Blockchain and Transactive Energy

How This Disruptive Technology May Affect Your Co-op

Blockchain and Transactive Energy:

How It May Affect Your Cooperative

Introduction

Blockchain — the latest disruptive technology facing electric cooperatives — does not generate, store or control the flow of electric power. It is not a piece of hardware like a solar panel or a lithium-ion battery.

Blockchain exists as a software-based technology that offers a financial platform for individuals to buy and sell goods and services. Some energy market participants see blockchain as a means to "elbow the utility aside," putting more power in the hands of consumers. Others see it as a useful tool—alongside other technologies and components that make up the palette of "transactive energy"—for allowing solar, battery storage and other distributed energy resources to become more productive grid assets.

Outside of the energy marketplace, blockchain has become known as a new means to execute financial transactions, most famously through the cryptocurrency bitcoin. Through unique architecture and construction, the digital technology permits direct and secure financial transactions between individuals without going through an established third-party intermediary, such as a bank.

Using cryptography to keep exchanges secure, blockchain provides a decentralized database, or "digital ledger," of transactions that everyone on the network can see. All of a network—essentially a chain of computers—must all approve an exchange before it can be verified and recorded.

How Does It Work?

In the case of bitcoin, blockchain stores the details of every transaction of the digital currency, and stops the same bitcoin being spent more than once.

The technology can work for almost every type of transaction involving value, including money, goods and property. Its potential uses are almost limitless: from collecting taxes to helping a homeowner with a solar array or battery storage, for example, sell some of his or her power directly to someone else—potentially outside the control and knowledge of the local utility.

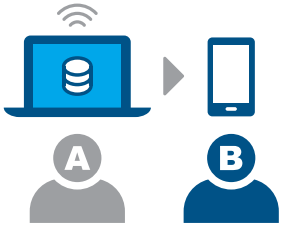
Blockchain could also help reduce fraud because every transaction would be recorded and distributed on a public basis for anyone to see. It will effectively serve as the Ledger of Everything for the Internet of Things—the billions of personal interconnected devices.

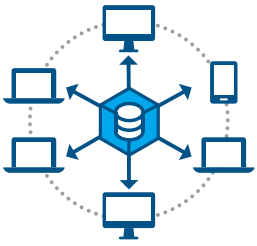
In theory, if blockchain goes mainstream, anyone with access to the Internet could tap it to make transactions. As a result, the technology has been dubbed the "Trust Protocol." On top of this, every business, institution, government and individual could benefit in profound ways.

Social scientists see blockchain as a way to distribute value and opportunity fairly from cradle to grave—protecting rights through immutable records such as land titles; replacing service aggregators like Uber with distributed applications; enabling citizens to own and monetize their data (and protect privacy) by owning their personal identities rather than having them controlled by big social media companies or governments; providing small

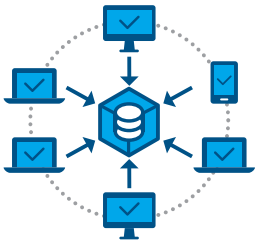
HOW DOES BLOCKCHAIN WORK

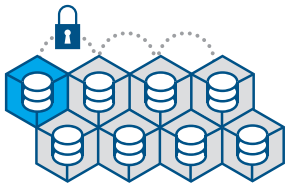
1. Person A wants to send money to Person B.
2. The transaction is represented online as a "block".
3. The block is broadcast to every party in the network.

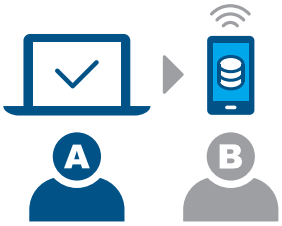




4. Those in the network approve the transaction is valid, preventing fraud.
5. The block then can be added to the chain, which provides an indelible and transparent record of transactions.
6. The money moves from Person A to Person B.







DEFINITIONS

BLOCKCHAIN
A software-based technology made famous by bitcoin that offers a secure financial platform for individuals to directly buy and sell goods and services without going through an established intermediary such as a bank. Some energy market participants see blockchain as a means to "elbow the utility aside," putting more power in the hands of consumers. Others see it as a useful tool—alongside other technologies and components that make up the palette of "transactive energy"—for allowing solar, battery storage and other distributed energy resources to become more productive grid assets. In energy, the peer-to-peer trading characteristics of blockchain can be used to help a homeowner who has installed a solar array or battery storage, for example, sell some of his or her power directly to a neighbor—potentially outside the control and knowledge of the local utility.

SMART CONTRACT
A peer-to-peer transaction enabled by blockchain.

TRANSACTIVE ENERGY
Techniques for managing the generation, consumption or flow of electric power within a utility's system through the use of economic or market-based factors while considering grid reliability constraints. Transactive energy technologies—including blockchain—can turn consumer-owned distributed energy resources into grid assets and minimize any erosion of load or potential new utility services.

companies with all of the capabilities of large corporations; and building more accountable government through transparency, smart contracts and revitalized models of democracy.

Currently, only a very small proportion of the global economy (around 0.025 percent, or $20 billion) is held in blockchain, according to the World Economic Forum Global Agenda Council. But the amount will surge significantly over the next decade as banks, insurers and tech firms look to speed up settlements and cut costs.

Companies racing to adapt blockchain include UBS, Microsoft, IBM and PwC. A report from financial technology consultant Aite estimated that banks spent $75 million last year on blockchain. Silicon Valley venture capitalists are also queuing up to back it.

The main risk with all blockchain applications, including bitcoin, lies in the unknown—just exactly how secure the system may be and whether there are flaws that could be exploited by hackers. One potential issue is the large number of different implementations, all based on different technological approaches. IBM, JP Morgan, Intel and a group of other companies have launched the "Open Ledger Project" more suited to companies wanting to restrict access to blockchain.

In addition, outside digital currency, the jury remains divided on whether blockchain actually does anything that can't be achieved with more conventional technologies. Folks also worry that by getting rid of third parties you also remove the positives they bring to the marketplace.

Blockchain in Energy

As of March 2018, the energy analysis firm GTM Research counted more than 120 new blockchain start-ups opening for business in the energy sector over the past year, attracting $324 million in investments in 2017 and more than 40 deployed projects.

When it comes to energy, blockchain remains in its early stages, with a few dozen modestly scaled pilots underway. But interest grows. As of March 2018, the energy analysis firm GTM Research counted more than 120 new blockchain start-ups opening for business in the energy sector over the past year, attracting $324 million in investments in 2017 and more than 40 deployed projects.

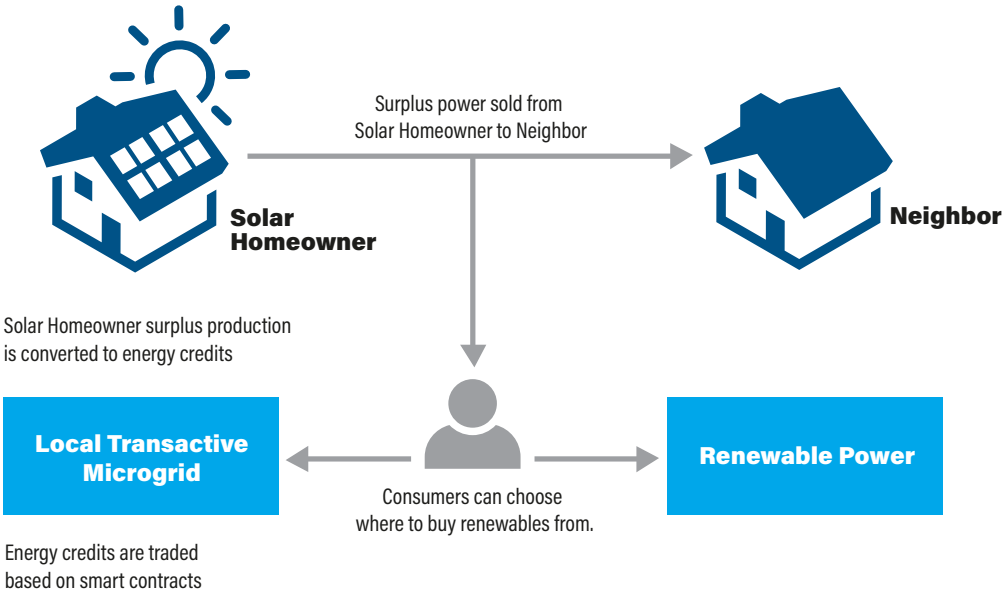
In 2016, the first U.S. demonstration of energy blockchain took place on President Street in Brooklyn, New York, when five homeowners with solar panels sold some of their excess power to interested neighbors. The event was managed by blockchain start-up company LO3, and the transactions handled automatically by computer using "smart contracts" software called Ethereum. The local distribution utility, Consolidated Edison (ConEd), was not involved.

In a 2017 interview with the Association of Ontario (Canada) Power Producers magazine, LO3's Scott Kessler acknowledged he "didn't want to wait for utility participation. We eventually see the utility providing this platform, but we think it starts with us in this more disruptive manner."

Energy trade press coverage largely sees blockchain as the beginning of the end for traditional electric utilities. An April 18 Bloomberg News article titled "Three Ways Blockchain Could Kill Old School Utility," saw author Chris Martin write, "If utilities think rooftop solar panels and batteries are bad for business, blockchain should scare the bejeezus out of them. That's because in addition to helping more people slap panels on their rooftops—which eats into power sales and taxes grids—the distributed, digital ledger that's proliferated across industries can also be used to trade electricity without a utility even knowing it."

In reality, things will likely be more nuanced. The utility-consumer relationship was already changing before blockchain arrived, thanks largely to transactive energy. A decade ago, Pacific Northwest National Laboratory demonstrated on Washington's Olympic Peninsula that with the right mix of distributed generation and software to manage demand, a transactive energy approach could ease grid congestion and replace the need to upgrade a transmission line.

Blockchain in a Utility Setting



Changing Value

Today, transactive energy has changed the way demand response and generation are looked at and dispatched. The most mature applications are found at the wholesale level, such as the use of dynamic pricing within the PJM Interconnection and other organized regional wholesale power markets.

Applying transactive energy technologies at the distribution level poses greater challenges. The Brooklyn-Queens Neighborhood Program—a demand response and distributed energy project—was launched in 2014 by ConEd to pay customers for not only changing their use of electricity but also contributing power to the grid at critical times. The goal: Avoid spending $1.2 billion on a substation upgrade.

The New York Public Service Commission (PSC), in the spirit of its Reforming the Energy Vision initiative, allowed ConEd to spend (and rate-base) $200 million on this non-wires alternative. Only 25 percent of the amount could go toward utility-side assets. By 2017, the effort bore fruit—a year ahead of time and under budget—and a new batch of distributed investments was approved by the PSC.

A few utilities are hosting transactive energy pilots that include blockchain and are investing in blockchain (notably through an open-source collaborative known as Energy Web Foundation). Killian Tobin, CEO of Chicago-based Omega Grid, a blockchain company focused on utilities and electricity markets, sees the partnership as a logical step. "Who do you do business with? We're not replacing the utility. A smart contract [the peer-to-peer transaction enabled by blockchain] won't fix wires when they fall down."

Tobin says while working at Oracle he studied how the Midcontinent Independent System Operator determined pricing. He was intrigued by the problem "of what to do with extra generation at the distribution system. You can't scale transmission software down to the distribution level. I discovered the transactive energy concept and thought that offered an answer."

Omega Grid soon developed its own blockchain solution for smart contracts that Tobin feels requires less computational intensity (and cost) than other approaches. The company also created "a proof-of-authority chain" that utilizes the utility as the authority. "We think this makes makes sense," Tobin says. "We need a utility's permission to operate a market on their grid."

Going forward, the most important long-term focus for electric utilities may be how—or whether—blockchain will find a useful niche within the greater world of transactive energy, specifically at the distribution level.

In 2017, Tobin's firm was one of seven start-ups out of more than 200 applicants selected for a place in the Ameren Accelerator, where the winners received seed capital and a 12-week business incubator experience paired with subject-matter experts from the St. Louis-based investor-owned utility as well as business advisers from the University of Missouri-St. Louis.

Omega Grid is working on an agreement with Ameren to test its blockchain scheme on a microgrid in Champaign, Illinois, and will deploy its technology with the Burlington, Vermont, municipal utility to reduce transmission demand charges. It further expects to run a pilot with a remote Alaska system.

"What I like to do in talking to utilities is to frame the discussion around what problems we might b e trying to solve," Tobin explains. "We can help the utility manage all new solar generation, battery storage and electric vehicles connecting to their grid with a local blockchain."

Possible Uses of Blockchain

Internet of Things	Automation of remote systems
Crowd-Based Funding	Uses the smart contracts feature to create venture funds
Financial Markets	Can change the way transactions are conducted, eliminating the need for exchanges and reduce transaction costs
Data Management	Data can be verified in a robust manner
Land Documents	Eliminates the risk of double transactions and creates a secure system
Decentralization	Makes it safer to save files in multiple locations
Logistics and Supply Chain	Goods can be tracked to their origin

Transactive energy technologies will set compensation for consumers who sell excess solar generation, for example, to their utility through a net metering arrangement.

Assessing Blockchain

When it comes to blockchain's energy and utility applications, the attention paid to bitcoin becomes a distraction. "When the price of bitcoin rises, you hear 'wow, blockchain is great,'" Tobin observes. "Then when bitcoin is down it's, 'oh, blockchain is dead.'"

Dave Hardin, chief architect at the Smart Energy Power Alliance—the Washington, D.C.-based trade organization focused on integration and deployment of solar, demand response, distributed energy resources and supporting technologies onto the grid—notes that the world of bitcoin remains highly speculative, while energy blockchain is not. "The bitcoin miners [who build blockchain 'blocks' by computer to earn bitcoins as payment] are running thousands of machines to make money. But in the energy ecosystem, you're not making money from bitcoins. The value of energy tokens resides in the value of the energy services being transacted."

Going forward, the most important long-term focus for electric utilities may be how—or whether—blockchain will find a useful niche within the greater world of transactive energy, specifically at the distribution level.

Solar and energy storage, when put into service by consumers, are perceived as disruptive technologies, while utility-owned or managed units are perceived as assets. By embracing transactive energy technologies—including blockchain—utilities can also turn consumer-sited distributed energy resources into grid assets.

Hardin contends that when introducing transactive energy to the electricity market, blockchain's value shines in its ability to enable sales at the distribution level. "Transactive energy provides a means of transferring value. In wholesale power markets, there are a smaller number of larger resources so it's easier to manage the value of the services that those resources might deliver. But on distribution systems there are very large numbers of smaller resources. Blockchain provides an orderly, secure way to execute the microtransactions for distributed energy systems."

Blockchain, for its part, offers "data trust"—the information cannot be changed as it is "cryptographically solidified." "You can verify it," Hardin remarks. "If you try to alter it I can see that immediately. That's one difference between blockchain and the typical database that utilities may be familiar with."

Transactive Energy Without Blockchain

Some new entrants in transactive energy are not using blockchain. Opus One of Ontario, Canada, has been testing a transactive solution with customers served by investor-owned utility National Grid in Buffalo, New York.

Gerhard Walker, Opus One director of grid evolution, describes the group's product, GridOS, as "allowing utilities to calculate the stacked benefits of any type of resource to the distribution grid at any location and in real time. With the resource's energy and services valued in dollars per kilowatt-hour, this information can be used to allow distributed energy resources to easily bid on pricing events, as with our initial commercial participants from the Buffalo Niagara Medical Campus. Or it can be leveraged by the utility as a non-wires alternative pricing mechanism to direct both DER dispatch and adoption."

Walker's understanding of the challenges facing American utilities comes from his work as a distribution engineer in Germany, where local utilities have become adept at handling a high penetration of solar power along with an influx of battery storage. He says that blockchain could be used to handle the financial transactions on Opus One's transactive energy platform, but it would depend upon a technology like GridOS to provide accurate pricing of a resource regarding its current value to the grid.

"Blockchain technology does not provide the ability to compute a full system power flow," he points out. "As a result, pricing indications are based on what each participant thinks his or her energy is worth. Since GridOS deals with technical aspects of evaluating real-time value and managing the distribution grid, it can be viewed as an enabling approach to a blockchain ledger system."

Walker adds that new transactive energy technologies will set compensation for consumers who sell excess solar generation, for example, to their utility through a net metering arrangement. "With a market managed by technologies like GridOS, a consumer can automate his or her sales of solar [produced or stored] to ensure optimal use of the resource. With distributed energy resources incentivized to behave in a grid-optimized way, the hosting capacity of distribution grids should rise."

He continues: "By applying a locational net-benefit analysis over time you build a very good understanding of the value a resource can provide, which could provide for new DER compensation mechanisms and potentially reform net metering, reduce demand charges and lead to better investment decisions like incentivizing customers to add energy storage."

At the medical center campus taking part in the National Grid pilot, the building's energy systems were "turned into a profit center for the center," Walker reports. "What were once single-purpose assets suddenly have multiple values, and with this revenue, the center can invest in new equipment to optimally participate in the energy market. This is driving business opportunities on the utility side as well—everybody sees a benefit."

About the author: *Bob Gibson is a writer, researcher and educator who has been exploring the intersection of electric utilities and renewable energy/emerging technologies for more than 20 years. He began working with electric cooperatives as a writer for NRECA's Rural Electrification Magazine (now RE Magazine) in the early 1980s.*

BLOCKCHAIN: AN OPPORTUNITY THAT CAN'T BE IGNORED

Electric cooperatives agree that the blockchain technology—as well as other forms of transactive energy—could eventually be an asset. If ignored, they could become a disruptive force.

Ajaz Sadiq, vice president of grid modernization and technology integration with North Carolina Electric Membership Cooperative, a Raleigh, North Carolina-headquartered generation and transmission cooperative (G&T), argues, "Blockchain is real, though it needs to evolve to meet the needs of a utility. We definitely need to experiment with it. You don't want to have blockchain develop in the marketplace without us and leave us playing catch up."

Mark Schwirtz, CEO of Golden Spread Electric Cooperative, a G&T based in Amarillo, Texas, sees consumer-sited generation as a big part of the utility of the future. "I don't think cooperatives should build another [generation] asset. With flat load growth and increased distributed generation options, we should seek to fill future resource needs at the distribution level.

He continues: "In the near future, our members will have the ability to sell to each other—for example, a neighbor that has solar could sell to someone in his own neighborhood, with the cooperative providing the platform that enables the transaction and moves the energy. A key component of the platform is blockchain, which documents and facilitates the transactions between the G&T and distribution co-ops, and then between consumers, all in ways that could s ave money."

Schwirtz believes that due to a combination of low energy prices and lagging adoption of distributed energy in rural areas, "We'll be mid- to late adopters of transactive energy. But that doesn't mean electric cooperatives can afford to stay on the sidelines."

He concludes: "Consumers are smart; if there's benefit they'll find ways to disrupt our industry or force regulators to require change. We're seeing solar and battery prices coming down, while people are building apps to take us out of the picture. In fact, third-party aggregation of distributed energy is being considered in a current proposed rulemaking by the Federal Energy Regulatory Commission."

TIP ONE

Use a multistage approach or pilot to test the waters with blockchain.

What Cooperatives Should Keep In Mind Before Starting a Blockchain Pilot

Dave Hardin, chief architect at the Smart Electric Power Alliance, believes electric cooperatives represent attractive candidates for the use of blockchain and other types of transactive energy technology. And gaining "hands-on" experience through a pilot project will be highly instructive.

"I see so much potential for cooperatives, but there are minefields out there," he says.

Hardin, an engineer, has worked in commercial smart grid and transactive energy applications for companies like EnerNoc and Schneider/Invensys. The first step he says is to "identify the problem you are trying to solve. What do you want the future to look like?"

A pilot, he comments, can be constructed using what he terms a "public blockchain," rather than a proprietary, private one. "In phase one, you are simply simulating transactions. In phase two, you start to go on-line."

By using a stage-gate process, he notes, "you will see how it works and what issues need to be resolved before you are ready to scale up. Participating in a public blockchain as part of a pilot lets you build a groundswell of support. As the seed starts to grow, others will want to join with resources. Your co-op will not go it alone, and the findings will have a far broader impact."

Although blockchain grows more secure and productive as the number of market players increase, all of the pilots involving utilities start with a discrete problem to solve and a small group—such as moving electric vehicle charging stations off peak or managing generation sources in a microgrid to optimize value.

"To talk about a co-op betting the farm on one system, to integrate all their resources into one platform, that's a huge commitment," Hardin admits. "That's why a multiphase approach is important and why cooperatives should work through a greater community."

Other Ways That Blockchain Might Meet Your Needs

In addition to providing a platform to better manage the integration of consumer-sited distributed energy resources like solar, battery storage and electric vehicles, blockchain carries potential applications for back-office utility functions such as billing and supply-chain management.

"We're looking at the potential for how we might use blockchain to solve some of our most challenging business problems," says David Bonnett, vice president of product management with the National Information Solutions Cooperative, the Lake Saint Louis, Missouri-based information technology cooperative that develops and supports advanced software applications primarily for electric cooperatives and rural telecommunications carriers, but also Fortune 1,000 corporations, throughout the United States, American Samoa and Canada. "One application might be in efficiently and securely managing the enormous number of transactions created by consumers with Internet-connected distributed energy resources."

Historically, Bonnett explains, cooperatives have billed using monthly data and in recent years have moved to hourly intervals thanks to advanced metering infrastructure (AMI). "For 10 to 15 years we talked about 'prices to devices,' but we didn't really have devices that could communicate and make decisions. Now all of a sudden we have Wi-Fi-enabled thermostats and electric cars with smart charging capability."

Bonnett points out that fiber buildouts are another factor. "We now have 75 distribution cooperatives installing fiber-to-the-home [FTTH] that not only provides high-speed broadband services for their members, but also enables real-time control and collection of vast volumes of data available from AMI and automated down-line components. This opens up an opportunity to move to more of a real-time transactive model. Right now, we have close to 100 members doing what I'd call complex rates—requiring a new level in the number and speed of transactions. As consumers add more connected resources like electric vehicles and PV solar they will also demand more flexibility in how these resources are used. Securely managing these types of transactions is where we see an opportunity for applications leveraging the blockchain foundation."

After attending a "Blockchain in Energy Forum" hosted by the energy analysis firm GTM Research, Tanuj Deora, chief content officer at the Washington, D.C.-based Smart Electric Power Alliance, noted in a blog that applications for upgrading utility billing systems were "perhaps the most compelling case for the technology. Options ranged from utility payments for smart thermostat control to community solar subscriptions. The reality is that utilities' billing systems are expensive to upgrade. A utility-managed, blockchain-based approach may well be much cheaper to develop, roll out, interface with and upgrade."

At the GTM forum, Vikram Singh of Alectra Utilities Corporation—which serves municipalities north and west of Toronto, Canada—provided an example of how blockchain supports billing adjustments required for the utility's demand-response gamification pilot. In exchange for allowing the dispatch of distributed energy resources a day ahead or in real-time to meet utility needs, consumers receive award points redeemable at local businesses. Crediting these awards using the legacy billing system proved cost-prohibitive. A blockchain solution enabled instantaneous rewards consumers were promised.

Blockchain may be able to fill purposes that don't involve either distribution automation or deep information technology. Margaret "Peg" Rupert, chief strategy and information officer at Golden Spread Electric Cooperative, a generation and transmission cooperative (G&T) based in Amarillo, Texas, notes that distribution members could use blockchain to track the sharing of technical, high-demand services, such as calling upon and accounting for help from distribution engineers at other cooperatives, and even using blockchain to maintain a general ledger of shared resources.

"You might call them cooperative coins," she reports. "You would be able to say, 'I have cooperative coins to spend, and I'd like to cash them in and get the services of an engineer at another cooperative to help with a substation project or storm recovery. The cooperative that provides the engineer then has additional coins to use for other services."

An added benefit of this application, Rupert suggests, is that "members gain experience with blockchain that may be less complicated than the buying and selling of energy. That could be very helpful before expanding into something like an energy blockchain."

TIP TWO

Blockchain offers multiple applications for electric utilities.

TIP THREE

Cooperatives should thoroughly vet any new blockchain application or product they consider, as players in an emerging market often come and go quickly.

Notes of Caution Regarding Blockchain

As with any emerging technology, utilities should continue to monitor the capabilities of blockchain as they evolve. But be wary of start-ups that are not familiar with the utility business. Expect to see smaller companies go out of business, be acquired or exit the space where they cannot compete.

As many pilot projects begin to emerge, be wary of products that might still be in a beta stage or otherwise not ready for full production mode, as well as companies that may outgrow their ability to support a customer base.

Utilities should also be wary of applications lacking a clear story of how blockchain technology improves or eliminates redundant processes, improves speed of delivery or provides other operational benefits.

In the Internet of Things (IoT) space many overstated claims exist of how using blockchain solves security issues, so dig deep and ask for demonstrated capabilities of blockchain-related products. Do not chase blockchain because it seems like a "magic bullet."

In cases where blockchain seems to provide a clear benefit, keep in mind that outcomes are still being determined.

For more information, contact Gerald R. Gray, ggray@epri.com.

Adapted from "Blockchain: The Technology Risks and Rewards for Utilities" (October 2017), published by the Electric Power Research Institute (EPRI), a nonprofit research consortium made up of electric utilities, including electric cooperatives, headquartered in Palo Alto, California.

Taking Load Management to the Next Step

Vermont Electric Cooperative, headquartered in Johnson, Vermont, sees itself as a candidate for adopting a transactive energy platform. The cooperative falls under an aggressive state renewable portfolio standard (55 percent of each utility's retail power supply mix must come from "clean and green" electricity sources by 2018 and 75 percent by 2032), with consumers adding solar photovoltaic systems and other distributed renewable energy technologies in response to an open net metering program.

To meet consumer calls for renewable energy, the 32,000-member cooperative recently built three community solar arrays totaling more than 7.5 MW. To help achieve cost savings by decreasing load during ISO New England (ISO-NE) yearly demand peaks and Vermont monthly peaks, Vermont Electric staff have been running load-shifting tests using a small distributed battery setup and plan to deploy a 4-MWh battery energy storage project in the near future.

Vermont Electric Manager of System Engineering Cyril Brunner notes that in the northern part of the state some large wind projects face transmission constraints, which prevents them from running at full capacity at all times. "This has cost ramifications for our members, and we have intervened in new generation projects above 150 kilowatts on certain substations to mitigate the impact. But in other areas we're trying to promote load growth that would allow for additional renewable generation."

In its quest for peak demand cost savings, the cooperative has stepped up installation of advanced metering infrastructure and automated smart grid components and recently launched a pilot in partnership with Packetized Energy, a Vermont-based start-up. Packetized Energy places a switch on electric water heaters in the homes of volunteer members that—following a signal from the cooperative when its determined the ISO-NE is nearing a peak—functions independently to maximize load reduction.

"We currently have 30 members enrolled, with a goal of 300," Brunner comments. "For every 1 MW we shave during the ISO-NE yearly peaks and Vermont monthly peaks, we trim approximately $200,000 off our transmission costs."

While similar to traditional load management initiatives employed by electric cooperatives for decades—direct control of specialized appliances and equipment (notably large-capacity, grid-enabled electric resistance water heaters, electric thermal storage furnaces and room heating cabinets, air conditioning and dual-fuel units)—Packetized Energy's scheme goes further by using intelligent design and software for real-time, automated decision-making. The company describes its technology as "building on approaches used to manage data packets in communication networks without centralized control and with a high level of privacy."

The eventual goal for Vermont Electric reflects the ideal application of transactive energy: to "allow millions of small end-use devices to cooperatively balance energy supply and demand in real time without jeopardizing reliability of the grid or quality of service to consumers… to optimally manage the rapid fluctuations that come from large amounts of renewable power generation, while simultaneously managing reliability constraints in bulk transmission and local distribution infrastructure."

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