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Distributed Energy Resources Interconnection: Overview of Process, Data and Queue Management

DOE Energy Innovator Fellows Informational Webinar

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January 21, 2026

Outline

- DOE i2X DER Interconnection Initiative
- Importance of Improved DER Interconnection Data
- Overview of Interconnection Process
- Data Limitations and Gaps
- Insights Into U.S. Interconnection Data
- Actions to Improve DER Interconnection Data, Timelines, and Queues

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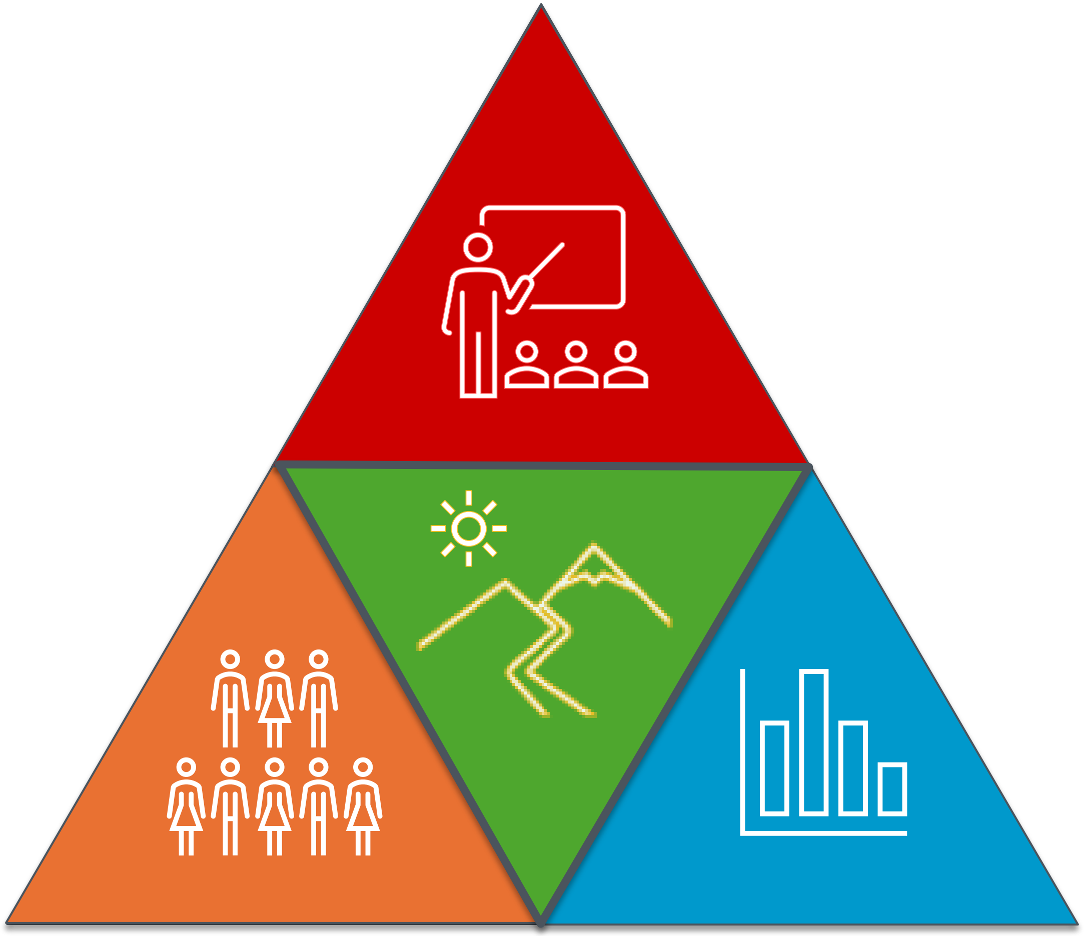
DOE's i2X DER Interconnection Initiative

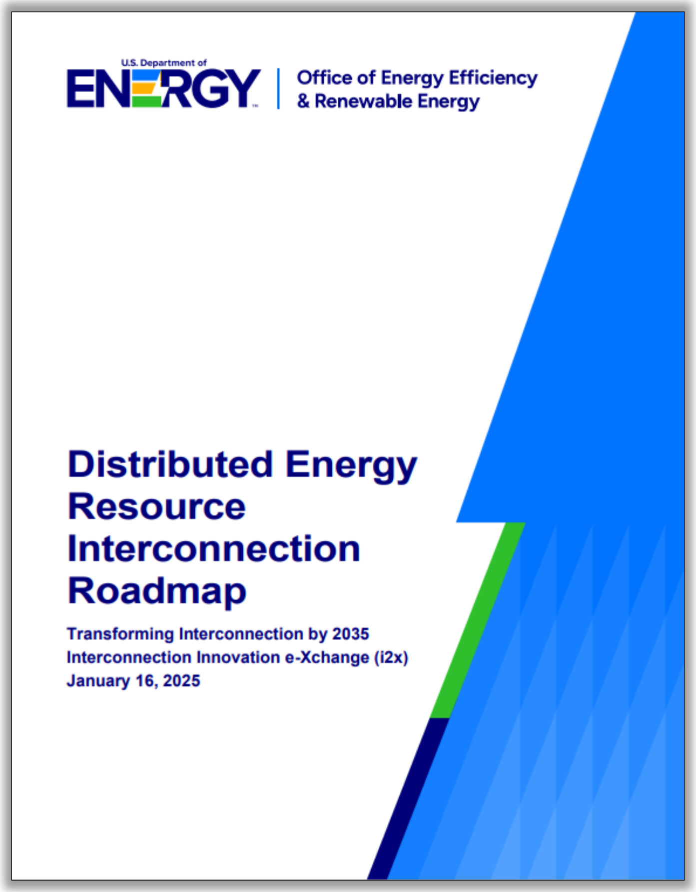
DOE's i2x Initiative

Key elements of the U.S. Department of Energy (DOE) Interconnection Innovation eXchange (i2x)

- **Strategic Roadmaps**
- **Stakeholder Engagement**
- **Data & Analytics**
- **Research & Innovation**



DOE i2X DER Interconnection Roadmap


U.S. Department of ENERGY | Office of Energy Efficiency & Renewable Energy

Distributed Energy Resource Interconnection Roadmap

Transforming Interconnection by 2035
Interconnection Innovation e-Xchange (i2x)
January 16, 2025

- The DOE i2x DER Interconnection Roadmap serves as a guide to actions that can be taken in the near-term to implement solutions designed to address current distributed energy resources (DER) interconnection challenges.

Distributed Energy Resource Interconnection Roadmap

Join i2X Connect at: https://groups.energy.gov/i2xconnect/

i2X DER Interconnection Roadmap Solutions

Goal 1: Increase data access, transparency, and security for interconnection
- Data sharing guidelines
- Strategic use of automation
- Broaden use of hosting capacity analysis

Goal 2: Improve interconnection process and timeline
- Queue management
- Inclusive and fair processes
- Workforce development

Goal 3: Promote economic efficiency in interconnection
- Cost allocation
- Coordination between interconnection and grid planning
- Interconnection studies

Goal 4: Maintain a reliable, resilient, and secure grid
- Interconnection models and tools
- Interconnection standards

i2X DER Roadmap 2030 Success Targets

1. Shorter DER interconnection times
2. Higher DER interconnection completion rates
3. Better availability of interconnection data
4. No bulk power system disturbance events exacerbated by inaccurate DER modeling
5. Lower Customer Average Interruption Duration Index (CAIDI)

	Target	System Size*	2030 Target Value
Timing	(1) Median time from DER interconnection request to agreement§	< 50 kW	Within 1 day†
		50 kW–5 MW	< 75 days
		≥ 5 MW	< 140 days
Access	(2) Completion rate from entering the queue to execution of interconnection agreement	< 50 kW	> 99%
		50 kW–5 MW	> 90%
		≥ 5 MW	> 85%
Data	(3) Availability of public state-level interconnection queue data	All	50 states, Washington, D.C., and territories have public, detailed, and current queue data
Reliability	(4) No BPS disturbance events exacerbated by inaccurate DER modeling	All	0
Resilience	(5) Lower Customer Average Interruption Duration Index (CAIDI)‡	All	25% improvement (e.g., from 4 to 3 hours per occurrence)

* System size thresholds will vary across utilities and jurisdictions.
§ For systems that do not trigger system upgrades.
† Defined as 1 business day.
‡ CAIDI with loss of load removed but major event days included.

Poll

- Which interconnection topics are your organization working on? Check all that apply.
  - Faster timelines
  - Higher application completion rates
  - Better data provision
  - More advanced studies
  - Improved reliability

Importance of Improved DER Interconnection Data

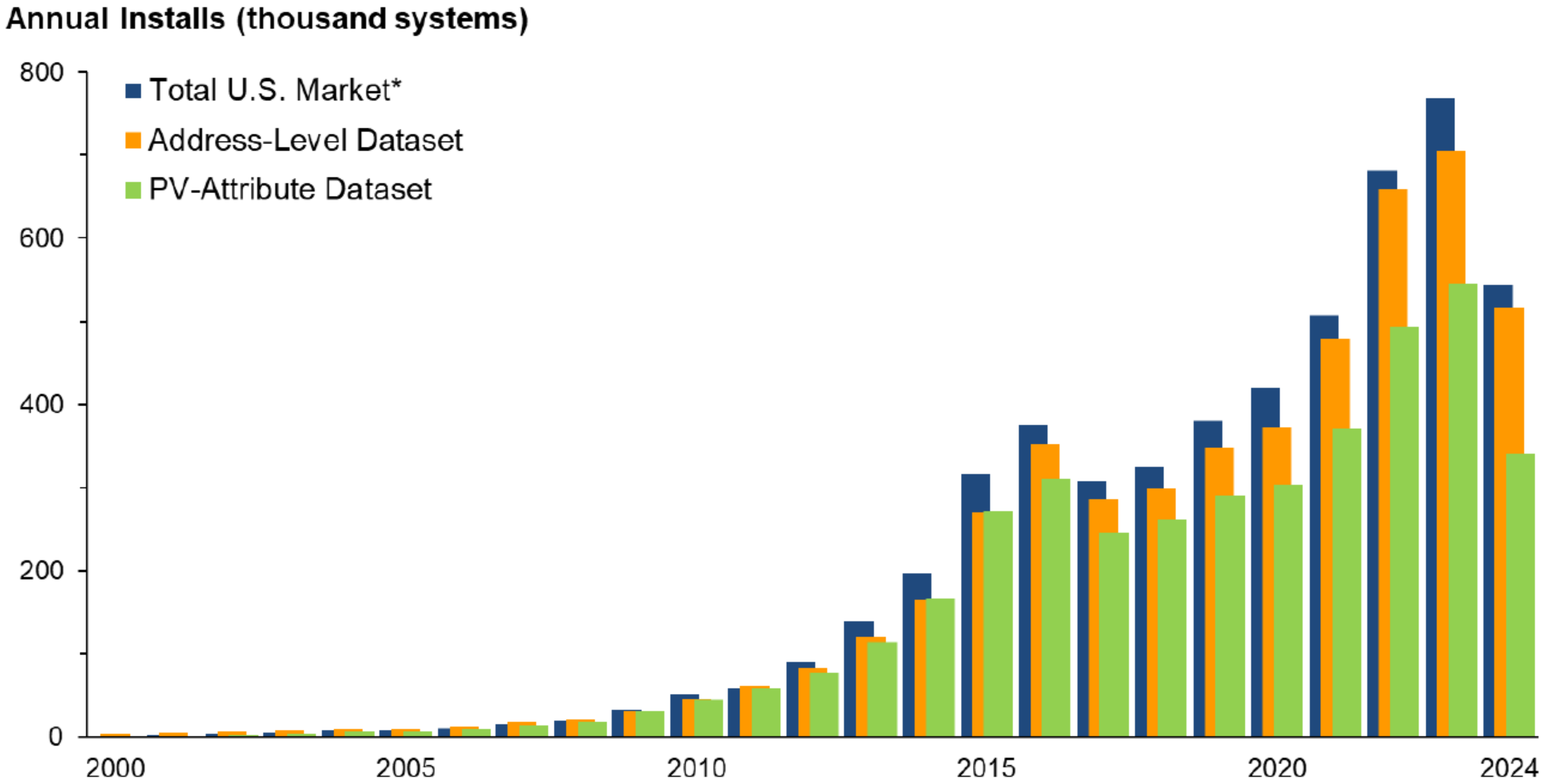
What Is Interconnection and Why Is It Important?

- Interconnection is the result of the process of adding a DER to a distribution system (IEEE Standard 1547-2018).
- The term may refer to the technical, procedural, and legal requirements of the interconnection process or the interface between the DER and the utility's distribution system—the physical location at which the DER provides certain electrical and interoperability capabilities.
- Interconnection allows utility customers and third-party service providers to connect solar energy systems, natural gas generators, energy storage, and other generating systems at customer premises and operate them in parallel with the utility system. In addition to providing services to meet their own electricity needs, customers can use interconnected DERs to sell power or ancillary services to the utility at the distribution or bulk electric system—for example, through a DER aggregator.

Source: LBNL

Growth in DER Deployment

- The deployment of DERs, such as natural gas generators, solar PV systems, and energy storage, has grown exponentially in the United States over the last 15 years.
  - For example, between 2010 and 2023, the number of residential PV systems grew from 89,000 to 4.7 million (800,000 residential PV systems were installed in 2023 alone) (DOE 2025).
- As DER deployment has grown, so have interconnection queues and timelines, stressing interconnection processes for distribution systems.



Total U.S. Market size is based on data from Interstate Renewable Energy Council for all years through 2010 and from Wood Mackenzie and SEIA's annual "Solar Market Insight" report for each year thereafter. Those data represent estimates of total U.S. annual installations each year.

LBNL tracks collects project-level data on distributed* solar photovoltaic (PV) and distributed PV+storage systems in the United States
Source: LBNL, October 2025, U.S. Distributed Solar and Storage: 2025 Data Update

Interconnection Data Are Vital to DER Deployment

- Utilities require customers and third-party developers to provide data for reviewing interconnection applications and conducting any technical studies that may be needed.
- Common data collected in applications
  - Rated power (kW)
  - Stored energy (kWh)
  - Technology/system type
  - Location: substation/feeder
  - IEEE 1547 Reactive Power Category, referred to as “Voltage and reactive power capability”
  - IEEE 1547 Disturbance Category, commonly referred to as “voltage and frequency ride-through capability”

- Utilities provide data to developers to support siting and estimated costs and timeframes
  - Projected upgrade costs
  - Timelines
    - Dates interconnection application submitted, agreement executed, and project in service
    - Dates of system impact study start and completion, construction completion date
  - Group study, if applicable
  - Queue position
  - Status of projects in queue: Active, operational, withdrawn, suspended
  - Technical screen failures and results, if applicable
  - Hosting capacity maps and underlying data

Interconnection data also are crucial for measuring performance over time and identifying areas for improvement.

Sources: DOE 2025, BATRIES 2022, Narang et al. 2021

Types of Interconnection Data

- Interconnection data can inform siting decisions, observe grid trends, evaluate interconnection performance, and track progress on reforms (DOE 2025).
  - Grid data inform and improve interconnection.
  - Utilities track and can provide outcome-based interconnection data to measure performance.

Example Interconnection Data to Measure Performance	Example Grid Data for Informing Interconnection
• Queue volumes • Processing timelines • Interconnection costs paid by customer or third-party developer	• Grid constraints • Locational net benefits • Available hosting capacity at a specific grid location • Used for forecasting upgrade costs • Cost ranges for common interconnection-related distribution system upgrades

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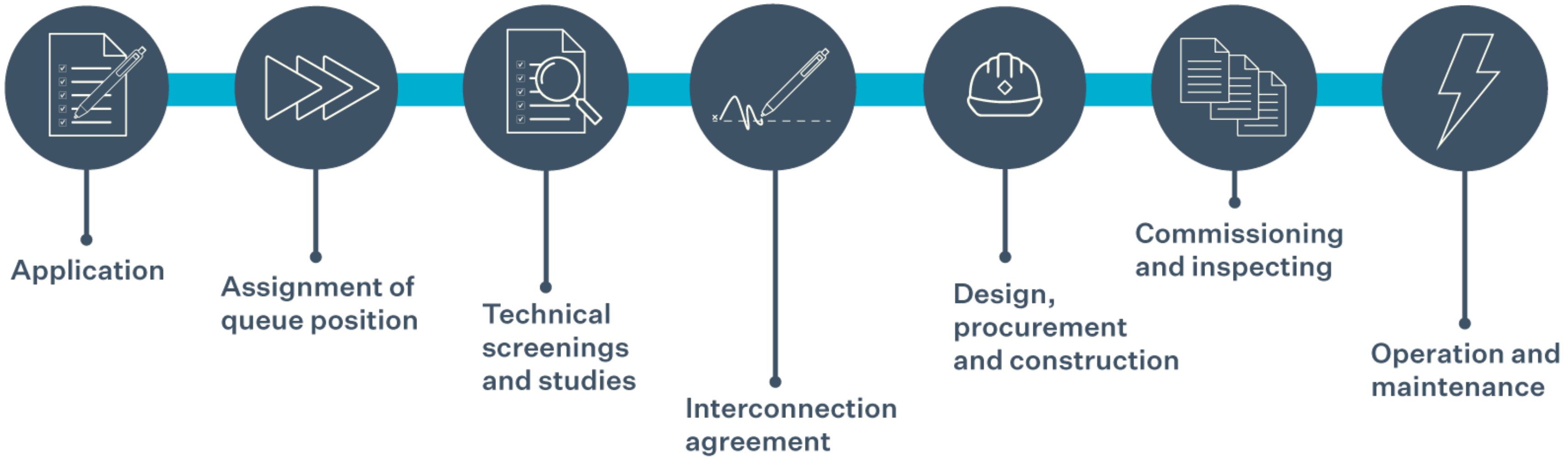
Overview of Interconnection Process

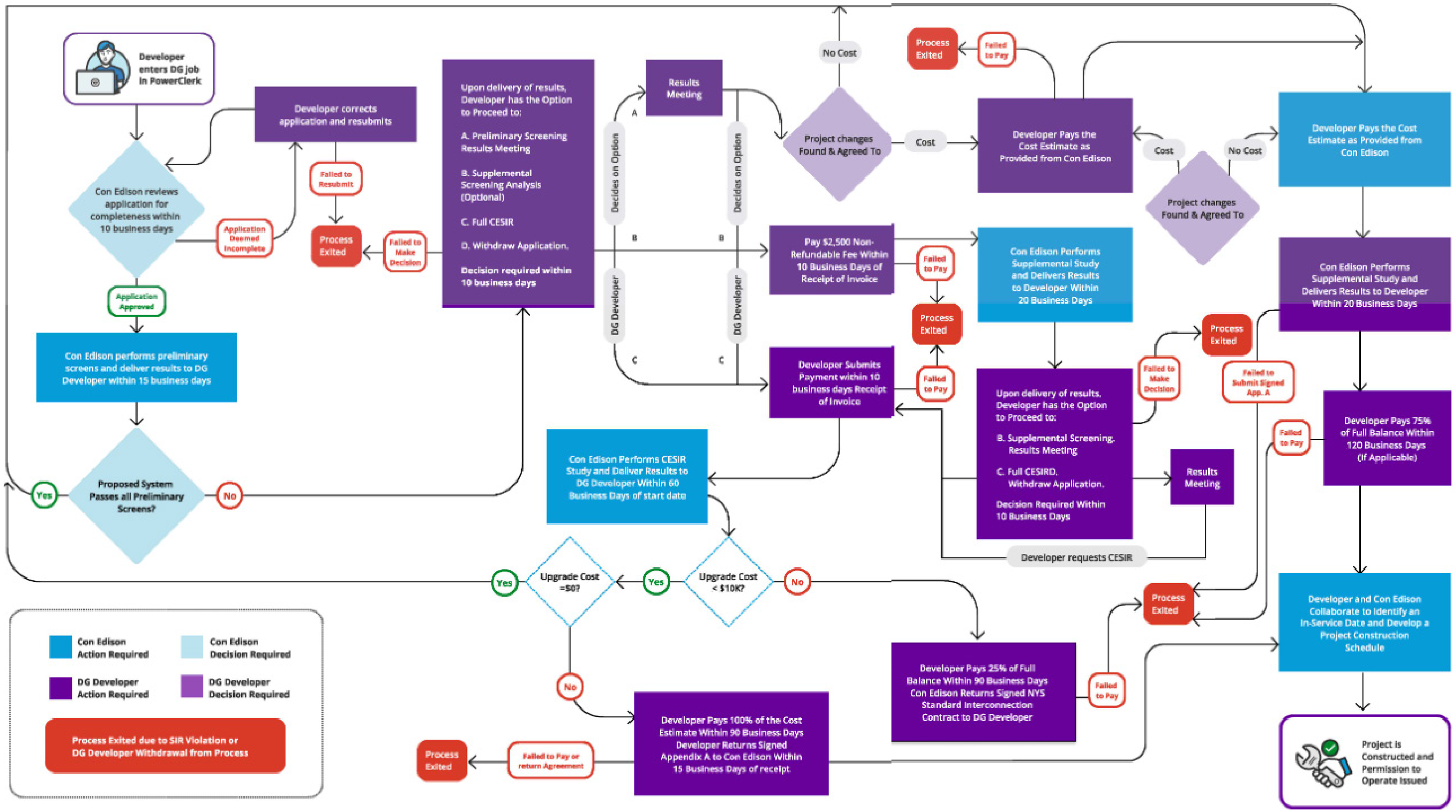
Steps in the Simplified Interconnection Process*



*Applies to projects that meet certain criteria (e.g., project size, type)

Source: PGE

Example of Interconnection Process Flow Chart: New York Standardized Interconnection Requirements: "Simplified" Process for Solar Projects 50 kW–5 MW

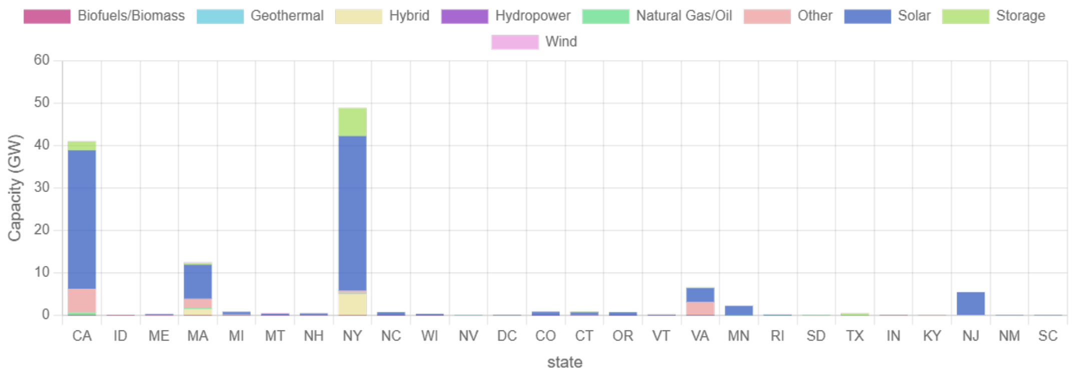


Source: [ConEd]

Data Limitations and Gaps

Data Standardization and Collection

- Data on distributed generation interconnection queues are not widely available and are not necessarily representative of queue backlogs across the country.
- Data sharing practices vary across the United States.
  - The types and frequency of data sharing are not standardized, aside from requirements for adoption and compliance with IEEE 1547-2018 (National Association of Regulatory Utility Commissioners (NARUC) 2023; Ingram et al. 2021).
  - Publicly available data are based on state requirements for data sharing and standardization.
  - While queues in some states look larger than others, it may be due to available data rather than indicative of higher levels of DER deployment.
- Major barriers to data sharing and data collection include:
  - Labor and resources needed to collect, aggregate, clean and standardize the data,
  - Computing requirements for data collection and sharing, and
  - Privacy and security of the data (Ingram et al. 2021).



Distributed Generation interconnection Queues by Technology, by State
Source: LBNL

Technology Complexity Adds Challenges to Standardization

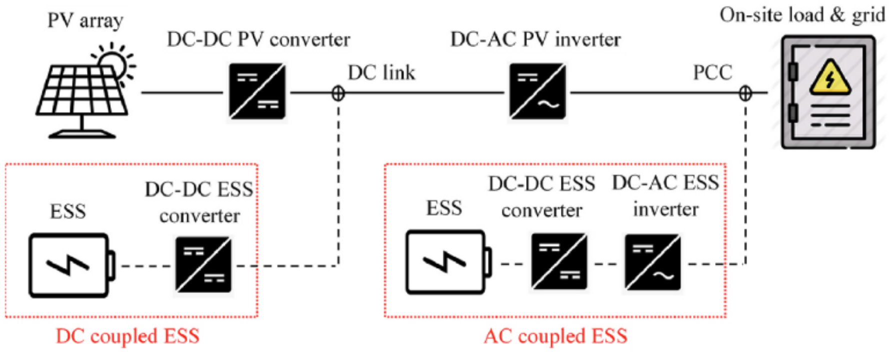
- Different types of DER technologies have distinctive characteristics that require specificity in interconnection rules since their capabilities and grid impacts vary (DOE 2025). Examples include:

  - Different types of solar PV and sizes
    - Small projects (≤25 kW) versus commercial / community solar (1<5 MW)
    - Behind-the-meter (located onsite behind the customer's meter) versus virtual/remote net metering or community solar (located offsite from the customer's premise)

  - Battery energy storage systems (BESS)—standalone or hybrid, DC-coupled or AC-coupled

  - Microgrids or hybrid technologies

  - Natural gas generators



Solar PV + BESS AC vs DC coupled configurations
Source: Rezaeimozafar et al. 2022

Market Complexity Adds Challenges to Interconnection Standardization

- The maturity of the DER industry in each jurisdiction varies. That can affect complexity of interconnection requirements, volume of DER applications in the queue, and utility workforce needs.
  - Market size, market saturation, and any incentive programs impact the pace of interconnection applications in a utility territory.
  - Each state/utility has different standards for data sharing, including the type of data shared and cadence.
- Interconnection standards vary across states and within in a state—differing across investor-owned utilities vs. rural electric cooperatives and municipal utilities.
  - Public utility commissions (PUCs) oversee interconnection regulations and standards for investor-owned utilities.
  - NARUC (2021) indicates 31 states* where the PUC has limited authority or oversight over other utilities, but in most of those states, that does not extend to interconnection.
- The pace of reforms needed to mitigate interconnection challenges varies depending on the market, regulations and resource availability (DOE 2025).

Source: Reuters 2024

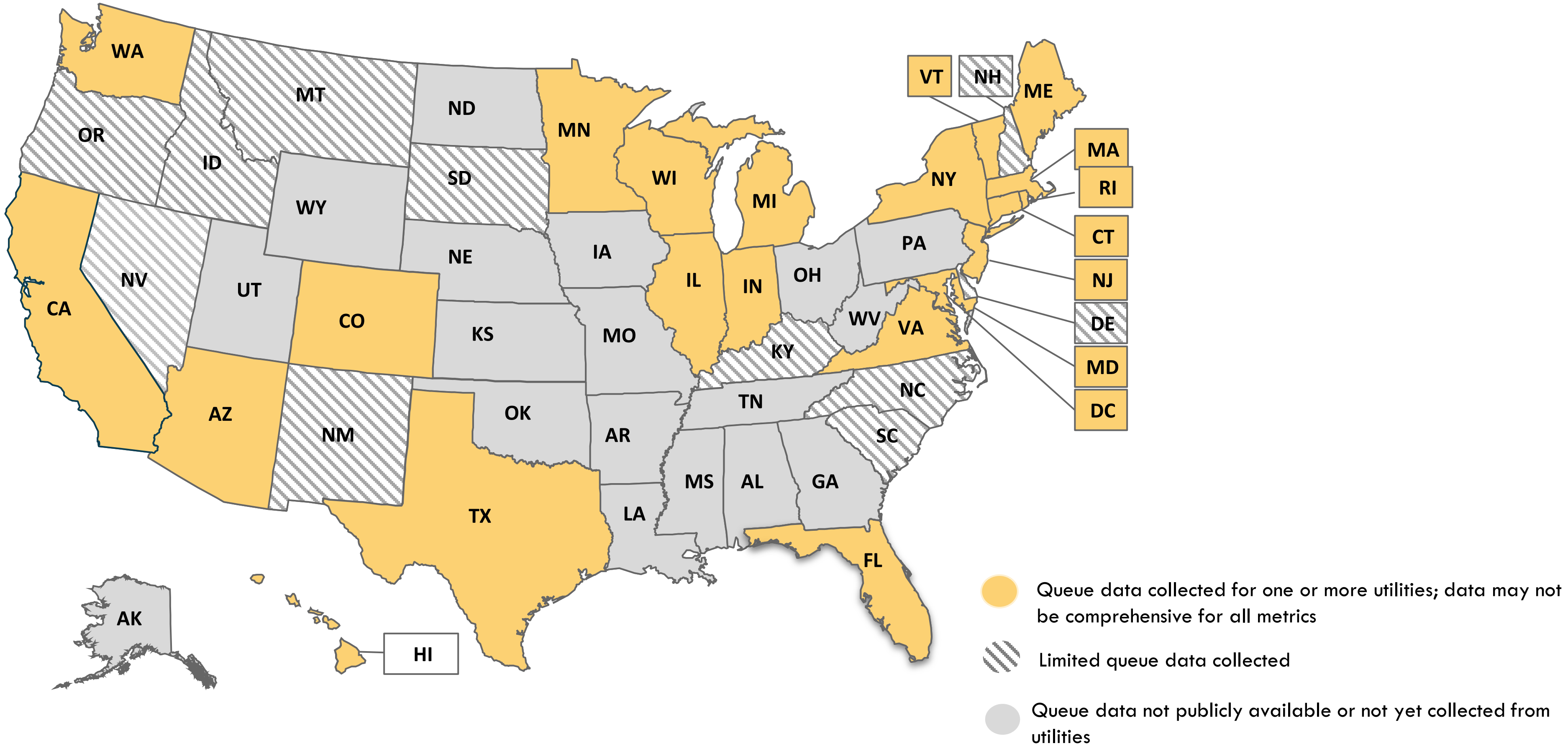
*States include AK, AZ, AR, CO, FL, GA, HI, IN, IA, KY, LA, ME, MD, MA, MI, MN, MS, NE, NV, NH, NM, NY, RI, SC, SD, TX, UT, VT, VA, WI, WY. See chart linked for NARUC 2021.

Poll

- What are the biggest interconnection challenges in your state? Check all that apply.
  - Large queues
  - Timeline delays
  - Upgrade costs
  - Projects sitting in queue (“zombie” projects)
  - Other

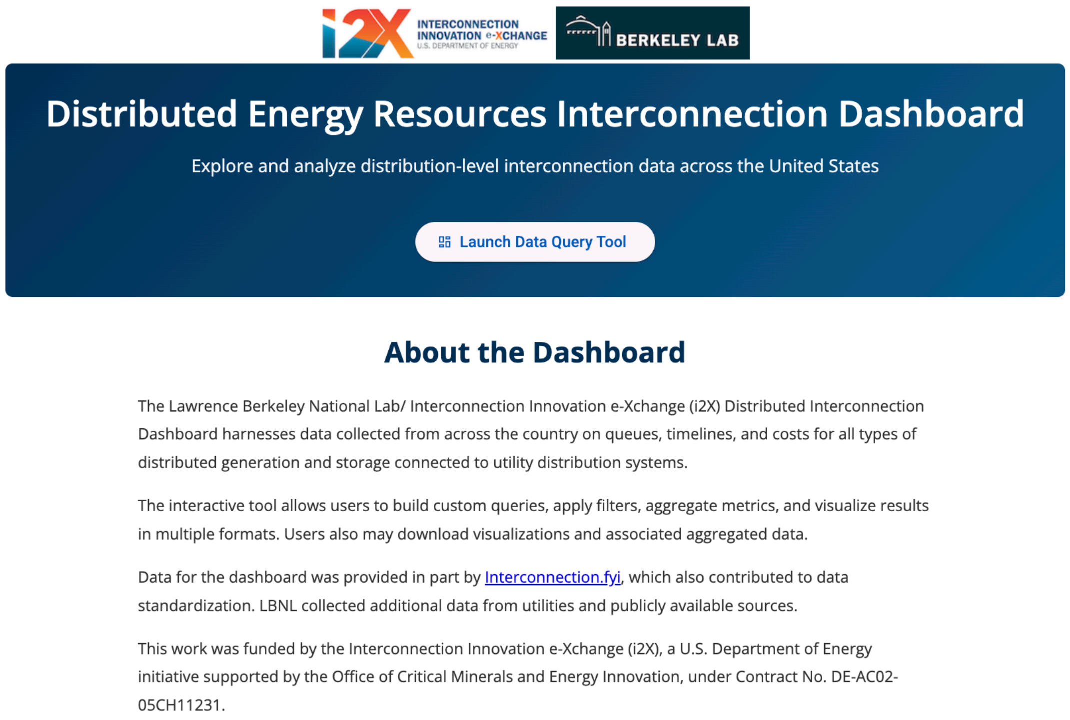
Insights Into U.S. Interconnection Data

DER Interconnection Data Collected by LBNL

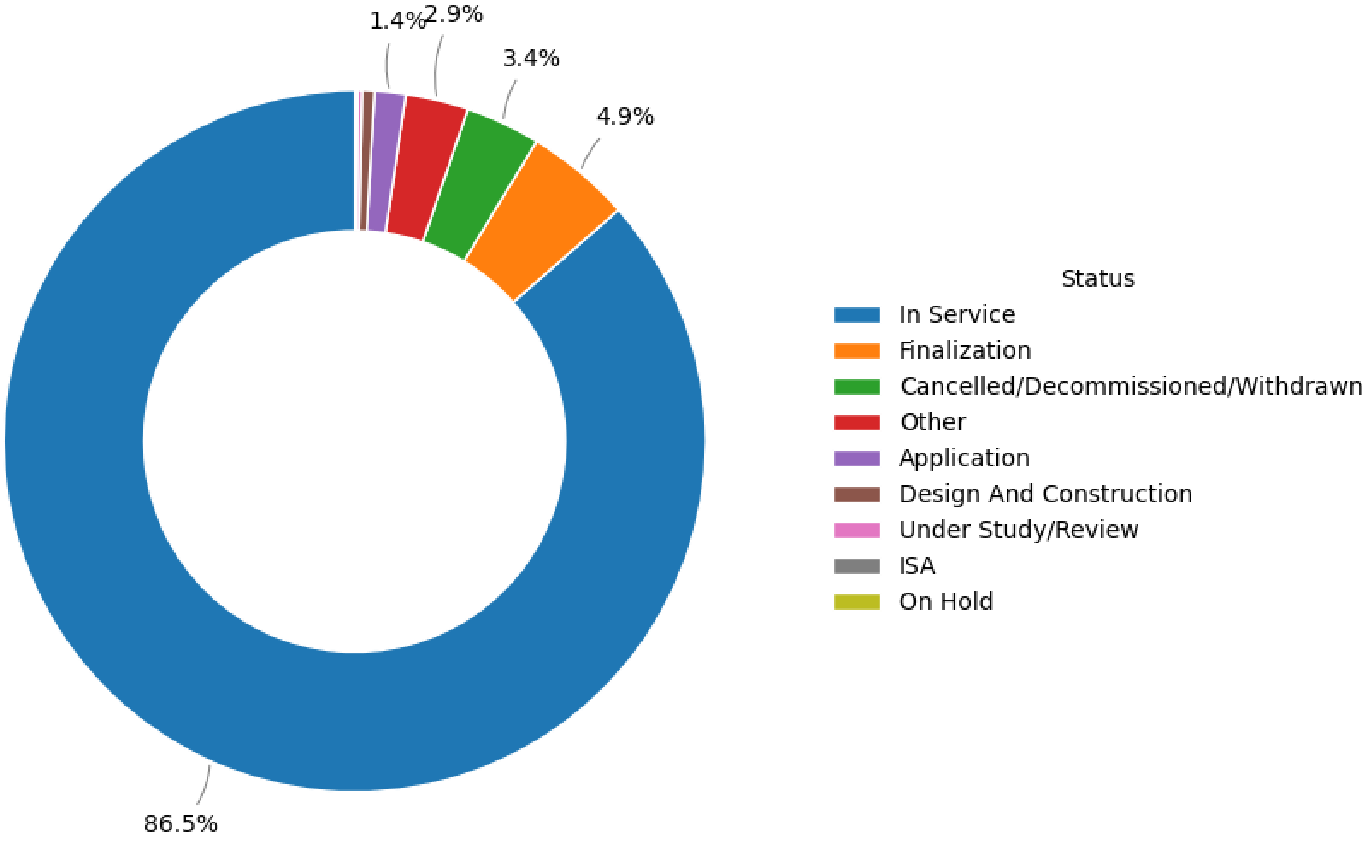


LBNL i2X DER Interconnection Dashboard Under Development

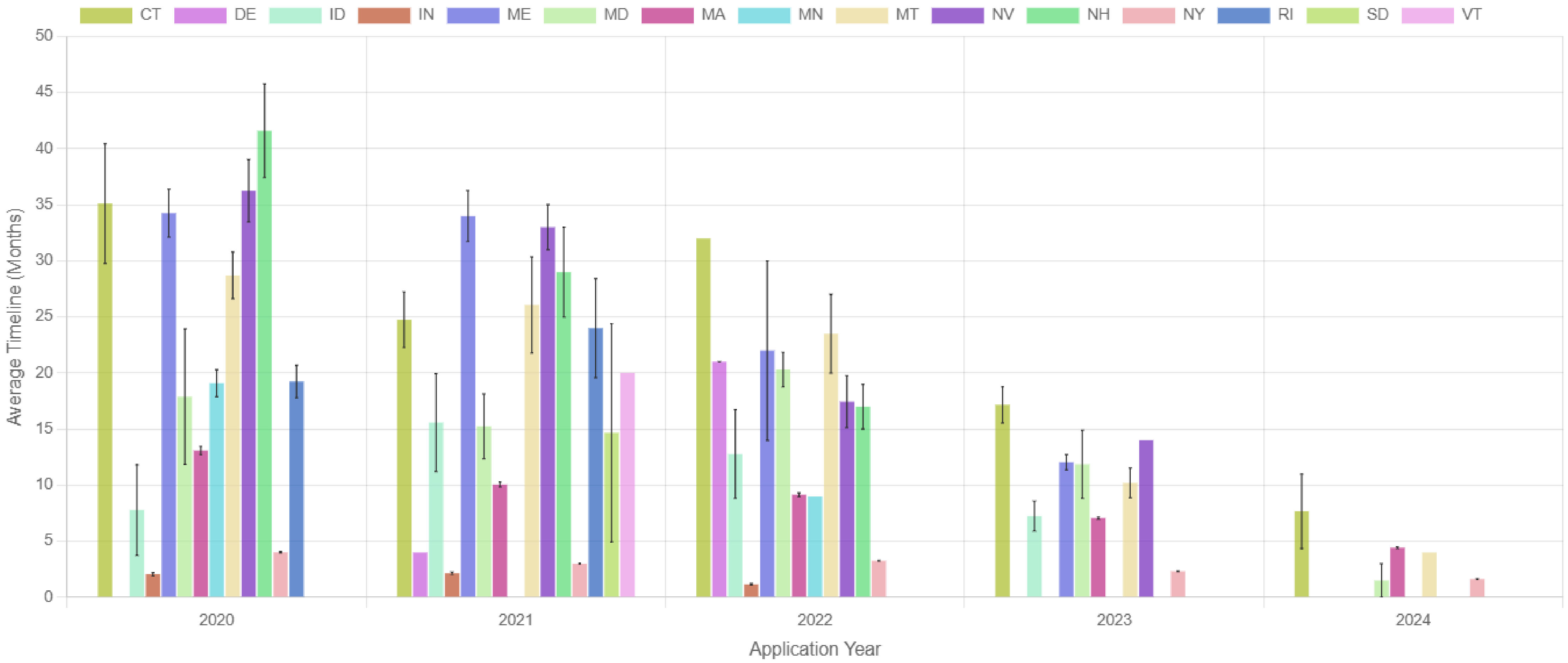
- The i2X/Lawrence Berkeley National Laboratory DER Interconnection Dashboard will harness data collected from across the country on queues, timelines, and costs for all types of distributed generation and storage connected to utility distribution systems (examples in following slides).
- The interactive tool will allow users to build custom queries, apply filters, aggregate metrics, and visualize results in multiple formats. Users also will be able to download visualizations and associated aggregated data.
- Utilities, regulators, policymakers, project developers, DER customers, and other stakeholders will be able to access the data for benchmarking and examining progress on DER interconnection performance metrics over time.



Share of Projects Collected to Date by Interconnection Status

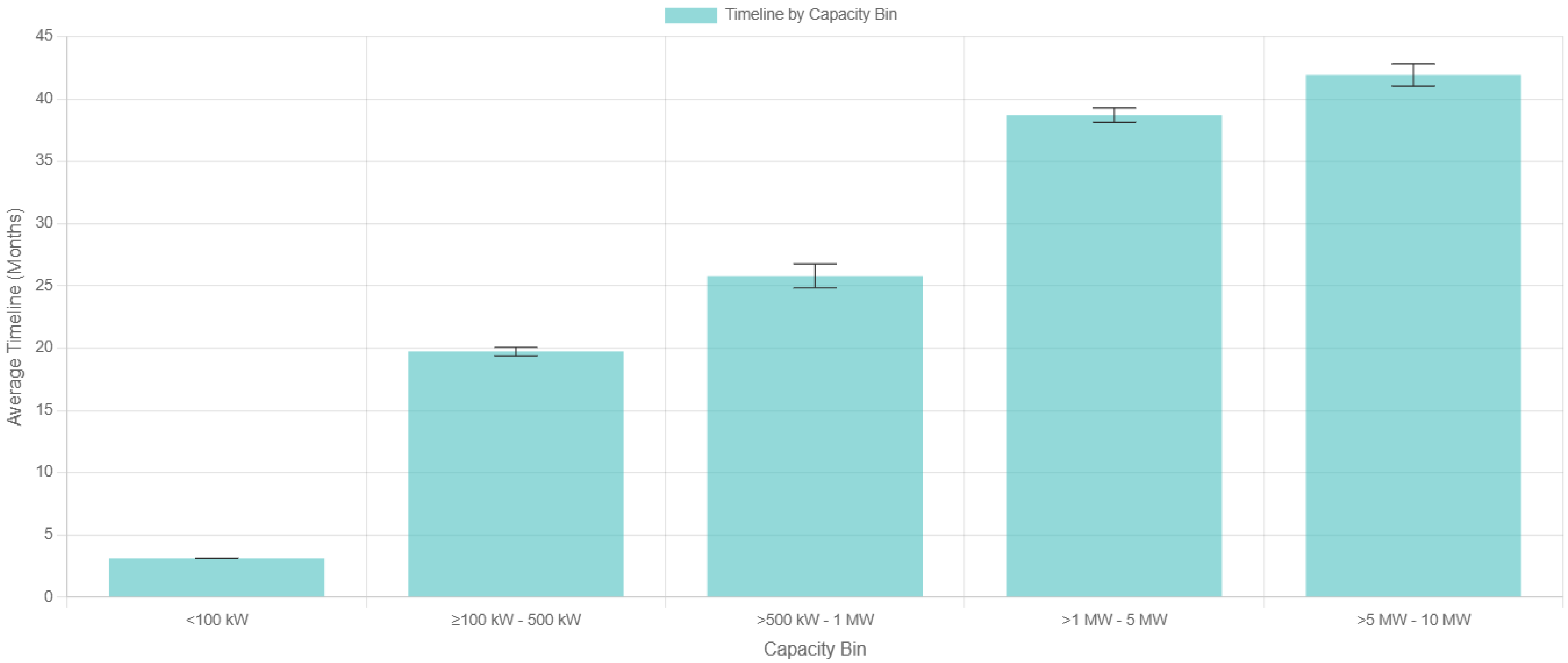


Average Timelines by State (2020-2024)*

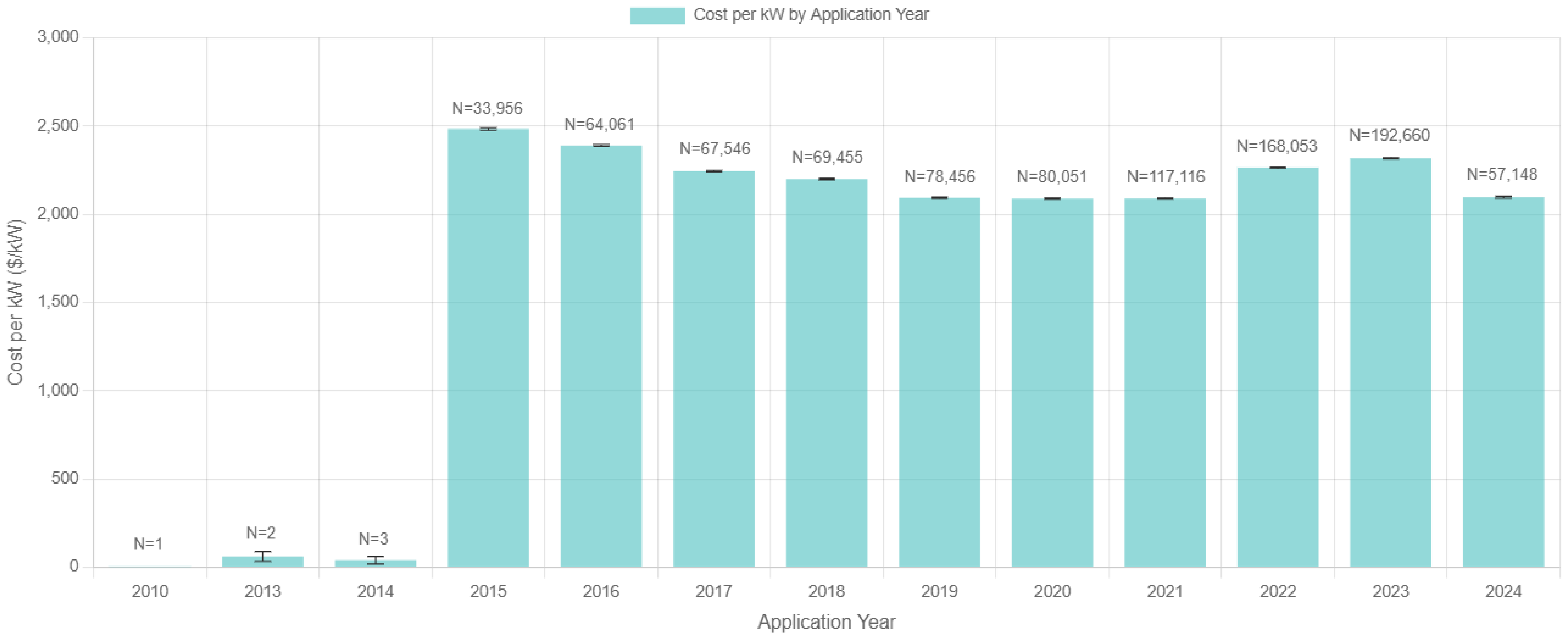


*Data are available from one or more utilities in the state.

Average Timelines for New York Projects by Capacity Bin (All Technology Types)

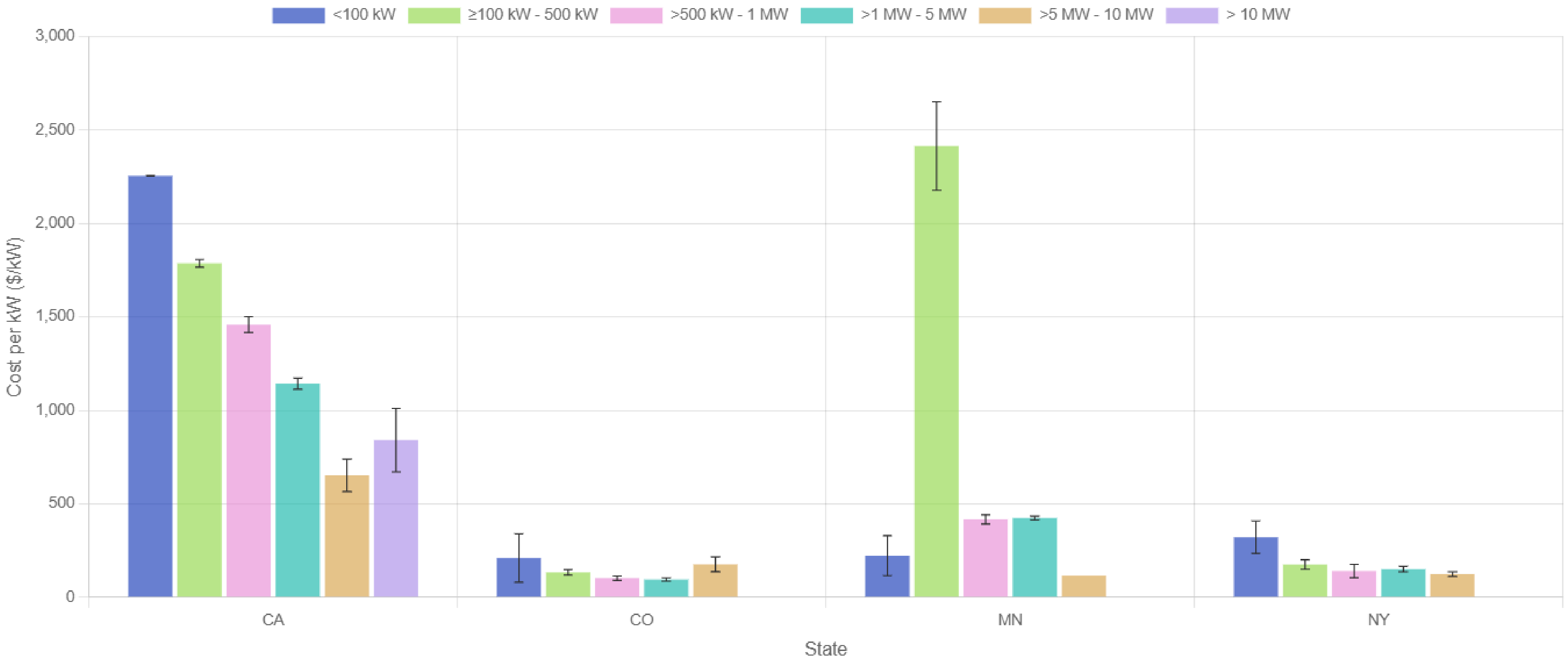


Average Cost of Projects by Application Year*

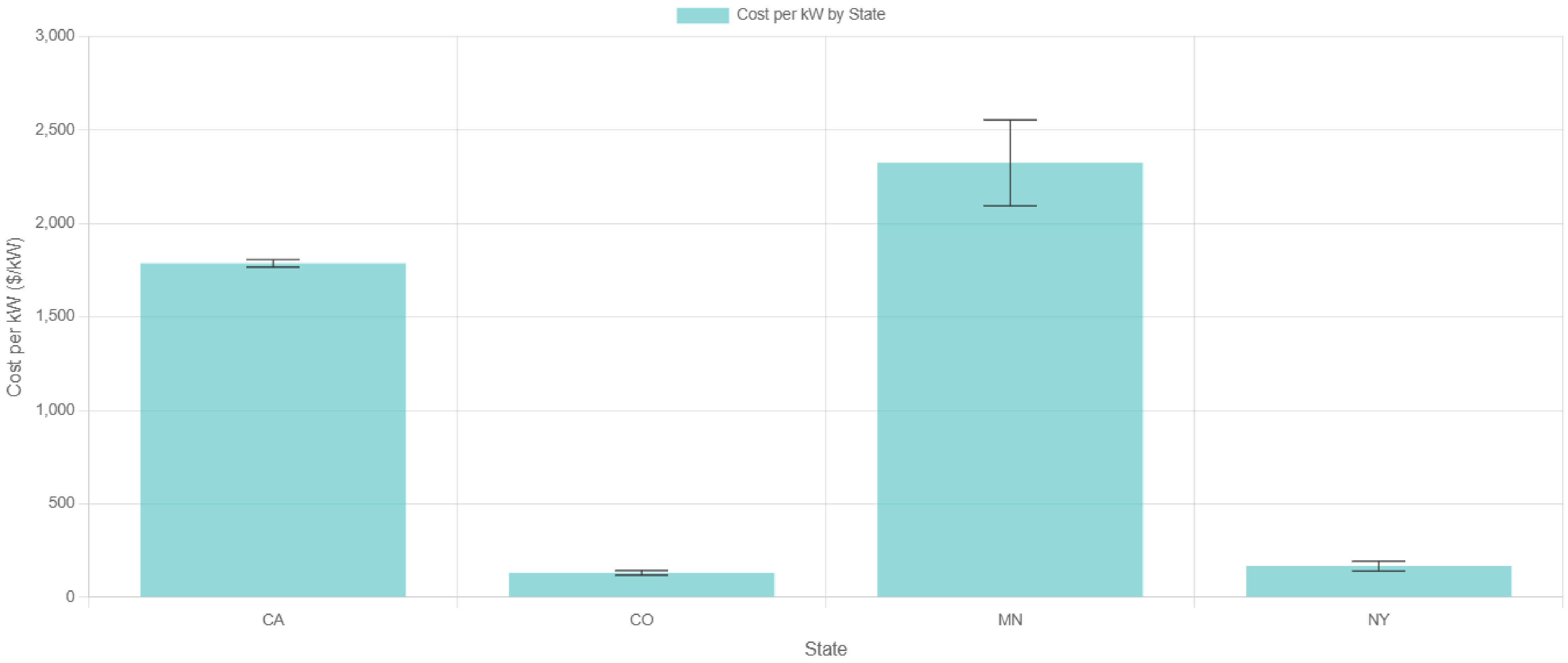


*Data are available from four states: CA, CO, MN, NY

Average Distribution Upgrade Cost by Project Size



Average Distribution System Upgrade Cost for Projects 100-500 kW



Actions to Improve DER Interconnection Queues, Timelines and Data Sharing

Example Solutions for Interconnection Queues and Timelines

Regulatory mechanisms

- Data sharing/transparency requirements
- Timeline enforcement
- Utility performance incentives
- Requirements for managing high-volume queues
- Ombudsperson

Technical mechanisms

- Pre-application process
- Fast track
- Group studies
- Technology settings
- IEEE standards

Regulatory Mechanisms to Address Interconnection Queues

- **Data sharing/transparency requirements –** Data sharing requirements improve availability of DER interconnection data.
- **Timeline enforcement mechanisms –** Required study timelines, and penalties for failing to meet them, provides accountability.
  - Example: The Massachusetts Department of Public Utilities established a mechanism that measured timelines and required utilities to report aggregated performance data. Noncompliance results in penalties paid to project owner commensurate with the financial impact of the delay.
- **Performance incentive mechanisms (PIMs) –** PIMs can be tied to specific metrics, such as improved interconnection timelines and planning processes.
  - See NARUC's Performance-Based Regulation State Working Group for resources and examples.
- **Managing high volume queues**
  - Establishing Fast Track or expedited review processes for small systems
  - Enabling the use of group studies (as opposed to serial studies) can aid in managing high- volume queues by increasing efficiency.
- **Ombudsperson**
  - A dispute resolution mechanism, such as an ombudsperson, helps reduce interconnection challenges and mediate disputes between DER applicants and utilities.
  - Establishing informal working groups can improve alignment among stakeholders.

Source: DOE 2025

Data Sharing

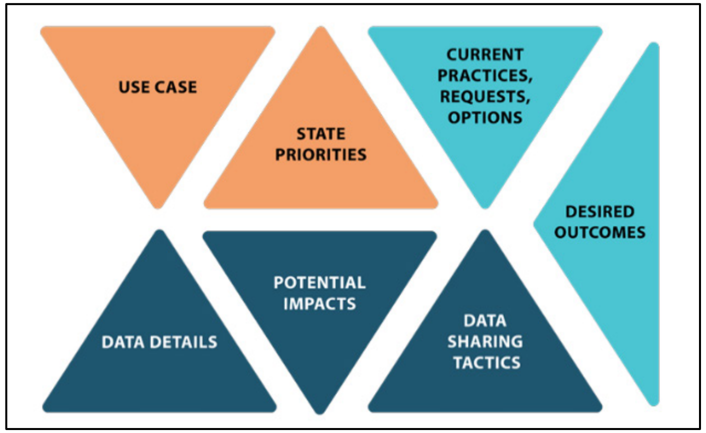
- **Considerations**
  - Clarify data required from utilities, utility customers, and project developers
  - Protect sensitive data
  - Balance utility costs/workloads with granularity and frequency of updates (e.g., queues, timelines, and hosting capacity)
  - Develop accessible and secure data sharing platforms

- Public reporting sites for interconnection data support transparency.

- Facilitate stakeholder groups that can support regulators and utilities by sharing data needs and use cases and providing feedback on utility data sharing.

DER Applications	Generated by Utilities
• Technology • Rated power (kW) • Stored energy (kWh) • IEEE 1547 Reactive Power Category, commonly referred to as "voltage and reactive power capability"[59] • IEEE Std 1547 Disturbance Category, commonly referred to as "voltage and frequency ride-through capability" • Location (census block group)	• Queue position • Application date and interconnection agreement date • Dates of system impact study start and completion • Construction completion date and permission to operate date • Status (active, operational, withdrawn, suspended) • Technical screen failures and results, if applicable[60] • Group study status, if applicable • Estimated cost of studies and fees ($ quoted by the utility) • Estimated cost of all system upgrades, including facilities charges and network upgrades ($ quoted by the utility) • Final cost of interconnection, including costs of all studies and any required system upgrades ($ billed by the utility)

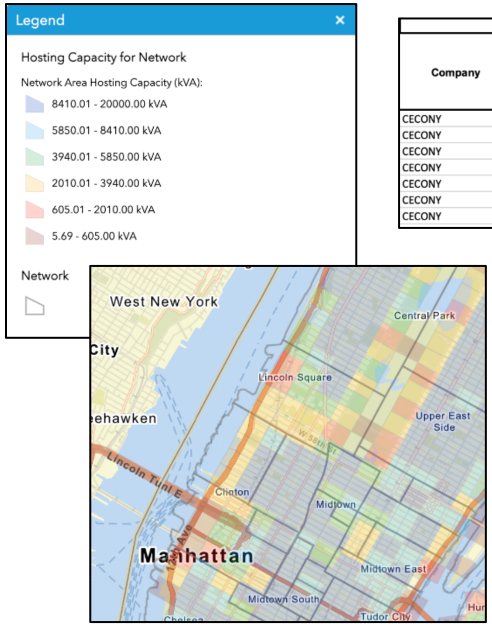
Grid Data Sharing Analysis Framework



Sources: NARUC 2023, DOE 2025

Data Sharing: Utility Example

ConEdison’s DER Interconnection Data



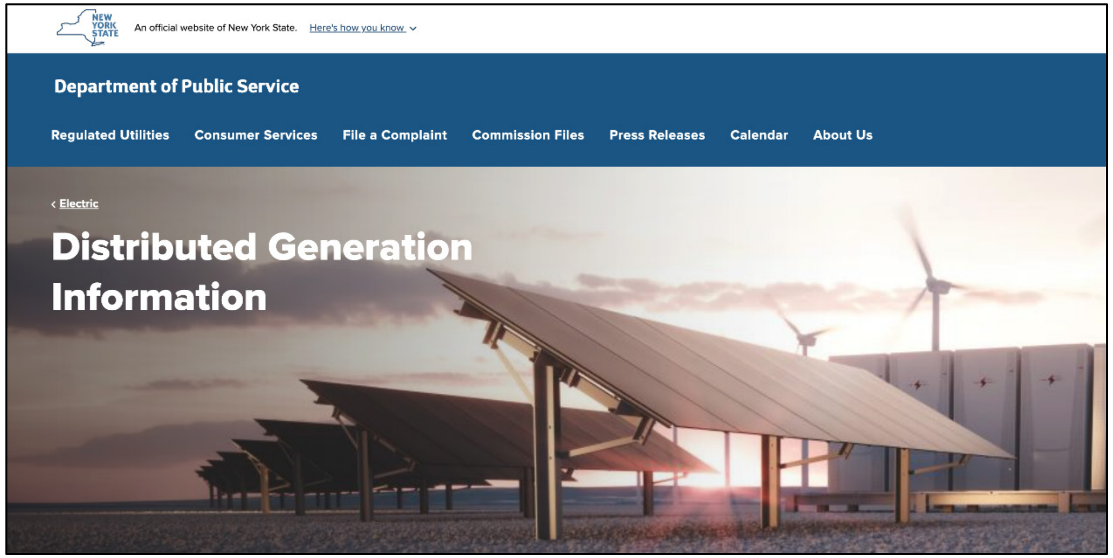
Company	Developer	Application / Job #	Division	City/Town	County	Zip Code	NYISO Load Zone	Circuit ID	Substation
CECONY	MOMENTUM SOLAR	SDG-80851	CENY-BK	Brooklyn	Kings	11234	J	4B09	Bensonhurst_2
CECONY	NYSS LLC	SDG-80850	CENY-SI	Staten Island	Richmond	10314	J	1R81	FRESH_KILLS
CECONY	Green Hybrid Energy Solutions, Inc.	SDG-80849	CENY-W	White Plains	Westchester	10601	I	WHITE2	White_Plains
CECONY	MOMENTUM SOLAR	SDG-80848	CENY-W	Yonkers	Westchester	10703	I	99U4	Granite_Hill
CECONY	MOMENTUM SOLAR	SDG-80847	CENY-W	Yonkers	Westchester	10704	I	79U3	Granite_Hill
CECONY	MOMENTUM SOLAR	SDG-80846	CENY-Q	Springfield Gardens	Queens	11413	J	9573	Jamaica
CECONY	MOMENTUM SOLAR	SDG-80845	CENY-Q	Jamaica	Queens	11435	J	5Q42	Jamaica

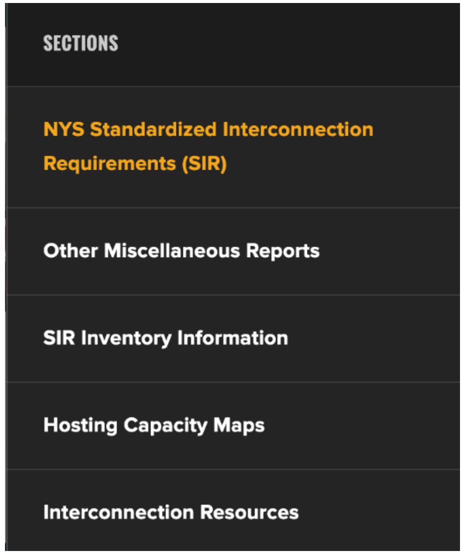
	APPLICATION REVIEW				PRELIMINARY REVIEW			CESIR				SIR Costs		
	10 business days				15 business days			60 / 100 business days				CESIR Costs	Project Installation / Upgrade Costs	
Protective Equipment	Start Date	End Date	Calculated Duration	Application Approved Date (Utility)	Start Date (Must Match Application Approved Date)	End Date	Calculated Duration	Payment Received Date	Start Date	End Date	Calculated Duration	CESIR Study cost paid by applicant	Estimated Upgrade Costs Identified by Utility (CESIR or Not)	Actual Project Costs Paid by Applicant
Inverter	12/31/24											$0.00	$0.00	$0.00
Inverter	12/31/24											$0.00	$0.00	$0.00
Inverter	12/31/24											$0.00	$0.00	$0.00
Inverter	12/31/24											$0.00	$0.00	$0.00
Inverter	12/31/24											$0.00	$0.00	$0.00

Source: New York Department of Public Service, ConEdison

Data Sharing: State Example

- New York State provides consolidated interconnection information on a public webpage.
  - The page links to standard and utility-specific interconnection requirements, hosting capacity maps, interconnection queue data, and other resources.
  - New York's standardized queue data provide equipment, timeline, and cost information.





Source: New York Department of Public Service

Technical Mechanisms – Expedited Review

Pre-application

- Utilities can provide customers with basic information (for a reasonable fee) about their proposed point of interconnection before they submit a full interconnection application.

Fast Track

- Utilities can expedite review processes for small (<25 kW), inverter-based systems (solar PV, storage, hybrid) at low risk of triggering adverse system impacts.
- Under FERC's Small Generator Interconnection Process, and many states' interconnection rules, Fast Track review is limited to systems ≤2 MW.
- Utilities are moving towards a more refined approach based on location factors, such as DER distance from the substation and line voltage ("table-based approach").

Supplemental Review

- If a project fails a Fast Track screen, the application can undergo a "supplemental review" to determine whether the DER can interconnect without a full study.
- This is the practice in Ohio, Massachusetts, Illinois, Iowa, and California. Other states, such as Maine and Minnesota, are considering this approach.

Sources: IREC 2017; IREC 2023a

Technical Mechanisms – Parallel Studies

- Historically, utilities studied DER applications serially, in the order of application receipt.
  - This practice slows down interconnection queues and creates backlogs, exacerbated by increasing DER deployment.
- Parallel study allows for two or more projects to be studied at the same time.
  - A **group study** process analyzes projects together — first for a system impact study and later for a facilities study.
  - A **cluster study** process take a similar approach, but also studies impacts of the DER project at both the transmission and distribution levels.
- A group study "evaluates whether groups of electrically-related DER projects can interconnect to the distribution system safely and identifies any grid upgrades that are needed to accommodate those projects." Projects typically share study and upgrade costs (IREC 2023b).
  - California, Massachusetts, Minnesota, Oregon, North Carolina and South Carolina have adopted or authorized utilities to pursue this approach.

Source: IREC 2023b

Study Pathways Can Impact Timelines

Major Steps	Common Timelines
Group Study Application Window	Between 40 business days and 12 months
Utility Forms Groups	15-30 business days
Initial Customer Engagement	35-55 business days
Group Study	100-160 business days **Note:** Several jurisdictions separate group studies into separate phases, e.g., a Phase 1 power flow study and a Phase 2 stability study, with defined periods of customer engagement after each phase.
Customer Review of Study Results and Decision to Proceed	15-30 business days
Restudy (if needed)	60-160 business days
Affected System Operator (ASO) Study	Group study procedures generally do not define the timeline for conducting an ASO study, which is subject to the procedures and requirements of other utilities and ISOs/RTOs.
Preparation and Execution of an Interconnection Agreement	25-55 business days **Note:** Some rules allow for an extension of time for additional negotiation of the interconnection agreement, if necessary.

Indicative Timelines for a Group Study
Source: Weaver 2023

- Serial study can create backlogs with projects waiting years in queues.
- Group studies and cluster studies are more technically accurate and are designed to alleviate queue challenges; however, they may also pose delays and challenges.
  - For example, when a project withdraws from the queue, it affects the study results and cost sharing across projects. In some cases, projects may need to be restudied.

Example Actions

Regulators can:

- Set standards for improving DER interconnection data sharing, such as frequent updates on queues, timelines, and costs
- Set timelines for interconnection processes and PIMs for meeting timeline standards
- Establish an ombudsperson role to assist with dispute resolution
- Consider establishing fast track or expedited review processes for small systems
- Consider the use of group studies to improve study timelines and cost sharing
- Facilitate stakeholder groups that can share data needs and use cases and provide feedback on data sharing

State agencies and other stakeholders can:

- Promote data sharing or transparency standards in planning proceedings
- Encourage data sharing that aligns with standards set in other states
- Provide feedback in forums on availability of data on DER interconnection queues, timelines and costs

Utilities can:

- Consider sharing DER interconnection data on queues, timelines, and costs

Join i2X Connect

: https://groups.energy.gov/i2xconnect/

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Resources for More Information

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- LBNL's Interconnection Innovation e-Xchange website
- Interstate Renewable Energy Council (IREC), *IREC Model Interconnection Procedures 2023*
- Building a Technically Reliable Interconnection Evolution for Storage (BATRIES), *Solutions to Improve Energy Storage Interconnection*
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