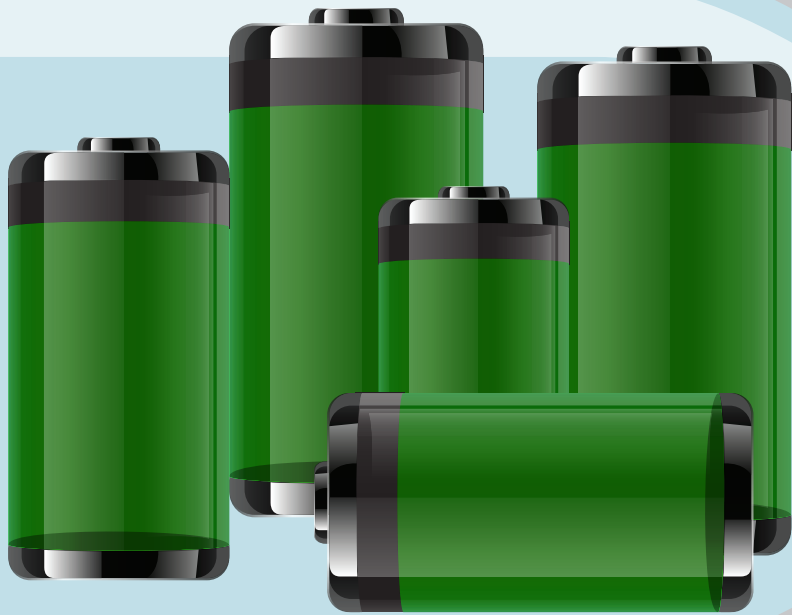


The Interconnection Bottleneck

Why Most Energy Storage Projects Never Get Built



MAY 2023

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Why Most Energy Storage Projects Never Get Built

A MASSACHUSETTS CASE STUDY

**Prepared by Applied Economics Clinic
for Clean Energy Group**

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About this Report

This report, prepared by the Applied Economics Clinic (AEC) on behalf of Clean Energy Group (CEG), presents an analysis of the grid interconnection processes for energy storage and renewable energy projects, and the barriers that create an interconnection bottleneck constraining the deployment of these clean energy resources. The report uses Massachusetts as a case study, but the findings are broadly applicable across the United States. The report addresses both transmission- and distribution-level interconnection barriers, and makes recommendations states should consider to reduce distribution-level barriers that are within the states' regulatory purview. This report is one of a series of reports CEG has published addressing energy storage policy and programs in Massachusetts and New England. Learn more about CEG's work on energy storage policy at www.cleanegroup.org/initiatives/energy-storage-policy-and-regulation.

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Executive Summary

Interconnection is the process by which electric generation and storage resources of all types receive permission to connect to the local distribution grid or to the transmission system. Interconnection also encompasses the changes to the grid necessary to connect new generation and storage. In many states, interconnection processes have not kept up with rising interest in and incentives for solar and storage resources in recent years. As a result, interconnection applications are increasing while interconnection authorizations lag behind. Lengthening wait times and rising interconnection costs dramatically restrict the rate at which renewable generation and energy storage resources are installed, creating impediments to realizing state energy policy goals such as greenhouse gas emissions reduction targets, renewable generation and energy storage procurement targets, and grid modernization plans.

For this white paper, the Applied Economics Clinic (AEC), acting under contract to Clean Energy Group, investigated these interconnection barriers using Massachusetts as a case study. AEC gathered information through interviews with key stakeholders in the energy industry and policy community. Interviewees provided insight into the obstacles to efficient interconnection and discussed potential solutions. AEC synthesized information from these interviews with the current policy and academic literature on interconnection to make the following recommendations to distribution utilities, state agencies tasked with overseeing interconnection, independent system operators, regional transmission operators, and the Federal Energy Regulatory Commission:

1. **Work towards proactive, integrated, and system-wide interconnection planning.** Policymakers need to create interconnection processes that take a systemic view of applications rather than examining interconnection applications and grid upgrades in isolation.
2. **Continuously iterate interconnection processes to build in regular improvements, examine effectiveness, and coordinate stakeholders to tackle ad hoc coordination problems.** Even if a “perfect” interconnection process were achieved in the near-term, new challenges (some that were anticipated and some that were not) will emerge that require iteration of improvements to tackle issues as they arise. For example, stakeholders may struggle to coordinate among themselves while a process change is still being tested.
3. **Tackle barriers and solutions comprehensively.** Eliminating various interconnection barriers will require integrating multiple solutions; no single solution is a silver bullet. If individual barriers are addressed in isolation, benefits will be limited. For example, anticipatory planning will have limited benefits if it does not also address the question of who pays or if the interconnection process remains slow and cumbersome.
4. **End cost causation by spreading distribution system upgrade costs over a broader set of stakeholders than just the projects applying for interconnection.** Cost determination should occur prior to and separately from specific individual or cluster project applications.

5. **Incorporate storage operational parameters into interconnection processes.**

Interconnection should study proposed storage resources in a manner reflecting how those resources would reasonably be expected to operate once interconnected, allow technologies such as smart inverters to regulate bidirectional power flows, and enable predictable charging and discharging from storage systems.

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Forward

This report addresses the seemingly mundane process of interconnecting new distributed energy resources (DERs) – in this case, energy storage and solar+storage – to the electric grid. In common terms, interconnection simply means “a mutual connection between two or more things.” In the context of DERs, interconnection is the necessary step by which a newly installed battery or solar+storage system gets physically connected to the local electric grid, so that it can exchange electrons with that grid.

This sounds like a simple process. But when new technologies like battery storage encounter legacy structures like the electric grid – which was designed for one-way power flows – things can get very complicated very quickly. In order to ensure the local grid has the ability to manage power flowing both to and from the proposed distributed energy resource – utilities call this ability “hosting capacity” – both the local grid and the proposed new DER must be studied by the distribution utility. If hosting capacity is found to be insufficient, the local grid will need to be upgraded; and the cost of these upgrades, which can run into hundreds of thousands or even millions of dollars, is borne solely by the project that caused the need. Frequently the added cost of grid upgrades will kill an energy storage project, by making it uneconomic. This model of cost allocation is known as “cost causation,” and it is used almost universally across the United States.

But cost isn’t the only issue that arises in the interconnection process. Because project interconnection studies and the resulting grid upgrades are taken one at a time by utilities, other proposed projects must wait their turn in the interconnection queue; and when the number of proposals grows faster than the utility can process them, the interconnection queue can become quite long. In some cases, projects must wait years in the queue before they can even begin the process of finding out what cost they will be asked to bear in order to achieve interconnection.

This isn’t an isolated problem. Across the US, at both the distribution and transmission levels, interconnection queues are getting longer. And, the problem is not economically insignificant: in Massachusetts alone, at this writing, the proposed capacity additions waiting in the interconnection queue represent approximately \$8 billion in planned investments, or 1.2 percent of Massachusetts’ total economic activity for 2022.

In part, expanding interconnection queues are a result of states’ growing commitment to decarbonization, and therefore to increased renewable energy deployment. If states can't scale up renewables, they will never be able to retire gas, coal and oil, because historically, demand for electricity only rises (and with increasing electrification of both the building and transportation sectors, is about to begin rising much faster than the historical trend would suggest). At this writing, 30 states, Washington, D.C., and two territories have active renewable or clean energy requirements, while an additional three states and one territory have set voluntary renewable energy goals; and in just the past few years, 22 states, plus the District of Columbia and Puerto Rico, have adopted 100% clean energy goals. Most of these 100% goals must be achieved between 2035 and 2050.

To meet these goals, states need to deploy more and more renewable generation. And because renewables are variable generators, they require the buffer of energy storage to make power generation match power demand in real time. This is the main impetus for states to scale up storage, and it is the reason states are increasingly adopting energy storage targets, policies and incentive programs. Currently, nine states have energy storage procurement targets; and along with these targets come incentive programs aimed at increasing the amount of energy storage independent developers install.

However, no amount of policy and programs will succeed if interconnection barriers prevent projects from connecting to the grid. Developers will not build, and financiers will not finance, a clean energy project that cannot interconnect. In the world of clean energy, interconnection is where the rubber meets the road – and right now the interconnection road resembles a bumpy, narrow donkey path more than the twelve-lane superhighway states will need to achieve their decarbonization and renewable energy targets.

The simple truth is that the vast majority of proposed energy storage projects now in interconnection queues will never be built, because developers cannot achieve interconnection approval within a reasonable time frame or for a reasonable cost. Increasingly, the number of projects withdrawn from interconnection queues outstrips the number that achieve an interconnection agreement and proceed to construction.

Until this interconnection bottleneck is fixed, the flow of clean energy resources will remain constricted, and energy storage markets will struggle. If states don't bring interconnection processes up to speed and find ways to socialize the costs, energy storage markets will never come to scale.

This report identifies and explains the friction points that make interconnecting distributed energy storage so time-consuming, costly and difficult, and begins to explore some potential solutions to these problems.

Todd Olinsky-Paul
Senior Project Director
Clean Energy Group

Introduction

Interconnection is the process by which distributed generation resources like rooftop solar panels and energy storage resources like residential- or commercial-scale behind-the-meter batteries—collectively called distributed energy resources (DERs)—secure permission to connect to electric transmission and distribution systems.¹

On its face, interconnection is a straightforward administrative process in which applicants propose a project to their local utility or regional transmission organization, have it evaluated for grid system impacts, and make whatever changes are deemed necessary by that study to interconnect. But as DER deployment rates increase, the situation becomes much more complicated, and numerous difficulties arise. Projects that are smaller in size could be expedited, but many projects go through a standard review process whereby the utility conducts a system impact study and then works with the applicant to modify the project so that the distribution grid upgrades necessitated by the proposed project (for which the applicant must pay) are reasonable. Such grid upgrades are often necessary because solar and storage resources can be configured to send power back to the grid, and utilities must ensure their equipment is ready to handle the resulting two-way power flows.

Various barriers to interconnection—allocating the costs for all grid upgrades solely to interconnecting customers, a lack of proactive planning for hosting capacity for power flows to and from the distribution circuit, disadvantages faced by storage resources during interconnection, and other process failures—occur due to this individualized and project-specific method of determining how to interconnect new renewable generation and energy storage resources.

Obstacles to interconnection are an increasingly important issue for state energy agencies as distributed solar and battery resources play an important role in numerous state policy goals, such as decarbonization of the energy sector and increased resiliency of on-site energy systems.² As states seek to increase DER deployment to meet decarbonization and clean energy targets, the role of the interconnection process in facilitating the installation of DERs is becoming more important – and failures of the interconnection process are becoming increasingly costly and frustrating to utilities, customers, developers, and state energy planners and regulators.

Interconnection barriers hinder renewable energy resource development because DER project applications may languish in lengthy interconnection queues without receiving an authorization to interconnect (and therefore proceed to construction), may quit the process due to higher costs, or may never be proposed in the first place if the interconnection process is anticipated to be lengthy and costly. The result—reduced numbers of energy storage and distributed generation projects coming online—can have significant impacts, not just for would-be DER project owners who cannot complete their projects, but for the state, the ratepayers, and society at large.

¹ MA DOER. *Utility Interconnection in Massachusetts*. Available at: <https://www.mass.gov/info-details/utility-interconnection-in-massachusetts#introduction-..>

² U.S. Department of Energy. “Distributed Energy Resources for Resilience.” Available at: <https://www.energy.gov/eere/femp/distributed-energy-resources-resilience>.

This white paper studies energy storage interconnection barriers, using Massachusetts as a case study. Massachusetts provides an instructive example due to its advanced energy storage targets and incentive programs, advanced decarbonization and clean energy goals, and the steps it has already begun to take to address interconnection issues. For example, the Massachusetts *Clean Energy and Climate Plan for 2025 and 2035* views the deployment of distributed solar and storage resources as vital to meeting electricity demand and to meeting solar and storage deployment targets.³ In addition, a breakthrough in the deployment of DERs is one of the net-zero compliant scenarios in Massachusetts' *2050 Decarbonization Roadmap*.⁴

However, interconnection barriers have already had negative impacts in Massachusetts. In 2019, more than 900 MW of proposed DER capacity, representing more than half the renewable target for the state's SMART solar incentive program, was delayed as a result of National Grid's DER cluster studies, resulting in a regulatory investigation of the utility.⁵ As of Summer 2021, 679 MW of solar resources were still under review in the Massachusetts interconnection process "group studies" (in which multiple projects can apply to be assessed for their anticipated impact on the grid as a group or cluster, rather than as single projects).⁶ At the end of 2022, solar capacity made up 2,321 MW total in the interconnection queue, standalone storage 429 MW, and hybrid capacity 868 MW.⁷ By comparison, Massachusetts had 1,195 MW of existing solar capacity in 2021 and 181 MW of storage capacity.⁸

Interconnection problems are not unique to a single state or region. At the national level, data from Lawrence Berkeley National Laboratory (LBNL) shows 1.9 million MW of solar, storage, and wind resources waiting in transmission interconnection queues.⁹ The queues for solar, storage, and wind

³ Massachusetts Executive Office of Energy and Environmental Affairs (MA EEA). 2022. *Massachusetts Clean Energy and Climate Plan for 2025 and 2030*. Available at: <https://www.mass.gov/doc/clean-energy-and-climate-plan-for-2025-and-2030/download>. p. 68

⁴ MA EEA. 2022. *Massachusetts 2050 Decarbonization Roadmap*. Available at: <https://www.mass.gov/info-details/ma-decarbonization-roadmap>. p. 15.

⁵ 1) Murphy, M. 2019. "DPU Investigating National Grid's Management." wbur. Available at: <https://www.wbur.org/news/2019/10/10/regulators-solar-power-installation-delays>. 2) MA DPU. 2019. *Petition of Massachusetts Electric Company and Nantucket Electric Company, each doing business as National Grid, pursuant to G.L. c. 164, § 94 and 220 CMR 5.00, for Approval of General Increases in Base Distribution Rates for Electric Service*. DPU 18-150. Available at: <https://fileservice.eea.comacloud.net/FileService.Api/file/FileRoom/11262053>. p. 501.

⁶ Kennedy, R. 2021. "Interconnection issues jeopardize New England's clean energy goals." *pv magazine*. Available at: <https://pv-magazine-usa.com/2021/06/23/interconnection-issues-jeopardize-new-englands-clean-energy-goals/>.

⁷ AEC calculations using source: MA DOER. Aggregated RAW DATA set through December 2022. Available at: <https://www.mass.gov/info-details/utility-interconnection-in-massachusetts#:~:text=Interconnection%20is%20the%20process%20of,and%20subsequent%20Authorization%20to%20Connect>.

⁸ 1) EIA. 2021. "Form 860 Data – Schedule 3 'Solar Technology Data' (Operable Units Only)." Available at: <https://www.eia.gov/electricity/data/eia860/>; 2) EIA. 2021. "Form 860 Data – Schedule 3 'Energy Storage Data' (Operable Units Only)." Available at: <https://www.eia.gov/electricity/data/eia860/>

⁹ LBNL. 2023. "Generation, Storage, and Hybrid Capacity in Interconnection Queues." Available at: <https://emp.lbl.gov/generation-storage-and-hybrid-capacity>.

resources represent 93 percent of all queued electric resources nationally.¹⁰ And according to research published by LBNL on the outcome of interconnection requests from 2000 to 2016 and on wait times in the 2000s and 2010s, much of this proposed capacity will never be built because projects will either languish in the review process or drop out.¹¹

This report investigates the barriers to more effective and efficient interconnection of distributed solar and storage resources. Section II provides data on the increasing disconnect between proposed and authorized solar and storage capacity in Massachusetts. Section III describes the interconnection process in Massachusetts and defines key concepts such as hosting capacity. Section IV describes the various barriers to interconnection in detail and how those barriers slow the deployment of distributed solar and storage resources. Finally, Section V discusses proposed solutions to interconnection barriers, and concludes with AEC's recommendations—chiefly, that solutions to address interconnection barriers for distributed solar and storage resources should be viewed as paths towards an increasingly anticipatory and integrated planning system that would allow states to more easily and equitably accommodate anticipated increases in interconnected DER capacity.

Interviews with industry stakeholders

Interviews with key stakeholders in interconnection policy debates were vital to developing the analysis presented in this white paper and for assessing the existing literature on interconnection. AEC conducted eleven interviews, most in August and September 2022, with one occurring in January 2023. Interview participants were selected based on their institutional affiliation and expertise, and included a mix of former- and current- interconnection project applicants, policy experts, and advocates from a variety of organizations with either direct business interest or advocacy and policy interest in interconnection policy. Participants were either in leadership roles in their respective organizations or were technical specialists on interconnection. Their titles include President, Lead Consultant, Lead Interconnection Engineer, or Senior Program Director.

Interview participants were asked to discuss the challenges to more rapid interconnection of solar and storage DERs, describe the operation of existing interconnection systems, and to discuss potential improvements to existing interconnection systems. Where possible, they discussed barriers in the context of Massachusetts, but otherwise highlighted findings or assessments from the jurisdictions about which they were most knowledgeable. The interviews shaped this white paper's evaluation of the available literature by providing commentary on how to evaluate and filter existing proposals or explanations of interconnection barriers. A list of interview participants is provided in the appendix of this white paper. Assertions and recommendations made herein should not be taken as representative of specific interviewees' views or the views of their respective institutions. This paper does not include direct quotes.

¹⁰ Ibid.

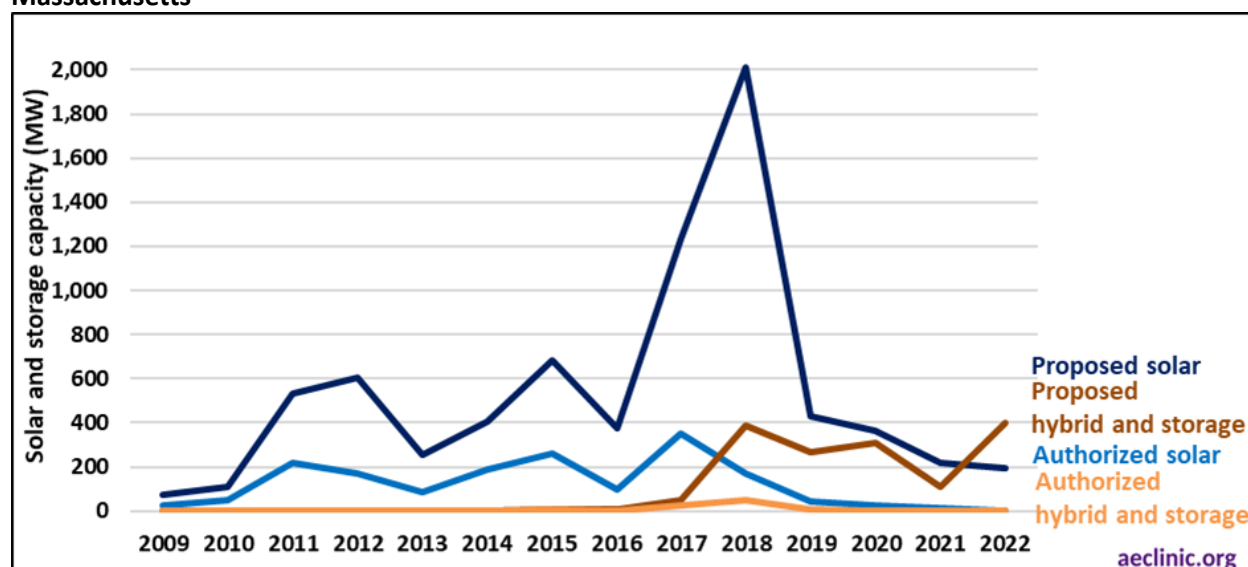
¹¹ LBNL. 2022. "Record Amounts of Zero-carbon Electricity Generation and Storage Now Seeking Grid Interconnection." Available at: <https://newscenter.lbl.gov/2022/04/13/record-amounts-of-zero-carbon-electricity-generation-and-storage-now-seeking-grid-interconnection/>.

Data on Massachusetts, ISO-NE, and National Interconnection

Proposed and authorized projects in Massachusetts

In Massachusetts, distribution utilities provide monthly interconnection reports that contain raw data on total proposed capacity, dates that projects were proposed and the dates they were authorized to interconnect to the distribution grid, the types of resources making interconnection requests, and the number of completed and withdrawn or incomplete applications.¹² The annual proposed capacity (of solar, storage, and hybrid solar-storage resources) increased by a factor of 8 between 2009 and 2022—with an even sharper spike in 2018.¹³ The annual authorized capacity, however, is no higher in 2022 than it was a decade prior (see Figure 1). During 2018, authorized capacity also spiked temporarily, but was only 10 times higher than in 2009 while proposed capacity was thirty-three times higher.

Figure 1. Proposed and authorized solar and storage capacity additions of solar and storage per year in Massachusetts



Note. This figure understates the number of completed and proposed projects because of data that was omitted by AEC due to unclear labelling by the utilities' monthly reporting. "Hybrid" refers to projects containing both solar and storage resources. "Storage" refers to standalone storage projects. AEC calculations used source data from Massachusetts Department of Energy Resources (MA DOER). Aggregated RAW DATA set through December 2022. Available at: <https://www.mass.gov/info-details/utility-interconnection-in-massachusetts#:~:text=Interconnection%20is%20the%20process%20of,and%20subsequent%20Authorization%20to%20Connect>.

¹² 1) The utilities providing data include National Grid, Eversource East, Eversource West, and Unitil. 2) MA DOER. *Utility Interconnection in Massachusetts*. Available at: <https://www.mass.gov/info-details/utility-interconnection-in-massachusetts#introduction-t>.

¹³ Ibid.

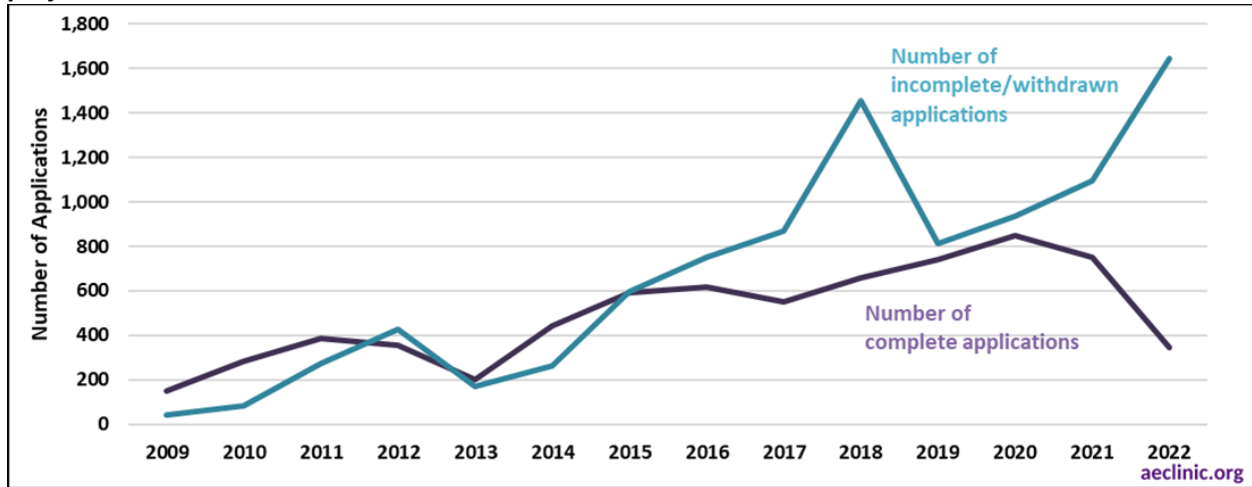
This pattern of proposed capacity for interconnection outpacing annual authorized capacity—with a spike in 2018—holds true as well when only solar resources are considered, which make up most of the proposed capacity and nearly all the authorized capacity shown in Figure 1. From 2011 to 2018, solar capacity made up over 80 percent of all proposed and installed capacity in Massachusetts.

Storage resources (encompassing both standalone storage and solar-storage hybrid projects) also display a large divergence between total annual proposed and authorized capacity. Further, examination of the storage interconnection data reveals that, with the exception of 2017 (28 MW) and 2018 (49 MW), authorized hybrid and standalone storage capacity never exceeded 7 MW per year between 2013 and 2022. Proposed storage capacity fell sharply during the COVID-19 pandemic but rebounded by 2022, when it outpaced the change in proposed solar capacity for the first and only time.

The continuing trend of proposed solar and storage capacity outpacing authorized capacity suggests that the number of applications awaiting interconnection or exiting interconnection processes are rising year after year. This is confirmed by data comparing the number of complete and “incomplete/withdrawn” applications in Massachusetts’ interconnection queue (see Figure 2).¹⁴ It is important to note that complete applications are “counted” in the year they were filed, not the year of completion—for example, if an application was started in 2015 and completed in 2017, data for 2015 are then corrected to attribute the completed application to the correct year. The drop in the number of complete applications after 2020 shown in Figure 2 may be due to applications filed in those years that are not yet complete (in other words, the downward trend in recent years may simply reflect that some applications from those years are still in progress, and the data will be updated for those years once these in-progress applications are complete).

¹⁴ Complete applications, with a small number of exceptions, are those that finish the application process and are authorized to interconnect. They are labelled “Connected,” “Online,” or “Application Completed/Closed” in the data provided by the MA DOER. Incomplete/withdrawn applications are applications that either exit the interconnection process before completion or are still in the process of completing their applications. They are grouped together due to the range of descriptions used by utilities in the data. Note that there are only 16 observations (out of a total 7,235) that are designated as complete but are not listed as having an interconnection agreement.

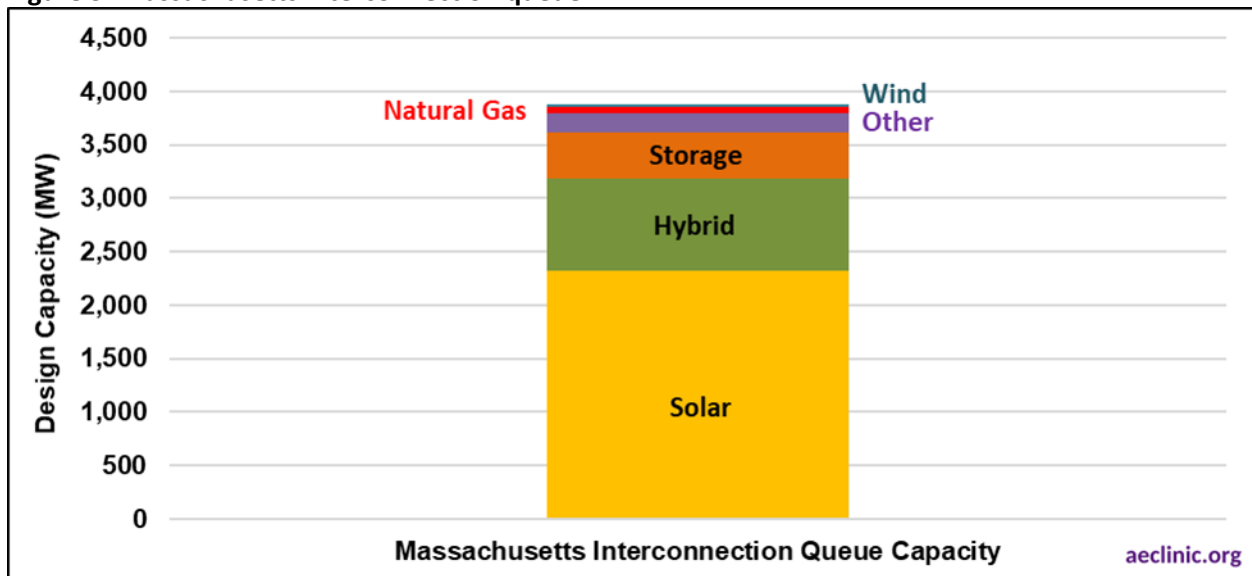
Figure 2. Massachusetts complete and incomplete/withdrawn applications of solar and storage projects



AEC calculations used source data from MA DOER. Aggregated RAW DATA set through December 2022. Available at: <https://www.mass.gov/info-details/utility-interconnection-in-massachusetts#:~:text=Interconnection%20is%20the%20process%20of,and%20subsequent%20Authorization%20to%20Connect.>

The result of the two trends noted above—proposed solar and storage capacity and the number of incomplete or withdrawn applications respectively and consistently exceeding authorized and complete applications—results in solar, storage, and hybrid capacity making up 93 percent of the Massachusetts interconnection queue (see Figure 3).

Figure 3. Massachusetts interconnection queue



Note. This figure omits 5 MW of capacity. AEC calculations used source data from MA DOER. Aggregated RAW DATA set through December 2022. Available at: <https://www.mass.gov/info-details/utility-interconnection-in-massachusetts#:~:text=Interconnection%20is%20the%20process%20of,and%20subsequent%20Authorization%20to%20Connect.>

According to the latest data published by Massachusetts DOER, solar alone makes up 60 percent (2,321 MW) of the state interconnection queue. This is more than double Massachusetts' existing solar capacity (1,195 MW) as of 2021.¹⁵ Hybrid solar-storage projects (868 MW) and standalone storage projects (429 MW) make up 22 percent and 11 percent respectively. Standalone storage project capacity in the queue is 2.4 times Massachusetts' 2021 installed storage capacity (181 MW).¹⁶

The capacity in Massachusetts' interconnection queue represents approximately \$8 billion¹⁷ in planned investments, or 1.2 percent of Massachusetts' 2022 economic activity.¹⁸

Interconnection queues for ISO-NE and the United States as a whole

Lawrence Berkeley National Laboratory (LBNL) collects data on transmission interconnection queues showing that the rapid increase in the amount of distributed solar and storage capacity in local interconnection queues is mirrored in national and regional interconnection queues for larger projects. Nationally, the transmission queue has quadrupled in size and is now approximately 63 percent larger than installed capacity (see Figure 4).¹⁹ By comparison, in 2010 the U.S. transmission interconnection queue was half the size of installed capacity. This dramatic growth of the transmission queue has predominantly resulted from increased interconnection requests for solar, storage, and hybrid solar-storage projects.²⁰

¹⁵ EIA. 2021. "Form 860 Data – Schedule 3 'Solar Technology Data' (Operable Units Only)." Available at: <https://www.eia.gov/electricity/data/eia860/>

¹⁶ EIA. 2021. "Form 860 Data – Schedule 3 'Energy Storage Data' (Operable Units Only)." Available at: <https://www.eia.gov/electricity/data/eia860/>

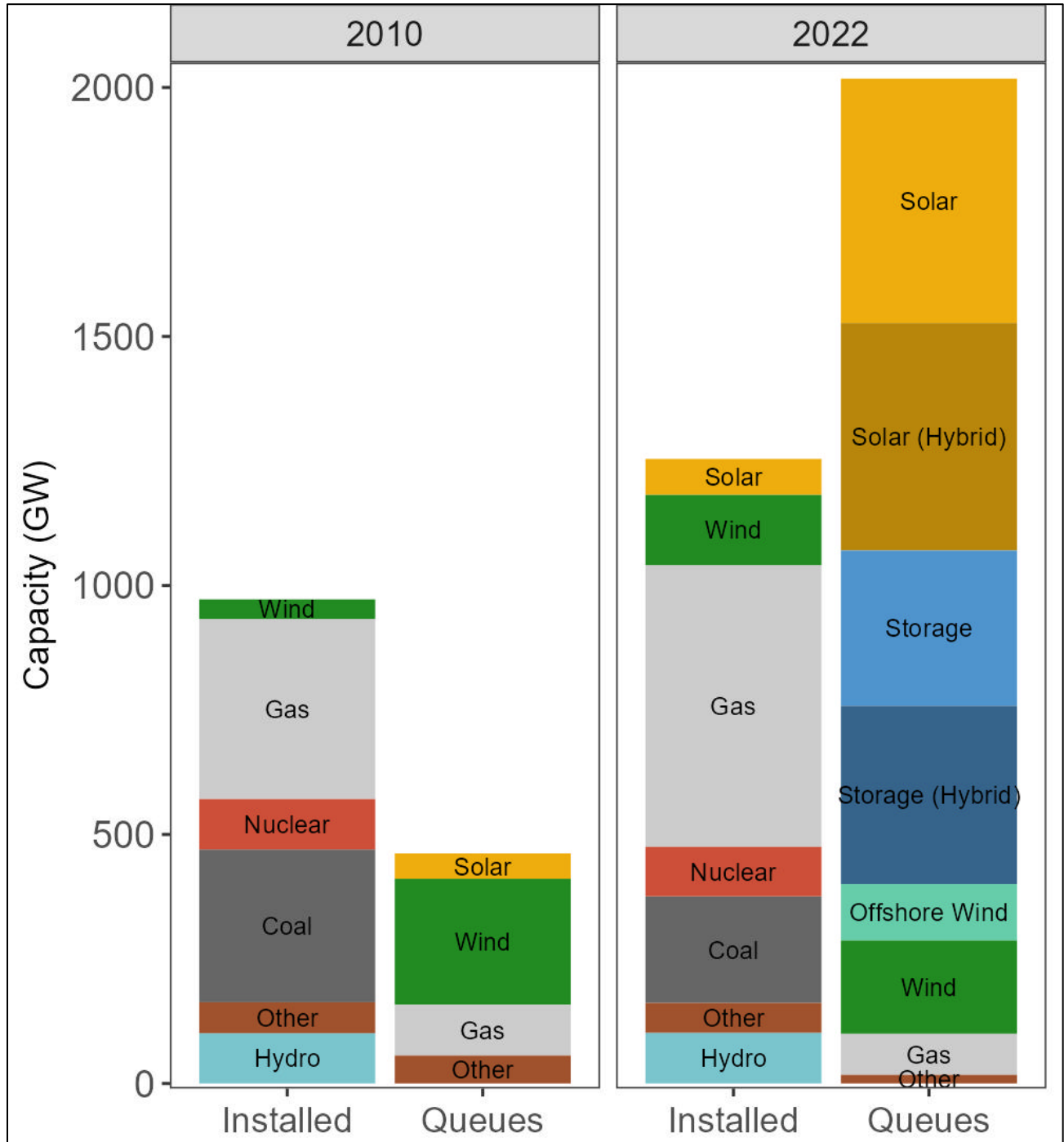
¹⁷ This is an approximate calculation. Queue capacity for each respective resource type was multiplied by "total overnight cost of capital" (OCC) estimates representative generation sources in ISO-NE. Solar capacity in the queue was multiplied by the OCC for base distributed generation. The estimated cost of building a plant - excluding interest, but including project contingencies such as undefined scope, pricing uncertainty, and owners' cost components—for Hybrid queue capacity was multiplied by the OCC for "Solar PV with storage," storage by the OCC for "battery storage," and natural gas by the OCC for "combined cycle—single shaft." "Other" capacity was multiplied by an average of the OCC values previously listed on account of its heterogenous character. The calculations also assume the OCC estimates are scalable to capacity. The calculations are undertaken in 2022 dollar values, regardless of when projects were started and do not net out any expenditures already undertaken on projects due to lack of available data. AEC calculations using source: EIA. 2023. *Assumptions to the Annual Energy Outlook 2023: Electricity Market Module*. Available at: https://www.eia.gov/outlooks/aeo/assumptions/pdf/EMM_Assumptions.pdf. p. 6-7.

¹⁸ AEC Calculations using source: FRED. 2023. "Gross Domestic Product: All Industry Total in Massachusetts (MANGSP)." Available at: <https://fred.stlouisfed.org/series/MANGSP>.

¹⁹ Berkeley Lab. 2023. *Generation, Storage, and Hybrid Capacity in Interconnection Queues*. Available at: <https://emp.lbl.gov/generation-storage-and-hybrid-capacity>.

²⁰ Ibid.

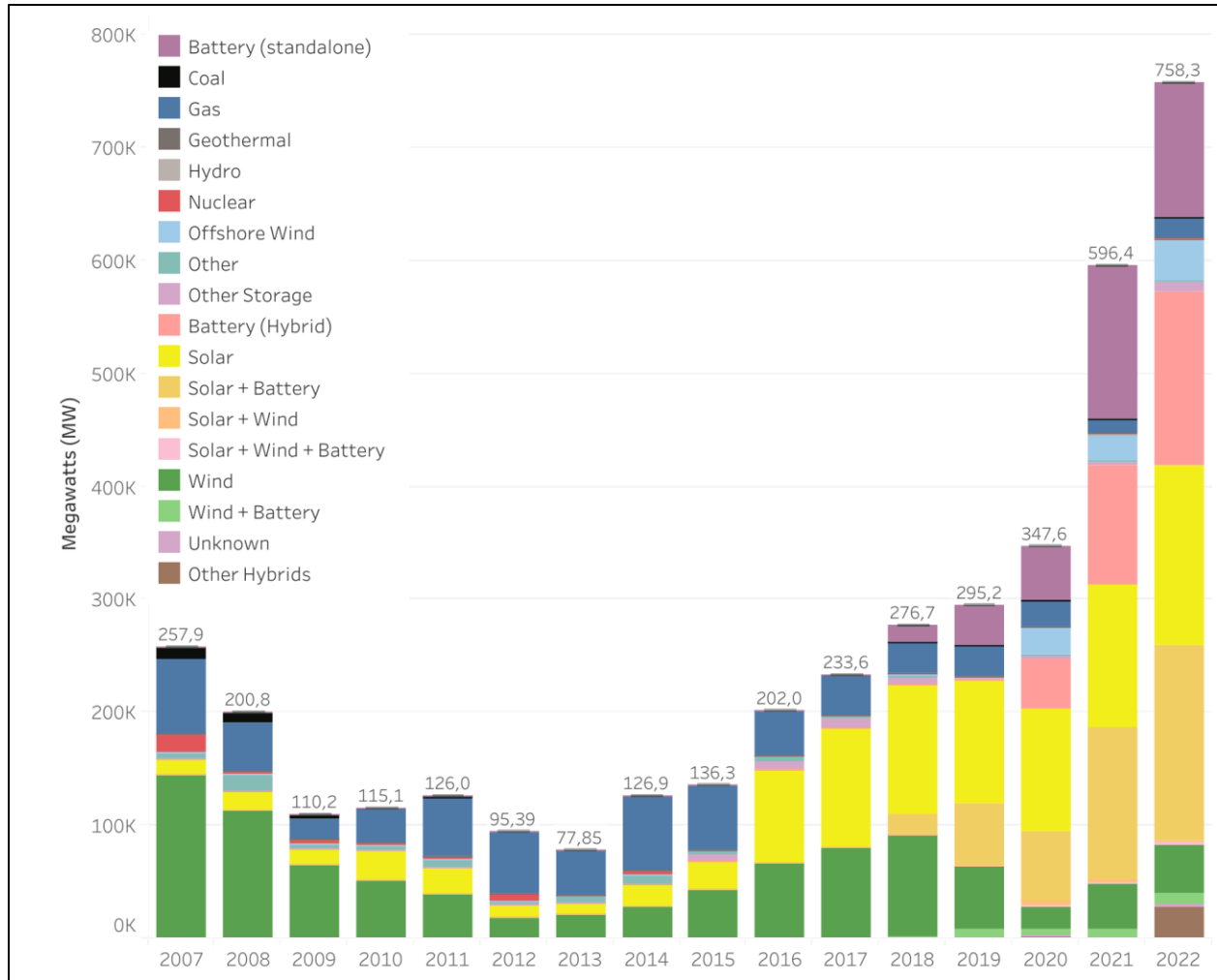
Figure 4. Changes in national interconnection queues and installed capacity



Reproduced from: LBNL. 2023. "Grid connection requests grow by 40% in 2022 as clean energy surges, despite backlogs and uncertainty." Available at: <https://emp.lbl.gov/news/grid-connection-requests-grow-40-2022-clean>.

The national transmission queue fell from 2007 to 2013 (see Figure 5);²¹ through 2015, gas remained a significant component, almost 43 percent in 2015. Starting in 2016, solar resources in the queue grew significantly, rising to 41 percent in 2016 alone. As with the distribution-level queues in Massachusetts, standalone and hybrid battery projects began to make up a significant percentage of the interconnection queue additions nationwide just in the last four years. Meanwhile, the national queue is larger now than at any time since LBNL began collecting data.

Figure 5. Historic national transmission queue from 2007 to 2022



Reproduced from: LBNL. 2023. *Generation, Storage, and Hybrid Capacity in Interconnection Queues*. Available at: <https://emp.lbl.gov/generation-storage-and-hybrid-capacity>.

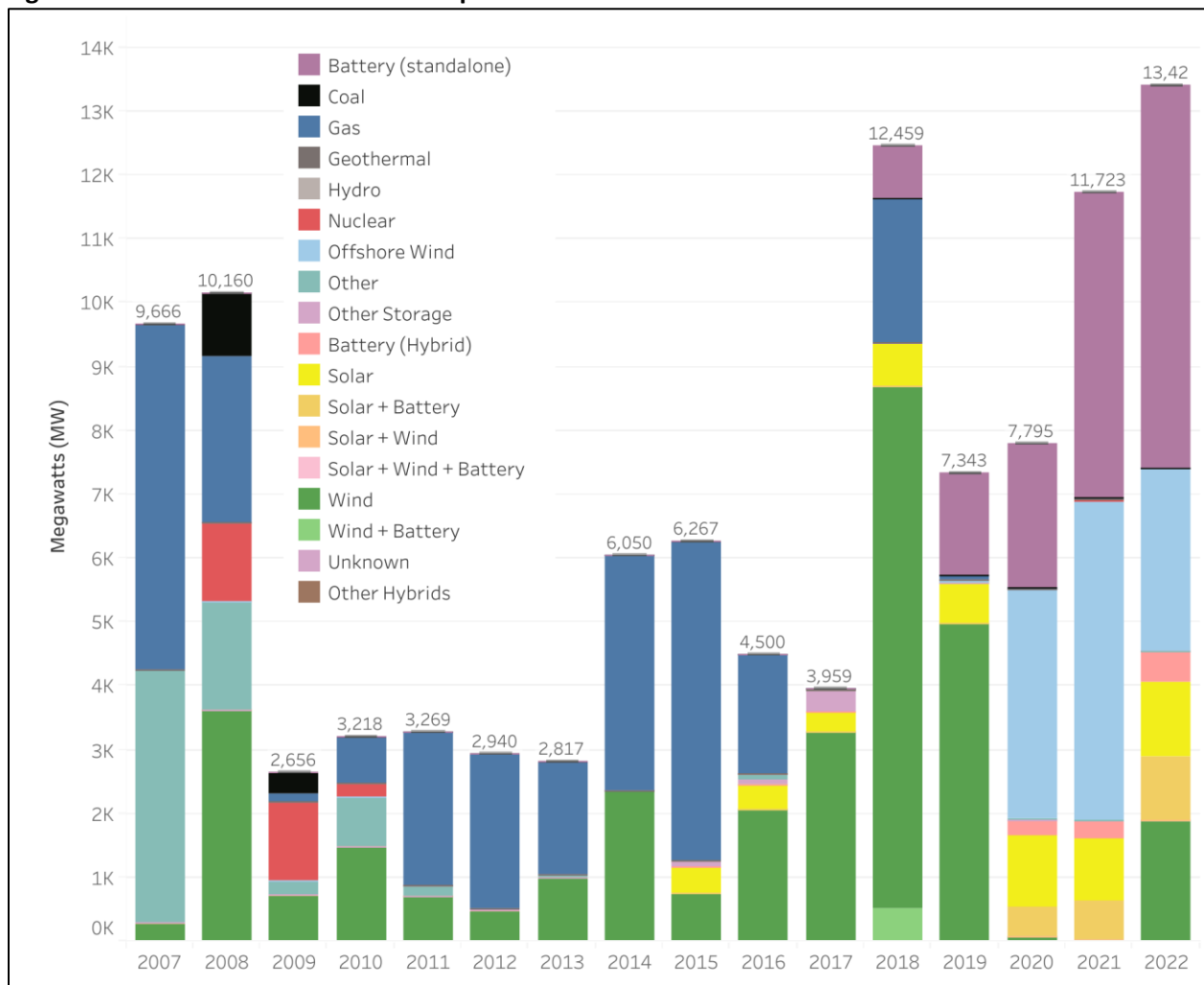
This national trend holds true in New England. The New England Independent System Operator (ISO-NE) interconnection queue still contained coal resources in 2009 and 2010.²² Since 2013 it has grown

²¹ Ibid.

²² Ibid.

each year and is now at its largest since LBNL began collecting data (see Figure 6). Unlike the national transmission queue, however, the ISO-NE queue's recent growth is due primarily to proposed wind resources (onshore wind, wind and battery projects, and offshore wind). It has only been since 2020 that battery storage projects become a substantial component of the ISO-NE interconnection queue. Solar constitutes only about 9 percent of the current ISO-NE queue compared to nearly 21 percent nationally. Projects with a battery or storage element are a much larger percentage of the ISO-NE queue than solar: 56 percent in 2022. At the national level, battery or storage resources constitute 60 percent of the queue.

Figure 6. Historic ISO-NE transmission queue from 2007 to 2022



Reproduced from: LBNL. 2023. *Generation, Storage, and Hybrid Capacity in Interconnection Queues*. Available at: <https://emp.lbl.gov/news/grid-connection-requests-grow-40-2022-clean>.

Characterizing the Interconnection Process

To understand the numerous barriers that make DER interconnection a slow and costly process, it is important to consider the processes proposed projects go through when applying to interconnect. Broadly, these processes fall into two categories: 1) smaller projects administered by local electric distribution company (EDC) processes, or 2) larger projects administered by regional transmission organization (RTO)/independent system operator (ISO) or Federal Energy Regulatory Commission (FERC) processes. In Massachusetts, the project applicant (or interconnecting customer) must obtain an interconnection agreement and an authorization to interconnect from either their local distribution company or the regional grid operator, ISO New England (ISO-NE), before proceeding to construction.²³

The ISO/RTO interconnection process

Only projects that 1) Intend to connect to the regional transmission system; and 2) Do not intend to sell 100 percent of their output to their electric utility must go through the ISO/RTO process.²⁴ Where no regional transmission organization or independent system operator exists, interconnection procedures go directly through the FERC.²⁵

The EDC interconnection process

Smaller projects go through the interconnection process run by the electric distribution company²⁶—in Massachusetts, this includes National Grid, Eversource East, Eversource West, and Unitil.²⁷ Each has its own interconnection processes regulated by the Commonwealth’s Department of Public Utilities (MA DPU), which requires each utility to maintain a standardized interconnection tariff²⁸ that describes the interconnection process and requirements for an interconnecting customer to connect a power-generating facility to the utility’s system (see Figure 7).²⁹

²³ MA DOER. *Utility Interconnection in Massachusetts*. Available at: <https://www.mass.gov/info-details/utility-interconnection-in-massachusetts#introduction->

²⁴ ISO-NE. “Is the ISO New England Interconnection Process Right for You?” Available at: <https://www.iso-ne.com/participate/applications-status-changes/interconnection-process-guide/is-the-interconnection-process-right-for-you>.

²⁵ 1) U.S. AID and the National Association of Regulatory Utility Commissioners. “An Introduction to Interconnection Policy in the United States.” Available at: <https://pubs.naruc.org/pub.cfm?id=5375FAA8-2354-D714-51DB-01C5769A4007>. p. 7; 2) EPA. 2019. *Interconnection: Plugging RE-Powering Sites Into the Electric Grid*. Prepared for EPA by ICF Incorporated, LLC. Available at: https://www.epa.gov/sites/default/files/2019-10/documents/interconnection_plugging_re_powering_sites_into_the_electric_grid_oct2019_508.pdf. p. 4.

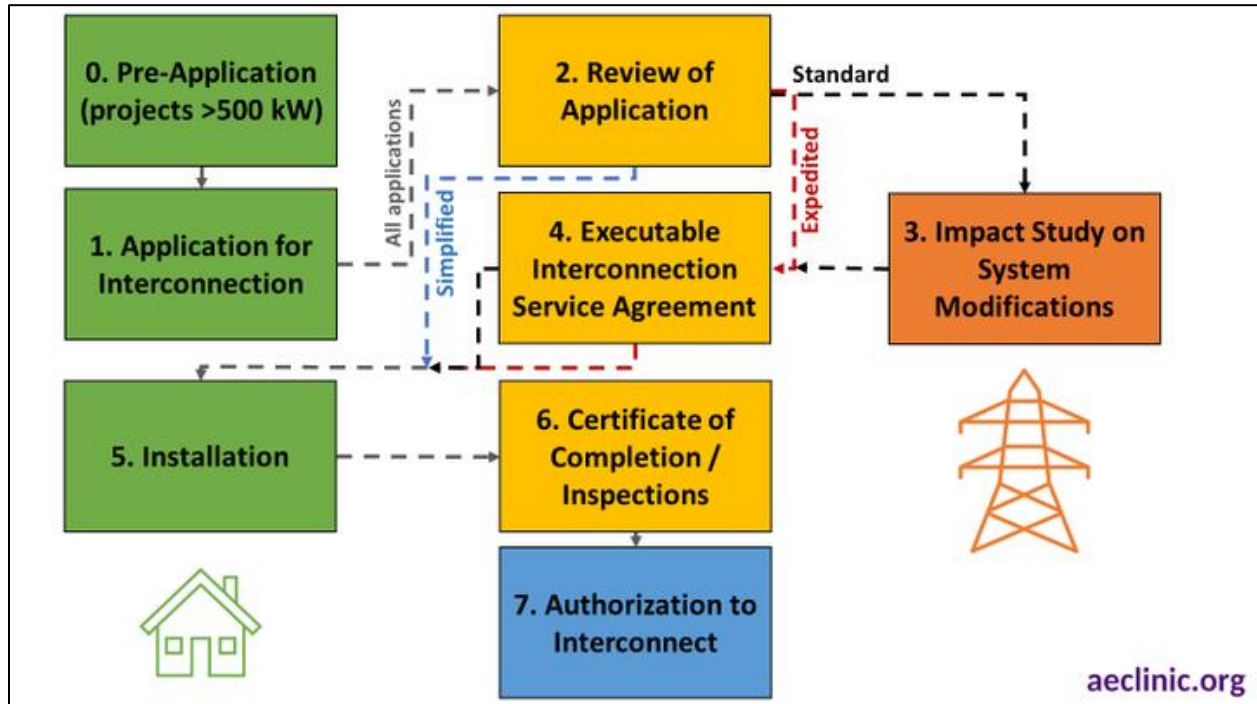
²⁶ ISO-NE. “Is the ISO New England Interconnection Process Right for You?” Available at: <https://www.iso-ne.com/participate/applications-status-changes/interconnection-process-guide/is-the-interconnection-process-right-for-you>.

²⁷ MA DOER. *Utility Interconnection in Massachusetts*. Available at: <https://www.mass.gov/info-details/utility-interconnection-in-massachusetts#introduction->

²⁸ Ibid.

²⁹ MA DPU. 2021. *Standards for Interconnection of Distributed Generation: NSTAR Electric Company d/b/a Eversource Energy*. Available at: https://www.eversource.com/content/docs/default-source/rates-tariffs/ma-electric/55-tariff-ma.pdf?sfvrsn=943800bb_5. p. 4.

Figure 7. Massachusetts interconnection process



Source: MA DPU Docket No.1320. October 2016. Standards for Interconnection of Distributed Generation. Submitted by Massachusetts Electric Company and Nantucket Electric Company d/b/a National Grid. Available at: https://www9.nationalgridus.com/non_html/interconnect_stds_ma.pdf.

There are three variations of the utility-level (state-regulated) interconnection application process (“Standard,” “Expedited” and “Simplified,” described in detail below). All involve a series of screenings to determine eligibility, followed by varying processes depending on the likelihood of grid system impacts.³⁰ Which process an interconnection application enters depends on system size—smaller projects are more likely to enter the simplified process—and the anticipated impacts on the distribution system.

1. **Standard:**³¹ Requires the customer to do an impact study in addition to signing an executable interconnection service agreement. The study is undertaken following a pre-study agreement to determine how the proposed system needs to be changed to mitigate impacts on the electric system from interconnecting the project; the study can result in proposed system modification costs that the customer must agree to pay before the project can proceed.

³⁰ MA DPU Docket No.1320. October 2016. Standards for Interconnection of Distributed Generation. Submitted by Massachusetts Electric Company and Nantucket Electric Company d/b/a National Grid. Available at: https://www9.nationalgridus.com/non_html/interconnect_stds_ma.pdf. Pg. 16.

³¹ Ibid. Pg. 25- 30.

2. **Expedited:**³² Allows the customer to sign an executable interconnection service agreement without completing an impact study. The utility may require the expedited application to conduct internal studies on the system (without committing to additional costs) or make modifications at the applicant’s expense to mitigate reverse load flow—when power flows back to a transformer on the distribution system from an end-use customer.
3. **Simplified:**³³ Projects on the simplified track can go straight from application review to the installation of the proposed facility, with the utility only requiring interconnecting customers to pay for minor system modifications.

Regardless of which process a project goes through, the Massachusetts interconnection process has three vital features: determination of hosting capacity, applicants’ payment of costs, and iteration between utilities and project applicants on the upgrades and system modifications the latter can accept to receive an authorization to interconnect. These three features ultimately help determine where the process creates barriers to more rapid interconnection.

Hosting capacity: Utilities subject interconnection applications to technical screenings (and applications in the standard process track to an impact study) out of concern for “hosting capacity”—the maximum estimated capacity of DERs that can be accommodated in a particular grid area without impacting safety, power quality, operations, or without additional grid upgrades.³⁴ Hosting capacity is not the same across an entire distribution network and can vary over small distances. Project modifications are done in the name of ensuring safety, reliability, and power quality. Hosting capacity (that is, the DER capacity that can be accommodated before upgrading the grid) will have different upgrade needs based on:

- The characteristics of a proposed distributed solar or storage system;
- The location and expected behavior over time of all DERs on the system;
- The existing equipment available on the system at any given time (which evolves over time due to new upgrades made from interconnections and the changing load and generational resources on the distribution grid); and
- The distribution planning practices used by a utility.³⁵

Hosting capacity does not represent a hard limit on further DERs; it is feasible to install more resources over the hosting capacity limit through certain incremental technical changes.³⁶ However beyond those incremental changes, upgrades will be necessary to forestall curtailments (i.e., localized blackouts).

³² Ibid. Pg. 21-24.

³³ Ibid. Pg. 16-21.

³⁴ Unitil. 2023. “Interconnection Hosting Capacity Map.” Available at: <https://unitil.com/ways-to-save/solar-private-generation/interconnection-hosting-capacity-map>.

³⁵ Interview with Ted Ko, August 26, 2022.

³⁶ 1) Ibid; 2) Palmintier, B., R. Broderick, B. Mather, M. Coddington, K. Baker, F. Ding, M. Reno, M. Lave, and A. Bharatkumar. 2016. On the Path to Sunshot: Emerging Issues and Challenges in Integrating Solar with the Distribution System. NREL. Available at: <https://www.nrel.gov/docs/fy16osti/65331.pdf>. p. 19.

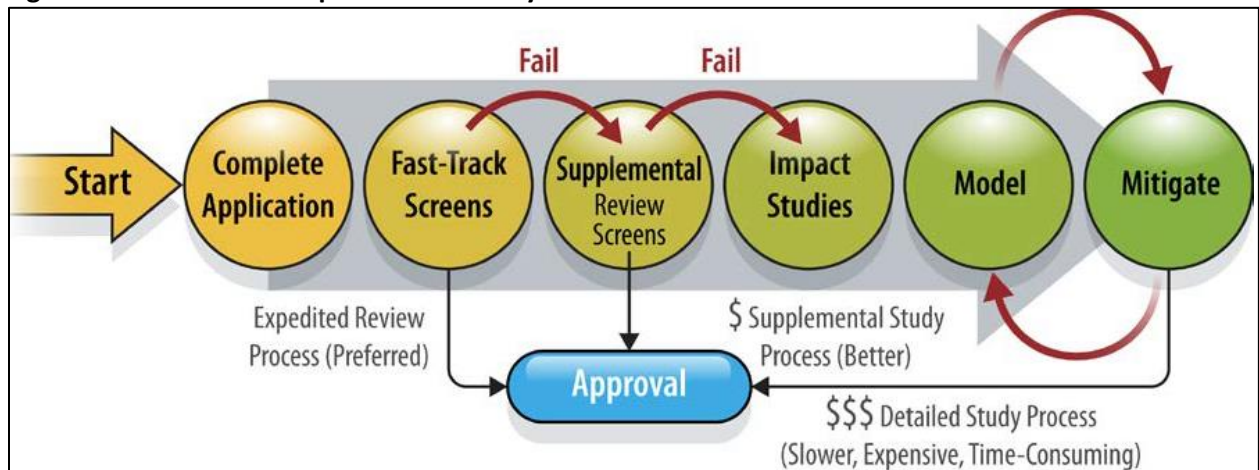
Cost causation: Interconnecting customers are the sole bearers of the costs of significant distribution system modifications needed because of their proposed projects (simplified projects bear no or minimal costs), even if those upgrades may benefit others in addition to the applicant.

The role of iteration: Interconnecting customers on standard projects must work with the utility to do a system impact analysis to determine what kind of hosting capacity is necessary to accommodate their project. This may involve lengthy back-and-forth over the details of the proposed project until both parties arrive at an agreed upon set of upgrades, project parameters, and costs.

Similarities between Massachusetts and other state-level interconnection processes

The essential features of the Massachusetts process— hosting capacity, cost causation, and the role of iteration—are common to all states (see Figure 8 for a generalized diagram of interconnection processes used by U.S. utilities; specific process details vary, but the overall structure is similar to the Massachusetts process).³⁷ And, in all states, the end result is the same. A review of U.S state processes by the National Renewable Energy Laboratory (NREL) shows that interconnection processes put the costs of any grid upgrades triggered by an application entirely on the interconnecting customer.

Figure 8. Interconnection processes used by U.S. utilities



Reproduced from: Palmintier, B., R. Broderick, B. Mather, M. Coddington, K. Baker, F. Ding, M. Reno, M. Lave, and A. Bharatkumar. 2016. *On the Path to Sunshot: Emerging Issues and Challenges in Integrating Solar with the Distribution System*. NREL. Available at: <https://www.nrel.gov/docs/fy16osti/65331.pdf>. p. 36.

Interconnection processes across the United States also involve iteration between the utility and the interconnecting customer when a project is deemed to require an in-depth impact study.³⁸ If an impact study determines that the distribution system must mitigate impacts of the proposed project on the

³⁷ Palmintier, B., R. Broderick, B. Mather, M. Coddington, K. Baker, F. Ding, M. Reno, M. Lave, and A. Bharatkumar. 2016. *On the Path to Sunshot: Emerging Issues and Challenges in Integrating Solar with the Distribution System*. NREL. Available at: <https://www.nrel.gov/docs/fy16osti/65331.pdf>. p. 36.

³⁸ Ibid, p. 36.

distribution grid, utility engineers must model changes to the proposed project and/or to the local grid.³⁹ The types of fixes for projects—including technological modifications (such as the use of advanced inverters) and other mitigation strategies—vary by utility, and costs will vary substantially from one mitigation strategy to the next.⁴⁰ Ultimately, the costs must be borne by the developer if the project is to proceed.

Costs of interconnection for larger projects

In 2022 and 2023, LBNL conducted analyses of interconnection costs for large generators in the NYISO, MISO, and PJM systems.⁴¹ In PJM and MISO, average interconnection costs have grown substantially in the last three years and the interconnection costs for wind, storage, and solar resources exceed those of natural gas.⁴² The primary driver of these cost increases are network upgrade costs during interconnection processes.⁴³ Higher costs are also associated with interconnection failures; large generator projects that successfully interconnect face lower costs than those actively in the interconnection process or those that have withdrawn from interconnection queues.⁴⁴

In PJM, for example, the interconnection costs of storage (\$335 per kW), solar (\$253 per kW), onshore wind (\$135 per kW), and offshore wind (\$385 per kW) all exceed those of natural gas (\$24 per kW).⁴⁵ The average interconnection cost for complete projects recently in PJM (\$84 per kW) have doubled relative to the 2000–2019 average (\$42 per kW).⁴⁶ Projects still in the transmission queue in the years 2020–2020 face average costs of \$240 per kW (compared to \$29 per kW before 2020). Withdrawn projects face average costs of \$599 per kW.⁴⁷

³⁹ Ibid, p. 37.

⁴⁰ Ibid, p. 37.

⁴¹ LBNL. “Generator Interconnection Costs to the Transmission System.” Available at: https://emp.lbl.gov/interconnection_costs.

⁴² LBNL. “Generator Interconnection Costs to the Transmission System.” Available at: https://emp.lbl.gov/interconnection_costs.

⁴³ Ibid.

⁴⁴ Ibid.

⁴⁵ Seel et al. 2023. *Interconnection Cost Analysis in the PJM Territory*. LBNL. Available at: https://eta-publications.lbl.gov/sites/default/files/berkeley_lab_2023.1.12- pjm_interconnection_costs.pdf. p. 1.

⁴⁶ Ibid, p.5.

⁴⁷ Ibid.

Barriers to Interconnection

Based on a review of publicly available literature and the interviews conducted to inform this white paper, AEC identified a set of key barriers to the interconnection process that slow the pace of interconnection of electric generation and storage projects to the grid (see Table 1). While the focus of AEC’s research was specifically on connecting DERs to the distribution grid in Massachusetts, the barriers identified are applicable across U.S. states, and also apply to projects connecting to the long-distance transmission system.

Table 1. Summary of interconnection barriers

Barrier	Description
Cost causation	Interconnecting customers pay for all system upgrades triggered by their project, even if other stakeholders benefit.
Lack of integrated planning for hosting capacity	Hosting capacity cannot proactively expand in advance of anticipated interconnections.
Increasing costs of interconnection	Utilities inflate the system upgrades required of DERs, raising costs of both the upgrades and the system impact study process.
Storage-specific barriers	Storage resources and their control technologies are not properly incorporated in interconnection rules.
Insufficient transmission capacity	Transmission capacity is insufficient to export DER generation, creating curtailment risk for new projects.

The barriers described in this section are neither independent nor mutually exclusive: They contribute to one another and may interact to produce worse interconnection outcomes than they would individually.

Cost causation

Cost causation assigns the costs of infrastructure modifications to the facility requiring interconnection.⁴⁸ This means the costs of distribution-system upgrades are allocated in their entirety to the project whose application triggered the need for those upgrades, even if those upgrades may benefit others in addition to the applicant. This has several negative impacts:

Hit to applicant project finances: By concentrating all project costs on a single applicant, cost causation disincentivizes projects that cannot shoulder upgrade costs, which can be quite high. This forces many projects to drop out of the queue altogether because the cost of upgrades asked of them irreparably

⁴⁸ Strategen Consulting. 2020. *DER Interconnection Cost Allocation Proposal: Docket No. 19-55*. Prepared for the Massachusetts Attorney General’s Office. Available at: <https://fileservice.eea.comacloud.net/FileService.Api/file/FileRoom/11883913>. p. 3.

damages the project's financial calculus.⁴⁹ Higher project costs can also discourage development in areas with higher penetration of renewables because those areas might require additional or more complex grid upgrades to handle additional two-way power flow than areas with lower renewables penetration.⁵⁰ (See discussion below on "project-dependent" hosting capacity upgrades. If upgrade costs are higher in areas with higher renewable penetration, it indicates that previous system upgrades did not size or plan upgrades to facilitate future increases in bidirectional power flow from new solar and storage interconnections).

Jockeying and delays in interconnection queues: By forcing projects to pay for all upgrades attributed to them (even if those upgrades may benefit others in addition to the applicant⁵¹ or are not strictly necessary for that project), cost causation incentivizes applicants to try and reduce the upgrades their projects are responsible for. As a result, applicants may spend long periods of time in the interconnection queue negotiating with the utility on which system upgrades they will be responsible for and which they will not shoulder. The queue stops moving especially when those negotiations drag on and when utilities insist on project upgrades that applicants do not feel are applicable to their proposed project. During such periods of negotiation, the remaining projects in the queue will have to wait until projects ahead of them arrive at an agreement; and they may be forced to pick up the costs of upgrades the project in front of them either passed on or avoided responsibility for.⁵² Jockeying and negotiation also result from fairness concerns: customers may argue they should not be responsible for some of the distribution grid upgrade costs because their systems can be operated to reduce peak demands or improve hosting capacity.⁵³

Project-dependent hosting capacity upgrades/Utility planning disincentivization: Since system upgrade costs are determined and allocated on a project-by-project basis through interconnection requests, distribution system upgrades become entirely dependent on the order and character of projects in the interconnection queue. This creates a reactive model for distribution system upgrades, rather than a proactive model that would be responsive to overall system needs, taking into account all the projects in the interconnection queue as well as anticipated areas of load and DER growth. As a result, the interconnection process does not encourage utilities to proactively plan for and invest in hosting capacity in response to anticipated interconnection needs.⁵⁴ If utilities were to plan ahead to develop additional bidirectional hosting capacity, they would have no path to recovering the costs from the resulting investments unless interconnecting customers first came along to make use of those

⁴⁹ Ibid, p. 40.

⁵⁰ McAllister, R., D. Manning, L. Bird, M. Coddington and C. Volpi. 2019. *New Approaches to Distributed PV Interconnection: Implementation Considerations for Addressing Emerging Issues*. NREL. Available at: <https://www.nrel.gov/docs/fy19osti/72038.pdf>. p. 9.

⁵¹ Horowitz, K., Z. Peterson, M. Coddington, F. Ding, B. Sigrin, D. Saleem, S. Baldwin, B. Lydic, S. Stanfield, N. Enbar, S. Coley, A. Sundararajan, C. Schroeder. 2019. *An Overview of Distributed Energy Resource (DER) Interconnection: Current Practices and Emerging Solutions*. NREL. Available at: <https://www.nrel.gov/docs/fy19osti/72102.pdf>. p. 40.

⁵² Ibid, p. 40.

⁵³ Interview with Ted Ko, August 26, 2022.

⁵⁴ Interview with Ariel Horwitz and Rees Sweeney-Taylor, August 10, 2022.

investments.⁵⁵ By contrast, utilities do undertake proactive planning exercises for investments to meet general customer load because there is a clear regulatory path to the recovery of investment costs that emerge from those planning exercises.⁵⁶ The lack of financial incentive for utilities to proactively plan for hosting capacity, combined with the fact that DERs can send power in both directions, may also result in utilities inflating the distribution upgrades required of individual interconnecting applicants (either by adding more modifications based on unreasonable projections of resource use or encouraging the applicant to change the project size to facilitate system upgrades).

Lack of integrated planning for hosting capacity

The lack of anticipatory or integrated planning for hosting capacity—by which investments in grid upgrades could be made in advance of anticipated interconnection—directly slows the rate at which new interconnection authorizations can be issued. New capacity upgrades typically are made to the distribution system based on the needs identified by project-specific impact studies. Each study adds time between a project application being filed and receiving an authorization to interconnect and is unique to the project being proposed; if the details of the project change, the study will have to be re-done.

This reactive, project-specific process means that grid capacity increases in fits and starts, and only in locations where projects are proposed, rather than increasing steadily towards a pre-designated, system-wide target so that numerous projects can be interconnected with the knowledge that the distribution grid can handle the load.

In Massachusetts, utilities have tried to improve on the one-by-one project approach by clustering numerous projects together in one geographic area and studying their collective grid impacts. While cluster study processes can be useful to speed up the planning process, cluster analysis is not a substitute for a grid-wide analysis. The clustering approach does not guarantee that the distribution grid as a whole will progress toward greater hosting capacity. Furthermore, cluster studies are vulnerable to the same delays as individual project studies, because if the makeup of a cluster changes (if a project enters or exits the pool), the study will have to be re-done.

In summary, the lack of integrated planning for new capacity interconnections, and the resulting unplanned upgrades for future applicants, creates a number of problems, including:

1. Added costs for project applicants
2. Increased numbers of projects in the queue and resulting wait times
3. Reduction in the rate at which new capacity can be added to the distribution system
4. Numerous isolated and uncoordinated distribution system upgrades due to the proliferation of impact studies across numerous individual projects rather than on a regular system-wide basis.

⁵⁵ Ibid.

⁵⁶ Ibid.

The current system also results in situations where utilities and policymakers do not have much control over how hosting capacity upgrades evolve over time, because the investments that are made in bi-directional hosting capacity are entirely dependent on which projects ultimately make it through the interconnection process, rather than on an anticipatory, holistic plan.

Increasing costs of interconnection

High interconnection costs can cause proposed projects to be scaled back, withdrawn, or (in anticipation) not proposed at all. Three main forces drive up the costs of interconnection:

- **Lack of agreement:** Repeated attempts by a utility and applicant to agree on project modifications can result in unanticipated application and study fees and raise project costs beyond the amount for which the applicant budgeted. When a cluster-based impact study takes place (in which multiple projects undergo impact analysis together), if any cluster participant withdraws, it can force the entire group to re-start the study process, increasing process costs.
- **Inflated modeling assumptions:** Interconnection costs can increase due to the modeling assumptions utilities use to determine the size of hosting capacity upgrades. Utilities may be wary of the bi-directional flow of power in DER systems and ask for upgrades that mitigate even the most unlikely scenarios in which DER technology would be pushed to extremes or operated in uneconomic ways.
- **High supply costs:** Interconnection costs can grow when labor or necessary inputs to complete hosting capacity upgrades are in short supply. Labor and material shortages occurred during and after the COVID-19 pandemic, for example.⁵⁷ Shortages of inputs for needed grid upgrades (such as inverters) are exacerbated by a lack of clarity in interconnection rules regarding which mitigation technologies and measures may be utilized.⁵⁸

Storage-specific barriers

Energy storage offers challenges for the management of a distribution grid because of its unique ability to either withdraw power from the grid or add power to the grid (charging and discharging) at any time. These inherent challenges can be exacerbated when interconnection processes fail to properly account for storage-specific challenges and operational requirements, making it more difficult to propose storage interconnections or to see applications successfully through the interconnection process.

The 2022 BTRIES Report by the Interstate Renewable Energy Council (IREC) presents several storage-specific barriers caused by prevailing interconnection processes:⁵⁹

⁵⁷ 1) Interview with William Acker, August 10, 2022; 2) Interview with Liz Argo, August 25, 2022.

⁵⁸ Interview with Liz Argo, August 25, 2022.

⁵⁹ BTRIES. 2022. *Toolkit & Guidance for the Interconnection of Energy Storage & Solar-Plus Storage*. Available at: <https://energystorageinterconnection.org/resources/btries-toolkit/>. p. 33.

1. Storage either is not included in many interconnection rules, or those same rules are unclear about their applicability to storage
2. Interconnection rules do not mention acceptable methods for controlling the export from storage systems that limit the amount of power sent back to the grid (“non- and limited-export systems”)
3. Non- and limited-export systems are assessed using unrealistic assumptions, leading to overestimated grid impacts
4. Interconnection rules lack uniform specification for export control equipment response times and the impacts of inadvertent export from non- and limited-export systems
5. Interconnection processes do not provide sufficient information on the state of the grid, its hosting capacity constraints, and locations available to interconnect
6. Interconnection processes cannot make system design changes (other than downsizing) to address grid impacts and avoid upgrades
7. States have not updated their interconnection procedures and technical requirements with the most recent standards
8. Interconnection processes lack rules for evaluating operating schedules of storage resources (what is considered reasonable for when storage systems plan to charge and discharge)

System impact studies may make unreasonable assumptions regarding how prospective storage projects will operate. For instance, utilities may assess storage systems as though they will be charging at times of peak electric demand, even when project applicants indicate no plans to do so (and when doing so would run counter to the project’s economic best interests). Utilities are routinely unwilling (or unable) to incorporate or consider technological solutions—such as inverters that operate by curtailing power for charging and discharging on storage systems—that would allow the utilities greater certainty regarding the operation of the storage resource.⁶⁰ Programming of inverters can also be achieved through external devices that signal the inverters to curtail power.⁶¹ However, utilities frequently lack historical load data and future load forecasting capability, as well a communications system to control curtailment in real time.⁶² Utility staff may also lack trust in the curtailment capability of inverter technology.⁶³ From the perspective of the project owner, the utility’s preferred solution—taking full control of the charging and discharging of storage—is almost always a nonstarter.

One alternative solution may be formal or contractual operational agreements between the project and the utility, which could serve to reduce the perception of risk on the utility’s side. New York is

⁶⁰ Interview w/ Kathryn Cox Arslan and Mrinmayee Kale, September 6, 2022.

⁶¹ Ibid.

⁶² Ibid.

⁶³ Ibid.

experimenting with including operational profile documents⁶⁴ as part of the application process. These are documents in which projects detail their expected charging and discharging times.⁶⁵ They are intended to ensure that projects are studied during the interconnection application process in ways that match realistic charging and discharging expectations.⁶⁶ However, absent additional data or built-in terms in an interconnection tariff, it is unclear how significantly a written profile alone will mitigate utility concerns about unexpected charging or discharging from storage resources.

Many of the storage-specific interconnection barriers also affect distributed solar-storage hybrid projects. This is because utilities are concerned that the flexibility of storage control settings would allow unrestricted charging and discharging and could cause a hybrid solar and storage system to act as a generator when the system already has sufficient capacity.⁶⁷ Potential solutions are problematic as well: Evaluating system impacts more carefully can take more time and increase upgrade costs. The operation of the system can be restricted, which may not be desirable for the interconnecting customer.⁶⁸ Solutions to prevent inadvertent export entirely could significantly restrict non-exporting storage resources or require costly protection equipment.⁶⁹

Insufficient transmission capacity

Adequate long-distance transmission capacity can ease pressures on the local distribution system by providing an opportunity to export power off the distribution grid and avoid curtailment of distributed solar or storage capacity. In addition, the same distribution system upgrades that facilitate increased DER interconnection can also relieve transmission system congestion.⁷⁰ A report published by NREL on increasing penetration of distributed solar resources claims that increased distributed solar deployment will require transmission system and distributions system operators to be increasingly aware of one another's constraints and to integrate operations.⁷¹ The *Massachusetts Clean Energy and Climate Plan for 2025 and 2030* also acknowledges the need for both electric distribution and transmission

⁶⁴ NYPSC. 2022. *APPENDIX K – Energy Storage System (ESS) Application Requirements / System Operating Characteristics / Market Participation*. In *Standardized Interconnection Requirements and Application Process For New Distributed Generators and/or Energy Storage Systems 5 MW or Less Connected in Parallel with Utility Distribution Systems*. Available at: <https://dps.ny.gov/system/files/documents/2022/11/may-2022-sir-final-dmm.pdf>.

⁶⁵ Interview w/ Schuyler Matteson, January 17, 2023.

⁶⁶ Ibid.

⁶⁷ McAllister, R., D. Manning, L. Bird, M. Coddington, C. Volpi. 2019. *New Approaches to Distributed PV Interconnection: Implementation Considerations for Addressing Emerging Issues*. NREL. Available at: <https://www.nrel.gov/docs/fy19osti/72038.pdf>. p. 15.

⁶⁸ Ibid, p. 15.

⁶⁹ Ibid, p. 16.

⁷⁰ Palmintier, B., R. Broderick, B. Mather, M. Coddington, K. Baker, F. Ding, M. Reno, M. Lave, and A. Bharatkumar. 2016. *On the Path to Sunshot: Emerging Issues and Challenges in Integrating Solar with the Distribution System*. NREL. Available at: <https://www.nrel.gov/docs/fy16osti/65331.pdf>. p. 46.

⁷¹ Ibid, p. 46.

upgrades to interconnect clean DERs.⁷²

Additional transmission capacity could mitigate some of the distribution system’s hosting capacity constraints by lowering local curtailment risk—the loss of potentially useful energy through deliberate reductions in solar generation exported to the grid or power discharged from a battery—in the event too much power is available for export on the local system.⁷³ Additional transmission capacity is a greater mitigating factor for renewable generation than for storage, because storage has more flexibility in terms of where it can be located.⁷⁴ Transmission is also not a constraint at all times; other barriers—cost causation, faulty processes, or poor hosting capacity planning—may be the proximate reason new capacity is not permitted to interconnect.⁷⁵ Transmission’s role is to offer an off-ramp in the event that sufficient hosting capacity elsewhere can facilitate the export of surplus power generation off the distribution grid. However, adding transmission capacity can be extremely expensive and time-consuming, and is unlikely to be undertaken in response to immediate shortfalls in local distribution system hosting capacity.

⁷² MA EEA. 2022. *Massachusetts Clean Energy and Climate Plan for 2025 and 2030*. Available at: <https://www.mass.gov/doc/clean-energy-and-climate-plan-for-2025-and-2030/download>. p. 68

⁷³ Interview with Jin Noh, August 22, 2022.

⁷⁴ Ibid.

⁷⁵ Interview with William Acker, August 10, 2022.

Recommendations for Overcoming Interconnection Barriers

Academics and state policymakers across the United States have proposed a variety of solutions to interconnection barriers. The best of these solutions directly tackles the core problems of interconnection: bottlenecks arising from deciding who should pay for system upgrades, not making system upgrades proactively, not considering storage or related control technologies adequately, and the tendency of interconnection processes to operate on autopilot as individual project and system impact studies create slow-moving and ever-lengthening interconnection queues. It is likely that a combination of solutions is needed, as smaller process-related changes will not overcome the main interconnection barriers on their own.

Based on interviews and a review of the literature, AEC synthesized recommendations on the most impactful changes to interconnection processes in the United States and grouped the proposed changes by category (see Table 2):

Table 2. Summary of recommendations for overcoming interconnection barriers

Integrated planning
Proactive, integrated, and system-wide interconnection planning: Use forecasts of hosting capacity needs to make system upgrades before interconnection requests.
Iterate interconnection solutions: Task an agency or group with coordinating interconnection stakeholders to solve ad hoc problems in meeting integrated plans.
Tackle barriers and solutions comprehensively
Reform cost allocation: In addition to interconnecting customers, stakeholders that also stand to benefit should help pay for system upgrades.
Incorporate storage resources into interconnection rules and processes: List acceptable control technologies, assess storage systems according to a reasonable operating profile, and expedite smaller storage projects.

Integrated planning

Policymakers need a planning system that will enable advanced preparation for future interconnection requests so that upgrades can be made in advance and interconnecting applicants can have a clearer sense of whether their project can be approved in its current state. To enable proactive investments in hosting capacity and more rapid project approvals, changes are required to the current system to upgrade planning and iteration. State policymakers, regulators, and the utilities need to work toward a new system in which system upgrades needs are forecast, capacity additions are integrated, costs are socialized, and energy storage operational parameters are realistically incorporated into interconnection processes.

Plan proactively: One path to proactively preventing hosting capacity constraints for interconnecting DERs is to anticipate DER growth and identify infrastructure upgrades to accommodate predicted growth rather than responding to interconnection projects as they individually file interconnection requests.⁷⁶ Forecasting hosting capacity needs would allow policymakers to determine and assess system upgrades in advance of large-scale increases in DER capacity and provide reformed and expedited approval processes for multiple projects or project clusters once they are approved. Proactive, integrated interconnection planning requires five steps:⁷⁷

1. Forecast DER growth on the distribution grid using a variety of modelling approaches and data on DER use
2. Estimate the maximum potential DER penetration given existing hosting capacity
3. Determine the available capacity left on the existing distribution grid by subtracting current DER penetration from the maximum potential calculated in Step 2
4. Plan hosting capacity upgrades to the distribution system and expedite interconnection procedures based on anticipated DER growth and available capacity left on the distribution grid
5. Publish the results

Continuously iterate interconnection solutions: Ideally, integrated interconnection planning would not stop there. It would be regularized and require an institution or actors to iterate the resulting plans with utilities and interconnecting customers. Such iteration would involve modifying DER growth forecasts as conditions on the grid change, assisting in determining and conducting hosting capacity upgrades, or meeting other coordination challenges and emergencies between interconnection stakeholders.⁷⁸ Iteration is necessary because problems with coordinating interconnection stakeholders can outlast or evolve past the terms of existing interconnection tariffs and require entities with legal authority to act flexibly based on up-to-date information.⁷⁹ An example of coordination with respect to planning grid upgrades is the “Coordinated Grid Planning Working Group,” which was convened in 2020 by the New York Public Service Commission to effectively implement the Accelerated Renewable Energy Growth and Community Benefit Act’s distribution and transmission upgrades, as well as capital expenditures and planning for those upgrades.⁸⁰ An interconnection planning system needs an entity with the authority, access to expertise, and data-collection capability to intervene and iterate as necessary to facilitate the interconnection system’s operation and plan for hosting capacity on the

⁷⁶ Palmintier, B., R. Broderick, B. Mather, M. Coddington, K. Baker, F. Ding, M. Reno, M. Lave, and A. Bharatkumar. 2016. On the Path to Sunshot: Emerging Issues and Challenges in Integrating Solar with the Distribution System. NREL. Available at: <https://www.nrel.gov/docs/fy16osti/65331.pdf>. p. 30.

⁷⁷ Lindl, T., and K. Fox. 2013. *Integrated Distribution Planning Concept Paper: A Proactive Approach for Accommodating High Penetrations of Distributed Generation Resources*. Interstate Renewable Energy Council. Available at: <https://irecusa.org/resources/integrated-distribution-planning-concept-paper/>. p. 10-12.

⁷⁸ Interview with Schuyler Matteson, January 17, 2023.

⁷⁹ Ibid.

⁸⁰ NY Department of Public Service. *Coordinated Grid Planning Working Group*. Available at: <https://dps.ny.gov/coordinated-grid-planning-working-group>.

distribution grid.⁸¹ Currently, the agencies like NYSERDA that research energy systems and planning are not the same agencies empowered to undertake investments or make policy changes.⁸² Utilities may also lack certain kinds of expertise with storage-related technologies because their internal systems did not improve as rapidly as the sharp increase in the scale of storage and interconnection requests over the last decade.⁸³

Tackle barriers and solutions comprehensively

An integrated planning process is not a substitute for changing the cost causation model or addressing other interconnection process dilemmas.⁸⁴ Instead, integrated planning permits distribution utilities, state agencies, and regional transmission organizations to take more control of interconnection planning and processes to ensure DER resources under development in particular are not encountering obstacles and that policymakers are being proactive about removing barriers as states work toward meeting their climate and clean energy targets. An interconnection process that plans hosting capacity in advance and then creates expedited processes to make use of newly available hosting capacity will eventually have to determine which interconnection stakeholders will have to pay for the system upgrades. This is because the upgrade determinations will no longer be made on a project-by-project basis and so even continued allocation in accordance with cost causation would require an updated method of determining individual projects' responsibility for their share of upgrade costs. Alternatively, if an integrated process does not incorporate storage resources, then forecasts of hosting capacity needs will not accurately reflect the full scope of resources available to decarbonize the grid or which might necessitate future grid upgrades.

Reform cost causation: Lowering the costs attributed to each project could incentivize additional interconnection requests and reduce the number of projects exiting queues. And incorporating more actors when allocating interconnection costs would create an incentive for more integrated planning in which distribution utilities—who would no longer have to wait for proposals before undertaking that analysis—could make anticipatory investments and determinations of system needs.

There are three primary ways that the costs of network upgrades could be allocated (none of which are mutually exclusive):

1. Allocating costs within a group of projects
2. Asking a single entity to pay up-front and be reimbursed, and
3. Having ratepayers pay for some or all the upgrade costs.

Grouping projects: First, costs can be allocated within a group of projects. A formula for allocating costs among a group of projects going through the interconnection process together (as a cluster) would be

⁸¹ Interview with Schuyler Matteson, January 17, 2023.

⁸² Ibid.

⁸³ Ibid.

⁸⁴ Lindl, T., and K. Fox. 2013. *Integrated Distribution Planning Concept Paper: A Proactive Approach for Accommodating High Penetrations of Distributed Generation Resources*. Interstate Renewable Energy Council. Available at: <https://irecusa.org/resources/integrated-distribution-planning-concept-paper/>. p. 15-16.

determined based on each project’s contribution to the cluster.⁸⁵ The 2022 FERC Notice of Proposed Rulemaking on *Improvements to Generator Interconnection Procedures and Agreements*—addressing reforms to large and small generator interconnection procedures—proposed allocating the shared costs of impact studies on a per MW basis for 90 percent of the costs and allocating the other 10 percent of costs to customers based on the number of requests each customer makes.⁸⁶ It should be noted that if 100 percent of project costs are allocated entirely within the group, then cost causation has not been changed because costs are still being placed entirely upon project applicants and not being shared among other stakeholders.

Single entity payment and reimbursement: A single entity can pay for interconnection-related grid upgrades up-front and be reimbursed by other stakeholders post-upgrade.⁸⁷ For example, a pilot by National Grid allows the utility to pay for grid upgrades for smaller sized projects in the interconnection queue and be reimbursed by customers with larger projects using a one-time pro-rated fee.⁸⁸ The New York State Energy Research and Development Authority’s (NYSERDA’s) “Cost-Sharing 2.0” framework allocates costs such that a project only pays for an assigned amount of distribution hosting capacity, as opposed to the entire upgrade cost.⁸⁹ For this proposal to truly adjust cost causation, the paying entity’s reimbursements cannot be wholly from the applicants whose applications triggered the upgrade costs.

Rate-based upgrades: Finally, the cost of needed distribution upgrades could be socialized, at least in part, across the statewide rate base.⁹⁰ Allocating costs to ratepayers would allow a utility to recoup its investments in distribution system upgrades from rate payments over time. The argument for including ratepayers when allocating interconnection costs (thereby “socializing” some percentage of the upgrade costs) is that ratepayers benefit from a grid with larger hosting capacity that can more effectively incorporate new DERs. Another argument in favor of including ratepayers is that it would facilitate proactive utility investments in hosting capacity because those costs could be recouped at least partly in advance of individual interconnection applications.⁹¹ However, allowing utilities to charge

⁸⁵ Peterson, Z., et al. 2019. *An overview of distributed energy resource (DER) interconnection: current practices and emerging solutions*. NREL. Available at: <https://www.nrel.gov/docs/fy19osti/72102.pdf>. p. 41.

⁸⁶ FERC. 2022. *Improvements to Generator Interconnection Procedures and Agreements*. Available at: <https://www.federalregister.gov/documents/2022/07/05/2022-13470/improvements-to-generator-interconnection-procedures-and-agreements>; Paragraph 82.

⁸⁷ Peterson, Z., et al. 2019. *An overview of distributed energy resource (DER) interconnection: current practices and emerging solutions*. NREL. Available at: <https://www.nrel.gov/docs/fy19osti/72102.pdf>. p. 41.

⁸⁸ *Ibid*, p. 42.

⁸⁹ NYSERDA. 2021. *New York’s 10 GW Distributed Solar Roadmap: Policy Options for Continued Growth in Distributed Solar*. Available at: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKewiWtNCHw9H8AhWejYkEHZeLD-sQFnoECCMQAQ&url=https%3A%2F%2Fdocuments.dps.ny.gov%2Fpublic%2FCommon%2FViewDoc.aspx%3FDocRefId%3D%257B4C42AAFF-0EB9-4890-AA0D-21C70B088F4B%257D&usg=AOvVaw171f_8uqnRwvpiFRxJrDD0. p. 29.

⁹⁰ Interview with Schuyler Matteson, January 17, 2023.

⁹¹ Interview with Ariel Horowitz and Rees Sweeney-Taylor, August 10, 2022.

ratepayers for distribution system upgrade costs could also result in utilities overbuilding hosting capacity.⁹² Potential solutions include: keeping ratepayer involvement in cost causation small; ensuring oversight from regulatory authorities; or scaling back ratepayer contributions after hosting capacity upgrades have been made or once intermediate or final climate targets are met.

The MA DPU established a provisional program for distributed solar and storage projects; it allows distribution utilities to file proposals to upgrade electric power infrastructure and fund the upgrades through contributions from interconnecting distributed facilities and through the distribution utility's own ratepayers.⁹³ Ratepayers would pay a portion of the costs initially through a charge on their electric bills; those costs would later be offset when distributed facilities interconnect and pay a share of the costs.⁹⁴ Those payments would then reimburse ratepayers.⁹⁵

Incorporate storage resources into interconnection rules and processes

Interconnection processes currently disadvantage storage resources by failing to include them in their rules or inappropriately treating their technological characteristics and accompanying control technologies. Fixing this would enable more project applicants to file interconnection requests with confidence that their storage project will get approval if it meets basic requirements.

The BTRIES Report recommends several storage-specific measures that would improve interconnection processes for these resources.⁹⁶ First, interconnection procedures need to define energy storage clearly and note that their procedures apply to both standalone storage and hybrid solar-storage systems.⁹⁷ Procedures should consider distinct screens for non-exporting projects and provide clear lists of acceptable methods for controlling export.⁹⁸ Rather than assuming a DER system will export its full nameplate rating, the export capacity (which is equivalent to the nameplate rating or a lower amount when using an acceptable means of control⁹⁹) should be considered and evaluated for its impacts.¹⁰⁰ Otherwise, systems impact will always assume the worst-case export scenario (by using nameplate capacity) for systems that may never be designed to export that much due to their manner

⁹² Interview with Schuyler Matteson, January 17, 2023.

⁹³ MA DPU. 2022. *Petition of NSTAR Electric Company d/b/a Eversource Energy for approval by the Department of Public Utilities of the Company's Marion-Fairhaven capital investment project proposal under the Provisional Program established by the Department in Provisional System Planning Program, D.P.U. 20-75-B (2021)*. DPU 22-47. Available at: <https://fileservice.eea.comacloud.net/FileService.Api/file/FileRoom/16827728>. p. 4.

⁹⁴ Ibid, p. 4.

⁹⁵ Ibid, p. 4.

⁹⁶ BTRIES. 2022. *Toolkit and Guidance for the Interconnection of Energy Storage and Solar-Plus-Storage*. Available at: <https://energystorageinterconnection.org/resources/btries-toolkit/>.

⁹⁷ Ibid, p. 41.

⁹⁸ Ibid, p. 46; 51-52.

⁹⁹ Ibid, p. 44.

¹⁰⁰ Ibid, p. 62.

of operation—such as behind-the-meter systems meant to serve onsite customer load.¹⁰¹

Fast-track procedures should be established for projects of nameplate capacity under 50 kilowatts and export capacity not exceeding 25 kilowatts because smaller projects will have smaller export potentials and create fewer issues for the distribution grid.¹⁰² Impact studies need to account for how projects limit export and the system’s operating profiles.¹⁰³ Research by NREL investigates specific rules and procedures to address inadvertent export—when storage systems export small amounts of power for very short durations due to mismatches between system output and consumption, such as when a large load suddenly shuts off while being supplied by a battery so the battery starts exporting.¹⁰⁴

An example of storage-specific interconnection policy is the Hawaiian Electric Quick Connect Program. In 2021, projects on the Oahu, Maui, and Hawaii islands could be installed prior to receiving approval from the utility if the hosting capacity on the circuit was greater than 30 percent.¹⁰⁵

Further research

The recommendations outlined in this white paper—an integrated and proactive planning process, iterating interconnection solutions, reforming cost causation, and incorporating storage resources into interconnection processes—would all benefit from:

- More comprehensive documentation of proposals, examples, and ongoing efforts aimed at their implementation in state and regional processes;
- Quantitative or qualitative evaluations of existing proposals to determine how or if they tackle the barriers outlined in this white paper;
- Quantitative or qualitative evaluations of prior interconnection-related policy changes to determine how or if they tackled the barriers outlined in this white paper;

¹⁰¹ Horowitz, K., Z. Peterson, M. Coddington, F. Ding, B. Sigrin, D. Saleem, S. Baldwin, B. Lydic, S. Stanfield, N. Enbar, S. Coley, A. Sundararajan, C. Schroeder. 2019. *An Overview of Distributed Energy Resource (DER) Interconnection: Current Practices and Emerging Solutions*. NREL. Available at: <https://www.nrel.gov/docs/fy19osti/72102.pdf>. p. 55.

¹⁰² BTRIES. 2022. *Toolkit and Guidance for the Interconnection of Energy Storage and Solar-Plus-Storage*. Available at: <https://energystorageinterconnection.org/resources/btries-toolkit/>. p. 61.

¹⁰³ Ibid, p. 67-69.

¹⁰⁴ Horowitz, K., Z. Peterson, M. Coddington, F. Ding, B. Sigrin, D. Saleem, S. Baldwin, B. Lydic, S. Stanfield, N. Enbar, S. Coley, A. Sundararajan, C. Schroeder. 2019. *An Overview of Distributed Energy Resource (DER) Interconnection: Current Practices and Emerging Solutions*. NREL. Available at: <https://www.nrel.gov/docs/fy19osti/72102.pdf>. p. 56.

¹⁰⁵ 1) Hawaiian Electric. 2021. “Hawaiian Electric speeds up rooftop solar interconnections.” Available at: [https://www.hawaiianelectric.com/hawaiian-electric-speeds-up-rooftop-solar-interconnections#:~:text=%22Quick%20Connect%20allows%20customers'%20solar,and%20reliable%20grid%20for%20all.%22](https://www.hawaiianelectric.com/hawaiian-electric-speeds-up-rooftop-solar-interconnections#:~:text=%22Quick%20Connect%20allows%20customers'%20solar,and%20reliable%20grid%20for%20all.%22;); 2) Solar Reviews. 2023. “Hawaii’s Quick Connect Program cuts red tape, increases solar savings.” Available at: <https://www.solarreviews.com/blog/hawaii-quick-connect-program-to-boost-solar-industry#:~:text=Hawaii%20Electric%20Company%20launched%20the,to%20approval%20by%20the%20utility..>

- Differentiating how the recommendations would be implemented differently for distribution- or transmission-level processes; and,
- Clarifying the statutory or regulatory changes necessary for implementation of this section's recommendations

Appendix

The list of interviewees is below (alphabetized by surname):

- William P. Acker, New York Battery and Energy Storage Technology Consortium (NY-BEST), Executive Director
- Liz Argo, Liz Argo Consulting, Lead Consultant
- Kathryn Cox Arslan, New Leaf Energy, Director of Interconnection Policy
- Ariel Horowitz, Massachusetts Clean Energy Center, Senior Program Director
- Mrinmayee Kale, New Leaf Energy, Utility Electrical Engineer
- Ted Ko, Policy and Strategy Consultant (formerly Stern, Vice President of Policy and Regulatory Affairs)
- Schuyler Matteson, NYSERDA, Senior Adviser
- Jeremy McDiarmid, Advanced Energy United, Managing Director and General Counsel (formerly Northeast Clean Energy Council, Vice President for Policy and Government Affairs)
- Danny Musher, Key Capture Energy, Director, Market Design
- Jin Noh, California Energy Storage Alliance, Interim Executive Director and Policy Director
- Steven Rymsha, Sunrun, Director of Grid Solutions, Public Policy
- Rees Sweeney-Taylor, Massachusetts Clean Energy Center, Net Zero Grid Program Manager
- Ethan Tremblay, Governor's Energy Office, State of Maine, Policy and Markets Program Manager
- Stephen Tuleja, Alternate Power Source Inc, President
- Kyle Wallace, PosiGen, Vice President, Public Policy and Government Affairs

The Interconnection Bottleneck

Why Most Energy Storage Projects Never Get Built

A MASSACHUSETTS CASE STUDY



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