Looking Beyond Demand Response: Barriers and Opportunities to Deploying Virtual Power Plants among Rural Electric Cooperatives in the United States

MS-STEP Professional Paper

In Partial Fulfillment of the Master of Science in Science, Technology, and Environmental Policy Degree Requirements
The Hubert H. Humphrey School of Public Affairs
The University of Minnesota

Mayukh K. Datta

May 16, 2024

*Signature below of Paper Supervisor certifies successful completion of oral presentation **and** completion of final written version:*

______________________	5/8/2024	5/16/2024
Dr. Gabriel Chan, Associate Professor Paper Supervisor	Date, oral presentation	Date, paper completion

______________________	5/8/2024
Dr. Elise Harrington, Assistant Professor Second Committee Member	Date

Signature of Second Committee Member, certifying successful completion of professional paper

Subject Keywords: Distributed Energy Resources, Energy Efficiency, Rural Electric Cooperatives

Abstract (250 words or less): Rural electric cooperatives (co-ops) find themselves in a unique position regarding deploying virtual power plants. Co-ops, which are consumer-owned utilities, have a vast history of deploying controllable demand-side management technologies that can fit perfectly into a VPP framework, with almost a gigawatt of demand-side management capacity across four generation and transmission cooperatives in Minnesota (G. Chan et al. 2019; Matthew Grimley and Chan 2023). This more than forty-year-long experience deploying controllable resources and their nonprofit, consumer-owned structure makes rural electric cooperatives perfectly positioned to deploy virtual power plants. However, several challenges, such as high upfront costs and uncertainties around market rules, hinder VPP deployment for rural co-ops. Furthermore, the fact that most co-ops comprise a complex network of distribution cooperatives that make up larger generation and transmission (G&T) cooperatives also complicates how VPPs can be deployed by rural coops.

Acknowledgments & Positionality Statement:

Having grown up in rural Mississippi, I decided to attend graduate school here at the Humphrey School of Public Affairs to understand energy and environmental challenges affecting rural communities. My work on this professional paper has been a significant step towards that goal and a perfect way to end my master's education. I want to take this opportunity to thank those who made this opportunity possible. First, I want to thank all co-op staff members who took the time out of their busy schedules to provide insights on co-op led VPP programs. Next, I want to thank my committee members – Dr. Gabe Chan and Dr. Elise Harrington – for their advice, expertise, and patience throughout this process. I also want to thank Matt Grimley and Mike Fogarty. This paper builds off a literature review study by Gabe, Matt Grimley, Mike Fogarty, and me on the various use cases of virtual power plants among rural electric cooperatives in the United States. This work would not have been possible without them and my peers at the Electric Cooperative Innovation Center. I also want to take a moment to thank my three closest friends, Dawn Jackson, Braeden Foldenauer, and Ryan Hopson, who inspire me daily to become a better public servant. Finally, I would be remiss if I didn't thank my cat, Leeloo, who kept me sane and on my toes over these last few weeks.

My childhood shapes my findings in this paper. Fifteen years ago, my parents, Chinmoyee and Mihir Datta, took me and immigrated from India to Mississippi to become public school teachers in one of the most underinvested school districts in the country. Their exemplary careers have inspired my passion for public service and policy, and their love for their students and community has inspired me to approach my equity and justice work through love and care. I owe them an unpayable debt for their foresight, courage, support, and tough-as-nails love.

AI Acknowledgement Statement:

I, Mayukh K. Datta, as the author of this paper, acknowledge that I utilized OpenAI's ChatGPT software to proofread and conduct line edits within my paper.

List of Relevant Terms

Distributed Energy Resources (DERs): are small-scale electricity supply or demand resources that are interconnected to the electric grid. They are power generation resources and are usually located close to load centers, and can be used individually or in aggregate to provide value to the grid.

Demand Response (DR): any program or technology that provides an opportunity for consumers to play a significant role in the operation of the electric grid by reducing or shifting their electricity usage during peak periods in response to time-based rates or other forms of financial incentives.

Independent System Operator (ISO): Interchangeably used with regional transmission operator (RTO), an ISO is an independent organization that handles electric grid operations, market facilitation for certain electric markets, and bulk electric system planning

Virtual Power Plant (VPP): comprised of hundreds or thousands of households and businesses that offer the latent potential of their thermostats, electric vehicles (EVs), appliances, batteries, and solar arrays to support the grid.

Distributed Energy Resources Management System (DERMS): Interchangeably used with the term "VPPs," DERMS is a software platform that helps mostly distribution system operators (DSO) manage their grids that are mainly based on distributed energy resources (DER).

Third-party DER Aggregator: are private firms that bundle DERs into a DERMS platform and dispatch them in response to market signals.

Non-wire Alternatives (NWA): are electric utility system investments and operating practices that can defer or replace the need for specific transmission and/or distribution projects, at lower total resource cost, by reliably reducing transmission congestion or distribution system constraints at times of maximum demand on the system.

Grid Edge Technologies (GETs): are any combination of technologies that advances the transition toward a decentralized, distributed, and transactive electric grid.

Supervisory Control & Data Acquisition (SCADA) Systems: are used for controlling, monitoring, and analyzing industrial devices and processes. The system consists of both software and hardware components and enables remote and on-site gathering of data from the industrial equipment.

Application Programming Interface (API): is a way for two or more computer programs or components to communicate with each other.

Table of Contents:

1 Introduction:

During the summer of 2022, climate-induced heat waves caused the demand for electricity to operate air conditioners and cooling centers to skyrocket, causing rolling blackouts throughout the United States (Rajamani 2022; Grove 2022; Lowe 2022). However, one utility in Vermont, Green Mountain Power (GMP), avoided this crisis by dispatching 4000 residential batteries, with almost 20 megawatts (MW) of aggregated capacity, to keep their customers' lights on and lower their energy bills by avoiding $1.2 million in peak demand payments to the New England Independent System Operator (ISO) (J. John 2015, 20; Rojo 2022; Spector 2022).

The grid architecture that allowed GMP to aggregate and control its fleet of batteries is known as a virtual power plant (VPP). While their exact definition varies across the industry, VPPs are conceptually comprised of hundreds or thousands of distributed energy resources (DERs), which are decentralized and often behind-the-meter technologies – such as electric water heaters, smart thermostats, electric vehicle (EV) chargers, solar plus storage systems, and other demand response technologies – that are aggregated and controlled from one or more centralized locations to achieve the same system-wide benefits of reliability, affordability, and sustainability as a traditional, centralized power plant (Brehm et al. 2023; Hledik and Peters 2023; Speetles, Lockhart, and Warren 2023).

In recent years, federal policies like the Inflation Reduction Act (IRA) and the Bipartisan Infrastructure Law (BIL) have led to significant investments into DERs, with the market for DERs expected to double in the next five years (Hertz-Shargel 2023; Downing et al. 2023). The boom in the market for DERs, along with regulatory pathways for DER aggregation, has created an incredible opportunity for utilities and third-party providers to dispatch and control these DERs as virtual power plants.

While energy practitioners and policymakers in the U.S. have only recently started to consider various market and policy levers needed to operationalize VPPs, they are a concept introduced previously. Rural electric cooperatives (co-ops) have a multi-decade history of aggregating load control technologies to meet system-wide economic and reliability goals. However, as indicated in Figure 1.1, much of the discussion and investment related to VPPs have focused on private, third-party aggregators and vertically integrated, investor-owned utilities.

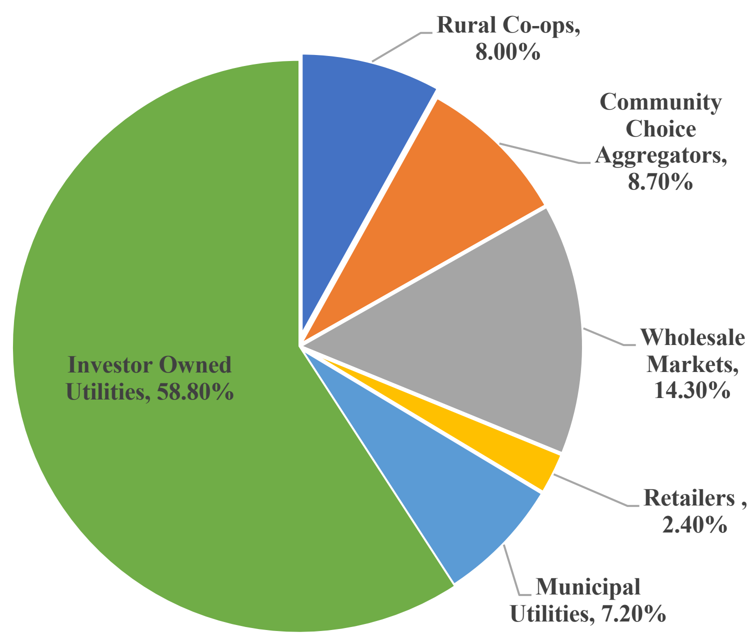

Figure 1.1: Primary Revenue Sources of North American VPPs across different Types of Utilities. This figure shows the revenue share for North American VPP programs across different utility types in the United States. Investor-owned utilities (IOUs) have the largest market share, with nearly 60% of VPP revenue from investor-owned utilities. On the other hand, rural co-ops have one of the lowest market shares after municipal utilities and retailers, with only 8% of the VPP revenue share coming from rural electric cooperatives (co-ops). Adapted from Hertz-Shargel & Noris (2023).

By focusing predominantly on private power providers, energy practitioners risk ignoring the unique challenges that rural co-ops face when deploying VPP programs and how co-ops could design innovative solutions by leveraging best practices and institutional knowledge gained through their multi-decade experience deploying load control programs. My work in this paper contributes to the literature by describing how other power providers, mainly rural electric cooperatives, think about VPP programs.

1.1 VPP Operations and Benefits

Understanding the benefits and value streams of VPPs involves grasping their operations. VPPs manage three main stages: DER aggregation and enrollment, grid orchestration & control, and value creation (Downing et al. 2023; Brehm et al. 2023). In the aggregation stage, stakeholders like DER installers and utilities enroll existing or incentivized DERs into the DER aggregation platform as distributed energy resources management software (DERMS) to optimize DER operations and forecast DER availability and value (Speetles, Lockhart, and Warren 2023; Downing et al. 2023). While a DERMS platform is the critical software that enables the aggregation and dispatch of DERs, I use the terms "virtual power plants" and "DERMS" interchangeably throughout this paper because, operationally, they might mean the same thing.

Grid orchestration involves establishing communication with DERs, maintaining grid stability through advanced distribution management systems (ADMS), and utilizing advanced metering infrastructure (AMI) for real-time data on DER performance and load consumption. Operators integrate this data into their DERMS platform using supervisory control and data acquisition (SCADA) systems to dispatch DERs based on grid and market signals (Gao et al. 2024).

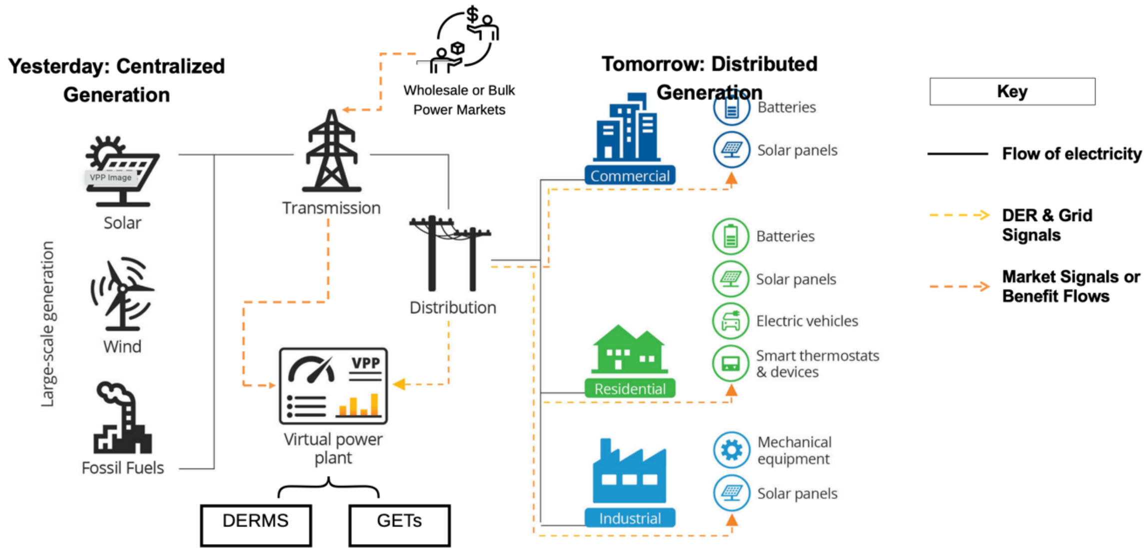

Figure 1.2: Description of VPP Operations. This figure shows the various stages of VPP operations. Adapted from Gao et al. 2024; Brehm et al. 2023; & Downing et al. 2023.

In the final value creation stage, VPP operators realize VPP benefits through two primary value streams: customer-side value, distribution-side value, and bulk power value[1] (Gao et al. 2024; Brehm et al. 2023; Saboori, Mohammadi, and Taghe 2011). Non-market-facing VPPs are not connected to a wholesale power market and provide benefits internal to the utility system. These include resource adequacy, deferral or avoidance of asset upgrades, reduced fuel use, and CO_2 consumption. In market-facing VPPs, utilities, or third-party DER aggregators, DERs meet economic and grid signals from a wholesale market operator (an ISO) or a bulk power provider (Brehm et al. 2023; Gao et al. 2024). Benefits from both types of VPPs can be put into the following two categories:

- **Economic Development, Public Health, and Decarbonization:** VPP operators can boost economic development by cutting electricity bills through demand response programs and wholesale market participation, possibly offering on-bill compensation to customers (Speetles, Lockhart, and Warren 2023; Downing et al. 2023; Brunner and

[1] Within the literature, the three different value streams are reflected as market and non-market-facing VPPs or commercial VPPs (cVPPs) and retail or technical VPPs (tVPP) (Brehm et al. 2023; Ramos and Neves Canha 2019; Gao et al. 2024)

Ahlen 2024). Workforce development across the VPP value chain is anticipated, as seen in the growth of clean energy jobs, which accounted for 84% of new jobs in electric power generation in 2022, suggesting future investments in installation, operation & maintenance, and market interactions (Keyser et al. 2023; Palmer, Gilland, and Hernandez 2023). Successful VPP deployment can also reduce reliance on fossil fuels, improving public health due to lower emissions (Power 2022).

- **Grid Services:** VPP projects offer grid services that translate into cost savings through dynamic load control techniques. They ensure system-wide resource adequacy at lower costs, maintain grid stability by providing frequency response and voltage regulation, and enable utilities to defer distribution upgrades, manage peak demand, and overcome grid constraints, enhancing system resiliency and avoiding peak demand charges (Lawrence Berkely National Lab (LBNL) 2020; Hledik and Peters 2023; Padullaparti et al. 2023).

1.2 Research Objectives, Framework, and Thesis Statement

This paper will examine the governance structure and history of rural electric cooperatives (co-ops) in the United States. I utilize literature-based desktop research and semi-structured interviews of co-op staff members to describe various opportunities and barriers to co-op-led VPP programs. As such, the central question to this study is: ***What kinds of programs, processes, and policies are rural cooperative utilities thinking about utilizing distribution-side resources, such as DERs, to meet system-wide goals of reliability, affordability, and sustainability?***

In the remainder of this paper, I provide a literature review of the history of rural co-ops and their load control programs, along with best practices that emerged from co-ops' decades-long experience in managing demand response programs. Then, I briefly describe how, at the fundamental level, the concept of a VPP might align with the cooperative business model and guiding principles. Next, I review the methodology utilized in this study and provide an industry landscape of various barriers and opportunities rural co-ops face in deploying VPP programs. Finally, I discuss various considerations that might be critical to co-op led VPP programs. I conclude this paper by discussing multiple limitations of my work and future research needs. I hope that co-op staff members throughout the country will find this work helpful in understanding various barriers, opportunities, and best practices co-ops can think through while designing VPP programs.

2 Literature Review: Rural Electric Co-ops and Virtual Power Plants

Rural electric cooperatives (co-ops) are nonprofit, member-owned utilities that predominantly serve rural communities in the U.S. While the cooperative business model dates to mid-19th century England, rural co-ops only emerged at scale in the United States in the mid-1930s. Despite early success in rural electrification, primarily guided by land-grant universities and electric industry associations, much of rural America did not have access to electricity until the mid-1930 because private investor-owned utilities, which at the time served electricity to 90% of Americans, did not have enough of a profit motive to build electric service lines out to sparsely populated rural communities (R. Hirsh 2018). In 1935, the Franklin D. Roosevelt administration created the Rural Electrification Administration (later known as the Rural Utilities Service under the US Department of Agriculture), which provided support to early cooperatives seeking to build out electric service lines in rural communities. However, because these cooperatives could not achieve economies of scale, Congress passed the Rural Electrification Act in 1936 to enable to REA to provide low-cost financing, along with administrative and programmatic support, to member-owned nonprofit utilities in rural communities throughout the U.S. (M. D. Grimley 2019; Klass and Chan 2020).

Unlike vertically integrated investor-owned utilities (IOUs), rural co-ops are operated through a multi-level governance structure (shown in Figure 2.1) where distribution is overseen by a board of directors elected by their member-consumers and strictly oversee the distribution grid. Distribution cooperatives established Generation and Transmission (G&T) cooperatives to leverage federal financing programs offered by the REA and benefit from economies of scale. These G&T cooperatives are governed by a board of directors elected from the distribution co-ops' boards (Klass and Chan 2020).

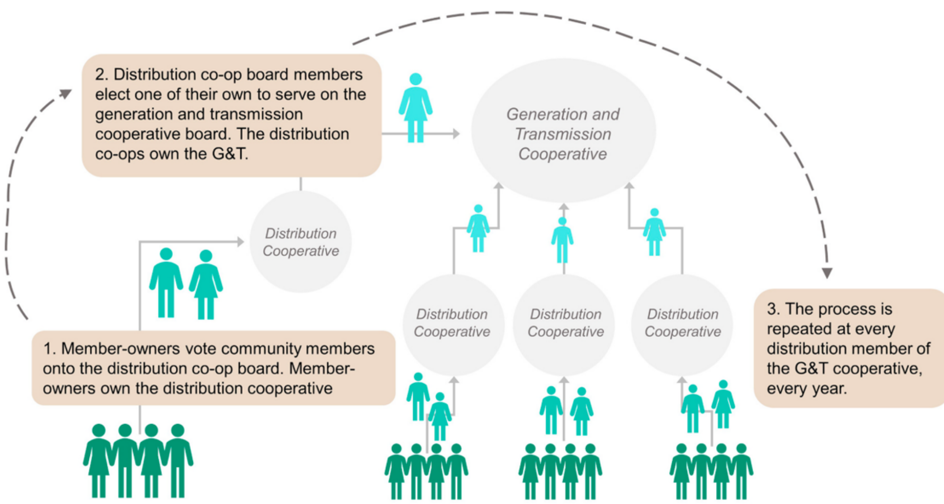

Figure 2.1: Multi-level Governance Structure of Rural Electric Cooperatives in the United States (Source: Matthew Grimley and Chan (2023))

Today, of the three types of utilities in the U.S. – IOUs, municipal utilities, and rural electric cooperatives, co-ops predominantly serve rural communities and cover over 55% of the country's landmass, overseeing nearly 40% (more than 2 million miles) of the U.S. distribution system (Takemura 2022). Table 1 compares other characteristics of rural co-ops with different types of utilities in the United States and gives a picture of the unique challenges faced by rural co-ops.

Utility Type	Share of Customers (2022)	Share of Transmission Lines (by mile, 2015)	Share of Distribution Lines (by mile, 2015)	Number of customers per mile of distribution line (2015)
Rural Electric Cooperatives	14%	17%	37%	8.0
Investor-Owned Utility	76%	66%	54%	29.1
Government (including municipal, state, and federally owned utilities)	10%	18%	10%	31.2

Table 2.1: Comparison of Key Statistics across Different Utility Types in the United States. This table shows share of customers served, share of transmission lines, share of distribution lines, and number of customers per mile of distribution line across the three main utility types in the United States. IOUs have the greatest share of customers and electric service lines, along with the highest customer to mile of distribution line ratio. On the other hand, rural co-ops have the highest share of distribution lines and the lowest customer to mile of distribution line ratio. Adapted from Klass & Chan (2020) and EIA 861 2015-2022.

First, distribution co-ops need help raising capital because they have to spread expenditures across service areas with much lower customer density than municipal utilities and IOUs. While the G&T structure has allowed co-ops to make significant capital investments at scale, co-ops continue to face new challenges and opportunities around vertical coordination and accountability as they grow their DER portfolio and design new VPP programs (Klass and Chan 2020). While different aspects of these challenges and opportunities are covered throughout this paper, I use the rest of this section to provide a brief description of co-ops' multi-decade history of deploying demand response programs, highlighting emerging best practices and learned lessons that could be foundational to successful deployment of co-op led VPP programs. I then conclude the chapter by showing how, at a conceptual level, various aspects of VPPs might align or be at odds with the cooperative business model and guiding principles.

2.1 History of Co-op Led Demand Response Programs

Rural co-ops have the most experience with demand response programs, which can include anything from water heaters and commercial and industrial (C&I) equipment to today's more sophisticated technologies, like battery storage, than any other utility in the United States (Matthew Grimley and Chan 2023). Conceptually, demand response (load management programs) provide similar benefits regardless of definition: reducing peak demand through utility or customer control. Figure 2.2 shows the current penetration of demand response and energy efficiency across the three main utility types in the United States.

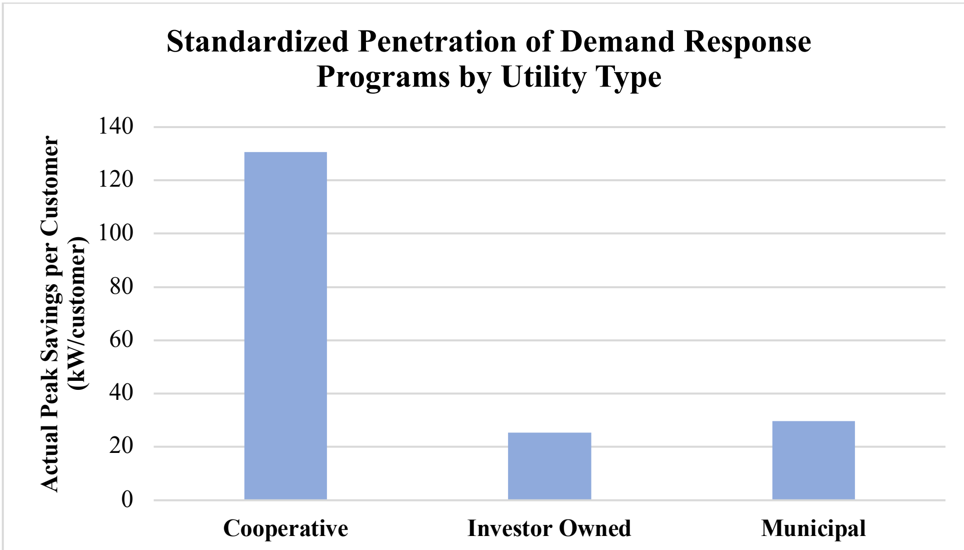

Figure 2.2: Penetration of Demand Response by Utility Type. This figure shows the penetration of demand response programs (shown in kilowatts of peak demand saved per customer) across the three main utility types in the United States. To compare across utility types, actual peak savings for each utility was standardized based on the total number of customers served by that utility. *(Source: EIA Form 861)*

Figure 2.2 shows that, relatively speaking, rural electric cooperatives have the highest penetration of demand response programs in the country. Additionally, historical analysis of co-op-led demand response programs shows that co-ops have the most experience in deploying these resources compared to any other utilities, having implemented some of the oldest and most successful load management programs in the country (M. D. Grimley 2019). While these programs became mainstream in the US in the mid-1970s, distribution co-ops pioneered load management programs as early as the 1950s. Because G&T cooperatives priced their power supply based on non-coincident peak demand (the demand for a single distribution co-op with a G&T system), some distribution co-ops installed load management programs as early as the 1950s to shave off-peak demand charges (M. D. Grimley 2019; Gellings 2017). These early systems were controllable water heaters relying on one-way radio frequency communication systems. While operators saw long-term economic benefits of their demand response programs, there would be limited real-time measurement and verification (M&V) data associated with demand response deployment (R. F. Hirsh 1999; Gellings 2017).

As load management evolved, load management programs helped distribution co-ops lower demand for their members and avoided peak demand charges (M. D. Grimley 2019). By the late 1970s, co-ops throughout the country adopted varying levels of load management programs, and today, almost all rural co-ops throughout the country have some load management program in place (National Rural Electric Cooperative Association 2024). The lessons that co-ops have learned from this multi-decade experience in deploying demand response programs, from member engagement strategies to innovative financing programs, set up a strong foundation for co-ops to transition their distribution-side assets into a VPP.

First, co-ops pooled resources and coordinated with third-party actors, such as workforce training organizations and state-wide industry associations, to reduce the upfront cost of load management resources and to create a network of trusted contractors who would support the installation of load management devices across their member-consumers. Co-ops also created new enterprises to develop supply chains, share costs, and advocate for state and federal-level policies on load management to build out the market for load management technologies in rural communities (Matthew Grimley and Chan 2023). As further elaborated in Section 4, co-ops today face similar challenges and are leaning upon similar best practices to lower costs and streamline coordination and accountability in their VPP programs.

G&T co-ops also faced challenges around garnering member buy-in and trust. By building collective agreement on various operational aspects of their demand response programs, such as data sharing and control strategies, G&T co-ops were not only able to build trust and buy-in from their members but, more importantly, they were able to educate their members on demand response programs' value propositions and collectively legitimized load management among their member distribution co-ops. Finally, G&Ts also worked with their member co-ops to design new rate structures and power supply contracts that embedded load management into the co-op's decision-making practices while offering members the flexibility to create and operate demand response programs to meet their unique needs. For instance, after seeing the benefit of load management to their member utilities, many G&Ts changed their power supply contracts from noncoincident peak pricing to billing their members on coincident peak demand (Matthew Grimley and Chan 2023). As elaborated in Sections 4.2 through 4.4, these practices to garner member buy-in and trust through education campaigns and new rate structures would be invaluable in setting new policies, standards, and practices around VPP operations and planning.

2.2 VPPs and the Cooperative Structure & Guiding Principles

As mentioned above, co-ops are member-owned utilities that can maintain a non-profit status so long as 85% of their core business revenue comes from serving their member-owners (O'Neal 2019). Additionally, co-ops are governed through a multi-level governance strategy, described above in Figure 2.1, that is founded upon the seven cooperative principles shown in Figure 2.3.

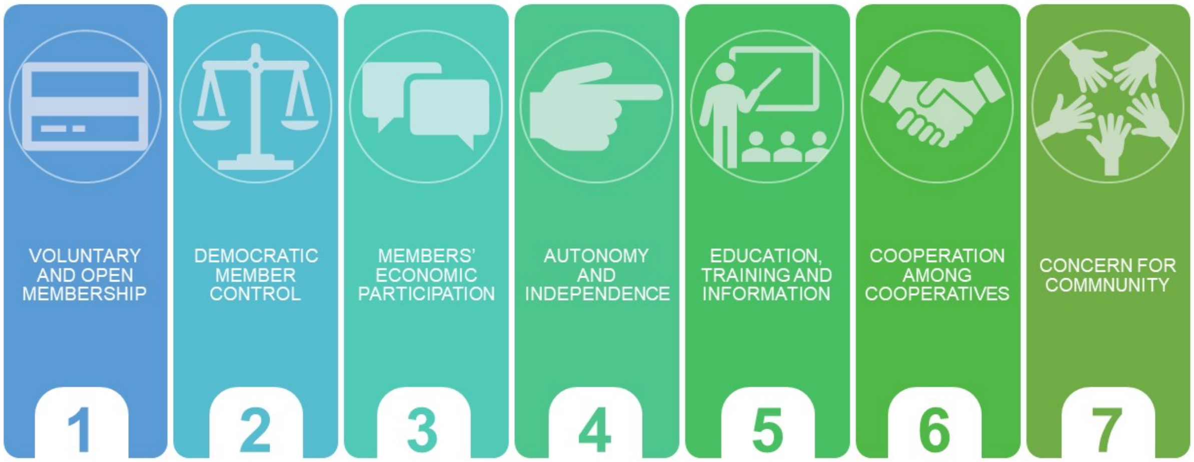

Figure 2.3: Seven Cooperative Guiding Principles. This figure shows the seven cooperative guiding principles the International Cooperative Alliance developed. Source: (National Rural Electric Cooperative Association 2016).

There are numerous ways that VPPs align with co-op business models, governance structures, and guiding principles. By leveraging customer-sited DERs, VPPs allow electricity consumers to become electricity *prosumers* who generate – and thereby receive equitable compensation for – value to the entire system (van Summeren et al. 2020). Similarly, the member-owned nonprofit structure will enable them to deliver the full benefits of their VPP program back to their member-owners in the form of rates or upfront incentives. Additionally, because the member-consumers ultimately own all equity in the co-op, co-ops can leverage a greater degree of capital efficiency in projects that blend ownerships between consumers and utilities, creating business opportunities to utilize customer-owned devices that complement utility-owned assets in meeting system-wide goals (Klass and Chan 2020; G. Chan et al. 2019). There are numerous examples of this across co-op-led VPP programs. For instance, Basin Electric Power Cooperative, which is a G&T in North Dakota serving 131 co-ops across nine states, has recently launched a new rate structure that enables each distribution co-op up to 150 kilowatts of battery storage for each of their member consumers, with control over charging and discharging within their service area, under certain conditions including output management and covering all associated delivery costs. In turn, the distribution co-ops share operational data with Basin, allowing the G&T to control members' batteries in response to the grid or market events (Cash 2023).

Additionally, VPPs conceptually align with the seven guiding principles governing rural co-ops. First, as democratic, member-owned organizations, rural electric cooperatives make decisions with the oversight of a board of directors elected by co-op members, and any decisions on DERMS and VPP programs involve building and maintaining trust with member-owners as well as ongoing engagement through educational and marketing programs. Co-ops also ensure that excess capital is democratically controlled and equitably allocated across the co-op's membership. While some portion of excess revenue from DERs is given back to the member who owns the asset, co-ops also allocate revenue for system-wide benefits like resource adequacy, building staff capacity, economic development investments, and in cases of G&Ts, providing services like financing and marketing to their distribution member utility (National Rural Electric Cooperative Association 2016). Additionally, guided by their principle of "concern for community," co-ops can make investment decisions based on external factors rather than just the economic benefits of VPPs, such as improved public health through lower air pollution, community development, and reliable service.

However, in reality, co-ops might not make decisions that perfectly align with their guiding principles. There has been a fair amount of research showing that co-ops suffer from institutional inefficiencies like a lack of member representation at the board of directors level, lack of vertical accountability, and low voter turnout (Matt Grimley 2016; Farrell 2016; Klass and Chan 2020). As shown throughout Sections 4 and 5, these inefficiencies create structural barriers for co-op-led VPP programs.

3 Data & Methodology:

To assess the various barriers and opportunities co-ops face in designing and operating VPP programs, I combined desktop-based literature research with a thematic analysis of semi-structured interviews of co-op staff from various rural co-ops. This section outlines the factors influencing the selection of rural cooperatives and their staff to interview.

3.1 Sample Selection

I interviewed 14 co-op staff members from 10 rural electric cooperatives (five G&T co-ops and five distribution co-ops) across the United States. Co-op staff members participating in my study essentially held positions that had complete oversight of co-op-led VPP and DER programs; however, some staff members also covered roles like member services and planning. Each interviewee's name, position, and contact information was obtained either through publicly available resources like LinkedIn or co-op websites or through personal contacts from myself or my advisor.

I considered several factors when selecting which co-ops to include in this study. First, in order to understand the different barriers and opportunities co-op-led VPP programs might face across each level of the VPP value chain, I selected co-ops that were at varying levels of maturity in their efforts to deploy DERs and VPPs. Information on co-ops' VPP programs was found in their individual integrated resource plans (IRP) and websites. Additionally, because regional factors like the presence of deregulated wholesale markets and state-wide regulations impact co-ops' decision-making strategies, I made sure to select at least one co-op that interacted with an ISO or RTO, at least one that operated within a regulated wholesale market, and at least one co-op from one of seven states that rate regulate distribution co-ops[2]. In the end, out of the five G&T co-ops

[2] The states that fully rate regulate G&T and distribution co-ops are Vermont, Maine, Maryland, Kentucky, Louisiana, Hawaii, and Arizona. In some cases, states only rate regulate certain co-ops – e.g. Minnesota – or oversee co-ops through other regulatory processes – e.g. renewable portfolio standards and decarbonization goals (Klass and Chan 2020; CFC 2008)

and five distribution co-ops that participated in my study, two were fully rate-regulated by their state public utility commissions, although only one came from one of the seven states that comprehensively regulate co-ops; three co-ops came from states that were not in a deregulated wholesale electricity market; two co-ops that were within the Midcontinental Independent System Operator (MISO) wholesale market, and one co-op that was within the PJM wholesale market. Table 3.1 provides a complete list of interviewees, their positions within their respective member co-ops, and additional characteristics representative of their cooperative utility.

Interviewee Designation	Co-op Characteristics	Interviewee's Seniority and Role	Presence in Deregulated Wholesale Markets	Presence in a State that Rate Regulates Co-ops
Interviewee 01	Distribution Co-op	Manager, DER & DERMS Operations	YES	YES
Interviewee 02	Distribution Co-op	Manager, DER & DERMS Operations	NO	NO
Interviewee 03	Distribution Co-op	Chief Executive Officer	YES	YES
Interviewee 04	Distribution Co-op	Vice President, Regulatory Services	YES	NO*
Interviewee 05		Vice President, Utility Operations & Engineering		
Interviewee 06	Distribution Co-op	Manager, Power Supply & Operations	YES	NO
Interviewee 07	G&T Co-op	Manager, Member Services	YES	NO
Interviewee 08		Manager, Planning & Operations		
Interviewee 09		Manager, DER & DERMS Operations		
Interviewee 10	G&T Co-op	Manager, DER & DERMS Operations	YES	NO
Interviewee 11	G&T Co-op	Manager, DER & DERMS Operations	NO	NO
Interviewee 12	G&T Co-op	Chief Executive Officer	NO	NO
Interviewee 13		Manager, DER & DERMS Operations		
Interviewee 14	G&T Co-op	Manager, DER & DERMS Operations	YES*	NO

Table 3.1: Unique Characteristics of Each Interviewee and their respective Co-ops. For each co-op staff member interviewed in this study, this table shows their positions and seniority, and different characteristics of their host co-ops, such as whether the co-op is a distribution or G&T co-op, whether it is in a deregulated wholesale market, or whether they are in state that rate regulates co-ops.

3.2 Interview Methodology

The primary data for this study was gathered through semi-structured interviews of 14 different co-op staff members from five different G&T co-ops and five distribution co-ops.. Building off the main research question and themes from the literature review, my interview questions were divided into the following sections: existing programs, challenges associated with deploying DER and DERMS programs, planning, wholesale market integration, and rates & other incentives. This structure allowed me to evaluate how legacy DER programs can impact co-op-led VPP deployment. It helped me identify the new processes and programs co-ops need to consider for operationalizing VPPs.

The first section on existing programs aimed to gather information on various co-op-led DERMS and DER programs, including legacy demand response initiatives. It also explored best practices and valuable partnerships that co-ops have developed through their extensive experience implementing these programs. Through these initial questions, I assessed how co-ops perceive the different value streams and benefits they can derive from their VPP programs. The next set of questions on challenges sought to determine operational, organizational, and systems-level barriers (regulatory, market, etc.). The following two sets of questions focus on how co-ops incorporate distribution-side resources into long-term utility planning and the integration with wholesale markets. They cover current and future processes, stakeholder involvement, and the resources necessary for effective planning. They also explore how co-ops can leverage VPPs to gain value from regulated and deregulated wholesale markets. The final two sections address the capacities co-ops build for deploying VPPs, including staff, hardware, and software. They also focus on the rate and incentive structures co-ops implement to deliver VPP benefits to their member-consumers. The complete list of questions and the interview protocol are provided in Appendix A.

Each interview lasted 60 to 80 minutes. I transcribed and scrubbed each interview recording using REV's AI-supported transcription software and subsequently scrubbed these transcriptions manually to ensure legibility and accuracy.

3.3 Coding and Analysis

I used inductive and deductive coding to analyze my interview transcripts. Using the structure presented within Downing et al.'s (2023) VPP Liftoff Report, I deductively identified various barriers and solutions to VPP deployment. I grouped them according to the following categories: installation & enrollment, VPP operations, valuation, and planning. The complete list of codes and their definitions is provided in Appendix B.

Within each category, I included specific barriers and solutions identified from the literature (e.g., upfront cost, data sharing & visibility, etc.). Additionally, I refined these codes by including new themes that emerged from my interviews. For example, codes such as "inertia," "nascency," and "co-op principles" were generated inductively throughout the coding process. This approach allowed me to base my codes on literature-identified VPP barriers and solutions while utilizing the grounded theory approach to coding. This coding strategy, particularly the overarching code categories, provides a framework for presenting my findings in Section 4

4 Results: Barriers & Solutions to VPP Deployment for Rural Co-ops

Although VPPs create several benefits in the form of economic and grid services, for rural co-ops and their member-consumers, co-ops, and rural communities face numerous challenges that make participating in a VPP more challenging. Across the literature and co-op staff interviews, challenges associated with VPP deployment and their specific solutions were organized across the four categories of VPP deployment: installation & enrollment, operations & management, valuation & rates, and planning (Downing et al. 2023; Speetles, Lockhart, and Warren 2023).

4.1 Installation and Enrollment

To effectively implement virtual power plants (VPPs) on a large scale and reap significant benefits for consumers and the grid, a comprehensive and robust network of VPP-compatible DERs is essential. However, the adoption of DERs faces substantial challenges, including financing availability, workforce shortages, and limited consumer awareness, which have impeded widespread adoption nationwide. The national deployment rates for VPP-compatible DERs, such as rooftop solar and smart thermostats, remain low, not surpassing 4% and 20%, respectively (Downing et al. 2023). With a substantial increase in DER deployment, the potential benefits of VPPs for communities will remain unrestricted.

Federal policymakers have made significant investments in response to these obstacles by providing expanded tax credits and upfront incentives for various DERs (Tankersley, 2023). Additionally, utilities, regulators, and stakeholders are increasingly adopting market transformation models focused on removing barriers and leveraging opportunities to accelerate the adoption of innovative energy efficiency practices, aiming for lasting market behavior changes. Market transformation involves strategic interventions to align energy efficiency innovations with market demands, enabling these innovations to become widespread industry standards (Bloom, 2001). These programs typically span 5-10 years and often require substantial initial investments, which has led to mixed acceptance across the industry. However, there are numerous examples where market transformation has successfully led to industry standards, such as high-efficiency clothes washers and LED residential lighting (York, Nadel, & Subramanian, 2022). Currently, DER technology is still in the nascent stages of market transformation.

To understand how market transformation can be applied to DERs within co-ops, it's essential to delve deeper into its concepts and practices. Market transformation requires a coordinated effort involving policy support, financial incentives, stakeholder engagement, and consumer education to shift market dynamics in favor of energy-efficient technologies. By creating demand and encouraging widespread adoption, these interventions can reduce costs over time and establish new market norms. The following section outlines significant barriers that hinder the broader market adoption of DERs and discusses potential strategies that cooperatives can employ to use market transformation practices. These strategies can expedite the deployment of DERs among their members by leveraging existing frameworks, engaging stakeholders, and aligning with federal and state incentives. By adopting these practices, co-ops can overcome initial resistance, reduce financial risks, and create a more sustainable and resilient energy future for their communities., as summarized in Table 4.1 below.

Installation & Enrollment	Barriers	Opportunities
Upfront Capital	• High Upfront Cost makes it difficult for member consumers to install DERs at scale. • High energy burden & energy limiting behavior among member consumers highlight the overall scarcity of capital in rural communities. • Lack of financing options in rural communities makes it difficult for member consumers to overcome the upfront cost barrier. • Lack of flexible capital, particularly among lower income households, creates benefit flows that might inequitably help higher income member consumers.	• Upfront Incentives: Provide upfront subsidies for DER acquisition • Access to public & private financing: Co-ops should connect members to public and private financing options, including utility-led on-bill financing programs. • Ownership Models allow utilities and their member consumers to share ownership of assets that complement utility-owned assets in system-wide value generation • Innovative and equitable rate structures allow lower income member consumers to take advantage of VPP services
Workforce Capacity	• Shortage of skilled workforce hinder the equitable and speedy installation of DERs. • Limited capacity among existing workforce could lead to extended DER installation timelines. • Varying levels of workforce availability across the co-op service territory create disparities within one co-op along the lines of DER penetration & workforce availability	• Engaging third-party actors: Building out relationships with unions, trade organizations, and non-profits to connect members with relevant contractors and vocation training opportunities • Creating practices and policies around sharing skilled workers across a G&T system • State & Local Government Engagement: Work with local government to adopt building codes more favorable to DER strategies
Consumer & Operator Awareness	• Lack of member awareness: creates opportunities for misinformation across member consumers. • Lack of installer or contractor awareness: creates opportunities for poor installation quality, leading to extended project timelines and costs. • Lack of capital to conduct marketing & education campaigns: this is particularly true for distribution co-ops who may need to rely on external organization to market their DERMS programs. • Concerns about Third-party Aggregators and DER Installer: creates situations where third-party VPP operations might negatively impact system-wide grid conditions	• Marketing and education campaigns: allow rural co-ops to • Cooperation between G&T and distribution co-op: • Standards on workforce & installation quality: internal or industry-wide standards on workforce can ensure proper installation quality • Creating partnership structures with third-party DER installers and aggregators: allows co-ops to recognize any value streams that third-party aggregators might provide to their members and to create avenues through which co-ops and third party aggregators can partner – rather than compete – to provide VPP service to the co-op membership.

Table 4.1: Summary of Barriers and Solutions for VPP installation & enrollment. This table summarizes various barriers and solutions to VPP installation & enrollment as they are discussed in Sections 4.1.1 to 4.1.3. Source: Interviews of Co-op Staff; Downing et al. (2023); and Speetles, Lockhart, & Warren (2023).

4.1.1 DER Penetration & Upfront Capital

<u>Barriers:</u>

Although the procurement costs of VPPs for utilities are up to 30% lower than those for gas peaker plants and utility-scale battery operations, the initial costs for consumers to purchase and install VPP-related hardware—like rooftop solar panels, battery storage systems, controllable water heaters, heat pumps, and communication and control technologies—are substantial (Hledik and Peters 2023; Speetles, Lockhart, and Warren 2023). For instance, replacing a traditional gas water heater with an electric model ranges from $1,000 to $1,700 ("Electric Hot Water Heater Cost Per Month and Year," n.d.). This high upfront investment is a significant barrier to the widespread adoption of DER, as each household and business must bear these expenses individually, and this sentiment is reflected in the following quote from a G&T co-op staff member,

> "We're enthusiastic about the potential of distributed energy resources (DERs) for our co-op, but the upfront costs are a significant concern. Balancing the initial investment with the long-term benefits and savings is challenging, especially given our limited budget and the need to ensure reliable service for our members" (Interviewee 07).

Without accessible and affordable financing options, these costs can severely limit the national penetration of DERs. Recognizing this, one distribution co-op staff member noted the importance of providing flexible financing options and utilizing federal funding opportunities to bring down the upfront cost of DERs:

> "The structure of how that's finance is changing a little bit with some of the IRA funding, but my understanding is the member right now has an option to pay for the battery themselves and then take the tax credits, or we can draw on some federal funding as well to finance the system upfront" (Interviewee 02).

The disparities in adoption rates are even more marked among rural households, which typically face more considerable median energy burdens, lower incomes, and lower credit scores than urban households (Ross, Drehobl, and Stickles 2018; Guzman et al. 2018; Kirkham 2019). Additionally, many of the co-ops' member-consumers from low-to-moderate-income households might already face high energy burdens. They might also adopt unsafe heating and cooling practices to save money on their electricity bills, showing what Cong et al. call "energy limiting behavior." This differs from energy efficiency measures, instead referring to a form of energy poverty where households can't keep their homes at comfortable temperatures due to severe financial limitations (Cong et al. 2022). On the issue of high energy burden and energy-limiting behavior, several co-op staff members stressed that a significant portion of their member-consumers were low-to-middle income and mentioned that specific pricing structures that attempt to modify consumer behavior (e.g., time of use rates) might be too cumbersome for their customers to participate in.

> "We have a significant portion of our membership who struggle to make their ends meet, and we don't want to add any added burden on them. Many of our members also want their services to work when they need them to and don't want to worry about turning off their lights or their water heaters during certain times of the month. This is where many of our members might want the co-op to control their resources, and in return, we might pay them a monthly incentive for allowing us to control their assets" (Interviewee 01).

The decline of financing services in rural areas further complicates access to traditional financing, pushing potential borrowers towards higher-cost non-bank financing options (Sebastian 2022). Cooperatives, which serve over two-thirds of the nation's Persistent Poverty Counties, encounter significant challenges in promoting widespread DER adoption due to the high prevalence of customers without access to necessary capital and financing (Jackson 2019). This issue underscores the difficulties in achieving equitable participation in VPPs.

Opportunities:

Co-ops recognize that addressing the high upfront cost of DERs poses a significant barrier to DER deployment across their membership base. Co-ops nationwide are taking advantage of recent federal investments, like tax credits for heat pumps provided by the Inflation Reduction Act (IRA), to provide upfront incentives to their member-consumers for DER adoption. All interviewees mentioned having some incentive for DER acquisition, delivered through rate structures, financing options, or upfront subsidies. For example, co-op staff members from four different distribution co-ops and three different G&T co-ops mentioned that they are utilizing incentives from the IRA, along with other federal and state funds, to provide battery storage systems, electric vehicle chargers, and smart thermostats to their member-consumers (Interviewee

01, 02, 07, & 10). Additionally, three of the same interviewees mentioned that their co-ops provide an additional incentive in the form of capacity payments to their member-consumers who allow the utility to control and dispatch their battery systems for a certain number of times during the month (Interviewees 01, 02, & 10). Along these lines, one interviewee recognized that their member-consumers might want for their DERs to be controlled only some of the time and emphasized the need to offer their member-consumers flexibility in how often and when the utility calls upon their resources. This interview stated they are building this flexibility by creating mechanisms that "compensate members on their DER *performance* rather than solely on availability during certain times of the month" (Interviewee 10). Other co-op staff members mentioned utilizing DERs to create innovative incentives geared toward low-income member consumers and other historically underinvested communities. For instance, one distribution co-op staff member mentioned using revenue from a community solar system located within a Native American reservation served by the co-op. This revenue provides direct bill credits to members living on the reservation, and any excess is used to reduce bills for low-income members.

> "For example, our 1 MW solar array [located within a Native American reservation] that's dedicated to our community solar project is virtual. Everybody that gets benefit from that system, it, it's an on-bill credit. We benefit the Indian tribe whose reservation it's located on, they get a direct bill credit. Then the balance is spread out around about 200 income qualified members that see about a $25 a month bill reduction, no strings attached" (Interviewee 03).

These kinds of compensation and rate structures that reward members based on capacity payments, DER performance, and income qualification enable LMI member-consumers to participate in VPP programs without worrying about energy-limiting behavior (Speetles, Lockhart, and Warren 2023).

To overcome the access to financing barriers, policymakers and practitioners can connect co-ops' member-consumers to public financing options, like green banks. Member consumers can seek financing through private-public partnership institutions like green banks, which offer low- or no-cost financing options for controllable DERs like controllable water heaters and heat pumps (Connecticut Green Bank 2022). Co-ops can also create internal financing options for their member-consumers by utilizing support from federal investment programs like the Rural Economic Development Loan & Grant Program, the Efficiency and Conservation Loan Program (EECLP), and the Rural Energy Savings Program (RESP), which offers loans to rural electric service providers for up to 20 years at a 0% interest rate and caps interest rates for lending to end-users at 5% (*Rural Energy Savings Program* 2020). For example, the Roanoke Electric Cooperative uses incentives from the Rural Energy Savings Program to fund home efficiency improvements, including weatherization and smart thermostats, with more than 10% of its consumer base enrolled in its on-bill energy efficiency program. Participants typically apply 75% of their energy savings towards on-bill tariff repayment, retaining 25% (Ross, Drehobl, and Stickles 2018; "Inclusive Utility Investments: Tariffed On-Bill Programs" 2023). Such programs were used throughout the interviews as co-op staff members mentioned deploying creative financing and ownership models to increase DER adoption across their membership base For instance, one interviewee from a G&T co-op mentioned that they take advantage of federal investments through the Rural Energy Savings Program to provide on-bill financing options to member co-ops and their member-consumers to install energy efficiency upgrades to their homes, with the possibility of extending these financing options to DERs.

> "Many years ago, one of our member co-ops created a pay-as-you-save program that allowed member consumers to finance costly weatherization and energy efficiency upgrades. We are not there yet, but we are trying to figure out whether we can use a similar process to finance things like heat pumps and controllable water heaters" (Interviewee 14).

Another staff member from a distribution co-op mentioned that they had created a lease-to-own model for their fleet of behind-the-meter batteries; under this model, the co-op would own and lease battery storage systems to their member consumers at no upfront cost, and in turn, the member consumer would allow the utility to control this fleet of battery resources for specific times during the month.

> "For our battery program, [the co-op] owns the battery for the first 10 years that it's in the member's home. Then after that, it's basically a lease to own model where the member is giving us control each month for 10 times a month, and then over the 10-year period, they're basically buying the battery in return for that. In the meantime, we control the battery 10 times a month and return any revenue generated through capacity payments to our member consumers in the form of bill credits or other incentives" (Interviewee 03).

Finally, cooperatives can leverage their community relationships to design financing structures and eligibility criteria that better meet their members' needs. Many have revised on-bill financing qualification standards to accommodate members with lower credit scores, opting instead to assess based on payment history (Vanvig 2016). These relationships can also enhance consumer education efforts, focusing on raising awareness about the availability and benefits of DER financing and combining cooperative-sponsored programs with public incentives to maximize capital support for their members.

4.1.2 Local Workforce Capacity

<u>Barriers:</u>

A shortage of skilled workers is a barrier to DER deployment throughout the country; with most US single-family homes requiring updates to their electrical infrastructure to accommodate the integration of electrified appliances and other DERs, an abundant and specialized workforce is required to facilitate the installation and operation of DERs and DER-compatible grid infrastructure (Calisch and Wyent 2020). However, half of all contractors across different trades report difficulties in filling open positions, and wait times for electrical home upgrades can be as long as eight months if contractors are even willing to accept the work (Pontecorvo 2023). With demand for jobs in the energy sector expected to dramatically expand in order to meet ambitious

US climate goals, robust and rapid workforce development is required to meet growing consumer demand (Griffith and Calisch 2020).

The workforce shortage is particularly acute in rural communities as the density of DER installers and electricians is concentrated in urban areas (Bureau of Labor Statistics 2022). This trend holds true for a wide range of other professions necessary for accessing the full DER value chain, such as energy auditors whose shortage has resulted in wait times for energy audits often required to access device rebates of over a year in many parts of rural Canada (Lamberink 2022). This rural shortage stems, in part, from the lack of local and accessible educational opportunities and lower customer density, resulting in a less profitable business model (Gadzanku, Kramer, and Smith 2023).

Because co-ops predominantly serve rural communities throughout the U.S., scarcity of skilled workers can significantly hinder progress on DER penetration and VPP deployment across the co-op's membership base. This was also reflected within the interviews as several co-op staff members cited workforce shortages preventing rapid deployment of DERs, causing significant delays in project timelines. One staff member from a distribution co-op said,

> "I don't know what our latest backlog for the [battery] program is, but it's quite long and it's hard to get enough trained folks on the ground that can put these systems in members' homes." (Interviewee 02)

Another staff member from a G&T co-op mentioned that existing DER and HVAC installers were already at capacity and could not take more work due to a scarcity of trained workers, supply chain shortages, and high demand for DERs.

> "But at this point, contractors are… overworked… have so much to do, [and] supply chain [shortage] is a huge issue." (Interviewee 08)

Furthermore, these shortages extend to the internal workforce of co-ops as well, with co-ops across the nation having difficulty recruiting and retaining linemen, engineering staff, and other skilled workers, in part due to the increasing complexity of the grid, rising housing costs in co-op territories, and broader rural out-migration. With 19% of co-op workers becoming retirement eligible in the next five years, compared to 9% for the energy industry as a whole, co-ops find themselves in a particularly severe labor crunch, potentially limiting their long-term capacity for incorporating DERs into their networks (Rocha 2023). Additionally, distribution co-ops have varying degrees of capacity constraints and workforce challenges, creating coordination challenges even across the same G&T system, as reflected by the following quote from a G&T staff member.

> "We had one distribution cooperative whose guy running the program was an ex-HVAC guy, so he was going out and installing thermostats. They got like 300 devices signed up. So all the other member co-ops wanted to hand out thermostats as well but [didn't] have an staff with HVAC installation experience. That really affected the quality of some of the installations." (Interviewee 10).

Finally, co-ops are increasingly struggling with installation challenges due to a lack of local workforce availability in the housing construction industry, as national homebuilders dominate new construction projects. Historically, co-ops have successfully partnered with local builders to coordinate energy efficiency initiatives, like the shift to more efficient air conditioning units during the 1990s. However, coordinating local DER installations with national homebuilders, who often adopt a uniform approach to development, has become problematic. With the top 100 largest domestic home builders now constructing about 50% of all new single-family homes in the U.S.—a significant increase from about 33% two decades ago—the capacity of co-ops to collaborate with local builders on DER strategies is diminishing (Ahluwalia, Baker, and Colton 2022).

Opportunities

Co-ops have several opportunities to solve workforce shortage barriers within their service territories. For instance, utilities throughout the country are partnering with local contractors, trade associations, and unions and create trusted networks of qualified contractors who can provide installation services to the co-ops members (Downing et al. 2023). These partnerships can be leveraged to expand awareness and accessibility of DER-related training, the lack of which has frequently been cited as a major barrier for those pursuing opportunities for specialized training and education (Hawkins et al. 2014). Several partnerships working to this extent already exist, such as the National Utility Industry Training Fund, a partnership between numerous national utilities and the International Brotherhood of Electrical Workers to establish targeted training programs for high need skill sets (NTUF 2022). Partnerships can additionally be established with nonprofits aiming to connect underrepresented groups with opportunities in the industry, such as the Construction Trades Workforce Initiative (Pontecorvo 2023). With the demographics of electricians being 87% white and 97% male, expanding outreach initiatives to underrepresented groups can help to increase the breadth of the pool of recruitment for high-demand skilled labor jobs (Bureau of Labor Statistics 2022).

In addressing the challenges of establishing a comprehensive local workforce, co-ops can build on their community relationships to pair members in need of DER services with local contractors, ensuring demand for local labor capacity. This could be as simple as maintaining a centralized catalog of local contractors for members to use as a reference point or partnering with local organizations, such as unions and trade associations, to create a trusted network of contractors, as mentioned by one staff member from a distribution co-op.

> "We've developed some good relationships with a couple of specialty contractors, electricians, plumbers, HVAC contractor in particular." (Interviewee 03)

Another staff member from one G&T co-op said that their co-op is building out a list of contractors who would not only provide quality installations to the member-consumers but also educate them on various co-op incentives for DERs and VPP programs.

> "We [are] starting to talk to HVAC installers and say, Hey, every time you sell somebody a thermostat, how about you tell 'em that they can get $75 back from that thermostat by signing up for our program and $50 a year and it'll start making them money." (Interviewee 10)

Co-ops can further build upon these relationships to connect people with accessible apprenticeship opportunities and identify unique barriers that may stand in the way of completing such programs (Downing et al. 2023). Co-ops can partner with training centers that may offer accessible opportunities, such as distance learning options, and work to connect local contractors with relevant opportunities. For instance, the same co-op staff member who mentioned limited capacity among existing contractors as a workforce barrier to DER deployment also mentioned that their member services department is working with several statewide organizations to understand where IRA incentives are flowing within the G&T service territories and the G&T is planning to utilize this data to inform which areas within its service territories might have the greatest workforce needs and opportunities.

> "We don't quite know the timeline yet, but a role that members have asked me to help play is contractors don't fit neatly into member service territories. And so there's a need to coordinate with either the state to understand how those tax credits and rebates are going to be eventually actually dispersed." (Interviewee 08)

Co-ops can extend these partnerships to vocational training organizations or establish internal apprenticeship programs to help recruit workers into the industry. Aside from education, co-ops can lean on "Cooperation among Cooperatives" principles to share contractors between co-ops, establishing a sort of mobile cadre of DER professionals similar to those utilized for weatherization programs in rural Alaska, Texas, and Utah (Ross, Drehobl, and Stickles 2018).

In aiding coordination with new home developments, co-ops can work with local governments to adopt and revise building codes that are more favorable to DER integration, limiting the capacity of national home builders to neglect local DER strategies. An example of this can be found in the New York State Energy Research and Development Authority's NYStretch Energy code, which is available for local governments to adopt voluntarily. The code includes specific provisions for required DER capabilities, such as stipulations requiring buildings to be constructed with automated demand response capabilities ("NYStretch Energy Code - 2020" 2019).

4.1.3 Lack of Customer or Operator Awareness

Barriers

Limited awareness of VPP programs, along with their benefits, among member-consumers can not only cause consumers not to take advantage of bill savings and other VPP benefits but also might cause misinformation about co-ops' VPP programs, leading to higher member engagement expenses such as marketing or education efforts (Downing et al. 2023). VPPs have struggled to penetrate the public consciousness, with surveys finding that as many as 92% of consumers were either unaware of VPPs or were aware of them but with no other knowledge (Newton et al. 2022). In the co-op space, a 2023 national survey of co-ops found that six out of fourteen co-ops with sponsored VPP programs reported less than 1,000 participants, with three reporting less than 100. Additionally, despite relatively high adoption rates of particular DERs in rural areas compared to the national average, such as high rates of heat pump deployment, the survey found that coops still frequently struggled with "limited [consumer] familiarity with DERs" and "lack of [consumer] awareness of utility DER programs" in their efforts to increase penetration of VPP-compatible DERs (Omotoso and MacAvoy 2023; Min and Mayfield 2023).

As a staff member from one of the distribution co-ops pointed out, there could be several reasons behind the lack of awareness of VPPs and their benefits among a co-op's member-consumers. For example, consumers may not interact frequently with their co-ops because they offer reliable and affordable services.

> "If your SAIDI numbers are good, your members don't know you… So it's really challenging. If you want to keep your quality of service high, you have to be willing to expect that there's going to be a lot of unintentional ignorance of your programs out in the wild" (Interviewee 03)

Another reason could be existing mistrust between rural co-ops and certain consumers within their membership. As noted above in Section 2, co-ops suffer from a lack of representation within their leadership, and this creates opportunities for certain member-consumers, particularly those from historically underinvested communities, to mistrust their local co-ops. Additionally, predatory practices by investor-owned utilities, including excessive energy costs and frequent utility disconnections, have fostered significant mistrust, particularly in numerous communities of color (Walton 2022). This is emphasized by the following quote from two distribution co-op staff members:

> "We have a Native American community on our lines and they're one of our largest members, but I think it's been energized now, but they just put in a four and a half megawatt solar facility. Negotiating the PPA with them was difficult at times because one of their attorneys is used to negotiating with IOUs. And it took a lot of back and forth before there was an understanding." (Interviewees 05)

Another challenge contributing to a lack of consumer and contractor awareness is the high cost of marketing and educational campaigns. Distribution co-ops, in particular, often lack the capacity and the capital to launch in-house marketing programs associated with their VPP platform (Omotoso and MacAvoy 2023). Additionally, third-party DER installers and contractors can lack prior experience in working with co-ops and, as a result, might lack awareness of co-op-led VPP programs and their unique needs. This might create challenges around poor installation quality, leading to future repair costs and lengthened project timelines. For instance, a staff member from a distribution co-op noted that the co-op had to allocate additional funds for repair and maintenance due to improper installation of certain battery systems, stemming from a lack of awareness among DER installers.

> "DER installers have an incentive to overbuild and may not be concerned about how that might affect the system as a whole. We have to worry about how new projects affect other members as well. We had a solar installer that sized the system too big and caused us to later spend money upgrading our transformers to accommodate for the larger system size" (Interviewee 04).

Finally, a lack of contractor awareness of co-op-led VPP programs and limited experience working with co-ops can also create distrust between co-ops and third-party DER aggregators and installers. For instance, one distribution co-op staff member mentioned that third-party aggregators could try to "poach C&I (commercial and industrial) customers away from the co-op," possibly leading to concerns around shifting costs onto non-C&I members (Interviewee 04). Additionally, limited engagement between third-party aggregators and co-ops can significantly impact the grid. The same co-op staff member pointed out that, without proper visibility into the co-op's grid conditions, third-party aggregators can make dispatch decisions that overload certain portions of the distribution system, leading to outages for the rest of their members (Interviewee 04).

Opportunities:

Collaboration and outreach efforts are essential to improving consumer, operator, and installer awareness. Several broader, national efforts to increase the public salience of VPPs have already been established, such as the Rocky Mountain Institute's VP3 initiative, and can be used as roadmaps for budding collaborative initiatives and opportunities to reach a greater diversity of audiences (Beitman 2023). Internally, co-ops can also pool resources to launch marketing and educational campaigns. For instance, even though distribution co-ops may have limited capacity, they can rely on their G&T co-op, which has access to significantly more capital, to create marketing and educational campaigns around their VPP programs, as one G&T staff member mentions.

> "Our member co-ops are extremely diverse. Some have the capacity to run their own demand response programs and don't need us for anything. Other members are not so advanced. Those obviously will have challenges if they want to run [demand response] at a minimum. The marketing component they don't have so we can try to support that at the [G&T] level" (Interviewee 11).

Longer-term VPP contracts can also be considered to amortize the cost of education and marketing over a longer period of enrollment and provide greater revenue certainty (Downing et al. 2023). However, consumers are unlikely to respond favorably to longer-term contracts without further efforts to increase trust in aggregators, with 17% of consumers indicating that a lock-in contract would reduce their trust in an aggregator. In pursuit of this trust, aggregators can focus outreach and educational efforts on topics consumers consider most important to establishing a trusting relationship, including consumer control, transparency, and consumer safeguards (Newton et al. 2022). For instance, co-ops can coordinate internally and create workforce and installation standards in order to protect customers against faulty installations. Co-ops can also improve consumer and operator awareness of and trust in VPPs by capitalizing on streamlined relationships and reputation within the community. Factors such as presence in the local community, brand reputation, and interactions with brand representatives have been identified as key drivers in establishing consumer trust in VPPs (J. J. John et al. 2023). This is particularly true for establishing trust in third-party VPP aggregators and DER installers. While several interviewees were concerned with the possibility of competition with third-party DER aggregators for C&I customers, many saw the value of third-party aggregators in delivering additional VPP benefits and engaging difficult-to-reach member-consumers and wanted to create internal programs and processes for forming partnerships rather than competition, with third-party entitles.

> "In the frequency regulation, the capacity market, we could see aggregators coming in, creating programs of value participating. I would argue that some of these aggregators might be savvier at building customer building and maintaining member relationships than the utility might be. [On the other hand], it could be detrimental to the electric grid if third-party aggregators dispatch all their batteries at once… They lack visibility into potential system overloads, which could lead to catastrophic outcomes [including] significant costs, grid issues, and reliability concerns. But because these third-party entities might bring much value to the table, I definitely see the need more partnerships." (Interviewee 02)

Ultimately, co-ops can utilize several avenues to create consumer and operator awareness of VPP programs, from sharing resources to creating marketing campaigns to creating standards on DER installation and third-party partnerships. Co-ops can further improve the efficiency of these initiatives by taking advantage of white glove marketing opportunities offered by consumer advocacy organizations. For example, Energy Wise MN provides ready-to-distribute templates for educational DER memos and rebate forms to 27 co-ops across Minnesota and Wisconsin (Energy Wise MN, n.d.)

4.2 VPP Operations & Management

As mentioned above in Section 1.0, VPP operations can be sorted into three different categories: DER aggregation, grid orchestration & control, and wholesale market interaction (Gao et al. 2024; Saboori, Mohammadi, and Taghe 2011). In this section, I present several barriers and opportunities around two particular segments of VPP operations and management: DER aggregation and grid orchestration & control. As presented in Table 4.2, I focus on three categories of barriers that might inhibit co-ops from efficiently operating and controlling their DERMS platforms to maximize system-wide benefits: organizational integration of VPP management systems, data sharing & visibility, and standardization.

Operations & Management	Barriers	Opportunities
Integration of VPP Management Systems	• Nascency of the DERMS market creates complexities around program and process development. • Organizational inertia might cause co-ops to maintain existing systems. • DERMS integration with DERs might have high enrollment costs: raising overall project costs and complexity. • DERMS integration might require upgrades to legacy utility management systems, raising adoption barriers and costs.	• Coordination and communication across co-ops and industry-partners can create avenues for knowledge and cost sharing on various DERMS use cases and capabilities. • Foster member buy-in, trust, and culture of innovation by showing the value proposition of VPP deployment • Take a measured approach to investment by creating programs that enable customers with the lowest barrier to entry into a DERMS platform to enroll first. • Upgrade legacy and incompatible utility management systems at the point of DER replacement • Co-ops can create or adopt third-party VPP platforms that are compatible with multiple OEMs
Data Sharing & Visibility	• Lack of access to real-time customer data can lead to system damage and suboptimal market dispatch decisions. • Distribution co-ops might be hesitant to share distribution-level data with their G&Ts, creating blind spots in DERMS operations • Small-scale distribution co-ops might face challenges leveraging data analytics services due to their limited size and resources	• Data sharing policies, formats, and best practices: G&T co-ops should build on existing initiatives to develop roadmaps for best practices for data sharing between co-ops within the same system and between co-ops and third-part service providers (e.g. DERMS providers or OEMs) • Member buy-in and trust: both distribution & G&T co-ops can garner member buy-in by showing the different VPP use cases and the value proposition of greater data sharing and visibility between the member and the co-op. • Coordination among cooperatives: co-ops can coordinate with each other or industry organizations to create low-cost, third-party data analytics tools (e.g. MultiSpeak)
Standardization	• Lack of standardized VPP assessment and forecasting methods • Lack of standardized VPP service agreements • Lack of standards for DER operations and reliability • Incompatible underlying IT and operational systems	• Develop internal guidelines to forecast and measure real-time VPP operations and performance. • Adopt industry-wide standards for DER reliability and interconnection.

Table 4.2: Summary of Barriers and Solutions for VPP installation & enrollment. This table summarizes various barriers and solutions to VPP operations and management as they are discussed in Sections 4.2.1 to 4.2.3. Source: Interviews of Co-op Staff and other literature sources.

4.2.1 Integration of VPP Management Systems

<u>Barriers</u>

There are several organizational and economic barriers to integrating virtual power plants with existing utility management systems among rural electric cooperatives. First, the nascency of the VPP market, including the process for integrating DERs into DERMS platforms, creates challenges for rural electric cooperatives in developing and streamlining programs and processes around their VPP programs, leading to increased costs and inefficiencies that could ultimately lengthen project timelines (Kerekes 2019). For instance, one interviewee from a G&T co-op mentioned that the nascency of the DERMS market, including grid-edge technologies that enable more streamlined operations of DERMS platforms, led to faulty installations, causing significant cost and project development hurdles that ultimately hinder the further penetration of DERs.

> "We have 17 battery energy storage projects, kind of those we started over two years ago, and they will probably go to COD after the projects we started last year, and it was contractors not following design documentation. So we have to make major transformer replacements for this board-level component in our power conversion systems, and chips have to be replaced. Those are all things though that happen when you have a very nascent technology that you're trying to deploy quickly" (Interviewee 14)

Additionally, the emerging nature of the VPP market creates challenges around setting data sharing policies and DER standards. Sections 4.2.2 to 4.2.3 elaborate on these barriers.

Another barrier hindering the speedy development of co-op-led VPP programs is co-ops' organizational inertia, which is not unique to co-ops and generally affects most nonprofits (Anheier 2014). As stated by one staff member from a G&T co-op, "It is just principles of the thing, and it's just this conversation [of] this is how we've done things forever, so we're going to keep doing them this way" (Interviewee 08). This inertia can result from a lack of democratic accountability, which creates governance challenges across vertical scales of cooperatives from distribution co-ops to G&Ts (Klass and Chan 2020; Pacyniak 2020). For instance, most G&Ts are governed by a board of directors comprised of directors from individual member distribution co-ops (National Rural

Electric Cooperative Association 2024). However, in many cases, the largest distribution co-ops have the same representation as the smallest cooperatives, leading to governance tensions around creating data-sharing and cost-allocation strategies for utilizing distribution-side assets to meet system-wide goals (Klass and Chan 2020). This point is elaborated by one staff member from a G&T co-op who said,

> "If a distribution co-op wants to invest in DERMS…. a challenge [the G&T] faces is showing how do we support the expenditure at the [G&T] level when maybe not all cooperatives are on board with DERMS" (Interviewee 10).

Another barrier to operationalizing VPP programs among rural co-ops is the high costs associated with integrating DERs into DERMS platforms, which can increase ultimate project costs, create inefficiencies in program development, and lead to investment risks. When enrolling DERs into a DERMS platform, original equipment manufacturers (OEMs) can impose fees on third-party DERMS providers to integrate with their DER software. These fees range from $100,000 to half a million dollars, and the DERMS provider typically passes this cost onto the co-op (Downing et al. 2023; Omotoso and MacAvoy 2023). As one G&T staff member pointed out, high integration fees can pose a serious challenge for smaller co-ops with limited access to capital to deploy VPP programs.

> "Because one of the challenges is this software could be a half million dollars a year in fees… and that's really hard for a distribution co-op to support." (Interviewee 10).

DER integration can also lead to inefficiencies in program development as different OEMs may have different integration fees and program design requirements. The nascency of the VPP market has led to limited partnerships between OEMs and DERMS providers. As a result, it is technically and administrative inefficient for co-ops to contract with multiple DERMS providers and DER platforms (Hertz-Shargel 2023). Instead, because co-ops tend to partner with a single DERMS provider, increased partnerships between DERMS providers and DER manufacturers can generally lead to increased adoption of VPPs. The same G&T staff member above, who brought up DER integration fees as being a significant challenge for co-op led VPP programs, also mentions that restrictive program design requirements and high integration fees from major market players like Google make it difficult for co-ops to create blanket incentives and policies for DER integration, leading to situations where co-ops are unable to integrate certain OEMs into their chosen DERMS platforms.

> "Each has their own rules and Google being Google tends to drive, have the most restrictive rules, some of the higher fees associated with their thermostats, they have some of the more restrictive notification times…. They want to pre-approve your incentives and they want to put a lot of restrictions on things. And our first thermostat pilot, we walked away from Google because of how hard they were to manage." (Interviewee 10)

Limited partnerships between DERMS providers and DER manufacturers also limit the number DERMS providers with whom co-ops can partner. As a staff member from one distribution co-op points out,

> "I've been surprised where some OEMs and some DERMS… have publicly traded companies behind them that are in competition, and so I think blacklist is probably the right term or they're sort of blocked from certain OEMs are blocked from working with certain DERMS [providers]." (Interviewee 02)

Finally, as elaborated within the Department of Energy Grid Modernization Report (2020), disparate DER integration requirements can also create investment risks. Investments that are excessively accelerated—surpassing immediate needs—might result in heightened costs for consumers or may be judged as imprudent by regulators. Conversely, overly delayed investments—falling significantly behind needs or failing to adapt to evolving technologies promptly—could compromise reliability and safety, necessitating costly ad hoc solutions. Furthermore, investments in communication networks, metering infrastructure, and grid or data management software may become outdated before their anticipated lifespan concludes (Martini, Taft, and Paladino 2020; Talley and DiMisa 2023). Moreover, technologies might prove costlier or underperform expectations, leading to increased acquisition costs, premature replacements, or issues with reliability and safety.

The final barrier to integrating VPP programs into existing utility systems is that upgrading legacy utility infrastructure to be compatible with DERMS platforms can significantly increase project costs and extend timelines. A major example of this is upgrading legacy communication hardware from existing demand response resources like water heaters and C&I load management resources. As mentioned above, while co-ops have utilized load management technologies for several decades, co-ops utilized rudimentary communication devices, such as radio frequency or power line carrier-based communication systems, that lacked the two-way communication capabilities necessary to verify VPP dispatch signals (M. D. Grimley 2019). AS mentioned by a G&T staff member, upgrading these systems to meet the requirements of a VPP platform would likely add to overall project costs.

> "Many of our old demand response assets, like your water heaters or your C&I loads, have outdated communication systems, and for many of our member co-ops, upgrading these radio-based systems can be expensive. So we [at the G&T] level are trying to replace these communication systems at the [point of asset replacement]" (Interviewee 08).

<u>Opportunities:</u>

Co-ops, DERMS providers, and DER manufacturers are addressing the barriers associated with integrating DERMS with legacy utility systems in several ways. First, to combat the nascency barrier, co-op staff members mentioned coordinating with other co-ops and statewide or regional organizations to create knowledge-sharing opportunities. For instance, a staff member from a distribution co-op mentioned that they are partnering with other co-ops and utilities in the region to share best practices on DER integration and program design,

> "I spend a lot of time sharing out and learning with the hopes of providing some level of guidance because I think this space is just so nascent. I also think there are so many stories of what can be done with IOUs and other types of utilities

> but there should be more case studies on VPP success stories for co-ops" (Interviewee 01).

Additionally, co-ops are also creating innovative solutions to share DER integration costs. For instance, the same distribution co-op staff member as above mentioned that their co-ops is seeking partnerships with a state-wide nonprofit organization to facilitate DER procurement processes and share customer integration costs,

> "We do have a statewide efficiency entity who's been very interested in getting into the load management space. And so they were able to facilitate an RFP process, which we're currently working through to see if there's a synergy that we can get and basically cover this annual component and then let the utilities do whatever programs they want." (Interviewee 01)

Another avenue to tackle the high DER integration cost barrier is to build in DERMS entrance fees into G&T power supply contracts. As a staff member from another distribution co-op mentioned, "[Integration fees] are included in the price of admission as being an all-requirements member, so we didn't really have to go out and buy something like that off the shelf" (Interviewee 03).

Increased partnerships between DER manufacturers and DERMS providers can also lower integration costs and lead to more streamlined program design. These partnerships are already occurring throughout the VPP industry. For example, Generac and Voltus, two major DERMS providers, have partnered with the top four smart thermostat OEMs, including Google, Ecobee, and Resideo (Hertz-Shargel 2023). Co-ops are also taking other approaches to solve the DER integration challenge. For example, rather than opening up their DERMS program to every OEM in the market, co-ops are developing bring-your-own-thermostat (BYOT) programs that are open only to OEMs that have existing partnerships with their DERMS platform (Interviewee 10). Additionally, as another co-op staff member pointed out, some G&T co-ops have developed their own internal DERMS platforms that are open only to OEMs that exist within their service territory. Such approaches ensure that co-ops make risk-based investment decisions by first integrating DERs that have the lowest barrier to entry.

> "Instead of going out and kind of getting a DERMS off the shelf like a EnergyHub or a Virtual Peaker so to speak, we've created our own and kind of growing the software as our needs and wants go what's needed out into the marketplace." (Interviewee 13)

This risk-based investment approach can also be applied to upgrading legacy utility infrastructure that might be incompatible with modern DERMS platforms (e.g., radio-frequency-based communication systems). In order to bring down costs and streamline infrastructure upgrades, co-ops can replace legacy communication systems at the point of DER replacement.

Regarding the organization's inertia barrier, co-ops can foster greater member and leadership buy-in by showing the various value streams that VPPs provide to their members. Co-ops can do so by showing case studies of successful co-op-led VPP programs, along with the various challenges those programs faced in their respective implementation stages, as one distribution co-op staff member mentioned:

> "I think what does success look like is something that's digestible, something that's provides insight kind of across the utility space, co-op space on what others are doing. There's a lot of talk about what can be done. That's what I feel like I read a lot about, whether it's a vendor or an IOU, it's like this is what we can do, but I'm more interested in what has been done." (Interviewee 01)

Co-ops can also foster a culture of innovation throughout their leadership by hiring younger and more forward-thinking managers and executives, as one G&T staff member mentions in the following quote:

> "And one of the things that I've seen, and this is of course just anecdotal, and this is my opinion, is as we've seen a transition to younger executives, younger CEOs and ones that are familiar with [the G&T] and what we do and how we do it, I've seen more of a willingness for them to cooperate with us and hold less of that empire building" (Interviewee 07)

Additionally, Coops can create new governance structures that allow for greater vertical accountability and representation. As Klass and Chan point out in their (2020) article, G&T cooperatives could enhance support for their members by fostering more effective stakeholder engagement, peer learning, and sharing technical expertise. Essential to this support is ensuring small members neither unfairly subsidize (nor are subsidized by larger member co-ops) but instead gain from clean energy transitions. This might involve the G&T cooperative pioneering new technologies such as electric vehicle rapid charging stations or investing in distributed energy resources with a wide variety of their distribution members, not only those that are politically influential or technically advanced. By doing so, clean energy solutions can be expanded more swiftly across the entire G&T cooperative, delivering benefits to a broad spectrum of distribution members (Klass and Chan 2020; Wilson 2021).

4.2.2 Data Sharing & Visibility

Barriers:

While rural co-ops have utilized load management resources for several decades, data sharing and visibility between the customers, distribution cooperatives, and G&Ts were not as sophisticated as they are today. As rural co-ops have started to modernize their demand response capabilities and increase penetration of DERs, they have also adopted some data sharing and visibility capabilities by adopting technologies like Advanced Distribution Management Systems (ADMS) and Supervisory Control and Data Acquisition (SCADA) systems. However, load monitored by utilities may be too high-level to provide operators with real-time visibility of DERs at the meter level, limiting the ability to make informed operational decisions (Cadmus Energy 2023). Furthermore, utilities relying on Advanced Metering Infrastructure (AMI) may struggle to achieve this real-time DER visibility, with battery energy storage devices for small vehicles and household use often being difficult to detect in AMI data (Dwyer 2018). This could be for several reasons. At the customer level, co-ops, in general, can face challenges in acquiring granular and real-time data (e.g. data from smart thermostats) from DER manufacturers because high data access fees imposed by OEMs, incompatible data formats between the DER manufacturer and the AMI interface, and simply because AMIs might not have the visibility into small DERs such as small battery vehicles or vehicles with short charging times (Downing et al. 2023; Ernst 2023). This was mentioned by one G&T co-op staff member in the following quote:

> "Many OEMs (original equipment manufacturers) have high data integration fees which can really affect project economics. We have also only recently started to really invest in AMI and other things like that so we don't have the historical data that would enable us to make investment decisions" (Interviewee 10).

Regarding co-ops, expectation and capacity for baseline levels of data access and sharing between G&Ts and distribution co-ops can significantly vary within the domain of a single G&T. Among staff at cooperatives engaging in DERMS/VPP initiatives, “competing distribution and G&T cooperative goals” is considered one of the major challenges in implementing DERMS/VPP software tools (Omotoso and MacAvoy 2023). This was reflected by several interviewees but perhaps captured best by the following quote from a G&T co-op staff member:

> “The other piece, you've got data sharing. You've also got why are you getting into our business this? You're not distribution, you're generation transmission, so you need to stay out of our business. And so and those are challenges.” (Interviewee 13)

Individual distribution co-ops may desire to maintain local flexibility in meeting member needs or may not see value in navigating the procedural complexities involved in reexamining their relationship with the G&T. These co-ops may then be more reluctant to involve G&Ts in meter-level DER planning and limit G&T visibility into historic member data, while G&Ts may be hesitant to go around distribution co-ops to directly coordinate with end users. Even with a wholly willing member base, DER interoperability and visibility on the distribution grid can be limited by a patchwork of member co-op levels of technology deployment, frustrating top-down collaborative efforts by the G&T (G. Chan et al. 2019). This sentiment was shared by a G&T co-op staff member, who describe the reluctance to share data between distribution and G&T co-ops as an issue of distrust between the two levels and organizational inertia:

> "The data sharing challenge really shows up when we talk about sharing data between [the G&T] and our members. Many of our members may not trust [the G&T] to have control over the distribution grid. Another reason could be that many of our members are reluctant to change... and say 'why change something that is not broken.'" (Interviewee 07).

Without creating more standardized procedures and developing hardware and software capabilities for data monitoring and visibility to assuage utility reliability concerns, co-ops might not be able to make market dispatch decisions that maximize the economic value of VPPs for their members, leading to members losing trust in the program which could hinder the overall rollout of VPPs as seen in only 25% of utilities utilizing VPP programs as of 2021 (Dickey et al. 2021).

Furthermore, having real-time and historic grid performance data is also necessary to make operational decisions that do not overload the grid and cause costly system damage. Rural co-ops might have a significantly diverse service territory comprising of suburban and more rural communities, and some members within the same cooperative system might not have the most up-to-date distribution system infrastructure that can accommodate the extra load created by and the bi-directional capabilities of DERs. Therefore, making VPP operational decisions without having clear and real-time grid conditions and performance data can cause system outages for small and more rural co-ops within the same G&T system (Costantini et al. 2023). Lastly, without coordination from the G&T, distribution co-ops may struggle to individually warrant attention from 3rd party aggregators due to their size. In a report by the National Rural Electric Cooperative Association (NRECA), a representative from a leading grid analytics startup was quoted as saying "We are absolutely looking for ways to get plugged into the co-op ecosystem... [but] have not taken the time to explore many of them individually, just given their size" (Stewart and Pinney 2022).

<u>Opportunities:</u>

The development of open-source data-sharing for DERs and VPPs can help reinforce reliability guarantees by providing utilities a more robust basis for forecasting and managing the impacts of DERs. In developing trusted, accessible databases and probabilistic models for examining VPP performance, research institutions and private organizations can help to alleviate burdensome demands for data collection and expedite regional pilot programs (Downing et al. 2023). The need for this type of service was reflected in the following quote from a G&T staff member:

> "I think [aggregating data on VPP performance and creating data sharing templates] is something that could be easily done by an industry player like NRECA [National Rural Electric Cooperative Association] or by a national lab. This market is very nascent, and the more involvement we have from these organizations, the better" (Interviewee 13).

For example, the open source Distributed Optimal and Predictive Energy Resources (DOPER) model, developed by Lawrence Berkeley National Lab, serves as a predictive control solution for DERs, forecasting and coordinating DERs and controllable loads to minimize total energy costs and provide various grid services. A more developed, publicly available network of modeling tools can help to resolve visibility barriers and assuage utility anxiety over DER predictability.

For co-ops to successfully navigate the complexities of DER interoperability and visibility, coordination between co-ops is essential. Co-ops engaging in effective data-sharing practices or developing software-driven solutions for DER coordination can work to act as a road map of best practices for other co-ops. This was reflected in the following quote from a staff member from a G&T co-op that created its own DERMS platform:

> "We are coordinating with other G&Ts across the country to figure what kinds of data needs and processes we need to incorporate into our DERMS capabilities so that it can meet co-ops needs. The positive about this coordination is that it can really allow us to share costs, but the downside is that this market is so nascent and messy" (Interviewee 13).

A case study for such collaboration can be found in Central Electric Power Cooperative's (CEPC) DERM program. CEPC launched the program, which utilizes DERMs software developed in-house, in 2018 in coordination with 11 of its 20 member coops. Since launching, the program has expanded to include Arizona Electric Power Cooperative G&T and Old Dominion Electric Power G&T, and has plans to build up to 25 MW of dispatchable resources over the next several years (Omotoso and MacAvoy 2023). Additionally, current efforts, such as NRECA's Community-Integrated Distribution Energy Resilience initiative, are working with co-ops of different sizes to test DERMS solutions across various distribution contexts, with the study results intended to inform co-ops nationwide. Participants of the program include co-ops and third-party aggregators, potentially allowing for further roadmaps for effective third-party collaborations (Cash 2024). In broadening engagement with third parties, co-ops can work to develop common data platforms to help provide both co-ops and third parties with common data pools and streamlined data request procedures, amplifying data access and reducing workforce burdens on individual co-ops in engaging third parties (Stewart and Pinney 2022).

In alleviating hesitance by member co-ops to engage with G&T data sharing initiatives, networks of collective action for planning, data gathering, and demand forecasting could be established between G&Ts and member co-ops to ensure equitable distribution of costs and benefits. This was reflected by a G&T staff member who called this the "shared control approach,"

> "We want to have a shared control concept to help manage demand response from a market perspective. We have visibility into the markets that our members don't, allowing us to see when it benefits everyone. Additionally, there are operational needs, such as managing feeder congestion or voltage issues, that can be addressed by dispatching load control or batteries. This shared control would allow DSOs [distribution system operators] to manage circuits more effectively, from the substation down to the end consumer" (Interviewee 11).

By removing DERMS from the exclusive purview of G&Ts and allowing member co-ops to call on and track DERs, member incentives for sharing data may be increased (Matthew Grimley and Chan 2023).

4.2.3 Standardization & Uniformity

<u>Barriers</u>

Significant challenges are encountered in deploying VPPs due to the absence of universally accepted operational standards. These challenges stem from various factors, including industry-wide variations in forecasting and assessment methodologies, discrepancies in data formats across organizations and platforms (incl. data fields, time resolution, level of granularity, aggregated versus individual DER visibility), and inconsistencies in service agreements and incompatible application program interfaces (APIs) between different types of DERs and VPP service providers. As one distribution co-op staff member explained, developing a DER integration strategy, given this lack of standardization in the VPP market, created a lot of complexities in program design that ultimately affected project economics (Interviewee 02). Additionally, incompatible APIs and non-standardized service agreements between DER manufacturers and DERMS providers can cause certain OEMs to be left out of co-op led DERMS platforms.

> "We were working with a battery OEM and he said it's possible that depending on the DERMS you're working with, we may not have an integration" (Interviewee 10).

Additionally, there is a lack of uniform interpretation of existing standards for DER interconnections and reliability, further complicating the landscape (Warren, 2023). Attempting to manage these variations can significantly increase transaction costs for utilities and even VPP aggregators themselves, with one VPP platform company reporting an inability to share staff across 16 out of 20 VPP operations due to unique complexities within each operation (Downing et al. 2023). An example of how these variations can manifest can be seen in EV telematics programs, which require EV manufacturers to share data with third parties. Nissan and Volvo don't accommodate data sharing, whereas Ford and GM do if owners pay a monthly subscription fee, cutting into savings of program participants. Furthermore, without formalized data-sharing agreements between manufacturers and aggregators, the accessibility of data is at the whim of the manufacturer, potentially limiting the long-term stability of telematics programs (Luciani and Shober 2014).

Moreover, the reluctance of VPP and DER providers to share this data may stem from their desire to maintain a competitive advantage over others in the market. Another significant challenge is the variation in service agreements and codes of conduct across different DER types and VPP service providers. These agreements outline specific services, performance expectations, operational coordination protocols, compensation structures, and customer consent specifications. The variation in these agreements may arise from incompatible underlying IT and operational systems or internal organizational policies, complicating standardization processes and hampering interoperability and collaboration across utilities and VPP providers. This challenge was articulated by a G&T staff member who noted that variation in service agreements might cause certain OEMs to be left out of the DERMS program.

> "This market is so young, and what I have found is that certain OEMs don't want to work with certain DERMS providers due to issues around competition or whatever, but for us, what this has meant is that certain members with certain OEMs might be left out of our DERMS programs just because data integration fees are too high or because certain aspects of DERMS does not align with the OEMs" (Interviewee 10).

Lastly, the myriad of interconnection rules and standards also complicates the liftoff of virtual power plants, especially for market-facing VPPs (Downing et al., 2023; Martini et al., 2020).

Solutions

Addressing these challenges requires concerted efforts to establish industry-wide standards, develop standardized methodologies for forecasting and performance measurement, and implement uniform data formats and sharing policies. Furthermore, there is a need to design standardized service agreements and codes of conduct, promote consistent interpretation of existing standards, and improve coordination among stakeholders to streamline DER interconnection processes. While this can be done through regional stakeholders or industry partners, co-ops can also establish internal standards for DERMS operations, as reflected by one distribution co-op staff member:

> "There is an old saying that when you know one co-op, you only know that one co-op. And that's true here. Industry partners can make all the standards they want but co-ops will continue to have unique needs and challenges, so there also needs to be a process internally to come up with some of the operational standards us and communicate those standards with DERMS providers" (Interviewee 02).

Improved coordination and resources are needed to overcome these challenges, and this coordination and resources should not only be developed by national organizations, such as the National Electric Reliability Council but also across the co-op system. To overcome the data-sharing and data format challenge, initiatives like the National Electric Reliability Council's (NERC) System Planning Impacts from Distributed Energy Resources Working Group (SPIDERWG) have developed standards on the type of data to gather when using or developing DER models, indicating a step towards addressing this challenge.

Furthermore, due to their vertically organized structure of generation & transmission cooperatives being owned by member distribution cooperatives, cooperatives can facilitate internal coordination and develop solutions tailored to standardizing VPP and DER operations. These coordination processes can allow co-ops to create standards and policies that work for their needs but also create opportunities for cost sharing.

> "One of the big advantages of setting up our own internal DERMS platform is that we can create standards and other things around this platform that fits our needs. Many of the other DERMS providers out there provide services that we may not need for our co-op, and this can lead to high costs. We are also allowing other G&T co-ops to utilize our DERMS programs, and any costs associated with upgrading our platform can be shared between us and our off-takers" (Interviewee 12).

Another example is the NOVA Power Portal established by the Great River Energy demonstrate the potential for cooperatives to streamline DER interconnection processes. Furthermore, G&T co-ops can provide capacity and resources to support the development of industry-wide standards and collaborate with stakeholders to design best practices for service agreements and interconnection processes. By leveraging their strengths and fostering collaboration, cooperatives can contribute to the widespread deployment of VPPs and enhance the reliability and efficiency of the power system.

4.3 VPP Valuation, Rates, and Incentives

VPPs are increasingly recognized for their ability to provide essential services to the distribution grid, such as peak shaving, voltage regulation, and enhancing grid reliability. Notably, as emphasized in sources like Hledik and Peters (2023) and Brehm et al. (2023), VPPs play a crucial role in optimizing the distribution side of the grid. This concept is illustrated in Figure 4.1, which indicates that most EV telematics programs' benefits are realized on the distribution side.

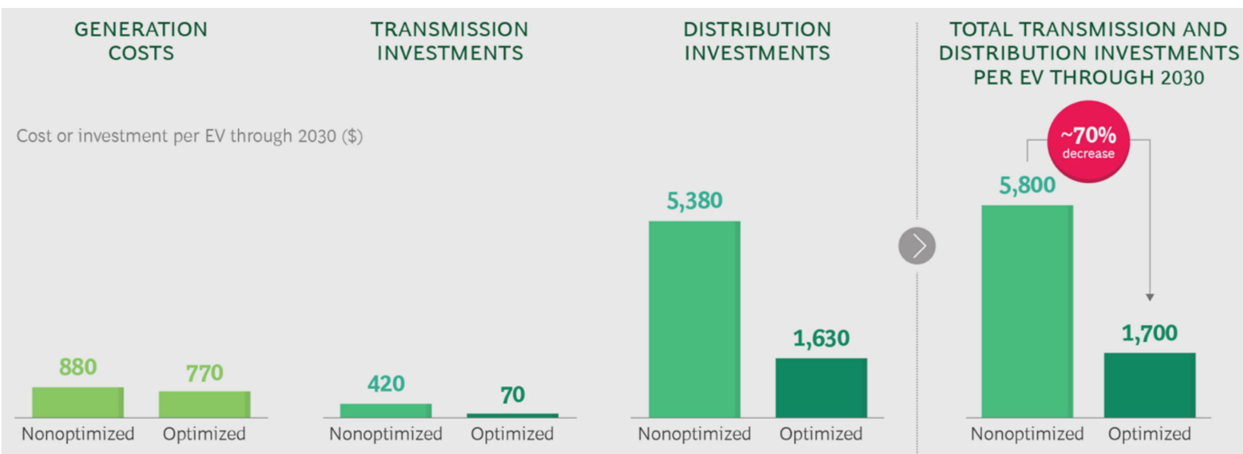

Figure 4.1: The Impact of Optimized EV Charging Location and Timing on Grid Investments. This figure shows that optimizing EV charging based on locational and timing constraints has the greatest impact on the distribution grid. Source: Sahoo, Mistry, and Baker (2021).

Additionally, due to unclear market participation and compensation rules, VPPs are also unable to fully maximize their value streams from wholesale markets. This section summarizes various barriers and opportunities with realizing distribution-side VPP benefits and wholesale market participation. Table 4.3 summarizes these challenges and their solutions as they are discussed in Sections 4.3.1 and 4.3.2.

Operations & Management	Barriers	Opportunities
Valuation of Distribution Side Benefits	• Unclear quantification of reliability and ancillary service benefits • Unclear allocation protocols for distribution benefits • Piecemeal reliability and interconnection regulations	• Industry associations (e.g. NERC) can set minimum reliability metrics. • Co-ops can develop processes to share reliability benefits equitably. • Co-ops or industry associations can develop customer reliability value guidelines. • Research groups or co-ops can expand reliability valuation models. • Co-ops can value non-wires alternatives benefits.
Valuation of Bulk-Power Benefits	• Limited IT and market interface capacity at the distribution co-op level • Lack of wholesale market rules for compensating BTM resources • Saturated wholesale ancillary markets	• Co-ops can partner with third-party providers to build IT and market-interface capacity. • Co-ops can participate in stakeholder forums, submit comments on proposed rulemakings, and collaborate with industry associations to make changes at the wholesale market level • Wholesale market operators can set clear rules on compensating BTM resources • Wholesale market operators can create opportunities for BTM resources to bid into wholesale ancillary services market

Table 4.3: Summary of Barriers and Solutions for Distribution and Bulk-Power VPP Valuation. This table summarizes various barriers and solutions to VPP valuation as they are discussed in Sections 4.3.1 and 4.3.2. Source: Interviews of Co-op Staff; and other literature sources

4.3.1 Distribution System Valuation

Barriers:

Because there are limited methodologies to property value these benefits, co-ops make decisions on VPP deployment based solely on economic variables like avoiding peak demand charges from their bulk-power supplier or accruing capacity payments from wholesale markets (Omotoso and MacAvoy 2023; Hertz-Shargel and Norris 2023). For instance, there are limited valuation methodologies that measure the reliability benefit of VPPs both from a customer's and utility's perspectives. Typically, the utility uses cost and benefit parameters that impact the utility's investment decisions to generate the value of grid resilience and reliability. However, this doesn't consider the full potential of demand flexibility because that happens at the customer's level. Current resilience valuation calculations do not incorporate granular customer dynamics and their response during extreme conditions and their impact on the overall power grid operation. For example, data are sparse regarding changes in customer behavior in response to outages (Hanif et al. 2022). As reflected in the quote below, one distribution co-op staff member mentions that this valuation challenge causes difficulties in planning for cost-reduction and grid-management strategies, such as deferring transmission & distribution (T&D) asset upgrades.

> "What I've found is that in reality, almost no one, and I have yet to find this, a good example of someone actually dispatching these EV chargers or batteries for a T&D constraint, whether that's a distribution transformer, whether that's a primary line, whether that's a substation transformer." (Interviewee 01)

Opportunities

One potential solution to address the challenges of accurately assessing and compensating VPP program participants is the development of standardized frameworks and methodologies for valuing the benefits derived from VPP integration into the distribution grid. To do this, co-ops can either partner with external stakeholders, such as industry associations or regulatory bodies, or establish clear internal guidelines for evaluating distribution side benefits of their VPP programs, such as reliability and voltage regulation. For example, co-ops can utilize SAIDI and SAIFI reliability metrics to develop reliability valuation methodologies, and in order to garner member buy-in, G&Ts can allow their distribution member co-ops to set their own valuation parameters, as one G&T staff member said in the quote below:

> "The other example is we have a cooperative that they use their SAIDI numbers, and they basically say, an hour of SAIDI is worth X dollars. And I'm not sure how they came up with that, but they do that internally to say, this is what reliability is worth to us. And that helps them drive decisions on where they do improvements to increase their SAIDI numbers." (Interviewee 14)

Co-ops can also strengthen their reliability valuation methodologies by incorporating VPP reliability benefits in their siting and investment decisions, even if project economics do not ultimately pencil out. This strategy was highlighted by a staff member of one distribution co-op who says,

> “If the project doesn't pencil for that, just purely financial value doesn't generate a return over a hurdle rate, it makes you kind of converge or sort of send those projects towards entities that value resilience. So that want to spend the extra money to configure a microgrid, for example, and put the battery on a microgrid or want the ability for their home to island.”

Coops can also incorporate customer perspectives on reliability service through customer experience and engagement surveys. Furthermore, implementing transparent and flexible compensation mechanisms, such as performance-based incentives or dynamic pricing structures, can ensure that program participants are fairly rewarded for their grid reliability and efficiency contributions.

Finally, to understand how rural co-ops can monetize distribution-side benefits to defer distribution asset upgrades, they can invest in non-wired alternatives (NWA) and adopt VPPs’ reliability and ancillary services benefits into NWA cost-benefit analyses (Paniagua 2023). To overcome the barriers associated with limited internal capacity at the distribution co-op level, distribution cooperatives can survey their member consumers and create alternative valuation strategies, as reflected by the following quote by a G&T staff member:

> "One of our member co-ops surveys its member [consumers] to understand how much they value reliability and what services they might want. Some folks said that they wanted to install an extra microgrid that would serve as a backup during weather. Our member co-op basically agreed to install the microgrid and charge member consumers a $25/month fee for O&M (operations and maintenance). So that $25 fee begins to quantify how much our members value reliability" (Interviewee 14).

Distribution co-ops can also explore partnerships and collaborations with G&T cooperatives and other industry stakeholders to utilize cutting-edge valuation methodologies. This collaborative approach can facilitate knowledge sharing, technical assistance, and resource allocation, ultimately enabling distribution cooperatives to maximize the value of VPP integration and better serve their customers.

4.3.2 Bulk Power System Valuation

Barriers:

One significant challenge facing rural electric cooperatives regarding VPP interactions with the bulk power system, particularly in wholesale energy markets, is the uncertainty and delays in regulatory frameworks and market rules governing DER aggregation. While policies like FERC 2222 and 841 have opened doors for DERs and storage resources to participate in wholesale power markets, RTOs/ISOs have proposed lengthy timelines for designing the rules governing these interactions. Some ISOs have projected timelines stretching as far as 2030, delaying the implementation of VPP programs that could provide valuable benefits to cooperatives (Franco 2021, 22). The lack of clear and expedited regulatory pathways creates uncertainty for rural cooperatives looking to monetize the benefits of VPP integration, hindering their ability to leverage these resources effectively in wholesale energy markets (Hertz-Shargel and Norris 2023). This is reflected by the following quote from a G&T co-op staff member:

> "We are in a market ecosystem where RTOs and ISOs have not created proper rules around how DERs and some of these other customer-sited assets can be deployed in the market. Part of that is being streamlined through FERC 2222, but still how these rules will actually show up at the wholesale market level is pretty nebulous" (Interviewee 11).

Moreover, rural electric cooperatives face challenges in capturing the full value of VPP benefits within the wholesale energy market structure. While VPPs offer opportunities for frequency regulation and resource adequacy at lower costs, cooperatives may struggle to quantify and monetize these benefits effectively. Developing wholesale rates that accurately reflect the value of VPP contributions requires in-depth analysis and understanding of market dynamics, which may be challenging for cooperatives with limited resources and expertise. Additionally, cooperatives must navigate complex market structures and regulations to ensure that they can fully capitalize on the value of their VPP programs within the wholesale energy market landscape. This requires collaboration with regulatory authorities, market operators, and industry stakeholders to develop transparent and efficient market mechanisms that recognize and reward the contributions of VPPs to grid reliability and stability.

Opportunities:

To address rural electric cooperatives' challenges in leveraging VPPs within wholesale energy markets, proactive engagement with regulatory authorities and market operators is essential. Cooperatives can advocate for expedited rulemaking processes within RTOs/ISOs to accelerate the integration of DER aggregation into wholesale market operations. This could involve participating in stakeholder forums, submitting comments on proposed rulemaking, and collaborating with industry associations to push for streamlined regulatory pathways (Omotoso and MacAvoy 2023; Talley and DiMisa 2023). By actively shaping the regulatory landscape, cooperatives can help reduce uncertainty and expedite the implementation of VPP programs, enabling them to realize the benefits more quickly.

Furthermore, rural electric cooperatives can explore alternative strategies to capture the full value of VPP benefits within wholesale energy markets. This may involve leveraging partnerships with third-party aggregators or energy service providers specializing in DER management and market participation. By outsourcing certain aspects of VPP operations and market engagement, cooperatives can access specialized expertise and resources, mitigating the challenges associated with limited internal capacity (Singh and Banunarayann 2024). Additionally, cooperatives can prioritize investments in data analytics and modeling capabilities to quantify better and monetize the value of VPP contributions to grid reliability and stability. By enhancing their analytical capabilities, cooperatives can develop more sophisticated pricing mechanisms and market strategies tailored to optimize the value of their VPP programs within wholesale energy markets. Overall, proactive engagement, strategic partnerships, and investments in analytical capabilities are key to overcoming the challenges and maximizing the benefits of VPP integration for rural electric cooperatives in wholesale energy markets.

4.4 VPP Planning Processes and Considerations

This section describes various barriers and opportunities around integrating virtual power plants in utility distribution, transmission, resource, and integrated planning processes, as summarized in Table 4.4 below. Integrated planning is a method that optimizes the orchestration of complex systems by integrating distribution, transmission, and resource planning alongside both demand and supply-side technologies. This holistic approach, supported by the National Association of Regulatory Utility Commissioners (NARUC) and the National Association of State Energy Officials (NASEO), involves grid modernization, distribution system planning, and resource planning. Despite many utilities initiating targeted efforts like evaluating non-wires alternatives, scaling these from pilots to full integration remains difficult. The potential benefits include cost savings and enhanced system reliability, but challenges like data availability, interoperability requirements, and stakeholder engagement persist. Transitioning from traditional, segmented planning to a comprehensive integrated approach demands rethinking assumptions and enhancing coordination across separate planning activities within utilities.

In rural areas, electric cooperatives often conduct formal planning at the G&T level, considering up to the transmission-distribution interface but often omitting DERs and other distribution solutions that could offer substantial system-wide value. Siloed planning might overlook the impacts of the rapid adoption of electrification technologies on long-term transmission and resource plans. Addressing DERs entails planning for changes on the distribution grid to be integrated into and informed by system-level planning, identifying both barriers and opportunities for integrating virtual power plants within utility distribution and planning processes.

Operations & Management	Barriers	Opportunities
Distribution Planning	• Lack of expertise or capacity might prohibit distribution co-ops from investing in comprehensive distribution planning. • Data aggregation and analysis required for granular locational forecasts. • Time-consuming and challenging tasks for distribution cooperatives, particularly those with limited internal capacity. • Inconsistencies and inefficiencies across cooperatives within the same G&T co-op system.	• Distribution co-ops create processes for comprehensive distribution planning by either partnering and cost-sharing with other distribution co-ops or asking their G&T to provide distribution-planning assistance as an as-requested service. • Work with external organizations to develop standard data sharing policies and forecasting methodologies. • Distribution co-ops should support investments into non-wired alternatives in their distribution planning processes. • Hosting capacity maps and analyses provided by G&T cooperatives to help distribution cooperatives identify and leverage DER assets.
Bulk Power Planning	• No clear framework on integrating VPPs into capacity expansion planning models for resource planning processes. • Limited historical data creates difficulty in assessing future DER adoption rates and load growth. • Siloed planning process create information asymmetries within one utility or across a co-op system.	• Co-ops should consider increased DER deployment rates in their resource planning processes and invest in data sharing agreements with DER manufacturers • Combine capacity expansion planning, asset investment decisions, and grid hardening into one planning process. • Co-ops should incorporate valuation methods discussed above to monetize the reliability and ancillary benefits of DER aggregation
Integrated Planning	• Co-ops should consider increased DER deployment rates in their resource planning processes and invest in data sharing agreements with DER manufacturers • Combine capacity expansion planning, asset investment decisions, and grid hardening into one planning process. • Co-ops should incorporate valuation methods discussed above to monetize the reliability and ancillary benefits of DER aggregation	• Collaborative efforts between G&T cooperatives and distribution cooperatives to pilot integrated planning studies. • Co-ops should mandate benefit-cost analysis around procurement of non-wired alternatives within their integrated planning processes. • Creating tools such as informational guides on market rules and policies to clarify roles and responsibilities for DER planning processes. • Engage DER manufacturer and distribution co-op to acquire visibility into DER performance and grid conditions data required for long-term load forecasting, fault analysis, and other distribution and resource planning processes. • Incorporate DERs into the resource planning process. • Data-sharing initiatives between distribution cooperatives and G&T cooperatives to provide visibility into member DER resources.

Table 4.4: Summary of Barriers and Solutions for VPP Planning Process & Considerations. This table summarizes various barriers and solutions to integrated VPPs into distribution, bulk power (transmission & generation), and integrated planning processes as they are discussed in Sections 4.4.1 to 4.4.3. Source: Interviews of Co-op Staff; and other literature sources

4.4.1 Distribution Planning

Barriers:

Integrated distribution planning (IDP) for rural electric cooperatives faces several barriers that hinder efficient and effective decision-making processes. One significant barrier lies in the complexity and resource-intensive nature of the distribution planning process itself, which prohibits many smaller, capacity-constrained distribution co-ops from participating in formal IDP processes (Martini, Taft, and Paladino 2020). When asked about their distribution planning capabilities, one co-op staff member noted that the resource and capital intensive nature of formal IDP processes causes them to engage in short-term (one to three year time horizon) and ad-hoc planning processes:

> “We've done a little bit of exploratory work in that regard here and there. We are very rural and small in size, and so we generally take the ‘spaghetti rule’ when it comes to distribution planning. You throw it all against the wall and see what sticks.” (Interviewee 03)

Access to granular locational data is also essential to IDP processes, and all data sharing barriers related to operational data, as mentioned in Section 4.3.2, might also apply to data sharing considerations for IDP processes. Granular locational forecasts, essential for assessing changes in load at various levels within the distribution grid, require meticulous data aggregation and analysis. However, operating SCADA systems and acquiring customer meter data can be time-consuming and challenging tasks for distribution cooperatives, particularly those with limited internal capacity and low DER penetration. Additionally, even if distribution co-ops invest in grid-edge technologies (e.g. SCADA and AMI) and have formal IDP processes, low DER penetration could mean that not enough historical data is available to make accurate dispatch decisions, as two distribution co-op staff members, whose co-op takes part in formal IDP process, mentions in the following quote:

> “In the last three or four years, we've implemented an AMI system where now we're getting that 15-minute reading. And so we now know to a much more granularly aspect what members do with their load. But that said, that's only

> been in place for a few years. Understanding that getting the history and having a better understanding, that's going to take some years to really understand what our members are doing." (Interviewees 05)

Moreover, the locational variation in data granularity further complicates the distribution planning processes, leading to inconsistencies and inefficiencies across cooperatives within the same G&T co-op system (Byrnett, Verclas, and Zetterberg 2021).

Another barrier arises in the realm of current distribution system assessments, where determining the condition of grid assets and forecasting performance over long time horizons present significant challenges. Monitoring and tracking the performance of distribution equipment, especially over 15 to 30-year time horizons, demands substantial time and financial investments, which may exceed the capabilities of many distribution cooperatives. Additionally, resilience and reliability analysis face barriers in coordinating distribution system impacts with the bulk power system, as distribution cooperatives often lack visibility beyond the substation or feeder level (Martini, Taft, and Paladino 2020). Finally, the system analyses encounter challenges such as complex power quality and protection analyses, exacerbated by the lack of locational understanding of DERs and their usage data. Distribution cooperatives typically conduct short-term modeling, limiting their capacity for long-term planning, further exacerbating the planning process's inefficiencies and uncertainties.

Distribution planning for sections of the grid with high concentrations of DERs requires visibility for load at the substation and feeder level, involving the development of granular locational and temporal forecasts that incorporate data on circuit-level DER adoption and patterns of use. These forecasts are necessary for accounting for net-load effects on the grid, particularly concerning DERs that have bi-directional grid-forming capabilities and meet certain reliability criteria (Martini, Taft, and Paladino 2020).

Solutions

Despite these barriers, solutions and opportunities exist for rural electric cooperatives to enhance integrated distribution planning processes. Collaborative efforts between G&T cooperatives and distribution cooperatives can provide critical support and resources to overcome these challenges. G&T cooperatives can offer coordination, data analysis capacity, and access to technologies like SCADA systems, empowering distribution cooperatives in their planning endeavors (Cadmus Energy 2023) By providing visibility into resources on the distribution grid; distribution cooperatives can incorporate DERs into resource planning processes at the G&T level, fostering synergy and efficiency across the cooperative network. Furthermore, G&T cooperatives can develop best distribution planning practices tailored to distribution cooperatives' needs, promoting consistency and standardization in planning methodologies.

Through data-sharing initiatives, distribution cooperatives can provide visibility into member DER resources to their G&T cooperative power suppliers, facilitating informed decision-making and resource optimization (Vijaykar 2021). Additionally, capacity hosting maps and analyses provided by G&T cooperatives can help distribution cooperatives identify and leverage DER assets during reliability events, enhancing grid resilience and reliability (Gibson 2020).

Moreover, G&T cooperatives can collaborate with third-party providers to offer low-cost data analysis and contracting services to distribution cooperatives, addressing the time and cost barriers associated with long-term forecasting and performance monitoring. By providing their members with support to conduct IDP as a fee-for-service option, G&T cooperatives can incentivize cooperation and information exchange while ensuring more granular visibility into the distribution grid, ultimately fostering a more resilient and efficient electric grid for rural communities.

4.4.2 Bulk Power System Planning

Barriers:

Bulk power planning deals with resource adequacy, reliability, and resilience planning on generation and high-voltage transmission resources (National Association of Regulatory Utility Commissioners (NARUC) 2020). On the generation side, assets are entered into capacity expansion models as a selectable resource (Byrnett, Verclas, and Zetterberg 2021). However, the relative nascency of the VPP market has meant that there are no clear methodologies on how different components of a VPP that can be entered as an aggregated selectable resource into capacity expansion models that are used to meet resource planning objectives (Duncan et al. 2021). This was mentioned by one G&T staff member who said,

> "We model long-term planning on econometric dynamic optimization models that integrate existing power generators that we have on our system and potential generators that we price out and introduce to the model as assets. And unless we're able to aggregate all the characteristics of a virtual power plant into a selectable resource model, choosing those as a part of a least-cost plan going forward becomes challenging" (Interviewee 07)

Furthermore, limited historical data and the customer-centric value proposition of DER adoption – along with current visibility into the distribution grid – makes it difficult for resource planners at the G&T level to accurately forecast variables, such as load growth and future DER adoption rates, that are important inputs into capacity expansion models, as reflected by the same G&T co-op staff member as above.

> "Now, our ability to forecast additional resource growth, that's something that's a little bit different. And I liken that to our ability to forecast distributed energy resources and small solar. I think it's hard to do because the value proposition is so dependent on each individual customer that's considering these potential assets. We can't forecast whether a small business… is going to find it cost-effective to install a demand response resource or a certain level of DSM." (Interviewee 07)

On the transmission side, siloed planning processes and inadequate DER modeling practices create barriers to considering VPP benefits in long-term transmission planning processes.

First, reactive planning transmission processes that do not consider distribution-side constraints can increase interconnection delays (Howland 2023). Additionally, current transmission planning processes often tend to be siloed between regions, reactive to specific needs, and narrowly focused on the benefits considered (focused on local area benefits instead of system-wide, quantifies only direct benefits based on the need considered). Transmission investments are also often established in forward-looking ten-year plans developed by various regional forums with limited interregional coordination and varying planning processes (e.g., ISO/RTO plans, West Connect, and sub-regional forums) (White et al. 2024; Luciani and Shober 2014).

Ensuring the visibility and controllability of DERs is a concern in grid operations. However, adequate modeling of DERs in transmission-planning studies is required to address concerns about ensuring adequate bulk system reliability in terms of voltage and frequency performance under high levels of DERs and to explore the contribution of new emerging technologies. Furthermore, these modeling techniques also do not meet certain criteria set by DER interconnection standards like IEEE 1547 (Electric Power Research Institute 2019).

Opportunities:

Co-ops and energy practitioners can think about several avenues to incorporate VPPs into their long-term bulk power planning processes. First, to accurately insert different components of a VPP as an aggregate in capacity expansion models, utility planners at G&T cooperatives can take what is known as a "bundled planning approach." In this approach, different "bundles" of VPP resources (e.g., demand response resources, distributed generation, storage, etc.) are modeled as selectable resources (Antonopoulos et al. 2021). A notable and recent example of such modeling techniques can be found in the most recent integrated resource plan filing for Xcel Energy Minnesota, where utility planners utilized this modeling technique to forecast the resource adequacy benefits of demand response and distributed generation technologies (Xcel Energy

2024). Such practices can also be extended to other types of DERs, like EV chargers and heat pumps, and planners across G&T cooperatives should coordinate internally to create standardized and co-op-specific assumptions around modeling DERs within their resource planning processes.

Additionally, standardized and non-siloed transmission planning can also be achieved through greater stakeholder engagement and transparency, and increased visibility and control of the distribution grid can help bulk-power planners think about how DERs can support reliability and resiliency needs at the transmission level.

4.4.3 Integrated Planning Considerations

Barriers:

Integrated planning for rural electric cooperatives represents an aspirational aim and a methodical approach to enhancing system efficiency. This process entails harmonizing distribution and resource planning while maximizing the effectiveness of demand- and supply-side technologies (D. G. Chan et al. 2019; Byrnett, Verclas, and Zetterberg 2021). The advantages of integrated planning are extensive, encompassing heightened stakeholder engagement in decision-making, cost reductions through refined resource allocation, and improved evaluation of investment risks (Schwartz et al. 2022). Nonetheless, implementing integrated planning faces persistent challenges, particularly in bridging the gap between assumptions, scope, objectives, and planning horizons across different planning initiatives.

First, a lack of integrated planning processes is, in and of itself, a major hurdle to planning long-term VPP investments. As a distribution co-op staff member mentioned,

> "I think as we get more and more DERs into our grid, the lines between the transmission, generation, and generation side are becoming more and more blurred. So I really see a need to coordinate activities across all three of these segments to really understand how we can utilize some of these behind-the-meter resources." (Interviewee 11)

Another challenge is that the lack of streamlined policies and standards creates challenges for data integration and sharing across the co-op system, from the member consumer up to the distribution co-op and the G&T. Without access and visibility into granular, locational, and historical distribution grid data, utility planners might not be able to accurately forecast how DERs might impact system-wide reliability and resilience needs. The lack of locational data on DER availability also creates challenges around DER deployment and market saturation. For example, one co-op staff member mentioned that there is a real need to figure out "which DERs are where" so that their co-op can make investment decisions that deploy DERs to least-cost areas. Furthermore, even if co-ops manage to create data sharing and standardization policies across the entire system, current DER modeling techniques are insufficient in capturing the reliability and resiliency benefits of DERs as an aggregate (Carvallo et al. 2018; Carvallo, Frick, and Schwartz 2022).

Significant heterogeneity across member co-ops within a single G&T can also cause challenges with integrated planning processes. Co-op member diversity spans multiple dimensions: rural versus suburban settings, variations in co-op staff numbers, a focus on residential versus commercial sectors, wholesale market interaction, and varying degrees of DER penetration and experience with third-party DERMS providers. As another G&T staff member noted, these heterogeneity factors can create significant equity and fairness concerns across a G&T's member co-op as cost deferred by one member distribution co-op's adoption of DERMS can shift costs onto smaller distribution co-ops (Interviewee 07 and 08).

Furthermore, distribution cooperatives may lack comprehensive proof-of-concept studies/examples that utilize DERs as a supply-side resource, particularly in rural settings with different governance and operational structures. As is reflected by the following quote from a distribution co-op staff member, this lack of evidence often leads to skepticism and reluctance to embrace new technologies, impeding progress toward integrated planning.

> "I think there needs to more case studies and success stories on various VPP use cases for rural co-ops. It should shed light on what others in these sectors are

> accomplishing. There's a prevalent discussion about potential actions—this is a common theme I notice in communications from vendors or investor-owned utilities, focusing on possibilities. However, my interest leans more toward actual achievements—what has already been implemented and proven effective." (Interviewee 03).

The absence of consistent roles and responsibilities for DER planning processes also exacerbates the challenges. As discussed above, several interviewees mentioned that distribution co-ops and G&Ts have mixed views on how much control G&Ts should have on the low-voltage side of the substation. Some interviews also mentioned that some distribution co-ops would like to have ownership of engaging and communicating with their member-consumers, while G&T's role should be on responding to market signals. On the other hand, one staff member from a small distribution co-op mentioned that "they would really like for the G&T to handle everything." Whichever the approach, G&Ts should clearly define roles for their member co-ops when partaking in integrated planning processes.

Opportunities:

Rural electric cooperatives face unique challenges in adopting integrated planning processes due to diverse geographic and operational contexts. Integrated planning, essential for managing the complexities of distributed energy resources (DERs) and transitioning to more sustainable and efficient operations, requires a systematic approach that considers both technical and community-based aspects.

One viable solution is the adoption of a hybrid cooperative model that combines elements of top-down (Total Transmission System Operator, TSO) and bottom-up (Total Distribution System Operator, DSO) approaches. This adaptable model allows for a nuanced application that caters to the specific needs and capacities of different member co-ops. It balances centralized guidance with the autonomy of local cooperatives, enabling each to navigate their transition towards integrating DERs according to their capability and pace. There are successful examples of G&Ts adoption this approach. For instance, North Carolina Electric Cooperative (NCEMC), a

G&T serving 19 distribution co-ops, conducted two pilot studies with the Duke Balancing Authority and the PJM Regional Transmission Operator to understand how NCEMC can act as a DSO and streamline DER data integration and share information with bulk power market operators (North Carolina Electric Cooperatives and PJM Interconnection LLC 2020; Talley and DiMisa 2023).

Rural co-ops can also enhance stakeholder engagement for effective governance by forming collaborative teams that bridge decision-making across the system. This could involve establishing advisory groups consisting of co-op staff and consumers who are actively using DERs, facilitating dialogue that informs policy adjustments and new initiatives. This participatory approach ensures that diverse stakeholder voices are considered in the planning process, promoting transparency and buy-in from the community (D. G. Chan et al. 2019).

In terms of operations, co-ops should focus on integrating data into common platforms. This enhances visibility and interoperability, crucial for managing the interplay between DERs and traditional grid operations. Creating integrated grid architecture documents can help define roles and operational protocols, setting the stage for more effective coordination and deployment of DERs (Howland 2023; Vijaykar 2021). Expanding pilot program opportunities is essential for DER interconnection and deployment. These pilots can test and refine processes for DER integration, from smart thermostats to larger-scale resources like community solar projects. Learning from these pilots can guide broader implementation strategies, helping co-ops understand the operational and economic impacts of DERs and tailor their approaches to local conditions. On the commercial and market activity front, rural co-ops can explore à la carte options for DER management and compensation. This flexibility allows co-ops to tailor services to their needs and capacities, facilitating gradual adaptation to market changes and new technologies without overwhelming their operational structures (D. G. Chan et al. 2019). Lastly, for grid planning and upgrades, co-ops should align their budgets and planning forecasts with enhanced modeling tools that consider both current and future grid capabilities. This involves collective data access and integrated planning that co-optimizes DER services with traditional grid upgrades. By establishing a unified framework for data management and planning, co-ops can better anticipate and respond to shifts in energy demand and generation.

By adopting these integrated planning strategies, rural electric cooperatives can not only improve their operational efficiency and grid reliability but also play a pivotal role in advancing the energy transition in their communities. This proactive approach ensures they remain competitive and responsive to the evolving energy landscape, ultimately benefiting their members and the broader grid network.

5 Discussion: Crosscutting Themes across Co-op Led VPP Programs

The section above highlights various barriers and opportunities to VPP liftoff in the rural co-op space. Rural co-ops have a significant opportunity to leverage their vast experience in deploying demand response programs. However, the member-owned, nonprofit structure of rural co-ops, along with the nascency of the VPP market, creates significant challenges for co-ops and other energy providers to deploy VPPs at scale and maximize the benefits that utilities can get out of such programs. For instance at the G&T level, which are governed by board of directors comprised of directors of the member distribution co-ops, disagreements between the G&T and one member on different aspects of DERMS and VPPs can lead to tensions between a member and other member co-ops (Klass and Chan 2020). Additionally, the independent and autonomous nature of rural co-ops makes it difficult to establish data sharing and control agreements between G&Ts and their member utilities because distribution co-ops might be unwilling to give up control of their grid operations or might have concerns around privacy and security when considering data sharing policies (Cadmus Energy 2023). This is particularly reflected by the fact that distribution co-ops might be unwilling to share control and access of the distribution system with their parent G&Ts. In this section, I build off the information presented in Sections 2 and 4 to discuss some overall considerations for deploying virtual power plants among rural electric cooperatives. Across the interviews with co-op staff members, I found that the emerging VPP market and its lack of standardization pose significant challenges for rural co-ops in designing VPP initiatives. These challenges hinder the effective implementation and operation of VPPs and slow the adoption and integration of distributed energy resources (DERs). To successfully deploy VPPs, co-ops must focus on flexibility, cooperation, and engagement. These core concepts are crucial for navigating the market's nascent state and lack of uniformity, enhancing co-ops' operational effectiveness, adaptability, and community support.

5.1 Biggest Barriers: Nascency of the VPP Market & Standardization

The VPP market's nascency and the associated lack of standardization stood out as the main barriers for rural electric cooperatives looking to create VPP programs. These barriers challenge the implementation and operational efficiency of VPPs and impede the broader adoption and integration of DERs within these cooperatives.

5.1.1 Nascency of the VPP Market:

The emerging VPP market is marked by rapid technological advancements and evolving regulatory frameworks, which often outpace the ability of rural co-ops to adapt quickly. This market immaturity leads to several specific challenges:

1. **High Integration Costs:** The nascent nature of the market means that technologies and practices are not yet standardized, leading to high costs for integrating VPP systems. These costs can be prohibitive for co-ops, particularly those in rural areas with limited financial resources.

2. **Complexity in Program and Process Development:** The lack of established protocols and benchmarks for VPP operations makes it challenging for co-ops to develop efficient and effective programs. This results in increased operational complexity and higher overheads as co-ops endeavor to navigate an underdeveloped market.
3. **Risk of Obsolescence:** Given the rapid evolution of technology in a nascent market, there is a significant risk that investments in specific technologies or systems may become obsolete quickly. This potential for rapid obsolescence can deter co-ops from making substantial investments in VPP technologies.

5.1.2 Lack of Standardization across VPP Providers and Off-takers

The absence of standardized processes and technologies in the VPP market complicates the deployment and scalability of VPP programs within co-ops. This lack of standardization manifests in several ways:

1. **Interoperability Issues:** Without standardization, the diverse array of DER technologies and management systems may not be interoperable, complicating the aggregation and management of these resources across a co-op's network.
2. **Varying Regulatory Environments:** The regulatory landscape for VPPs is still forming, with significant variations across jurisdictions. This inconsistency can create confusion and compliance challenges for co-ops, which often operate across multiple regulatory environments.
3. **Difficulties in Valuation and Compensation:** The lack of standard methods for assessing the value created by VPPs complicates the process of setting fair compensation rates for DER owners and operators, which is crucial for ensuring participant engagement and the long-term viability of VPP programs.

5.1.3 Impact on Co-op Led VPP Programs

The combination of these factors — the nascency of the VPP market and the lack of standardization — particularly impacts rural electric cooperatives in several ways:

4. **Increased Barriers to Entry:** The upfront costs and complexity of initiating VPP programs can be daunting for co-ops, especially those with limited capital and expertise in new technologies.
5. **Operational Inefficiencies:** The absence of standardized processes can lead to inefficiencies in VPP operation, as co-ops may need to custom-tailor systems and procedures, increasing both the cost and time required for VPP deployment.
6. **Challenges in Stakeholder Engagement:** The uncertainty and complexity associated with a nascent and non-standardized market can make it difficult for co-ops to engage members and other stakeholders effectively, thereby hindering the adoption of VPP programs.

5.2 Biggest Success Factors: Flexibility, Cooperation, and Community Engagement

Across the interviews, the successful deployment of VPPs by rural electric cooperatives depended significantly on three core concepts: flexibility, cooperation, and engagement. These concepts can provide solutions to overcome the inherent challenges presented by the nascent VPP market and lack of standardization, ultimately enabling co-ops to enhance their operational effectiveness, adaptability, and community support.

5.2.1 Flexibility in Technology and Policy Adoption:

Flexibility is crucial for co-ops to navigate the rapidly evolving landscape of VPP technologies and regulatory frameworks. By adopting a flexible approach, co-ops can:

1. **Adapt to Technological Changes:** Co-ops can adopt modular and scalable VPP systems that allow for incremental upgrades as newer technologies become available. This approach mitigates the risk of obsolescence and ensures that the systems remain at the forefront of technological advancements.
2. **Innovative Financing and Business Models:** Flexibility in financial modeling, such as offering various financing options like on-bill financing, grants, and incentives, can make the initial costs of DERs more manageable for members. Flexible business models, including partnerships with technology providers, can also spread out the investment risks associated with VPPs.

3. **Tailored Solutions for Diverse Needs:** Given the varied nature of the communities they serve, co-ops can develop VPP solutions that are customized to local needs and conditions, enhancing the effectiveness and acceptance of these programs among their members.

5.2.2 Cooperation among Stakeholders & Cooperatives

Cooperation among co-ops, members, and other energy stakeholders is essential for sharing resources, knowledge, and best practices in VPP deployment. Cooperative efforts can be manifested in several ways:

1. **Partnerships with Technology Providers:** By collaborating with developers of DER technologies and VPP platforms, co-ops can gain access to cutting-edge solutions and shared expertise, which can facilitate smoother integration and operation of VPPs.
2. **Joint Ventures with Other Co-ops:** Collaborations with other rural electric cooperatives can allow co-ops to pool resources, share costs, and mitigate risks associated with VPP projects. These partnerships can also foster a more standardized approach to VPP deployment across different regions.
3. **Engagement with Regulatory Bodies:** Active cooperation with local, state, and federal regulatory agencies can help co-ops influence policy-making processes that affect VPP operations. This includes advocating for favorable regulatory conditions that support the financial and operational viability of VPPs.

5.2.3 Community & Member Engagement

Member and community engagement is vital for the acceptance and success of VPP initiatives. Co-ops need to focus on:

1. **Educational Initiatives:** Providing ongoing education and information about the benefits and operations of VPPs can help demystify the technology for co-op members and foster a deeper understanding of how individual and collective contributions support broader grid stability and sustainability.
2. **Transparent Communication:** Keeping lines of communication open with members about the goals, processes, benefits, and challenges of VPP projects ensures that member expectations are managed effectively. Transparency in operations and results also builds trust and strengthens member relationships.

3. **Incentive and Reward Programs:** To encourage participation, co-ops can develop incentive programs that reward members for their contributions to the VPP, such as reduced electricity rates, rebates, or direct payments for energy provided back to the grid.

By embracing flexibility in their operational and technological strategies, fostering cooperation among a broad network of stakeholders, and actively engaging with their member base, rural electric cooperatives can effectively implement VPP programs. These strategies not only address the challenges of the nascent VPP market but also align with the cooperative principles of democratic member control, economic participation, and concern for the community, thereby enhancing the resilience and sustainability of rural electric grids.

6 Conclusion, Recommendations, and Limitations

Rural electric cooperatives (co-ops) face distinct challenges and opportunities in the virtual power plant (VPP) market due to its newness and lack of standardization. Despite these obstacles, co-ops can succeed with a focus on flexibility, cooperation, and community engagement. Flexibility allows co-ops to adapt to technological changes and regulatory shifts without disruptions. By adopting flexible technological solutions and financing models, they can integrate distributed energy resources (DERs) into their systems, reducing the risk of obsolescence. Cooperation among co-ops and with external stakeholders, such as technology providers and regulatory bodies, is essential. Collaborative efforts lead to shared learning, cost-sharing, and standardized approaches, benefiting the entire cooperative network. Partnerships also help in advocating for favorable regulatory frameworks supporting VPPs' economic and operational viability. Community engagement is critical. Co-ops can secure member participation by communicating VPPs' benefits, like grid stability, cost savings, and energy independence. Educational initiatives that demystify VPP technology foster trust and support among members, ensuring active community backing. Addressing initial high costs and operational complexities is vital. Co-ops should explore innovative financing models, such as on-bill financing, grants, and incentives, to reduce the financial burden on members. Supporting policies should make renewable energy technologies and energy efficiency upgrades accessible and affordable, especially in rural areas. By leveraging their community roots, cooperative business model, and commitment to localized service, co-ops can overcome VPP market challenges and lead toward a sustainable and resilient energy future. Their successes can serve as models for similar initiatives worldwide, showcasing the benefits of operational efficiencies, cost savings, enhanced community relations, and environmental stewardship.

The rest of this section provides a series of recommendations on how VPPs can be leveraged to spur energy democracy and energy justice in co-op territories, and how co-ops with limited capacity and low deployment of demand response programs can create their own VPP programs.

6.1 Utilizing VPPs to Advance Energy Justice and Energy Democracy

Rural co-ops have a unique opportunity to leverage VPPs to enhance wealth for their member consumers and promote energy democracy and energy justice. VPPs integrate Distributed Energy Resources (DERs) such as solar panels, battery storage, and demand response systems to create a virtual power entity that can provide grid services and participate in energy markets. This technology offers significant potential to decentralize power generation and democratize energy access, aligning with the cooperative principles of local control and member benefits.

6.1.1 VPPs as a Lever for Wealth Creation

The cooperative model is inherently suited to the deployment of VPPs. Co-ops are member-owned and operate on a not-for-profit basis, focusing on providing benefits to their members rather than maximizing profits. This structure allows co-ops to prioritize investments in DERs that serve the community's needs, such as reducing energy costs, improving grid resilience, and supporting local economic development. VPPs enable co-ops to generate revenue by participating in energy markets and providing grid services such as frequency regulation, voltage support, and demand response. For instance, Green Mountain Power in Vermont has successfully utilized residential batteries to avoid peak demand charges and generate revenue from grid services, which is then reinvested into the community.

By integrating DERs into a VPP, co-ops can reduce their reliance on expensive peaker plants and lower their overall energy procurement costs. This cost reduction can be passed on to members through lower electricity rates. Additionally, VPPs can defer the need for expensive grid infrastructure upgrades by managing demand and smoothing out load peaks. Investment in DERs creates local jobs in installation, maintenance, and operation of these systems. By supporting local businesses and workforce development, co-ops can stimulate economic growth within their communities.

6.1.2 VPPs as a Level to Promoting Energy Democracy

VPPs offer a pathway to greater community engagement and empowerment in the energy sector. By decentralizing energy production and management, VPPs enable local communities to have a direct stake in their energy futures. This participatory approach aligns with the principles of energy democracy, where decisions about energy production and distribution are made collectively by those most affected. VPPs can be structured to ensure that DERs are owned by the community or the co-op members themselves, fostering a sense of ownership and control over local energy resources. This aligns with the principles of energy democracy, which emphasize local and equitable control over energy systems.

Co-ops can design VPP programs to be inclusive, ensuring that low-income households and marginalized communities have access to the benefits of DERs. This can be achieved through targeted incentives, on-bill financing, and grants that reduce the upfront cost barriers for participating in VPPs. Co-ops operate on a democratic governance model, where members have a say in decision-making processes. This model can be leveraged to ensure that the deployment of VPPs aligns with the community's values and needs, promoting transparency and accountability in energy decisions.

6.1.3 VPPs as a Lever to Promote Energy Justice

VPPs can help address energy inequities by providing affordable and reliable energy to underserved communities. By reducing energy costs and enhancing grid reliability, VPPs can alleviate energy poverty and improve living conditions for low-income households. VPPs support the integration of renewable energy sources, reducing reliance on fossil fuels and lowering greenhouse gas emissions. This transition to cleaner energy sources can significantly improve air quality and public health in rural communities, which often suffer from higher pollution levels due to proximity to peaker plants.

VPPs enhance grid resilience by distributing energy resources across a network, making it less vulnerable to disruptions. This resilience is particularly important for rural areas that are more prone to extreme weather events and grid failures. By ensuring a stable and reliable energy supply, VPPs can help rural communities better adapt to climate change impacts.

One of the main barriers to VPP deployment is the high upfront cost of DERs and the necessary control infrastructure. Co-ops can address this challenge through innovative financing models, such as on-bill financing, grants, and partnerships with technology providers. Additionally, leveraging federal and state incentives can reduce the financial burden on co-ops and their members. Integrating diverse DERs into a cohesive VPP requires advanced control systems and expertise. Co-ops can overcome this barrier by partnering with technology providers and investing in workforce training programs to build the necessary skills within the community. Existing regulatory frameworks may not fully support the integration of VPPs into the grid. Co-ops can play a proactive role in engaging with regulators and advocating for policies that facilitate VPP deployment and recognize the value of distributed energy resources.

6.2 VPP Considerations for Co-ops with Low DER Investment

"When you know one co-op, you only know one co-op." This saying captures the essence of the diverse and unique nature of rural co-ops across the United States. Each co-op operates under different conditions, serves varying member needs, and faces distinct challenges. Consequently, the extent to which co-ops have invested in advanced technologies like demand response, DERs, and VPPs varies dramatically. While some co-ops have made significant strides in integrating these technologies, many others have limited investments and face substantial barriers to adopting such innovations. Much of this paper relies on the experience of rural co-ops that have made significant investments in deploying VPPs. While this demonstrates how successful co-op-led programs can be implemented, it lacks guidance for co-ops with limited investments in DERs and VPP-enabling technologies on how to create their own VPP programs. This section provides some recommendations that rural co-ops with limited DER investments can consider to deploy their own VPP programs.

6.2.1 Strategic Planning and Technical Development

To begin with, co-ops need to understand the fundamental concepts and benefits of VPPs and DERMS. A VPP aggregates various DERs, such as solar panels, battery storage, and demand response systems, to form a single virtual power plant that can provide grid services and participate in energy markets. DERMS are software platforms that manage and optimize the operation of these distributed resources, enabling co-ops to efficiently control and dispatch DERs to meet grid demands and provide ancillary services (Omotoso & MacAvoy, 2023).

Building the necessary technical capabilities is crucial for co-ops. This includes investing in software platforms for DERMS that can integrate with existing grid management systems. These platforms should be capable of handling real-time data, forecasting demand and generation, and executing control commands to balance the grid. Training staff and collaborating with technology providers can help co-ops build the expertise needed to operate these advanced systems (Omotoso & MacAvoy, 2023). Implementing scalable and flexible solutions that can grow with the co-op's needs is essential. Starting with pilot projects can help co-ops test and refine their VPP strategies before expanding. Flexible solutions that accommodate various DERs and adapt to changing grid conditions will be more effective in the long run. Cloud-based orchestration platforms, for example, can provide the scalability and flexibility needed to manage a growing portfolio of DERs (Camus Energy, 2022).

6.2.2 Financial and Regulatory Considerations

One of the primary considerations for co-ops looking to develop VPP programs is leveraging federal and state incentives. The U.S. Inflation Reduction Act provides significant financial support for clean energy projects, including grants and loans specifically for electric cooperatives. These funds can be used to offset the initial costs of DERs and VPP infrastructure, making it more feasible for co-ops to invest in these technologies (Utility Dive, 2023). Navigating regulatory and policy challenges is another critical consideration. Co-ops must stay informed about relevant regulations and work with policymakers to create a supportive environment for VPP development. This includes advocating for policies that recognize the value of distributed resources and provide fair compensation for the services they provide. Collaborative efforts with other co-ops and industry stakeholders can strengthen advocacy efforts and lead to more favorable regulatory outcomes (Utility Dive, 2023).

6.2.3 Community Engagement and Cybersecurity

Successful VPP programs require active engagement and participation from member-consumers. Co-ops should educate their members about the benefits of DERs and VPPs, including potential cost savings, increased reliability, and environmental benefits. Incentive programs, such as rebates for installing solar panels or battery storage, can encourage members to invest in DERs. Clear communication about how member data will be used and the benefits of participation can build trust and support for VPP initiatives (Abhyankar et al., 2023).

As co-ops adopt more advanced technologies, ensuring cybersecurity is paramount. Protecting DERMS and VPPs from cyber threats involves implementing robust security protocols, regular monitoring, and updating systems to address vulnerabilities. Co-ops should also provide training for staff on cybersecurity best practices and establish clear procedures for responding to potential cyber incidents (Omotoso & MacAvoy, 2023).

By addressing these key considerations, rural electric cooperatives can successfully develop and manage their own VPP programs. Leveraging federal and state incentives, enhancing distribution-level visibility, building technical capabilities, implementing scalable solutions, engaging member-consumers, addressing regulatory challenges, enhancing cybersecurity, and building partnerships are all critical steps in this process. Through strategic planning and collaboration, co-ops can harness the benefits of VPPs to provide reliable, affordable, and sustainable energy to their member-consumers, while also promoting energy democracy and justice.

6.3 Limitations of this Study and Areas of Future Research

In this study, I adequately describe the various barriers and opportunities to VPP liftoff by matching points from the VPP literature to industry insights gathered from co-op staff interviews. However, my work has real limitations. First, given the time constraint and the quality of each interview, my analysis captures various VPP barriers and opportunities only at a very high level. Additionally, I took a scattered coding approach, with my codes largely coming from the literature, and while I did “ground” my analysis by creating new codes throughout the coding process, a more serious coding approach that is based on some theoretical framework would be able to find missed details within my data.

Another factor is that most of the co-op staff whom I interviewed were based in departments that had oversight of DERMS operations and management; however, as my paper points out, creating a DERMS program is a task that takes coordination across multiple utility departments, including planning, member engagement, and regulatory services. While I was able to interview some staff from departments like planning and member services, future research in this space should consider speaking with additional co-op staff within the *same* cooperative to understand the various challenges and opportunities co-op staff members face in coordination across different departments. Finally, my work only considers that perspective of rural co-ops, and in order to get a holistic picture of VPP development in the co-op space, future researchers should also consider interviewing third-party aggregators, DERMS providers, and industry associations to understand their perspective on working with co-ops to create VPP solutions.

7 Appendices

7.1 Appendix A: Full Interview Protocol

Introduction

Thank you again for meeting with me today. As brief background to our conversation, I am a graduate student at the University of Minnesota's Humphrey School of Public Affairs. For my final capstone project, I am conducting a research project to inform how rural electric cooperatives in the United States are conducting planning, operations, and deployment of distribution-side resources to meet long-term co-op goals of reliability, sustainability, and affordability.

Some examples of these resources could be distributed energy resources, such as electric vehicles chargers, smart thermostats, distributed generation & storage, heat pumps, or other general load-management technologies/programs. Some cooperative utilities are meeting these goals through aggregation of distributed energy resources by implementing distributed energy resources management software (DERMS) or through virtual power plants. My questions today are aimed at answering the overarching research question of this study: **What kinds of coordination, planning activities, and investments are rural electricity cooperatives thinking about to enable distribution-side assets to advance system-level goals of reliability, affordability, and sustainability?**

I am speaking with staff members from your cooperative, along with other cooperatives throughout the country, to understand how consumer-owned utilities are thinking about programs, policies, and processes that can support virtual power plant development.

If it is okay with you, I would like to record our conversation so that I can summarize your responses in an eventual summary document. All takeaways would be anonymized to protect your identity. Furthermore, while your participation in this study poses little risk to you or your organization and nor does it provide any direct benefits, your participation in this study is completely voluntary. You can choose to leave at any time you see fit. I'll also be taking some notes on our computers as I go. If it is okay with you, I would like to now begin recording.

Interview Questions:

1) **Could you briefly take a moment to introduce yourself, your role, how long you've been with the organization, and what your general duties are?**
2) **Thinking about distribution-side resources (e.g. DERs such as electric water heaters, heat pumps, solar + storage, electric vehicles, demand response, etc.), what programs are in place to deploy these assets?**
   a) Prompt: How effective have been these programs?
3) **What value do these resources currently – or will in the future – provide to the larger system in the form of energy, capacity, reliability, or other value streams?**
   a) Prompt: What is the history of deploying load-control w ithin the co-op system?
   b) Prompt: What best-practices have you gained form these programs/policies/technologies?
4) **Thinking more broadly, what challenges hinder distributed-side resources from providing system-wide value?**
   a) Prompt: What challenges hinder the deployment of DERMs/VPP programs within the cooperative system?
   b) Prompt: Specifically, what challenges do the enrollment, upfront cost, and lack of standardization pose for distribution side resources?

5) **What kinds of process do you currently have in place to take into account distribution side resources into your long term planning processes?**
   a) Prompt: What processes are you considering for the future?
   b) Prompt: How are DERs incorporated into your long-term resources planning process?
   c) Prompt: How are DERs incorporated into long-term distribution (or transmission) planning?
   d) Prompt: What kinds of stakeholders do you consider when incorporating distribution-side assets, such as DERs or load-management technologies/programs, into long-term planning process?
   e) Prompt: What role do virtual power plants, DERMS programs, or resource aggregation programs play in long-term planning processes?
   f) Prompt: What current or future rules – such as data sharing between distribution cooperatives and G&Ts, flexible financing and power supply contracts, etc. – can enable distribution side resources from providing system-level benefits?
6) **What potential, if any, do you see for DERs to derive value from the bulk power system?**
   a) Prompt for G&T & Market-Facing VPPs: How does the absence of rules for DER aggregation or FERC 222 in your RTO present challenges for your cooperative and VPP program?
      i) Follow up: What programs/process/policies is your cooperative implementing to generate value from the bulk-power system in the short term?
   b) Prompt for Distribution Cooperatives only: What are ways that you're working with your wholesale power supplier to leverage the value of distribution-side assets, such as distributed energy resources or load-management technologies/programs?

7) **What kind of capacity are you building to support the integration of distribution-side resources?**
   a) Prompt: What kinds of partnerships are you building?
   b) Prompt: What kinds of hardware or software are you considering?
   c) Prompt: How are you increasing your staffing capacity to meet future DER needs?
   d) Prompt: What role do you think third-party providers of DERMS or VPPs play in leveraging distribution-side resources to provide system-level value?
8) **How are you thinking about delivering the benefits of electrification, and distributed energy resources more generally, to the end user to incentivize further adoption of these assets?**
   a) Prompt: How might you leverage the benefits provided by your distribution-side assets to compensate members and further incentivize DER adoption?
   b) Prompt: What consumer protection rules/programs/policies do you have in place to deliver the full benefits of electrification to the end-user?
9) **Is there anything today I asked which was unclear or are there any questions that you wished I asked today?**
   a) Prompt: How do you think your VPP program can evolve in the future?

7.2 Appendix B: Full List of Codes and their Definitions

Code	Definition
Barriers	
Big Brother	Any text where the interviewee mentions distribution co-ops not willing to share data or control with the G&T co-op.
Competition	Any text about competition between a co-op and a third-party provider (e.g. third-party DER installer or aggregator)
Coordination	Any challenges arising due to a lack of coordination (at the state/regional level, co-op level, or between co-ops and other orgs.)
DER Acquisition	Any barriers, such as upfront cost, related to procuring DERs or related software/hardware.
DER Enrollment	Any barriers related to enrolling customers to the DER or VPP program.
Governance	Describes any governance barriers (including board of directors, voting, contracts, etc.) that hinder the deployment of DERs/VPPs
Inertia	Any text that describes inertia (technological, organizational, regulatory, etc.) as being a challenge for VPP innovation.
Limited Capacity	Any text that mentions limited staff, hardware, software, or resource capacity as being a barrier
Nascency	Any text that mentions nascency as being a barrier to VPP deployment.
Process and Program Development	Any text that mentions challenges with process and program development
Regulatory	Any text that mentions regulatory barriers
Workforce	Any text that mentions workforce barriers as being a challenge to VPP and DER deployment
Capacity Building	
Hardware Capacity	Any text that describes any new hardware that co-ops had to acquire to operationalize VPPs
Software Capacity	Any text that describes new software that co-ops had to acquire to operationalize VPPs
Staff Capacity	Any text that describes different types of staffing capacity for virtual power plant or deployment
Partnerships	Any text that describes any new partnerships that the co-op is pursuing to deploy VPPs.
Rates and Compensation	

Behavioral Rates	Describes rate structures like time of use rates that modify consumers' behavior through price signals.
Direct Compensation	Describes any incentive or rate structure that provides a flat compensation to consumers and DER offtakers for their ability to be controlled by the co-op.
Incentives to the Distribution Co-op	Describes any economic incentives at the distribution co-op level that might drive VPP investment
Performance-based Incentives	Describes any incentive program that reward consumers on their DER performance. This shows up mainly in the form of three-part rate structures.
Wholesale Rates	Describes any value that is derived form wholesale markets.
Existing Programs	
Best practices and learned lessons	Describes any best practices from legacy demand response programs that could transfer over to VPP programs.
Communication strategy	Describes any legacy communication and control strategies
Demand Response	Describes each co-op's demand response capabilities
Phasing out legacy systems	Describes each co-op's plans to phase out legacy infrastructure and practices.
Planning Rules & Considerations	
Distribution Planning	Any considerations for distribution planning
Resource & Transmission Planning	Any considerations or rules for bulk power system planning
Integrated Planning Considerations	Any current or future planning rules or considerations that would enable integrated planning
Solutions	
Co-op Principles	Describes any solution to co-op led VPP deployment that utilized one of the seven co-op principles.
Member Consumer Buy-in	Describes any solution that hinges on engaging the member consumer.
Coordination	Describes any solution in which coordination was required across various stakeholders in order to deploy VPP programs.
Services provided by G&T	Describes any services provided by a G&T to their member co-ops that enabled VPP deployment
Flexibility	Describes any text in which flexibility was ingrained into the program design

Member Co-op Buy-in	Describes any test in which the G&T was required to garner buy-in and trust form their member distribution co-ops.
Ownership Model	Describes any innovative ownership models.
Purchasing and Financing	Describes any innovative purchasing and financing models.
Policy and Regulation	Describes any policy and regulatory solutions enabling VPP development in the co-op space.
Workforce Solutions	Describes any workforce solutions
Standardization Solutions	Describes any solutions around creating VPP standards and streamlining processes.

Bibliography

Ahluwalia, Gopal, Kermit Baker, and Kent Colton. 2022. "Concentration in Homebuilding Driven by a Few Large Builders." Joint Center for Housing Studies. April 19, 2022. https://www.jchs.harvard.edu/blog/concentration-homebuilding-driven-few-large-builders.

Anheier, Helmut K. 2014. *Nonprofit Organizations: Theory, Management, Policy*. 2nd ed. London: Routledge. https://doi.org/10.4324/9781315851044.

Antonopoulos, Ioannis, Valentin Robu, Benoit Couraud, and David Flynn. 2021. "Data-Driven Modelling of Energy Demand Response Behaviour Based on a Large-Scale Residential Trial." *Energy and AI* 4 (June):100071. https://doi.org/10.1016/j.egyai.2021.100071.

Asmus, Peter. 2022. "Inflation Reduction Act: A Boon for VPP Industry." *AutoGrid Uplight* (blog). August 29, 2022. https://blog.auto-grid.com/inflation-reduction-act-a-boon-for-vpp-industry/.

Beitman, Adam. 2023. "RMI Launches 'Virtual Power Plant Partnership' With Support from General Motors & Google Nest." Rocky Mountain Institute. January 10, 2023. https://rmi.org/press-release/rmi-launches-virtual-power-plant-partnership-with-support-from-general-motors-google-nest/.

Bloom, J. 2001. "Market Transformation: A Practical Guide to Designing and Evaluating Energy Efficiency Programs." Electric Power Research Institute. https://www.epri.com/research/products/1001492.

Brehm, Kevin, Avery McEvoy, Connor Usry, and Mark Dyson. 2023. "Virtual Power Plants, Real Benefits." Rocky Mountain Institute. https://rmi.org/insight/virtual-power-plants-real-benefits/.

Brunner, Cyril, and Jan Ahlen. 2024. “Learn How a Vermont Co-Op Is Building a Virtual Power Plant | CFC Solutions News Bulletin.” https://www.nrucfc.coop/content/solutions/en/stories/podcast/learn-how-a-vermont-co-op-is-building-a-virtual-power-plant.html.

Bureau of Labor Statistics. 2022. “Occupational Employment and Wage Statistics (OEWS) Survey.” Department of Labor. https://www.bls.gov/oes/tables.htm.

Byrnett, Danielle Sass, Kirstin Verclas, and Johanna Zetterberg. 2021. “Blueprint for State Action: NARUC-NASEO Task Force on Comprehensive Electricity Planning.” National Association of Regulatory Utility Commissioners. https://pubs.naruc.org/pub/14F19AC8-155D-0A36-311F-4002BC140969?_gl=1*rbju96*_ga*MTgyMzU4MTU3Ny4xNzA2NTY0OTgw*_ga_QLH1N3Q1NF*MTcwNjU2NDk4MC4xLjEuMTcwNjU2NTAzNy4wLjAuMA.

Cadmus Energy. 2023. “The Big Data Problem For Utilities.” *Camus Energy* (blog). December 23, 2023. https://www.camus.energy/blog/the-big-data-problem-for-utilities.

Calisch, Sam, and Cora Wyent. 2020. “Circuit Breakers: Upending Electrification Myths.” Rewiring America. 2020. https://www.rewiringamerica.org/circuit-breakers-the-grid.

Carvallo, Juan Pablo, Natalie Mims Frick, and Lisa Schwartz. 2022. “A Review of Examples and Opportunities to Quantify the Grid Reliability and Resilience Impacts of Energy Efficiency.” *Energy Policy* 169 (October):113185. https://doi.org/10.1016/j.enpol.2022.113185.

Carvallo, Juan Pablo, Peter H. Larsen, Alan H. Sanstad, and Charles A. Goldman. 2018. “Long Term Load Forecasting Accuracy in Electric Utility Integrated Resource Planning.” *Energy Policy* 119 (August):410–22. https://doi.org/10.1016/j.enpol.2018.04.060.

Cash, Cathy. 2023. "Co-Ops Leverage Basin Electric's Rate to Build Grid-Level Battery Storage." *National Rural Electric Cooperative Association* (blog). January 19, 2023. https://www.electric.coop/co-ops-leverage-basin-electrics-rate-to-build-grid-level-battery-storage.

———. 2024. "NRECA Picks Five Electric Co-Ops to Test DERMS Grid Reliability Solution." *National Rural Electric Cooperative Association* (blog). January 23, 2024. https://www.cooperative.com/news/pages/nreca-picks-five-electric-co-ops-to-test-derms-grid-reliability-solution.aspx.

CFC. 2008. "Setting Rates: Best Practices for Electric Cooperatives: A Brief History of Electric Cooperative Rate Setting." National Rural Utilities Cooperative Finance Corporation. https://www.cooperative.com/cfc/documents/rates_setting_part3.pdf.

Chan, Dr Gabriel, Matt Grimley, Eric Barry, Dr Sanya Carley, Cecelia Kincaid, Emma Schuster, and Dr Keith Taylor. 2019. "Hoosier Energy Integrated Planning Initiative." Universtiy of Minnesota.

Chan, Gabriel, Stephanie Lenhart, Lindsey Forsberg, Matthew Grimley, and Elizabeth Wilson. 2019. "Barriers and Opportunities for Distributed Energy Resources in Minnesota's Municipal Utilities and Electric Cooperatives." Report. http://conservancy.umn.edu/handle/11299/201624.

Cong, Shuchen, Destenie Nock, Yueming Lucy Qiu, and Bo Xing. 2022. "Unveiling Hidden Energy Poverty Using the Energy Equity Gap." *Nature Communications* 13 (1): 2456. https://doi.org/10.1038/s41467-022-30146-5.

Connecticut Green Bank. 2022. "Smart-E Loans - Accelerating Green Energy Adoption in CT." Connecticut Green Bank. July 14, 2022. https://www.ctgreenbank.com/home-solutions/smart-e-loans/.

Costantini, Lynn P., Danielle Sass Byrnett, Benjamin Stafford, and Christopher Villarreal. 2023. "NARUC Grid Data Sharing Playbook." National Association of Regulatory Utility Commissioners.

Dickey, Cyntressa, Ryan Levine, Hetal Patel, and Laura Sciuto. 2021. "If Tech Powers the Future, Who Powers the Tech?" Ernst & Young LLP. https://assets.ey.com/content/dam/ey-sites/ey-com/en_us/topics/power-and-utilities/ey-power-and-digital-survey.pdf.

Downing, Jennifer, Nicholas Johnson, Mailinh McNicholas, David Nemtzow, Rima Oueid, Joseph Paladino, and Elizabeth Bellis Wolfe. 2023. "Pathways to Commercial Liftoff: Virtual Power Plants." U.S. Department of Energy. https://liftoff.energy.gov/vpp/.

Duncan, Jake, Julia Eagles, David Farnsworth, John Shenot, and Jessica Shipley. 2021. "Participating in Power: How to Read and Respond to Integrated Resource Plans." Institute of Market Transformations. https://imt.org/wp-content/uploads/2021/10/rap_imt_participating_in_power_how_to_read_and_respond_to_integrated_resource_plans_2021_october.pdf.

Dwyer, Matthew. 2018. "Distribution Forecasting Working Group Meeting 1 Summary." Itron Inc. https://drpwg.org/wp-content/uploads/2018/07/R1408013-et-al-SCE-DFWG-Progress-Report.pdf.

"Electric Hot Water Heater Cost Per Month and Year." n.d. Inspire Clean Energy. Accessed February 8, 2024. https://www.inspirecleanenergy.com/blog/sustainable-living/electric-hot-water-heater-cost-per-month.

Electric Power Research Institute. 2019. “The New Aggregated Distributed Energy Resources (Der_a) Model for Transmission Planning Studies: 2019 Update.” https://www.epri.com/research/products/000000003002015320.

Energy Wise MN. n.d. “Find Your Cooperative.” Energy Wise MN. Accessed February 12, 2024. https://www.energywisemn.com/cooperative.

Ernst, Anne. 2023. “Data Integration, Human Involvement Are Key for Virtual Power Plants.” NewsData, LLC. July 21, 2023. https://www.newsdata.com/california_energy_markets/regulation_status/data-integration-human-involvement-are-key-for-virtual-power-plants/article_ccc8ed18-27fc-11ee-8186-ff4e49f9fe29.html.

Farrell, John. 2016. “Being Black Still a Barrier to Rural Cooperative Board Membership.” Institute for Local Self-Reliance. May 23, 2016. https://ilsr.org/being-black-still-a-barrier-to-rural-cooperative-board-membership/.

Franco, Mary. 2021. “Power Move: Applying FERC Orders 841 and 2222 to Mitigate Use of Peaker Plants in Environmental Justice Communities.” *Vermont Law Review* (blog). October 21, 2021. https://lawreview.vermontlaw.edu/power-move-applying-ferc-orders-841-and-2222-to-mitigate-use-of-peaker-plants-in-environmental-justice-communities/.

Gadzanku, Sika, Alexandra Kramer, and Brittany L. Smith. 2023. “An Updated Review of the Solar PV Installation Workforce Literature.” NREL/TP-7A40-83652. National Renewable Energy Laboratory (NREL), Golden, CO (United States). https://doi.org/10.2172/1971876.

Gao, Hongchao, Tai Jin, Cheng Feng, Chuyi Li, Qixin Chen, and Chongqing Kang. 2024. “Review of Virtual Power Plant Operations: Resource Coordination and Multidimensional

Interaction.” *Applied Energy* 357 (March):122284. https://doi.org/10.1016/j.apenergy.2023.122284.

Gellings, Clark W. 2017. “Evolving Practice of Demand-Side Management.” *Journal of Modern Power Systems and Clean Energy* 5 (1): 1–9. https://doi.org/10.1007/s40565-016-0252-1.

Gibson, Bob. 2020. “The Evolving Value of Battery Storage For Electric Co-Ops: Takeaways from NRECÅs Business and Technology Strategies Case Studies of Current Cooperative Deployments.” National Rural Electric Cooperative Association.

Griffith, Saul, and Sam Calisch. 2020. “Mobilizing for a Zero Carbon America: Jobs, Jobs, Jobs, and More Jobs A Jobs and Employment Study Report.” Rewiring America. https://content.rewiringamerica.org/reports/mobilizing-for-a-zero-carbon-america-technical-whitepaper.pdf.

Grimley, Matt. 2016. “Just How Democratic Are Rural Electric Cooperatives?” Institute for Local Self-Reliance. January 13, 2016. https://ilsr.org/just-how-democratic-are-rural-electric-cooperatives/.

Grimley, Matthew, and Gabriel Chan. 2023. “‘Cooperative Is an Oxymoron!’: A Polycentric Energy Transition Perspective on Distributed Energy Deployment in the Upper Midwestern United States.” *Energy Policy* 172 (January):113328. https://doi.org/10.1016/j.enpol.2022.113328.

Grimley, Matthew David. 2019. “‘Cooperative Is an Oxymoron’: The Polycentric Energy Transition of Midwestern Electric Cooperatives to Load Management Technologies, 1940s to Present.” University of Minnesota. https://conservancy.umn.edu/handle/11299/206182.

Grove, Dustin. 2022. "Dangerous Heat Causing Energy Concerns, Blackout Warnings for Midwest." Wthr.Com. June 13, 2022. https://www.wthr.com/article/news/local/dangerous-heat-causing-energy-concerns-for-midwest-blackout-climate-change-indiana/531-a9ed881e-561a-4023-ad9f-068dc6f9fb08.

Guzman, US Census, Kirby Posey, Alemayehu Bishaw, and Craig Benson. 2018. "Poverty Rates Higher, Median Household Income Lower in Rural Counties Than in Urban Areas." US Census Bureau. December 6, 2018. https://www.census.gov/library/stories/2018/12/differences-in-income-growth-across-united-states-counties.html.

Hanif, Sarmad, Sadie R Bender, Juan Carlos Bedoya, Hayden M Reeve, Trevor D Hardy, and Monish M Mukherjee. 2022. "A Granular Approach to Resilience Valuation." Lawrence Berkeley National Lab.

Hawkins, Beth, Erin Rose, Bruce Tonn, and Ingo Bensch. 2014. "Findings from Survey Administered to Trainees of Weatherization Training Centers." ORNL/TM-2014/306. Oak Ridge National Laboratory. https://weatherization.ornl.gov/wp-content/uploads/pdf/WAPRetroEvalFinalReports/ORNL_TM-2014_306.pdf.

Hertz-Shargel, Ben. 2023. "Transformation in the US Distributed Energy Resource Market | Wood Mackenzie." June 20, 2023. https://www.woodmac.com/news/opinion/transformation-distributed-energy-resource-market/.

Hertz-Shargel, Ben, and Ken Norris. 2023. "North America Virtual Power Plant (VPP) Market Report: H1 2023." Wood Mackenzie. https://www.woodmac.com/reports/power-markets-north-america-virtual-power-plant-vpp-market-h1-2023-150103190/.

Hirsh, Richard. 2018. "Shedding New Light on Rural Electrification: The Neglected Story of Successful Efforts to Power Up Farms in the 1920s and 1930s." *Agricultural History* 92 (3): 296–327. https://www.jstor.org/stable/10.3098/ah.2018.092.3.296.

Hirsh, Richard F. 1999. *Power Loss: The Origins of Deregulation and Restructuring in the American Electric Utility System*. MIT Press. https://mitpress.mit.edu/9780262582193/power-loss/.

Hledik, Ryan, and Kate Peters. 2023. "Real Reliability: The Value of Virtual Power." Brattle Group. https://www.brattle.com/wp-content/uploads/2023/04/Real-Reliability-The-Value-of-Virtual-Power_5.3.2023.pdf.

Howland, Ethan. 2023. "Utility Regulators Urge PJM to Move Away from 'Reactive' Planning for Grid Reliability." Utility Dive. 2023. https://www.utilitydive.com/news/opsi-pjm-interconnection-transmission-planning-grid-reliability/701105/.

"Inclusive Utility Investments: Tariffed On-Bill Programs." 2023. EPA. September 29, 2023. https://www.epa.gov/statelocalenergy/inclusive-utility-investments-tariffed-bill-programs.

Jackson, Lexi. 2019. "Energizing Rural America: A Cooperative Effort to Advance Renewable Power | Bipartisan Policy Center." Bipartisan Policy Center. August 8, 2019. https://bipartisanpolicy.org/blog/energizing-rural-america-a-cooperative-effort-to-advance-renewable-power/.

John, Jeff. 2015. "What's the Value of a Tesla Powerwall? $50 per Month, Bets Green Mountain Power." Greentech Media. 2015. https://www.greentechmedia.com/articles/read/green-mountain-powers-bet-on-tesla-powerwall-value-50-per-month.

John, Jubin Jacob, Virginia Weber, Jeffery Rotman, and Michael Gatumu. 2023. "Project EDGE: Surveying Customers to Understand Their Experiences Participating in a Virtual Power Plant Field Trial." Deakin University. https://aemo.com.au/-/media/files/initiatives/der/2023/project-edge---survey-insights-for-customers-in-the-edge-vpp.pdf?la=en.

Kerekes, Steve. 2019. "More Clarity on DERMS." EPRI Journal. November 25, 2019. https://eprijournal.com/more-clarity-on-derms/.

Keyser, David, Mary Fiori, Betony Jones, Hugh Ho, Shrayas Jatkar, Kate Gordon, Gina Copland-Newfield, Carla Frisch, and Christy Veeder. 2023. "United States Energy & Employment Report 2023." U.S. Department of Energy. https://www.energy.gov/sites/default/files/2023-06/2023%20USEER%20REPORT-v2.pdf.

Kirkham, Elyssa. 2019. "Country vs. City: Which Has Larger Balances, Better Credit Scores?" LendingTree. April 10, 2019. https://www.lendingtree.com/debt-consolidation/country-vs-city-which-has-larger-balances-and-better-credit-scores/.

Klass, Alexandra B., and Gabriel Chan. 2020. "Cooperative Clean Energy." SSRN Scholarly Paper. Rochester, NY. https://doi.org/10.2139/ssrn.3735189.

Lamberink, Liny. 2022. "N.W.T. Brings on More Home Energy Auditors to Address 'huge' Backlog." *CBC News*, April 25, 2022. https://www.cbc.ca/news/canada/north/home-energy-audit-capacity-increased-1.6428372.

Lawrence Berkely National Lab (LBNL). 2020. "Grid Services | GEB." 2020. https://connectedcommunities.lbl.gov/resources/general-information/grid-services.

Lowe, James. 2022. "Summer 2022 Recap: Grid Reliability Maintained through Heat Waves, Rising Gas Prices." ISO Newswire. October 28, 2022. https://isonewswire.com/2022/10/28/summer-2022-recap-grid-reliability-maintained-through-heat-waves-rising-gas-prices/.

Luciani, Ralph, and Maggie Shober. 2014. "EISPC & NARUC Transmission Planning White Paper." National Association of Regulatory Utility Commissioners. https://pubs.naruc.org/pub/53A151F2-2354-D714-519F-53E0785A966A.

Martini, Paul De, Jeffery Taft, and Joe Paladino. 2020. "Modern Distribution Grid: Strategy Volume IV." Pacific Northwest National Laboratory. https://gridarchitecture.pnnl.gov/media/Modern-Distribution-Grid_Volume_IV_v1_0_draft.pdf.

Min, Yohan, and Erin Mayfield. 2023. "Rooftop Solar, Electric Vehicle, and Heat Pump Adoption in Rural Areas in the United States." *Energy Research & Social Science* 105 (November):103292. https://doi.org/10.1016/j.erss.2023.103292.

National Association of Regulatory Utility Commissioners (NARUC). 2020. "Bulk Power System Planning." NARUC. 2020. https://www.naruc.org/core-sectors/electricity-energy/bulk-power-system/.

National Rural Electric Cooperative Association. 2016. "Understanding the Seven Cooperative Principles." America's Electric Cooperatives. December 1, 2016. https://www.electric.coop/seven-cooperative-principles.

———. 2024. “America’s Cooperative Electric Utilities The Nation’s Consumer Owned Electric Utility Network: Fact Sheet.” National Rural Electric Cooperative Association.

Newton, Josh, Jubin John, Virginia Weber, and Rotman Jeffrey. 2022. “General Community Perceptions of Distributed Energy Resources.” Project EDGE. Deakin University: Better Consumption Lab. https://aemo.com.au/-/media/files/initiatives/der/2022/community-perceptions-of-der-and-aggregation-services.pdf?la=en.

North Carolina Electric Cooperatives and PJM Interconnection LLC. 2020. “NCEMC/PJM Distribution Operator Pilot Project.” National Rural Electric Cooperative Association. https://www.ncelectriccooperatives.com/wp-content/uploads/2020/08/NCEMC-PJM-DO-Pilot-Project-20200814.pdf.

NTUF. 2022. “About NTUF.” National Utility Industry Training Fund. 2022. https://nuitf.org/.

“NYStretch Energy Code - 2020.” 2019. https://www.nyserda.ny.gov/All-Programs/Clean-Resilient-Building-Codes/NYStretch-Energy-Code-2020.

Omotoso, Tolu, and Manning MacAvoy. 2023. “Energy Transition Behind the Meter: DERs, DERMS & VPPs.” Business & Technology Report. National Rural Electric Cooperative Association.

O’Neal. 2019. “Rural Electric Co-Ops See Need for Tax Fix as ‘Existential Issue.’” *Bloomberg Tax*, 2019. https://news.bloombergtax.com/daily-tax-report/rural-electric-co-ops-see-need-for-tax-fix-as-existential-issue.

Pacyniak, Gabriel. 2020. “Greening the Old New Deal: Strengthening Rural Electric Cooperative Supports and Oversight to Combat Climate Change.” *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3605515.

Padullaparti, Harsha, Annabelle Pratt, Ismael Mendoza, Soumya Tiwari, Murali Baggu, Chris Bilby, and Young Ngo. 2023. "Peak Demand Management and Voltage Regulation Using Coordinated Virtual Power Plant Controls." *IEEE Access* 11:130674–87. https://doi.org/10.1109/ACCESS.2023.3334607.

Palmer, Avery, Ed Gilland, and Mari Hernandez. 2023. "2022 National Solar Jobs Census." Interstate Renewable Energy Council (IREC). https://irecusa.org/census-executive-summary/.

Paniagua, Jam Angulo. 2023. "Identifying High Value Pportunities for Non Wire Alternatives: A Retrospective of State Led Approaches." University of Minnesota. https://conservancy.umn.edu/bitstream/handle/11299/254242/Identifying%20high%20value%20opportunities%20for%20non%20wire%20alternatives_A%20retrospective%20of%20state%20led%20approaches.pdf?sequence=1&isAllowed=y.

Pontecorvo, Emily. 2023. "We Need a Lot More Electricians If We're Going to Electrify Everything." Canary Media. January 11, 2023. https://www.canarymedia.com/articles/clean-energy-jobs/we-need-a-lot-more-electricians-if-were-going-to-electrify-everything.

Power, Dan. 2022. "Virtual Power Plants Are Essential to Environmental Equality." *Guidehouse Insights* (blog). 2022. https://guidehouseinsights.com/news-and-views/virtual-power-plants-are-essential-to-environmental-equality.

Rajamani, Maya. 2022. "Thousands of New Yorkers Lose Power amid Heat Wave." Spectrum News NY1. 2022. https://ny1.com/nyc/all-boroughs/news/2022/07/21/con-ed-urges-central-queens-residents-to-limit-power-usage.

Rocha, Victoria. 2023. "Workforce Challenges: Co-Ops Face Unfamiliar Recruiting, Retention Pressures." *Rural Electric Magazine*, January 17, 2023. https://www.cooperative.com/remagazine/articles/Pages/Workforce-Challenges-Co-ops-Face-Unfamiliar-Recruiting,-Retention-Pressures.aspx.

Rojo, Victor. 2022. "ISO New England: Summer 2022 Peak Review." ISO New England. https://www.iso-ne.com/static-assets/documents/2022/09/lf2022-summerpkrev.pdf.

Ross, Lauren, Ariel Drehobl, and Brian Stickles. 2018. "The High Cost of Energy in Rural America: Household Energy Burdens and Opportunities for Energy Efficiency." American Council for an Energy-Efficient Economy. https://www.aceee.org/sites/default/files/publications/researchreports/u1806.pdf.

Rural Energy Savings Program. 2020. https://www.federalregister.gov/documents/2020/04/02/2020-06215/rural-energy-savings-program.

Saboori, H., M. Mohammadi, and R. Taghe. 2011. "Virtual Power Plant (VPP), Definition, Concept, Components and Types." In *2011 Asia-Pacific Power and Energy Engineering Conference*, 1–4. https://doi.org/10.1109/APPEEC.2011.5749026.

Sahoo, Anshuman, Karan Mistry, and Thomas Baker. 2021. "The Costs of Revving Up the Grid for Electric Vehicles." *Boston Consultancy Group* (blog). January 8, 2021. https://www.bcg.com/publications/2019/costs-revving-up-the-grid-for-electric-vehicles.

Schwartz, Lisa, Kevin Lee, Adam Cooper, Lisa Wood, Anne Hoskins, Christopher Worley, Kyle Horton, et al. 2022. "The Role of Innovation in the Electric Utility Sector Future Electric Utility Regulation Report No. 13." Future Electric Utility Regulation. Lawrence Berkeley

National Lab. https://eta-publications.lbl.gov/sites/default/files/feur_13_-_innovation_20220511final.pdf.

Sebastian, Shawn. 2022. "New Effort Focused on Financial Issues Facing Rural Communities." Consumer Financial Protection Bureau. March 10, 2022. https://www.consumerfinance.gov/about-us/blog/new-effort-focused-on-financial-issues-facing-rural-communities/.

Singh, Ravindra, and Venkat Banunarayann. 2024. "Distribution Automation Roadmap for Electric Cooperatives." National Rural Electric Cooperative Association (NRECA). https://www.cooperative.com/topics/transmission-distribution/Pages/Distribution-Automation-Roadmap-for-Electric-Cooperatives.aspx.

Spector, Julian. 2022. "This Utility Keeps Customers Cool during Heat Waves While Saving Them…." Canary Media. August 11, 2022. https://www.canarymedia.com/articles/batteries/this-utility-keeps-ac-on-during-heat-waves-while-saving-customers-money.

Speetles, Brittany, Eric Lockhart, and Adam Warren. 2023. "Virtual Power Plants and Energy Justice." NREL/TP-7A40-86607. National Renewable Energy Laboratory (NREL), Golden, CO (United States). https://doi.org/10.2172/2008456.

Stewart, Emma, and David Pinney. 2022. "The Value of Cooperative Data." Business & Technology Survellance. National Rural Electric Cooperative Association. https://www.electric.coop/wp-content/uploads/2022/11/Surveillance-Co-op-Data-Value-Nov-2022.pdf.

Summeren, Luc F. M. van, Anna J. Wieczorek, Gunter J. T. Bombaerts, and Geert P. J. Verbong. 2020. "Community Energy Meets Smart Grids: Reviewing Goals, Structure, and Roles in

Virtual Power Plants in Ireland, Belgium and the Netherlands." *Energy Research & Social Science* 63 (May):101415. https://doi.org/10.1016/j.erss.2019.101415.

Takemura, Alison F. 2022. "Electric Utilities 101: A Breakdown of the Basics on US Power…." *Canary Media*, October 12, 2022. https://www.canarymedia.com/articles/guides-and-how-tos/power-by-people-glossary-bundle.

Talley, Johnathan, and Chris DiMisa. 2023. "DERMS Platforms Capabilities, Use Cases, and Case Studies - NCEMC." National Rural Electric Cooperative Association. https://www.oati.com/case-studies/smart-energy/ncemc/.

Tankersley, Jim. 2023. "Biden's Climate Law Is Reshaping Private Investment in the United States." *The New York Times*, September 13, 2023, sec. U.S. https://www.nytimes.com/2023/09/13/us/politics/biden-climate-law-investment.html.

Vanvig, John. 2016. "On-Bill Financing: The Ins and Outs of Providing Consumer Loans for Efficiency Upgrades." *Rural Electric Magazine*, August 20, 2016. https://www.cooperative.com/remagazine/articles/Pages/On-Bill-Financing.aspx.

Vijaykar, Nikhil. 2021. "Midwest Grid Planning: Transparency and Inclusion to Maximize Distributed Energy Resources." *Environmental Law & Policy Center* (blog). January 26, 2021. https://elpc.org/blog/midwest-grid-planning-transparency-and-inclusion-to-maximize-distributed-energy-resources/.

Walton, Robert. 2022. "The Energy System Is 'Inherently Racist,' Advocates Say. How Are Utilities Responding to Calls for Greater Equity?" *Utility Dive*, 2022. https://www.utilitydive.com/news/energy-system-inherently-racist-utilities-responding-equity-ej-justice40/634203/.

White, Louise, Eshaan Agrawal, Angelena Bohman, Avi Gopstien, Charles Hua, Isabel Sepulveda, and Lucia Tian. 2024. "Pathways to Commercial Liftoff: Innovative Grid Deployment." U.S. Department of Energy.

Wilson, Stephanie Lenhart, Gabriel Chan, Matthew Grimley, Elizabeth. 2021. "Comparing and Contrasting the Institutional Relationships, Regulatory Frameworks, and Energy System Governance of European and US Electric Cooperatives." In *Routledge Handbook of Energy Democracy*. Routledge.

Xcel Energy. 2024. "Xcel Energy Minnesota - Integrated Resource Plan." https://www.edockets.state.mn.us/edockets/searchDocuments.do?method=showPoup&documentId={A0BD668D-0000-C311-BA08-1136E5F66A42}&documentTitle=20242-203027-01.

York, Dan, Steve Nadel, and Sagarika Subramanian. 2022. "U.S. and International Experience With Market Transformation." White Paper. American Council for an Energy-Efficient Economy. https://www.aceee.org/sites/default/files/pdfs/market_transformation_6-13-22.pdf.