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RESEARCH ARTICLE

The promise and perils of exclusion: using institutional design principles and the theory of clubs to analyse regional transmission organization governance

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Abstract

Organized, competitive wholesale power markets emerged in the U.S. during the 1990s, driven by technological change and regulatory restructuring. Regional Transmission Organizations (RTOs) manage these markets while governing a congestible transmission network whose physical coupling creates ill-defined property rights and persistent coordination problems. The growth of new generations, storage, and digital technologies further strains RTO governance by increasing heterogeneity in participants and business models. Integrating Elinor Ostrom's common-pool resource (CPR) framework with James Buchanan's theory of clubs, this paper analyses how RTOs govern reliability through rule-defined exclusion. The analysis argues that reliability is a CPR, but that RTOs formalize a scalable, club-like exclusion regime as a governance institution. Because transmission systems are non-replicable, governance institutions and polycentric oversight must substitute for competitive discipline. Institutional reforms that make boundary rules adaptive and participation more inclusive are essential to preserve reliability while enabling innovation and long-run efficiency.

Keywords: clubs; electricity; governance; innovation; institutions; regulation; technology

Introduction

Many settings in which governance affects performance involve networked resources. These network environments often feature shared and congestible systems with ill-defined or incomplete property rights, where individual actions impose external costs on others through the network itself. Governance institutions – and the organizational forms through which they operate – enable coordination among diverse users, but tension arises when the technological, economic, or policy environment evolves in ways that strain existing rules and demand institutional change. Institutions typically evolve more slowly than technology, especially during periods of rapid technological advance (Kiesling, 2024). This mismatch, often described as the pacing problem (Hagemann et al., 2018), can delay or prevent the realization of the economic and social gains that innovation could otherwise deliver.

The U.S. electricity sector illustrates this institutional–technical tension in a particularly clear form. Regulatory restructuring and technological change in the 1990s contributed to the emergence of competitive wholesale power markets and the creation of Regional Transmission Organizations (RTOs). As independent, non-governmental, non-profit entities, RTOs coordinate the operation of high-voltage transmission networks and administer wholesale electricity markets within defined geographic boundaries. Their dual mandate – maintaining reliability while facilitating competitive markets – has delivered substantial consumer and producer benefits and has supported the integration of lower-carbon resources (Kiesling et al., 2024; Park and Kaffine, 2025). Yet RTO governance remains contested and complex, and its responsiveness to emerging technologies and shifting policy priorities has become a central issue in both practice and the academic literature (Johnson et al., 2023; Lenhart and Fox, 2022; Welton, 2021).

This paper analyses how RTO governance navigates the evolving tension between maintaining system reliability and enabling innovation. Over the past decade, RTOs have faced pressures driven by two intertwined forces: policy objectives that increasingly emphasize resilience and decarbonization, and technological advances that include distributed energy resources (DERs), variable renewable energy (VRE), battery storage, and digitalization. These developments diverge sharply from the centralized, fossil-based technological assumptions that shaped the early RTO market and governance templates. The result has been intensifying conflict over market design, interconnection and planning processes, and the governance procedures through which RTO rules are revised (Johnson et al., 2023; Klass et al., 2022; Lenhart and Fox, 2022; Peskoe, 2021, 2023; Welton, 2021; Yoo and Blumsack, 2018a, 2018b). As Johnson et al. (2023) emphasize, RTO stakeholder processes are increasingly strained by the growth of policy-driven objectives, the proliferation of narrow and heterogeneous stakeholder interests, and internal organizational responses that complicate efforts to maintain independence and manage controversy.

The mechanism at the centre of this paper's analysis is exclusion. In this paper, exclusion refers to the bundle of rule-defined participation rights and obligations that governs access to a congestible network and to the market platform built on top of it. Exclusion is necessary in transmission governance because the underlying physical system is a synchronized alternating current (AC) network where injections and withdrawals affect flows throughout the grid and where reliability is congestible under stress. In such a setting, access must be defined through rule-based participation rights and obligations rather than through fully specified property rights. Yet exclusion is also a primary channel through which institutional inertia can suppress entry and slow adaptation. Rules that condition market participation, assign performance obligations, and allocate costs can preserve reliability and market integrity, but they can also raise the fixed costs of participation and entrench legacy technologies and organizational forms, particularly when innovation expands the set of feasible participants and services. The pacing problem in RTOs, therefore, often appears not as an abstract lag between 'technology' and 'regulation', but as a concrete misalignment between evolving technological capabilities and the rule-defined boundaries of participation.

To analyse this issue systematically, this paper integrates Elinor Ostrom's institutional design principles with James Buchanan's theory of clubs. Transmission reliability exhibits key characteristics of a common-pool resource (CPR): it is difficult to exclude users at the level of physical flows, yet it is rivalrous under congestion and reliability stress. RTO market platforms, by contrast, are club-like institutional arrangements: they are governed through membership and participation rules, and they bundle shared services – dispatch, settlement, and market coordination – under a common set of obligations. In this paper, exclusion refers to the bundle of rule-defined participation rights and obligations that governs access to the congestible network and to the market platform built on top of it. Ostrom's design principles provide a way to characterize how those rule systems operate – through boundaries, proportionality, monitoring, sanctions, and nested governance – while Buchanan's framework highlights the logic of optimal exclusion and the trade-off between congestion control and the benefits of entry and contestability.

The analysis departs from canonical club theory in one crucial respect that is central to the paper's institutional contribution: the replicability condition that disciplines clubs through exit and competitive entry is constrained away from holding in transmission systems. High fixed costs, network effects, and siting and permitting constraints make replicating the transmission 'club' generally infeasible. In Buchanan's setting, dissatisfied users can form new, identical clubs; in transmission governance, that option is rarely meaningful. As a result, the governance institutions that define exclusion – and the polycentric institutional environment in which they are embedded – must supply much of the discipline that competition among clubs would otherwise provide. This shift elevates the importance of constitutional and organizational design under non-replicability and sharpens the exclusion–innovation trade-off: the same

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rules that make a reliability commons governable can harden into procedural barriers that limit the primary margin of dynamic adaptation, entry by new technologies and business models.

As an institutional analysis, this paper presents a case study in the institutional tension between the benefits of exclusion and the benefits of innovation (Skarbek, 2020). The case of RTO governance illustrates how governance institutions (and institutional choices) can affect whether or how a CPR can be managed as a club good. This institutional analysis also shares common themes with Kuran (2011), who argued that the Middle East fell behind Europe in the 17th century because persistent legal-institutional features of classical Islamic law that once fostered commerce (such as the waqf) eventually impeded economic growth. Only under nineteenth-century Western pressure did Middle Eastern states transplant corporate and commercial codes, by which time the gap had become large. Kuran thus framed divergence as a pacing problem between legal institutions and economic innovation, not an intrinsic aversion to commerce.

This paper makes three original contributions to institutional economics. First, it extends club theory to a non-replicable infrastructure setting, shifting attention from static club-size optimization towards governance design when replication and exit provide limited discipline. Second, it operationalizes exclusion as a layered institutional technology – participation criteria, performance obligations, monitoring and sanctions, and cost responsibility – that shapes entry, minimum efficient scale, and innovation incentives in network industries. Third, it develops polycentricity as an explanatory mechanism that complements public choice accounts by showing how vertically and horizontally distributed authority creates both opportunities for experimentation and multiple veto points that raise the transaction costs of institutional adaptation. These contributions are generalizable beyond electricity, while the RTO case provides unusually clear stakes and observability because reliability is a real-time constraint and because rule changes are formalized through tariffs and stakeholder processes.

Section *Institutional theory: governance and clubs* presents the institutional theory employed in this analysis, defining grid reliability as a CPR, introducing Ostrom's design principles, and summarizing Buchanan's theory of clubs. Section *Regional transmission organization origins and governance* introduces RTOs, detailing their emergence, governance functions, and the technological and policy pressures reshaping their institutional landscape. Section *RTOs as clubs and governance organizations* applies the framework to analyse RTOs as club-like institutions governing CPR reliability and shows how technological change stresses the exclusion regime. Section *Conclusion* synthesizes key findings and identifies avenues for further research.

Institutional theory: governance and clubs

To analyse the challenges that RTOs face in balancing participation, innovation, and governance, I integrate Ostrom's CPR design principles with Buchanan's theory of clubs. This framework provides insight into how RTOs govern transmission reliability as a CPR, with governance turning reliability into a club good.

This analysis follows a logical progression: transmission reliability as a CPR (Section *Reliability as a common-pool resource*) requires governance for sustainable provision, which leads to Ostrom's CPR principles (Section *Ostrom's design principles*). Buchanan's theory of clubs complements those design principles (Section *Theory of clubs*) to create a fuller theoretical framework for analysing RTOs as clubs implementing governance institutions to provide the CPR of reliability (Section *RTOs as clubs and governance organizations*).

Reliability as a common-pool resource

Transmission grid reliability is best understood as a CPR rather than a pure public good, due to its physical and economic characteristics.[1] Unlike a public good – non-excludable and non-rival – a CPR is non-excludable but rivalrous: congestion diminishes availability for others.

[1]This analysis pertains only to transmission reliability and draws on Kiesling, 2009, Chapter 8.

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CPR dilemmas fall into two types: appropriation and timing/spacing. In appropriation, users deplete a finite stock (e.g., fisheries (Gordon, 1954), oil fields (Libecap and Wiggins, 1985; Wiggins and Libecap, 1985)). In timing/spacing dilemmas, value depends on coordinated use; uncoordinated actions impose congestion or interference costs. Examples include radio spectrum (Coase, 1959), irrigation (Ostrom, 1992), and electric grids (Blomkvist and Larsson, 2013).

The electric grid is non-excludable, since connected users cannot easily be denied access, and rivalrous, since finite capacity makes it congestible. In an AC grid, Kirchhoff's Laws and Ohm's Law mean that electricity flows along all available paths, preventing allocation through contracts alone. Translating from physics to economics, power flow in an AC system necessarily has ill-defined property rights.

This environment of ill-defined property rights creates three governance challenges: shared vulnerability to congestion, non-excludability, and the need for collective management. RTOs address these challenges institutionally, through reliability standards, loop flow management, and congestion mitigation.[2]

Reliability may appear public good-like under normal conditions; benefits are non-rival when the grid is stable. But under congestion, it becomes rivalrous: increased use constrains others' access, revealing its CPR nature. The classification also depends on perspective. For RTO participants – transmission owners, generators, buyers – reliability is rival and interdependent. For end users, it resembles a public good, especially when grid stability is ensured through centralized coordination or private backup systems.[3]

Viewing reliability as a CPR offers a more realistic governance framework than treating it as a pure public good. It highlights the externalities participants impose on each other and supports mechanisms to internalize them, such as transmission rights, capacity limits, and enforcement. RTOs function as self-organized institutions that govern access, coordinate investment, and preserve reliability in an increasingly complex and decentralized grid.

Ostrom's design principles

Elinor Ostrom's work on CPR governance highlights the importance of user-developed rules to mitigate the risk of resource depletion (or in this context, degraded reliability due to a lack of coordination).[4] Ostrom found that voluntary, self-organized institutions can govern CPRs effectively if they establish:

1. *Clearly-defined boundaries:* Participants know what constitutes the resource system and who is part of the resource system, and access is controlled.
2. *Proportional equivalence between benefits and costs.* Rules should ensure that those who benefit from resource use bear the costs or responsibilities commensurate with those benefits.
3. *Collective choice arrangements:* Stakeholders directly participate in rulemaking that governs the resource.
4. *Monitoring*: Users and/or third parties monitor one another's behaviour.
5. *Graduated sanctions:* Rule violations incur penalties calibrated to the seriousness of the offense.
6. *Conflict-resolution mechanisms:* Accessible dispute-resolution processes manage conflicts
7. *Minimal recognition of rights:* Government or other external authorities recognize the legitimacy of user-developed institutions.
8. *Nested enterprises:* Multiple layers of governance structures build upon smaller units of local governance as appropriate to handle complexity. (Ostrom, 2005: 259)

[2]Loop flow is a consequence of the physics of alternating current. It occurs when a current flow follows an unintended detour in the grid due to congestion, and can challenge grid stability and market efficiency.

[3]For a related analysis that reaches different conclusions, see Joseph (2022), who argues that resource adequacy is a public good. The analysis presented here focuses on short-run reliability, distinct from long-run resource adequacy planning.

[4]Ostrom's work using this framework is extensive; see, for example, her seminal work *Governing the Commons* (Ostrom, 1990), her later book *Understanding Institutional Diversity* (Ostrom, 2005), and her Nobel Prize address (Ostrom, 2010).

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A key dimension of Ostrom's framework is polycentric governance, where multiple decision-making centres operate autonomously yet interact at different levels – local, regional, and national. This structure emerges in complex resource systems where diverse stakeholders coordinate across overlapping jurisdictions. The concept originated in Vincent Ostrom's work with Tiebout and Warren (Ostrom et al., 1961) and was further developed by Elinor Ostrom (Ostrom, 2005, Chapter 9). RTO governance reflects both external and internal polycentricity (to be analysed in Section *Polycentricity in RTO governance*).

For the transmission grid, these principles are embodied in rules for allocating scarce transmission capacity, ensuring real-time operational coordination for balancing supply and demand, managing congestion, procuring ancillary services, and assigning the costs of maintaining and enhancing reliability services. These rules are implemented through the RTO's governance structure, which is typically approved by the Federal Energy Regulatory Commission (FERC). The RTO becomes the institutional 'hub' that integrates Ostrom's CPR principles into operational practice by setting detailed membership and market participation requirements and credit policies, establishing sophisticated real-time monitoring of system flows and market operations, applying a schedule of sanctions for non-compliance with reliability standards or market rules, and managing conflicts among diverse members through established dispute resolution procedures.

Theory of clubs

Buchanan's theory of clubs (Buchanan, 1965) fills a gap in neoclassical public goods theory by addressing goods that fall between purely private and purely public. He defined clubs as groups that jointly consume goods or services, where costs vary with membership size. Unlike Samuelson's model of pure public goods – with theoretically infinite optimal group size (Samuelson, 1954) – Buchanan focused on identifying the optimal size that balances marginal costs and benefits.

In Buchanan's formal setup, an individual's utility depends on the consumption of a private numeraire good and on access to a shared facility whose service quality declines with congestion as membership rises. Let utility for a representative member be $U(x, s(N))$, where x is private consumption and $s(N)$ is the service flow from the club good. $s(N)$ is decreasing in membership N because crowding reduces each member's enjoyment. Providing the facility entails a cost $C(N)$, which can include fixed costs and member-dependent operating costs, and these costs are shared among members through dues or a fee schedule. The club's problem is to choose membership N (and implicitly the fee and facility scale) to maximize representative net benefit, trading off the marginal gain from spreading fixed costs over more members against the marginal congestion cost imposed by an additional member. The optimal club size N^* occurs where the marginal benefit of adding a member (lower per-member cost or expanded provision) equals the marginal congestion damage, yielding Buchanan's condition that the marginal rate of substitution in consumption equals the marginal rate of transformation in production for the club good.

This framework launched a broad literature (e.g., Anderson et al., 2004; Cornes and Sandler, 1986; Marciano, 2021; Sandler and Tschirhart, 1980, 1997; Sandler, 2013) that refines our understanding of collective consumption and partial publicness. Club goods are partially excludable and rivalrous, and the optimal club size arises when the marginal rate of substitution in consumption equals that in production (Buchanan, 1965: 5). The literature explores how these properties shape provision, pricing, and incentives to join or form clubs.

Club theory has clear policy relevance where governments provide goods that could be managed more efficiently by voluntary groups, such as parks, highways, and other local public goods. It is especially applicable to goods with partial publicness, where sharing arrangements fall between purely private and purely public provision.

At its core, club theory is a theory of optimal exclusion. As Buchanan observed, few goods are inherently non-excludable due to physical constraints alone (Buchanan, 1965: 13–14). Where exclusion is feasible, flexible property rights and enforcement mechanisms (e.g., prosecuting poachers in a hunting preserve) can reduce free riding and facilitate voluntary cooperation.

Buchanan's model assumes replicability: any excluded individual can, in principle, form a new, identical club. This capability ensures competitive entry and prevents durable market power. When the population is an integer multiple of the optimal club size N^*, society naturally partitions into equal-sized clubs. Each club sets entry fees precisely high enough to cover operating costs, eliminating durable market power since dissatisfied members can always establish a new club. Buchanan thus characterizes this approach explicitly as a 'theory of optimal exclusion' suited specifically for goods where physical exclusion is practical.

However, this assumption breaks down in the context of electric power grids. The physical and economic characteristics of transmission networks make replication infeasible. Yet this lack of replicability does not invalidate club theory's relevance for RTOs. Instead, it reshapes how exclusion operates, a topic explored further in Section RTOs as clubs.

Regional transmission organization origins and governance

RTOs are unusual organizations, grounded in a history of bilateral agreements between utilities to provide emergency backup generation. This history has shaped their creation, their functions, and their complicated governance, establishing strong institutional path dependence. Understanding their current role and the challenges they face requires an examination of their origins and the evolving economic and technological landscape in which they operate.

Emergence and core function of RTOs

The evolution of RTOs and wholesale power markets traces back to early inter-utility agreements for interconnection and emergency backup, beginning in the late 1920s (Neufeld, 2019). Investor-owned utilities formed power pools to coordinate bulk power operations, centralizing dispatch (the decision of when to use which generators), spinning reserves, emergency power supply, and maintenance scheduling. These arrangements improved generation efficiency through economies of scale, enhanced reliability, reduced energy prices, and provided resource adequacy while lowering environmental costs (Cramer and Tschirhart, 1980: 217–218). The first power pool, the Pennsylvania-New Jersey-Maryland Interconnection (PJM), was established in 1927, and additional power pools emerged after World War II that later evolved into today's RTOs (Cramer and Tschirhart, 1980: 216).[5]

The turbulent energy environment of the 1970s set the stage for power pools to evolve into competitive wholesale markets. The U.S. electricity industry embarked on a significant transformation in the late 20th century, moving from a structure dominated by vertically integrated utility monopolies towards the establishment of competitive wholesale power markets (Borenstein and Bushnell, 2015). Several factors propelled this shift, including the aim for increased economic efficiency and enabling federal policy changes, such as the Public Utility Regulatory Policies Act of 1978 (PURPA) and the Energy Policy Act of 1992 (EPAct). PURPA unintentionally stimulated competition by requiring utilities to purchase power from independent qualifying facilities, while EPAct reduced barriers to wholesale competition by allowing non-utility wholesale generators (Hirsh, 1999). Technological advancements, particularly in combined-cycle gas turbine technology, also played a crucial role by making smaller-scale generation economically viable and challenging the natural monopoly model (Joskow, 2008).

[5] Two RTOs, ERCOT (1970) and CAISO (1997), were established by state statute, although ERCOT is also based on pre-existing 'tight power pools' with central dispatch (Cramer and Tschirhart, 1983: 32). Federal Power Commission (1970), Appendix C, provides a discussion of the range of different organizations that emerged to coordinate within and across power pools.

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In the 1990s, independent power producers gained greater access to expanding wholesale markets, while regulated utilities were required to maintain operational and financial separation from their unregulated affiliates.[6] EPAct promoted *wholesale* competition, leaving retail restructuring to the states. Fifteen states and the District of Columbia enacted legislation requiring utilities to divest generation assets and support retail competition.[7] Some states retained regulated monopolies in transmission and distribution while introducing competition in generation; others adopted full retail choice. Restructuring, however, faced significant challenges, including market manipulation, price volatility, and weak regulatory oversight. The California electricity crisis of 2000–2001 revealed the dangers of poor market design and market power abuse (Joskow, 2008; Wolak, 2005).

At the core of successful competition was non-discriminatory transmission access, which was difficult to achieve when incumbent utilities continued to operate most transmission assets. These conflicts of interest spurred the formation of RTOs, which aimed to separate transmission operations from generation ownership and ensure open access for all market participants. This move marked a structural shift from vertically integrated monopolies towards regionally coordinated, market-based oversight (Joskow, 2005: 106).

RTOs emerged as independent entities with two core responsibilities: maintaining transmission reliability and operating wholesale power markets. The FERC regulates most RTOs to ensure transmission rates and market outcomes remain 'just and reasonable'.[8] The original intent of both RTO organizers and FERC was for RTOs to manage the regional grid independently and impartially, a critical function underpinning all market activity (Joskow, 2005: 103–104), although that independent impartiality is not always realized in practice (Peskoe, 2023). FERC Order 888 (1996) laid the foundation for open access by mandating functional unbundling and non-discriminatory transmission tariffs (Lenhart and Fox, 2022, Table 1).

Alongside reliability, RTOs administer competitive wholesale markets, including day-ahead and real-time energy markets and ancillary services. Participation is governed by defined rules and protocols. FERC Order 2000 (1999) encouraged voluntary RTO formation and outlined features such as independence from market participants and operational control over transmission.

An important link between reliability and market efficiency is security-constrained economic dispatch (SCED), which uses uniform-price auctions to optimize generation dispatch while maintaining system security. This auction mechanism promotes truthful bidding and efficient outcomes.

Transforming legacy power pools into RTOs required significant changes to organizational structure and oversight, guided by FERC Order 2000. Existing coordination efforts helped ease the transition but also created institutional path dependencies that continue to shape RTO governance. By formalizing both market operations and grid management, RTOs have enabled competitive wholesale markets while preserving reliability.

Since the mid-1990s, RTOs and ISOs have expanded and evolved. Figure 1 shows their geographic boundaries as of 2022. PJM, MISO, and SPP span partial-state territories due to differing utility participation. PJM and MISO expanded as additional utilities joined.[9] SPP's members remain vertically integrated and state-regulated, while MISO includes restructured states like Illinois and Michigan. The other ISOs are composed of utilities in restructured states.[10]

[6]The extent of functional unbundling is still debated (Kovvali and Macey, 2022).

[7]Five states later repealed restructuring: Arizona, Arkansas, Montana, Nevada, and Virginia.

[8]PJM is a limited liability company; others are non-profit corporations. ERCOT operates independently of FERC jurisdiction.

[9]For example, Entergy joined MISO following a DOJ investigation (Kovvali and Macey, 2023; Reuters, 2013).

[10]California halted retail competition after the 2000–2001 crisis but retained generation divestiture and CAISO markets. MISO-member Michigan limits retail choice but required divestiture. PJM includes West Virginia and parts of Kentucky, which retain vertical integration; Virginia rescinded restructuring in 2007 but kept divestiture. In New England, Vermont participates in ISO New England's wholesale power markets but retains a vertically-integrated utility structure.

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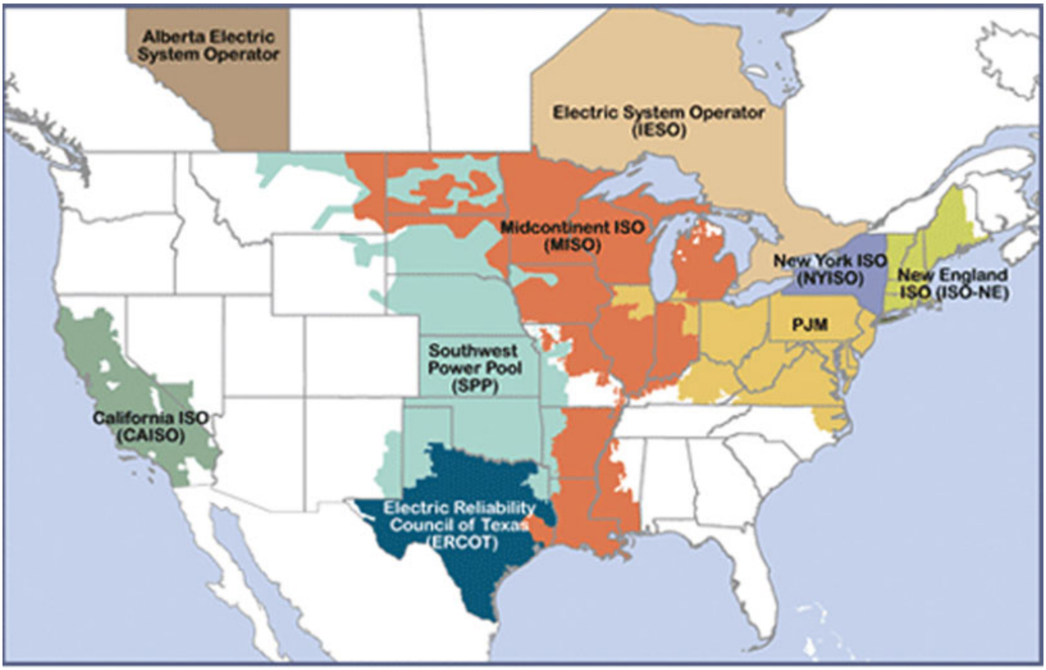

Figure 1. ISO/RTO territories in the United States, 2022 (Federal Energy Regulatory Commission, 2020).

Each RTO developed governance structures defining membership, voting rights, and stakeholder participation, governance structures that have some common features across the seven RTOs in the US but also reflect regional variations in economic activity, fuel portfolios, geography, and climate. These institutions were designed for independence, transparency, and representation, but now face pressure from accelerating technological change.

The challenge of a shifting landscape: the pacing problem

The evolution of the electricity industry reveals a dynamic interplay between technological innovation and regulatory adaptation. The context that gave rise to RTOs in the 1990s has shifted dramatically in the 21st century, creating a 'pacing problem' in which institutional change struggles to keep up with rapid technological and policy developments (Hagemann et al. 2018; Kiesling, 2024). RTOs emerged during a period shaped by centralized, fossil-fuelled generation, and their design reflects that era's technological and policy assumptions.

Today's power systems look markedly different. The rise of variable renewable resources, such as wind and solar PV, has introduced significant supply-side variability and reshaped market dynamics. These technologies, with near-zero marginal costs, alter price formation and dispatch. Wind capacity in the U.S. grew from 2.4 GW in 2000 to over 150 GW by April 2024 – a 62-fold increase – driven by technological progress, declining costs, and policy support (U.S. Energy Information Administration, 2024). Solar power followed, with nearly 50 GW installed in 2024 alone, up 21% from 2023, and continued growth projected in 2025 and 2026 (U.S. Energy Information Administration, 2025a). Large-scale storage, crucial for resilience and for integrating renewables, reached 62 GW in 2024 and is expected to expand by nearly 20 GW in 2025 (U.S. Energy Information Administration, 2025b).

At the distribution level, DERs are proliferating. Rooftop solar PV installations grew 11% annually between 2010 and 2020, reaching 2.7 million by 2022, especially in states with favourable climates and policies (Solar Energy Industries Association, 2023). U.S. EV sales rose from 115,000 in 2014 to over 755,000 in 2022, supported by battery improvements (International Energy Agency, 2023). Meanwhile,

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battery storage – both grid-scale and behind-the-metre – has expanded system flexibility and enabled greater resilience and renewable integration.

These decentralized resources reflect a shift away from centralized generation. Their aggregation for wholesale market participation raises new challenges in coordination, visibility, and data management. Advanced sensors, automation, and analytics offer tools for managing this complexity, but realizing their value often requires changes to market rules and data-sharing protocols. FERC Order 2222 (2020) mandates RTOs to create pathways for DERs to participate in wholesale markets, but implementation remains slow and uneven (Walton, 2023).

These technological shifts undermine the economies of scale that once justified vertically-integrated monopolies and expose frictions in legacy governance institutions, particularly in the misalignment of market participation rules. Decentralized, modular resources with distinct cost and operational profiles do not fit neatly into existing interconnection, market participation, and cost allocation frameworks; they strain legacy governance institutions.

Policy goals have also evolved. Reliability and affordability remain core concerns, but decarbonization and resilience have become prominent policy drivers. Federal and state initiatives, such as renewable portfolio standards, tax incentives, and emissions reduction targets, are accelerating the deployment of clean energy (Barbose, 2019). At the same time, resilience – a system's capacity to endure and recover from disruptions – is now a key focus amid rising risks from extreme weather, wildfires, and other threats. Together, these shifting priorities place new demands on RTO planning, operations, and governance.

The resulting strain on RTO governance

The convergence of rapid technological change and evolving policy goals is straining RTO governance structures, market rules, and operational practices – many of which were designed for a centralized, fossil-fuelled system. This mismatch creates a pacing problem, in which deliberative, stakeholder-driven institutions struggle to adapt complex rule sets at the speed of external change.

Technologies like DERs, utility-scale renewables, and storage challenge legacy governance by introducing variable, decentralized resources that do not align with conventional interconnection processes or resource adequacy metrics. Maintaining reliability under these conditions often requires new protocols for integration, monitoring, and dispatch – protocols that lag the pace of technological change. Lenhart and Fox (2022) showed how stakeholder processes are strained by these shifts, while Johnson et al. (2023) highlighted how diverging state policies within RTO footprints amplify institutional stress. This widening gap between clean-energy mandates and outdated governance models underscores the need for institutional reform to ensure system reliability and market efficiency.

Lenhart and Fox (2022) argued further that greater transparency and public-interest accountability would better serve the growing diversity of stakeholders – DER owners, consumers, and environmental groups – now shaping electricity policy agendas. Johnson et al. (2023) emphasized how expanding stakeholder participation and complex policy contexts strain consensus-based decision-making. Welton (2021) critiqued legacy, industry-dominated governance structures for lacking public accountability, potentially distorting decisions around renewable integration. Collectively, these studies reveal how legacy frameworks are increasingly misaligned with the demands of a more diverse, decentralized, and policy-driven electricity system.

These pressures manifest in rising stakeholder complexity, administrative burdens, and accountability challenges. Governance structures built in the 1990s assumed centralized base-load generation and minimal DER presence. Today's policy landscape emphasizes distributed systems, demanding major reforms in interconnection, adequacy metrics, and cost allocation. The dual mandate of reliable operations and efficient markets is being tested by the volume and diversity of new market participants enabled by technology and motivated by policy.

One of the clearest indicators of this strain is the interconnection queue. All RTOs maintain queues to track generation and storage projects seeking grid access. Because interconnection involves extensive

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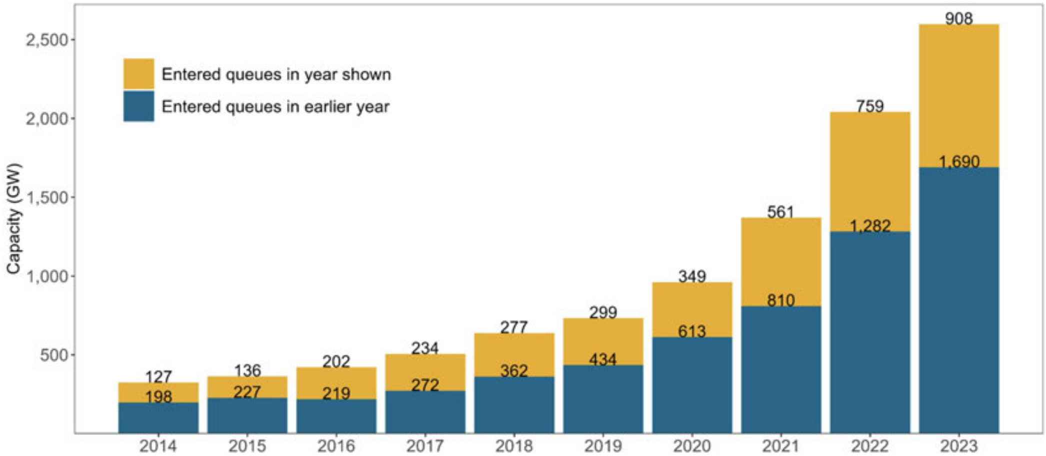

Figure 2. Active U.S. Interconnection queue capacity, 2014–2023 (Rand et al., 2024).

technical and economic studies to preserve grid reliability, the process can be slow and costly. With a surge in renewable and storage proposals, queues have grown dramatically – totalling 2,600 GW of capacity in 2024, more than twice the current U.S. generation fleet, as seen in Figure 2. Many of these requests are speculative, and aligning requests with realistic demand growth has become a complex exercise in managing uncertainty. Since 2014, new capacity entering queues has increased annually, with solar, wind, and storage now comprising 95% of requests. Projects often spend 14 to 43 months in the queue, and mean development timelines are nearing five years (Rand et al., 2024).

FERC and RTOs recognize these governance challenges, but institutional reform in such complex systems is inherently slow. The growing mismatch between emerging technologies, policy drivers, and existing institutions points to an urgent need for reform in governance, market design, and grid operations – reform that can support decentralization while preserving core goals of reliability, cost recovery, and sustainability.

This challenge sets the stage for analysing RTO governance through the institutional lenses of Ostrom and Buchanan, with particular attention to the role of exclusion and its implications for adapting to innovation and a changing electricity system.

RTOs as clubs and governance organizations

Understanding what kind of organizations RTOs are and how well their governance institutions and market designs accommodate technology shocks requires a historical, evolutionary perspective. While RTOs are expected to be technology-neutral, their participation rules, agenda-setting processes, and initial governance structures emerged in a technology-contingent context – the regulatory restructuring of the mid-1990s and the increased investment in gas-fired generation.

RTOs are complex organizations because they perform multiple interdependent tasks that must align to fulfil their core mission. This complexity is compounded by technological contingencies, raising the question of whether RTOs function as complex adaptive systems capable of responding to uncertain and evolving conditions, particularly those driven by technological change.

RTOs as clubs

Club theory offers a valuable framework for understanding how RTOs govern the congestible CPR of transmission reliability by layering structured membership and exclusion. Historically rooted in power pools, the first 'reliability clubs', RTOs transform grid access from a CPR into a club good by setting

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tariffs, interconnection standards, and participation rules. Transmission and market services are non-rival until congestion arises, but are rendered excludable by rules: only entities that meet technical, financial, and operational criteria may participate. This transformation mitigates free riding and manages reliability risks (Welton, 2021).

At the heart of this governance model is a tension between physical reality and institutional discretion. AC power flows follow Kirchhoff's and Ohm's laws: electrons do not obey contracts, and every injection or withdrawal affects the entire network. These physics make reliability non-excludable in practice much of the time but rivalrous under stress.[11]

This observation implies a narrower and more precise institutional claim than the shorthand 'RTOs turn reliability from a CPR into a club good'. The reliability commons exists in both RTO and non-RTO regions; what differs is the governance technology used to manage it and to define who may use the system and under what obligations. In traditionally regulated, non-RTO regions, vertically integrated utilities largely 'govern the commons' through internal hierarchy, backed by state regulation: the same organization plans and operates generation and transmission within its territory, bears residual balancing responsibility, and relies on relatively limited, often bilateral interchange and emergency support arrangements at the seams with other transmission systems. In RTO regions, open-access transmission and market restructuring expand the number and heterogeneity of actors interacting through the network, and those interactions become routine rather than exceptional. That shift increases the need for multilateral rules that specify participation conditions, performance obligations, and cost responsibility.

From this perspective, RTOs do not make electrons excludable. Instead, they formalize and scale exclusion in the institutional sense by bundling access to centralized dispatch, standardized market participation, and settlement systems with enforceable reliability obligations. These rule systems function as a club-like governance regime that allows a larger membership to share a congestible network while limiting free riding and managing congestion and reliability risk.[12]

RTOs impose legal and economic order onto this system. While they cannot change the physics, they apply excludability strategically – not to the physical flow of power, but to market access, risk management, and governance. FERC's open-access transmission tariff requirements ensure non-discriminatory physical access. Participation rights like scheduling, hedging, and governance are reserved for members and market participants who meet credit, telemetry, and performance standards.[13] Congestion pricing captures rivalry by assigning marginal costs at the point of transaction. Reliability standards, however, remain universally binding.

Yet exclusion carries risks. Membership rules designed for large, centralized generators can turn RTOs into gated communities, deterring participation by DER aggregators, storage, and flexible demand. These actors still affect system conditions as market participants but lack equivalent access to decision-making. The policy challenge is to lower unnecessary barriers, such as scale-insensitive collateral or telemetry requirements, while maintaining the institutional mechanisms that support shared infrastructure.

[11]This physical reality holds in power systems that are not part of an RTO, which have always had to manage reliability. In this sense, transmission grids have always been some form of a club, and the diversity in the industry is different types of institutional designs used for exclusion.

[12]In what follows, the analysis treats these participation and obligation rules as the practical mechanism through which exclusion is implemented in RTOs, without offering a comprehensive typology of operational, market-participation, and governance-participation exclusion.

[13]The distinction between members and market participants is important. Members of a Regional Transmission Organization (RTO) typically belong to specific 'sectors' (e.g., transmission owners, generators, consumer organizations) and participate in the formal stakeholder committees and working groups. Members have voting interests within the stakeholder process, which is the primary way RTO market rules are developed, modified, and proposed to FERC. A market participant is any entity, other than the RTO itself, that engages in activities within the wholesale electricity market, such as generating, buying, and selling electricity to meet demand and ensure grid balance. Membership grants a voice in the operation and governance of the RTO, while market participation refers to the commercial and operational activities within the RTO's administered wholesale power markets.

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RTOs operate along a CPR–club continuum, using exclusion to enhance governance and efficiency while keeping the physical fabric of power flows and the duty to maintain reliability squarely in the commons.

RTO governance reflects Buchanan's club model in its use of exclusion, cost-sharing, and collective decision-making to manage reliability and market access. Entry rules prevent free riding; cost-allocation mechanisms distribute the burden of infrastructure and market administration. Investment decisions mirror club logic, as members weigh the costs and benefits of upgrades. Larger RTOs gain economies of scale and risk pooling, but growing and diversifying membership raises coordination costs, reinforcing the need for adaptable governance.

Like clubs, RTOs must balance static efficiency considerations of minimizing operational costs with the dynamic efficiency of accommodating technological and policy change. While exclusion supports reliability, it can stifle innovation if not calibrated to evolving conditions. Polycentric governance, involving RTOs, states, and local actors, helps recalibrate rules, internalize externalities, and reduce transaction costs through centralized operations.

RTOs do differ, though, from Buchanan's model in one important respect: they are not replicable. High fixed costs, network externalities, and economies of scale in dispatch make it infeasible for excluded parties to form competing clubs. Without the exit option, exclusion becomes more consequential as a governance mechanism. RTO tariff structures, queueing procedures, and governance rules determine who can inject or withdraw power, on what terms, and using which technologies. This structure creates economic rents and strong incentives for incumbents to shape rules to their advantage, while raising participation barriers for new entrants.

These conditions do not invalidate club theory but require its adaptation. RTOs remain organized platforms that structure access to a shared resource. The definition of market prices (locational marginal pricing) reflects Buchanan's principle of charging users for marginal congestion costs, while cost allocation parallels his distinction between membership fees and tolls. Yet in the absence of replicability, fair access and innovation must be safeguarded through internal institutional design and external oversight. For those reasons, Ostrom's design principles and model of polycentric governance are crucial to understanding RTO governance and its adaptation to technological change.

FERC's open-access rules, state policy initiatives, and independent market monitoring function as Ostromian polycentric governance mechanisms, compensating further for the lack of club competition. Buchanan explains why exclusion is necessary; Ostrom shows how it can be managed. Together, they provide a robust framework for RTO governance.

Ultimately, the challenge in this setting is not optimizing club size but ensuring that exclusion does not entrench incumbency or obstruct technological evolution. RTOs must balance short-term reliability with long-term adaptability, aligning governance with emerging technologies and shifting policy goals to support both system stability and innovation.

Ostrom's design principles applied to RTOs

Ostrom's design principles provide a useful lens for characterizing how RTOs function as a club to govern the transmission reliability commons while also operating market platforms. In this paper, exclusion refers to the bundle of rule-defined participation rights and obligations that governs access to a congestible network and to the market platform built on top of it. Technological change – particularly the growth of renewables, storage, and DERs – stresses this exclusion regime by expanding the set of feasible participants and increasing heterogeneity in capabilities, observability, and performance risk. Rather than treating each design principle as a separate checklist item, this section organizes them around four governance functions that are central in RTOs: (i) boundary-setting and proportionality (Principles 1–2), (ii) collective choice and legitimacy (Principle 3), (iii) monitoring, enforcement, and dispute resolution (Principles 4–6), and (iv) external recognition and nesting across governance scales (Principles 7–8). This organization retains Ostrom's analytical approach while highlighting the mechanisms through which RTOs implement exclusion and manage the exclusion–innovation trade-off under technological change.

Boundary-setting and proportionality: defining access, obligations, and cost responsibility (Principles 1–2)

RTOs implement clearly defined boundaries by specifying the relevant resource system (the transmission network within the footprint, along with associated operational and market systems) and by establishing formal participation criteria. Boundary rules define who can inject or withdraw power and under what conditions, including requirements for registration, creditworthiness, metering and telemetry, and compliance with operational protocols. These rules are implemented through tariffs and operating manuals that standardize participation and create enforceable obligations across a heterogeneous set of actors. In Ostrom's terms, these boundaries operationalize inclusion and exclusion: they determine who has use rights in the congestible network and, crucially, what behaviour counts as compliant use. As the resource mix becomes more distributed and software-mediated, these boundary rules increasingly function as an institutional entry technology: telemetry standards, aggregation eligibility, and verification requirements determine whether new resource types can be integrated legibly into centralized dispatch and settlement.

Proportionality rules then translate participation into cost responsibility and performance obligations. RTOs must allocate costs for congestion management, reliability services, transmission upgrades, and administrative functions among participants who benefit from access to the shared network and the market platform. These cost-allocation rules are persistently contested because the benefits of transmission expansion and reliability enhancements are often diffuse, while costs are immediate and can be assigned in ways that shape investment incentives. Capacity accreditation rules play a similar role: they convert heterogeneous physical capabilities into standardized obligations and eligibility for revenues, thereby linking benefits (payments) to responsibilities (availability, performance, and compliance). When technology changes the set of feasible resources, these boundary and proportionality rules become a focal point because they jointly determine whether innovative resources can enter, how their contribution is measured, and which parties bear the cost and risk of integration.

Participation criteria, telemetry and measurement requirements, interconnection prerequisites, and accreditation methods implement exclusion by drawing the boundary between eligible and ineligible resources and by translating heterogeneous technologies into standardized rights and obligations. This boundary-setting has a clear reliability rationale: these rules reduce free riding and help manage congestion by coupling access to the network and markets with enforceable performance obligations and cost responsibility. Yet this same architecture can create innovation friction, because fixed compliance costs and measurement burdens can raise the minimum efficient scale for entry and deter smaller or novel resources, particularly when legacy assumptions are embedded in metering standards, accreditation methods, or cost-allocation design.

Collective choice and legitimacy under heterogeneity (Principle 3)

RTOs institutionalize collective choice through stakeholder-driven governance processes that develop and revise tariffs, operating rules, and market designs under FERC oversight. Stakeholder participation typically occurs through committees and working groups organized around functional domains (markets, operations, planning, and reliability), with voting rights generally restricted to RTO members. Stakeholder categories commonly include transmission owners, generators, power marketers, distribution utilities, end-use customers, and other suppliers. PJM, for example, categorizes stakeholders into Generation Owners, Transmission Owners, Other Suppliers, Electric Distributors, and End-Use Customers, while SPP integrates member input via a Members Committee and specialized task forces (Lenhart and Fox, 2022).

Sector-based and weighted voting systems are intended to balance influence across heterogeneous interests (Yoo and Blumsack, 2018a, 2018b). In practice, these systems create a structured bargaining environment that can differ from the deliberative 'consensus' ideal often associated with participatory governance. Technical complexity and the volume of proceedings can limit effective participation and privilege well-resourced incumbents (James et al., 2023). Transparency and opportunities for

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meaningful input by non-members can also be limited and have been criticized in the literature (Lenhart and Fox, 2022; Simeone, 2021). Supermajority thresholds for major changes, combined with the need for subsequent FERC approval, reinforce stability but can slow adaptation when technology and policy conditions shift quickly. As decarbonization policy and distributed technologies bring in new categories of participants and new operational possibilities, governance systems designed around a smaller set of legacy actors face a familiar polycentric challenge: more stakeholders, more contested problem definitions, and more potential veto points in the process of revising boundary rules.

Stakeholder procedures implement exclusion in a subtler but consequential way by determining how boundary and participation rules are proposed, amended, and ratified, and therefore whose information and interests are incorporated into rule revisions. These collective-choice arrangements have an important reliability rationale because they bolster legitimacy and compliance by giving affected parties a role in shaping the rules that govern a shared, high-stakes infrastructure. Yet this same process can generate innovation friction when technological change increases heterogeneity and expands the set of affected parties, since consensus-oriented procedures and sector-based voting can entrench legacy interests and slow rule change, amplifying the pacing problem even when the reliability case for reform is widely recognized.

Monitoring, enforcement, and dispute resolution: maintaining compliance in a complex network (Principles 4–6)

RTO governance relies on intensive monitoring because real-time reliability depends on continuous balance and because market outcomes can be manipulated when system constraints are complex. Operational monitoring systems provide visibility into flows, voltage, outages, and contingencies, supporting rapid intervention when reliability is threatened. Market oversight is commonly complemented by Independent Market Monitors – internal or external – who review transactions and bidding behaviour, publish reports, recommend rule changes, and refer suspected manipulation to FERC. Reliability compliance is further reinforced by NERC and regional entities through standards and periodic audits of both system operators and participants.

Enforcement practices supply graduated sanctions that preserve credibility while recognizing that compliance failures vary in severity and intent. Sanctions can range from warnings and corrective actions to financial penalties, tightened credit requirements, or suspension of participation privileges. Dispute-resolution mechanisms provide structured pathways for contesting outcomes and interpreting rules, often beginning with internal processes and escalating, when necessary, to external adjudication at FERC. These mechanisms lower the cost of resolving recurring conflicts in a dense transaction environment, even if escalation can become time-consuming when issues are politically salient or technically complex. As resources become more distributed and digitally mediated, the compliance problem shifts from monitoring a small number of large dispatchable units towards measurement, telemetry, baseline verification, and performance attribution across many smaller units and aggregations. That shift increases the stakes of monitoring design and can make enforcement rules an important determinant of whether new resources can participate at scale.

Monitoring requirements and performance verification rules implement exclusion by determining whether participation obligations can be credibly enforced and, in turn, whether entry is granted in the first place or sustained over time. This monitoring infrastructure has a clear reliability rationale because monitoring and graduated sanctions deter opportunism and sustain both system reliability and market integrity in a congestible network governed by complex rules. Yet these same features can create innovation friction, since verification burdens and enforcement risk can impose disproportionately high costs on smaller or newer entrants, especially where standards were designed around centralized resources, thereby indirectly tightening exclusion even in the absence of explicit barriers to entry.

External recognition and nesting across scales (Principles 7–8)

RTO governance depends on minimal recognition by external authorities because RTOs exercise quasi-regulatory functions through tariffs and operating rules. FERC approval provides legal force and external validation for RTO governance, while also constraining the feasible set of institutional designs. Nested governance is equally central: reliability and market coordination occur at multiple scales, from asset owners and distribution utilities to regional system operators, to inter-RTO seam coordination and interregional planning, and to continental reliability standards through NERC and its regional entities. State public utility commissions regulate distribution utilities and shape state-specific policy goals, which then interact – sometimes contentiously – with regional market rules and planning processes. Internally, RTO committee structures and specialized subcommittees create additional nesting that supports expertise and division of labour. In an era when many innovations and decarbonization policies are initiated at the state level while market rules are administered regionally and approved federally, nested governance shapes whether boundary rules can adjust in a coordinated way across levels.

External recognition and nested governance implement exclusion by allocating authority over participation and performance rules across multiple venues – state policy processes, RTO tariff design and stakeholder procedures, federal approval, and reliability standards – so that changing exclusion often requires coordinated action rather than a single decision. This nesting has a clear reliability rationale because it allows decisions to be made at the appropriate scale, combining local knowledge with regional coordination and higher-level oversight. Yet the same structure can generate innovation friction when coordination failures across layers create jurisdictional gaps and conflicting incentives that slow rule revision and raise procedural barriers to entry, particularly when state policy objectives collide with regional market designs and interregional planning needs.

Why these principles matter for technological change and the exclusion–innovation trade-off

This section's application of Ostrom's principles yields a small set of mechanisms that generalize beyond the RTO case study. Because the transmission network is non-replicable, institutional design rules are the primary margin of adaptation: they substitute for the disciplining force of replication and exit that is available in other club settings. Boundary and proportionality rules determine who can participate and at what cost, translating heterogeneous physical capabilities into market rights and obligations (for example, metering and telemetry requirements, aggregation eligibility, derating methods, and interconnection upgrade assignment). Collective choice and nested governance determine how quickly those boundary rules can be revised when technology and policy goals shift (for example, committee structures, voting thresholds, and escalation pathways). Monitoring and graduated sanctions determine whether performance can be verified and, therefore, whether participation is sustainable at scale (for example, capacity performance penalties and dispatch-compliance rules). Under technological change, the exclusion regime that makes a congestible reliability commons governable also becomes a leading source of institutional friction: distributional conflict and procedural complexity raise the transaction costs of rule revision, thereby amplifying the pacing problem and increasing barriers to innovative entry.

Polycentricity in RTO Governance

RTO governance is usefully understood as polycentric because the exclusion regime that protects reliability and enables market exchange is not set by a single authority. Instead, multiple decision-making centres determine jointly who can participate, on what terms, and how quickly those boundary rules can change as technology evolves. This polycentric structure matters for the paper's core argument because the exclusion–innovation trade-off is shaped not only by the content of rules, but also by the number of venues that can revise, contest, or block them. When the grid is a non-replicable network commons, this governance architecture becomes a central determinant of dynamic adaptation.

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Polycentricity has vertical and horizontal dimensions. Vertically, authority is distributed across several levels. State institutions pursue procurement and policy objectives that affect the resource mix and the location of new investments, while RTOs administer market rules, interconnection processes, and centralized dispatch to maintain reliability and coordinate trade across a larger footprint. Federal regulatory oversight through FERC constrains and enables RTO rule changes through tariff approval and policy directives, and reliability standards operate as an additional constraint that limits the feasible set of market and operational designs. Internally, RTO decision-making is itself multi-centred: boards, stakeholder committees, and market monitoring functions occupy distinct roles in agenda setting, rule development, adjudication, and enforcement. This layered structure means that participation, representation, and formal authority do not always coincide, which can become especially salient when new technologies seek entry or when policy objectives diverge across states within an RTO.

Horizontally, polycentricity arises because RTOs and balancing authorities must coordinate across seams and across regional transmission interconnections (except ERCOT). Interregional transmission planning, congestion management across borders, and the compatibility of participation models for emerging resources all require coordination among adjacent governance 'centers' that are formally autonomous. This horizontal fragmentation matters for innovation because many of the benefits of new resources depend on scale – moving power across regions, sharing reserves, and expanding the effective scope of the market platform – yet the institutional ability to expand or harmonize rules often lags the technological and investment impetus.

This polycentric architecture has a dual effect on innovation. On one hand, it can facilitate experimentation and learning because different RTOs and states can pilot participation models, procurement approaches, and market products without mandating uniformity, and successful designs can diffuse through observation and emulation. Polycentricity also provides checks on unilateral decision-making through overlapping oversight and escalation pathways. On the other hand, polycentricity can raise the transaction costs of adaptation by creating multiple veto points. When entry by new technologies requires aligned changes in market rules, interconnection procedures, and compliance frameworks, disagreement at any one node can delay reform, amplifying the pacing problem and indirectly strengthening exclusion.

Two recurring patterns illustrate this mechanism in a way that is directly relevant to the exclusion–innovation trade-off. First, vertical conflict emerges when state policies accelerate renewable and DER deployment while existing RTO participation and performance rules remain calibrated to centralized resources; integrating new entrants then requires changes that pass through stakeholder processes, board approvals, and federal review, often under binding reliability constraints. Second, horizontal conflict emerges when scaling renewables and improving reliability depend on interregional transmission expansion and seam coordination. Where planning and cost allocation cannot be agreed across neighbouring regions, congestion and queue delays increase, and the system responds by tightening or effectively hardening boundary rules through procedural barriers and higher entry costs. In both cases, polycentricity clarifies why exclusion persists even when many actors endorse innovation in principle: the costs of revising the exclusion regime are distributed across venues, and the benefits are often unevenly realized across participants and jurisdictions.

Viewed through this lens, polycentricity adds explanatory power to the Ostrom–Buchanan framework by showing how the governance system that transforms a reliability commons into a club-like regime can simultaneously enable and impede dynamic adaptation. Ostrom's CPR framework explains why multi-layered rule systems, monitoring, and enforcement are necessary for a shared, congestible network. The polycentricity lens reveals why adapting those rules under technological change is itself a collective-action problem across multiple, partially autonomous decision centres.

The trade-offs of exclusion

Synthesizing Ostrom's institutional design principles with Buchanan's theory of clubs suggests that exclusion is the linchpin of RTO governance, but it also clarifies why the exclusion–innovation

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trade-off is unusually sharp in transmission systems. Exclusion in RTOs performs an essential static-efficiency function: by conditioning access on enforceable obligations, it limits free riding, manages congestion, and protects reliability in a congestible network where individual actions impose system-wide externalities. Yet exclusion also creates dynamic-efficiency costs because it restricts entry and contestability, the central processes through which innovation typically occurs. This tension becomes deeper once the transmission system's non-replicability is taken seriously. In Buchanan's canonical club setting, inefficient or stagnant clubs can be disciplined by exit and replication: dissatisfied members can form or join alternative clubs, and competition among clubs limits the exercise of exclusionary power. Transmission networks are constrained away from this competitive margin. High fixed costs, physical network effects, siting and permitting constraints, and the institutional realities of cost recovery mean that 'building another club' is rarely a feasible form of discipline. As a result, governance rules and the broader polycentric institutional environment must supply much of the disciplining force that replication and exit would otherwise provide.

Ostrom's framework helps explain why this substitution is necessary. In a non-excludable-in-physics but congestible-in-practice network, rule-defined boundaries and obligations are the institutional technology that makes the reliability commons governable. RTOs have implemented this principle by specifying participation criteria, performance requirements, and compliance processes that enable centralized dispatch and coordinated planning across many heterogeneous users. Buchanan's club theory then illuminates the risk of static membership and rigid boundary rules in a setting where replication is not feasible: the benefits of exclusion in producing an 'optimal' quantity of reliability and congestion management can come at the cost of Schumpeterian dynamism. When the primary margins of adaptation are institutional rather than competitive, a club that becomes procedurally rigid can lose the evolutionary advantages of entry by new participants with innovative business models, advanced digital tools, and DER capabilities, even when those entrants could lower system costs or improve flexibility.

This trade-off is particularly salient as the technological and policy environment shifts. Many RTO participation and market rules were established in the 1990s to support restructuring, open-access transmission, and investment in then-dominant technologies such as combined-cycle natural gas generation. Those institutional templates are now being stress-tested by a more heterogeneous portfolio of resources and services – intermittent renewables, storage, DER aggregations, and digitally mediated grid services – that create new reliability capabilities but also require new modes of measurement, verification, and coordination. Because the network cannot be replicated to accommodate competing institutional designs, adaptation must occur through rule revision within the existing governance architecture and through interactions across polycentric layers (RTO stakeholder processes and boards, FERC oversight, state policy, and reliability standards). In this environment, the exclusion problem is less about whether to exclude – some exclusion is unavoidable for reliability – and more about how to recalibrate boundary rules at the margin so that they preserve reliability while lowering unnecessary barriers to technologically valuable entry.

RTOs enforce exclusion through institutional mechanisms originally designed for large, centralized generators that can now function as barriers for newer technologies such as DER aggregators, demand response providers, and storage operators. Market participation rules often require substantial financial collateral,[14] creditworthiness standards, and extensive metering and telemetry[15] capabilities that can be cost-prohibitive for smaller or aggregated resources, limiting their ability to compete on equal footing with traditional generators. Capacity accreditation methods can disadvantage non-traditional

[14]For example, PJM requires market participants to have tangible net worth in excess of $500,000-$1 million or tangible assets in excess of $5-10 million, depending on the type of participant. In the absence of such market capitalization they must post collateral that will be held in escrow (PJM Settlement, 2024: 12).

[15]In electric power systems, telemetry refers to the automated process of measuring and transmitting data from remote or inaccessible points in the system to a central location for monitoring, analysis, and control. These data can include electrical parameters like voltage and current, as well as physical data like temperature and pressure; these sensing and communications capabilities require financial investment.

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resources by relying on historical performance metrics and conservative adjustment factors that do not fully reflect the reliability contributions of fast-ramping storage or aggregated demand response. Interconnection queues and related governance hurdles further constrain entry, as the backlog of pending generation and storage projects (notably in PJM, MISO, and CAISO) delays participation for years, often reflecting study processes and cost-allocation rules that assign a disproportionate share of network upgrade costs to later-arriving projects (Johnston et al., 2023). More broadly, Lenhart and Fox (2021) find that participation structures designed around legacy technologies and the initial objectives of restructuring are misaligned with newer participants and interests.

These exclusionary structures were originally designed to support reliability and market integrity, but under technological change, they can become institutional bottlenecks that impede the integration of distributed, flexible resources. Because the network cannot be replicated to provide an 'exit' option for excluded entrants, the fixed costs embedded in participation, accreditation, and interconnection rules can translate directly into higher minimum efficient scale for market participation and slower competitive experimentation. In effect, the same governance machinery that stabilizes a congestible reliability commons can harden into a procedural form of exclusion that limits the main margin of dynamic adaptation – entry – precisely under conditions when entry is most valuable.

This dilemma is a concrete manifestation of the pacing problem: when technological possibilities change faster than the institutions that define participation rights and obligations, the resulting mismatch produces congestion in governance as well as congestion on the grid. The institutional task is therefore not to eliminate exclusion, but to design exclusion that is appropriately contingent, evidence-based, and revisable – so that, in a non-replicable network club, polycentric governance and rule revision can supply the adaptive discipline that competition among clubs would otherwise provide.

An Ostrom-Buchanan approach to reconciling reliability and innovation

Effective RTO governance requires balancing congestion costs and reliability risk against the benefits of broader participation and technological variety. Buchanan's club framework helps clarify the logic of this balance: exclusion is valuable because it limits congestion and free riding, but in a setting where the club cannot be replicated, exclusion also becomes a powerful lever that can harden into a barrier to entry. Ostrom's adaptive governance principles then help identify how a non-replicable, congestible network can remain open to innovation without abandoning the institutional structure that preserves reliability. In transmission systems, the key implication is that the margin of adjustment is institutional rather than competitive: because exit and replication provide limited discipline, RTO rules and the surrounding polycentric governance environment must supply the adaptive 'pressure' that would otherwise come from competition among clubs.

A first implication is that RTOs should treat boundary rules as deliberately revisable, rather than as fixed participation templates inherited from the restructuring era. One practical approach is to define evolving boundaries by recognizing new categories of participants and participation models – such as DER aggregators, microgrids, storage providers, and other service providers – while nesting those participation arrangements within the broader RTO framework. This approach is consistent with Ostrom's 'nested enterprises' principle: specialized sub-arrangements can operate within a larger governance regime, lowering the fixed costs of entry by tailoring measurement, telemetry, and performance obligations to the operational characteristics of new resource types. A second implication is that tiered participation structures can substitute for the missing competitive discipline that replication would otherwise provide. Rather than a binary choice between full inclusion and exclusion, tiering can allow limited but well-specified access rights and obligations that scale with a resource's system impact. In practice, tiering can mean differentiated telemetry requirements, phased performance obligations, and scaled financial assurances, with clear pathways for moving towards fuller participation as compliance and performance are demonstrated. A third implication is that RTOs should adopt explicit protocols for periodic rule revision – including network integration rules, capacity accreditation methods, and cost-allocation frameworks – so that the exclusion regime remains evidence-based and

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adaptive as technology changes. In a non-replicable club, such protocols operate as a constitutional substitute for exit: they create predictable opportunities to revisit boundary rules in light of observed performance and changing system conditions, rather than leaving reform to episodic conflict.

These institutional adjustments must be complemented by governance capacities that make inclusion credible. Stronger monitoring, performance verification, and graduated sanctions can reduce the reliability risks associated with new entrants and thereby lower the informational and political barriers to inclusion. Advanced monitoring and data systems can improve visibility into DER performance and load patterns, reducing uncertainty, and enabling more targeted incentives and penalties, including penalties that reflect real-time deviations where appropriate. Graduated sanctions can also be structured as a learning-oriented pathway for entry: heightened supervision and conservative performance assumptions can apply initially, with requirements relaxed as resources demonstrate reliable compliance. At the same time, collective-choice arrangements must evolve to prevent the exclusion regime from being locked in by legacy participation structures. If technological change expands the set of affected parties, then stakeholder processes that were engineered around a smaller number of incumbent categories can become an institutional bottleneck. RTOs can respond by creating specialized committees for emerging technologies, adjusting sector definitions, or otherwise ensuring that entrants with materially different capabilities and business models can participate meaningfully in rulemaking. In Ostromian terms, this is not political reform for its own sake; it is an institutional design requirement for maintaining legitimacy and adaptive capacity in a rapidly changing governance environment.

Several RTOs have begun experimenting with governance and market reforms to accommodate emerging technologies while maintaining reliability, illustrating pathways for reconciling exclusion with innovation. CAISO's DER Provider model was one of the first attempts to integrate aggregated DERs into wholesale markets, allowing multiple small resources to participate as a single entity, although challenges remain in metering and market dispatch alignment, and demand-side resources are still redefined as supply to enable their market participation.[16] NYISO has piloted programmes for storage and demand response, including its market design for storage as a dispatchable resource, aiming to better reflect the fast-response capabilities of batteries and aggregated loads in wholesale price formation. Meanwhile, FERC has facilitated stakeholder information sharing around questions of integrating new technologies in bulk power systems, such as their Innovations and Efficiencies in Generator Interconnection Workshop in September, 2024.[17] FERC's ongoing efforts to reform interregional transmission planning also highlight the structural barriers to integrating new, heterogeneous technologies and balancing supply across large geographic footprints, as legacy cost allocation rules and jurisdictional conflicts have slowed investment in needed transmission capacity (Macey et al., 2024). These examples reinforce the central implication of the Ostrom–Buchanan lens: in a system constrained away from replication, innovation depends on the capacity of institutions to revise boundary rules and to coordinate reforms across nested and adjacent governance centres.

These reforms are difficult precisely because the incentives for institutional change are endogenous to the existing exclusion regime. Institutional path dependence gives incumbent stakeholders substantial influence over rulemaking, and incumbents may resist reforms that lower entry barriers or reallocate governance rights. In a replicable club environment, dissatisfied users could respond by forming alternative clubs; in transmission governance, that disciplinary mechanism is weak, which increases the importance of polycentric checks and externally recognized pathways for reform. FERC oversight, state policy pressures, market monitoring, and inter-RTO coordination can therefore play a

[16]A description of the DER participation rules is available at https://www.caiso.com/generation-transmission/generation/distributed-energy-resources. Integrating active demand into wholesale power markets in CAISO (and elsewhere) has involved administratively defining a benchmark consumption level, against which reductions in consumption are measured as supply offered in the market.

[17]Recordings of the workshop are available at https://www.ferc.gov/news-events/events/innovations-and-efficiencies-generator-interconnection-workshop-day-1-2-09102024.

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constructive role as complementary sources of discipline – helping to keep the exclusion regime adaptable when internal governance would otherwise tilt towards stasis. The practical challenge is to design exclusion so that it remains reliability-preserving while also being contingently adjustable, allowing the transmission network club to capture the static gains from coordination without sacrificing the dynamic gains from entry and experimentation.

Conclusion

This paper has analysed the complex institutional dynamics that shape RTO governance under technological and policy change, emphasizing how RTOs manage a reliability commons through rule-defined exclusion while also operating market platforms that depend on broad participation. By synthesizing Elinor Ostrom's institutional design principles with James Buchanan's theory of clubs, the paper develops a framework that clarifies a central tension in modern electricity systems: the same exclusion-and-obligation machinery that stabilizes a congestible AC network and supports efficient market coordination can also suppress entry and slow adaptation when new technologies and business models become feasible. This exclusion–innovation trade-off is an institutional implication of governing a physically coupled network where access rights must be defined through rules rather than through fully specified property rights.

This paper makes several original contributions that generalize beyond the particulars of U.S. electricity markets. First, it extends club theory to a setting in which Buchanan's replicability axiom is constrained away from holding. In the canonical club model, inefficient exclusion can be disciplined by exit and replication – members can form or join alternative clubs, and competition among clubs limits the persistence of stagnant governance. Transmission systems are a boundary case: high fixed costs, strong network effects, and siting and permitting constraints mean that 'building another club' is rarely a realistic disciplining mechanism. In this non-replicable infrastructure setting, the relevant margin of adjustment is institutional rather than competitive. This contribution shifts attention from static club-size optimization towards constitutional and organizational design under non-replicability, where governance rules and the broader polycentric environment must substitute for competitive discipline.

Second, this paper operationalizes exclusion as an institutional technology composed of layered rules – participation criteria, performance obligations, monitoring and sanctions, and cost responsibility – rather than treating exclusion as a simple membership decision. This conceptual refinement matters because it identifies the concrete mechanisms through which a reliability commons becomes governable in practice and through which innovation can be enabled or impeded. When technology becomes more distributed and digitally mediated, these mechanisms function as entry thresholds by determining the minimum efficient scale of participation and the feasibility of aggregating smaller resources. This analysis, therefore, provides an institutional account of how boundary rules shape industry structure and innovation incentives in network industries with shared operating constraints.

Third, this paper demonstrates how Ostrom's design principles apply in engineered, high-complexity, partially privatized governance arrangements, not only in community self-governance settings. RTOs are deliberately designed organizations that combine technical operations with platform governance and are nested within legal oversight and reliability standards. The electricity case shows how Ostrom's principles of boundaries, proportionality, monitoring, sanctioning, and nested enterprises operate when the commons is a real-time synchronized network and when governance is implemented through tariffs, stakeholder processes, and regulator-supervised rulemaking. This application also refines the pacing problem: institutional mismatch arises not simply because 'regulation lags technology', but because rules that optimize reliability and coordination under one technological regime can become a source of institutional friction under another.

Fourth, this paper develops polycentricity as an explanatory mechanism. In RTO governance, authority is distributed across internal bodies (boards, stakeholder committees, market monitors), vertically across state and federal institutions, and horizontally across adjacent regions and seams. This polycentric structure helps explain why reform is persistently difficult even when reliability is a shared

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objective: adaptation often requires coordinated action across multiple venues, which raises transaction costs, creates multiple veto points, and fragments reform trajectories across jurisdictions. At the same time, polycentricity creates opportunities for experimentation and learning, allowing innovations in market design and participation models to emerge in pockets and diffuse. This duality is central to understanding institutional adaptation in non-replicable network clubs.

The paper's substantive conclusion is that RTOs have succeeded in governing transmission reliability as a congestible commons by building club-like layered rule systems that define access and obligations, enabling both reliability and gains from trade through centralized dispatch and market coordination. Yet the same exclusion regime can harden into procedural barriers that restrict entry by new resources and service models precisely when those entrants can contribute flexibility and reduce costs in an evolving system. Because the network cannot be replicated, and because exit provides limited discipline, institutional adaptability must come through revisable boundary rules and through polycentric checks that prevent exclusion from becoming static. The practical implication is to design exclusion that is contingent, evidence-based, and systematically revisable, so that reliability-preserving coordination does not come at the expense of dynamic adaptation.

Institutional adaptation is, therefore, both necessary and challenging. The analysis suggests that reducing unnecessary barriers to innovation requires deliberate attention to how participation boundaries are defined, how obligations and fees scale with system impact, and how accreditation and cost-allocation rules are updated as technologies change. It also implies that governance reform cannot be understood solely as an internal RTO design problem: in a polycentric environment, adaptation depends on coordinated adjustments across RTO processes, state policy, federal oversight, and reliability standards, as well as across interregional seams where transmission expansion and cost allocation become binding constraints.

Finally, future work can apply the Ostrom–Buchanan lens to specific ongoing reforms – such as DER aggregation implementation, interconnection and accreditation redesign, and interregional transmission planning – to evaluate how changes in boundary rules affect entry, performance, and reliability outcomes across RTOs. Comparative analysis across regions can identify which institutional designs best preserve reliability while remaining open to technological discovery. In non-replicable network industries, the path to long-run efficiency runs through governance: the task is to maintain the club's capacity to manage a congestible commons while preserving, within that club, the institutional conditions for experimentation, contestability, and innovation.

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