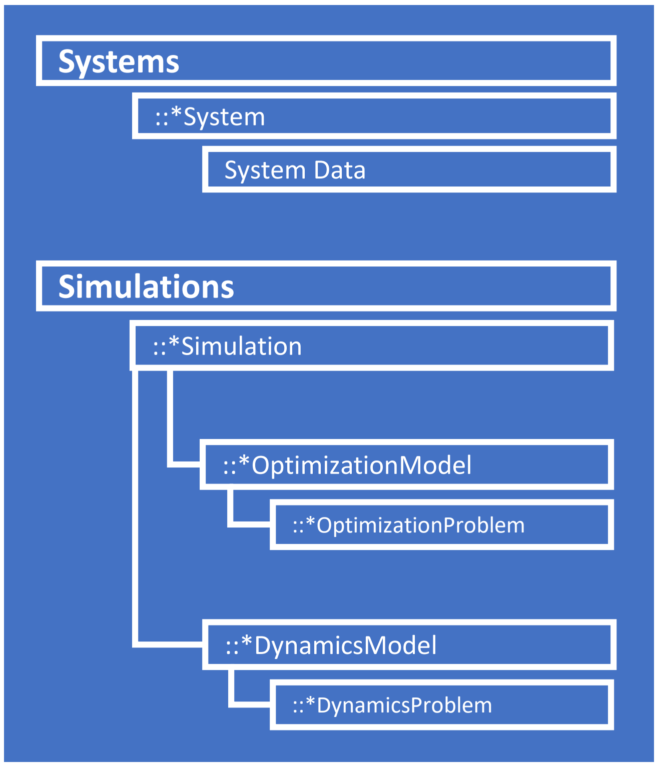
SIIP Framework Anatomy



Data driven system simulations

- **Simulations** define a set of **problems** that can be solved using numerical techniques

- **Problems** are generated by expressing **model formulations** against **system data**

NREL POC: Clayton Barrows

* Infrastructure System: Power, Water, Gas, Buildings, Thermal, Transportation, Liquid Fuels

SIIP FRAMEWORK:
AN EXAMPLE FOR ELECTRICITY SYSTEMS

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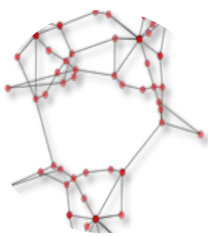
Modular, interoperable, modeling components that define infrastructure modeling problems informed by system data

SIIP::Power



PowerSystems.jl

Rigorous data model that defines infrastructure systems

- Collects information required for device level modeling
- Includes parsing capabilities
- Exploits Julia's parametric dispatch for efficient code development
- Agnostic to simulations that will be performed

PowerSimulations.jl

Mathematical formulations and simulation assemblies

- Support for optimization and dynamic simulation models
- Modular problem assembly to enable rapid development and extension
- Includes standard simulations (e.g. UC/ED)

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SIIP PROVIDES PLATFORM FOR ADDITIONAL CAPABILITIES

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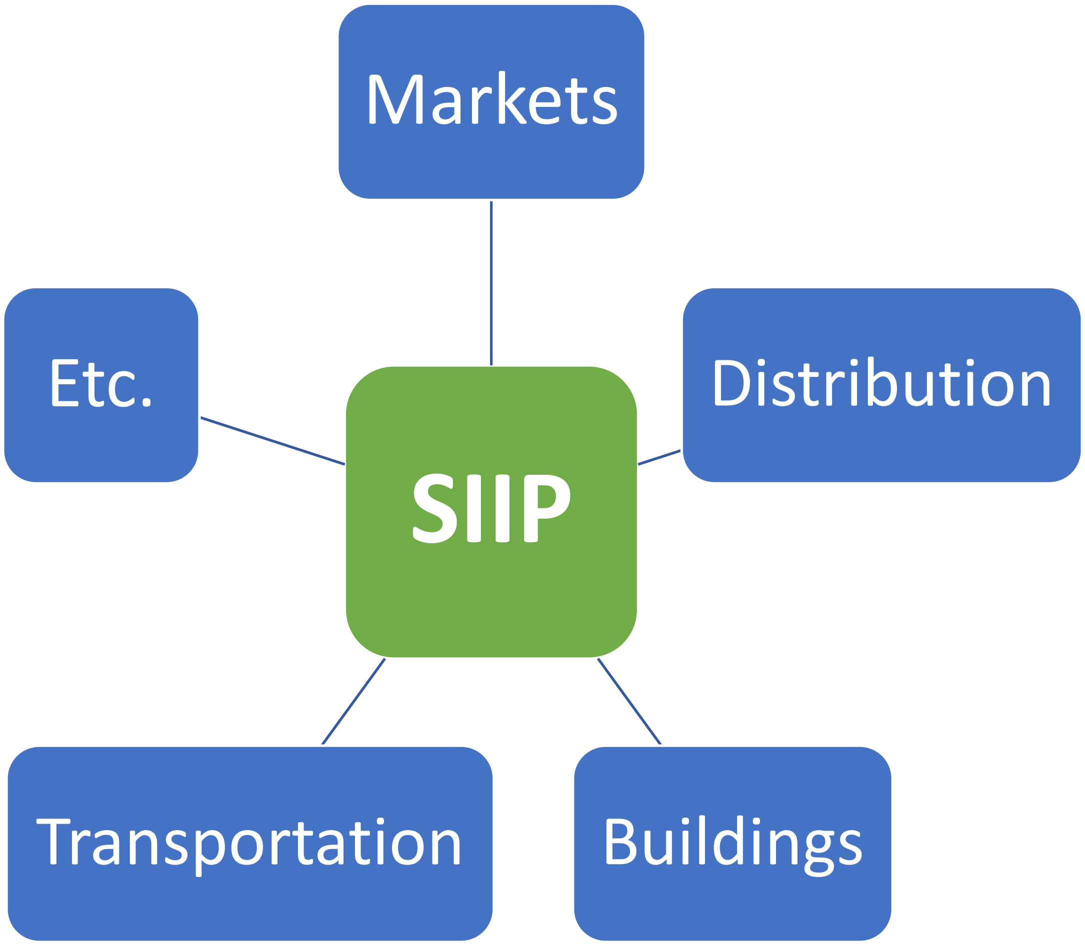

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MOVING TO JULIA: A NEW SCIENTIFIC PROGRAMMING LANGUAGE

julia

21st Century POWER PARTNERSHIP
Accelerating the transformation of power systems

- Provides high-level language abstractions
- Makes efficient use of researcher time
- Access to low-level functionality
- Enables computational performance

Figure: benchmark times relative to C (smaller is better, C performance = 1.0).

		Commercial		Open-source	
Instance	**JuMP**	AMPL	GAMS	Pyomo	YALMIP
clnlbeam-5	9	0	0	5	117
clnlbeam-50	11	2	3	43	>600
clnlbeam-500	28	21	34	424	>600
acpower-1	22	0	0	3	-
acpower-10	28	1	6	26	-
acpower-100	54	16	471	263	-

TABLE 2

Time (sec.) to generate each model and pass it to the solver, a comparison between JuMP and existing commercial and open-source modeling languages for derivative-based nonlinear optimization. Dash indicates not implemented.

http://www.optimization-online.org/DB_HTML/2015/04/4891.html

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GITHUB POWERSYSTEMS.JL RECENTLY RELEASED

NREL / PowerSystems.jl

Watch 13 | Star 13 | Fork 0

Code | Issues 14 | Pull requests 1 | Projects 0 | Wiki | Insights

Data structures in Julia to enable power systems analysis https://github.com/NREL/PowerSystems.jl

816 commits | 4 branches | 8 releases | 1 environment | 4 contributors | View license

Branch: master | New pull request | Create new file | Upload files | Find file | Clone or download

jd-lara Merge pull request #114 from NREL/v-update ... Latest commit 32b0976 5 days ago

deps	an attempt at cloning data in build	16 days ago
docs	Add docs.md	6 months ago
src	fixing an omitted `flag` definition in thermal limit calc function	5 days ago
test	Update to MonitoredLine	5 days ago
.appveyor.yml	FIx CI fails	3 months ago
.codecov.yml	update codecov.yml	4 months ago
.gitignore	update .gitignore and remove wrong readmes	3 months ago
.travis.yml	remove allowfails for v1.0	5 days ago
CHANGELOG.md	update changelog and readme	2 months ago
CONTRIBUTING.md	Create CONTRIBUTING.md	4 months ago
LICENSE	removing the md file extension from license	3 months ago
Manifest.toml	resolving braking changes from TimeSeries v0.14.0, closes #104	8 days ago
Project.toml	Remove Authors from Project	5 days ago
README.md	update changelog and readme	2 months ago

THANK YOU!

21st Century
POWER
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Accelerating the transformation of power systems

bethany.frew@nrel.gov

CLEAN ENERGY
MINISTERIAL
Accelerating the Transition to Clean Energy Technologies

Brazil **China** **India** (co-lead) **Denmark** **Finland** **Mexico (co-lead)** **South Africa** **Spain** **United States** (co-lead, under review)