Pacific Northwest
NATIONAL LABORATORY

PNNL-33051

Small Hydropower Interconnections: State Interconnection Processes

August 2022

Travis Douville
Mark Severy
Todd Wall
Kendall Mongird

U.S. DEPARTMENT OF ENERGY

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

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information,
P.O. Box 62, Oak Ridge, TN 37831-0062;
ph: (865) 576-8401
fax: (865) 576-5728
email: reports@adonis.osti.gov

Available to the public from the National Technical Information Service
5301 Shawnee Rd., Alexandria, VA 22312
ph: (800) 553-NTIS (6847)
email: orders@ntis.gov <https://www.ntis.gov/about>
Online ordering: http://www.ntis.gov

1.0 Introduction

Small hydropower projects with rated power output between 0 to 20 MW have been the predominant source of hydropower growth over the past decade in the United States (DOE 2016; Johnson et al. 2018). However, interconnection to electricity distribution and transmission grids is a persistent barrier. Interconnection of an electricity generating unit is overseen by the distribution or transmission owner, who use interconnection standards and requirements that vary by state. The differences between standards in standards may affect the final cost, timeline, and success of a small hydropower project.

Small hydropower project developers across the United States have found interconnection procedures to be fraught with cost surprises and schedule overruns. System operators have struggled to understand impacts to overburdened or rapidly evolving transmission and distribution grids. The results of these shortcomings have been stranded costs and unrealized small hydropower potential. Though regulatory actions and policy recommendations at the state level have increased the situational awareness of interconnection challenges, the remote locations of small hydropower resources and the relatively small revenues associated with energy production through small hydropower facilities continue to make interconnection processes and requirements confusing and costly.

Noting these challenges, the U.S. Department of Energy Water Power Technologies Office enlisted Pacific Northwest National Laboratory (PNNL) and Oak Ridge National Laboratory (ORNL) to investigate the small hydropower interconnection landscape across the United States. The second in a series, this paper investigates the interconnection process in each state in the U.S. to compare their attributes. Subsequent papers in the series will analyze these interconnection processes ("Small Hydropower Interconnections: Analysis of Interconnection Processes") and present best practices ("Small Hydropower Interconnections: Best Practices") that will help overcome barriers to future small hydropower development. The first paper in the series examined the state of small hydropower projects in the United States ("Small Hydropower Interconnections: Small Hydropower in the United States") to understand the industry characteristics.

2.0 Interconnection Processes for Small Hydropower

Before delivering power to the grid, all electrical power generation facilities regardless of, electrical power generation facilities, including small hydropower generators, must interconnect to the grid through an approval process with the transmission or distribution owner in the area. The process of interconnection involves (1) the generator applying for interconnection, (2) the distribution owner reviewing the application, and (3) the distribution owner determining whether interconnection is approved or requires additional infrastructure improvements to allow for interconnection. The specifics of executing this process and the technical requirements used to evaluate an interconnection request vary significantly based on the jurisdiction.

The interconnection process creates challenges to deploying small hydropower. The interconnection process, timeline, and requirements influence the cost and commercial operation date of a new hydro project, which adds uncertainty for developers as they consider new projects. Limited access to information prior to preparing and submitting an interconnection application can make it difficult for developers to understand the expected costs, which can significantly change a project's levelized cost of energy, a measure often used to determine the economic viability of a project.

This section describes the background of interconnection guidance in the United States and outlines the key indicators of interconnection processes in different jurisdictions. Several indicators are highlighted to note the influential decisions that may affect interconnection of small hydropower generators. Additional details comparing the interconnection processes in the United States are included in 0.

2.1 Background and Standards

Small hydro generators[1] typically interconnect directly to electricity utility distribution systems (<66 kV) and not the higher voltage transmission systems. Interconnection to the distribution system falls under the purview of the operator of the distribution system, which may be a cooperative, a municipal utility, or an investor-owned utility (IOU). IOUs and, in several states, cooperatives[2] are regulated by a Public Utilities Commission (PUC), sometimes referred to as a Public Service Commission (PSC), as authorized by state governments.

The Federal Energy Regulatory Commission (FERC) Small Generator Interconnection Procedures (SGIP) requires all public utilities to develop standard rules for interconnecting new sources of electricity with a rated power capacity (nameplate capacity) of 20 MW or less (FERC 2018). The SGIP includes model interconnection procedures that can be adopted by distribution owners and include a Fast Track process that uses screening criteria to approve some qualifying projects in an expedited process and a more detailed study process for all other projects.

---

[1] This report defines small hydroelectric generators to be less than 20 MW. Though the U.S. Department of Energy *Hydropower Vision* classifies small hydropower to be between 0.5 to 10 MW nameplate capacity (DOE 2016), FERC uses a 20 MW differentiation, which many interconnection processes adapt.

[2] The PSCs/PUCs of Alaska, Arizona, Oklahoma, and Utah indicate some level of jurisdiction over cooperatives. However, most states only regulate IOUs. Municipal utilities are self-regulated and not governed by PSC/PUCs.

State PUCs or PSCs have the authority to mandate interconnection processes for the electric service providers they oversee. The service providers can set their own interconnection processes to meet or exceed the requirements set up by the PUC or PSC authority. With these layers of jurisdiction, interconnection processes can vary from state to state and even between electric service provides within a state. To understand the differences and similarities, the interconnection procedures for all 50 states were reviewed as described below.

Most electric service providers use a tiered structure for reviewing interconnection applications. The tiers allow for a simple review of some small projects and a more detailed review of larger projects that may have greater impact to the distribution system. In a tiered application structure, there are expedited review processes for projects below a certain capacity threshold. In general, these are the application tiers available to review different projects:

- **Small, Inverter-Based Projects:** Some states have a streamlined tier for small inverter-based generators (e.g., 10 kW capacity or less) to review the safety and design of the small generator for interconnection. These are mainly targeted toward facilitating residential photovoltaic interconnection.
- **Fast Track:** Many states also include an application tier for expedited review of projects up to a few MW of capacity. This application tier, called Fast Track in the SGIP, will review projects below a maximum capacity threshold (often 2 MW or 5 MW) using a set of 10 or more technical screening criteria to determine if there are expected impacts to the distribution system. Generators that pass the screening criteria can be approved for interconnection, but if the screening criteria are not met, the application can be passed to a detailed study process for review.
- **Detailed Study:** Projects which are too large or do not pass the technical screens trigger a more detailed study review to determine if mitigations or distribution system improvements are required for interconnection. Primary phases of the study process include the Feasibility, System Impact and Facilities Studies, as described in 0.

After approval of interconnection through one of the above processes, the interconnection applicant will sign an interconnection agreement (IA) with the relevant electric service provider to approve interconnection. If distribution upgrades were required based on the detailed study, the distribution owner must implement the upgrades before the generator is cleared for commercial operation.

2.2 Process Indicators

The characteristics of interconnection procedures between different states can be summarized by reviewing the key indicators that define the process. Table 1 categorizes and describes the key characteristics of the interconnection process. A discussion of how each indicator changes by state is provided in this section and in 0.

Table 1. Key Indicators that Describe the Interconnection Procedures

Category	Indicator	Description
General Information	Capacity	The power rating of the generation equipment was often used as a filter to different process routes. Smaller capacity limits typically corresponded to net metering standards, which would apply at the scale of an individual distribution customer. Larger sizes, reaching into megawatts, typically corresponded to standards for systems for parallel operations with the distribution system. These standards were directly labeled as distributed generation in many cases. For hydropower, capacity referred to the rated (i.e., “nameplate”) alternating current capacity of the generator.
	Expedited process	The smallest of stratified capacity thresholds typically corresponded to a less rigorous technical review based on known equipment performance and the decreased likelihood of adverse system impact.
	Pre-application reports	Another overlap with the FERC SGIP, pre-application reports allow a developer to acquire significant information of value with regards to the distribution system at a potential point of interconnection. If accurate information is provided in timely fashion through a pre-application report, the developer can site generation in a way that is most helpful to the distribution system operator. Pre-application reports hold great potential to facilitate interconnection for small hydropower.
System Requirements	IEEE 1547	The Institute of Electrical and Electronics Engineers Standard (IEEE) for Interconnecting Distributed Resources with Electric Power Systems dictates requirements for the entire facility behind the point of common coupling to the distribution system. It includes requirements relevant to performance, operation, testing, safety, and maintenance, is technology-neutral, and valid for resources as large as 10 megavolt amperes.[1]
	UL1741 or other certifications	In contrast to IEEE 1547 specifications relevant to the entire facility, Underwriter’s Laboratory (UL) Standard 1741 establishes performance requirements specific to inverters, converters, controllers, and balance-of-plant equipment. Requirements for UL1741 certification of equipment usually but not always coincided with a general requirement for equipment certification by some other standard. In most states, UL1741 certification was indicated for some equipment types and the certification of equipment was also required generally for all applications. In some states, if UL 1741 was not required for any equipment, general equipment certification was not either. Finally, some states did not require UL 1741 but certification to standards was required for all equipment. Field label certification was nearly always permitted under the certification requirement, though lab-tested and pre-certified equipment was preferred.
	IBR	Inverter-based resources (IBRs) permit a generator the flexibility to provide more than active power to the distribution system. Depending on inverter technology, these systems may be controlled to produce a range of power factors, support fault ride-through, and offer a remote disconnect capability.
	SGIP-type technical screens	As the national cornerstone of interconnection standards, to which many regulators refer, the FERC SGIP was evident in many of the state standards. In particular, the set of SGIP technical screens were often adopted in slightly modified form at the state level (FERC 2018).
	Disconnect switches or isolation devices	Many states required stand-alone, visible, and manual disconnect switches or other isolation devices for interconnecting generators. However, these requirements were circumvented by IBRs in some states.
	Insurance	Requirements for general liability insurance varied greatly. Some regulators did not require a certain coverage amount, while others suggested “reasonable” coverage, while still others required specific coverage as a function of nameplate capacity.
Fees & Timelines	Application fees	Though the interconnection review process may necessitate significant and project-specific system upgrade costs, the interconnection process review focused on the predefined fees required for submitting an interconnection application. The application fees may vary by generator capacity and tier of the review process that is required.

[1] For the IEEE 1547-2018 standard, see: https://standards.ieee.org/standard/1547-2018.html.

2.3 Review of State Interconnection Processes

A few key takeaways highlight the differences between state interconnection procedures across the United States: process type, expedited processes, pre-application availability, and Underwriter's Laboratory (UL) 1741-listed equipment.

2.3.1 Process Type

State interconnection processes can be characterized based on common attributes between their overarching procedures and state guidance. State interconnection processes were grouped based on the structure, sophistication, and level of complexity of the process, as described below (Figure 1).

- **Detailed, refined process:** This group includes states that have a specific and detailed process to accommodate many uses and applications in a large, diverse state. The only state in this category is California, which has two sets of interconnection processes (Rule 21 and Wholesale Distribution Access Tariff) based on the how electricity is exported to the grid.
- **Tiered process:** This group includes states that implement a tiered process with three or four different interconnection tracks—or tiers—depending on the capacity and complexity of an interconnection request. Most states use a tiered process
- **Limited information:** This group includes states that have limited or no guidance in place for interconnection. These states have a lack of standardization, which may create significant differences between utilities. Within this group, there may be some guidance at the state level, but it is limited to net metering projects or allows for significant differences between regulated utilities. A total of 10 states were found to have limited information on interconnection processes.

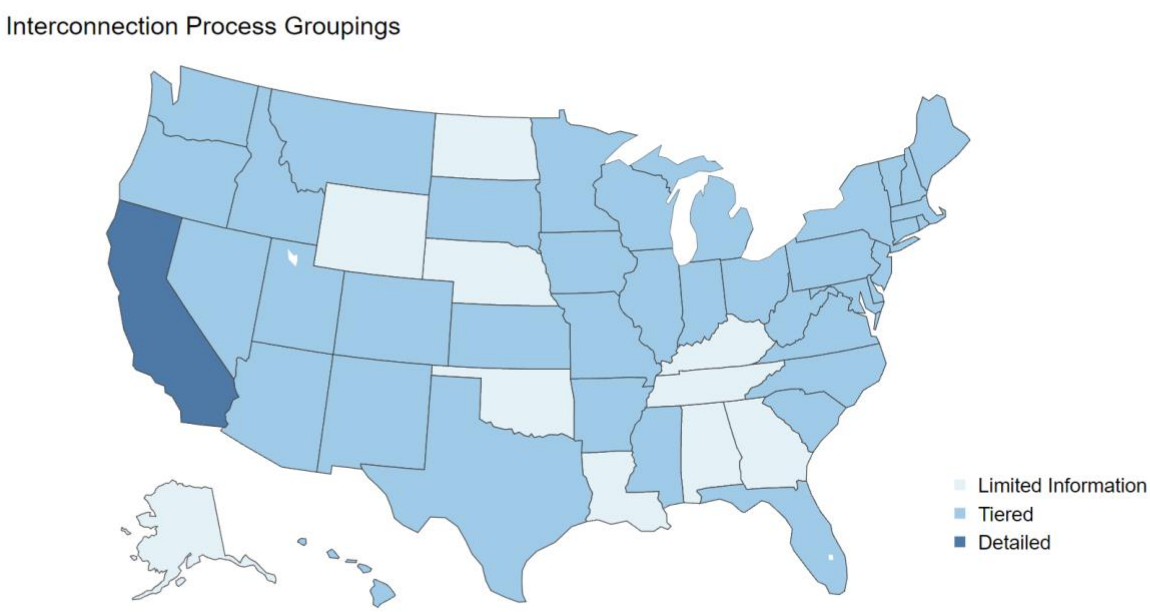

Figure 1. Interconnection Process Group by State

2.3.2 Expedited Processes

Expedited processes are available in some states to simplify interconnection for small projects (Figure 2). Unsurprisingly, most expedited application tracks are for small capacity projects because smaller systems are less likely to require additional studies. The typical capacity limits for these processes are either 2 MW or 5 MW, but some states limit the maximum capacity to as little as 300 kW (New York) or up to 20 MW (Nevada).

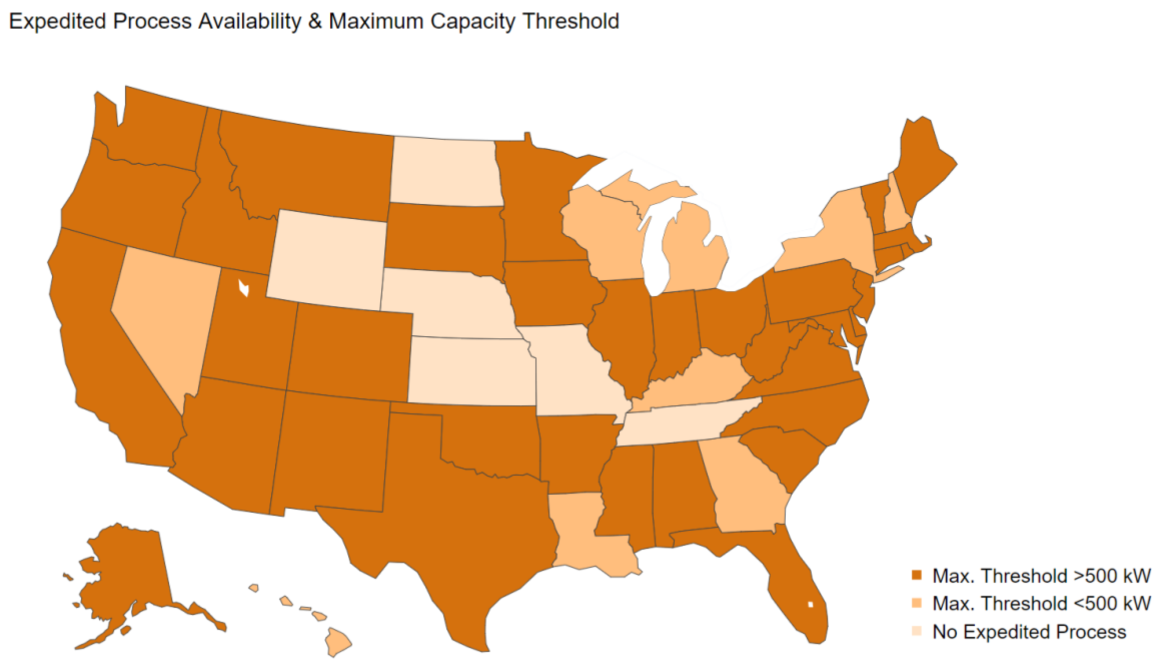

Figure 2. Expedited Processes Availability (shaded states) and Expedited Capacity Threshold [greater than 500 kW (dark orange) and less than 500 kW (light orange)] by State

If a hydropower generator is of suitable scale, an expedited process will have a shorter timeline and lower cost to the applicant because the reviewing authority is checking technical screens rather than conducting a full study. However, many hydropower projects will not qualify for expedited processes because they exceed a predefined capacity threshold set for their jurisdiction (commonly 2 MW or 5 MW, shown in the >500 kW states in Figure 2). Some states near the Great Lakes and Appalachian Mountains regions limit the expedited process to less than 500 kW capacity threshold, so the expedited processes in these regions may not be suitable for hydropower generators. On the other hand, most states in the Western United States and New England have expedited processes that may be suitable for some small capacity hydropower projects.

2.3.3 Pre-Application Availability

Pre-application reports are made available to potential applicants in some states (Figure 3) and are available at low to no cost with fees ranging from $0 to $750. Pre-application reports provide basic information about the distribution circuit at a proposed point of interconnection (POI) and can give a hydropower developer early insight into the hosting capacity or potential challenges of connecting to that point on the circuit. Pre-application reports have been linked to higher approval rates for interconnection applications in Massachusetts (Peterson and Lockhart 2018).

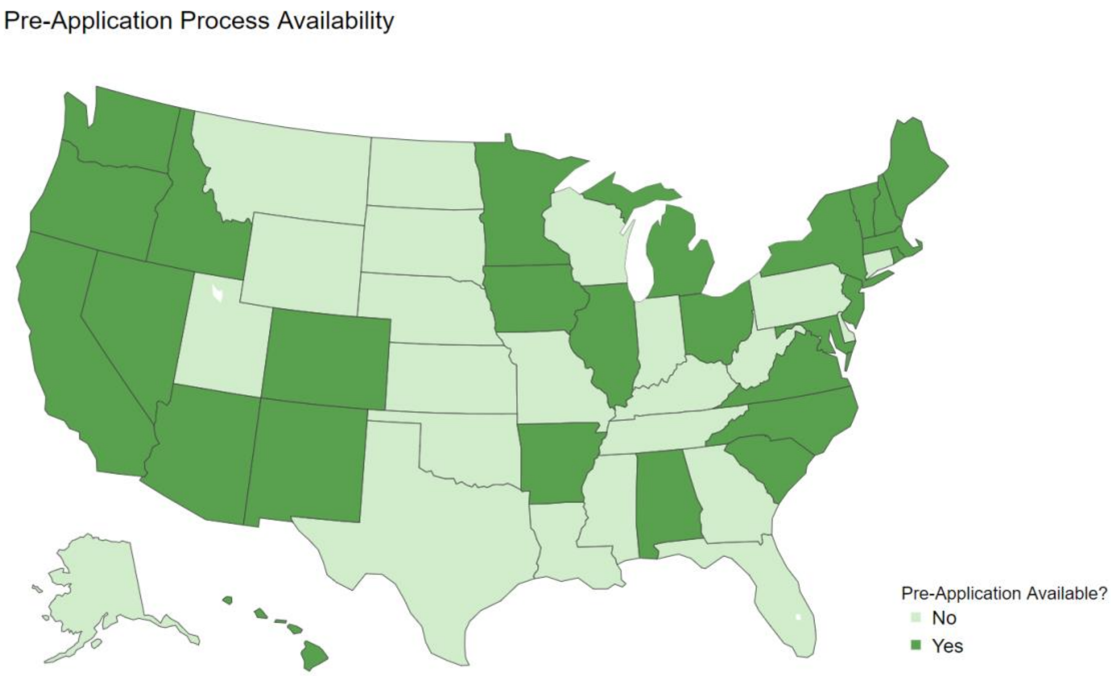

Figure 3. Pre-Application Availability by State

Some jurisdictions, including California, Hawaii, Massachusetts, and the Midcontinent Independent System Operator (MISO), also publish hosting capacity maps that estimate the available capacity for new generator interconnection. Tools like the hosting capacity maps and pre-application reports can allow hydropower developers to pre-screen potential interconnection points before investing in a full system design and interconnection application.

Regions with a significant number of states that offer pre-application reports include the West, Southwest, Northeast, and Mid-Atlantic. Pre-application availability in the Midwest is more sporadic, with about half offering the option. Pre-application reports can be especially valuable for projects that have the potential to require significant infrastructure upgrades, which more commonly coincide with projects of higher installed capacity (MW). Similarly, comparing the pre-application availability map with the map of NPD potential shows that the Appalachian Mountains region—an area with significant potential for systems of higher capacity—does not consistently offer pre-application reports and projects and may face more unexpected upgrade requirements through their formal application process.

2.3.4 UL 1741

Some PUCs or utilities require Underwriter's Laboratory (UL) 1741-listed equipment specifically to qualify for an application track. UL 1741 listed equipment has been pre-tested and certified to operate within the standards for power electronics outlined in the UL documentation. UL 1741 listed equipment are often required to qualify for Fast Track or expedited processes. When UL 1741 listed equipment is required but not used, the interconnection application may be pushed into a more detailed review process or the utility may require lab testing or certification of the equipment so they can better understand the impact to the distribution system. Certification can be performed through field label certification or through lab testing to pre-certify the power electronics.

UL 1741 equipment is a common requirement for application tracks that are limited to 5 MW in nameplate capacity. Areas of active small hydropower development in the Rust Belt and New England often have equipment certification requirements that apply below 5 MW. The use of UL 1741 equipment for hydro projects less than 5 MW and even up to 20 MW may facilitate a better interconnection process by requiring the equipment to meet certain standards and by using power electronics to control the quality of power reaching the POI.

3.0 Implications for Developers

This analysis of state interconnection procedures highlighted the substantial differences between the process, fees, timelines, and requirements from state to state, which can affect developer decisions to undertake small hydropower projects. For example, the minimum insurance requirements for a 5 MW generator range from $100,000 to $2,000,000 in different states and in some states is not specified at all (0). Other significant differences occur between states with respect to the tiered processes and timelines for review. These differences are notable because even small changes between interconnection requirements can influence where a developer chooses to build and interconnect a project.

The inconsistency of interconnection standards across state or utility boundaries may limit or incentivize development in certain jurisdictions. Particularly in areas that do not have high penetration of distributed energy resources (DER), information about the interconnection process is opaque and difficult to navigate. In states where DERs are more common, such as California and New York, there are streamlined interconnection processes with informational guides and online application processes.

Interconnection for small, distributed generators is likely easier to obtain in states that have clearly defined interconnection processes with early access to pre-application reports, which is explored more in the next paper of this series, “Small Hydropower Interconnections: Analysis of Interconnection Processes.” But the locations with clearly defined interconnection processes do not necessarily coincide with the existing pipeline for small hydropower generation, as indicated in the first paper in this series, “Small Hydropower Interconnections: State Interconnection Processes”. In the future, the overlap of hydropower resources with states and distribution systems that do not have clear interconnection processes is likely to be a barrier to project development.

4.0 References

DOE–US Department of Energy. 2016. *Hydropower Vision: A new chapter for America's first renewable electricity source*.

FERC–Federal Energy Regulatory Commission. 2018. *Small Generator Interconnection Procedures*. Available at https://www.ferc.gov/sites/default/files/2020-04/sm-gen-procedures.pdf.

Johnson K, B Hadjerioua, and R Martinez. 2018. *Small hydropower in the United States.* Oak Ridge National Laboratory. ORNL/TM-2018/999.

Peterson Z and E Lockhart. 2018. *Evaluating the Role of Pre-Application Reports in Improving Distributed Generation Interconnection Processes*. National Renewable Energy Laboratory. Golden, CO. NREL/TP-7A40-71765. https://www.nrel.gov/docs/fy19osti/71765.pdf

Appendix A – Interconnection Processes

The process of interconnection generally maps to the following steps, irrespective of jurisdiction (transmission/wholesale or distribution/retail):

- Generator project submits an interconnection application to a utility
- The interconnection requested is reviewed by receiving utility
- The utility makes an approval determination with any caveats (e.g., required grid upgrades) in accordance with regulatory oversight.

However, the specifics of executing this process and the associated technical requirements used to evaluate a requested generator interconnection vary jurisdictionally (transmission or distribution). The process and criteria for interconnection may further vary by region (by independent system operator [ISO]/regional transmission organization [RTO], or even by individual electric utility). The guidance provided below is organized to capture these and other aspects that can complicate this critical step in a generator project's implementation.

Due to the need for site-specific, technical reviews of potential impacts to the utility system that receives the power from the interconnected facility, the interconnection process often constitutes a significant development project risk hurdle. Success through the process, as measured by a signed interconnection agreement (IA) between the project owner and the utility, constitutes the achievement of a significant project milestone. While interconnection in any single location presents technical and legal challenges, the complexity of interconnection scales rapidly as projects of different technologies and locations are considered. In this paper, interconnection procedures will be introduced and then categorized across the regions of active small hydropower development in the United States.

A.1 Interconnection Authority

Small hydropower generation in the United States is defined in this report as facilities under 20 megawatts (MW) in facility nameplate power rating, based on the Federal Energy Regulatory Commission (FERC) Small Generator Interconnection Procedures (SGIP) and subsequent interconnection processes demarcation.[1] It is less common for generation projects of this scale to interconnect to transmission systems, at voltages of 66 kV or more, than to distribution systems. These transmission networks, designed for regional electricity conveyance, support interstate energy and electricity commerce under the jurisdiction of the FERC. There are transmission systems in Texas, Alaska, and Hawaii that do not extend into other states, and thus FERC does not maintain jurisdiction in these areas. However, processes and rules for most transmission system interconnection are generally consistent with the FERC Small Generator and Large Generator Interconnection Procedure (SGIP and LGIP) rules. The FERC SGIP rules apply to projects rated 20 MW or less and connected to the transmission system. The North American Reliability Corporation (NERC) ensures reliability of transmission networks by issuing standards[2] and providing interconnection requirement recommendations to transmission operators. Though these standards are not typically tied to small hydropower generators, the

[1] However, note that the DOE Hydropower Vision defined small hydropower as facilities 10 MW or less in capacity rating (DOE 2016).

[2] NERC establishes generator, transmission, and distribution equipment relay settings, power control, and cybersecurity standards to ensure reliability of the electric power system.

system operators with which a hydropower project owner may wish to secure interconnection may require compliance with the standards as a prerequisite to interconnection.

Typically, generation of 20 MW or less in capacity rating interconnects directly to electricity utility distribution systems. Interconnection of generation connected to distribution systems falls under the purview of the operator of the distribution system, which may be a cooperative, a municipal utility, or an investor-owned utility (IOU). IOUs, and, in several states, cooperatives, are regulated by a Public Utilities Commission (PUC), sometimes referred to as a Public Service Commission (PSC), as authorized by state governments. Municipals and most cooperatives often conform to interconnection policies and criteria of the PUCs in the states they operate. However, municipals and most cooperatives are not under formal jurisdiction of PUC's.[1]

Ultimately, the distribution utility or cooperative specifies the most restrictive standards and processes of interconnection. These distribution standards may be distinct from any interconnection standards that may apply at the transmission level, as enforced through ISOs, RTOs, or individual balancing authorities. Though cooperatives and municipalities are not bound by FERC, and often not regulated by state PUCs, IOUs are regulated by state PUCs. Further, IOUs establish interconnection rules through an open access transmission tariff (OATT), which is reviewed and approved by FERC with input from the state PUC (Chernyakhovskiy et al. 2016). Depending on the state, small hydropower project developers may face interconnection oversight from multiple authorities.

A.2 Interconnection Standards and Procedures

Federal interconnection standards were initially outlined by the Public Utilities Regulatory Policy Act (PURPA) of 1978, which individual utilities adopted in the evaluation of applications at their discretion, seeking system reliability, but also disincentivized to facilitate distributed generation (Chernyahovskiy et al. 2016). For new facilities seeking to produce and then export power to the grid, the process was unclear and generally not conducive to development. Beginning in 2000, state and federal policymakers issued reforms to improve interconnection processes. The Institute of Electrical and Electronics Engineers (IEEE) released the IEEE 1547 standard for interconnection of distributed generation resources less than 10 MW in 2003. Drafted in this same year, the National Association of Regulatory Utility Commissioners (NARUC) model rules informed the FERC SGIP, which were published in May 2005 (Fink 2010).

Today, although FERC establishes national interconnection technical processes and specifications for large and small generators connected to transmission systems, there remains no unified set of interconnection requirements in the United States at distribution scale. Still, in some states, FERC's standards function as a foundational reference to which state level standards revert.

A.3 FERC SGIP

For projects seeking to interconnect through a transmission system rated 20 MW or less, the FERC SGIP provides a clear and well-documented process (FERC 2018). The SGIP final rule "requires all public utilities to adopt standard rules for interconnecting new sources of electricity no larger than 20 MW." The following elements are key procedural components:

---

[1] The PSCs/PUCs of Alaska, Arizona, Oklahoma, and Utah indicate some level of jurisdiction over cooperatives. However, most states only regulate IOUs. Municipal utilities are self-regulated and not governed by PSC/PUCs.

- Fast track: For facilities with synchronous and induction generators less than 2 MW in size, or certified inverter-based systems complying with the size limitations presented in Table A.1, and which pass a set of 10 screening criteria, a fast track process is available, in which formal studies are avoided. Formal studies are typically costly and time intensive. The technical screening criteria may be found in FERC (2018) section 2.2.1.

Table A.1. FERC SGIP Fast Track Eligibility for Inverter-Based Resources

Line Voltage	Eligibility Regardless of Location	Eligibility within 2.5 Electrical Circuit Miles from Substation
< 5 kV	≤ 500 kW	≤ 500 kW
≥ 5 kV and < 15 kV	≤ 2 MW	≤ 3 MW
≥ 15 kV and < 30 kV	≤ 3 MW	≤ 4 MW
≥ 30 kV and ≤ 69 kV	≤ 4 MW	≤ 5 MW

Projects that satisfy the relevant capacity and certification constraints but fail one of the technical screens may provide additional information under a supplemental review process. The more in-depth supplemental review may still conclude acceptable system impact without detailed studies, as described in the study review process.

- Study reviews: Projects that are too large or do not pass these screens, but are below 20 MW, trigger study reviews. Primary components include Feasibility, System Impact, and Facilities Study phases.
  - The Feasibility Study targets an initial review of the impact of the project to the surrounding grid at the point of interconnection (POI), including generating facilities with approved applications that are not yet operational.
  - The System Impact Study (SIS) estimates the generator's impacts to the utility grid, assuming no utility grid upgrades were made. System load flow and, optionally, dynamic stability study results are analyzed for grid performance impacts; any necessary upgrades by the generator project to mitigate impacts are identified.
  - The Facilities Study evaluates grid upgrade scope options for generator impacts identified in the SIS, and further examines safety of interconnection as well as transformer, switchgear, control, and communications systems designs.

Upon successful completion of the fast track, fast track with supplemental review, or study review processes, the project developer will sign an IA with the relevant utility. Securing the IA is a requisite step to achieving FERC licensure. The FERC Small Generator Interconnection Agreement (FERC, 2018) provides pro forma language that is typically used by transmission-owning entities to create utility specific FERC-approved agreements.

FERC SGIP also details pre-application reports, which increase a project developer's situational awareness of the utility system that the project is connecting to. Total capacity, including aggregate queue capacity of nearby circuits, substation and circuit voltages, circuit distances, relevant line section load, number of phases available, distribution infrastructure type (e.g., spot network, grid network, or radial supply), and existing or known constraints, are included in the pre-application report. The fee to the project developer for the report is $300.

For projects rated over 20 MW that intend to interconnect to a transmission system, FERC LGIP applies. This paper does not cover large generator interconnection, which are irrelevant to small hydropower.

A.4 State Interconnections

As with federal policy, state interconnection standards began to change significantly in late 2000 when California introduced Rule 21 (Chernyahovskiy et al. 2016). Subsequently, the Energy Policy Act (EPAct) of 2005 mandated that each state regulatory authority and each nonregulated utility consider establishment of an interconnection standard (NARUC n.d.). In addition, EPAct Section 1254 cites that interconnection services (U.S. Congress, 2005):

> "… shall be offered based upon the standards developed by the Institute of Electrical and Electronics Engineers: IEEE Standard 1547 for Interconnecting Distributed Resources with Electric Power Systems, as they may be amended from time to time."

IEEE 1547, in combination with the related Underwriter's Laboratory (UL) listing for compliance with IEEE 1547 interconnection performance requirements (i.e., UL 1741 certification for interconnection equipment used with distributed energy resources (UL, 2021)), has contributed to some level of national level consistency. However, there remain opportunities to leverage these proven technical guides (IEEE 1547) and compliance tools (UL 1741) further, for streamlining the interconnection standards and processes for distribution connected generation.

To date, established interconnection standards and procedures are often available through state PUCs. However, national and state level organizations of cooperatives and municipalities appear to lack guidance of equivalent specificity and consistency. In the absence of a unified interconnection procedure that applies to all states, the variability in the interconnection process as required by PUCs on IOUs must be considered. Though municipality and cooperative utilities are often not bound by specific interconnection process or standards, the small hydropower development industry has indicated that interconnection with these smaller entities is often much less complex, opaque, time-consuming, and costly. For this reason, IOUs were the focus of a review of interconnection standards and procedures by state. The IOU approach provided a useful lens through which to gauge interconnection in nearly all states. One exception was found in Tennessee, where nearly all power is distributed through unregulated cooperatives and interconnection standards are not readily available. Policies relative to distributed generation were prioritized as the most relevant for small hydropower projects. For the most part, distributed generation was supported across the country. For some states, such as West Virginia, Wyoming, and Nebraska, only net metering guidance was available. In other states, such as Michigan and Florida, interconnection procedures are defined distinctly from net metering procedures. Still other states, such as Kentucky or Oklahoma, have drafted interconnection procedures, but nonetheless limit interconnections to capacities that are unlikely to garner interest from the hydropower industry.

To characterize the interconnection processes across all states, the sources of the procedures, whether in state law, PUC docket or utility docket, were reviewed. State law or PUC guidance were the primary targets of the search. However, in some states, the regulators established a minimum set of requirements and then gave the individual utilities the latitudes to draft specific standards and procedures that complied to the general requirements. For example, the regulator might indicate that reasonable general liability insurance should be carried by the interconnection applicant for the project of interest, but the IOU documents may specify the exact amount of insurance coverage and, potentially, any additional details with regards to aggregate coverage or the infrastructure to be covered under the applicant's policy. Where the procedures of multiple IOUs were reviewed, the various standards were aggregated among all IOUs and with the state regulations, to represent the statewide standards.

Across states, significant variations in standards were encountered. To facilitate a summary of the variations, a set of key indicators was identified through consultation with the Technical Advisory Group (TAG) and presented in Section 2.2. The following section includes analysis of additional key indicators not covered in Section 2.2.

A.5 Analysis of the Database by Key Indicator

Application types were sorted into one of four groups based on kilowatt (kW) capacity limit for the specific application process. The capacity groupings include values up to and including the specified amount, not including any that fall within a lower group. For example, the 5,000 kW group includes all applications that have capacity limits between 51 kW and 5,000 kW. Figure A.1 shows the original capacity limits for each application type by state and the corresponding group that application was sorted into. Blanks cells indicate that the specific state does not have an interconnection application option that falls within that grouping. Multiple entries under one group indicates that the specified state has multiple applications within that range, potentially with different capacity limits or other requirements.

It should be noted that in some cases, a single application type provided by a state or utility can have multiple capacity limit options. For example, an application level that initially states a 10,000 kW capacity limit may also have an additional constraint to a 50 kW capacity limit if the equipment is area-network connected, as is the case in states such as Delaware. For the purposes of the data sorting, this was considered as two separate application types to better capture the full range of application paths dependent on capacity. It should be noted that, in some cases, the limits for a specified application were given in kVA instead of kW. For the purposes of simplifying categorization, these were grouped as if they were provided in kW. The kVA limitations, however, are shown in Figure A.1. Finally, some capacity limits for specific applications are dependent on one or more factors, such as network type, voltage, location, ownership, and others. These restrictions have been individually color coded in Figure A.1, with the color legend specifying the type of exception or condition. For example, Illinois has multiple application tracks within the less than 5,000 kW capacity group that have voltage-related conditions (color coded light blue). This should be interpreted as the specified capacity limit being available only if voltage-related conditions are met by the applicant.

Groupings by Application Capacity (kW) Limit

State	0-50 kW	<5,000 kW	<20,000 kW	No Limit
AK	25	100 kVA 2000	5000 kVA	
AL	10	5000	20000	
AR			20000 kVA	No Limit
AZ	20	2000		
CA	30	1500 2000 5000 5000	20000	No Limit No Limit
CO	10	2000	10000	
CT	20	2000	20000	
DE	10 50	2000	10000 10000	
FL	10	100 2000	10000 kVA	No Limit
GA		3000		
HI		100 3000		No Limit
IA	20 kVA 50 kVA	2000 kVA	10000 kVA 10000 kVA	
ID	10 25	2000	20000	
IL	25 50	500 2000 3000 4000 5000	10000 10000 kVA 10000 kVA	
IN	10 50	2000		No Limit
KS	25 25	100 100 200		No Limit
KY	45			No Limit
LA		300		
MA	15 25			No Limit
MD	10	2000	10000 10000	
ME	25	2000	10000	No Limit
MI	20	150 550 2000		
MN	20	2000 5000		No Limit
MO		100 1000		
MS	20	2000		No Limit
MT	50	2000	10000	
NC	20	100		No Limit
ND				No Limit
NE	25			
NH	25 10 kVA	100 kVA 1000 kVA		No Limit
NJ	10	100 2000 2000		No Limit
NM	10	2000	10000	
NV			20000	
NY	50	300 5000		
OH	25	5000	20000	
OK		300		
OR	25	2000	10000	
PA	10	2000 5000		
RI	25 15			No Limit
SC	20	2000 100 500 1000 2000		
SD	10	2000	20000 10000	
TX	20	500	10000	
UT	25	2000	20000	
VA		500 2000		No Limit
VT				No Limit
WA	25	500	20000	
WI	20	200 1000	15000	
WV	25	2000		
WY	25			

Exceptions/Conditions for Capacity Limits?
- No Restrictions
- Restrictions/Requirements Apply

* TN is excluded from this list as it does not have any state-level guidance for interconnection

** The values in the table represent both individual application types with specific capacity limits as well as instances where there are various capacity "offramps" within a single application. That is, many of the kW limits shown here represent various capacity options stemming from a single process and not separate application processes themselves .

Figure A.1. Capacity Groupings by Interconnection Application Capacity Limits

A.5.1 Other System Requirement Indicators

A.5.1.1 Targeted IBR Evaluations

Whether or not an inverter-based resource (IBR) may be evaluated more efficiently than a non-IBR for a specified application track varies considerably based on several factors. In many cases, the requirement is determined by whether the system is network connected, or more specifically, area-network or spot network connected. These specifications are shown individually in Figure A.2. States grouped into "Potentially" included those with a wide variety of rules and conditions and, therefore, have been grouped together.

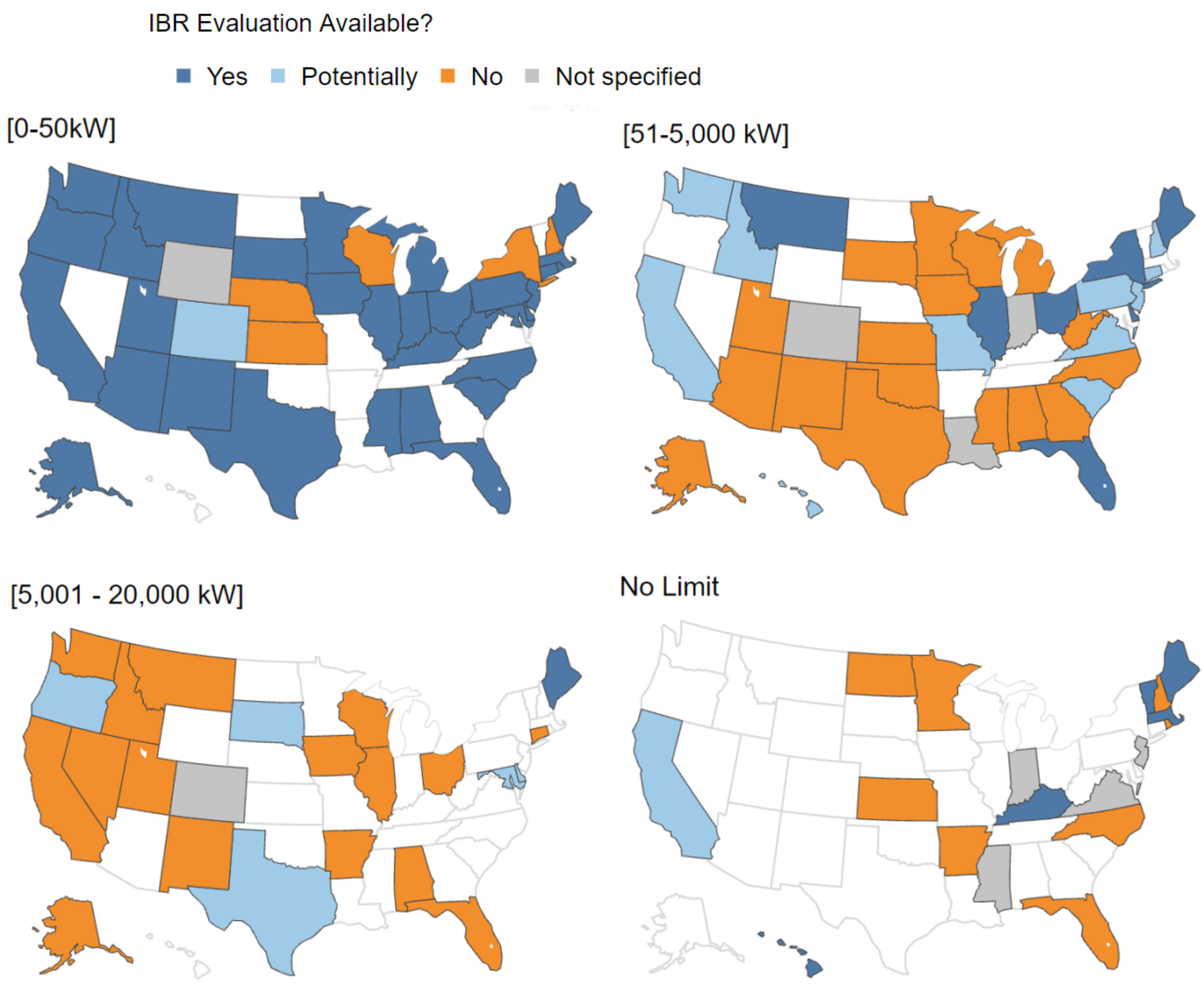

Figure A.2. Inverter-based Resource Evaluations by Capacity Group. Blank states are those where IBR-specific evaluation processes could not be found.

As with the expedited process, most of the application tracks that separate IBR evaluations predominantly fall within the 0–50 kW grouping. The 5,000 kW group shows that there is a mix of processes as the system size increases, and exceptions are present in a variety of states that targeted IBRs for a smaller capacity application track.

A.5.1.2 IEEE 1547 Compliance

IEEE 1547 was explicitly required in nearly all states and is assumed to be the common standard for facility-level interconnection design review.

A.5.1.3 Disconnect Switches Required

Most states explicitly required a disconnect switch or equivalent isolation device with visible airgap to facilitate safe operations and maintenance of grids. Though some states were less explicit in interconnection guidelines, the small hydropower developer should treat disconnect switches as a common requirement for project interconnection.

A.5.1.4 SGIP-Type Technical Screens

Figure A.3 shows the presence of SGIP-type technology screen requirements by capacity group. Note that this figure only tracks if these filters apply and does not provide information where they do not apply. That is, if no information on these filters was found within each state and application track, it was not assumed that they did not apply. However, the TAG indicated that developers may apply similar screens in their own prioritization of projects. This was done to avoid stating a requirement was not present when the documentation of such requirements may not have been available.

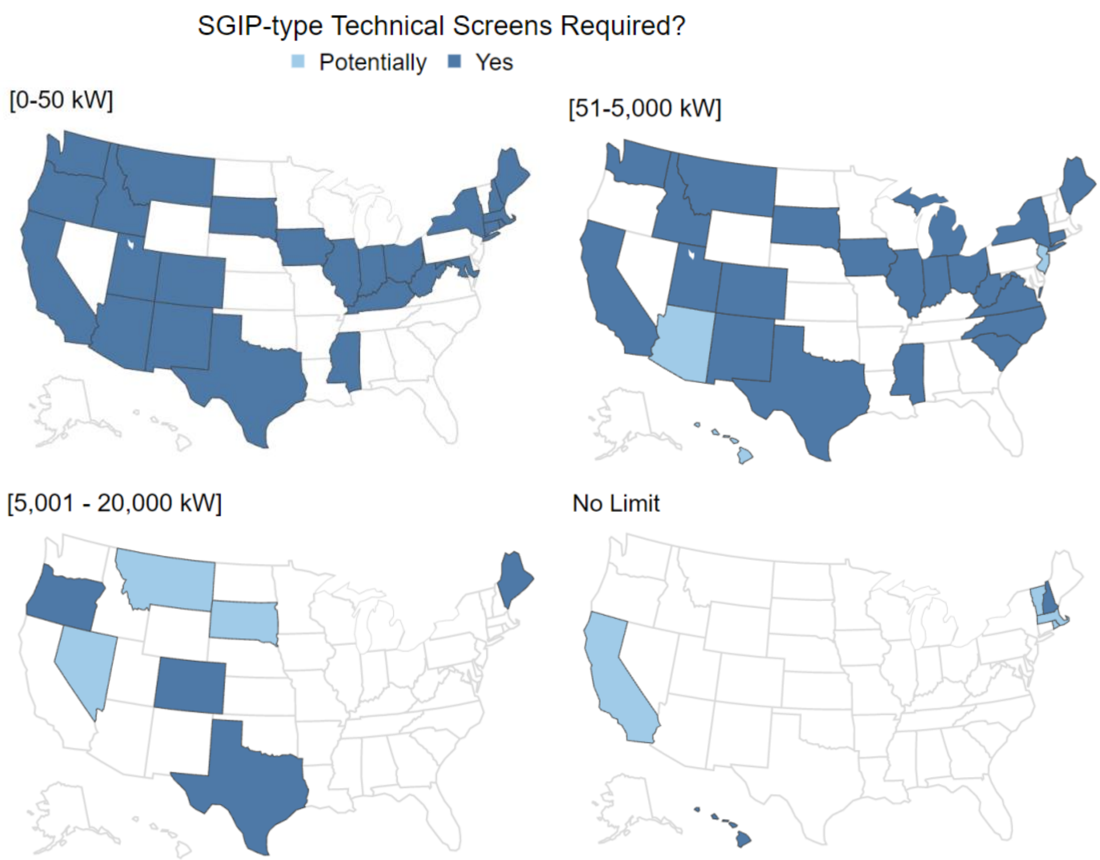

Figure A.3. SGIP-type Technology Filter Requirement by Capacity Group. Blank states are those where no information was found or states did not have an application for the specified capacity group.

SGIP-type filters are most often required in both the less than 50 kW group and the less than 5,000 kW group. Upwards of these groupings, SGIP-type requirements start to appear with exceptions and caveats where they may not always apply. In the case of Arizona in the less than 5,000 kW category and multiple Northeastern states in the No Limit category, whether SGIP-type requirements applied was strictly tied to whether the applicant was using an expedited application process.

A.5.1.5 Insurance Requirements

Figure A.4 documents the presence of insurance requirements by capacity group. Note that the visual only tracks states in which insurance is absolutely required or potentially required for the given capacity group.

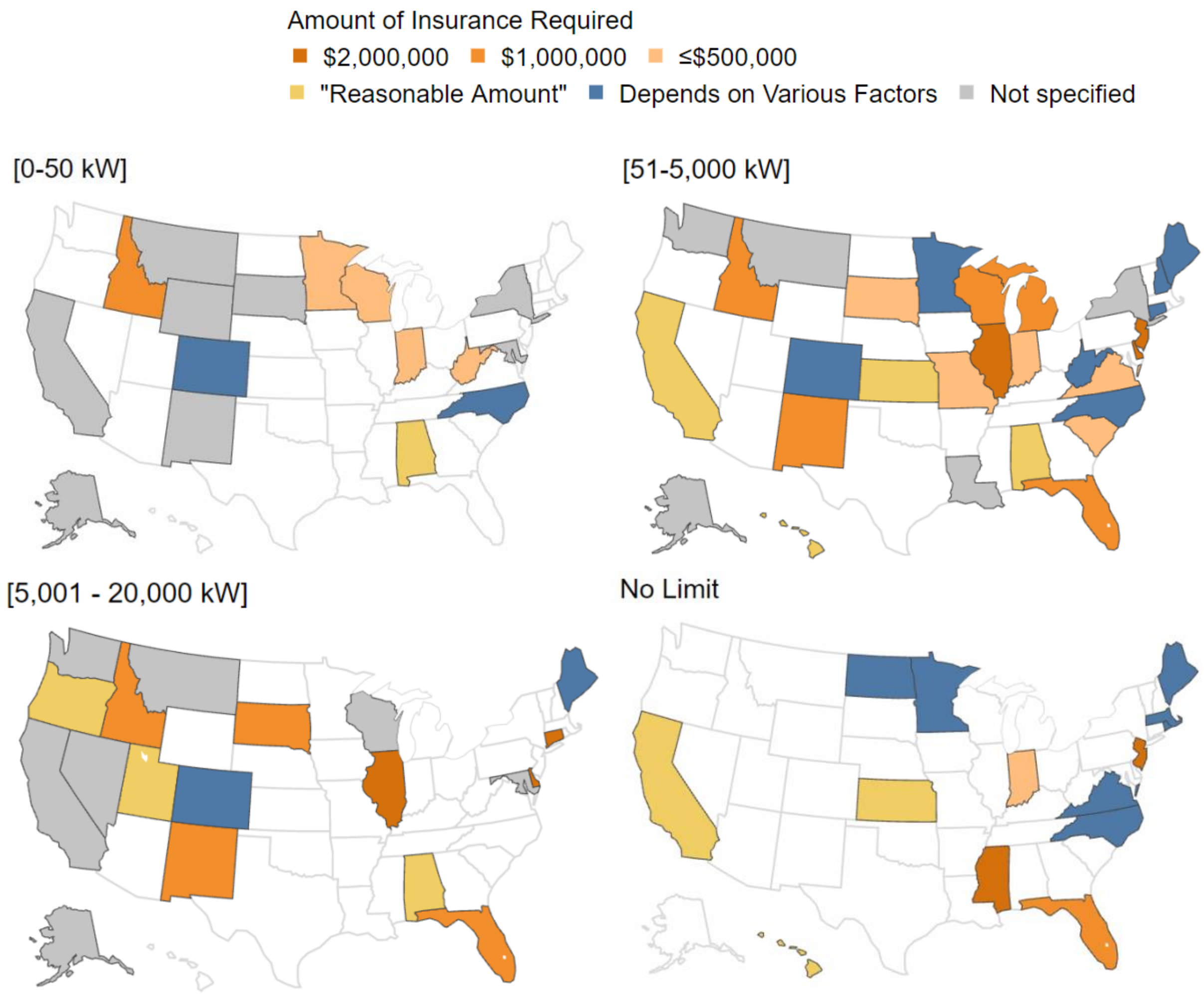

Figure A.4. Insurance Requirements and Associated Amounts by Capacity Group

Insurance requirements and their respective amounts vary considerably both by state and by capacity group. Many application tracks require insurance but have many requirements or various amounts that apply depending on several factors. Overall, individual states tend to be consistent across the capacity groups in how they determine insurance requirements.

A.5.1.6 Application Fees

Flat and variable interconnection application fees were surveyed across U.S. states, and these fees, which in almost every state fall within $3/kW, are often significantly less costly than facility construction or network upgrades. Overall, smaller capacities (i.e., less than 50 kW) offer the lowest fees on average, and many states reserve free applications at this tier. Some states, however, have much higher fixed values for this level. Other states impose variable fees even within this lowest capacity tier. As capacity increases, the average application fee climbs, with the highest, unbounded capacity tiers reaching an average of approximately $750 to $1,250 per application in states with fixed fees and $100 plus $1 to $3 per kW in states with variable fees. For projects less than 5,000 kW in capacity, states with fixed fees dictate approximately $500 to $700 application costs and variable fee states typically add a $1/kW on top of a $50 to $100 base fee. Within the less than 20,000 kW category, the values predominantly focus around the $1,000 mark in fixed-fee states and $100 + $2/kW in variable fee states.

A.6 References

Chernyakhovskiy I, T Tian, J McLaren, M Miller, and N Geller. 2016. *U.S. laws and regulations for renewable energy grid interconnections*. NREL/TP-6A20-6724.

FERC–Federal Energy Regulatory Commission. 2018. *Small Generator Interconnection Procedures*. Available at https://www.ferc.gov/sites/default/files/2020-04/sm-gen-procedures.pdf.

Fink S, K Porter, and J Rogers. 2010. *The relevance of generation interconnection procedures to feed-in tariffs in the United States*. NREL/SR-6A20-48987.

NARUC– National Association of Regulatory Utility Commissioners. *An introduction to the interconnection policy in the United States*. Available: https://pubs.naruc.org/pub.cfm?id=5375FAA8-2354-D714-51DB-01C5769A4007.

UL – Underwriters Laboratory. 2021. Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distrubuted Energy Resources. Standard 1741, Edition 3. https://standardscatalog.ul.com/ProductDetail.aspx?productId=UL1741.

U.S. Congress. 2005. *Energy Policy Act of 2005*. https://www.congress.gov/109/plaws/publ58/PLAW-109publ58.pdf

Pacific Northwest National Laboratory

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99354

1-888-375-PNNL (7665)

www.pnnl.gov