Title

Interconnection Cost Analysis in the NYISO Territory

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Interconnection costs have escalated as interconnection requests have grown

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Executive summary

Interconnection queues have grown dramatically throughout the United States. In NYISO, the cumulative capacity of projects actively seeking interconnection more than doubled from 2019 through 2022 to equal more than three times the peak load. Based on project-level interconnection costs in NYISO from 2006 to 2021, our analysis finds:

- **Project-specific interconnection costs can differ widely** depending on many variables and do not follow a normal distribution. For example, among in-service projects studied by NYISO since 2017, more than half cost less than $100/kW to interconnect, yet one project cost almost $1000/kW. All costs in this report are expressed in real $2022 terms based on a GDP deflator conversion.
- **Interconnection costs have grown**. Costs have doubled for projects studied since 2017 (mean: $86/kW to $167/kW, median: $66/kW to $115/kW) relative to costs for projects studied from 2006 to 2016. This increase in interconnection costs is especially pronounced for recent projects that are now in service ("complete") or have withdrawn from the queue ("withdrawn"), where costs have approximately tripled (complete – mean: $83/kW to $234/kW, median: $67/kW to $150/kW, withdrawn – mean: $87/kW to $241/kW, median: $66/kW to $129/kW) relative to historical projects. Projects still actively moving through the queue ("active") also have higher costs (mean: $145/kW, median: $108/kW) than historical projects (all of which have withdrawn from the queue or been completed).
- **Costs increased both at the point of interconnection (POI) and for broader network upgrades.** Interconnection costs for complete and active projects are evenly divided between POI and network categories, while withdrawn project costs are weighted towards POI facilities. The proportion of projects responsible for network upgrades increased from 73% of projects during 2006-2016 to 90% during 2017-2021.
- **Solar project interconnection costs are generally 8-18% higher than costs for other resources.** Further, one of the three complete solar projects is a high-cost outlier. There is not a consistent pattern in the relative costs of natural gas, onshore wind, offshore wind, or storage projects.
- **Larger generators have greater interconnection costs in absolute terms, but economies of scale exist on a per kW basis for solar and wind projects.** Specifically, average costs for small (<50 MW) and large (≥250 MW) solar projects are $224/kW and $70/kW, respectively, and the corresponding costs for small and large onshore wind projects are $264/kW and $45/kW. Natural gas and storage projects do not display a clear trend between project capacity and interconnection costs per kW.
- **Cost estimates increase as projects complete more studies in the interconnection process.** Costs for the same project increase by $30/kW on average from their system impact study to their facilities study, with costs at least doubling for more than a quarter of projects. Between the feasibility study and the system impact study, cost increases are usually more modest: $16/kW on average with a median change of 0%.

The cost sample analyzed here represents at least 43% of all new unique generation and storage resources requesting interconnection in NYISO from 2003-2019. Additionally, the sample includes three projects that entered the queue in 2020-2021. While interconnection studies can contain Critical Energy Infrastructure Information (CEII) and therefore are not publicly available, interconnection cost data are not CEII. We have posted project-level cost data from this analysis at https://emp.lbl.gov/interconnection_costs.

1. NYISO faces a surge in interconnection requests

As of November 2022, the New York Independent System Operator (NYISO) had nearly 107 gigawatts (GW) of generation and storage capacity actively seeking grid interconnection. The volume of proposed projects is large relative to NYISO's peak load, which was 30.5 GW in 2022. This "active" capacity in NYISO's queue is dominated by wind (65 GW of offshore and onshore wind, combined) and, to a lesser extent, battery storage (20 GW) and solar (20 GW) power capacity; those three resources alone account for 98% of all capacity actively seeking interconnection in NYISO. NYISO's data also contains additional information for projects that are no longer actively seeking interconnection: 87 GW of projects have withdrawn their applications, and 12 GW of projects are already in service. In 2022 alone, nearly 36 GW of new generation and storage capacity entered the NYISO interconnection queue – a 61% increase over the 22 GW that entered the queue in 2021. However, most projects have historically withdrawn their applications: only 17% of all projects requesting interconnection in NYISO between 2000 and 2016 (by number of projects) have ultimately achieved commercial operation at the end of 2021 (Rand et al. 2022).

Under current NYISO rules, developers (i.e., interconnection customers) are financially responsible for any necessary upgrades to the point of interconnection or broader network that are required but for a proposed project. The interconnection study process in NYISO is similar to other independent system operators, beginning with an optional feasibility study followed by a system reliability impact study, and culminating in a two-part "class year" facilities study that first refines the system reliability impact study and then evaluates the cumulative impact of a group (or cluster) of projects together to determine required system upgrades. In anticipation of the surge in interconnection requests for wind, solar, and storage, NYISO initiated substantial interconnection process reforms in 2019, which were designed to expedite the interconnection study process. The reforms included requiring deliverability evaluation earlier in the process, removing duplication between studies, and shortening the timeline for developers to submit data for class year studies (Nguyen, Thinh 2019). With the queue reaching an unprecedented volume in 2022, NYISO began considering additional interconnection process improvements and reforms, such as developing system impact study report templates, adding staff dedicated to interconnection support, enhancing the interconnection portal, and moving to a "queue window-based approach with a binding multi-phase study structure" (Smith 2022), the details of which are not yet available.

2. Cost sample represents at least 43% of projects requesting interconnection from 2003-2019

This brief analyzes generator and storage interconnection cost data from 310 projects that were evaluated in interconnection studies between 2006 and 2021. This sample is based on all available studies on NYISO's website as of May 2022. The first of these projects entered the interconnection queue in 2003, and the sample represents 33% of all 942 non-transmission projects requesting interconnection to the NYISO system during 2003-2021 (see left panel of Figure 1). It takes time to conduct interconnection studies; only 3 of 238 of the most recent projects (2020 or 2021 queue entry) had cost studies available as of May 2022. Focusing on 2003-2019 queue entry, the sample improves to 43%. Cost data is "Not Available" for projects because either no cost studies were conducted or the study report(s) were not posted to NYISO's website.[1] Projects which were studied and reported to have $0 in interconnection costs are included in the analysis.

[1] The list of projects considered "Not Available" likely includes projects to repower, uprate, or otherwise modify existing plants – projects whose costs are not being analyzed here – but, because no interconnection studies are available, there is insufficient information to systematically identify and exclude them. As a result, 43% is likely an underestimate of the true analyzed sample.

Cost data was gleaned from the following study types: feasibility, system (reliability) impact, class year facilities – part 1, and class year facilities – part 2. Some projects had only a scoping memo available, which does not contain cost estimates. Some detailed upgrade information found in interconnection studies is Critical Energy Infrastructure Information (CEII) and therefore these studies are not publicly available; "Stakeholder" access was granted by NYISO to view these studies for research purposes. Manually extracting cost information from study PDFs typically took 25-40 minutes per project for a total of about 430 hours. The lack of easily accessible interconnection cost data poses a crucial barrier for third-party analysis and for prospective developers trying to include these costs as a factor when proposing project locations, resulting in a less efficient interconnection process.

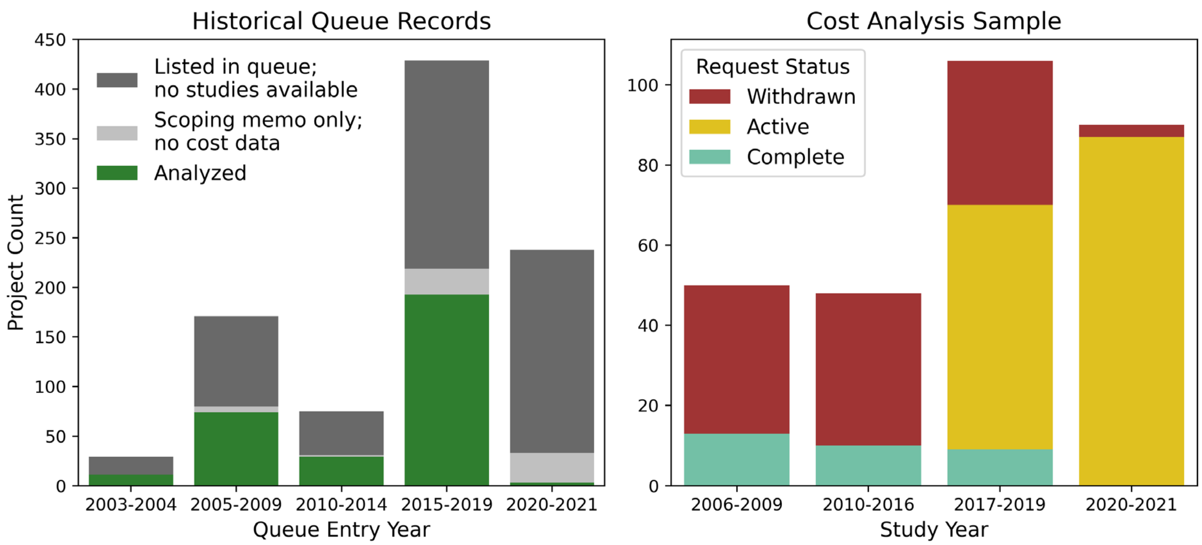


Figure 1 Sample: Availability of Cost Data Relative to Historical Queue Records *(left)*, **and Cost Data by Request Status** *(right). The left graph shows all historical projects seeking interconnection since 2003 (earliest entry year among projects with available cost data), indexed by their queue entry year. The right graph represents our cost analysis sample, with projects indexed by the year of the most recent available interconnection study. The remainder of this briefing will index projects by their study year.*

Interconnection Request Status Definitions

Complete: These projects are in service.

Active: These projects are working through the interconnection process and have completed at least one of the following: an optional feasibility study, a more detailed system impact study, or a refined facilities study.

Withdrawn: These interconnection requests have been withdrawn from the queue (cancelled).

The analyzed sample varies over time and by request status (see right panel in Figure 1 and data rows in Figure 3). All projects analyzed that are still active in the queue (150 projects; 23 GW) have been studied since the beginning of 2017, while the most recent study for a completed project (of which there are 31, totaling 5 GW) occurred in 2019. Based on these study dates and the period of rapid queue growth beginning in 2018, the study time horizon is segmented into 2006-2016 and 2017-2021 throughout this report. Some projects ultimately withdraw from the interconnection process for a variety of reasons; our data includes 114 such projects (18 GW). From 2006 to 2016, over 70% of the sample is onshore wind projects. Since then, the number of solar and storage projects in the sample has increased dramatically, the number of offshore wind projects remained small but increased, and the number of onshore wind projects has declined. Natural gas has a similar number of projects in both time periods, among all projects and among completed projects. Overall, the average project size has decreased by 32 MW or 18% in 2017-2021 studies compared to earlier years. In recent years, small projects have been more likely to withdraw from the queue, with the average withdrawn project for 2017-2021 sized considerably smaller (97 MW) than for withdrawn projects from 2006-2016 (186 MW) and other contemporary projects (complete: 181 MW, active: 154 MW). Finally, complete project costs are usually based on a facilities study (either part 1 or part 2 of the class year study), while active and withdrawn project costs are typically collected from studies executed earlier in the process, i.e., feasibility or system impact studies. (See Figure 3 for the percentage of projects in the sample that have costs based on facilities studies.)

3. Interconnection costs have grown, driven equally by network upgrade and point of interconnection expenses

The interconnection cost data summarized here correspond to the most recent cost estimates in the available interconnection study reports. We assume the reported costs refer to nominal dollars at the time of the interconnection study and present costs in real $2022 terms based on a GDP deflator conversion. Additional detail on the processing of cost data is found in the Appendix. We present interconnection costs in $/kW to facilitate comparisons, using each project's nameplate capacity. We report simple means with standard errors throughout the briefing, as explained in the following textbox.

Interconnection Cost Metrics

The cost data are not normally distributed: many projects have rather low costs (or cost components), most have moderate costs, and a few projects have very high costs. We give summary statistics throughout this briefing as **simple means** to judge macro-level trends. Below is an illustrative example using completed project costs. The histogram shows that more than 85% of all projects in this sample have interconnection costs under $200/kW, but a few have considerably higher costs, including one project that cost nearly $1,000/kW (Figure 2, left). Medians (dashed line in the center of the boxplot; Figure 2, center) describe a "typical" project, with costs of $81/kW, but medians of individual cost components cannot be added to meaningful sums. Means (Figure 2, right) are susceptible to the influence of a small number of projects with very high costs and are typically higher than medians ($122/kW), but cost-components can easily be added. We include the standard error of the mean ($\hat{\sigma}_{\bar{x}}$) as a measure of dispersion to give a sense of how scattered the data are.

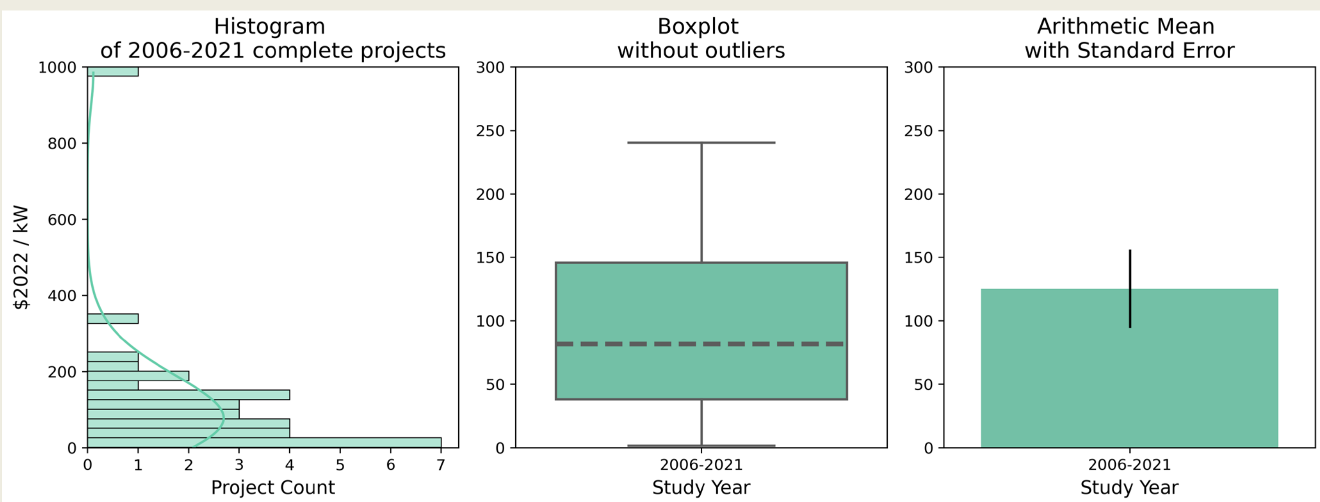


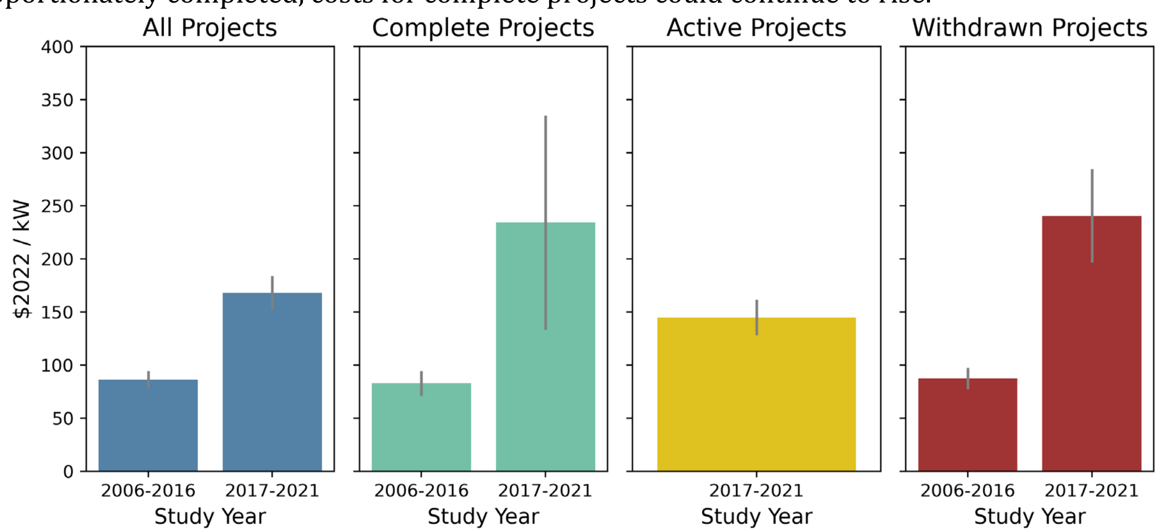
Figure 2 Interconnection Cost Metrics Example: Complete Projects, 2006-2021.

The Appendix contains more information about the median and distribution of the cost data, showing box-plot versions of all graphs and illustrating the wide spread in the underlying data from which the averages in this briefing are derived.

3.1 Interconnection costs have grown over time, but show signs of slowing

Potential interconnection costs for projects studied in recent years (2017-2021) are almost twice as high, on average, than projects studied between 2006 and 2016 ($167/kW versus $86/kW with the standard error of the means $\hat{\sigma}_{\bar{x}}$=$16/kW and $8/kW, respectively) (see Figure 3, "All Projects"). Comparing within subsets of projects with the same outcomes (see Figure 3, "Complete Projects" and "Withdrawn Projects"), we see the trend is even more pronounced, with costs increasing around threefold (to $234/kW for complete and $241 for withdrawn, $\hat{\sigma}_{\bar{x}}$=101&44).[2] From 2006-2016 interconnection costs do not seem to be a key driver of whether projects are completed, as complete projects ($83/kW, $\hat{\sigma}_{\bar{x}}$=12) only cost $4/kW less than withdrawn projects ($87/kW, $\hat{\sigma}_{\bar{x}}$=10) to interconnect on average.

Projects still actively moving through the queue (see Figure 3, "Active Projects") also have higher costs ($145/kW, $\hat{\sigma}_{\bar{x}}$=17) than historical projects, but lower costs than complete or withdrawn projects in the same time period. This could be a sign that high interconnection costs have begun factoring into withdrawal decisions in recent years, though the high cost of recent complete projects complicates this narrative. Among active projects, those studied most recently (2020-2021) cost $132/kW to interconnect on average – less than the $163/kW for active projects last studied prior to 2020.[3] As these active projects complete additional interconnection studies, we expect their average costs will increase, if the historical patterns discussed later continue (see the textbox associated with Figure 5). Together, these trends suggest that projects completed in the near future may see interconnection costs that are significantly higher than those paid by complete generators from 2006-2016 ($83/kW) but lower than complete projects in recent years ($234/kW). However, there are high-cost outliers among the active projects (see Figure 11 in the Appendix), and, if they are disproportionately completed, costs for complete projects could continue to rise.



	All 2006-2016	All 2017-2021	Complete 2006-2016	Complete 2017-2021	Active 2017-2021	Withdrawn 2006-2016	Withdrawn 2017-2021
Mean capacity	175 MW	144 MW	140 MW	181 MW	154 MW	186 MW	97 MW
Facilities Study	29%	21%	74%	100%	19%	15%	10%
Project count	98	196	23	9	148	75	39
Solar	2	106	1	2	80	1	24
Wind Onshore	70	31	15	3	20	55	8
Wind Offshore	2	8	0	0	8	2	0
Natural Gas	15	13	3	4	5	12	4
Storage	0	36	0	0	33	0	3
Other	9	2	4	0	2	5	0

Figure 3 Interconnection Costs over Time by Request Status *(bars show simple means, gray lines represent standard error). Data rows below the figure convey how the sample of recent projects differs from the sample of past projects.*

[2] Median costs approximately double when including all projects ($66/kW to $115/kW) or focusing on complete ($67/kW to $150/kW) or withdrawn ($66/kW to $129/kW) projects.

[3] The median cost among all active projects is $108/kW. For active projects last studied in 2017-2019 and 2020-2021, the median interconnection costs are $116/kW and $97/kW, respectively.

3.2 Broader network upgrades and point of interconnection facilities contribute to recent cost increases

We group costs identified in the interconnection studies into two large categories as shown in Figure 4: (1) local interconnection facility costs describing investments at the point of interconnection (POI) with the broader transmission system, and (2) broader network upgrade costs.[4] Costs in these two categories are driven by different types of equipment and may be affected differently by interconnection and transmission expansion processes and policies.

Among complete[5] projects and those that are still actively being evaluated[6], costs are divided fairly evenly between POI and network categories. Specifically, POI costs represented 48% and 53% of the average total for complete and active projects from 2017-2021, up from 40% for complete projects during 2006-2016. In both time periods, at least 90% of projects expected some (nonzero) POI costs. POI costs comprise a greater portion of the total for projects that ultimately withdraw from the interconnection process[7], a situation that is distinct from MISO (Seel et al. 2022) and PJM (Seel et al. 2023), where network upgrades dominate withdrawn project costs. Network costs did grow at a faster rate than POI costs among withdrawn projects, however, decreasing POI's share of the total from 69% during 2006-2016 to 62% during 2017-2021. While the proportion of projects requiring investments at the POI was consistently high in both time periods, the prevalence of network upgrades grew from 73% of projects during 2006-2016 to 90% during 2017-2021.

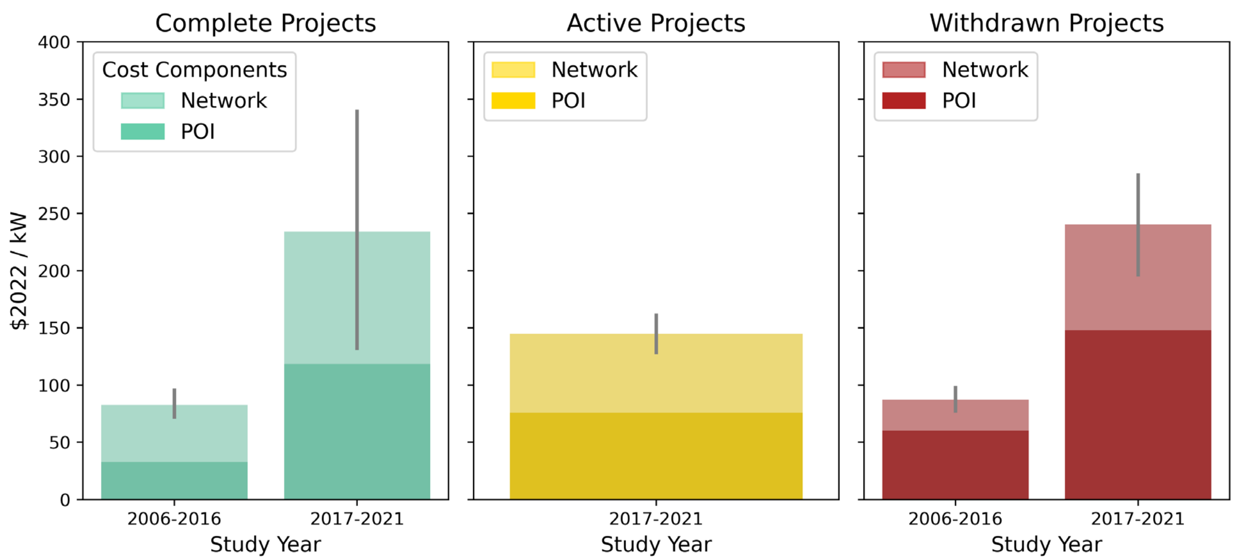


Figure 4 Interconnection Costs by Cost Category and Request Status *(bars: means, gray lines: standard error of total costs).*

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[4] POI costs usually do not include electrical facilities at the generator itself, like transformers or spur lines. Instead, they are predominantly driven by the construction of an interconnection station and transmission line extensions to those interconnection stations. The categories are referred to in the interconnection studies as "Connecting Transmission Owner Attachment Facilities" and "Stand-alone System Upgrade Facilities." Commonly listed equipment includes new POI stations, revenue metering, and disconnect switches at the point of change of ownership.

Network costs are referred to in interconnection studies as "System Upgrade Facilities," "System Deliverability Upgrades," "Affected System Upgrades," "Part 2 Allocation," and "Headroom Payments." A wide array of upgrades and equipment can fall in this category, including remote substation work, transmission line protection upgrades, and other transmission line work.

[5] Complete (mean) - 2006-2016: POI: $33/kW, $\hat{\sigma}_{\bar{x}}$=8; Network: $50/kW, $\hat{\sigma}_{\bar{x}}$=12. 2017-2021: POI: $112/kW, $\hat{\sigma}_{\bar{x}}$=81; Network: $123/kW, $\hat{\sigma}_{\bar{x}}$=47
Complete (median) - 2006-2016: POI: $24/kW; Network: $14/kW. 2017-2021: POI: $6/kW; Network: $56/kW

[6] Active (mean) - 2017-2021: POI: $76/kW, $\hat{\sigma}_{\bar{x}}$=8; Network: $69/kW, $\hat{\sigma}_{\bar{x}}$=10
Active (median) - 2017-2021: POI: $60/kW; Network: $33/kW

[7] Withdrawn (mean) - 2006-2016: POI: $60/kW, $\hat{\sigma}_{\bar{x}}$=9; Network: $28/kW, $\hat{\sigma}_{\bar{x}}$=5. 2017-2021: POI: $148/kW, $\hat{\sigma}_{\bar{x}}$=30; Network: $93/kW, $\hat{\sigma}_{\bar{x}}$=21
Withdrawn (median) - 2006-2016: POI: $40/kW; Network: $14. 2017-2021: POI: $72/kW; Network: $55/kW

Costs increase as projects complete more studies in the interconnection process

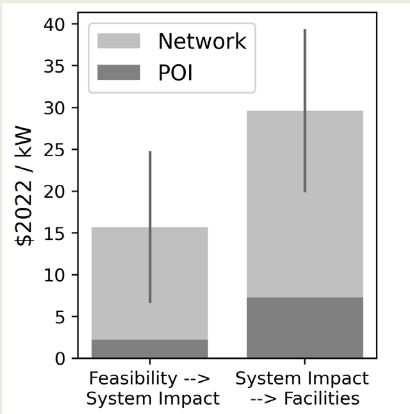

Figure 5 Interconnection Cost Increase Between Study Types *(bars: means, gray lines: standard error of total cost) Cost increase is calculated on projects for which both study types are available (left: 75 projects, right: 60 projects).*

The core results in this report are based solely on the most recent cost estimates available. However, expected interconnection costs for a project may change at each step of the interconnection process, as more studies are conducted and the system evolves (see Figure 5, Appendix Figure 13 and Figure 14). In NYISO, the change in a project's expected interconnection costs from their feasibility study to their system impact study is typically modest, with the majority of projects experiencing an increase between 25% and -5% (where a negative value indicates a cost decrease). This corresponds to an increase of $16/kW on average ($\hat{\sigma}_{\bar{x}}$=9). Between the system impact study and the most recent facilities study, cost increases are more substantial: costs change by at least 50% for around half the projects, and more than a quarter of projects see costs at least double. The average increase of $30/kW ($\hat{\sigma}_{\bar{x}}$=10) is due to cost increases both at the POI and in the broader network.

Not all projects in the sample have multiple cost estimates available; this analysis is based on the subset of projects for which we had access to multiple studies. Cost estimates for active projects are primarily based on system impact studies (74%), suggesting the current costs reported for this group may underestimate the costs that will ultimately be paid to interconnect.

3.3 Solar project interconnection costs are generally 8-18% higher than costs for other resources

The cost sample contains primarily solar (108), onshore wind (103), storage (36), natural gas (28), and offshore wind[8] (9) projects, for which we present costs in this section, but also some biomass (4), hydropower (2), fuel cell (2), flywheel (1), nuclear (1), and pumped hydro (1) plants, for which we do not present costs here. Figure 6 (left) shows that solar projects cost the most to interconnect, both when considering mean and median costs. Based on means[9], solar interconnection costs are 8% higher than the second-most costly resource (storage) in recent years; based on medians[10], solar interconnection costs are 18% higher than the second-most costly resource (natural gas) in recent years. The majority of solar projects in the interconnection queue are small (<50 MW) which contributes to their high cost, since we show in following section that economies of scale exist for solar interconnection costs. The other resource types do not present consistently high or low costs relative to one another, unlike in MISO (Seel et al. 2022) and PJM (Seel et al. 2023), where natural gas had the lowest interconnection costs in recent years.

Drawing conclusions about longitudinal trends in complete project costs is not possible for individual resource types due to the small number of complete projects. As a reminder, Figure 3 shows that costs for completed projects in aggregate are trending higher since 2017. This also holds for natural gas and onshore wind projects when considering all request statuses (Figure 6, left). Figure 6 (right) shows the cost of complete projects by resource type and by study date. Only three solar projects have completed the

[8] Offshore wind interconnection costs do not include the interconnection costs of transmission lines connecting offshore wind to onshore substations where they proposed to interconnect.

[9] Mean interconnection costs ($\hat{\sigma}_{\bar{x}}$), in order of Figure 6-left ($/kW): **natural gas**: 2006-16: 98 (20), 2017-21: 157 (64), **solar**: 2006-16: 227 (170), 2017-21: 182 (20), **storage**: 2017-21: 169 (57), **wind onshore**: 2006-16: 86 (9), 2017-21: 122 (22), **wind offshore**: 2006-16: 21 (7), 2017-21: 150 (77).

[10] Median interconnection costs, in order of Figure 6-left ($/kW): **natural gas**: 2006-16: 55, 2017-21: 106, **solar**: 2006-16: 227, 2017-21: 125, **storage**: 2017-21: 60, **wind onshore**: 2006-16: 77, 2017-21: 105, **wind offshore**: 2006-16: 21, 2017-21: 40. See Appendix Figure 12 for boxplots.

interconnection process, one of which stands out as having by far the highest interconnection costs among all complete projects in the sample ($985/kW; second-highest cost for a completed project is $329/kW).

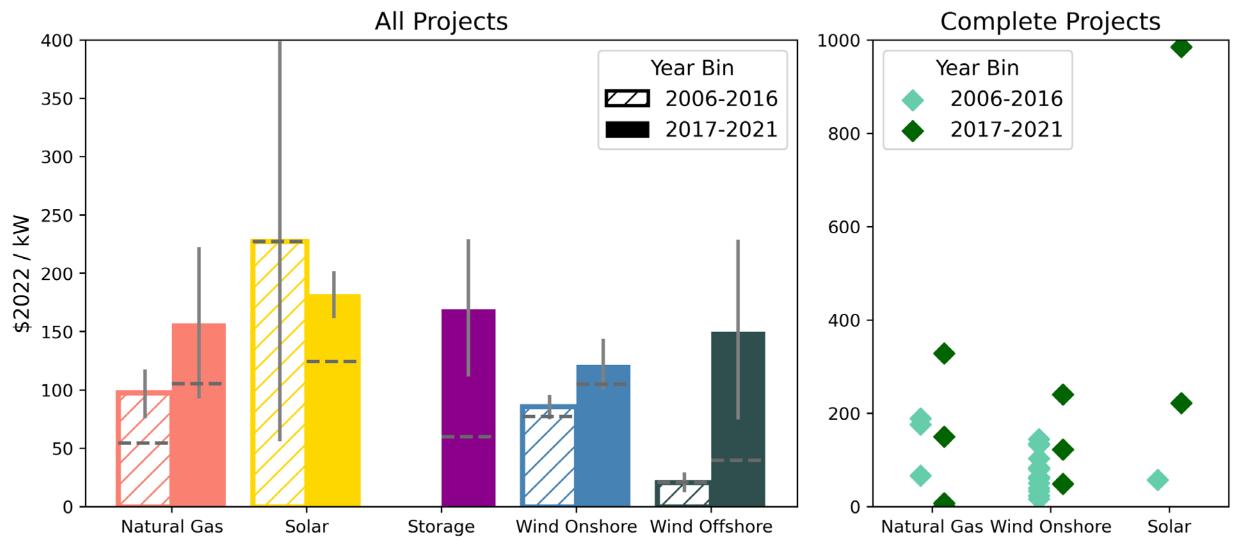

Figure 6 Interconnection Costs by Resource Type (left) and Over Time for Complete Projects (right) *(bars: means, vertical gray lines: standard error, horizontal dashed grey lines: medians, diamonds: individual data points). For complete projects, the sample sizes are small (see* **Figure 1** *for counts) and best portrayed by showing each data point. As a reminder, the most recent study for a complete project was reported in 2019, but bins are marked as ending in 2021 for consistency with the overall sample period.*

Interconnection costs for each resource type vary by request status and cost category. Figure 7 investigates the distribution of interconnection costs across all projects in our 2017-2021 sample. The data suggest that high interconnection costs play a role in withdrawal decisions for natural gas and solar projects, do not support the same conclusion for storage, and are inconclusive for onshore wind. For active and withdrawn solar projects, the mean interconnection costs represent 11% and 21%, respectively, of the typical installed solar costs in the United States in 2021 (Bolinger et al. 2022). For onshore wind projects, the average interconnection costs are 7-10% of installed costs for each request status (Wiser et al. 2022). Storage projects experience the highest average network costs among active projects, despite most being located near load centers.

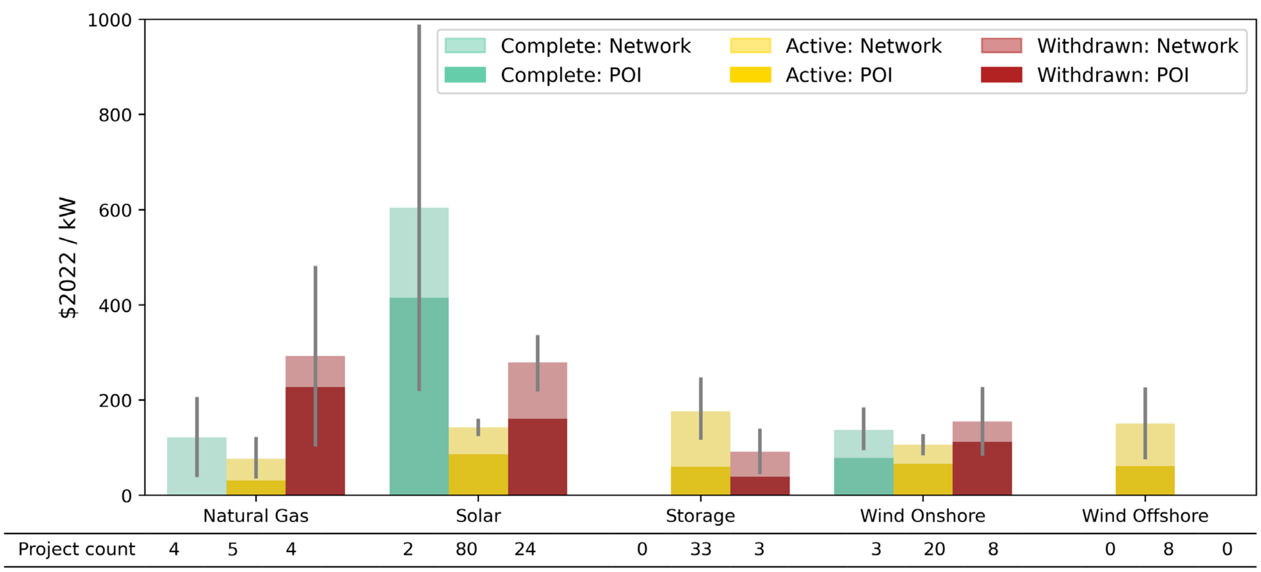

Figure 7 Interconnection Costs by Resource Type, Cost Category, Request Status *(bars: means, gray lines: standard error of total costs, 2017-2021).*

Offshore wind policy impacts transmission development and interconnection costs

Offshore wind development in New York offers an example of how public policy, transmission development, and generator interconnection interact. In general, transmission needs can be driven by public policy, reliability concerns, or economic benefits. A recent example of a public policy-driven transmission need stems from the Climate Leadership and Community Protection Act (CLCPA) of 2019 that mandates New York State procure 9 GW of offshore wind by 2035. Long Island offers the closest interconnection location for several offshore lease areas. Based on the expected influx of offshore wind power driven by the CLCPA, the Long Island Power Authority identified, and the New York Public Service Commission (PSC) established, the need for (1) increased export capability "from Zone K to Zones I and J to ensure the full output from at least 3,000 MW of offshore wind is deliverable from Long Island to the rest of the State" and (2) upgraded local transmission facilities to support the increased export capability ("Order Addressing Public Policy Requirements For Transmission Planning Purposes" 2021). This is known as the Long Island Offshore Wind Export Public Policy Transmission Need (LI PPTN).

Multiple transmission projects have been proposed to fulfil the LI PPTN, and NYISO is currently evaluating the proposals. The selection of LI PPTN projects will affect offshore wind developers' costs, by influencing the length of cables needed to reach the point of interconnection, the POI costs of interconnection, and the network upgrades needed to deliver power (NextEra Energy Transmission New York 2022).The costs of selected LI PPTN transmission project(s) will be allocated to all load zones in the state based on their share of total energy consumption. Statewide allocation, as opposed to assigning most costs to Long Island and New York City where the project(s) will be located, was deemed most appropriate by the PSC because "the entire focus of the identified transmission need is on facilitating compliance with the CLCPA" ("Order On Petitions For Rehearing - Case 20-E-0497 and Case 18-E-0623" 2022). Once LI PPTN projects are selected and sufficiently advanced, they will be incorporated into NYISO's Existing System Representation – the baseline relative to which interconnection impacts are assessed – at which point they will begin to influence interconnection studies and costs. Interconnection customers pay for the cost of system upgrades that would not be needed but for their interconnection. So, while interconnection costs for resources of any type, anywhere in the system could change because of LI PPTN projects, it is reasonable to expect that offshore wind projects interconnecting in Long Island are among the most sensitive to this change and will likely see reduced costs. There are six such active projects that have not yet completed all interconnection studies analyzed in this report.

3.4 Larger generators have greater interconnection costs in absolute terms, but economies of scale exist on a per kW basis for solar and onshore wind projects

Projects with larger nameplate capacity ratings have greater interconnection costs in absolute terms, but these costs do not always scale linearly on a per kW basis. Between 2017 and 2021, projects smaller than 50 MW have average interconnection costs of $4.7 million, which compares to $8.2 million for medium projects between 50 and 100 MW, $14.5 million for large projects between 100 and 250 MW, and $78.4 million for those very large projects with a capacity of at least 250 MW. Figure 8 shows clear economies of scale for recent solar and onshore wind projects, with average costs falling from $224/kW to $70/kW and from

$396/kW to $45/kW respectively.[11] Size efficiencies are not apparent among natural gas projects (though the sample is small) or storage projects.[12]

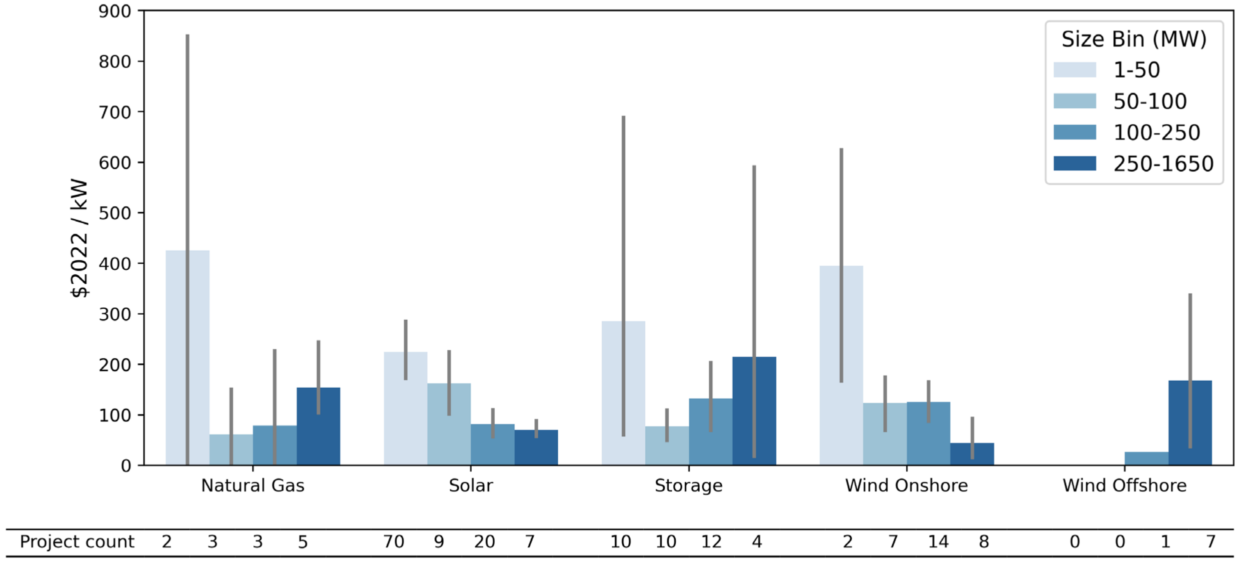

Figure 8 Interconnection Costs by Capacity and Resource Type *(bars: means, gray lines: standard error of total costs, 2017-2021). Includes complete, active, and withdrawn statuses. Note that the smallest projects in the sample are 3 MW and the largest is 1640 MW.*

3.5 Interconnection costs vary by location

Interconnection costs also vary by location, as shown in Figure 9 and Figure 10. Nassau County (on Long Island) and Monroe County (includes Rochester) have the highest costs among counties with more than one project. The most northern and western counties tend to have lower costs than those located more centrally or to the southeast. Location, at the county level, does not appear to have a significant impact on the cost to interconnect onshore wind projects, compared to other resources which have more geographic variation.

Suffolk County (on Long Island) is an expensive location to interconnect solar projects (4 projects studied since 2017, mean: $665/kW, median: $612/kW), but has much lower costs for proposed storage (10 projects studied since 2017, mean: 002499/kW, median: $60/kW) and offshore wind (4 projects studied since 2017, mean: $53/kW, median: $19/kW). As background, Suffolk County belongs to Zone K, where capacity prices were the highest in NYISO nearly every month in summer 2021 and summer 2022, reaching at least twice the price of the broader New York Control Area in some months. This Suffolk County example highlights the challenge of estimating interconnection costs in advance of completing interconnection studies, even within a small geographic area.

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[11] Mean cost ($\hat{\sigma}_{\bar{x}}$) - Solar: 1-50 MW: $224/kW (28), 50-100 MW: $162/kW (34), 100-250 MW: $82/kW (14), 250 MW+: $70/kW (9)
- Onshore Wind: 1-50 MW: $396/kW (228), 50-100 MW: $123/kW (29), 100-250 MW: $126/kW (21), 250 MW+: $45/kW (21)
Median cost - Solar: 1-50 MW: $138/kW, 50-100 MW: $154/kW, 100-250 MW: $94/kW, 250 MW+: $66/kW
- Onshore Wind: 1-50 MW: $396/kW, 50-100 MW: $147/kW, 100-250 MW: $115/kW, 250 MW+: $21/kW

[12] Mean cost ($\hat{\sigma}_{\bar{x}}$) - Natural gas: 1-50 MW: $425/kW (424), 50-100MW: $62/kW (45), 100-250MW: $79/kW (74), 250MW+: $154/kW (44)
- Storage: 1-50 MW: $286/kW (189), 50-100MW: $78/kW (16), 100-250MW: $133/kW (36), 250MW+: $215/kW (188)
Median cost - Natural gas: 1-50 MW: $425/kW, 50-100 MW: $35/kW, 100-250 MW: $8/kW, 250 MW+: $117/kW
- Storage: 1-50 MW: $76/kW, 50-100 MW: $64/kW, 100-250 MW: $73/kW, 250 MW+: $32/kW

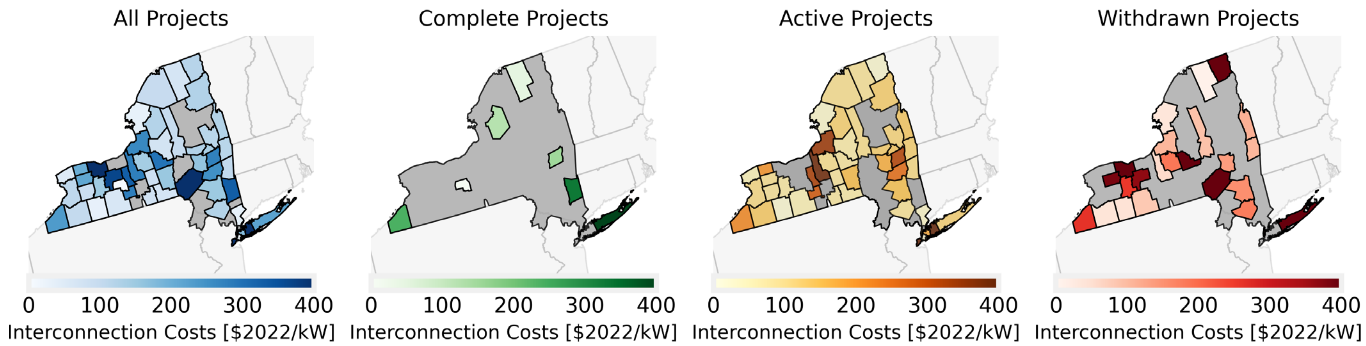

Figure 9 Interconnection Costs by County and Request Status *(means, 2017-2021, grey areas indicate no data available).*

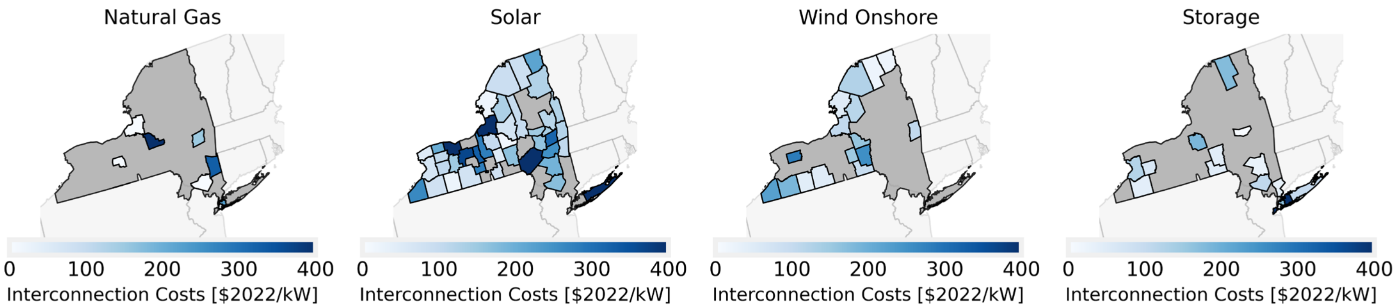

Figure 10 Interconnection Costs by County and Resource Type *(means, 2017-2021, grey areas indicate insufficient data; all request statuses are included).*

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For other interconnection related work, see https://emp.lbl.gov/interconnection_costs and https://emp.lbl.gov/queues
For the DOE i2X program, see https://www.energy.gov/eere/i2x/interconnection-innovation-e-xchange
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4. Appendix

4.1 Appendix A – Methodological Notes

This section describes our approach to refining the raw cost data collected from interconnection studies into the final interconnection cost dataset reflected in this report.

- Cost estimates used were generally from the most recent available interconnection study report for each project. However, when the most recent study was a class year facilities study – part 2, which lacks the cost detail present in other studies, information from the second-most recent study was also incorporated. Specifically,
    - Connecting transmission owner attachment facility (CTOAF) costs from second-most recent study were used, since they are not reported in the most recent study, and
    - The ratio of POI to network costs within system upgrade facilities costs in the second-most recent study is applied to the reported total of system upgrade facilities costs in part 1.
- When a breakdown of costs into POI and network costs was not available, we assumed a ratio equal to that of all known POI costs to all known network costs in the sample within the relevant cost categories.
- Two-phase projects with two interconnection requests (one request per phase) are treated as one project with aggregated costs and capacity. There were 7 such projects.
    - Two-phase projects are considered complete if the first phase is in service and the second phase has completed a class year facilities study – part 2. There were no other cases of two-phase projects for which the two requests had different statuses.
- Interconnection requests that do not refer to new generation or storage projects, such as transmission, repowering, or uprate projects, are excluded.
- Each project's request status is based on NYISO's published interconnection queue as of 7 December 2021, and all studies in the sample precede this date.
- When projects owe headroom payments, that is included in their interconnection costs. However, those headroom payments are not subtracted from a different project's costs, because we usually don't know who receives it.

4.2 Appendix B – Additional Figures

This Appendix includes boxplot versions of the graphs in the core report, highlighting the broad distribution of interconnection costs that underlie the previously presented means. The boxplot median is highlighted with a bolder dashed line, the lower and upper box line represent the 25th and 75th percentile. The lower/upper whiskers are 1.5x of the interquartile range below/above the 25th and 75th percentile. Not all outliers are shown to keep the graphs legible. Y-axes differ by figure.

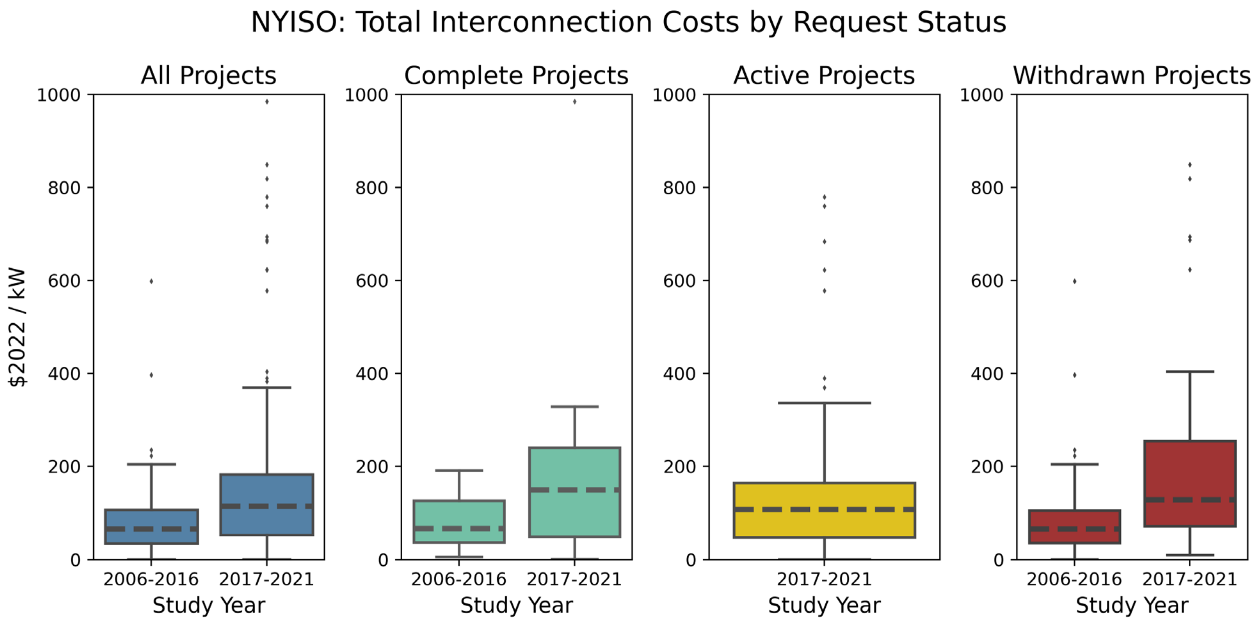

Figure 11 Interconnection Costs over Time by Request Status *(not all outliers outside 1.5x interquartile range are shown).*

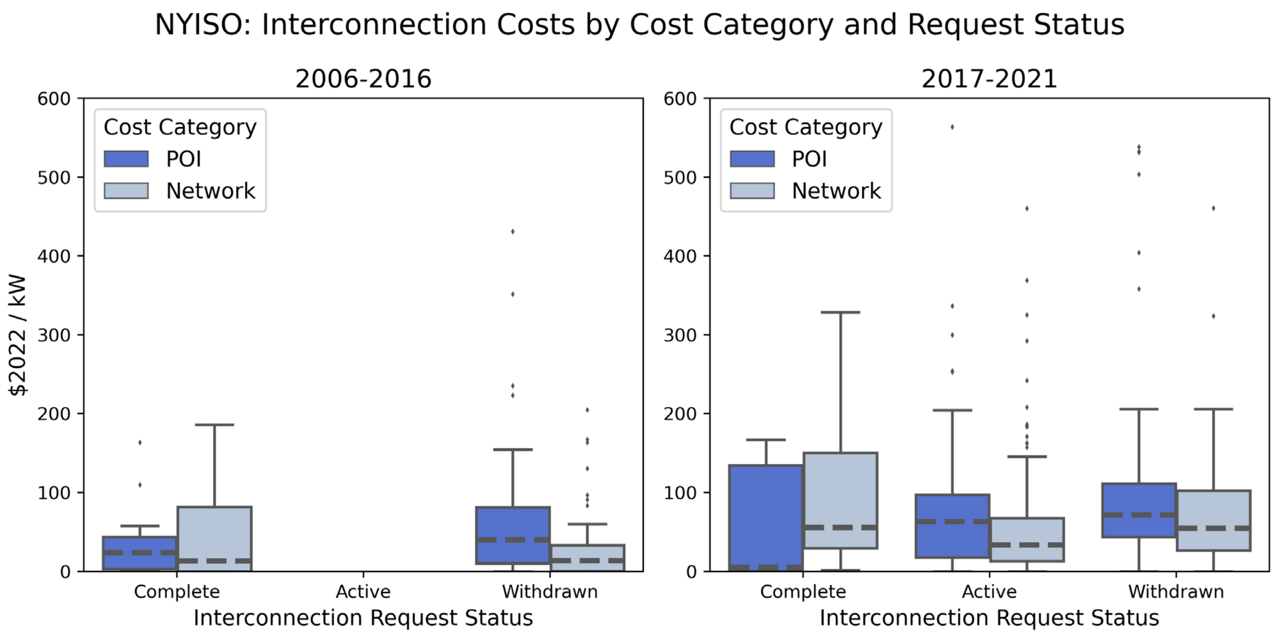

Figure 12 Interconnection Costs by Request Status and Cost Category *(not all outliers outside 1.5x interquartile range are shown).*

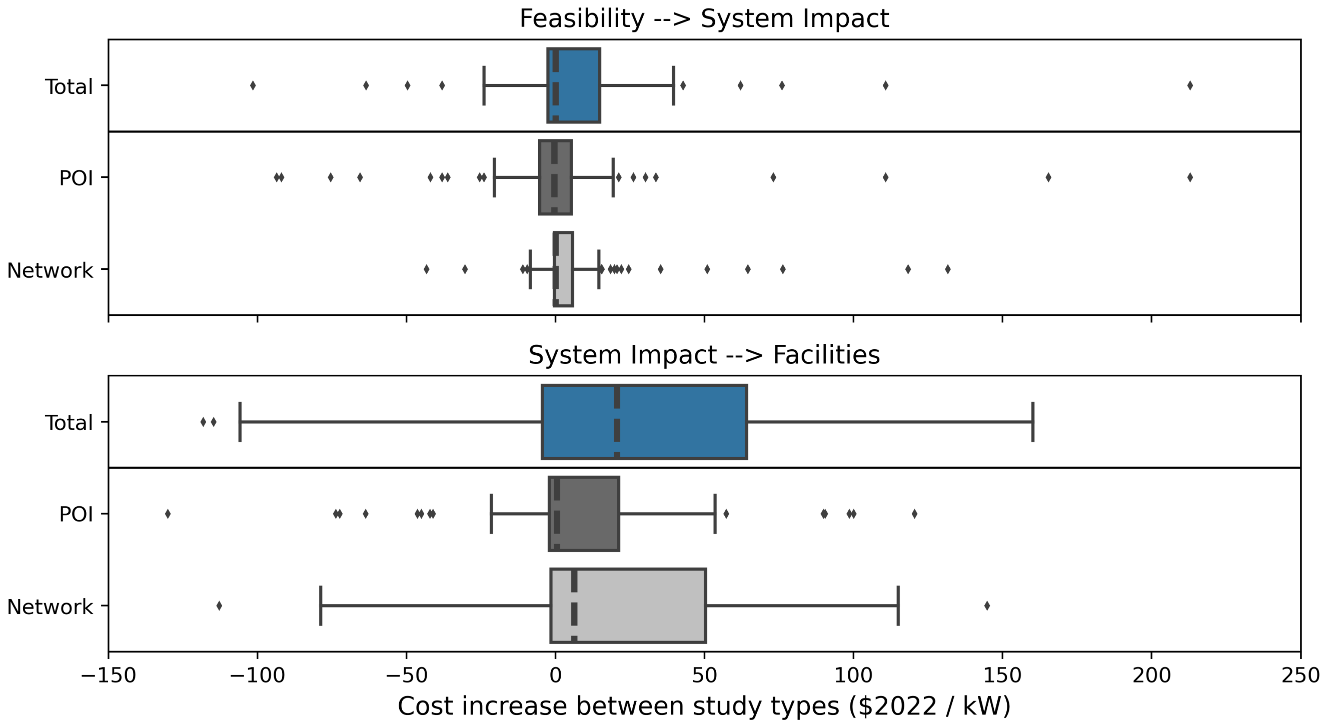

Figure 13 Change in Interconnection Costs Between Study Types by Cost Category *Cost increase is calculated for all projects for which both study types are available (top: 75 projects, bottom: 60 projects). Not all large-increase outliers above the 1.5x interquartile range are shown.*

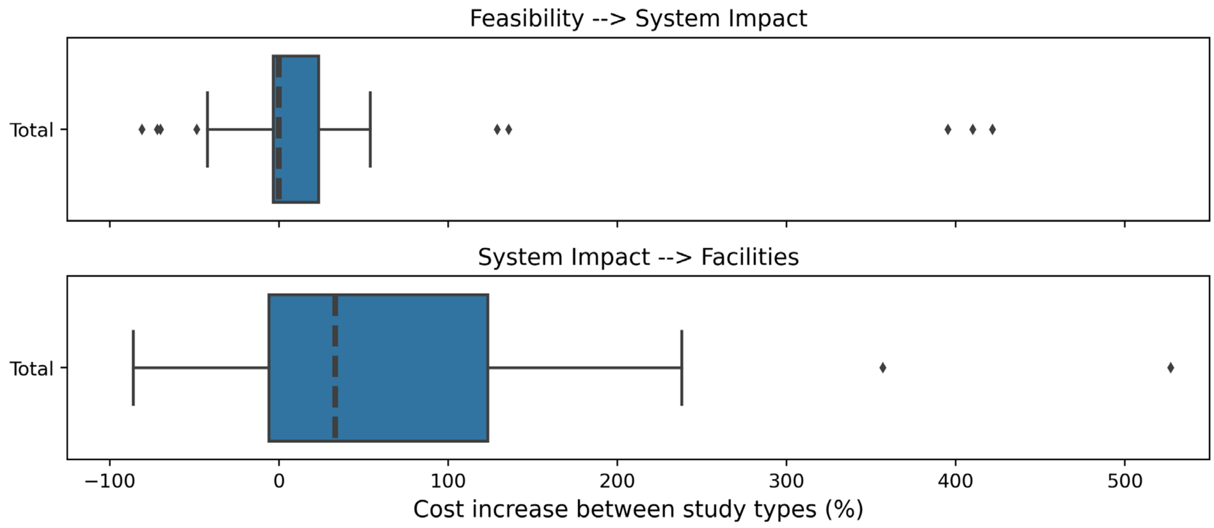

Figure 14 Change in Interconnection Costs Between Study Types *Cost increase is calculated based on the $2022/kW cost for all projects for which both study types are available (top: 75 projects, bottom: 60 projects). Not all large-increase outliers above the 1.5x interquartile range are shown.*

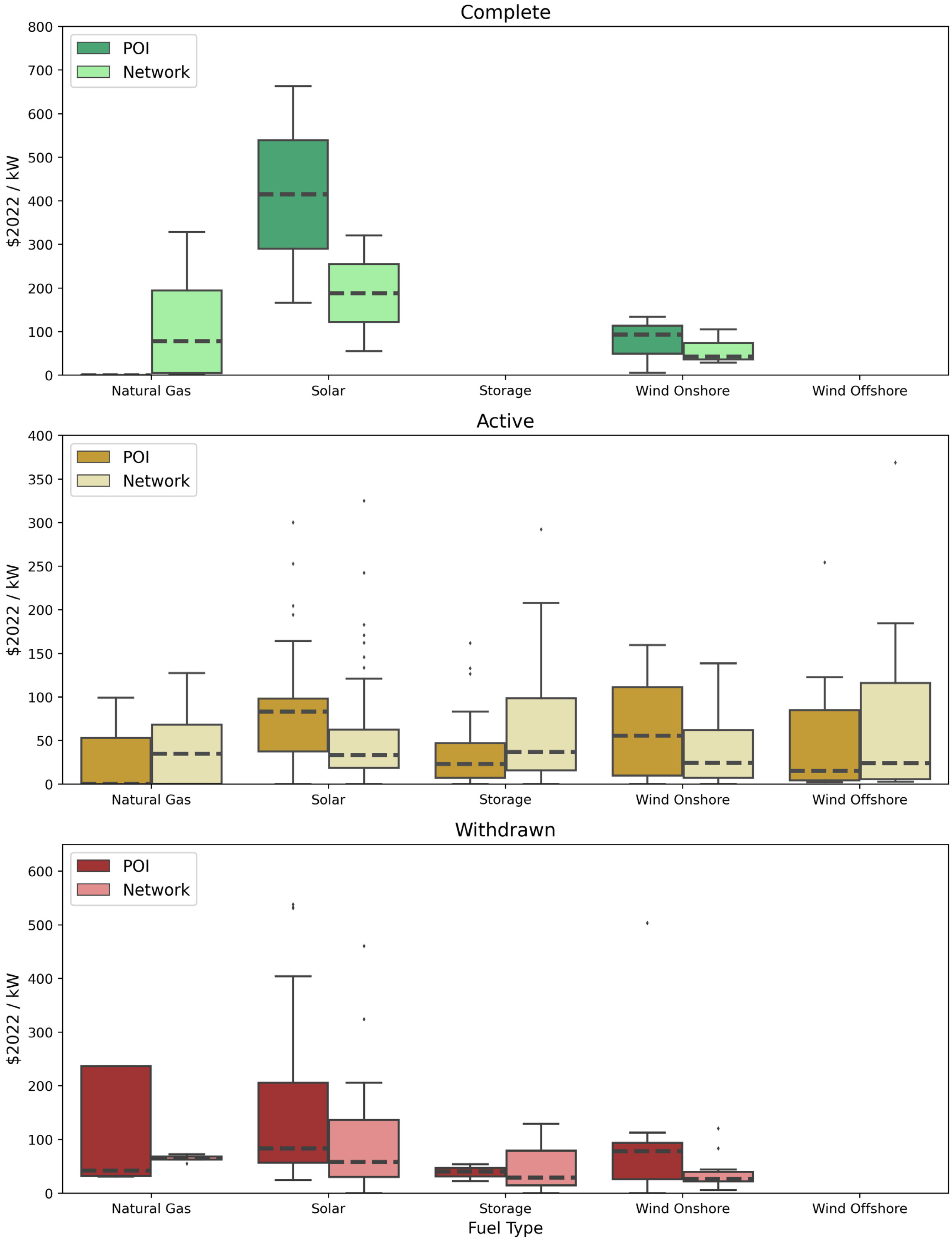

Figure 15 Interconnection Costs by Resource Type, Request Status, and Cost Category *(2017-2021, not all outliers are shown).*

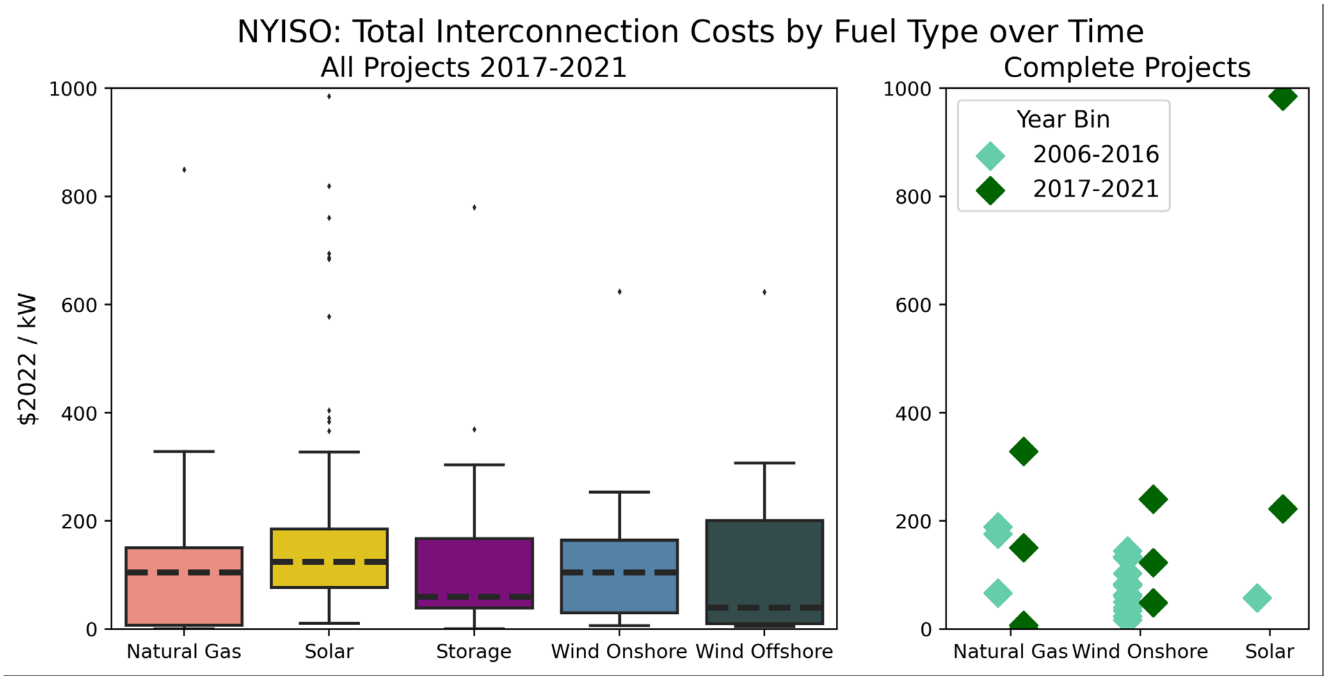

Figure 16 Interconnection Costs by Resource Type (left) and Over Time for Complete Projects (right) *(not all outliers are shown).*

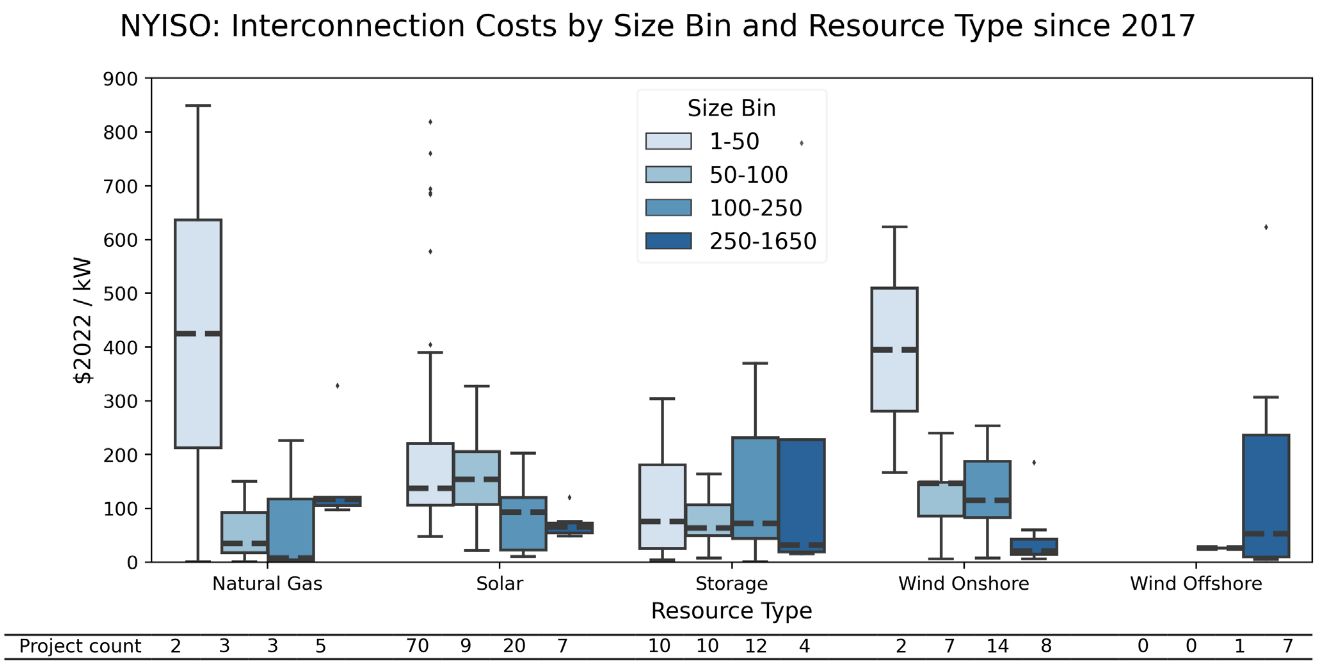

Figure 17 Interconnection Costs by Resource Type and Size Bin *(2017-2022, not all outliers are shown).*