Researchers demonstrate feasibility of collaborative energy transactions via blockchain

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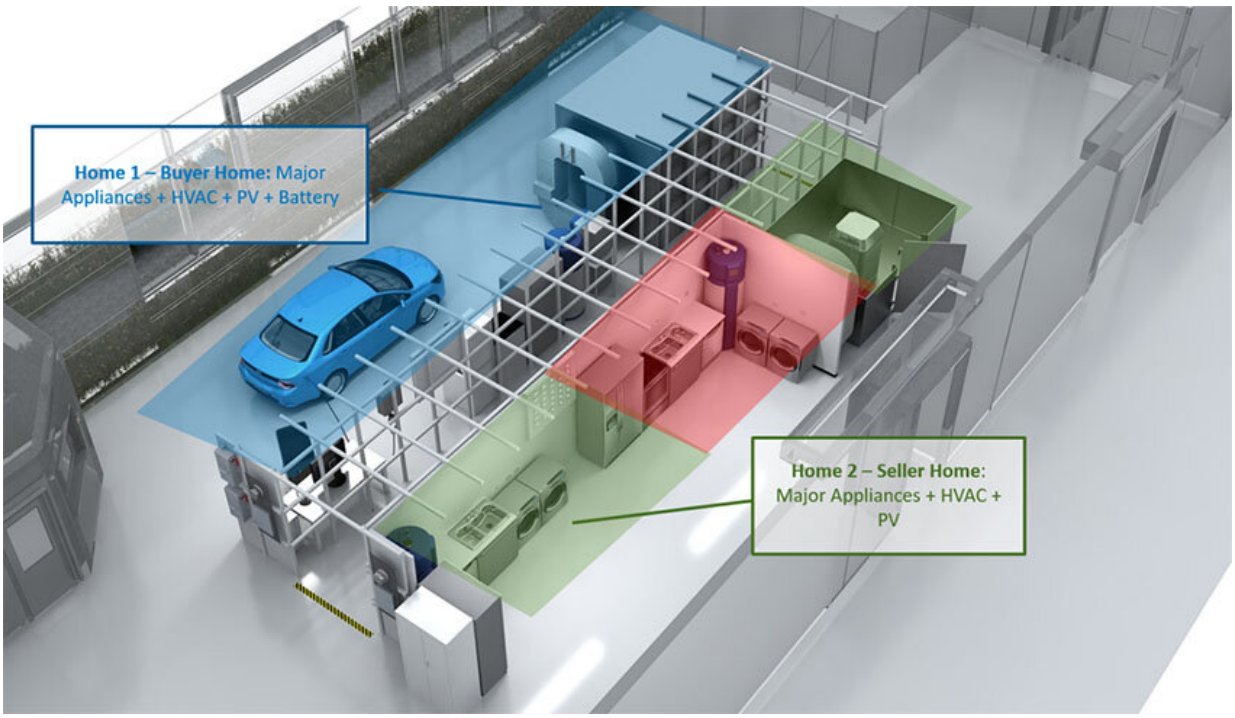

Hardware in the ESIF used to simulate actual homes proved key to showing how blockchain technology can enable peer-to-peer energy transactions. Credit: National Renewable Energy Laboratory

A common vision for the future of the nation's energy grid involves homeowners selling unused power generated from rooftop solar panels

to others in their communities, and working together to help ensure the reliability, resiliency, and security of the power grid everyone uses. Sounds great in theory. But how can the grid manage such complex energy transactions at scale?

Several emerging solutions to this opportunity rely on blockchain technology. Researchers at the National Renewable Energy Laboratory (NREL) are evaluating the use of blockchain for transactive energy using hardware in the laboratory's Energy Systems Integration Facility (ESIF) and it may reshape the world of electric systems operation.

"Distributing grid operational decision-making is revolutionary," said Dane Christensen, a mechanical engineer in NREL's Residential Buildings Research Group and a principal investigator on a blockchain pilot project. "It's really like somebody in the 1980s expounding on the economic opportunity of the Internet. Everyone would have laughed at you. That's kind of what's happening right now with blockchain applications—the foundational tools for another technology revolution are emerging, and this could be one of them."

The Potential for Blockchain in the Energy Sector

For the uninitiated, blockchain serves as a distributed digital record of actions agreed and performed by multiple parties. Blockchain's primary value is providing mathematical proof about the state of data, so that different parties to a transaction can agree on the outcome even if they do not know or trust each other. Though commonly associated with cryptocurrencies such as Bitcoin, blockchain technology can be used with virtually any type of transaction involving digital ownership in real time. These technologies rely on established cryptography and consensus mechanisms to ensure transactions remain secure, and an entire industry has emerged to apply blockchain technology in resolving real-world challenges.

Potential opportunities abound for the use of blockchain in the energy sector. The Congressional Research Service last year noted increasing interest among producers of distributed energy resources (DERs)—such as rooftop solar—to sell electricity to neighbors. Congress' public policy research arm predicted that if this approach proves "practical and economical, blockchain technology could alter the manner in which electricity customers and producers interact."

Today, utilities use complex software platforms called an energy management system (EMS) and advanced distribution management system (ADMS) to manage the demand, supply, and reliable delivery of electricity on the power grid. But it is difficult to scale EMS and ADMS to interoperate transactions between thousands of homes, let alone the millions of connected devices in use in those homes.

"When you have hundreds of thousands or millions of devices out there that want to interact, you face a significant trust challenge," said Tony Markel, a senior engineer in the Energy Systems Cyber-Physical Security Research Group at NREL. "Trust between devices can only be achieved through methods that verify and enable proof that each system does what it said it was going to do. With blockchain, we may have a path to achieve secure, trusted communications between players without a need for central control."

NREL Researchers Evaluate a Peer-to-Peer Blockchain

NREL researchers conducted experiments to learn what could happen when two homes were connected via a blockchain with the ability for one to sell excess solar power to another. This required two blockchain transactions: a secure transmission of data about the amount of energy generated, and a payment to the seller.

Central to this research is an NREL-developed software solution called foresee. The software uses homeowners' energy preferences—such as the temperature of their home, or their energy budget—to control connected appliances within the home. In the blockchain experiment, foresee alerted the second home when it would be cheaper to buy renewable energy from its neighbor rather than paying the utility's charges, then used a digital currency to complete the transaction. The demonstration showed the ability to automatically match energy generation and demand between these two homes.

"There's a lot of talk and buzz out there about blockchain but very little documentation," said Dylan Cutler, principal investigator on the project. "This project was a necessary first step in this field—for me, at least, and I think the lab in general—to get some comfort with the technology."

The results highlighted the path for future research. Notably, Cutler pointed out, the use of blockchain in the energy markets will require an examination of grid reliability and resiliency and cybersecurity concerns. One area Cutler's initial research did not consider was the role a utility would play in peer-to-peer energy transactions, and that is something he said a future study must consider.

"I think we just have to recognize that utilities own our grid infrastructure and are on the hook to deliver and maintain a reasonable power quality," he said. "If you were to sell power to your neighbor, it would be using the utility's assets. Somehow, the utility needs to be aware and maybe compensated for that."

Cutler, a senior researcher in NREL's Integrated Applications Center, said the emergence of blockchain technology requires a newly designed market. While the common assumption of blockchain is the end user holds sway over the distributed control of energy, in reality it is likely

that electric power utilities will at minimum be responsible for coordinating these neighborly transactions. "That's the logical entity that would step in and operate this," he said, "but the nature of blockchain enables it to not be a single party. It doesn't have to be a utility."

Community-Scale Energy Collaboration

NREL is building on this prior work to study the benefits for building owners and utilities. Using a blockchain-based market technology, the research centers on the operation of the electrical grid as homes and businesses continue to adopt rooftop solar generation, battery storage, electric vehicles, and smart appliances. The laboratory's partners are Exelon Corporation, a utility based in Chicago, and Energy Web Foundation, which develops open source blockchain software solutions.

Christensen and Sivasathya Pradha Balamurugan, NREL's co-principal investigators on the project, said the use of blockchain would allow increased coordination between utilities and customers to achieve mutual benefits. Electricity generated from renewable resources such as solar and wind that customers cannot use can be diverted to the grid, but there are limits. Feeders—which carry voltage from a substation to transformers—were not designed for the bidirectional flow of electricity.

"There will soon be feeders in the U.S. where if you plug in one more electric car, you could damage transformers or activate safety cutoffs because we're reaching the limits of the capacity of the distribution grid," Christensen said. "Utilities are very interested in how to manage electric service without having to up-size all the grid equipment. Coordination of buildings' energy use is a way to keep costs down, make better use of distributed generation, and improve reliability of the power grid."

Using NREL's ESIF systems, the research team is examining how blockchain-based energy markets can allow buildings to coordinate within a distribution feeder, under appropriate constraints defined by the utility. In particular, the team will explore how a blockchain-based approach to digital identity can help utilities verify the attributes and the operations of distributed energy resources in their territory. The project goal is to allow high levels of solar and flexible loads to be installed in buildings, while eliminating the occurrence of energy backfeed into the bulk power grid. If successful, this will allow building owners and utilities to work together to accelerate adoption of advanced energy technologies. It may also unlock new opportunities for customers with solar or storage assets to earn money or lower their bills by providing grid services.

Ted Kwasnik, Dylan Cutler, Sivasathya Pradha Balamurugan, and Bethany Sparn

work on the blockchain demonstration project in NREL's Energy Systems Integration Facility. Credit: Dennis Schroeder, NREL

By relying on blockchain, Christensen said, utilities could integrate many different types of DER with core operational tools (such as EMS and ADMS software) securely and efficiently. "Traditionally, integrating new resources into the grid comes at a substantial cost for a utility. A large part of that cost is driven by custom and manual processes for different DER types. Every feeder is different. Every home is different. As more renewables are adopted, as more electric vehicles are adopted, continuous expert engineering has to be done."

The engineering to ensure one feeder operates efficiently and effectively in balancing supply and demand does not necessarily translate to another feeder. "What blockchain allows," Christensen said, "is a scalable solution that you can easily set up on another feeder because it can be self-customizing."

NREL and Exelon said a utility can use the findings of the new blockchain research to make a case for allowing a pilot project. "The virtual pilot occurring at NREL is as close as possible to installation on a live grid. The project will establish customer benefits, utility cost/benefit, and help to de-risk the blockchain market solution prior to a deployment."

Other National Laboratories Collaborate with NREL

NREL has also embarked on a two-year effort with other national laboratories to accelerate the use of blockchain in the energy sector. A new collaborative effort called Blockchain for Optimized Security and Energy Management (BLOSEM) intends to develop the architecture and

infrastructure so that utilities can safely explore the technology.

"The interest specifically around blockchain is knowing that utilities need to be able to move faster on the integration side of things," Markel said. "There's an expectation that this could provide them some consistency in outcomes and knowledge that accelerates the adoption process. There are still quite a few unknowns: How do you make this work and what information sets will stakeholders need to share? Would the blockchain systems help highlight an untrusted device that's been compromised by a cyber attack? It's a good space for the lab to really spend the time and effort to clarify those unknowns so we can guide necessary future developments."

NREL's initial role in BLOSEM expands on the laboratory's previous accomplishments, with additional simulations planned to expand the use of blockchain. The National Energy Technology Laboratory is the lead organization on the project, with Ames Laboratory, SLAC National Accelerator Laboratory, and Pacific Northwest National Laboratory also part of the research team. The Grid Modernization Laboratory Consortium is funding BLOSEM. U.S. Department of Energy offices funding this project include the Office of Fossil Energy, Office of Nuclear Energy, and Office of Electricity Delivery and Energy Reliability.

"From a national lab perspective," Markel said, "we are in a good position to lead energy and security related application of blockchain technologies. Our work should offer consistent metrics relevant to utilities on leveraging blockchain to enable millions of systems to behave in a trusted manner. That's a big chunk of what we need to demonstrate along with resolving some key unknowns."

Blockchain Technology Connects Us to the Future

Juan Torres, NREL's associate laboratory director for energy systems integration, estimates it will take 5-10 years before blockchain technology solidifies its place in the energy sector. The mechanisms allowing neighbors to buy electricity from each other are not operational today.

"There is a significant amount of communication that's required across the users, the folks who want to buy the energy," Torres said. "There's communication and negotiation between the various devices. And somewhere along the way, we have to make sure those micro transactions won't cause instabilities on the larger grid. Utilities need to be able to get information about these transactions. It's a system with a lot of moving electrons is the way I would describe it."

Provided by National Renewable Energy Laboratory