# Network Governance and Effectiveness on Renewable Energy Integration: A Comparative Case Study on Power Transmission Networks in the United States

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## 1 Introduction

To achieve carbon emission reductions and energy security, state governments in the United States are promoting renewable energy in the power sector through a variety of policy tools. Among all renewable energy, wind power, because of its unpredictable intermittent production features, imposes high level of variability and uncertainty to the power system. Massive integration of this variable energy resource (VER) [1] in the current power system requires regional collaboration among power producers, transmission system operators, load-serving entities, and different levels of regulatory agencies to maintain system resilience and ensure reliability (Koch, 2009; Hall et al., 2009; Klass and Wilson, 2012). These organizations from different sectors interact in the regional transmission service networks.

Following the Federal Energy Regulatory Commission (FERC)'s orders to develop a competitive and transparent electricity market,[2] the restructuring of the US electricity wholesale market resulted in two different models of regional transmission network governance since early 2000s. In most regions, as shown in Figure 6-1, transmission networks are coordinated by seven Independent System Operators or Regional Transmission Organizations (ISO/RTOs). Created by partnered power producers, utilities that own transmission assets, and load serving entities, these ISO/RTOs are nonprofit and interest-neutral network administrative organizations (NAOs). While they do not own any transmission or generation assets, they serve as regional transmission system controllers, coordinate transmission services, and organize the electricity wholesale market. In other regions (i.e. Non-RTO West and Non-RTO Southeast in Figure 1), the transmission system is controlled and managed by one or multiple integrated utilities that owns both generation and transmission assets. Without a centralized independent transmission operator, these large utilities coordinate with each other to ensure region-wide reliability of the power system. In these shared-governance networks (Provan & Kenis, 2008), external regional coordinating agencies also exist, which

[1] Wind energy is often referred to "variable energy resource" (VER) because it is intermittent and the variability of generation is subjected to limited control of wind power plant operators.
[2] The Federal Energy Regulatory Commission (FERC) is an independent agency that regulates the interstate transmission and wholesale sales of electricity, natural gas, and oil. For details about FERC's deregulation orders, see FERC Order 888 and 889.

only take on some governance activities while leaving transmission system operation and market coordination to those integrated utilities (Hall et al., 2009).

A few empirical studies have shown that growth of wind generation capacities and wind farm performance in RTO-governed transmission networks are significant higher than non-RTO regions (Hitaj, 2011; Tang, 2016). However, the underlying mechanisms through which a particular transmission governance model facilitates or impedes wind power deployment are not fully revealed, particularly from the perspective of network governance. In this paper, I am filling this intellectual gap and examining how transmission network governance affects wind power integration. Based on network governance theoretical framework, this paper addresses two research questions: 1) how structural properties of a transmission network affect its effectiveness in integrating wind power; and 2) how coordinating mechanisms in a transmission network affect its effectiveness in integrating wind power. Using archival data and interviews with key network participants, a comparative case study is conducted between an ISO/RTO-governed transmission network and a transmission network in non-RTO region.

This paper contributes to both literature on network governance, and studies on renewable energy deployment in the power sector. Previous literature on network governance has proposed a theoretical framework to evaluate network effectiveness, and identified contingencies that explain why a certain governance mode is likely to be effective or not (Provan & Milward 1995; Provan and Kenis, 2008). Most empirical studies testing these hypotheses concentrate in the fields of public health (Provan and Milward, 1995; Milward et al., 2009), education (O'Toole and Meier, 2004), economic development (Savas and Savas, 2000; Feiock et al., 2010), and emergency management (Kapucu, 2006; Moynihan, 2009; Kapucu et al., 2010; Kapucu & Garayev, 2012). This paper will be the first to examine the relationship between network governance and network effectiveness in the power sector. On top of that, the transmission network cases extend existing theories by highlighting the underlying mechanisms through which particular network structural properties or coordinating processes can achieve both system stability and flexibility, particularly when the network is embedded in a turbulent environment with uncertainties and disruptions. These new findings can be applied to studies on resilience of other complex resource management and delivery networks that operate over large spatial scales.

While most literature on renewable energy diffusion in US is at state level and focuses on renewable generation (Carley, 2009; Yin and Powers, 2010; Buckman, 2011; Gaul and Carley, 2012; Shrimali, et al., 2013; Kim and Tang, 2014), this paper adds to existing studies a regional perspective and makes substantial contribution to understanding the links between regional transmission network governance and their outcome in terms of renewable energy integration. It also informs electricity market design for high renewable energy penetration, and sheds light on how to forge effective collaboration among power producers and transmission system operators to manage variable energy resources in different types of electricity market.

## 2 The Context: Power System Operation and Renewable Energy Development in US

### 2.1 Multiple Public Interests in Transmission Network Operation

The US power system is a vast network that consists of two layers. Physically, the power system is a network of electric generating units, loads, and transmission and distribution systems that move electric energy from generators to ultimate loads. From an organizational perspective, it is a cross-sectoral network of power generators, transmission system operators, load serving entities, end consumers, and other entities involved in the electricity market (MIT, 2011).[3] These two layers of network are interdependent of each other. This paper examines both layers of the power network with a focus on the electricity wholesale market operated within the transmission network, since the wholesale market involves interstate transactions and energy transmission, and is where most regional coordination occurs.

[3] Electricity market includes wholesale market and retail market. Electricity wholesale market is the marketplace for a generating entity to sell its power generation to a utility or other retailers which then resell the power to end consumers in the retail market. Electricity is delivered from generators to retailers through the transmission system. In retail market, electricity is directly sold to consumers who consume power themselves. Electricity is delivered through distribution system to end-consumers.

While electricity delivery services are provided mostly through market, the US power system also serves multiple public interests. The primary goal of the power system is to ensure the reliable delivery of electricity at the lowest cost to consumers. Because electricity demand is variable in time, and uncertain in quantity, power producers, transmission system operators, and load serving utilities must be constantly coordinated in real time[4] to ensure the balance between generation and demand in the power system according to the reliability standards set by regulatory agencies. Otherwise, power system failure, such as outages, will cause huge societal costs. This balancing service is coordinated by a balancing authority (BA), which matches generating resources to electricity demand within its territory—the balancing area.[5]

In response to climate change and energy security concerns, increasing the share of renewable energy in power supply is an emerging public interest that the power sector serves. Boosted by federal and state level renewable energy policies, utilization of VERs such as wind and solar power has increased substantially in US over the past ten years. High penetration of variable generation in the power system create new challenges to the operation of power system and wholesale markets. First, it increases the variability and uncertainty of generating resources in the power system because its output is intermittent and cannot be accurately predicted at all time horizons. In addition, VERs have unique diurnal and seasonal patterns which may not correspond to the electricity demand pattern (MIT, 2011; NREL, 2014). Therefore, it requires the transmission network to have enough resilience from reserves, storage, or other forms of backup power supply

[4] The wholesale market in US operates in two time frames: day ahead and real time. The real-time market reflects actual physical supply and demand conditions. The day-ahead market operates in advance of the real-time market. The day-ahead market is largely financial, establishing financially-binding, one-day-forward contracts for energy transaction. Resources cleared in the day-ahead receive commitment and scheduling instructions from the system operator based on day-ahead results and must perform these contractual obligations or be charged the real-time price for any products not supplied. However, a number of factors, such as unexpected generation or transmission outages, and load forecasting errors, can cause deviation between day-ahead scheduling and real-time dispatching.

[5] Balancing area refers to the collection of generation, transmission, and loads within the metered boundaries of a balancing authority.

to accommodate high level of generation from renewable energy while maintaining its reliability at the same time.

## 2.2 Restructuring of the Electricity Market and Transmission Network Governance

The restructuring of the US electricity market from mid-1990s and the heterogeneous electricity market structures after restructuring formed different transmission network governance models across regions. Before the restructuring, electricity markets were served by vertically integrated utilities (see Figure 6-2), which possessed and operated all parts of the power system including generators, transmission and distribution system. In the wholesale market, electricity transactions were between these utilities based on bilateral contracts, either short-term to take advantage of one utility having cheaper generation at a moment in time than another utility, or longer term to provide needed capacity to the purchasing utility. These transactions were regulated by federal governments. Balancing authorities that match electricity generation and demands to keep system balance were mostly overlapped with major large utilities.

Following the FERC's deregulation orders that promoted competition in the electricity wholesale market through opening the access to transmission services, vertically-integrated utilities were required to divest all or some of their generating assets to third parties, and more independent power producers also entered the wholesale market. In addition, new forms of transmission network governance also emerged in regions that are deregulated. Seven ISO/RTOs were set up in 2000s as user-supported and interests-neutral non-profit companies overseen by FERC, which do not have any generation and transmission assets, or retail consumers. The ISO/RTO operates as a consolidated BA over a large jurisdiction that consists of multiple balancing areas before restructuring. As a centralized transmission network coordinator, it controls transmission system operation and organizes regional wholesale market transactions using a competitive bidding system. [6] Currently, ISO/RTO-governed transmission networks serve two thirds of the electricity

[6] In the bidding process, generators participating in the wholesale market offer an amount of electricity (MWh) for sale during specific periods of the next day at a specific price based on their production costs. These bids are either accepted or rejected by the ISO/RTO based on projected electricity demand within its territory. Generators are scheduled and dispatched from the least-cost bid to higher cost ones until the total demand is matched. The market clearing price is the offer of the last generator dispatched at their location, which is also called locational marginal price and paid to all the generators that are dispatched.

demand in US (MIT, 2011; Aggarwal and Harvey, 2013). The Southeast and most Western states are still dominated by traditional vertically-integrated utility model. In these non-RTO regions, transmission networks are controlled and operated by utilities that own the transmission systems, and the wholesale market transactions are mostly based on bilateral contracts.

Understanding whether and how these two different transmission network governance models affect power system to achieve its multiple public goals is important for future institutional designs in the power sector. As for the goal of integrating renewable energy, a few empirical studies have provided evidence that wind generation capacity and wind farm performance in RTO-governed transmission networks is significant higher than non-RTO regions (Hitaj, 2011; Tang, 2016). However, how different transmission network governance models affect wind generation capacity and performance has not been examined. Several works identify regional collaboration on transmission planning and siting as a barrier to renewable energy development and introduce recent efforts in both RTO-regions and non-RTO regions to overcome this barrier (Brown and Rossi, 2010; Bloom et al., 2010; Wilson and Klass, 2012; Fischlein et al., 2013). Studies on the transmission operations are mostly from a technical perspective, which conduct engineering simulations to evaluate the performance of different electricity wholesale market designs assuming different levels of renewable energy penetration (Milligan and Kirby, 2007; MIT, 2011; Aggarwal and Harvey, 2013; Ela et al., 2014; Hunsaker et al., 2013; E3, 2015). There has been a lack of network management perspective to compare the two models of transmission network governance and analyze how this might be related to different outcomes in renewable energy integration between RTO-governed transmission network and non-RTO regions. This paper draws upon network governance scholarship to fill this intellectual gap.

## 3 Theoretical Framework: Network Governance and Effectiveness in Power System

The term "organizational network" has many different definitions. In fields related to public interests, where collective actions are often needed for problem solving, policy implementation, or public service delivery, networks are often viewed as groups of legally autonomous organizations that work together to achieve collective goals which cannot not be effectively achieved by one single organization (Agranoff & McGuire, 2001; O' Toole, 1997; Provan and Kenis, 2008; McGuire, 2006; Provan and Milward, 2006; Keast, 2014; Hu et al., 2015).

In light of this definition, the US power system can be viewed as service delivery networks, which consist of multiple electricity market participants that are connected both physically through power grids and institutionally in the electricity market to deliver electricity from generators to end consumers. In addition to delivering reliable electricity, another important public good it provides is to facilitate large-scale renewable energy deployment so as to reduce greenhouse gas emissions in the power sector, which requires regional collaboration among all network participants (Koch, 2009; Hall et al., 2009).

This paper focuses on how the collective actions among participants in the transmission networks are organized and coordinated. While network governance in the power sector and its possible link to multiple network outcomes has not been studied in existing literature, there has been increasing theory building and empirical research on public service implementation networks, such as mental health networks (Provan and Milward, 1995; Milward et al., 2009), education networks (O'Toole and Meier, 2001 & 2004), and economic development networks (Savas and Savas, 2000; Feiock et al., 2010), and problem solving networks such as emergency management networks (Kapucu, 2006; Moynihan, 2009; Kapucu et al., 2010; Kapucu & Garayev, 2012). In this paper, I draw upon these existing network studies to build a theoretical framework analyzing network governance and outcomes in the US transmission networks. Particularly, I focus on the structural properties and coordinating mechanisms adopted in different network governance models.

## 3.1 Network Effectiveness

Network effectiveness can be evaluated at network level, community level, or individual network participant level (Provan and Milward, 2001). In this paper, I follow the network level analysis approach, and define network effectiveness as "the attainment of positive network-level outcomes that could not normally be achieved by individual organizational participants acting independently" (Provan and Kenis, 2008). However, the specific type of network-level outcome depends on particular constituency assessing the functioning of the network (Milward and Provan, 1995 & 2001). This paper examines the effectiveness of regional power network in achieving its emerging goal– environmental sustainability and energy security. At operational level, increased utilization of renewable energy in the power sector is one of the intermediate goals to attain this environmental and energy sustainability (Miranda, 2009; Koch, 2009). Therefore, I will look at the effectiveness of the transmission networks in achieving this intermediate goal—increased utilization of renewable energy in power supply.

### 3.2 Network Structure

Most existing works that examine the determinants of network effectiveness identify network structure as a key factor associated with network outcomes. Network structure concerns the degree of integration in the network (Provan and Milward, 1995; Provan and Kenis, 2008; Raab et al., 2013). Three aspects of network structure are most frequently studied in the literature on interorganizational networks: network density, level of centralization, and cliques. Density describes the general level of interconnectedness among network participants while centralization describes the extent to which this cohesion is organized around particular central agencies (Provan and Milward 1995). Instead of considering the whole network system, cliques focuse on the subgroups within a large network. A network is more integrated if subgroups within the network overlap with each other (Provan and Sebastian, 1998).

Among these three aspects, this paper focuses on examining how network centralization and cliques within the networks affect network outcomes. Density is not considered because all the network participants in the regional power system are interconnected through the physical power grids. The density of institutional linkages are heavily relied on physical density of transmission lines in the regional interconnection, which are more related to transmission siting and planning. Since this paper focuses on operations of the power system given existing transmission infrastructure rather than transmission planning, network density is beyond the scope of this paper.

### 3.2.1 Network centralization

Network centralization describes the power and control structure of the network – whether links and activities are organized around any particular one or small groups of organizations (Provan and Milward, 1995; Borgatti et al., 2013). Previous studies on different public management networks measure level of network centralization through two indicators. The first indicator is the centrality of core agencies, which is measured as the percentage of the link that the core agency has in total network links. This linkage-based measurement indicates that the core agency is in the central structural position in the network. The second indicator, concentration of influence, concerns more about the actual influence of core agencies. This is measured as whether influence over decisions related to a particular service is concentrated within a single agency or a group of agencies. When agencies in a system act in ways consistent with the wills and expectations of core organizations, centrally controlled and coordinated actions are attainable (Provan and Milward, 1995).

Centralized integration is beneficial for network effectiveness, because it facilitates both integration and coordination of resources and actions in the network. In addition, a centralized network allows effective monitoring of the services because the central broker is in a better position to oversee and control the activities of network members. Existing empirical research on community mental health service, crime prevention networks, emergency management, and regional economic development all suggests that the presence of a powerful lead organization, acting as system controller or facilitator, can be critical to the effectiveness of collaborative management (Provan and Milward, 1995; Agranoff and McGuire, 2003; Moynihan, 2005 & 2009; Raab et al., 2015).

Thus, I expect that the regional transmission network will be more effective in integrating wind generation if the network is more centralized, particularly if it is operated under the coordination of a single system operator.

### 3.2.2 Cliques

In addition to the overall centralization of network, a stream of scholarship in network structure research focus on the sub-structure of networks. Within a large network, participants may form subgroups in which network members are more interconnected with each other than with members outside the subgroups. Clique overlap describes the degree that subgroups within a large network overlap with each other. Network effectiveness is enhanced when small cliques of agencies have overlapping linkages (Provan and Sabastian, 1998). Where the sub-groups have large overlap with each other in terms of network members, we can expect that conflict between them is less likely than when the groups don't overlap. Moreover, mobilization and diffusion may spread rapidly across the entire network. In empirical network research, a few studies have conducted clique analysis to identify sub-groups of key stakeholders with similar beliefs or with closer collaborations (Kapucu et al, 2009 &2010; Ansell et al., 2009; Weibel 2011). However, they did not analyze the overlaps among cliques.

In this paper, the substructure of regional transmission network and its relationship to network outcome is also examined with the expectation that degree of overlap between cliques facilitate the power system to accommodate more wind generation.

### 3.2.3 Mode of governance

Another series of concepts that describe structural properties of network governance are the three modes of governance—shared governance, lead organization governance, and network administration organization (NAO) governance (Provan and Kenis, 2008). These three modes of governance are differentiated by two dimensions: 1) whether the network is highly centralized; and 2) whether this network is participant governed or externally governed. Shared governance is at one extreme of the first dimension since it is a highly decentralized form – each network participant interacts others to govern the network collectively. In contrast, network governed by a lead organization or by NAO is highly administrated by a single core agency (or a couple of core agencies), with less direct interactions between network participants. The difference between these two centralized modes is whether the core agency is a network participant (lead organization governance), or is a third party coordinator (NAO governance).

The relationship between governance modes and network effectiveness has been discussed on these two dimensions. Regarding network centralization, Provan and Kenis (2008) propose that brokered forms of network governance, like lead organization and NAO governance, are likely to be more effective than shared governance when trust among network participants are moderate or low, when the size of network becomes larger, when network has diverse goals, and when the need for network level competencies are increasing. The power transmission network seems to be a typical case that needs brokered network governance since it has multiple goals to meet and demands high level of network competencies to manage both internal and external uncertainties. As for the second dimension, Raab et al. (2013) argue that an independent external agency would be more effective to coordinate a diverse set of participants because it is not embedded in the logic or culture of any groups within participants and will be more neutral. However, they do not empirically confirm if NAO governed networks lead to better effectiveness than lead agency governed networks.

In this paper, the modes of governance in regional power network are more complicated than any single governance mode. I will examine how their structural properties affect network outcomes based on the primary modes proposed by Provan and Kenis, and extend their theoretical framework according to the practice in the power sector.

## 3.3 Coordinating Mechanisms and Process

In addition to the structural attributes of network, the coordination mechanism and decision making process in network also affects its outcome.

### 3.3.1 Coordination mechanisms

Starting from Powell (1990), a common approach in network research views network as a unique form of governance. This stream of literature compares network with market and hierarchy, and discusses the strengths and weaknesses of each form. Market is viewed as spontaneous coordination mechanism through price signals, and agreements between participants are supported by the power of legal sanction. As a paradigm of "individually self-interested, non-cooperative, unconstrained social interaction", competitive market offers choices and flexibility. In hierarchies, communication and exchange is organized through clean lines of authority, detailed reporting mechanisms, and formal decision-making procedures. Therefore, this form of coordination provides reliability and accountability. Comparing to exchange through discrete transactions or administrative orders, communication and inter-organizational exchange within network is mostly based on reciprocal relationship between network participants. Participants are interdependent on each other and they gain through the pooling of resources (Powell, 1990; Jones et al., 1997, Raab, 2004). Thus, network can achieve outcomes that market or hierarchies cannot, such as reduction of uncertainty, fast access to information, and responsiveness.

However, this network as a form of governance approach treats network undifferentiated and ignores the variations among networks in terms of structural patterns and relations among participants. Therefore, this paper takes an alternative approach and focuses on the governance and management of network themselves (Provan and Kenis, 2008). Recent case studies show that interorganizational networks are governed through a blending of multiple coordinating mechanisms (McGuire, 2006). A study on environmental governance network from Robins et al. (2011) suggests that older governance forms, including those involving hierarchies and markets, are embedded in their own forms of network-like relationships among institutions and actors. Networks governed by NAOs or lead organizations in economic development or emergency management are often coordinated through command and control procedures by the central coordinators while network participants work together collaboratively (Agranoff and McGuire, 2003; Moynihan, 2006). The transmission networks are also a combination of hierarchical coordination, network, and market. I will explore how these coordinating mechanisms blend together to improve the utilization of renewable energy in the power system.

### 3.3.2 Managing the tension between flexibility versus stability

Network governance involves inherent tensions, such as efficiency-inclusiveness (or unity-diversity), and flexibility-stability tensions (Provan and Kenis, 2008; Saz-Carranza and Ospina, 2011). How to manage these basic tensions are critical to network effectiveness. As for integrating renewable energy into the power system, the most salient issue is the need for both system stability (reliability) and flexibility.[7] Reliability is the primary goal for power system operation while a certain level of system flexibility is required to respond to the external uncertainties from variable wind resources.

In network governance literature, several case studies have either confirmed the importance of flexibility or stability in achieving satisfactory network outcomes. Marc et al. (2012) suggest that, in the context of disaster response, effective network governance often requires a more flexible and sparse network structure. A series of articles on mental health networks find that network stability is a major determinant of satisfactory performance and the stability is mostly attained through NAO's utilization of consistent contracting procedures, regulations and monitoring (Provan and Milward, 1995; Milward et al., 2010). However, there is lack of empirical research on governance process and mechanisms that can achieve flexibility and stability at the same time, particularly when the network is embedded in a turbulent environment with high uncertainties. Integrating wind power into the power grid requires the power system operation to be both flexible and stable, which provides a perfect case to examine how flexibility and stability are reconciled in network governance to improve system resilience.

## 4 Research Design and Methods

I use a comparative case study approach (Yin, 1984) to examine the impacts of transmission network governance on renewable energy integration between two transmission

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[7] Flexibility in a power system refers to the ability of the system to cope with variability and uncertainty in both generation and demand at various operational timescales (Lannoye et al., 2012; Ma et al., 2013; Ela et al., 2014).

networks with different governance models. I start from the theoretical framework set up in Section 3 to analyze the two cases using content analysis. New themes and insights emerged from the transmission network cases are then used to extend the theoretical framework.

## 4.1 Case Selection: Internal Validity and External Validity

Among all regional transmission networks shown in Figure 6-1, I select two cases to compare: 1) the Midcontinent ISO (MISO) network—an ISO/RTO governed regional transmission network, where the electricity wholesale market is organized by MISO; and 2) the Non-RTO West network, which are transmission systems in the Western Interconnection excluding ISO/RTO governed network.[8] The two cases are selected based on network size, electricity demand, renewable energy policy support, wind resource endowment, existing wind generation capacity, transmission infrastructure, and other factors that affect network governance and/or wind power generation. Control of these factors allows me to focus the comparison on network governance and examine how these governance attributes affect wind power integration in these two regions.

In addition to the internal validity established through case comparison, insights drawn from these two cases can also inform transmission network governance design in other regions in US. MISO and the Non-RTO West represent two major transmission network governance models in the US–the ISO/RTO model and non-RTO model respectively. While there are some variations among regional transmission networks within each category, there has been a large degree of convergence in general principles of market design and transmission system operation among regions governed by the same model (Miranda, 2009).

[8] The only ISO/RTO-governed transmission network in the Western Interconnection is the area coordinated by the California Independent System Operator (Figure 4-1), which is excluded for the purpose of comparing different transmission governance models.

## 4.2 Data Collection and Analysis

To develop an in-depth picture of each case, I draw on extensive qualitative and quantitative archival data collected from all network participants in each case, U.S. Energy Information Administration (EIA), FERC, and Fectiva news database. This secondary data is supplemented by data from interviews with multiple key stakeholders from each network. A detailed account of each case is established based on triangulation of these different data sources, which reassures that the interpretations of these two cases are not shaped by idiosyncratic evidence.

As mentioned in Section 4.3.1, effectiveness of wind power integration in transmission network is measured by the utilization rate of wind power in each region. One common indicator for the utilization rate is capacity factor, which is the ratio of actual wind generation to the potential maximum generation if all wind farms in the region were operated at their full capacities throughout the year.[9] Wind generation and generating capacity data for the two regions is collected from the EIA database.

For network structural properties and coordinating mechanisms in MISO network and the Non-RTO West, I collect archival documents from all network members[10], coordinating agencies (i.e. MISO, West Electricity Coordinating Council (WECC), and other sub-regional coordinators in Non-RTO West), state regulators that involved in the two regional transmission networks, and FERC. To triangulate with this archival data, I also extract news articles about transmission system operation and renewable energy integration in these two regional networks from Fectiva database. These news articles cover the years from the formation of MISO till the end of 2015.[11]

In addition, I use data from semi-structured phone interviews with a diverse set of stakeholders from MISO network and Non-RTO West to supplement the findings from secondary data sources. For

[9] Capacity factor of wind power $= \frac{Observed\ annual\ \ wind\ generation}{Total\ exsiting\ wind\ generating\ caapcity \times 24\ hours \times 365\ days}$

[10] I collect annual market reports and/or reliability reports from 432 participants in MISO network and 420 participants in the Non-RTO West. These reports summarize market operation or transmission system operation from the perspectives of participants in different segments of the power system, including generation and transmission. Balancing authorities in Non-RTO West are mostly overlapped with large utilities that also own and operate transmission systems.

[11] News articles are extracted from Fectiva through key words searching. Key words include “transmission”, “wind power”, “renewable energy”, “interconnection”, “grid operation”, “wholesale market”, and “curtailment”.

MISO, seven interviews were conducted with staff from MISO, independent wind power producers, transmission system owners, and an academic researcher. For Non-RTO West, five interviews were conducted with staff from WECC, two balancing authorities/transmission system operators, independent wind power producers. In all interviews, people were asked to talk about their agency's daily operation regarding power scheduling and real-time dispatching, and the advantages or barriers for the regional transmission network to integrate wind power. Through coding this interview data, I obtain more insights into the transmission system operation, market coordination process adopted in each regional network, and how these coordinating mechanisms or market designs have promoted or impeded the utilization of wind power.

All textual data is coded using a qualitative software NVivo 10. A total of 4026 text units (including technical or market reports, news articles, and interview transcripts) are coded. I start the coding process with key concepts of network structure and coordinating mechanisms identified in my theoretical framework and then modify this framework with new codes emerged from the two cases. The coding process shapes the relevance, meaning, and interconnection of concepts. The interconnections of key concepts in the context of transmission networks emerge through recursive cycling among case data, existing literature on network governance, and emerging theory.

## 4.3 Case Summaries

In the MISO network, MISO, serves as the centralized system operator and reliability coordinator, operates the transmission system and a centrally dispatched market in portions of 15 states in the Midwest and the South. This centralized market was developed over the past 15 years. MISO was formed as an ISO in December 2001 and began to organize the regional electricity wholesale market in 2005. In 2009, MISO started operating an ancillary services market and combined its 24 separate balancing areas into a single balancing area. In 2013, the MISO transmission network extends to the South region, including parts of Arkansas, Mississippi, Louisiana, and Texas.

The Non-RTO West network includes transmission systems in the Western Interconnection within the US territory except for CAISO. The Western Interconnection is one of four major electric system networks in North America, which covers all or part of 15 states in the US. While the whole network consists of 38 balancing areas operated as separate wholesale markets, they are coordinated by WECC to ensure system reliability.

In this paper, comparison between these two networks focuses on their most recent structure and governance mechanisms after MISO consolidated its balancing authorities in 2009. Table 6-1 shows the comparison between these two networks on a series of case selection criteria (based on 2014 statistics), which affect both network governance and utilization of wind power. First, we see that the two regional transmission networks have similar size in terms of service territory, network participants, and electricity demand they serve. Network participants mainly include power producers, transmission system owners/operators, and load serving entities (utilities that purchase electricity in the wholesale market).

In addition to the size of network and scope of operation, we can observe that most states in either MISO territory or Non-RTO West have adopted Renewable Portfolio Standards, which is a major policy tool that state-level governments often use to increase the utilization of wind power in power supply (Kim & Tang, 2014; Yin & Powers, 2010; Carley, 2009; Carley & Browne, 2013).

Despite the fact that MISO has significantly less high voltage transmission lines for wind farms than Non-RTO West in 2014, there are similar existing wind power generation capacity with comparable wind resources on average in these two regions in 2014. Moreover, available wind generation capacity in these two regions are very close from 2009 to 2014 as shown in Figure 6-3.

Given existing transmission network infrastructure and similar features in network size, renewable energy policy support, wind resources, and wind generation capacity between the two cases, the relationship between network governance and the effectiveness of these two networks in integrating wind power will be analyzed in the following section.

# 5 Case Analysis and Findings

## 5.1 Network Effectiveness in Wind Power Integration

In this paper, I adopt objective measurement—the average capacity factor of wind power in the network—to measure network level effectiveness regarding wind power integration. This measurement captures utilization/performance of existing wind generation capacity in the power system (Wiser et al., 2011 & 2012). Since wind generation capacities and wind resources for these generating units are similar between MISO network and non-RTO West, higher utilization of existing capacity indicates that the regional transmission network better integrates wind energy into the system.

Figure 6-4 shows the average capacity factor of wind power in these two regional networks over the period 2010-2014, which covers the period after MISO network has consolidated as one balancing area. While the utilization rate of wind power increases about 10 percentage points in both regional networks, the average capacity factor of wind power in MISO is 3 to 4 percentage points higher than Non-RTO West across all these five years. This is equivalent to approximately 10% higher than the utilization rate of wind power in Non-RTO West. At individual wind farm level, as shown in Figure 6-5, MISO has larger share of wind farms with higher capacity factor than Non-RTO West among wind farms in the same wind quality class. Thus, the comparisons at network level and individual wind farm level both indicate that MISO network does a better job integrating wind power than the Non-RTO West.

Since the case selection process has controlled factors that may affect wind power utilization, such as network and market size, policy support for renewable energy, wind resources, and wind generating capacity, different effectiveness in integrating wind power between MISO and Non-RTO West may be attributed to network governance factors. Following the theoretical framework in Section 4.3, I will discuss how network structure and coordinating mechanisms in these two networks affect wind power utilization.

## 5.2 Network Structure and Resource Pooling

### 5.2.1 Level of centralization

The two regional transmission systems have apparently different level of centralization. To be more specific, one major difference between the two networks is whether the operation of transmission system and wholesale market is integrated and coordinated centrally through an independent system operator. This structural difference is important in understanding case outcome. For both cases, the most recurring theme came up from the data regarding wind power integration and grid operation is “consolidation” or “centralized operation”.

Following the theories on network centralization, I further examine two aspects of network centralization: core agency centrality and centration of influence (Provan & Milward, 1995). In a transmission network, the first aspect concerns whether network links are organized around any particular one or small groups of organization while the second aspect captures whether influence over decisions related to system operation and electricity market coordination is concentrated within a single core agency.

The MISO network has a highly centralized structure. MISO is the single core agency that connects all power producers and load serving entities within its territory. As for the concentration of influence, MISO serves as the central authority that controls and oversees the transmission system operation, and coordinates the wholesale electricity market.

In contrast, the non-RTO West has more decentralized network structure, where the transmission system and electricity wholesale market is jointly coordinated by 33 balancing authorities (BA).[12] These BAs are each responsible for balancing the generation to loads within its balancing area so that their combined efforts will keep the entire non-RTO West balanced and reliable. A stakeholder in the Western Interconnection commented that “the divided operation of the interconnected western grid is not unlike having a bus with 38 drivers”. From the perspective of linkage-based centrality, each BA connects and coordinates limited generators and load serving entities within its balancing area.

Comparing to decentralized system operation in Non-RTO West, centralized system operation and market coordination in MISO network allows resource pooling. The larger resource pool provides the central network broker with more options that can be used to accommodate variations in electricity supply and demand, particularly when there is high penetration of wind energy. Given similar generating capacity and electricity demand between the two regional networks as summarized in Table 6-1, each BA in Non-

[12] The Western Interconnection has 38 BAs. Here, I did not include the four BAs outside the US territory and California ISO in my case.

RTO west only has control over generating and transmission resources within its territory while MISO, as the single network administrative organization, can allocate all the generating and transmission resources within the whole MISO network to balance generation and loads. This resource pooling is even more important for wind power integration. Since wind power increases the variability and uncertainty in power system operation, it demands more fast-response operating reserves[13] in the system to deal with the imbalances when any wind generator fails to commit to the scheduled generation. As mentioned in the reports and interview data, "MISO can take on more renewable energy with minimal curtailment because this pooled market has more generating units to ramp up and ramp down quickly to balance the variable generation". In addition, variation in aggregate wind output tend to be less correlated over larger geographic regions, which is another benefit of resource pooling. In contrast, BAs in Non-RTO West can only mobilize resources within its territory to accommodate the variation and uncertainty caused by wind power. Existing studies have demonstrated that "this method drives up integration costs, and limits the amount of wind and other variable generation that can be connected to the system in a region" (WECC, 2013).

The above comparison shows that transmission network integrated and coordinated centrally through a single core agency is likely to be more effective in integrating wind power than a less centralized networks. This finding is consistent with previous literature studying service implementation networks in mental health services, crime prevention, and emergency management. Moreover, the two cases on transmission networks add to existing theory the underlying linkage between centralization and network effectiveness. A centralized network enables resources pooling, which provides the NAO with comprehensive information and more available resources to allocate than a less cohesive system does. This is crucial for the entire system to effectively manage the variation and uncertainty imposed by the environment.

[13] In power systems, operating reserves are the generating capacities available to the system operator within a short interval of time to meet demand in case there is an unplanned event disrupt scheduled generation or changes in demand. These may be additional generating units that are standby or generators that are already producing power but can ramp up or down their output upon request.

### 5.2.2 Mode of governance

A related concept to level of centralization is the “mode of governance” proposed by Provan and Kenis (2008). MISO network is an NAO governed network, where MISO serves as the single NAO that coordinates transmission operation and market transactions. The mode of governance in Non-RTO West is more ambiguous. First, it is a hybrid of lead organization governed network within each balancing area, and shared governance among these lead organizations at aggregate level. However, there are several external brokers that have organizational links across several balancing areas, or even connects all network participants in the non-RTO West. One example of these external brokers is the WECC–an independent non-profit agency that coordinates all network participants to achieve mandatory reliability standards from FERC. While centrality of WECC is equivalent to MISO according to organizational links, it only takes on part of the governance activities that MISO does, which is ensuring system reliability. The authority over system operation and market coordination is fragmented and shared among 33 balancing authorities. On the contrary, MISO is the sole decision making authority for electricity scheduling and dispatching, market coordination, and reliability coordination.

The comparison between MISO and Non-RTO West indicates that structural position is not equivalent to the actual influence (Provan and Milward, 1995). Concentration of influence tends to be a more essential aspect of centralization. The mere existence of an NAO does not necessarily lead to better network outcome, it is more important that decision making authorities on all relevant aspects of transmission network operation are concentrated in that single agency. Coming back to the two dimensions that characterize different modes of governance (Provan and Kenis, 2008), the two transmission network cases suggest that the level of centralization does matter for network effectiveness. However, it is not clear whether the centralized control from an external agency or from a lead participant results in better network outcomes. Within the dimension of centralization, the concentration of influence is a more substantial determinant than structural position.

### 5.2.3 Resource exchange among cliques

I now turn to examine the subgroups within network, which is referred to as "cliques" in the network analysis literature. While the transmission system operation and wholesale market sales in Non-RTO West are not governed through a central agency, it consists of 33 sub-regional cliques coordinated by separate BAs. These cliques are formed based on geographic proximity. In theory, an alternative approach to network integration is through overlap of cliques (Provan and Sabastian, 1998). However, I did not find any document or interview mentioning "overlap" between these subgroups. Instead, they mention the "interchange" or "exchange" of resources between neighboring cliques. One interviewee from the Non-RTO West comments that "increased coordination between neighboring balancing areas allows greater utilization of load and resource diversity, which reduce the magnitude of wind curtailment". This improved coordination occurs through two ways–increasing the frequency of resource exchange between neighboring balancing areas, or reducing the interchange limits between them. Currently, the Western interconnection has initiated "Intra-Hour Transaction Accelerator Platform (I-TAP)" to replace the hourly interchange and facilitate interactions across balancing areas, which can provides each clique with more ramping capacity to manage the variability and uncertainty of wind power (Hunsaker et al., 2013). In addition to more frequent resource exchange, relaxing the constraints on interregional exchange is also expected to reduce curtailment of renewable energy (Hunsaker et al., 2013; E3, 2015).

Therefore, if resource pooling cannot not be achieved through centralized coordination in a regional transmission network, increased exchange of resources among cliques, as an alternative, can also improve wind power integration.

## 5.3 Governance Processes to Achieve Flexibility and Stability

#### 5.3.1.1 Coordinating mechanisms: A hybrid of hierarchy, market, and collaboration

In this section, I compare how transmission system and the electricity wholesale market are coordinated in these two networks and whether different coordination mechanisms and processes lead to variation in wind power utilization.

As introduced in Section 4.2, the primary goal of power system operation is to ensure system stability, or "reliability of the bulk power system" as used in electricity regulatory documents. However, integration of renewable energy, particularly the variable generation such as wind power, challenges system stability because wind output are more variable and unpredictable than traditional generating resources. This requires a certain level of flexibility in the power system to manage the variability and uncertainty from the environment in order to maintain system reliability. Having adequate operational reserves on the system is essential to provide this flexibility. These reserves may be provided through generating units that are not dispatched or generators that are already producing power but can ramp up or down their output upon request by the system operator.

To achieve system stability, both MISO network and Non-RTO West network use hierarchical control schemes. As described in Section 4.5.2, both MISO and Non-RTO West have core coordinating agencies—MISO and BAs in the Western Interconnection—to balance generation and load continuously. While these agencies have coordinating authorities over different levels of territories, their functions are similar. They collect information from load serving entities to conduct demand forecasting for their balancing areas, schedule and dispatch generators to meet the demand, and employ different types of operating reserves to offset the deviations due to changes in generation or demand in real time. All these operations are conducted according to established protocols approved by FERC. In addition, compliance of reliability standards in MISO system and Non-RTO West is monitored and enforced by reliability coordinators. MISO is the reliability coordinator while the Western Electricity Coordination Council (WECC) ensures reliability for the non-RTO West.

Despite similar hierarchical control to maintain system stability, the wholesale markets in these two networks are coordinated differently, which leads to different levels of flexibility to manage the variable wind generation. MISO coordinates the wholesale market through competitive bidding mechanism while most of the electricity transactions in Non-RTO West occur through long-term bilateral contracts negotiated between generator and buyer directly.

As the central system operator and balancing authority in the network, MISO uses competitive bidding process to organize and co-optimize energy market (i.e. match generation with electricity demand) and the transactions of operational reserves. This bidding process allows system operator to schedule and dispatch generating resources at their most efficient operating point based on their bid-cost curve. The bidding process for operational reserve transactions incentivizes generators to offer their surplus generating capacity into the reserve market pool based on the marginal cost of reserve supply, and provides flexibility for MISO to mobilize reserves when they are needed.

In Non-RTO West, most electricity transactions operate through bilateral contracts. Within each balancing area, generators with bilateral contractual commitments provide the balancing authority with scheduled output before the market clears, and this schedule is fixed regardless of the market price. Although the balancing authority still dispatches these resources to meet the expected demand in its balancing area, it cannot utilize these generating units as operational reserves to respond to changes in generation or demand in real time. Thus, considerable generating resources scheduled based on bilateral contracts reduces the flexibility that the system/market operator has in order to respond to variability or uncertainty in the system. As mentioned in reports from several BAs in the Non-RTO West and interviews, this insufficient flexibility drives the need for more expensive sources to provide flexibility, such as regulating reserves and storage, which increases costs to accommodate high level of variable generation in the grid.

From a network governance theory perspective, the above two cases demonstrate that hierarchy, market, and collaborative process coexist in transmission networks to coordinate system operation. This finding reinforces the perspective from Provan and Kenis (2008) that we should combine the network analytical approach and network as a form of governance approach to study how networks themselves are managed. Depending on the tasks that the network needs to complete and the structural patterns among participants, network can be governed through market, hierarchy, reciprocity, or other hybrid mechanisms.

In addition, the transmission network governance also demonstrates how to manage the tension between flexibility and stability in network governance through the deployment of hybrid governance forms. In the power sector, where the system is constantly facing internal and external uncertainties, hierarchical control and formal rules are essential to coordinate various network participants to achieve system stability. However, those external centralized coordinators are usually created by network participants in order to achieve shared goals. At the same time, various market mechanisms are employed to provide flexibility in the system. Comparing to bilateral contracts, competitive bidding process organized by the system/market operator allows more flexible utilization of generating resources through price signals.

#### 5.3.1.2 Timeframe for resource exchange

Another important theme of system operation and market coordination emerged from the data is the timeframe of market operation or dispatch in real time. As introduced in Section 4.2, the day-ahead scheduling requires generators to commit a certain amount of generation hourly based on demand during a particular hour of a day. The real energy exchange between suppliers and buyers may deviate from the schedules due to changes in demand or supply, which requires timely response and adjustment to ensure system stability. The market operation design in MISO and Non-RTO West provides different timeframe for network participants to respond to changes and make adjustment.

MISO's real-time market operates on a five-minute time frame, where generating units hold their output at a specific level for each five-minute dispatch period. The balancing authorities in Non-RTO West conduct hourly dispatch so that generators need to follow hourly schedules set one hour or more in advance. This constrains the ability of the system operator to manage variability, particularly with high penetration of wind power in the grid. Wind output can vary significantly over the timeframe of an hour due to the variability of wind speed, but it tends to be relatively constant over ten to fifteen minutes. In Non-RTO West with hourly schedules and dispatch, significant deviations in wind output over the course of an hour often need be accommodated through the use of regulation services, which are typically the most expensive type of reserves (Hunsaker et al., 2013). Shorter market timeframe provides better access to generator flexibility than longer market periods. The five-minute markets in MISO plays a large role in keeping incremental load following costs for higher wind penetrations low.

# 6 Conclusion and Discussion

This paper examines how network governance affects the effectiveness of power transmission networks in regards to wind power integration through a comparative case study. Massive integration of variable generation from wind imposes higher level of variability and uncertainty to the power system and requires better coordination among network participants to maintain system resilience. I compare the performance and governance between two regional transmission networks in the US—the MISO network and the Non-RTO West network. They represent two major types of transmission network governance models in the US, which are different in terms of network structure and coordinating mechanisms/processes. MISO network is a NAO-governed network with MISO as the single core agency among stakeholders from different segments of the power sector. In contrast, Non-RTO West is a hybrid of shared-governance among local balancing authorities at aggregate level and lead organization governance within each balancing area.

## 6.1 Implications for Theories on Network Governance

Through the case of integrating wind energy into the power system, this paper studies the impacts of network structure and coordinating mechanisms on the resilience of complex service delivery and resource management systems that operate over large geographic scales. It extends existing network theories by highlighting the underlying mechanisms that particular network structural properties and coordinating processes can achieve both system stability and flexibility, thus lead to better network performance.

Consistent with previous studies on network structure, this paper finds that a centralized transmission network is more effective in integrating wind power than a less centralized structure. Moreover, the transmission network case adds to existing theory the linkage between centralization and network effectiveness. A centralized network coordinated by a single core agency allows resource pooling and optimal allocating of the resources by the central coordinator, which is crucial for the entire system to effectively manage the variability and uncertainty imposed by the environment. This paper also suggests an alternative path to improved network effectiveness for a less cohesive network, which is through more frequent resource exchange among subgroups within a large network. This finding extends the existing theories on cliques, which argues that overlap among cliques enhances network effectiveness (Provan and Sabastian, 1998). This paper finds that enhanced effectiveness can also be achieved through more resource exchange between cliques instead of having overlapped members.

Since integrating wind energy into the power system requires the whole system to be flexible and stable at the same time, this paper also contributes to the network governance literature by providing empirical evidence on how to manage the tension between flexibility and stability, particularly when the network operates in a turbulent environment with changes and uncertainties. The two transmission network cases show that a hybrid of different coordinating mechanisms are embedded in the network governance process to address the needs for system stability and flexibility. Hierarchical control through orders, formal rules, and reporting mechanisms can ensure system stability while market mechanisms through price and competition, or collaboration formed among participants provides more flexibility in the system. Instead of viewing these forms as discrete governance forms, they actually coexist in some complex service delivery systems and complementary to each other to enhance system resilience.

Coming back to Provan and Kenis's three modes of governance (Provan and Kenis, 2008), the transmission network cases indicate that network governance configurations in the real world are usually more complicated, and sometimes ambiguous to be captured by a single mode. It is worth considering from the two dimensions that characterize different modes of governance—level of centralization and source of control. While it is still not clear whether control from an external agency or from a network participant leads to better outcome as previous empirical analysis indicates (Raab et al., 2016), this paper suggests that the level of centralization does matter for network effectiveness. Particularly, concentration of decision making authority is a more substantial determinant than the structural position of the central broker.

## 6.2 Implications for Transmission Network and Wholesale Market Design

Drawn upon network governance theoretical framework, this comparative case study of two regional transmission networks in US also informs future design of transmission system and electricity wholesale market.

The findings regarding network structure suggest that effective integration of variable generation from renewable energy can be achieved either through consolidation of balancing authorities into a more centralized coordinator like MISO, or through more frequent resource exchange between neighboring balancing areas. If fully consolidation of balancing authorities is not feasible due to institutional barriers or historical reasons for the non-RTO regions in the West or in the Southeast, agreement between adjacent balancing areas on shorter resource interchange timeframe or lower exchange limits could be alternative mechanisms to better integrate VERs. These findings provide justifications for the ongoing efforts in non-RTO regions to consolidate BAs into a single system operator in some balancing areas, or to improve coordination among a few BAs to facilitate more frequent resource sharing among their balancing areas (Kirby and Milligan, 2008; PNNL, 2010; Pierce, 2014). [14]

As for network coordinating mechanisms, this paper finds that the co-optimization of energy market and reserve market through competitive bidding process offer the system operators more flexibility to address the unexpected deviation caused by variable wind generation than bilateral contracts and self-scheduling. Therefore, it is desirable to incentivize suppliers to allow the system/market operator to dispatch their output to meet the changing energy and ancillary service demand.

[14] Examples of these efforts are the Reserve Sharing Program of the Northwest Power Pool (NWPP), and the within-hour transmission purchase and scheduling business practice in the Western Interconnection. The NWPP reserve sharing program is a collaborative initiative among more than ten balancing authorities in the northwest region within the Western Interconnection. Participating BAs are entitled to use not only the reserve resources in its balancing area, but also to call on other participants for help if internal reserve cannot fully cover the deviation between schedules and real-time dispatch. The within-hour transmission purchase and scheduling business practice allows better use of capacity within and outside BA by using shorter timeframe for scheduling.

## References


Aggarwal, S., and Harvey, H., 2013. Rethinking Policy to Deliver a Clean Energy Future. The Electricity Journal, 26(8): 7-22.

Agranoff, R. 2007. Managing within networks: Adding value to public organizations. Washington, DC: Georgetown Univ. Press.

Borgatti, S. P., Martin G. Everett, and Jeffrey C. Johnson. 2013. Analyzing social networks. Los Angeles, CA: Sage Publications Ltd.

Bloom, D., Forrester, J.P., Lugman, N., 2010. Current conflicts in U.S. electric transmission planning, cost allocation and renewable energy policies: more heat than light? Electricity Journal, 23 (10).

Brown, A.C., Rossi, J., 2010. Siting transmission lines in a changed milieu: evolving notions of the ''Public Interest'' in balancing state and regional considerations. University of Colorado Law Review 81(3), 705–770.

Buckman, G., 2011. The effectiveness of Renewable Portfolio Standards banding and carve-outs in supporting high-cost types of renewable electricity. Energy Policy, 39: 4105-4114.

Carley, S. 2009. State Renewable Energy Electricity Policies: An Empirical Evaluation of Effectiveness. Energy Policy, 37 (8): 3071–81.

Carley, S. and Browne, T. R. 2013. Innovative US energy policy: a review of states' policy experiences. Wiley Interdisciplinary Reviews: Energy and Environment, 2 (5): 488-506.

Ela, E., Milligan, M., Bloom, A., Botterud, A., Townsend, A., and Levin, T. 2014. Evolution of Wholesale Electricity Market Design with Increasing Levels of Renewable Generation. NREL Technical Report, NREL/TP-5D00-61765.

Energy and Environmental Economics Inc. (E3), 2015. Western Interconnection Flexibility Assessment, Final Report.

Feiock, Richard C., In Won Lee, Hyung Jun Park, and Keon-Hyung Lee. 2010. Collaboration networks among local elected officials: Information, commitment, and risk aversion. Urban Affairs Review 46:241–262.

Gaul, C. and Carley, S. 2012. Solar set asides and renewable electricity certificates: Early lessons from North Carolina's experience with its renewable portfolio standard. Energy Policy, 48: 460–469.

Hall, W. R., Barry, K. A., Dyson, D., Moore, J., White, G., and Breakman, P. 2009. History, objectives, and mechanics of competitive electricity market. Capturing the power of electric restructuring, Miranda, J. L., ed.. Chicago, IL: American Bar Association.

Hunsaker, M. et al., 2013. Balancing Authority Cooperation Concepts to Reduce Variable Generation Integration Costs in the Western Interconnection: Intra-Hour Scheduling. WECC Final Technical Report.

Jones, Candace, William S. Hesterly, and Stephen P. Borgatti. 1997. A general theory of network governance: Exchange conditions and social mechanisms. Academy of Management Review, 22:911–45.

Kapucu, Naim, Maria-Elena Augustin, and Vener Garayev. 2009. Interstate partnerships in emergency management: Emergency management assistance compact in response to catastrophic disasters. Public Administration Review 69:297–313.

Kapucu, Naim, Tolga Arslan, and Matthew Lloyd Collins. 2010. Examining intergovernmental and interorganizational response to catastrophic disasters toward a network-centered approach. Administration & Society, 42:222–247.

Kim, J., and Tang, T. 2014. Keep the Diversity for the Future: Impacts of Renewable Portfolio Standards (RPS) on Diversifying Renewable Energy Technologies. Conference paper at the 2014 APPAM Fall Research Conference.

Klass, A., and Wilson, E., 2012. Interstate Transmission Challenges for Renewable Energy: A Federalism Mismatch. Vanderbilt Law Review, 65(6): 1801-1873.

Koch, C.H., 2009. Collaborative governance: Lessons for Europe from U.S. Electricity Restructuring. Administrative Law Review, 61: 71-102.

Lannoye, E.; Flynn, D.; O'Malley, M. (2012). "Evaluation of Power System Flexibility," IEEE Transactions on Power Systems, (27:2), p. 922-931.

Ma, J.; Silva, V.; Belhomme, R.; Kirschen, D.S. (2013). "Evaluating and planning flexibility in sustainable power systems," IEEE Power and Energy Society General Meeting Proceedings: July 21-25, 2013, Vancouver, British Columbia.

Milligan M. and Kirby B., "Analysis of Sub-Hourly Ramping Impacts of Wind Energy and Balancing Area Size," Proc. WindPower 2008, Houston, Texas, June 1-4, 2008. Available: www.nrel.gov/wind/pdfs/43434.pdf.

Miranda, J. L., ed., 2009. Capturing the power of electric restructuring. Chicago, IL: American Bar Association.

MISO, 2016. MISO Corporate Fact Sheet. Retrieved at https://www.misoenergy.org/Library/Repository/Communication%20Material/Corporate/Corporate%20Fact%20Sheet.pdf.

MIT, 2011. The future of the electric grid. MIT Study retrieved at: http://web.mit.edu/mitei/research/studies/the-electric-grid-2011.shtml.

O'Toole, Laurence J., and Kenneth J. Meier. 2004. Public management in intergovernmental networks: Matching structural networks and managerial networking. Journal of Public Administration Research and Theory 14: 469–94.

Pierce, E., 2014. Inside Colorado's Wind Integration Successful Story. North American Wind Power, 11(12). Retrieved at http://nawindpower.com/online/issues/NAW1412/FEAT_01_Inside-Colorado-s-Wind-Integration-Success-Story.html.

Piwko R., Clark K, Freeman L., Jordan G., Miller N., 2010. "Western Wind and Solar Integration Study", GE Energy Subcontract Report, National Renewable Laboratory, February 2010. Available at: http://wind.nrel.gov/public/WWIS/.

Powell, Walter W. 1990. Neither market nor hierarchy: Network forms of organization. In Research in organizational behavior, ed. Barry M. Staw and Cummings L. L., vol. 12, 295–336. Greenwich, CT: JAI Press.

Provan, Keith G., and Juliann G. Sebastian. 1998. Networks within networks: Service link overlap, organizational cliques, and network effectiveness. The Academy of Management Journal, 41 (4):453–463.

Provan, Keith G., and Patrick Kenis. 2008. Modes of network governance: Structure, management, and effectiveness. Journal of Public Administration Research and Theory, 18:229–252.

Provan, Keith G., and H. Brinton Milward. 1995. A preliminary theory of interorganizational network effectiveness: A comparative study of four community mental health systems. Administrative Science Quarterly, 40:1–33.

Provan, Keith G., and H. Brinton Milward. 2001. Do networks really work? A framework for evaluating public-sector organizational networks. Public Administration Review 61:414–423.

Raab, J., 2004. More than just a metaphor: The network concept and its potential in Holocaust research. In Networks of Nazi Persecution: Bureaucracy, Business, and the Organization of the Holocaust, ed. G. D. Feldman and W. Seibel, 321–39. London: Berghahn.

Raab, J., Mannak, R., and Cambre, B., 2013. Combining Structure, Governance, and Context: A Configurational Approach to Network Effectiveness. Journal of Public Administration Research and Theory, 25:479–511.

Robins, Garry, Lorraine Bates, and Philippa Pattison. 2011. Network governance and environmental management: Conflict and cooperation. Public Administration 89:1293–313.

Saz-Carranza, Angel, and Sonia M. Ospina. 2011. The behavioral dimension of governing interorganizational goal-directed networks—Managing the unity-diversity tension. Journal of Public Administration Research and Theory 21 (2):327–65.

Shrimali, G., Jenner, S., Groba, F., Chan, G., and Indvik, J. 2015. Evaluating Renewable Portfolio Standards for In-State Renewable Deployment: Accounting for Policy Heterogeneity. Economics of Energy & Environmental Policy, 4(2).

Wiser, R., and Bolinger, M., 2011. 2010 Wind Technologies Market Report. National Renewable Energy Laboratory, DOE/GO-102011-3322.

Wiser, R., and Bolinger, M., 2012. 2011 Wind Technologies Market Report. National Renewable Energy Laboratory, DOE/GO-102012-3472.

Yin, H., and Powers, N., 2010. Do State Renewable Portfolio Standards Promote In-State Renewable Generation? Energy Policy, 38 (2): 1140–49.

Yin, Robert K. 2003. Case study research, design, and methods, 3rd ed. Thousand Oaks, CA: Sage.

**Table 6-1 Comparison between MISO and Non-RTO West on Case Selection Criteria**

| **Transmission Network** (based on 2014 statistics[15]) | **MISO** | **Non-RTO West** |
|---|---|---|
| **<u>Size of the Network</u>** | | |
| **1) Number of states in its service territory** | 15 states | 15 states |
| **2) Number of network participants** | 432 | 420 |
| **3) Annual Electricity Demand** (GWh) | 691,000 | 614,000 |
| **Policy Support for Renewable Energy:** # of states having Renewable Portfolio Standards (RPS) | 11 | 11 |
| **Wind Resources** (Average wind quality class[16] of all wind farms) | 2.30 | 2.24 |
| **Existing Wind Installed Capacity** (MW) | 13,988.8 | 13,349.4 |
| **<u>Transmission Infrastructure</u>** | | |
| 1) Circuit miles of transmission lines | 65,800 | 101,700 |
| **2)** Average Interconnecting Voltage of Wind Farms (kV) | 98.6 | 165.8 |

**Source:** 2015 WECC SOTI Final Report (WECC, 2015); CAISO lists of market participants: http://www.caiso.com/about/Pages/OurBusiness/Default.aspx; MISO corporate fact sheet (MISO, 2016); MISO current members by sector; EIA 860 survey (EIA, 2014).

**Note:**

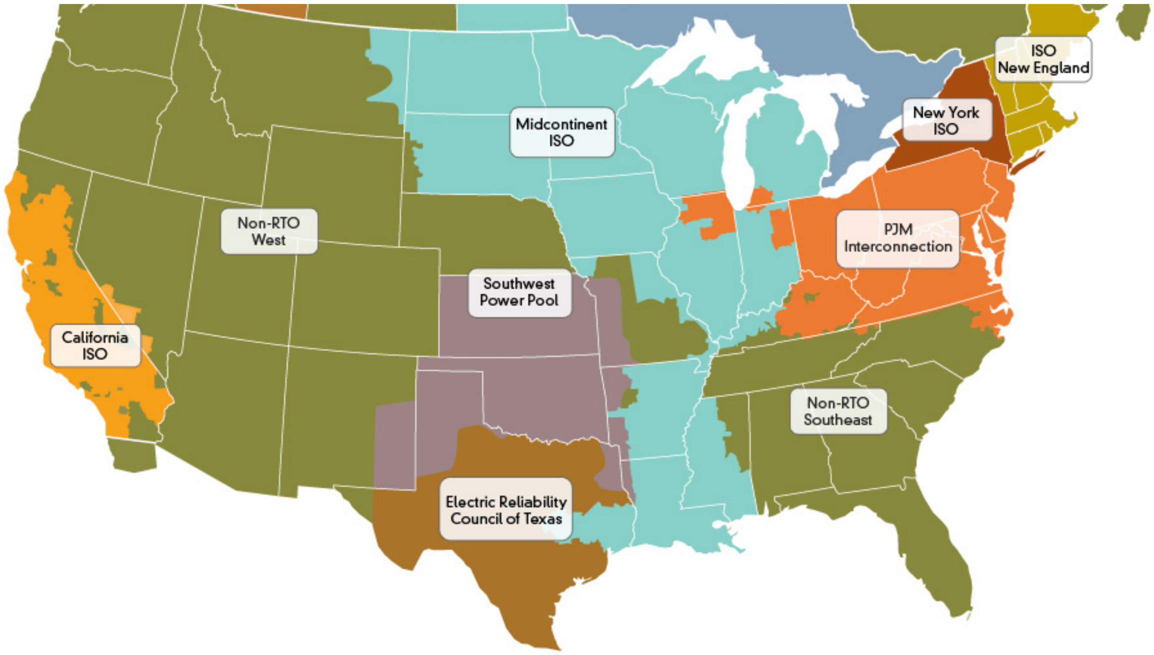
1. Wind Resources: The Energy Information Administration (EIA) distinguishes between 7 classes of wind power resources based on wind speed at a height of 50 meters. In general, areas designated class 3 or greater are suitable for most utility-scale wind farms, whereas class 2 areas are marginal for utility-scale wind plants.

[15] The 2014 data is most recent and comprehensive data available for both regional networks.

**Table 6-2 Comparisons between MISO and Non-RTO West on Structural Properties and Governance Processes**

| | MISO | Non-RTO West |
|---|---|---|
| **Structural properties: Centralization (particularly concentration of influence)** | Highly centralized through the coordination of a single core agency (MISO) → better resource pooling and allocating | Decentralized; Multiple sub-regional transmission coordinating agencies → resource pooling is limited |
| **Structural properties: Coordination between cliques** | No Cliques | Resource exchange between cliques is hourly based; Interchange cap → limit resource pooling among cliques |
| **Governance processes: Coordinating mechanisms** | Hierarchical control: external independent system coordinator→ system stability<br><br>Competitive bidding process in both energy and reserve market→ improved system flexibility | Hierarchical control: lead agency coordination→ system stability<br><br>Bilateral long-term contract between generators and load-serving entities → limited flexibility of resource allocation for system operator |
| **Governance processes: Frequency of resource exchange** | Five minutes market → more flexible and timely to respond to generation deviation | Hourly market → less flexibility |

**Figure 6-1 ISO/RTO Service Territories**




*Source: Sustainable FERC Project, 2016.*

**Figure 6-2 Organization of the US Electricity Market Before and After Restructuring**

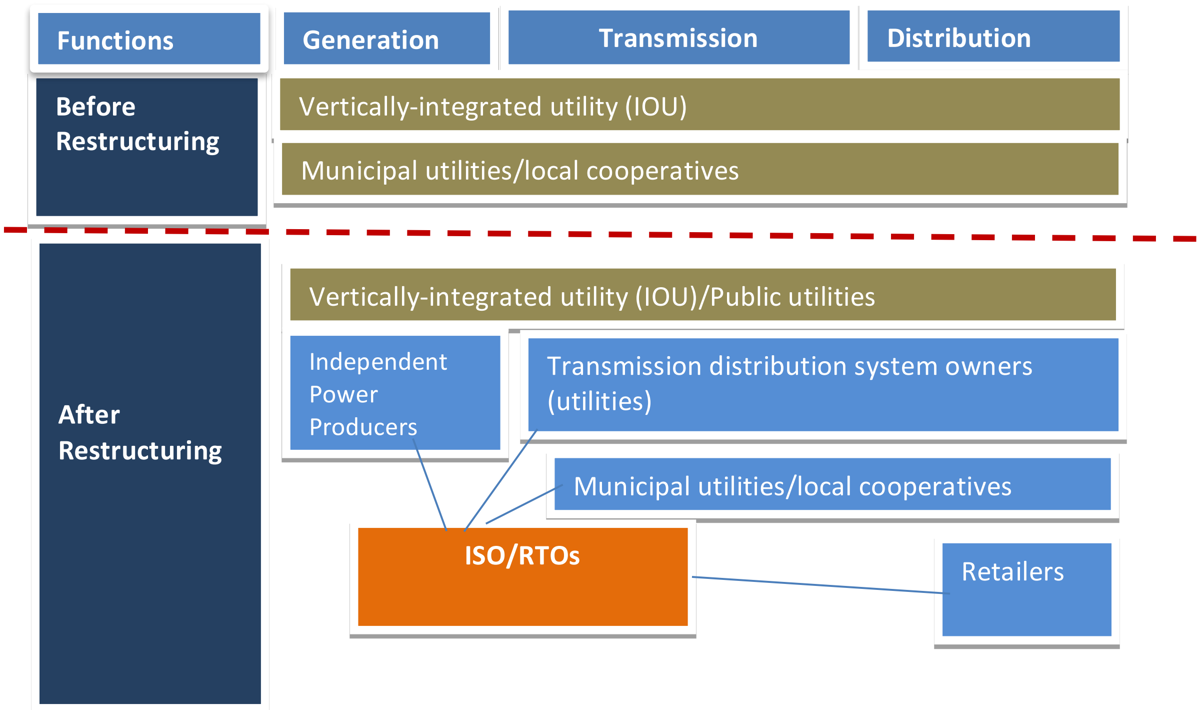


**Figure 6-3 Existing Wind Generation Capacity in MISO and Non-RTO West**

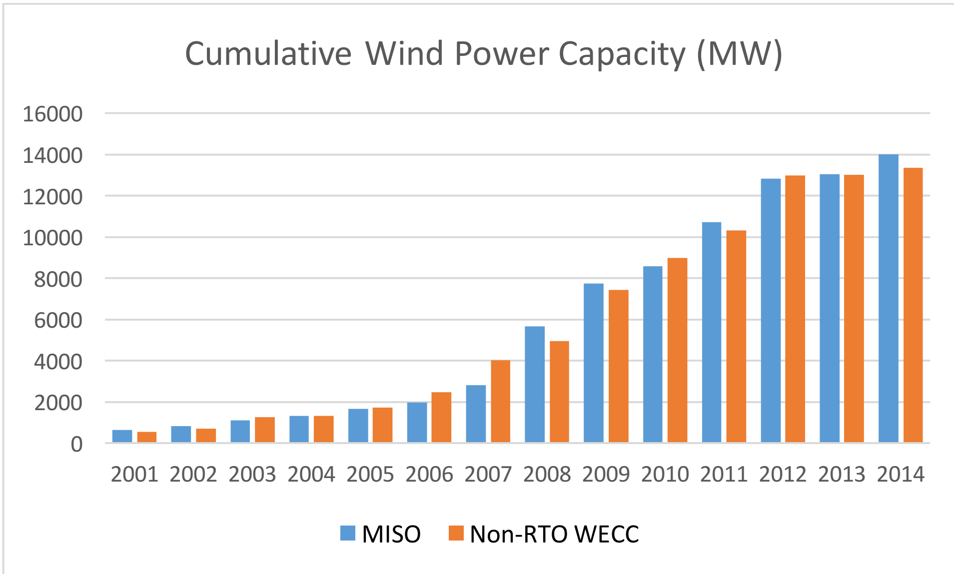
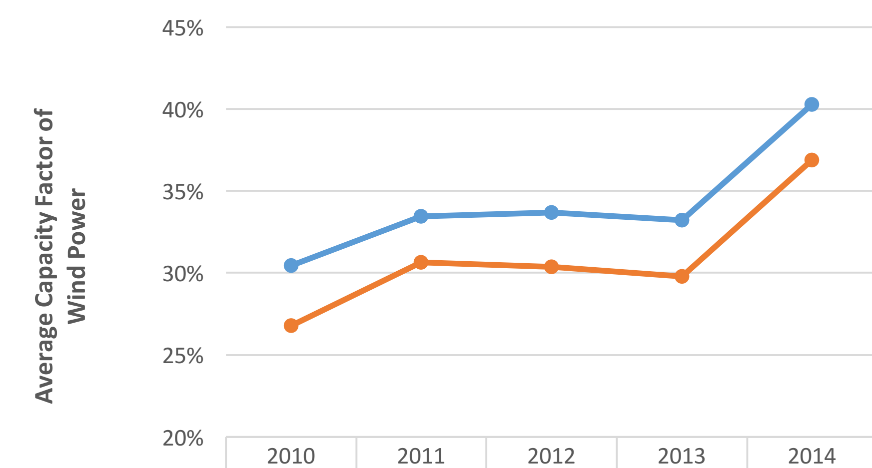
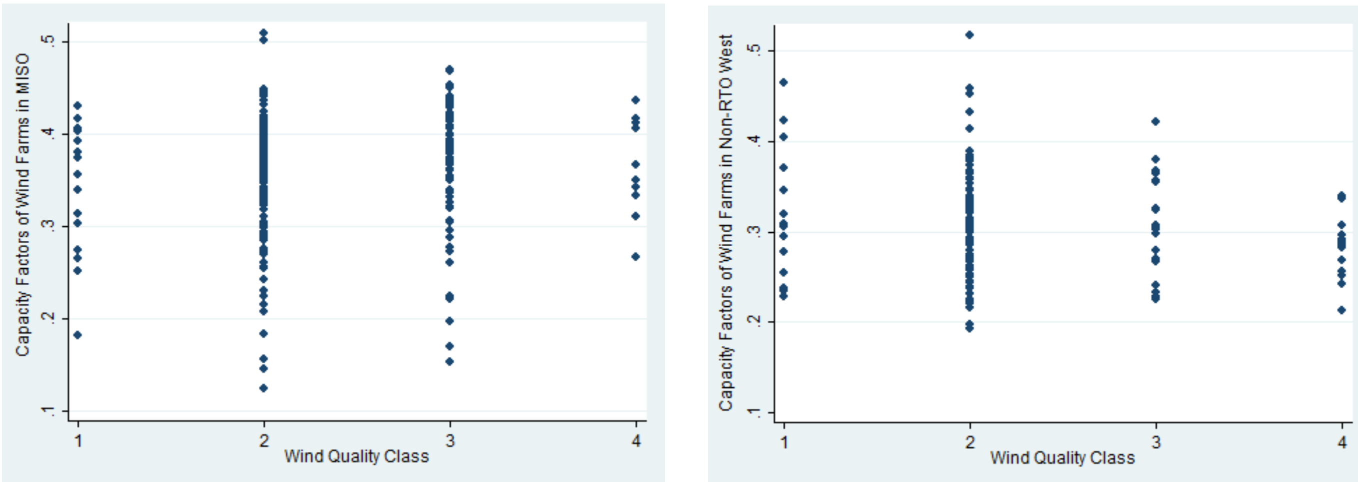


**Figure 6-4 Utilization Rate of Wind Power in MISO and Non-RTO West**




| | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|
| MISO | 0.304 | 0.335 | 0.337 | 0.332 | 0.403 |
| Non-RTO West | 0.268 | 0.306 | 0.304 | 0.298 | 0.369 |

**Figure 6-5 Performance of Wind Farms by Wind Quality Class (Year 2014)**




Note: The EIA distinguishes between 7 classes of wind power resources based on wind speed at a height of 50 meters. In general, areas designated class 3 or greater are suitable for most utility-scale wind farms, whereas class 2 areas are marginal for utility-scale wind plants.