INTRODUCTION TO BLOCKCHAIN TECHNOLOGY IN ENERGY

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SEEA
SOUTHEAST ENERGY EFFICIENCY ALLIANCE

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About the Southeast Energy Efficiency Alliance (SEEA)

The Southeast Energy Efficiency Alliance (SEEA) is one of six regional energy efficiency organizations in the United States working to transform the energy efficiency marketplace through collaborative public policy, thought leadership, outreach programs, and technical advisory services. SEEA promotes energy efficiency as a catalyst for economic growth, workforce development and energy security across eleven southeastern states. These states include Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee and Virginia.

For additional information, visit www.seealliance.org

Acknowledgements

Introduction

The Southeast Energy Efficiency Alliance (SEEA) began researching blockchain in response to an increased interest in energy-related technologies from among SEEA's members, industry promotion, and general confusion about this complex, evolving technology. While the fervor surrounding blockchain has somewhat diminished, use cases have become more realistic and attainable. The goal of this paper is to help SEEA Members and others in the energy industry to better understand this technology and its potential role in our energy future. This paper will provide an overview of blockchain, offer a simplified explanation of how it works, and highlight several potential applications for the technology in the energy sector. For clarity, "blockchain" refers to the technology platform as a whole, while "a blockchain" is any single ledger of stored, verified data created using blockchain technology. For additional information, please contact Emme Luck, SEEA Policy Associate, at eluck@seealliance.org or at 404-719-4888.

Overview of Blockchain and its History

The Beginnings of Blockchain: From Finance to Energy

Blockchain entered the global market in 2009 with the launch of **Bitcoin**, a cryptocurrency[1] that uses blockchain as its underlying technology. At the time of its debut, Bitcoin was revolutionary in the financial sector because of its ability to facilitate secure transactions without any single controlling entity, such as a bank.

Ethereum, a second-generation, wholly blockchain-based cryptocurrency, launched in 2015, with the new capability of creating and executing "smart contracts" (explained on page 4).[2] This additional functionality inspired the transition of blockchain into a platform for other innovations.

Over the past several years, there has been increased interest in potential applications of blockchain technology to the energy sector; 180 new energy blockchain startups materialized in 2018 alone.[3] The U.S. electric grid is a centralized, fossil fuel-based system that has struggled in some cases to effectively integrate new technologies and approaches, including renewable energy, distributed energy resources (DERs), and electric vehicles (EVs). Blockchain proponents argue that the technology could enable simpler, cheaper, faster, and more transparent transactions between utilities, regulators, and consumers by providing a way to "record and verify transactions without requiring a central entity to maintain or validate the ledger."[4] The automation of utility and grid processes in addition to more transparent data handling using blockchain could encourage the integration of DERs.

The Basics of Blockchain: A Distributed Ledger

According to the Energy Blockchain Consortium, "blockchain's core innovation[s] [are] its distributed ledger, "trustless" protocol, and consensus-driven capabilities that can track almost any asset, rewire any transaction, and reduce dependency on traditional intermediaries."[5]

Blockchain is a **distributed ledger technology** (DLT) in which all transaction data is replicated and stored on servers, called **nodes**, across the system. Each block has a unique ID that corresponds to the data it holds. When a block is deemed valid, it is added to the chain and becomes unalterable. Each time a block is added to a chain, the new block includes the unique ID of the previous block, linking them together to form a "blockchain." In other words, the fields on the ledger are linked together within the database. If anyone tries to make changes to the transaction data or any field in the block once it has been validated, the chain will "break" and all participants are alerted of the change.

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[1] Per the Oxford English Dictionary, a cryptocurrency is any "digital currency in which encryption techniques are used to regulate the generation of units of currency and verify the transfer of funds, operating independently of a central bank."
[2] Peyrott, Sebastian, Blog. March 28, 2017. https://auth0.com/blog/an-introduction-to-ethereum-and-smart-contracts-part-2/
[3] Presentation at the Global Power & Energy Blockchain Conference, October 30, 2018
[4] *Applying Blockchain Technology to Electric Power Systems*, Council on Foreign Relations, July 2018
[5] Energy Blockchain Consortium, *Value Proposition White Paper*. Page 2. 2018

To visualize this process, imagine a spreadsheet that has been duplicated on a network of many computers. Each user checks each transaction to make sure it is valid, and every time a change is made, each user receives an updated copy of the spreadsheet. There is no central entity that verifies or stores the data; instead, this decentralized structure ensures that all those involved have a chance to participate in checking the data being added to the spreadsheet, which greatly reduces the risk that any one actor could control or manipulate the whole spreadsheet to the detriment of the others.

Security and Consensus

Blockchain provides effective security that has protected hundreds of thousands of transactions over the last decade. While this security is not yet infallible, blockchain combines several elements of security and trust to verify transactions and to maintain the ledger.[6] These elements include:

1) **Distributed ledger technology (DLT)** that maintains records on servers across the system;

2) **Cryptography**, which is used to ensure that incoming and outgoing data is unreadable by hackers;[7] and

3) A **consensus-based mechanism** that validates transactions.

The blockchain validation model incentivizes constructive participation by all network participants using consensus mechanisms, economic incentives, and software proof concepts. Each time a transaction is initiated, participating computers must reach a **consensus** on whether a block of transaction data is valid or not. In order to participate in this validation process, these large computer nodes must solve an algorithm, or a computational puzzle. When the puzzle is solved, the computer has provided **"proof of work"** and is given a financial reward[8] if the work was done correctly. Often, if a given node is the first to solve a puzzle, or the first to correctly validate a block, the user receives a full reward. If they are not the first to solve it but they do the work correctly, they receive a partial reward. If they validate an invalid block or invalidate a valid block (according to the consensus), they receive no reward.

The validation work must be easy enough to check and require a significant but feasible amount of effort to solve. This "work" on the part of the computer uses electricity and therefore money; thus the "proof of work" validation process can be very energy intensive. Participants are disincentivized from spending time, money, and energy doing incorrect work, and incentivized to receive financial rewards for work done accurately.[9] The proof of work software concept predates blockchain and is now widely used on blockchain systems to encourage good behavior, among other "proof" models.[10]

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[6] Blockchain cannot verify that incoming data is accurate or correct; mistakes or fraud are still a possibility at the interface between blockchain and the real world. Incoming data will only be as accurate as the sensor that is validating it, such as the mechanisms in credit card readers that verify your bank account before your transaction is approved. For this step, blockchain users must rely on traditional verification or security measures to ensure accurate data.

[7] Presentations by the Energy Blockchain Consortium at the Global Power & Energy Blockchain Conference, October 30, 2018

[8] The financial reward can be in the form of government-issued currency (e.g. dollars), cryptocurrency (e.g. Bitcoin), renewable energy credits, or any "currency" or token the developers have assigned to that blockchain platform. See **tokenization**, page 4.

[9] Investopedia, https://www.investopedia.com/terms/p/proof-work.asp

[10] PwC Global Power and Utilities, *Blockchain – an opportunity for energy producers and consumers?* Pages 7-8. June 2016.

Some blockchain critics have cited privacy concerns due to the unalterable, or immutable, nature of the ledger. Once your data is a part of the blockchain, that record can never be erased. However, the **cryptography** built into the data can allow users to remain anonymous, if public identity is not a system requirement of that particular blockchain. Although transactions may be public in order to allow for validation and consensus building, the data itself is protected. The transparency that blockchain provides by using consistent, ordered, and distributed blocks of information enables users to have more control over their data than in traditional business models. Blockchain could allow customers to access their utility, bank, health, or other transaction data without needing to get permission from a controlling operator. This ability to access and control one's own energy data without compromising sensitive information or involving a third party is a growing desire among consumers.[11] The distributed nature of the blockchain exists to ensure that no one user or party can manipulate the data.[12]

While the technology remains a mystery for most, some energy experts have promoted blockchain and its many applications as a disruptor in the energy sector during a time of technology advances and more engaged energy users, both at the business and the consumer level. The following section introduces smart contracts and some blockchain use cases relating to energy.

Energy Applications of Blockchain

Distributed Ledger

The most basic use of blockchain is simply using it as a distributed ledger. In theory, if a utility used a blockchain-powered distributed ledger for storing and sharing transaction data, the technology could effortlessly process large quantities of transaction data quickly and securely without having several intermediaries involved (e.g. lawyers, accountants, consultants, etc.), thus cutting down on administrative costs and time. In practice, blockchain is not yet faster than other existing authentication or transaction platforms because experts are still exploring the most efficient and secure ways to reduce latency. The continual improvement of blockchain's speed and security could result in resource savings and efficiency. In addition, the immutability of the data stored on the distributed ledger could also be useful for evaluation, measurement, and verification (EM&V) processes.

In addition, there are various points along the commodity or energy supply chain where blockchain could reduce back-office work. For example, blockchain could be used to streamline price discovery and

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[11] Durand, Patty. https://www.utilitydive.com/news/three-things-consumers-want-from-electricity-providers-1/520821/. Utility Dive, April 10, 2018

[12] If a big enough user (or a group of users working together, called mining pools) is incentivized to go through the "proof" process to reach a consensus validating an invalid block, or vice versa, the move must be caught and corrected by the software developer. This is not common but has occurred. As of March 2019, there is no mechanism built into blockchain technology that can recognize this kind of trick, so the decentralized nature of the blockchain may be compromised by the need for a central entity to monitor and reverse false transactions or mistakes due to human or software error. However, many groups are testing more proof models to solve these issues and technological improvements are constantly changing the possibilities.

verification, logistics coordination, trade entry and execution, and also reconciliation, settlements, and reporting on a shared and traceable ledger. The characteristics of decentralization and trust can be leveraged to improve utility- or company-customer relations by reassuring consumers that their energy data is securely stored and easily trackable. Utilities can use this kind of trustworthy system to reduce administrative and operating costs by automating processes such as billing and data tracking on a blockchain platform. Moreover, multiple parties accessing data from the same ledger increases transparency and ensures that all parties are working from the same data.

Smart Contracts

Smart contract functionality drives many energy applications of blockchain. It is a versatile tool on which one can set up an automated contract on a blockchain with as many terms and conditions as needed and have the associated transactions occur on the same blockchain. This keeps the entire transaction on one trackable blockchain and reduces reliance on intermediaries to verify details at each step of the transaction.[13] The following example provides a very basic description of a smart contract being used simply as a contract.

> **EXAMPLE:** Suppose that "Utility A" agreed to purchase up to two megawatts of excess hydropower from "Utility B" at 0.123 cents per kilowatt when the cost for Utility A to generate its own electricity exceeds 0.130 cents per kilowatt. This agreement could be encoded into a smart contract on a blockchain, where each utility could access the data and see the transaction details, increasing transparency and decreasing the risk of misunderstandings.
>
> Once all the conditions are met, or Utility B has excess hydropower and the price of Utility A's generation is at least 0.130 cents per kilowatt, the smart contract would execute. Execution in this case would mean that as soon as all conditions are met, Utility B would release the allotted amount of energy, and Utility A would be charged the agreed-upon price. This transaction would occur without the traditional internal and external intermediaries verifying the price, time, and amount of the transaction at each step.

Energy Performance Contracts

Energy Performance Contracts (EPCs) are intelligent contractual frameworks that measure energy savings as the difference between a predictive baseline model and actual consumption. Most predictive models use large data sets from an external source as well as complex algorithms, often requiring a third party to ensure mutual understanding and transparency.

Blockchain can eliminate the need for a third party in executing EPCs while ensuring transparency and immutability by hosting the entire transaction on a blockchain platform.[14] EPCs involve multiple parties,

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[13] Blockchain Technologies, Smart Contracts. https://www.blockchaintechnologies.com/smart-contracts/
[14] *An Industrial Prototype of Trusted Energy Performance Contracts using Blockchain Technologies*, Gurcan et al. April 2018

including utilities, customers, financial institutions, and energy service companies (ESCOs), each maintaining their own records; there are many opportunities for errors and disagreements. Administrative costs for carrying out these contracts can be expensive due to data verification between parties.

EPCs on blockchain could integrate the rules for determining energy savings and the conditions for authorizing payments or penalties while automating execution, thus reducing administration costs. By reducing the total cost of EPCs, ESCOs may be able to engage smaller facilities that might not have been previously targeted because their savings were previously insufficient to cover the costs.[15]

Energy Trading

If American policy and grid infrastructure were modified to allow for peer-to-peer energy trading, blockchain could support these transactions in a simple and trustworthy way using smart contracts. Smart contracts could integrate DERs and automate customer-to-grid trading based on the needs of the grid at a given moment in time, helping to manage load. The use of blockchain-powered smart contracts for utility-scale energy trading might offer more real-time visibility for independent system operators (ISOs) and regional transmission organizations (RTOs) by offering a platform for transparency and collaboration across companies. Energy transactions, even small or simple ones, require many processes within each company and across parties, meaning that transaction data must be verified and reconciled several times from execution to settlement. Blockchain's immutable distributed ledger can facilitate the tracking of a resource along the supply chain from source to destination, which can be useful for EM&V. In addition, similar to cryptocurrencies, one can set up any kind of "currency" using **tokenization**. Software developers can create tradable tokens that can represent anything from Renewable Energy Credits (RECs) to carbon offset credits.

EXAMPLE: Nasdaq offers a new service on its LINQ platform that makes solar energy certificates available via blockchain. To accomplish these transactions, solar panels are connected to an Internet of Things (IoT) device that measures the wattage of the power produced and delivered to the grid. Certificates supporting solar photovoltaic growth can be bought and sold anonymously on the LINQ platform.[16]

EXAMPLE: SP Group, an energy utilities group in Singapore, launched a blockchain-powered renewable energy certificate (REC) marketplace in October 2018. The marketplace enables local and international trading of RECs and automatically matches buyers with sellers according to their preferences.[17]

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[15] Rogers, Ethan. *How can blockchain save energy? Here are 3 ways*. American Council for an Energy-Efficient Economy (ACEEE), Oct. 16, 2018.
[16] See Image 1 in Appendix. NASDAQ, http://ir.nasdaq.com/news-releases/news-release-details/nasdaq-linq-enables-first-ever-private-securities-issuance?releaseid=948326.
[17] SP Group, News Release. October 29, 2018

It is important to note that this type of decentralized energy trading does not align with the traditional utility business model. The proliferation of renewables, DERs, and EVs has revealed pain points for the grid, utilities, consumers, and regulators; proponents of blockchain believe that it could be used to alleviate some of the challenges associated with the rapidly changing energy sector by integrating and automating processes.[18] Some utilities and other energy companies are beginning to look into blockchain as a way to meet consumer demand for clean energy or other services, lessening the potential long-term risk that consumers may leave the utility by having their own DERs or choosing a competitor under a new business model.

Smart Connectivity

Increasing numbers of "smart" devices are entering the electricity industry, on residential, commercial, industrial, and utility scales. These smart devices offer a plethora of potential use cases for blockchain. Many companies, and therefore devices, use proprietary or legacy systems that can't always communicate easily with devices or systems using another system or software. This communication barrier and the susceptibility of these devices to hacking make blockchain a potential solution.

The interconnection of smart meters, thermostats, and other smart household appliances using blockchain could facilitate and simplify energy data management for consumers and for utilities. Several companies are testing blockchain's ability to improve device interoperability.[19] These examples are a small sample of the companies and start-ups working to integrate blockchain with existing technologies.

Some other potential blockchain energy applications include, but are not limited to:

- Peer-to-Peer and Prosumer-to-Grid Energy Trading
- Energy Data Management and Transparency
- DER Service Coordination and Grid Optimization
- Time-of-Use Rates and Granular Price Signals

- Grid Security
- Grid Load Management
- Customer Data & Service
- Electric Vehicle Charging
- Energy Battery Storage
- Microgrid Operator
- Net Energy Metering

Challenges and Conclusions

Although blockchain offers some potentially exciting opportunities, its large-scale use is not yet feasible due to several regulatory, infrastructural, and technological barriers. First, traditional utility business models and accompanying regulatory structures are centralized by design, whereas blockchain is a

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[18] Bitcoin and other cryptocurrencies using blockchain were borne from the 2008 financial crisis, leading consumers to distrust traditional financial intermediaries and to seek more decentralized platforms.
[19] Chain of Things, https://www.chainofthings.com/; Internet Node Token, https://intchain.io/

distributed, decentralized ledger technology. These inherent structural differences could cause conflict in some areas but blockchain can be adapted to various business models. Because blockchain is a newer technology, the regulatory and legal implications of its widespread use in energy are unknown. Some utilities have begun initiating pilot projects to identify ways that blockchain could improve their internal or external processes. In the meantime, energy blockchain proponents recommend that regulators and other policymakers begin to improve their understanding of blockchain at a strategic level and avoid setting restrictive rules that could curb innovation;[20] utilities could consider joining a consortium or working group to reduce potential risk and to share lessons learned across the industry.[21]

Second, the grid is not yet equipped to handle multidirectional energy transactions. But, as utility business models begin to shift, blockchain's ability to securely and quickly facilitate energy transactions and device connectivity could ease the incorporation of existing technologies and encourage further innovation. Experts continue to believe that blockchain, in conjunction with other technologies and changing consumer demands, has the potential to change the utility business model as well as utility regulation in ways we can't currently anticipate.[22]

Lastly, other barriers to blockchain adoption include scalability and also the high electricity usage required to validate transactions. Due to its inherent energy-intensive nature, the validating method "proof of work" on a public blockchain[23] is currently too expensive to scale for use on large projects, which is why other validation methods are being explored.[24] Although blockchains are able to process and store large quantities of data, the technology cannot currently securely process data at a speed that is competitive or cost-comparable with traditional technology. Until more research is done, and more pilot projects are completed, there remain many regulatory, legal, and technical unknowns for blockchain. However, a growing number of pilots and projects show that it offers the potential for many beneficial and attainable energy applications. While these applications aren't currently competitive nor efficient in most markets, there is large potential for future optimization of electricity use and human resources.

Despite existing barriers, ongoing developments related to blockchain suggest that it will continue to advance in the coming months and years. Many global companies have already launched pilot projects, created research teams, and declared that parts of their businesses will move to blockchain.[25] As with any complex nascent technology, stakeholders should first carefully test blockchain in the most prudent use cases before expanding its use in the energy sector more broadly.

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[20] Jamison, Mark A. *Five Things Regulators Should Know about Blockchain (and Three Myths to Forget)*, Page 2. Aug. 16, 2018

[21] Presentations by the Energy Blockchain Consortium at the Global Power & Energy Blockchain Conference, October 30, 2018

[22] Jamison, Mark A. *Five Things Regulators Should Know about Blockchain (and Three Myths to Forget)*, Pages 5-6. Aug. 16, 2018
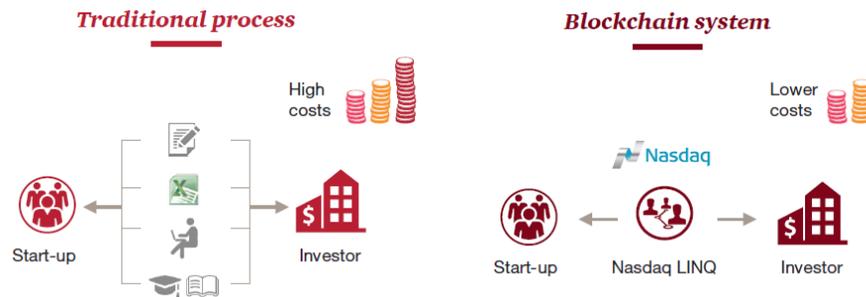
[23] See Image 2 in the Appendix to compare public and private blockchains

[24] Castor, Amy. *A Short Guide to Blockchain Consensus Protocols*. Coindesk, March 4, 2017

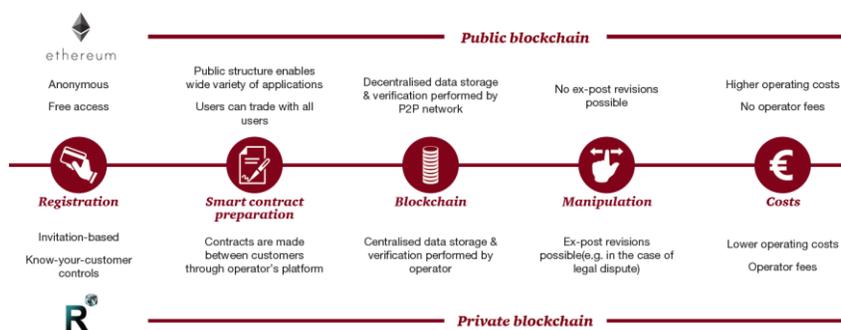[25] See the *More Resources* section of the Appendix for more information.

Appendix

Image 1 – NASDAQ LINQ Platform

PwC Global Power and Utilities, Blockchain – an opportunity for energy producers and consumers? *Page 12. June 2016.*

Image 2 – Comparison of Public and Private Blockchains

PwC Global Power and Utilities, Blockchain – an opportunity for energy producers and consumers? *Page 14. June 2016.*

More Resources on Blockchain and Energy

Understanding Blockchain

- [**Energy Blockchain Consortium YouTube Channel**](#) **– Webinars**
- **Blog Posts from the American Council for an Energy-Efficient Economy (ACEEE):**
  - https://aceee.org/blog/2018/04/blockchain-and-energy-efficiency
  - https://aceee.org/blog/2018/10/how-can-blockchain-save-energy-here
- **Forbes Articles:**
  - https://www.forbes.com/sites/jamessellsmoor/2019/04/27/blockchain-is-the-next-big-thing-for-renewable-energy/#60c66e6448c1
  - https://www.forbes.com/sites/jamessellsmoor/2019/04/27/meet-5-companies-spearheading-blockchain-for-renewable-energy/#2900694bf2ae
- **Navigant Due Diligence Framework: Vetting Utility Use Cases:**
  https://s3.amazonaws.com/bizzabo.users.files/130628/208912/1073557/4%20-%20ebc_webinar_blockchain_utility_usecases_091418.pdf

- **Blog Post on Validation on a Private Blockchain:** http://sammantics.com/blog/2016/3/6/how-transactions-are-validated-on-a-shared-ledger

Cautionary Tales

- **Big Mistakes Enterprises are Making on Blockchain:** https://www.coindesk.com/the-big-mistakes-enterprises-are-making-on-blockchain
- **Blockchain is not the Solution to All Applications:** https://hackernoon.com/why-blockchain-is-a-terrible-idea-for-applications-8393d44f6cab

Companies Using Blockchain

- **IBM, Veridium Labs:** https://pr.blonde20.com/veridium-ibm/
- **Walmart:** https://www.ibm.com/annualreport/2018/walmart.html
- **Maersk:** https://www.forbes.com/sites/tomgroenfeldt/2017/03/05/ibm-and-maersk-apply-blockchain-to-container-shipping/#59ca309e3f05
- **Vakt:** https://www.vakt.com/

Utilities Using Blockchain

- **Exelon** – American Investor-Owned Utility
  - https://news.bloombergenvironment.com/environment-and-energy/pg-e-and-exelon-jump-on-blockchain-for-renewables-electric-cars
- **Alectra** – Canadian Utility
  - http://www.sunverge.com/alectra-deploys-nzee-and-blockchain/

Other Use Cases

- **Smart Cities:** https://www.disruptordaily.com/blockchain-use-cases-smart-cities/

Blockchain in Healthcare: https://e-estonia.com/blockchain-healthcare-estonian-experience/