The Pennsylvania State University

The Graduate School

STUDIES IN THE GOVERNANCE OF REGIONAL TRANSMISSION ORGANIZATIONS

A Dissertation in

Energy and Mineral Engineering

by

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Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Doctor of Philosophy

December 2021

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ABSTRACT

The introduction of Regional Transmission Organizations (RTOs) in the US was done in order to lower consumer costs and increase reliability through the power of markets. Since their introduction 20 years ago the landscape in which RTOs find themselves has changed dramatically with the introduction of new public policy measures and technologies. RTOs now have a much more complex environment to operate in, with the core RTO functions of running energy markets, ensuring reliability, and operating the grid having become increasingly interconnected. As voluntary, member-driven organizations, it has been up to the stakeholders to manage the market and operational changes necessary while also developing the stakeholder processes that allow them to do so. In the PJM Interconnection, the expanded scope of responsibilities, complexity, and member body size has created tensions within the stakeholder processes that has led some to question the efficacy of existing decision-making structures, and in Chapter 1 we present a case study examining PJM stakeholders' perceptions of the PJM stakeholder process in order to better understand what the external and internal stresses are to the process and how they might be addressed. We find three primary factors underpinning the current stresses in the stakeholder process: the emerging influence of new energy policy objectives at both the state and federal levels, a narrowing of stakeholder interests as markets mature, and increasing reactions by RTO staff to address these first two issues when PJM members are unable to do so. Chapter 2 examines community structure in the voting networks of the three RTOs in the northeast: the New England Independent System Operator, the New York Independent System Operator, and PJM. We ask what the structure of the network says about the distribution of political power with the RTOs, how the voting networks of capacity market votes differ from the voting networks of other issues, and how stable communities remain over time. We find strong evidence that stakeholder sector affiliation is a prime driver of community structure, but that different voting structures in each RTO's stakeholder process leads to diverse outcomes. In PJM coalition stability for votes about capacity market issues over time are less strong than expected. In NE-ISO we find stability of votes when analyzed by issue. In Chapter 3 we illustrate how daily electrical grid management decisions can incorporate information from air quality forecasts in an attempt to avoid daily O_3 exceedances—non attainment days—by shifting the location of electricity generation. Temporarily redispatching generation away from forecasted regions of high O_3 has the potential to reduce the costs associated with traditional emissions control strategies while still achieving pollution reductions. We use the direct decoupled method integrated sensitivity analysis tool in CAMx to estimate the sensitivity of 8-hr O_3 to NOx emissions from two sets of power plants within the Eastern Interconnect and PJM. Those sensitivities are then used to estimate the least-cost means of reducing high O_3 by coupling them with electricity dispatch done via OPF run PowerWorld Simulator. This coordinated modeling system provides a framework for an adaptive air quality management system that dynamically targets individual power plants through redispatch. This, in effect, reduces emissions from critical sources without requiring costly investment in smokestack controls, thereby eliminating much of the cost associated with traditional pollution abatement strategies. It is found in some scenarios that key power plants lie outside the PJM control region, indicating the need for cross-RTO coordination.

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The research in Chapter 1 was supported by the National Science Foundation under the grant: Collaborative Research: Planning for Renewables: Regional Transmission Organizations Managing Tension and Networking Innovation (Awarded July 2013, SES-1261670). Chapter 3 was made possible by EPA STAR grant number 8351901. The findings and conclusions in this dissertation do not necessarily reflect the views of the National Science Foundation and the US Environmental Protection Agency.

INTRODUCTION

Electric utilities in the US have historically been governed by government-granted monopolies. The oil crises of the 1970s, along with a national trend towards privatization, led to changes in the utility regulatory structure driven in part by 1978's Public Utility Regulatory Polices Act which took the first step towards the deregulation (or rather restructuring) of the industry. In the 1990s The Federal Energy Regulatory Commission (FERC) took several significant steps towards addressing regional electricity trading and rate pancaking and introduced the concept of independent system operators which grew into the idea of regional transmission operators (RTOs).

In 1999 FERC advocated in Order 2000 or all utilities to join RTOs to address the increasing complexity of interstate electricity transmission and decrease wholesale electricity market costs. Since then, FERC had consistently underlined the market-driven approach of RTOs and strengthened the rules when necessary based on the theory that competition in wholesale electricity markets will lower costs to consumers. From the outset, RTOs were mandated to be voluntary and stakeholder driven. This has meant that different RTOs have developed different stakeholder processes with different allocations of intra-RTO decision-making and authority, and in about 30% of the country they haven't been implemented. Since their inception, RTOs have developed more and more complex markets in an effort to maintain the operational reliability of the grid, lower wholesale prices, incorporate new technologies, and address public policy, particularly state and federal level mandates for renewable energy and state-level restructuring of the industry. The evolving roles of RTOs has introduced multiple complexities including the need for coordination across and education of a growing number of stakeholders and the increasing interconnectedness of traditionally siloed areas of markets and operations. The relationship between RTOs, their members or stakeholders, and FERC is the nexus for the decisions being made for the future of the power grid. One aspect of this relationship that has not been well studied is the internal processes and relationships that make up the RTOs themselves. Because these processes provide the environment for the decision-making of stakeholders, a better understanding of them could lead to increased efficiencies and better outcomes.

To learn how stakeholders interact with the stakeholder process, whether there exist informal processes (and mechanisms for power) separate from formal processes, and what the tensions exist that are causing difficulties in addressing stakeholder issues, we interviewed 50+ stakeholders evenly split across three RTOs: California Independent System Operator, the Midcontinent Independent System Operator, and the PJM Interconnection. The findings of these interviews have given rise to several journal papers and form the basis for the largest investigation yet done into the RTO stakeholder process [1]–[5]. Chapter 1 presents a case study of PJM based on the interviews and other documentation. This paper contributes a more systematic understanding of the tensions within RTOs, the processes used to address these tensions, and what mechanisms are most useful in ensuring reliability while ensuring stakeholder buy-in and satisfaction. As RTOs continue to evolve, we hope that this research will provide insights for refinements of RTO stakeholder processes.

Chapter 2 uses network analysis to probe votes taken at the top-level committees in three RTOs: the New England Independent System Operator, the New York Independent System Operator, and PJM. Whereas CAISO, MISO, and PJM were chosen because of the diversity in their stakeholder processes, ISO-NE, NYISO, and PJM were chosen because of their similarities, particularly their hierarchical voting structure and divisions of stakeholders into similar classes (i.e generators, transmission owners, end-use customers, and so on). This network approach allows us to look at how political power structures vary across the three RTOs based on the unique differences in the voting structures between the RTOs. We ask three questions:

1. Can we identify specific constituencies in the RTO voting networks? If so, how does the structure of the voting network relate to the RTO's distribution of political power within a given RTO stakeholder process?
2. Do different constituencies form around different issues in the network?
3. Do the constituencies remain stable over time?

The major contributions of this chapter is that it is a detailed analysis of stakeholder decision-making within the

RTOs that allows direct comparison, particularly in how the top-level committee structure (particularly the voting threshold, the voting weights allocated per sector, and the number of sectors) affect the outcomes. In regards to PJM particularly, Chapter 2 also allows us to quantitatively analyze stakeholder perception from Chapter 1, such as perceptions of power dynamics and the causes of them.

Chapter 3 shows a method for coupling electricity dispatch modeling—which is heavily based on the properties of the physical characteristics of the components of the grid, such as the impedance of transmission lines—and air pollution modeling—which is heavily influenced by physical topography and weather. This method is unique in that it can be applied to specific communities or cities and doesn't rely on state-level averaging.

CHAPTER 1

THE EVOLUTION OF PARTICIPATORY POLICY-MAKING IN PJM

1. Introduction

"I've said it before and I'll say it again – democracy simply doesn't work!"
--Kent Brockman, *The Simpsons* [6]

The North American electric grid has been called the "the largest and most complex machine in the world" [7] and regional transmission organizations (RTOs) have become an established part of this system in the United States. RTOs manage approximately 70% of wholesale electricity supply [8], [9]using combinations of administrative procedures and market mechanisms. The seven RTOs in the United States are shown in Figure 1-1. As the independent regional transmission system operator and market organizer, the RTO is required by the Federal Energy Regulatory Commission's (FERC) Order 2000 to "have a decision making process that is independent of control by any market participant or class of participants" [10]. RTOs are organizations whose success depends on voluntary participation and engagement by a large number and variety of stakeholders, including generating companies, electric distribution utilities, industrial energy consumers, public consumer advocates and others. Despite the goal of achieving independence from any individual stakeholder or class of stakeholders, RTOs are subject to both political forces and technological innovations, placing them under continuous pressure to evolve.

RTOs are responsible for some wholesale functions that were previously filled by electric utilities whose prices and practices were highly regulated at the state level. This includes operation and planning of the high-voltage bulk power system. Retailing functions, such as direct sales to end-users, and the planning and operation of local distribution grids, are still performed by utilities that operate under state regulation, municipal control or cooperative type governance. RTOs use market mechanisms to ensure system reliability including adequate transmission and generation capacity. RTOs have also become critical players in facilitating technological change in the electric power grid, including grid integration of renewable resources; including new market actors such as energy storage and third-party demand response; and negotiating inter-technology competition such as the increased use of natural gas in place of coal for power generation. While RTOs do not make energy policy choices per se, they serve as a focal point for implementation of energy policy promulgated at both state and federal levels. As specific examples, RTOs in various portions of the United States administer compliance with state-level renewable portfolio standards, engage in planning activities to support renewable energy interconnections, and incorporate market products and rules that allow small-scale power generation and demand response resources to participate directly in markets originally designed for large power generation participants.

Different RTOs have approached these problems in different ways, reflecting the diversity of regional resources, institutional relationships, business models, regulatory approaches, political environments, and stakeholders. RTO decision-making and stakeholder engagement processes form a critical part of the energy policy landscape in North America, because the rules that come out of these processes determine the wholesale multilateral market value of existing and emerging technologies for electric power production.

To better understand the dynamics of the changing context for RTO decision making, we interviewed stakeholders who participate in the PJM stakeholder engagement process. PJM is the largest of the RTOs in terms of total demand served, whose footprint covers all or parts of thirteen states plus the District of Columbia in the Mid-Atlantic US. Our study reveals perceptions among PJM management, staff and stakeholder members and identifies emerging tensions that have made it increasingly difficult to move some issues forward to resolution through PJM's stakeholder process (see, for example, [3], [11]). Key factors contributing to these tensions include:

1. The *emerging influence of new energy policy objectives* has broadened the original responsibilities of RTOs, adding stress to the fundamental nature of RTOs' missions. While energy policy originally

focused RTOs on reliability and affordability, more recent policy choices at the state and federal level have had the result of putting RTOs in the position to meet additional policy goals for sustainability and technological innovation.

2. As RTOs and their practices have matured and as their markets have opened to a broader array of participants, a *narrowing of both stakeholder interests and the scope of RTO decisions* has created tension by asking a diverse group of stakeholders to consider RTO rule changes that create increasingly apparent winners and losers.
3. *Internal reactions* to these tensions by RTO staff reflect serious concern about the ability of RTOs to maintain their core reliability mission, but an increasingly active role by RTO staff in steering the stakeholder process through some issues raises questions among some stakeholders and RTO staff about the efficiency of the process and the spirit of Order 2000.

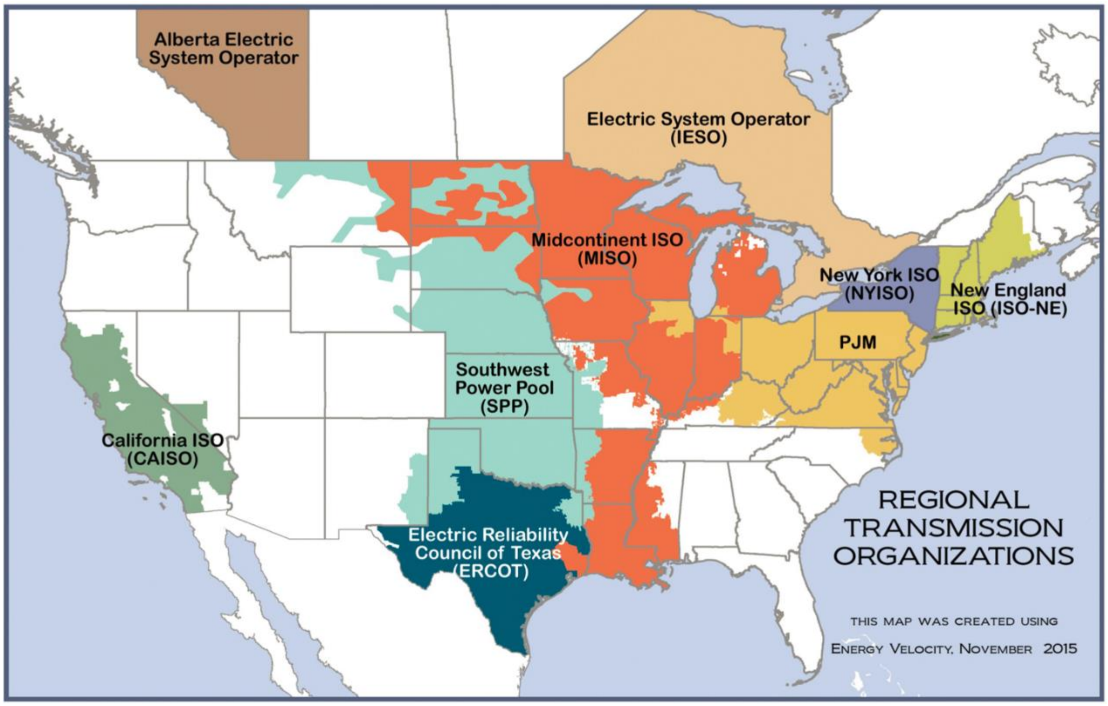

Figure 1-1. Regional Transmission Organizations of North America. Source: [8]

At the same time the decision-making process has become more complex, and the increasing complexity of the market systems managed by RTOs means that changes to RTO rules increasingly create unanticipated interactions within and across RTO markets and practices. These interactions create specific winners and losers among the RTO stakeholder population, and the losers in a specific situation naturally turn back to the stakeholder decision-making process for adjustments that will ameliorate their losses.

The core contributions of this paper are to highlight the critical importance of stakeholder-driven decision-making processes in shaping the implementation of energy policy over large areas of North America, and explain the tensions PJM is facing. All elements of RTO decision making, including the formulation of objectives, statements of constraints and enumeration of feasible alternatives, are shaped by the stakeholder processes that we describe and analyze in this paper. While the power grid has long been recognized as a complex socio-technical system, there has been very little work that takes a serious look at the implications of organizational decision-making for the structure and function of the power grid. This is, in part, because both the literature about electric power systems and the literature about energy policy often treat the RTO as a kind of philosopher-king whose market rules are formulated or handed down by a decision-maker or regulator with well-defined interests and objectives.

Our work in the present paper takes a step towards a more systematic understanding of the tensions within RTOs, the processes used to address these tensions, and ultimately what mechanisms are most useful in ensuring reliability while ensuring stakeholder buy-in and satisfaction. We hope that this research will yield insights for refinement of RTO stakeholder processes as they continue to evolve in response to complex market, regulatory, and technical demands under which critical infrastructure decisions are made.

We first provide an overview of the differences in RTO governance structures of RTOs and the impetuses for their evolutions. Section 3 presents the study methodology and results. We use our interview data to articulate specific tensions that have arisen within the PJM stakeholder process. These results are discussed, in Section 4, and we conclude in Section 5.

2. Background

All RTO decision processes are complex and all involve varying degrees of stakeholder involvement. There are differences in how much authority RTOs vest in stakeholder groups to craft RTO rule/protocol alternatives and decide which rule changes are filed before FERC. As shown in Figure 1-2, the balance of decision-making authority between each RTO and its stakeholder group exists on a spectrum, with the northeastern RTOs vesting more formal authority in their stakeholder groups than their counterpart RTOs in the Midwest and in California.

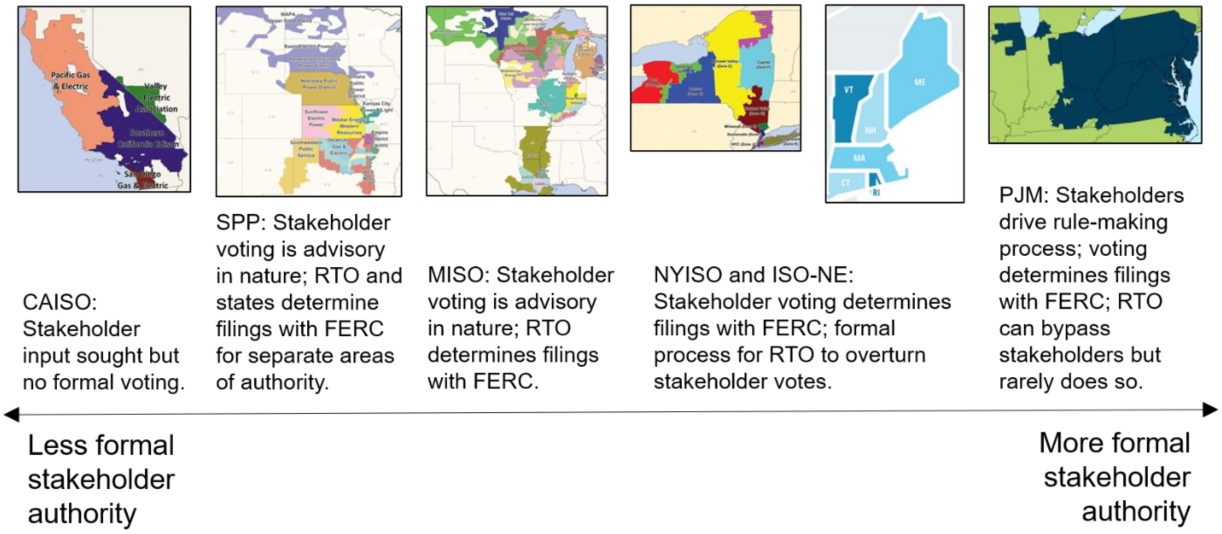

Figure 1-2. Stakeholder decision-making authority varies across RTOs. (Independent System Operators that are not RTOs—notably the Electric Reliability Council of Texas, are not shown.)

The California Independent System Operator (CAISO) engages with stakeholders in its decision-making process, but only in advisory capacity; CAISO is the only RTO to not have voting in the stakeholder process. The Southwest Power Pool (SPP) has just two sectors amongst its members: transmission owning and transmission using. Member voting is advisory in nature. The Member's Committee is limited to 24 participants representing six sectors of interests. The board of directors appoints the chairs of organizational groups, and it directs the activities of the groups [12]. The stakeholder process for the Midcontinent Independent System Operator (MISO) is governed by the 25-member Advisory Committee, which is notable for having by far the most sectors of any RTO (eleven), and for uniquely including environmental groups as one of the sectors. Voting is advisory in nature, with ultimate discretion for final policy structures lying with the MISO Board [13].

The three RTOs in the northeast also grew out of historically strong power pools, which had provided a long history of coordinated decision-making among utilities in those regions. While the PJM power pool transformed itself completely into the PJM RTO, the power pool in New England still exists as an organization whose primary function is to run the stakeholder process for ISO New England (ISO-NE). ISO-NE, PJM, and the New York Independent System Operator (NYISO) all have a hierarchical committee structure and employee sector-weighted voting at the top committee level, but allocate voting rights differently amongst sectors and have different voting thresholds for the passage of a proposal. PJM is unique amongst RTOs in that members maintain certain Federal Power Act Section 205 filing rights with FERC [14]. Because the outcome of the PJM stakeholder process may, in some cases, result in a filing directly to FERC without the approval of the PJM Board, the decision process in PJM arguably gives more power directly to stakeholders than other RTOs. However, the sector-weighted voting threshold is the highest of the three northeastern RTOs at 66.67%. The unique structure of PJM's decision-making authority is discussed in detail in Section 3.1. In NYISO and NE-ISO the state governments retain more authority than they do in PJM.

A major reason for these differences in the structure of stakeholder deliberations and the power balance between the RTO Board and its stakeholders is the state regulatory environment and organizational history in which the various RTOs operate. State-level restructuring of electric utilities has been much more common in the northeastern states and less common in Midwestern states, leaving state public utility commissions in the Midwest with a more important policy role in setting rates for generation, transmission and distribution. California's state regulators have also played a strong role in the operations of the California ISO since its inception. To illustrate the contrast of the opposite ends of the spectrum shown in Figure 1-2, Figures 1-3 and 1-4 show a comparison of the governance structures of the California ISO and PJM, and how the differences in balances of power between the RTO Board, state governments, and other stakeholders.

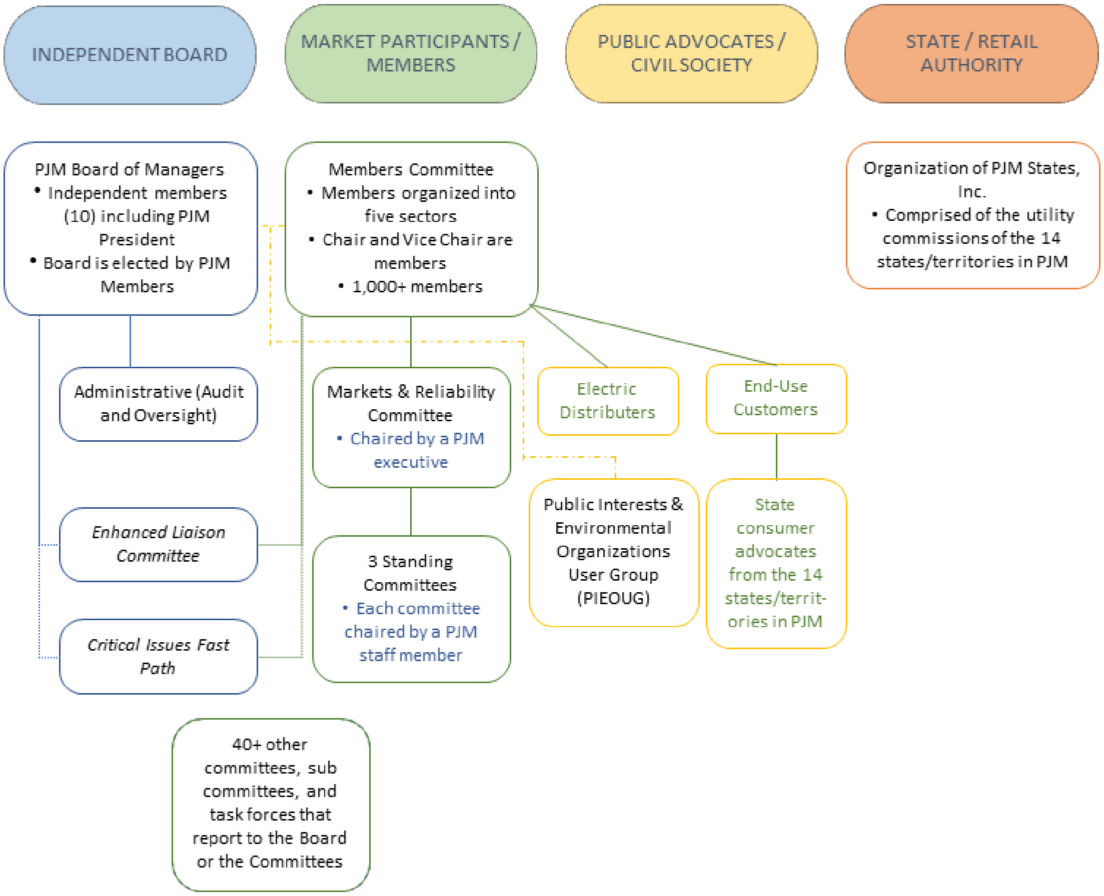

Figure 1-3. The PJM governance structure. The relationships between four governance structure spheres of influence related to PJM are illustrated: PJM's Board of Directors (blue), market participants (green), civil society (gold), and state authority (orange). Solid lines (blue and green) represent direct authority. Alternating dash-dot lines (gold) represent a two-way communication process. Electric distributors and end-use customers comprise two of the five member sectors and are shown in gold; they are able to participate at all committee levels shown in green. The dispute resolution processes are shown in italics.

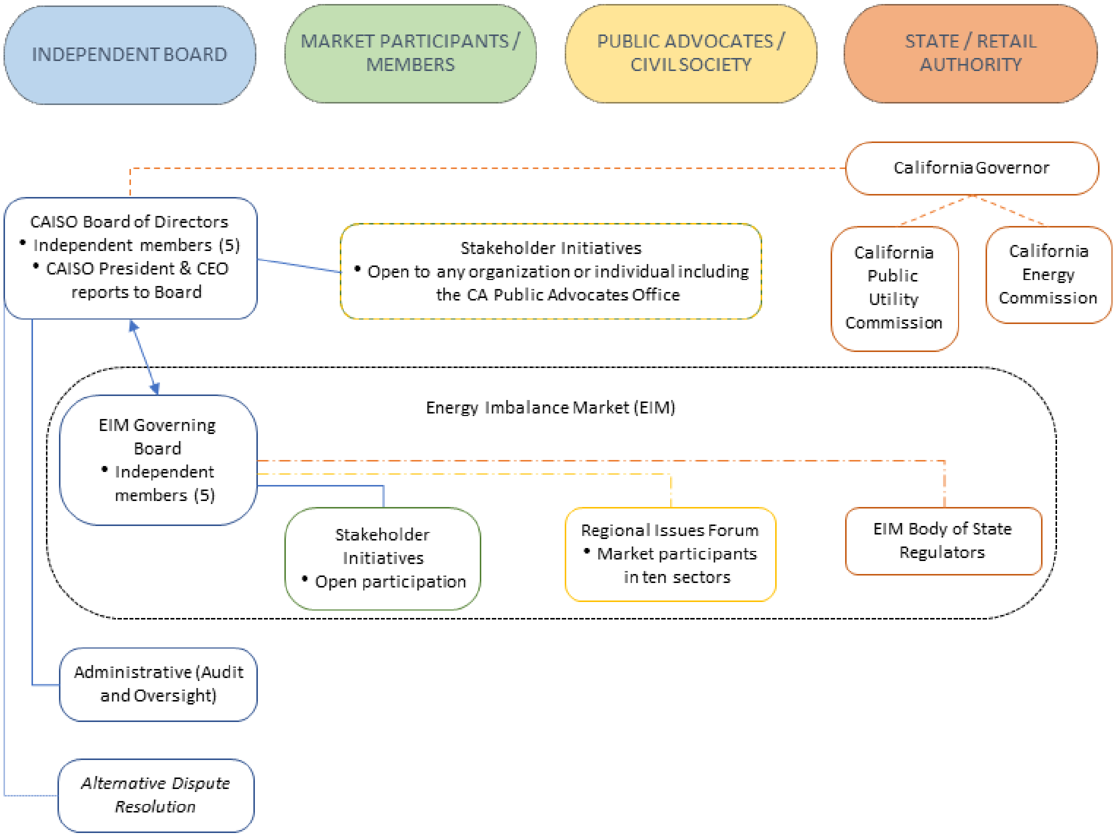

Figure 1-4. The California ISO governance structure. The relationships between four governance structure spheres of influence related to CAISO are illustrated: CAISO's Board of Directors (blue), market participants (green), civil society (gold), and state authority (orange). Solid lines (blue) represent direct authority. Arrows indicate delegated authority; the CAISO Board and the EIM Board share oversight of the Energy Imbalance Market (EIM). The dashed lines (orange) indicate appointment authority. The alternating dash-dot lines (gold and in orange) represent a two-way communication process, as opposed to a decision-making process. The EIM (black) has a separate governance structure from the other CAISO-administered markets. The dispute resolution process is shown in italics.

Most RTOs have shown substantial growth in membership, as shown in Figure 1-5. CAISO is not represented because their organizational structure does not contain a decision-making body comprised of member organizations[1]. While PJM membership has shown extraordinary growth by more than quintupling in 20 years, the other RTOs have shown growth as well. SPP and MISO have more than doubled the number of members in their respective decision-making bodies. ISO-NE and NYISO have also shown growth. The intensity of participation in the stakeholder process of members varies, with some choosing not to participate. Some members have multiple participants. The number of *market participants* (who do not participate in the stakeholder process) in each RTO far outnumber the number of members of each RTO.

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[1] On a related note, CAISO is the only RTO in which members are not responsible for electing their respective boards.

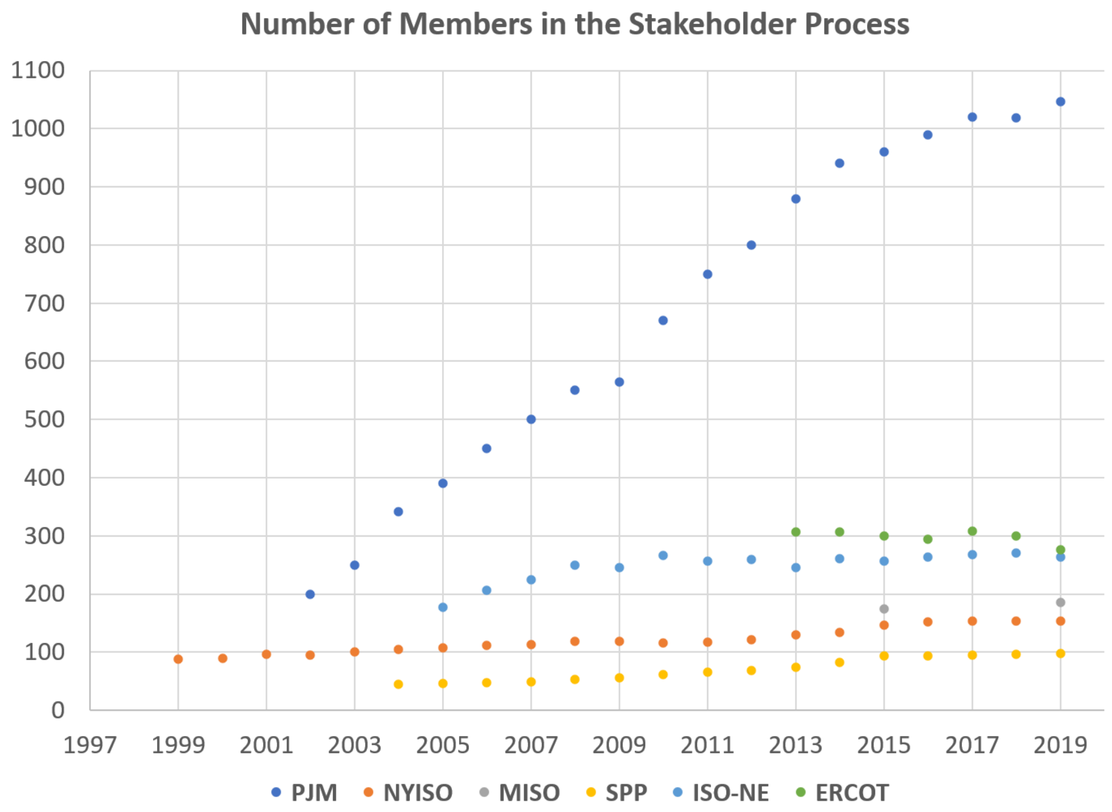

Figure 1-5. The growth in RTO membership. PJM membership data includes full, associate, and ex officio members. NYISO membership data represents both voting and non-voting organizations that belong to the Management Committee. ISO-NE membership data represents members of the Participant's Committee that have voting rights. ERCOT membership data includes both corporate and (non-voting rights) associate members. All SPP members have voting rights. Limited historical data for MISO is available.

3. Methods and Results

While RTO markets have been studied to understand their effect on consumer prices, grid security, renewable energy and distributed energy integration, etc, predicting behavior of RTOs is complicated because the market rules are determined (and modified) by the market participants themselves, as are the processes for determining the rules; the endogenous nature of the rules of the markets means that to learn how RTOs will adapt to current and future policy and regulatory demands the motivation, desires, and behavior of the market rule-makers must be understood. The understanding of how an RTO has overcome challenges previously when market participants (i.e. the rule makers) couldn't initially find consensus on important market decisions and/or had to adapt to changing structural, political and economic environments may be able to shed light on how current and future challenges may be overcome. PJM, as the RTO that has the greatest level of formal stakeholder authority within the decision-making process, the largest electricity market in the world, and one of the two oldest RTOs makes for a particularly compelling case.

This case study aims to determine how both the context for decision making in PJM have evolved, and what tensions have arisen as a result. We suggest that this changing context consists of three interrelated factors. First, there has been a rapidly evolving policy context influencing decisions made about planning and operating the power grid. When first implemented, RTOs were focused on operational issues (real-time reliability and generator adequacy), planning (of transmission lines), and implementing a market for competition amongst generators. State-level RPSs along with federal and state policies aimed at increasing renewable energy and energy storage deployment) have added layers of complexity to RTO decision making. Second, there has also been an explosion in the number of people participating, or at least voting, in the decision-making process, with many of the new participants having narrow financial interests. Third, as RTOs and their markets have matured as institutions there has been a progressive narrowing of the kinds of issues that stakeholders are asked to consider; in particular these increasingly narrow issues tend to produce starkly different economic winners and losers.

The conclusions drawn here will shed insight into the larger discussion of RTO governance by using PJM as a case study to describe the implications of a changing regulatory and market environment and allowing for more analytical work to be done (including Chapter 2).

3.1 PJM's Organizational Structure

The PJM Board of Managers is an independent body that receives recommendations from standing committees of stakeholders representing specific industry sectors. The stakeholder engagement process is structured, with a hierarchy of committees, sector representation, membership requirements, and voting. PJM began as a power pool in 1927, and since 2001 PJM has been North America's largest RTO. As of 2020 it serves 65 million people across thirteen Mid-Atlantic states, with 84,000 miles of transmission lines, 187,000 MW of generating capacity, and annual billings of about $40 billion [15]. Most PJM states have restructured their electric utilities, effectively handing over additional jurisdiction from state utility regulators to federal RTO regulators [16].

PJM has about 1,050 members categorized in five membership sectors: Transmission Owners (52, 5%), Generators (347, 34%), Electricity Distributors (51, 5%), End Use Customers (41, 4%), and Other Suppliers (522, 51%). The Other Suppliers sector is significantly larger than the other sectors and is a highly heterogeneous group including power marketers, financial institutions and municipal and cooperative utilities [17].

Stakeholder-driven decision making at PJM usually involves a multi-layered and highly hierarchical structure (Figure 1-6). For a stakeholder or group to change PJM's rules or protocols they must introduce the change in one of the thematic or issue-specific standing committees, working groups or task forces and then manage it as it is deliberated in the Markets and Reliably Committee (MRC) and the Members Committee (MC) before moving on to the Board of Managers and, if needed, a formal filing with the FERC. Appendix A shows how an issue moves through the stakeholder process beginning with an issue's creation, the development of a problem statement and formal charge, and to voting in the committee bodies on issue resolution.

Figure 1-6. The PJM stakeholder process. Source: Author adaptation from [18].

Voting in the MRC and MC are highly structured and segmented by defined sectoral affiliations [18]. Voting in the subcommittees and working groups is done by a majority vote, and it is possible (and common) for multiple proposals to pass through to the MRC. Voting in the MRC and the MC is done through sector-weighted voting. Each sector receives one vote, which is allocated equally amongst the members of the sector. To pass, a supermajority of the weighted five votes (3.35, i.e. 66.7%) is required. Affiliate members, which are subsidiary companies, are not allowed to vote at the MRC and MC. The number of members in each sector and the percentage of the overall number of companies each sector has is: Transmission Owners (14, 3%), Generators (118, 23%), Electricity Distributors (42, 8%), End Use Customers (20, 4%), and Other Suppliers (325, 63%) [17].

The MC takes on particular importance since this Committee has the authority to over-ride decisions of the Board in some circumstances.[2] It is also possible under certain circumstances for proposals to fail the MRC vote but still go to the MC for a vote if consensus building amongst stakeholders can be done to gain support for a modified proposal. PJM's Independent Market Monitor may make proposals to the MC that did not pass through the stakeholder process.

3.2 Methods

Our case study is generally divided into two quasi-equal timeframes. The first comprises approximately 13 years, from PJM's start as an Independent System Operator in 1997 through an overhaul of the stakeholder process that PJM went through circa 2010 [18], [19]. The second timeframe covers the implementation of a consensus-based decision-making process through current events in 2020. During these two periods PJM had to adapt to significant changes in the external policy environments including state RPSs during the first period and in the second period federal policy focused on addressing climate change (in particular the 2015 Clean Power Plan), the negative externalities of coal generation (e.g. the 2011 Clean Air Interstate Rule and its successor the 2015 Cross-State Air Pollution Rule, the 2012 Mercury and Air Toxics Standards, and 2015 coal ash regulation), and a ramp-up of renewable energy deployment due to the preexisting federal Production Tax Credit and Solar Investment Tax Credit. This renewable energy focus was seen at the state-level as well, with RPSs ramping up and storage mandates being implemented. During this time FERC continued its strong support for natural gas development and ruled for demand-response proponents. This policy mix has created significant pressure on generators to modify their portfolios which is capital intensive and creates economic winners and losers; in just the five-year period of 2013-2017 PJM saw 19% (14.4 GW) of its coal capacity retired while its natural gas capacity by increased by 18% (9.2 GW) [20]. Our data collection was primarily conducted in 2014. This year was also a particularly significant period in PJM's history because tensions within the RTO had increased to a point that an alternative stakeholder engagement approach, the Enhanced Liaison Process, was triggered for the first time [21]. We chose a single case study of PJM for several reasons. PJM is not only one of the two oldest RTOs (along with CAISO) and the largest electricity market in the world, but it has served as the archetype for other RTOs and for deregulated markets globally. A single case study has the advantage of more readily allowing for "deep insights" [22] which are context dependent [23], and a singular focus provides a stronger initial theoretical basis, which can later be tested—in our case, across RTOs [24]. Finally, a single case study allows for the researcher to target a particular audience [25].

To develop the PJM case study, we drew on case study methodology developed by Merriam [26], [27] and [28], [29]. We analyzed data collected through review of public documents, field observations of PJM stakeholder meetings, and semi-structured interviews. We reviewed PJM and FERC documentation on the stakeholder process, including reports, meeting minutes, court cases, presentations, and other materials, all available at the PJM and FERC websites. We attended PJM committee meetings both over the phone and in person including the MC, MRC, and lower-level committee/subcommittee meetings. We went through the in-person stakeholder process training for new members. To help us interpret, contextualize and better understand how the stakeholder process works in practice, we interviewed 21 individuals with experience or expertise related to PJM including

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[2] Sections 205 and 206 of the Federal Power Act give FERC much of their authority over the transmitting and selling of interstate power by the electric power industry and are relevant to utility and RTO documents that are filed with and reviewed by FERC. Documents that are filed to FERC through Section 205 need to show that the submitted changes are "just and reasonable." Documents that are filed through Section 206 must also prove that the current document is "unjust and unreasonable" which may be considerably more difficult to do and thus having Section 205 filing rights is a powerful tool. Uniquely in PJM of all of the RTOs, the Members Committee (MC) has Section 205 filing authority over the Operating Agreement. In a disagreement between the MC and the PJM Board over the Operating Agreement, the PJM Board would have to utilize Section 206 filing rights to try and override the MC [14]. There are two other foundational documents in PJM. The PJM Board has Section 205 filing authority over the Reliability Assurance Agreement. Section 205 filing authority over most of the Open Access Transmission Tariff is split between PJM Board and the PJM transmission owners.

PJM staff, outside experts, and stakeholders such as asset owners, public sector interests, and industry associations during the summer and fall of 2014.

3.3 Interview Protocol

In developing the interview protocol (Appendix B) we sought to reveal differing stakeholder perceptions so that we could understand and address a problem in practice [30]. More specifically, we want to understand the challenges that have arisen from the context changes PJM has faced externally (e.g. a more complex policy environment and a restructuring of electric utility business models) and internally (e.g. a manyfold increase in the number and diversity of PJM members and market participants). Thus, in the interviews we asked stakeholders about transmission planning and the integration of renewable energy, as well as about perceptions and interpretations of their own and other stakeholder interests for participating, and the formal and informal nature of communication within the stakeholder process. This initial information allowed us to fine tune our interview protocol [31] and later respondents were directly asked about the stakeholder process if they had not mentioned the topic previously.

A semi-structured interview format allowed us to engage with the interviewees about the topics and experiences that were most important to them due to differing job responsibilities and ways of engaging in the stakeholder process. Methodologically, we stayed neutral in our interviews and used our questions to probe values and attitudes about how the stakeholder process works in practice including asking "'how' and 'why' questions" [32] (q.v. Appendix B) while looking for a wide range of perspectives (i.e. "dialoguing with a polyphony of voices" [32]).

Participants were chosen through purposeful sampling [33]. We identified initial participants by using recommendations from our research advisory committee. Next, PJM documents of committee meetings were used to identify individuals who were active and experienced in the organization. Here we targeted participants categorically, to get representation amongst all five member categories, PJM staff, and other stakeholders who weren't necessarily members. At the end of each interview we also asked participants if they felt that there was anyone in particular we should talk with.

Eleven of the interviews were conducted in person and ten over the phone ranging from 46 to 95 minutes in length for a total of 1,433 minutes of recorded material. The interviews were professionally transcribed, and the resulting 588 pages were reviewed for errors. Merriam's [26] constructivist reliance on inductive reasoning and interpretation, in contrast with Yin's [25] hypothesis testing, indicate that given our research interest, utilizing grounded theory is appropriate as a primary analysis methodology [34]. The interviews were coded in NVIVO separately by three of the authors. Second-level coding focused on categories such as relationships, power dynamics, parties (i.e. various stakeholder groups), time-dependent changes, and complexity of the stakeholder process. Cultural values, relationships, and power structures are at the heart of RTO organizational behavior, so phronetic analysis is a natural lens to view the results through; the use of power amongst community members differs and is context dependent [30], [32], [35]–[37], so the actions of the PJM stakeholders must be viewed in the context of PJM's specific stakeholder process. We were then able to develop a narrative to explain the challenges of the stakeholder process [32], [38]. Quotes used in this paper are representative of ideas shared by multiple respondents and shown as (PJM-XX).

3.4 Results

Respondents identified challenges with the stakeholder process that we categorized into three factors: (1) The increasingly complex *policy influence* on the decisions that the stakeholder process is asked to make; (2) the narrowing *scope* of decisions and narrowing *interests* of individual stakeholders; and (3) the *internal response* by PJM to tension in the stakeholder process. We now turn to a discussion of each of these three factors.

3.4.1 The Emerging Influence of New Policy Objectives

In the initial years of the PJM RTO, the organizational mission of maintaining electric reliability was highly aligned with the missions of the electric utilities whose transmission responsibilities PJM was assuming. This mission was also familiar to the primary stakeholders participating in developing rules for PJM, and those stakeholders were fewer in number. As one of our interview participants, who worked in the PJM stakeholder process in the early days of the RTO's formation put it, "There were fewer people, so we knew people better" (PJM-01). A separate respondent stated, "You needed significantly smaller rooms to have the meetings. The intensity of disagreements was just as great as today. There were things they never reached agreement on but there was definitely more of a spirit of, 'We're all in this together and we need to make it work,' than there is today" (PJM-02). The interviewees who were involved with the earliest days of PJM RTO expressed some sense of lost comradery that made things seem simpler (even if the issues themselves were complex).

Because the critical mission of the RTO was viewed narrowly in the initial years, many decisions and rules formulated by the RTO had some degree of independence or separability from one another. Proposed policy and rule changes within the RTO did have costs and benefits, and they did create winners and losers, but our interview participants described an environment in which decisions were ultimately made in light of the critical reliability mission, as described by one participant:

> "The nature of the problems in the beginning were isolated. You could work on one area and make a fix and be oblivious to the surrounding areas. As things got more interconnected and interdependent that wasn't working. The nature of the problem-solving got more difficult." (PJM-02)

Some of our interview participants pointed towards a shifting set of responsibilities within the RTO, driven primarily by changes in the policy environment. RTOs were increasingly viewed not only as the keepers of a reliable power grid, but also as market-makers and promoters of economic efficiency (following the issuance of Order 2000); a mechanism to absorb renewable power generation investments to comply with state Renewable Portfolio Standards and federal climate regulation; and the means to accommodate new technologies wanting to participate in electricity markets such as demand response and energy storage. A 2011 FERC ruling, Order 1000, cemented this role of the RTO by mandating that RTO transmission planning processes consider relevant policy factors and expanding the range of technology solutions that can be considered to meet reliability goals [39]. The expansion of RTO responsibilities appears to have had two related impacts on the functioning of the stakeholder process. First, it expanded the size and diversity of PJM's voting membership, as highlighted in Figure 1-5. Second, it created complex interactions between rule changes. This additional complexity has induced reinforcing feedbacks with a change in one set of rules inducing a need for more rules and additional complexity. As put by two stakeholders:

> "It's the complexity of the rules that I think is really throwing a lot of people off…If you got one rule that's designed on how FTRs are funded, there's five or six other things that could affect that FTR under funding. Peeling that onion back has been very difficult. It was simple when we started.... Now, as the years have gone by and we keep on having this plethora of rule changes— because 'oh, we didn't think of that' or 'oh, that's not working.'" (PJM-03)
>
> "Most of the conflicts, within our industry, have, if you think about it, they don't come from the operation of the system. They come from the fact that we have broader public policy goals that aren't enshrined at the federal level…a lot of them are state initiatives, because we have no agreement on what our energy policy should be. Different states have different energy policies… There are a number of states that have encouraged renewable, but there are other states that don't. They have not. They have no interest in encouraging renewables. They don't want to pay for transmission lines that are there to support renewables." (PJM-04)

Much of the broadening of the RTO responsibilities can be attributed to policy initiatives coming from the FERC. Perhaps unintentionally, the cumulative effects of FERC policy over the past two decades – each element of which in isolation may have been sensible and viewed as improving the state of the electric power sector – may have been to create much of the tension in the stakeholder process, ironically affecting the ability of PJM to fill FERC's mandate to be a highly stakeholder-driven organization. Two of our interview participants emphasize the importance of FERC's role in particular:

> "PJM is within their rights—if they wanted to—to make unilateral decisions; a unilateral filing to FERC. They choose not to do that and work through the stakeholder process because they want to be able to go through FERC and basically say, "Hey, here's a new contract that we plan to put in place or we put in our tariff. It was developed through the stakeholder process…we wouldn't be making this filing if it wasn't for the fact that the majority of the stakeholders want us to make this filing." (PJM-05)

> "There was a huge settlement at FERC regarding the capacity markets. That had a, in my opinion, a tremendous impact on governance effectiveness, because FERC basically put the buyers and sellers into opposite teams, and those teams largely transcended the end of the settlement process at FERC. The hard feelings that came along with the FERC experience definitely came back into the stakeholder process." (PJM-02)

3.4.2 *The Narrowing of Issues and Interests*

As PJM has evolved, it has faced a narrowing of issues that the stakeholder process is asked to address. At the same time, the scope of its markets has grown to encompass a large number of new stakeholders beyond the integrated utilities whose service territories make up the physical footprint of PJM. Many of these new stakeholders have narrowly defined business interests that have arisen from the interplay of policy initiatives and technological innovation; examples include curtailment service providers who manage demand response, or financial firms who engage in arbitrage activities involving two or more of PJM's markets. This stands in contrast to the vertically-integrated utilities that comprised PJM's initial membership. Many of these companies were for-profit vertically-integrated businesses, with assets spread across generation, transmission and distribution. At the same time this has been happening, large utilities in deregulated/restructured states have led to the utilities effectively being "unbundled," in the sense of removing vertical integration in favor of outright divestiture of power generation or decoupling the financial interests of the power generation business from those of the distribution business. The combination of narrow decision problems, narrow business interests and an expanding number of participants has made coordination difficult and has created clear financial implications for specific issues. As (PJM-06) said,

> "We probably have [fewer] of the big policy decisions. In the beginning I think there was more policy direction, big ticket decisions of how the industry wanted to move particularly under open access deregulation. The members had a better understanding of getting their arms around that. Maybe because most of them didn't necessarily know how ultimately financially that would impact them. As we matured and the details are getting much more specific…it's less about what necessarily is what's good for the industry. It's much more now just coming out with this either impacts my business or doesn't."

The result was described by our interview participants as "pocketbooking" - voting in response to clearly delineated financial positions. Pocketbooking is a natural response towards the increasingly narrow and technical issues put before the PJM stakeholder process but a number of our respondents reported that it has made compromise and informal collaboration more difficult with one stakeholder putting it thusly:

> "In PJM in particular, much of the infighting about rule changes is on narrow and detailed parts of the rules that naturally, as you winnow down a problem, you have less degrees of freedom to move and less room for compromise… I don't want to diminish the potential for cost impact…the stakes are high—but it just leaves stakeholders with less room to move." (PJM-07)

In other words, stakeholders have become more focused on economic impacts of specific decisions and less focused on the broader reliability mandate that was a cornerstone for vertically integrated utilities. In response, the PJM staff has had to participate in a more active manner to fill the void due to their mandate to maintain reliability. PJM-06 sees it this way: "Part of the issue now is members are not really being held accountable…It's more like I'll just vote 'no' and I don't really need to tell anybody why I'm voting no."

3.4.3 *Internal Reactions to Maintaining the Core Reliability Mission*

In the course of our interviews, many PJM stakeholders described ways in which PJM, through actions by its staff and other initiatives related to policy formation within the RTO, has begun to play a more active role in the stakeholder process. One stakeholder (PJM-08) described how "the perception, always, is that PJM is doing more and more stuff on its own or, let me say, being less flexible in some of the solutions that it's looking for."

Perhaps explaining this perceived shift, we also found a shared perception among PJM staff that the increased difficulty of stakeholder coordination may threaten reliability of the electricity system – viewed within PJM as the primary mission of the RTO.

Another stakeholder pointed out that PJM has always had the right to unilaterally bypass the stakeholder process. "PJM is within their rights—if they wanted to—to make unilateral decisions; a unilateral filing to FERC. They choose not to do that and work through the stakeholder process because they want to be able to go through FERC and basically say, "Hey, here's a new contract that we plan to put in place or we put in our tariff. It was developed through the stakeholder process…we wouldn't be making this filing if it wasn't for the fact that the majority of the stakeholders want us to make this filing" (PJM-05).

While PJM and other RTOs have, on the surface, a highly complex mission to maintain the reliability of the electric grid, accommodate new technologies driven by public policy, promote efficiency where possible through the use of market mechanisms, and to make decisions in a stakeholder-driven way, it is the first of these (electric reliability) that tends to be internally prioritized within the RTO. As one customer-side stakeholder put it,

> "I think they have to because they have certain absolute responsibilities, and I think that there are some things that are entirely within PJM's purview. It's their responsibility. The reliability stuff is theirs, and they can't not perform that function because stakeholders can't agree on how to move forward." (PJM-08)

This view was echoed by a state regulator: "Reliability really is the fundamental reason that the [PJM] board will [go over stakeholder heads]—if they can't get a stakeholder consensus, will go forward [to the FERC] with something" (PJM-04). If policy changes relevant to electric reliability are contentious, then a tension is created between this critical mission of the RTO (and the focus of the PJM staff) to keep the grid functioning and the desire to drive stakeholder groups to consensus.

Discussions of this tension among our interview participants revealed some willingness to defer to the expertise of PJM's staff, its market monitor and ultimately to the FERC. This deference appears to cut across sectoral or other interest lines among the PJM stakeholders. Ultimately, the increasingly active role taken by PJM, according to the perceptions of our interview participants, may not simply be necessary but also welcome. Some stakeholder comments reflected the view that PJM management or the board will recognize sub-optimal actions taken by the stakeholder process and will take steps to correct those sub-optimal actions. One board member explained that members rely on PJM management and the Board to balance conflicting interests and that members have stated:

> "We have to vote this way because we represent our members and this is their interest, but in the end, we know that the PJM management and the board will do the right thing, even if we vote for what they know in their hearts is the wrong thing." (PJM-09)

Some control has been ceded to PJM's Independent Market Monitor (IMM), who has in some cases been viewed as a safety valve. Some issues take a great deal of time to understand the long-term ramifications of. One respondent told us,

> "…just below the surface [of some stakeholder issues] is a very significant conflict. Sometimes it's only all supposing things because people don't have the time or the energy to deal with all of it. People just let things go… [and] voted in favor of things which are clearly against their own interest…and said, 'We know [the market monitor will] take care of it if anything comes up.'" (PJM-10)

Two outcomes of this deference to PJM and the IMM are the removal of check and balances of the voting structure process and a weaker filing to FERC, which is turn is less incentivized to accept the proposed filing.

4 Discussion

Our interviews with PJM stakeholders and staff have pointed to three factors that have driven the functioning of the stakeholder process in PJM: *the emerging influence of policy, the narrowing of issues and interests, and internal reactions to maintaining the core reliability mission*. Here we illustrate the relevance of these factors for specific issue, the design of PJM's "capacity market." The capacity market is important for PJM because it is one of the chief mechanisms that PJM uses to ensure adequate future electricity supply. It has also been a highly contentious issue for over a decade.

The capacity market is a mechanism used to ensure that the RTO will have enough power generation capacity to meet future peak electricity demand, plus some extra capacity for reserve. This is known as "resource adequacy." Traditionally, vertically integrated utilities maintained resource adequacy based on central planning under state regulation and held individual reserves.[3] Capacity agreements have been in place in PJM since its days as a power pool with an informal market existing between vertically integrated utilities in which those short on their resource adequacy requirement could purchase annual temporary capacity from those with a surplus. In the late 1990s this caused a conflict between PJM's newly created energy markets and newly created state retail markets, and in 1999 a daily capacity market opened to facilitate purchases and sales of surplus capacity among utilities within the PJM footprint. As PJM integrated new territory in the early and mid 2000s, transmission capacity constraints, a shortfall in revenue for peaking plants, and a reduction in investment in new generation facilities threatened resource adequacy in PJM. In 2007 PJM implemented a new capacity market called the Reliability Pricing Model (RPM) [40], [41].

The RPM is a three-year forward market designed to ensure forward price signals in an industry where large-scale capacity development can take ten years or longer. Between 2007 and 2014 the RPM was repeatedly adjusted and fine-tuned[41], [42]. One of the fundamental problems with it is that the demand curve for new generation is highly inelastic, and so a small adjustment to it shifts the market-clearing price, incentivizing PJM to move cautiously in changes to it. Yet, the demand curve is necessarily modeled on simulated demand, with forecasts showing demand increases while actual demand remained flat or was even negative year to year [43]. This contributed to what some feel are excess payments for excess capacity.

One interviewee used the following analogy to explain the capacity market:

> "I had a pitcher of water and an empty glass. I said, now, if I am thirsty, and I just want to fill this glass with water, I can empty that pitcher into the glass. Alternatively, I can turn on the sprinklers and fill up the entire auditorium with three inches of water. Hopefully, it would include the three inches I want to put into my glass. That is sort of the capacity market. The money is coming down from the sprinklers and filling everybody, paying all these guys down here." (PJM-11)

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[3] Under restructuring, many utilities no longer need to hold reserves, thus (from an economic point of view) removing their shared commitment to reliability.

Within this context, we examine the tensions that have contributed to the stalemate in resolving stakeholder positions on the PJM capacity market.

First, multiple policy drivers external to PJM affect the PJM capacity market. These are largely state-led and mostly related to environmental policy. When PJM's electricity markets first opened in 1997, none of the states in its footprint had an RPS [44]. Today all states within PJM (and DC) have some variation of an RPS, except for Kentucky and West Virginia [45]. In 2011 two states attempted to subsidized new generation specifically to affect capacity market prices, according to the market monitor [40]. More recently, states have begun subsidizing existing nuclear plants from 2016 on [46], [47]. PJM is now needing to determine how the carbon pricing will affect PJM markets, and in 2019 enacted a new senior task force to address the questions [48].

Second, the narrowing of issues and interests has been particularly clear within the capacity market. Because the capacity market is set up to allow RTOs to meet regulatory requirements with respect to resource adequacy, price outcomes in capacity markets can be driven by the administrative rules determined through the stakeholder process. Generators naturally benefit from rules that support higher capacity prices, and customer-side interests benefit from lower prices, and stakeholder behavior in capacity market deliberations has reflected this. One longtime PJM member stated,

> "How do you even allocate the costs between the energy market and the capacity market? What are the things that we should be pricing into the energy market versus the capacity market? … We're not, as a stakeholder community, sort of reconciling all of those pieces together. We're looking at individual silos of issues." (PJM-12)

Stakeholders with clear financial stakes in capacity market outcomes have focused on the implications of these administrative capacity market rules rather than thinking systematically about how capacity markets support larger regulatory goals or interact with other aspects of PJM's power grid operations. The narrowing of interests can also be seen in the results of MC votes since 2014, where there is strong evidence of bloc voting [3], [11].

Third, PJM's response to these stressors has been to take a more active role in market development by making unilateral decisions, relying on alternative processes or looking to FERC for solutions. Because capacity markets have been controversial the financial stakes have been high, the PJM stakeholder process has exhibited repeated difficulties in supporting decisions on capacity market rules. The stakeholder process has not able to move forward a set of administrative rules for the capacity market since 2011. On three separate occasions (2011, 2014 and 2018) stakeholders rejected every set of capacity market rules put before them, with supply-side interests voting down proposals that would tend to depress prices and customer-side interests voting down proposals that would tend to increase prices. In each of these cases, PJM responded to the stalemate in the stakeholder process. In 2011, after stakeholders voted down every set of capacity market rule changes (including a proposal to make no changes to the rules at all), the PJM Board selected the set of rules most preferred by PJM staff. In 2014, the PJM Board triggered an alternative mechanism for stakeholder engagement rather than take unilateral action. This alternative stakeholder mechanism, known as the Enhanced Liaison Committee, involves stakeholders forming organic coalitions that present proposals directly to the Board. The Board ultimately makes the decision (and in this case files the changes with FERC). In 2018, PJM asked FERC to convene a settlement process rather than prolong fundamental disagreements among stakeholders.

The capacity market serves as a useful example of how a changing policy environment and evolving focus of stakeholder interests have jointly introduced tensions into PJM's stakeholder process, affecting its ability to move issues forward. The internal responses of the PJM Board to these tensions illustrate a more fundamental regulatory tension in the design of RTOs themselves. FERC has endowed RTOs with a fundamental mission to maintain a reliable power grid, and ensuring resource adequacy is a core aspect of that mission. FERC has also sought to ensure a prominent role for stakeholder-driven decision making within RTOs, and in PJM that has resulted in a particularly high level of formal authority within the stakeholder group. When these design goals for RTOs have clashed, as they have repeatedly in the case of PJM's capacity market, the organizational response by

PJM has been to support the reliability mission in ways that reveal the organization's preferences [3], [11]. These responses – which constitute backstop mechanisms for organizational decision-making – represent a valid part of RTO stakeholder responses whose structure and function have received relatively little attention in the emerging RTO governance literature e,g [1], [3], [11], [16], [19], [49]–[51].

This issue persists. In 2018 PJM conducted a poll—of which 1/5 of PJM members responded to—that asked questions about the goals of PJM's stakeholder process, it's effectiveness for responding to reliability issues and market issues, workload for stakeholder process participants, the perceived role of PJM staff and management in the process, and perceptions of communication lines amongst members, the PJM staff and management, and the Board [52]. There were at least 11 stakeholder comments that suggested there are concerns that PJM pushes its own solutions. Representative comments include "Staff does an excellent job at facilitation. However PJM lately seems to have their minds made up on the solution before stakeholders begin deliberations," "[PJM should] work with stakeholders to develop solutions rather than provide a PJM solution without input from stakeholders," and "After a year and a half of discussions, it was disheartening to see PJM move forward with two proposals, neither of which garnered stakeholder approval, and then ask FERC to convene a settlement process in lieu of resuming the stakeholder process" [53].

That being said, it is worth noting that even here the stakeholders don't agree, and several comments expressed satisfaction with PJM's role in the process. One member commented, "The current decision-making process at PJM is very good. When consensus is not reached within the stakeholder process, the PJM Board of Managers have the authority to determine if change is needed and what is best for the market" [53].

One outcome of the survey was the 2019 development of a stakeholder processes called The Critical Issues Fast Path. Like the ELC, this process is intended to be used only rarely and for particularly important and contentious issues. This companion to the ELC acts as a hybrid model of decision-making by giving PJM more control over the timeline and solution proposal than it would otherwise have, but still allows members to vote on PJM's solution and any proposed alternative solutions. One benefit to this model is that it provides more evidence for an eventual FERC filing by Members or the Board [54].

5. Conclusion

Regional Transmission Organizations are highly complex organizations that will continue to be critical focal points for electricity policy implementation in North America. These complex organizations have been evolving in ways that reflect the complexity of industry feedbacks induced by policy change. State and federal policies have opened the doors to new types of participants in RTO markets, and in an effort to accommodate these new participants (whose business models tend to be highly focused) RTOs have allowed their missions to broaden. These broader missions have, in turn, induced organizational stresses that has been reflected in tensions arising within stakeholder-driven decision processes.

The early stakeholders in the PJM RTO shared a collective set of organizational goals focused around power grid reliability. These goals emerged both from the national regulatory environment and from PJM's prior incarnation as a multi-utility power pool. Interviewees agree that PJM's original operational mission has evolved into being the focal point for implementation of a wide variety of energy and environmental policies. This is not limited to federal policy initiatives but also includes state policies that support both renewable power supplies (through renewable portfolio standards, tax credits, or other means) and other new technologies (through permissive policies for demand response, distributed power generation and energy storage).

As our interview participants reported, PJM has needed to adapt to new policies and technologies by enlarging its traditional membership. While reliability still plays an important role, other priorities like market efficiency and integration of new technologies are being embedded in PJM planning, markets and operations, increasing the complexity of systems for stakeholders to negotiate. Operational decisions now incorporate both reliability-driven rules and a more heterogeneous set of priorities.

This is not to say that reliability is not important; PJM staff continue to ensure that system reliability is maintained and they are perceived to take an active role in the stakeholder process. The PJM stakeholders we interviewed generally expressed the belief that PJM's increased role in the stakeholder process represented a series of evolutionary steps in response to the changing industry and regulatory environment. This evolution is important in that it highlights tensions between differing views of PJM as an organization. On the one hand, the internal culture of PJM (and among some original PJM's stakeholder members) still appears to view PJM as operating, with a clearly-defined mission and deference towards expertise consistent with that mission. On the other hand, PJM's mission has expanded and more diverse stakeholders view PJM as a forum to further and negotiate their own interests. A smaller group of stakeholders gave great consideration to how proposed rule changes would affect the spectrum of tools available to system operators for keeping the grid reliable and stable; the rule changes were proposed, debated and enacted by a well-defined group of professionals with extensive experience in the regulated electric utility world, which had shared the same deference towards reliability considerations.

The broadening stakeholder positions, the more defined business interests, and the evolution of demands on PJM, have made reaching decisions on some issues within PJM much more difficult. Despite these challenges, we perceived a belief in the system among some participants that have been active for many years. One stakeholder commented,

> "It's not [any longer] the Wild West, where we just have to throw up a market design, and hope that it works, and then tweak it over the years, as we've done. I think things used to be easier to get through, meaning we didn't have to go through all this process, and if we had the votes, we could just trample on everybody. There [now] may be some frustration with that because that isn't any longer the case. There's a fairly onerous process in place, and sometimes it is too onerous for its own good. Other times it gives us all time to stop, and think, and usually, I think, work out a better solution." (PJM-08)

There are still few comparative studies across RTOs and there is a critical need for social science research on stakeholder engagement in electricity system governance and on the dimensions of institutional design that affect stakeholder engagement and democratic accountability; PJM is not the only RTO learning how to accommodate a growing set of state and federal mandates related to renewable power resources, new technologies, and environmental and climate policy—and the accompanying increase in market complexity. We next plan to explore how contexts are changing in RTOs other than PJM, how other RTOs are adjusting their stakeholder processes to address these context changes, and what specific mechanisms are being used to address stakeholder conflict.

CHAPTER 2

AN ANALYSIS OF VOTING NETWORKS IN ISO-NE, NYISO, AND PJM

1. Introduction

Regional Transmission Organizations (RTOs) are central hubs for operating much of the US electric grid, ensuring reliability, developing and implementing electricity markets, and conducting transmission planning [10], [41], [55], [56]. At the same time, RTO's are needing to respond to increasing complexities driven by public policy, new technologies, and large numbers of stakeholders, as discussed in Chapter 1. While RTOs are often considered as monolithic entities in the consideration of their implementation of operations, market rules, and planning processes, in reality they are complex systems of their own, with a wide range of stakeholders both designing and participating in many of the core functions of the RTOs—including markets—as well as designing and modifying the stakeholder processes themselves.[4] To better understand the nature of the stakeholders that operate within RTOs, we use a dataset of votes taken at the top-level of the stakeholder committees for the three RTOs in the northeastern United States to conduct a network analysis of voting structures. (Together, the three RTOs cover 30% of the US's population and operate in 20 states plus DC.) Specifically, we ask the following three questions:

1. Can we identify specific constituencies in the RTO voting networks? If so, how does the structure of the voting network relate to the distribution of political power within a given RTO stakeholder process?
2. Do different constituencies form around different issues in the network? More specifically, we examine votes on capacity market issues and examine whether the communities within these voting networks are similar to the voting networks for all other issues.
3. How stable are the constituencies over time? Here we examine changes to the found communities in all three RTOs and also look specifically for stability in ISO-NE's capacity market voting networks[5].

In Section 2 we provide background about the history and function of RTOs and their stakeholder processes and review the relevant literature about RTO governance and voting network analysis. In Section 3 we detail how we processed the data set, describe our approach to modularity maximization, and give the metrics we use to analyze our results before answering our research questions in Section 4 and providing a conclusion in Section 5 that indicates possible directions for future work.

2. Background

Throughout much of the 1900s electric utilities were governed by government-granted monopolies [57], [58]. In 1999 FERC advocated for all utilities to join RTOs to address the increasing complexity of interstate electricity transmission and decrease wholesale electricity market costs and thus costs to consumers [10], [16]. This following several previous FERC orders on the same topic [59], [60] and related Congressional steps, particularly those that that introduced a limited amount of competitive generation, notably 1978's Public Utility Regulatory Policy Act and the Energy Policy Act of 1992 [61].

The main functions of RTOs are to coordinate electricity markets, economically optimize the dispatch of generation, ensure reliability across timescales (i.e. from minute-to minute balancing of supply and load on the grid to long-term planning of transmission and generation capacity) [10], [41], [55], [56]. RTOs are intended to be stakeholder-driven organizations and have independence from market participants [10]. Since their formation, the environment RTO's operate has become increasingly complex driven by the need to incorporate public policy mandates [1], [5], [62]–[65] and environmental interests, carbon pricing [66], [67], a shift in generation type

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[4] Here we focus on the role that RTO members/participants/stakeholders play and ignore the role of the RTO Board and staff as stakeholders, although in practice they wear multiple hats including content experts, backstop reliability assurers, neutral stakeholder process operators, and consensus drivers, as discussed in Chapter 1.

[5] NYISO and PJM don't have enough capacity market votes to allow for this particular analysis.

towards natural gas and renewables [68]–[70], integration of new technologies and markets [71]–[73], and the increasing interconnectedness of traditionally siloed areas of regulation [68], [74], [75]. Chapter 1 provides more details. A map of RTO territories is shown in Figure 1-1.

Because of the stakeholder-driven mandate of RTO governance, there has not been a one-size fits all model to RTO governance structure [2], [49], [76]. [49] proposes that, broadly speaking, RTOs can be divided into three categories of structures based on the relationship between boards and members: shared governance, advisory-only, and governor-appointed boards. PJM retains some Section 205 filing rights with FERC [14] while the NYSIO board and management committee must jointly agree on 205 filings [49], [77].[6] ISO-NE, MISO, and SPP are structured similarly to PJM and NYISO in having a hierarchical grouping of formal committees with a voting process, but voting results are considered advisory to the board.[7]. CAISO's board of governors is appointed by the governor of California and the stakeholder process contains no formal committees nor has sector representation with voting [1]. The Electric Reliability Council of Texas (ERCOT) falls into a fourth and unique category. While filling many of the RTO functions, ERCOT does not engage in regular interstate electricity transmission so that FERC has no official jurisdiction over it [79]. ERCOT is overseen by the state public utility commission (and state legislature) and has a board comprised of a mix of members, sector representatives, and state-appointed officials [80]. [81] gives a comparison of the RTO structures as well as the relationships, responsibilities, rights, and practices of each stakeholder category.

Governance issues of RTOs have been raised since their development, with early focuses being on the market rules of RTOs (particularly in light of the 2000-2001 energy crisis in California--with at least two economists defending Enron's role in CAISO's collapse [82]—and the 2003 blackout in the Northeast [83]) as well as to the question of whether or not RTOs provide economic value [84]–[86]. In 2007 two US senators asked the US GAO to "investigate RTO and ISO costs, structure, processes, and operations" [76]. At the same time, Dworkin and Goldwater [16] began investigating the governance structure of RTOs. Using ISO-NE as a case study, they examined governance-related concerns such as the balance between representing the interests of market participants and the public, board structures and selection process, RTO self-interest, the role and effectiveness of independent market monitors and other mechanisms for RTO accountability. [87] examined RTOs from the perspective of principle agent theory.

More recently, Simeone has examined the causes of tensions within PJM's stakeholder process [51]. [4], [11] have examined the formation of coalitions within PJM's stakeholder process and how the processes for determining market rules effects the rules themselves. As discussed in Section 3, capacity markets have been the most-voted on issue in each of ISO-NE, NYISO, and PJM over the past decade and remain a contentious issue.[8]

Simeone [92] has examined how FERC has responded to these challenges within PJM and proposed two new principles that should guide FERC in addressing all RTOs. Lenhart has compared RTO organizational structure from the perspective of the RTO board, market participants/members, public advocates and civil society, and state authorities [2].

Scientific analysis of voting data has a long history, such as utilizing correlational techniques (e.g. quasi-regression analysis) to determine explanatory factors of Iowa voters in the 1932 and 1936 US presidential election [93] and examining bloc voting patterns in the UN General Assembly in the 1940s and 1950s e.g. [94], [95]. The recent development of network analysis as a field [96]–[98], along with computational techniques and processing power, has allowed for much deeper analysis into voting behavior. Studies of the US House of Representatives have been done to determine community detection, party cohesion, polarization, stability of these metrics over time [99], [100], to examine the politics of committee assignments based on the network properties [101], and as a

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[6] Transmission owners in all RTOs retain some Section 205 rights pertaining to the use of their facilities [16].

[7] However, ISO-NE has a provision that requires that in the RTO's Section 205 filings on market changes it must include an alternate Participants Committee proposal if at least 60% of the Committee agrees with the alternative [78]. This is known as the jump ball provision/filing/privileges.

[8] For discussions of past and current issues with capacity markets see: [4], [40], [46], [88]–[91].

tool for signed networks [102], including quantifying and ranking polarization [103]. Network analysis has been applied to multi-party systems such as Brazil's Congress (which had 29 parties in the lower Congressional House in 2019). One novel analysis predicted political corruption within its Congress based on voting patterns with a 90% success rate [104] while [105] and [106] have conducted dynamic analyses of coalition stability.

In 2018 Yoo and Blumsack [11] modeled the role of potential swing voters in PJM's Members Committee by using a series of votes PJM members took about proposed changes to its capacity market. They examined how modifications to the stakeholder voting process (such as changing the voting threshold needed for a proposal to pass) would affect voting outcomes. This model extends naturally to the other RTOs in the northeast due to similarities in their voting process and further analysis was done in 2020 to incorporate NYISO [4]. Yoo and Blumsack [3] also used network analysis to examine voting patterns in PJM, specifically looking for communities in "yes" and "no" vote networks—finding that the demand-side members (Electric Distributers and End-Use Customers) formed a formidable voting bloc in both, whereas the Generation and Transmission sectors showed a preference for voting together but not nearly as strongly as the Electric Distributers and End-Use Customers did.

Capacity markets have been the most-voted on issue in ISO-NE, NYISO, and PJM over the last decade [107]. Using projected future demand for electricity, capacity markets provide payments for generators to commit to providing generation in future years. In theory this provides the market signals well ahead of time for when additional capacity needs to be built, which is important because of the time lag it takes to invest, design, and construct power generation facilities [42]. However, capacity markets have proved controversial in implementation due to costs; the very clear market economic gains and losses from specific market designs make it difficult for RTO members to find agreement on the market features. Even small tweaks to the market designs can significantly encourage or discourage specific fuel sources and undermine state climate goals [46], [64], and criticisms have been leveled at capacity markets for effectively being an expensive wealth transfer from consumers to existing generators [108], [109].[9] Further complicating the picture in recent years has been FERC's strong preference for certain components of market design in addressing state subsidies for renewables. This work builds off these previous analyses by examining a fuller range of networks in each aforementioned RTO—including the separation of capacity market votes from other votes—as well as by looking for community stability over time and—in ISO-NE—within specific issues within the capacity market itself.

3. Methods

The analysis draws on a voting database developed by [107] of participant votes in ISO-NE, NYSIO, and PJM. Table 2-1 shows some key statistics for PJM, NYISO, and ISO-NE. Together these three RTOs cover 30% of the US population and parts or all of 20 states plus D.C. These three RTOs have somewhat similar organizational structures and processes for addressing members' issues. All three use a hierarchical committee structure in which issues are moved upward through committees before a sector-weighted vote is taken at the top-level committee. The voting data consists of all votes taken at the respective top-level committee for each RTO for the timeframes indicated below.

There were 102 votes taken by ISO-NE[10] participants from 2013 – 2019 (inclusive), 36 votes taken by NYISO members from 2010 – 2018, and 46 votes taken by members in PJM from 2010-2019. Issues were categorized by topic. Multiple votes on the same proposal were counted as separate votes. Participants were classified by sector from the voting data. In the very rare cases companies changed sectors, the most recent sector identifier was used. Participants were further classified by generation capacity (zero, small, medium, large), load server, and transmission capacity (zero, small medium, and large) based on 2018 Form EIA 860, Form EIA 861 data [107].

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[9] For instance, PJM's most recent capacity market clearance price—one of the lowest ever, and 36% of last year's price—provides generators with a minimum of $18,250 per annual MW of committed capacity [43]. In 2018 the capacity market cost was responsible 20% of the cost of wholesale electricity in PJM [46]. Prices in NYISO and ISO-NE are comparable [110], [111].

[10] Technically, the voters are part of the New England Power Pool—known as NEPOOL—which in turn is represented in ISO-NE by the Participant's Committee.

Table 2-1. Key statistics of PJM, NYISO, and ISO-NE. Source: [112]–[115]

RTO	**Members**	**Generation Capacity (MW)**	**Peak Demand (MW)**	**Transmission Lines (miles)**	**Annual Energy (GWh)**	**Annual Billing ($ billions)**	**Territory (sq miles)**	**Population Served**
NE-ISO	500	31,000	28,000	9,000	119,000	7.6	72,000	15,000,000
NYISO	434	38,000	34,000	11,000	156,000	5.3	55,000	20,000,000
PJM	1,038	185,000	165,000	85,000	757,000	33.6	369,000	65,000,000

A voting network shows the relationships between members of assembly based on how they vote. In our networks the nodes (alternatively called vertices) represent companies and the edges (alternatively called links and branches) between nodes represent the frequency of voting the same way. The weighting of the network is represented mathematically as:

$$A_{ij} = w_{ij} \tag{2-1}$$

where A is the network's adjacency matrix and w is the weight of the vote. For each of our networks w is normalized linearly such that $0 \leq w \leq 1$ where $w = 1$ for the two (or more) companies that voted together the most for any given network and $w = 0$ for companies that never voted together. Non-votes and abstensions were discarded in each network. In ISO-NE, one transmission company has two subsidiaries which sometimes split their vote, so each subsidiary was treated as a separate company. For clarity's sake, one provisional member was removed. (The provisional member is in a sector awarded 1% of the sector-weighted vote if it is populated with five or more members.) In PJM there were several companies that changed their name over the timeframe of the study—in these cases the voting records were combined into a single voter under the newest company name.

There are a several popular schemes for community detection in networks and a variety of algorithms to implement them [97], [98], [116]. We chose modularity maximization specifically because we want to identify actors in a voting network that tend to vote in alignment with each other. We use the Leiden algorithm [117], an updated version of the popular Louvain algorithm [118], a greedy algorithm that maximizes the modularity by first assigning each node to be a community and then combining neighboring communities in any instances where local modularity will be increased. Once the local modularity values have been maximized, each multi-node community has internal edges removed so that it becomes a single node that preserves edge weight with neighboring communities. These two steps are repeated iteratively until the global modularity value cannot be increased further. The Leiden algorithm refines the process by preserving information about previous partitions so that in some cases nodes may be moved to a different community. Modularity [119] can be described for a weighted network [120] as:

$$Q = \frac{1}{2m}\sum_{ij}\left[A_{ij} - \gamma\frac{k_i k_j}{2m}\right]\delta(c_i, c_j) \tag{2-2}$$

where Q is the modularity, A is the adjacency matrix, k_i is the degree of node i, c_i is the community in which node i is assigned, m is the number of edges, δ represents the Kronecker delta function, and γ is a resolution parameter [120], [121]. This formation of the equation is the most common, although there are equivalent versions [122], [123]. Maximizing Q shows how many communities there are and what nodes below to each. Gephi was used to implement the Leiden algorithm and to produce the visual layout.

Three well-known issues to address in community detection are 1) the resolution limit of the community sizes [97], [98], [124]–[128], 2) the possibility that modularity maximizing algorithm finds a local instead of global maximum [97], [98], 3) and the possibility that the communities found aren't real, i.e. that the network happens to have random communities in it [129].

1. [126] states that communities with less edge weight than $(2W\varepsilon)^{.05} - \varepsilon$ will fail to be resolved where W is the sum of the weighted links and epsilon is the maximum weight of an inter-community edge (where $0 < \varepsilon \leq 1$). Let w[11] be the number of edges in that community. The value of W and ε for the ISO-NE network of all votes where W = 1,661 and ε = 1 (i.e. two companies voted the same way on every vote) and thus and thus the minimum intra-community edge weight for community is w = 58, which is 3.5% of the total edge weight. The minimum community size for PJM's network of all votes (W = 2,390) is w = 70 (which is 3.0% of the total edge weight) and for NYISO's network of all votes (W = 503) is w = 32 (which is 6.3% of the total edge weight). These values suggest a maximum number of communities we can resolve (although the number of communities we find is much smaller).[12]
2. Modularity maximization algorithms may find local maximums instead of the global maximum because some networks have a high modularity plateau, where rearranging subgraph clusters could change the modularity by much less than 1% [97]. We address this by—for each network—running the Leiden algorithm 10,000 times while randomly seeding the starting node communities each time and choosing the network with the highest modularity of the 10,000.
3. Randomly wired networks cannot have an inherent community structure [97]. However, [129] show that it is possible for community-detecting algorithms to (mistakenly) find community structure. Here we address this issue by choosing a well-benchmarked algorithm [117] (although to the authors' knowledge the algorithm has yet to be tested against a random network.) At the end of the day, human judgement remains important in community detection, in that the researcher(s) need to use some judgement (including determining whether to include sub-communities in a hierarchical network) and we know that the voting network is not random because votes are cast based on incentives.

There are many metrics for comparing communities. In Tables 2-2 through 2-4 we report seven common metrics [129], [134], [135]. Two of them (average internal strength and internal weight density) measure internal connectedness of the community, two of them (average external strength and external weight density—aka cut ratio) measure how connected the community is with the rest of the network, and three of them (average strength, weighted conductance, and separability) are combined metrics, with both weighted conductance and separability measuring the internal connectivity against the external connectivity of the same community; weighted conductance provides an intuitive "surface area to volume" measurement [136] of the community whereas separability provides an intuitive measurement based on its namesake. The equations for the metrics are:

- Average Internal Strength k_c^{int}/n_c
- Internal Weight Density $k_c^{int}/n_c(n_c - 1)$
- Average External Strength k_c^{ext}/n_c
- External Weight Density (Cut Ratio) $k_c^{int}/n_c(n - n_c)$
- Average Strength k_c/n_c
- Weighted Conductance k_c^{ext}/k_c
- Separability k_c^{int}/k_c^{ext}

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[11] The value of w is equivalent to the value of m in Equation 2-2. In the explanations of [120] and [126] I have preserved the well-known original notation.

[12] Related to resolution limit issue is a fourth community detection issue. Some modularity maximization algorithms artificially force there to be too few communities whereas others split off individual nodes and provide too many communities [128], [130]. As [131] state, "In realistic networks where edges are heterogeneously distributed within different communities, however, there may not be a single resolution parameter γ sufficient to avoid the resolution limit anomaly [124], [132]. As a result, small well-formed communities are likely to be merged into inappropriate large groups, while large well-formed communities spread across smaller ones." Incidentally, the well-known Constant-Potts algorithm [133] exhibits the node splitting-off behavior with the RTO voting networks.

where k_c is the degree of the community, n_c is the number of nodes in the community, n is the number of nodes in the network, and *int* and *ext* refer to whether the vertices in community c are connecting to internal or external nodes respectively.

Of particular importance to our analysis is the average internal weight density which measures how tightly bound a community is and the separability which expresses how apart from the network a community is. In our network a community's density indicates how strong of an identity the community has (such as bloc voting) whereas the separability indicates how far apart the community is from the other community(s). We can use a 2x2 matrix model (Figure 2-1) to intuit how these two metrics relate to each other.

		Separability	
		Low	High
Density	Low	Weak community identity, strong intercommunity agreement (e.g. random voting)	Weak community identity, weak intercommunity agreement (e.g. votes about multiple mututally exclusive proposals)
	High	Strong community identity, strong intercommunity agreement (e.g. bipartisan Congressional votes such as the "Honoring Hometown Heros Act")	Strong community identity, weak intercommunity issue agreement (e.g votes about hot button issues such as immigration, taxes, and gun rights)

Figure 2-1. The relationship of network metrics density and separability in a voting network.

We also report Q (Equation 2-2) as a matter of record, although it is context dependent and there are numerous variations which can be applied [125], [128].

To compare network stability over time, we turn our attention to pair counting. Consider a network that has been divided into communities in two different ways: subset *C* and subset *C'*. Now consider a pair of nodes. The two nodes could be in the same community in both *C* and *C'*, the pair of nodes could be in different communities in *C* and *C'*, the pair of nodes could be in the same community in *C* but not in *C'*, and the pair of nodes could be in different communities in *C* but not in *C'*. This pair counting approach has given rise to numerous popular indexes. We use the (unadjusted) Rand index [137] which has the form:

$$R(C, C') = \frac{(N_{11} + N_{00})}{\frac{n(n-1)}{2}} \tag{2-3}$$

where N_{11} represents a pair of nodes that are in in the same community in both *C* and *C'*, N_{00} represents a pair of nodes that are in different communities in *C* and different communities *C'*, and *N* represents the total number of nodes in the network. Note that the denominator represents all possible pairings of nodes and that the number of communities in *C* and *C'* don't need to be identical. $R = 1$ indicates subsets *C* and *C'* are identical while $R = 0$ indicates subsets *C* and *C'* have no common pairs in their respective communities. Random networks have an average value of $R = 0.5$.

4. Results

Figures 2-3 through 2-5 show the detected communities in the RTOs, and Figure 2-2 shows the nodal coloring by sector for each community. While the labels vary slightly across the same color in different RTOs, if a given stakeholder were to change RTOs their color label would nearly always stay the same. An exception is that the stakeholders in the Alternative Resources sector in ISO-NE (yellow) would largely end up in the Other Supplier sector (light blue) in NYISO and PJM, with perhaps a few ending up in the generation (Green) sector. For each RTO the Full Network has been split into a network of votes about the capacity market and a network with the capacity market votes removed. The All Other Issues network includes votes on topics like energy markets, ancillary services, transmission planning, financial transmission rights, and procedural and general administration topics.

Network edges are weighted by total number of votes in agreement (not by percentage of agreement), so a darker line indicates a higher quantity of agreement after normalization for the number of votes in the network. Edge weight also indicates the amount of voting participation by stakeholders due to the normalization. Tables 2-2 through 2-4 give seven metrics for each detected community, including average internal weight density and separability. Average strength is also an important metric as it indicates frequency of voting.

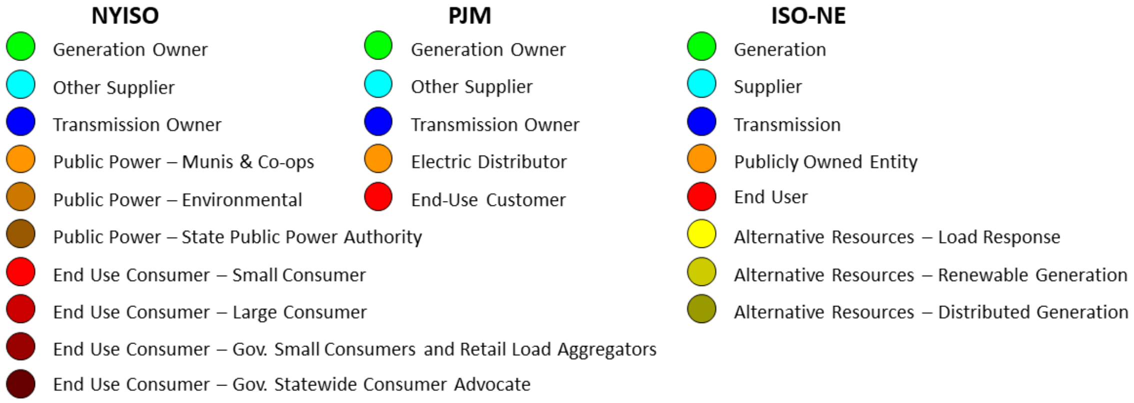

Figure 2-2. RTO node coloring key. Stakeholder participants' sector membership is represented by color. Colors in ISO-NE and NYISO with different tones represent subsectors.

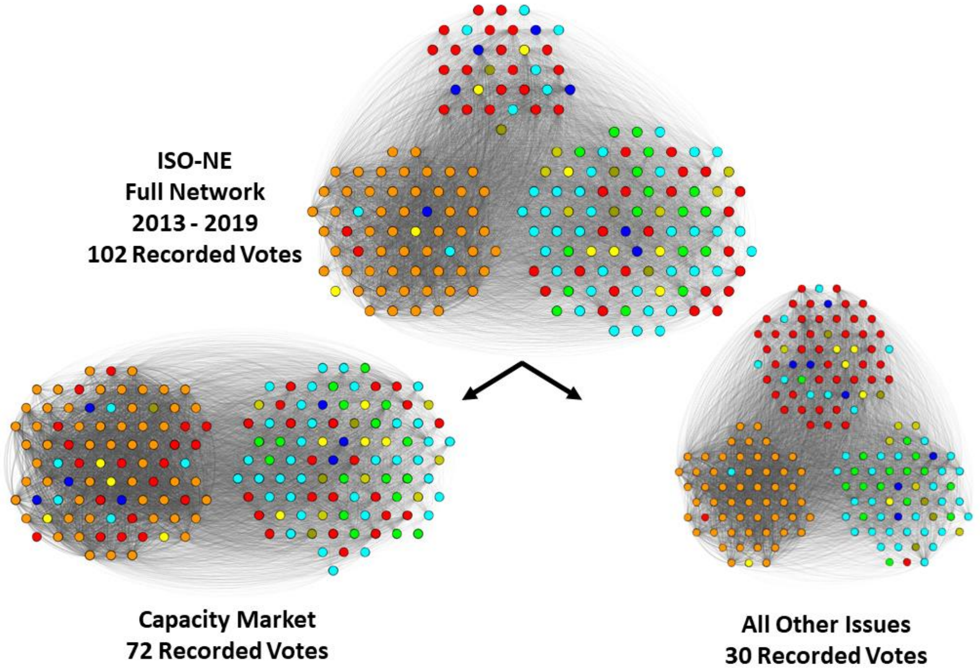

Figure 2-3. ISO-NE voting networks. Nodal colors are given in Figure 2-2. Edge density is weighted. Metrics for the networks are given in Table 3, where the relevant community A is on the left of each network.

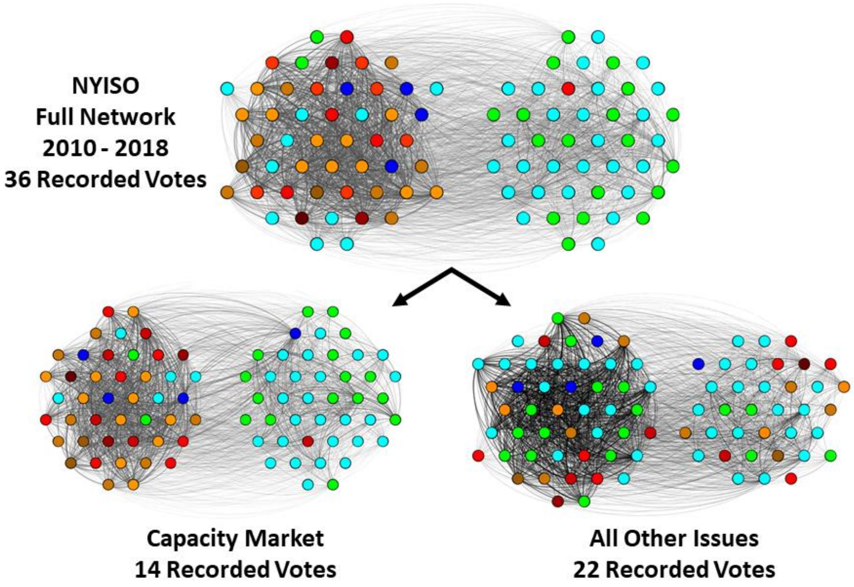

Figure 2-4. NYISO voting networks. Nodal colors are given in Figure 2-2. Edge density is weighted. Metrics for the networks are given in Table 3, where the relevant community A is on the left of each network.

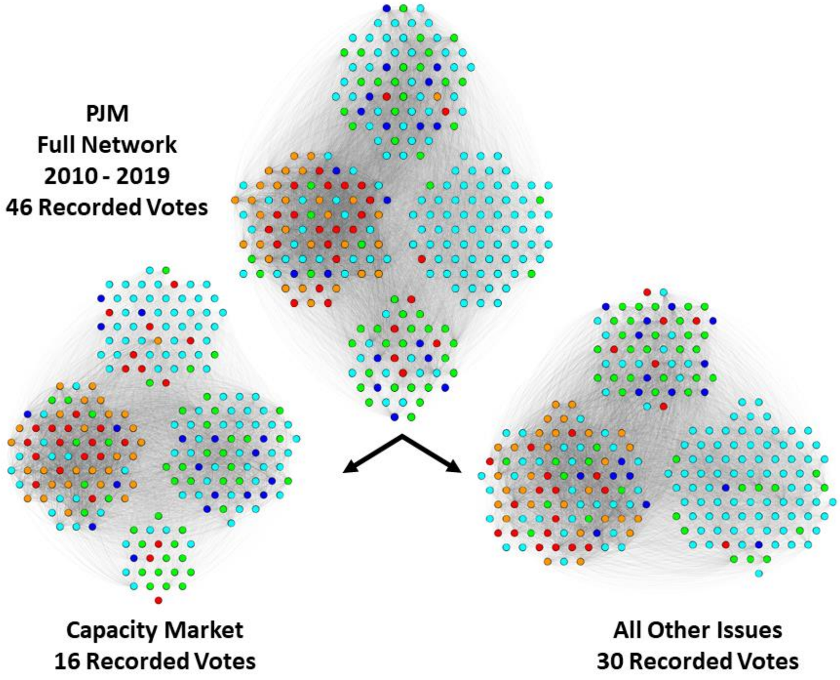

Figure 2-5. PJM voting networks. Nodal colors are given in Figure 2. Edge density is weighted. Metrics for the networks are given in Table 3, where the relevant community A is on the left of each network.

Table 2-2. Community metrics for ISO-NE. For each associated network graph in Figures 2-3 through 2-5 and 2-7 through 2-10 community A is in the lower left-hand corner and additional communities are identified in a counterclockwise fashion. Coloring in the table represents commonly discussed metrics where green shows community cohesiveness, orange shows participation levels of the stakeholders in the community, and yellow shows the separability of the community from the rest of the network.

ISO-NE

			Nodes	Weighted Edges	Average Internal Strength	Internal Weight Density	Average External Strength	External Weight Density	Average Strength	Weighted Conductance	Separability
Network Name	**Full Network**										
Q	0.129	**Community A**	60	797.03	26.57	0.23	27.16	0.11	53.73	0.51	0.98
Recorded Votes	102	**Community B**	90	299.54	6.66	0.04	13.29	0.07	19.95	0.67	0.50
Nodes (Stakeholders)	184	**Community C**	34	77.23	4.54	0.07	48.25	0.16	52.80	0.91	0.09
Edges (Votes)	219,410										
Network Name	**Capacity Market**										
Q	0.136	**Community A**	86	1,301.10	30.26	0.18	13.40	0.07	43.66	0.31	2.26
Recorded Votes	72	**Community B**	91	314.46	6.91	0.04	12.66	0.07	19.58	0.65	0.55
Nodes (Stakeholders)	177										
Edges (Votes)	157,809										
Network Name	**Capacity Market Timeseries 1**										
Q	0.135	**Community A**	51	673.23	26.40	0.26	30.43	0.19	56.83	0.54	0.87
Recorded Votes	31	**Community B**	60	344.03	11.47	0.10	21.56	0.15	33.03	0.65	0.53
Nodes (Stakeholders)	133	**Community C**	22	75.65	6.88	0.16	43.87	0.20	50.75	0.86	0.16
Edges (Votes)	63,412										
Network Name	**Capacity Market Timeseries 2**										
Q	0.169	**Community A**	70	1,534.38	43.84	0.32	11.98	0.10	55.81	0.21	3.66
Recorded Votes	24	**Community B**	61	311.04	10.20	0.08	13.74	0.10	23.94	0.57	0.74
Nodes (Stakeholders)	131			1,534.38							
Edges (Votes)	54,349										
Network Name	**Capacity Market Timeseries 3**										
Q	0.099	**Community A**	57	679.82	23.85	0.21	34.72	0.23	58.58	0.59	0.69
Recorded Votes	17	**Community B**	45	164.35	7.30	0.08	23.34	0.13	30.65	0.76	0.31
Nodes (Stakeholders)	134	**Community C**	32	291.88	18.24	0.29	57.30	0.28	75.54	0.76	0.32
Edges (Votes)	39,982										
Network Name	**All Other Issues**										
Q	0.133	**Community A**	56	661.77	23.63	0.21	27.87	0.12	51.50	0.54	0.85
Recorded Votes	30	**Community B**	56	165.97	5.93	0.05	19.44	0.08	25.36	0.77	0.30
Nodes (Stakeholders)	174	**Community C**	62	228.80	7.38	0.06	21.01	0.09	28.39	0.74	0.35
Edges (Votes)	61,331										
Network Name	**Capacity Market - All Other Issues**										
Q	0.162	**Community A**	65	840.93	25.87	0.20	20.52	0.11	46.40	0.44	1.26
Recorded Votes	44	**Community B**	76	295.50	7.78	0.05	12.19	0.07	19.97	0.61	0.64
Nodes (Stakeholders)	161	**Community C**	20	60.41	6.04	0.16	46.58	0.17	52.62	0.89	0.13
Edges (Votes)	87,776										
Network Name	**Capacity Market - Delist Bids and Substitution Auction**										
Q	0.183	**Community A**	86	1,472.07	34.23	0.20	6.27	0.06	40.50	0.15	5.46
Recorded Votes	15	**Community B**	55	261.67	9.52	0.09	9.80	0.06	19.31	0.51	0.97
Nodes (Stakeholders)	141										
Edges (Votes)	30,047										
Network Name	**Capacity Market - Winter Reliability Program / Fuel**										
Q	0.094	**Community A**	60	466.23	15.54	0.13	40.59	0.20	56.13	0.72	0.38
Recorded Votes	13	**Community B**	63	881.92	28.00	0.23	40.03	0.21	68.03	0.59	0.70
Nodes (Stakeholders)	160	**Community C**	37	138.77	7.50	0.10	37.79	0.15	45.29	0.83	0.20
Edges (Votes)	39,986										

Table 2-3. Community metrics for NYISO. For each associated network graph in Figures 2-3 through 2-5 and 2-7 through 2-10 community A is in the lower left-hand corner and additional communities are identified in a counterclockwise fashion. Coloring in the table represents commonly discussed metrics. Coloring in the table represents commonly discussed metrics where green shows community cohesiveness, orange shows participation levels of the stakeholders in the community, and yellow shows the separability of the community from the rest of the network.

NYISO			Nodes	Weighted Edges	Average Internal Strength	Internal Weight Density	Average External Strength	External Weight Density	Average Strength	Weighted Conductance	Separability
Network Name	**Full Network**										
Q	0.173	**Community A**	50	354.92	14.20	0.14	3.27	0.04	17.47	0.19	4.34
Recorded Votes	36	**Community B**	45	66.22	2.94	0.03	3.64	0.04	6.58	0.55	0.81
Nodes (Stakeholders)	95										
Edges (Votes)	18,107										
Network Name	**Capacity Market**										
Q	0.210	**Community A**	44	329.07	14.96	0.17	4.95	0.06	19.91	0.25	3.02
Recorded Votes	14	**Community B**	43	102.36	4.76	0.06	5.07	0.06	9.83	0.52	0.94
Nodes (Stakeholders)	87			329.07							
Edges (Votes)	7,565										
Network Name	**Capacity Market Timeseries 1**										
Q	0.262	**Community A**	44	435.50	19.80	0.23	2.88	0.07	22.67	0.13	6.89
Recorded Votes	4	**Community B**	43	115.75	5.38	0.06	2.94	0.06	8.33	0.35	1.83
Nodes (Stakeholders)	66										
Edges (Votes)	2,458										
Network Name	**Capacity Market Timeseries 2**										
Q	0.169	**Community A**	30	253.60	16.91	0.29	18.72	0.28	35.63	0.53	0.90
Recorded Votes	5	**Community B**	17	84.80	9.98	0.31	25.65	0.28	35.62	0.72	0.39
Nodes (Stakeholders)	63	**Community C**	16	116.20	14.53	0.48	27.00	0.29	41.53	0.65	0.54
Edges (Votes)	4,060										
Network Name	**Capacity Market Timeseries 3**										
Q	0.349	**Community A**	36	324.25	18.01	0.26	5.67	0.07	23.68	0.24	3.18
Recorded Votes	4	**Community B**	41	266.25	12.99	0.16	4.98	0.07	17.96	0.28	2.61
Nodes (Stakeholders)	77										
Edges (Votes)	2,770										
Network Name	**All Other Issues**										
Q	0.149	**Community A**	48	368.82	15.37	0.16	3.27	0.05	18.64	0.18	4.69
Recorded Votes	22	**Community B**	36	55.00	3.06	0.04	4.37	0.05	7.42	0.59	0.70
Nodes (Stakeholders)	84										
Edges (Votes)	11,053										

Table 2-4. Community metrics for PJM For each associated network graph in Figures 2-3 through 2-5 and 2-7 through 2-10 community A is in the lower left-hand corner and additional communities are identified in a counterclockwise fashion. Coloring in the table represents commonly discussed metrics. Coloring in the table represents commonly discussed metrics where green shows community cohesiveness, orange shows participation levels of the stakeholders in the community, and yellow shows the separability of the community from the rest of the network.

PJM			Nodes	Weighted Edges	Average Internal Strength	Internal Weight Density	Average External Strength	External Weight Density	Average Strength	Weighted Conductance	Separability
Network Name	**Full Network**										
Q	0.156	**Community A**	79	876.96	22.20	0.14	21.68	0.06	43.88	0.49	1.02
Recorded Votes	46	**Community B**	43	62.67	2.92	0.03	19.63	0.05	22.55	0.87	0.15
Nodes (Stakeholders)	261	**Community C**	71	113.00	3.18	0.02	8.23	0.02	11.41	0.72	0.39
Edges (Votes)	109,923	**Community D**	68	220.20	6.48	0.05	19.51	0.05	25.98	0.75	0.33
Network Name	**Capacity Market**										
Q	0.193	**Community A**	69	877.50	25.43	0.19	24.28	0.08	49.72	0.49	1.05
Recorded Votes	16	**Community B**	24	14.31	1.19	0.03	14.27	0.04	15.46	0.92	0.08
Nodes (Stakeholders)	213	**Community C**	63	463.88	14.73	0.12	21.63	0.07	36.36	0.60	0.68
Edges (Votes)	39,956	**Community D**	57	88.50	3.11	0.03	14.30	0.05	17.40	0.82	0.22
Network Name	**Capacity Market Timeseries 1**										
Q	0.227	**Community A**	60	1,248.29	41.61	0.35	17.85	0.15	59.46	0.30	2.33
Recorded Votes	7	**Community B**	58	797.86	27.51	0.24	18.47	0.15	45.98	0.40	1.49
Nodes (Stakeholders)	118										
Edges (Votes)	18,072										
Network Name	**Capacity Market Timeseries 2**										
Q	0.100	**Community A**	55	862.60	31.37	0.29	48.28	0.27	79.65	0.61	0.65
Recorded Votes	5	**Community B**	54	354.80	13.14	0.12	36.13	0.20	49.27	0.73	0.36
Nodes (Stakeholders)	144	**Community C**	35	263.60	15.06	0.22	62.77	0.29	77.83	0.81	0.24
Edges (Votes)	15,909										
Network Name	**Capacity Market Timeseries 3**										
Q	0.241	**Community A**	43	214.25	9.97	0.12	19.40	0.11	29.36	0.66	0.51
Recorded Votes	4	**Community B**	52	582.50	22.40	0.22	18.27	0.11	40.67	0.45	1.23
Nodes (Stakeholders)	133	**Community C**	38	174.50	9.18	0.12	8.05	0.04	17.24	0.47	1.14
Edges (Votes)	5,975										
Network Name	**All Other Issues**										
Q	0.156	**Community A**	92	867.47	18.86	0.10	18.18	0.06	37.04	0.49	1.04
Recorded Votes	30	**Community B**	93	251.80	5.42	0.03	10.40	0.04	15.82	0.66	0.52
Nodes (Stakeholders)	240	**Community C**	55	187.60	6.82	0.06	26.58	0.07	33.40	0.80	0.26
Edges (Votes)	69,967										

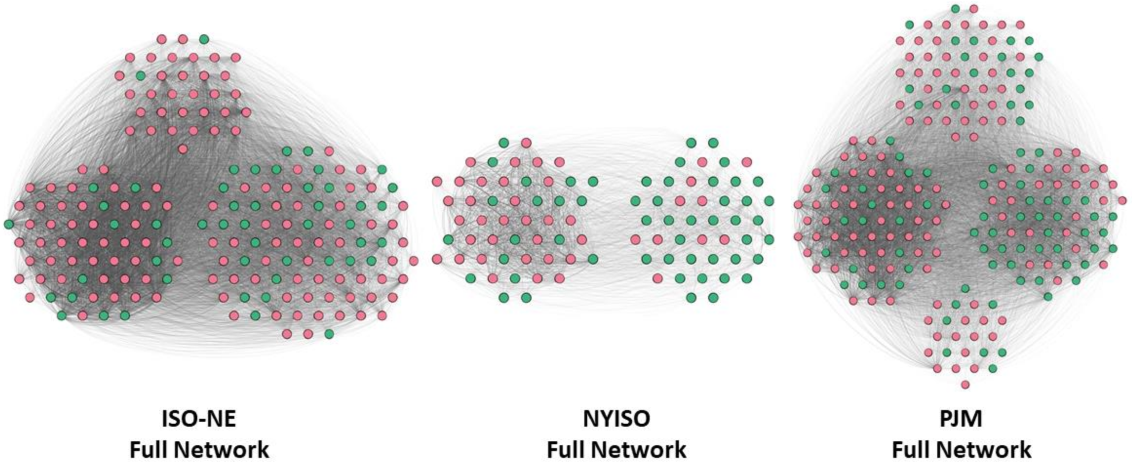

Figure 2-6. Voting networks for the three RTOs when viewed by the buyer (pink) seller (green) attribute.

We also examined communities through attributes other sector affiliation based on 2018 Form EIA 860 and EIA 861 data as mentioned in Section 3. Visually, none of the attributes (generation capacity, load size served, and transmission capacity) provided useful information (other than certain groupings within communities that are also evident when viewed by sector). Each stakeholder was also assigned a label as a net-buyer or a net-seller and when the nodes were colored against this metric they surprisingly, they did not show strong evidence that this metric was a determining factor in the communities. As an example, Figure 2-6 shows the Full Network of each

RTO according to the buyer-seller metric.

4.1 Can we identify specific constituencies in the RTO voting networks? If so, how does the structure of the voting network relate to the RTO's distribution of political power within a given RTO stakeholder process?

To address the distribution of political power, we first look at the distribution of voting rights and the voting thresholds required for a passage of a proposal at the top-level committee within each RTO. All three RTOs use sector-weighted voting in their top-level decision committee. Table 2-5 gives a breakdown of the threshold required for proposal passage and the weight of the vote each sector gets.

Table 2-5. Sector-weighted voting thresholds and sector vote percentages for ISO-NE, NYISO, and PJM. Adapted from [4], [81].

	ISO-NE		**NYISO**		**PJM**	
Passage Threshold	60.00%*		58.00%		66.67%	
Sector's Voting Weight	Generation	16.5%	Generation Owner	21.5%	Generation Owner	20%
	Supplier	16.5%	Other Supplier	21.5%	Other Supplier	20%
	Transmission	16.5%	Transmission Owner	20%	Transmission Owner	20%
	Publically Owned Entity	16.5%	Public Power and Environmental	20%	Electric Distributor	20%
	End User	16.5%	End Use Consumer	17%	End-Use Customer	20%
	Alternative Resources	16.5%				

*The 60% threshold is for market rule changes. Non-market rule changes have a 66.67% threshold.

All RTO networks, when examined from the perspective of sector affiliation, show patterns of coalitions forming based on sector affiliation. In total we examined 21 networks and 19 of them show this pattern (with NYISO All Other Issues and PJM 2017-2019 being the two exceptions).

In ISO-NE both the Publicly Owned Entity and Generation sectors form (nearly) complete blocs in every network. The Supplier Sector shows a strong affiliation with generation, but the 60% voting threshold for market issues means that near consensus is needed across four sectors to pass legislation. Conversely, two sectors sufficiently determined to alone stop passage of a proposal are unable to do so with only 33% of the vote. Note that the average internal weight density of the Publicly Owned Entity sector bloc—represented as community A in all ISO-NE graphs—is more than 4x stronger than any other community found in any ISO-NE network. It's noteworthy that community B, has a much lower average strength than community A meaning that the Generation's coalition is much less likely to cast votes than the Publicly Owned Entity sector. Surprisingly, the End User sector doesn't show a strong affiliation with Publicly Owned Entity sector as happens in NYISO and PJM.

In PJM we find that the Electric Distributor and End-Use Customer sectors—that is to say the load side stakeholders-- form a tight coalition. These results are consistent with those revealed in our interview data collected for Chapter 1 and found by [11]. Because the sector-weighted voting threshold is 66.67% of the vote in PJM, a coalition of two of the five sectors is a strong political force at the top level of the stakeholder process because they can block passage of any proposals. Community C, despite being the second largest community, has a low average strength value indicting the average member does not vote often. The community's separability value and internal weight strength also means they aren't all that unified as a group. Unlike ISO-NE, some generators belong to community A.

NYSIO's networks have fewer communities than ISO-NE, which isn't surprising given the smaller number of stakeholders and the lower number of votes. The Full Network of NYISO shows a split with the Public Power, End Use Customer, and Transmission Owner sectors in community A and Generation Owner and Other Supplier in community B. Community A has an average internal weight density 4.7 times higher than community B. Note the similarity between Communities A and B in the Full Network and the Capacity Market network with only a handful of nodes switching communities. The dense community A in the All Other Issues network is due in part to the eleven of the 22 proposals being procedure-related, which often show 80+ % agreement for (or against) by stakeholders. It's conceivable that the Transmission Owner sector could conceivably be a separate community within the Full Network, but the number of stakeholders within that segment is smaller than the resolution limit and couldn't be detected if they were. In practice, the four NYISO transmission sector companies all have substantial holdings at distribution utilities and have a natural financial affinity with the Public Power sector. However, because the sectors don't have equal voting rights, the combined voting power of the Public Power, End Use Customer, and Transmission Owner sectors is only 57% (and 1% less than the voting threshold of 58%). This suggests that the voting threshold (or sector weighted voting distribution) was chosen to maintain a close balance of power between the two communities we find.

Uniquely in PJM is the emergence of four communities in its Full Network. [11] found evidence of three communities. The difference in the number of communities could be explained by several factors—us having a larger dataset, the consideration of the Full Network rather than looking at "yes" and "no" voting networks separately, and/or the use of the Leiden instead of the Louvain algorithm. Communities B and C have a low average internal strength (just 0.02 and 0.03 compared with A's 0.14 and D's 0.05.)

ISO-NE, NYISO, and PJM have some similarities in their sector weighted voting but the three of them don't share a voting threshold, number of sectors, or voting weight allocation between sectors. PJM's high voting threshold with low number of sectors means consensus can be hard to find. In PJM alone the high voting threshold the minority community maintains a strong grip of power [3], [11]. In contrast, NYISO's lower threshold means that, unlike PJM, a group of three sectors can pass legislation even with complete opposition from two sectors. This means that transmission becomes the swing sector, and the network indicates they have typically been voting as a bloc with the demand side sectors. ISO-NE's addition of a sixth sector, but lowering of the voting threshold, means that like NYISO no two sectors can alone block passage of legislation, but strong contributions from at least four sectors are needed to pass legislation. PJM's lack of unification in its generation sector raises the question as to whether the commonly used grouping of sectors is still appropriate. The Midcontinent Independent System Operator reorganized its stakeholder sectors so that there are ten (not weighted equally). The Southwest Power Pool only has eleven sectors for committee representation but only two (transmission owning and transmission using) when voting market-related issues. Going even further, sectors could instead be divided regionally with weighted voting based on population served; by capital investment; or by a different buyer-seller dynamic.

4.2 *Do different constituencies form around different issues in the network?*

Following from Section 3, the dominant voting issue for all three RTOs in the data set has been capacity markets representing 72/102 votes in ISO-NE, 16/46 votes in PJM (plus the use of the Enhanced Liaison Committee and other stakeholder process mechanisms) and 14/36 votes in NYISO. All three RTOs show distinctively different community structures in the Capacity Market network and the All Other Issues network.

In ISO-NE a division between the Public Power and Generation Owners is apparent in both the Capacity Market and All other Issues networks but the behavior of the other sectors changes with the dissolution of a community B in the All Other Issues network and the End Use Customer splitting evenly between the two communities. It's notable this happens, but isn't clear why it does. The metrics across the board indicate that the Capacity Market network community A votes together and votes more frequently than the members of community B. Other Suppliers largely join with Generation, as does Alternative Resources except for half of the Load Response subsector. If we consider community A's "average" voting potential by just looking at the nodes in the community, they get approximately 16.5% from Publicly Owned Entity, 8% from End User, >9% from Transmission, > 2% from Load Response and >3% from Supplier, for a total of >38.5%, which is very close to the 40% threshold they would need to block a market-based proposal[13], particularly given the stronger average strength (indicating each node in community A votes, on average, more often than nodes in community B).

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[13] Alternatively, of course, community B has <61.5% of the vote, which is barely enough to pass a proposal.

Especially given the split of the Transmission, End User, and Load Response sectors, this indicates the presence of coalition building in a way not seen in NYISO (and probably not PJM due to its high voting threshold).

In NYSIO the Capacity Market network is dominated by Public Power and End Use Customer sectors in community A and the Generation Owner and Other Supplier sectors in community B. Although the communities are about equal size, community B shows a much smaller average internal weight density (0.04, compared to 0.14 of community A). This is in part due to many stakeholders not voting as often (or abstaining); note the disparity in average strength between the communities with community A having an average strength 2x greater than community B. In All Other Votes this disparity is even larger (2.5x). This All Other Issues is the only network that doesn't show an obvious correlation between community and sector. This is evidence that the Capacity Market is the dominating issue that drives the results of the Full Network despite there being fewer votes in the Capacity Market network than there are in the All Other Issues network.

Overall, PJM shows little change between the Capacity Market network and All Other Votes network, particularly in the coalition between the Electric Distributor and End-Use Customer segments shown in community A in both networks. This is consistent with the findings in Section 4.1 and those in [11]. What stands out in the comparison of the PJM Capacity Market network when compared with the All Other Issues network is the emergence of a new community (B) comprised mostly of generation owners although this is a weak one (internal weight density = 0.03 compared with 0.19 for community A). A secondary observation is the split in the Other Supplier sector into two communities (C and D) although community C is relatively weak (internal weight density = 0.03). The communities dominated by the Other Supplier sector show relatively low Average Strength, reflecting the lower participation rate of voting. One reason for the redistribution of generators and the inability for them to form a coalition in the capacity market network may be because different types of generators are affected by capacity market issues differently. For instances, some proposed adjustments by FERC to the Minimum Offer Price Rule (MOPR) have the effect of raising capacity market prices and helping fossil fuel plants while hurting some state-subsidized renewables and some nuclear. However, if a particular generator clears the market then it will make more than it would have without MOPR. Thus, the Electric Distributor sector—which will see costs increase—can remain nearly unanimous in opposition, whereas generators will be distributed across groups of certainly being for it, certainly being against it, and possibly being for/against based on individual circumstance and risk assessment. Note that in the Capacity Market network nine of the eleven End-Use Customers not in Community A with the Electric Distributor sector are state consumer advocates so the corporate End-Use Customers largely remain aligned with the Electric Distributors.

4.3 *How stable are the constituencies over time?*

Figures 2-7 through 2-10 show the detected communities in the RTO capacity networks and Figure 2-2 shows the nodal coloring by sector for each community. For all three RTOs capacity markets have been broken up into three timeframes. The timeframes were chosen to make the number of votes taken in each network roughly commensurate. Figure 2-8 shows ISO-NE's Capacity Market network broken down by issue as an alternative means to analyzing capacity-market related votes. There is not enough data to do this for NYISO and PJM. Note that NYISO and PJM have only a small number of votes per timeframe network so it would be wrong to read too much into the results for their networks, but they do make a useful comparison to ISO-NE's networks.

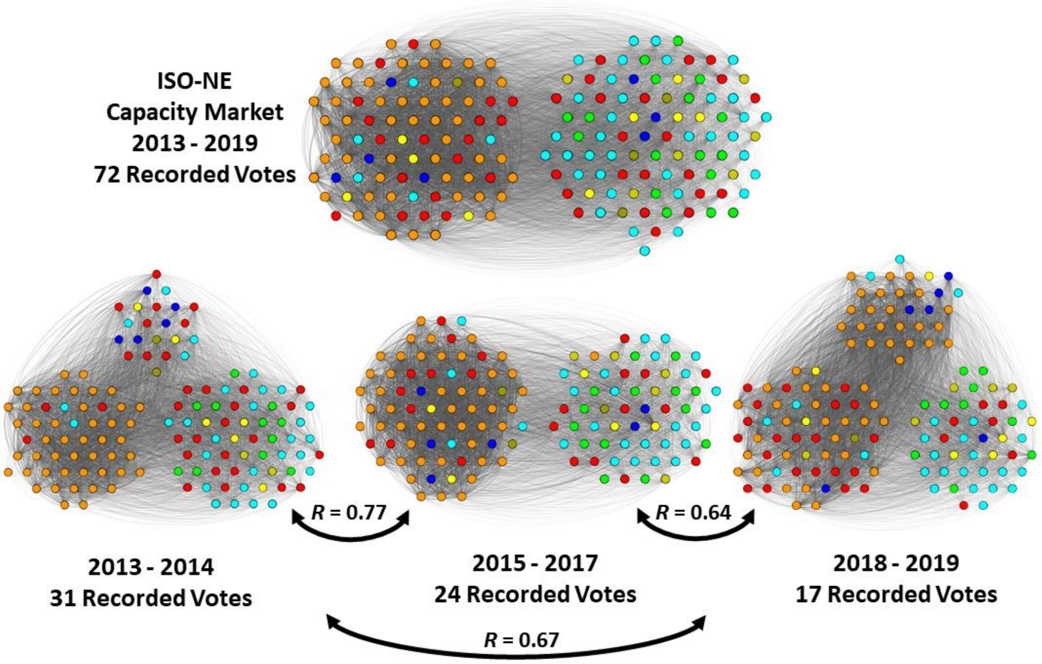


Figure 2-7. ISO-NE capacity markets by timeframe. Nodal colors are given in Figure 2-2. Edge density is weighted. Metrics for the networks are given in Table 3, where the relevant community A is on the left of each network. R is the Rand index, given for each pair of networks.

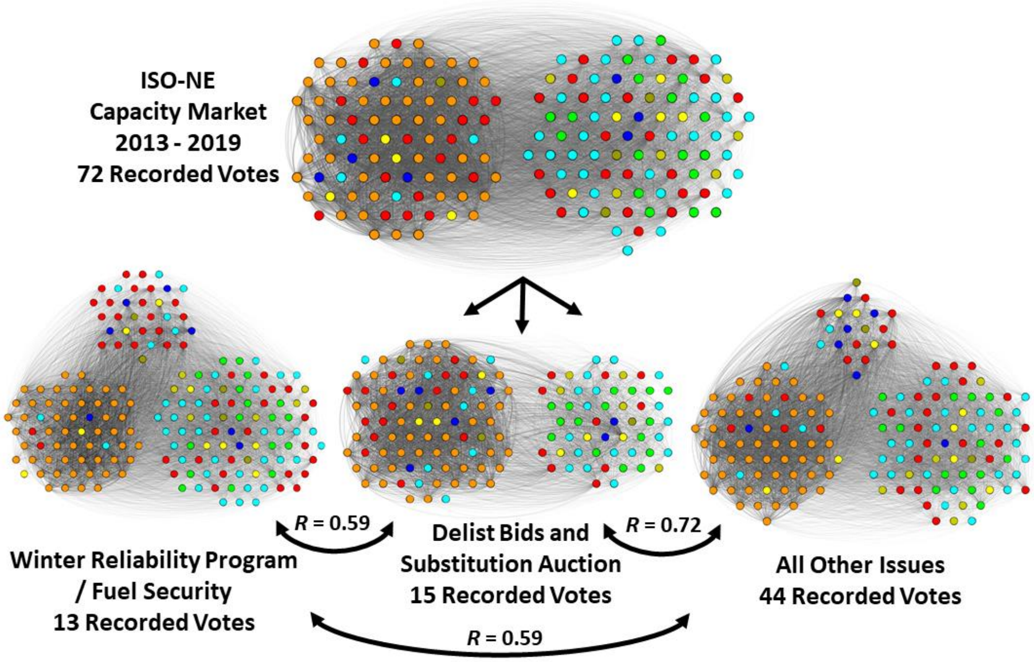


Figure 2-8. ISO-NE capacity markets by issue. Nodal colors are given in Figure 2-2. Edge density is weighted. Metrics for the networks are given in Table 3, where the relevant community A is on the left of each network. R is the Rand index, given for each pair of networks.

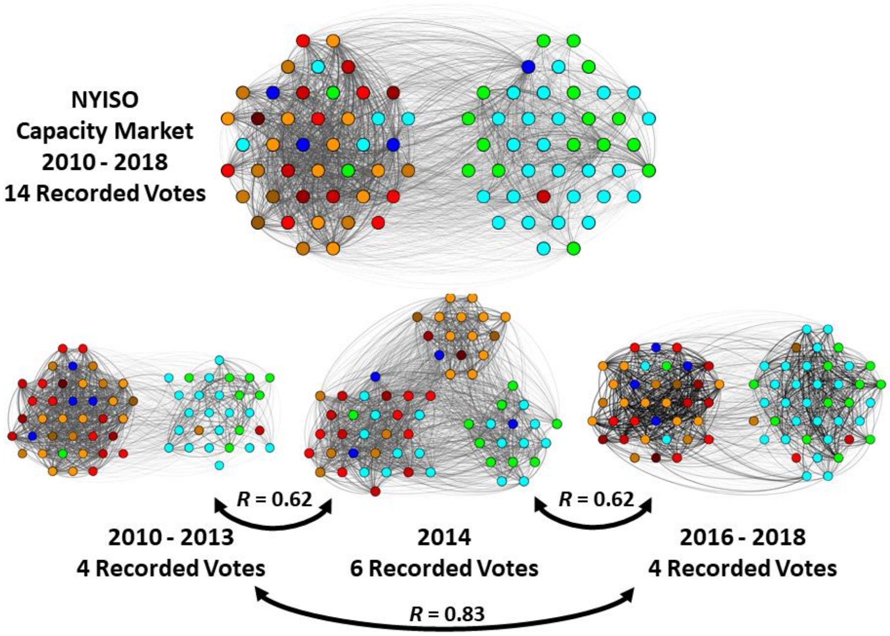


Figure 2-9. NYISO capacity markets by timeframe. Nodal colors are given in Figure 2-2. Edge density is weighted. Metrics for the networks are given in Table 3, where the relevant community A is on the left of each network. R is the Rand index, given for each pair of networks.

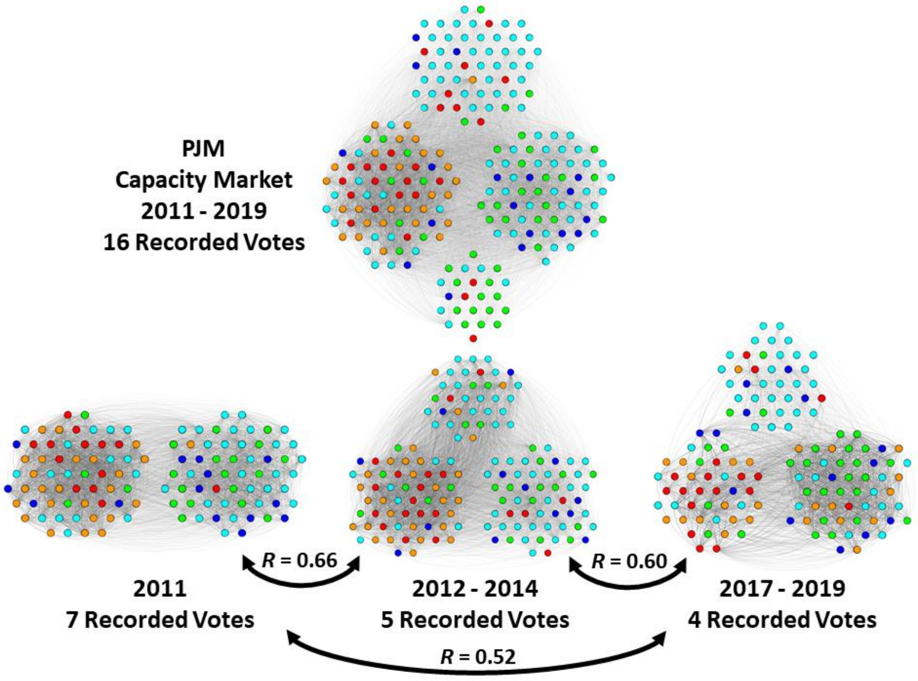


Figure 2-10. PJM capacity markets. Nodal colors are given in Figure 2-2. Edge density is weighted. Metrics for the networks are given in Table 3, where the relevant community A is on the left of each network. R is the Rand index, given for each pair of networks.

Figure 2-8 shows us that, apart from votes about winter reliability/fuel security, ISO-NE has relatively strong stability across issues given the R value of 0.72 between votes about substitute auctions and all other issues. Comparing the R values in Figures 2-7, we see that ISO-NE has relatively consistency stability values.

NYISO has the strongest coalition of any two communities—$R = 0.83$ when comparing the first and final timeframe. The (only) six recorded votes in the middle timeframe (2015) were about the same issue and taken at only two meetings three months apart. One hypothesis is that, given more votes, NYISO would show strong community stability (echoing the results of Sections 4.1 and 4.2) across all three timeframes and the middle timeframe is simply an outlier due to the small sample size.

The results in PJM were a surprise, given the results in Chapter 1 and Sections 2.2 and 2.3. The R value found when comparing the first and third timeframes indicates near-randomness and the R value results comparing the first and second and second and third timeframes aren't particularly strong. One cause of this could be that there is stakeholder effort towards coalition building that is issue-driven but still contentious, meaning companies switch allegiances frequently (thus keeping N_{11} of Equation 2-3 low) while forming coalitions, but not large enough coalitions to consistently reach consensus (keeping N_{00} low). But, recall that the sample size is small. It's also worth noting that PJM had a surprisingly small number of participants voting in both networks (just 65) and the most voting in any two pairs of networks was 95. All of these were fewer than ISO-NE, which ranged between 97 and 114 for the results in Figure 2-7 and 133-147 when broken down by issue in Figure 2-8.

5. Conclusion

RTOs are voluntary stakeholder driven organizations responsible for operating much of the US electric grid that have had to evolve in response to an increasingly complex mandate. To better understand the decision-making of the RTO stakeholders we examined the voting networks of the three northeastern RTOs in the US—ISO-NE, NYISO, and PJM—using modularity maximization to detect communities. We found sector affiliation is a strong indicator of community, particularly for electric distributors in all three RTOs, demand side affiliation in NYISO and PJM, in and for suppliers in ISO-NE and NYISO. Further, the differing number of sectors, distribution of voting rights, and setpoint of sector-weighted voting thresholds leads to different stakeholder behavior. In ISO-NE we find evidence of coalition building amongst participants because it is necessary if a side wants to pass or fail a proposal. In PJM we find that the demand side sectors form a bloc. In NYISO we find evidence that the voting threshold and allocated sector weights was done with great intention. We also significant differences when comparing the networks of capacity market votes to the networks for all other votes in ISO-NE and NYISO. Most notable in ISO-NE is the lack of cohesiveness by the End Use Customers. In NYISO the capacity market shows a split between the load and supply sectors whereas the network comprised of all other votes showed much more homogeneity and agreement. Overall, we find less community stability than we expected to find. In NYISO and PJM the analysis (and results) are hindered by the small dataset. ISO-NE shows more stability by capacity market issue rather than the timeframe the vote is taken in. NYISO hints that it might have strong stability over time. These results provide a basis for follow-up questions with RTO stakeholders to better determine explanations.

Three issues warrant more attention in future analysis of RTO voting networks. First, community detection (and network analysis in general) has mostly been concerned with sparse networks, where a sparse network is defined as one in which the density approaches zero as the number of nodes approaches infinity. Of course, in many situations this isn't possible to measure n going to infinity (including voting networks where the number of nodes may be static). However, we can compare the voting networks' densities with those of other networks. The density of a network is the fraction of edges present out of the fraction of edges possible. The number of edges possible in a simple network is given by $\frac{N*(N-1)}{2}$ where N represented the number of nodes. Table 2-6 shows a comparison of network density between RTO voting networks and commonly studied undirected networks.

Table 2-6. Comparison of densities for different types of undirected networks. Non-RTO voting network data adapted from [97]. N represents the total number of nodes in the network and L represents the total number of edges in the network. Note the disparity in densities between the RTO voting networks and the other networks;

when weighted, the densities of the RTO networks are one to three orders of magnitude denser.

Network	Nodes	Links	N	L (Unweighted)	L (Weighted)	Clique (N)	Density (Unweighted)	Density (Weighted)
Internet	Routers	Internet Connections	192,244	609,066	-	18,478,781,646	0.000033	-
Power Grid	Power Plants, Transformers	Cables	4,941	6,594	-	12,204,270	0.00054	-
Science Collaboration	Scientists	Co-authorship	23,133	93,439	-	267,556,278	0.00035	-
Actor Network	Actors	Co-acting	702,388	29,397,908	-	246,674,100,078	0.00012	-
Protein Interactions	Proteins	Binding Interactions	2,018	2,930	-	2,035,153	0.0014	-
NE-ISO	Voters	Votes	187	13,067	2,149	17,391	0.75	0.12
NYISO	Voters	Votes	103	2,891	503	5,253	0.55	0.10
PJM	Voters	Votes	268	18,994	2,390	35,778	0.53	0.07

Note that voting networks are one to four orders of magnitude more dense. Second, it would be unsurprising to find overlapping communities [138], [139] within a voting network as voting blocs may reform based on issues, yet only [106] have examined overlapping communities within voting networks. A major challenge for looking for overlapping communities within RTO voting networks is the relatively small number of votes taken each year. [106]'s dataset of Brazil and the US's Congresses include a 15-year period with 2,2196 and 10,306 votes respectively. Finally, the use of an abstention as strategic vote—as opposed to a non-vote—hasn't been well studied, perhaps because on the surface abstensions and non-votes seem to be the same thing. However, an abstention vote doesn't necessarily indicate indifference and can and has been used strategically in a wide variety of voting situations [140]. [141] have found that in Congressional roll call votes abstensions were used purposely and strategically for differing reasons of supporters and detractors of an issue and to trade votes for indifferent parties. Also looking at the US Congress, [142] found evidence that abstensions were "more prone to abstain than to take sides when the demands from personal connections conflict with those of the legislator's party" with [143] finding similar results in Sweden.

CHAPTER 3

COUPLING AIR QUALITY FORECASTING AND ELECTRICITY DISPATCH MODELING TO AVOID OZONE VIOLATIONS

1. Introduction

Power plants have historically been an important contributor to air quality problems [144]. Electric utilities and transmission system operators already make electricity generation scheduling decisions on a day-ahead basis, re-dispatching power plants as demand changes and as generators, transmission lines, and other equipment in the electric grid are taken off line (e.g., for maintenance). Electric power is also clearly a major source of emissions. Electric power plants account for 11 million to 16 million metric tons of nitrogen oxide emissions in 2016, contributing 10%-15% of total US anthropogenic nitrogen oxide (NO_x) and 44%-54% of anthropogenic sulfur dioxide (SO_2) emissions in 2016 . However, these emissions are not distributed homogenously. For instance, in the same year, power plants in the US Environmental Protection Agency Region 3 (Delaware, Maryland, Pennsylvania, Virginia, West Virginia, and Washington DC) were responsible for 19% of NO_x emissions due to the high concentration of coal-fired power plants, whereas in Region 1 (Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island, and Vermont) they are responsible for only 4% [145]. Nitrogen oxide emissions contribute to high ambient concentrations of ground-level ozone and particulate matter [146], which in turn lead to a variety of negative health effects and increased morbidity and mortality rates [147]–[149]. While individual power plants may have run-time limitations or other constraints on annual emissions, the systems responsible for dispatching those power plants do not currently respond to air-quality exceedances in any systematic way. The scheduling and dispatch of electricity generation is done by minimizing generation costs given various physical constraints of the power plants and electric grid [150], [151]. Incorporating additional constraints and decision rules into the scheduling and dispatch optimization problems would allow for the some of the externalized costs of air pollution to be monetized so that costs are more aligned with the socially marginal cost of generation.

This paper couples the output of an atmospheric chemical transport model (CAMx) with an electricity dispatch model (run via PowerWorld Simulator). The models were integrated by calculating sensitivities which describe how much power plants contribute to the ozone peak. Individual power plants were then ranked by their sensitivities. A cost curve describing the overall system cost of reducing pollution in nonattainment zones was developed by running lossless de-coupled optimal power flows (DCOPFs) for before and after scenarios in seven regions near Pittsburgh, PA for an August 2005 event. In each scenario power plants were shut off based on their ranked sensitivity. This method is notable in that a pollution limit is set, rather than a cost limit, thus allowing for a cost curve to be built so that the marginal cost of abatement can be determined. This dynamic approach allows for the targeting of a socially optimal level of abatement that targets specific nonattainment areas rather than an entire dispatch region. This technique could be extended further to target multiple nonattainment areas.

2. Background

2.1 Historical Context of Emissions in Electricity Modeling

Emission constraints were first added to the dispatch model in the early 1970s (e.g. [151]). [152] provides a useful introduction as to how different pollutants differ in intensity and transport characteristics and then gives a literature review (up through 1993) of how the dispatch problem can be solved based on the following strategies: 1) minimization of emissions, 2) minimization of emissions while constraining fuel costs, 3) minimization of fuel costs with controlled emissions, 4) minimization of ground level concentration of emissions, 5) minimization of costs with constrained concentrations (i.e. a combination of 3 and 4), and 6) minimization of the weighted sum of costs and emissions. The basic mathematical models for all of these strategies are given and explained. [153] expands on this by applying these techniques over a five-period time-independent 30-bus scenario. The results for both fuel cost minimization and emissions cost minimization are compared.

Much of the existing literature largely focuses on novel ways to consider and solve the theoretical OPF and additional pollution constraints without taking into consideration air-modeling. As a result, these models more accurately describe how emissions of global pollutants such as carbon dioxide can be constrained instead of reactive pollutants such as NO_x for which concentration is dependent on the length of time in the atmosphere as well as atmospheric and environmental factors. There are many typifying examples. For instance, [154] use dynamic programming to solve a multi-objective framework. A price penalty is introduced which effectively is a tax on the pollutant. [155] use fuzzy logic genetic algorithms to solve the OPF. Other common techniques include artificial neural networks [156]. It is typical in these that the pollutant is represented as a quadratic cost function, which implies that it is the cost of the emitted pollutant which is relevant, not the atmospheric concentration of secondary pollutants such as ozone. Our focus is on the quantity limits as determined through the NAAQS, so this body of prior work is not immediately applicable to our modeling framework.

However, there has been some work done combining air-modeling electricity-modeling. [157] were the first, and used the Gaussian puff model. A three-node example was used to demonstrate their technique with SO_2 as the pollutant considered, and they showed that the cost of constraining the pollutant varied both by generator and by time. Thus, the cost of the pollutant is shown to vary over time and depend on demand and weather conditions. More recently, [158] considered an air quality constraint in a six node test scenario by using the Gaussian puff model to couple air-modeling with electricity-modeling in the consideration of transmission and generation planning.

Our work differs from [159] in that we focus on localized ozone concentrations, and use quantity limits rather than cost limits in our problem formation. Also considering ozone abatement, [159] modeled NO_x emissions in PowerWorld for a 2002 test case as an additional uniform fuel cost for each fossil fuel generator in the consideration of a time-differentiated cap and trade scheme for PJM. In a time differentiated cap and trade scheme the quantity of emissions permits made available varies in this case daily. So, when ozone creation is predicted to be high, the quantity of permits available is low, and vice versa. The OPF was run with and without the additional fuel cost to compare how NO_x emissions would be reduced and prices would change. Fuel costs between \$30,000 $\frac{\$}{\text{ton}}$ and \$125,000 $\frac{\$}{\text{ton}}$ were tested. Effectively, an arbitrary price increase in NOx emissions per ton is applied uniformly to all power plants within PJM. This was done for a representative peak demand day in July and typical demand day in July. It was found that a reduction in NO_x emissions during the non-peak day had a greater effect on ozone reduction because of the lag in the formation of ozone from NO_x. These results were then compared with the cost of several technologies which remove NO_x emissions at the generator (e.g. a command and control approach). CAMx was used to model the expected ozone reduction as a result of the lower NO_x emissions. This process was done for PJM as a whole rather than for specific non-attainment areas.

2.2 Atmospheric Chemistry

The combustion of fossil fuels releases particulate matter (PM), Sulfur Dioxide (SO_2), Nitrogen Oxides (NO_x) and other primary pollutants into the atmosphere, which lead to the formation of secondary pollutants. Ground level ozone is created via complex photochemical reactions involving NOx and VOCs [159], [160].[1] It can cause a number of respiratory problems in humans, both acute and chronic. Chronic exposure is correlated with higher mortality rates due to respiratory problems [161]. Ozone also contributes to photochemical smog [160]. The scheduling and dispatch of electricity generation is done according to cost minimization models, and air quality is not considered. Thus, areas of the country with high concentrations of fossil fuel-based power plants tend to have worse air quality. Metropolitan areas often have numerous power plants to serve the electric load (as well as a high density of vehicles), and thus are more likely to violate National Ambient Air Quality Standards (NAAQS) [162].

2.3 Ozone Standards

The NAAQS for ground-level ozone is considerably more complicated than what is addressed here due to the long time horizon. The standard states that the annual fourth-highest daily maximum 8-hr concentration, averaged over three years, cannot exceed 75 ppb [163]. Instead, we treat a single 8-hr average of 75 ppb on a single day as a violation to demonstrate feasibility of the changes in dispatch decisions. In the case this model were to be implemented within a dispatch region, it would be trivial to adjust the 75 ppb threshold level for a potential violation once the previous daily maximum 8-hr concentrations were known.

In PA, the Pennsylvania Air Quality Partnership (PAQP) forecasts an air quality action day one day in advance when it is expected that ozone levels will be at high enough levels that human health will be impacted. (This is also done for $PM_{2.5}$.) PAQP forecasts nonattainment days from May-September. Across 13 cities/regions from 2008-2017, 8 days were forecast at a red level, meaning predicted peak ozone concentrations in excess of 95 ppb for the following day; 326 action days were forecast at the orange level (predicted ozone peak concentration between 76 and 95 ppb); and 2,114 days were forecast at the yellow level (predicted peak ozone concentration between 60 and 75 ppb). The five regions with the vast bulk of the air action days are concentrated around Pittsburgh and Philadelphia in the west and southeastern parts of the state [164], [165].

2.4 Electricity Scheduling and Dispatch

Electric generators are typically dispatched according to a minimum cost model. In many parts of the US, each generator sends an hourly bid 24 hours in advance to the regional balancing and reliability authority—the Regional Transmission Operator (RTO)—detailing what quantity of power it is willing to supply and at what price. The RTO then creates a supply curve from the bids and schedules which generators are expected to be utilized based on expected demand moving up the supply curve until the predicted demand is met. The cost at the equilibrium point is the initial system-wide wholesale price. (Additionally, there are ancillary markets which are utilized to balance supply and demand in real-time, provide frequency and voltage control, and supply other services since demand constantly fluctuates.) During the real-time dispatch, adjustments to the dispatch schedule are made in five minute increments, with automatic controls adjusting at finer timescales.

Figure 3-1 gives a timeline of the process and shows at what steps the air modeling fits in.

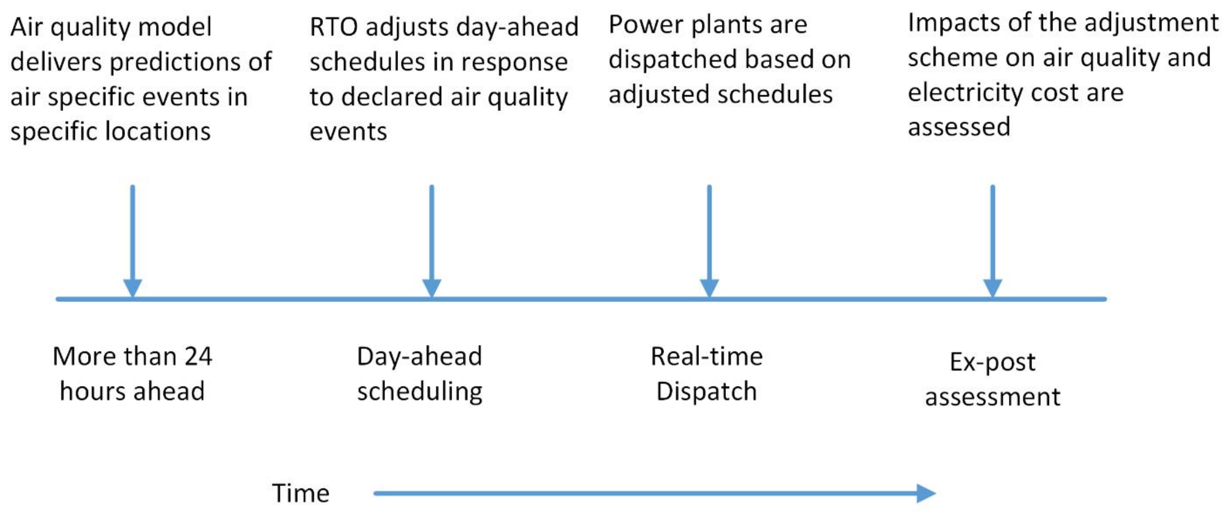


Figure 3-1. A timeline of electricity dispatch for an RTO.

When transmission constraints arise, more expensive (or "out of merit") power plants must be substituted for lower-cost plants. This gives rise to locational price separation within electric grids. The concept of the locational marginal price (LMP) illustrates this price separation by measuring the marginal cost of delivering electricity to a specific point in the grid [166].

3. Optimization Model

To determine the optimal path over time for which generators should scale back generation so as to avoid nonattainment with the 1-hr standard, we use the following DC cost minimization equation, which in this case represents the cost minimization of the system operator PJM:

$$\min_{x_{it}} \sum_{i=1}^{N} \sum_{t=1}^{T} C_i(P_{it} + x_{it}) \qquad (3\text{-}1)$$

Where:

- x_{it} , the decision variable, is the quantity *decrease* of generation for generator *i* at time *t* (*MW*)
- P_{it} is the current level of generation
- C_i is the per unit cost for generator x_i ($\frac{\$}{MW}$)

There is also the stock of ozone in the atmosphere to consider:

$$S_t \leq \bar{S} \qquad (3\text{-}2)$$

Where:

- S_t is the concentration of ozone in the atmosphere at time *t* (*ppb*)
- $\bar{S}$ is the maximum concentration of ozone allowed in the atmosphere (*ppb*)

Second, there is a lag effect between the time the power generation is decreased and the time at which the ozone concentration will decrease because of the physical mechanics it takes for nitrogen oxide emissions to be converted to ozone in the atmosphere. Therefore, there is a time-*dependent* effect which must be accounted for. Further, because atmospheric conditions (e.g. wind) change over time, there will be unique sensitivities for the change in ozone for each x_{it}. The transition equation is:

$$S_{t+1} = S_t - \sum_{i=1}^{N} \sum_{k=1}^{T} a_{i,t-k}^{t+1} \, x_{i,t-k} \;\; \forall i, k \qquad (3\text{-}3)$$

Where:

- a_{it} is the sensitivity factor for generator i at time t, i.e. the expected change in ozone concentration in the air over the nonattainment area in the future due to a current change in generation at a generator now ($\frac{ppm}{MW}$)
- k is an arbitrary counter

This model assumes that perfection information is available, particularly meteorologically so that the sensitivities can be calculated accurately and that they are correct given that they are predicted 24 hours in advance.

4. Data and Modeling

4.1 Generation of Sensitivities

The details of how sensitives were generated is outlined in [167]. In brief, sensitivities were calculated for each of the 80 facilities, which were shut down 24 hours before 00:00 EST August 4. A 12-hr time frame and 36-hr time frame were also considered. The 12-hr time frame had significantly smaller ozone sensitivities (i.e., less ozone reduction), while the 36-hr time frame had only marginally larger sensitivities. Given that the 36-hr time frame would likely incur greater costs for minimal benefit, the 24-hr time frame was selected.

Sensitivities were generated for seven regions near Pittsburgh, centering on the cities: Altoona, Butler, Clarksburg, Columbia, Friendsville, Newcastle, and Pittsburgh. Each region represents a 36 k x 36 k box, which is a 3 x 3 grid of 12 k x 12 k cells in CAMx. The regions were considered because, like Pittsburgh, they had high maximum 8-hr ozone concentrations and are close to plumes of predicted ozone sensitivity. Figure 3-2 shows a map of the regions.

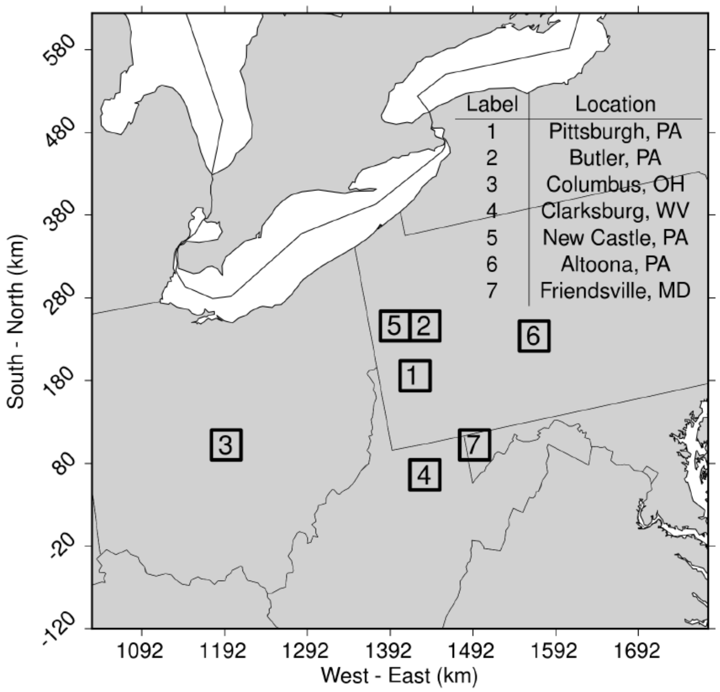


Figure 3-2. Spatial plot showing the gridded locations and extent of the seven selected area based on maximum ozone sensitivity and 8-hr ozone concentrations.

4.2 Electricity Modeling

PowerWorld Simulator is a popular power flow modeling program. It allows for power systems to be modeled and analyzed and contains a unique graphical interface so that one-line diagrams can be drawn to visually represent all system components and power flows. SimAuto is an add-on that gives Simulator Microsoft Component Object Model (COM) compatibility, so that it can interface with Matlab (and other programs).

Two data packages from Energy Visual are used in conjunction with Simulator. The FirstRate Multiregional Modeling Working Group (MMWG) data package is a database of generator information for the entire Eastern Interconnection and contains data such as the ownership, fuel type, and cost curve for each individual generator. The Transmission Atlas PJM Monthly Network Model is a set of complete “oneline” diagram cases for the PJM market. For the oneline diagram, a visual representation of all of the power lines, loads, generators, and other system components is given based on GIS data. The 2007 MMWG projected 2008 summer load was the case used. The PJM region in the data set has 9,900 generators.

4.3 Combining Data Sources

To determine the generators which have the strongest impact on nonattainment, two sets of power plants were used as shown in Figure 3-3. The first used the largest coal fired power plants in the Eastern Interconnect, identified from MMWG data. These were then coupled with the EPA Continuous Monitoring Emissions Database (CEMS) using latitude and longitude coordinates; any NOx emission sources within 750 m were considered a match. To reduce the inclusion of non-power plant point sources from this group, sources emitting less than 1000 moles/hr were excluded. This left a list of 332 generating units at 80 power plants representing approximately 63,200 MW of capacity of coal.

The second set of data considered all fossil fuel power plants within approximately 200 miles of Pittsburgh within PJM, and the same process as above was used to match the data sets resulting in 85 generators at 36 power plants, representing approximately 40,500 MW of capacity.

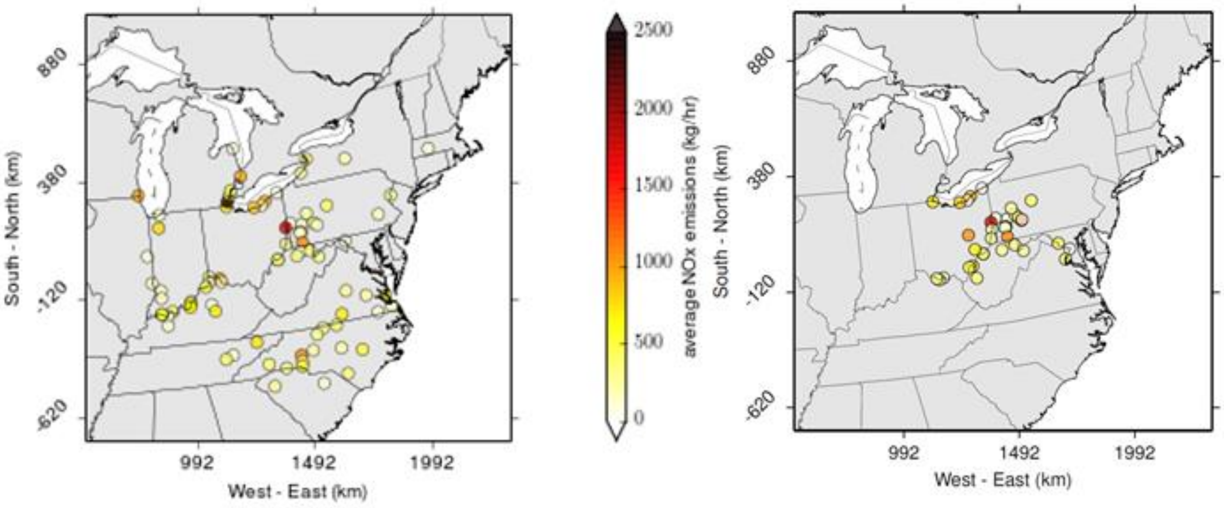
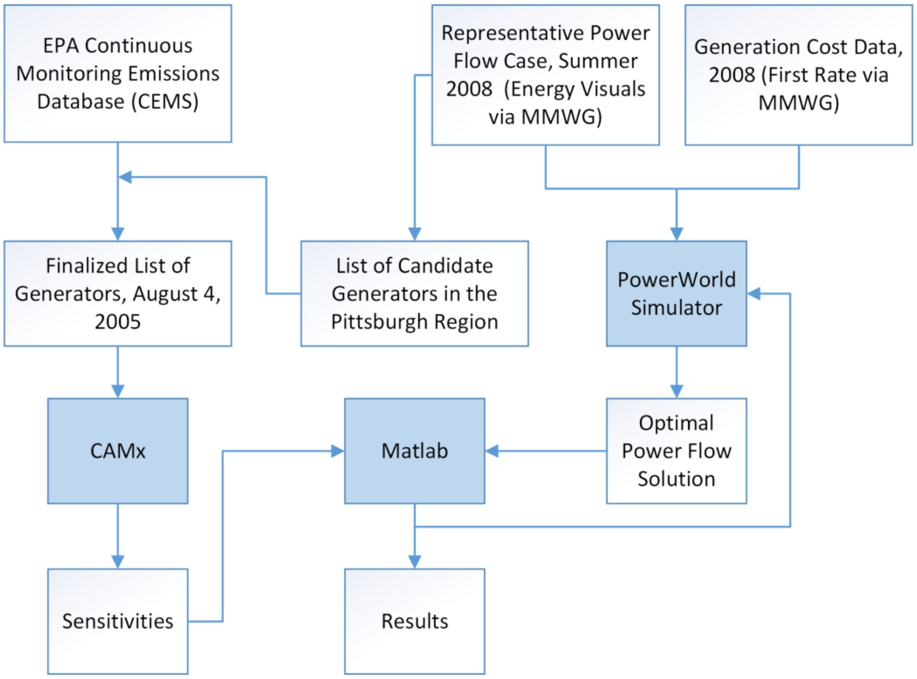


Figure 3-3. Power plants used in the analysis. A darker color indicates higher NOx emissions. The map on the left represents 80 power plants in the Eastern Interconnection used in the first scenario, while the map on the right represents 40 power plants in PJM Interconnection used in the second scenario.

An overview of the data integration is shown in Figure 3-4. A business-as-usual base case is run, which the seven scenarios are then compared against.



CAMx: For each time period, creates a sensitivity for each power plant given the atmospheric variables

Matlab: Ranks generators by sensitivity and shuts them off systematically to build a cost curve; sends each scenario to Simulator.

PowerWorld Simulator: Runs the OPF and returns system cost and generator data to Matlab

Figure 3-4. The flow chart of the data. Boxes in light blue represent data and boxes in dark blue represent programs.

4.4 Decision Rules

The complex nature of AC OPFs make them notoriously difficult to solve [150], [168]. Several decision rules are used here to enable this OPF to be solved in a reasonable timeframe. First, the dynamic element is greatly simplified by using 8-hr averages of sensitivities rather than eight separate hourly dispatches. Ozone reaches a maximum during the day because it is produced photochemically, and in all cases the highest eight hour-long sensitivities for all generators were consecutive. Figure 3-5 shows ozone concentrations in the Pittsburgh region over a two day period. The daylight hours show a clear spike in concentration.

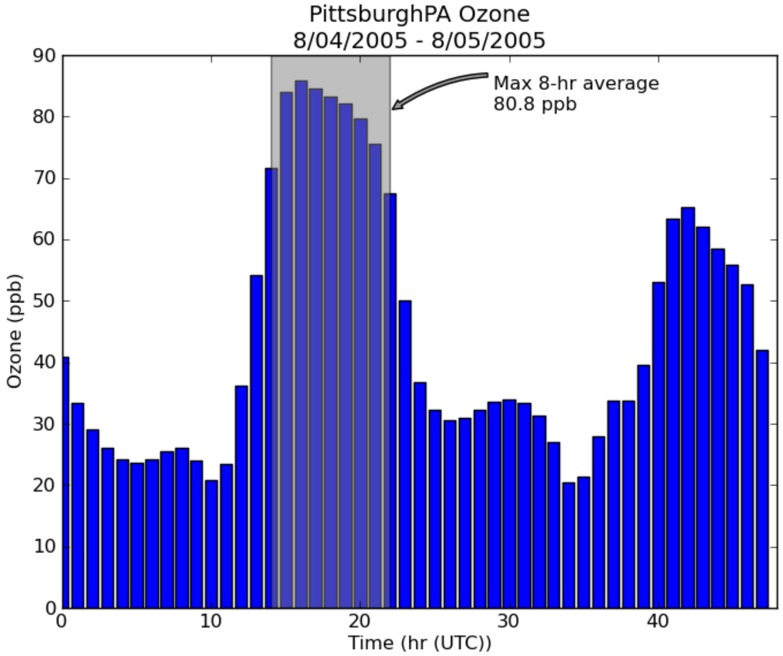


Figure 3-5. Ozone contribution clearly peaks during daylight hours.

Generators were then ranked by their 8-hr average sensitivities from greatest to least. For each target ppb reduction point in the cost curve, the minimum number of generators was turned off to meet the reduction threshold. It was assumed the marginal plant was shut down completely rather than throttled down partway. Alternatively, the sensitivities could have been used to calculate an expected average cost for each plant, and then been ranked that way instead. PowerWorld's lossess DC OPF was used, and generator ramping limits and unit commitment were ignored. The OPF was run over the entire PJM footprint.

5. Results and Discussion

Only a few of the power plants are relevant in each scenario. There are clear differences in the seven regions of the magnitude of how much abatement can be managed and at what cost. In Pittsburgh, the levels will remain virtually the same regardless of how the dispatch is modified, and reductions in ozone levels in New Castle and Columbus are also minimal following redispatch. Friendsville shows the greatest potential in reduction. Note that Butler, Clarksburg, and Friendsville could all see ozone reductions of more than 1.0 ppb with just single power plant being shut down. One of the most important atmospheric factors is the prevailing wind direction, and so regions directly in the downwind plume of major power plant emissions—on this particular day—are the most easily adaptable. In some cases, turning off power plants in advance can actually increase ozone concentrations because of the chemistry is highly non-linear, although only to effects of < 0.01 ppb. Table 3-1 gives the basic results for each region. Surprisingly, it was found that generators outside the PJM control area were highly important. For instance, a cluster of generators located along the Ohio River on the Indiana Kentucky are highly relevant (Figure 3-3). Note particularly the increase in possible ozone reduction in Friendsville when the dispatch is done over the Eastern Interconnection rather than PJM. Surprisingly, in four of the scenarios optimizing over the larger area if the Eastern Interconnection resulted in less abatement.

Table 3-1. Possible amounts of ozone reduction for August 4th for each region.

Region	**Maximum Possible Ozone Reduction (ppb)**		**Number of PPs with sensitivity > 1.0 ppb**		**Number of PPs with sensitivity > 0.1 ppb**	
	EI	PJM	EI	PJM	EI	PJM
Altoona	1.58	2.24	0	0	3	6
Butler	1.73	2.38	1	1	2	4
Clarksburg	3.98	3.75	2	1	6	5
Columbus	0.97	0.13	0	0	5	0
Friendsville	4.48	1.56	2	1	5	3
New Castle	0.90	1.71	0	0	3	6
Pittsburgh	0.00	1.69	0	0	0	6

For each region, a cost curve is developed as shown in Figure 3-6. For each point on the target pollution reduction curve, the minimum number of generators necessary is shut down. The plant with the highest sensitivity in the region is shut off. If the target pollution goal is not met, the second is shut off, and so on. The actual pollution reduction exceeds from the target because the marginal generator is shut completely off rather than being partially dispatched down.

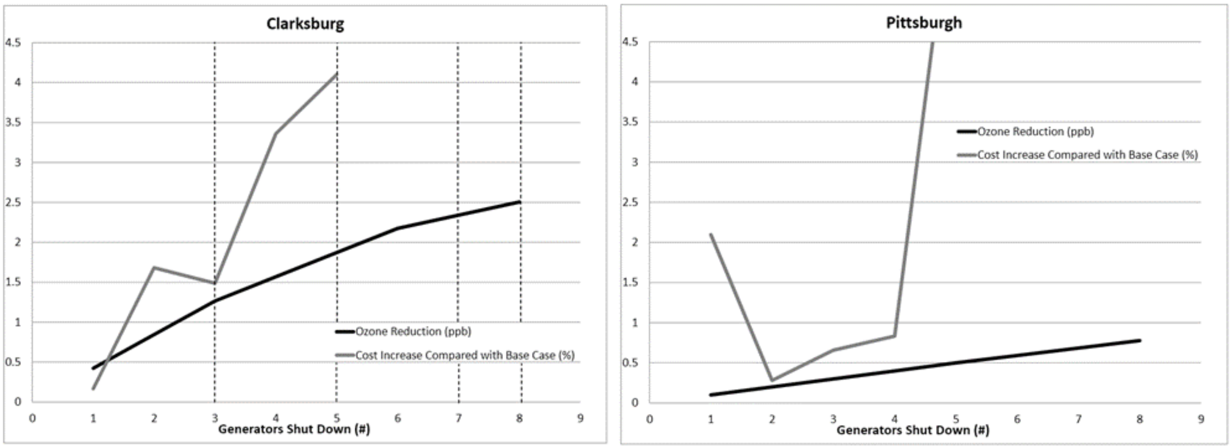


Figure 3-6. Ozone reduction (ppb) against marginal costs for Clarksburg and Pittsburgh, which represent the most and least amount of ozone which can be mitigated in the seven scenarios.

In some test regions, the cost curves sharply increase as the pollution reduction increases, implying the marginal cost curve is upward sloping. This suggests that it may be most cost effectively to target specific ozone reduction quantities in specific regions on specific days rather than the NAAQS. At times the costs are downward sloping because the transmission grid becomes overtaxed and the OPF unsolvable, so Power World relaxes a constraint.

If the RTOs were to incorporate NAAQs limits into their OPF then it should be determined who is bearing the cost of the shift of pollution. In the case of transboundary pollutants such as ozone, the health effect costs are borne mostly by those downwind of the stacks emitting high NOx emissions; they may or may not be the ones consuming the electricity generated by the upwind power plants. The target ozone reduction shifts the emissions elsewhere, as well as the associated costs of negative health effects. The exposure-response curve of ozone is not well known, but evidence suggests that if there is a threshold it is likely about 20 ppb, which is much lower than the NAAQS 8-hr standard [169]. At the same time, it is known that the co-benefits of reducing emissions are important, and so the benefits in a reduction of particulate matter would need to be considered as well [170].

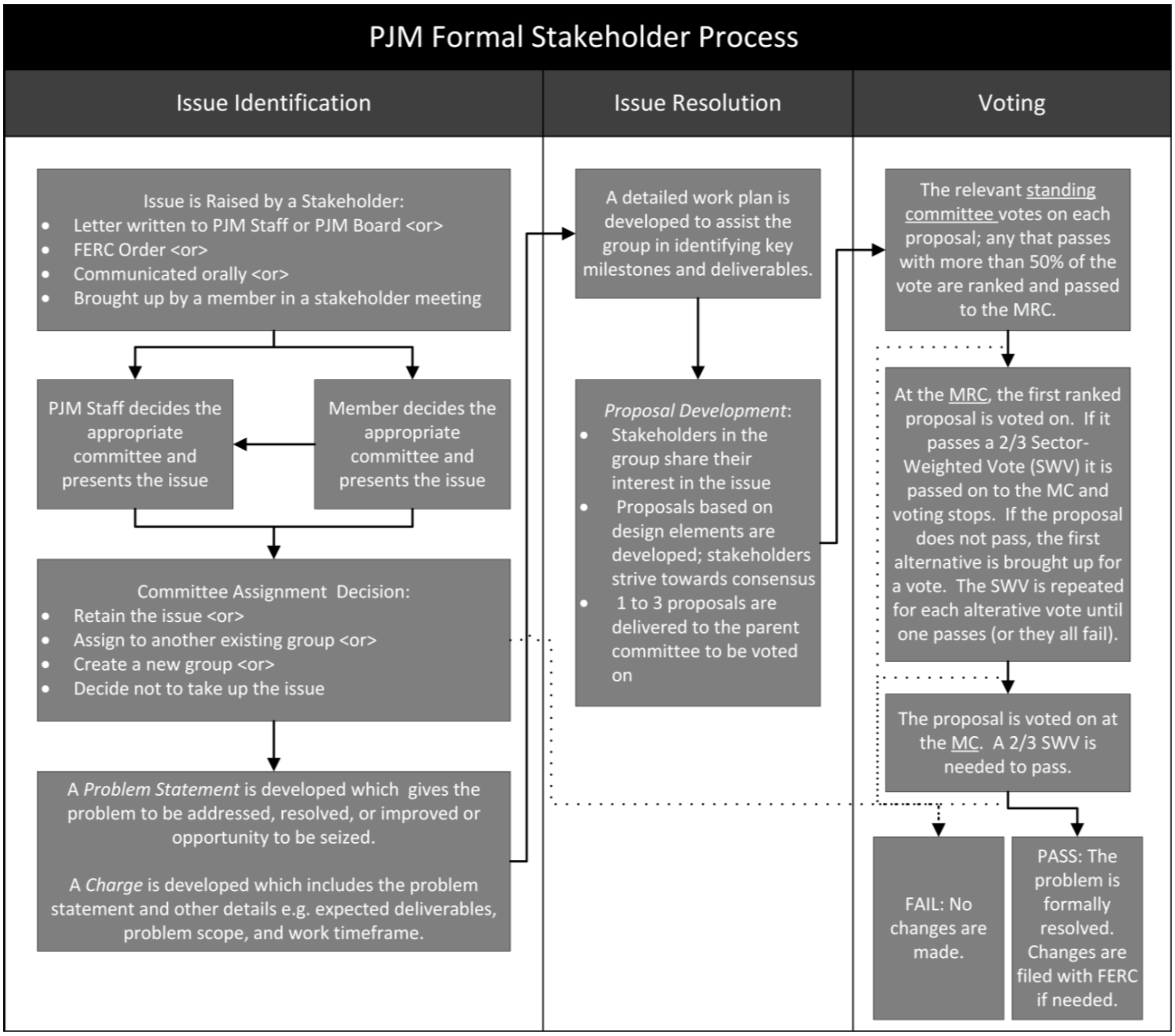
More important than the individual results in this case is the demonstration of a method which could potentially be utilized by RTOs in a targeted fashion. For areas projected to be in nonattainment, a cost curve could be developed. The addition of a marginal cost cap would avoid a scenario of an unreasonable cost. For instance, if ozone concentration was projected to be at 77 ppb, it may cost only a trivial amount to reduce this to 76 ppb through a redispatch, whereas reducing the concentration to 75 ppb would be significantly higher to the region's ability to meet the NAAQs standards.

One of the most challenging aspects to implementing this would be the lack of accessible real-time emissions data from power plants. It could also have an impact on electricity markets in at least two ways. First, certain generators which cleared the day-ahead market but are curtailed would still need to be paid. Second, ancillary services markets could be negatively affected in that fewer generators would be available for balancing and regulation. This is especially important in considering that the most likely time a power plant would need to be curtailed due to emissions is during peak summer loads when there is little slack in the system. This modeling also assumes that the predicted weather patterns would hold.

This model could be extended further in several ways. First, the model could be run hourly instead of just once a day using the 8-hr average. Solving this problem is considerably more complex due to the need to use optimal control theory to account for the time-dependent states. The next natural step would be to incorporate ramping limits and unit commitment. This is a significant step towards a more realistic model because these features are an important part of the OPFs the RTOs use. Stochasticity could be included in either the sensitivities or expended demand to account for these real-world situations. The model could be run for an entire season provided accurate load data could be obtained. Finally, other decision rules could be explored. For instance, it might be possible to shut down power plants with the highest ozone reductions per dollar of substitute electricity rather than simply the power plants with the highest absolute sensitivity. Further, this model could incorporate particulate matter from both anthropogenic and natural sources.

Appendix A

Issue Movement Through the PJM Stakeholder Process. Author adaptation from [171]**.**



Issue is Raised by a Stakeholder:

- Letter written to PJM Staff or PJM Board <or>
- FERC Order <or>
- Communicated orally <or>
- Brought up by a member in a stakeholder meeting

PJM Staff decides the appropriate committee and presents the issue

Member decides the appropriate committee and presents the issue

Committee Assignment Decision:

- Retain the issue <or>
- Assign to another existing group <or>
- Create a new group <or>
- Decide not to take up the issue

A *Problem Statement* is developed which gives the problem to be addressed, resolved, or improved or opportunity to be seized.

A *Charge* is developed which includes the problem statement and other details e.g. expected deliverables, problem scope, and work timeframe.

A detailed work plan is developed to assist the group in identifying key milestones and deliverables.

Proposal Development:

- Stakeholders in the group share their interest in the issue
- Proposals based on design elements are developed; stakeholders strive towards consensus
- 1 to 3 proposals are delivered to the parent committee to be voted on

The relevant standing committee votes on each proposal; any that passes with more than 50% of the vote are ranked and passed to the MRC.

At the MRC, the first ranked proposal is voted on. If it passes a 2/3 Sector-Weighted Vote (SWV) it is passed on to the MC and voting stops. If the proposal does not pass, the first alternative is brought up for a vote. The SWV is repeated for each alterative vote until one passes (or they all fail).

The proposal is voted on at the MC. A 2/3 SWV is needed to pass.

FAIL: No changes are made.

PASS: The problem is formally resolved. Changes are filed with FERC if needed.

Appendix B

Interview protocol

There were three versions of the interview protocol used. Shown here is the second and main version. The first version used for early interviews was modified in language, especially in the probing questions, to better reflect a natural flow of conversation. The content remained essentially the same. A customized protocol was used for the final interview to target the respondent's specific employment background. All interviews were semi-structured.

Opening Script: The primary goal of our research project is to understand how the decision making process works at RTOs. We've been trying to understand the formal process; we need to understand better the experiences of those who participate in the actual process. Our questions are really a conversational guide to help us understand your experience at/with ___ [RTO].

Demographics/History

1. How have you been involved with _____ [RTO]?
    a. Probe: How long have you been involved with ________ [RTO]?

Understanding the Process for Decision Making

2. How would you characterize the stakeholder process at _____ [RTO]?
    a. Probe: What is a typical meeting like?
    b. Probe: Are there any other elements in the process that I wouldn't understand from information on the website?
    c. Probe:
        i. It sounds like you've had a *positive experience*; can you tell me more about what works well in the process? Is there anything that you would change?
        ii. It sounds like you've had a *negative experience*; what were some of the challenges or what would you change in the process?

3. How would I know when a decision has been made?
    a. Probe: Who is involved in deciding what items are put on the agenda or how quickly issues move through the process?
    b. Probe: Could you provide an example?

4. Do stakeholders or staff work on issues outside of the formal meetings?
    [UNDERSTAND EXPERIENCE / SENSE OF RTOs]
    a. Probe: How does that work?
    b. Probe: Is it important to have certain stakeholders or staff involved in an issue?

Understanding the Stakeholder Groups

5. Who are the stakeholder groups involved [in the issues you are working on?
    a. Probe: Who are the stakeholders frequently involved in stakeholder processes?

6. How would you characterize the stakeholders?
    a. How would you describe the influence of certain stakeholder groups?
    b. How would I recognize different stakeholder groups in a meeting?

7. What is it like for newcomers to participate in the stakeholder process?
    a. Probe: What have _____ [names of new stakeholder groups] had to do to be part of the process?
    b. Probe: How would you know if a newcomer is doing something wrong or how would you help a newcomer figure out the process?

Understanding Influences

8. Are issues regarding transmission, markets and reliability related?
    a. Are these coordinated in the decision making process?
    b. What are some common disagreements you see in the process?

9. How do people enter into leadership positions?
    a. I’m trying to understand leadership. Do stakeholder groups identify formal or informal leaders?
    b. Can you describe the board/advisory committee nomination process?

Conclusion

10. That’s all for my questions. What else should I know or be asking in order to understand the ______ [RTO]’s processes, stakeholder groups and participation?

11. Is there anything you would like to ask me?

12. Would you mind recommending anyone else who you think I should speak with that would be interested in participating?

Thank you for your time. We really appreciate it!

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PUBLICATIONS

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