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Renewables in the queue: capital landing and the present crisis in power transmission

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ABSTRACT

As renewable energy investment continues to boom internationally, where this capital is landing – and, conversely, where and why it is *failing* to land – are equally important questions. This paper examines renewable power transmission as a crucial yet under-researched influence. Ability to interconnect to grids and to do so in a timely manner, the affordability of that access and the state of the grid once projects are connected all shape how profitable new generation will be. Financial expectations about those conditions may determine whether projects are built at all. Transmission grids thus have an important capacity to either enable or block renewable capital landing. Moreover, grid assets are increasingly becoming an object of speculative investment in their own right. We explore these questions via current dilemmas in the fragmented US grid. Ballooning costs and delays in interconnecting new renewables are a mounting crisis, shaped by neoliberal legacies of electricity deregulation/market liberalisation and underinvestment and exacerbated by expanded Biden-era subsidies for renewable generation. They have become a leading cause of US project abandonment. Ongoing US transmission debates speak to the vital role of the state despite mainstream narratives of an 'after-subsidy' renewables transition, in a derisking capacity but also beyond.

KEYWORDS

Renewable power; green finance; transmission grid; United States; state derisking; electricity deregulation/market liberalisation

JEL O13; P16; Q4; P48

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1. INTRODUCTION

As climate change-related investment continues to grow, where such public and private resources are landing – and, conversely, where and why they are *failing* to land – are equally crucial questions. In high-level mainstream accounting of these global investment trends, ongoing booms in renewable power internationally have been a much-acclaimed success story, lately joined by the even more rapid rise of electrified transport. BloombergNEF (2023) estimated that this energy transition investment exceeded $1.11 trillion in 2022 alone. The problems created by these supposed successes, notably the rollout of large renewable power projects in contested peripheries and neo-sacrifice zones, preoccupy a growing critical scholarship.

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In this paper, conversely, we take up ongoing failures in this capital landing, an equally vital question for critical research and praxis. A framing concept for this Special Issue, 'capital landing' refers to the realisation of investment on the ground, in contrast to speculative investment frontiers that may be articulated but do not necessarily materialise. Today's booming private investment in renewables has frequently engendered a certain market triumphalism: mainstream arguments that the sector has outgrown the need for the many forms of state subsidy and support that have enabled its rise internationally, and that corporate and financial sector players may now lead an 'after-subsidy' future (Christophers, 2024). This questionable proposition looms large in increasingly active debates over the state's role in low-carbon energy transition, including diverse international campaigns for public power ownership. Questioning goes beyond well-justified equity concerns over where and who will be left out if for-profit interests lead, and what avoidable harms might be inflicted in the process. Critics argue that an active state is required to accomplish a full renewables transition at all, in a capital derisking capacity (e.g., Gabor, 2021) but also beyond.

Joining these critiques, we take up the question of electric power transmission as a crucial yet underexamined factor in whether capital lands for renewable generation systems, as well as a frequent object of new state strategising. All but the most decentralised or isolated renewable generation technologies (e.g., 'behind the meter' generation and storage, or certain 'island' microgrids) must be connected to broader grids to transport the power they generate to users, sometimes for very long distances. Successful project interconnection to high-voltage transmission grids, and the ability to move power to market once hooked up, are central concerns for renewable power developers and investors. Ability to connect and to do so in a timely manner, the affordability of that connection, and the state of the grid once projects are connected all shape how profitable new generation projects will be. Moreover, expectations about those conditions may determine whether projects are built at all, particularly where for-profit development dominates. As we will argue, building particularly on Spivey (2022), transmission grids thus have an important capacity to either facilitate or block capital landing for other renewable infrastructures. Increasingly as well, transmission projects in the form of new lines or grid upgrades are becoming an object of speculative investment in their own right, alongside a broadening wave of interest in renewables which also encompasses diverse forms of energy storage (Turley et al., 2022; Ventrella & Knuth, 2024).

2. MATERIALS AND METHODS

We illustrate this discussion through reference to current challenges in the US renewable power transition. Difficulties in connecting new renewable power projects to the grid have become a serious concern as the US renewable transition otherwise gains speed, prompting reform efforts under the Biden Administration. Central problems include interconnection queues that climbed through the 2010s and skyrocketed in the 2020s, with new renewable projects now waiting years to be brought onto the grid, ballooning costs charged, and equity concerns in how those fees have been set. In recent years, industry players have frequently cited interconnection queues as the chief obstacle to deploying renewable energy in the United States (Penrod, 2023), and a major driver of project abandonment. As expanded federal renewable subsidies in the 2022 Inflation Reduction Act sparked a raft of new projects, the US grid connection crisis only worsened – and though the US case is notably severe, the country is far from alone. For this empirical case, we drew on three years of participatory research undertaken by the lead author with The Climate & Community Institute on renewable power and transmission politics in the United States. Additional document analysis by both authors included examination of transmission policies and data from the US federal government and regional grid operators, US national lab data, and research papers, as well as several years of following utility industry trade press and relevant financial industry reporting.

3. THEORISING TRANSMISSION AS A CAPITAL LANDING ISSUE

Scholarly examinations of ongoing booms in renewable energy investment have often focused on the price of supposed successes – what happens when capital lands, but does so in problematic ways for a just transition. Particularly, a geographically wide-ranging scholarship (now too extensive to do more than nod to here) focuses on dispossessions associated with the sector's spatially extensive power generation infrastructures, particularly the larger utility-scale wind and solar projects favoured by investors. More directly relevant for this paper's discussion is work scrutinising profitability in the renewables sector, particularly questions about the ongoing role of the state as renewable-based power has become cheaper than incumbent fossil sources. Mainstream arguments lean on ideas of technological and market maturation of wind and solar – though as interventions such as Baker (2022) and Knuth (2023) have pointed out, associated capital cheapening applies unevenly to bigger utility-scale generation projects, larger and more established developers, and favoured geographic locations as preferred capital landing sites. Challenging narratives that the sector has grown beyond a need for subsidies, Christophers (2024) argues for states' ongoing role in enabling renewables' profitability, including both direct subsidies and price supports provided by policies like feed-in tariffs. For the United States, research on government policies like state-level Renewable Portfolio Standards and related utility Power Purchase Agreements (Behrsin et al., 2022) and on federal tax credits for renewables (Knuth, 2023) likewise speaks to renewable project developers' ongoing reliance on these supports to make investment calculations pencil out – even if that also embeds extractive relationships with some fractions of finance capital, as Knuth explores for renewable tax equity finance.

Much of the discussion above relates to individual renewable power projects as assets and objects for investment. What scholarship has done much less of so far is to consider capital landing for a full renewable power transition – a necessarily systemic question that extends beyond electricity generation. Such broader questioning of capital landing requires a more holistic view on power systems, including as electrification itself becomes an increasingly central transition strategy with the expansion of fossil replacement technologies like electric vehicles and building heat pumps. When understood as more than a series of low-carbon projects cumulatively added to electricity generation capacity, renewable power transition is better appreciated as a holistic transformation in how power systems look, work, and must be managed. Here Thomas Hughes' (1993) insights into the birth of modern electricity remain influential, including into decisive US experiences like the late nineteenth century 'war of the currents' between competing direct current- and alternating current-based transmission systems. It is also well worth noting Jane Bennett's (2005) influential work on the grid as a complex human-nonhuman assemblage and on the ways in which this can break down and fail, as well as scholarship exploring how partial, unstable and informal connections continue to shape grid experiences in much of the world (e.g., Luque-Ayala & Silver, 2016; Silver, 2015).

In the United States, building on the important early insights of Hirsh (1999), Bennett (2005) and others into then-new experiments with de/reregulation and market liberalisation of the electricity system, scholars have discussed many grid questions through the lens of this broader market-based reorganisation. Independent power producers (IPPs) allowed into US electricity markets via liberalisation are still the chief owners of US wind and solar generation projects (Harrison, 2022; Knuth, 2023). In the US twentieth century 'utility compromise' explored by Hirsh (1999), private investor-owned utilities (IOUs) were permitted to operate so-called natural monopolies within their service territories, with relevant state-level public utility commissions charged with regulating capital spending plans and rates charged to customers. In this system, IOUs historically built, owned, and operated both generation facilities and grid assets. The latter include high-voltage transmission lines, electric substations, distribution transformers, and lower-voltage distribution lines used to transport power from substations to end users – a stepping down of voltage needed for compatibility with common appliances. As we will see, deregulation has complicated this picture, even as some states have continued to reject liberalisation (Harrison & Welton, 2021).

Despite insights from more holistic examinations of fixed capital in power systems like Kennedy and Stock (2022), Harrison (2022) and Luke and Huber (2022), political economies of the grid and grid access remain relatively underdeveloped in geography, though there is a now substantial technical literature on grid capacity challenges under renewables transition (also see Ventrella & Knuth, 2024). However, Spivey (2022) has recently advanced important insights into renewables' grid entry issues. Spivey examines how national grid regulators seeking to defend the country's incumbent nuclear sector after the 2013 Fukushima disaster resisted new renewables specifically by blocking transmission grid access. He also explores how they deployed expertise politics to do so, including seemingly neutral technical appeals to limited transmission grid capacity and the ostensibly necessary grid-stabilising role of nuclear baseload power. In another key point for the current discussion, Spivey underlines the dual political economic life of the grid – again, simultaneously a central enabling/constraining influence on whether capital lands for fixed capital investment in renewable generation, and significant fixed capital in its own right.

As we will see below, investors are now expressing growing interest in directly building and owning transmission and grid assets, despite a fitful start in the US context. Turley et al. (2022) explore this broadened capital landing for grid-scale energy storage. A growing search for energy storage solutions responds to changing needs of power grids as renewables assume a greater share of total generation. These include complex multi-directional flows in the case of prosumer net-metering and some non-wires grid solutions. However, many challenges relate to renewables' intermittency, such as the generation of surplus power on windy days (and risk of deficit on non-windy ones) or more predictable diurnal fluctuations like California's 'duck curve', where solar farms produce surplus during the day and a potential deficit at night. As the transition progresses, the withdrawal of fossil baseload and readily deployable 'peaker' plants (more costly, often dirtier power deployed onto the grid as needed to cover peak demand) will increase pressures for transformed grids and forms of grid management.

These challenges are propelling a push for new grid-scale energy storage solutions to help regulators balance and manage the grid in new ways. This drive has awakened a range of investor interest, from venture capital for early-stage innovations to project and corporate finance for infrastructural assets. As Turley et al. (2022) explore, storage infrastructures already rolling out at scale include both standalone grid-scale storage like lithium-ion battery farms and pushes for solar+storage and other hybrid options (also see Rand et al., 2023). New system needs are also sparking speculative interest in more established forms like hydroelectric pumped-storage, still the dominant source of longer-duration energy storage on grids, and in new dam infrastructures to enable it. It is also worth noting energy-shifting strategies like electric vehicle expansion which may balance loads and provide mobile battery storage for the grid. Similarly, 'Power-to-X' initiatives seek to channel surplus renewable power generated in certain sites into the energy-intensive production of hydrogen and other carrier energy forms, converting surplus into another energy resource for use and potential export. All these trends are shaping a broadening field of transition investment from the private sector and governments.

Finally, there are clear overlaps between the grid technologies and questions discussed here and longer-running public and private interest in smart grids and smart cities (e.g., Wiig, 2015). Advocates now regularly appeal to digitalisation, automation and other modernisation options (most recently including generative AI) to improve grid efficiencies. Such efforts include experimentation with 'non-wires' solutions like behind the meter energy storage, cloud-based virtual power plants and microgrids – more or less islandable to maintain power in a grid disruption (Rutherford & Marvin, 2023). Though less a focus in the current discussion, it is important to note that decentralised and digital infrastructures have been no less a target for speculative capital landing than large-scale grid assets like power lines. More decentralised infrastructures are also increasingly invoked around questions of grid resilience under climate change and climate-related financial risks on the grid (Cederlöf, 2023; Ponder, 2023; Schmidt, 2024) – a discussion returned to in the conclusion.

4. THE US CASE: THE GRID AS CAPITAL LANDING OBSTACLE

The early 2020s were a significant moment in ramping up US renewable power transition, particularly via the Biden Administration's passage of the Inflation Reduction Act (IRA) in 2022. In significant ways, the IRA fell short of a thoroughgoing overhaul of US federal support for renewables. Biden-era measures enhanced federal support through tax credits and public-private partnership initiatives, particularly via the Department of Energy (DOE). However, the IRA did not expand the federal government's own ability to build new power generation or transmission infrastructure. After a failed effort to implement a national clean energy standard (not the first such failure for the United States), the Biden Administration also again left procurement mandates to individual state Renewable Portfolio Standards, for the just over half of US states that have them (Behrsin et al., 2022). Neither did the IRA fully reform the federal government's main direct subsidy for renewables, which has continued to take the form of two major non-permanent tax credits, one tied to new investment in various kinds of renewable projects and another to the production of power once projects are built – though, crucially, it did significantly extend and refund both. As Knuth (2023) has discussed, it has historically been difficult for project developers to use these credits without contracting with third-party tax equity investors, a practice frequently critiqued as overly complex and extractive. Since the IRA's passage, tax equity finance has remained a player in the sector. However, new provisions for transferability and direct pay opened up US tax subsidies to new kinds of financiers, developers and owners – via direct pay, newly expanded to include non-profit entities like state, local and Tribal governments; energy cooperatives; and schools. Important for the discussion here, it also qualified new kinds of non-generation projects for tax credits, including energy storage. Estimates suggest the total value of IRA climate and clean energy tax credits at $660 billion (PwC, 2023).

The IRA's expanded federal support thus meant important capacity both to facilitate private capital landing and in theory to resource public and non-profit projects. However, what kind of renewable transition the United States will actually have remains in question – even more so as the 2024 Presidential election has meant fresh political hostility and turbulence for the sector. An influential mainstream argument has been that the United States should strive to maximise productivity of its diverse renewable energy resources. This might include, for example, capitalising on high insolation rates in the US Southwest for utility-scale solar development or windiness in the Great Plains for a concentrated belt of onshore wind – production geographies already taking shape. Effectively, this vision imagines large, land-intensive solar and wind farms clustering regionally in a similar way to US agro-industrial geographies – for example, the US Corn Belt or California's Central Valley. The sell here is the ability to get the most possible power out of each renewable generation asset in use. In theory, such productivity in resource-rich areas will maximise profits for project owners. Advocates equate this concentration with broader national interest via arguing that it will land more capital in the sector and bring the cheapest available renewable power to market.

Notably, visions of concentrated utility-scale renewables production presume that most renewable power will be exported out of the regions in which it is produced, sent to cities and coastal metropolitan belts where most US power demand (or 'load') is located. This is a very different vision from notions of decentralised energy futures, prosumption and potential decommodification imagined by original renewable power advocates and many community power movements today. However, its support for large-scale renewable production is echoed to an extent by Green New Deal visions, though more progressive and radical versions (e.g., Bozuwa et al., 2021, 2023; Bozuwa & Mulvaney, 2023), push for public power development and ownership, at-cost provision of generation and transmission services, just siting of these infrastructures, and long-term decommodification. Meanwhile, new utility-scale renewable generation facilities are typically farther from urban load centres than the incumbent fossil generation plants they are intended to replace; they are also more numerous but on average smaller than these natural gas-, coal- or oil-fired facilities.

All of this means that to move power to market in the profitable, investable ways imagined by mainstream champions, wind and solar farm developers must be able to access long-distance transmission grids – for distances of easily over a thousand miles, depending on where projects are concentrated. With this dependence, fears have grown that US high-voltage grids are simply not built in the locations needed, and will require line upgrades, modernisation (e.g., implementation of grid enhancing technologies like advanced power flow control), and basic repairs to handle major increases in extra-regional flows. In other words, they are likely organisationally ill-equipped for – and, as in Spivey's (2022) case, potentially politically resistant to – an influx of interconnection requests for renewable power, which may not directly serve the regions transmission infrastructure passes through. (Certainly, a dimension of potential renewable sacrifice zones that is not confined to the United States.)

Without transmission lines, projects cannot proceed. Where lines exist but are not sufficiently upgraded or modernised, insufficient transmission capacity to interconnect generation and consumption centres means bottlenecks, grid congestion, climbing grid congestion costs and likely curtailment of generation by grid managers to preserve the overall stability of the system. Congestion costs can arise from forced inefficiencies in real time grid management. When bottlenecks in a particular location mean that operators are blocked from getting the lowest-cost power to users, they must send them a more expensive alternative instead. Overall, power produced will not be able to flow to where it is needed, users will pay extra costs for power, and excess power elsewhere may be offloaded at a loss. Grid Strategies estimates that congestion costs on the US grid climbed to $20.8 billion in 2022, up from $13.3 billion just a year before (Doying et al., 2023).

These new system demands occur in a US transmission grid which is highly fragmented and otherwise poorly equipped to meet them. The US grid could be argued to lead a dual existence today. In a basic material sense, the transmission network in the United States is comprised of two relatively independent Interconnections (the Western and Eastern) alongside Texas' infamously isolated grid, all running on alternating current. Under normal operating conditions, grid operators and regional balancing authorities tie together all electric utilities via collectively shared lines and synchronise them all up on a standard 60 Hz frequency. Operators must ensure that power supply always balances demand in real time for the grid to maintain reliable service, with enough redundancy in grid design to prevent service disruption if major transmission lines or generators fail unexpectedly. Because the federal government counts power flows across state boundaries as interstate commerce, most transmission comes under its regulatory jurisdiction via the Federal Energy Regulatory Commission (FERC).

However, the grid must also be scrutinised in a parallel organisational sense, via asking who plans, builds, owns, operates, repairs and upgrades this infrastructure. Unlike the US Interstate Highway System, for example, the federal government has never directly built or directly planned transmission on a national scale. Instead, a variety of actors have cobbled together the US grid piecemeal. In states that have resisted market liberalisation, particularly concentrated in the Southeast (Harrison & Welton, 2021), IOUs retain vertical monopolies over power generation, transmission, and distribution in their service territories. Some IPPs operating nationally, like the market leader NextEra, are deregulated spin-offs, and now parent companies, of IOUs – in NextEra's case Florida Power & Light. More traditional vertical monopoly structures also persist in US regions where federal public power remains a leading player, mostly New Deal legacies. These major public power regions include most of the Southwest and Pacific Northwest. In the latter service areas, the United States' four federal Power Marketing Administrations have played a central role in selling hydropower generated in federal dam projects, as well as some additional generation; they generally have owned and managed their own transmission infrastructures.

However, two thirds of the US power load lies in states that liberalised their electricity systems under pushes for market-based de/reregulation in the 1990s (FERC, 2023). In deregulated states, IOUs still build and own high-voltage transmission and distribution infrastructures as well as power plants, though were expected to formally separate generation and grid operations. However, they hand off actual running of their transmission systems to one of seven regional grid managers, which generally operate across multiple deregulated states. First, in 1996 FERC Orders 888 and 889 established a set of Independent System Operators (ISOs) to perform this regulatory function. In 1999, FERC Order 2000 added Regional Transmission Organisations (RTOs), some building upon existing power pool arrangements.

The United States' seven ISOs and RTOs work identically in most respects today. They are non-profit organisations run by independent boards of governors, not government regulators, though FERC creates overarching rules that govern them. They are not permitted to own any power infrastructure themselves, whether generation or grid assets. Instead, they obtain electricity from generators in their territories, dispatch this power, and coordinate its bulk flow through shared regional grids as needed to meet market demand and maintain reliability of the system. Furthermore, each runs the region's wholesale electricity market, in which IOUs, other generators and spot (or day-ahead) traders exchange power and other ancillary services. One such service is transmission congestion contracts, derivative products which allow buyers and sellers to hedge/speculate on future wholesale power prices. Wholesale electricity markets also often include the sale of system capacity itself, in capacity auctions which may be held every one to three years. Here entities enter bids to produce a specified amount of power at a relevant future date. Though these totals do not perfectly correspond to power actually produced, such advanced contracts help with ISOs/RTOs' forward planning, making sure enough power will be available to balance projected demand and reliability needs.

Supporting market liberalisation and new capital landing in the US electricity system has been central to ISOs' and RTOs' mandate. In ramping-up deregulation in the 1990s, that era's FERC and other liberalisation advocates feared that incumbent IOUs would otherwise use their ownership of transmission infrastructures to effectively block competing IPPs. Accordingly, they imposed rules such as requiring each IOU to provide competing power producers access to grids at service fees comparable to what it would charge itself. The creation of ISOs and RTOs was meant to provide another safeguard, as these operators were charged with maintaining open-access grids and fair electricity markets – a charge tainted quickly by the 2001 California Electricity Crisis, created by Enron and other power traders' manipulation of the region's newly deregulated wholesale electricity market.

Across much of the United States, ISOs and RTOs hold default responsibility for ensuring that renewable capital lands on the grid, alongside FERC in its market-enabling role. A recent major grid assessment by the DOE suggests that by 2035 the United States will need 20–128% more regional transmission capacity and 25–412% more inter-regional capacity (Howland, 2023). ISOs and RTOs are authorised to conduct grid planning and commission significant projects like new transmission lines and upgrades to meet future grid capacity and reliability needs, in theory working with IOUs to coordinate this collective investment. Where operators deem the construction of such transmission infrastructures to be of general benefit to IOUs in their service territory, they may charge each IOU a share of the project's costs commensurate with its specific expected benefits; IOUs in turn may recover such payments via cost of service rates (Peskoe, 2021).

However, deepening breakdowns in US grid capacity today, including the scope of the immediate needs indicated above, are exposing key weaknesses in this laissez-faire market arrangement. Peskoe (2021) and other recent industry and government research (e.g., Lieberman, 2021; Pfeifenberger et al., 2019; Rand et al., 2023) argue that in practice, ISOs/RTOs and IOUs are systematically under-investing in regional and inter-regional transmission infrastructure of the kind needed to open up grid capacity for renewables, as well as meet rising reliability challenges associated with climate change and other new strains like fast-rising demand from generative AI data centres. For many years, almost all existing transmission grid investment has remained local, often undertaken outside of regional planning processes. In this sense, 'local' means IOUs' investment to service their individual capacity and reliability needs, including repairs, upgrades and replacements of their existing transmission infrastructure – much aging, originally constructed in the 1960s–70s. As Bennett (2005) and Schmidt (2024) have explored, deregulated IOUs may be failing at even this basic maintenance investment. More ambitious regional backbone projects have accordingly been limited, and there have been almost no inter-regional projects to date.

In scrabbling together some of today's needed grid upgrades without more fundamental reforms to transmission planning, grid operators have recently forced new interconnecting projects to bear the brunt of associated costs – an active obstruction to renewables seeking to access the grid. A major outcry has arisen over FERC rules, particularly its Order 2003, which allow ISOs and RTOs to push upgrade costs onto the newest projects onto the grid – even though incumbent power generators and the grid in general will also benefit from improvements. Lieberman (2021), St. John (2021) and others suggest that this unjust cost burden was unlikely to have been FERC's original intention. St. John notes that these rules were less burdensome when the typical new projects being interconnected were natural gas plants more able to choose siting to minimise new grid upgrades needed. Renewable projects are in comparison smaller, more numerous, more rural and more remote, as they are generally located around wind, solar and other resource geographies rather than existing grids. This means more grid upgrades are needed to accommodate them. Meanwhile, smaller projects and developers will have less ability to pay associated costs, and new renewables risk becoming an exploitable source of funds for broader grid upgrade needs.

Such renewable projects, power and now energy storage (both standalone and hybrid, such as solar+storage projects) accounted for 80% of new projects applying for grid interconnection nationally in 2022 (Rand et al., 2023). Because these renewable sources made up the vast majority of new projects, they also bore the brunt of grid upgrade charges. Accordingly, fees that renewable project developers pay for grid interconnection rose sharply, climbing from approximately 10% of a projects' total costs in the late 2010s to 50–100% by the early 2020s; in total they can run into the hundreds of millions of dollars (St. John, 2021). These charges have significantly chilled renewable capital landing in the United States. According to Lieberman (2021, p. 11), '[t]he cost of network upgrades assigned to interconnecting generators has been a major factor contributing to projects withdrawing from the interconnection queues'.

The case of the PJM Interconnection, the United States' largest transmission grid operator, exemplifies some of the problems that new renewable projects face in entering grids and wholesale electricity markets. PJM's RTO service territory and wholesale electricity market now extend across thirteen states in the Mid-Atlantic region, with over 65 million customers (PJM, 2024a). Part of PJM's electricity market design is a mandatory capacity auction every year, again intended to secure the region's power capacity in advance, as well as set wholesale prices for this period. For example, in PJM's June 2022 capacity auction, the RTO spent $2.2 billion to buy 145,345 megawatts (MW) of supply for 2023–24 (PJM Inside Lines, 2022) (this power would normally have been secured three years out, but disputes with FERC delayed PJM's normal auction by two years).

In the 2010s, cheap natural gas sourced from Pennsylvania and neighbouring states in the fracking boom came to dominate PJM's wholesale market, as coal fell in the mix and nuclear remained a third major generation source. Though PJM reporting has emphasised recent growth of renewable sources in its fuel mix, Figure 1's numbers show that renewables are still vastly overwhelmed by fossil and nuclear sources in its capacity markets, especially natural gas (PJM, 2023). A similar trend appears when examining PJM's generation mix, which reflects actual production instead of the advance amount that capacity markets formally secure. In 2023, PJM's generation mix included approximately 42% gas, 34% nuclear, 15% coal and less than 10% combined wind, hydroelectric power and solar (PJM, 2024b).

Welton (2021) argues that RTOs' privatised governance has historically blocked renewable energy goals, particularly in that it has been dominated by and inherently biased toward industry incumbents, private energy companies which largely represent fossil fuel interests. Incumbent IOUs have important power to shape RTOs' rules for electricity markets and grid operation. In PJM's case, critics have called out the RTO's rules governing grid access (Howland, 2022). For example, PJM's minimum offer price rule (MOPR) sets a price floor for participation in capacity auctions. Ostensibly, the rule is intended to prevent utilities that buy more capacity than they sell from artificially lowering prices. In effect, it long froze out lower-cost renewable generation (Aagaard et al., 2022). PJM also sets rules related to reliability, establishing relative capacity values for different generation sources. Before Winter Storm Elliot exposed the fallacies of such assumptions, coal and natural gas were considered to have the ability to deliver 100% of their available capacity at all times. In contrast, due to their intermittency, renewables have been deemed to only have a portion of their full capacity available at any given time (S&P Global, 2024).

Renewables seeking entry to PJM's wholesale electricity market have also met more active resistance from fossil interests intervening at both regional and federal levels. After PJM loosened its MOPR price floor to exempt low-cost renewable energy facilities, these industry players

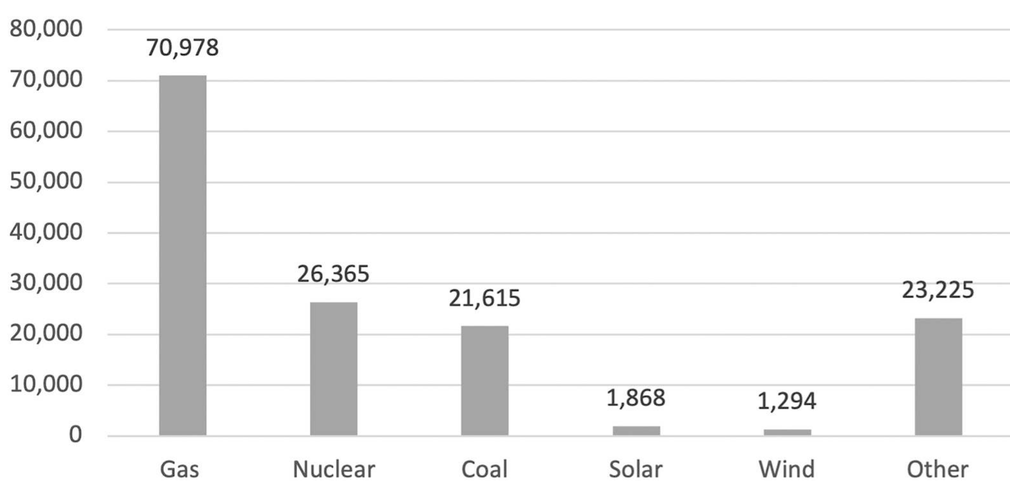

Figure 1. PJM capacity auction for 2023–24 (June 2022): Cleared capacity by fuel type in MW. Source: data from PJM (2023).

attempted to bar them in other ways. Particularly noteworthy for this paper's argument, they implored PJM's board to remove renewable generation from the supply stack in its 2023–24 capacity auction via appeals to insufficient transmission capacity to handle it (Howland, 2022).

At the federal level, an important consideration in understanding such US grid politics is that FERC's five commissioners are US Presidential political appointments. Though the makeup of the commission must remain bipartisan, changing administrations can make for appointees with sharply diverging attitudes toward renewables. Another recent controversy for PJM – the reason for the delay of its 2023–24 capacity auction – resulted from FERC's particular susceptibility to fossil industry interests during the 2017–2021 Trump Administration. The commission aligned with lobbying from fossil generators who sought to economically penalise renewable sources in PJM's capacity market. In addition to the barriers discussed above, it proposed an order that would raise the floor price of new resources at auction if they received any form of state subsidy. Fossil interests' argument was that these governmental supports would otherwise give renewable generators an unfair advantage.

Broader questions of the state's appropriate role in guiding and investing in renewable energy transition aside, such claims selectively ignore the United States' longstanding subsidies for fossil energy – a point made by a dissenting FERC commissioner in PJM's case, who called arguments for the rule 'just plain garbage' (Morehouse, 2020). PJM initially caved to FERC's directive, but was forced to reverse this decision amid widespread outcry, including sharp critiques from many states in its service area. States called out inconsistency with their own Renewable Portfolio Standards and decarbonisation targets; all much harder to meet if the regional grid remains locked into fossil sources. Some threatened to exit PJM entirely if the rule went through. While FERC under the Biden Administration resolved these PJM disputes in favour of renewable producers, it and other ISOs/RTOs face renewed uncertainty today.

Facing these multi-sided barriers, the problem of rapidly lengthening interconnection queues has become a major capital landing issue for US renewables, worsened in the early 2020s as expanded IRA subsidies encouraged a raft of new projects and interconnection applications. IOUs and ISOs/RTOs require that before projects can be approved to join the grid (or even begin construction), applying developers must pay their IOU or ISO/RTO to conduct a series of studies pre-researching grid upgrades that may be required to connect them. This is the information used to generate the costs and fees for developers noted above. According to recent Lawrence Berkeley National Lab research (Rand et al., 2023), by 2022 the United States had 1,350,000 MW of power waiting in interconnection queues nationally, and a further 680,000 MW of energy storage – over 10,000 projects. Only a tiny portion of that queued power was conventional generation: renewables and storage made up 95% of all energy waiting on the grid in 2022.

Furthermore, queue wait times continued to ramp up. The average project finished in 2022 spent more than five years waiting for interconnection approval. With waiting times stretching so long, some developers have applied speculatively to preserve the option to build, further increasing uncertainty about which projects will ultimately complete or be abandoned (Lieberman, 2021). One noteworthy point of contention and barrier for Tribal groups seeking to build renewables is that interconnection fees meant to discourage such speculative private investment have devolved to them – contrary to the spirit of IRA reforms like direct pay that aimed to diversify US renewables ownership. In November 2024, the Alliance for Tribal Clean Energy filed a petition with FERC to expedite a rulemaking that would exempt Tribal energy projects from these fees to enable their entry to the grid (Downing, 2024).

Again, PJM's exemplary experience shows what this waiting time can mean on the ground. Rand et al. (2023) calculate that PJM had 3042 energy projects waiting in interconnection queues in 2022, 298,000 MW overall. Virtually all of these projects were renewable generation or energy storage, with a small amount of natural gas. Projects' median time spent in PJM interconnection queues in the later 2010s and 2020s stretched considerably from the previous norm, again skyrocketing to over five years in 2022. These long waits had consequences. For interconnection requests made from 2000–2017, Rand et al. noted that only 27% of proposed projects in PJM ultimately reached completion; 16% of proposed capacity. The operator decided to refuse new projects altogether until at least 2025, while it worked through its backlog.

Meanwhile, PJM's July 2024 capacity auction clearing prices reached a record high, 10 times higher than the preceding auction, an outcome attributed to narrow supply-demand margins (Howland, 2024a). On top of PJM supply issues, the latter were also influenced by mounting regional power demand from data centres, an issue of fast-growing national concern amid skyrocketing energy usage for generative AI. To address its short supply, PJM introduced several options for queue reform to bring more generation online, one of which would develop a list of generators to receive an accelerated interconnection review (Howland, 2024b). This Reliability Resource Initiative has faced opposition from renewable energy developers, who contend that the proposed initiative may become a tool for fresh discrimination in favour of fossil and nuclear incumbents (Howland, 2024c).

5. DISCUSSION AND CONCLUSIONS: THE STATE'S ROLE IN AND BEYOND CAPITAL LANDING

A key argument of this intervention has been that amid rapid ramping up of renewable power transition in the United States and beyond, affordable and timely access to the grid must be considered as an important influence on whether capital successfully lands for new renewable generation projects. The US case discussed here presents particular difficulties due to the country's fragmented grids and legacy of laissez-faire planning. Capital landing bottlenecks caused by years of grid underinvestment and failures to plan became particularly acute in the early 2020s, paradoxically worsened by the increased generation-side support presented by the IRA. However, the United States is far from alone in its renewable grid challenges. Capital landing obstacles are propelling transmission difficulties and reform initiatives in the United Kingdom and European Union, with concerns arising even in China's better resourced and coordinated, but perhaps brittle grid (McDonnell, 2023).

One influential response to the transmission dilemmas discussed here is consistent with broader US pushes for market liberalisation. Pro-market advocates such as The Brattle Group (Pfeifenberger et al., 2019) argue that 'competitive transmission' can get needed lines built more quickly. They have promoted transmission as an area of capital landing in its own right, especially via the entry of new private investors as merchant developers and owners of transmission assets. Successive FERC rulings a decade ago made this liberalisation of transmission possible in theory. Notably, in 2011 FERC Order 1000 rolled back IOUs' assumed natural monopoly over regional and inter-regional transmission development and ownership. While IOUs retained Right of First Refusal to develop local transmission projects paid for entirely by their customers, FERC thus opened these bigger, chronically underinvested areas to new IPP-style competitors.

In the near term, Order 1000 failed to create a hoped-for wave of non-utility transmission investment (Pfeifenberger et al., 2019; Trabish, 2019). Between 2013 and 2017, only 3% of ISO/RTO transmission investments were made under competitive bidding processes (Pfeifenberger et al., 2019). Peskoe (2021) has argued that this lack of movement is in part due to legacy planning and state siting rules which still effectively blocked most proposed projects from open competition – though we suggest that more attention should also be paid to the high costs, long timelines and substantial risks of transmission development, which only some for-profit developers may be willing to take on. However, the US grid crisis of the 2020s, and the prospect of expanded Biden Administration subsidies to address it, awoke fresh corporate and financial sector interest (Wilson, 2022).

Rising merchant transmission developers in the United States have included major IPPs like NextEra but also a broader range of financial players such as Berkshire Hathaway, the Canada Pension Plan Investment Board and Blackstone. The last has attracted significant attention and critique for its New York State transmission projects, including a controversial proposed international interconnector to Canada (Ventrella & Knuth, 2024). In the international sphere, BloombergNEF (2023) has begun tracking power grid investment as a standalone category for capital landing (representing $274 billion in investment in 2022), as well as a key enabler for the broader transition. Nevertheless, US merchant developers have continued to face challenges in realising projects on the ground. One recent example is the high-profile cancellation of the Blackstone-backed Clean Path NY transmission contract in New York (French, 2024).

The Biden Administration attempted various reforms to the US interconnection crisis, the fate of which are uncertain following the 2024 Presidential election. For example, FERC opened up multiple major proceedings on transmission planning and procedural reform; its Order 2023 proposed significant reforms to interconnection queue issues and fees. Biden-era reforms did not stretch to reimagined federal public transmission development and ownership in the style of legacy Power Marketing Administrations, one Green New Deal proposal (e.g., Bozuwa et al., 2023). Instead, many of its programmes channelled public resources into derisking transmission investments for hoped-for private capital entry, a speculative strategy which also provokes important equity and distributional questions.

In the latter vein, the Biden Administration's Building a Better Grid Initiative, launched in 2022, represented a significant effort to accelerate buildout of regional and inter-regional transmission infrastructure. The initiative included more than $13 billion in grants for transmission projects, open to various types of developer (Grid Deployment Office, n.d.). For example, the administration's $2.5 billion Transmission Facilitation Program required the DOE to issue capacity contracts for major new lines. In committing to purchase a major share of new capacity, these contracts significantly derisked projects for developers. Initial funding recipients included IPPs and asset management capital (Grid Deployment Office, 2023). Notably too, the draft but not the final version of the IRA also included new federal tax credits for transmission infrastructure – a subsidy more like those long used by IPP developers of renewable generation. Its unused funds fed into some of other support discussed here (Lawson, 2024).

A growing body of literature has demonstrated the inherent misalignments of finance entering fixed capital and the role of the state in facilitating its entry. For example, Simpson (2019) describes how oil producers' attempts to manipulate the market for oil production and storage to increase profits result in system-wide inefficiencies. Scholars have also demonstrated similar challenges with the privatisation and financing of networked infrastructures like water, roads and the Internet (Loftus & McDonald, 2001; Ponder, 2017; Ranganathan, 2016; Torrance, 2008), asserting that these projects are intended to serve a public good rather than generate substantial private profits. Recent work by Birch and Ward (2024) has grouped these disparate examples under the framework of assetisation (also see Langley, 2021). Such processes have frequently relied on state derisking to improve the profitability of fixed capital projects without necessarily ensuring public benefit (Gabor, 2021). Similarly, in his work on housing finance, Gotham (2012) discusses the role of the state in contributing to crises such as the 2008 US housing crash, implementing compounding fixes that sacrificed societal outcomes like democracy and justice in favour of short-term market-based priorities.

Electricity transmission represents a relatively new and particularly challenging realm for finance, requiring investors to identify paths to profitability and forms of project derisking to enable such profits. The actual realisation of profitability is not necessarily occurring in merchant transmission. It is difficult to build, own and operate transmission lines profitably over the long term. Investing in these networked infrastructures means potentially crossing municipal, state and federal jurisdictions, confronting risks of blockage and project failure at any point along the line. This speculative frontier for merchant capital demands extraordinary amounts of derisking on top of the challenges of owning and operating profitable generation assets (Christophers, 2024) for merchant developers that endeavour to do both. Overall, the United States' market-based approach to renewables transition is demonstrating clear limits today as interconnection queues mount – limits felt not least by investors themselves as more projects are abandoned and capital fails to land.

The United States does have models of more directed transmission investment to get renewables on the grid. One private sector version lies in vertically integrated IOUs in the Southeast, which as noted previously have retained more control of their transmission infrastructure. For example, Florida Power & Light and Duke Energy (headquartered in North Carolina, though now with subsidiaries across multiple US states) have achieved relatively quick siting of major solar projects in their Florida and North Carolina service areas. In 2023, these states ranked third and fourth in the country, respectively, for growth in solar capacity (Climate Central, 2024). However, both utilities have also blocked renewables from the grid; for example, in Florida Power & Light's controversial efforts to deter the entry of rooftop solar in Florida (Klas & Ariza, 2021).

State-level governments have also experimented with more active grid investment to facilitate renewable capital landing. For example, from 2005 to 2014, the State of Texas' Competitive Renewable Energy Zones (CREZ) project built out advance transmission lines in areas with high wind potential – a key support for Texas' rise as a centre of onshore wind generation (Dorsey-Palmateer, 2020; Welton, 2024). In a recent multi-state example, ten Northeastern states signed a memorandum of understanding to collaboratively build inter-regional transmission for offshore wind, currently a major cost borne by private wind developers (Walton, 2024). Under Biden, a subset of these states was awarded \$389 million from the DOE's Grid Innovation Program for advance investments in interconnection points and battery storage (Massachusetts Government, 2024).

It is worth noting that the United States' biggest recent-historical success in bumping up transmission investment came from the federal government taking a more active role, in a wave of direct policy support under the Obama Administration. This boost especially came from federal stimulus funds under the Administration's 2009 American Reinvestment and Recovery Act, and was already justified by the need to ready the US grid for renewable energy transition. Similar to Biden-era programmes, some of this funding went to derisking private capital; for example, via matching grants for utilities to undertake smart grid upgrades. However, it also encompassed a drive to push Power Marketing Administrations to upgrade their transmission grids for renewables – a more direct public power lever to pull which also supported publicly owned generation.

Ultimately, taking the state's role in grid futures seriously demands thinking beyond initial capital landing and a narrow derisking role to systemic questions of grid planning, ownership, and maintenance into an uncertain future. To cite a narrow example, rising costs from climate-related disasters present new financial risks to grid owners. In Schmidt's (2024) discussion of Pacific Gas & Electric's culpability in the 2021 Camp Fire, which was sparked by undermaintained transmission lines, the author shows that IOUs have certain powers to legally transfer and socialise such climate-related financial risks – for now. This capacity will be tested as costs mount. More broadly, physical climate risks have added new fuel to public campaigns for non-wires solutions, for example as more frequent severe storms strike the Caribbean and rebuilding large-scale grids becomes an ever more expensive proposition (Cederlöf, 2023). This issue of waiting for the grid became particularly problematic in the case of Puerto Rico after Hurricane Maria, resulting in more than a year without power for some (Ponder, 2023).

Reimagining the state's role to encompass more holistic grid concerns may also produce more progressive and democratic answers. Compared to other networked infrastructures, the transmission grid poses distinct challenges for private takeover, as the integration of renewables requires significant technical planning and management to ensure that the electricity system remains operational. These shortcomings represent an opportunity to reconsider and reassert the role of the state in leading collective low-profit planning, or in building electricity infrastructure itself (Bozuwa et al., 2023; Welton, 2024). At a minimum, this may involve reclaiming system components that have proven clearly unsuitable for assetisation; ultimately, it may require comprehensive electricity system redevelopment. The grid's combined profitability challenges and mounting need for coordinated planning make it a site where transformative approaches, including the return of the state, could prove particularly effective.

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