

Members-Only Interconnection Standards Technical Assistance Workshop

Danielle Sass Byrnett – NARUC

Michael Ingram, David Narang – NREL

Ravi Subramaniam - IEEE

July 17, 2022

Welcome!

Start jotting down on sticky notes:

What are you worried about re:

DER interconnection?

(one thought per sticky)



Facilitators

- Danielle Sass Byrnett – NARUC
- Michael Ingram, David Narang – NREL

Guest Speakers

- Ravi Subramaniam – IEEE
- Kerry Worthington – BCS for DOE EERE

You!

- Name, organization, <5 words on your exposure to DER interconnection issues to date

Logistics & Safety

- Restrooms
- Emergency procedures
- Please initial the sign in sheet

Workshop Goals

1. Increase awareness of existing materials & support to help state PUCs move forward on DER interconnection activities
2. Help members make connections to colleagues with similar challenges (and solutions!)
3. Support development of future interconnection improvement cohorts (technical assistance)

NARUC & NREL thank the U.S. DOE Energy Efficiency & Renewable Energy Office and National Institute of Standards and Technology for their support of this workshop.

Agenda for Today's Interconnection Workshop

Time	Topic	Activity
8:30am	Welcome & Level-Setting <ul style="list-style-type: none">• Introductions• Objectives & agenda review	Journaling & Sharing <ul style="list-style-type: none">• What are you worried about re: DER interconnection?
9:10am	Existing Resources & Support <ul style="list-style-type: none">• When & how to approach updating stds• Hands-on with NREL-developed guides• IEEE resources	Walk-Through with Participant Questions <ul style="list-style-type: none">• Myth busting
10:25am	Break	
10:45am	Interconnection Challenges & Needs <ul style="list-style-type: none">• DOE's new I2X initiative• Identify needs for technical assistance	Brainstorm & Prioritize <ul style="list-style-type: none">• Topics requiring assistance• Activities that can be helpful
11:45am	Resources & Next Steps <ul style="list-style-type: none">• Available & forthcoming support	Update Your Calendars
12:00pm	Adjourn	

Today's Starting Points

Please jot down on sticky notes:
***What are you worried about re:
DER interconnection?***
(one thought per sticky)

Process / Policy Challenges

Technical Challenges

Other

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Interconnection Workshop

Michael Ingram and David Narang
NREL Power Systems Engineering Center

NARUC Interconnection Workshop
July 17, 2022

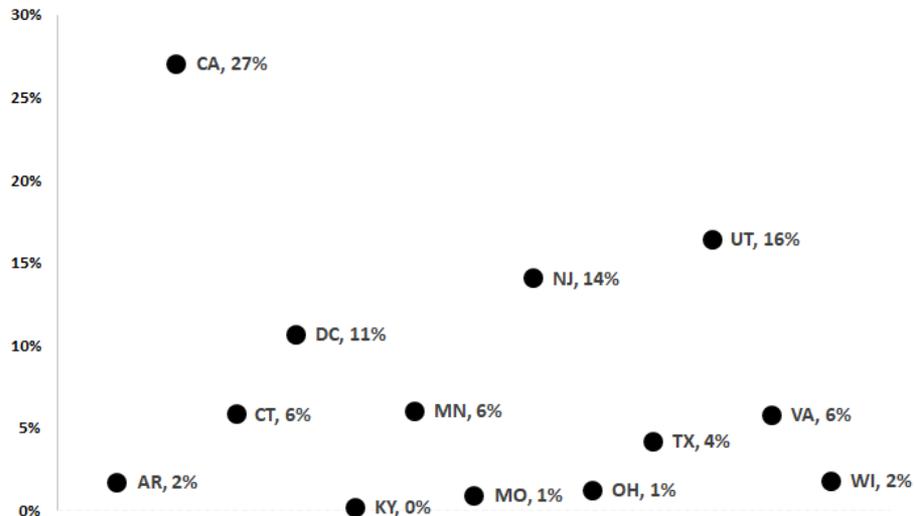
Acknowledgement

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under the Solar Energy Technologies Office Award Number 34808 and DOE SETO/WETO i2X project.

Context for DER Integration and Interconnection Landscape

2020 PV Installed Capacity and Forecast

PV Capacity as % of Total Generation Capacity (2020)



data sources: Wood Mackenzie/Solar Energy Industries Association US Solar Market Insight 2021 Year in review full report and U.S. Energy Information Administration <https://www.eia.gov/electricity/data.php#summary>

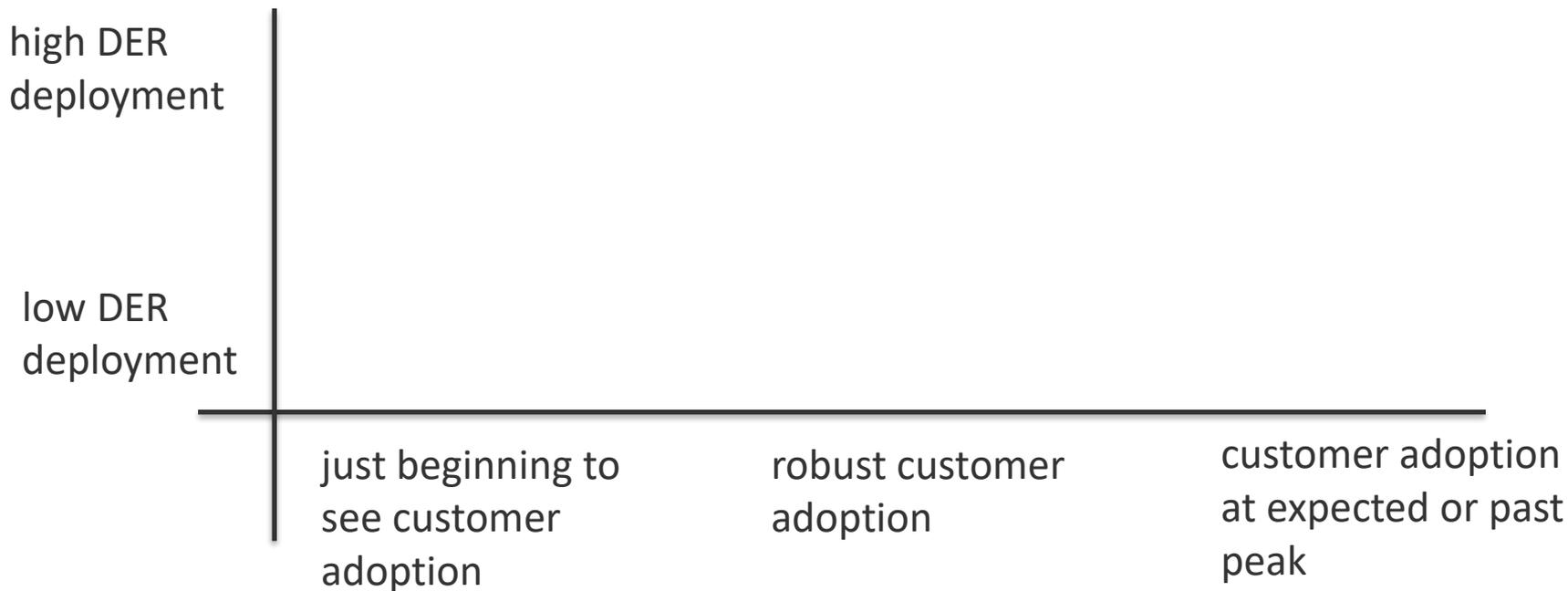
*Original data given in MWdc – converted to AC using 15% derate

State	2020 PV Capacity (MWac)*	PV Capacity as % of Total	2032 Forecast (MWac)*
AR	286	1.7%	2,667
CA	22,531	27.1%	56,244
CT	662	5.9%	2,669
DC	93	10.7%	580
KY	45	0.2%	2,522
MN	1,181	6.0%	6,150
MO	229	1.0%	2,442
NJ	2,688	14.1%	6,949
OH	377	1.3%	11,626
TX	5,839	4.2%	44,174
UT	1,660	16.5%	4,226
VA	1,733	5.8%	14,599
WI	332	1.8%	6,971

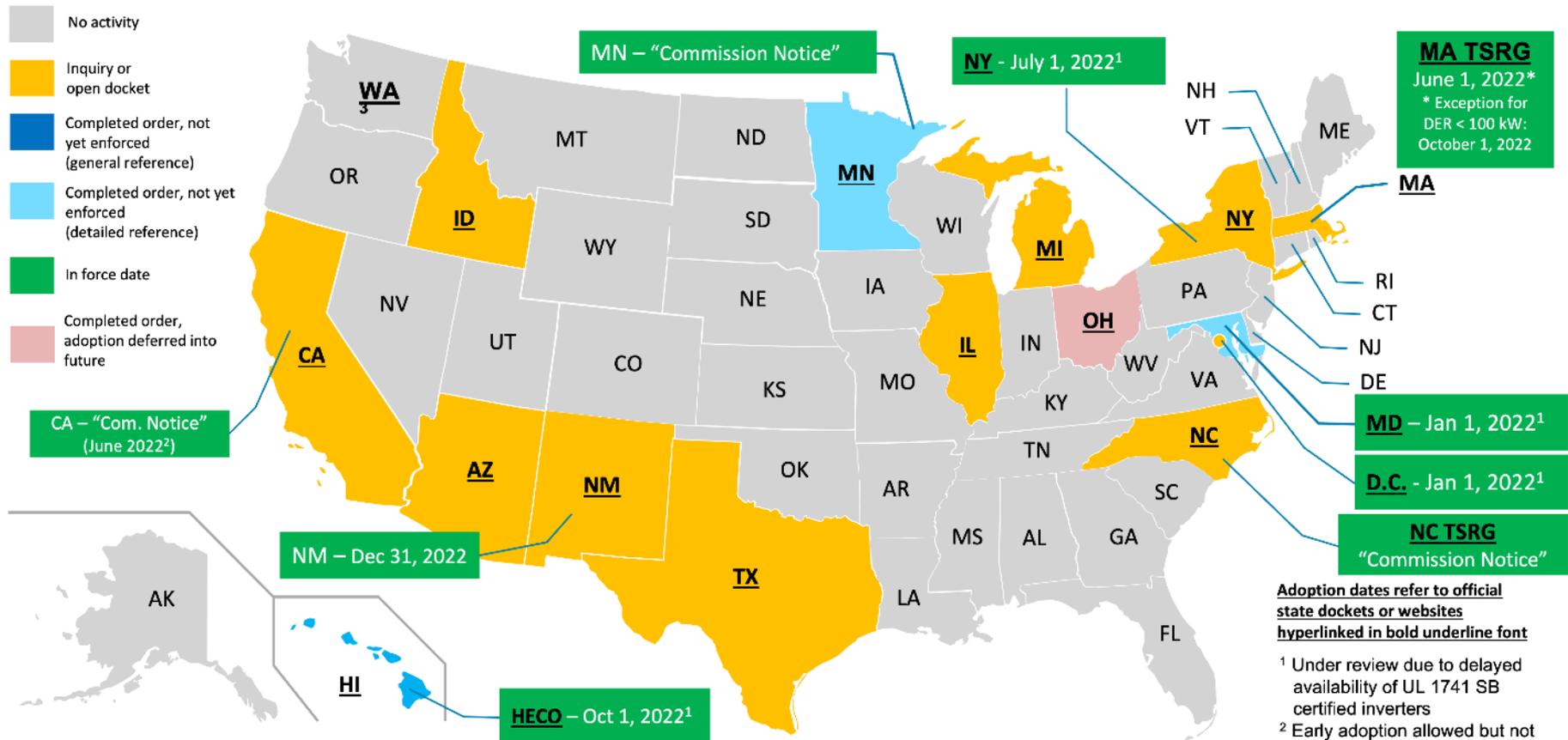
Group Activity

1: Where would you place yourself right now?

2: When do expect to reach the top right?



State Activity on IEEE Std 1547-2018



Adoption dates refer to official state dockets or websites hyperlinked in bold underline font

¹ Under review due to delayed availability of UL 1741 SB certified inverters
² Early adoption allowed but not required
³ Reference to "latest" IEEE 1547

Considerations for Developing Interconnection Rules Within a Broader DER Integration Framework



A Guide to Updating Interconnection Rules and Incorporating IEEE Standard 1547

Michael Ingram, Akanksha Bhat, and David Narang

National Renewable Energy Laboratory

www.nrel.gov/grid/ieee-standard-1547/guide-to-updating-interconnection-rules.html

Recommended Approach to DER Interconnection Rule Update

1. (Preplanning)

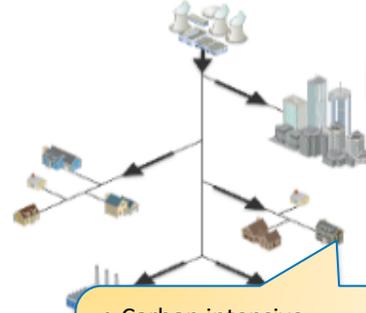
Determining the context, stakeholders, and major drivers

- **Internal motivations**
(e.g., reason for regulatory action, technical, market, policy)
- **Broader context**
(e.g., distribution system planning)
- **Stakeholders and roles**
(key decision makers)
- **Structure of the interconnection process** (e.g., performance indicators, data collection, process map, and analysis)
- **Procedural timeline**
- **Related/relevant procedures**

Develop an Internal Vision Aligned with Broader Context

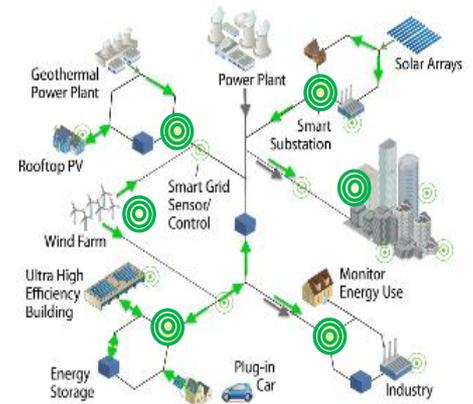
DER interconnection must be considered within the broader context of DER integration which includes national energy policy goals, market trends, technical requirements and stakeholder viewpoints and other efforts such as grid modernization.

Current Power System



- Carbon intensive
- Large generation
- Central control
- Highly regulated.

Future Power Systems



Our evolving power system context:

- New energy technologies and services
- Increasing penetrations of variable renewables on the grid
- New communications and controls (e.g., smart grids)
- Electrification of transportation
- Integrating distributed energy storage
- A modern grid needs increased system flexibility.
- Updated standards—e.g., IEEE Std 1547-2018, IEEE Std 2800 (distributed energy resources [DERs] as grid assets).

DRIVERS

- Increased variable generation
- More bidirectional flow at distribution level
- Increased number of smart/active devices
- Evolving institutional environment.

Determine how you want to use DER in early stages

Technical aspects of DER interconnection regulations are directly linked to the intended use of DER capabilities. Therefore, the intended use should be clearly defined PRIOR to developing technical interconnection aspects.

reactive power support
ride-through AGIR
interoperability
power quality ROCOF
performance categories
area EPS faults
LVRT
momentary cessation
synchronization
constant power factor
Intentional islanding

volt-var

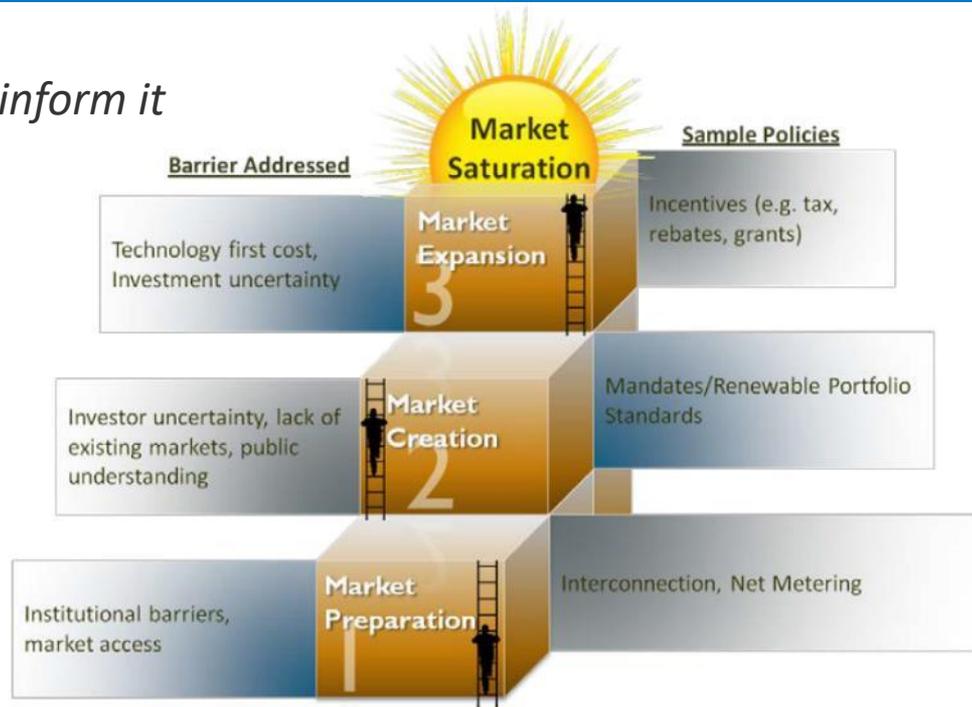
composite

communications protocols

Coordinate Requirements With Policy and DER Deployment

Regulators may not set policy but should inform it

Regulators should consider developing technical interconnection requirements in coordination with a “policy stacking” framework sensitive to DER deployment maturity levels *(needs early and continued coordination with the other entities responsible for policy setting and market development)*



Example generalized policy stack for DER

Image source: Krasko and Doris, 2012

References:

Strategic Sequencing for State Distributed PV Policies: A Quantitative Analysis of Policy Impacts and Interactions, V.A. Krasko and E. Doris, 2012

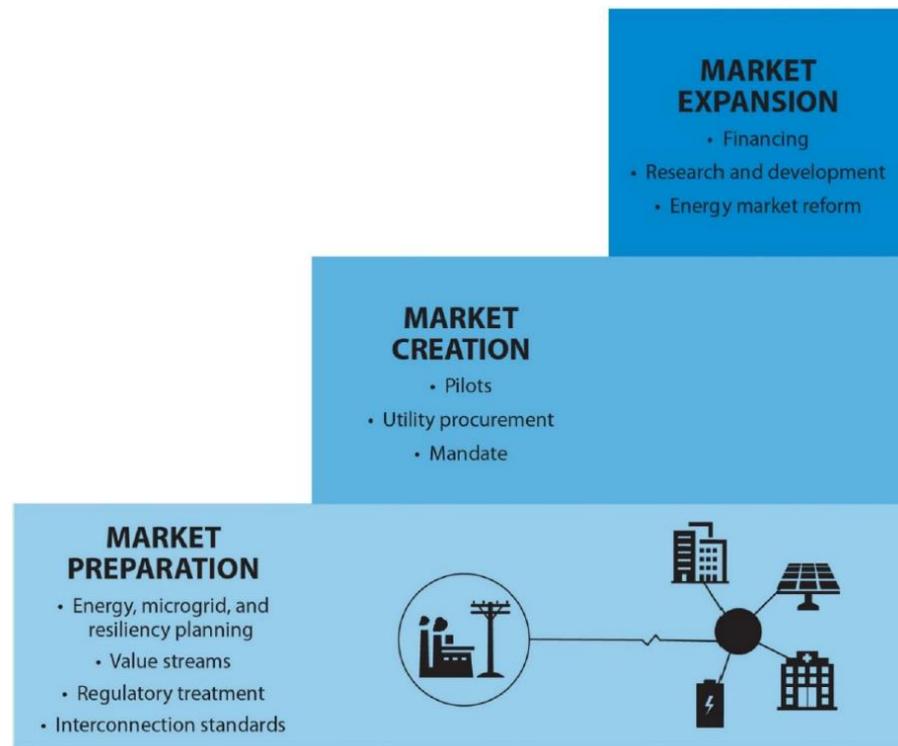
<http://www.osti.gov/servlets/purl/1054826/>

“Policy Building Blocks: Helping Policymakers Determine Policy Staging for the Development of Distributed PV Markets”, E. Doris, 2012,

<https://www.nrel.gov/docs/fy12osti/54801.pdf>

Consider all Types of DER Desired/Planned/Market-Indicated

Different types of DER will likely require specific consideration of their policy stack, market adoption characteristics, intended use, and technical requirements.



Example policy stack for microgrids

Image source: Cook, 2018

References:

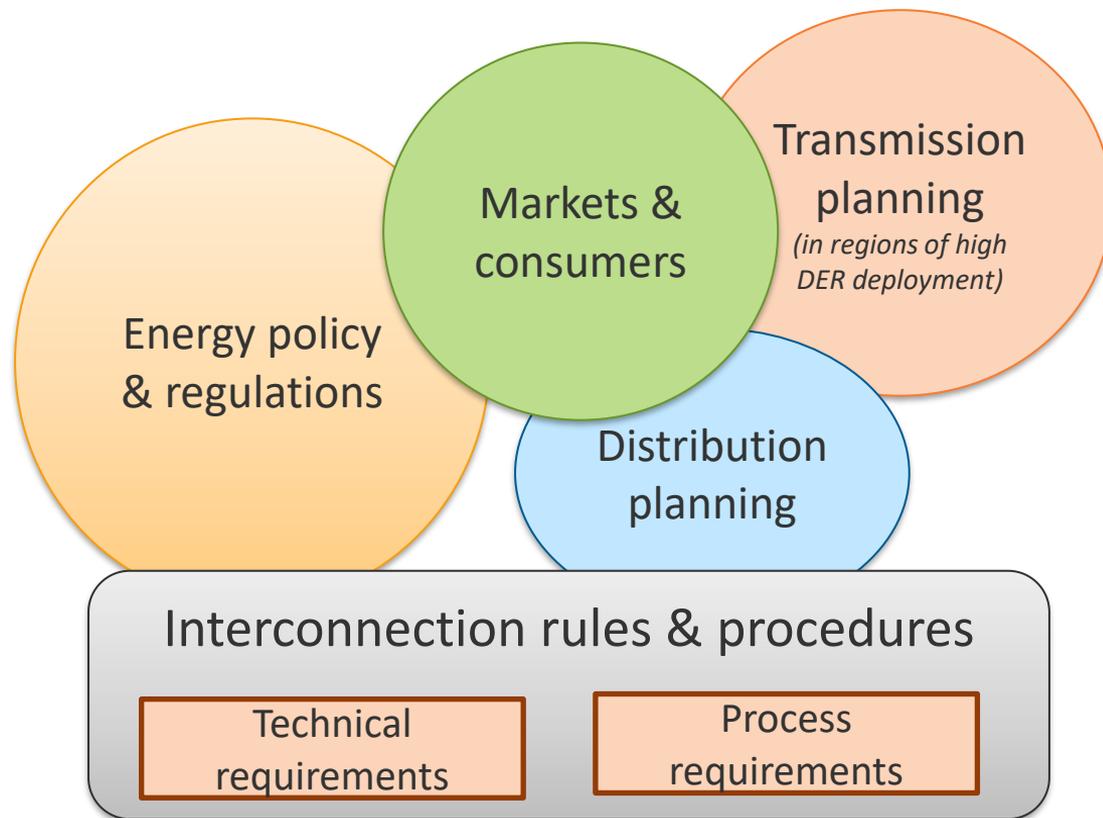
- “Check the Stack: An Enabling Framework for Resilient Microgrids”, Cook et. al., 2018, <https://www.nrel.gov/docs/fy19osti/71594.pdf>

2. Developing the DER interconnection rule

- **Broad goals for technical requirements**
(e.g., safety, reliability, power quality, protection, affordability, markets, regulatory compliance)
- **IEEE Std 1547-specific**
(e.g., reactive power support, fault ride-through, interoperability, intentional islanding, energy storage)
- **Jurisdiction/utility-specific**
(e.g., metering, protection)
- **Other coordination required**
(e.g., bulk power sys.)

Use of DER Capabilities Evolves over Time

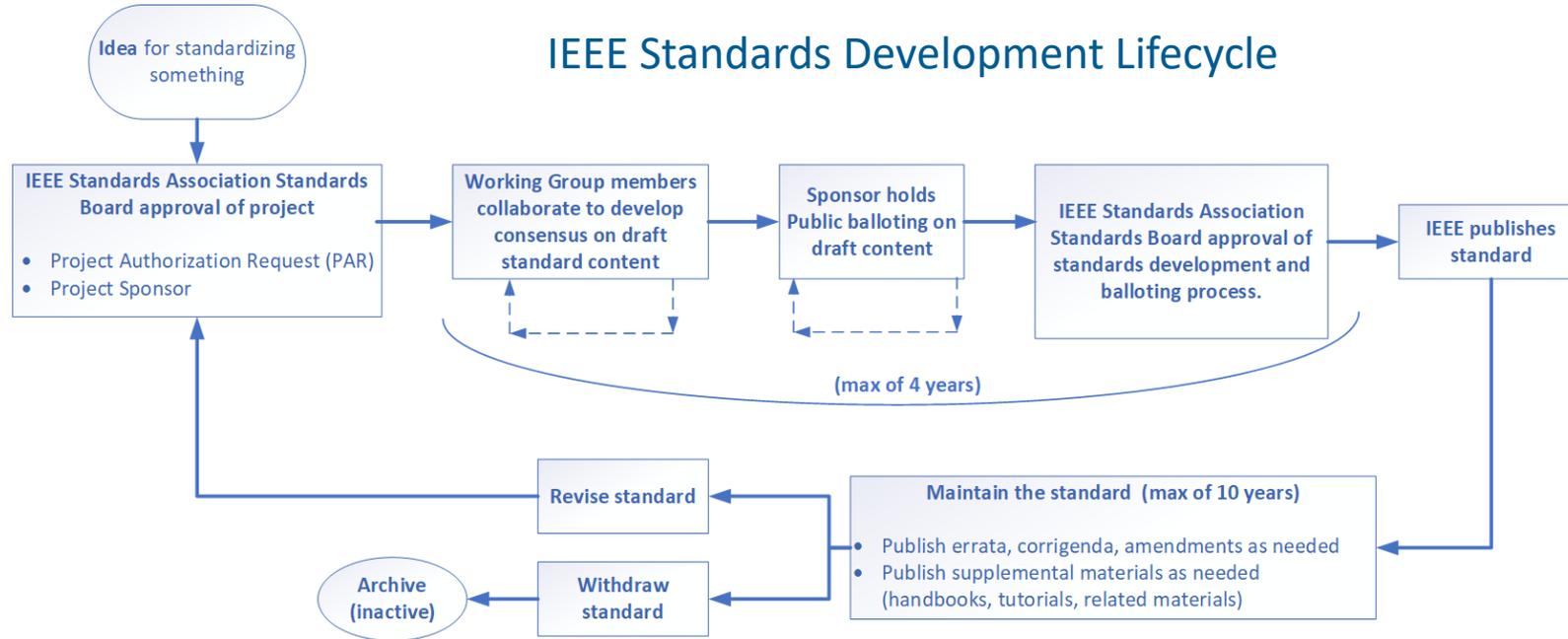
DER interconnection process and technical issues often overlap and are not easily segregated, and regulations must consider and evaluate issues for both types of topics.



References:

Rely on the Latest National Standards

IEEE Standards Development Lifecycle



Source: based on <https://standards.ieee.org/develop/develop-standards/process.html>

Rely on the latest (most up-to-date) national technical standards.

e.g.,

- IEEE Std 1547-2018
- IEEE Std 2800-2022

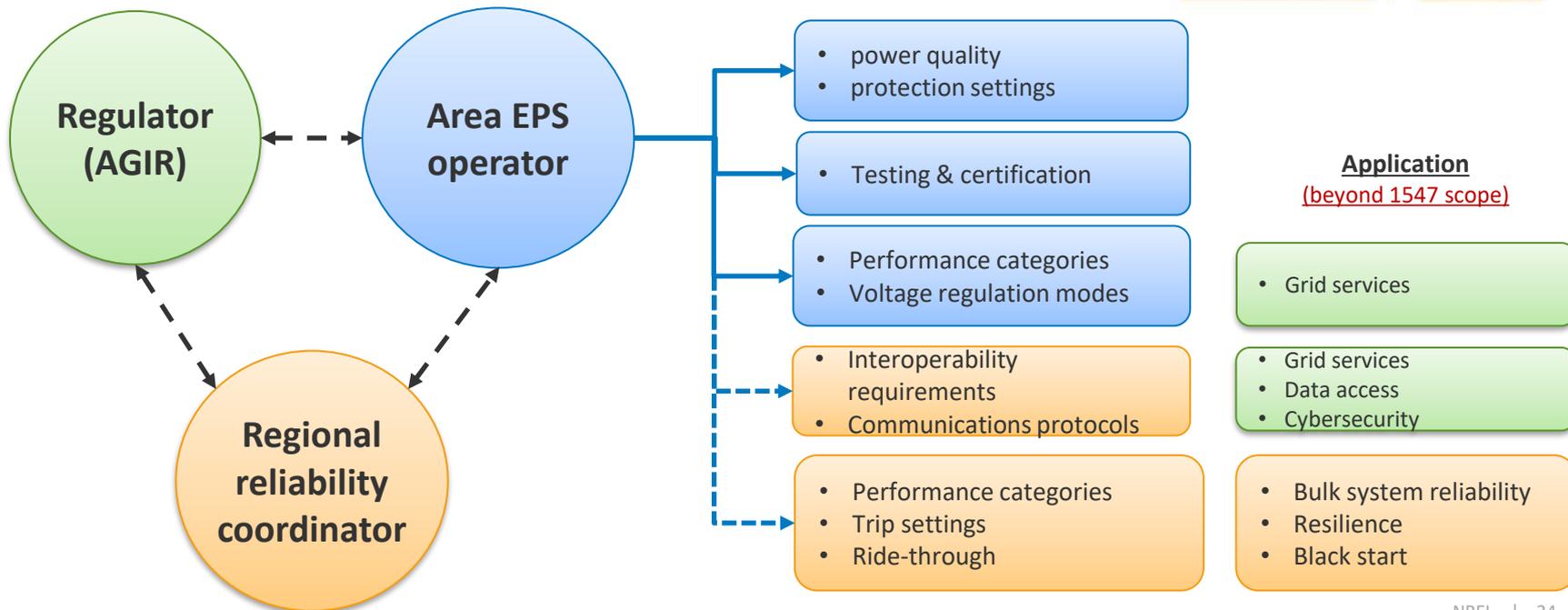
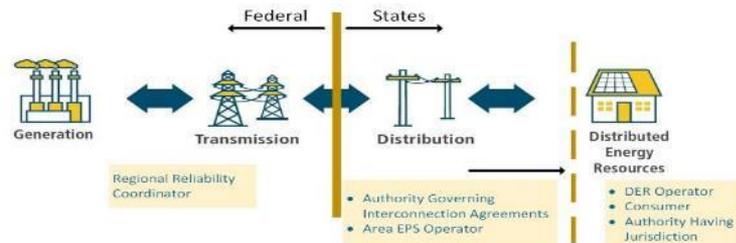
The National Association of Regulatory Utility Commissioners (NARUC) resolution in February 2020 recommends state commissions act to adopt and implement the revised standard. <https://pubs.naruc.org/pub/E86EF74B-155D-0A36-3138->

[B1A08D20E52B](#)

Ref: IEEE standards process overview: <https://standards.ieee.org/develop/index.html>

Coordination is Required for Utilization of Certain DER Capabilities

Closer and earlier coordination is required with relevant stakeholders for using and applying capabilities that affect other functions/ across jurisdictional boundaries



Recommended Approach to DER Interconnection Rule Update

1. (Preplanning)

Determining the context, stakeholders, and major drivers



2. Developing the DER interconnection rule



3. Maintaining and revising

- **Internal motivations**
(e.g., reason for regulatory action, technical, market, policy)
- **Broader context**
(e.g., distribution system planning)
- **Stakeholders and roles**
(key decision makers)
- **Structure of the interconnection process** (e.g., performance indicators, data collection, process map, and analysis)
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(e.g., metering, protection)
- **Other coordination required**
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- **Triggers for updates**
- **Scope of update**
- **Maintainability of the rule**

Suggested Reading for Regulators

Interconnection Rule Update

Setting the Scope of the
Interconnection Rule

Considerations for Technical
Requirements

Considerations for Use of
IEEE Std. 1547-2018



<https://www.nrel.gov/grid/ieee-standard-1547/curriculum-agirs.html>

Live walk-through of existing educational resources

<https://www.nrel.gov/grid/ieee-standard-1547/curriculum-agirs.html>

IEEE Std 1547-2018 Decision Matrix

Topic/1547 Clause	AEPSO	DERO	RRC	AGIR
General requirements (Clause 4)	Lead	Coord.	Limited Consult	
Enabling/utilization of reactive power and voltage/power control capabilities (Clause 5)	Lead	Coord.		Consult? Based on policy and market goals? enabling voltage regulation, specification of which capabilities, grid services desired?
DER response to area EPS abnormal conditions (Clause 6 & 7)	Lead	Coord.	Consult (BPS req.)	Consult? Based on policy and market goals? Specification of “robustness” of response. Cat I, II, III
Islanding	Lead	Coord.		Consult? Based on policy and market goals, stakeholder input, microgrid application and uses.
Enabling/Utilization of interoperability capabilities (Clause 10)	Lead	Coord.	Consult? (BPS req.)	Consult? Based on policy and market goals, stakeholder input, RRC situational requirements (if noted).
Test and Verification*	Lead	Lead		

AEPSO (area EPS operator), DERO (DER operator), RRC (regional reliability coordinator),

AGIR (authority governing interconnection requirements, typ. regulator), OEM (equipment manufacturer, e.g., inverter)

*type testing is led by the OEM

Reflections

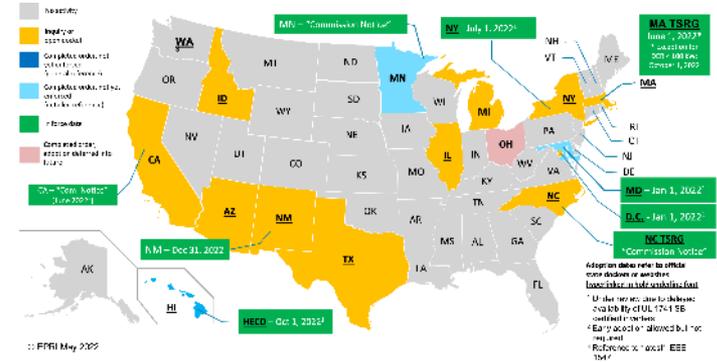
Myth Busting!
What worries can you let go?

Highlights of other public education efforts

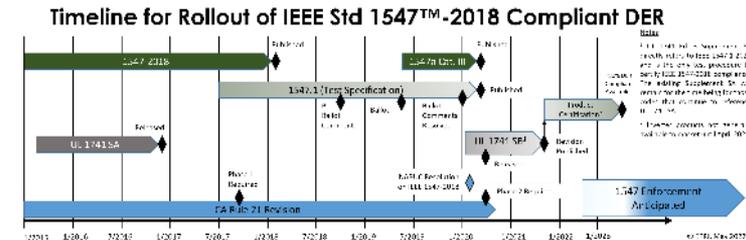
- EPRI U:
Public (with free EPRI account):
<https://www.epri.com/#/epri-u/courseslang=en-US>
- IREC
 - Publications: <https://irecusa.org/blog/tag/ieee-1547/>
 - Informal inverter manufacturer discussion forum (FIIGI, typ. weekly)
- others?

IEEE Standards Coordinating Committee 21 (SCC21) Resources and Outreach

- **Public web site on IEEE Std 1547**
<http://sites.ieee.org/sagroups-scc21/standards/1547rev/>
 - Discount/free copies of the standard for select stakeholders (e.g., regulators)
 - Education and training/reading material – papers, webinars
 - “approved” presentation content for SMEs
 - Catalog of ISO/RTO T&D coordination activities
 - State activity map (maintained ~ quarterly)
 - Inverter rollout timeline (“regularly” maintained)
- **Informal industry/stakeholder coordination calls (quarterly)**
- **Coordination with other IEEE societies, committees & related standards (constant)**



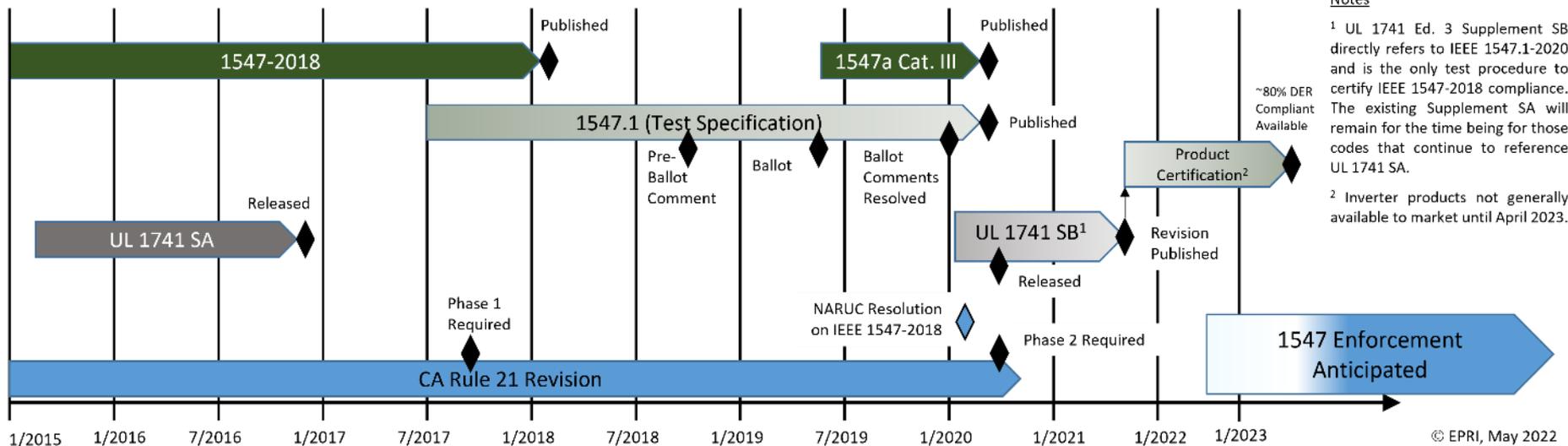
State activity map



Inverter rollout timeline

IEEE Std 1547-2018 Compliant DER Rollout Timeline

Timeline for Rollout of IEEE Std 1547™-2018 Compliant DER



Recurring Reliability Issues with IBRs

- Unexpected tripping, cessation of active power, oscillations, etc.
- Mis-application of IEEE 1547 standard for Transmission connected resources
- Analysis found **opportunity for standardization** of IBR performance to maintain grid reliability



Slide courtesy of IEEE 2800 leadership team

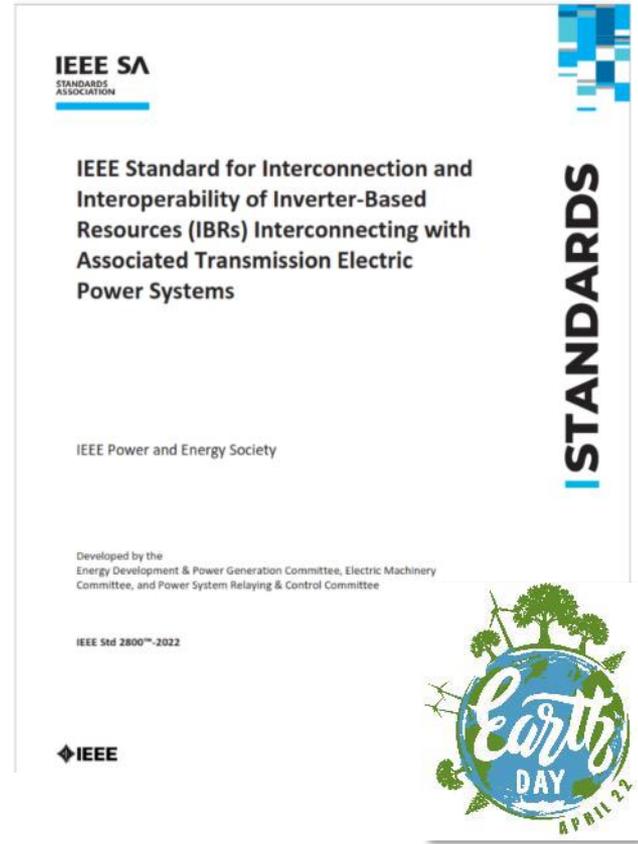
Source: NERC, 2017-2022

Summary of IEEE 2800 Standard

- ❑ The standard **harmonizes** Interconnection Requirements for Large Solar, Wind and Storage Plants
- ❑ It is a **consensus-based** standard developed by over ~175 Working Group participants from utilities, system operators, transmission planners, & OEMs over 2 years
- ❑ It has successfully passed the IEEE SA ballot among 466 SA balloters (**>94% approval**, >90% response rate)
- ❑ **Published on April 22, 2022 (Earth Day)**

More Info at <https://sagroups.ieee.org/2800/>

Slide courtesy of IEEE 2800 leadership team



Available from IEEE at <https://standards.ieee.org/project/2800.html> and via IEEEExplore: <https://ieeexplore.ieee.org/document/9762253/>

Guest speaker

- Ravi Subramaniam, IEEE

Break time! Return at 10:45am

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Interconnection Challenges & Needs

- DOE's new I2X initiative
- Identify needs for future / additional technical assistance



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

Selected Slides from Launch Webinar

June 7th, 2022

an EERE collaboration between SETO & WETO

~15 mins



Program Organization & Focus Areas

DOE Solar & Wind
Energy Technologies
Offices of EERE



Program Owner &
Lead, lead facilitator

Pacific Northwest
National Laboratory
(PNNL)



Lab lead, project
management,
stakeholder engagement,
TA, communications

Lawrence Berkley
National Laboratory
(LBNL)



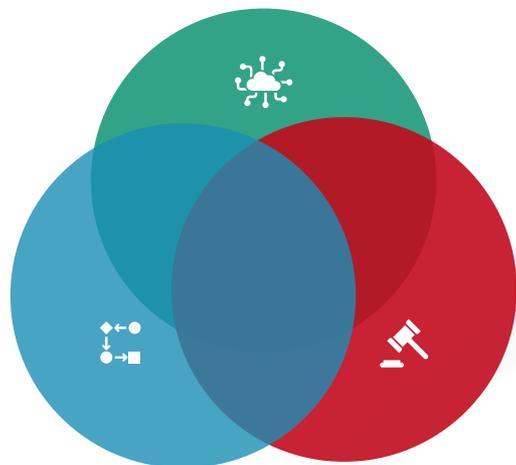
TA – transmission,
data collection &
analysis

National Renewable
Energy Laboratory
(NREL)



TA – distribution, data
collection & analysis

Prior 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

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

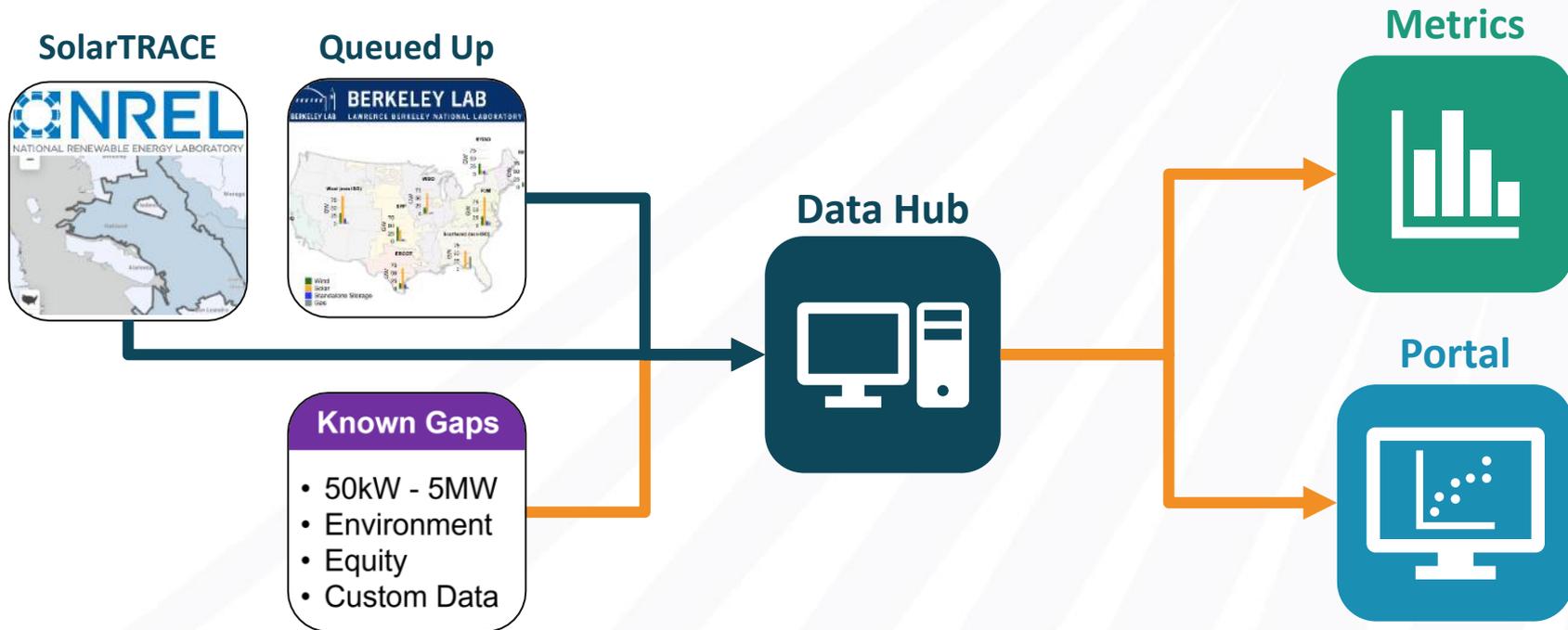


For-Profits

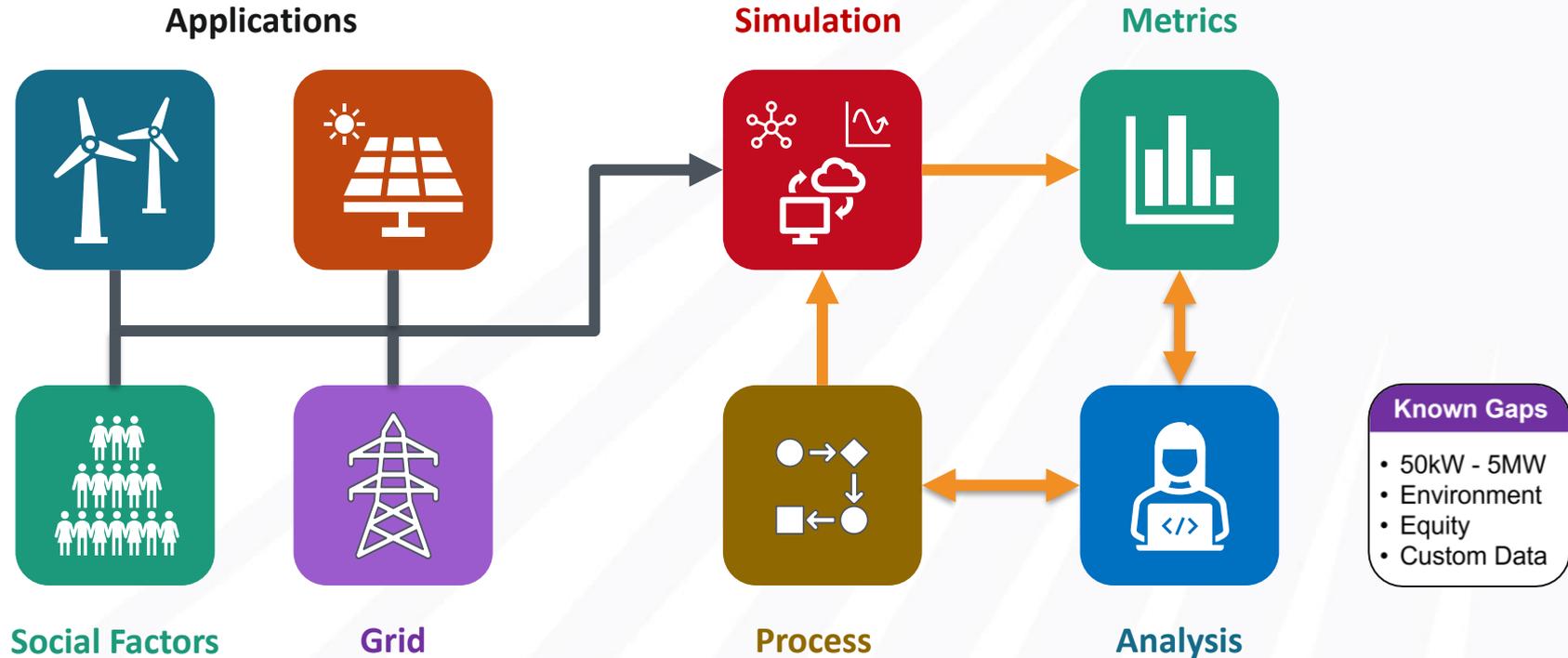
Developers / Consultants / Off-Takers / Solutions Providers

Work Focus Areas

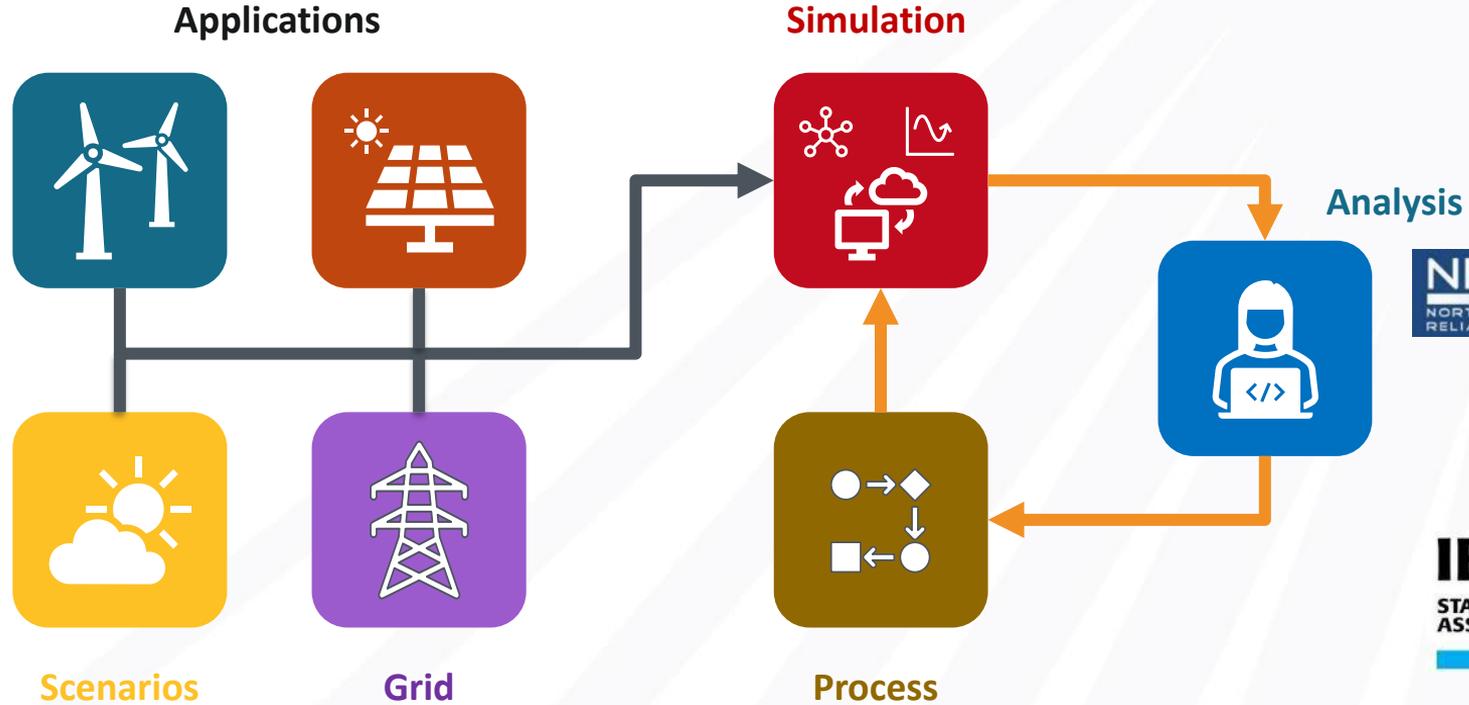
Filling Data Gaps to Support New Metrics



Sprint Studies with Public Data and Tools



Technical Guide to Interconnection Studies



5-Year Strategic Interconnection Roadmap

- 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

i2X “Information Clearinghouse”



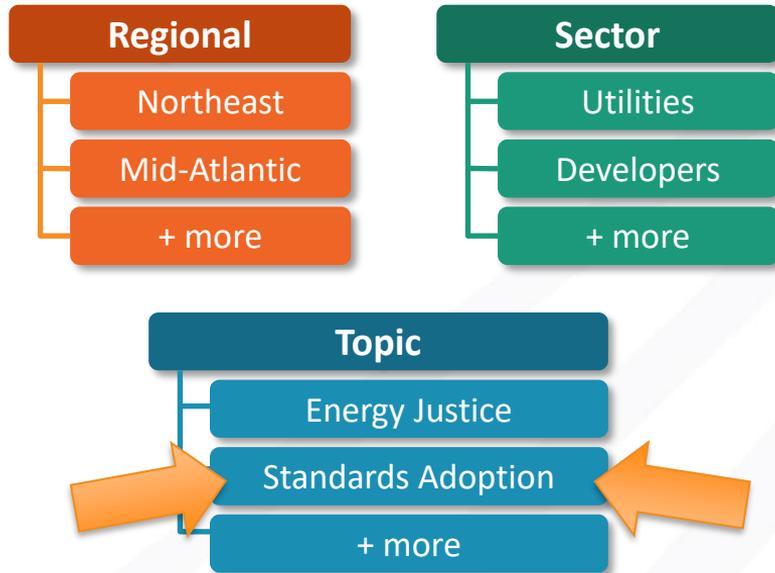
BOOKMARK THE WEBSITE

Be sure to visit the i2X website for any and all information regarding the program: energy.gov/i2x

The image shows a screenshot of the i2X website homepage. The main header includes navigation links for 'Home', 'About EERE', 'Initiatives', 'Resources', 'Energy Efficiency', 'Renewable Energy', and 'Sustainable Transportation'. Below the header is a large blue banner with the text 'i2X: The Interconnection Innovation e-Xchange' and a 'Join i2X >' button. To the right, a callout box titled 'About the Interconnection Innovation e-Xchange (i2X)' provides more details. The callout box text reads: 'Interconnection Innovation e-Xchange (i2X) About Interconnection Innovation e-Xchange (i2X) Led by U.S. Department of Energy's (DOE) Solar Energy Technologies Office (SETO) and Wind Energy Technologies Office (WETO), the Interconnection Innovation e-Xchange (i2X) convenes diverse stakeholders involved in the interconnection of solar energy, wind energy, and energy storage resources to facilitate peer-learning and knowledge exchange and inspire new interconnection ideas and capabilities. i2X is supported by the Pacific Northwest National Laboratory (PNNL), National Renewable Energy Laboratory (NREL), and Lawrence Berkeley National Laboratory (LBNL). Interconnecting solar energy, wind energy, and energy storage resources to the grid requires navigating complex regulatory structures and technical impact assessments, which vary by jurisdictional authorities of the distribution or transmission grid systems. Current interconnection procedures are not designed to accommodate the deployment of hundreds of gigawatts of solar and wind energy resources needed each year to meet clean energy goals.' Below the callout box is the i2X logo and the text 'INTERCONNECTION INNOVATION e-XCHANGE U.S. DEPARTMENT OF ENERGY'.

Engagement Mechanisms

Working Groups

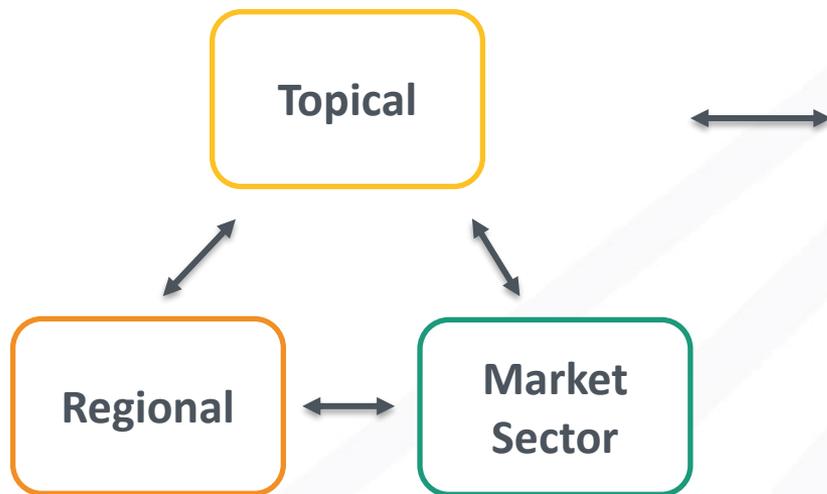


Engagement Platform



Planned Cross-Coordination

i2X Working Groups & Roadmap



Other DOE/Lab Assistance Work Efforts

- Market Information/Reports
- GMLC State Technical Assistance
- Office of Clean Energy Demonstrations (OCED) Efforts, e.g., Rural-Remote TA
- Labs Support for Technical Standards Development, Leadership & SME Engagement

Potential Workgroups to Date – Distribution Standards Focus

Topical Workgroup

- Technical Standards Implementation – **Distribution** (IEEE Std 1547)

Market Sector Subgroups

- Regulators
- Developers
- Utilities
- Govt. (e.g., FEMP)

“Urgent Need” or Targeted Focus Areas (potential application of i2X Rapid Technical Assistance and Sprint Studies)

- Safety/anti-islanding/alternatives to direct transfer trip
- Data access & privacy
- Energy Equity/Justice Focus
 - Remote-Rural?
 - Tribal?

Regional Subgroups

- Geographical?
- Utility territory?
- By deployment maturity?

i2X Technical Assistance

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

- **Interconnection Office Hours**
 - Direct Access to i2X Leadership
- **Preliminary i2X Working Groups**
 - Energy Justice Working Group
 - IEEE 1547-2018 Adoption Support Working Group
 - Experienced Peer Learning Webinar Series
- **Additional Topics For Consideration**
 - Implementing Queue Management Methods
 - Accelerated Tool Development and Deployment
 - Best Practices and Training
- **Others? - Suggest a topic!**

Workshop Team Activity

Prioritization & Discussion

What worries are still going to keep you up tonight?

1. Jointly develop list of current interconnection challenges for PUCs
2. Prioritize
3. Discuss what types of assistance would be most helpful

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11:45am	Resources & Next Steps <ul style="list-style-type: none">• Available & forthcoming support	Update Your Calendars
12:00pm	Adjourn	

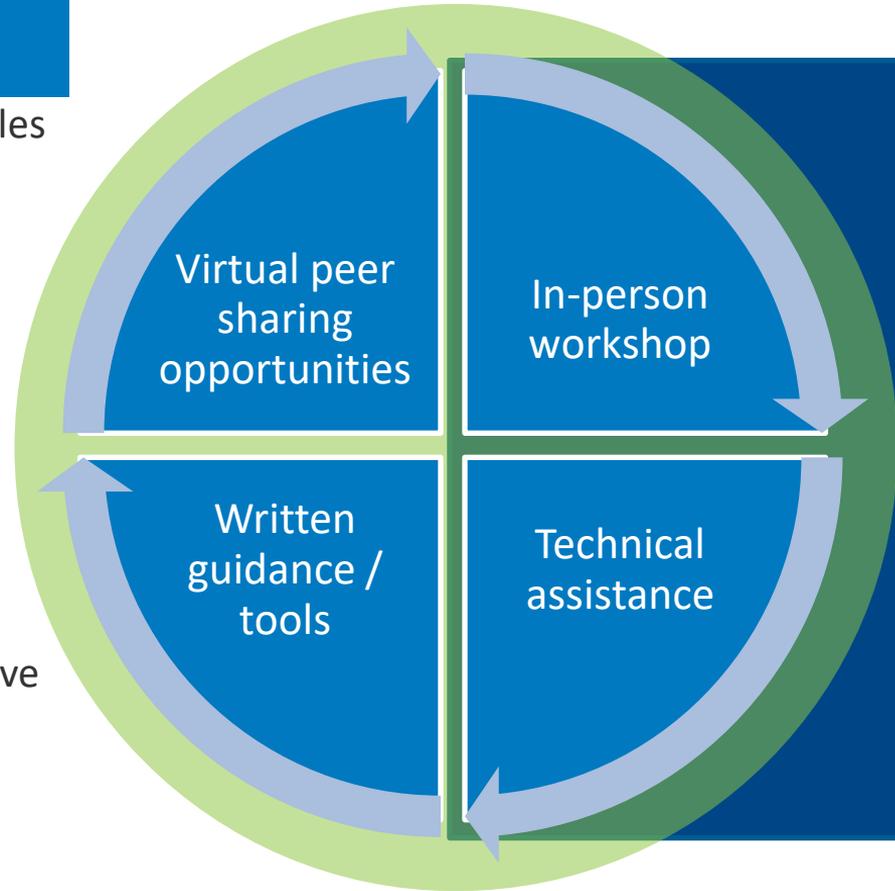
Resources & Next Steps

Guest speaker

- Kerry Worthington, BCS for DOE EERE

UPCOMING NARUC EVENTS & OPPORTUNITIES

- Members-only Regulators' Roundtables on DER Interconnection Processes
virtual, Summer 2022
- NARUC-NASEO DER Integration & Compensation Initiative:
DER Interconnection Workshop
Washington, DC, Sept. 20-21, 2022
- NIST Smart Grid interoperability technical assistance
ongoing
- NARUC Grid Data Sharing Collaborative
framework for demo in Spring 2023



NARUC
Center for
Partnerships
& Innovation

Contact us for existing and future resources on DER
and BPS interconnection

Danielle Sass Byrnett
Senior Director
dbyrnett@naruc.org
202-898-2217

Jeffrey Loiter
Technical Director
jloiter@naruc.org
202-656-2128

Tanya Paslawski
Partnerships & Policy Director
tpaslawski@naruc.org
517-819-9683

Kiera Zitelman
Technical Manager
kzitelman@naruc.org
202-898-2212

www.naruc.org/cpi

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

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

Partner Benefits

- Access to the Online Stakeholder Platform
- Participate in Working Groups
- Direct Access to Interconnection Experts
- Workshops and Informational Resources
- Feedback on Deliverables
- Technical Assistance Opportunities



PARTICIPATE IN UPCOMING EVENTS

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



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

Upcoming: Rural & Remote TA

Program Design In Progress



Michael Ingram | Michael.Ingram@NREL.gov

David Narang | David.Narang@NREL.gov



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

Thank You!

Website: energy.gov/i2X