



**INTERCONNECTION  
INNOVATION e-XCHANGE**  
U.S. DEPARTMENT OF ENERGY

*an EERE collaboration between SETO & WETO*

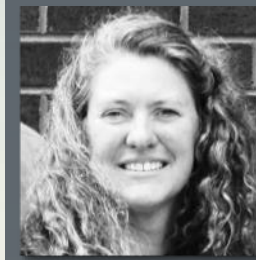
## ESIG Workshop

August 11<sup>th</sup>, 2022

- Program Overview
- 5-year Roadmap

[energy.gov/i2x](https://energy.gov/i2x)





Presenter

**Dr. Cindy Bothwell**

Grid Integration Engineer  
Wind Energy Technologies Office

# AGENDA

1

Interconnection  
Background

2

i2X Program

3

Roadmap  
Development

4

Audience  
Input

# What is Interconnection?

The complex network of regulatory electricity market laws, administrative processes, and integration technologies that together define the processes for connecting new generation to grid networks

# Background of the Interconnection Challenge

Interconnection is Changing as the Grid Transforms

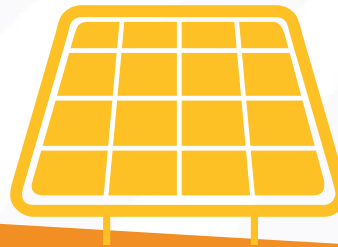
## Zero-Carbon Future

Need for paradigm-shifts to  
deploy clean energy technologies  
at exponential scales



## Complexity

Rapid grid transformation  
Complex and varying processes  
High penetration weather based  
Technology advancement



## Equity

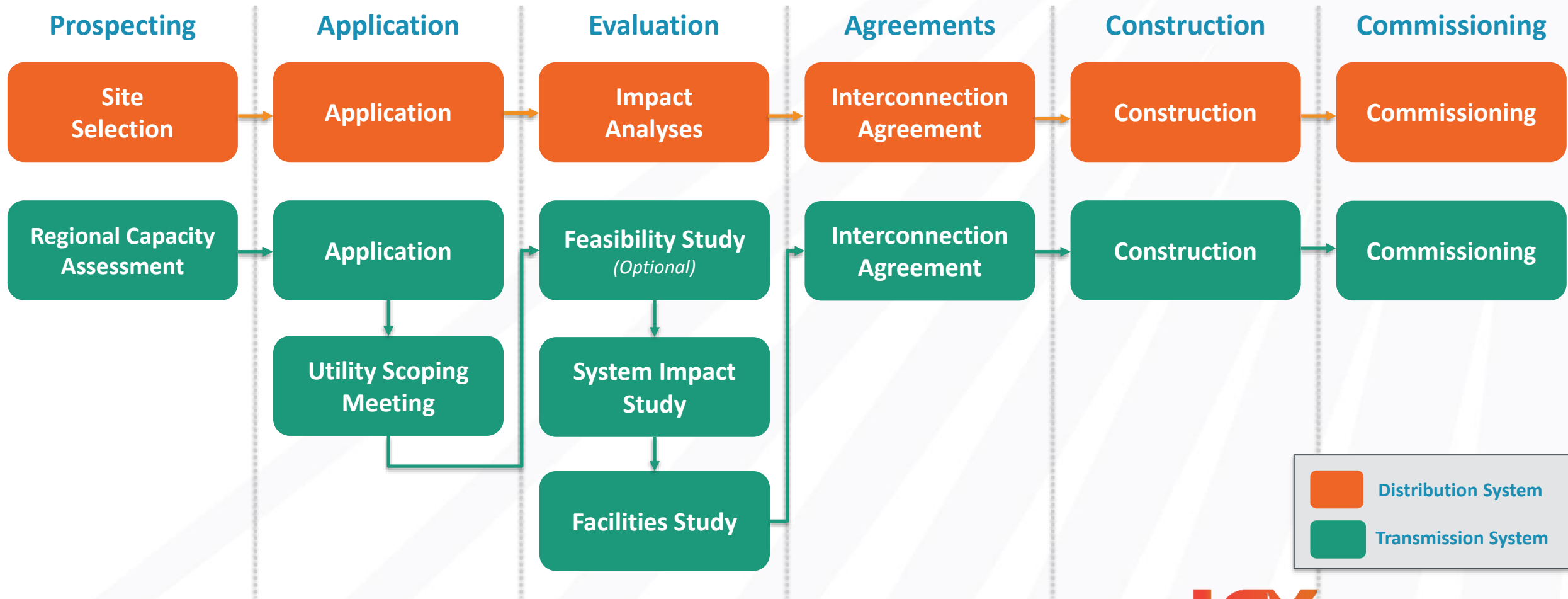
Enable new entrants with more  
affordable access.  
Diverse stakeholders required to  
fully understand regulatory,  
technical, and process



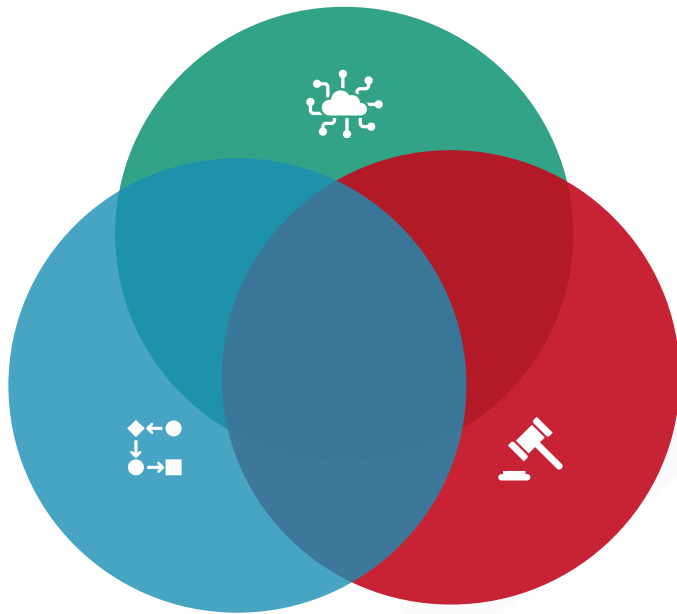
5x

Expected increase in the number of Solar & Wind  
Deployments every year to meet 2035 targets

# A Framework for Examining Interconnection



# Workshop Feedback on Interconnection Challenges



## Technology & Engineering

- Complex grid reliability impact assessments of intermittent generation assets
- Outpaced Transmission planning and expansion by high incentives for renewables
- Fragmented Transmission & Distribution institutional coordination

## Administrative Process

- Insufficient human resources and capabilities to manage long queues
- Unfair cost allocations triggered by unpredictable grid networks upgrades
- Opaque grid networks data and modeling informational asymmetries

## Markets & Regulation

- Dizzying rules and regulations for interconnecting to distribution networks
- Misaligned utility models for private ownership of distributed generation
- Insufficient regulatory oversight of queue management and compliance

# Greatest interconnection challenges

Limited Grid-  
Capacity  
Transparency

Lengthy Queue  
Processing  
Timelines

Lack of Fair Cost  
Allocation  
Procedures

High Impact Study  
Costs

High Complexity of  
Interconnection  
Application

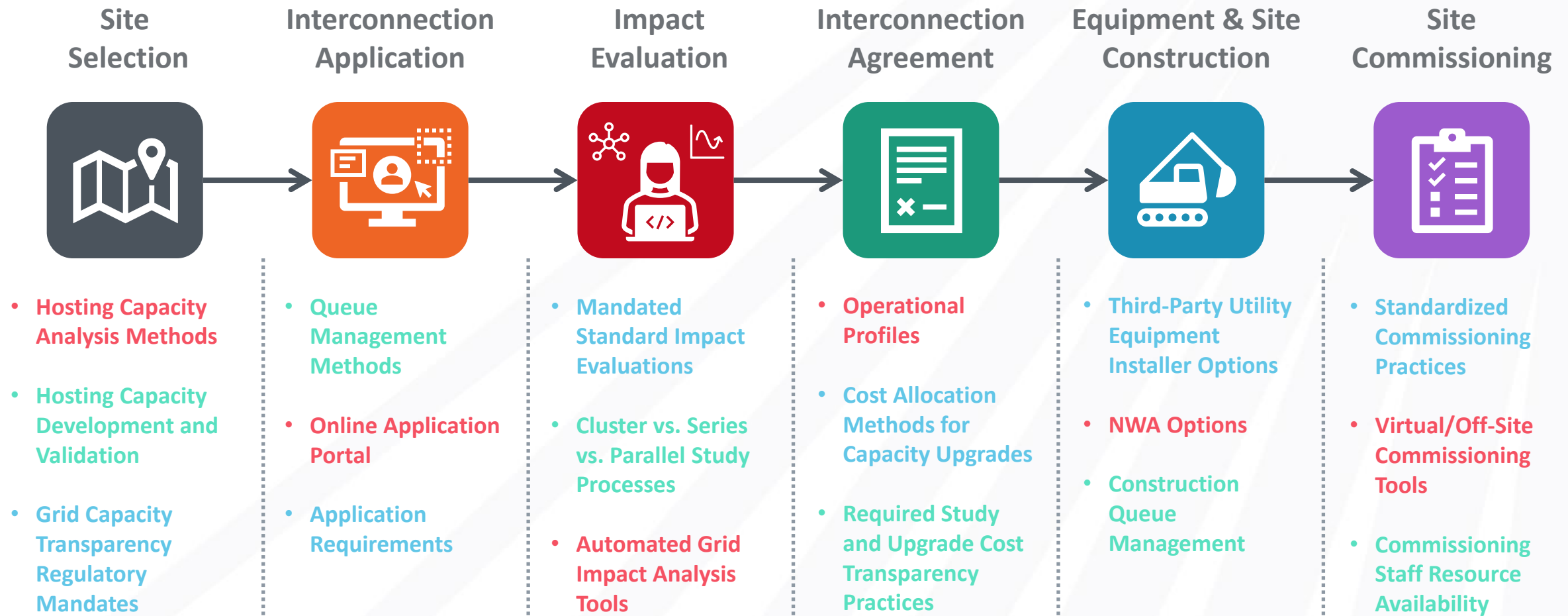
Uncertainty in Cost  
of System  
Upgrades

Multi-Study  
Timeline  
Coordination  
Issues

- Lack of hosting capacity analysis or similar tools linking availability of land to available interconnection capacity.
- High integration cost that are inconsistent with project size.
- Slow and cumbersome interconnection process can lead to off-takers opting out of community solar.
- Misalignment of interconnection application requirements with ability to bid community solar projects – requirements modified.
- Regulatory restrictions on interconnection timeline ensuring operation within 12-months or less.

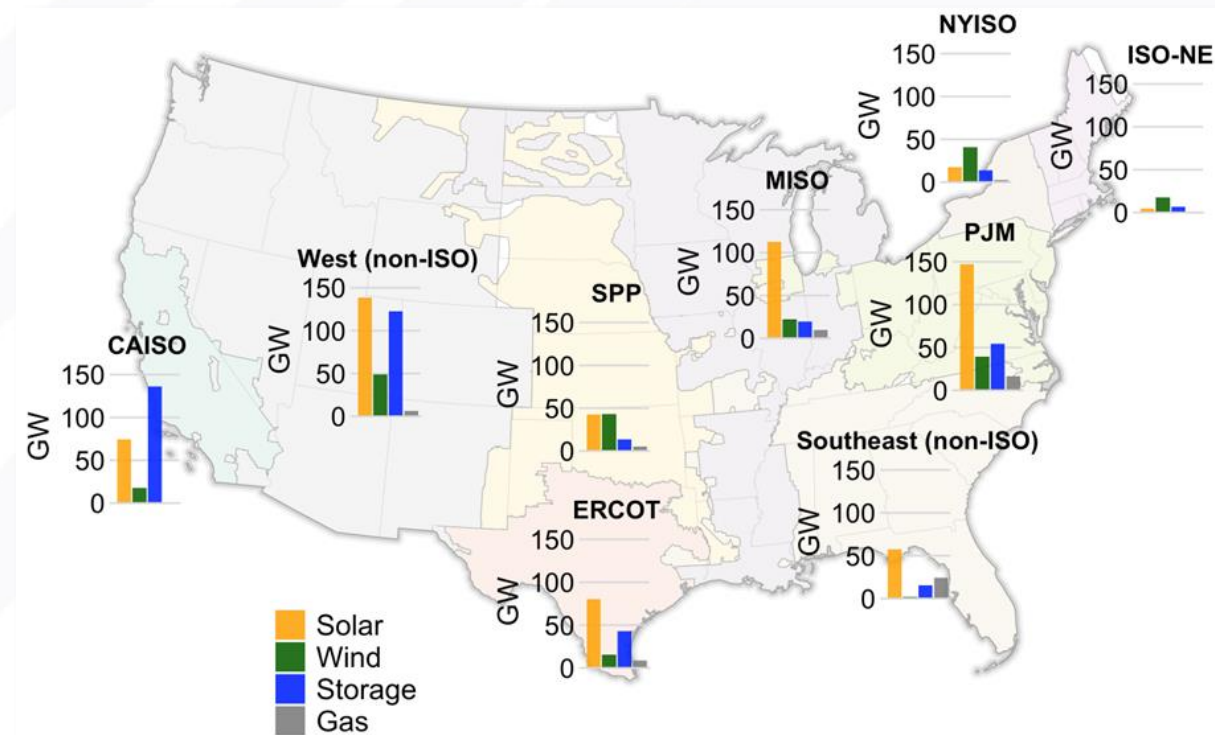
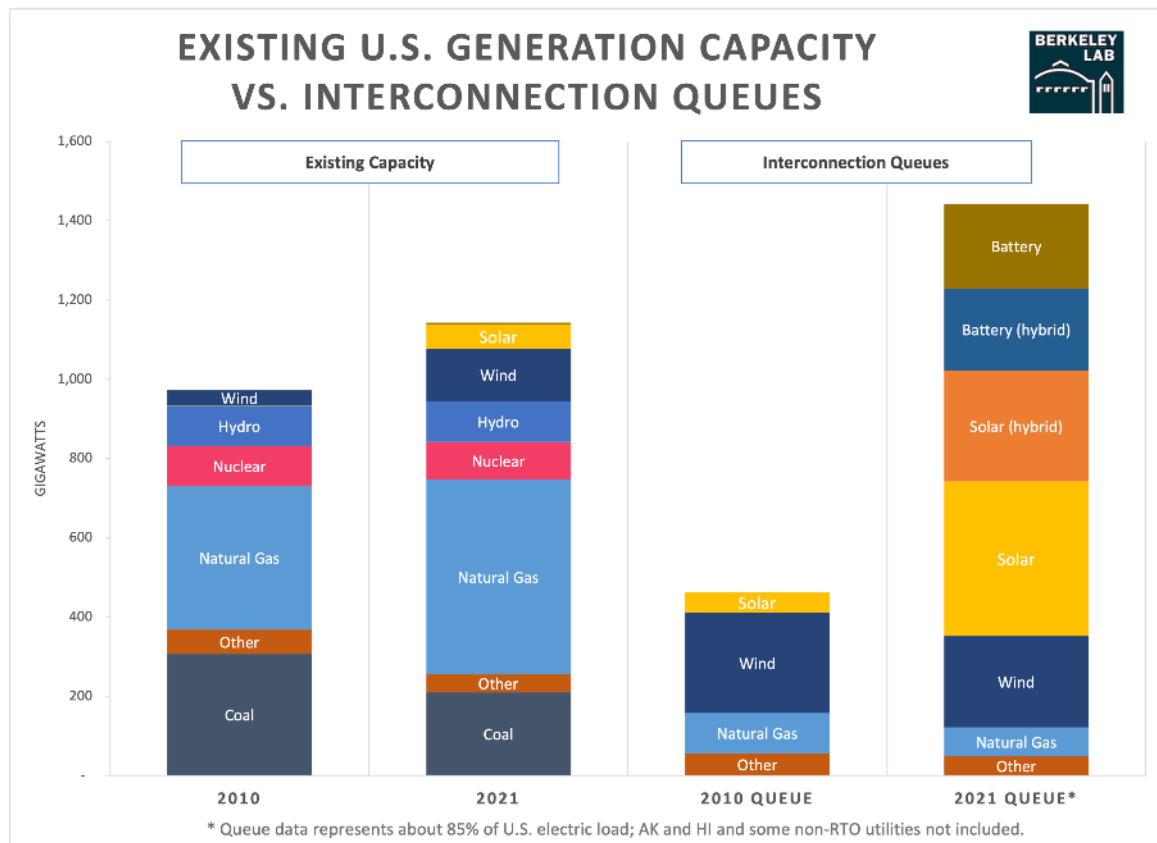


# A Framework for Examining Interconnection





# Status of Interconnection Queue



# The i2X Mission

To enable the **simpler**, **faster**, and **fairer** interconnection of solar and wind energy resources all while boosting **reliability**, **resiliency**, and **security** of our electric grid.



Stakeholder  
Engagement



Data Collection  
and Transparency



5-Year Strategic  
Roadmap



Technical  
Assistance

# Stakeholder Diversity



## Government

State / Local / Federal / Tribal / Regulators / Agencies



## Utilities

Investor-Owned / Public Power / Munis / Cooperatives



## Grid Operators

Independent Service Operators (e.g. PJM, MISO, CAISO)



## Non-Profits

Trade Groups / Energy Justice / Environmental Conservation

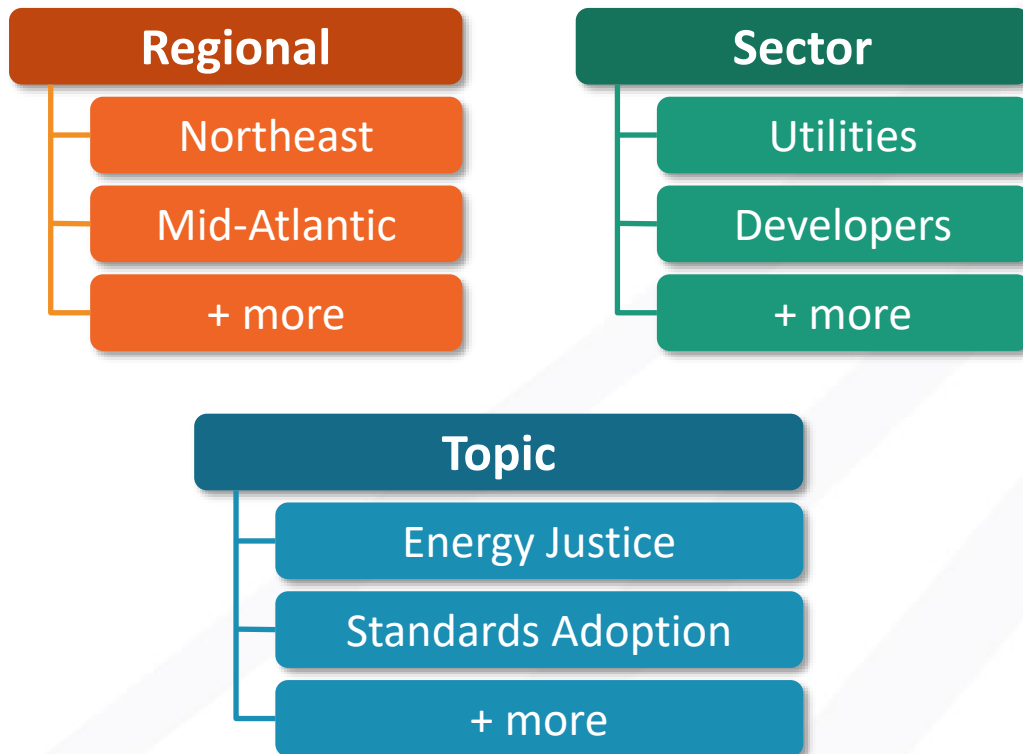


## For-Profits

Developers / Consultants / Off-Takers / Solutions Providers

# Engagement Mechanisms

## Working Groups



## Engagement Platform

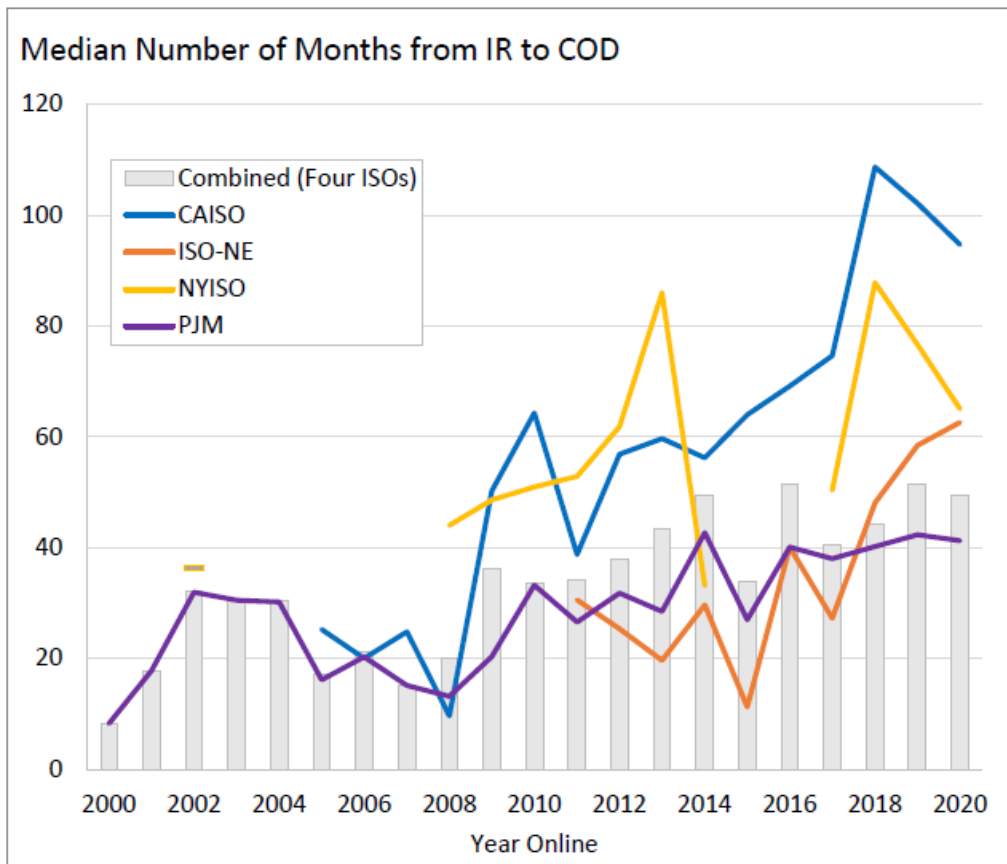




# i2X Program Overview

## Data Collection and Transparency

Completed Projects: Time in Queue, by ISO



Source: LBNL Queued Up 2.0 briefings

**Increase the availability, transparency, and standardization of transmission data (interconnection queue timing and cost)**

Gap in distribution data for the 50kW - 5MW PV scales (e.g., community solar projects)

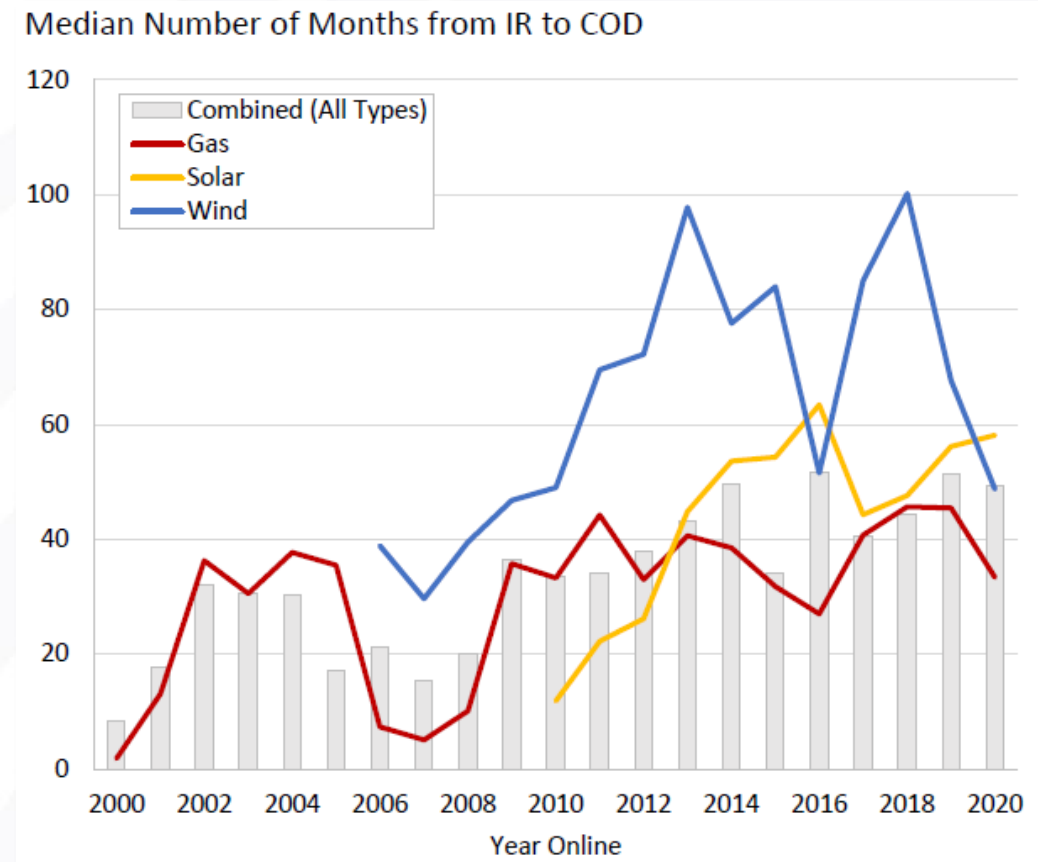
Data collection and transparency efforts limited by privacy and security concerns

# i2X Program Overview

## Transmission Analysis

### Examples of Analysis:

- Industry survey on interconnection costs, delays, withdrawal reasons, etc
- Case studies and analysis of past, current, and proposed BPS interconnection queue reforms
- Assessment to determine if interconnection procedures are leading to higher-cost or lower-value renewable projects
- Examination of criteria and dispatch conditions for system stability
- Examination of the timing mismatch of detailed equipment models



Source: "Queued Up v2: Extended Analysis on Power Plants Seeking Transmission Interconnection as of the End of 2020" by J. Rand, W. Gorman, D. Millstein, A. Mills, J. Seel, and R. Wider at Lawrence Berkely National Laboratory presented to DOE-SETO in January 2022

# Technical Assistance Opportunities

**Goal:** To provide access to various interconnection technical assistance opportunities to support our partners in their implementation of developed reforms

Implementing Queue  
Management Methods

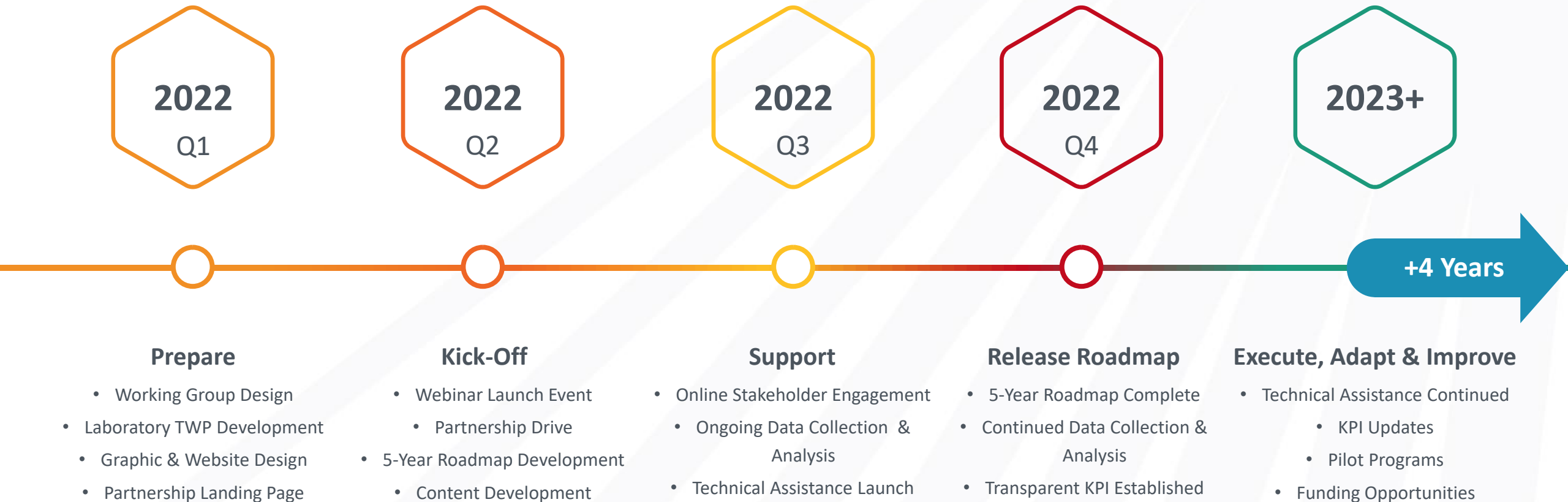
Accelerated Tool  
Development and  
Deployment

Direct Access to  
Interconnection  
Experts

Best Practices and  
Training

# i2X Program Overview

## i2X Timeline





# What's Next?



## BOOKMARK THE WEBSITE

Be sure to visit the i2X website for any and all information regarding the program:  
[energy.gov/eere/i2x](https://energy.gov/eere/i2x)



## JOIN THE PARTNERSHIP

Join the growing list of i2X partners to benefit from all that the i2X program has to offer



## PARTICIPATE IN UPCOMING EVENTS

Join any one of the amazing opportunities to connect with i2X leadership such as our **Interconnection Office Hours**

# Join Our Growing List of i2X Partners!

- 8minute Solar Energy
- AC Power LLC
- Advanced Battery Concepts
- Alegna Technologies, Inc.
- Altitude Grid, LLC
- Amazon Web Services
- American Council on Renewable Energy
- American Microgrid Solutions
- American Renewable Energy Standards and Certification Association (ARESCA)
- AnnDyl Policy Group
- Appalachian Voices
- Audubon
- Black & Veatch
- Bob Wolfson Consulting
- BrightNight Energy
- Capstone Green Energy
- Center for Renewables Integration, Inc.
- ChargeNet Stations
- City of Los Angeles - Mayor's Office
- City of Santa Barbara
- Clean Catch Energy
- CleanTech Energy Solutions, Inc.
- Coalition for Community Solar Access (CCSA)
- Cold Volt
- Colorado Clean Transportation Coalition
- Community Renewable Energy
- Compass Energy Consulting
- Cornell University
- Cox Enterprises

[energy.gov/i2x](http://energy.gov/i2x)

- Czero, Inc.
- DAE Technologies, Inc.
- Daheco Engines & Energy
- Dividend Finance, Inc.
- DRG Technical Solutions
- Eastman Kodak Co
- Ecogy Energy
- EDP Renewables
- Electric Power Energy Services LLC
- Electric Power Research Institute (EPRI)
- Elia Grid Inc.
- Elysian Co
- Energy Inc.
- Energy Partners
- Enovation
- Environmental
- Environmental Solutions Work
- EPC LLC
- Exeter Associates, Inc.
- Fluor Corporation
- Flux XII LLC
- Fusion Power Energy Systems
- GE Research
- GismoPower LLC
- Green Energy Enterprise Ltd. (GEEL Power)
- Green Lantern Development, LLC
- Grid Strategies LLC
- GridBright
- GridUnity
- Grow Greater Englewood
- GRUPO ROCHA
- GTI Energy

- IAEM
- ICE Thermal Harvesting
- Idaho National Laboratory
- InnoGrid
- Intengy Co, Inc.
- Iowa State University
- IPLC/Vantera [www.pf-one.com](http://www.pf-one.com)
- Jacobs Engineering
- K&A Engineering Consulting
- K. R. Saline & Associates, PLC
- LADWP
- Lehigh University
- LineVision
- Longroad Energy
- Marathon Digital Holdings
- Marquette University
- Mercury Solars LLC
- Michigan Energy Innovation Business Council
- Midwest Agrivoltaic Systems LLC
- Midwest Climate Collaborative
- Mid-West Electric Consumers Association
- Modern Grid Solutions
- National Grid
- National Grid Partners
- Navia Energy Inc
- NERC
- NextEra Energy Resources, LLC
- Oak Ridge National Laboratory
- OATI
- Ostendo Technoogies
- Override Industries
- Pearl Street Technologies

- [illegible]

- Sustainable Bitcoin Standard
- Sylvamo
- SynerGen Solar, LLC
- Synergics
- Texas A&M University
- Tom's Service
- TotalEnergies Renewables USA
- U.S. DOE
- Univeristy of New Mexico
- University of Alaska Fairbanks
- UT Austin
- Utah Office of Energy Development
- Utilidata. Inc.
- Virginia State Corporation Commission
- W International SC, LLC
- Wallaby Capital
- Wilson Sonsini Goodrich & Rosati, P.C.
- Xcel Energy Inc.

570

# i2X Individual Partners

380

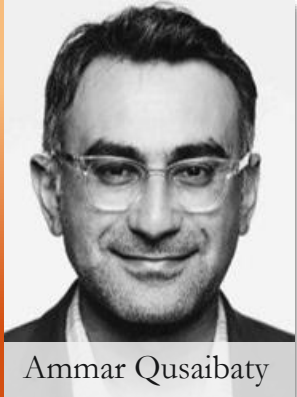
# Unique Companies



**INTERCONNECTION  
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U.S. DEPARTMENT OF ENERGY

# Leadership Team

SETO



Ammar Qusaibaty

WETO



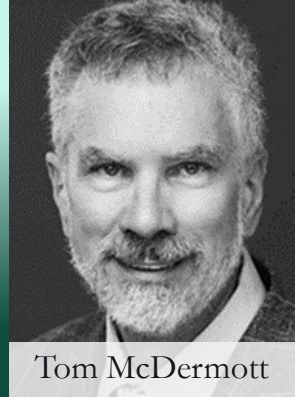
Cindy Bothwell

SETO



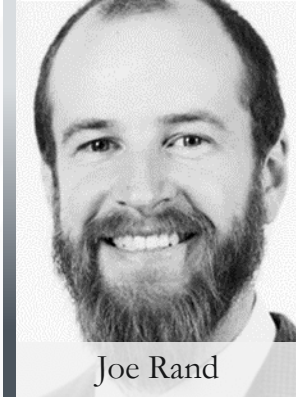
Shay Banton

PNNL



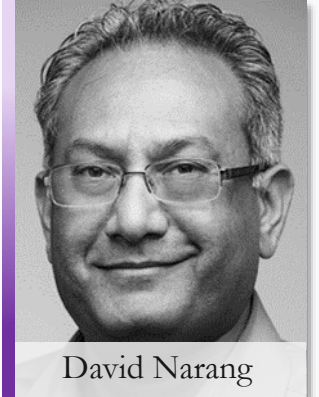
Tom McDermott

LBNL



Joe Rand

NREL



David Narang

SETO



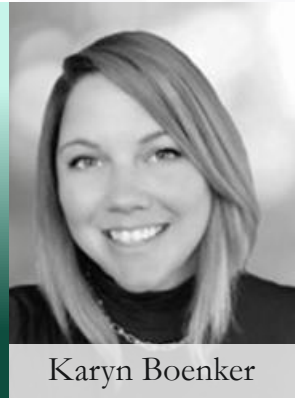
Michele Boyd

WETO



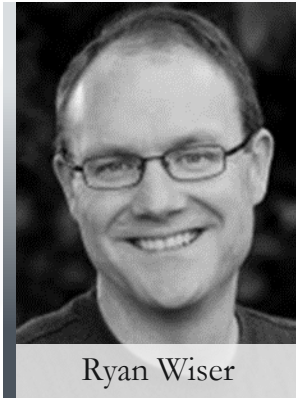
Jian Fu

PNNL



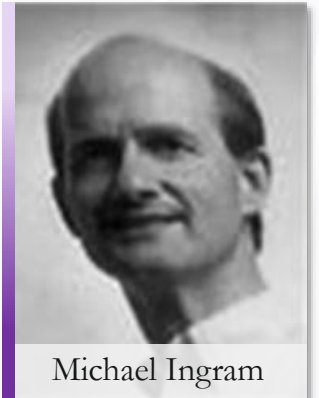
Karyn Boenker

LBNL



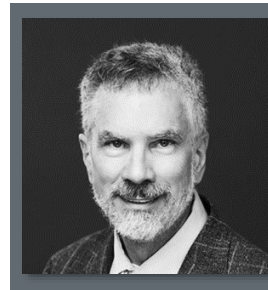
Ryan Wiser

NREL



Michael Ingram





Presenter

**Tom McDermott**

Chief Engineer & Solar Lead

Pacific Northwest National Lab

# 5-Year Strategic Roadmap



# 5-Year Strategic Interconnection Roadmap

50% cost and 50% schedule  
reduction in 5 years

- Expert-Informed Goal Setting
- Success Milestones & Research Gaps
- Transparent Key Performance Indicators
- Customizations for Size and Region
- Transition Planning for New Processes
- Buy-in, Adoption, and Updates

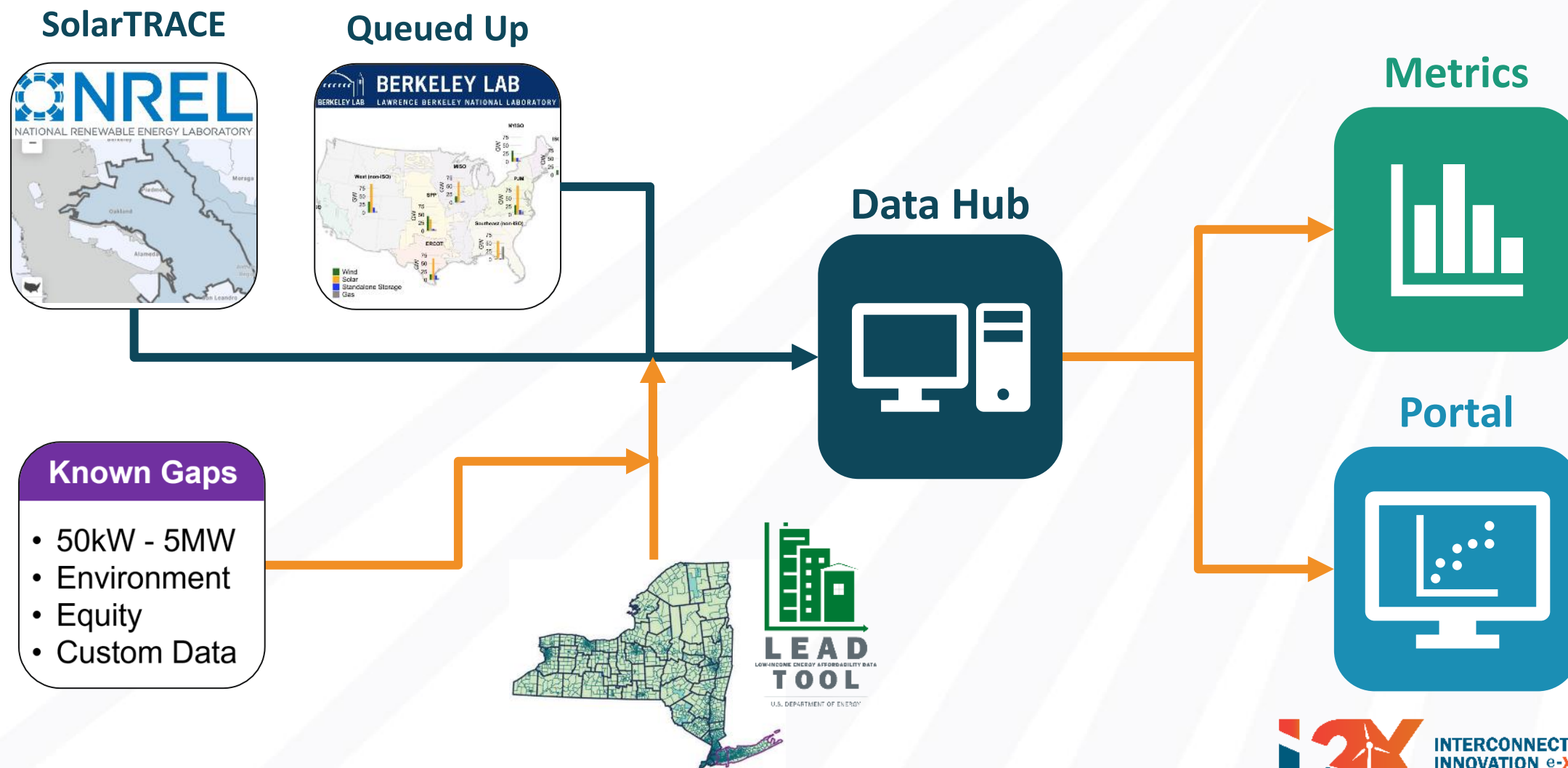
# Roadmap Outline

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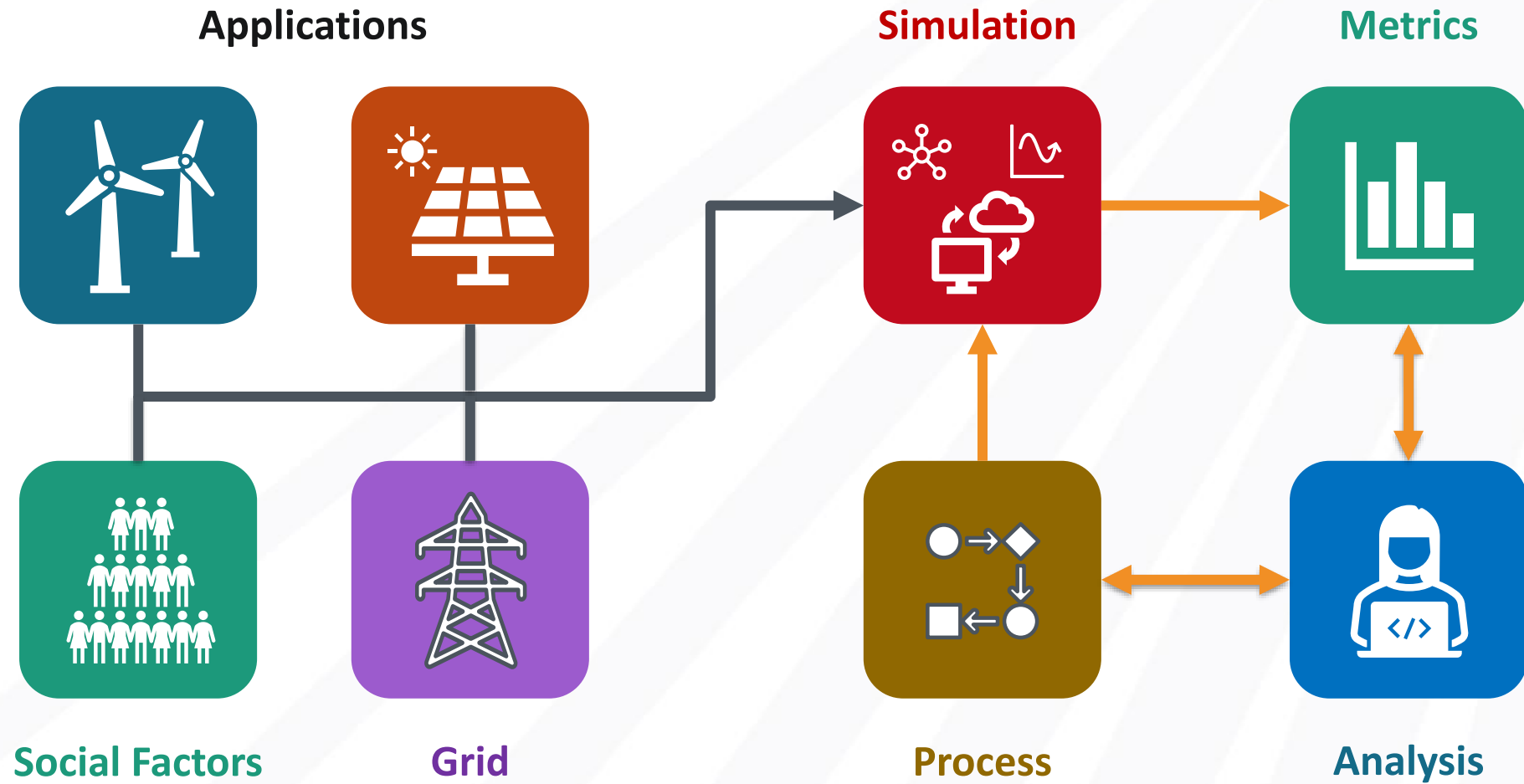
- Baseline for 2022, post-NOPR
- Discussion and justification of the 50% goal, and other new metrics for equity and environment
- Data collection plan; start-up and maintenance
- Sprint studies of better queue and alternative queue
- Model adoption language for new procedures
  - Include transitional periods
  - Include energy equity considerations beyond cost
- Pilots allowed within the FERC regulations
- Gaps in standards, regulations, and policies
- Yearly targets for metrics

\* Interconnection study guidelines referenced as separate documents.

# Filling Data Gaps to Support New Metrics



# Sprint Studies with Public Data and Tools

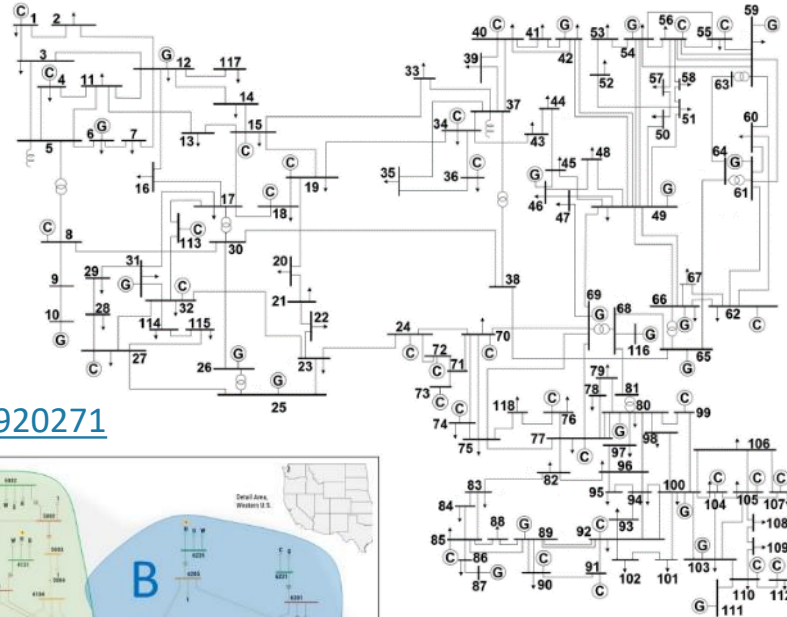




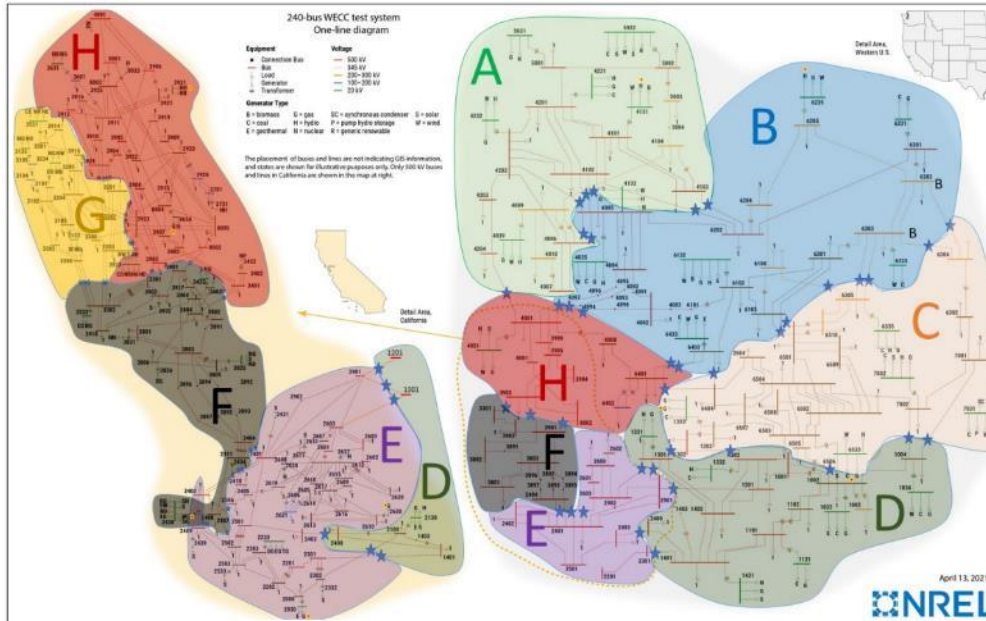
# Public Test Systems for Replicability

## IEEE 118-Bus with IBR

<https://doi.org/10.1109/TEM.C.2019.2920271>



## IEEE (proposed) 9500-node



[energy.gov/i2x](https://energy.gov/i2x)

## WECC 240-Bus with IBR

<https://www.nrel.gov/docs/fy22osti/82287.pdf>

## IEEE Low-Voltage Network

<https://doi.org/10.1109/PESGM.2014.6939794>

# Technical Guide(s) to Interconnection Studies

## Bulk Power Systems Guide

- Assumptions and Criteria
- Standards and Guidelines
- Data Collection
- When to use EMT Tools
- Model Development and Validation
- Analytical Steps and Automation
- Cluster Studies
- Re-study Criteria and Steps
- Post-Commissioning Models
- DER Aggregation
- Transmission Hosting Capacity
- Report Formats

## Distribution System Guide

- Assumptions and Criteria
- Standards and Guidelines
- Data Collection
- When to use EMT (or Dynamics)
- Model Development and Validation
- Analytical Steps and Automation
- Hosting Capacity Studies
- DER Impact Studies
- Multi-DER (Feeder Cluster) Studies
- Influence of Storage and Chargers
- Report Formats



# Two Sprint Studies with New Metrics

## A Better Queue

- Assume clusters per NOPR
- Incorporate new equity metrics
- Shared costs of system upgrades
- Cluster formation and management options
- Model building improvements
- Tool and re-study automation

## An Auction Process

- Discuss parallels to wideband spectrum auction
- Incorporate new equity metrics
- Identifying locations and quantities for new solar and wind resources
- Investing in renewable energy development zones (transmission)
- Requirements to participate
- Bid clearing mechanisms

# Example: Model Adoption of 1547-2018 & 1547.1-2020

- Benefits of the base standard still leave some important choices open:
  - Gold: high-penetration DER; category III ride-through, category B for Q, island time 5 seconds
  - Silver: BPS reliability; category II ride-through, category A for Q, island time 3 seconds
  - Bronze: minimal pre-2018; category I ride-through, category A for Q, island time 2 seconds
- Role of communications
  - Protection-grade for direct transfer trip (DTT)
  - SCADA-grade for permissive anti-islanding
  - AMI-grade or SCADA-grade for dispatch and grid services; should consider a facility management system to handle communication failures (gap in 1547-2018)
- Communication standards – utility chooses SunSpec Modbus, IEEE 2030\*, IEEE 1815 (DNP3)
- To justify DTT, perform a probabilistic risk assessment of unintended islanding greater than the 2-, 3-, or 5-second limit. Use 1-second load data. Consider permissive anti-islanding.
- Define any relevant edge cases, e.g., sub-transmission
- Which of these choices are regulatory? Which are left to the utility?
- Regulators could require the collection of interconnection process metrics for DER.

\* Partially incorporates IEC 61850

Also see: <https://www.nrel.gov/grid/ieee-standard-1547/guide-to-updating-interconnection-rules.html>



# Six Dimensions of Energy Equity

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1. Access, e.g., eligibility for / participation in programs
2. Affordability, e.g., energy cost burden
3. Decarbonization, e.g., renewable energy target
4. Environmental Impact, e.g., air quality improvement
5. Resilience, e.g., sustained critical loads during extreme events
6. Social Impact, e.g., community ownership

# Project Timeline

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- August 2022 – Data and metrics plans, first technical assistance (TA) outline, sprint study outlines, roadmap outline.
- December 2022 – First TA study completed.
- March 2023 – Interconnection studies guide completed. Draft roadmap completed. New data sources stood up.
- June 2023 – Sprint studies and roadmap peer reviewed and published.
- September 2023 – Second round of TA studies completed.
- Ongoing – Friday i2X office hours, peer learning groups, working groups, other events



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**Thank You!**

**Website: [energy.gov/i2X](https://energy.gov/i2X)**