WHO OWNS THE CLEAN ENERGY FUTURE?
COMPARING PUBLIC AND PRIVATE ELECTRIC UTILITIES' PATHWAYS TO DECARBONIZATION

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By
Devyn Weis Powell, B.A.

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Devyn Weis Powell, B.A.

Thesis Advisor: Andrew M. Wise, Ph.D.

ABSTRACT

This paper compares investor-owned, public, and cooperatively-owned utilities' performance in transitioning their power mix to low- or zero-carbon sources, as well as different utilities' responsiveness to state policy mandates. As the worsening impacts of climate change have accelerated the urgency of transitioning to carbon-free sources of energy, understanding how to design effective policies to decarbonize the power sector — responsible for more than a quarter of U.S. greenhouse gas emissions — is imperative for regulators and policymakers. Most electric utilities in the United States fall into one of three ownership categories: investor-owned, public, and cooperative. A renewable portfolio standard (RPS), which mandates a renewable energy generation target by a certain date, is one of the most widely-adopted state-level policies to drive utilities and other electricity providers to increase their generation of renewable energy. Several RPS policies are designed to exclude certain utility types. In analyzing the relationships between utility ownership, RPS policy design, and renewable generation, this paper finds that investor-owned and cooperative utilities may outperform public utilities in renewable generation, and also finds stronger evidence that RPS policies that are more ambitious in their target and apply to all utility ownership types are more effective at increasing renewable generation at both the utility and the state level.

The research and writing of this thesis is
dedicated to everyone who helped along the way.
With special thanks to Jacqui, Lyra, and my parents,
for whom I am grateful every day.

Many thanks,
Devyn Weis Powell

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I. INTRODUCTION

This paper aims to compare investor-owned, public, and cooperatively-owned utilities' performance in transitioning their power mix to low- or zero-carbon sources, as well as different utilities' responsiveness to state policy mandates. I aim to help policymakers, regulators, and advocates understand the impacts of utility governance on the renewable energy transition. This analysis should serve as a resource in developing recommendations both for effective policy design to accelerate the renewable energy transition, as well as for what shape the low-carbon electric utilities of the future should take.

The scientific consensus has been clear for decades: in order to mitigate the worst impacts of climate change, the world needs to slash carbon dioxide emissions — and quickly. The United States — both the world's largest economy and the country responsible for more carbon emissions to date than any other — has a uniquely important role to play in decarbonizing the global economy (Gillis and Popovich 2017).

As of 2018, the electric power sector was responsible for 27% of U.S. greenhouse gas emissions, a close second to the transportation sector, which is responsible for 28% (United States Environmental Protection Agency 2018). Electricity already accounts for a significant proportion of emissions, and its importance will only continue to grow: electrification of other sectors of the economy, including transportation, industry, and buildings, has been identified as one of the most crucial and effective pathways toward rapid reduction of U.S. carbon emissions (D. Steinberg, et al. 2017).

Most electric power utilities in the United States fall into one of three ownership categories: private investor-owned utilities (IOUs); public power utilities (POUs), which are generally managed by cities, public utility districts, or states, and are often referred to as “municipals” or “munis”; and rural electric cooperatives (or “co-ops”) owned by their ratepaying members (Larson 2019). IOUs are by far the most widespread type of utility: according to the Energy Information Administration (EIA), 72% of Americans received their electricity from an investor-owned utility in 2017 (Energy Information Administration 2019). Yet most states have a mix of publicly- and privately-owned electricity providers. At least one public utility operates in every state but Hawaii, and according to estimates from the American Public Power Association, one in seven Americans’ electricity is provided by a POU (American Public Power Association 2017).

Some studies have shown differences in electricity rates, innovation, or service reliability between IOUs and publicly or cooperatively owned electric utilities. The American Public Power Association has reported that electricity rates for customers of public utilities are, on average, 11% lower than IOUs, although the difference between rates can vary significantly from state to state (American Public Power Association 2017). Other research has concluded that public entities, including electric utilities, are less responsive to government regulations and slower to make infrastructure upgrades or adopt new technological improvements (Konisky and Teodoro 2016).

On the policy side, 37 states and the District of Columbia have currently passed a renewable energy portfolio standard (RPS), a total that includes both mandatory and voluntary targets. Some of those standards are written to apply only to IOUs, or have different standards for public and private utilities (National Conference of State Legislatures 2020).

Based on evidence from existing literature, I hypothesize that investor-owned utilities may outperform public and cooperative utilities in their renewable energy generation. At the same time, while all renewable portfolio standard policies do not apply to all utility types, my hypothesis is that all utilities will respond to the introduction of a renewable portfolio standard that applies to them. Given that all renewable portfolio standard policies do not apply their standards to all utility types, these findings should offer relevant insight for policymakers looking to implement and improve clean energy standards.

Given the climate importance of decarbonizing the electric power sector, the narrowing scientific timeline for decarbonization, and increasing public support for and political interest in a clean energy transition, examining electric utilities' ability to quickly adopt low-carbon power sources is an important topic for future research.

The paper proceeds as follows: in the next section, I summarize the related literature and present background on the electric power sector and renewable energy policy for the reader. In Section 3, I describe the theoretical and empirical models used to conduct the analysis, as well as the data used to construct the model. In Section 4, I predict results and offer preliminary policy recommendations for state and federal regulators.

II. BACKGROUND AND LITERATURE REVIEW

The electricity sector will play a critically important role in reducing economy-wide carbon emissions as part of addressing the impacts of climate change. Steinberg et al (2017) have identified electrification of other sectors of the economy, such as transportation and buildings, as an effective pathway to reducing carbon emissions economy-wide. However, in order for electrification to reduce emissions effectively, significantly more electricity must be generated from low-carbon sources, especially zero-carbon renewable sources like solar and wind. Renewable energy sources currently comprise only 17.6% of electricity generation in the United States, or merely 10.6% if hydropower is excluded from the calculation (Energy Information Administration 2019).

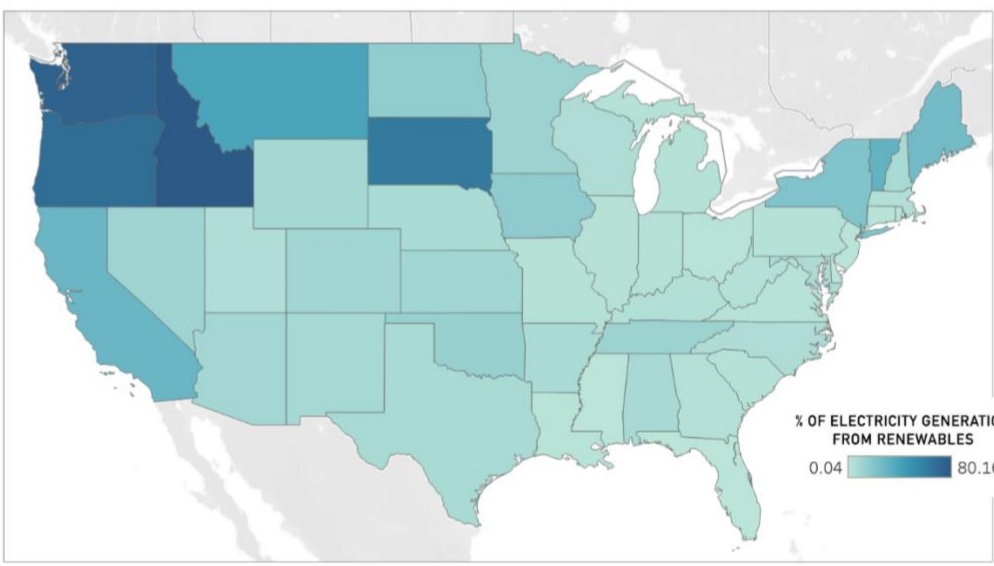

Figure 1: Percent of electricity generation from renewable sources by state

Data source: Energy Information Administration. Note: "Renewables" here includes wind, solar, geothermal, and hydroelectric power. Alaska and Hawaii have been omitted from this map and model.

Figure 1 shows the percentage of total electricity generated in each state from renewable sources, defined here as wind, solar, geothermal, and hydroelectric energy. Hydroelectric represents the largest proportion of renewable energy in the United States and is dominant in the Pacific Northwest.

Ownership and Generation in the U.S. Electricity Sector

Electric utilities in the United States can be privately investor-owned (IOUs), publicly owned (most often by municipalities), or cooperatively owned by ratepayer-members. Public municipally-, state-, or federally-owned utilities (POUs) represent the majority of electric utilities in the U.S., with just under 2,000 operating nationwide. Most of these public utilities are municipally-owned and each serve a small number of customers, while IOUs tend to be larger and serve more customers. For example, in 2017, 1,958 POUs provided electricity to approximately 16% of customers, while only 110 IOUs serve 72% of households (Energy Information Administration 2017).

In most states and territories, electricity is provided by a combination of all three utility ownership types. There is at least one POU operating in every state but Hawaii (American Public Power Association). Co-ops, meanwhile, exist in 47 states, with a higher concentration in the Midwest and Southeast (Energy Information Administration 2017). While IOUs serve the majority of electricity customers in most states nationwide, public and cooperatively owned utilities provide the majority of power in a few notable states, including Nebraska and Tennessee (Boylan 2016). Nebraska is the only state in the country for which electricity is provided entirely by public and cooperative utilities (Patent 2018).

812 rural electric co-ops — which serve approximately 13% of electricity customers — are currently operating in the United States (Energy Information Administration 2017). Co-ops fall into two general categories: generation and transmission cooperatives (G&Ts) and distribution-only cooperatives. G&T cooperatives, as their name suggests, generate and/or procure electricity, operate transmission networks, and sell wholesale power to their members — the distribution co-ops. Those distribution co-ops, in turn, provide retail electricity to their members — retail electricity customers. While a majority of distribution co-ops are members of G&Ts, not all are. The remaining independent distribution co-ops can choose to purchase power from other utilities or power producers (Jang 2020).

Rural areas of the country are generally served by electric cooperatives (Cruz 2014). The geographic distribution of utility ownership types can be traced back to the New Deal-era programs that brought electricity to rural communities. Prior to the Rural Electrification Act (REA) of 1936, less than 10% of rural households had access to electricity, in contrast to the widespread electrification of more urban areas (Ek and Abel 1991). IOUs were responsible for bringing electricity to more densely populated regions, but the comparatively much higher costs of constructing grid equipment and maintaining service in more spread-out rural communities disincentivized private utilities from expanding service to those areas. The Rural Electrification Act authorized the creation of the Rural Electrification Administration, which issued loans to fund the construction of grid infrastructure in rural communities and enabled the establishment of electric cooperatives to provide electric service (Kitchens and Fishback 2015).

In the way that public investment overcame adverse market incentives to provide electricity — and the public benefits associated with electric service — to rural communities, several researchers have hypothesized that public ownership of the electric power sector could enable a more rapid and effective transition to clean energy in order to address the impacts of climate change. Haney and Pollitt contrast the profit motive driving IOUs with government enterprises' ability to focus on social welfare and internalize the external costs of carbon pollution (2013). They also point to historical examples of governments leveraging their unique power and investment ability to drive economic transformations at a scale and urgency that the private sector was unable or unwilling to match, such as the initial electrification of rural communities during the New Deal era in the United States (Haney and Pollitt 2013). Referring to the economics of the public and private sectors, as well as these historical examples of large-scale government investment in the interest of public welfare, they believe that public power ownership would be more effective than private ownership at driving a rapid clean energy transition in the face of climate change. Mayer and Rajavuori (2017) concur, and encourage states to leverage their social characteristics, financial power, and ability to avoid the risks associated with private-sector investments to spur initial large-scale development and deployment of clean energy technologies in order to meet the rapid decarbonization demands of climate change.

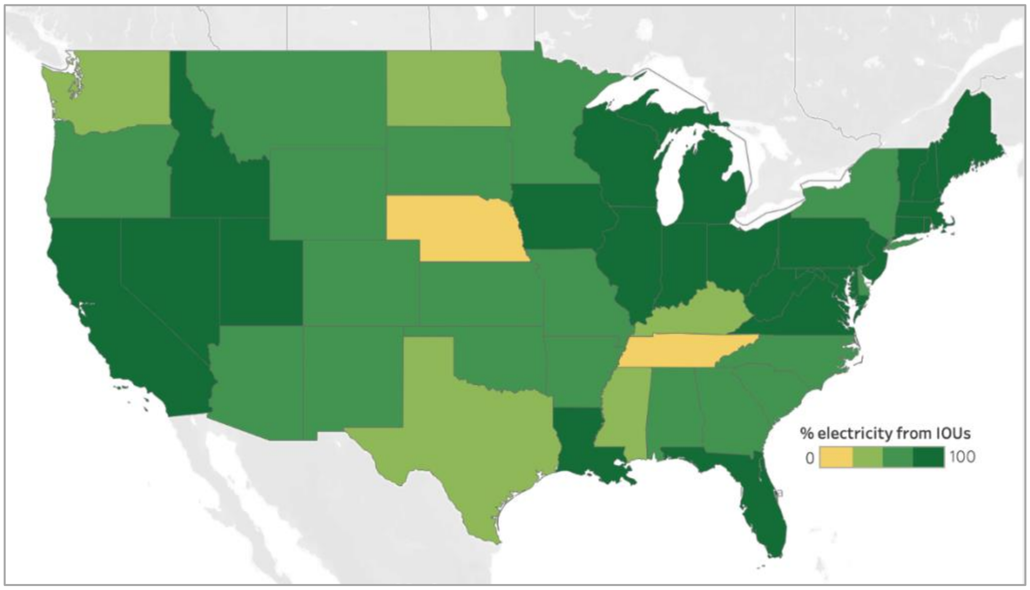

Figure 2: Percentage of electricity generation from investor-owned utilities (IOUs)

Data source: Energy Information Administration. Note: These percentages represent mean values for generation between the years 2001 – 2019. Alaska and Hawaii have been omitted from this map and from the models used in this study.

Figure 2 illustrates the percentage of total electricity generation from IOUs, as compared to public or cooperative utilities. While most states have a mix of all three utility types, several states receive power exclusively or almost exclusively from IOUs. As described above, only one state — Nebraska — has no IOUs operating in the state. Tennessee is the only other state that comes close to Nebraska's ownership mix, with only 2% of electricity coming from IOUs, 76% from public utilities — the federally-controlled Tennessee Valley Authority (TVA) largest among them — and 22% from cooperatives.

Most electric utilities in the U.S. were historically vertically integrated monopolies, with generation, transmission, distribution, and retail electricity sales functions all performed by the same company. *The Energy Policy Act* (EPAct) of 1992 dramatically shifted the market landscape of the power sector by opening the wholesale electricity market to competition. After the 1992 EPAct and successive Federal Energy Regulatory Commission (FERC) orders further enabling competitive markets, close to half of states and the District of Columbia passed laws deregulating their electricity markets. As a result of deregulation, the services traditionally performed by integrated monopoly utilities are unbundled, and generation and retail sales providers compete with each other in a market (Goto and Tsutsui 2008). Transmission and distribution — functions tied to the infrastructure of the electric grid — remain natural monopolies.

Studies on the impact of deregulation on efficiency, reliability, electricity prices, innovation, and utilities' generation mix have shown varied results. Goto and Tsutsui (2008) found that utilities in states with deregulated markets were less efficient in general administration and in technical efficiency of generation, but showed more efficiency in transmission and distribution. They suggest performance-based regulation as a policy incentive to improve overall efficiency in deregulated states. Cruz (2014) found that state renewable energy policy mandates were more effective at encouraging greater shares of electricity generation from renewable sources in regulated states, while utilities in deregulated markets were more likely to purchase renewable energy credits, when allowed under state policy, instead of investing in their own generation.

State Policies and Other Drivers of Renewable Energy Adoption

With no national clean energy standard in place, implementing policies to incentivize a transition to renewable energy sources has been left to states. One of the most widely adopted energy transition policy mechanisms has been the renewable portfolio standard (RPS), a policy that places a requirement on electric power providers to supply either a quantity or percentage of total electricity sales from renewable energy sources (Barbose 2018). 29 states and the District of Columbia have adopted an RPS law, while some additional states have embraced broader clean energy targets or voluntary goals, either alongside or instead of an RPS target (Barbose 2018). Iowa adopted the first RPS in 1983, and the majority of other states who have followed suit enacted their own policies between 1997 and 2008, although many policies have been revised in more recent years (Barbose 2018).

Research on the effectiveness of RPS policies on pushing electric utilities to increase generation and sales of electricity from renewable sources has shown mixed results. Zhou and Solomon found that, with the exception of states with high renewable energy generation potential, utilities are unlikely to generate a proportion of renewables greater than the targets mandated by their state's RPS law. They therefore conclude that RPS policies could be setting a cap on renewables generation in most states (Zhou and Solomon 2020). Bhattacharya et al (2017) found that RPS policies increased retail electricity prices, but whether or not they increased the proportion of clean power sold varied by state. In a study for the Lawrence Berkeley National Laboratory, Barbose (2018) concluded that state RPS targets were responsible for "roughly half" of the growth in renewable electricity generation and capacity in the United States since 2000, but also found that RPS policies were responsible for a declining proportion of new renewables capacity over the same time period. Like Bhattacharya et al, Barbose also found state and regional differences in the effectiveness of RPS targets at driving new investments in renewable energy, and found these policies to be most effective in northeastern, mid-Atlantic, and western states.

Not all state RPS policies are designed to regulate all utilities. Several state policies include exemptions or modifications to their RPS target, with many policies applying only to IOUs (Stokes 2015). Sixteen states completely exclude some utilities from their RPS based either on utility ownership type or size, with size generally defined as a percentage of the state's total electricity load served by a given utility (Fischlein and Smith 2013). Due to these exclusions, as Fischlein and Smith point out, the stated targets in several state RPS policies do not accurately reflect the proportion of electricity impacted by the policy. For example, before being revised and expanded in 2011, California's RPS set a target of 20% renewable electricity by 2020, but applied the target only to large IOUs — effectively reducing its target to 14% (Fischlein and Smith 2013). Fischlein and Smith warn researchers that, due to the exclusions and loopholes present in many state policies, analyses of RPS effectiveness that rely on a simplified understanding of state policy goals could result in incomplete or inaccurate conclusions.

Meanwhile, a range of factors impact states' adoption of RPS policies in the first place, including the partisan makeup of state governments and electric utilities' lobbying efforts. Stokes and Breetz (2018) find that Democratic legislators are more likely than Republicans to introduce renewable energy policies overall, although Republicans have led on policy introduction in a minority of states. They also identified a strong pattern of incumbent electric utilities, public and private, lobbying against renewable energy policies, especially net metering policies that require utilities to buy back electricity generated by households with distributed solar resources. A number of other studies have also concluded that Democratic control of state governments predicts the adoption of RPS and other clean energy policies, and that party polarization has increased the relationship between Democratic control and RPS adoption since the mid-to-late 2000s (Karapin, 2020; Yi & Feiock, 2014).

In addition to policy incentives, a range of factors impact utilities' adoption of renewable energy sources in their generation mix. Some researchers have found that the renewable energy generation potential of a state predicts a higher proportion of electricity generated from renewables, while other studies have shown no relationship between potential and adoption. Kelsey and Meckling (2018) found that renewable energy policies generally had only a minor impact on the adoption of utility-scale renewable energy generation, while states with high wind generation potential were more likely to deploy wind energy than less windy states whether or not policy incentives were in place. Cruz (2014) found that renewable energy potential had no impact on renewable generation in regulated states, and actually correlated negatively with renewable generation for IOUs in states with deregulated electricity markets, implying that high upfront costs of investing in renewable generation may dissuade IOUs mindful of their bottom line in competitive markets.

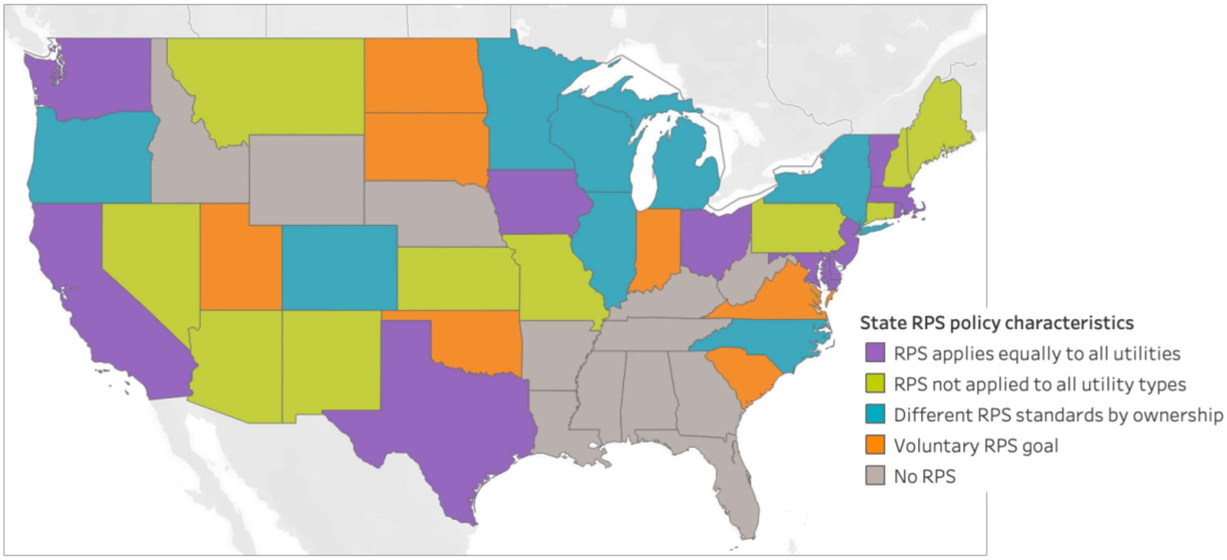

Figure 3: Renewable portfolio standard policy characteristics by state

Data source: Database of State Incentives for Renewables & Efficiency (DSIRE) and the National Council of State Legislatures (NCSL). Note: This map reflects policies in effect as of 2019, the most recent year for which utility-level electricity generation data was available and used for this model. In 2020, Virginia passed a binding RPS, replacing the previous voluntary RPS goal shown on this map. Alaska and Hawaii have been omitted from this map and model.

Figure 3 maps state RPS policies by their inclusion of utilities based on ownership type. Some policies apply only to IOUs, while others exclude one ownership type (generally either municipal utilities or cooperatives). Other policies apply targets to all utilities, but set different generation targets based on ownership, with IOUs usually receiving higher targets than public or cooperatively owned utilities in these cases. As Fischlein and Smith (2013) discuss, the difference in RPS applicability based on utility type impacts any analysis of how ownership type predicts policy effectiveness.

Impacts of Ownership on Generation, Innovation, and Reliability

Little research has yet been done on the differences between privately- and publicly-owned utilities' energy generation mix and their responsiveness to energy transition policies. In terms of overall generation mix, an American Public Power Association report offered a snapshot of generation by ownership type in 2016, which showed that cooperatives have the highest proportions of both coal and natural gas in their overall generating capacity, followed by IOUs and then by municipal utilities (American Public Power Association 2018). The snapshot did not offer details on non-hydroelectric renewables, in part because those sources remain a small percentage of overall generation. Stokes (2020) referenced the same data to suggest that cooperatives are likely more laggards than leaders in the clean energy transition and discussed examples of POUs and cooperatives lobbying to oppose clean energy mandates and broader regulatory oversight, though also noted that IOUs have generally been the most vocal and organized utility opponents of clean energy and climate policies. Wilson et al (2008) similarly observed that POUs and co-ops serve more customers in more coal-intensive states, and conjectured that public and cooperative utilities are likely "more coal-intensive" than IOUs.

Delmas and Montes-Sancho (2011) published what they claim to be the first paper to differentiate the impact of state renewable energy mandates on utilities by ownership type. Their study looked at the efficacy of RPS policies in incentivizing increases in renewable capacity among different utility ownership types, and found that IOUs are more responsive to RPS mandates than publicly-owned utilities. However, in their own broader analysis of state RPS policies, Fischlein and Smith (2013) pointed to Delmas and

Montes-Sancho's paper as an example of a study that had not fully accounted for the size and ownership exclusions present in RPS design, and encouraged more detailed research.

A number of studies have illustrated other areas where public and privately-owned utilities respond differently to policy mandates, market incentives, and opportunities for innovation, several of which could shine light on the impact of ownership type on the energy transition. A few researchers have concluded that private ownership and size both predict the adoption of new technologies, such as smart grid innovations or demand response technologies (Rose and Joskow 1990) (Cruz 2014). Rose and Joskow (1990) found that IOUs were generally more likely than POUs to adopt new technologies, and that larger utilities were similarly more likely to innovate than smaller ones. Dedrick et al (2015) did not find conclusive evidence that IOUs were more or less likely than POUs to adopt "smart grid" technologies designed to improve the efficiency and reliability of electric service, but did find that any utility in a state with a competitive, deregulated electricity market was more likely to adopt the technologies than utilities in regulated states. Cruz (2014) compared the effectiveness of policies at encouraging the adoption of demand-side management programs in POUs and cooperatives, and concluded that technical mandates had a greater impact on adoption for POUs. Cruz hypothesized that POUs are more responsive to mandates since they otherwise lack the market incentives to pursue efficiency and greater performance than cooperatives or IOUs.

Other research has compared the impact of utility ownership type on service reliability and electricity prices. Anecdotal evidence has suggested that IOUs experience longer and more significant disruptions to electricity service after storms and other natural disasters: for example, municipal utilities rapidly restored service to customers in Massachusetts and Connecticut after Hurricane Sandy, while customers of the two largest IOUs in each state suffered outages for a week or more (Boylan 2016). Boylan (2016) found that POUs spend more on maintaining their transmission and distribution networks than IOUs, but did not in fact experience fewer outages or quicker restoration of power after storms on average, and suggested that public utilities' higher spending on infrastructure maintenance may be simply inefficiency instead of effective investments in reliable service. Stepping back, Lenhart et al (2020) also pointed out that IOUs have been the subject of significantly more research overall than POUs or co-ops. They identified a need for more studies that include or focus exclusively on public and cooperatively owned utilities and how different factors impact their generation mix and investment decisions.

Meanwhile, debates over the merits of public versus private ownership of electric utilities is of particular salience in some cities and states that are re-evaluating the ownership structures of IOUs that are underperforming on safety, reliability, or delivery of renewable energy. For example, in response to concerns about the utility's management and safety practices after faulty Pacific Gas & Electric (PG&E) equipment was found to have started several major wildfires, a number of California elected officials have put forward proposals for a public takeover of PG&E, including a bid for municipalization by the city of San Francisco and a statewide bill introduced in 2020 by Senator Scott Weiner (Hering 2019). The city of Boulder, Colorado has been pursuing efforts to municipalize the assets of IOU Xcel Energy as a strategy to increase the proportion of renewable energy in the city's electricity supply. An analysis by city officials concluded that a public takeover of Xcel would be both legal and cost-effective over a 20-year period (City of Boulder 2013).

Since studies on how utility ownership type impact utilities' adoption of renewable energy generation, including their responsiveness to state policy, has been limited and produced mixed results, this study will add a new dimension to the evolving — and increasingly important — subject of climate mitigation and energy transition policy research.

III. DATA

The primary data used to construct this model were obtained from the United States Energy Information Administration (EIA). The model also includes data on state renewable portfolio standard policies from the Database of State Incentives for Renewables & Efficiency (DSIRE), statistics on state-level solar and wind generation potential from the Department of Energy, and information on state population and per-capita state income from the Bureau of Economic Analysis. The resulting panel, once accounting for missing observations, results in 857 utility-level observations across 18 years.[1] The data are also collapsed to the state level, which results in 49 state observations across 18 years.[2]

EIA Form 861 collects information from all electric power operators in the United States, including all electric utilities, and contains utility names, the state in which the utility operates, the utility's ownership type (e.g. investor-owned, municipal, cooperative, state, etc.), total electricity sales per utility in megawatt-hours (MWh), and total number of customers served and revenue generated on an annual basis. The EIA has Form 861 data available from 1990 to 2019, though this study is based on the last 20 years of data available (2001 to 2019).

Data from EIA Form 861 were merged with data from EIA Form 923, a survey that collects data on generation and fuel consumption at the plant level for all electric

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[1] There are 697 utilities in the dataset, but several operate across state lines. Because policies are adopted at the state level, this analysis was conducted at the utility-state level, with utilities that operate in multiple states split into multiple observations.
[2] This number counts Washington, DC as a state. Alaska and Hawaii were omitted due to limited data and the unique energy characteristics of those states.

power plants in the United States. Form 923 contains data on plant fuel type, total net electricity generation, state, and the name of the utility that owns or operates the plant. Merging the Form 861 and 923 data enables analysis of the fuel mix of each utility's generating capacity by the utility's ownership structure. Form 923 data are published for the years 2001 to 2019, and all of those years have been included in the panel dataset constructed for this model. This utility and power-plant level data were then combined with years 2001-2019 of the EIA's "Net Generation by State by Type of Producer by Energy Source" aggregated dataset, which reports electricity generation by energy source at the state level.

The DSIRE database, maintained by the North Carolina Clean Energy Technology Center at North Carolina State University, contains comprehensive information about which states have enacted policies incentivizing clean or renewable energy. The data from DSIRE categorize policies by jurisdiction and type, as well as by date of passage (and, where applicable, date of expiration). This model included information about the existence of state-level renewable portfolio standard (RPS) policies from the DSIRE database, the date of passage of those policies, and variables indicating whether or not policies applied to particular utilities by ownership type, as several state-level RPS laws set targets that apply only to IOUs.

The Department of Energy (DOE) publishes data about the generation potential for wind and solar energy across the United States, and those data were included as controls in my model. DOE's Office of Energy Efficiency and Renewable Energy (EERE) publishes data on state-level potential wind capacity in megawatts (MW). DOE's National Renewable Energy Laboratory (NREL) publishes information on solar generation potential via its National Solar Radiation Database (NSRD), measuring Direct Normal Irradiance a measurement of potential kilowatt-hours per square meter per day). The solar generation data used here was NREL’s “Rooftop Solar Photovoltaic Technical Potential” dataset.

In addition, data on state population as well as per-capita personal income by state were obtained from the Bureau of Economic Analysis (BEA), which publishes this information on a quarterly basis. Annual income and population data were incorporated for years 2001-2009.

Table 1: Descriptive statistics for utility-level model

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
utilitynumber	9,866	11,464	6,905	34	56,146
utilitynum_state	15,426	429	247.4	1	857
year	15,426	2,010	5.188	2,001	2,018
renew_percent	9,408	16.71	35.65	-152.6	139.8
fuel_renewables	9,866	206,337	1.242e+06	-122	2.469e+07
util_iou	9,866	0.179	0.383	0	1
util_public	9,866	0.778	0.416	0	1
util_coop	9,866	0.0432	0.203	0	1
policy_iou	9,866	0.486	0.500	0	1
policy_muni	9,866	0.252	0.434	0	1
policy_coop	9,866	0.297	0.457	0	1
state_rps	9,866	0.486	0.500	0	1
year_enacted	9,866	1,221	976.5	0	2,020
target_year	9,866	893.5	1,006	0	2,050
percent_target_year	9,866	0.146	0.276	0	1
mstate_fuel_renewables	9,866	8.759	17.08	0	98.08
mrevenues_total	9,865	0.229	0.753	0	11.63
msolar_generation_potential	7,042	4,170	3,570	115.5	18,620
mwind_weighted_total	7,081	0.141	0.147	5.32e-05	0.767
mstate_population	9,866	7.085	7.558	0.495	39.46
state_income_percapita	9,866	39,196	7,843	22,781	74,855

Table 2: Descriptive statistics for state-level model

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
stateid	824	24.42	14.11	1	48
mstate_fuel_renewables	824	8.581	15.96	0	98.08
state_rps	824	0.453	0.498	0	1
policy_all_utilities	824	0.274	0.446	0	1
year_enacted	824	1,209	981.1	0	2,020
target_year	824	1,071	1,013	0	2,050
percent_target_year	824	0.198	0.311	0	1
msolar_generation_potential	538	3,350	3,370	115.5	18,620
mwind_weighted_total	550	0.0960	0.139	5.32e-05	0.767
mstate_population	824	6.561	6.923	0.495	39.46
state_income_percapita	824	40,123	9,192	22,781	74,855
year	842	2,009	5.191	2,001	2,018

Data Limitations

While the results discussed below should help provide insight for policymakers and analysts into the relationship between utility ownership, state policy design, and renewable energy generation, the data used and analysis conducted for this study include limitations that should be addressed in future research.

First, due to limitations in the data available from the Energy Information Administration (EIA), the source data used represent only power generation owned by any given utility, and as such do not offer a full picture of the total electricity sales to customers from each utility — as most utilities do not sell exclusively power they generate themselves, but instead also purchase power from independent power producers or other utilities (Murphy 2019). In addition, because the dataset constructed for this analysis involved merging two separate EIA source datasets — Form 923 and Form 861 — only utilities present on both forms were included. As a result, this analysis excludes many other utilities currently operating in the United States, or excludes some years of data for some of the utilities that were included. Nevertheless, the available measures are good proxies for the ideal measure and thus provide useful results.

Second, many factors impact the design and effectiveness of an RPS policy in any given state, and it is not possible to include every relevant factor in the design of the models used here. For example, differences between policies' definitions of "clean" or "renewable" fuels were beyond the scope of this model, as were different policies' approaches to Renewable Energy Certificates (RECs) or other trading mechanisms. Nonetheless, as many relevant and quantifiable factors as possible were included in order to give the fullest possible picture of the scope of an RPS policy: year of passage, level of ambition, target year, and applicability across utility types. Data about the applicability of state RPS policies to different utilities by ownership type were sourced from the Database of State Incentives for Renewables & Efficiency (DSIRE) and the National Conference of State Legislatures (NCSL) and are as accurate and up-to-date as those sources at the time of study.

In addition, utilities were collapsed into three ownership types for this analysis, but those categories naturally cannot capture the full spectrum of granular difference between utilities of those ownership types. For example, the "public utilities" included all electric utilities owned by a government entity, from small municipal utilities to the federally-owned Tennessee Valley Authority. While variables for utility size were introduced to help control for some of this variation, a more robust and nuanced examination of different public utilities would require future analysis.

Finally, Alaska and Hawaii were excluded from this analysis due to a lack of data and the distinct characteristics of those states.

IV. MODELS AND METHODOLOGY

Theoretical Model

In order to examine the impact of a utility's ownership model on the utility's share of renewable energy generation, I develop a model to illustrate the factors impacting an electric utility's generation mix in order to isolate the impacts of public, private, or cooperative ownership.

$$RE = f(O, P, E, R, Si, Sp, e) \qquad (1)$$

Where RE is proportion of renewable energy generated at the utility level; O is utility ownership type; P is state RPS policy; E is the energy generation mix at the state level; R is the utility's annual total revenues, used as an indicator of size; S*i* is state-level income per capita; S*p* is state population; and e is random error.

A range of factors have been shown to impact renewable energy generation, and the logic of this model is built on considering those major factors in order to isolate the impacts of utility ownership type. As discussed above, policies that set clean energy targets incentivize utilities to generate more renewable energy; utility size impacts generation mix; and renewable energy generation potential can impact adoption of renewables.

Empirical Model

$$RENEWABLES = \beta_0 + \beta_1(OWNERSHIP) + \beta_2(RPS) + \beta_3(RPSCHARACTERISTICS) + \beta_4(STATEMIX) + \beta_5(REVENUES) + \beta_6(SOLARPOTENTIAL) + \beta_7(WINDPOTENTIAL) + \beta_8(POPULATION) + \beta_9(INCOME) + \mu \quad (2)$$

Where:

- RENEWABLES is the proportion of a utility's energy generation mix that comes from wind, solar, hydroelectric, or geothermal sources.
- OWNERSHIP is a utility's ownership type. Separate regressions were run for each of the three ownership types analyzed — IOUs, POUs, and co-ops. For each of those regressions, each OWNERSHIP variable was given a value of "1" for utilities of that ownership type, and "0" otherwise. For example, the ownership variable *util_iou* has a value of "1" for all investor-owned utilities and "0" for all other utilities.
- RPS is whether or not a state has a policy in place that sets a target or incentives for renewable energy generation. Like OWNERSHIP, RPS was constructed as three separate variables for three separate regressions, based on ownership type and the applicability of the RPS to the utility ownership type in question. For example, the RPS variable *policy_iou* contains a value of "1" for a state that has an RPS policy that applies to IOUs, and a value of "0" for a state with no RPS or one that does not apply to that utility type. In addition, a variable *state_rps* was

used for state-level regressions, with a value of “1” for a state with any binding RPS policy, and “0” otherwise.

- RPSCHARACTERISTICS were used in some versions of the model, and include the year a policy was enacted *(year_enacted)*, its target percentage of clean energy generation *(percent_target_year)*, and the target year by which the goal is to be realized *(target_year)*.
- STATEMIX is the percentage of a state’s total electricity generation from renewable sources *(mstate_fuel_renewables)*.
- REVENUES is a utility’s total annual revenues, in millions of dollars.
- SOLARPOTENTIAL is a state’s potential capacity for rooftop solar in kilowatts (kW).
- WINDPOTENTIAL is a state’s potential wind energy generation capacity in megawatts (MW).
- POPULATION is a state’s population.
- INCOME is average personal income by state.
- μ is the random error.

The variables used in the empirical model and their expected signs are described in Table 3 below.

Table 3: Model variables, descriptions, and predicted signs

	Variable	Description	Predicted Sign	Rationale
Y1	*renew_percent*	Percentage of utility's generation from renewable sources	N/A	
Y2	*fuel_renewables*	Utility's total renewable generation (in megawatt-hours)	N/A	
X1	*util_iou*	The first OWNERSHIP variable, indicating whether a utility is an IOU	Positive	Delmas and Montes-Sancho 2011, Rose and Joskow 1990
X2	*util_public*	Indicates whether a utility is a public utility (POU)	Negative	Delmas and Montes-Sancho 2011, Rose and Joskow 1990
X3	*util_coop*	Indicates whether a utility is a cooperative (co-op)	Negative	Delmas and Montes-Sancho 2011
X4	*policy_iou*	The first RPS variable, indicating whether an RPS policy is in place that applies to IOUs	Positive	Delmas and Montes-Sancho 2011
X5	*policy_public*	Indicates whether an RPS policy in place that applies to POUs	Positive	Delmas and Montes-Sancho 2011, Fischlein and Smith 2013, Cruz 2014
X6	*policy_coop*	Indicates whether an RPS policy in place that applies to co-ops	Positive	Delmas and Montes-Sancho 2011, Fischlein and Smith 2013, Cruz 2014
X7	*state_rps*	For state-level regressions, indicates whether a binding RPS policy is in place at all.	Positive	Barbose 2018, Bhattacharya et al 2017, Fischlein and Smith 2013

Table 3 (Cont.)

X8	*year_enacted*	The year in which an RPS policy was enacted.	Unknown[3]	Bhattacharya et al 2017
X9	*target_year*	The year by which an RPS's clean energy goal is to be achieved.	Unknown[4]	Bhattacharya et al 2017
X10	*percent_target_year*	The target goal for an RPS policy (e.g. 50% or 100% clean energy).	Positive	Zhou and Solomon 2020
X11	*mstate_fuel_renewables*	A state's total generation of renewable energy, in megawatt-hours (MWh)	Positive	Stokes 2020, Kelsey and Meckling 2018
X12	*mrevenues_total*	A utility's total revenues in dollars	Positive	Delmas and Montes-Sancho 2011, Rose and Joskow 1990
X13	*msolar_generation_potential*	A state's solar generation potential capacity in kilowatts (kw)	Positive	Kelsey and Meckling 2018
X14	*mwind_weighted_total*	A state's wind generation potential in megawatts (MW)	Positive	Kelsey and Meckling 2018
X15	*mstate_population*	A state's population	Positive	Stokes 2020
X16	*state_income_percapita*	A state's average per-capita personal income	Positive	Stokes 2020

[3] Predicted impact of *year_enacted* is unclear because a policy enacted earlier will have had more time to see impact; on the other hand, some more recently-adopted policies have more ambitious targets.
[4] Predicted impact of *target_year* is unclear because a policy with a more immediate target may provide stronger incentive for actors to reach the policy's target; on the other hand, many policies with earlier target years were enacted earlier and have lower targets, or those target years have passed.

V. RESULTS

Table 4: Regression results for how ownership and RPS policy predict percentage of utility generation from renewable sources

VARIABLES	(1) % Renewables: IOUs	(2) % Renewables: POUs	(3) % Renewables: Co-ops
util_iou	**3.184**		
	(4.450)		
policy_iou	**-6.193**		
	(4.413)		
util_public		**-10.25****	
		(4.193)	
policy_public		**3.023**	
		(3.435)	
util_coop			**27.99*****
			(9.941)
policy_coop			**3.003**
			(3.335)
mstate_fuel_renewables	**0.679*****	**0.647*****	**0.669*****
	(0.0946)	(0.0881)	(0.0944)
mrevenues_total	**-5.743****	**-6.881****	**-4.144***
	(2.670)	(2.892)	(2.086)
msolar_generation_potential	**-0.00308*****	**-0.00256****	**-0.00269****
	(0.00114)	(0.00119)	(0.00120)
mwind_weighted_total	**-68.04*****	**-64.78*****	**-65.97*****
	(15.48)	(14.66)	(14.92)
mstate_population	**0.940**	**0.652**	**0.665**
	(0.577)	(0.569)	(0.575)
state_income_percapita	**-0.000246**	**-0.000342**	**-0.000453**
	(0.000706)	(0.000737)	(0.000714)
Constant	**41.14***	**50.69****	**45.22***
	(23.53)	(23.70)	(22.68)
Observations	6,703	6,703	6,703
R-squared	0.168	0.174	0.186

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4 shows the results of three regressions analyzing the impact of utility ownership type and RPS policy on the proportion of a utility's generation mix from renewable sources. Due to limitations on the data available from the Energy Information Administration, the source data in both Table 4 and Table 5 below represent only power generation owned by any given utility, and — as was discussed in the Data Limitations section above — as such does not offer a full picture of the total electricity sales to customers from each utility.

Each model in Table 4 represents a regression run for each of the three examined ownership types — IOUs, public utilities (which includes municipal, state, and federally-owned electric utilities, as well as Public Utility Districts), and electric cooperatives. All standard errors are calculated as robust to heteroskedasticity and clustered at the state level because some of the control variables are at the state level instead of the utility level.

The regressions in Table 4 use the dependent variable *renew_per9*, which is the percentage of each utility's net generation mix from renewable sources based on the sum total of its net generation from all power plants. These data are based on EIA Form 923. Each of the variables *util_iou*, *util_coop*, and *util_public* are dummy variables with a value of "1" for each utility of the corresponding ownership type, and "0" otherwise. The variables *policy_iou*, *policy_public*, and *policy_coop* represent an RPS policy that applies to that type of utility. RPS policies that apply to all utility ownership types have a value of "1" for all three variables.

The results in Table 4 show that private ownership of a utility could positively predict a greater proportion of renewables in a utility's generation mix — approximately

3% — although the coefficient on *util_iou* is not statistically significant. The coefficients on *util_public* and *util_coop* are significant at $p < 0.05$. The results indicate that public ownership predicts that approximately 10% less of a utility's generation mix will come from renewable sources than the other ownership types, while cooperative ownership predicts approximately 28% more renewables in a utility's generation mix.

None of the three coefficients for RPS policy are significant. While not statistically significant, the coefficient on *policy_iou* is negative. It is worth noting that, while some RPS policies exclude utilities by ownership type or size, IOUs are never an excluded category. As a result, values for *policy_iou* could be at least somewhat correlated with less ambitious or comprehensive policies overall, a question for future research. Regardless, taken together, these results indicate that RPS policies may not effectively incentivize utilities to increase the percentage of their renewable energy generation, regardless of ownership type.

One of the most consistently significant variables across ownership types is *mstate_fuel_renewables*, a variable indicating the proportion of energy from renewable sources in the state. (Variables with the *m* prefix have been divided by one million in order to produce more readable results.) The results here may indicate that simply operating in a state that outperforms others on renewable generation is a better predictor of additional renewable generation at the utility level than ownership or the direct impact of policy.

Table 5: Regression results for how ownership and RPS policy characteristics predict percentage of utility generation from renewable sources

VARIABLES	(1) % Renewables: IOUs	(2) % Renewables: POUs	(3) % Renewables: Co-ops	(4) % Renewables: All
util_iou	**1.609**			**-24.04****
	(4.884)			(10.53)
policy_iou	**-12.40**			
	(10.29)			
util_public		**-10.05****		**-27.37*****
		(3.988)		(9.086)
policy_public		**3.396**		
		(5.080)		
util_coop			**28.14*****	
			(9.862)	
policy_coop			**2.108**	
			(6.657)	
state_rps				**-10.51**
				(9.886)
year_enacted	**0.000626**	**-0.00317**	**-0.00327**	**7.08e-05**
	(0.00548)	(0.00332)	(0.00330)	(0.00528)
target_year	**0.00384***	**0.00123**	**0.00178**	**0.00334**
	(0.00216)	(0.00299)	(0.00350)	(0.00205)
percent_target_year	**6.637**	**5.504**	**6.245**	**7.507**
	(6.765)	(6.091)	(6.493)	(6.433)
mstate_fuel_renewables	**0.631*****	**0.614*****	**0.635*****	**0.646*****
	(0.108)	(0.0998)	(0.105)	(0.105)
mrevenues_total	**-5.317***	**-7.043****	**-4.318****	**-5.276***
	(2.693)	(2.922)	(2.059)	(2.653)
msolar_generation_potential	**-0.00301****	**-0.00272****	**-0.00285****	**-0.00277****
	(0.00125)	(0.00132)	(0.00132)	(0.00121)
mwind_weighted_total	**-66.29*****	**-65.18*****	**-66.06*****	**-62.58*****
	(16.44)	(15.17)	(15.85)	(15.88)
mstate_population	**0.795**	**0.672**	**0.682**	**0.691**
	(0.584)	(0.608)	(0.620)	(0.570)
state_income_percapita	**-0.000352**	**-0.000446**	**-0.000549**	**-0.000356**
	(0.000651)	(0.000735)	(0.000711)	(0.000629)
Constant	**45.11****	**55.88****	**50.36****	**70.45*****
	(21.78)	(24.12)	(22.98)	(22.93)
Observations	6,703	6,703	6,703	6,703
R-squared	0.177	0.179	0.191	0.199

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5 shows the results of the three regressions from Table 4, with the addition of three variables adding some additional context to the nature of the RPS policies operating in each state: *year_enacted* for the year a policy was first passed; *target_year* for the year an RPS policy sets as its target for achieving its policy goals (e.g. a value of 2050 would mean an RPS policy with a goal of achieving its target by 2050); and *percent_target_year* for the goal to be achieved (e.g. a value of 0.3 would reflect a goal of 30% renewables by the target year). Table 5 also includes an additional regression incorporating all three utility ownership types.

The demonstrated impacts of ownership type on the percentage of renewables in a utility's ownership mix are largely unchanged from Table 4. Once again, co-ops are significantly more likely to generate a higher percentage of their own energy mix from renewables when controlling for ownership alongside state policy, utility size, and a state's overall energy mix. Public utilities continue to lag behind the other ownership types in generation of renewables as a proportion of their total generation mix.

The impacts of an RPS policy by ownership type are similar to the Table 4 results with no significance on any of the RPS coefficients *policy_iou*, *policy_public*, or *policy_coop.* Once again, the coefficient on *policy_iou* is negative, while the coefficients on *policy_public* and *policy_coop* are positive. While also not significant, the coefficients are positive for *percent_target_year* for all ownership types, suggesting an obvious relationship between greater ambition in an RPS policy target and higher proportion of renewable generation from all utilities covered by the policy.

Table 6: Regression results for ownership and RPS policy prediction of total utility generation from renewable sources, in megawatt-hours (MWh)

VARIABLES	(1) Total MWh: IOUs	(2) Total MWh: POUs	(3) Total MWh: Co-ops
util_iou	**-69,128**		
	(158,264)		
policy_iou	**-93,282***		
	(49,814)		
util_public		**79,435**	
		(142,109)	
policy_public		**-43,709**	
		(62,086)	
util_coop			**-103,407**
			(66,829)
policy_coop			**-47,642**
			(56,478)
mstate_fuel_renewables	**26,691*****	**26,451*****	**26,412*****
	(2,256)	(2,404)	(2,420)
mrevenues_total	**223,465***	**230,120***	**210,686****
	(123,367)	(119,263)	(90,931)
msolar_generation_potential	**-100.2***	**-100.3***	**-98.27***
	(58.48)	(59.22)	(55.45)
mwind_weighted_total	**-931,698****	**-958,962****	**-926,408****
	(403,577)	(416,697)	(385,643)
mstate_population	**23,022**	**22,928**	**22,326**
	(27,769)	(28,145)	(26,971)
state_income_percapita	**8.923**	**8.382**	**9.215**
	(14.52)	(14.55)	(15.58)
Constant	**161,747**	**93,901**	**128,396**
	(335,521)	(417,815)	(378,984)
Observations	7,042	7,042	7,042
R-squared	0.162	0.162	0.161

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6 repeats the same regressions as shown in Table 4, but using the variable *mfuel_renewables*, which represents net total generation from renewables in MWh (divided by one million), in place of *renew_per9.* The variable *mrevenues_total*, representing a utility's total annual revenue in dollars (also divided by one million), is included to control for the impact of utility size. As with Table 4, standard errors are heteroskedastic robust and clustered at the state level. Like in Table 4, none of the coefficients on the RPS policy variables — *policy_iou, policy_public,* and *policy_coop* — are statistically significant. In addition, none of the coefficients on the ownership variables — *util_iou, util_public*, and *util_coop* — are statistically significant.

While the lack of significance makes drawing clear conclusions about policy or ownership on renewable generation difficult, it is nonetheless interesting to note that the signs on the ownership coefficients are reversed in Table 6 from Table 4. Also notable, though also not statistically significant, is that the coefficients are negative on all three RPS variables. The lack of significance means that these results are not sufficient to conclude that the introduction of an RPS policy actually has a negative effect on utility generation of electricity from renewable sources, but does raise questions for further research.

Table 7: Regression results for RPS and total renewables generation at the state level

VARIABLES	(1) State FE	(2) State OLS
state_rps	**0.831**	**2.755****
	(0.912)	(1.234)
msolar_generation_potential	**-0.00344**	**-0.000592***
	(0.00280)	(0.000319)
mwind_weighted_total	**-10.34**	**-0.0928**
	(31.01)	(3.790)
mstate_population	**2.819***	**1.080*****
	(1.561)	(0.142)
state_income_percapita	**0.000162*****	**5.84e-05**
	(4.49e-05)	(6.24e-05)
Constant	**-4.535**	**-0.916**
	(3.900)	(2.325)
Observations	538	538
R-squared		0.196
Number of stateid	47	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7 uses data collapsed to the state level, rather than the utility-level analysis presented in the previous tables. The previous two tables used variables measuring renewable generation in total MWh and as a percent of total electricity generation, which rely on summed totals from a subset of the power plant-level generation data available from EIA Form 923. The dependent variable in Table 7, by contrast, reflects a fuller picture of each state's electricity generation mix, based on data from EIA's "Electric Power Annual" report. The "State FE" column represents a model incorporating state fixed effects, while the "OLS" column displays results from an OLS model without the use of fixed effects.

The OLS model in Table 7 does show a statistically significant positive relationship between generation of electricity from renewable sources at the state level and the introduction of an RPS policy, although the fixed effects model does not show significance. The lack of significance in the latter model may only indicate a lack of variation in the RPS variable.

Table 8: Regression results for RPS and total renewables generation at the state level, incorporating RPS policy characteristics

VARIABLES	(1) State FE	(2) State OLS
state_rps	**-0.197**	**-3.922*** **
	(2.314)	(1.350)
policy_all_utilities	**-0.503**	**6.154*** **
	(1.264)	(1.754)
year_enacted	**-0.000208**	**-0.000107**
	(0.00111)	(0.000417)
target_year	**0.000180**	**-0.00308*** **
	(0.000455)	(0.000824)
percent_target_year	**5.861** **	**23.78*** **
	(2.722)	(4.059)
msolar_generation_potential	**-0.00356**	**-0.000767** **
	(0.00290)	(0.000304)
mwind_weighted_total	**-8.341**	**7.126** **
	(30.92)	(3.222)
mstate_population	**2.850***	**0.960*** **
	(1.627)	(0.141)
state_income_percapita	**0.000294*** **	**-0.000148** **
	(9.85e-05)	(6.58e-05)
Constant	**-8.476** **	**5.788** **
	(3.601)	(2.430)
Observations	538	538
R-squared		0.351
Number of stateid	47	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8, like Table 7, uses state-level data. Like Table 5, it also incorporates additional variables for different characteristics of a state-level RPS policy: *year_enacted, target_year,* and *percent_target_year*. The results in Table 8 add texture to the previous results about the impact of a state RPS policy. The Table 8 results show that the existence of an RPS policy alone actually negatively predicts additional renewable electricity generation at the state level, and that particular elements of the policy design appear to have a strong impact on whether an RPS is effective.

Perhaps unsurprisingly, a more ambitious RPS target is associated with more renewable generation. An additional percentage point of target ambition is associated with an additional 5.9 million MWh of renewables generation in the fixed effects model, and a notable 23.8 million MWh more in the OLS model. This effect is especially pronounced in the OLS model, which shows more significance overall. Both the fixed effects and OLS models also indicate that RPS policies passed earlier (a lower value for *year_enacted*) are associated with more renewable generation, an intuitive result given that policies passed earlier have had more time to go into effect. The OLS model also indicates a statistically significant relationship between applying an RPS to all utility ownership types and higher generation of renewables, predicting an additional 6.2 million MWh compared to an RPS that excludes certain categories of utilities. Some endogeneity might be impacting the OLS model, in that it is not unlikely that states already overperforming in renewable energy generation are more likely to set higher goals, which are in turn easier for them to reach. Future research should explore this relationship further.

VI. DISCUSSION AND POLICY IMPLICATIONS

These results do not definitively point to under- or over-performance in generation from renewable sources based on ownership type, nor paint a clear and universal picture about utilities' response to RPS policy. Nonetheless, some evidence about RPS policy design and ownership-based targeting should raise questions for scholars and policymakers, and provide foundations for future, more detailed research.

First, these results may suggest a challenge to conventional wisdom that electric cooperatives will lag behind IOUs in renewable generation. Some researchers have observed that cooperatives tend to operate more extensively in states with a more fossil-fuel-dominated energy mix (Wilson, et al. 2008), while others have suggested that IOUs, simply as a factor of their generally larger size, will have more capacity to innovate and add renewables capacity while smaller public and cooperative utilities lag in adoption (Rose and Joskow 1990). However, when controlling for both utility size and a state's overall energy mix, the results from Table 4 indicate that cooperative utilities may in fact overperform both IOUs and POUs in generation from renewable sources. This suggests that, when isolating the impacts of ownership from the impacts of utility size or state energy mix, IOUs are not as dominant in leading the renewable energy transition in the electric utility sector as previous assumptions may suggest — and cooperatives may in fact be more likely than other utilities to adopt a higher proportion of renewable generation when controlling for factors including utility size and a state's energy mix.

Second, these results show that RPS policies — particularly widely applicable and ambitious RPS policies — are likely responsible for increasing the generation of electricity from renewable sources at the state level. However, there is not clear evidence here that an RPS incentivizes more renewable generation at the utility level, especially when looking at IOUs. While the positive relationship between RPS and state-level renewables generation should be heartening for policymakers, the utility-level results may raise questions about the longer-term efficacy of credit trading or other mechanisms that allow power generators to comply with the policy without making significant changes to their own generation mix, given many such policies' ultimate goals of full decarbonization.

Third, the results underscore that the design of an RPS policy is as, if not more, important than a binary question of whether or not an RPS exists in a state. There is a strong, statistically significant relationship between greater ambition in an RPS's renewables target and greater generation of renewables at the state level, as well as a positive — though not statistically significant — relationship between increased ambition and a higher proportion of renewables generation at the utility level across all utility ownership types. While this finding may not come as a surprise, this analysis does make it clear that an RPS with a target of 100% clean energy is in fact more effective at driving more generation of renewable energy than an RPS with a target of only 25%, indicating that policymakers whose primary goal is a rapid and comprehensive decarbonization of their state's electricity mix should prioritize setting ambitious standards that reflect those goals.

In addition, the state-level OLS model results also indicate a statistically significant relationship between designing an RPS to apply to all utility types, rather than excluding some ownership categories, and greater generation of electricity from renewable sources at the state level. This conclusion is buttressed by the results in Tables

4 and 5 that, while not statistically significant, imply that public and cooperative utilities may even be more likely than IOUs to respond to the introduction of an applicable RPS by increasing the proportion of their own generation mix from renewable sources.

Finally, these results may be of interest to policymakers and campaigners interested in municipalization or other public takeovers of IOUs in order to improve a utility's renewable energy generation or other climate practices. Though the data limitations described above should be kept in mind in drawing any policy conclusions, the models used here do show that — when controlling for factors including utility size, state policy, and state energy mix — public utilities lag behind both IOUs and electric cooperatives in adding more renewables to their generation mix. However, there is also some indication that public utilities, along with cooperatives, may be more likely to increase the share of renewables in their generation mix in response to the introduction of RPS policy. If any policy conclusions are to be drawn from this finding for supporters of utility municipalization for climate or clean energy reasons, they should be that a public utility on its own may not be a better steward of the climate than a privately-owned one, and that any efforts to enact a public takeover of an IOU should be paired with efforts to pass thoughtfully-designed and ambitious renewable portfolio standards with targets that public utilities are required to meet.

VII. CONCLUSION

In the context of the fight to stop the worst impacts of climate change and decarbonize the American economy, the electric power sector remains one of the most important actors — and, as discussed, will only grow in importance as more sectors of the economy are electrified. The critical role of the sector underscores the need for extensive research and analysis to help policymakers and business leaders understand what policy mechanisms, governance structures, and infrastructure will most effectively help the power sector make the most equitable, rapid, and cost-effective transition to clean and renewable energy.

A number of studies have examined the topline effectiveness of renewable portfolio standards in driving clean energy adoption and reducing emissions — but especially as more states adopt, implement, and modify policies, there remains room for much more research on the effectiveness of RPS policies of varying scope, ambition, and design. In particular, there is a demonstrated need for more research evaluating how nuanced differences between RPS policies impact their effectiveness at incentivizing greater generation of electricity from renewable sources. In addition, research on how the ownership structure of electric utilities impacts their adoption of renewable energy generation has so far been very limited — a gap that this study has intended to help fill in.

The results of this analysis show that ownership may have an impact on a utility's generation mix and responsiveness to policy, and should invite additional researchers to further explore the relationship between ownership and responsiveness to RPS policy design. The finding that electric cooperatives may in fact generate a higher proportion of renewable energy compared to IOUs and POUs when controlling for size and policy constraints is particularly interesting, and deserves additional examination. In addition, this study suggests that POUs may lag behind other utilities in adding more renewables to their generation mix. While the results should not be taken as conclusive enough to dissuade organizers from campaigning to convert IOUs to public ownership — especially since clean energy targets are not often the only goal of those efforts — these results should invite additional research on the environmental and social governance practices of publicly owned utilities, and should also encourage campaigners and policymakers to ensure that any efforts to municipalize utilities are paired with strong policy incentives that target those public utilities.

The clearest and perhaps most important results from this study relate to the importance of an RPS policy's scope and ambition in increasing renewable energy generation at both the state and utility level. While policymakers must weigh a range of considerations in designing, passing, and implementing climate policy, this model clearly indicates that RPS policies that are both more ambitious and designed to apply as broadly as possible to electric utilities will be the most effective in achieving a greater and more rapid clean energy transition.

Given the urgency of climate change and the utmost importance of rapidly decarbonizing the electric power sector, policymakers should take these results to heart and embrace the boldest possible policies in order to meet their climate goals. This directive should take on even more urgency given the fact that, when it comes to the rapidly unfolding crisis of climate change, the stakes could not be higher.

VIII. APPENDIX: ADDITIONAL REGRESSION RESULTS

Analysis using robust standard errors instead of clustering at the state level

Table A1: Regression results for how ownership and RPS policy predict percentage of utility generation from renewable sources, un-clustered robust standard errors

VARIABLES	(1) % Renewables: IOUs	(2) % Renewables: POUs	(3) % Renewables: Co-ops
util_iou	**1.609**		
	(1.420)		
policy_iou	**-12.40*** **		
	(1.553)		
util_public		**-10.05*** **	
		(1.335)	
policy_muni		**3.396** **	
		(1.567)	
util_coop			**28.14*** **
			(3.045)
policy_coop			**2.108**
			(1.657)
year_enacted	**0.000626**	**-0.00317*** **	**-0.00327*** **
	(0.000825)	(0.000544)	(0.000534)
target_year	**0.00384*** **	**0.00123**	**0.00178** **
	(0.000733)	(0.000799)	(0.000855)
percent_target_year	**6.637** **	**5.504* **	**6.245** **
	(2.993)	(3.017)	(2.997)
mstate_fuel_renewables	**0.631*** **	**0.614*** **	**0.635*** **
	(0.0466)	(0.0468)	(0.0465)
mrevenues_total	**-5.317*** **	**-7.043*** **	**-4.318*** **
	(0.719)	(0.793)	(0.513)
msolar_generation_potential	**-0.00301*** **	**-0.00272*** **	**-0.00285*** **
	(0.000278)	(0.000281)	(0.000276)
mwind_weighted_total	**-66.29*** **	**-65.18*** **	**-66.06*** **
	(2.945)	(2.945)	(3.030)
mstate_population	**0.795*** **	**0.672*** **	**0.682*** **
	(0.144)	(0.146)	(0.145)
state_income_percapita	**-0.000352** **	**-0.000446*** **	**-0.000549*** **
	(0.000139)	(0.000147)	(0.000145)
Constant	**45.11*** **	**55.88*** **	**50.36*** **
	(4.566)	(4.693)	(4.652)
Observations	6,703	6,703	6,703
R-squared	0.177	0.179	0.191

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A1 repeats the regression used in Table 5, but uses simple robust standard errors instead of clustering standard errors by state. Of note, the coefficients on RPS effectiveness are significant at $p<0.05$ for both IOUs and POUs in this model, buttressing the finding that public utilities may be more responsive to the introduction of an applicable RPS and IOUs may be less responsive in adjusting their generation mix. However, since RPS policies, state generation mix, and solar and wind generation potential are measured at the state level, the state-level clustered errors will result in a more accurate model. Nonetheless, this finding is of note for researchers and policymakers interested in further analysis of the impacts of utility ownership on policy responsiveness and renewables generation.

Analysis excluding hydroelectric power from the definition of renewables

Table A2 below repeats the regressions used in Table 6 above, but excludes hydroelectric energy from the definition of "renewables" used in the analysis. Many analysts, including the federal Energy Information Administration, will sometimes exclude or separate hydroelectric generation, as hydroelectric power constitutes a disproportionate amount of total renewables, is subject to highly variable generation year-by-year, and is also disproportionately concentrated in Western states (Energy Information Administration 2012).

Table A2: Regression results for how ownership and RPS policy predict percentage of utility generation from renewable sources, excluding hydroelectric

VARIABLES	(1) % Renewables: IOUs	(2) % Renewables: POUs	(3) % Renewables: Co-ops
util_iou	**0.399**		
	(0.479)		
policy_iou	**1.778****		
	(0.796)		
util_public		**-2.607****	
		(1.028)	
policy_muni		**1.445**	
		(1.158)	
util_coop			**8.800****
			(4.060)
policy_coop			**0.391**
			(0.992)
target_year	**-0.000812***	**-0.00109**	**-0.000784**
	(0.000411)	(0.000664)	(0.000631)
percent_target_year	**1.153**	**1.208**	**1.538**
	(1.590)	(1.487)	(1.615)
mstate_fuel_renewables	**-0.0148**	**-0.0163**	**-0.00789**
	(0.0199)	(0.0198)	(0.0222)
mrevenues_total	**-0.231***	**-0.776****	**-0.0359**
	(0.127)	(0.364)	(0.0729)
msolar_generation_potential	**0.000247***	**0.000338****	**0.000309**
	(0.000138)	(0.000151)	(0.000185)
mwind_weighted_total	**0.795**	**2.239**	**2.180**
	(1.889)	(1.712)	(2.174)
mstate_population	**-0.179****	**-0.212*****	**-0.207****
	(0.0705)	(0.0706)	(0.0921)
state_income_percapita	**0.000251*****	**0.000277*****	**0.000261****
	(9.07e-05)	(9.98e-05)	(0.000100)
Constant	-7.652***	-6.655**	-8.528***
	(2.539)	(2.641)	(2.819)
Observations	6,703	6,703	6,703
R-squared	0.027	0.033	0.046

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In this case, excluding hydroelectric power from the model changes the magnitude of the coefficients on each utility type, but not the basic conclusions of the model that includes it: public utilities still generate a smaller proportion of their overall energy mix from renewable sources, and electric cooperatives continue to overperform both POUs and IOUs in renewable generation.

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