INL/MIS-23-72148-Revision-1

Building the Case for Hybrid Energy Developments: Webinar Recording Day 2

April 2023

Changing the World's Energy Future

Megan Jordan Culler, Kevin McCabe, Caitlyn Clark, Daniel Boff, Michael Leitman, Heidi Tinnesand

Idaho National Laboratory

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http://www.inl.gov

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Building the Case for Hybrid Energy Developments

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Idaho National Laboratory

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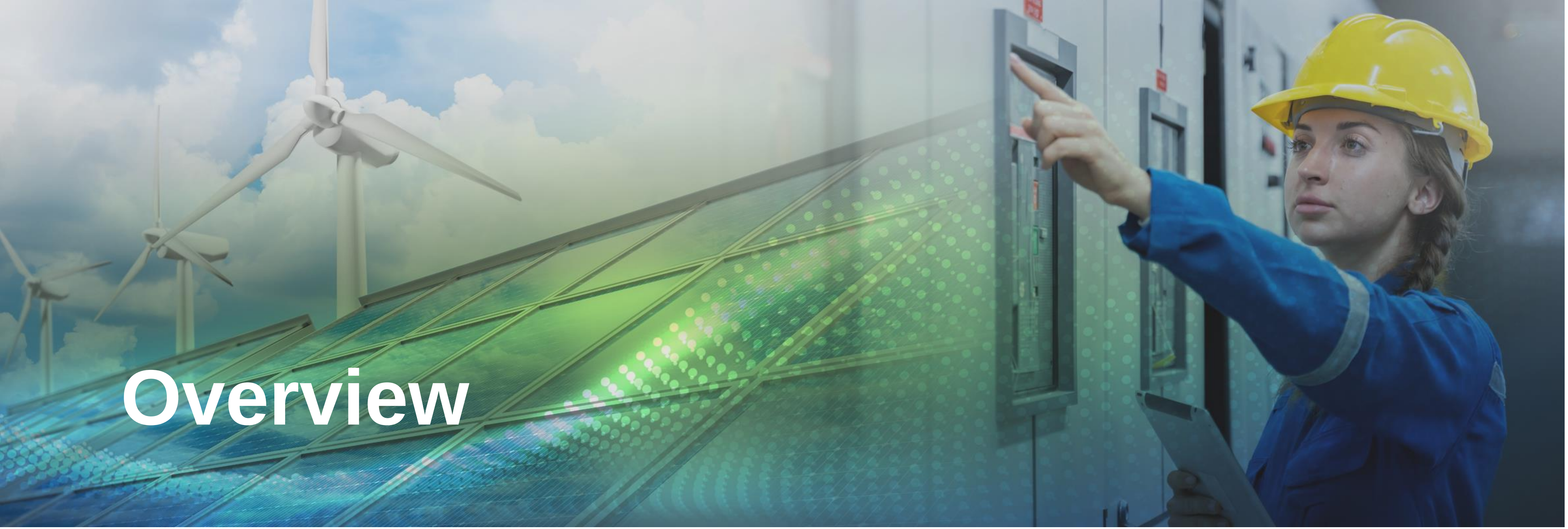


Overview

Housekeeping

- Same link for tomorrow’s meeting
- Meeting will be recorded
- Put questions in the chat or unmute
- Presentations and key resources will be available on the website

  https://inl.gov/national-security/hybrid-energy-webinar/
- Please register if you haven’t already

Preview

Applications for hybrid systems

- Case studies
- Opportunities

Justifying the cost of hybrid systems

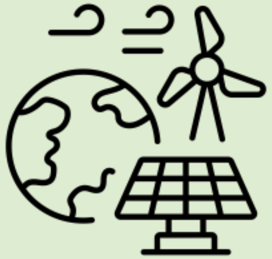
- Valuation framework

Using renewable resources to enhance resilience

- Resilience framework

Siting of hybrid systems

- Wind resource assessment
- Tools assessing performance (TAP)



Tools to design hybrid systems

- Resilience application
- Hybrid Optimization and Performance Platform (HOPP)

Funding opportunities

- Opportunities and technical assistance

Funded by the Wind Energy Technologies Office

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Agenda

Why should I consider a hybrid system?

- Benefits of wind hybrid systems

How can I design a system that works for me?

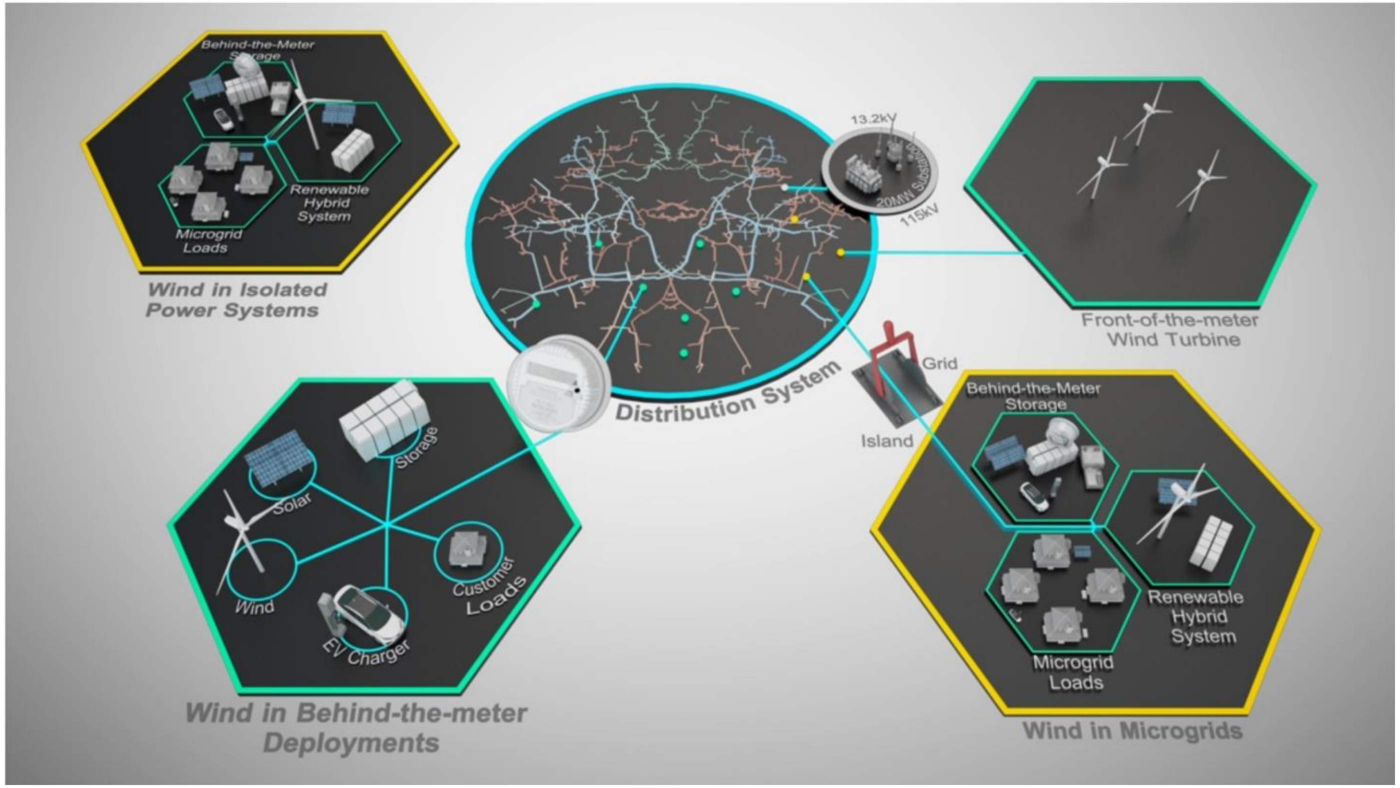
- What does “work for me” mean?
- Valuation Framework
- Resilience Framework
- Design Considerations

Technical Assistance Opportunities

- How can national laboratories help?
- Discussion

Project Overview

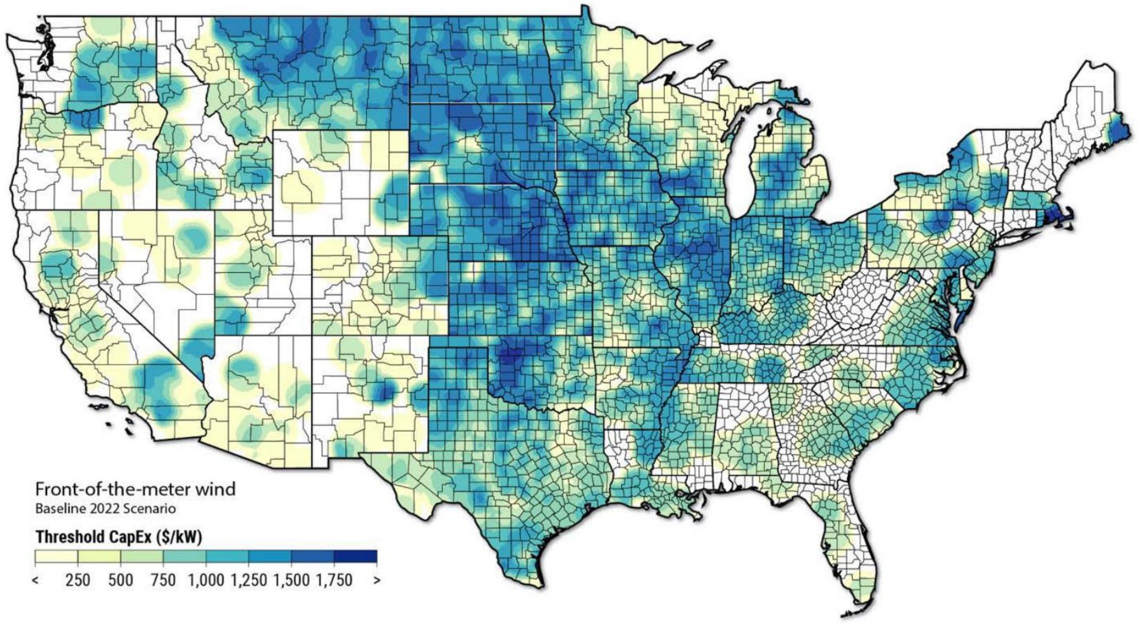
On Site Wind for Rural Load Centers

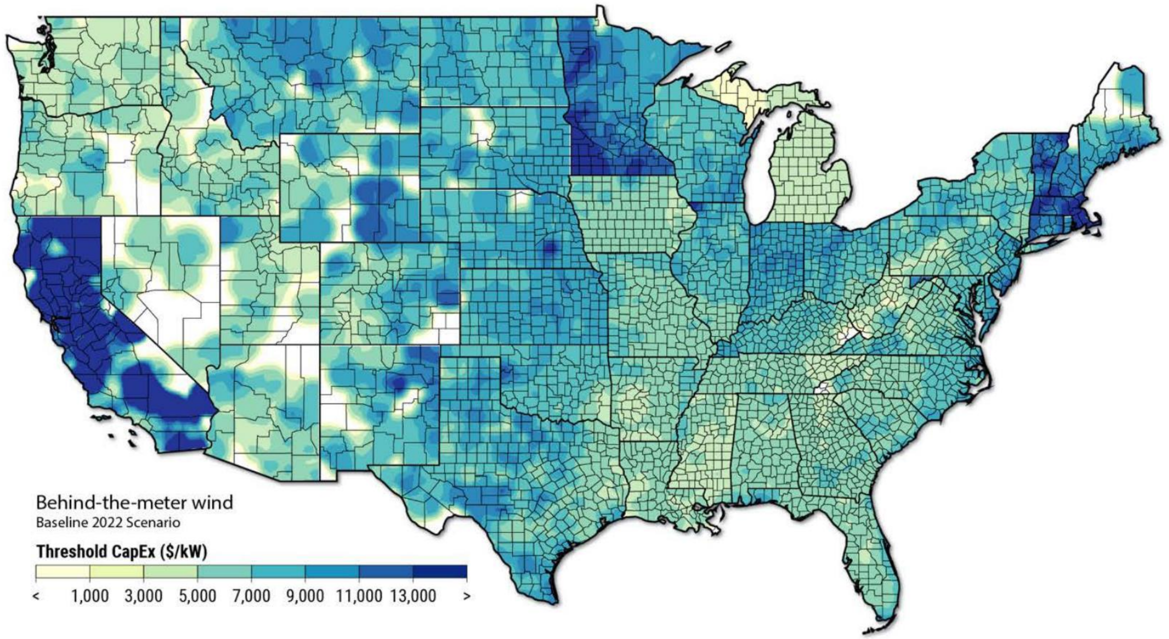


https://www.nrel.gov/docs/fy22osti/82519.pdf

Project Overview

On Site **Wind for Rural** Load Centers





https://www.nrel.gov/docs/fy21osti/76918.pdf

Project Overview

On Site Wind for Rural **Load Centers**

Residential

Industrial

Commercial

Agricultural

Project Team

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

- Hybrid system design
- Add features for HOPP

INL
Idaho National Laboratory

- Resilience needs of different load types
- Resilience boosters for distributed wind
- Lead TA and case study engagements

Pacific Northwest
NATIONAL LABORATORY

- Valuation of distributed wind
- Valuation service as a user tool
- Energy equity

IOWA STATE UNIVERSITY

- Connect labs to community interests
- Resilience analysis
- Rural applications for distributed wind

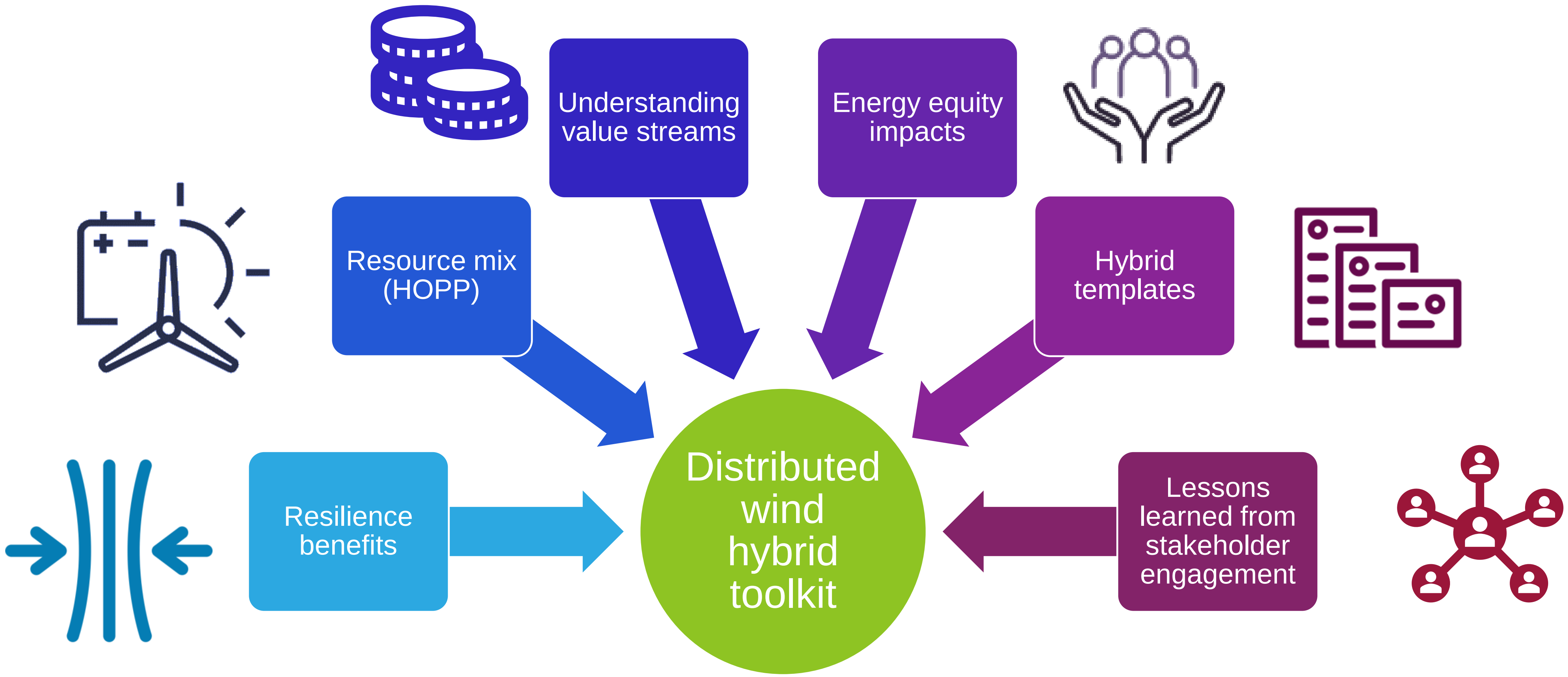
NRECA
America's Electric Cooperatives

- Leverage previous distributed wind work with co-ops

Mana Group LLC

- Stakeholder engagement
- Coordination with other projects
- Outreach

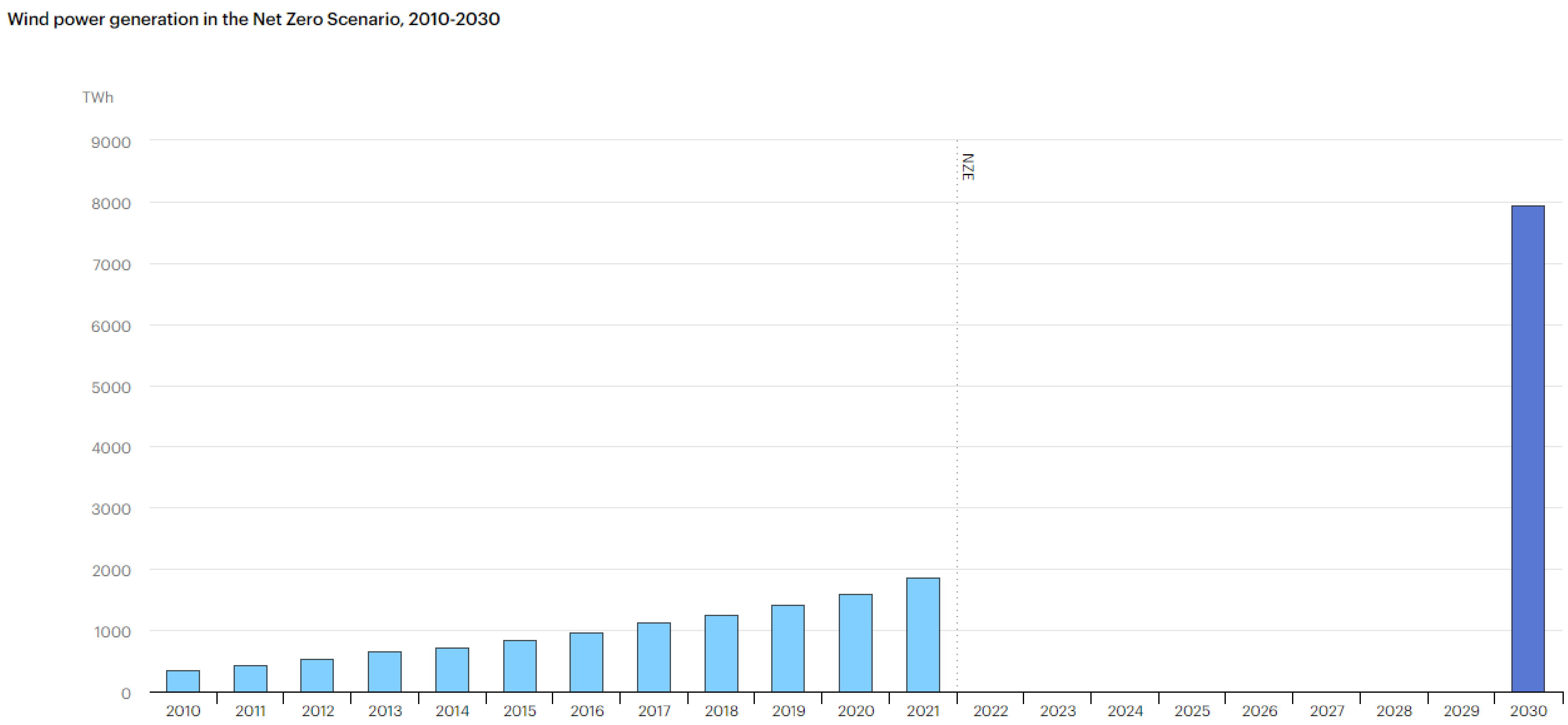
Distributed Wind Hybrid Toolkit



Why should I consider a hybrid system?

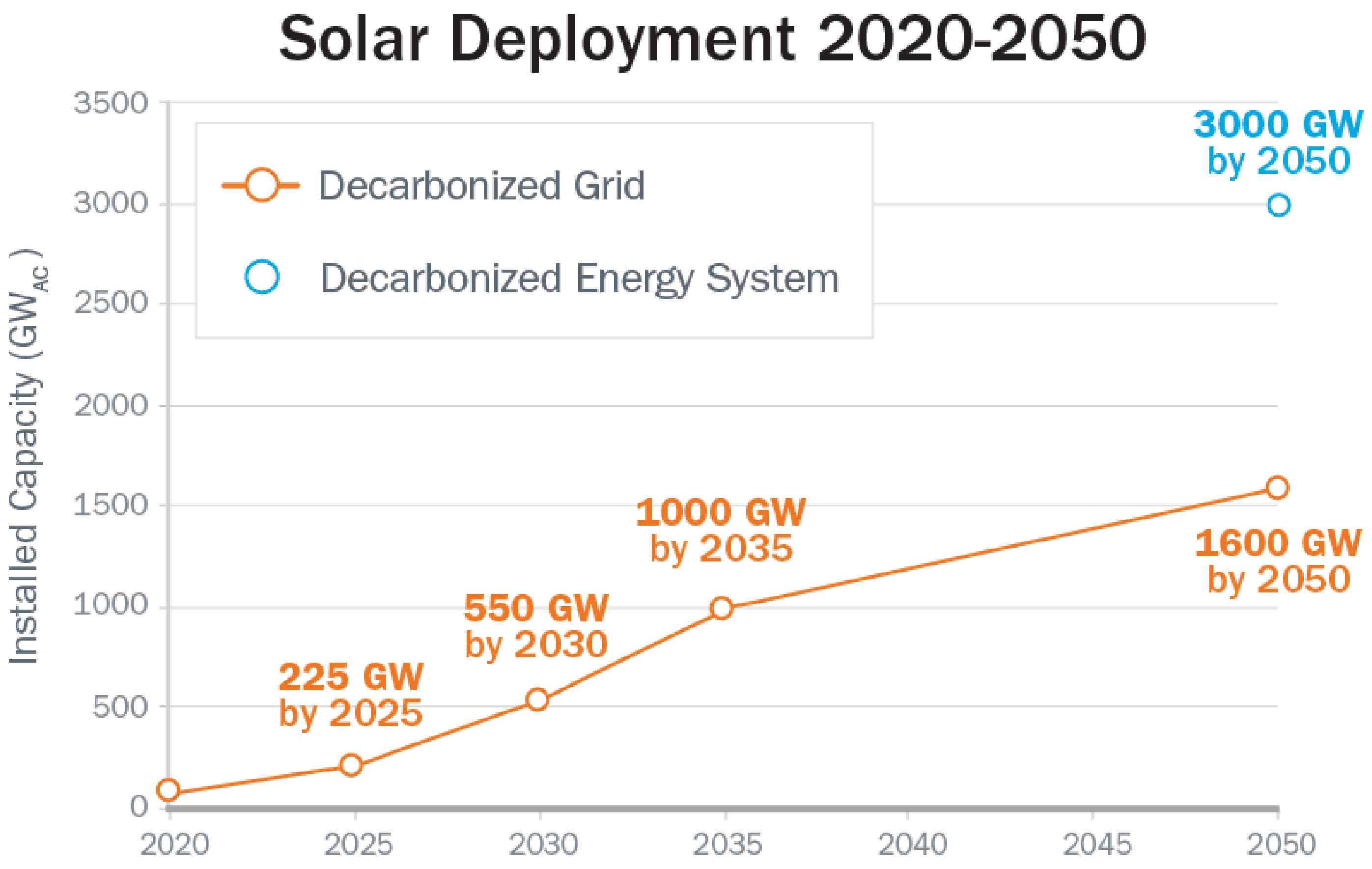
Benefits of wind-hybrid systems

Wind energy targets



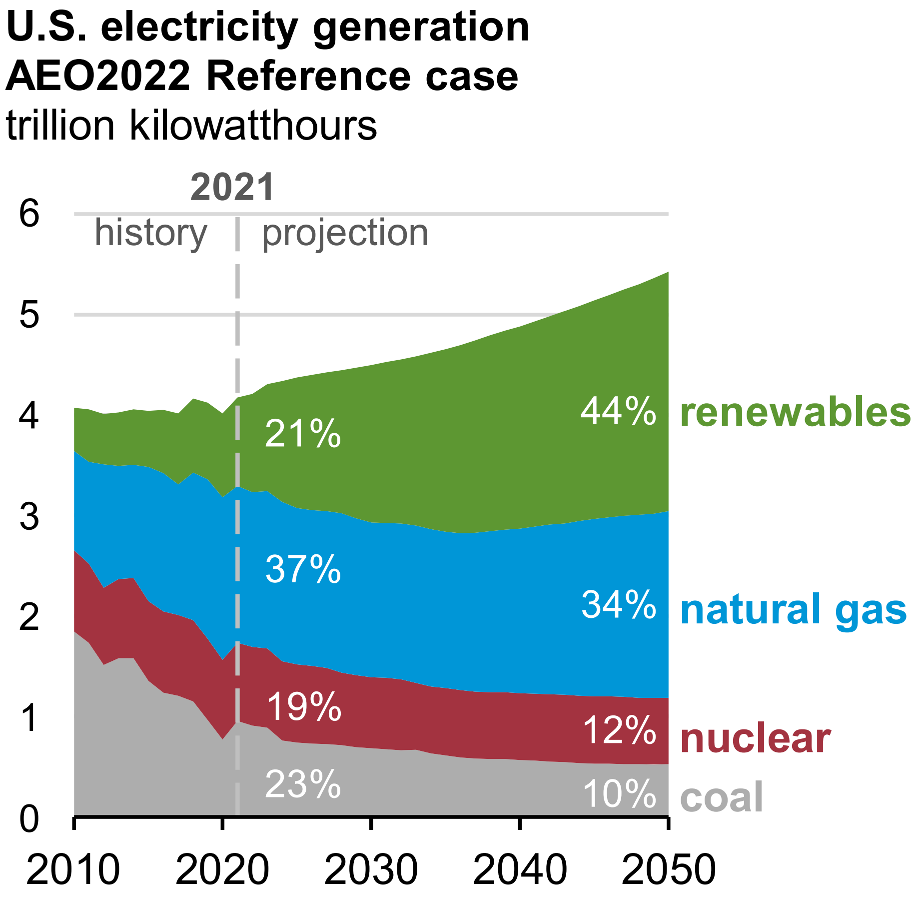
https://www.iea.org/reports/wind-electricity

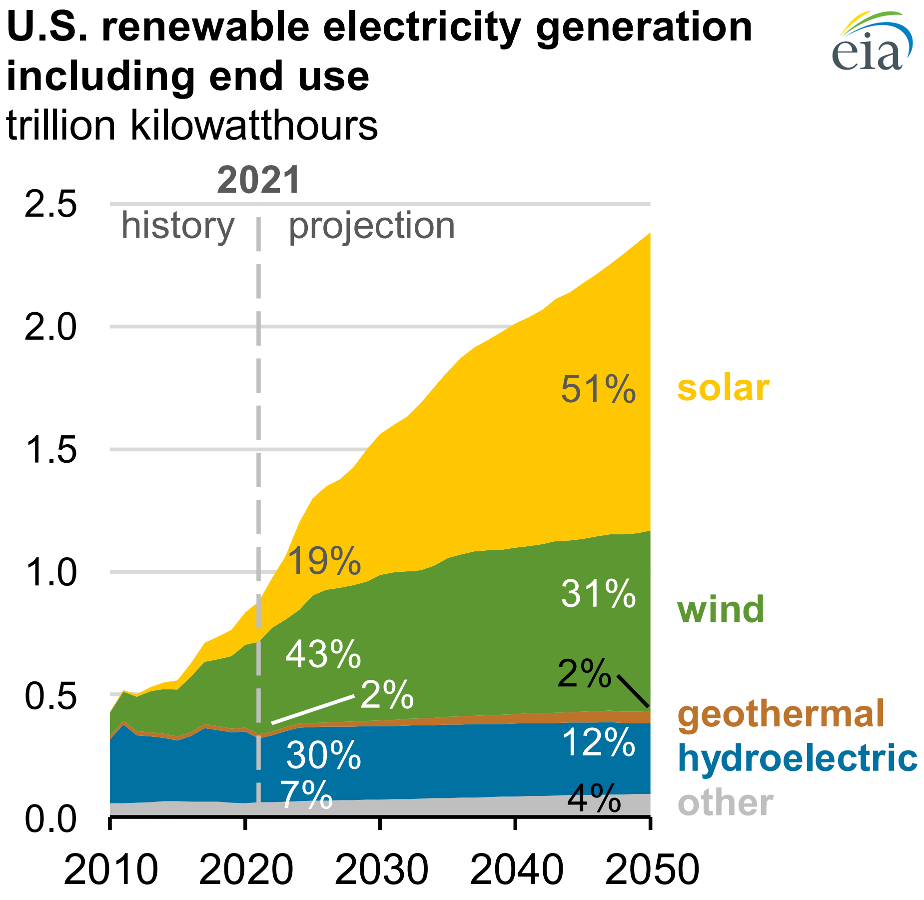
Solar energy targets



https://www.energy.gov/eere/solar/solar-futures-study

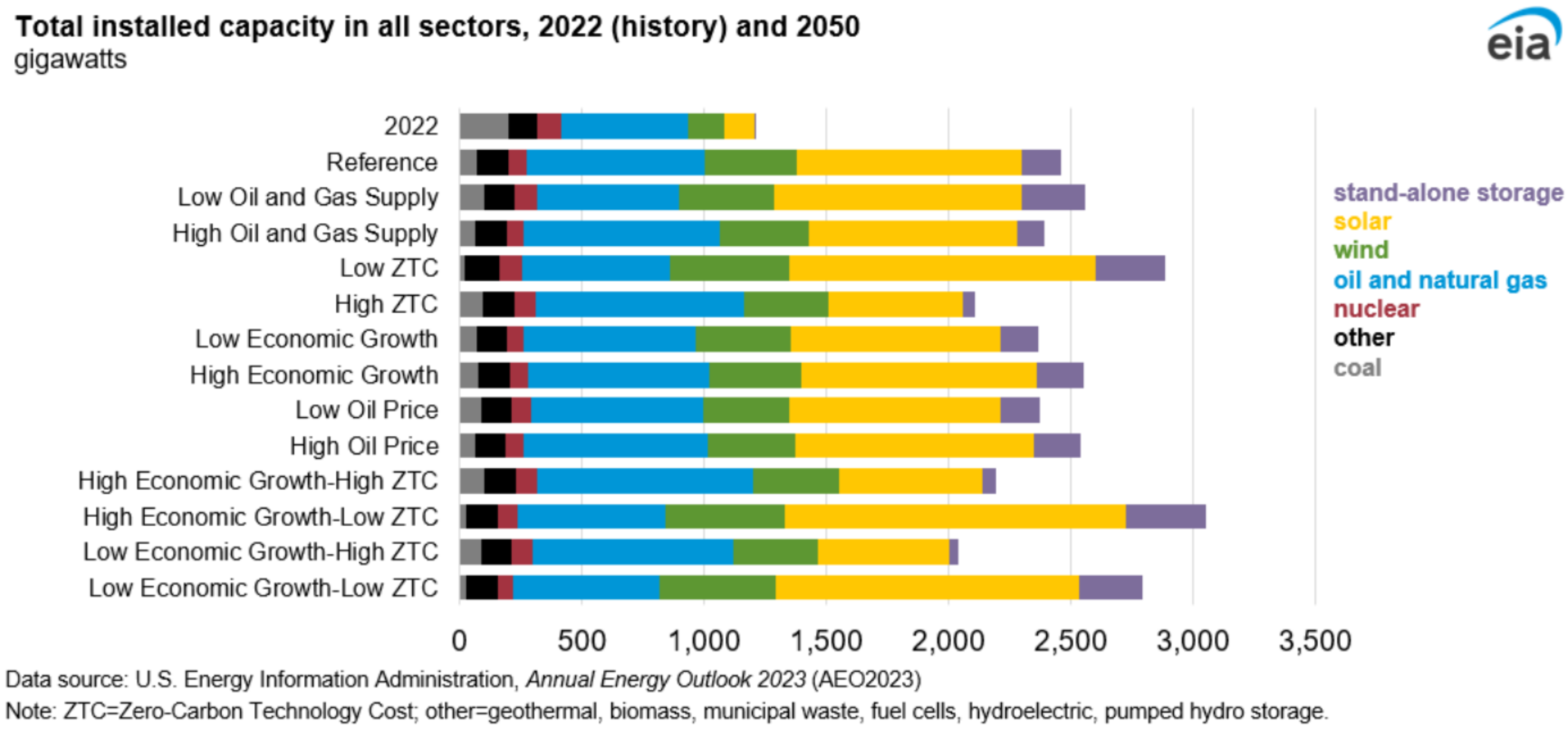
Projected growth





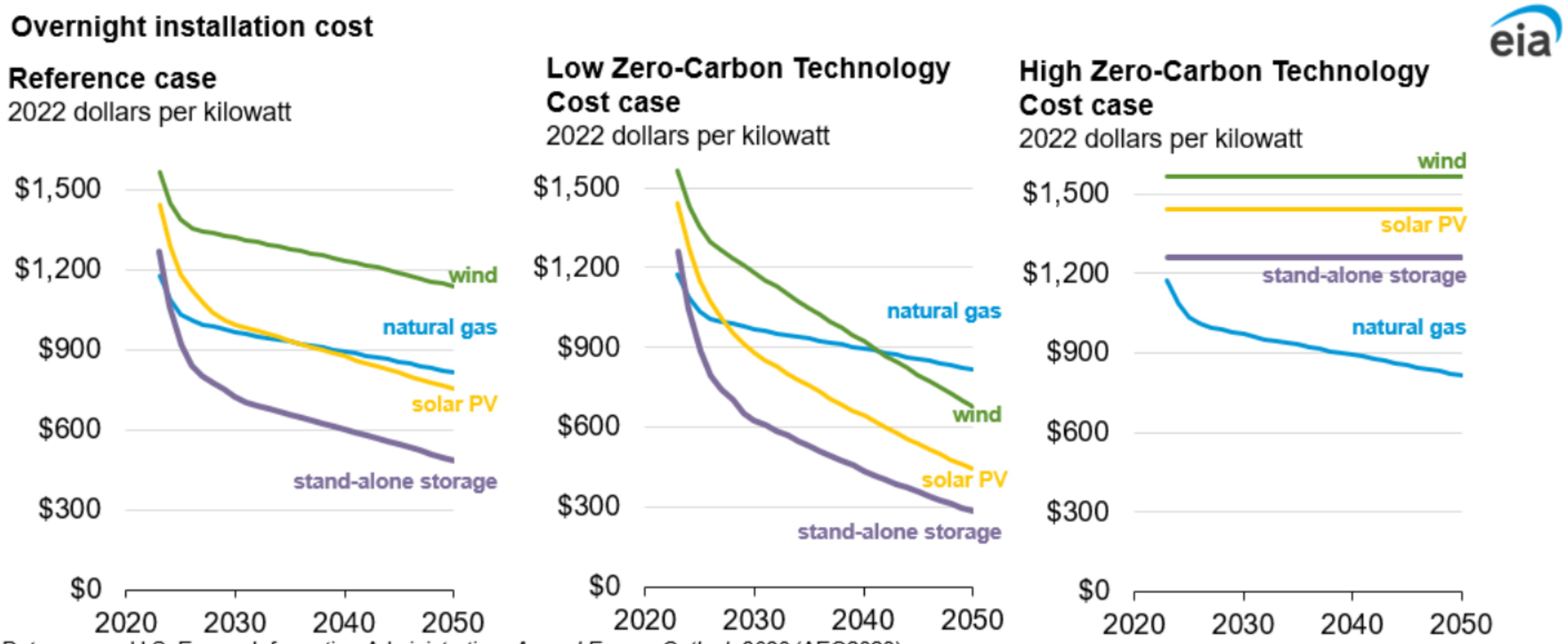
https://www.eia.gov/outlooks/aeo/narrative/

Projected growth cases



https://www.eia.gov/outlooks/aeo/narrative/

Costs

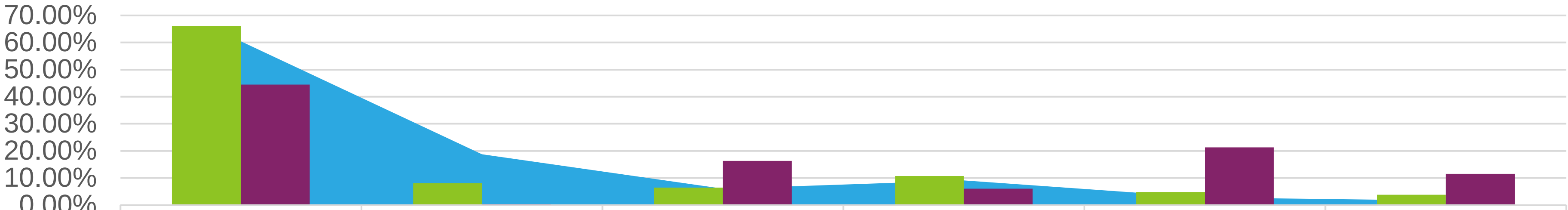


Data source: U.S. Energy Information Administration, *Annual Energy Outlook 2023* (AEO2023)
Note: Series in all charts begin in 2023. Overnight installation cost for natural gas refers to combined-cycle, multi-shaft technologies. Nuclear costs decline in the Reference and Low Zero-Carbon Technology cases, but they are not shown given the large differences in absolute cost compared with renewables. In the Reference case, nuclear begins at $7,900 per kilowatt (kW) and declines to $5,000/kW in 2050. In the Low Zero-Carbon Technology case, the cost of nuclear declines to $3,000/kW in 2050. Solar PV=stand-alone solar photovoltaic.

https://www.eia.gov/outlooks/aeo/narrative/

% Total Units, Energy, and Capacity

2021

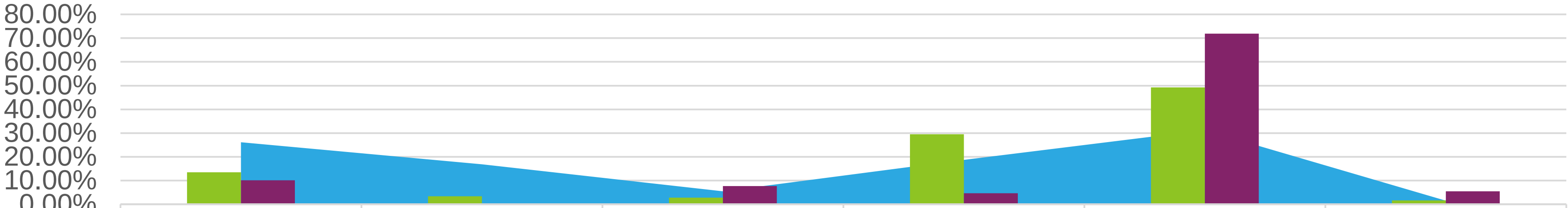


	Fossil Fuel Generation	Nuclear	Hydroelectric Conventional	Wind	Solar PV Utility	Other Renewable Energy Sources
% Total Energy by Type	60.42%	18.75%	6.06%	9.11%	2.78%	1.69%
% Total Capacity	66.03%	8.05%	6.44%	10.75%	4.86%	3.87%
% Generator Count	44.44%	0.38%	16.30%	6.03%	21.33%	11.53%

% Total Energy by Type   % Total Capacity   % Generator Count

% Total Units, Energy, and Capacity

2030

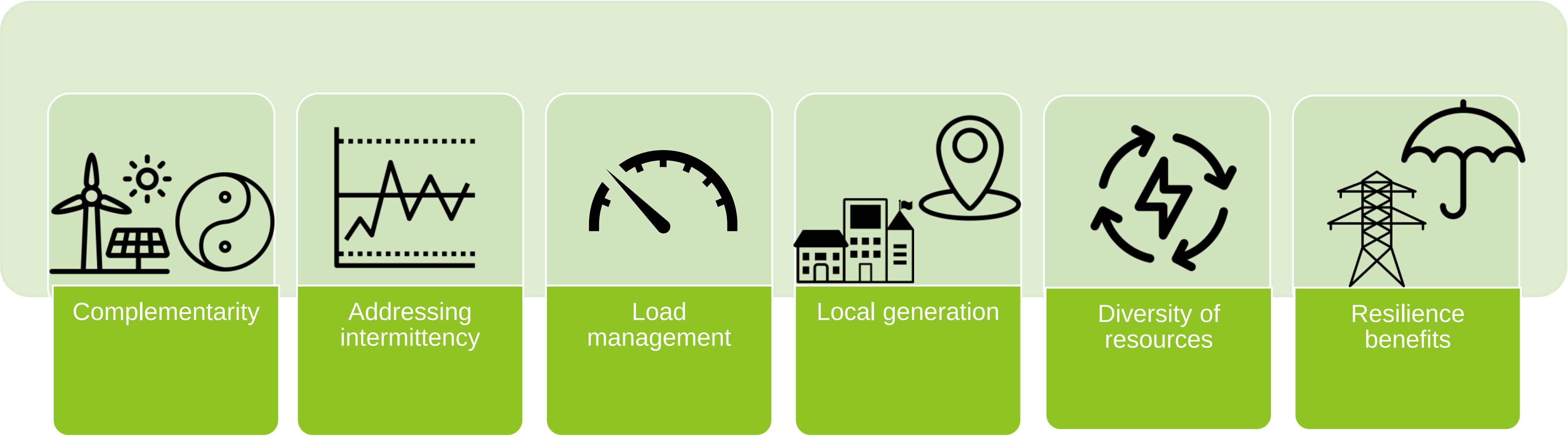


	Fossil Fuel Generation	Nuclear	Hydroelectric Conventional	Wind	Solar PV Utility	Other Renewable Energy Sources
% Total Energy by Type	26.13%	16.89%	5.46%	18.73%	31.27%	1.52%
% Total Capacity	13.45%	3.42%	2.73%	29.50%	49.25%	1.64%
% Generator Count	10.10%	0.18%	7.72%	4.67%	71.88%	5.46%

% Total Energy by Type   % Total Capacity   % Generator Count

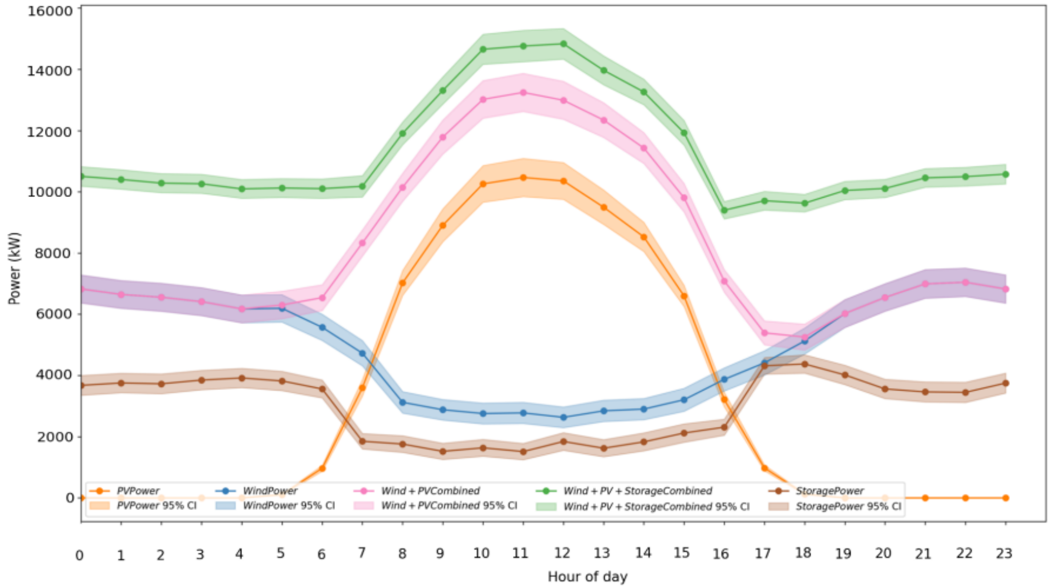
Based on EIA Data

How can we maximize the impact of renewable resource deployments?



Complementarity

- Leverages complimentary nature of variable resources, like wind and solar



Temporal complementarity

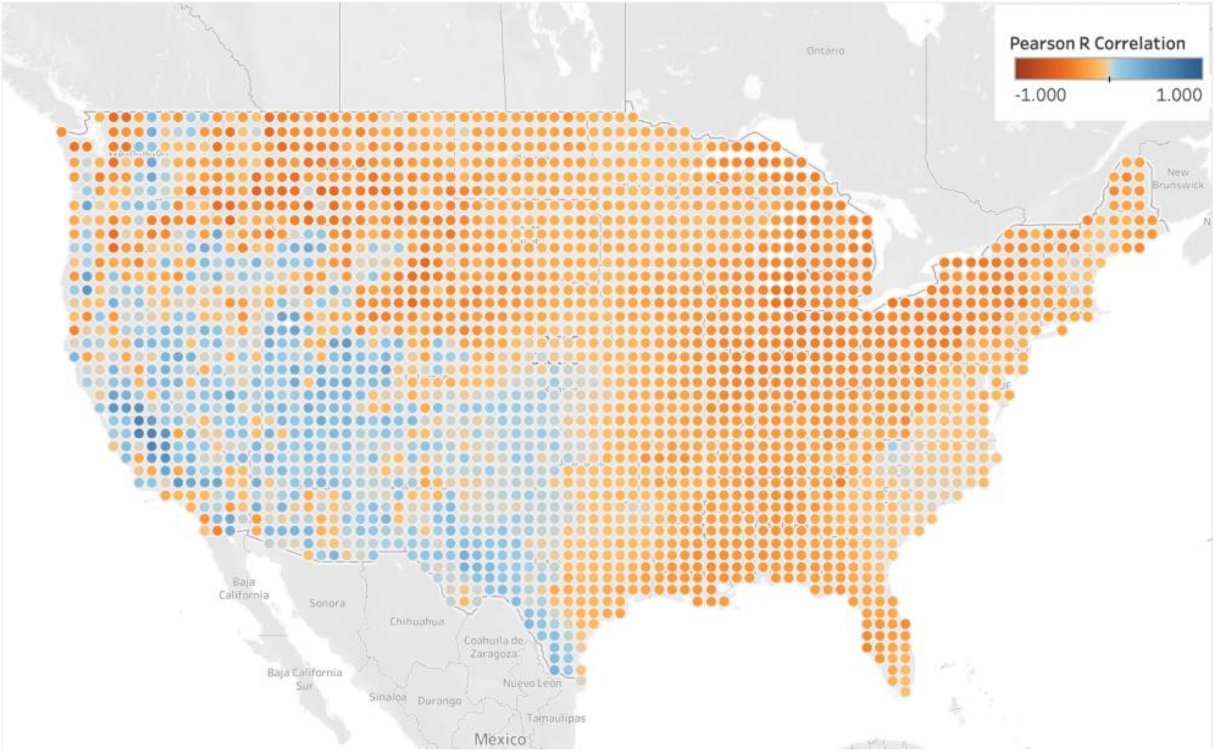


Figure Appendix A.1. Annual, daily-averaged complementarity (represented by the Pearson correlation metric) for 2013 in the contiguous United States

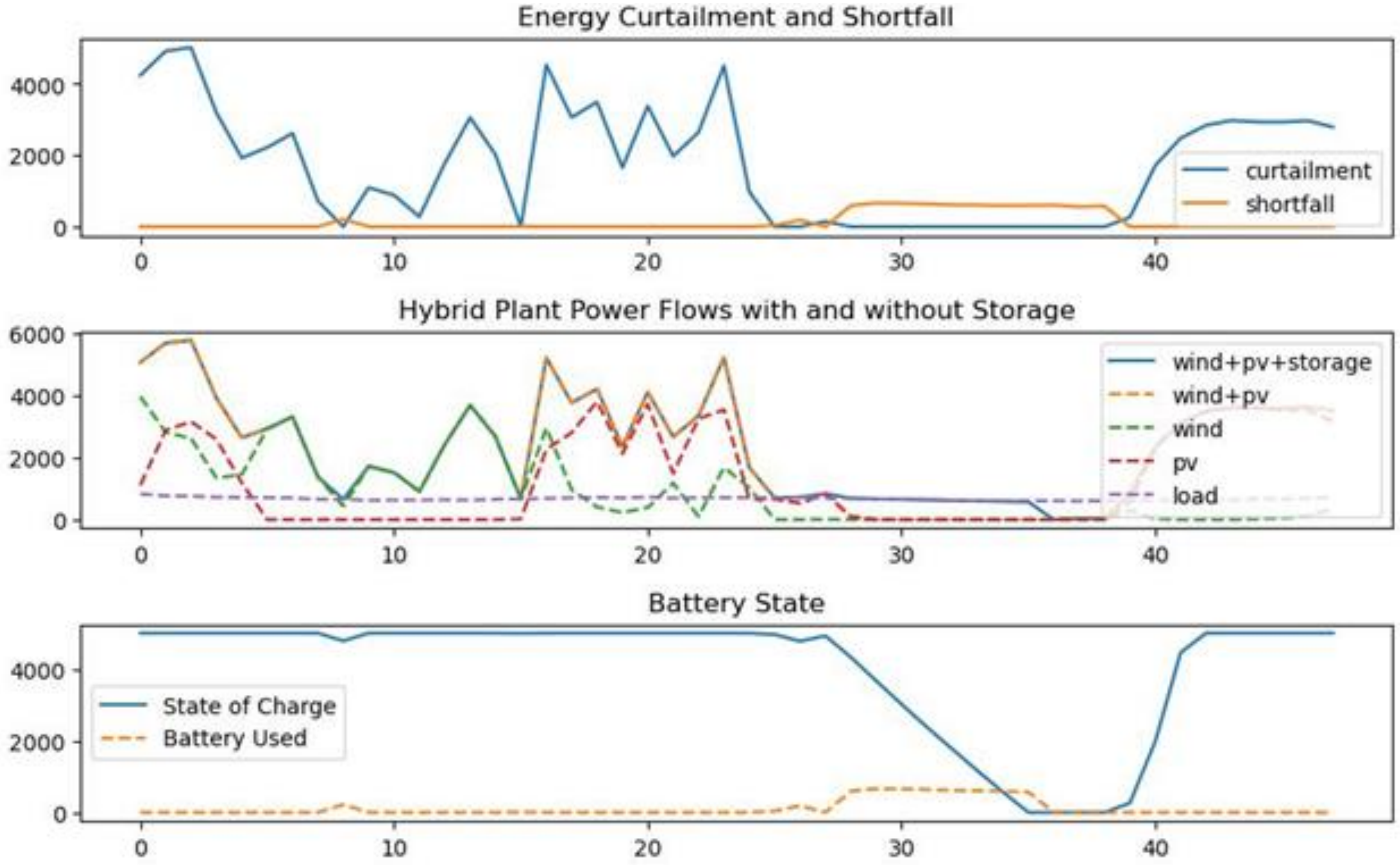
Spatial complementarity

https://www.nrel.gov/docs/fy22osti/80415.pdf

Case Study: Algona, Iowa

- Three existing distributed wind turbines with net capacity of 1.8 MW
- 2 substations, west and east, connected by transmission tie line
- West sub served by 2 incoming transmission lines from G&T provider
- East sub served by 1 incoming transmission lines from G&T provider
- 14 distribution feeders, 5 from the west sub, and 9 from the east sub
- Four local diesel generators provide net capacity of 16.1 MW
- Resilience goals:
  - Reduce dependence on transmission system
  - Maintain power under cyber or other disruption
- Resilience hazards:
  - Tornado event
  - Winter weather event

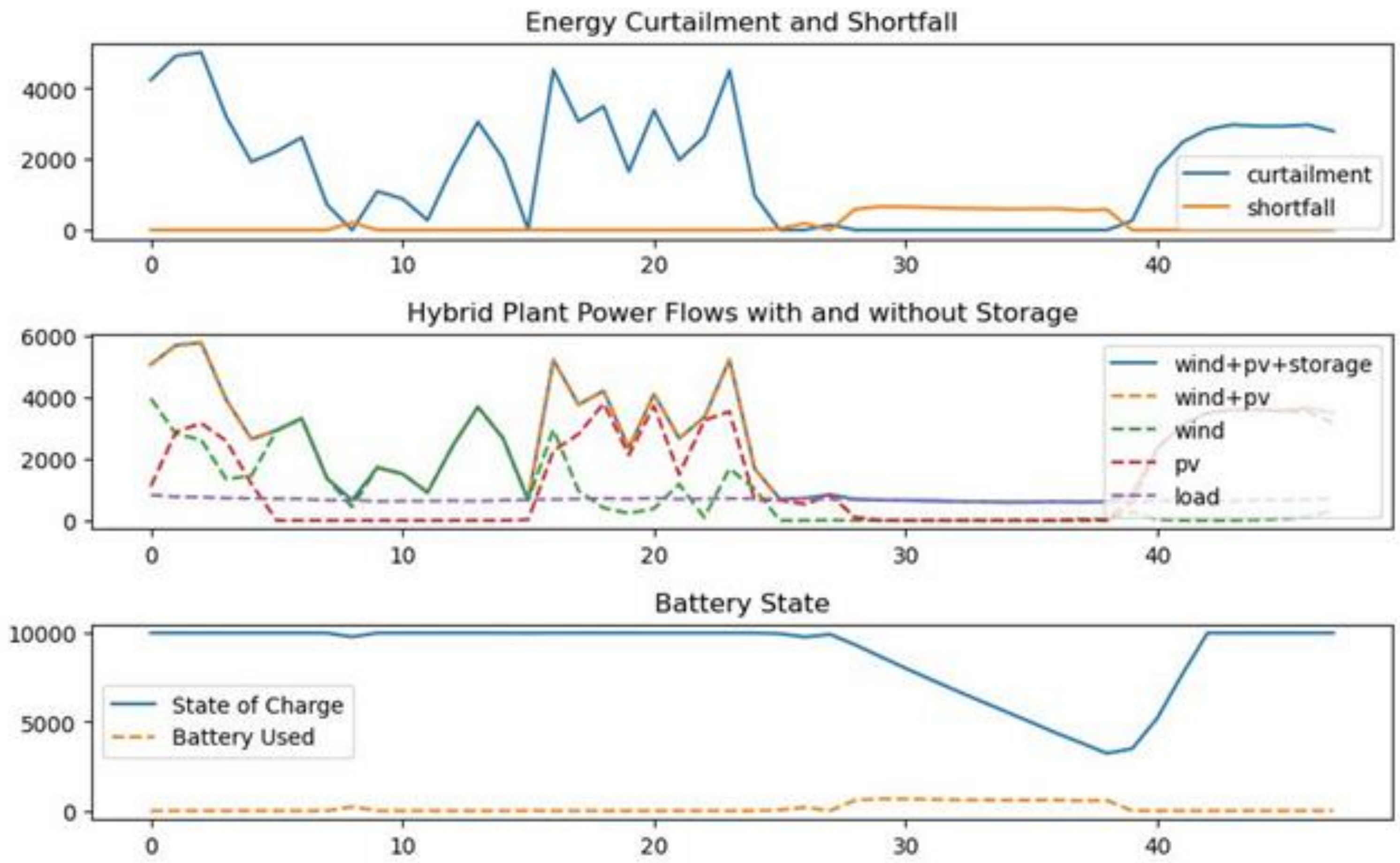
Complementarity of resources



- PV (red) and wind (green) compliment each other during this 48-hour simulated tornado scenario
- There is overproduction from this combination for the first 24 hours
- After first 24 hours, battery is used to supplement wind+solar

5 MW wind, 5 MW solar, 5 MW/ 5 MWh battery

Addressing Intermittency

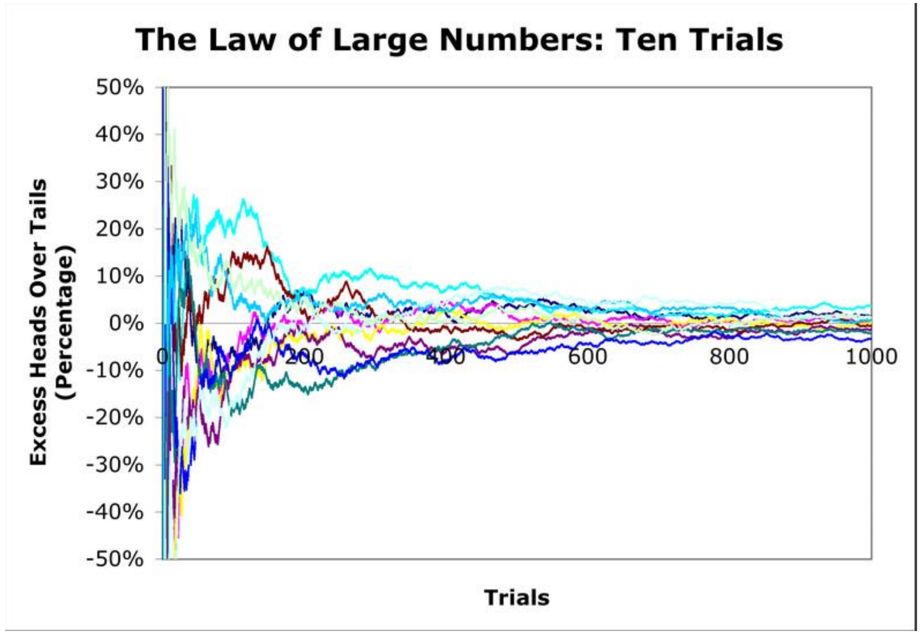


5 MW wind, 5 MW solar, 5 MW/ 10 MWh battery

- Even with complementarity, this optimized system experiences shortfalls due to wind and solar intermittency
- Increasing the size of the storage system addresses this issue
- Other resources could be used in a hybrid system to fill this gap

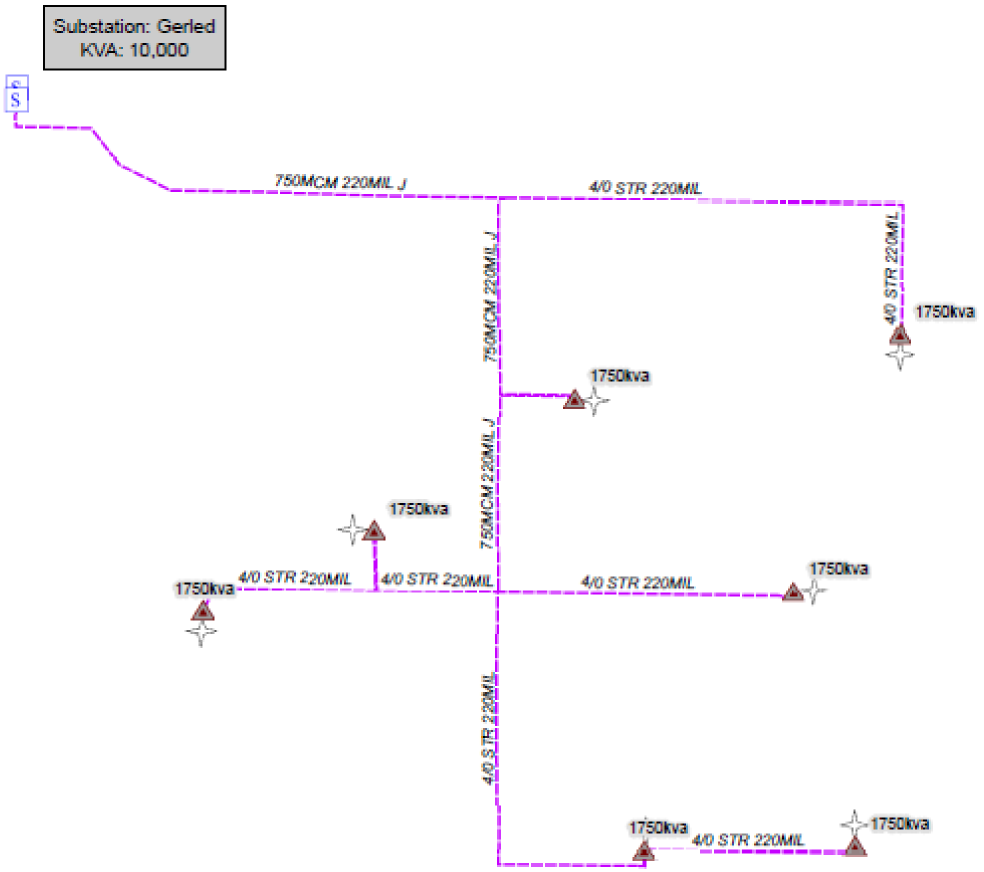
Addressing intermittency

- Intermittency makes it difficult to plan for reliability
- Often spinning reserves are used as a backup for unpredictable variability
  - Better prediction of resources can improve efficiency and reliability
- Law of large numbers: aggregate result of a large number of uncertain processes becomes more predictable as the total number of processes increases.
  - Use more assets to apply this principle
- Minimize curtailment: ensure storage systems are sized appropriately to minimize curtailment and maximize storage use

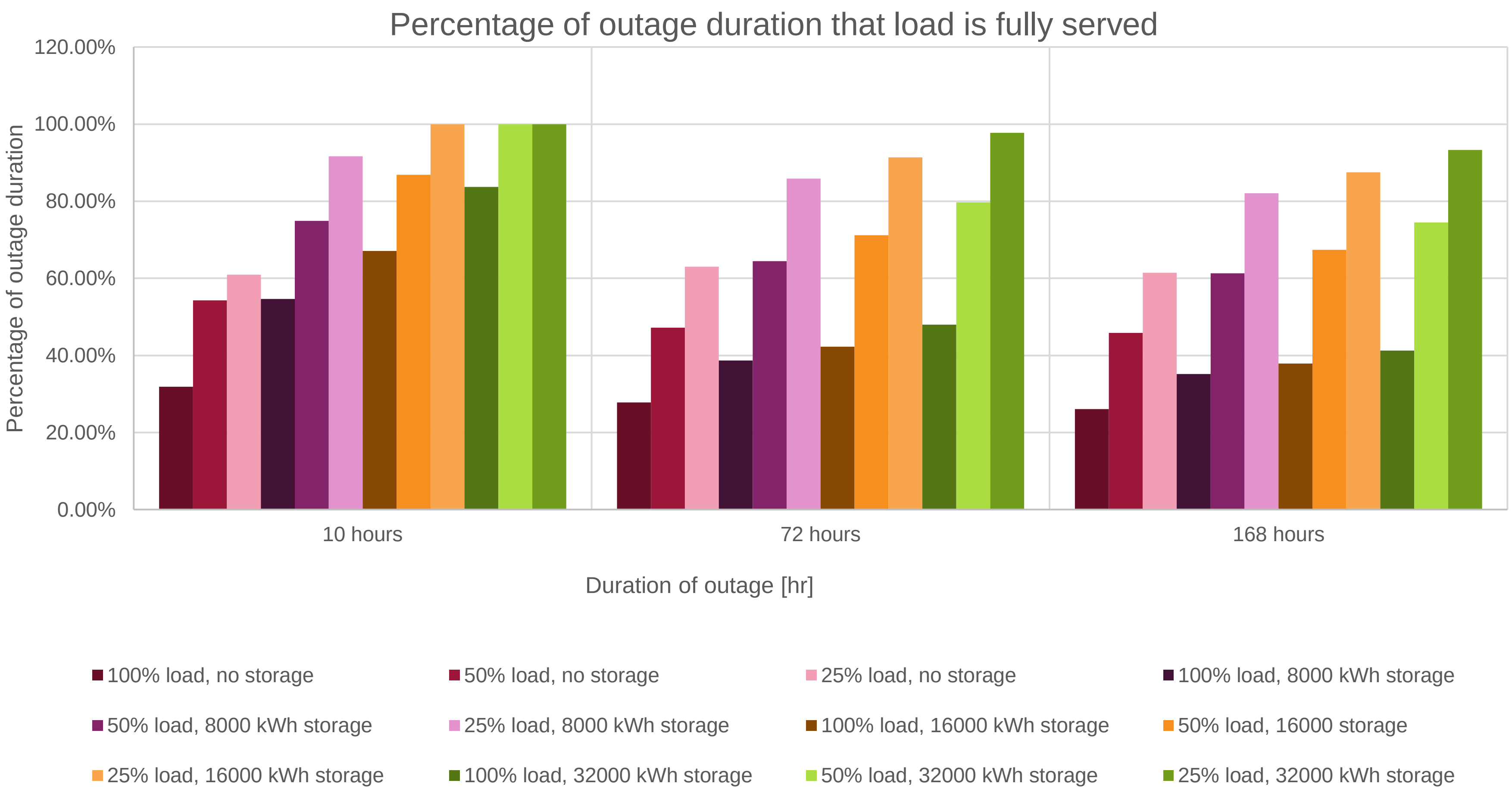


Case Study: Iowa Lakes, Iowa

- Two 7-turbine wind farms serve two ethanol plants 6-8 MW each
- Resilience goals:
  - Reduce dependence on transmission system
  - Maintain power under cyber or other disruption
- Resilience hazards:
  - Ransomware
  - DoS
  - Cryptojacking
  - APT



Key results: Iowa Lakes case study
Ransomware on TO blocks local power imports



Load Management

- Load management is the active control of electricity consumption
- Use of DERMS for optimization

Increase the load: prevent curtailment	Decrease the load: demand response	Shift the load
Water heater storage	Consumer enrollment	Use of storage systems
Co-production	Smart home devices	
	Rolling brownouts	
	Load shedding	

Case Study: Lake region Electric Cooperative

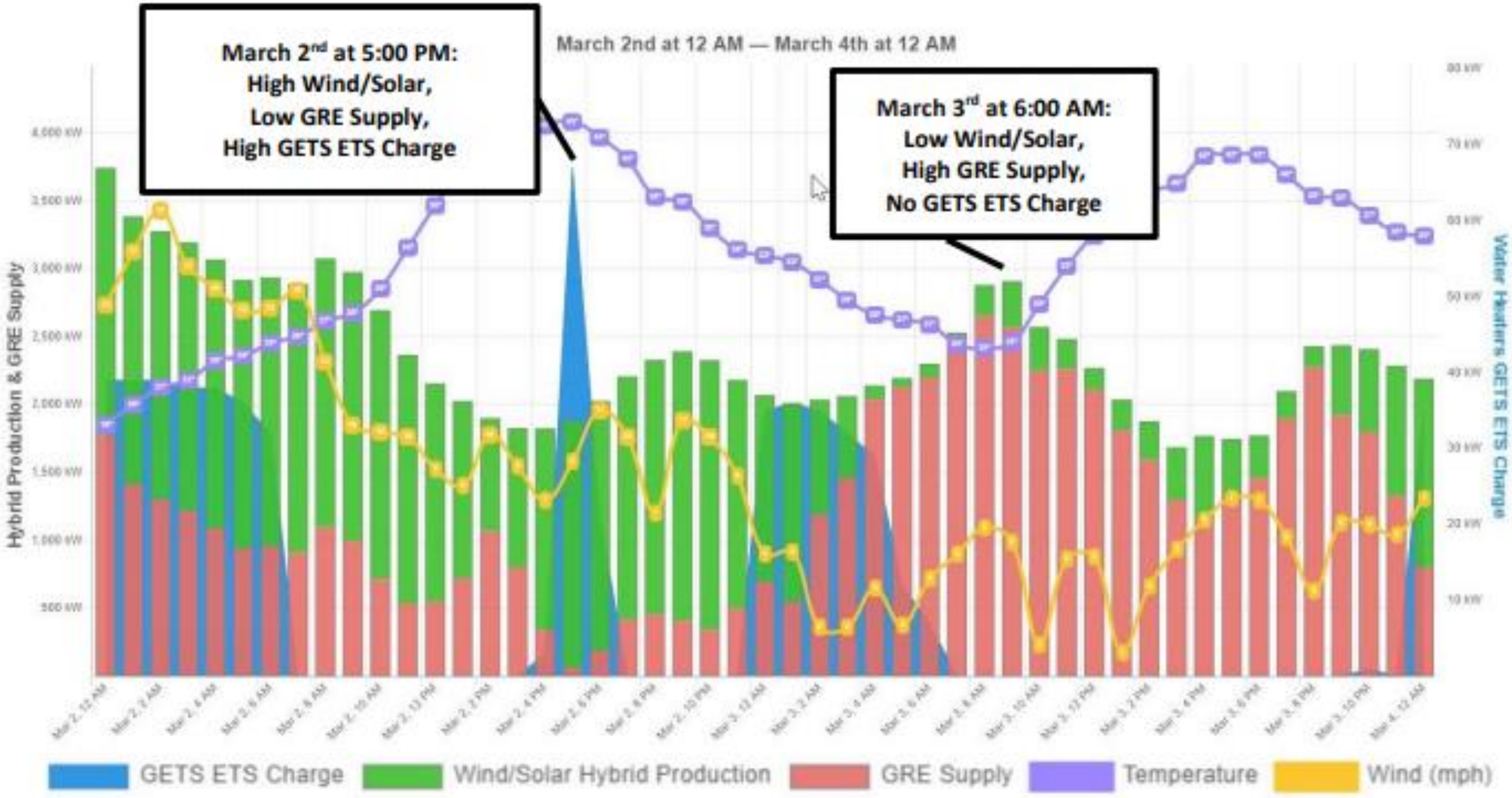
- 2 MW front-of-the-meter wind-solar hybrid project
  - 2.3 MW GE wind turbine
  - 500 kW PV solar array
  - 2 MW GE inverter
- Pilot of an electric thermal storage (ETS) program

Energy Thermal Storage Pilot

- Cloud-based water heater control system that utilizes grid-enabled thermal storage (GETS) controllers
- Installed on LREC member-owned 80- to 100-gallon electric water heaters.
- 40 devices installed

https://www.cooperative.com/programs-services/bts/radwind/Documents/RADWIND-Case-Study-Lake-Region-May-2021.pdf

Intermittency results



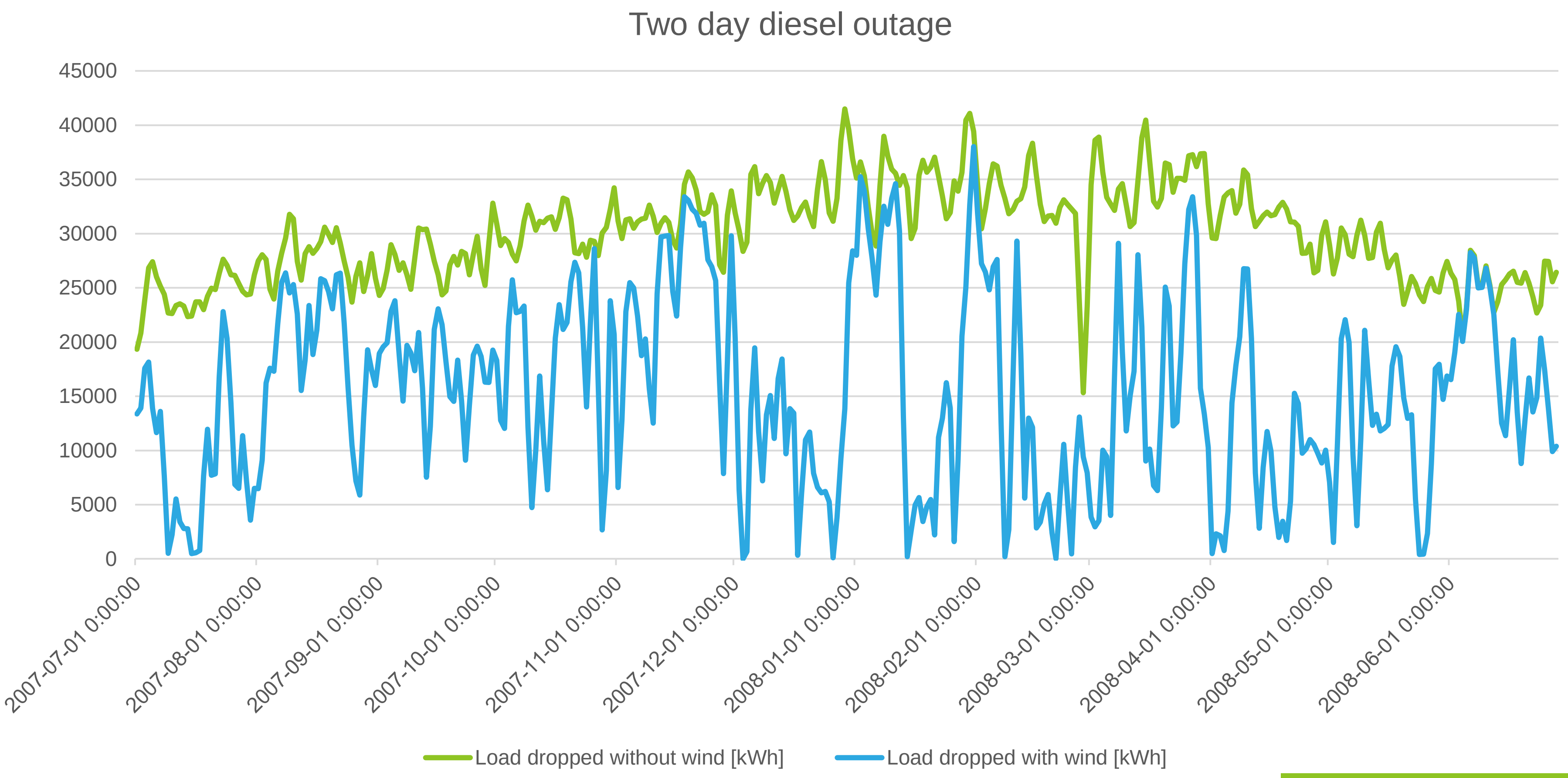
Local generation

- Reduces dependency on transmission system
- Reduces dependency on generation providers
- Reduces transmission line congestion
  - Can help delay the need for transmission upgrades
- Reduces line losses
- Reduces potential impact of a regional weather event
  - Winter storm congestion, wildfires, tornados and hurricanes

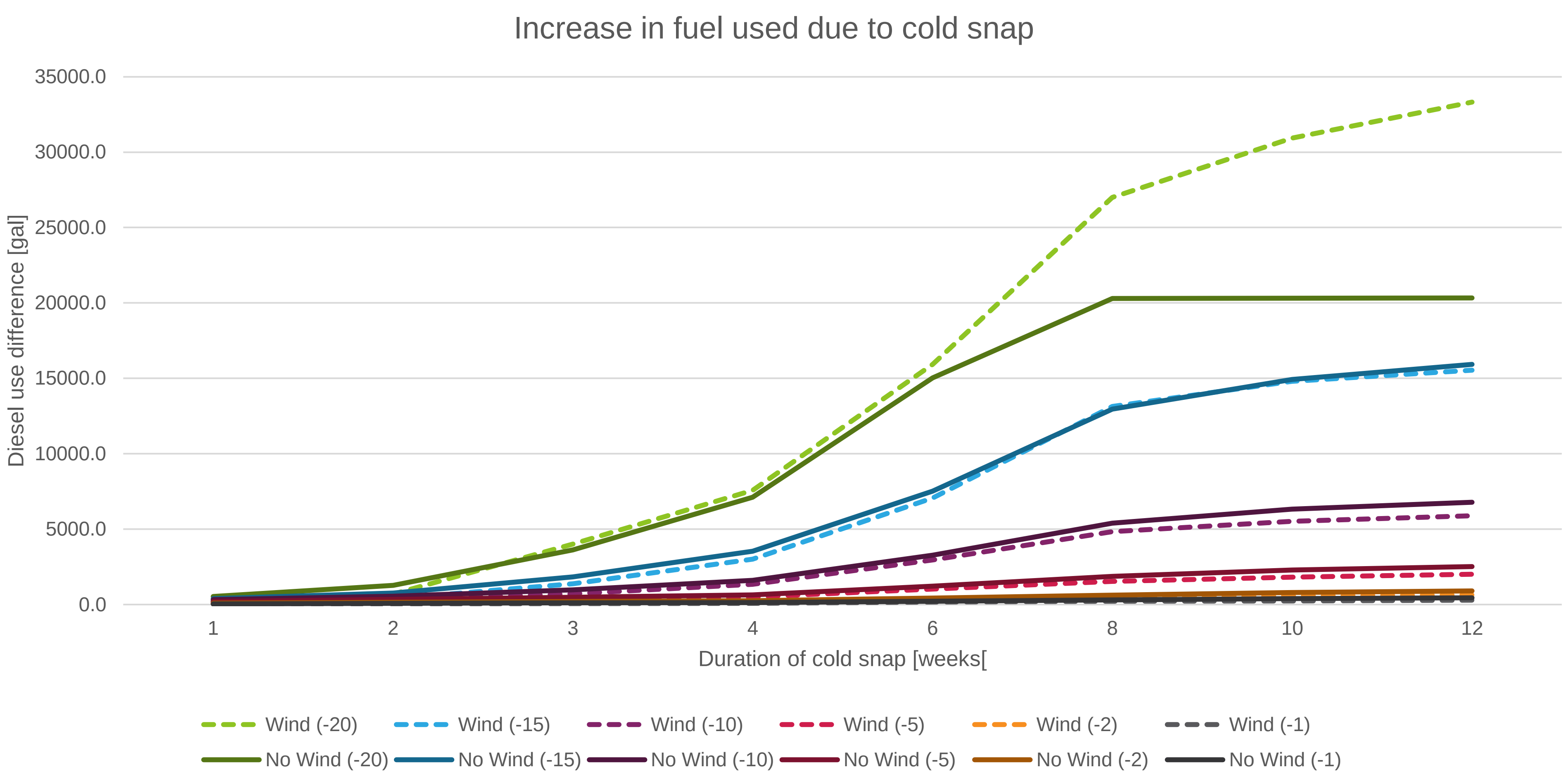
Case Study: St. Mary's, AK

- 900 kW turbine installed 2019
- Resilience goals:
  - improve power quality
  - reduce dependency on fuel
- Resilience hazards:
  - Fuel shortage
  - Winter weather
  - Loss of turbine comms

Key results: St. Mary's, AK case study
Two-day diesel outage



Key results: St. Mary's, AK case study
Cold winter conditions

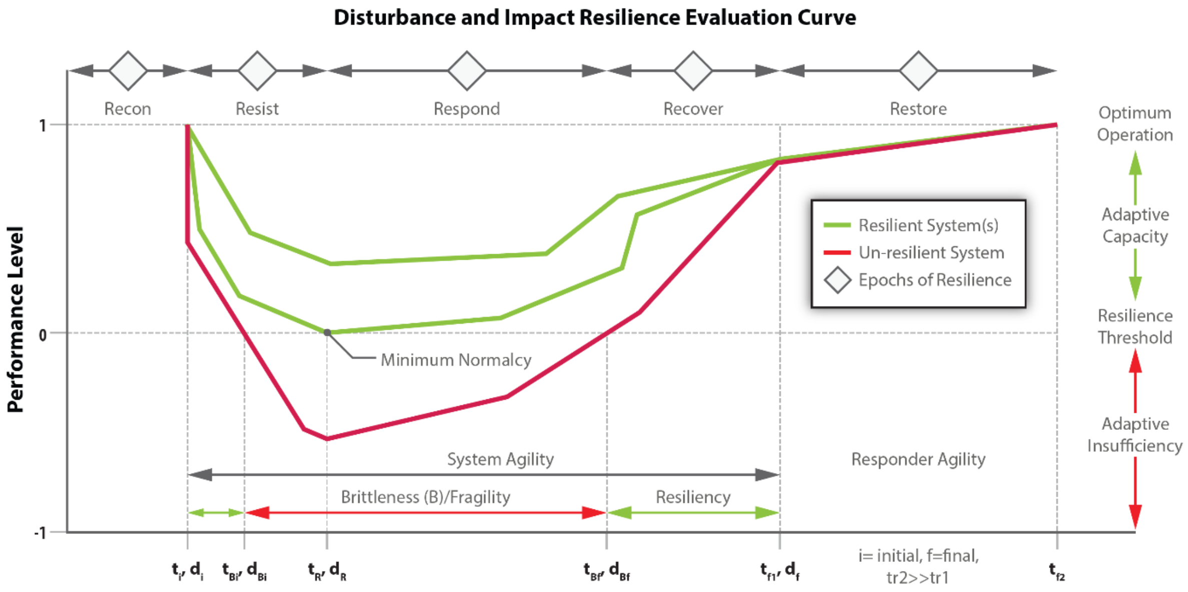


Diversity of resources

- Complementarity and addressing intermittency are a result of diverse resource mix
- Other benefits of a diverse mix of resources include:
  - Reduced risk from component or system failure
  - Reduced supply chain risk
  - Reduced risk from market swings

Resilience benefits

- Grid forming inverters
- Automatic islanding
- Grid supporting features
- Demand response
- Management of storage resources
- Metrics
  - Time until first outage
  - Total load served



How can I design a system that works for me?

What does “work for me” mean?

Valuation Framework

Resilience Framework

Design Considerations

INL/EXP-23-71978-Rev000

What does “work for me” mean

Nick David - ISU

What does “work for me” mean

Nicholas David, PhD
Research and Demonstration Engineer
Electric Power Research Center
Iowa State University
ndavid@iastate.edu

Resilience through hybrid power systems

- Suit the needs of my community.
- Balance cost AND benefits.
- Economically viable and operationally practical.
- Create a level of self-sustenance.
- Drive system development by local interests.
  - Know the historic events
  - Know the customer needs and flexibilities
  - Know the neighboring communities and mutual aid networks
  - Know the system strengths and weaknesses

Think about the needs, resources, and social capital of your community.

Perspectives

- Customer needs/expectations
  - Residential – reliability and price transparency
  - Commercial – aggregating/buying/selling
  - Industrial – manufacturing/interruptible rates
- Developers
- Utilities
- Governance
- Emergency responders

Characteristics

- Cost
- Feasibility
- Operations
- Maintenance
- Zoning and codes
- Machine/shift flexibility
- Workforce knowledge and skill
- Multiple uses and value streams
- Permanent and temporary installations

The National Laboratories’ frameworks provide a common structure to build considerations and guide decisions.

Conditions and limitations

Match the resource and the load with goals of the locality and constraints of the region.

- What drives the load/generation profiles and development constraints?
  - Environment suitability – fires/floods, land cost/use (e.g. ag, housing), right-of-ways
  - Community values, social and economic activity
  - Industry and commerce
  - Infrastructure (power lines, pipelines, roads, rails, ports…)
- What drives how resource and load are paired?
  - Location of load center, and surrounding landscape
  - Space availability, surface area, height, setbacks
  - Distribution network and transmission terminals
  - Costs of repowering machines or facilities

Utility service

- Energy and emissions
- Ancillary services
- Fuel network
- Access and repair
- Communication and controllability
- Metering networks
- Hardening
- Funding mechanisms
  - Hybrid and distributed systems create opportunity that blends business, utility, commerce, and social function.

Community interests

Communities have varied & unique interests.
Resilience is created by serving all of those.

- What is fiscally feasible?
- What is politically easy?
- What is technically achievable?
- Ownership benefits are rate dependent.
  - Commercial owners?
  - Residential owners?
  - Utility owners?
- Beyond conventional use
  - disaster response plans for critical loads

Business operations

Microgrids can provide cost-effective process solutions.
Local energy storage can avoid critical shutdowns.
Modular and mobile units for remote interim power.

- Habits may change to match available resources.
  - Machines paired with a rich natural resource.
  - Processes located to capture onsite energy.
- Markets may shift with evolution of energy systems.
  - Forecasting is as important as historical views.

It is important to have a mix of resources. Each type has a role.
The amount of generation needed to match load is finite and may have numerous contributors.
Each rate class may experience benefit differently – What ownership model brings the most community benefit?
Use the natural resource as it is available. Cache energy in storage mechanisms to fill gaps in natural resource.

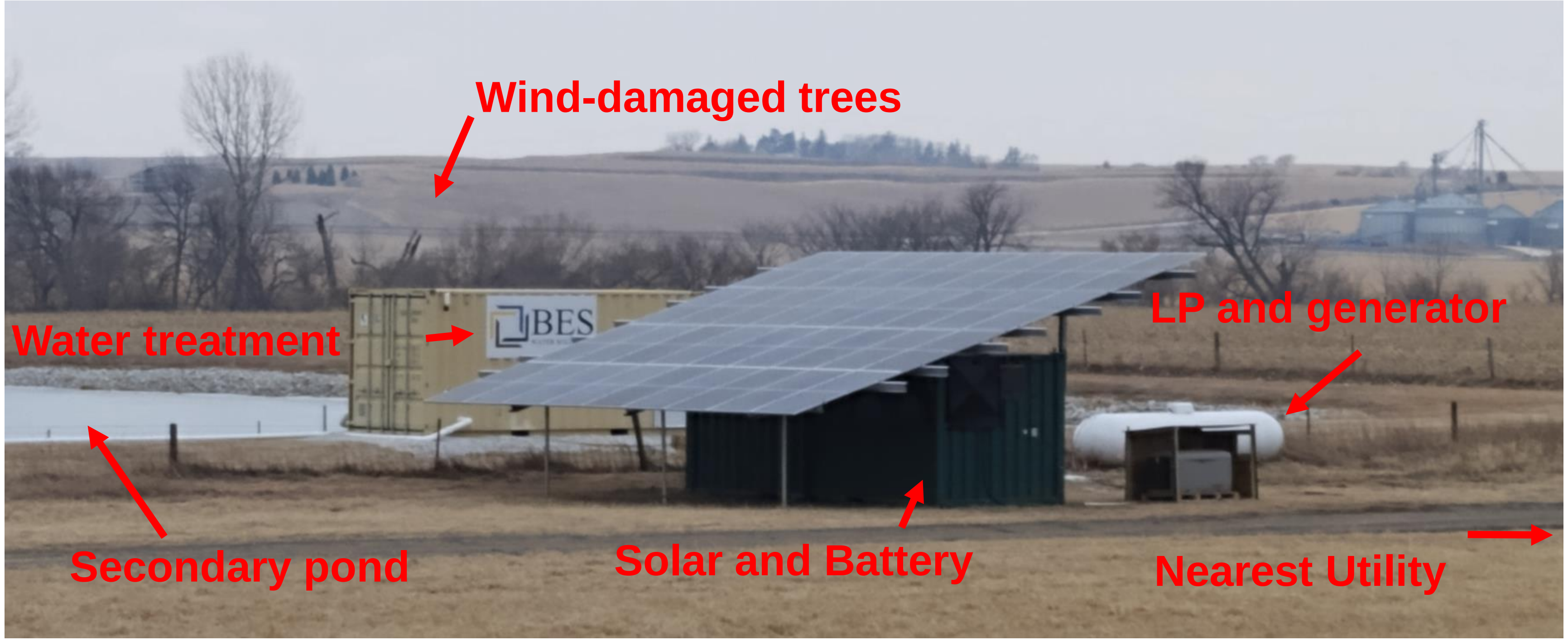
What this means to us

Demonstration Project: “Mobile Microgrids for Community Resilience”

Iowa State University, SunCrate Energy, PowerFilm Solar, Iowa Army National Guard
Funded by Iowa Economic Development Authority

- Initiated in 2019 – coincidence of farmer’s initiative, resilience research, and state funding.
- Goals:
  - Demonstrate working off-grid microgrid for disaster recovery
  - Create an economical and self-contained system.
  - Reduce fuel consumption and emissions
- System provided a real benefit during 2020 Iowa derecho.
  - Vehicle charging (cars and ebikes), refrigeration, and food preparation.
- SunCrate for wastewater treatment – a process that can sustain some downtime.
  - An opportunity to use the energy asset for remote emergency response.

SunCrate Mobile Microgrid powering BES Water Solutions' wastewater treatment



Constant pumping and aeration to stimulate biologic activity; 3-5 kW. Improve rural water quality.

Serve load and be available for relocation with 10-hour+ at 7.5 kW.

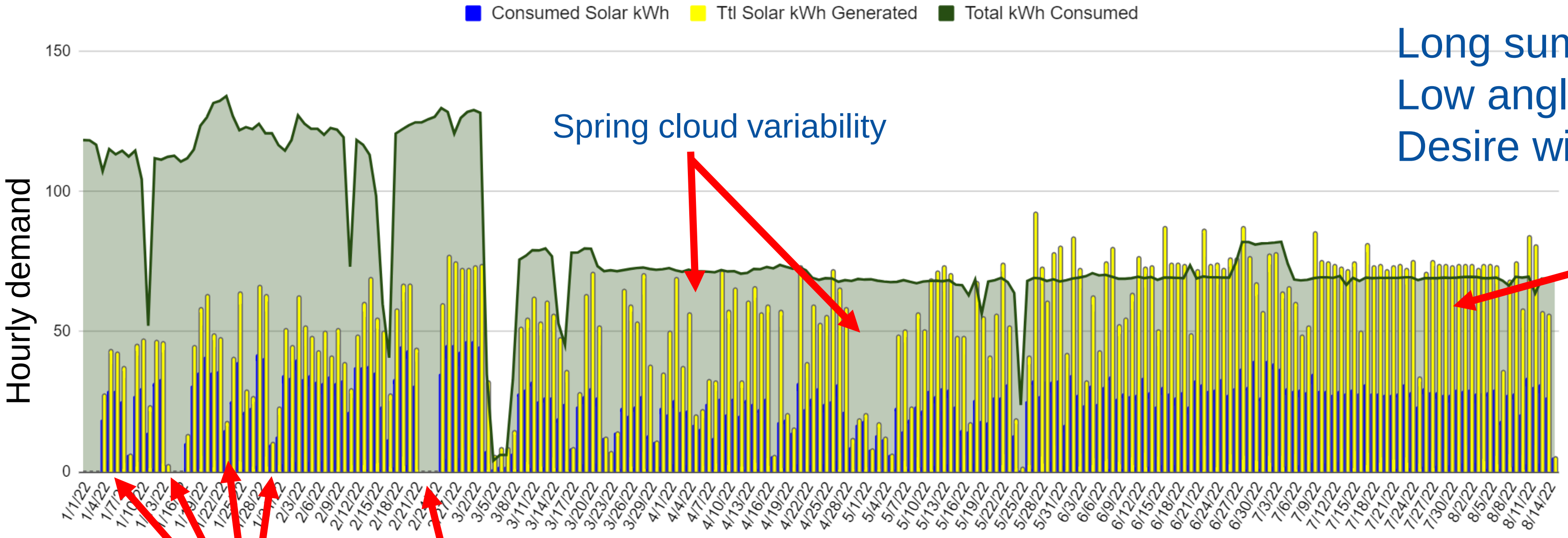
Led to second design:
PowerPallet –
Battery+converters, 12 kW, 90 kWh

Battery served 50-60% of the time.
If use propane alone (2 gal/hr, $2/gal): $21,792 for 8 months.
Actual generator fuel cost: $3,904 (976 hours of runtime)
Fuel-cost savings by adding PV+Battery: $17,888.

Onboard propane used for setup, extreme cold, and night operation.
The addition of wind power would further reduce fuel usage.

Suncrate Mobile Microgrid powering BES Wastewater treatment plant

Long summer days are mostly self-powered.
Low angle in winter reduces PV power.
Desire wind power for winter and spring.



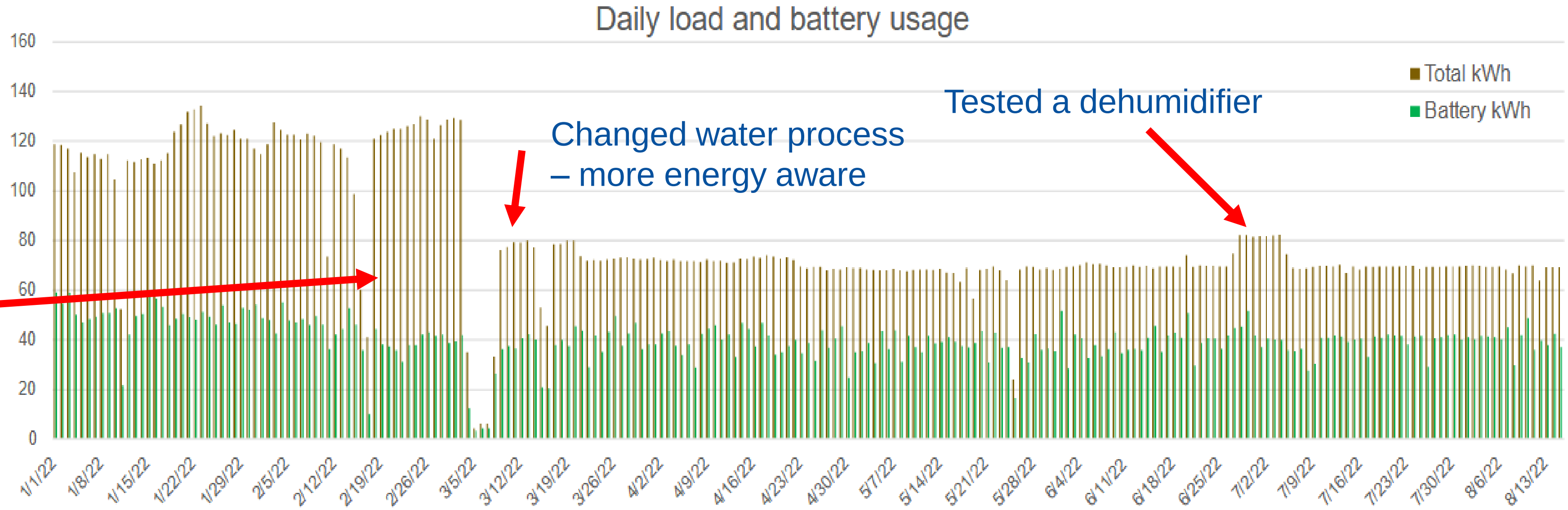
Spring cloud variability

Self-powered with PV+Battery

Snow covered PV; ran gen exclusively

Use of battery is relatively constant throughout duration.

Generator is used more in winter and during cloudy spring days.



Tested a dehumidifier

Changed water process – more energy aware

Blizzard and extreme cold reduced the PV generation and small battery heaters couldn't keep up.

Resilience during Emergency Response

Breakfast after 2020 Derecho:

- Keep society functional and gain comfort
- Profiles of critical load
- Location and natural resource access
- Modularity for scaling to disaster size and breadth
- Mobility and time to issue
- Ease of use
  - Operator setup
  - Transportation
  - Pairing with other units
  - Maintenance requirements
- Exercise options, practice and be ready

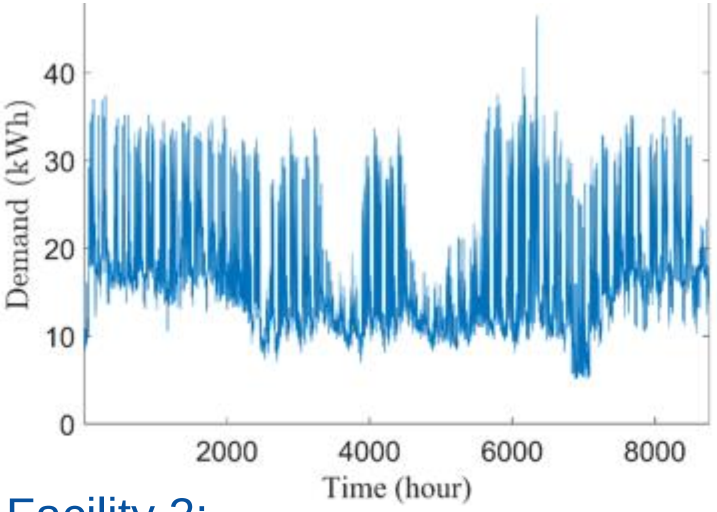
PowerFilm 220 W fold-out panels

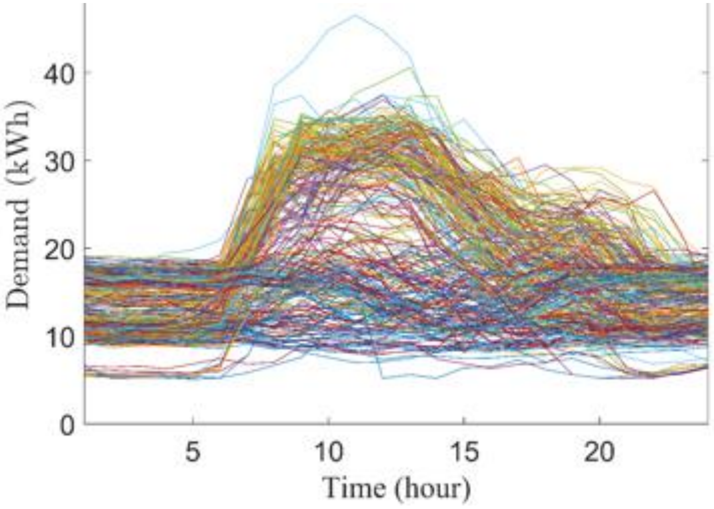
Applying mobile energy: Know your load, resource, and community

- Communities are unique, so are load and resource profiles, built and social infrastructure, funding mechanisms.
- What and where is the critical load?
- How do we deliver power to that location?
- Can the critical loads within a building be isolated and served during a disaster?
- Examples of load profiles we’ve measured, using hourly AMI data:
  - Grocery stores
  - Fuel stations
  - Schools
  - Hospitals
  - Retirement homes
  - Communication towers

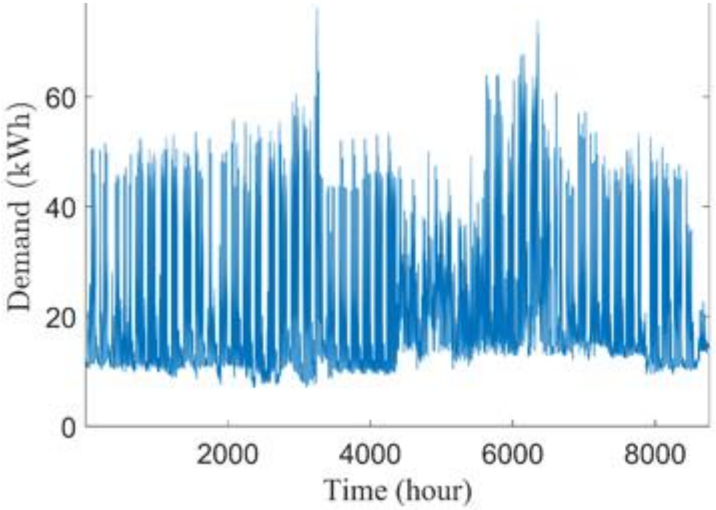
Schools (same town)

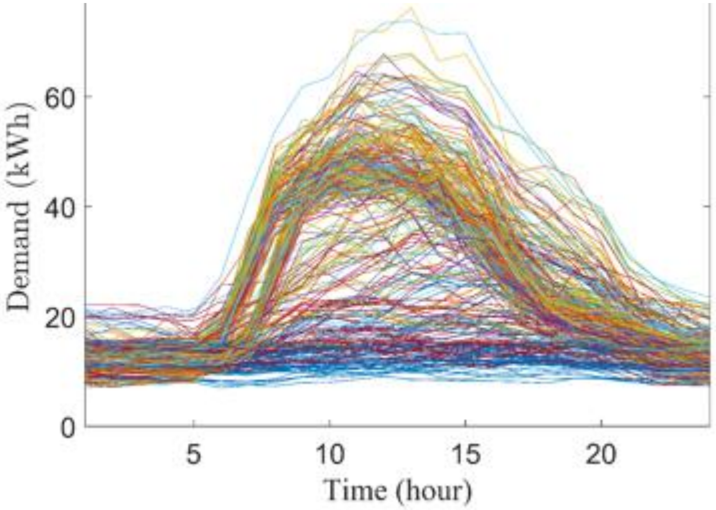
Facility 1:





Facility 2:





Social activities demand power.

Building size, efficiency, and heating/cooling methods may vary.

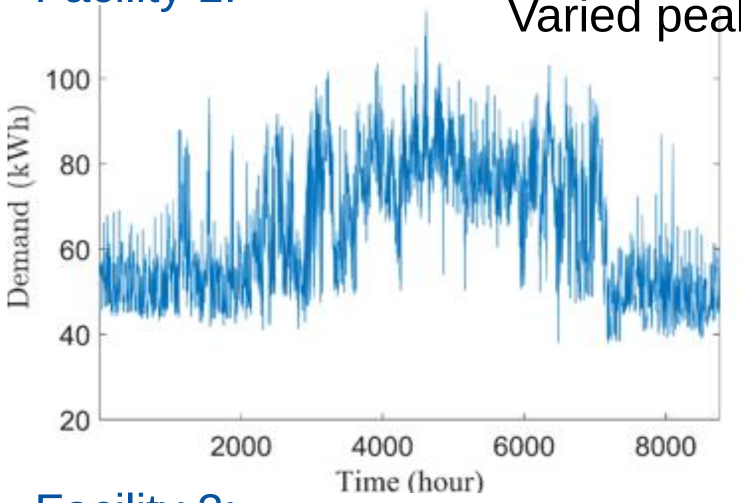
Some may be used as shelters.

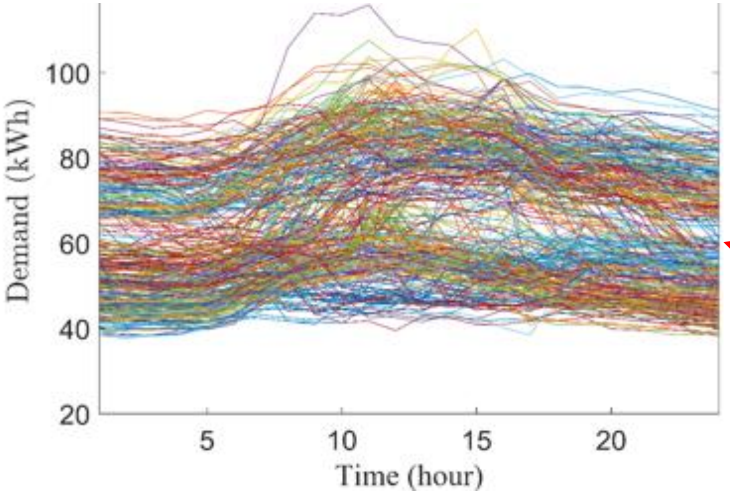
Healthcare facilities (same town)

Variance in bed count, heating/ cooling method, building efficiency, and type of services.

Facility 1:

Varied peaking

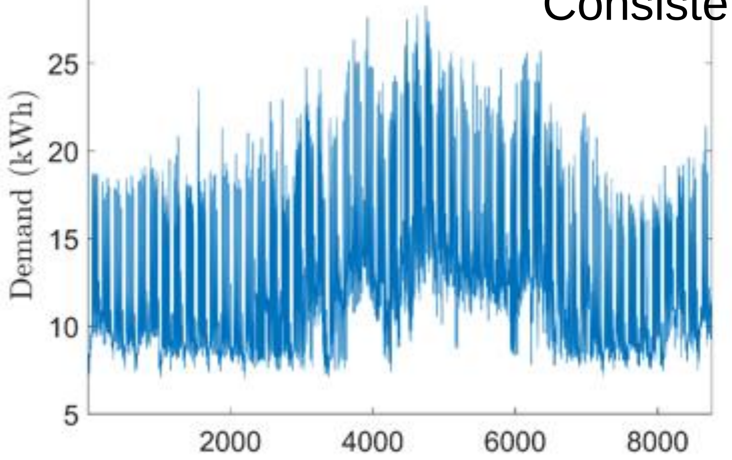


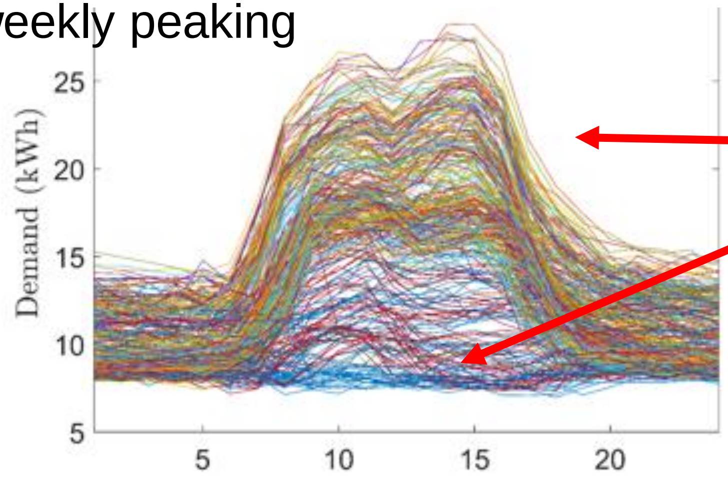


More random peaking,
but relatively constant window.
Notice gap in mid-range power.

Facility 2:

Consistent weekly peaking

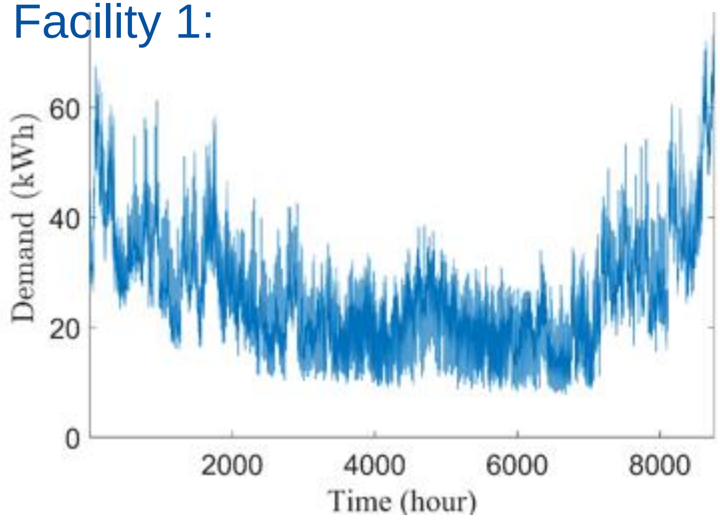


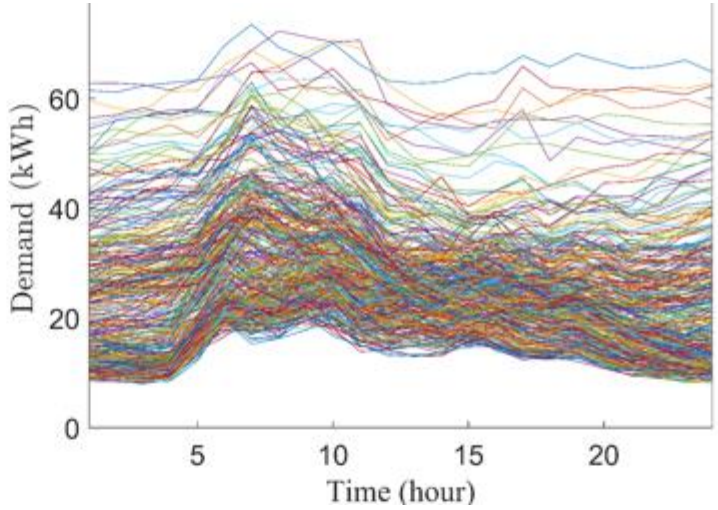


High relative daily peaks,
But not all days have peaking.

Living-care facility (same town)

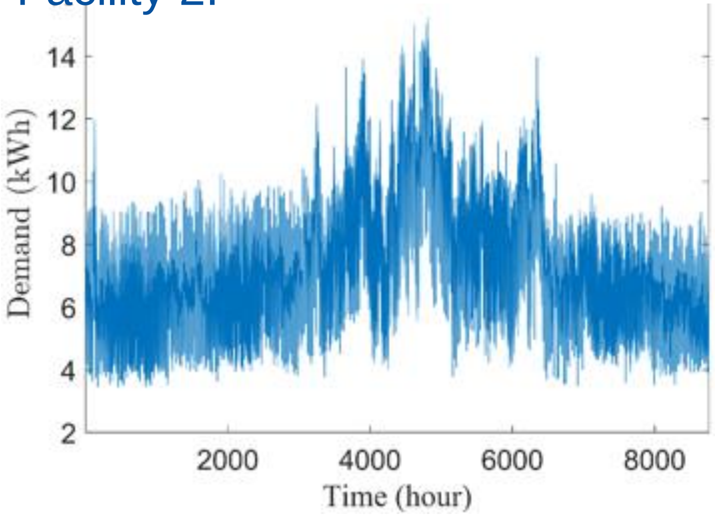
Facility 1:

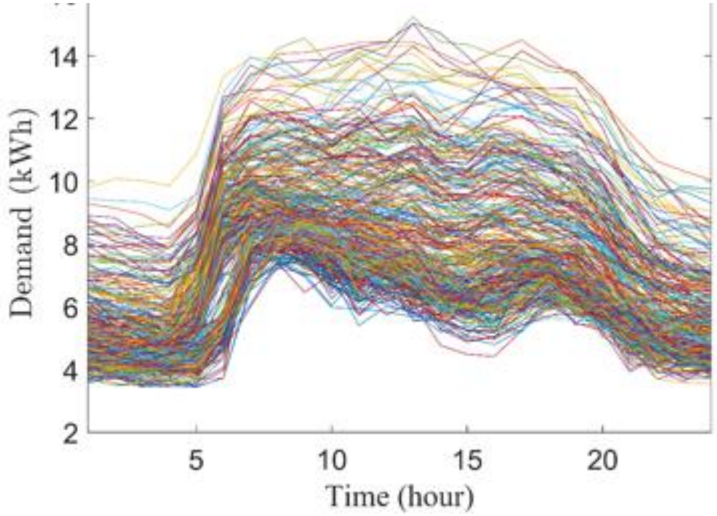




Larger seasonal winter demand

Facility 2:

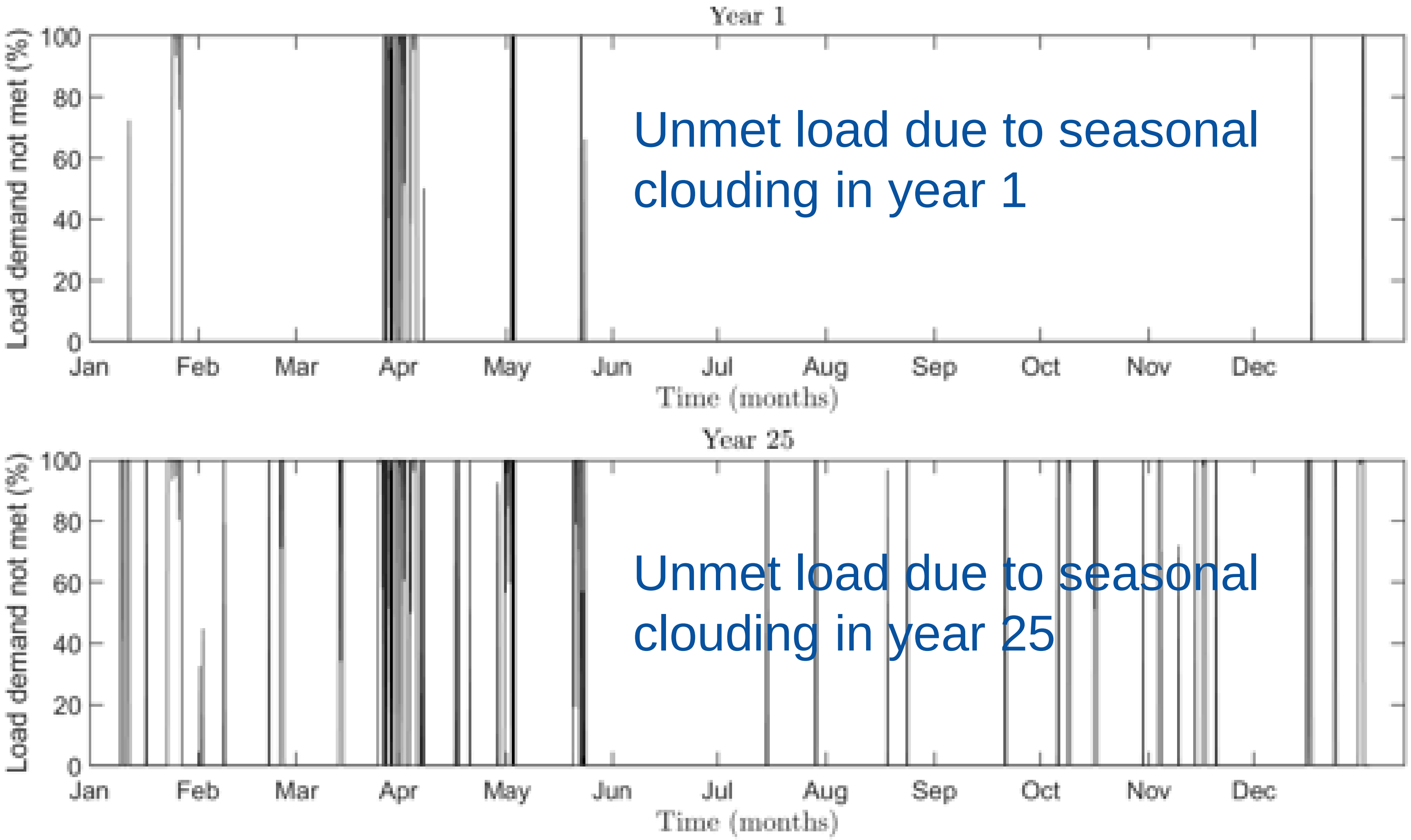




Larger seasonal summer demand

Generator degradation

D. Miley, A. Mannan, N. David and A. Kimber, "Energy Adequacy Analysis Simulation for Renewable Energy Systems," *2022 North American Power Symposium (NAPS)*, Salt Lake City, UT, USA, 2022, pp. 1-6.

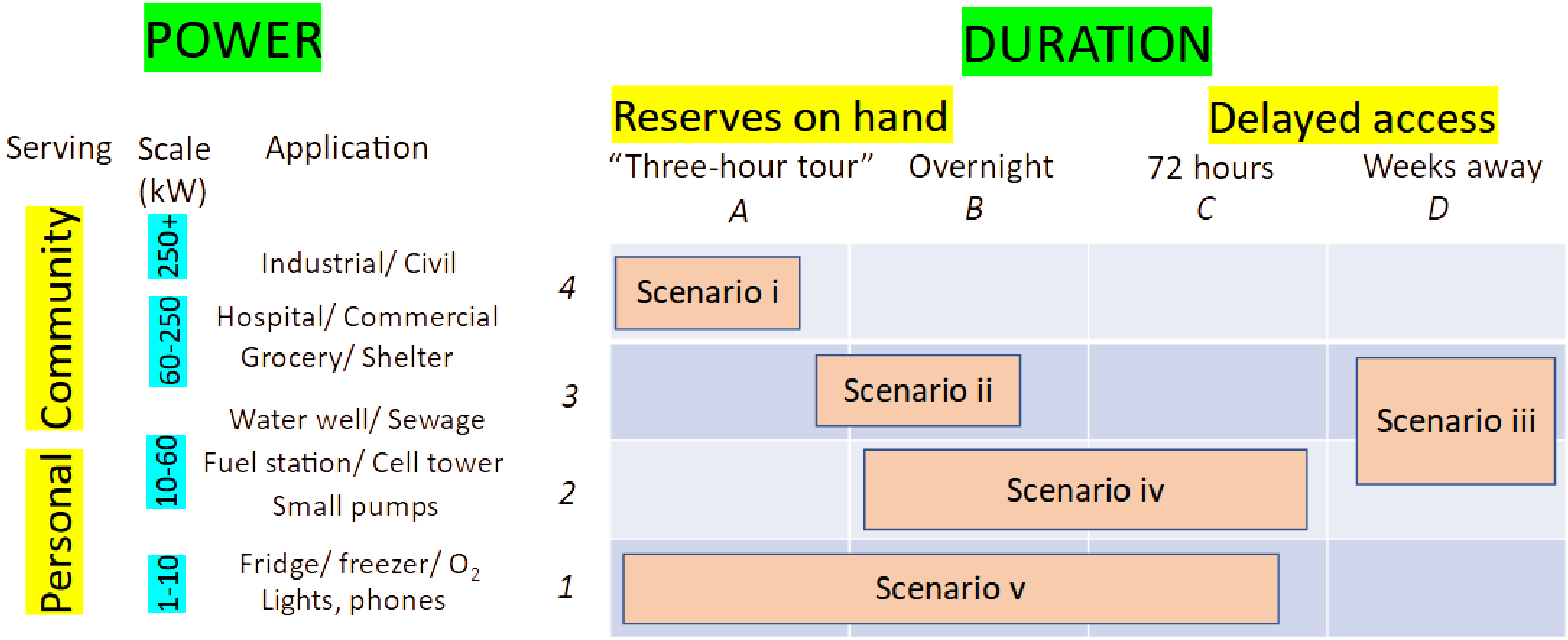


Aging PV leads to more times of added need – Can wind complement?

Toward modular systems for emergency preparedness

Consider demand, duration, mobility, and resources.

A hypothetical classification system:



A new modular systems design standard:

Tactical Microgrid Standard (MIL-STD-3071) https://quicksearch.dla.mil/qsDocDetails.aspx?ident_number=285095

Solutions are not "one size fits all", but the National Laboratories' frameworks help reach the solution.

Sandia National Laboratory’s “Microgrids & Energy Storage for Emergency Grid Resilience Webinar Series”

https://energy.sandia.gov/programs/energy-storage/policy-and-outreach/regulatory-webinars/microgrids-and-es-webinar-series/

Colonel Perkins: “Midwest National Guard Responses to Emergencies & Needs for Microgrids & ES”

https://energy.sandia.gov/wpcontent/uploads/2021/12/4_Perkins_Col.John_MicrogridsES_Session2_11-12-2021.pdf

Warehouse of assets ready to deploy:

Valuation Framework

Sarah Barrows - PNNL

Pacific Northwest
NATIONAL LABORATORY

Distributed Wind Valuation Framework

April 4, 2023

Sarah Barrows
Research Economist
Pacific Northwest National Laboratory

U.S. DEPARTMENT OF ENERGY BATTELLE

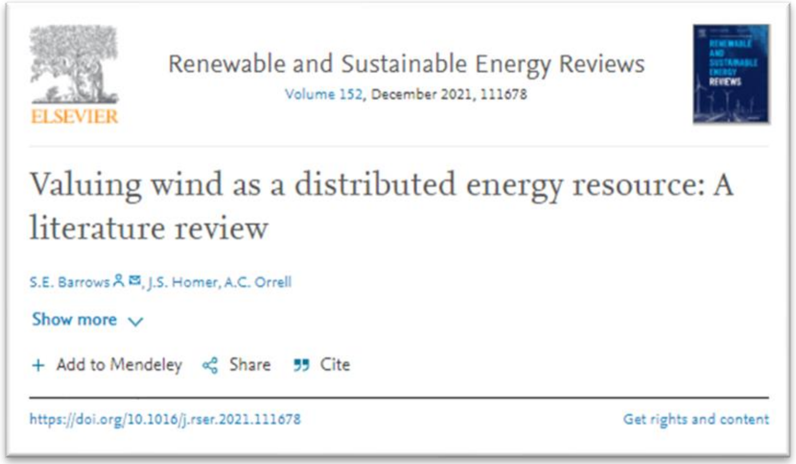
PNNL is operated by Battelle for the U.S. Department of Energy

Understanding distributed wind's value enables better decisions

- Distributed wind systems create value for stakeholders that can go beyond electricity savings
- Understanding these costs and benefits are essential for project owners and other affected parties

- What is valuation?
  - Valuation is "the process of determining the relative worth, utility, or importance (i.e., value) of options or alternatives to allow their comparison in ways that are clear, transparent, and repeatable."[1]

- Valuation methods and best practices for distributed wind have historically lagged behind other technologies


ELSEVIER

Renewable and Sustainable Energy Reviews
Volume 152, December 2021, 111678

Valuing wind as a distributed energy resource: A literature review

S.E. Barrows, J.S. Homer, A.C. Orrell

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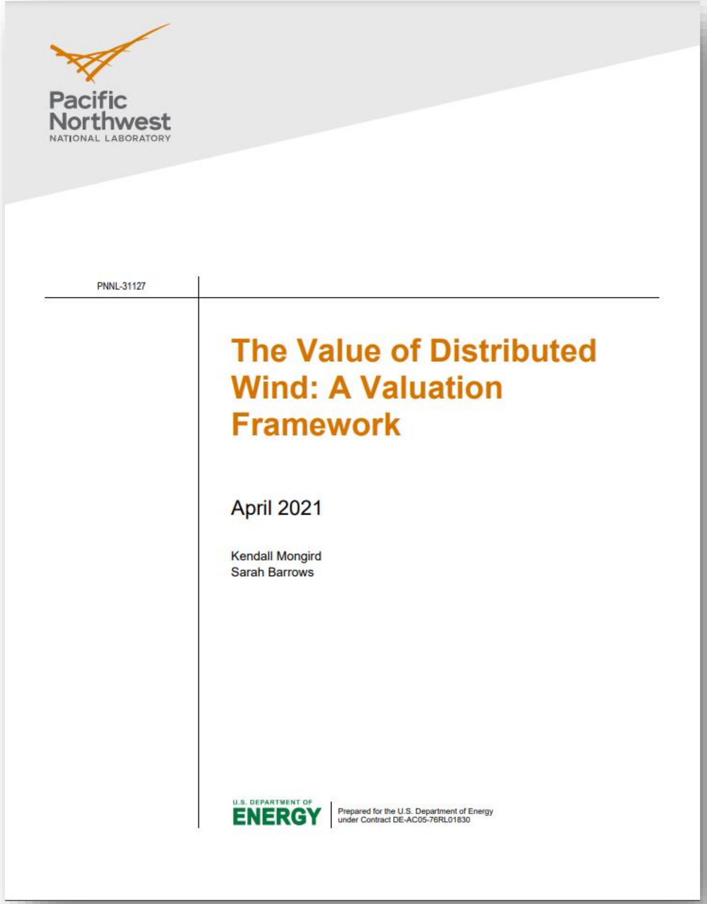
https://doi.org/10.1016/j.rser.2021.111678

[1]Markel L, Cooke A, Hadley S, Mills A, O'Connor P, Vargas V, et al. A Valuation Framework for Informing Grid Modernization Decisions: Guidelines on the principles and process of valuing grid services and technologies. 2019

Framework to tools


Pacific Northwest NATIONAL LABORATORY

PNNL-31127

The Value of Distributed Wind: A Valuation Framework

April 2021

Kendall Mongird
Sarah Barrows

U.S. DEPARTMENT OF ENERGY | Prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830

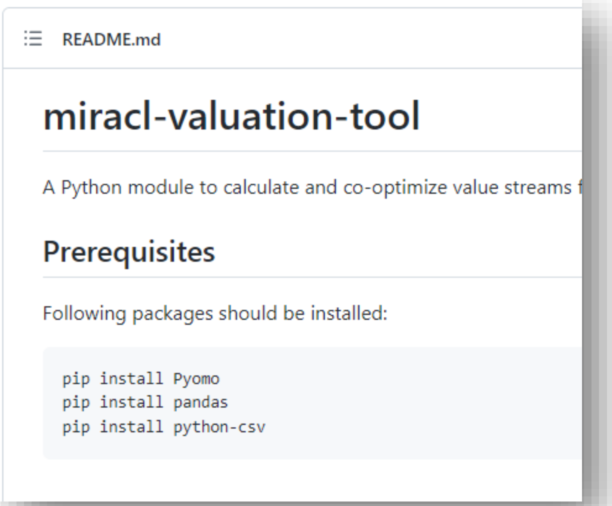
https://tinyurl.com/fh2sc2dc

Case studies in St. Mary's, AK & Iowa Lakes, IA

Image source: AVEC Annual Report 2019

Image source: ilec.coop/renewable-energy

https://doi.org/10.3390/en14216956
https://www.nrel.gov/docs/fy22osti/81792.pdf


README.md

miracl-valuation-tool

A Python module to calculate and co-optimize value streams f

Prerequisites

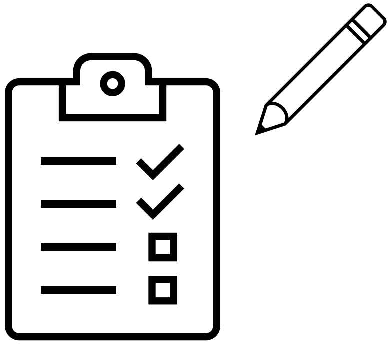
Following packages should be installed:

```
pip install Pyomo
pip install pandas
pip install python-csv
```

https://github.com/pnnl/miracl-valuation

Valuation steps

- Step 1: Define project details and perspectives
- Step 2: Determine which value elements apply
- Step 3: Define calculations for value elements
- Step 4: Model operation of asset(s), co-optimizing benefits, over project lifetime
- Step 5: Summarize non-quantifiable impacts
- Step 6: Compare co-optimized present value benefits and costs
- Step 7: Repeat process as desired



Value Elements in Framework – Benefits

Benefits identified through literature review on DER valuation and distributed wind capabilities

Category	Value Elements in Framework
Bulk Energy Services	• Energy generation • Capacity/resource adequacy
Ancillary Services	• Frequency regulation and response • Load following • Voltage support • Black start • Inertial response • Flexible ramping
Transmission Services	• Avoided need for additional transmission capacity or avoided transmission congestion
Distribution Services	• Avoided need for distribution system upgrades
Customer/Energy Demand Management Services	• Energy charge reduction • Time-of-use related bill items (e.g., demand charge reduction) • Renewable programs and Renewable Energy Credits (RECs) • Demand response program incentives • Power reliability/resilience/outage mitigation • Land use compensation
Economic/Societal Impacts	• Job creation • Policy goals • Environmental benefits

Value Elements in Framework - Costs

Stakeholder Affected	Value Elements in Framework
Distributed Wind Owner	• Capital costs • Operations and maintenance (non-fuel related) • Fuel costs • Major overhauls and replacements • Contingency fees • Taxes • Insurance • Interconnection costs
Non-DW Owner	• Rate/bill impacts
Utility and Transmission/Balancing Authority	• Power quality costs • Distribution losses • Lost revenue • Administrative costs
Society	• Viewshed impacts • Wildlife impacts • Human-environment interactions (e.g., sound, ice fall, shadow flicker)

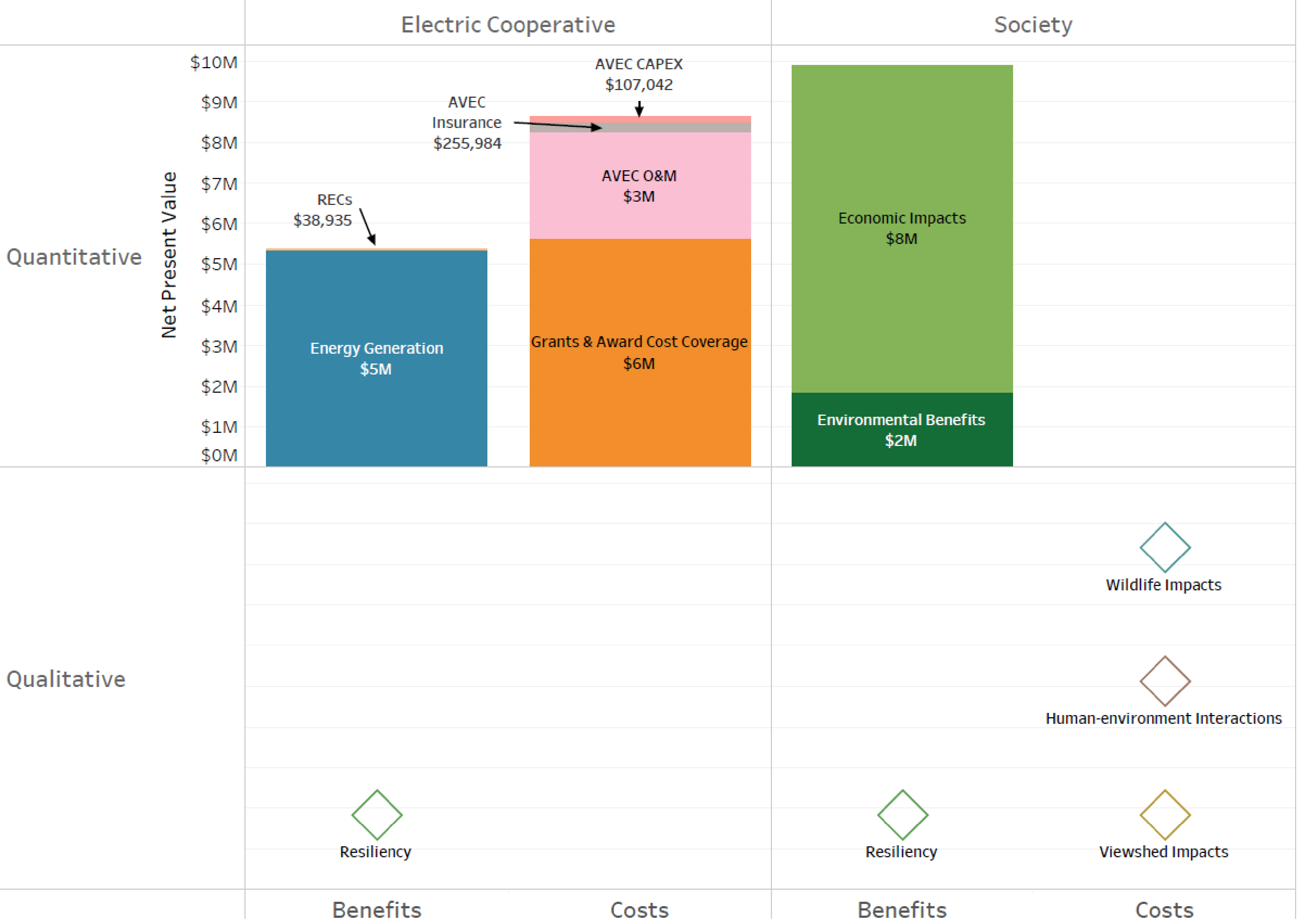
System Connection Type	Grid-Connected Assets/Microgrids										
System Location of Assets	Front-of-meter								Behind-the-meter		
Ownership Structure †	Utility-Owned				Community-Owned				Customer-Owned		
Value Perspective	Transmission & Balancing	Utility	Customer	Society	Transmission & Balancing	Utility	Customer	Society	Utility	Customer	Society
Roles											
Transmission Operator/Provider	✓	✓			✓	✓			✓		
Distribution System Operator/Provider		✓				✓			✓		
Energy Generation Owner/Operator		✓				✓	✓		✓	✓	
Wholesale Energy Purchaser		✓				✓			✓		
Retail Energy Purchaser			✓				✓			✓	

Multiple ownership structures and roles considered in the valuation framework

- *Value perspective is important in determining benefits and costs*

		System Connection Type	Grid-Connected Assets/Microgrids										
		System Location of Assets	Front-of-meter								Behind-the-meter		
		Ownership Structure †	Utility-Owned				Community-Owned				Customer-Owned		
		Value Perspective	Transmission & Balancing	Utility	Customer	Society	Transmission & Balancing	Utility	Customer	Society	Utility	Customer	Society
Roles		Transmission Operator/Provider	✓	✓			✓	✓			✓		
		Distribution System Operator/Provider		✓				✓			✓		
		Energy Generation Owner/Operator		✓				✓	✓		✓	✓	
		Wholesale Energy Purchaser		✓				✓			✓		
		Retail Energy Purchaser			✓				✓			✓	
Category	**Value Elements**	**Quantifiable?**											
Bulk Energy Services	Energy Generation	Yes	X	X			X	X	X			X	
	Capacity/Resource Adequacy	Yes	X	X			X	X			x		
Ancillary Services	Regulation	Yes	X	X			X	X					
	Frequency Response	Yes	X	X			X	X					
	Load Following	Yes	X	X			X	X					
	Voltage Support (providing reactive power)	Yes	X	X			X	X					
	Black Start	Yes	X	X			X	X					
	Inertial Response	Yes	X	X			X	X					
	Flexible Ramping	Yes	X	X			X	X					
Transmission Services	Transmission Upgrade Deferral	Yes	X	X			X	X					
	Transmission Congestion Relief	Yes	X	X			X	X					
Distribution Services	Distribution Upgrade Deferral	Yes		X				X					
Energy Management / Customer Services	Time-of-Use Related Bill Items (demand charge reduction, transmission charge reduction, etc.)	Yes		X					X			X	
	Energy Charge Reduction	Yes		X	X‡				X			X	
	Renewable Programs & Renewable Energy Credits (RECs)	Yes		X				X	X			X	
	Demand Response Program Incentives	Yes		X				X	X			X	
	Renewable Tax Credits	Yes		X				X	X			X	
	Power Reliability/ Resilience/ Outage Mitigation	Yes		X	X		x		X			X	
	Land Use Compensation	Yes				X				X			
Economic/Societal Impacts	Renewable Portfolio Standard Goals	Potentially		X						X			
	Job Creation	Potentially				X				X		X	
	Environmental Benefits	Potentially		X		X				X		X	X
	Policy Goals	No				X				X			X

Benefit/Cost Results for St. Mary's, AK



How can you use this framework?

- Compare project designs, operational strategies, and revenue streams
- Evaluate third-party bids
- Estimate impact of specific value elements on overall value
- Investigate project impacts to different entities

Pacific Northwest NATIONAL LABORATORY

Thank you

Sarah Barrows,
sarah.barrows@pnnl.gov

Acknowledgments: Dan Boff, Kendall Mongird, Kamila Kazimierczuk, Abigail King

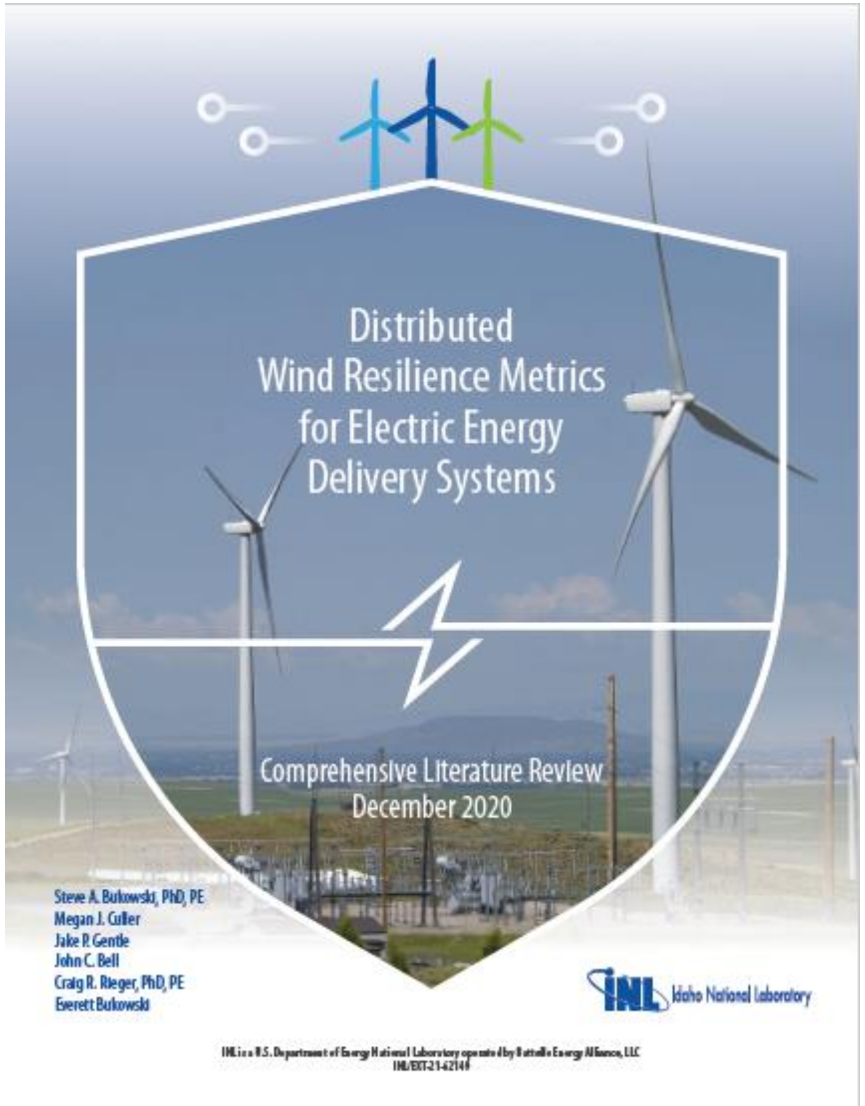
This work was authored by Pacific Northwest National Laboratory which is operated for the U.S. Department of Energy by Battelle under contract DE-AC05-76RL01830. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Wind Energy Technology Office.

Resilience Framework

Megan Culler - INL

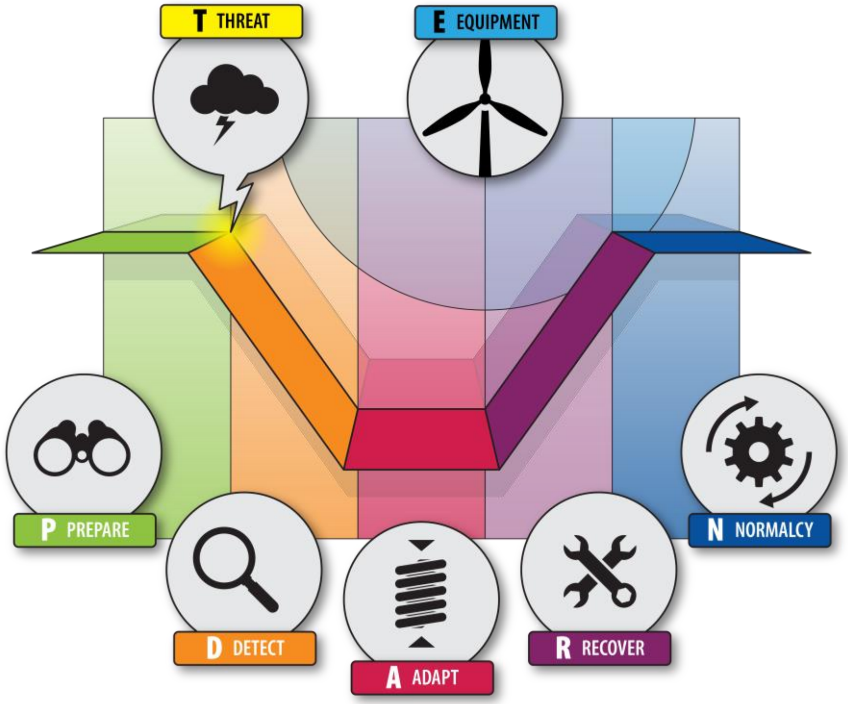
Goals

- Define resilience for Electric Energy Delivery Systems (EEDS)
- Define metrics for resilience
- Define framework for resilience
  - Evaluate the status of system resilience.
  - Prioritize critical activities aimed at improving their performance.
  - Monitor their system resilience.
  - Establish resilience requirements with stakeholders.



Definition

- **“The resilience of an EEDS is described as a characteristic of the people, assets, and processes that make up the EEDS and its ability to identify, prepare for, and adapt to disruptive events (in the form of changing conditions) and recover rapidly from any disturbance to an acceptable state of operation.”**
- Defined with respect to a particular system
- Defined with respect to events and disruptions
- Focus is on response to disturbance, not properties of disturbance



Resilience Metrics

Categories

- Inputs
- Capacities
- Capabilities
- Performance
- Outcomes

Properties

- Direct vs. Indirect
- Qualitative vs. Quantitative
- Operational vs. Infrastructure

Characteristics

- Specific
- Actionable
- Qualitative
- Extensible
- Understandable
- Comprehensive
- Risk-based
- Time-sensitive
- Data driven
- Comparable
- Transparent & Documented
- Confidence-ranked

Example Metrics

Resilience Metrics

- Possible metric for distributed wind
- Common metric for distributed wind
- All other proposed resilience metrics

Inputs

- Energy feedstock
- Energy not supplied
- Energy storage
- Generators available
- Key replacement equipment stockpile
- Redundant power lines
- Reinforced concrete vs wood
- Siting infrastructures
- Underground, overhead, & undersea lines
- Unique encrypted passwords for utility smart distribution
- Workers employed
- Hydrophobic coating on equipment
- Distribution poles
- Number of transmission lines available
- Hierarchical levels

Capacity

- Communication/control systems
- Electrical protection and metering
- Equipment and positioning
- Flow paths, line flow limits
- Generation/load bus distribution
- Reserve/spare capacity
- Functional zones
- Substations, overhead lines, underground cables
- Hierarchical level (I, II, III)
- Operator training
- Mutual assistant agreements
- Transformers
- Tree trimming metrics

Capabilities

- Ancillary service
- Hazard rate relating function
- Line mitigation
- Load biasing
- Net-ability
- Path redundancy
- Protective and switching devices
- Viability of investments
- Adequacy
- Congestion control

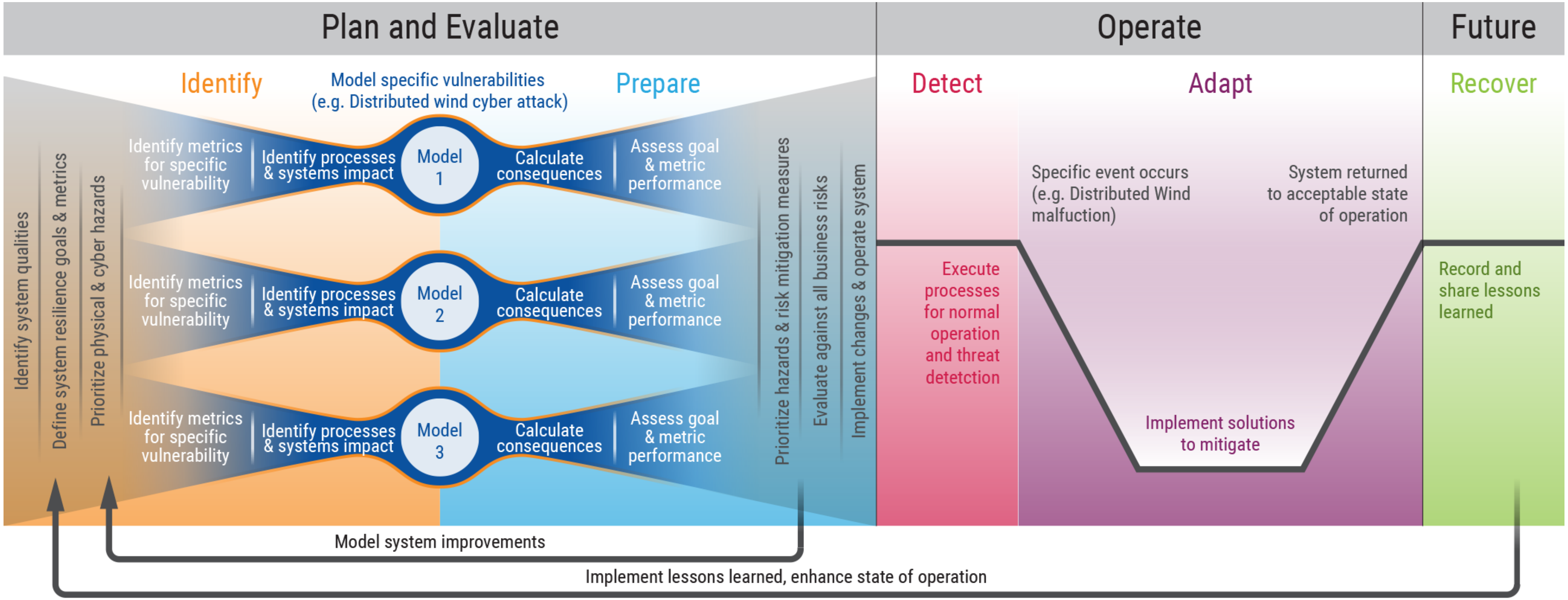
Performance

- Coefficient of variation of the frequency index of sags
- Control performance
- Standard 2 violations
- Bulk electric system reliability performance indices
- Derated power
- Dropped/lost phase
- Edge resilience trajectory
- Energy efficiency/intensity
- Failure rate
- Harmonic distortions
- Overhead and underground line segments
- Peak to peak voltage
- Phase imbalance
- Protective switching devices
- Rapid voltage changes
- Resilience indices
- Survivability
- SAIDI & SAIFI
- Unscheduled generator outages
- Voltage dips
- Voltage level variations
- Voltage sags/swells
- Voltage unbalance
- Average service availability index
- Average service interruption duration index
- Customer average interruption duration index
- Customer average interruption frequency index
- Customer experiencing longest interruption durations
- Customer experiencing multiple interruptions
- Customer experiencing multiple momentary interruptions
- Customers interrupted per interrupted index
- Economy
- Fairness
- Interrupted energy assessment rate
- Load point indices per customer
- Loss of offsite power
- Minimum level of service targets
- Momentary average interruption frequency index
- Security
- Transmission losses

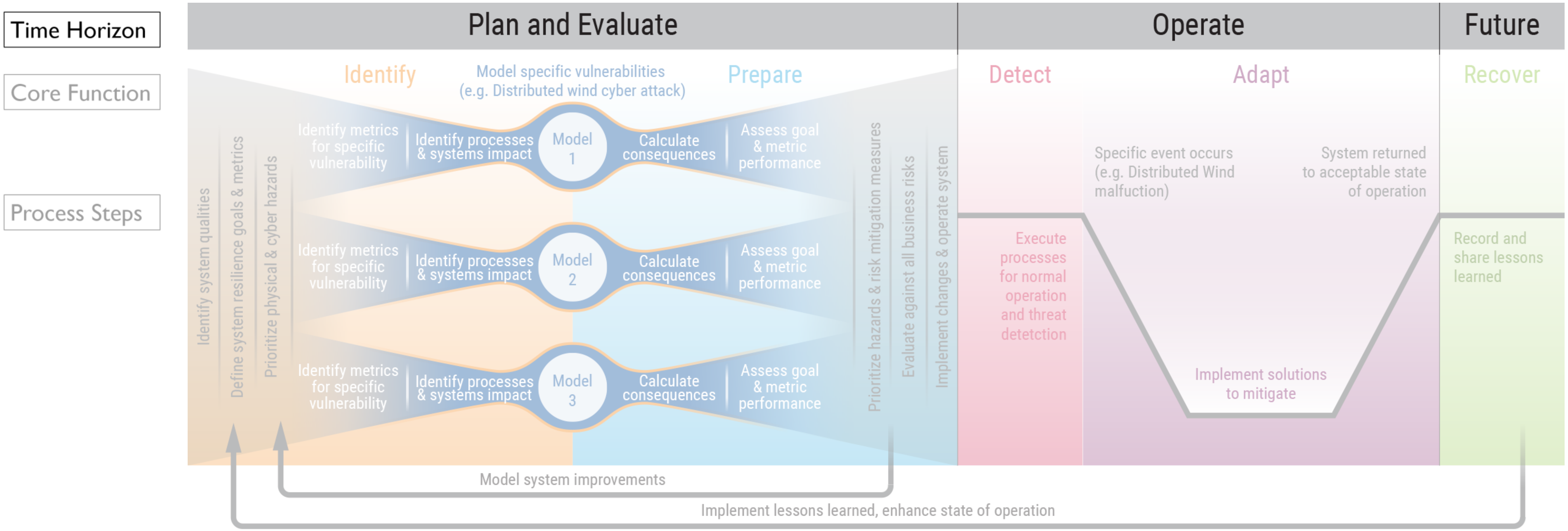
Outcomes

- Load loss damage index
- Annual price cap
- Annual allowed revenue
- Cost of interruption
- Impact factor on the population
- Noise
- Long distance transmission cost
- Performance based regulation regard/penalty structure
- Price of electricity
- Value of lost load

Full Framework



Framework – Time Horizons

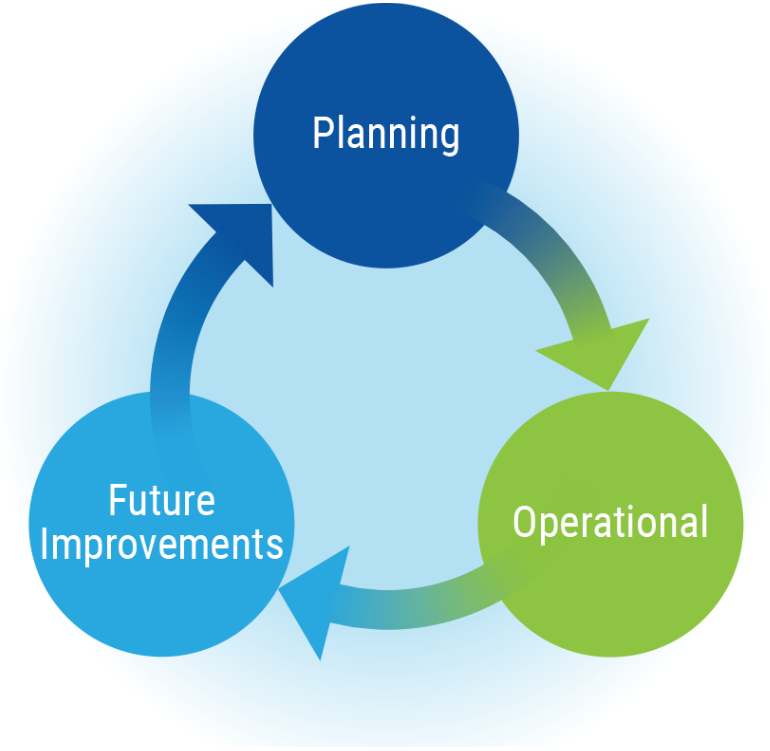


Time Horizons

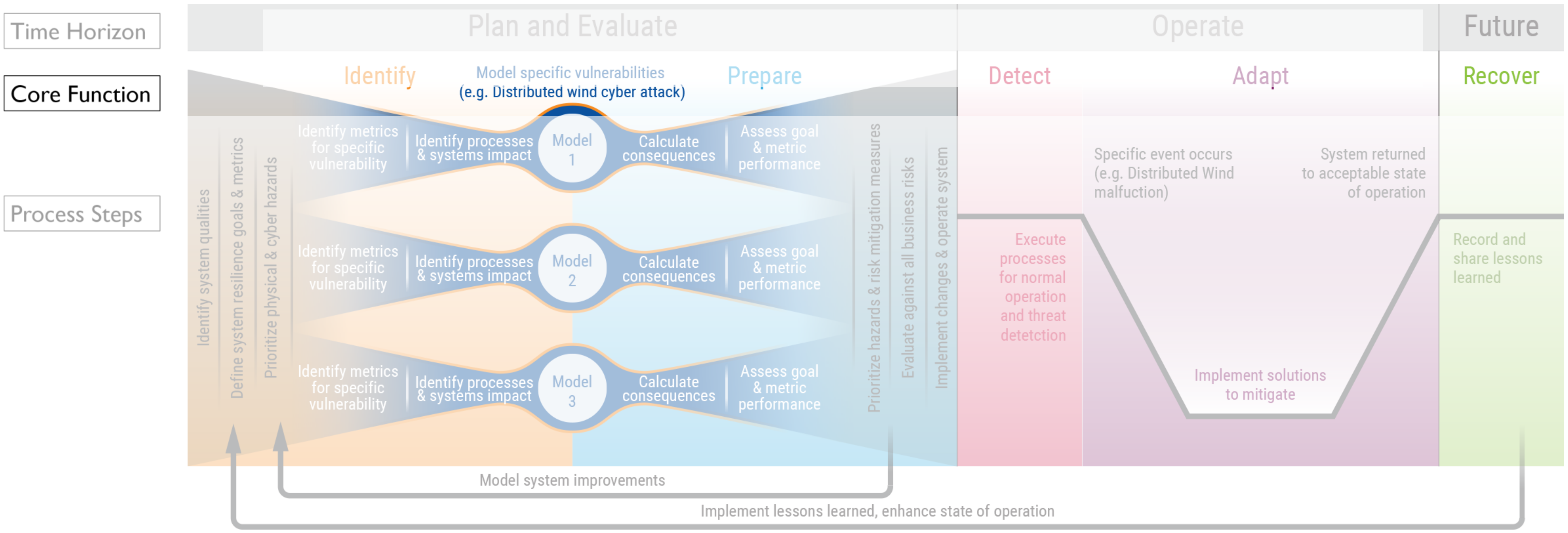
Three phases of resilience:

- Planning:
  - All hazards approach
  - Identify mitigations
  - Carefully select investments
- Operational:
  - “Hands on” phase
  - Response to hazards
- Future:
  - Improve state of system after a disruption
  - Use lessons learned for system growth

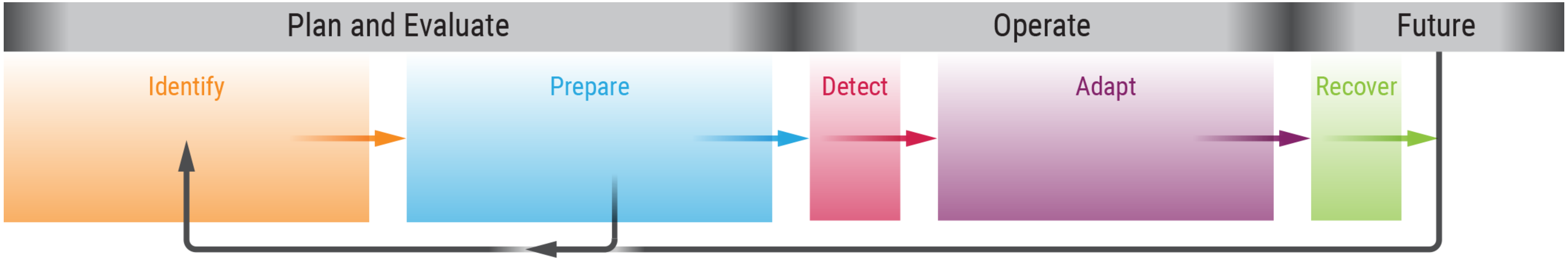
Cyclical process



Framework – Core Functions

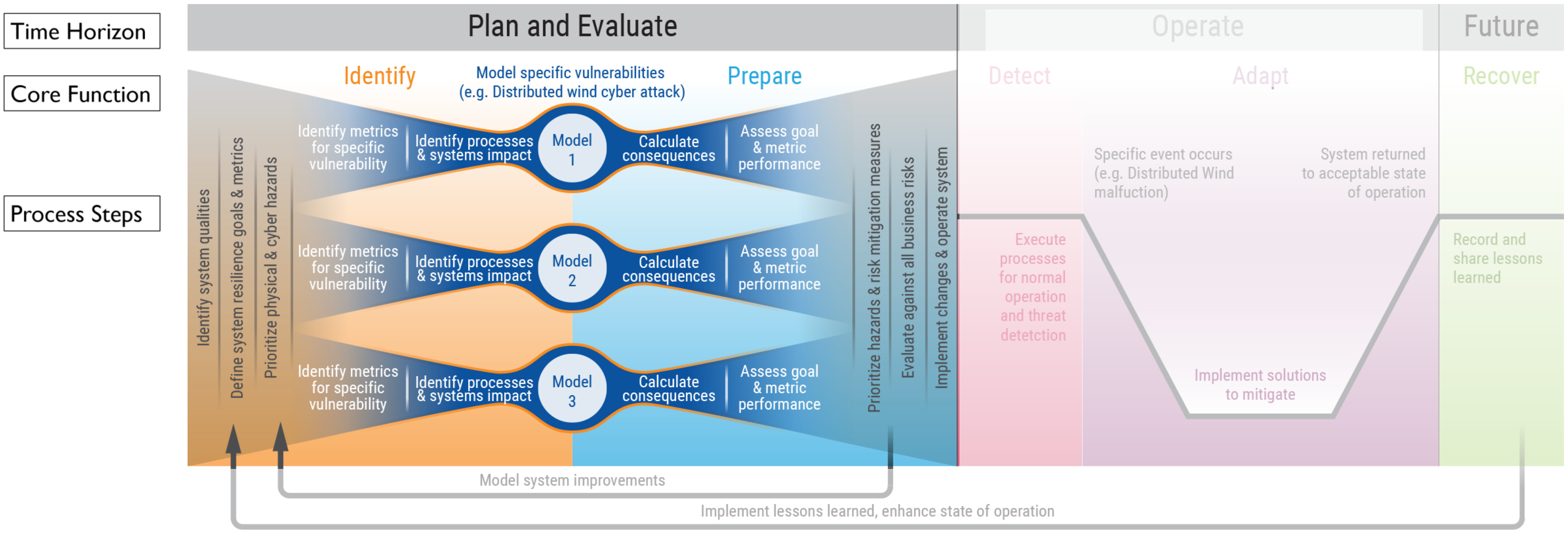


Core Functions

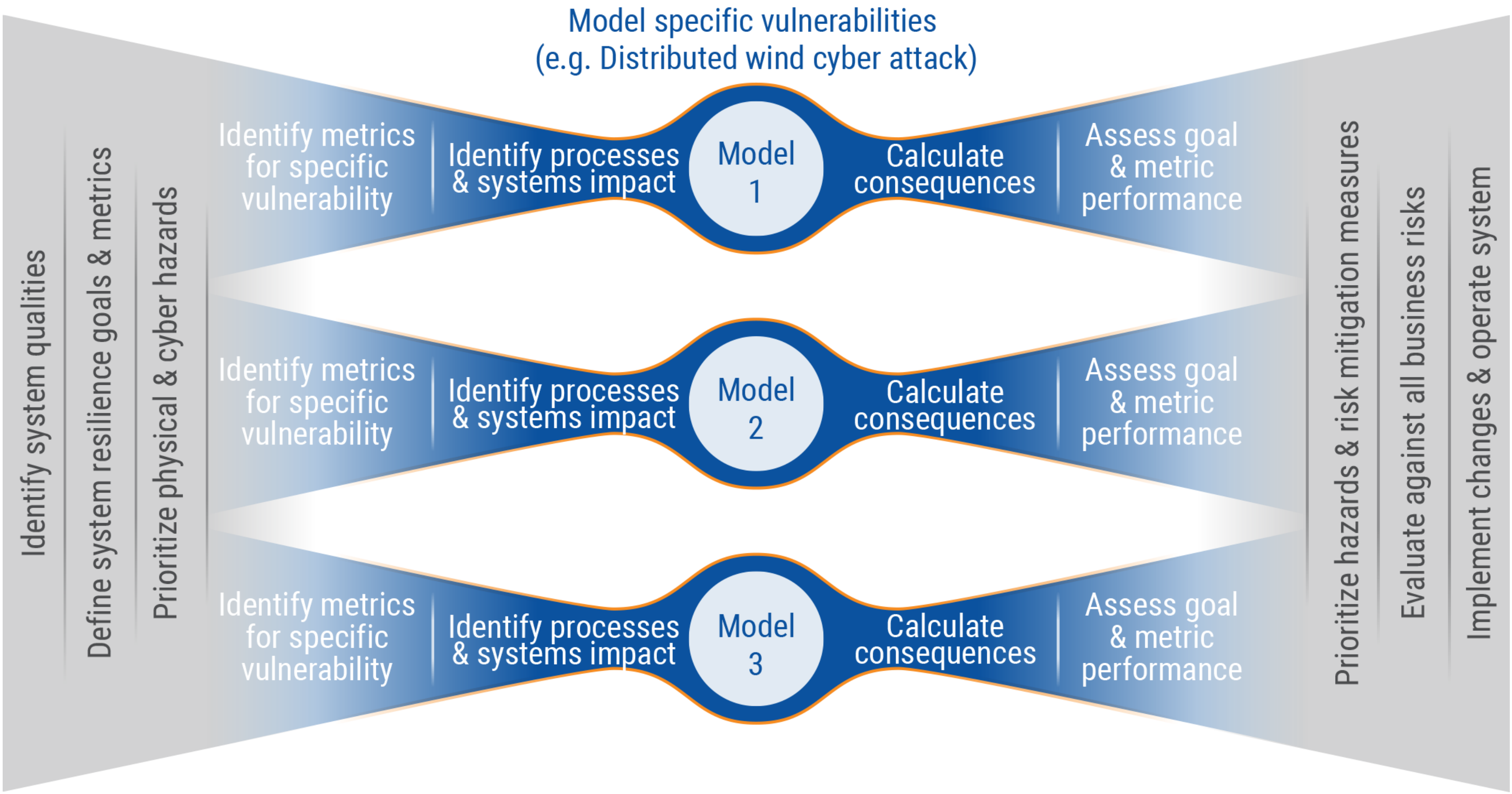


- Built based on definition of resilience
- Parallels NIST Cybersecurity Framework
- Time horizon transitions are smooth

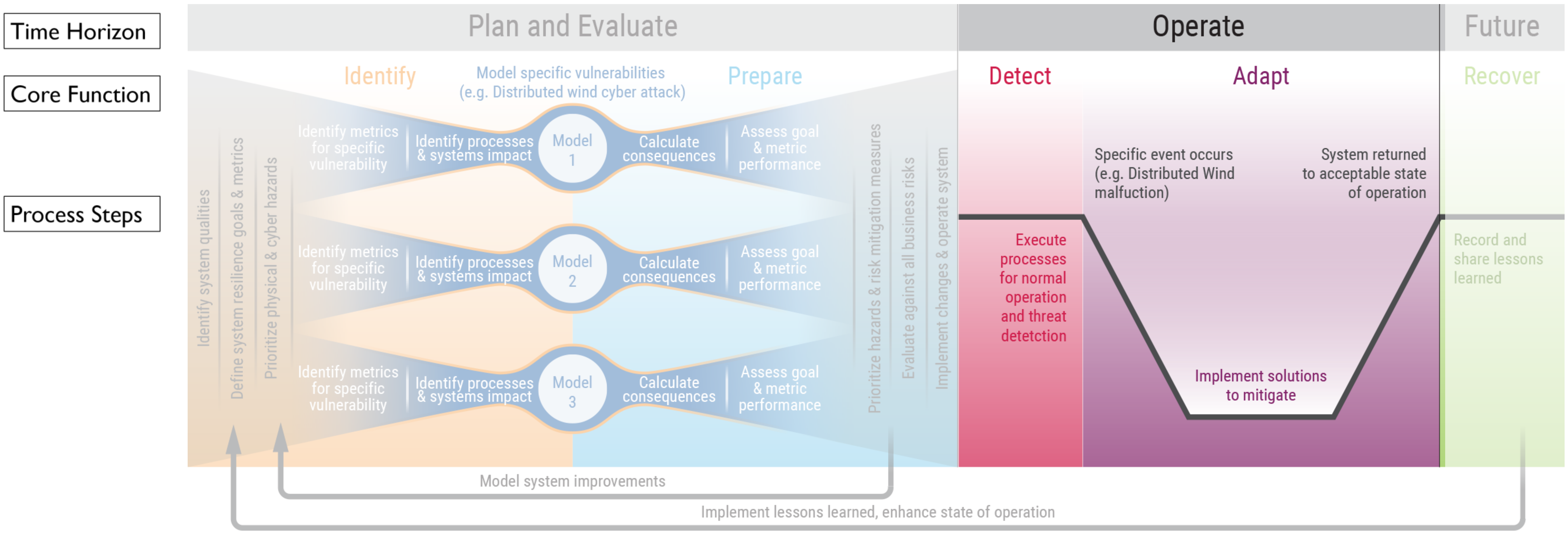
Framework – Process steps for planning



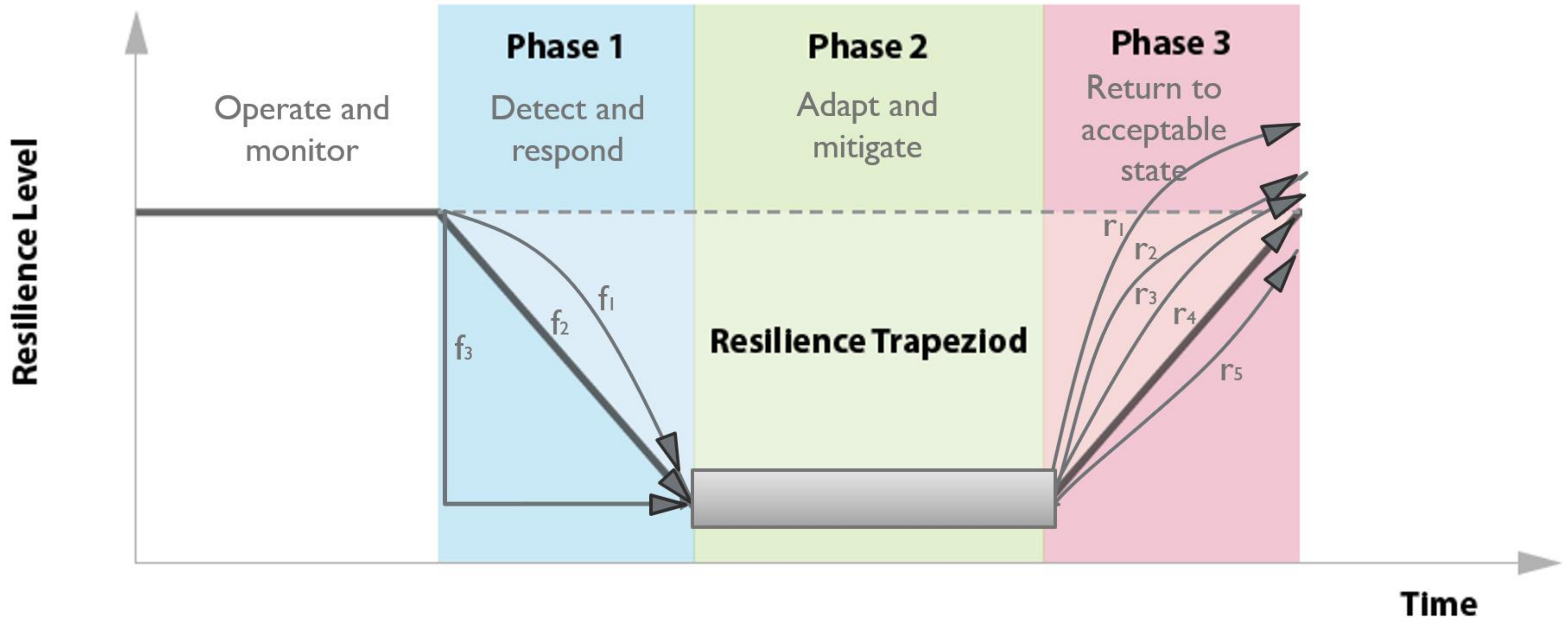
Framework Process: Identify and Prepare



Framework – Process steps for operation

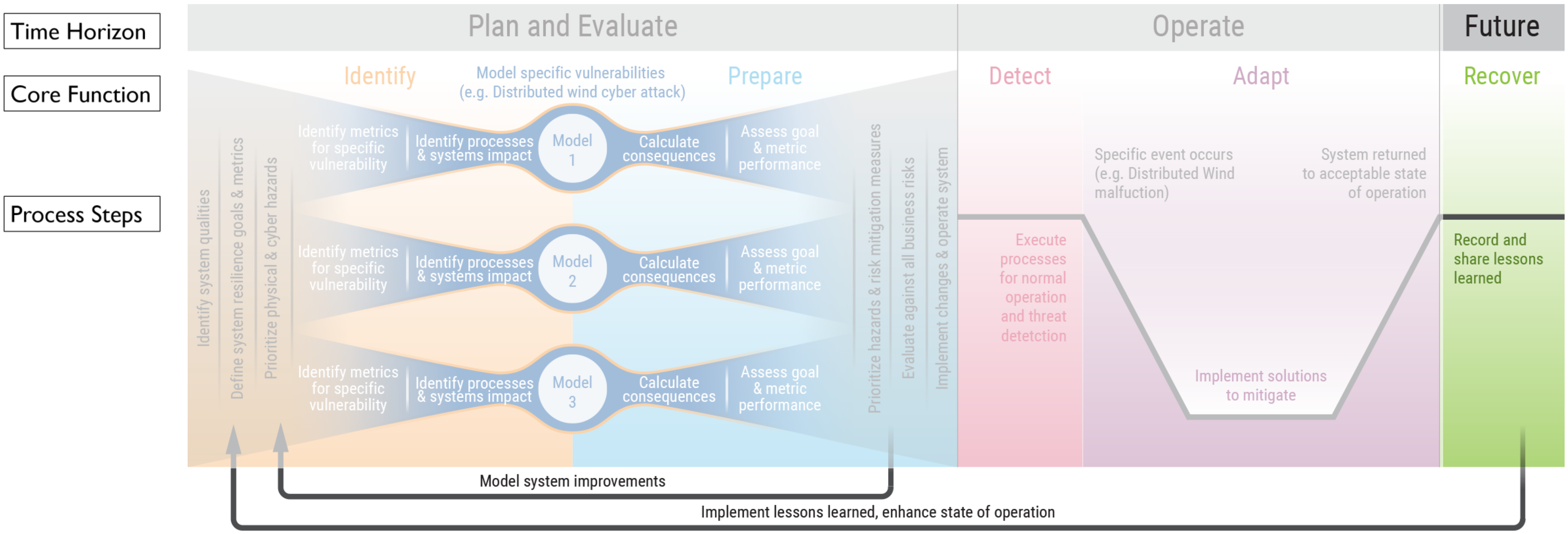


Framework Process: Detect and Adapt



- Based on resilience trapezoid
- Path to degraded state and return to acceptable state matter
- Degraded state not predetermined

Framework – Recover



Iterative Process

- Record and share lessons learned
- Return to Planning stage to reevaluate hazards
- Improve operational state directly
  - Making repairs
  - Upgrading parts

Design Considerations

Caitlyn Clark - NREL

NREL
Transforming ENERGY

Hybrid Systems: Design Considerations

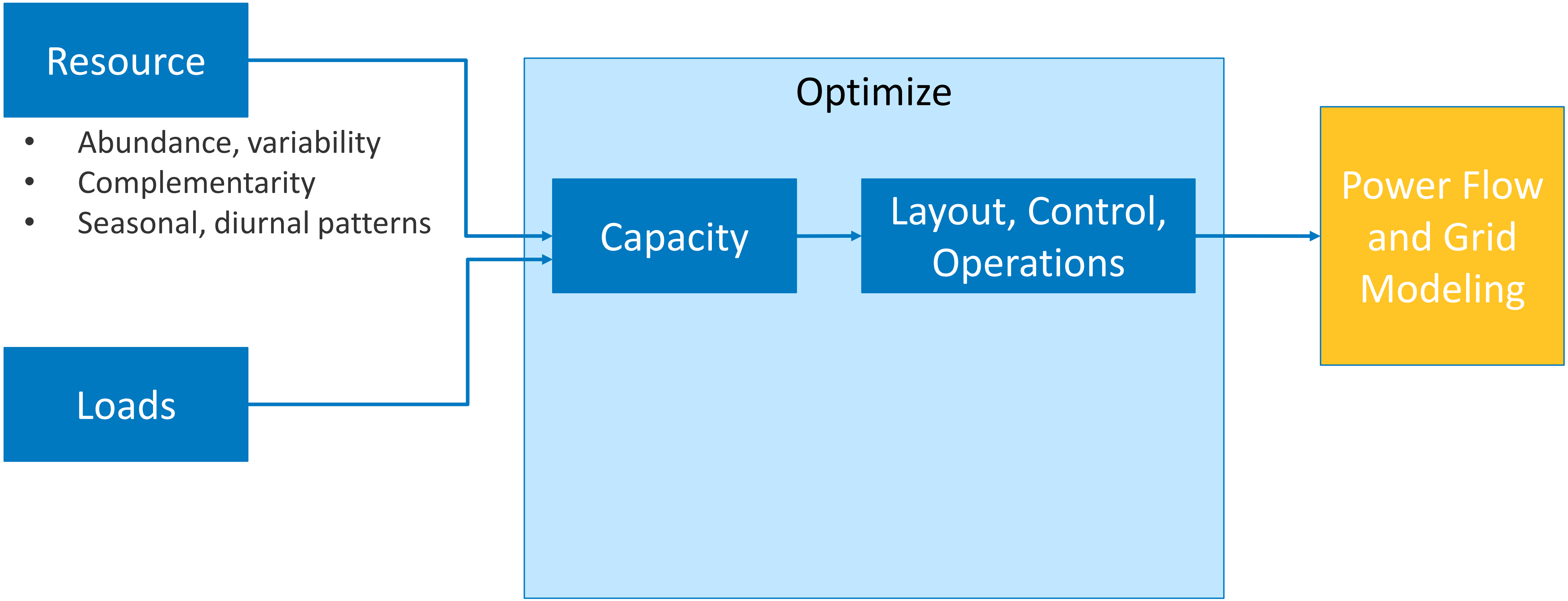
Caitlyn (Caity) Clark
National Renewable Energy Laboratory (NREL)

Building the Case for Hybrid Distributed Energy Developments Workshop – Day 1

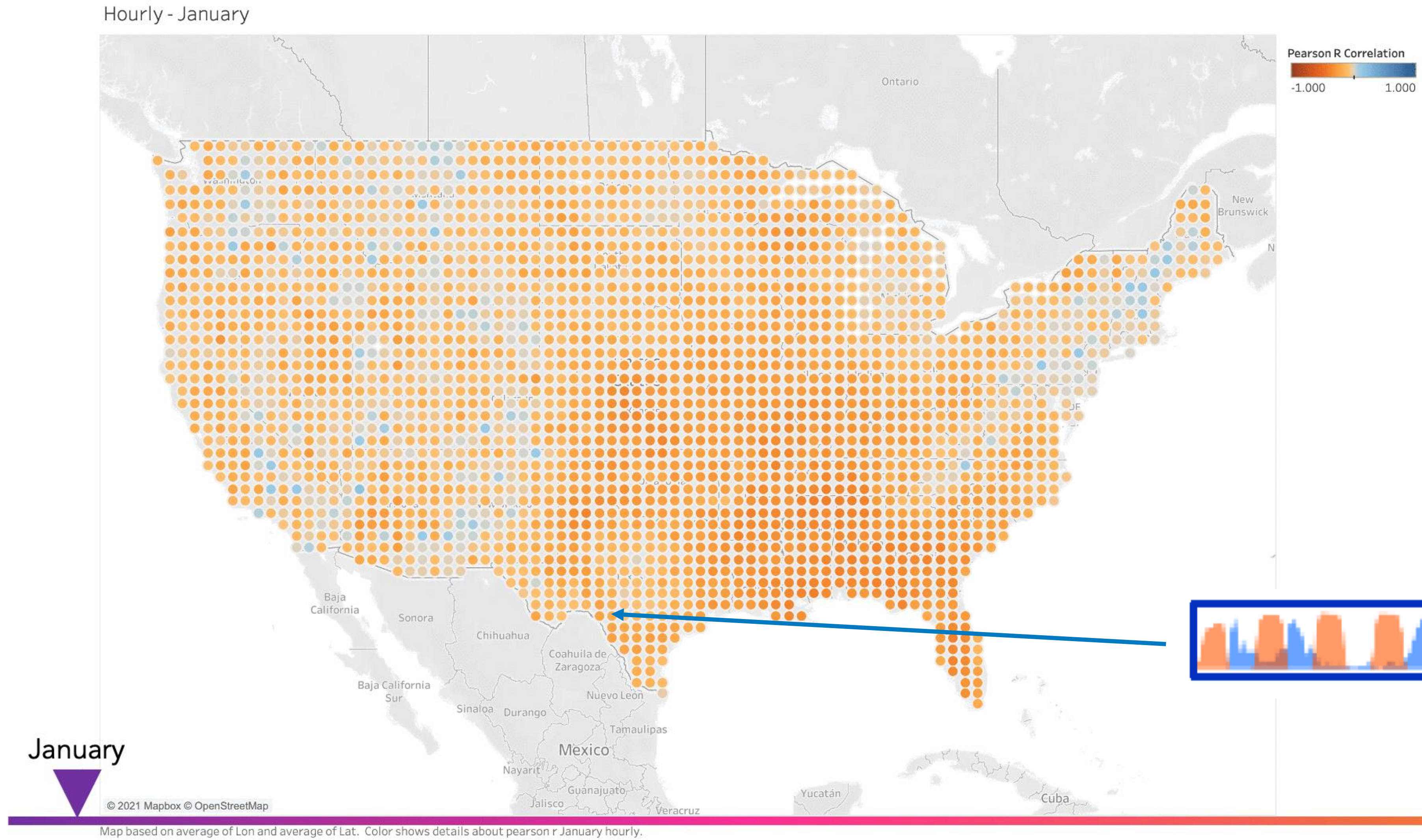
April 4, 2023

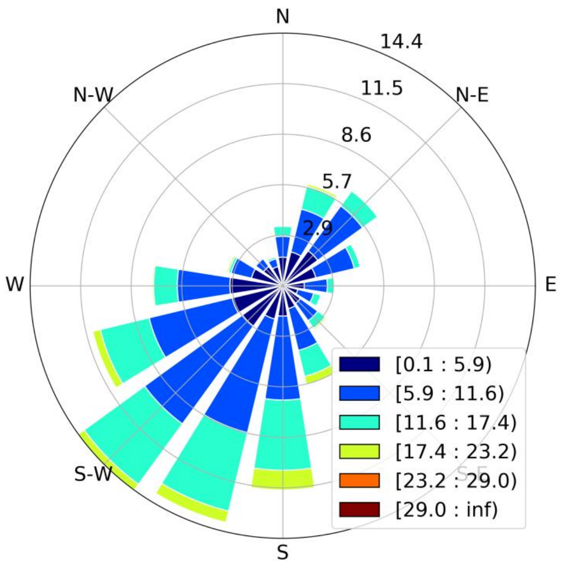
Photo by Dennis Schroeder, NREL 55200

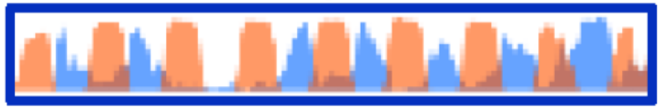
Design Considerations



Abundance, Variability, and Complementarity







Clark, Caitlyn E., et al. Wind and Solar Hybrid Power Plants for Energy Resilience. No. NREL/TP-5R00-80415. National Renewable Energy Lab.(NREL), Golden, CO (United States), 2022.

Design Considerations

Resource

- Abundance, variability
- Complementarity
- Interannual, seasonal, and diurnal patterns *and* variability

Loads

- Critical versus total loads
- Flexible loads, load response
- Existing assets

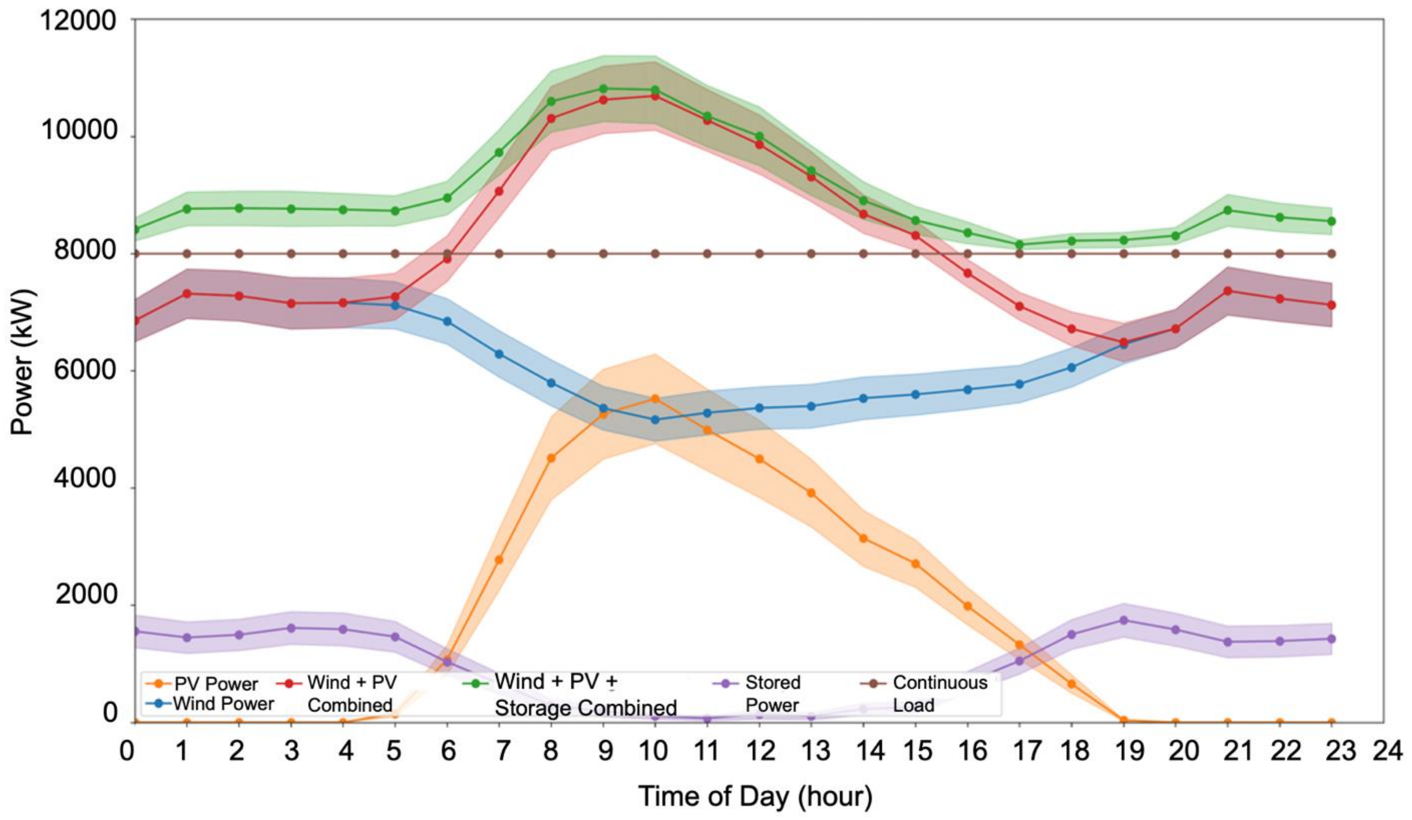
Optimize

Capacity

Layout, Control, Operations

- Can be optimized for technical, market, and resilience objectives
- Should include nominal and extreme worst-case scenarios

Load and Resilience Considerations



Example of a hybrid plant simulation in Tennessee

Reilly, Jim, et al. Fiscal Year 2021 Isolated Grids and Grid-Connected Turbine Reference Systems; Microgrids, Infrastructure Resilience, and Advanced Controls Launchpad (MIRACL). No. NREL/TP-5000-81792. National Renewable Energy Lab.(NREL), Golden, CO (United States), 2022.

Overview

Resource

- Wind Toolkit
  https://www.nrel.gov/grid/wind-toolkit.html
- Tools Assessing Performance (TAP)
  https://www.nrel.gov/wind/tools-assessing-performance.html
- National Solar Radiation Database
  https://nsrdb.nrel.gov/

Loads

Optimize

Capacity

- REopt®
  https://reopt.nrel.gov/tool
- Hybrid Optimization and Performance Platform (HOPP)
  https://github.com/NREL/HOPP

Layout, Control, Operation

- TAP
- HOPP

Thank you

www.nrel.gov

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Photo from iStock-627281636

NREL
Transforming ENERGY

Technical Assistance Opportunities

How can national laboratories help?

Discussion

INL/EXP-23-71978-Rev000

How can national laboratories help?

How can you engage in this project?

Technical assistance opportunities

Join a wind-hybrid cohort	Become a case study partner
• Focus on quick transfer of knowledge and tools • 6-12 week engagement • Engage with peers • Strengthen proposals for funding	• Focus on full analysis to meet a targeted end goal • Lab SME support to develop metrics and language in support of a new project • 3-6 month engagement

What does “engage” look like?

- The more you put into it the more you get out!
- Our analyses work best with more data. If we don’t have data we will make assumptions, which may or may not be accurate.
- Continued discussions allow us to better understand your goals and revise our analyses to fit your needs.

State, Local, and Tribal Government Assistance

- Island and remote communities
  - Energy Transitions Initiative Partnership Program
- Clean Cities Technical Assistance
- Clean Energy to Communities Program
- Clean Energy Demonstration of Mind Land technical assistance
- Waste-to-Energy technical assistance
- Technical assistance through the Office of Indian Affairs

https://www.nrel.gov/state-local-tribal/technical-assistance.html

General Lab Engagement Methods

- Partnerships on proposals
- Strategic Partnership Programs (SPPs)
- Cooperative Research and Development Agreements (CRADAs)
- Licensing of lab technology
- Technical assistance programs

https://procurement.inl.gov/Documents/INL%20Industry%20Engagement%20Technology%20Deployment.pdf
https://inl.gov/inl-initiatives/economic-and-workforce-development/

Discussion

Idaho National Laboratory

Battelle Energy Alliance manages INL for the U.S. Department of Energy's Office of Nuclear Energy. INL is the nation's center for nuclear energy research and development, and also performs research in each of DOE's strategic goal areas: energy, national security, science and the environment.

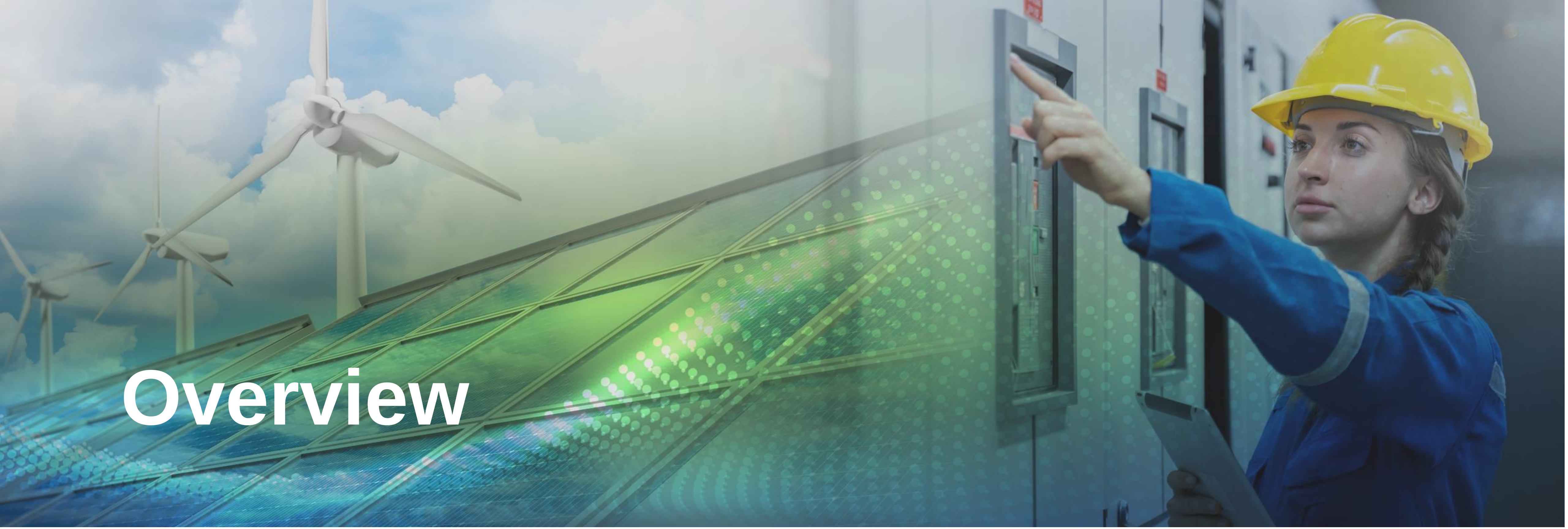
April 5, 2023

Building the Case for Hybrid Energy Developments

Battelle Energy Alliance manages INL for the
U.S. Department of Energy's Office of Nuclear Energy

Idaho National Laboratory

INL/EXP-23-71978-Rev000

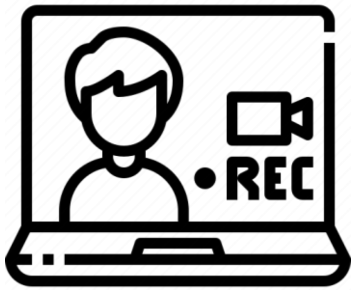


Overview

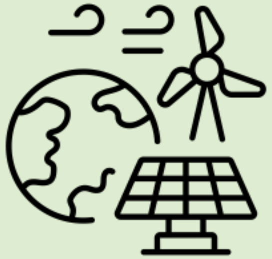
Housekeeping

- Meeting will be recorded
- Put questions in the chat or unmute
- Presentations and key resources will be available on the website

  https://inl.gov/national-security/hybrid-energy-webinar/
- Please register if you haven't already



Preview

Applications for hybrid systems	Justifying the cost of hybrid systems	Using renewable resources to enhance resilience	Siting of hybrid systems	Tools to design hybrid systems	Funding opportunities
• Case studies • Opportunities	• Valuation framework	• Resilience framework	• Wind resource assessment • Tools assessing performance (TAP)	• Resilience application • Hybrid Optimization and Performance Platform (HOPP)	• Opportunities and technical assistance
					

Funded by the Wind Energy Technologies Office

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Agenda

How can hybrid systems be developed?

- Wind resource modeling and analysis
- Resilience calculator
- Hybrid Optimization & Performance Platform (HOPP)
- Valuation Tool
- Tools Assessing Performance (TAP)

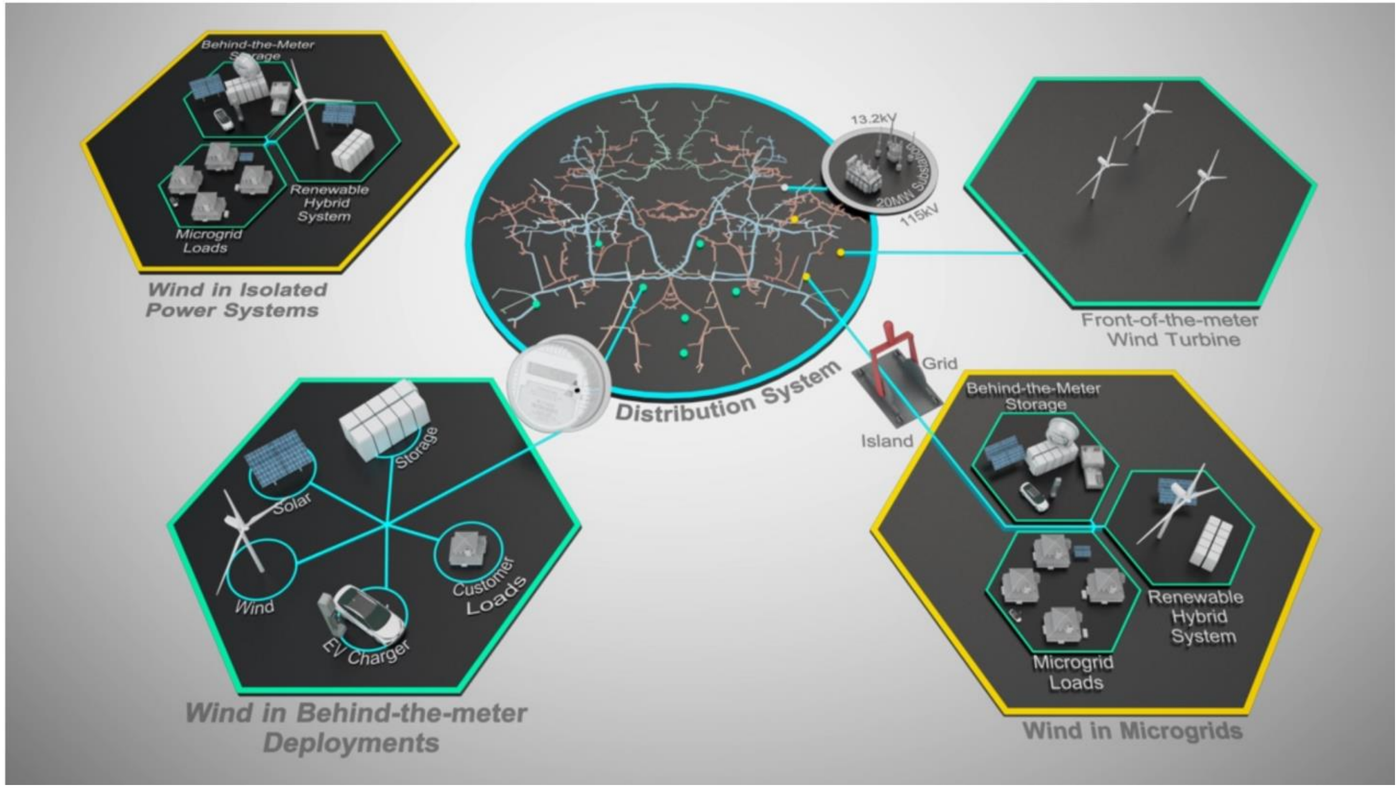
Funding Opportunities

- Types of opportunities
- Resources availability

Closeout

Project Overview

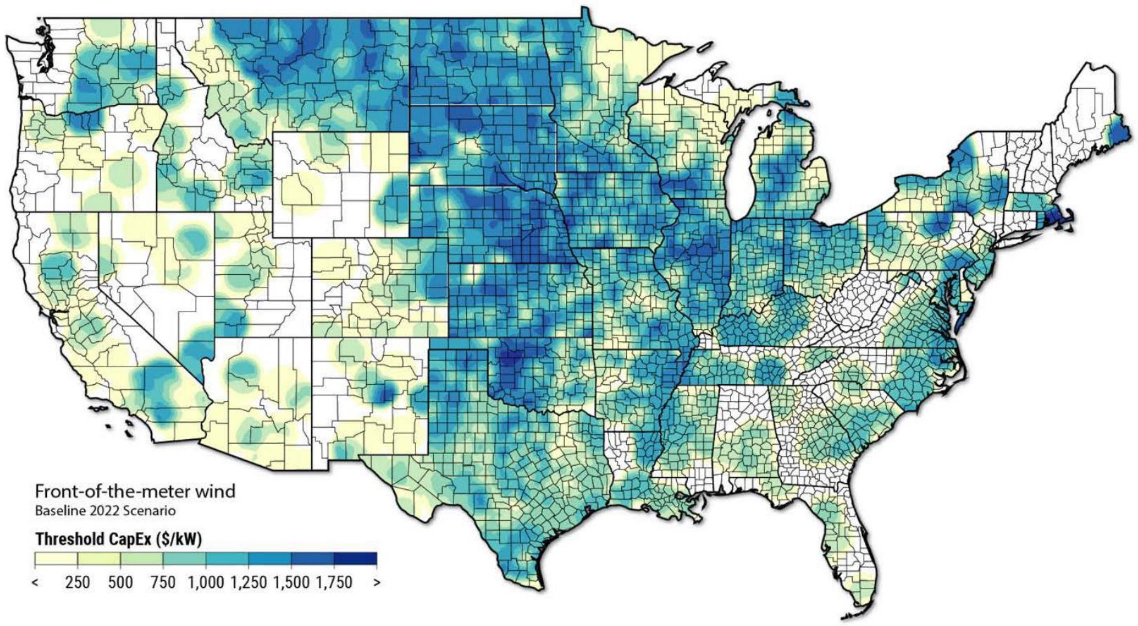
On Site Wind for Rural Load Centers

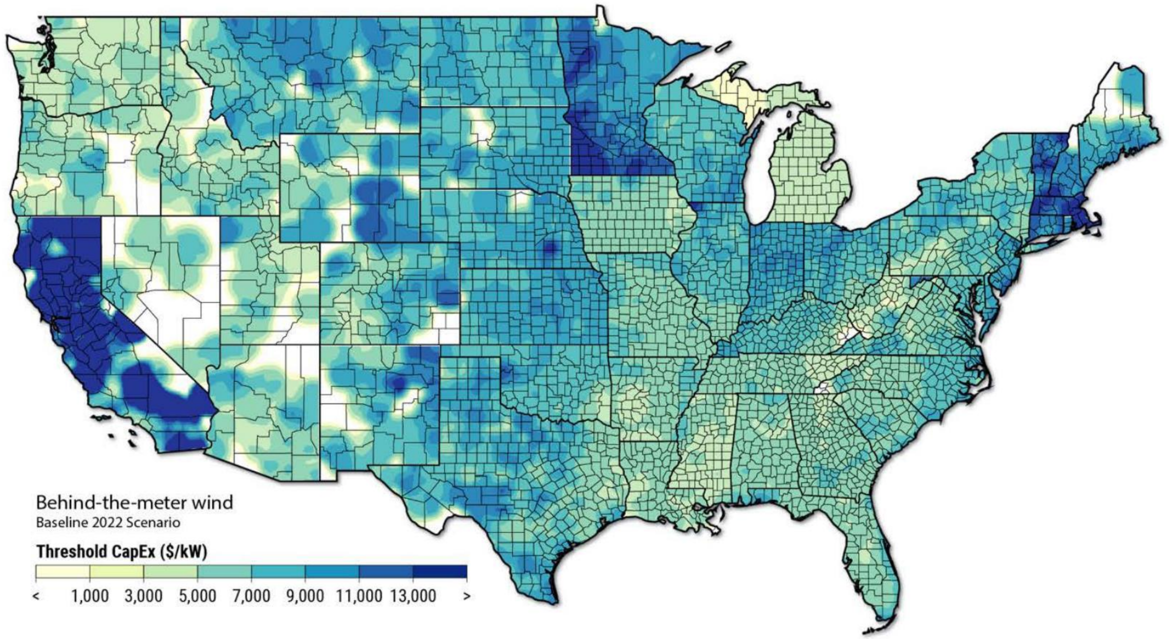


https://www.nrel.gov/docs/fy22osti/82519.pdf

Project Overview

On Site **Wind for Rural** Load Centers





https://www.nrel.gov/docs/fy21osti/76918.pdf

Project Overview

On Site Wind for Rural **Load Centers**

Residential

Industrial

Commercial

Agricultural

Project Team

NREL

NATIONAL RENEWABLE ENERGY LABORATORY

- Hybrid system design
- Add features for HOPP

INL

Idaho National Laboratory

- Resilience needs of different load types
- Resilience boosters for distributed wind
- Lead TA and case study engagements

Pacific Northwest

NATIONAL LABORATORY

- Valuation of distributed wind
- Valuation service as a user tool
- Energy equity

IOWA STATE UNIVERSITY

- Connect labs to community interests
- Resilience analysis
- Rural applications for distributed wind

NRECA

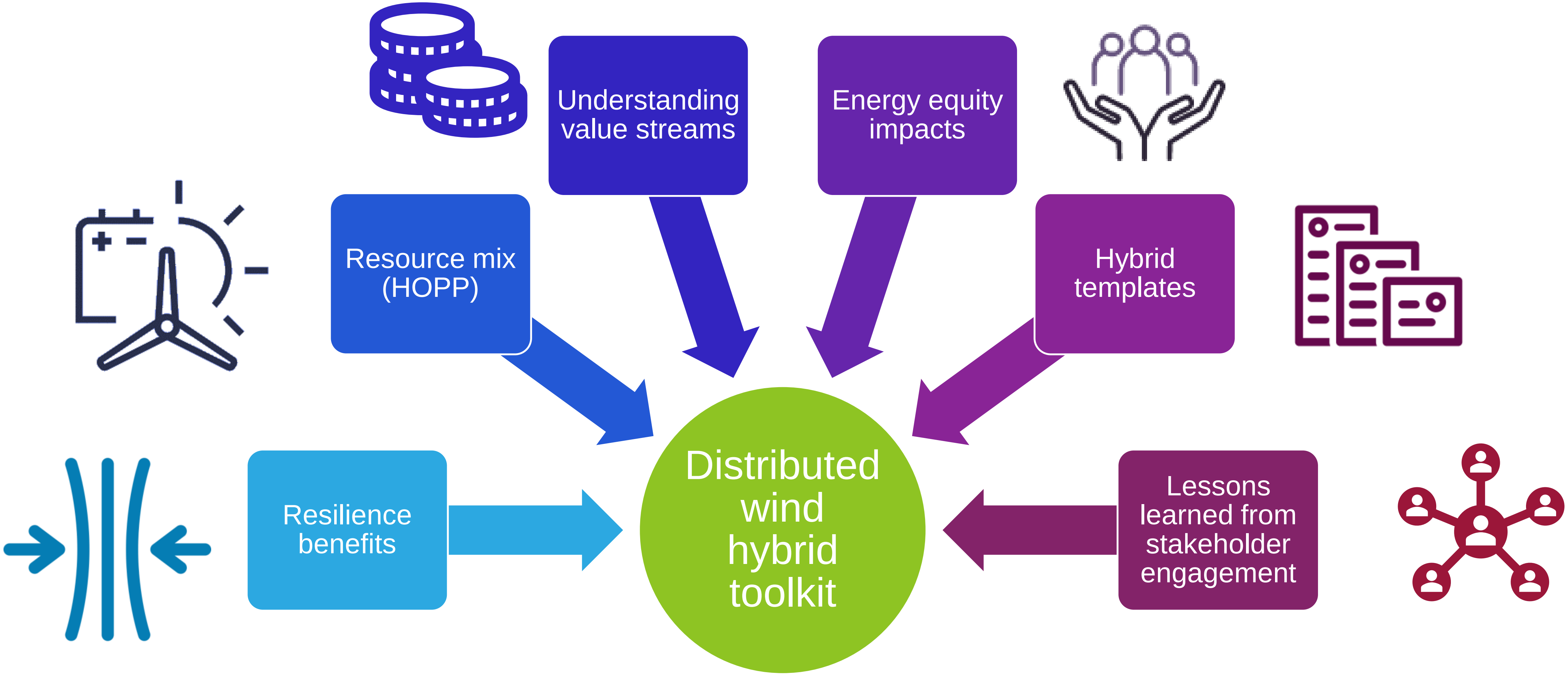
America's Electric Cooperatives

- Leverage previous distributed wind work with co-ops

Mana Group LLC

- Stakeholder engagement
- Coordination with other projects
- Outreach

Distributed Wind Hybrid Toolkit



How can I develop a robust, efficient hybrid system?

Modeling and Analysis Capability

Resilience Calculator

HOPP – Hybrid Optimization and Performance Platform

Valuation Service

TAP – Tools Assessing Performance

INL/EXP-23-71978-Rev000

IDAHO NATIONAL LABORATORY

Modeling and Analysis Capability

Kevin McCabe - NREL

NREL
Transforming ENERGY

Distributed Wind Modeling and Analysis to Inform Strategic Deployment Decisions

Kevin McCabe
National Renewable Energy Laboratory

Building the Case for Hybrid Distributed Energy Developments Workshop – Day 2

April 5, 2023

Photo by Dennis Schroeder, NREL 55200

Distributed Wind Energy Futures Study (DWEFS)

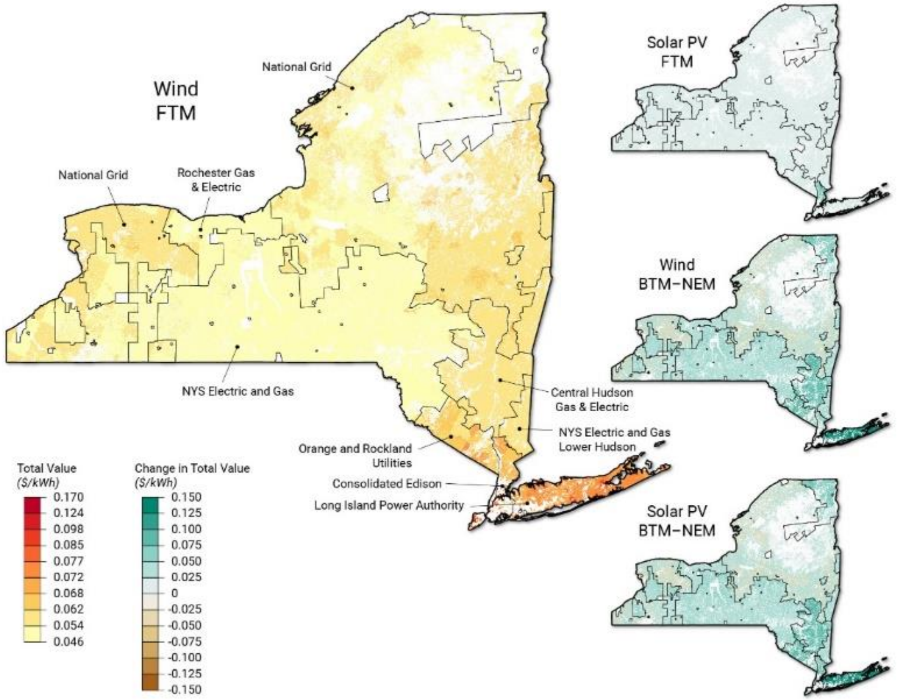
What is the role of distributed wind in a 2035 clean electricity power system?

Key Innovation: Use of parcel data to assess location-specific land use, resource, and siting. Assess each parcel's technical and economic viability:

- By technology: distributed wind (DW) vs. solar (DPV)
- By business model: behind-the-meter vs. front-of-the-meter.

Primary metric is the threshold capital expenditures (CapEx, $/kW) by site, or the capital costs required to reach a project hurdle rate (i.e., net present value [NPV] = $0).

Scenarios vary alternative DER valuation, policy financing, and cost and performance improvement pathways to 2035.



Example results for recent New York state analysis piloting the DWEFS parcel-level methods

Figures by NREL

DWEFS Capability Development

Significant model development enabled by the Distributed Wind Energy Futures Study

- Development of **parcel-level** database (n = ~150 million)
- Development of robust geospatial methods for **turbine siting and sizing**
- Integration of **reV[1] resource processing**
- Integration of Cambium[2] for **front-of-the-meter** revenue streams
- Integration of PySAM[3] library – enables **hybrid system modeling**
- Consideration of **environmental justice** outputs and opportunities.

Scenario analysis revealed **large quantities of technical potential** for distributed applications of all forms, in addition to large areas corresponding to **nearly 1,400 gigawatts of economic potential**.

[1] https://www.nrel.gov/gis/renewable-energy-potential.html
[2] https://www.nrel.gov/analysis/cambium.html
[3] https://sam.nrel.gov/software-development-kit-sdk/pysam.html

Parcel-Scale Analysis

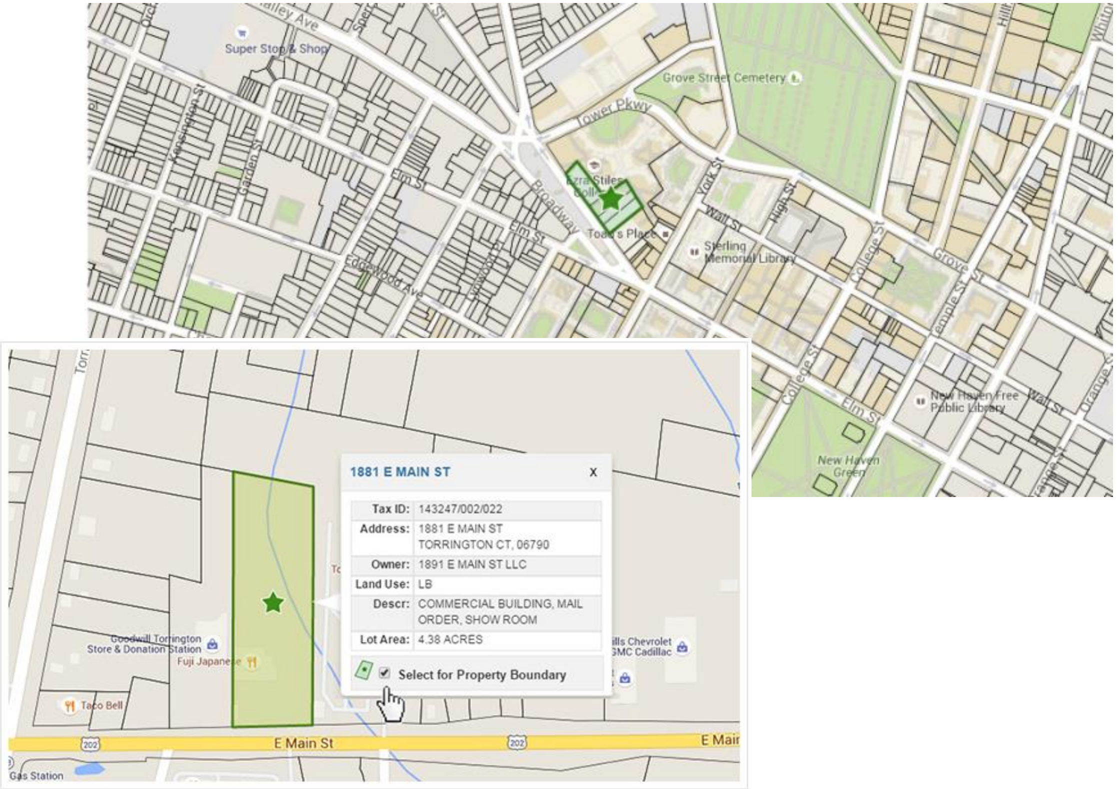
Use of data at parcel scale to identify location-specific land use, resource, and siting.

Assessment of each sampled parcel's technical and economic viability:

- **By technology**: distributed wind and distributed solar
- **By application**: behind-the-meter and front-of-the-meter.

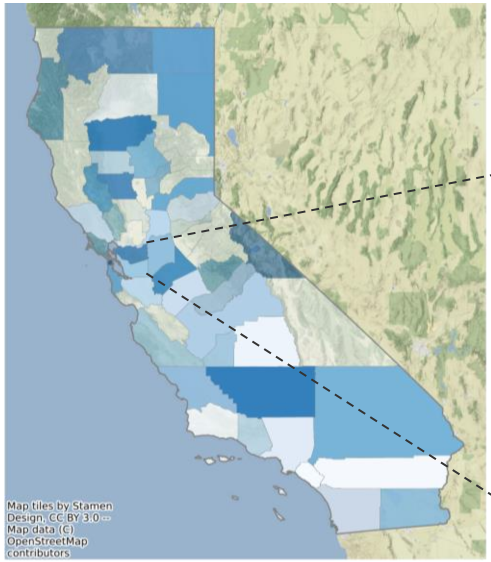
Parcel = taxable plot of land

Homeland Infrastructure Foundation-Level Data (HIFLD) (2020). Parcel Data - Lightbox. https://gii.dhs.gov/hifld/content/hifld-data-catalog



Example of parcel scale data from Lightbox
https://edrnet.com/introducing-edr-tax-parcel-maps/

Parcel-Level Example of BTM Wind Analysis



Attribute	Value
State	California
County	San Joaquin
Land Use	Single-Family Residence
Year Built	1978
Land Area	7,388 sq. ft.
Building Area	1,527 sq. ft.
Utility	Pacific Gas & Electric

Figures by NREL

Parcel boundary and building footprint

Largest circle

Available turbine siting area (with setback)

Parcel-Level Example of Behind-the-Meter (BTM) Wind Analysis

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County	San Joaquin
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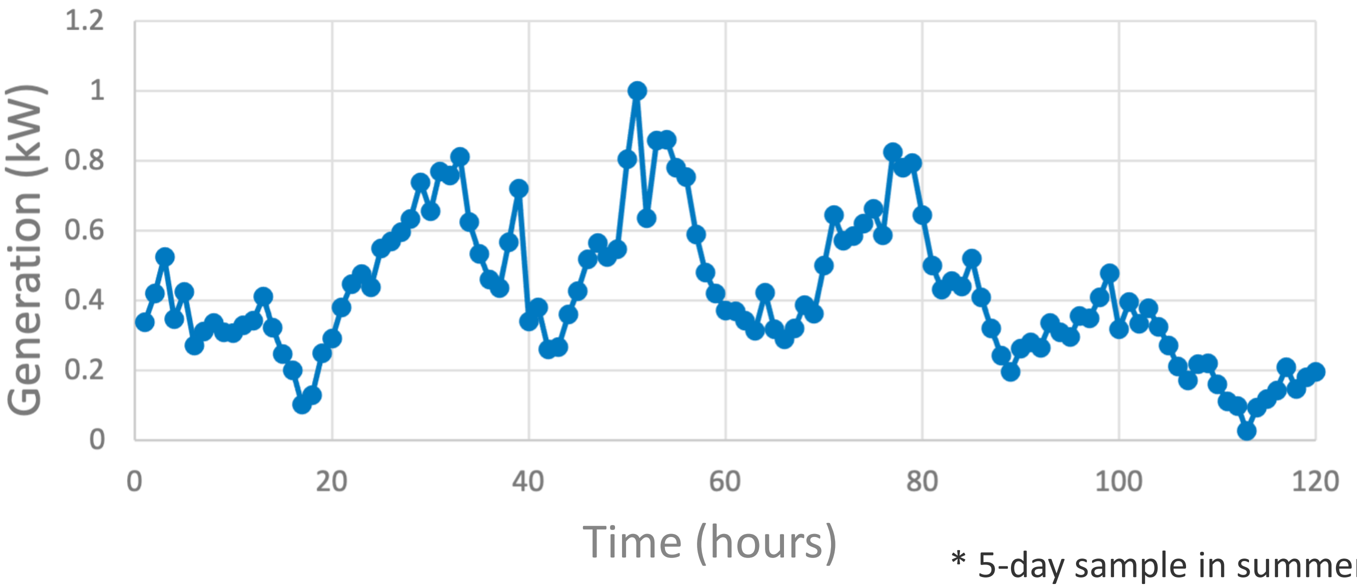

* 5-day sample in summer

Figures by NREL

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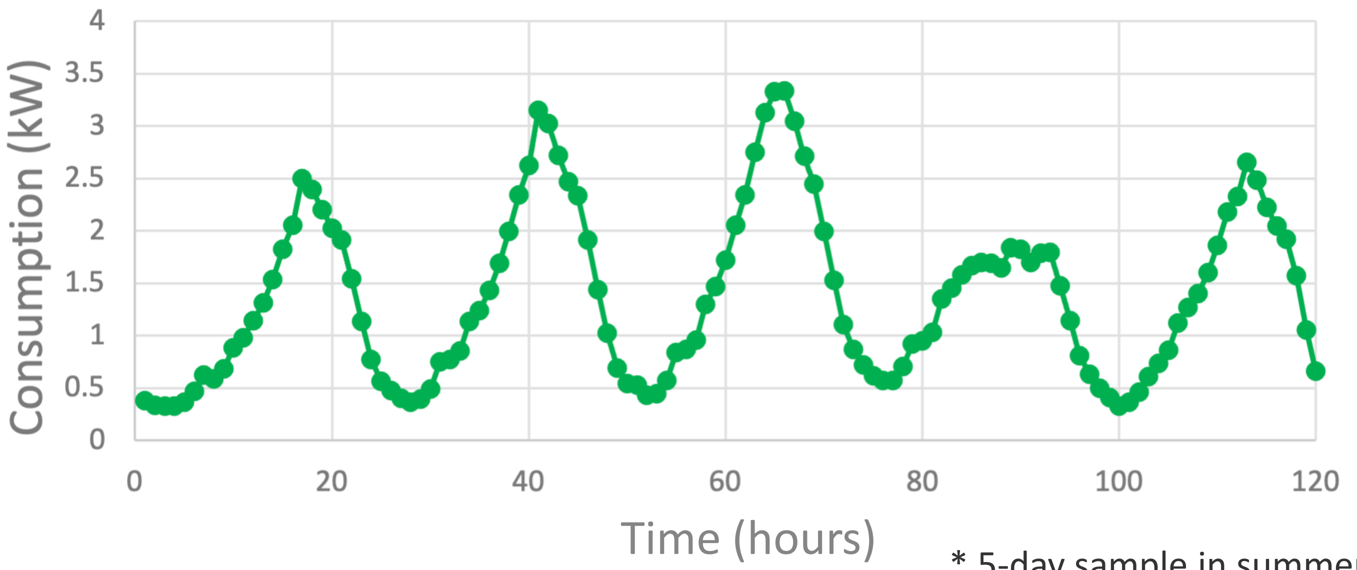

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Figures by NREL

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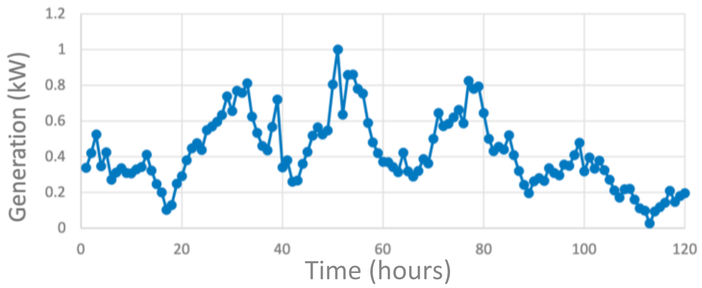
Tiered Energy Usage Charge Structure

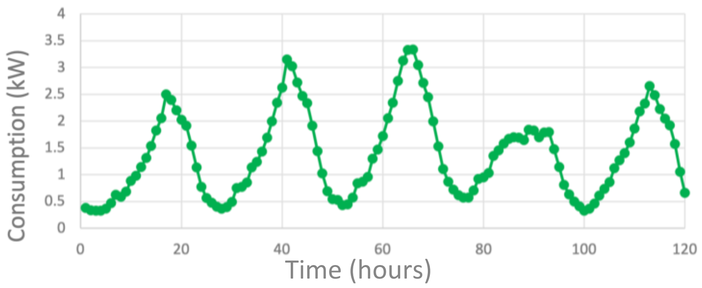
Period	Tier	Max Usage ?	Max Usage Units ?	Rate $/kWh ?	Adjustments $/kWh ?	Sell $/kWh ?
1	1	15.8	kWh daily	0.30226		
	2		kWh daily	0.38412		
2	1	15.8	kWh daily	0.23882		
	2		kWh daily	0.32068		
3	1	11.1	kWh daily	0.21517		
	2		kWh daily	0.29703		
4	1	11.1	kWh daily	0.19784		
	2		kWh daily	0.2797		

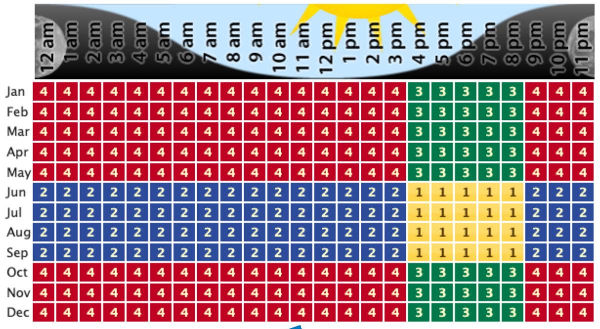
	12 am	1 am	2 am	3 am	4 am	5 am	6 am	7 am	8 am	9 am	10 am	11 am	12 pm	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm	7 pm	8 pm	9 pm	10 pm	11 pm
Jan	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	4	4	4
Feb	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	4	4	4
Mar	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	4	4	4
Apr	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	4	4	4
May	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	4	4	4
Jun	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	2	2	2
Jul	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	2	2	2
Aug	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	2	2	2
Sep	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	2	2	2
Oct	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	4	4	4
Nov	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	4	4	4
Dec	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	4	4	4

E-TOU-C3 Residential Time of Use Baseline Region S, Figure by NREL

Parcel-Level Data Informs BTM Economic Metrics

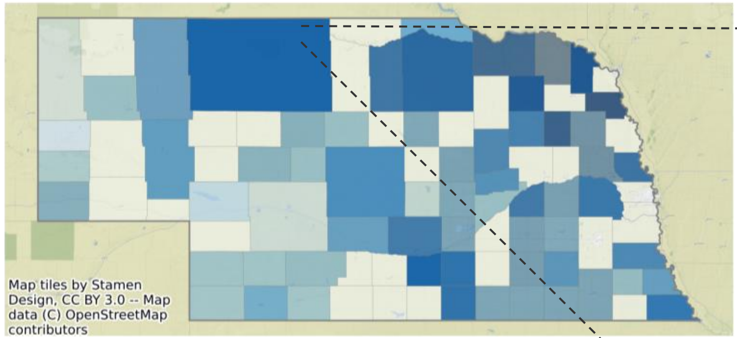




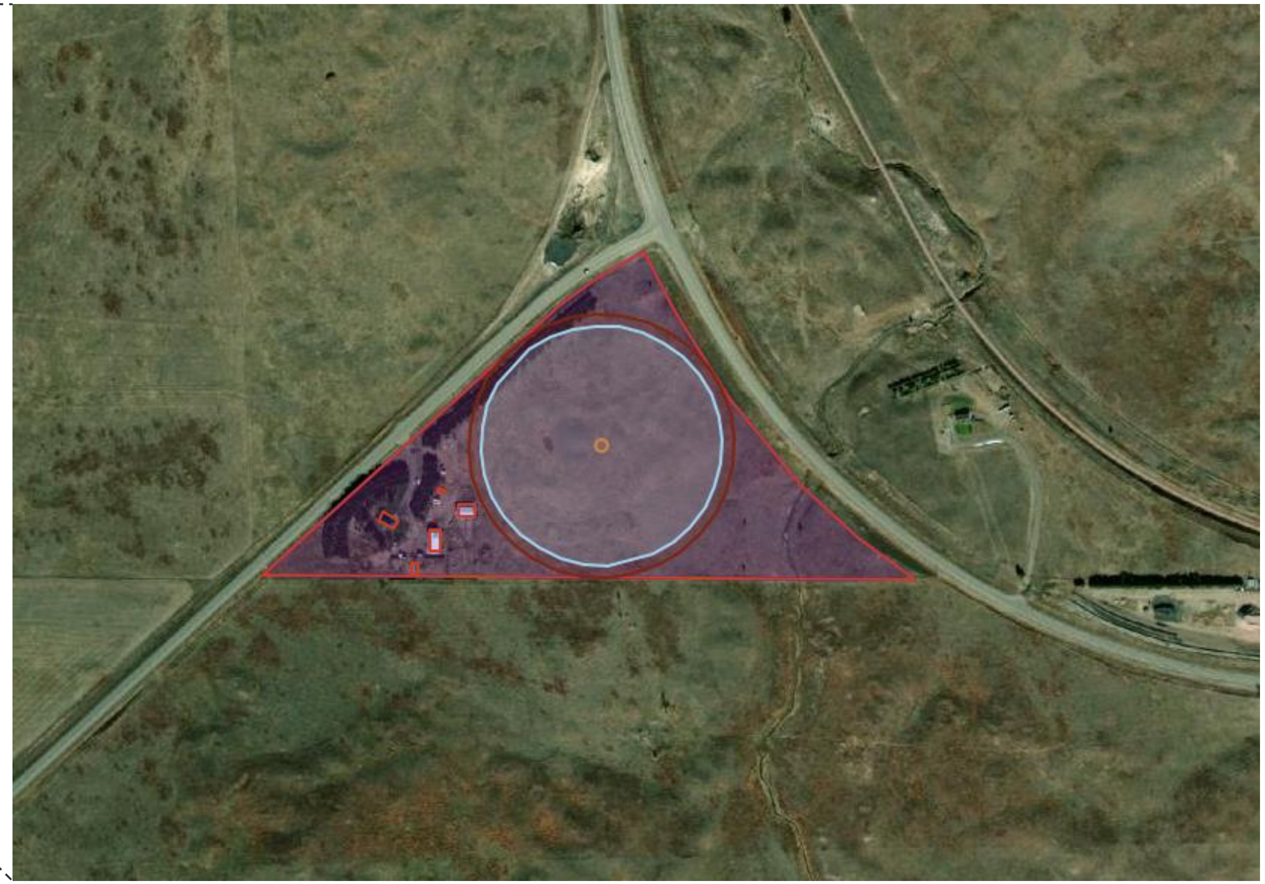


Attribute	Value
NPV	-$3,489
Payback Period	24 years
Threshold CapEx	$1,100/kW

Parcel-Level Example of Front-of-the-Meter (FOM) Wind Analysis



Attribute	Value
State	Nebraska
County	Cherry
Land Use	Rural Residence Agricultural
Zoning	Agricultural
Land Area	34 acres (1.5 million sq. ft.)
Building Area	1,456 sq. ft.



Parcel boundary and building footprint

Largest circle

Available turbine siting area (with setback)

Parcel-Level Example of FOM Wind Analysis

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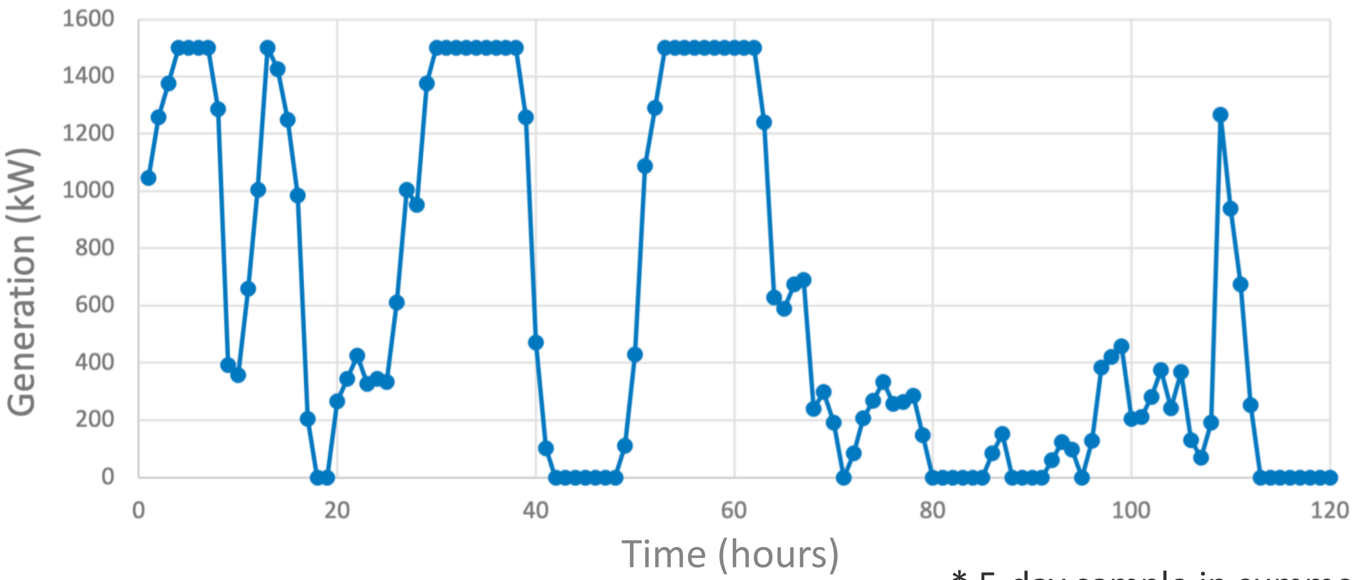

* 5-day sample in summer

Figures by NREL

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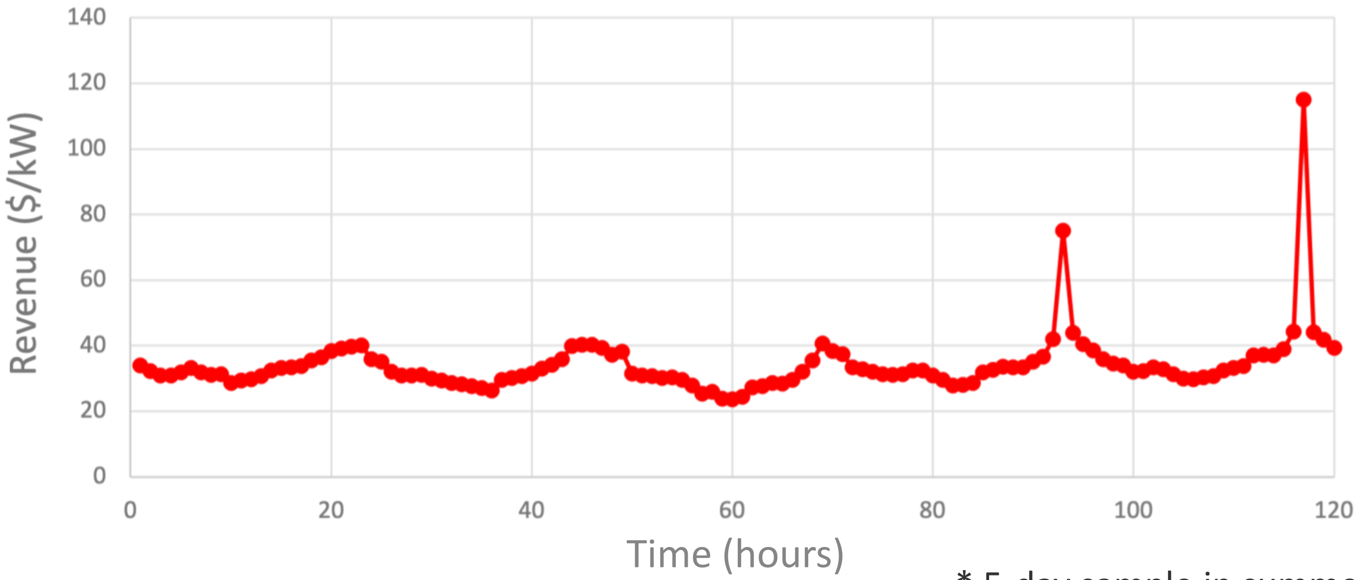
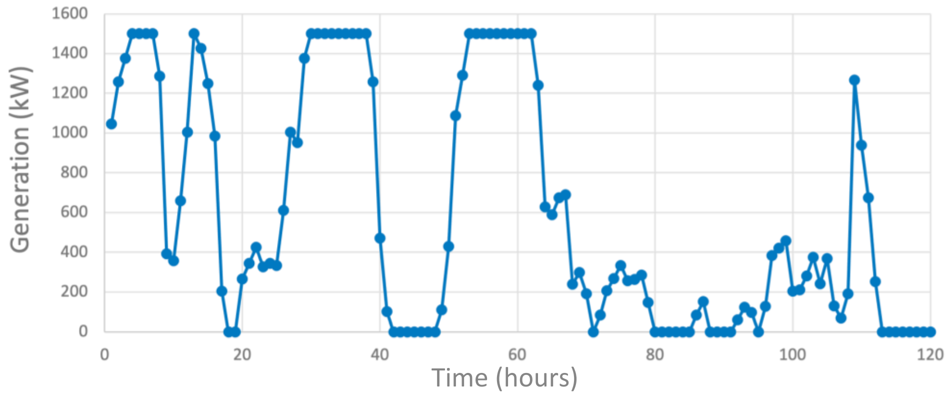
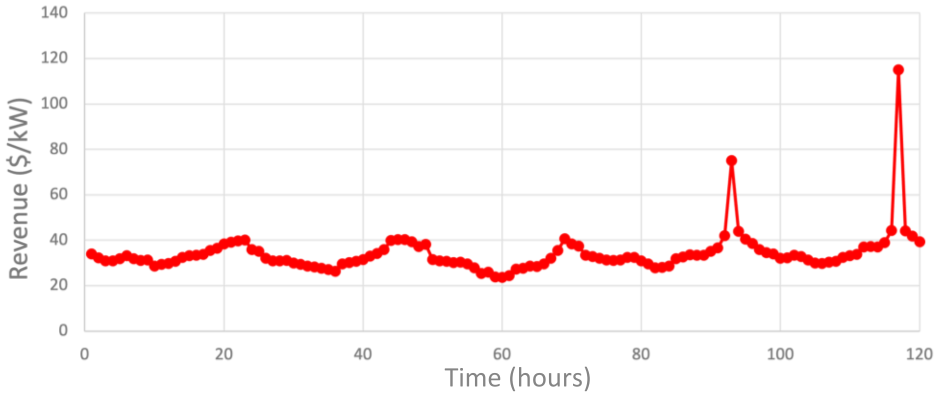


* 5-day sample in summer

Figures by NREL

Parcel-Level Data Informs FOM Economic Metrics

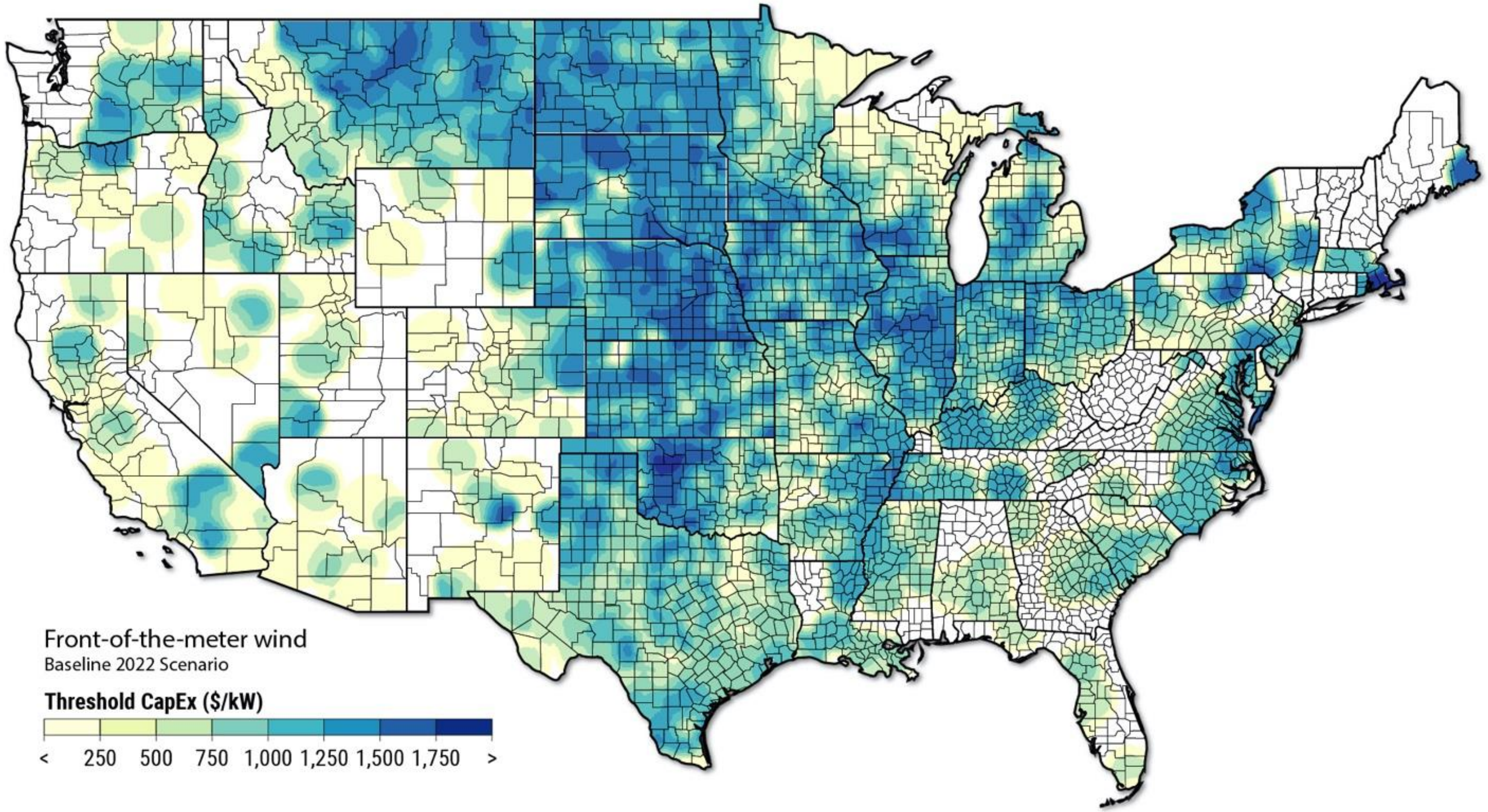




Attribute	Value
NPV	+$124,850
Payback Period	4.3 years
Threshold CapEx	$6,770/kW

Baseline 2022 Scenario Results by Region

Front-of-the-meter opportunities for wind

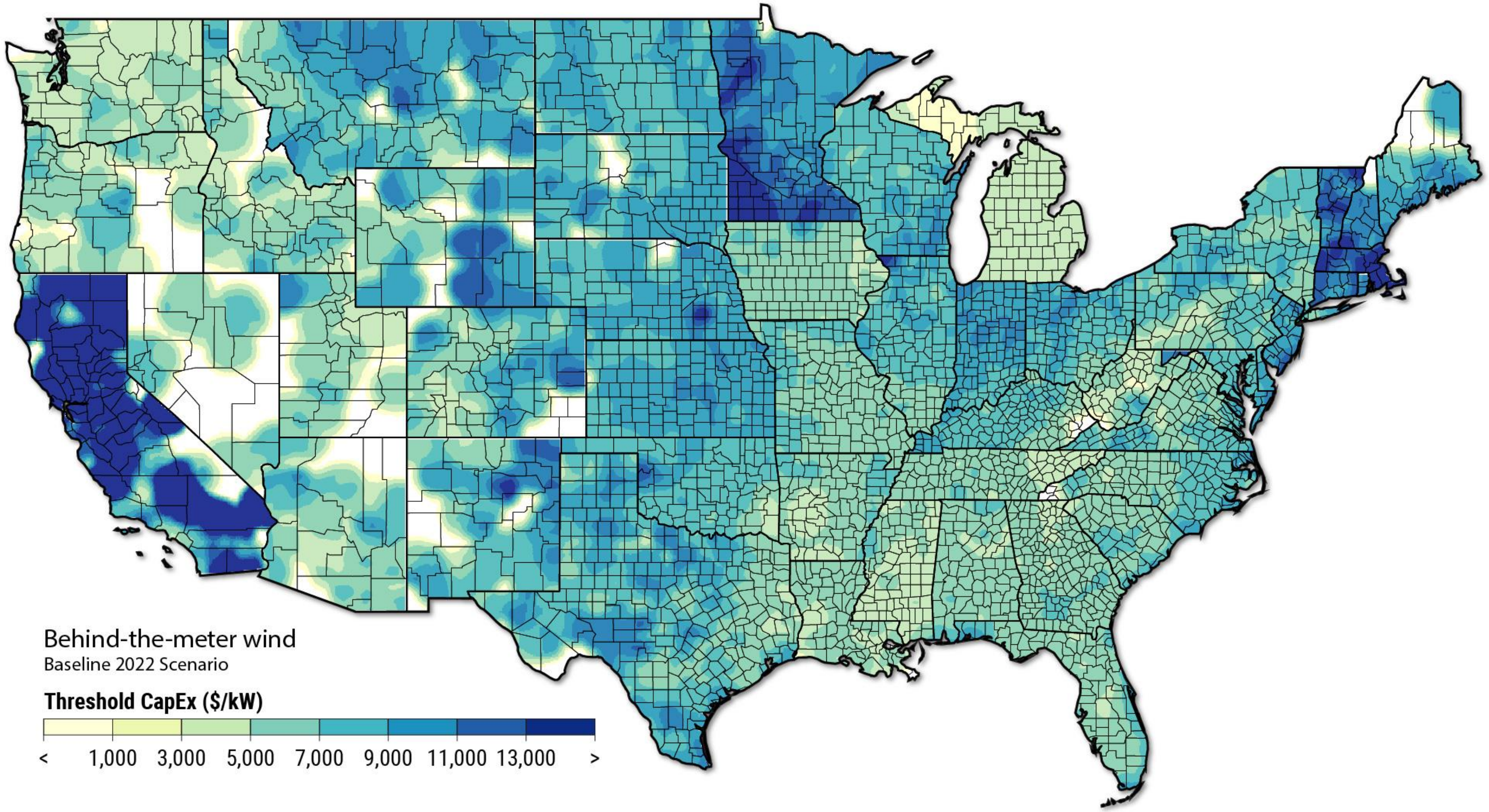


- Areas of interest: **Great Plains**, **Midwest**, and **South Central**.
- **Higher-quality wind resource** is the primary driver of economically viable front-of-the-meter applications.
- Regions with **high-cost wholesale electricity** can also return high-threshold CapEx values.

McCabe, Kevin, et al. Distributed wind energy futures study. No. NREL/TP-7A40-82519. National Renewable Energy Lab.(NREL), Golden, CO (United States), 2022.

Baseline 2022 Scenario Results by Region

Behind-the-meter opportunities for wind



- Areas of interest: **California**, **Minnesota**, and **Northeast** region.
- A combination of **good resource, high retail electricity prices, and favorable policies contribute to profitable behind-the-meter applications**.

McCabe, Kevin, et al. Distributed wind energy futures study. No. NREL/TP-7A40-82519. National Renewable Energy Lab.(NREL), Golden, CO (United States), 2022.

FY23 Current Development

- Leverage NREL high-performance computing environment to run DWEFS model at much **larger scale**
- Implement latest **cost, performance, and financing** inputs from NREL Annual Technology Baseline (ATB) effort
- Integrate provisions from **IIJA and IRA** – include investment tax credits and adders, energy justice metrics, etc.
- **Disseminate results** to broader DW community at granular resolution (census tract or finer)

Homeland Infrastructure Foundation-Level Data (HIFLD) (2020). Parcel Data - Lightbox. https://gii.dhs.gov/hifld/content/hifld-data-catalog

Thank you!

www.nrel.gov

Kevin McCabe

For future questions, contact **Eric Lantz at Eric.Lantz@nrel.gov** .

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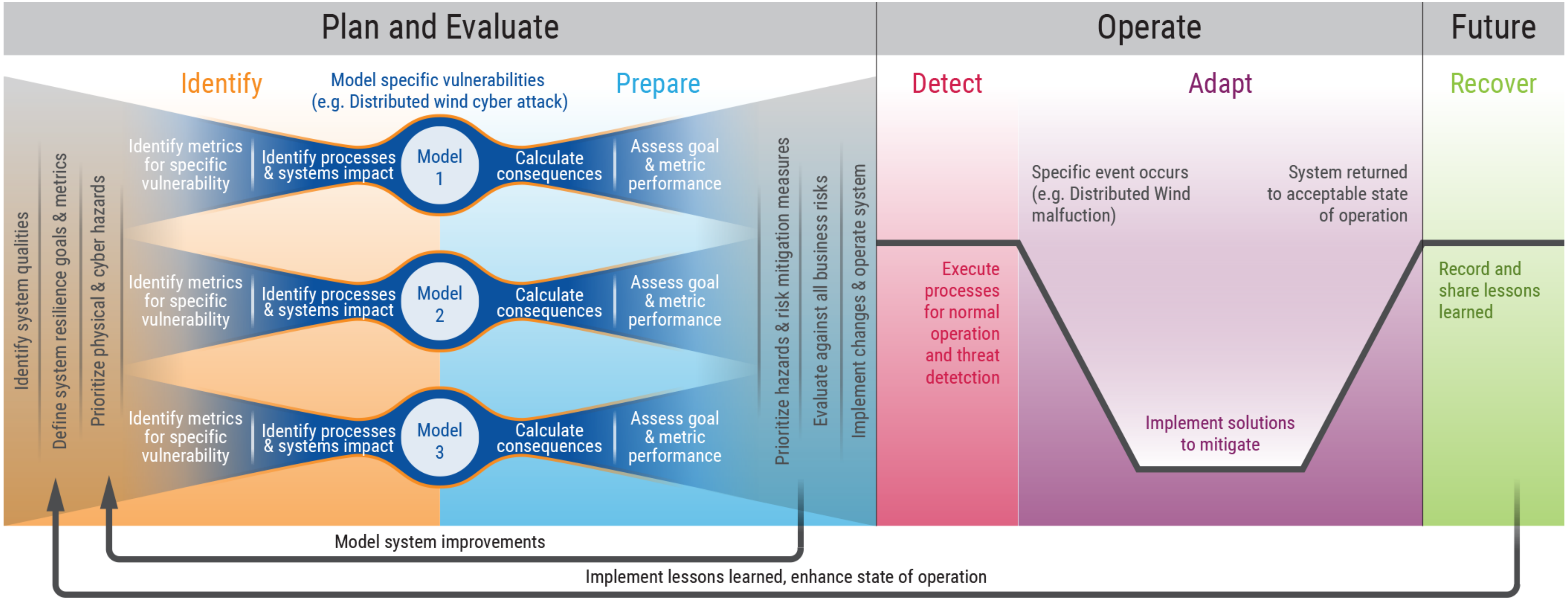
Photo from iStock-627281636

NREL Transforming ENERGY

Resilience Calculator

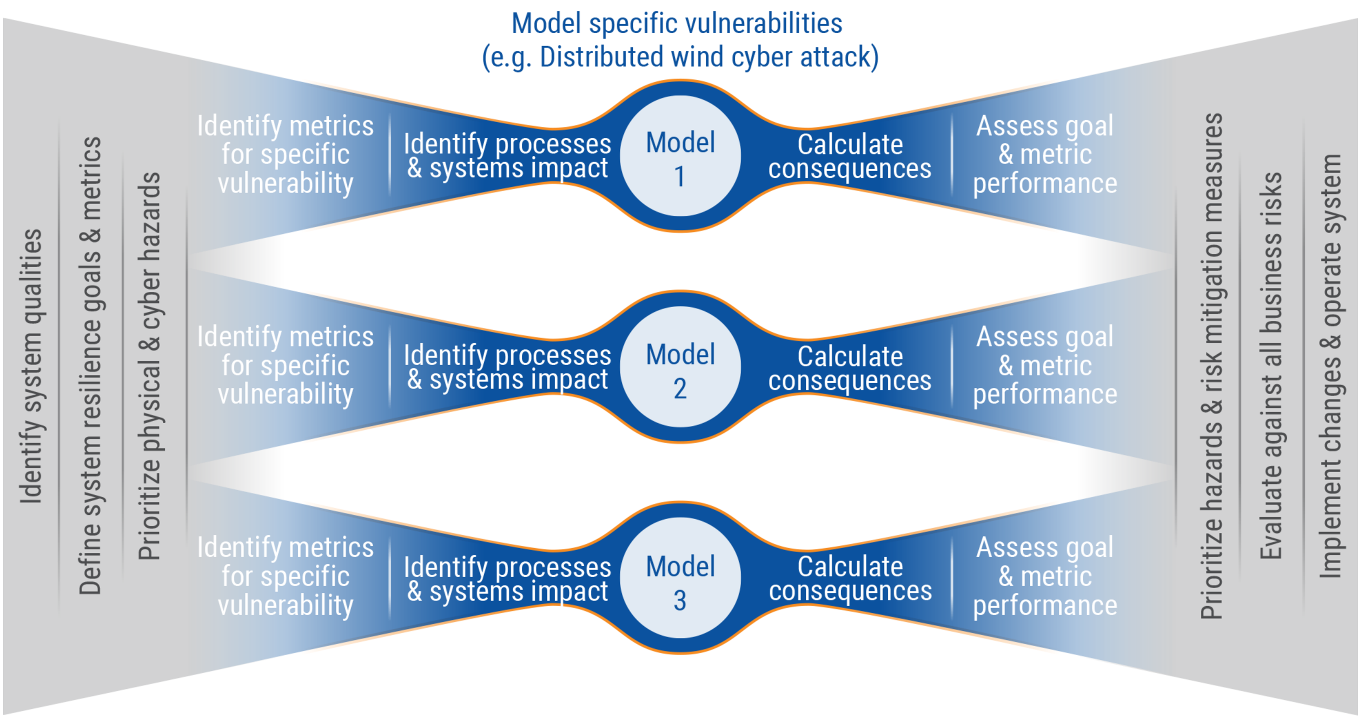
Megan Culler - INL

Resilience Framework for Electric Energy Delivery Systems



Resilience Planning Tool: Motivation

- Make the resilience framework more accessible
- Allow users to customize analysis to their system
- Hazards are difficult to model – tool can help motivate

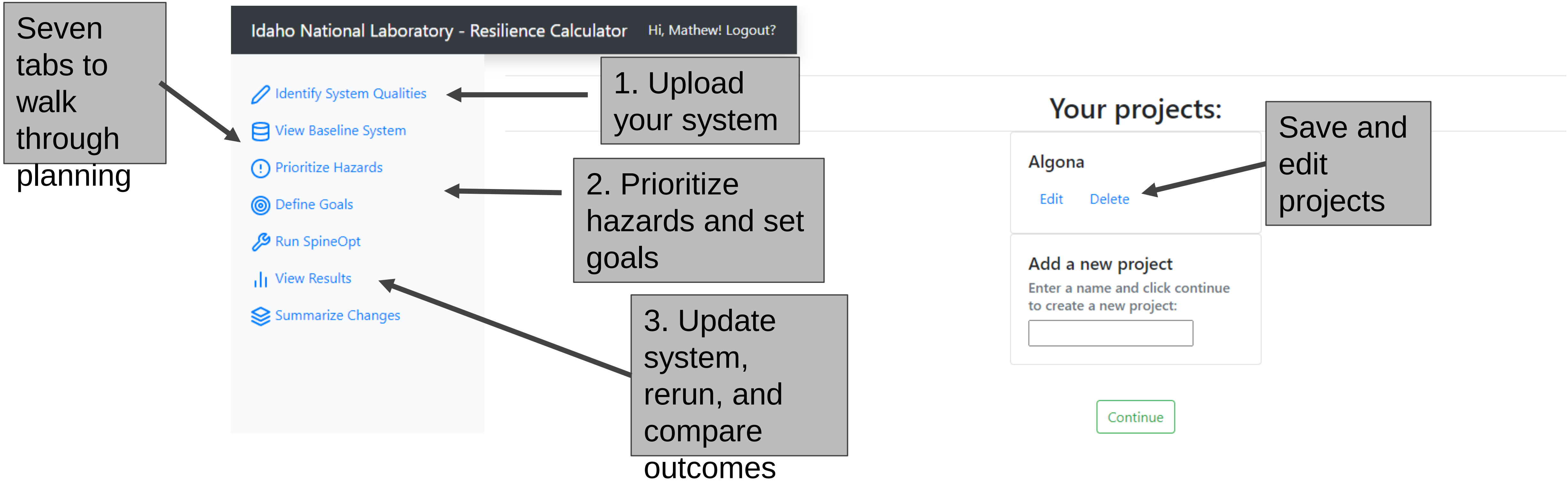


Partners

IOWA STATE UNIVERSITY

ENERGY REFORM CONSULTING SERVICES

Resilience Planning Tool:
Web Application



Resilience Planning Tool:
Workflow

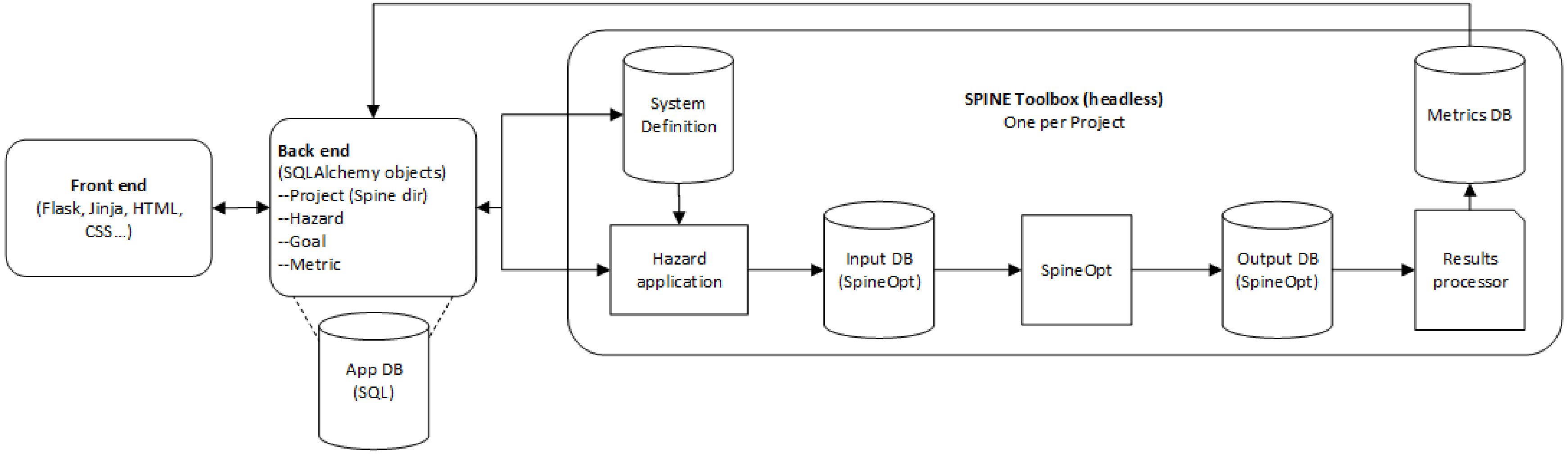
- Automate the resilience framework planning process
- Modeling and simulation performed using Spine

Web Framework — Flask

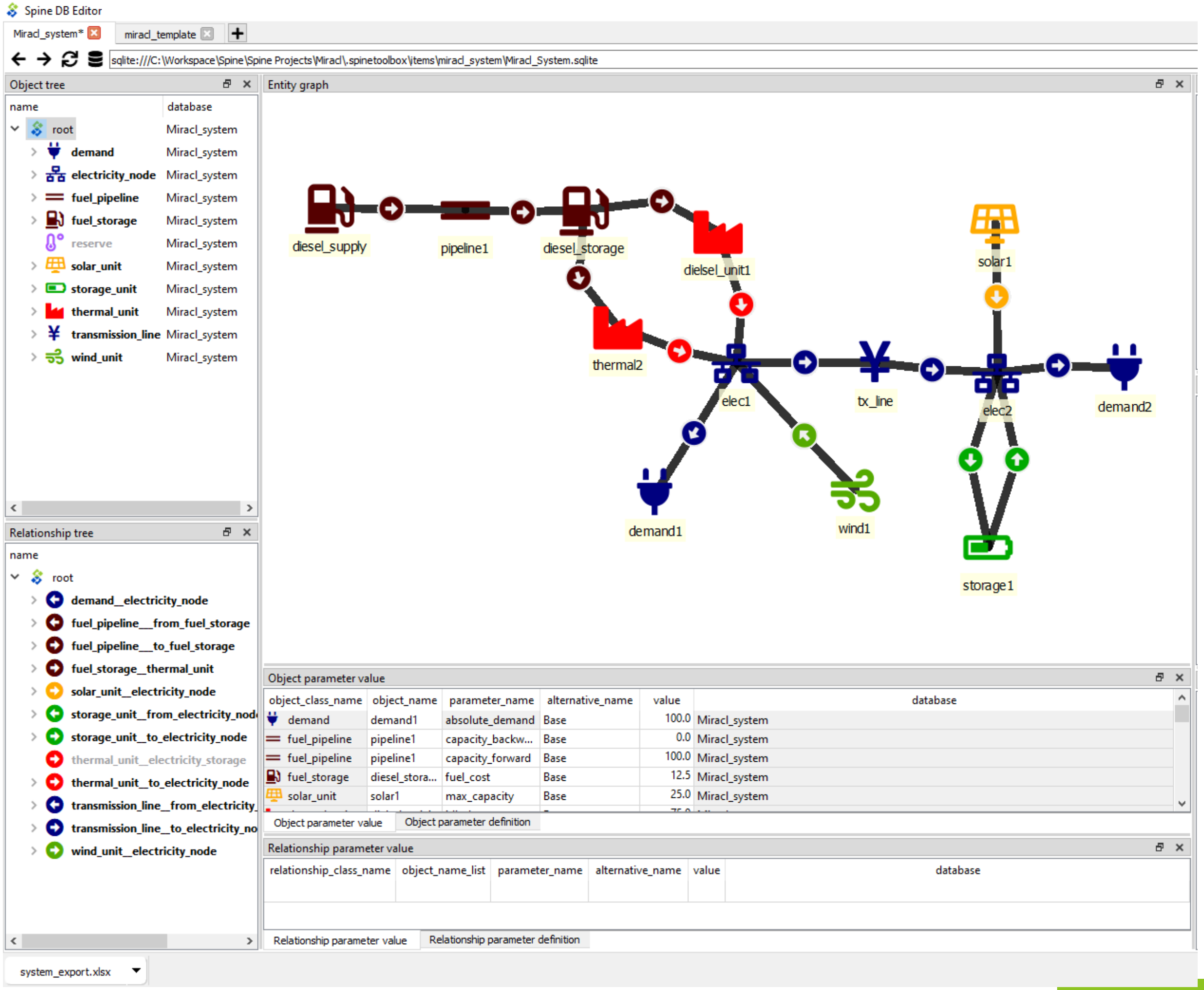
Authentication — okta

Database Toolkit — SQLAlchemy

Database — MariaDB

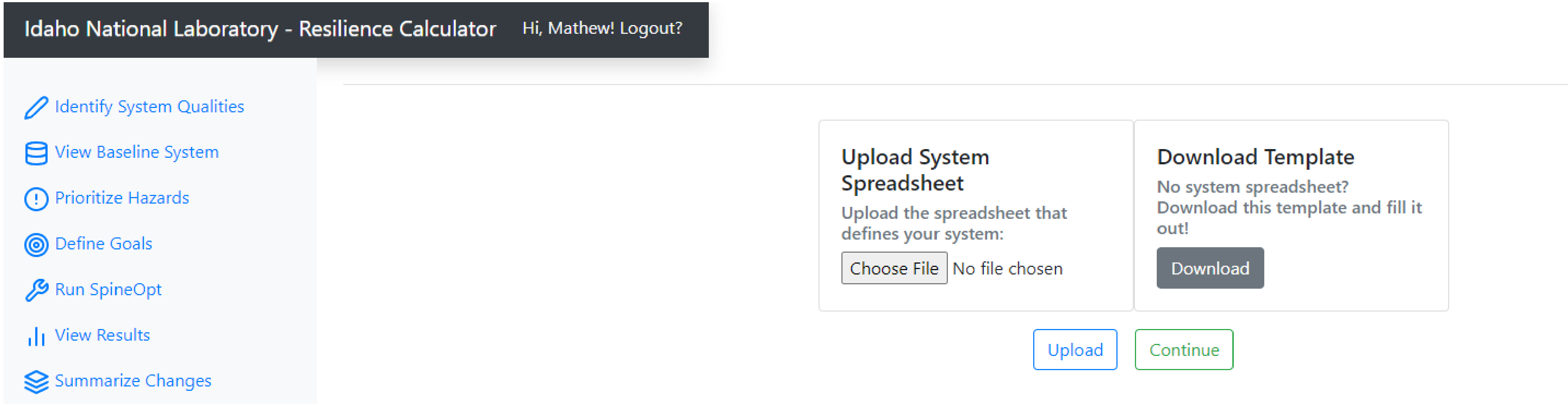


Resilience Planning Tool:
Defining a system in Spine



Spine DB editor, part of Spine Toolbox

Resilience Planning Tool:
Uploading Spine System as a Spreadsheet



Resilience Planning Tool:
Viewing Spine System in Web Application

Idaho National Laboratory - Resilience Calculator   Hi, Mathew! Logout?

- Identify System Qualities
- View Baseline System
- Prioritize Hazards
- Define Goals
- Run SpineOpt
- View Results
- Summarize Changes

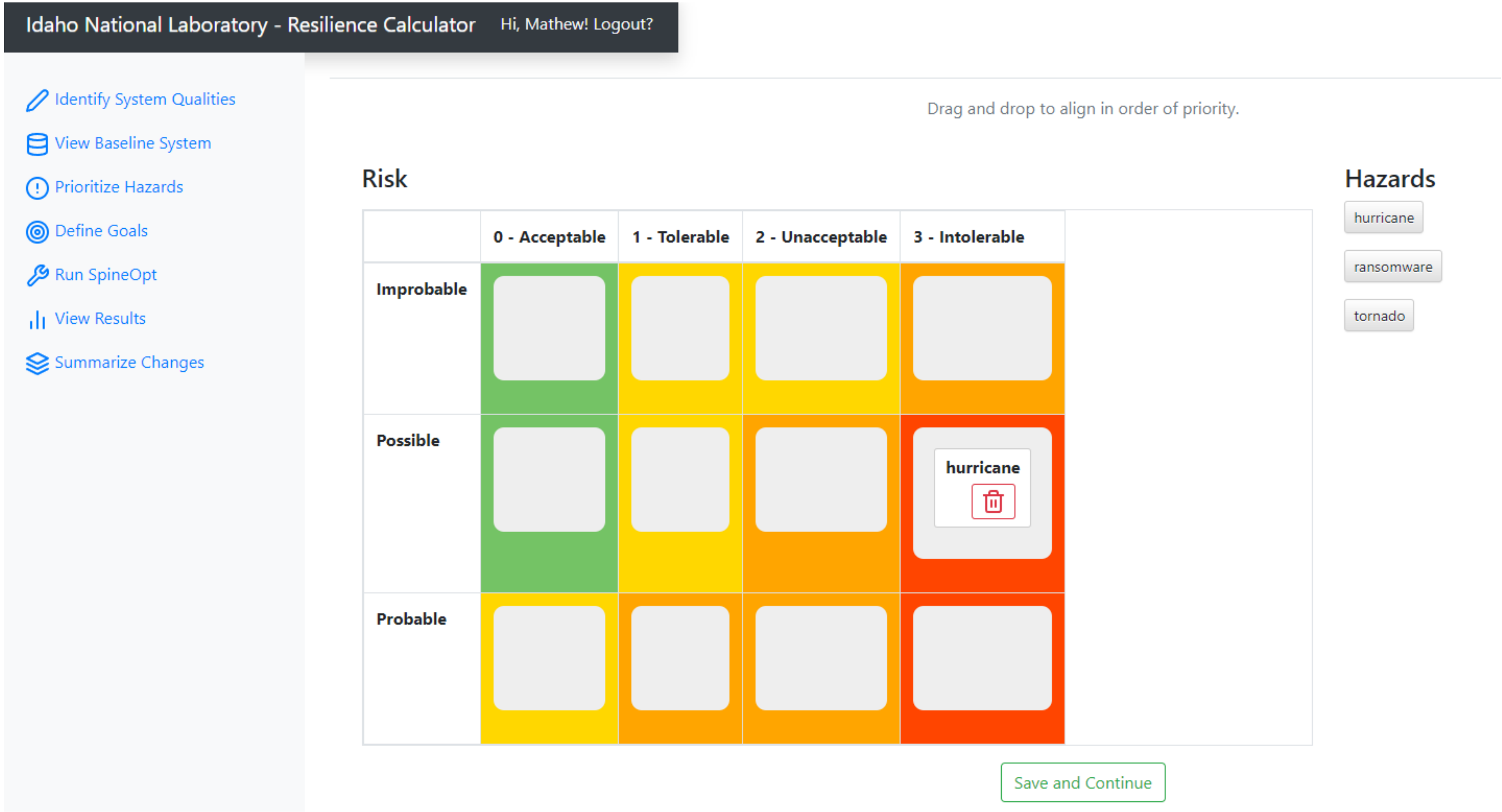
The baseline system loaded from the spreadsheet is shown below.

Click Next to continue, or Back to upload a different spreadsheet.

Back   Next

Object Name	Object Class	Parameters
diesel_unit1	thermal_unit	*forced_outage_rate* *idle_heat_rate* 0.075 *incremental_heat_rate* 0.008 *max_capacity* 3200.0 *min_stable* 25.0 *minimum_down_time* 3.0 *minimum_up_time* 3.0 *ramp_down_rate* *ramp_up_rate* *shutdown_cost* *start_up_cost* 100.0 *start_up_fuel_use* 45.0
diesel_unit3	thermal_unit	*forced_outage_rate* *idle_heat_rate* *incremental_heat_rate* *max_capacity* 4400.0 *min_stable* *minimum_down_time* *minimum_up_time* *ramp_down_rate* *ramp_up_rate* *shutdown_cost* *start_up_cost* *start_up_fuel_use*

Resilience Planning Tool:
Prioritizing Hazards

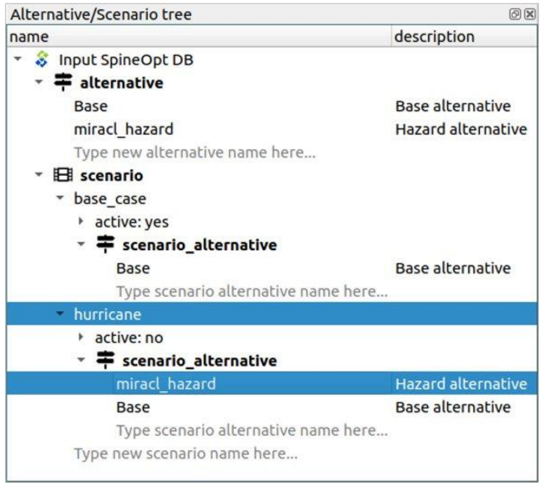


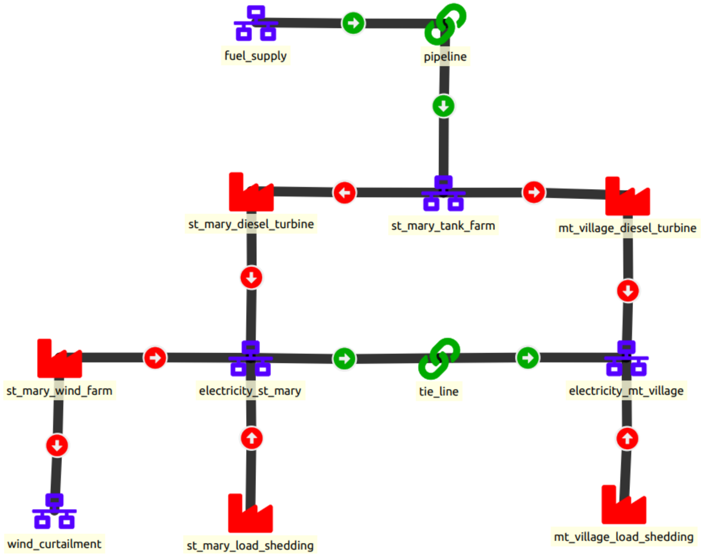
Resilience Planning Tool:
Hazard Modeling

- Alternatives represent different states of components
- Scenarios are collections of alternatives

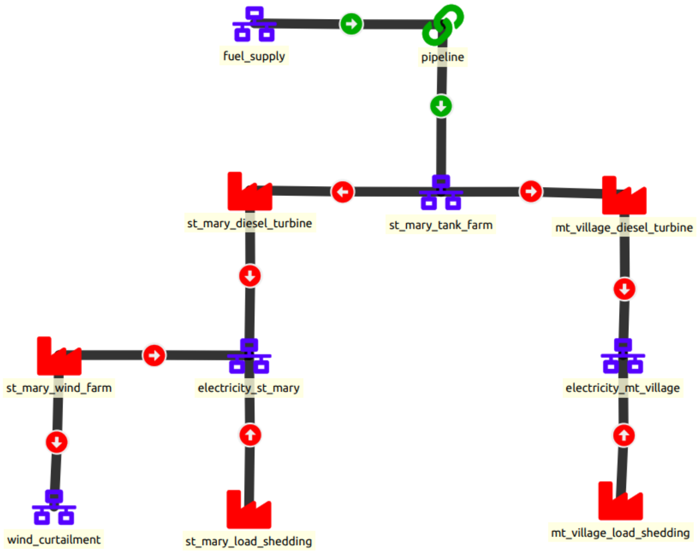
Object parameter value

object_class_name	object_name	*parameter_name*	alternative_name	value	database
connection	tie_line	is_active	miracl_hazard	False	Input SpineOpt DB
connection	tie_line	is_active	Base	True	Input SpineOpt DB



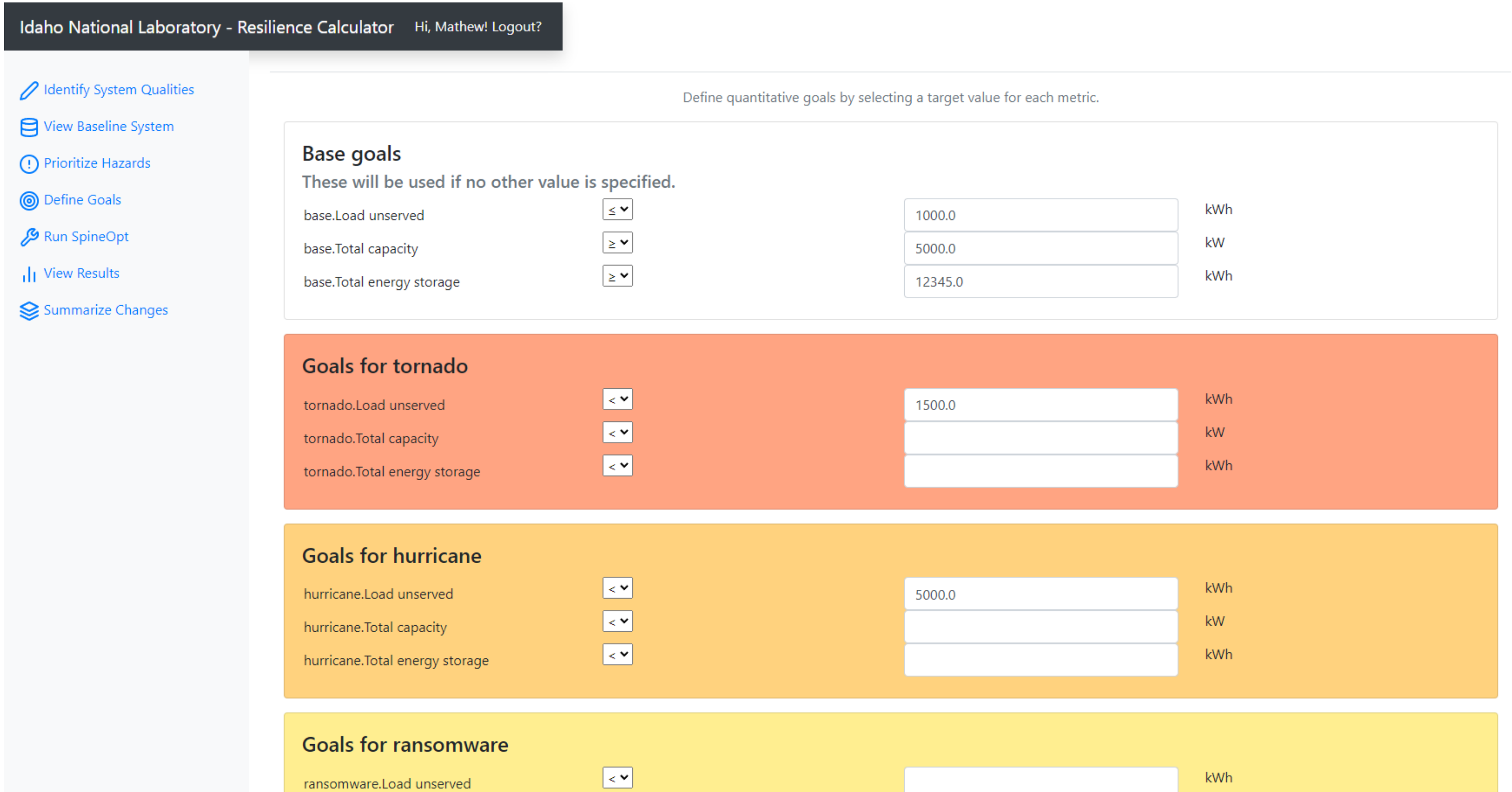


Base case system

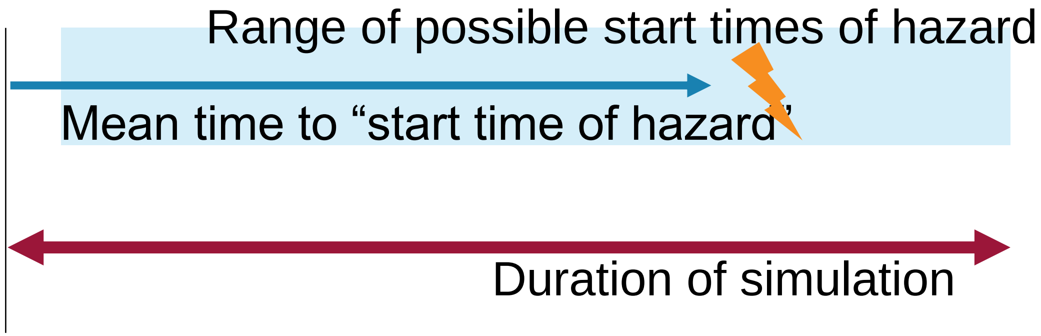


System with hazard applied

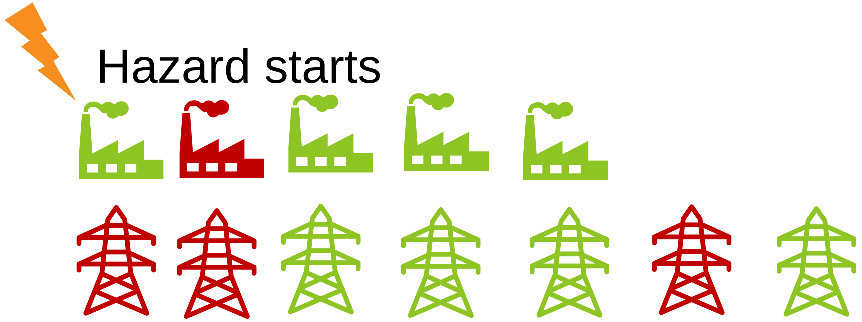
Resilience Planning Tool:
Setting Resilience Metric Goals for each Hazard



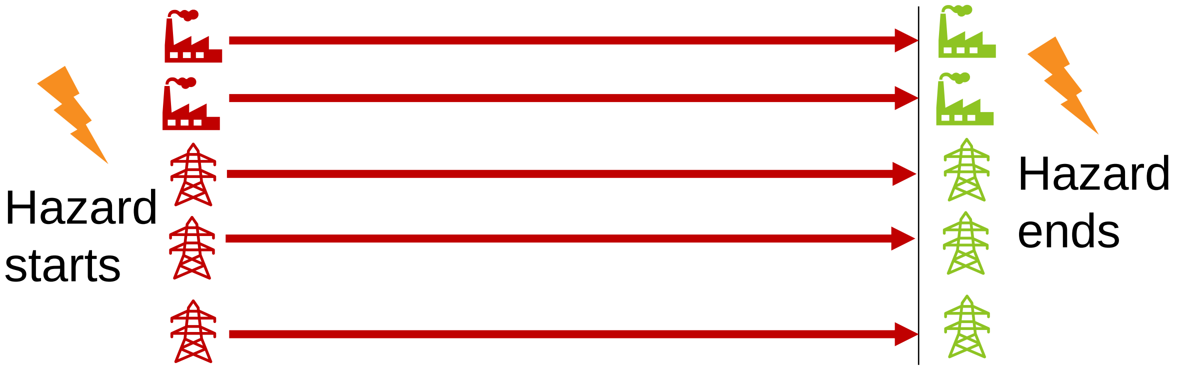
Resilience Planning Tool:
Automated Hazard Analysis



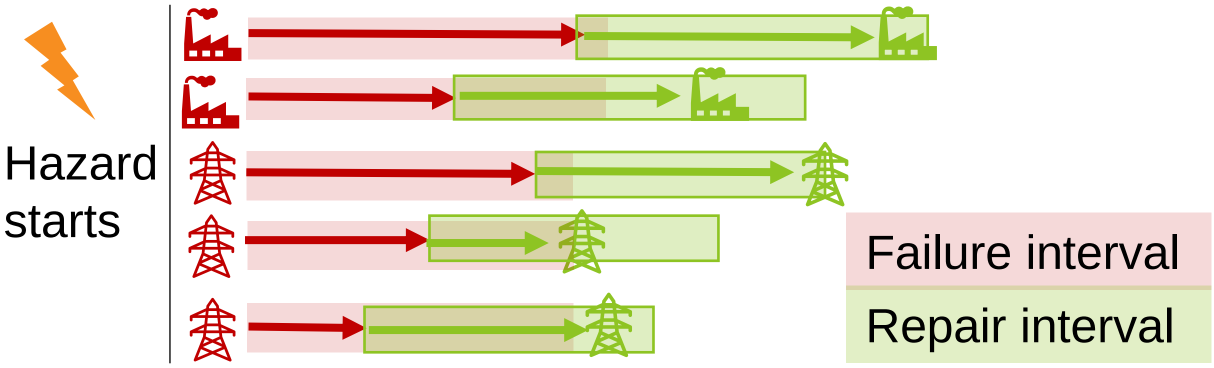
Randomizing start time of hazard



Define components that could be

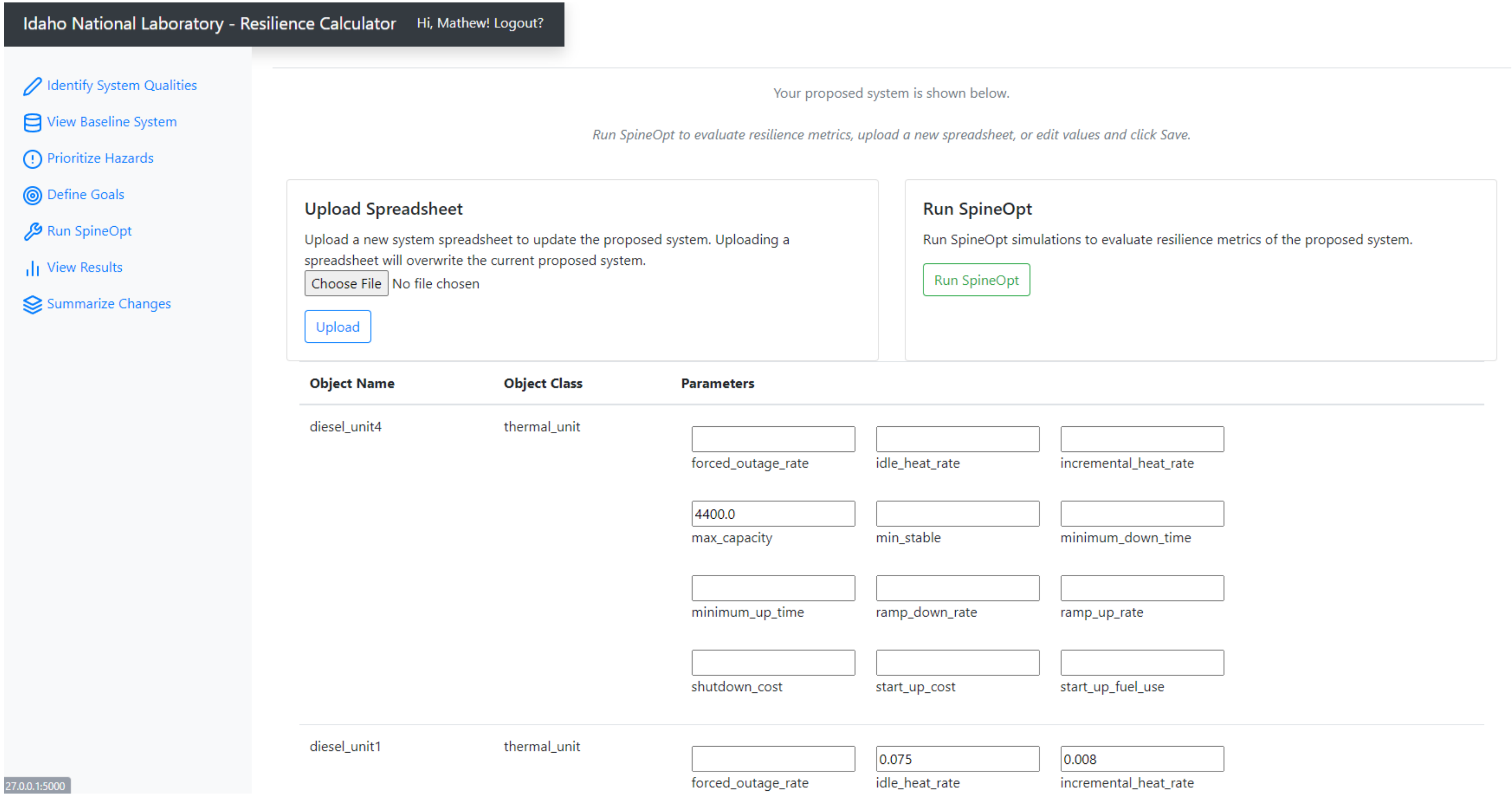


a) Apply hazard for duration of failure

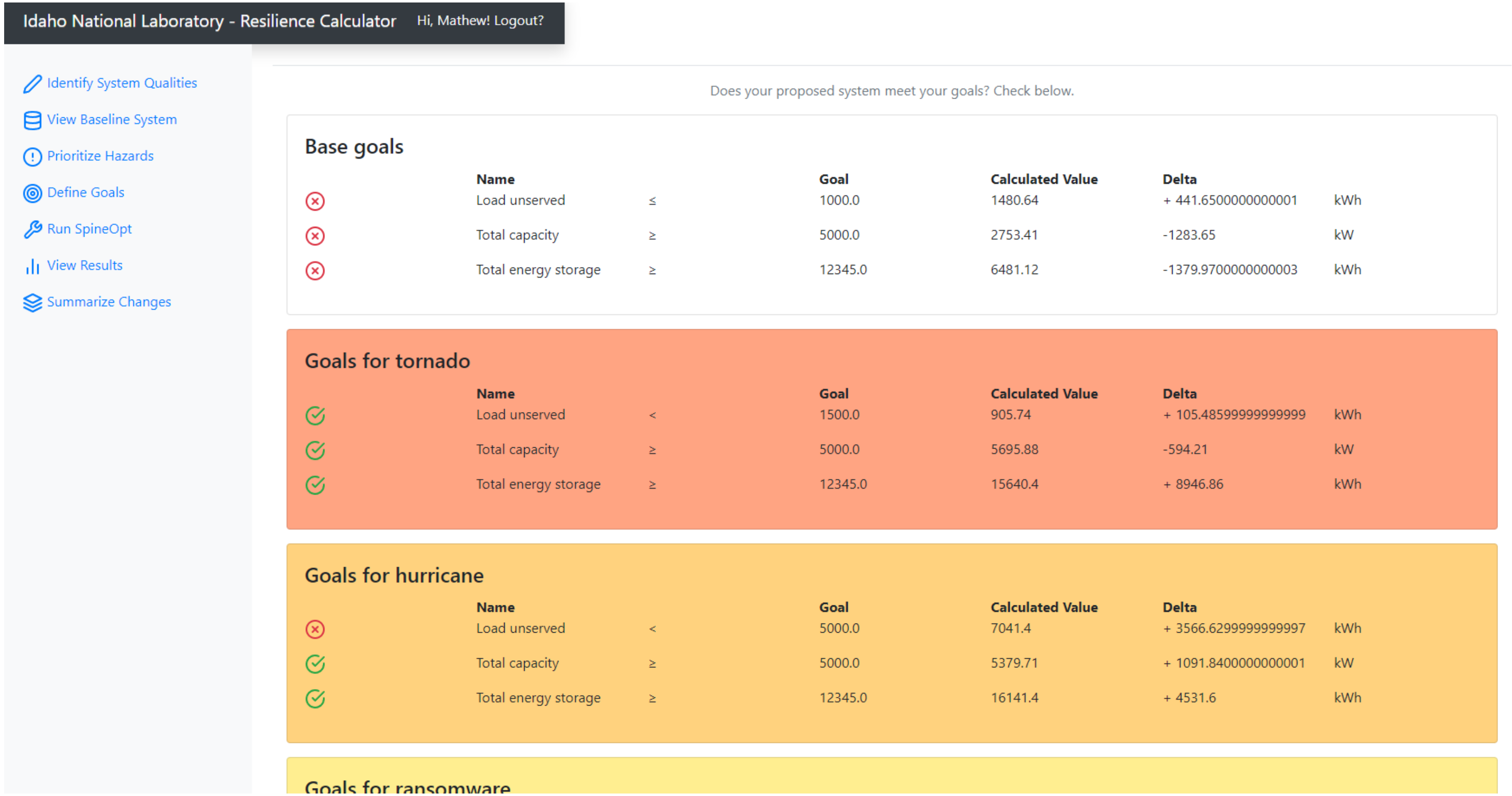


b) Apply mean time to failure/repair

Resilience Planning Tool:
Automated Hazard Analysis from Web Application



Resilience Planning Tool:
Web Application Results



Idaho National Laboratory - Resilience Calculator   Hi, Mathew! Logout?

- Identify System Qualities
- View Baseline System
- Prioritize Hazards
- Define Goals
- Run SpineOpt
- View Results
- Summarize Changes

Does your proposed system meet your goals? Check below.

Base goals

	Name		Goal	Calculated Value	Delta	
✗	Load unserved	≤	1000.0	1480.64	+ 441.6500000000001	kWh
✗	Total capacity	≥	5000.0	2753.41	-1283.65	kW
✗	Total energy storage	≥	12345.0	6481.12	-1379.9700000000003	kWh

Goals for tornado

	Name		Goal	Calculated Value	Delta	
✓	Load unserved	<	1500.0	905.74	+ 105.48599999999999	kWh
✓	Total capacity	≥	5000.0	5695.88	-594.21	kW
✓	Total energy storage	≥	12345.0	15640.4	+ 8946.86	kWh

Goals for hurricane

	Name		Goal	Calculated Value	Delta	
✗	Load unserved	<	5000.0	7041.4	+ 3566.6299999999997	kWh
✓	Total capacity	≥	5000.0	5379.71	+ 1091.8400000000001	kW
✓	Total energy storage	≥	12345.0	16141.4	+ 4531.6	kWh

Goals for ransomware

Release

- Going through final DOE approvals now
- Will be released on INL Github with supporting documentation and examples

HOPP

Caitlyn Clark – NREL

NREL Transforming ENERGY

Hybrid Operation and Performance Platform

Caitlyn (Caity) Clark
National Renewable Energy Laboratory (NREL)

Building the Case for Hybrid Distributed Energy Developments Workshop – Day 2

April 5, 2023

Photo by Dennis Schroeder, NREL 55200

Fully Coupled Hybrid System Design

- **Objective:** Accelerate the nationwide understanding, development, and deployment of wind-based hybrids
- Developing a nationwide, end-to-end approach—from design to demonstration—of **fully coupled** wind-based hybrid plants
- **Utility to community scales**
- **Firm power** to minimize uncertainty in renewable energy through combination of storage, forecasting, and controls

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Can the Power Grid Handle a Wave of New Electric Vehicles?

The consensus is that utilities can generate enough electricity. The problem is going to be getting it to people's homes and businesses.

By *Bart Ziegler* Follow

Feb. 5, 2023 11:00 am ET

2/23/23, 2:47 PM Wind and Solar Energy Projects Risk Overwhelming America's Antiquated Electrical Grids - The New York Times

The New York Times https://www.nytimes.com/2023/02/23/climate/renewable-energy-us-electrical-grid.html

The U.S. Has Billions for Wind and Solar Projects. Good Luck Plugging Them In.

An explosion in proposed clean energy ventures has overwhelmed the system for connecting new power sources to homes and businesses.

By Brad Plumer

Feb. 23, 2023 Updated 12:37 p.m. ET

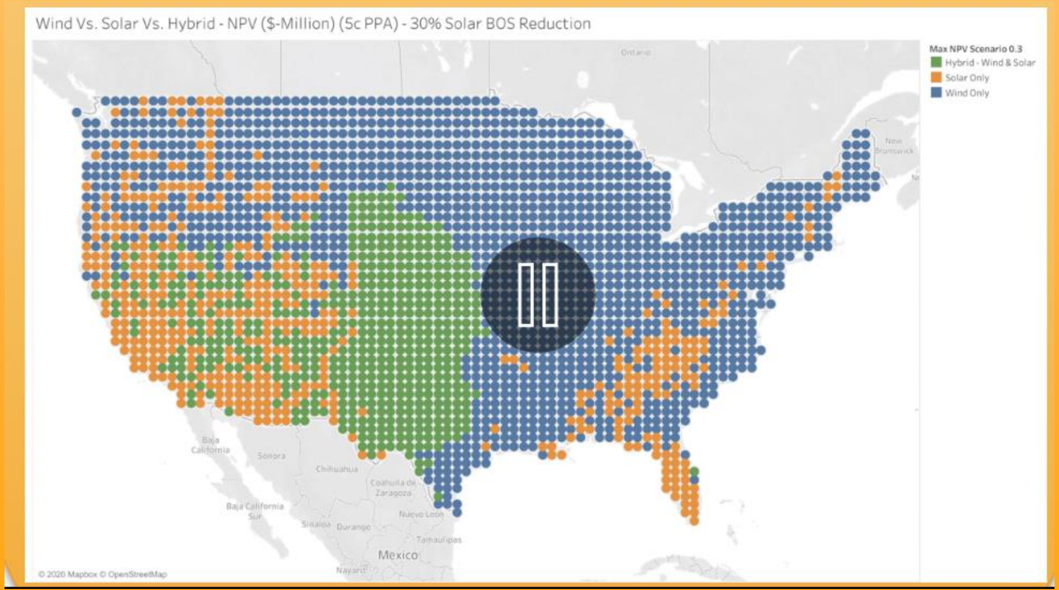
7 MIN READ

Hybrid Optimization and Performance Platform Capabilities

Analysis

Where to build co-located hybrid plants?

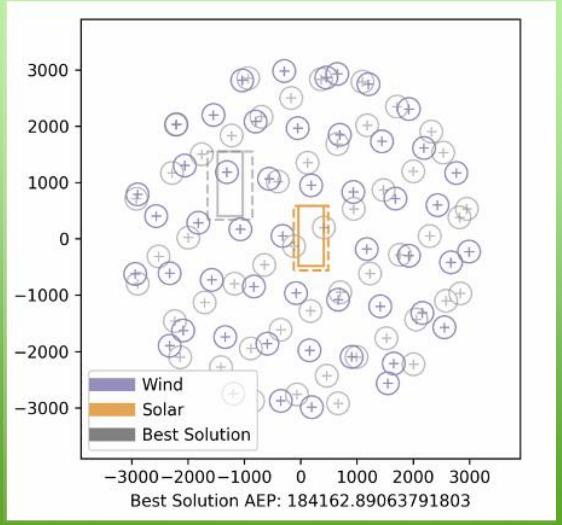
- Resources are complementary
- Overbuild (E.g., 200-megawatt [MW] plant at 100-MW interconnect)
- Include storage



Strong solar during day and strong wind at night

Design

Optimize hybrid plants down to the *component* levels



Control/Dispatch Algorithms

- **Wind-solar-storage** dispatch algorithms developed in Hybrid Optimization and Performance Platform (HOPP)
- Operation of plants down to the **1-minute timescale**
- Improve performance of hybrid power plants by > 5%

Hybrid Optimization and Performance Platform

Optimize co-located, utility-scale hybrid plants down to the component level for different markets

Generation
- Wind
- Solar - PV
- Solar - CSP
- Geothermal
- Hydro, MHK
- Custom

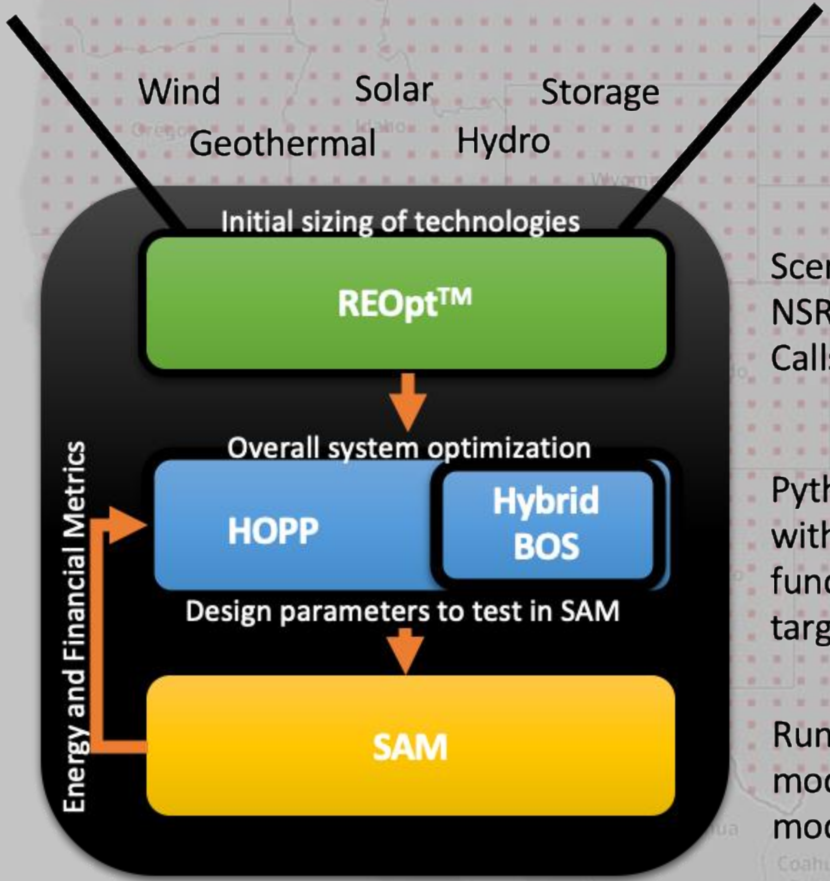
Storage
- Lithium-Ion
- Pumped Hydro
- Pumped Thermal
- EVs
- Custom

Controls
- Smart Dispatch
- Custom

Markets
- Energy
- Capacity
- Custom

End Uses
- Electricity
- H2
- Ammonia
- Steel
- EVs
- Custom

Hybrid Optimization and Performance Platform



Repeat until **convergence** on a feasible and economically viable solution

Scenario setup: interface with NSRDB, WindToolKit, URDB, Calls the REOpt API

Python-based optimization with customize objective function depending on the target markets

Run SAM performance models and financial models

Wind Design Variables

1. Number of turbines
2. (x,y) locations – layout
3. Hub height
4. Rotor diameter

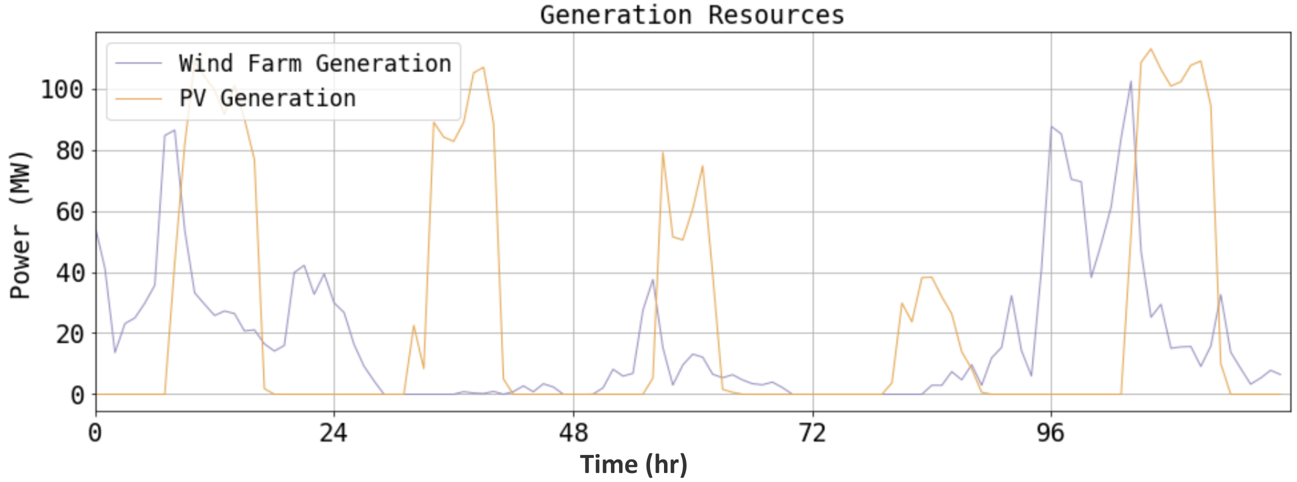
Solar Design Variables

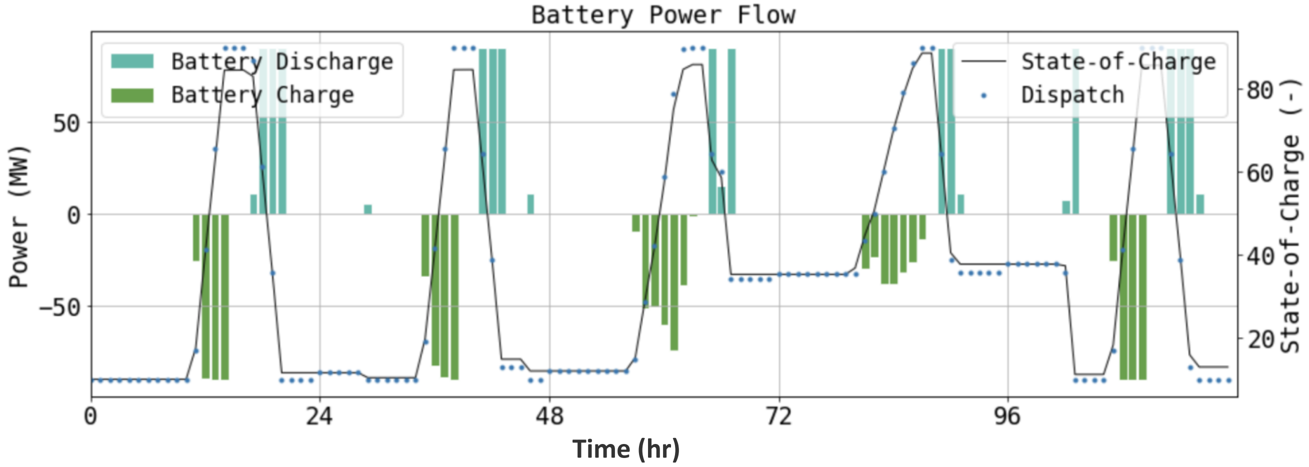
1. Number of panels in a row
2. Number of rows
3. Tilt angle
4. Spacing between rows
5. *Future:* controls

Storage Design Variables

1. Charge/discharge rate
2. Operational timescale

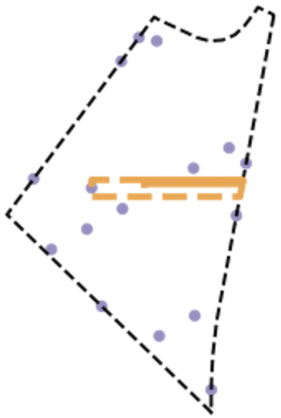
Wind-Solar Hybrid Layout Example





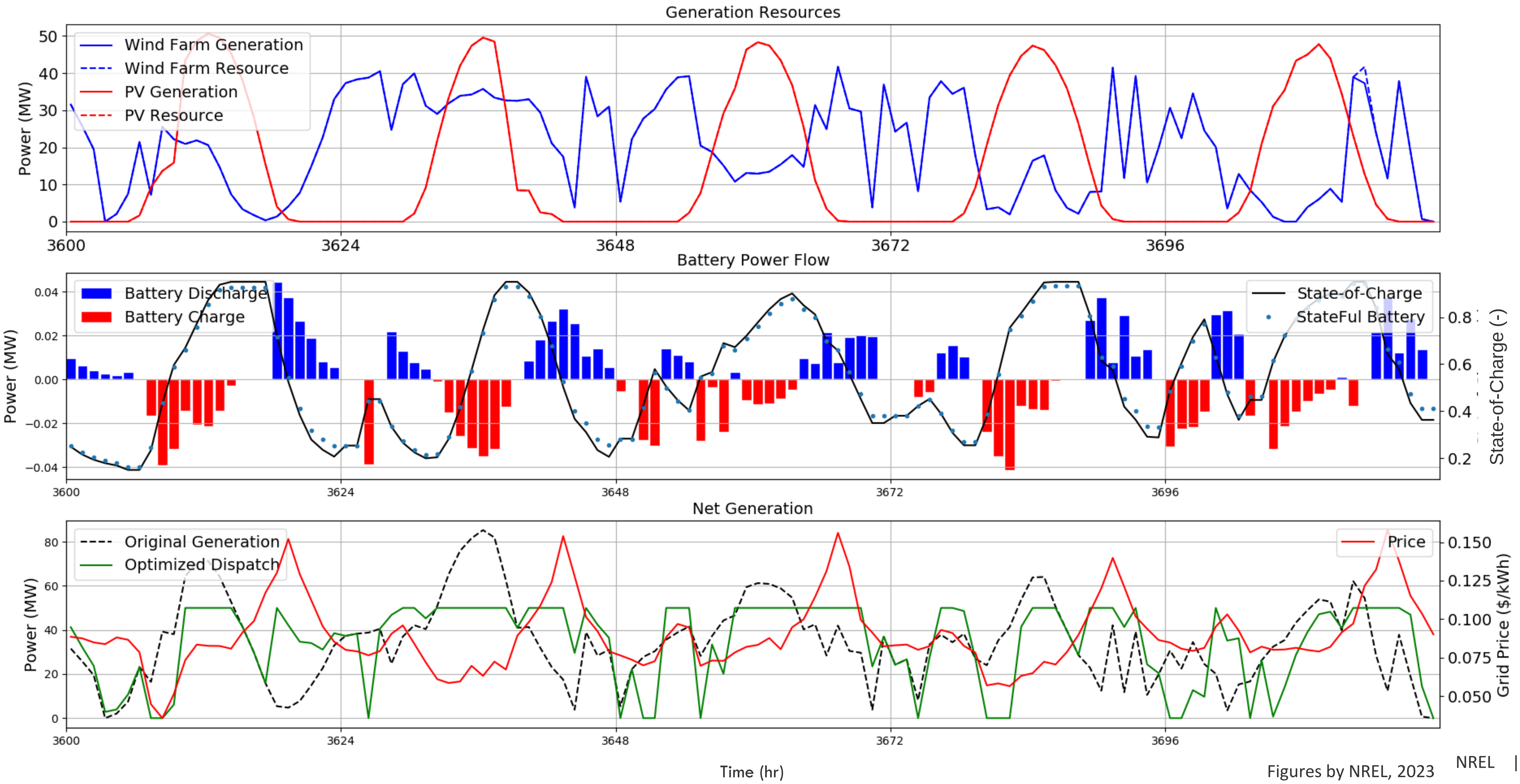
Best NPV $21.64M

96 MW Wind, 6 MW Solar, 0 MW Battery



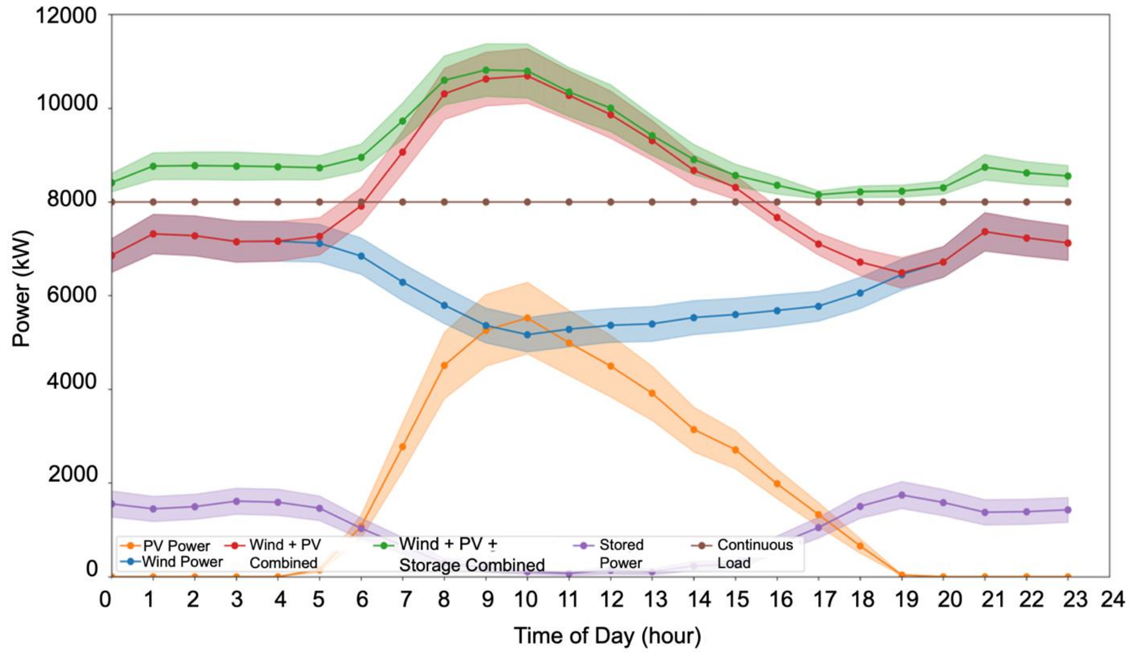
Figures by NREL, 2023

Dispatch Optimization Results – With Forecasting

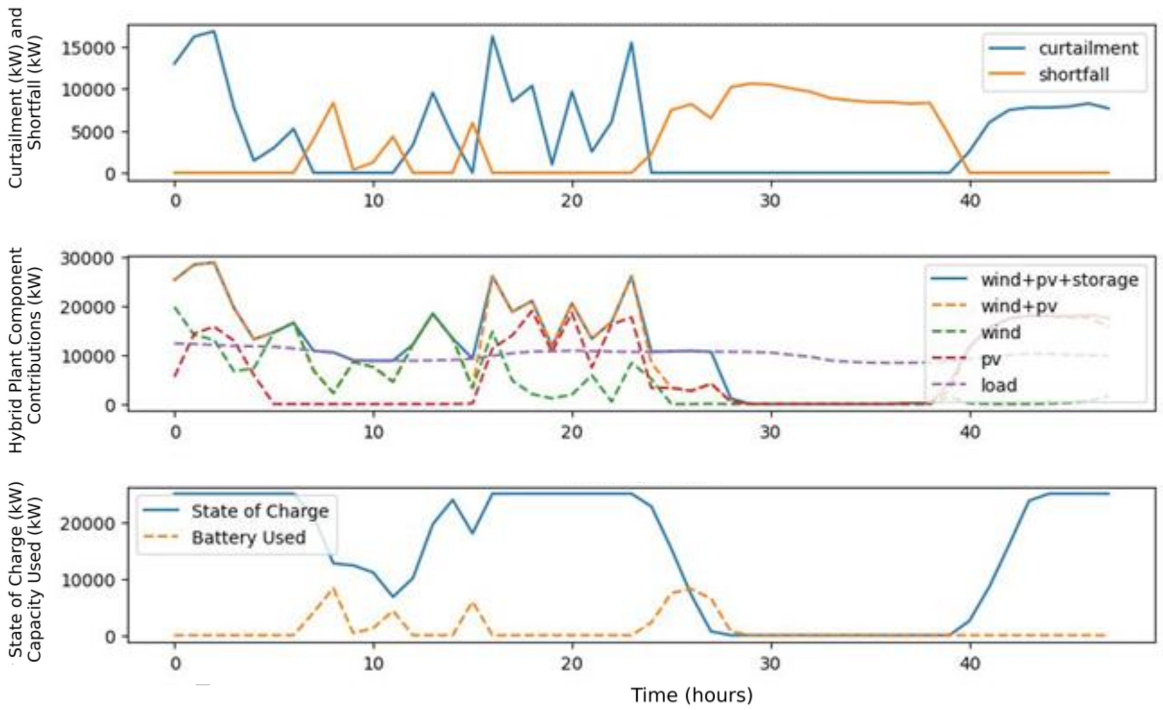


Figures by NREL, 2023

Community Hybrids



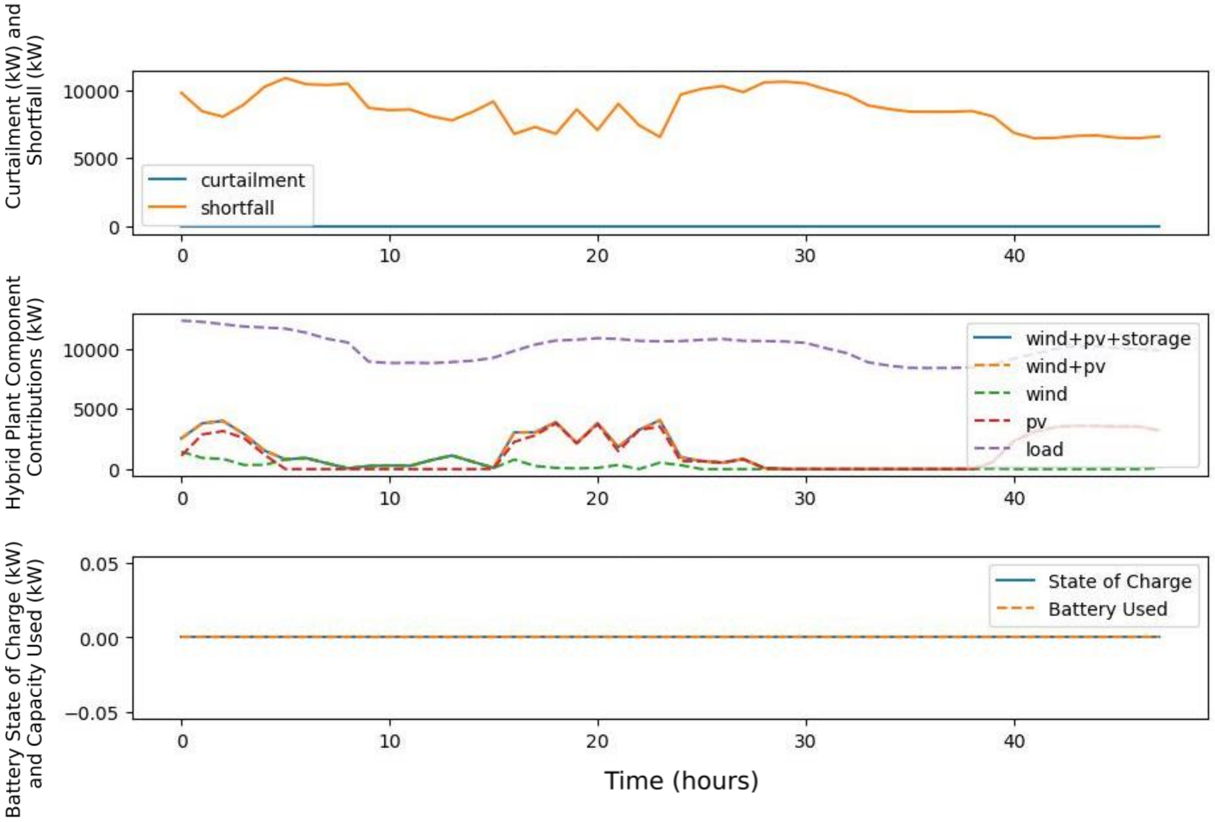
Example of a hybrid plant simulation in Tennessee



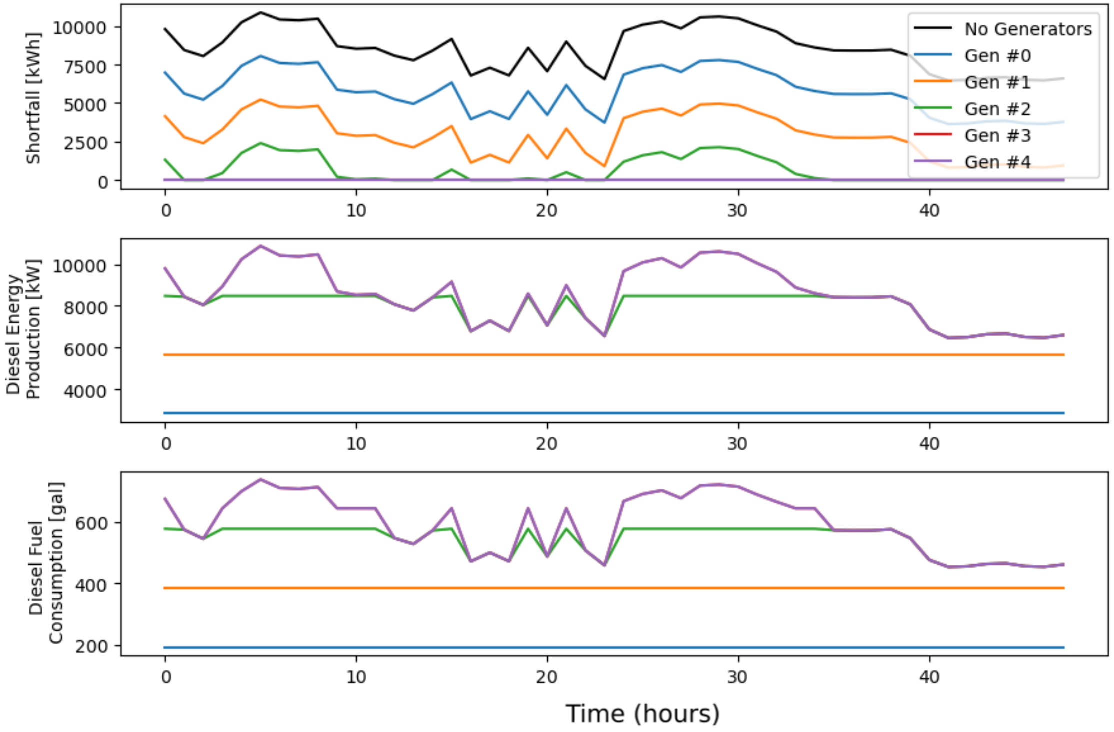
Example of a hybrid plant simulation in Iowa to meet specific load

Figures by Caitlyn Clark, 2023

Community Hybrids



Example of a wind-solar-battery hybrid plant simulation in Iowa



Example of a diesel generator simulation in Iowa as part of a hybrid plant

Figures by Caitlyn Clark, 2023

New Capabilities for Hydrogen

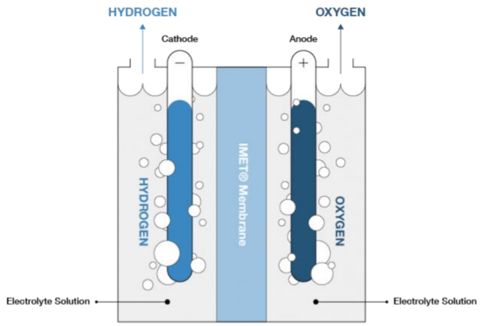
On vs. Off-Grid Systems

Demonstrate the cost trade-offs between on/off-grid with ultra-cheap energy

Impact: Can cost-effectively build in remote locations without transmission

Electrolyzer Simulation

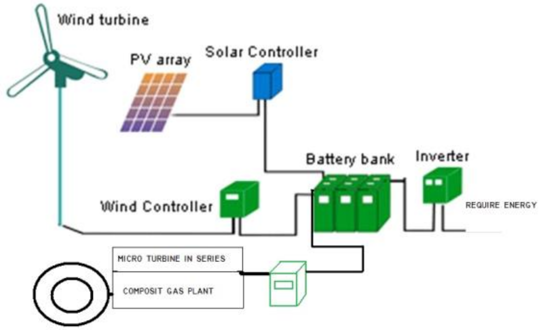
State-of-the-art electrolyzer models that include realistic operation, degradation, and cost modeling that accounts for scale



Impact: Realistically model how to achieve cost-competitive hydrogen (H_2)

Optimal Design for End Uses

Optimal design inform the user how to design their power plant for different objectives and end uses

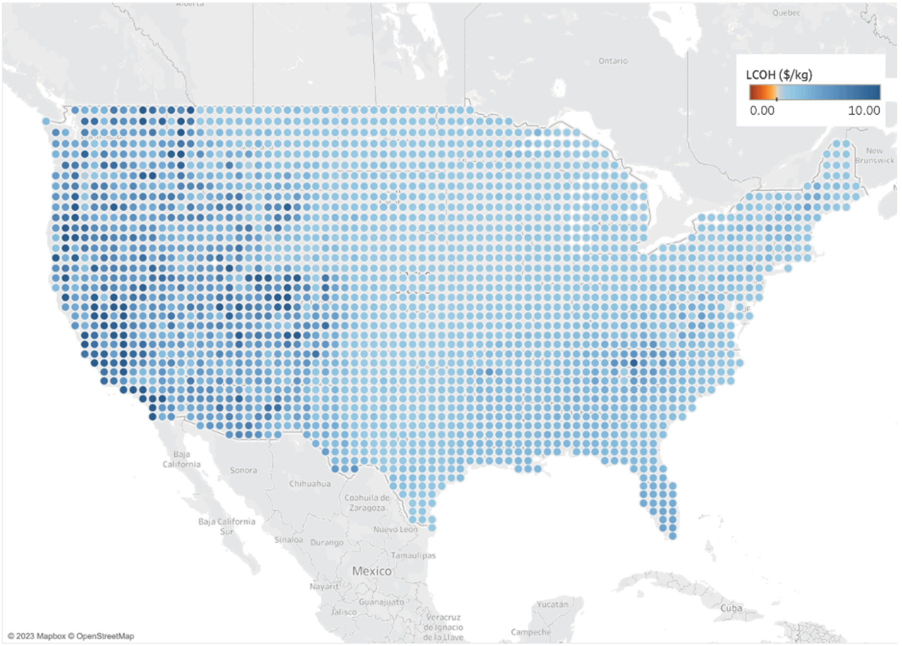


Impact: Different designs required for different objectives/markets/locations

Land-Based Wind to H_2

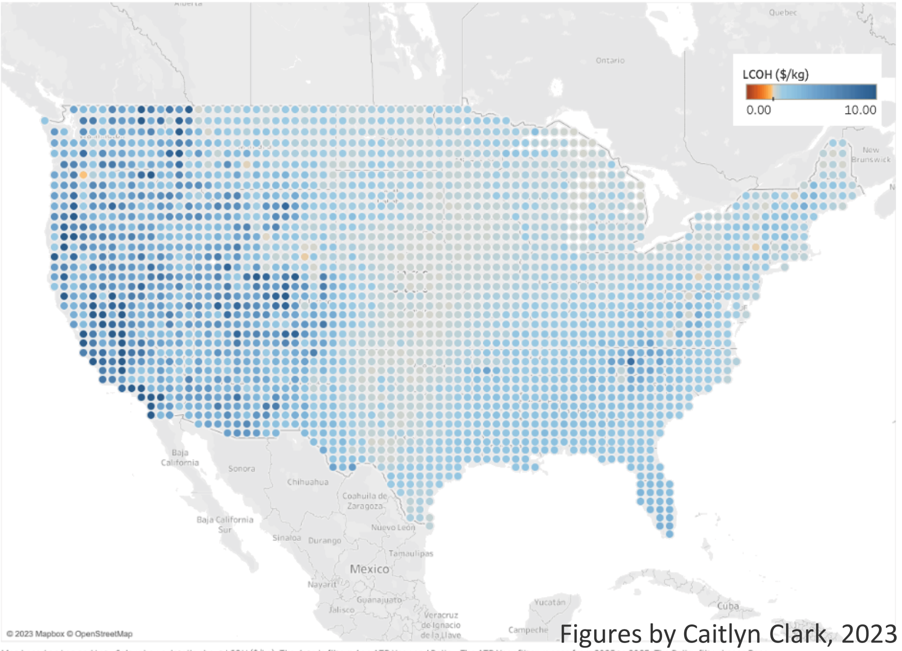
- Off-grid, onshore wind, solar, battery, hydrogen
- Fixed and optimized capacities
- Vary technology costs, financial assumptions, policy support (add a layer of stacking)

2025: No Policy ($2)



Map based on Lon and Lat. Color shows details about LCOH ($/kg). The data is filtered on ATB Year and Policy. The ATB Year filter ranges from 2025 to 2025. The Policy filter keeps No Policy.

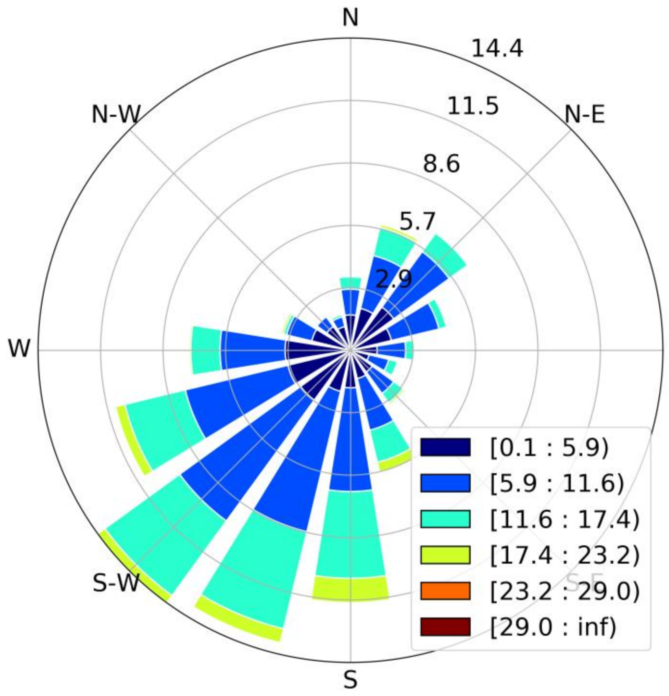
2025: Base Policy ($2)

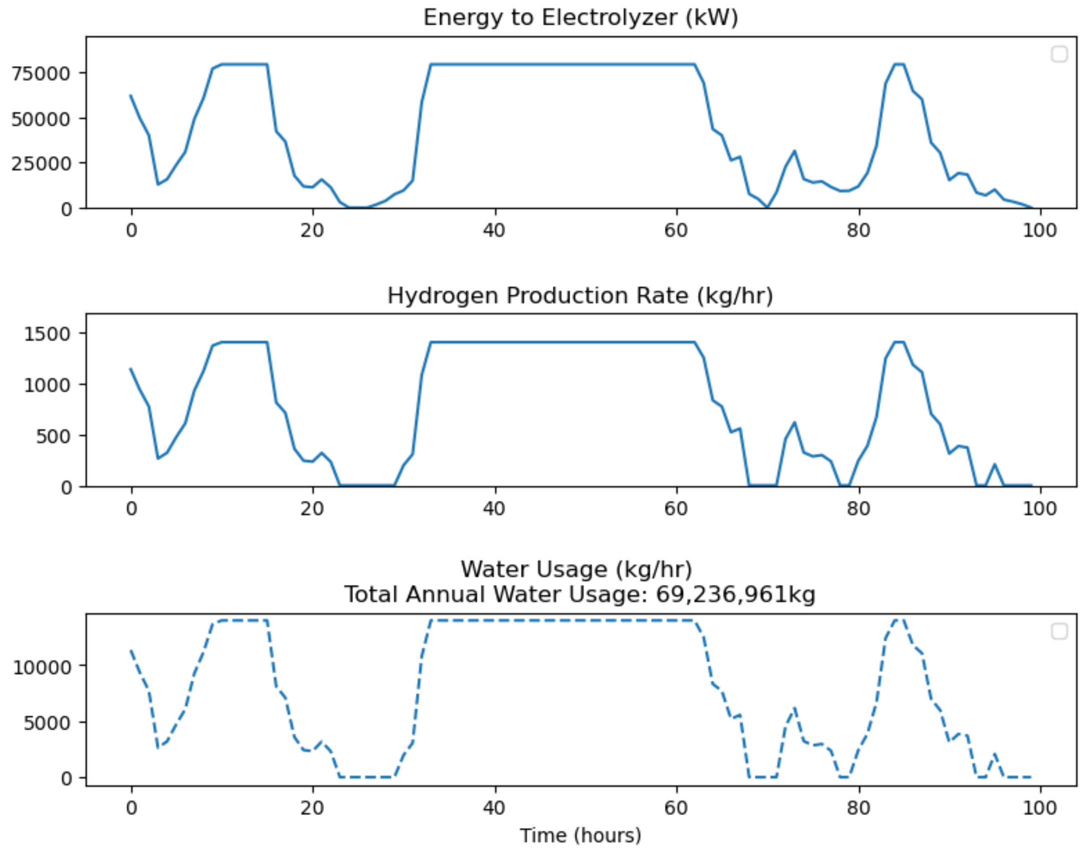


Map based on Lon and Lat. Color shows details about LCOH ($/kg). The data is filtered on ATB Year and Policy. The ATB Year filter ranges from 2025 to 2025. The Policy filter keeps Base.

Figures by Caitlyn Clark, 2023

Land-Based Wind to H_2

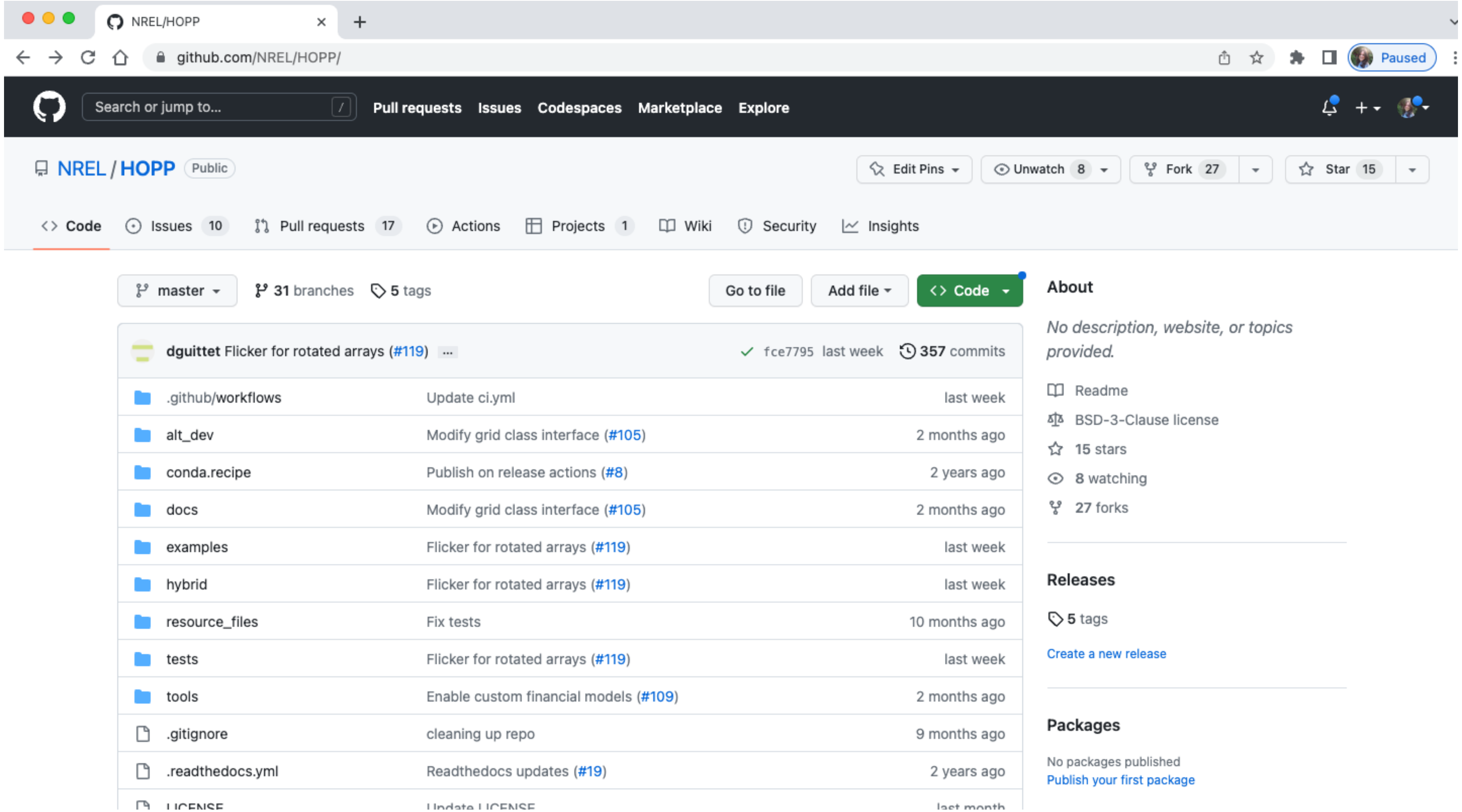




Figures by Caitlyn Clark, 2023

Example of a wind electrolyzer system simulation in Texas

Let's Take a Look…



Where to Next?

Current Work:

- Revenue models
- Community hydrogen
- Resilient-optimal dispatch
- V2G strategies/behaviors
- Design and control for reliability

Resources:

- On-Site for Rural Loads (megan.culler@inl.gov)
- Microgrids, Infrastructure Resilience, and Advanced Control Launchpad: https://www.nrel.gov/wind/miracl-report/
- Hybrid Optimization and Performance Platform: https://github.com/NREL/HOPP
- Turbine Model: https://github.com/NREL/turbine-models/
- Complementary work: https://www.nrel.gov/docs/fy22osti/80415.pdf
- Land-Based Wind to Hydrogen (in prep)
- Hybrid Power Plants for Energy Resilience: A Case Study (in prep)
- Hybrid Power Plants – An effective way for decreasing loss of load expectation (in prep)

Caitlyn.Clark@nrel.gov

Thank you

www.nrel.gov

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Photo from iStock-627281636

NREL

Transforming ENERGY

Valuation Tool

Dan Boff - PNNL

Pacific Northwest
NATIONAL LABORATORY

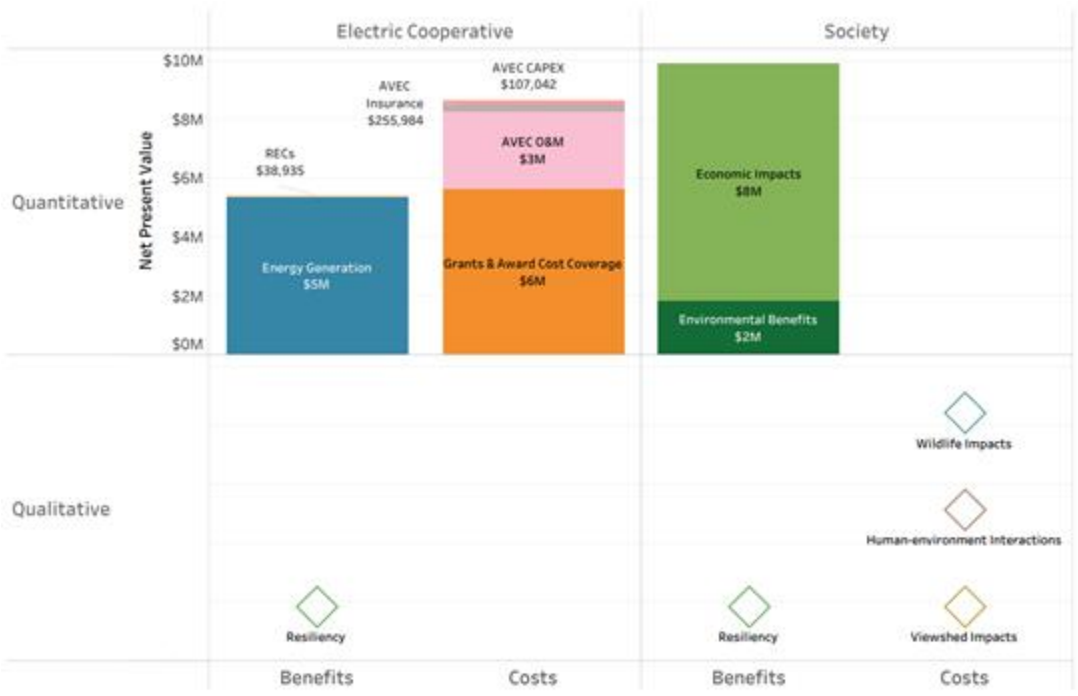
Distributed Wind Valuation Tool

Dan Boff, Sarah Barrows

U.S. DEPARTMENT OF ENERGY BATTELLE

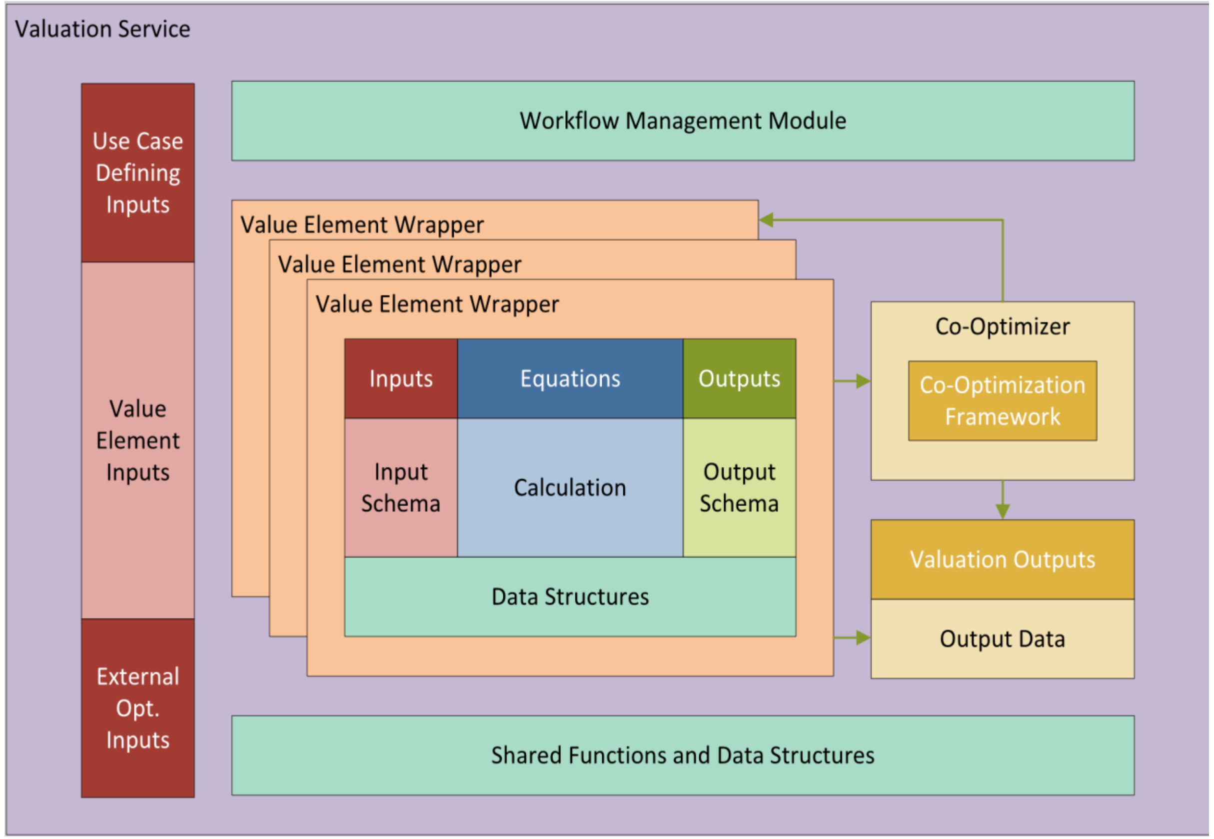
PNNL is operated by Battelle for the U.S. Department of Energy

Distributed Wind Valuation Background



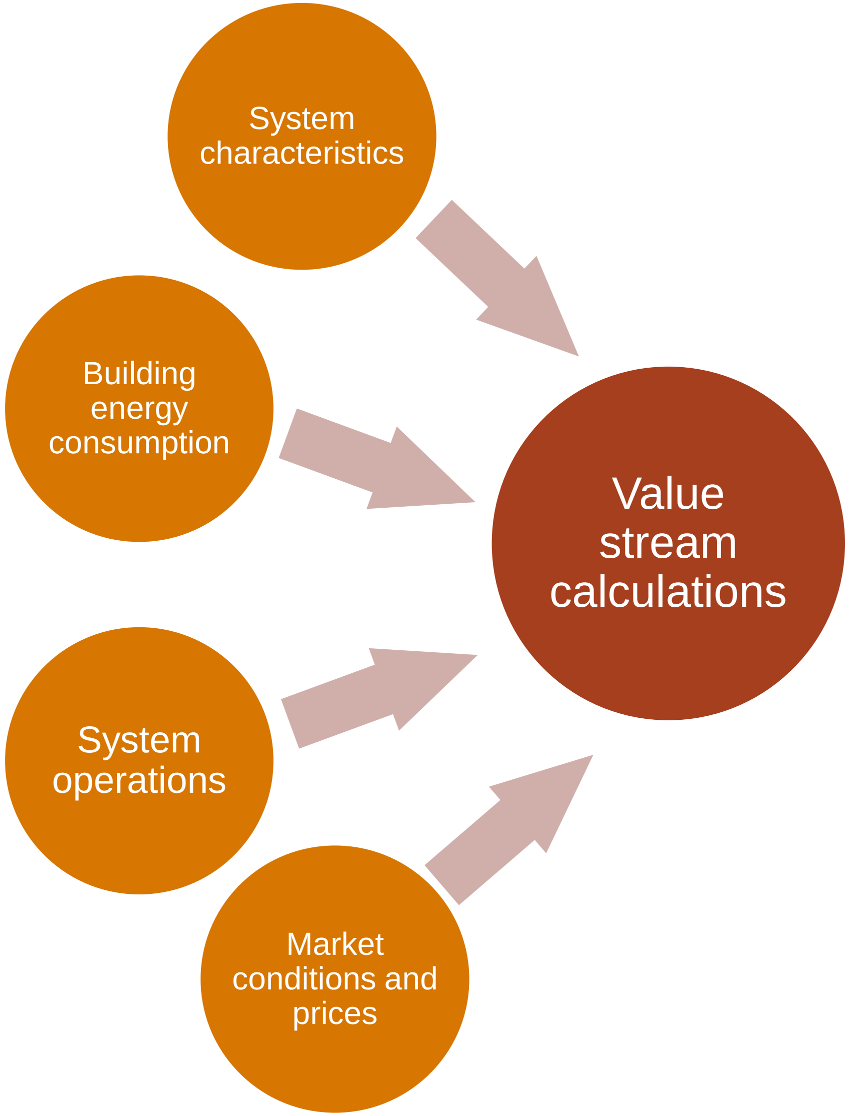
- Distributed wind systems create value for stakeholders that can go beyond electricity savings
- Understanding these costs and benefits are essential for project owners and other impacted parties
- In order to correct this PNNL developed a valuation framework for distributed wind systems
- The framework demonstrates how to trace different value flows from a project, and show their accrual to unique stakeholders
- The framework also provides an overview on how qualitative and quantitative analysis can be used for valuation
- Two examples of the framework in practice:
  - St. Mary's, Alaska
  - Iowa Lakes Electric Cooperative

PNNL's Valuation Service



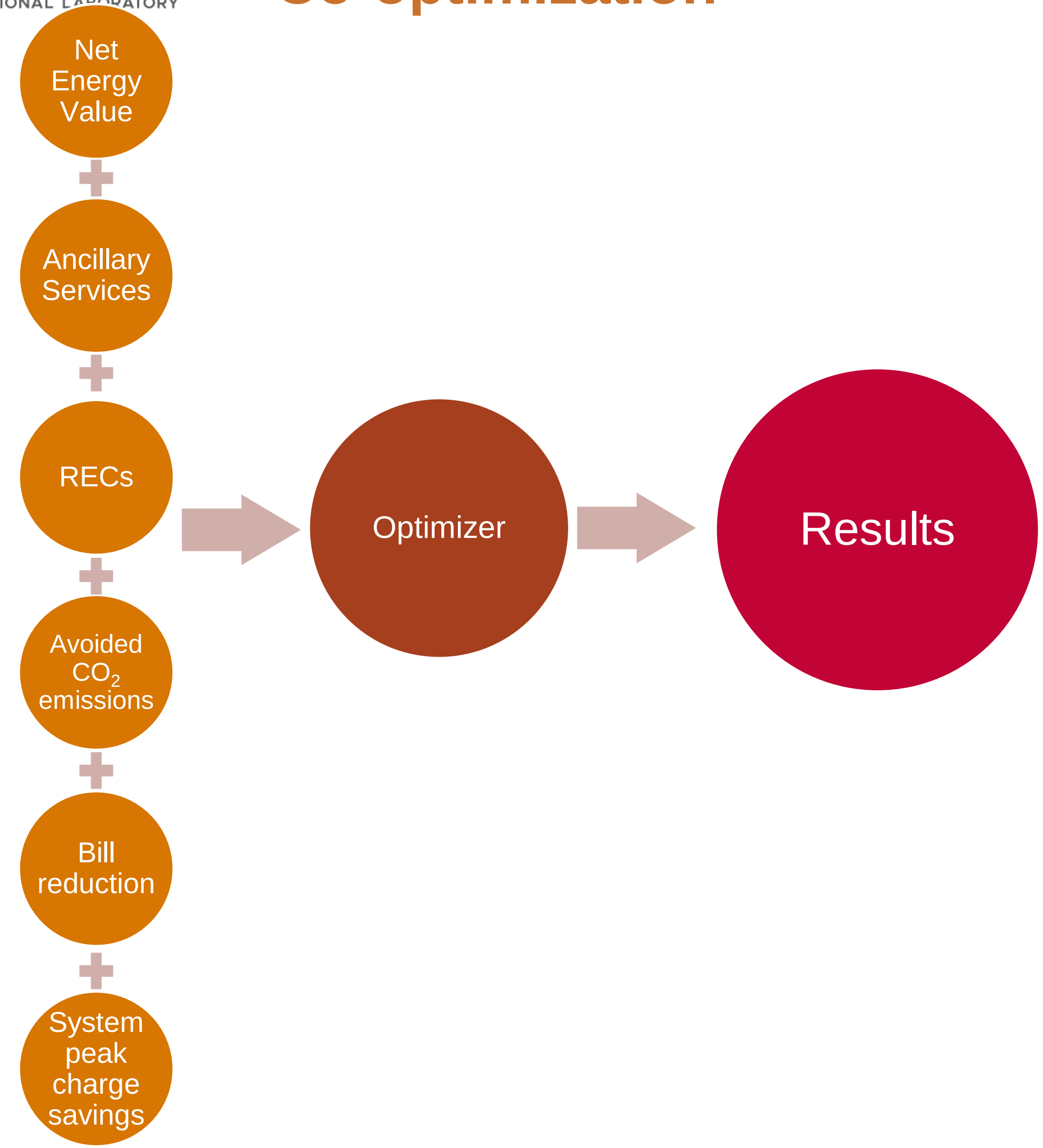
- PNNL automated this framework into a more useable service for distributed wind stakeholders
- Service based in Python, results export as a csv for post-estimation analysis
- Allows users to understand values related to:
  - Net energy value
  - Ancillary Services
  - Renewable Energy Credits (RECs)
  - Economic value of avoided CO_2
  - Bill reduction (flat-rate, time of use, and demand charges)
  - System peak charge savings
- Can also perform co-optimization of mutually exclusive value
- Available in GitHub

Inputs and Calculations



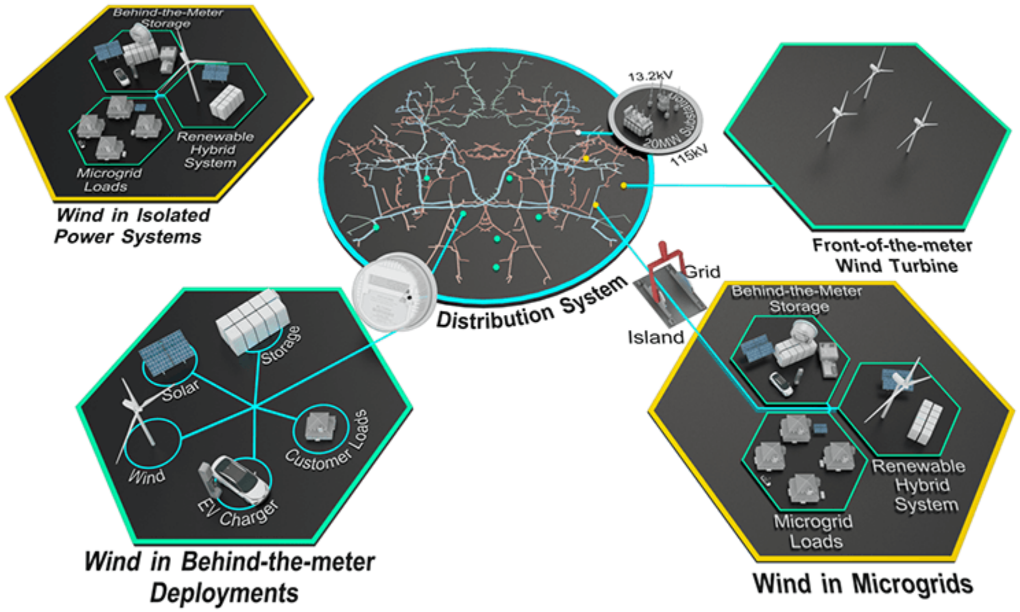
- The service is powerful but requires a significant number of inputs
- Users should be prepared to include information like wind project production data, energy sales data, building consumption data, emissions, and RECs, CO_2, or ancillary services prices
- The service can calculate all values over any system lifetime
- Suggested sources of data are available in our GitHub

Co-optimization



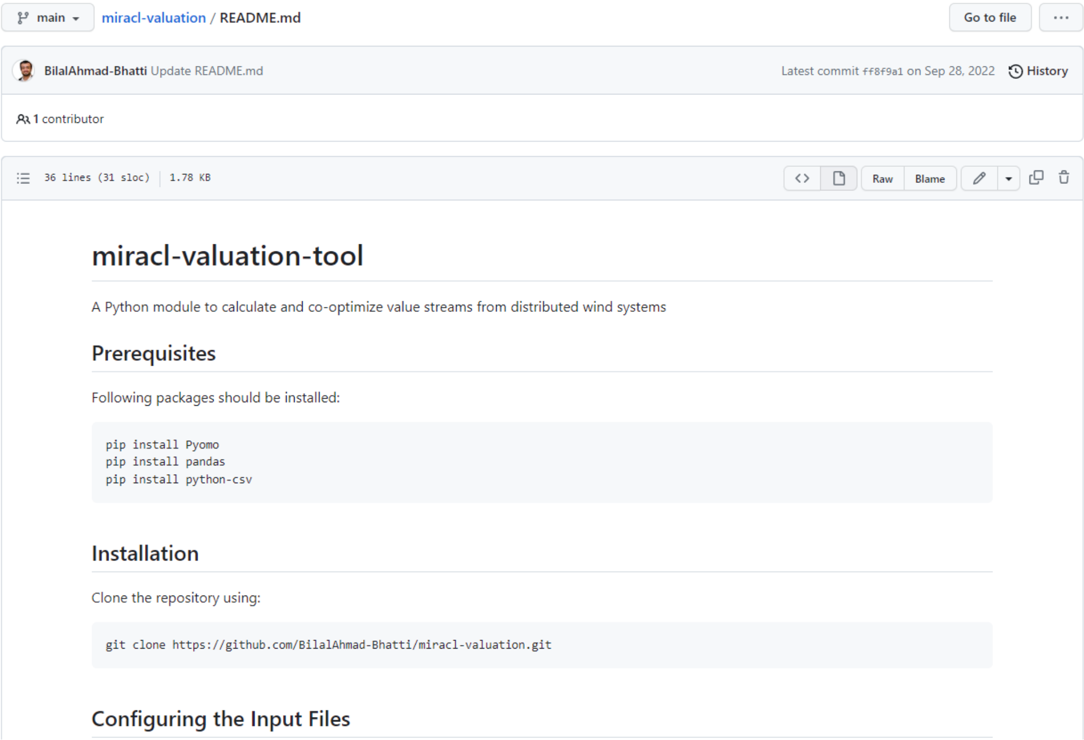
- After the initial value streams are calculated, the resulting values are fed into a co-optimizer
- The co-optimizing function identifies potential value flows that may be mutually exclusive
- The algorithm will select the operational strategy that produces the most economic value

Use Cases



- The service can assist with several types of analysis:
  - Comparison of different revenue streams, operational strategies, and system design options
  - Economic value/payback analysis
  - Evaluating third-party bids
  - Estimating the impact of tariff/policy reform on distributed wind
  - Understanding nonmonetary benefits of distributed wind

How to Use



- Watch the demonstration video and read the user manual
- Ensure you have downloaded Python and an integrated development environment (e.g., Jupyter, Visual Studio)
- Install the necessary packages
- Clone the GitHub repository
- Edit the input files and run
- Results are displayed in the terminal, and saved to a csv file

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What's next?

- We'll be working on making the service more powerful and functional over the next year
- Priorities:
  - Improving the user interface, and functionality
    - ✓Move from being a service to a more usable tool
  - Allow for analysis of hybrid systems
    - ✓Few developers/OEMs are offering a hybrid product right now, but they expect to in the future
    - ✓Customer demand is driving the switch
  - Expanding the service to consider other value streams
- We need your input!

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Thank you

PNNL Publications

- Valuing Wind as a Distributed Energy Resource: A Literature Review
- The Value of Distributed Wind: A Valuation Framework
- Valuation of Distributed Wind in an Isolated System
- Valuation Service GitHub
- Potential Data Sources for Valuation Service
- Valuation Service Demonstration Video
- Valuation Tool Overview

TAP

Heidi Tinnesand - NREL

NREL
Transforming ENERGY

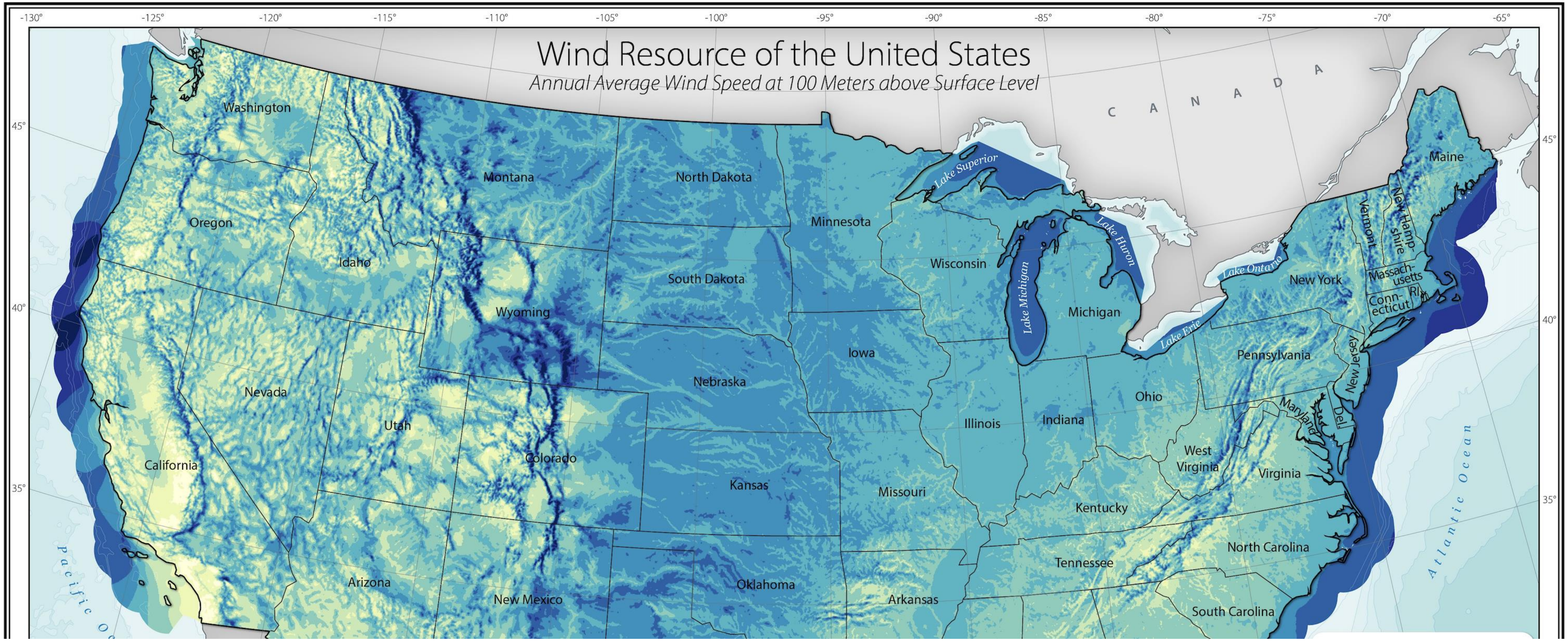
Tools Assessing Performance (TAP) 2.0

Heidi Tinnesand
National Renewable Energy Laboratory (NREL)

Building the Case for Hybrid Distributed Energy Developments – Day 2

April 5, 2023

Photo by Dennis Schroeder, NREL 55200



Current Wind Integration National Dataset (WIND) Toolkit:

- Seven years (2007–2013)
- Deterministic data set
- Contiguous United States
- Developed as a grid integration data set to mimic forecast errors.

WIND Toolkit Long-Term Ensemble Data Set (WTK-LED):

- Updated Weather Research & Forecasting (WRF) version (4.1.3)
- 2-km, 5-min data set
- Twenty years (2001–2020)
- Regional bias guidance
- Uncertainty quantified (ensembles)
- Includes Alaska and Hawaii.

Work led by Caroline Draxl, NREL

Data Availability

WIND Toolkit is:

- Available on Eagle (NREL's high-performance computing machine)
- Available in the cloud (more on how to access it can be found here: https://github.com/NREL/hsds-examples/blob/master/notebooks/01_WTK_introduction.ipynb).

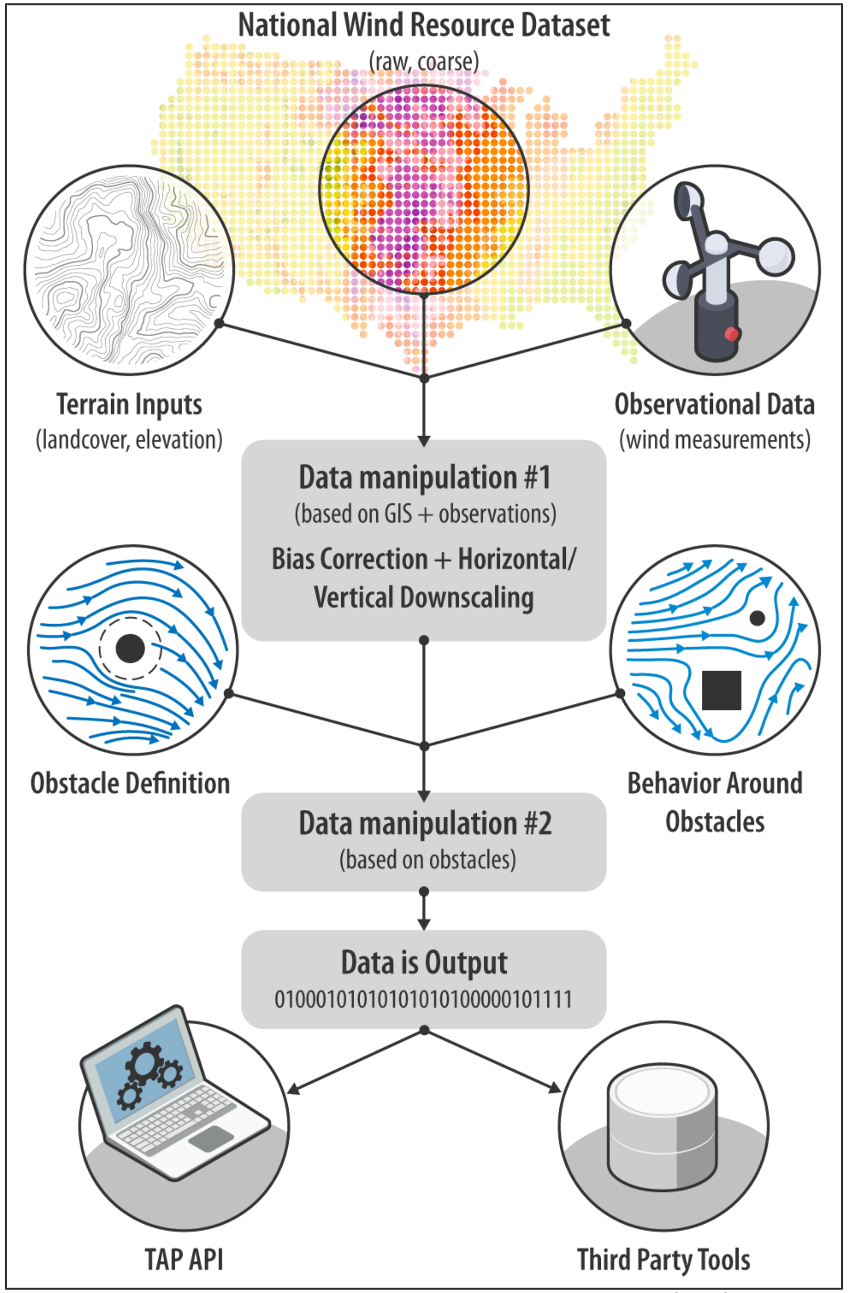
WTK-LED:

- Is currently available on Eagle (internal to NREL)
- Soon will be available in the cloud
- Will be leveraged by the tools we develop in the future.

TAP Computational Pipeline

Design targets:

- Efficient
- Accurate
- Validated
- User-friendly
- Open-source



Graphic by NREL

Tools Assessing Performance (TAP) Computational Pipeline

Inputs

(on NREL's high-performance computer or in the cloud)

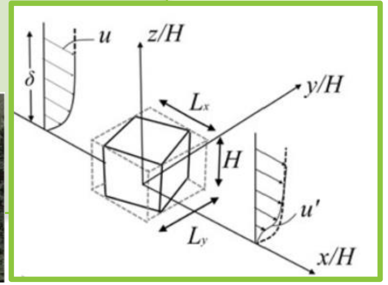
WTK (2007–2013), 2-km resolution, hourly

--- or ---

WTK-LED (2001–2020), 2–4-km res., 5-min to hourly

Site Analysis

1. Selection of (min, median, max) years for wind speed
2. Regional bias correction
3. Vertical and horizontal interpolation
4. Obstacle modeling



Estimates

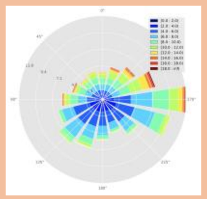
1. **Wind speed**
2. **Wind direction**
3. Pressure
4. Temperature

Visualizations

(produced locally or on NREL's high-performance computer or in the cloud)

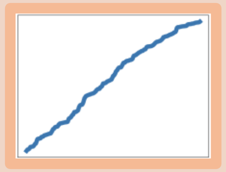
(single point)

Wind rose



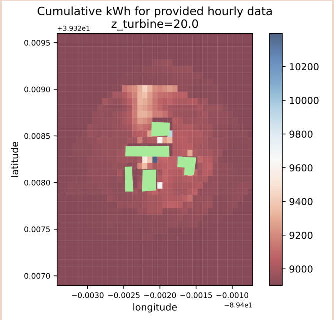
(single point)

Cumulative energy



(multiple points)

Site heat map



Integration of Obstacle Line Operations Monitoring System

Inputs

(on NREL's high-performance computer or in the cloud)

WTK (2007–2013), 2-km res., hourly

--- or ---

WTK-LED (2013–2020), 2–4-km res., 5-min to hourly

Site Analysis

1. Selection of (min, median, max) years for wind speed
2. Regional bias correction
3. Vertical and horizontal interpolation
4. Obstacle modeling

Quick Urban & Industrial Complex (QUIC)

- or -

Physics-Informed, Low-Order Obstacle Wake Flow Model (PILOWF)

1. Atmospheric data

[5]:

	datetime	ws	wd	temp	pres	inversemoninobukhovlength_2m
0	2007-01-01 00:00:00	7.744876	232.969856	282.541870	98493.965337	0.011512
1	2007-01-01 12:00:00	9.165510	278.610485	272.009949	99037.753033	0.001730
2	2007-01-02 00:00:00	5.667914	294.372393	275.522644	100177.180992	0.042600
3	2007-01-02 12:00:00	1.196242	199.775672	272.208313	100652.980804	0.048113
4	2007-01-03 00:00:00	6.783602	194.172807	276.606049	100410.263947	0.047254
...	...	...	...	...	...	...
726	2007-12-30 00:00:00	3.874950	176.357785	272.583710	99716.562444	0.108205
727	2007-12-30 12:00:00	4.888072	152.960520	271.582703	99367.990863	0.015526
728	2007-12-31 00:00:00	6.975717	191.885982	275.272369	98836.610143	0.056662
729	2007-12-31 12:00:00	4.802318	227.441046	270.859406	98993.799386	0.027217
730	2008-01-01 00:00:00	7.361367	303.598820	272.241882	98926.921183	0.010325

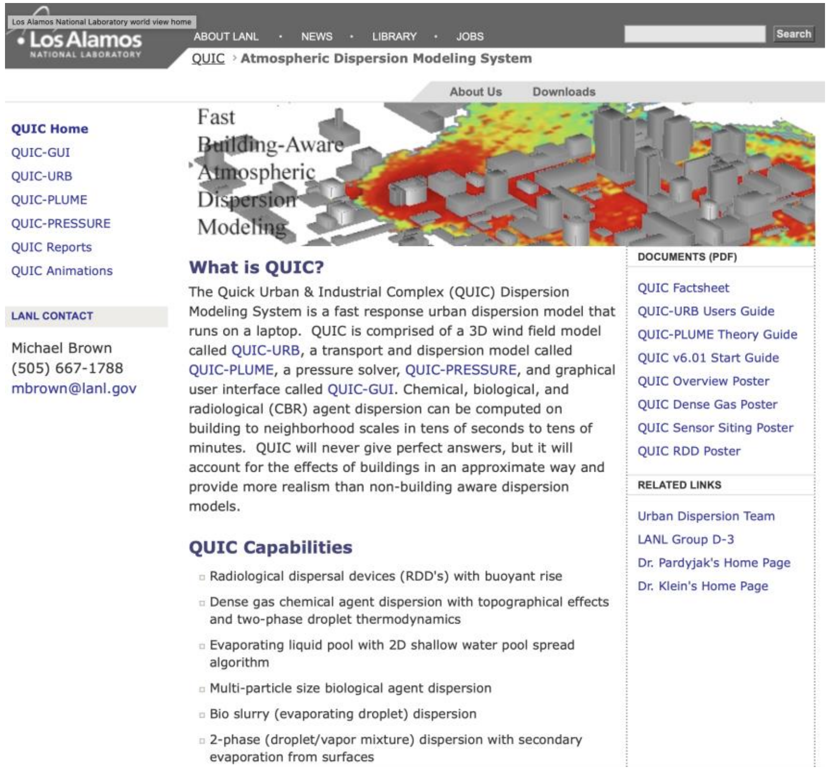
2. Obstacle data

3. Site specs:

```
latitude=39.3
longitude=-89.4
hub_height=40
```

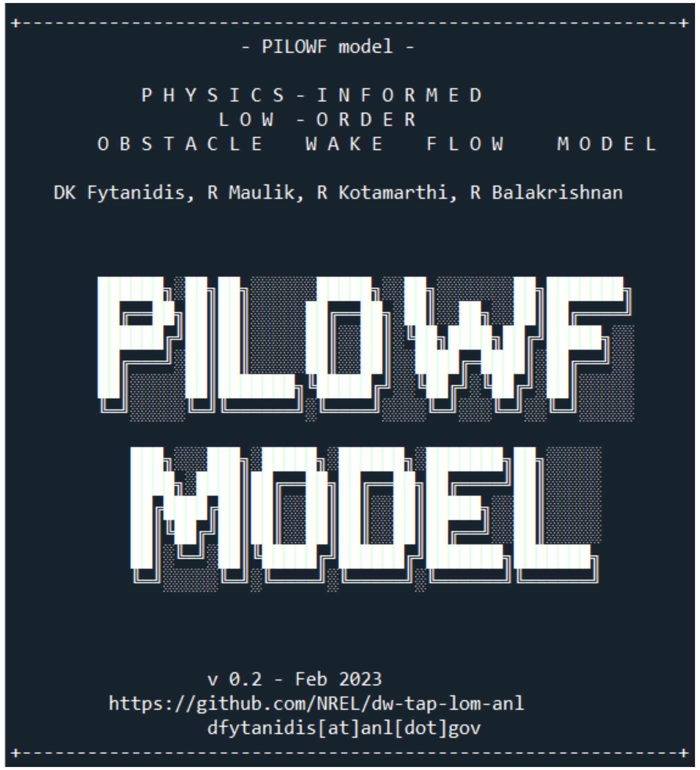
Obstacle Models

QUIC by Los Alamos National Laboratory



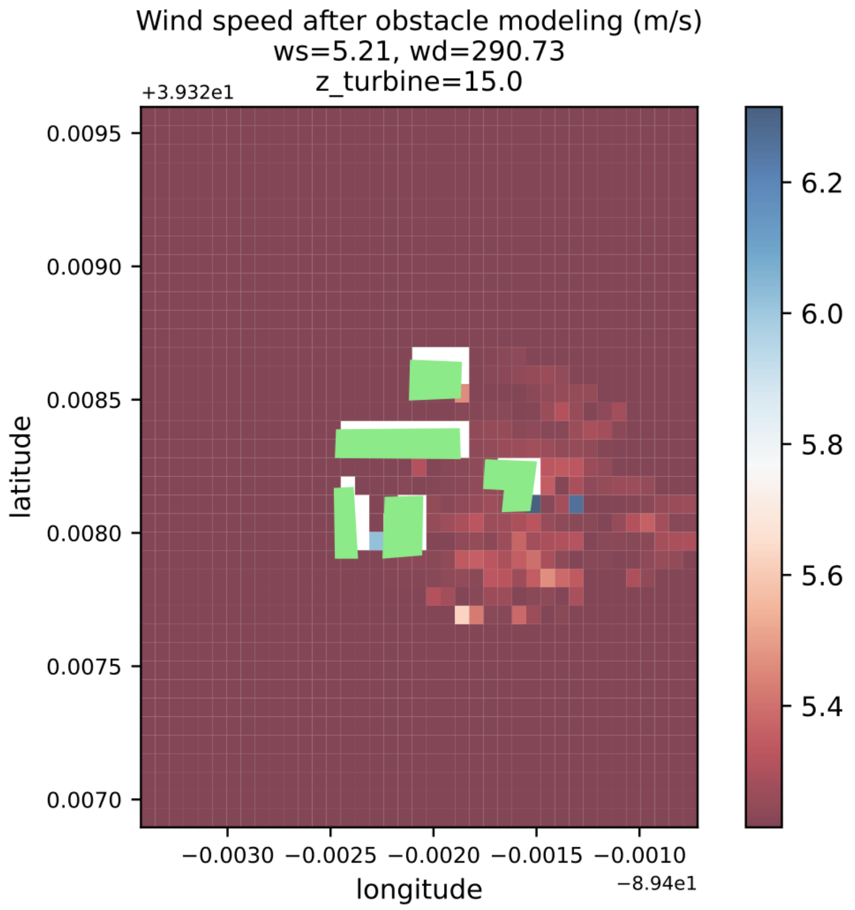
More at: https://www.lanl.gov/projects/quic/

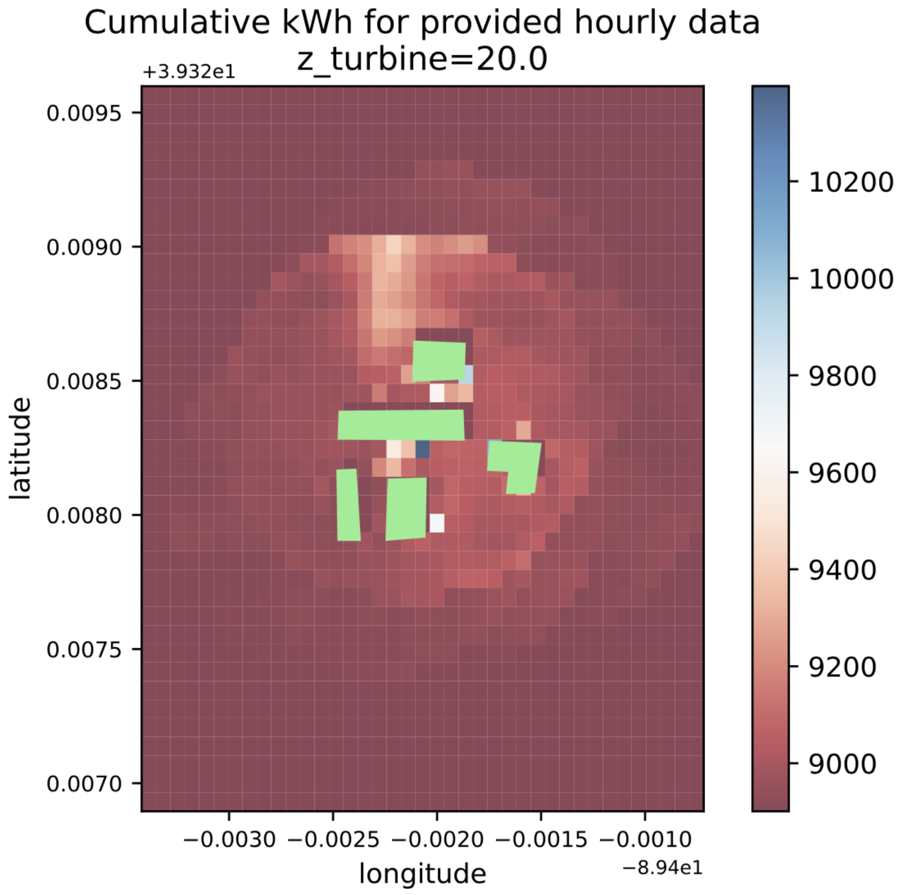
PILOWF by Argonne National Laboratory



More at: https://doi.org/10.2172/1782670

Visualizing Obstacle Effects





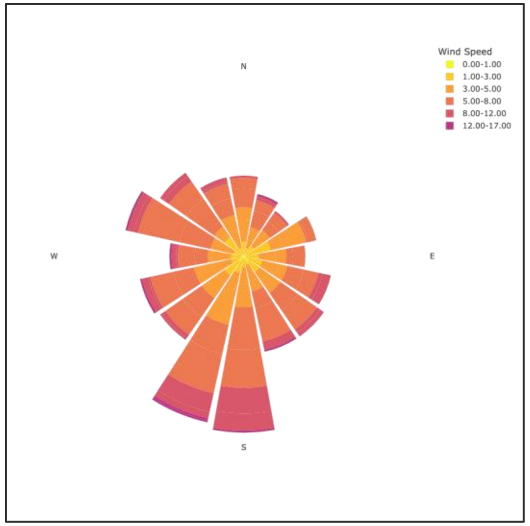
Figures by NREL

Left: Impact of buildings on wind speed for a single moment in time

Right: Impact of buildings on the cumulative energy produced over a period of time

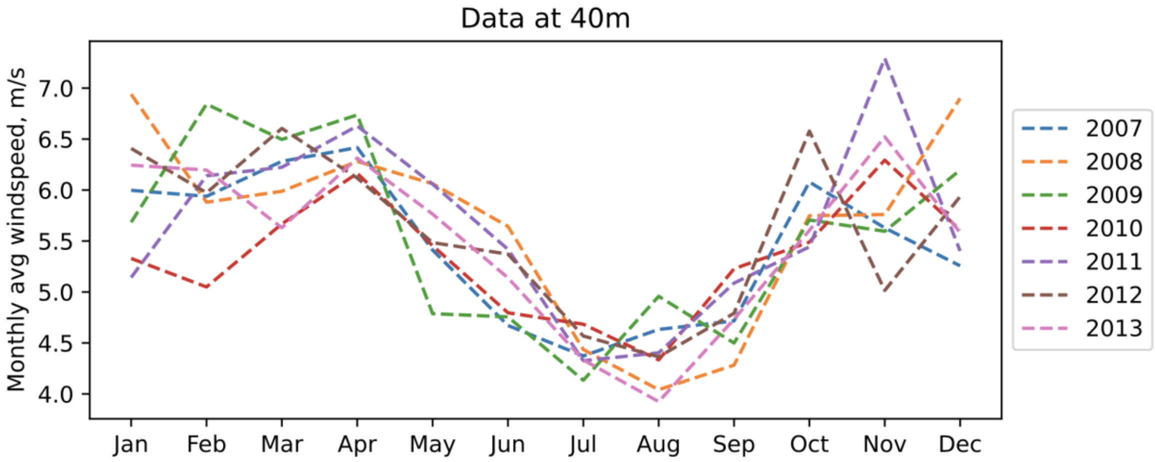
TAP Capabilities

Analyze wind roses for the studied sites



Can produce wind roses for each month, or at greater fidelity.

Use WTK data to understand year-to-year and month-to-month variability
and compare to observational data where available

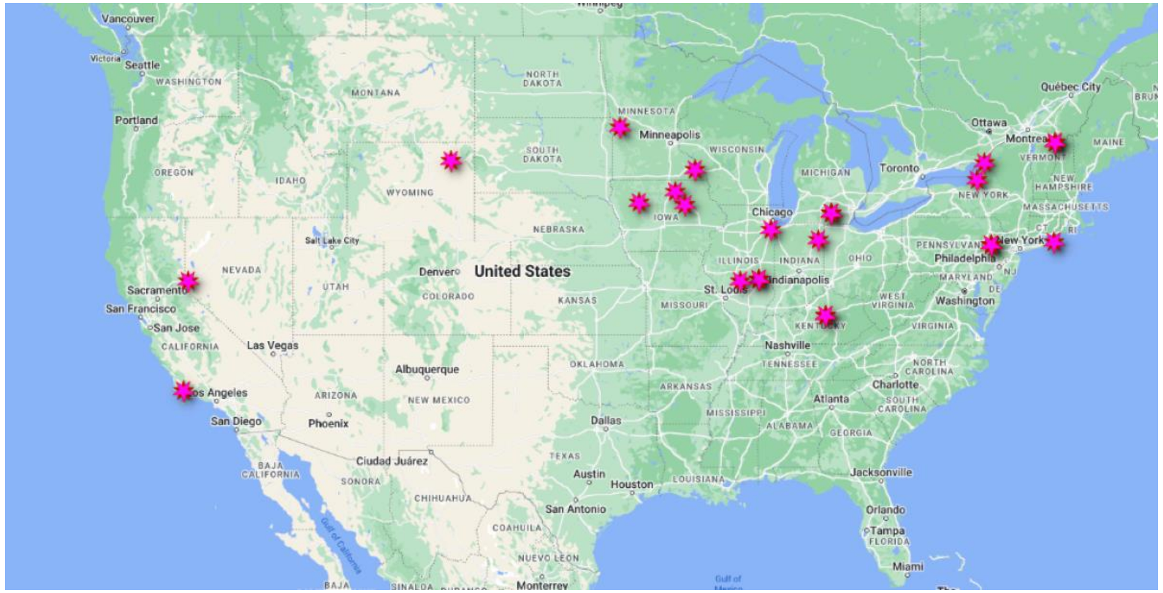


Output will characterize high, low and average wind years.

Figures by NREL

Upcoming Validation

- Selected a number of actual distributed wind sites across the United States
- Plan to evaluate the entire TAP pipeline as well as individual components, studying both wind speed estimates and energy produced estimates
- Plan to evaluate the quality of our estimates as a function of turbine location, number of nearby obstacles, hub height, and use of obstacle models.



Working With YOU

- Tool is not yet available for public use, but please get in touch if you would like us to evaluate some sites!
- We are seeking feedback on the functionality of the tool and the outputs of the analysis!

For more information, go to:
https://www.nrel.gov/wind/tools-assessing-performance.html.

Or email Heidi.Tinnesand@NREL.gov.

www.nrel.gov

Thank you!

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NREL Transforming ENERGY

Funding Opportunities

Federal Funding Opportunities

National Lab Resources

Federal Funding Opportunities

Michael Leitman - NRECA

Funding Opportunities Available for Distributed Hybrid Projects

April 5, 2023

NRECA
America's Electric Cooperatives

Michael Leitman, Director of System Optimization

Extensive New Federal Funding Support

- The Bipartisan Infrastructure Law and the Inflation Reduction Act (IRA) include extensive funding support for wind, solar, battery storage, and other potential hybrid technologies
- These include an extension/restoration of tax credits, including a “direct pay” option for not-for-profit utilities, as well as “transferability” for for-profit entities; **guidance is pending from the Treasury/IRS**
- Also, tax credits to support for domestic manufacturing and supply chains for renewable technologies
- There are also significant new funding programs that can be used for distributed hybrid deployment at both DOE and USDA

NRECA
America's Electric Cooperatives

Tax Credits Extended with Direct Pay/Transferability

- In the IRA, the Production Tax Credit (PTC) and Investment Tax Credit (ITC) for renewables restored at their full rate through 2025 before transitioning to a technology-neutral tax credit that will not start phasing out until 2032 or later
- There are apprenticeship and prevailing wage requirements to receive the full credit (2.6 cent per kWh PTC / 30% ITC), as well as "stackable" 10% bonus credits for meeting domestic manufacturing and materials thresholds and for locating in "energy communities"
- The Inflation Reduction Act (IRA) includes "Direct Pay" provisions which give not-for-profit utilities like electric cooperatives and rural public power districts tax parity with for-profit entities when deploying non-emitting generation technology
- Also includes "transferability" for for-profit entities, allowing them to sell the tax credits to an unrelated their party; this is much simpler from a legal, accounting, and administrative standpoint compared to prior "tax equity" models, allows a wider range of financial partners, and is especially useful to smaller developers without enough tax appetite to utilize tax credits themselves

Tax Credits – Specific to DER

- There are additional bonus credits for projects under 5 MW
  - 10% for locating in low-income communities or on tribal lands
  - 20% for locating as part of a low-income residential project or as part of a low-income economic benefit package
  - Only one of these four bonuses can be used per project
- The ITC can also be applied toward interconnection costs for projects up to 5 MW
- Projects of 1 MW or less do not need to meet labor and apprenticeship requirements to receive the full tax credit
- The residential renewable tax credit for projects 100 kW or less was also extended
- The standalone tax-credit for battery storage also levels the playing field for wind + battery hybrid development (which had previously required solar charging to receive the ITC)
- All issues related to direct pay, transferability, and bonus credits should be discussed with your tax advisor, **though note that guidance from Treasury/IRS on many details and implementation questions is still pending**

USDA Programs

- Creates a new $9.7 billion USDA Financial Assistance for Clean Energy loan and grant program designed specifically for electric cooperatives that purchase or build new clean energy systems that reduce emissions, with grants covering up to 25% of a projects cost up to $970 million for any one entity
- Also creates a $1 billion USDA forgivable loan program for new renewable and storage projects open to all clean energy developers, not just co-ops, with forgiveness of up to 50% of project cost
- An additional $2 billion in funding for USDA's existing Rural Energy for America Program (REAP) for rural ag producers and small businesses, including electric cooperatives

USDA

NRECA
America's Electric Cooperatives

DOE RD&D and Other Programs

- The Energy Improvements in Rural or Remote Areas (ERA) program includes $1 billion in funding for innovative demonstration projects, including hybrid generation, serving small communities under 10,000 people, with the first $300 million in funding currently open for applications
- Adds $3.6 billion for DOE’s Clean Energy Loan Guarantee Program
- Funding for Technical Assistance Programs (like this one) led by national labs to create tools and assistance for deployment

Q&A and Contact Information

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www.cooperative.com/radwind

NRECA America's Electric Cooperatives

National Laboratory Resources

Megan Culler - INL

How can you engage in this project?

Technical assistance opportunities

Join a wind-hybrid cohort	Become a case study partner
• Focus on quick transfer of knowledge and tools • 6-12 week engagement • Engage with peers • Strengthen proposals for funding	• Focus on full analysis to meet a targeted end goal • Lab SME support to develop metrics and language in support of a new project • 3-6 month engagement

What does “engage” look like?

- The more you put into it the more you get out!
- Our analyses work best with more data. If we don’t have data we will make assumptions, which may or may not be accurate.
- Continued discussions allow us to better understand your goals and revise our analyses to fit your needs.

State, Local, and Tribal Government Assistance

- Island and remote communities
  - Energy Transitions Initiative Partnership Program
- Clean Cities Technical Assistance
- Clean Energy to Communities Program
- Clean Energy Demonstration of Mind Land technical assistance
- Waste-to-Energy technical assistance
- Technical assistance through the Office of Indian Affairs

https://www.nrel.gov/state-local-tribal/technical-assistance.html

General Lab Engagement Methods

- Partnerships on proposals
- Strategic Partnership Programs (SPPs)
- Cooperative Research and Development Agreements (CRADAs)
- Licensing of lab technology
- Technical assistance programs

https://procurement.inl.gov/Documents/INL%20Industry%20Engagement%20Technology%20Deployment.pdf
https://inl.gov/inl-initiatives/economic-and-workforce-development/

Next Steps

- Recording and slides will be made available on the website
  - https://inl.gov/national-security/hybrid-energy-webinar/
- Email will be sent when materials are available
  - Please fill out the **survey** to gauge utility of workshop and express interest in follow up activities

- Contacts:
  - Megan Culler: megan.culler@inl.gov
  - Sarah Barrows: sarah.barrows@pnnl.gov
  - Caitlyn Clark: caitlyn.clark@nrel.gov

Discussion

Battelle Energy Alliance manages INL for the U.S. Department of Energy's Office of Nuclear Energy. INL is the nation's center for nuclear energy research and development, and also performs research in each of DOE's strategic goal areas: energy, national security, science and the environment.