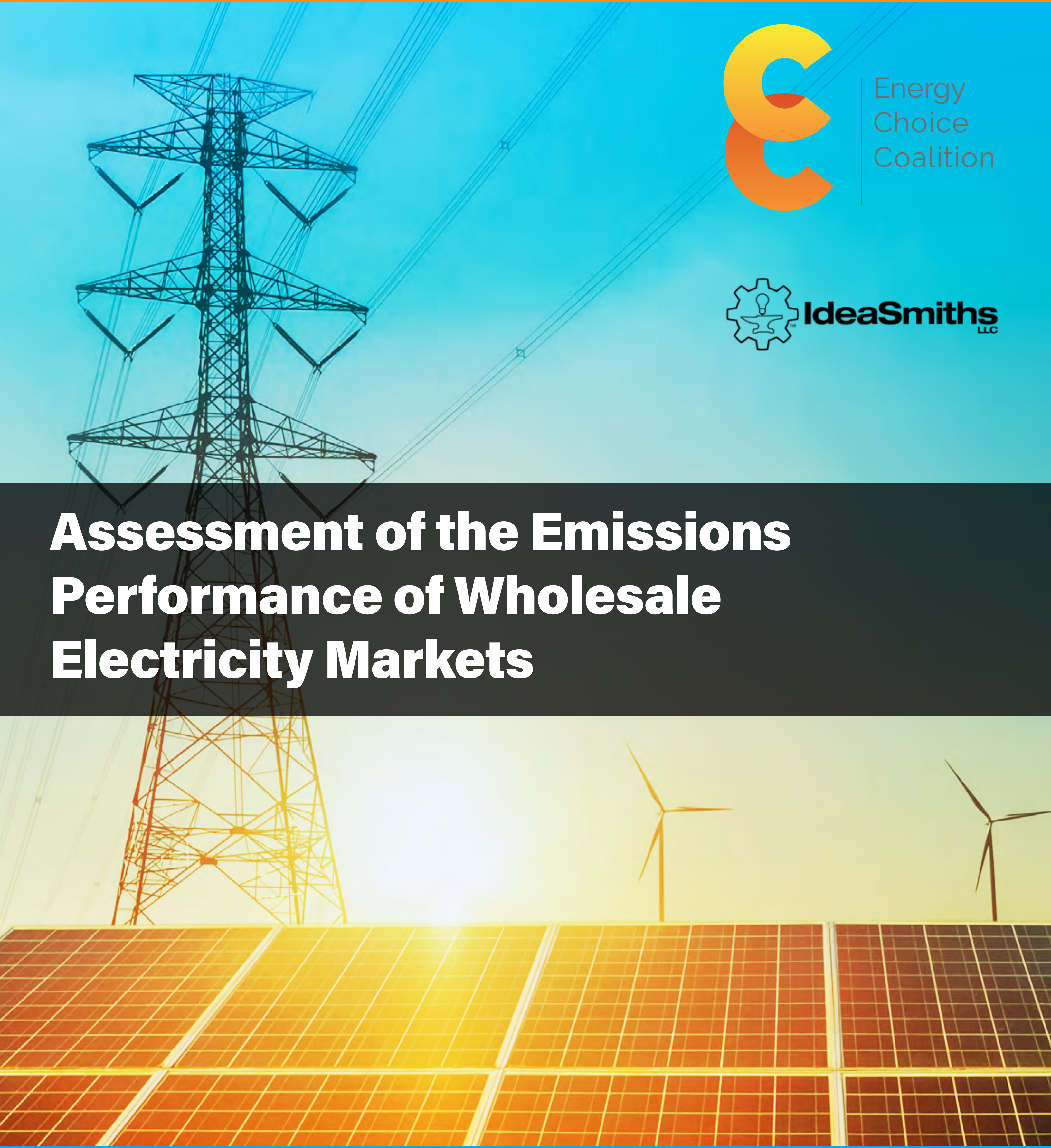

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Assessment of the Emissions Performance of Wholesale Electricity Markets

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Executive Summary

This report presents a data-driven analysis to determine whether the existence of competitive wholesale markets is correlated with reduced carbon emissions from the power sector. The economic logic for the effects of competitive markets in reducing emissions generally falls into four interacting pathways:

- Markets promote innovation and new technology adoption.
- In general, the design of energy markets favors technologies like wind and solar that have very low (near zero) marginal costs, which make them more likely to be dispatched, as compared to plants that have higher marginal costs, such as coal.
- Market designs can include environmental mechanisms to address externalities.
- Markets better reflect consumer preferences, whereas under traditional utility regulation, regulators define the market and its products.

While the above pathways provide the mechanisms for which markets can result in lower carbon emissions, this analysis also sought to quantify the actual emissions reduction trajectories of competitive vs. non-competitive regions in the U.S. electricity sector. More specifically, this report compares the environmental outcomes of areas of the U.S. power grid under the jurisdiction of Independent System Operators (ISOs)[1] (i.e., regions with competitive wholesale power markets) to those that are not. Comparing the seven ISO regions of the U.S.[2] with the non-ISO regions we find that:

- ISO regions have reduced their power sector CO_2 emissions by about 35% from 2005 levels while non-ISO regions have reduced their power-sector CO_2 emissions by about 27% over the same period (see Figure 1).
- Furthermore, ISO regions with more competitively owned generation, such as ISONE, NYISO, and PJM generally led with deeper CO_2 emissions reductions, with 61%, 56%, and 41%, respectively.
- ISO regions have seen lower overall electricity growth and have reduced their CO_2 emissions intensity of electricity (tons/MWh) by about 39% from 2005 levels, where non-ISO regions have reduced their emissions intensity by about 32% (see Figure 2).
- ISO regions deployed almost 80% of all utility-scale renewable generation capacity, despite only accounting for about 67% of all existing power plant capacity, of all types.
- ISO regions have seen stronger growth in distributed solar PV, increasing by about 214% versus non-ISO regions at 199%, since the U.S. Energy Information Administration began keeping track in 2014.

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[1] *Some of the regions studied in this analysis are also Regional Transmission Organizations (RTOs) in addition to being ISOs. In this report, we refer to those regions as ISOs given its focus on the electricity market and not necessarily on the transmissions network administration, but the two competitive market structures are closely linked.*

[2] *The seven ISO regions are CAISO: California ISO, ERCOT: Electric Reliability Council of Texas, ISONE: ISO New England, MISO: Midcontinent ISO, NYISO: New York ISO, PJM: PJM Interconnection, and SPP: Southwest Power Pool.*

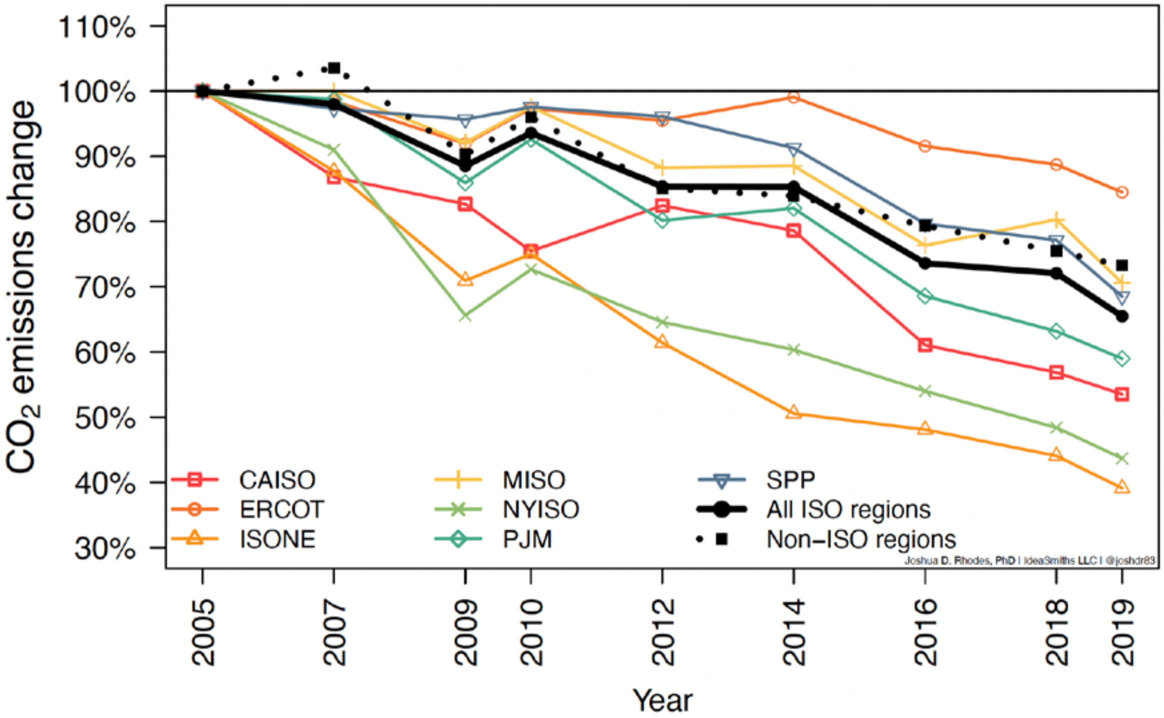

Figure 1: Figure showing the relative change in carbon emissions from 2005 to 2019 for each ISO region, the ISO average, and the non-ISO average. Each point along the line represents a year for which data were available for analysis.

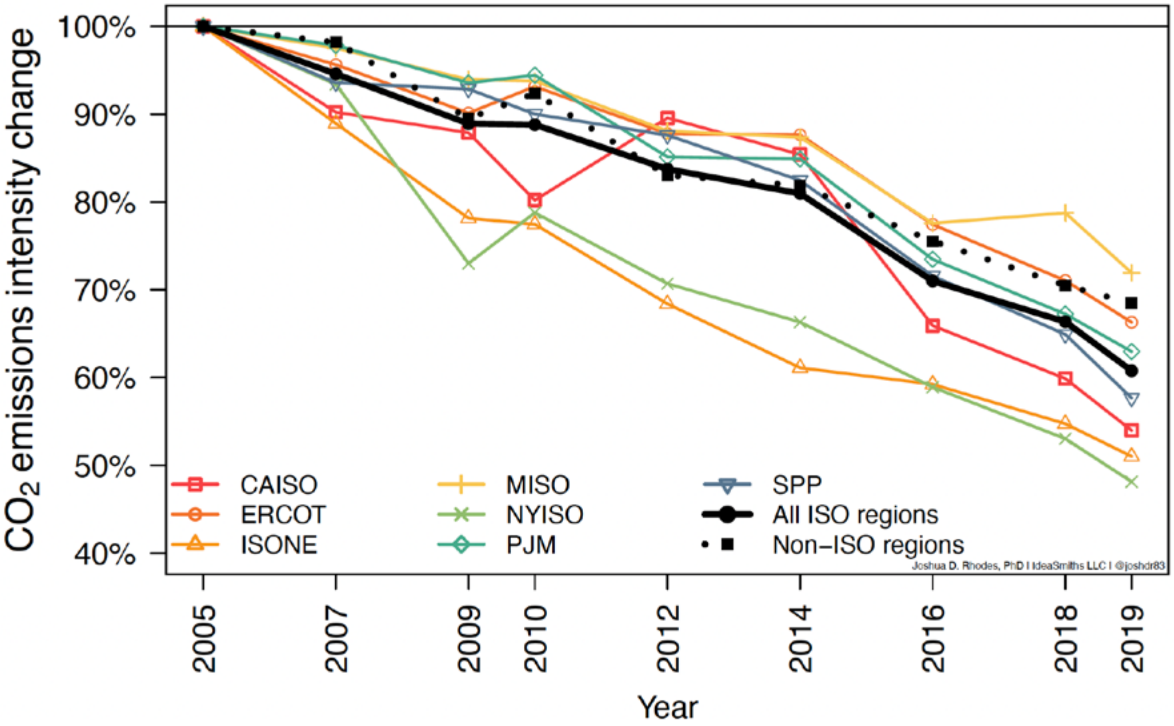

Figure 2: Figure showing the relative change in carbon emissions intensity from 2005 to 2019 for each ISO region, the ISO average, and the non-ISO average. Each point along the line represents a year for which eGRID data were available for analysis. Because the individual ISO region lines are normalized by generation, the "ALL ISO" line is a simple average of the individual ISO region lines.

Introduction

Existing research implicitly suggests the connection between power market participation and emissions reduction/decarbonization.[3] However, to the authors' knowledge, no explicit analysis of this relationship exists. The primary objective of this work is to fill that knowledge gap and provide a data-driven assessment of whether competitive power markets are associated with improved environmental outcomes.

This report first provides a summary of how market characteristics can drive environmental outcomes and then presents a real world analysis to determine whether the data support the assumption that competitive wholesale electricity markets are correlated with reduced carbon emissions. To assess this question, we compare areas of the U.S. power grid under the jurisdiction of Independent System Operators (ISOs)[4] to those that are not. A bottom-up assessment of the emissions associated with power plants in each region from 2005 to 2019 served as the basis for our quantitative analysis. These time-series data allowed us to assess the overall emissions and emissions intensity of electricity over time for each region.

Wholesale markets in the United States are not homogenous and differ in levels of competitiveness. In some regions, such as the Electric Reliability Council of Texas (ERCOT) and ISO New England (ISONE), commercial or independent power producers own the majority of power plants. By comparison, vertically integrated utilities own most of the power plants in the Southwest Power Pool (SPP). Despite the regional differences in structure, competitive wholesale markets often share some similarities, including the use of least-cost marginal dispatch of power plants and price transparency through real-time locational marginal pricing (LMP).

Market Characteristics that can Affect Environmental Outcomes

The logic for the why competitive markets may accelerate emissions reductions generally falls into four interacting pathways:

- Markets promote innovation and new technology adoption
- Markets favor low-cost resources
- Market designs can include mechanisms to address environmental externalities
- Markets reflect consumer preferences

The question of the effects of markets on emissions and decarbonization arose in the context of regulatory restructuring in the 1990s. States in the Northeast, Mid-Atlantic, California, Illinois, Ohio, and Texas restructured their utility regulation. The changes in regulations introduced wholesale market competition (and in some cases retail competition) and reductions in the monopoly footprint to transmission and distribution.[5] The move to competitive markets has also introduced rivalry in generation, leading to increased efficiency and customer savings compared to how prices likely would have evolved under utility regulation.

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[3] *Winegarden, Wayne. Competitive Markets Reduce Electricity Costs, Improve Reliability, Lower Emissions. Pacific Research Institute, September 28, 2021. https://www.pacificresearch.org/new-study-competitive-markets-reduce-electricity-costs-improve-reliability-lower-emissions/.*

[4] *i.e., regions with competitive wholesale power markets*

[5] *Hartman, Devin. Environmental Benefits of Electricity Policy Reform, R Street Policy Study No. 82, January 2017. https://www.rstreet.org/wp-content/uploads/2018/04/82-1.pdf*

In 2005, Karen Palmer and Dallas Burtraw of Resources for the Future revisited the economic arguments for regulatory restructuring and movements to markets in the 1990s.[6] At the time, analysts anticipated moves from coal-fired generation to natural gas generation based on the argument that organized markets would induce innovation and investment in new, more energy-efficient gas generation. It is worth noting that those projections were made prior to the shale revolution of the late 2000s that brought reductions in the price of natural gas compared to then-recent historical averages.[7] In retrospect, the increase in natural gas generation and the reduction in gas prices compared to coal prices since 2008 (after Palmer and Burtraw published their analysis) has helped accelerate decarbonization beyond original expectations.

More recently, researchers at Lawrence Berkeley National Laboratory compared business as usual (BAU) projections of CO_2 emissions from 2005 with actual emissions from the power sector.[8] They found that 2020 power sector CO_2 emissions are about 40% lower compared to 2005 and 52% lower than projected 2020 levels in 2005. Drivers that they identified as decarbonization factors include market incentives to reduce production costs in wind and solar, market incentives to substitute natural gas for coal as the shale revolution pushed down gas prices, and the continued operation of the existing nuclear fleet at low marginal cost.

Markets Promote Innovation and New Technology Adoption

One of the most powerful social effects of markets is dynamic incentives to entrepreneurs and innovators to create new technologies and new value propositions. Markets harness creativity and turn it into useful technologies that enable entrepreneurs to profit from creating new forms of value for consumers.[9] Hartman (2017) contrasts innovation and new technology adoption under the regulated monopoly model and a market model.[10] Markets and their competitive dynamics drive faster adoption and change: "By virtually guaranteeing the recovery of sunk costs, the monopoly model inhibits rapid adaptation to new technologies." (p. 3) The accelerated retirement of coal generation in RTO regions (e.g., PJM) compared to monopoly regions since 2010 illustrates how significant this driver can be in enabling clean technology adoption. Hartman also points out that, while not perfect, markets are more likely than vertically integrated utilities to facilitate and adapt to new, unconventional generation technologies.[11]

Another dimension of the ability of markets to promote new technology adoption is the size of the market. Other things being equal, larger markets create more potential profit opportunities. Historically, transportation networks have been the primary way to integrate markets and increase their size. In wholesale power markets, the equivalent to transportation networks is the transmission grid. Texas provides a recent example in which new transmission construction enlarged previously balkanized markets. The increase in market size created incentives for investors to build new generation, in this case wind power located in the western regions of the state.[12]

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[6] *Palmer, Karen, and Dallas Burtraw, "The Environmental Impacts of Electricity Restructuring: Looking Back and Looking Forward," Resources for the Future Discussion Paper 05-07, April 2005.*

[7] *"Henry Hub Natural Gas Spot Price (Dollars per Million Btu)." Energy Information Administration. https://www.eia.gov/dnav/ng/hist/rngwhhdm.htm.*

[8] *Wiser, Ryan, Dev Milstein, Joseph Rand, Paul Donohoo-Vallett, Patrick Gilman, and Trieu Mai. Halfway to Zero: Progress Toward a Carbon-Free Power Sector, Lawrence Berkeley National Laboratory, April 2021, https://eta-publications.lbl.gov/sites/default/files/halfway_to_zero_report.pdf.*

[9] *Greenstein, Shane. "Innovation and the Evolution of Market Structure for Internet Access in the United States," Chapter 3 in William Aspray and Paul Ceruzzi, eds., The Internet and American Business. Cambridge, MA: MIT Press, 2008.*

[10] *Hartman (2017).*

[11] *Hartman (2017), pp. 4-5. These technologies include wind and solar generation, digital management of demand to adapt to grid conditions, and, increasingly, storage.*

[12] *Kiesling, Lynne, and Michael Giberson. Electric Competition in Texas: A Successful Model to Guide the Future, CTEI Research Paper, July 2020. https://www.conservativetexansforenergyinnovation.org/wp-content/uploads/2020/07/CTEI-Research-Paper-July-2020-3.pdf*

By the mid-2000s, wind generation's share of the resource portfolio in Texas was increasing, but the most attractive sites for wind power had no transmission infrastructure to connect to customers. The Competitive Renewable Energy Zones project (CREZ) in ERCOT was a transmission investment plan to connect wind-rich regions of the state with demand-intensive population centers. The goal of the CREZ plan was to reduce barriers to innovation in wind generation by creating a larger and more integrated market in which they could participate. Changes to ERCOT market design around the same time, from zonal pricing to nodal pricing, also facilitated this change. It is worth noting that the formation and construction of the CREZ plan required leadership from public officials and legislative bodies, highlighting a unique case-study of public-private partnership that went on to enable greater competition and more rapid adoption of wind power in the restructured ERCOT market.

In examining the effects of the CREZ transmission investments, Jang (2020) found that price differences across the state decreased, which is a sign of reduced market barriers and a larger and more efficient integrated market.[13] He also found that the increased transmission network-enabled wind generation to enter the market, substituting for fossil fuel generation and reducing NO_x, SO_2, and CO_2 emissions. Similarly, Fell et al. (2021) found that reducing transmission constraints in ERCOT and the midcontinent region reduced emissions and that transmission constraints affect the spatial pattern of the avoided environmental damages created through the increased use of renewable resources.[14]

Markets Favor Low-Cost Resources

The competitive dynamics of markets create profit incentives for rival firms to reduce their production costs. If they do so, they can submit lower bids in markets and can be dispatched more frequently.[15] A striking example of this process has been the dramatic reduction in coal-fired generation as the cost of natural gas has fallen since the shale revolution of the late 2000s. As the marginal cost of natural gas decreased relative to coal, gas generators could submit lower bids in power markets and be dispatched more frequently, resulting in lower capacity utilization and idle coal plants, as well as reduced emissions. Fell and Kaffine (2018) identify this market pathway as a significant factor in reducing CO2 emissions.[16]

Fell and Kaffine also identify market-driven renewables substitution for coal as a contributor to emissions reductions. Production costs for wind and solar photovoltaics (PV) have fallen dramatically over the past decade, increasing renewables' competitiveness.[17] The design of existing energy markets also favors technologies like wind and solar that have very low (near zero) marginal costs, which make them more likely to be dispatched, as compared to coal plants that have higher marginal costs.[18]

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[13] *Jang, Heesun. "Market Impacts of a Transmission Investment: Evidence from the ERCOT Competitive Renewable Energy Zones Project," Energies 13 (2020): 3199.*

[14] *Fell, Harrison, Daniel Kaffine, and Kevin Novan. "Emissions, Transmission, and the Environmental Value of Renewable Energy," American Economic Journal: Economic Policy 13(2) (2021): 241-272.*

[15] *Davidson, F. Todd, Rhodes Joshua D., Webber, Michael E., and Deetjen, Thomas. Are Solar and Wind Really Killing Coal, Nuclear and Grid Reliability? The Conversation, May 12, 2017. https://theconversation.com/are-solar-and-wind-really-killing-coal-nuclear-and-grid-reliability-76741.*

[16] *Fell, Harrison, and Daniel T. Kaffine. "The Fall of Coal: Joint Impacts of Fuel Prices and Renewables on Generation and Emissions." American Economic Journal: Economic Policy 10(2) (2018): 90–116.*

[17] *"Renewable Power Generation Costs in 2020." Irena.org, June 2021. https://www.irena.org/publications/2021/Jun/Renewable-Power-Costs-in-2020.*

[18] *"Lazard's Levelized Cost of Energy Analysis – Version 14.0." Lazard. October 2020. https://www.lazard.com/media/451419/lazards-levelized-cost-of-energy-version-140.pdf*

Another change arising from the combination of innovation and markets is the change in the economic scale of operation for different energy technologies. From the large coal and nuclear power plants of the 1970s and 1980s to combined-cycle natural gas turbines of the 1990s, to residential rooftop solar, distributed storage, electric vehicles, and demand management tools of today, smaller-scale technologies have become increasingly economical and thus increasingly deployed.[19] They also provide different benefits from conventional large-scalegeneration in terms of environmental profile, locational benefits to provide grid services, and in some cases, flexibility and adaptability to fast-changing grid conditions.

An August 2020 report from Energy Innovation estimated the economic and environmental effects of implementing an RTO with an integrated wholesale power market in the Southeast.[20] Their comparison of an RTO scenario with an integrated resource plan (IRP) scenario suggests a cumulative economic savings of $384 billion over 20 years and a reduction in CO_2 emissions of 46% by 2040, compared to the base year 2018. Another DOE-funded analysis found that a "Western States" ISO/RTO could result in approximately $2B/year savings by 2030.[21] SPP alone estimates that its coordination provides $2.2B/year in benefits to its constituents[22] and expanding their footprint to include additional parts of Colorado, Wyoming, and Montana would increase those benefits by about $50M/year.[23]

Market Designs Can Include Environmental Mechanisms

Markets operate within an institutional framework, a set of rules governing how participants interact. The double-auction market design, for example, requires sellers and buyers to simultaneously submit offers and bids, respectively. These market signals are then used to construct supply and demand curves for that market period, yielding a market-clearing price that determines which sellers sell and buyers buy at that price. These market-clearing prices reflect the marginal cost of production to suppliers and the marginal value of consumption to buyers, but by design, these electric market rules do not reflect the environmental costs and value associated with electricity generation from different technologies. Over the past 50 years, electricity generators have been subject to environmental regulation, which may incorporate environmental attributes into generator decision-making and costs but can do so in a way that introduces inefficiencies and other costs to the delivery of power to consumers. More market-based approaches to environmental regulation, such as the SO_2 emission permit trading under the Environmental Protection Agency's Acid Rain Program in the 1990s and 2000s, can incorporate environmental attributes into production and market decisions reflected in the electricity market, allowing generators to meet environmental quality targets at a lower overall cost.[24] Previous analysis indicates that including environmental price signals in dispatch decisions would reduce emissions and water use at power plants.[25]

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[19] *Rhodes, Joshua D. The Old, Dirty, Creaky US Electric Grid Would Cost $5 Trillion to Replace. Where Should Infrastructure Spending Go? The Conversation, March 16, 2017. https://theconversation.com/the-old-dirty-creaky-us-electric-grid-would-cost-5-trillion-to-replace-where-should-infrastructure-spending-go-68290.*

[20] *Gimon, Eric, Mike O'Boyle, Taylor McNair, Christopher T. M. Clack, Aditya Choukulkar, Brianna Cote, and Sarah McKee. Summary Report: Economic and Clean Energy Benefits of Establishing a Southeast U.S. Competitive Wholesale Electricity Market. Energy Innovation, August 2020. https://energyinnovation.org/wp-content/uploads/2020/08/Economic-And-Clean-Energy-Benefits-Of-Establishing-A-Southeast-U.S.-Competitive-Wholesale-Electricity-Market_FINAL.pdf*

[21] *Energy Strategies. "The State-Led Market Study," (2021) https://static1.squarespace.com/static/59b97b188fd4d2645224448b/t/6148a012aa210300cbc4b863/1632149526416/Final+Roadmap+Technical+Report+210730.pdf*

[22] *"SPP Brattle Study Stakeholder Meeting Materials." Southwest Power Pool. SPP Documents & Filings. spp.org, December 2020. https://spp.org/spp-documents-filings/?document_name=brattle&docket=&start=&end=&filter_filetype=&search_type=filtered_search*

[23] *Tsoukalis, John et al., "Western Energy Imbalance Service and SPP Western RTO Participation Benefits." (2020) The Brattle Group http://www.enelytix.com/Content/downloads/20622_western_energy_imbalance_service_and_spp_western_rto_participation_benefits.pdf*

[24] *Kiesling, L. Lynne. "Applied Transaction Cost Economics: Emission Permit Trading," Chapter 5 in L. Lynne Kiesling, The Essential Ronald Coase. Vancouver: Fraser Institute, 2021.*

[25] *Nawaf S. Alhajeri, Pearl Donohoo, Ashlynn S. Stillwell, Carey W. King, Mort D. Webster, Michael E. Webber, and David T. Allen, "Using market-based dispatching with environmental price signals to reduce emissions and water use at power plants in the Texas grid," Environmental Research Letters, Volume 6, Number 4, 23 November 2011. https://iopscience.iop.org/article/10.1088/1748-9326/6/4/044018*

Market operators can include environmental mechanisms in their market designs, such as Production Tax Credits or emissions costs. Those mechanisms can be voluntary or can reflect environmental regulations, including agreements at the local, state, regional, federal, or international levels. As competition has driven down production costs for wind and solar, this merit-order prioritization reflects both cost and environmental attributes. Moreover, even in the absence of binding national emissions policies, markets can incorporate clean energy attributes into operations, further driving environmental outcomes.[26]

Markets Reflect Consumer Preferences

At a high level, markets reflect the interplay of supply and demand, of producers and consumers, which means that consumer preferences can be discovered, expressed, and satisfied in markets in ways that regulated procurement might be too blunt to address. Under traditional utility regulation, regulators define the market and its boundaries, specify the characteristics of the product being sold, and authorize investment to supply the product. This structure suppresses consumer preferences and treats electricity products as uniform commodities.

With new digital and distributed energy technologies, the suppression of customer preferences may become increasingly costly. Consumer preferences are more varied, and with increasing awareness of the environmental impacts associated with energy consumption, many consumers value ways to modify the environmental footprint of their consumption.[27] Markets offer opportunities to express those preferences. For instance, real-time or indexed pricing plans can allow customers that are willing to modify their energy use behavior to access electricity costs that are often well below those of a fixed-rate plan. However, these types of plans first require the transparent formation of prices offered by wholesale electricity markets. Wholesale markets can be leveraged to express consumer preferences in the aggregate, through the consumption choices individuals make with their retail energy providers. However, additional price transparency at the retail level will be required to fully capture customer preferences that could enable system architectures with lower environmental footprints.

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[26] *Olsen, Arne et al., "Scalable Markets for the Energy Transition: A Blueprint for Wholesale Electricity Market Reform", Energy and Environmental Economics, Inc., 2021 https://www.ethree.com/wp-content/uploads/2021/05/E3-Scalable-Clean-Energy-Market-Design-2021-05-24-vFinal.pdf*

[27] *Hartman (2017), p. 5.*

Analytical Assessment of the Environmental Outcomes of Electricity Markets

This section assesses the power sector emissions performance of wholesale electricity markets (ISOs) in the U.S. to those regions that do not participate in such markets. To do so, we compiled a time series of emissions data that were measured at power plants located within each region. The observations were then compared across each region to identify whether there is evidence that a market-oriented region might reduce emissions at a rate different from vertically regulated monopoly utility regions (i.e. non-ISO regions).

Data and Methodology

To assess the environmental impacts of different regions, we analyzed U.S. Environmental Protection Agency (EPA) Emissions & Generation Resource Integrated Database (eGRID)[28] data for the years 2005 to 2019.[29] eGrid data include, among other things, power plant level information about location, power generation, fuel consumption, and emissions levels.

Because power plants are generally stationary, these data allow for a "bottom-up" approach to assessing how different regions' energy consumption and emissions have changed over time. The data analysis begins in 2005, as most ISO regions were formed by then.[30] Some ISO regional footprints have changed somewhat since then, but for consistency, this analysis assessed ISO boundaries as if they were the same as 2019.[31] Figure 3 shows a map of the geographical footprints of the seven ISO regions considered in this analysis.

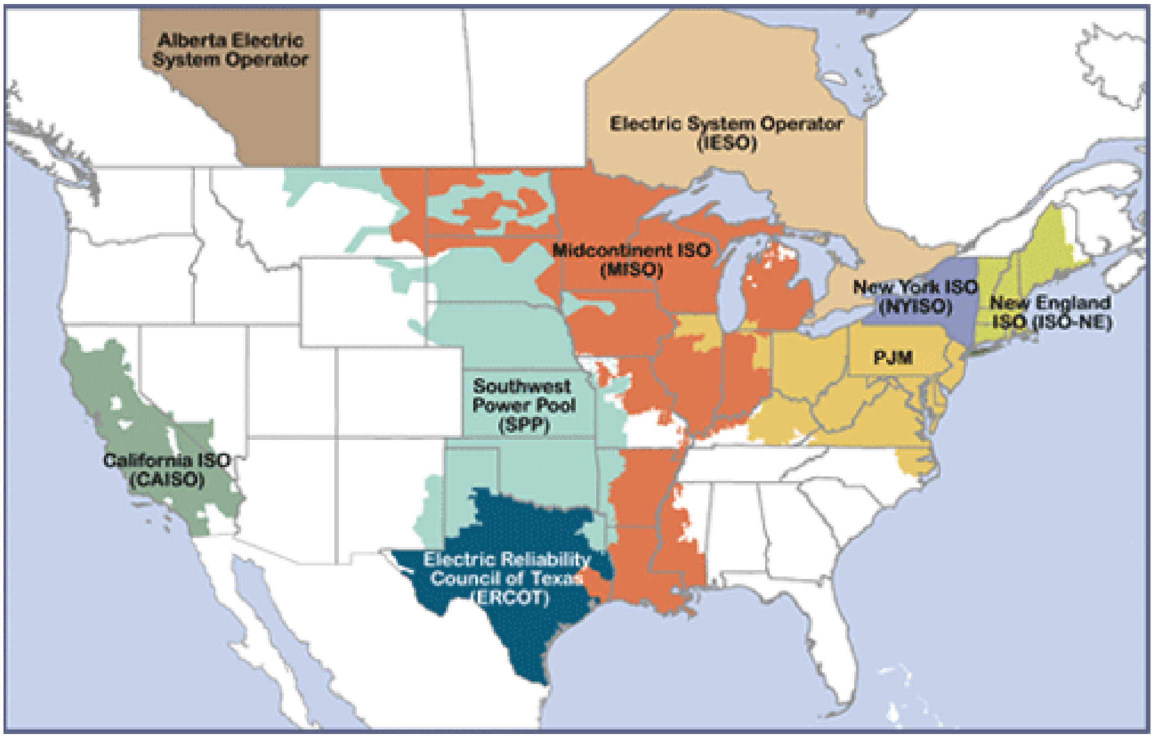

Figure 3: Figure showing the geographical location of the seven ISO regions under consideration in this report. The non-ISO regions are the non-shaded areas of the U.S. on the map. The non-ISO regions also include Alaska and Hawaii, but they are not shown on this figure. The light brown shaded area in Canada is an ISO but is not considered in this work. Source: BlckAssn, CC BY-SA 4.0, via Wikimedia Commons

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[28] *"Emissions & Generation Resource Integrated Database (EGRID)." U.S. Environmental Protection Agency, July 27, 2020. https://www.epa.gov/egrid.*

[29] *eGrid data were available for the years 2005, 2007, 2009, 2010, 2012, 2014, 2016, 2018, and 2019.*

[30] *ERCOT formed by 1996, CAISO and ISONE formed by 1998, NYISO by 2000, MISO (north) by 2002, SPP by 2004, and PJM around 2006. https://isorto.org/*

[31] *More specifically the June 12, 2020, version of the Independent System Operators spatial data from the Department of Homeland Security Homeland Infrastructure Foundation Level Database (HIFLD). https://hifld-geoplatform.opendata.arcgis.com/datasets/geoplatform::independent-system-operators/about*

We aggregated the generation and emissions for every active power plant during a given year within each region to compile totals for each region over time. This methodology allowed us to track changes in total emissions and changes in the emissions intensity[32] of electricity within each region. Because the eGRID dataset only began keeping track of ISO/RTO regions in 2009, some spatial analysis was required to properly sort power plants that existed in 2005 and 2007 but retired before 2009. A more detailed description of how these data were sorted is available in the Appendix.

Results

Overall, this analysis indicates that ISO regions have reduced total carbon emissions and carbon emissions intensity on average faster than non-ISO regions since 2005. We find that ISO regions have reduced total CO_2 emissions by about 35% since 2005, whereas non-ISO regions reduced CO_2 emissions by 27% over the same period. We also find that ISO regions have reduced the CO_2 emissions intensity of electricity faster than non-ISO regions. Other emissions, such as NO_x, N_2O, and SO_2 that are also captured in the eGrid data, declined in both ISO and non-ISO regions similarly.[33] Table 1 shows a summary of total electricity generation trends and CO_2 emissions, total and intensity, for both ISO and non-ISO regions.

Table 1: Table showing the changes, from 2005 to 2019, for ISO and non-ISO regions for total electricity generation, CO_2 emissions, and CO_2 emissions intensity.

Metric	Region	Change
Total Generation	ISO	0.5%
	Non-ISO	7.0%
CO_2 emissions Total	ISO	-35%
	Non-ISO	-27%
CO_2 emissions Intensity	ISO	-39%
	Non-ISO	-32%

Both types of regions increased their electricity generation over the period, with non-ISO regions generating about 7% more electricity in 2019 than in 2005 and ISO regions increasing total electricity generation by about 0.5%. In theory, stronger growth in electricity generation could have allowed non-ISO regions to reduce their emissions intensities faster because the additional growth in electricity demand could have been met by lower-emissions sources of energy; however, the data indicate that was, on average, not the case. Below we provide time series charts for generation and CO_2 emissions for the entire timespan considered.

Figure 4 shows the change in electricity generation from 2005 to 2019 for each of the ISOs, the average for all ISO regions (solid black), and the average for the non-ISO regions (black, dotted). While some ISOs have seen demand growth over that time, such as ERCOT and SPP, most have seen flat or declining generation due to stable demand levels. Non-ISO regions have, in general, seen electricity generation growth over the same period. Total U.S. electricity generation grew about 3% from 2005 to 2019. Thus, generation growth in non-ISO regions has been more than double the national rate.

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[32] *Emissions intensity is defined as tons of pollutant per unit of electricity, i. e., tons of CO_2 per MWh.*

[33] *Some of these pollutants have been subject to national reduction standards that could cross ISO lines: https://www.epa.gov/acidrain/acid-rain-program*

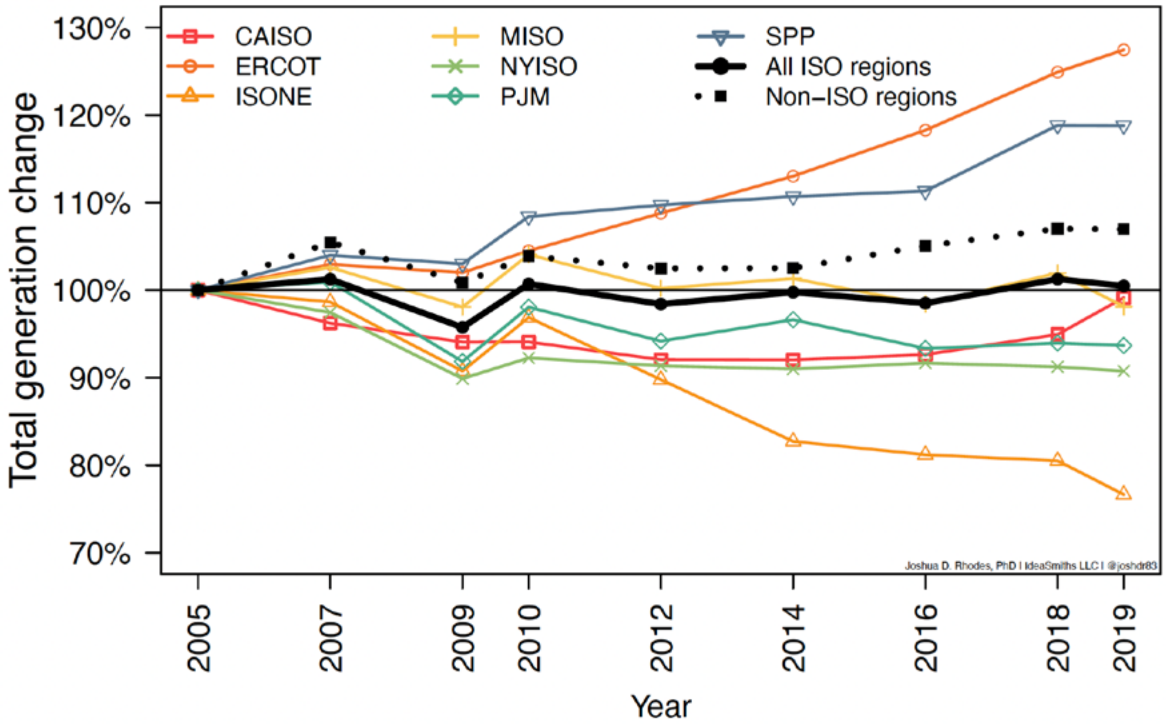

Figure 4: Figure showing the change in electricity generation from 2005 to 2019 in each ISO, the ISO average, and the non-ISO average. Note that this figure shows generation, not consumption and does not contain information about imports. Also note that eGRID data do not cover all years and thus the lines just show trends and do not reflect data for in-between years, such as 2015.

CO_2 Emissions

Figure 5 shows the time series data for total CO_2 emissions as well as CO_2 emissions intensity for each ISO and year available, benchmarked to their 2005 levels.

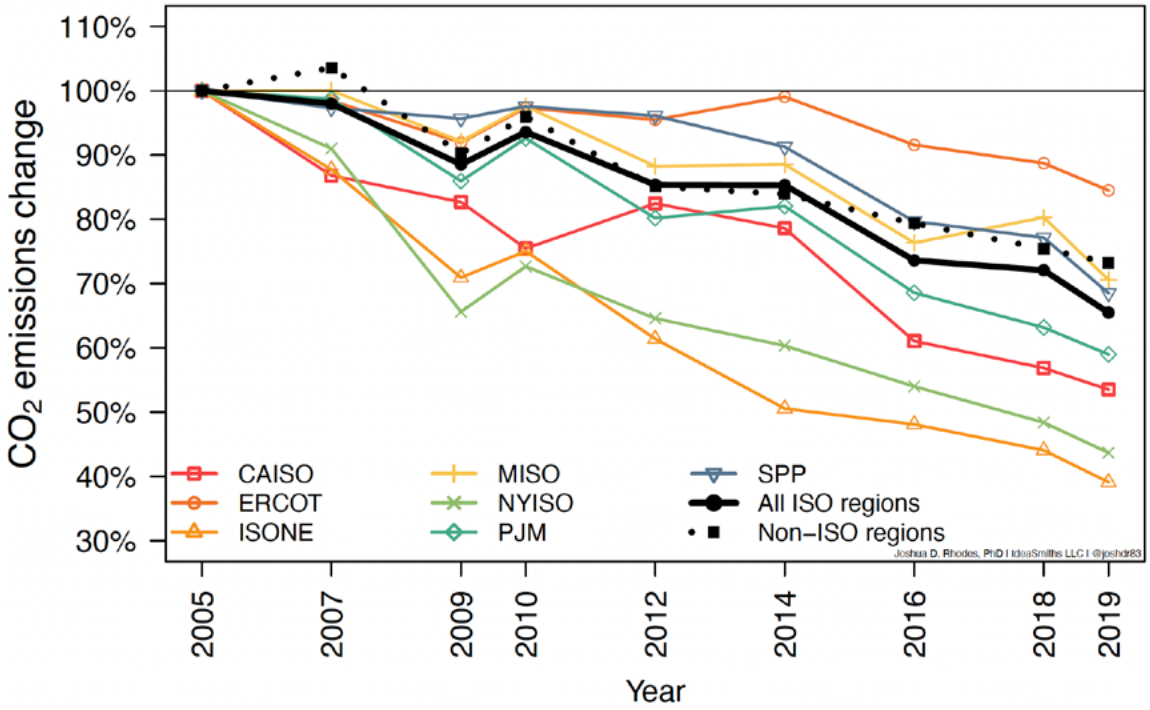

Figure 5: Figure showing the relative change in carbon emissions from 2005 to 2019 for each ISO region, the ISO average, and the non-ISO average. Each point along the line represents a year for which eGRID data were available for analysis. The “ALL ISO” region average is a generation-weighted average of the individual ISO regions.

Overall, ISO regions have reduced total carbon emissions more than non-ISO regions since 2005 and have generally widened that gap since 2014. From 2005 to 2019, the entire U.S. electricity sector reduced its CO_2 emissions by about 878.5 million tons, with 74% of the reductions coming from ISO regions. Over the same time period, PJM reduced CO_2 emissions by about 262.9 million tons, more than any other ISO and the entire non-ISO region, which reduced CO_2 emissions by about 225.3 million tons. Further, while MISO and PJM (together) only consumed about 13% more electricity than the non-ISO regions in 2019, they accounted for about twice as many tons of CO_2 reductions, about 451.7 million tons (together), than the non-ISO regions.

CO_2 Emissions Intensity

Figure 6 shows how the carbon intensity of electricity has also changed over the same period.

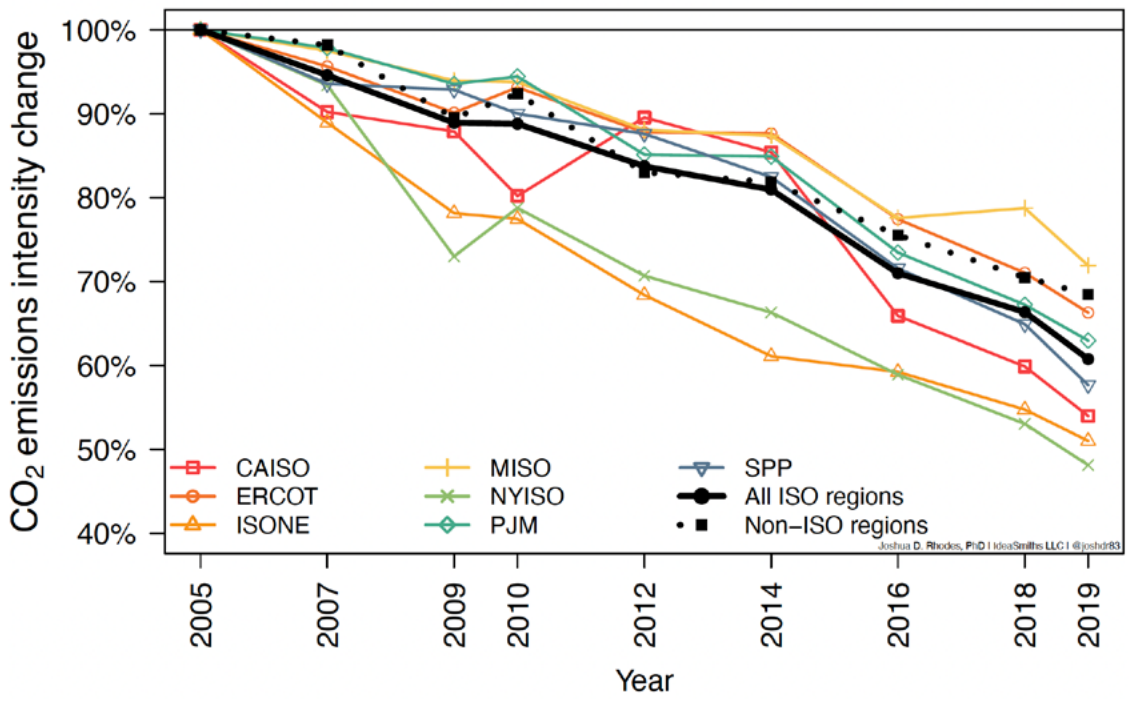

Figure 6: Figure showing the relative change in carbon emissions intensity from 2005 to 2019 for each ISO region, the ISO average, and the non-ISO average. Each point along the line represents a year for which eGRID data were available for analysis. Because the individual ISO region lines are normalized by generation, the "ALL ISO" line is a simple average of the individual ISO region lines.

The carbon emissions intensity of electricity is the total amount of carbon emitted in a region divided by the total amount of electricity generated in that region. On an absolute basis, the data indicate that the 2019 carbon emissions intensity of electricity for ISO regions was, on average, about 0.37 tons-CO_2/MWh. The carbon intensity of non-ISO regions were about 0.43 tons-CO_2/MWh, about 17% higher than ISO regions.

There are generally two major ways that carbon emissions and carbon intensities have changed over the past couple decades: 1) the increased deployment of zero-carbon resources such as wind and solar, and 2) a change in the other fuels used to generate electricity, such as the substitution of natural gas for coal. Stronger growth in electricity generation (Figure 4) could have allowed non-ISO regions to reduce their emissions intensities faster because the additional growth in electricity demand could have been met by low-emissions sources of energy. For example, the carbon intensity of non-ISO regions would have dropped to approximately 0.40 tons-CO_2/MWh[34] if zero-carbon sources, such as renewables, had been used to meet all the increased electricity demand in the non-ISO regions. However, the higher adoption rate of renewables to meet growing demand was not found in the non-ISO regions.

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[34] *Assuming the rest of the electricity use decarbonized at the same rate.*

Fuel shifts can also play an important role in emissions. From 2005 to 2019, total U.S. coal fleet capacity net declined by about 78.4 GW, with about 81%, or 63.6 GW[35], of that reduction coming from ISO regions. As of 2019, the non-ISO regions still used a higher percentage of coal for their total electricity generation, 23% versus 17% on average in the ISO regions, and a lower percentage of natural gas, 37% versus 39% on average in the ISO regions.

Renewable Energy Deployment

Competitive regions are also continuing to lead in the deployment of new renewables.[36] The same eGRID data utilized in the emissions analysis part of this work, coupled with EIA 860 data indicate that, as of 2019, even though ISO regions only accounted for 67% of total power plant capacity (of all types) and generated about 66% of all U.S. electricity, they have deployed almost 80% of all utility-scale renewable energy capacity.[37]

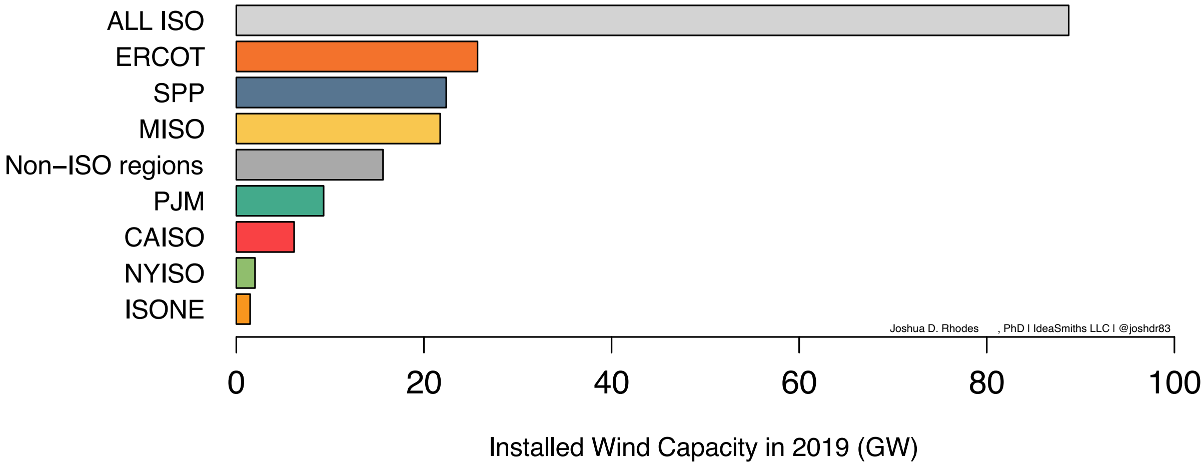

Figure 7: Figure showing the 2019 installed capacity of utility-scale wind in ISO and non-ISO regions in the U.S. (GW).

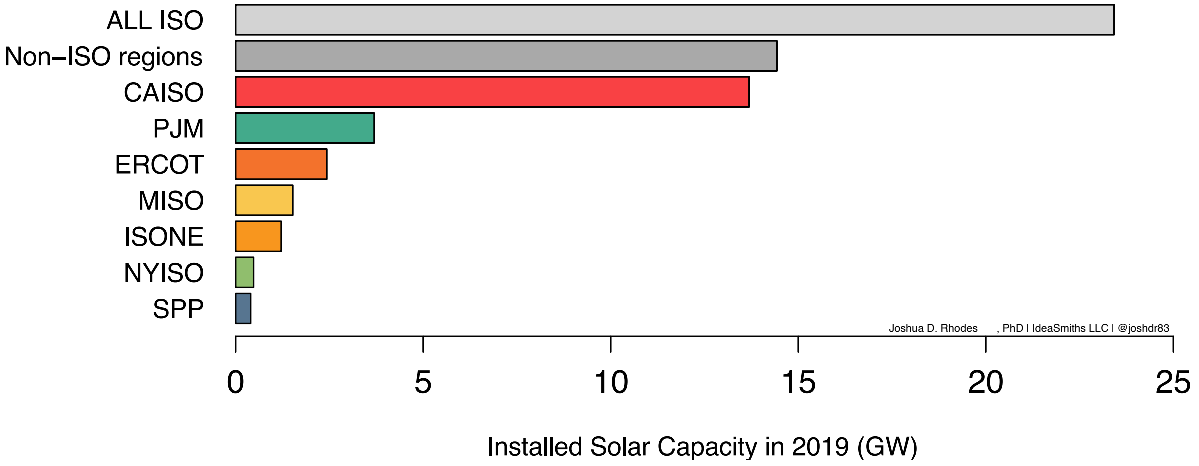

Figure 8: Figure showing the 2019 installed capacity of utility-scale solar in ISO and non-ISO regions in the U.S. (GW).

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[35] *MISO saw a net coal fleet reduction of about 37 GW and PJM saw a net coal fleet reduction of about 28.6 GW from 2005 to 2019.*

[36] *"New Data Products from Berkeley Lab Summarize Proposed Projects in Interconnection Queues." Berkeley Lab Electricity Markets and Policy Group. May 24, 2021. https://emp.lbl.gov/news/new-data-products-berkeley-lab-summarize.*

[37] *ISO regions have deployed about 85% of wind and 62% of utility-scale solar.*

Figure 9 shows the growth of distributed rooftop solar photovoltaic (PV) generation, indexed to 2014 values. The eGRID data only include utility-scale power plants and thus miss small-scale units such as rooftop solar PV. The Energy Information Administration began recording small-scale solar generation (GWh), but not capacity (GW), in their Annual Energy Outlooks in 2014. However, in places like California, where the majority of CAISO is located, distributed solar PV generation is non-negligible at over 15 GWh in 2019 (~8% of total). See the Appendix for how distributed generation (small-scale solar PV) was included in the total generation changes shown in Figure 4.

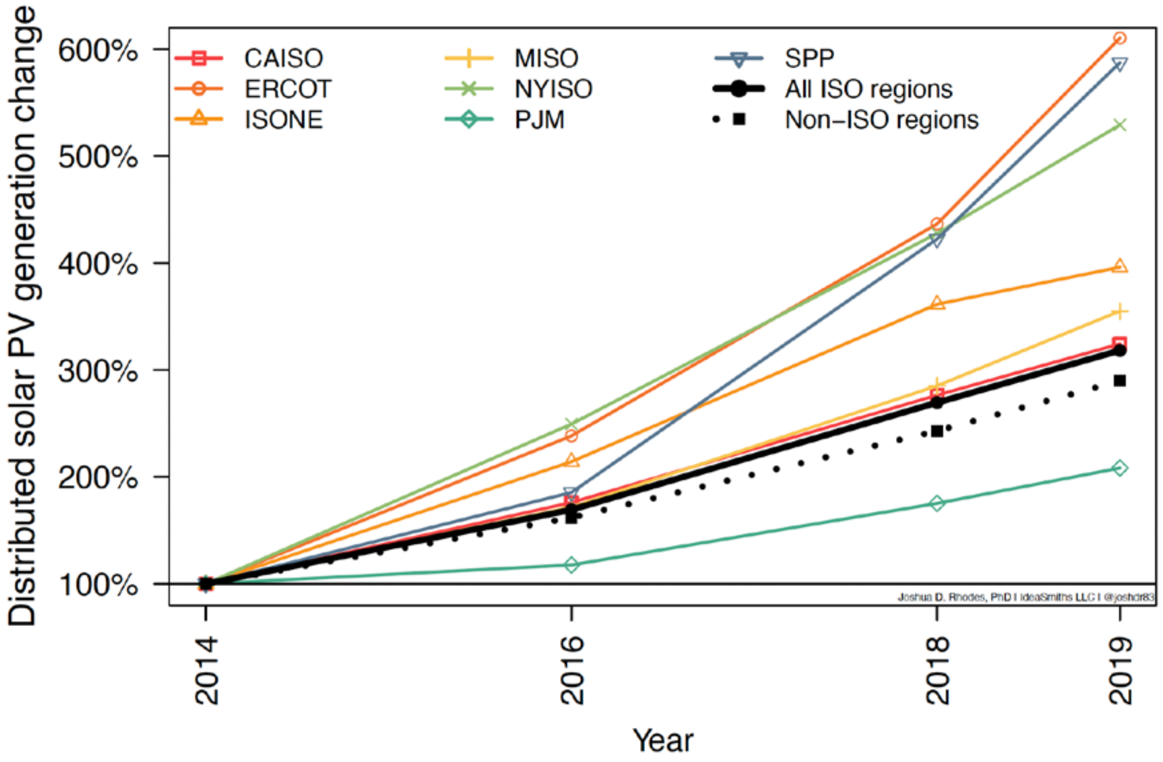

Figure 9: Figure showing the change in distributed electricity generation (distributed solar PV) from 2014 to 2019 in each ISO, the ISO average, and the non-ISO average. These data are not part of the eGRID data, which only includes utility-scale power plants and are estimated from additional EIA data that began in 2014.

From 2014, ISO regions have seen stronger growth in distributed solar PV generation than non-ISO regions on average and individually, with the exception of PJM.

One of the somewhat outliers in this analysis is ERCOT. From 2005-2019, ERCOT reduced its total CO_2 emissions by about 16% which is less than other regions. However, ERCOT's electricity consumption growth was not only positive, but was the highest of all regions, increasing about 27%, almost four times the non-ISO region growth rate. During this time, ERCOT reduced its CO_2 emissions intensity by about 34%, which while less than the ISO region average, was still more than the non-ISO region average of 32% (Figure 6).

Analysis Limitations

The available EPA eGRID data allowed us to complete an assessment of the relationship between competition and reduced CO_2 emissions. However, this analysis is limited by the fact that different regions have different characteristics and resources. Confounding factors, such as the local wind and solar resource, the existence of supporting technologies, such as natural gas pipelines, dispatch behavior, labor costs, legacy infrastructure, and differing societal preferences can be found across each region.

Conclusions

This report summarizes a data-driven analysis of how regions in the U.S. that have more competition in their electricity sectors (through the ISO construct) have reduced carbon emissions and carbon emissions intensities faster than non-competitive regions. Regions in the U.S. that are associated with an ISO reduced their total carbon emissions (from 2005 to 2019) by about 35%, whereas other regions only reduced their carbon emissions by about 27% over the same period. ISO regions also deployed more renewable energy resources, about 80% of the U.S. total, even though they only account for about 67% of total overall capacity. Competitive regions have also seen stronger growth in distributed generation.

The economic theory that underlies these patterns is multifaceted. Markets promote innovation and new technology adoption and thus are likely to incorporate new technologies more quickly, such as renewables, whose production costs have fallen steeply. We see this behavior when ISO regions incorporated wind power faster than non-ISO regions. Markets reflect consumer preferences better and more quickly, preferences that are changing to include more awareness of the environmental impacts of our energy choices and have led large and small customers to choose low-carbon sources of energy when given the chance. Further, market designs can readily and transparently incorporate environmental mechanisms, including proposals currently under consideration at the federal level that provide incentives to increase low-emissions electricity generation.

Acknowledgements

This work was funded by the Energy Choice Coalition.[38] The Energy Choice Coalition (ECC) is an educational and advocacy nonprofit organization committed to promoting competition and innovation in electricity markets without discriminating against technologies. The ECC is based in Washington, DC. For more information, contact Executive Director Robert Dillon at robert@energychoicecoalition.org.

About Us

IdeaSmiths LLC[39] was founded in 2013 to provide clients with access to objective professional analysis and development of energy systems and technologies. Our team focuses on energy system modeling and assessment of emerging innovations, and has provided support to investors, legal firms, and Fortune 500 companies trying to better understand opportunities in the energy marketplace.

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[38] *Energy Choice Coalition. November 14, 2021. https://www.energychoicecoalition.org/*

[39] *"IdeaSmiths LLC." 2018. https://www.ideasmiths.net/*

Appendix

Data Cleaning

This analysis was constructed via a “bottom-up” approach in that every power plant in the U.S. was assigned to an ISO (if it belonged to one by 2019) or to be part of a non-ISO region. The energy generation and emissions from each power plant were then summed up for each year and ISO or all of the non-ISO regions to generate a time series dataset for each region.

The eGrid data only began incorporating a data field for power plant ISO affiliation in 2009. Thus, a unique pairing between every power plant unique identifier[40] and its ISO affiliation was created, and the appropriate ISO label was applied to power plants in the years (pre-2009) for which it did not exist. However, any power plant that was operational after 2000, but retired before 2009 was not explicitly assigned to a region. To address this set of power plants, a spatial merging of the location of the remaining power plants and the footprint of the ISO regions was used to assign them into the correct area.

Distributed Generation

The eGRID data only cover utility-scale power plants. However, some regions, such as California, have significant amounts of distributed generation – over 15,000 MWh in 2019. The U.S. Energy Information Administration began tracking distributed, small-scale, solar PV production in 2014.[41] While latitude and longitude data are available for utility-scale power plants, the same information is not available for distributed generation installation locations and is simply aggregated to the state level. Thus, to account for this energy, each state’s distributed energy generation was assigned, via visual inspection, to an ISO (or non-ISO) for which the state was a majority part of. Besides CAISO and California, small scale solar PV represented, on average, about 1% of generation.

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[40] *“ORISPL” – a unique identifier assigned to each power plant by the U.S. Department of Energy.*

[41] *It was assumed all other forms of distributed generation were de minimis.*

Author Biographies

Dr. Joshua D. Rhodes is a Research Associate at The University of Texas at Austin, and a Founding partner of IdeaSmiths LLC. His current work is in the area of smart grid and the bulk electricity system, including spatial system-level applications and impacts of energy efficiency, resource planning, distributed generation, and storage. He is also interested in policy and the impacts that good policy can have on the efficiency of the micro and macro economy. He is also a regular contributor to Forbes and is an AXIOS Expert Voice. He sits on the boards of the Texas Solar Energy Society and Pecan Street Inc. (Data Advisory Board). He holds a double bachelors in Mathematics and Economics from Stephen F. Austin State University, a masters in Computational Mathematics from Texas A&M University, a masters in Architectural Engineering from The University of Texas at Austin and a Ph.D. in Civil Engineering from The University of Texas at Austin.

Dr. Lynne Kiesling is an economist focusing on regulation, market design, and the economics of digitization and smart grid technologies in the electricity industry. She is a Research Professor in the School of Engineering, Design and Computing at the University of Colorado-Denver, and Co-Director of the Institute for Regulatory Law & Economics. Lynne also provides advisory and analytical services as the President of Knowledge Problem LLC, and is an Adjunct Professor in the Masters of Science in Energy and Sustainability program at Northwestern University. She is currently a member of the U.S. Department of Energy's Electricity Advisory Committee, has served as a member of the National Institute of Standards and Technology's Smart Grid Advisory Committee, and is an emerita member of the GridWise Architecture Council. Her academic background includes a B.S. in Economics from Miami University (Ohio) and a Ph.D. in Economics from Northwestern University.

Dr. F. Todd Davidson is an Assistant Professor in the Department of Civil & Mechanical Engineering, United States Military Academy. Dr. Davidson's research focuses on the technical, financial, security and policy challenges related to the interdependent nature of energy systems, including transportation, energy storage, renewable resources, water, food, and oil and gas. Dr. Davidson has taught courses on fluid mechanics, thermodynamics, and energy technology and policy during his teaching career at both West Point and UT Austin. He holds a B.S. in engineering science from Trinity University; and an M.S. and Ph.D. from the University of Texas at Austin, both in mechanical engineering. Dr. Davidson holds an affiliated research position with the Department of Mechanical Engineering at UT Austin and is a Partner with IdeaSmiths, LLC a consulting firm providing expertise in analyzing energy systems.

Dr. Michael E. Webber is the Josey Centennial Professor in Energy Resources at The University of Texas at Austin and CTO of Energy Impact Partners, a $1.5 billion cleantech venture fund. From September 2018 to August 2021, Webber was based in Paris, France where he served as the Chief Science and Technology Officer at ENGIE, a global energy & infrastructure services company. Webber's expertise spans research and education at the convergence of engineering, policy, and commercialization on topics related to innovation, energy, and the environment. His latest book Power Trip: the Story of Energy was published in 2019 by Basic Books with an award-winning 6-part companion series that aired on PBS, Amazon Prime and iTunes starting Earth Day 2020. His first book, Thirst for Power: Energy, Water and Human Survival, which addresses the connection between earth's most valuable resources and offers a hopeful approach toward a sustainable future, was published in 2016 by Yale Press and was converted into an hourlong documentary. He was selected as a Fellow of ASME (the American Society of Mechanical Engineers) and as a member of the 4th class of the Presidential Leadership Scholars, which is a leadership training program organized by Presidents George W. Bush and William J. Clinton. Webber has authored more than 400 publications, holds 6 patents, and serves on the advisory board for Scientific American. A successful entrepreneur, Webber was one of three founders in 2015 for an educational technology startup, DISCO Learning Media, which was acquired in 2018. Webber holds a B.S. and B.A. from UT Austin, and M.S. and Ph.D. in mechanical engineering from Stanford University. He was honored as an American Fellow of the German Marshall Fund and an AT&T Industrial Ecology Fellow on four separate occasions by The University of Texas at Austin for exceptional teaching.