ENERGIZING THE FUTURE WITH BLOCKCHAIN

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Synopsis: Blockchain technology may ultimately prove as transformative as the internet. While the initial buzz surrounding blockchain revolved around cryptocurrencies and the financial services industry (including Bitcoin, the first example of blockchain), there is growing evidence that blockchain applications can positively transform the energy industry and enable a decentralized, resilient, and stable electrical grid. This article explores blockchain's potential to impact the electric power industry, and is written to inform regulators and industry participants about the opportunities and challenges associated with this new technology.

Section II of the article provides an overview of blockchain technology and its characteristics, with particular focus on the unique features that make it well-suited for energy industry applications. Section III discusses how blockchain might transform the electric power industry, highlighting a number of initiatives and pilot programs that are already underway in the United States and abroad. In Section IV, we explore how blockchain and blockchain-powered use cases fit within the legal and regulatory frameworks that govern existing transaction and compliance protocols, including whether current utility business models are compatible with blockchain, and whether smart contracts are legally enforceable. Finally, in Section V, we discuss some of the opportunities and challenges that will arise for regulators as they seek to understand and evaluate the impacts of this potentially transformative technology.

I. INTRODUCTION

You should care about blockchain. Not because blockchain companies are raising huge sums of money, but because nearly every electric power regulator, consumer advocate, utility executive, and grid operator will, in the next few years, be asked to evaluate and make decisions about blockchain-related projects. More significantly, you should care about blockchain because the technology can play a critical role in the transformation of the electricity sector over the next decade.

Recent years have seen cost declines and technological improvements for renewable and distributed energy resources (DERs) that, combined with innovative financing and third-party business models, empower consumers to produce, store, and manage electricity on their own terms at prices competitive with conventional utility tariffs.[1] These advances have driven a steady trend towards decentralization in electricity markets, with larger and more diverse participation than ever before.[2] Regulators today face a fundamental challenge: how can they best meet their regulatory compact with utilities while empowering consumers to capture value from

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1. *Tumbling Costs for Wind, Solar, Batteries Are Squeezing Fossil Fuels*, BLOOMBERGNEF (Mar. 28, 2018), https://about.bnef.com/blog/tumbling-costs-wind-solar-batteries-squeezing-fossil-fuels/; BLACK & VEATCH, STRATEGIC DIRECTIONS: ELECTRIC REPORT (Oct. 4, 2017), https://www.bv.com/insights/expert-perspectives/distributed-generation-still-part-plan-technology-adoption-matures.

2. New Energy Outlook 2018, BLOOMBERGNEF (2018), https://bnef.turtl.co/story/neo2018?teaser=true. This trend is being driven by economics, policy, and consumer preferences [hereinafter *New Energy Outlook*].

distributed generation, storage, smart controls, and other digital solutions that are becoming more widespread? And how does that compact sit alongside mandates for resiliency (the ability to resist and rapidly recover from physical and cyber disruptions), environmental outcomes (notably decarbonization), consumer choice, and energy access and equality?[3]

Until recently, regulators have mainly relied on centralized technology – owned and operated by utilities and independent power producers - to manage electricity markets and the operation of the electricity grid.[4] These central approaches are ill-equipped to efficiently and effectively coordinate the dramatically increasing number of distributed energy resources on the grid while maintaining security and reliability. Regulators have a need and an opportunity to adopt new approaches and technologies that can leverage DERs to create a reliable, affordable, secure, low-carbon grid that benefits end-consumers.

Blockchain technology, which was invented, in part, to coordinate distributed market actors, is particularly well suited to efficiently and securely coordinate a decentralized network of energy resources and can help make electricity markets more secure, open, and efficient.[5] Blockchain can enable the decentralized, resilient, and stable electrical grid that utilities, regulators and consumers seek.

The blockchain market is active. Over $350MM USD has been raised by more than 150 new companies operating at the intersection of blockchain and energy since January 2017.[6] Established electricity market participants are investing in blockchain startups and joining industry consortium efforts.[7] The largest consortium effort at the intersection of blockchain and energy—The Energy Web Foundation (EWF)–has over 70 large energy companies as Affiliates including Shell, Centrica, TEPCO, Duke Energy, and PG&E as well as a similar number of startup companies.[8]

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3. The FERC's docket on Grid Reliability and Resilience Pricing summarizes much national and state-level work in this area. Order Terminating Rulemaking Proceeding, Initiating New Proceeding and Establishing Additional Procedures, *Grid Reliability and Resilience Pricing,* 162 F.E.R.C. ¶ 61,012 at P 17 (2018). In the United States, lawmakers in many states have implemented renewable portfolio standards, but implementation is incomplete and targets vary. *State Renewable Portfolio Standards and Goals*, NATIONAL CONFERENCE OF STATE LEGISLATURES (July 20, 2018), http://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx. New York, Illinois, Texas, and California have all enabled a high penetration of customer choice. *See also* Joe Rafalowicz, *Fact Sheet: Tracking Energy Access Targets*, POWER FOR ALL (April 4, 2017), http://www.powerforall.org/blog/2017/4/4/fact-sheet-tracking-energy-access-targets.

4. *Distribution Operator Simulation Studio*, ARPA-E (Nov. 2015), https://arpa-e.energy.gov/?q=slick-sheet-project/distribution-operator-simulation-studio.

5. Esther Mengelkamp et al., *A Blockchain-based Smart grid: Towards Sustainable Local Energy Markets*, 33 COMPUTER SCI. – RES. & DEV. 207 (Feb. 2018), https://link.springer.com/article/10.1007/s00450-017-0360-9.

6. Stephen Lacey, *Energy blockchain Startups Raised $324 Million in the Last Year. Where's the Money Going?*, GREENTECH MEDIA (Mar. 12, 2018), https://www.greentechmedia.com/articles/read/energy-blockchain-startups-raised-324-million-since-2017#gs.BFcre2I; Chris Martin, *Investors Put $300 Million in Crypto Energy Investments*, BLOOMBERG (Mar. 5, 2018), https://www.bloomberg.com/news/articles/2018-03-05/more-than-buzz-blockchain-s-300-million-in-energy-investments.

7. David Livingston et al., *Applying Blockchain Technology to Electric Power Systems*, COUNCIL ON FOREIGN RELATIONS (2018), https://cfrd8-files.cfr.org/sites/default/files/report_pdf/Discussion_Paper_Livingston_et_al_Blockchain_OR_0.pdf.

8. *Affiliates*, ENERGY WEB FOUNDATION, https://energyweb.org/affiliates/ (last visited Oct. 10, 2018).

Though blockchain technology remains in its infancy, large investments paired with the rapid pace of innovation will enable blockchain to play a significant role in electricity markets over the coming years. To help regulators and others understand the implications of blockchain, we offer an explanation of the technology and the unique capabilities that differentiate it from other technologies, outline how it may be practically applied in the electricity sector, and note some of the legal and regulatory issues that promote and impede its progress.

II.   BLOCKCHAIN TECHNOLOGY – WHAT IS IT?

A.   *The Fundamentals – A Secure, Trusted, Distributed Ledger*

There is not a singular definition for blockchain. Rather, the term blockchain refers to computing networks with a novel combination of technologies and governance that allow parties who do not know or trust each other, including competitors, to reach consensus. At first glance, it may seem simple to create a technology that allows competitive parties to agree on conditions of an economic transaction, for example, the volume of electricity they have traded on a certain day and the bargained for price of that electricity. In practice, wholesale electricity markets take days to weeks to reach financial settlement, and demand response settlements can take months.[9] Disputes around data agreement often lead to time-intensive back-office verification and can lead to significant auditing and even litigation.[10]

One reason why parties on opposite sides of a transaction may have difficulty in reaching an agreement over the exact data at issue is because, in most cases, every entity stores its transactions and other work on its own private ledger.[11] Each private ledger contains its own inputs and errors that lead to discrepancies in information.[12] These discrepancies create disagreement and distrust. Blockchain technology aims to replace each party's individual ledger with a common, secure, shared ledger—one single record of the truth—that is held and agreed upon by all parties.[13]

While it might seem that a public ledger would be inherently less secure, the opposite is in fact true. The first large scale implementation of blockchain technology, Bitcoin, maintains a publicly accessible ledger that anyone can read and edit (via initiating transactions to transfer value in the form of cryptocurrency between parties; "Bitcoin" refers to the ledger itself as well as its native digital asset,

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9. ISO New England, for example, bills twice weekly. *Billing Process*, ISO NEW ENGLAND 1-3 (2015), https://www.iso-ne.com/static-assets/documents/2015/01/billing_process_final_123114.pdf [hereinafter *NE Billing Process*].

10. New Zealand's Electricity Code, for example, devotes an entire section to rules and processes for data reconciliation. *Part 15 – Reconciliation*, ELECTRICITY AUTHORITY (Oct. 5, 2017), https://www.ea.govt.nz/code-and-compliance/the-code/part-15-reconciliation/.

11. Marco Iansiti & Karim R. Lakhani, *The Truth About Blockchain*, HARVARD BUSINESS REVIEW (Jan. 2017), https://hbr.org/2017/01/the-truth-about-blockchain.

12. *Elexon Beginners Guide to Settlement Performance*, ELEXON, https://www.elexon.co.uk/wp-content/uploads/2017/03/Beginners-Guide-to-Settlement-Performance-for-Suppliers-FINAL.pdf/ (last visited Oct. 26, 2018).

13. Iansiti & Lakhani, *supra* note 11.

or cryptocurrency).[14] The Bitcoin ledger is essentially a list of accounts (known as "addresses") and balances (which are the result of all historical transactions). Bitcoin has been worth billions in USD equivalent for almost ten years, making it a large target for cyber-attacks.[15] Because the Bitcoin ledger resides on a distributed, open network, it is unable to use traditional cybersecurity defense services (e.g. firewalls) administered by a central authority.[16] Despite this transparency, the Bitcoin blockchain has never been hacked successfully.[17]

Many technical components that enable blockchain existed before the invention of Bitcoin.[18] The anonymous inventor of Bitcoin, Satoshi Nakamoto, combined these technologies in a novel way that allows every participant to share and have faith in a common version of the truth.[19] While there is no standard definition of blockchain, there are three characteristics that define the technology: immutability, public/private key cryptography, and distributed consensus.[20]

1. Immutability – to ensure the ledger is not tampered with, sets of transactions submitted to the chain are bundled together into 'blocks' and then stamped with a unique identifying code.[21] If any information in a historic block is altered, the latest identifying code will change, alerting users to the attempted tampering.[22] Computers validating information on the blockchain have economic incentives to preserve correct information and disallow any malicious attempts to tamper with information.[23] Tampering with blockchains requires coordination by a massive

14. *Frequently Asked Questions: Who Controls the Bitcoin Network?*, BITCOIN, https://bitcoin.org/en/faq #who-controls-the-bitcoin-network (last visited Oct. 2, 2018).

15. Bitcoin is worth over $100 Billion USD equivalent. *Number of Bitcoins in circulation worldwide from 1st quarter 2011 to 2nd quarter 2018 (in millions)*, STATISTA (2018), https://www.statista.com/statistics/247280/number-of-bitcoins-in-circulation/.

16. Mike Ocrutt, *How Secure is Blockchain Really?*, MIT TECHNOLOGY REVIEW (Apr. 25, 2018), https://www.technologyreview.com/s/610836/how-secure-is-blockchain-really/.

17. The Bitcoin protocol itself has never been compromised. Individual users have had Bitcoin balances exposed through mismanagement of private security keys.

18. Bernard Marr, *A Very Brief History of Blockchain Technology Everyone Should Read*, FORBES (Feb. 16, 2018), https://www.forbes.com/sites/bernardmarr/2018/02/16/a-very-brief-history-of-blockchain-technology -everyone-should-read/#5f60b6b77bc4.

19. Robert Hackett, *Why Big Business is Racing to Build Blockchains*, FORTUNE (Aug. 27, 2017), http://fortune.com/2017/08/22/bitcoin-ethereum-blockchain-cryptocurrency/.

20. Alid Castano, *How to Explain the Power of Blockchains to Your Non-Tech Friends*, HACKERNOON (Sep. 20, 2017), https://hackernoon.com/how-to-explain-the-power-of-blockchains-to-your-non-tech-friends-a3eda6cbe47a.

21. Known as a "hash." A hash function translates data of any size into data of uniform size; the hash of a single digit, or a word, or an entire paragraph would be the same length. For a given input, it is very easy to verify the output of the hash function but impossible in practice to determine the input given only the output. In the context of blockchain, transaction data such as sender, recipient, etc. as well as metadata like a timestamp are hashed to create a unique, pseudonymous identifier for each block. Antony Lewis, *A Gentle Introduction to Immutability of Blockchain*, BITS ON BLOCKS (Feb. 29, 2016), https://bitsonblocks.net/2016/02/29/a-gentle-introduction-to-immutability-of-blockchains/.

22. Satoshi Nakamoto, *Bitcoin: A Peer-to-Peer Electronic Cash System*, https://bitcoin.org/bitcoin.pdf.

23. Bryan Chia, *What is cryptocurrency? (Part 2: Trustless, Decentralized & Immutable)*, MEDIUM (Nov. 27, 2017), https://medium.com/@dashrandom/what-is-cryptocurrency-part-2-trustless-decentralized-immutable-c6e82833bd5c.

network of decentralized computers, making attempts to alter information expensive to the attacker and highly unlikely to succeed.[24] For these reasons, blockchain ledgers are probabilistically immutable, meaning that once a block is created, it cannot be changed.[25]

2. Public/private key cryptography – every account on a blockchain has a unique matching public/private key pair, which is an unpredictable string of characters generated by an algorithm.[26] Public keys are visible to all on the network, and serve as identifiers that allow users to transact with each other.[27] To ensure that transactions submitted on behalf of a user have their consent, users must sign each transaction with their private key.[28] A transaction is deemed valid and included in a block if the private key matches the public key.[29]

3. Distributed consensus – to create an immutable ledger that is agreed upon by all users, blockchains employ a tactic known as distributed consensus.[30] Distributed consensus is fundamental to blockchain and is what makes the technology decentralized.[31] There are several types of consensus, but all share a similar core concept: users, who do not necessarily know or trust one another, take turns serving as the validator for a block of transactions and are economically incentivized to maintain the integrity of the network.[32] The method by which the validator is chosen differentiates consensus types.[33] To validate a block, the chosen user ensures that correct private keys are included in transactions, then creates a unique identifying code to label the entire block.[34] This user then distributes their work to the other users (or sometimes an eligible subset of users) on the network who accept the new block if and only if (1) they double check the validation and find it correct and (2) the validator can prove that they have expended significant effort (either through staking their reputation, staking financial capital, or expending

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24. Ross Mauri, *Three Features of Blockchain That Help Prevent Fraud*, IBM (Sept. 19, 2017), https://www.ibm.com/blogs/blockchain/2017/09/three-features-of-blockchain-that-help-prevent-fraud/.

25. Lewis, *supra* note 21.

26. *Public Keys and Private Keys*, COMODO, https://www.comodo.com/resources/small-business/digital-certificates2.php (last visited Oct. 2, 2018).

27. Toshendra Kumar Sharma, *How Does Blockchain Use Public Key Cryptography?*, BLOCKCHAIN COUNCIL (Jan. 27, 2018), https://www.blockchain-council.org/blockchain/how-does-blockchain-use-public-key-cryptography/.

28. *Id.*

29. *Public Key*, INVESTOPEDIA, https://www.investopedia.com/terms/p/public-key.asp (last visited Oct. 2, 2018).

30. *What is Distributed Consensus in Bitcoin?*, QUORA, https://www.quora.com/What-is-distributed-consensus-in-Bitcoin (last visited Oct. 2, 2018).

31. *Blockchain Fundamentals*, BUSINESS BLOCKCHAIN HQ, https://businessblockchainhq.com/blockchain-fundamentals/ (last visited Oct. 2, 2018).

32. In this paragraph "user" refers to a computer operating as a validator node on a blockchain. The processes required to validation transactions and create a new block are automated and performed by computer code. Chris Hammerschmidt, *Consensus in Blockchain Systems. In Short*, MEDIUM (Jan. 27, 2017), https://medium.com/@chrshmmmr/consensus-in-blockchain-systems-in-short-691fc7d1fefe.

33. Juri Mattila, *The Blockchain Phenomenon – The Disruptive Potential of Distributed Consensus Architectures*, ETLA WORKING PAPERS NO. 38 at 24 (May 10, 2016), https://www.etla.fi/wp-content/uploads/ETLA-Working-Papers-38.pdf.

34. Lewis, *supra* note 21.

computational work) to execute the block validation. [35] For the process to complete, blockchain governance structures typically require that a specific percentage of users (often a simple majority) accept the new block.[36] When a user successfully creates a new block, they are financially rewarded via a combination of transaction fees and block validation awards denominated in digital tokens or cryptocurrency.[37] If enough users on the network find the new block to be invalid, then the first user's staked capital, reputation, or work is lost without any gain, creating a mutually reinforcing system where all actors are incentivized to contribute to the overall health and validity of the network.[38] The process of creating new blocks is known as "mining" or "block validation", depending on the consensus type.[39]

While it is not critical for all actors in the electricity sector to intimately understand the internal workings of blockchain networks, actors should be wary of self-proclaimed 'blockchain' projects that do not contain all three of the technical building blocks mentioned above. Networks that exclude one or more of these technical elements are likely either taking security shortcuts or are centralized database solutions, not blockchains. Such networks do not share the benefits that make blockchains truly unique and potentially transformative to the energy industry.

Bitcoin, the first blockchain, combines these three technical building blocks: immutable ledger, public/private key cryptography, and distributed consensus.[40] The result is a ledger that performs calculations, such as adding and subtracting amounts from different accounts, in a secure and trusted way.[41] However, the Bitcoin blockchain does not have features that add significant value to the energy industry. The true value of blockchain, in particular for energy sector applications, came with the addition of one final technical building block: smart contracts, as described below.

B. The Result – A Decentralized "Computer"

While Bitcoin created a mechanism to ensure trusted, secure, and distributed records, Ethereum, the most widely used blockchain, added a native programming language and code execution engine, creating a mechanism to facilitate more complex actions – in effect, any process that can be written in computer code – with those blockchain records.[42]

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35.   Mattila, *supra* note 33, at 6–7.

36.   *Blockchain Glossary for Beginners,* BLOCKCHAINHUB, https://blockchainhub.net/blockchain-glossary/ (last visited Sep. 27, 2018) [hereinafter *Blockchain Glossary*].

37.   *Id.*

38.   *Id.*

39.   *What is Cryptocurrency Game Theory: A Basic Introduction*, BLOCKGEEKS (2017), https://blockgeeks.com/guides/cryptocurrency-game-theory/.

40.   Bitcoin employs a proof of work consensus protocol. The following article provides an overview and comparison of popular consensus protocols: Amy Castor, *A (Short) Guide to Blockchain Consensus Protocols*, COINDESK (Mar. 4, 2017), https://www.coindesk.com/short-guide-blockchain-consensus-protocols/.

41.   Lewis, *supra* note 21.

42.   Ethereum has the most robust, fastest-growing developer community in the public blockchain space, with more Github repositories, developers and code updates than any other open-source blockchain. James Martin

At the most basic level, smart contracts are simply conditional logic (i.e. "if/then") statements recorded in lines of code that run on a blockchain.[43] Blockchains like Ethereum that feature native programming languages and code execution environments are often referred to as "smart contract platforms".

A simple Ethereum smart contract might state that if Mark pays Alice 5 Ether (native Ethereum currency), then Alice pays Bob 10 Ether. This is a simple example, but one can already begin to see the applications in wholesale market settlement. For example, consider two parties who agree to execute a sale of 100 MWh of electricity once a specific wholesale price is reached. These two parties could encode that agreement in a smart contract, record it on the Ethereum blockchain, and the contract would execute automatically (including financial settlement) when an outside source of wholesale pricing information indicated that the agreed-upon price was achieved. The execution and settlement would be near instantaneous, in contrast to current wholesale markets that typically require a multi-day lag time to settle.[44]

As of late October 2018, the public Ethereum blockchain, on average, processed over 550,000 transactions per day.[45] However, Ethereum is not the smart contract platform in existence; there are a variety of alternative blockchain networks that offer similar capabilities[46]. Active smart contracts are used for everything from prediction markets to settling electric vehicle charging transactions.[47] The technical capabilities of blockchain, along with the market's understanding of how to use them, is only growing, and smart contracts are being paired with accessible user interfaces in internet browsers and mobile applications. Predictions that envision blockchain becoming as transformative as the internet are premised on these features, and view future blockchains as accessible and highly functional decentralized computers.[48]

C. The Path Forward – A Technology in Development

While blockchain technology is exciting and its market applications are promising, it is important to remember that blockchain is still at an early phase of development. Technical limitations as well as evolving legal regulatory frameworks preclude mass-market adoption at present. However, some important hurdles have already been overcome.

Duffy, *Ethereum Will Be the Backbone of the New Internet*, LOOM NETWORK (June 4, 2018), https://medium.com/loom-network/ethereum-will-be-the-backbone-of-the-new-internet-88718e08124f; CRYPTO CODE WATCH (2018), https://cryptocodewatch.com/ (last visited Oct. 10, 2018).

43.   *Bits on Blocks*, *A gentle introduction to smart contracts*, https://bitsonblocks.net/2016/02/01/gentle-introduction-smart-contracts/.

44.   *See, e.g., NE Billing Process*, *supra* note 9, at 4.

45.   *Ethereum Transaction Chart*, ETHERSCAN (Sept. 27, 2018), https://etherscan.io/chart/tx.

46.   Michiel Mulders, *Comparison of Smart Contract Platforms*, HACKERNOON (Mar. 5), https://hackernoon.com/comparison-of-smart-contract-platforms-2796e34673b7.

47.   *Blockchain in Energy and Utilities*, INDIGO ADVISORY (2018), https://www.indigoadvisorygroup.com/blockchain/.

48.   *Blockchain: A Beginners Guide*, BLOCKCHAIN HUB (Sept. 20, 2017), https://s3.eu-west-2.amazonaws.com/blockchainhub.media/Blockchain+Technology+Handbook.pdf.

A notable example is the high energy use associated with validating block-chain transactions. Many popular blockchains, including the Bitcoin and Ethereum networks, achieve consensus through a mechanism called "Proof of Work."[49] Because the network security provided by Proof of Work relies on the ability of any user to compete in the mining process, Proof of Work is a competitive and computationally intensive process that requires lots of electricity. Much attention has been given to the potentially problematic energy consumption of widespread blockchain use, particularly Bitcoin[50]. In response, alternate consensus mechanisms that are less energy intensive have been developed and accepted to varying degrees by the blockchain developer community. [51] For instance, Energy Web Foundation's blockchain designed for the energy sector uses a "Proof of Authority" mechanism that restricts the pool of parties eligible to host consensus validators.[52] On the Energy Web Chain, blockchain eligibility to validate transactions is limited to known entities, which include large energy companies, smaller startups, regulators, and other government agencies.[53] To ensure network security, however, even this restricted pool must include an adequate number of participants and be geographically diverse. Proof of Authority takes orders of magnitude less energy to achieve consensus than Proof of Work, and is an important achievement to scaling blockchain technology in the energy sector.[54]

Energy use aside, traditional centralized IT solutions still outperform decentralized blockchains in many respects. For blockchain to play a meaningful role in the global economy, and the energy sector in particular, there are three critical technical hurdles that must be addressed:

1. Storing data in a cost-effective, decentralized manner that does not tax the overall network;

2. Processing a high rate (i.e. tens to hundreds of millions) of transactions;

3. Protecting sensitive personal or commercial data, and allowing users to engage in fully private transactions that other network users cannot view.[55]

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49.   *Blockchain Glossary, supra* note 36.

50.   Why Bitcoin Uses So Much Energy, THE ECONOMIST (July 9, 2018), https://www.economist.com/the-economist-explains/2018/07/09/why-bitcoin-uses-so-much-energy.

51.   *Consensus Protocols – Proof –of-Work, Proff-of-Stake, Proof-of-Authority, Raft and Federated Consensus*, ADJOINT, https://www.adjoint.io/news/entry/consensus-protocols (last visited Oct. 26, 2018).

52.   *Energy Web Foundation Launches Blockchain and Application Layer Test Network*, ENERGY WEB FOUNDATION (Oct. 3, 2017), http://energyweb.org/wp-content/uploads/2017/10/EWF_Test_Network_Launch_PR_Oct_3_2017.pdf.

53.   The EWF governance structure includes criteria that organizations must meet to qualify as EWF Blockchain validators, and is explained in the EWF White Paper: *The Energy Webchain*, ENERGY WEB, https://energyweb.org/papers/the-energy-web-chain/.

54.   Alicia Naumoff, *Why Blockchain Needs 'Proof of Authority' Instead of 'Proof of Stake'*, COINTELEGRAPH (Apr. 26, 2017), https://cointelegraph.com/news/why-blockchain-needs-proof-of-authority-instead-of-proof-of-stake.

55.   *Why Blockchain is the Future of Data Storage*, CRYPTODIGEST (July 7, 2018), https://cryptodigest-news.com/why-blockchain-is-the-future-of-data-storage-b5636b823293; Connor Blenkinsop, *Blockchain's Scaling Problem, Explained*, FRACTONET (Aug. 22, 2018), https://cointelegraph.com/explained/blockchains-scaling-problem-explained; Didil, *Enterprise Ethereum: Private Transactions with Quorum*, MEDIUM (Dec. 28, 2017), https://medium.com/@didil/enterprise-ethereum-private-transactions-with-quorum-b0574bb60700.

Blockchain companies are deploying billions of dollars and significant resources to overcome these hurdles, and there are many promising solutions under development. While blockchain technology in its current form may not be ready for mass-market adoption, there are applications for the energy industry that can be supported by currently available capabilities. For regulators and others energy market players, now is the critical time to understand and influence these applications as well as technical research and development.

III. USING BLOCKCHAIN TO FACILITATE A CLEANER AND MORE EFFICIENT POWER SYSTEM

A. *Vision of the Future – Where Might Current Trends Lead Us?*

The 20th century electricity grid was centrally managed. Power was delivered one way over vast distances from massive generation assets to largely passive customers, who in turn paid the utilities that historically owned and operated those generation and transmission assets.[56] By the early 21st century, this model started to fundamentally transform.[57]

> [M]utually reinforcing technological advances—[] the rise of cost-effective and zero-marginal-cost renewables, distributed energy resources (including flexible loads), and sophisticated software-enabled services—along with governmental policies, changing consumer behaviors, and external events such as extreme weather and cyberattacks, [began] challenging [the] fundamental assumptions about the way the grid [historically] operated.[58]

In the past two decades, a number of high-profile events have significantly influenced the way regulators and grid operators now plan for, manage, and think about the electrical grid. In the U.S., the Western Energy Crisis in 2001 reshaped energy markets; the Northeast Blackout in 2003 called into question transmission system reliability; and Hurricane Sandy in 2012 caused $10.5 billion in damages prompting states to seek a path toward resilient and distributed electricity supply.[59] Internationally, the 2015 Paris Agreement codified commitments to climate change mitigation and inspired countries, states, cities, and companies to adopt energy efficiency and renewable energy targets.[60] This period has also been characterized by a transition toward more flexible and distributed energy resources,

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56. *GridWise Transactive Energy Framework Version 1.0*, GRIDWISE ARCHITECTURE COUNCIL (Jan. 2015), https://www.gridwiseac.org/pdfs/te_framework_report_pnnl-22946.pdf.

57. *Id.*

58. Sam Hartnett et al., *The Decentralized Autonomous Area Agent (D3A) Market Model*, ENERGY WEB FOUNDATION (2017), https://energyweb.org/wp-content/uploads/2018/04/EWF-D3A-ConceptBrief-FINAL 201804.pdf.

59. David Dudley, *To Storm-Proof Hoboken, a Microgrid*, CITYLAB (Aug. 24, 2016), https://www.city-lab.com/solutions/2016/08/to-storm-proof-hoboken-a-microgrid/497144/; Bill Dulude, *California's 2000-2001 Energy Crisis*, UTIL. MGMT GROUP (Aug. 31, 2006), https://www.energycentral.com/c/um/californias-2000-2001-energy-crisis; Rod Walton, *13 Years After: The Northeast Blackout of 2003 Changed Grid Industry, Still Causes Fear for Future*, ELEC. LIGHT & POWER (Aug. 23, 2016), https://www.elp.com/Electric-Light-Power-Newsletter/articles/2016/08/13-years-after-the-northeast-black-of-2003-changed-grid-industry-still-causes-fear-for-future.html.

60. *The Paris Agreement*, UNFCCC (July 3, 2018), https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement.

driven by rapidly declining costs. Solar PV unit costs have dropped by a factor of five since 2008, and over the past 40 years costs have fallen by 28% every time installed capacity doubles.[61] Wind turbine costs have declined by over 30% since 2010 and another 40% reduction is anticipated by 2030.[62] Global cumulative PV and wind capacity grew from 17,025 MW in 2000 to 958,083 MW in 2017, a 27% CAGR; an additional 170,000 MWs is projected to come online in 2018 alone.[63] These resources use no fuel and have low maintenance costs, and adoption has been exponential at the utility, commercial, and residential scales.[64]

Markets for energy storage and advanced control systems are less mature than generation technologies, but are growing quickly. Lithium-ion battery costs have decreased at a 20% CAGR since 2010 and decreased by 24% from 2016 to 2017 alone.[65] Production costs for electric vehicles, which could serve as grid balancing batteries, are projected to fall below internal combustion engine cars by 2030, with EV sales meeting over one-third of global auto demand.[66] By 2020, smart meter installations are expected to surpass 1.8 billion, and 30 billion energy-using devices may be connected to the "Internet of Things" (IoT).[67] According to the International Energy Agency ("IEA"), broad adoption of active controls and IoT-enabled devices could save 65 PWh cumulatively through 2040, equivalent to double the consumption of the world's building stock today.[68] Mass-market technologies are becoming available that allow individuals to produce, store, and intelligently control energy on their own terms at prices competitive with grid-supplied electricity.[69]

By 2040, some analysts believe that near-zero marginal cost renewables will have largely displaced fossil generation and billions of intelligent devices will be deployed at the grid edge.[70] The electric system could be increasingly characterized by active consumer participation in markets, bidirectional power flows, and complex financial transactions between consumers, utilities, and third-party service. The central question informing regulators, grid operators, and utilities would

61.   *Digitalization & Energy*, IEA (2017), http://www.iea.org/publications/freepublications/publication/DigitalizationandEnergy3.pdf; *Tumbling Costs for Wind, Solar, Batteries Are Squeezing Fossil Fuels*, BLOOMBERGNEF (Mar. 28, 2018), https://about.bnef.com/blog/tumbling-costs-wind-solar-batteries-squeezing-fossil-fuels/.

62.   *New Energy Outlook*, *supra* note 2.

63.   *Id.*

64.   *Solar Leads the Charge in Another Record Year for Renewables*, IEA (Oct. 4, 2017), https://www.iea.org/publications/renewables2017/.

65.   Claire Curry, *Lithium-ion Battery Costs and Market*, BLOOMBERGNEF (July 5, 2017), https://data.bloomberglp.com/bnef/sites/14/2017/07/BNEF-Lithium-ion-battery-costs-and-market.pdf.

66.   *Electric Vehicle Outlook 2018*, BLOOMBERGNEF (2018), https://about.bnef.com/electric-vehicle-outlook/.

67.   *Outlook on Number of Installed Smart Electric Meters as of December 1, 2020*, STATISTA (2018), https://www.statista.com/statistics/476964/global-installed-smart-electric-meters-projection-by-select-country/.

68.   *Digitalization & Energy 2017*, *supra* note 61.

69.   *The Future of Electricity New Technologies Transforming the Grid Edge*, WORLD ECONOMIC FORUM (Mar. 2017), http://www3.weforum.org/docs/WEF_Future_of_Electricity_2017.pdf.

70.   Jeremy Rifkin, *The Rise of the Internet of Things and the Race to a Zero Marginal Cost Society*, HUFFINGTON POST (Dec. 6, 2017), https://www. huffingtonpost.com/ jeremy-rifkin/internet-of-things_b_8306112.html.

therefore be: How can we run a grid that is rich in distributed and renewable resources while giving customers the access and choice that they want and ensuring continued reliability and affordability?

Current approaches to controlling distributed energy resources in a centralized manner have been effective at certain scales.[71] However, optimizing larger numbers of decentralized resources from a central point of control is slow and resource-intensive.[72] Grid operators and utilities are daunted by the prospect of scaling up these centralized controls to billions of devices.[73]

Blockchain technology can help coordinate these resources and enable a decentralized, resilient, and stable electrical grid. In a decentralized grid, the traditional central operator or market maker could transfer its authority over distributed generation and storage resources to a network of autonomous actors.[74] Without a central authority, a functional grid could be recursive, meaning that each boundary area scale (e.g., device, building, neighborhood, distribution grid) could function as a self-contained ecosystem. Each scale would be nested within the next layer of the system, and each scale would have operational decision-making capabilities. Market structures in such a grid would be very different than market structures today, and blockchain technology would be able to facilitate coordination and settlement by commoditizing trust between parties (and physical devices). While protecting participant identities and sensitive transaction information, blockchain could increase transparency of other market conditions, including the physical state of the grid, external conditions (e.g., weather), as well as anticipated and actual behaviors of market participants. A decentralized, recursive, and transparent grid is the logical extension of contemporary technological trends, political pressures, and consumer demands.

B. *Potential Use Cases – Capturing Value in the Near Term*

The technologies and profoundly different economic models of energy transition are causing regulators and grid operators difficulties in managing the grid today. The infamous duck curve in California, high PV penetration in Hawaii, and negative pricing in many wholesale energy markets have stressed the capabilities of existing policy and grid management frameworks.[75] Rooftop solar advocates

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71.   *Modernizing the Electric Power System to Support the Development and Deployment of Increasingly Clean Technologies*, *in* THE POWER OF CHANGE: INNOVATION FOR DEVELOPMENT AND DEPLOYMENT OF INCREASINGLY CLEAN ELECTRIC POWER TECHNOLOGIES (2016), https://www.nap.edu/ read/21712/chapter/8.

72.   Preethi Kasireddy, *Fundamental Challenges with Public Blockchains*, MEDIUM (2017), https://medium.com/@preethikasireddy/fundamental-challenges-with-public-blockchains-253c800e9428.

73.   *Managing Variable and Distributed Energy Resources*, DELOITTE CENTER FOR ENERGY SOLUTIONS, (2016),   https://www2.deloitte.com/content/dam/Deloitte/us/Documents/energy-resources/us-er-grid-integration.pdf.

74.   James Basden & Michael Cottrell, *How Utilies Are Using Blockchains to Modernize the Grid*, HARVARD BUS. REVIEW (Mar. 23, 2017), https://hbr.org/2017/03/how-utilities-are-using-blockchain-to-modernize-the-grid.

75.   *What the Duck Curve Tells Us About Managing a Green Grid*, CALIFORNIA ISO (2013), http://large.stanford.edu/courses/2015/ph240/burnett2/docs/flexible.pdf.

and utilities argue over the sufficiency of state net metering policies.[76] The creation, tracking, and trading of Renewable Energy Certificates (RECs) and other carbon compliance instruments is characterized by high transaction costs, inefficiencies, and sometimes fraud.[77]

Implementing a decentralized, recursive, and privately transparent power system may be decades in the making, but power sector participants can leverage blockchain to address immediate challenges. Blockchains are not a panacea, and designing markets for a DER and customer-centric electricity system is a challenge that goes well beyond the technology. But blockchain's unique characteristics are well suited to resolving specific challenges in the energy space today.

In the following section, we describe challenges faced in five corners of the electricity sector—certificates of origin, utility billing, market optimization, new market creation, grid security—and how blockchain may be able to address them.

1. Certificates of Origin

Customers increasingly wish to choose the source and/or attributes of their electricity. Markets have responded to the demand for renewably generated electricity with certificates of origin (CO), which are tradeable credits that represent a unit of green electricity.[78] Trade in CO is now possible across the globe, including the guarantee of origin (GO) market in the European Union and both compliance and voluntary renewable energy certificate (REC) markets in the United States.[79] CO markets enable customers and regulators to measure and verify the use of renewable electricity for personal or state mandated renewable energy purchasing goals.[80]

Despite strong interest, several critical challenges face CO markets today. First, buying and selling COs is complicated and costly. In all markets, the process for tracking CO includes many steps, each with unique transaction and administration costs.[81] Brokers and other intermediary fees cost renewable generators and CO buyers around 5% of CO value.[82] High overhead costs effectively shut out smaller renewable generators and CO buyers.[83] Second, the integrity of CO track-

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76.   Hiroko Tabuchi, *Rooftop Solar Dims Under Pressure From Utility Lobbyists*, N.Y. TIMES (July 8, 2017), https://www.nytimes.com/2017/07/08/climate/rooftop-solar-panels-tax-credits-utility-companies-lobbying.html.

77.   William Newell & John A. Charles, Jr., *Renewable Energy Certificates: A Costly Illusion*, CASCADE POLICY INSTITUTE (2014), https://docs.wind-watch.org/Cascade-RECs-5-22-14.pdf.

78.   *The Definitive Guide to Global Energy Attribute Certificates for Commercial, Industrial, and Institutional Buyers*, RENEWABLE CHOICE ENERGY 13 (2017), https://3blmedia.com/sites/www.3blmedia.com/files/other/EAC.Definitive_Guide_-_ESS.pdf [hereinafter *The Definitive Guide to Global Energy Attribute Certificates*].

79.   *Id.* at 5, 15.

80.   *Id.* at 3.

81.   *Id.* at 15.

82.   WREGIS FEE MATRIX (Jan. 1, 2017), https://www.wecc.biz/Administrative/WREGIS%20Fee%20Matrix%202018.pdf (last visited Oct. 29, 2018).

83.   Nancy Rader, *Green Buyers Beware*, PUBLIC CITIZEN (1998), https://www.citizen.org/sites/default/files/greenbuy.pdf.

ing systems is weak. COs are prone to double-counting due to time lags and loopholes in the system.[84] The sheer number of steps involved and organizations that touch each CO can cause confusion among buyers. Finally, each CO market has unique rules for participation and reporting.[85] All of these challenges constrain CO market size and, by extension, limit their value.

Blockchain technology can help resolve many of these challenges. First, using a shared and trusted ledger can enable renewable generators and certificate buyers to interact directly, bypassing the need for expensive intermediaries. A peer-to-peer system for CO trading would enable real-time settlement and reduce internal administration and auditing costs. This streamlined, lower-cost system would open markets to smaller renewable generators and certificate buyers. Second, smart contracts can enable streamlined reporting and eliminate double-counting. As electricity is generated, a CO could automatically be issued for each MWh, and ownership would be tracked on a blockchain-based registry until that CO is retired. Due to the immutable blockchain ledger, certificate buyers and regulators would be confident that the CO accurately represented a unit of renewable energy, and had not already been purchased or retired. Finally, open-source blockchains encourage standardization across markets to facilitate a unified method of carbon accounting.[86] A single and integrated global market for COs would enable frictionless trading, open new markets for renewables generators, and allow buyers to purchase COs from locations they believe have achieve the greatest impact.

EWF estimates these opportunities amount to at least $1BN in annual savings.[87] This figure does not account for the likelihood that a lower-cost and more secure system would expand the market for COs, and so the impact of blockchain in CO markets could be even greater.

2. Utility Billing Systems

Billing and financial settlement are the cornerstones of electricity systems, providing "the mechanism for data exchange between customers, utilities and generators."[88] This makes utility billing both the foundation for the utility-customer relationship (and thus indirectly, utility-investor relationship) and the main point of access for customers to information regarding the electricity system. As the utility business model and the grid undergo significant transition, consumer advocates would like billing systems to be more responsive, connected, bidirectional, and personal.

As a whole, utility billing processes have yet to fully embrace modern opportunities enabled by advances in IT capabilities and increases in DER accessibility to customers. First, billing remains expensive, costing between 5-15% of total

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84. Double-counting describes a case where a single CO is claimed more than once. *The Definitive Guide to Global Energy Attribute Certificates*, *supra* note 78, at 12.

85. *Id.* at 7.

86. Jesse Morris, *Blockchain in Energy: Powered by EWF*, ROCKY MOUNTAIN INSTITUTE (2017), https://www.rmi.org/blockchain-energy-powered-ewf/.

87. Based on the avoided 5% broker margins for CO sales. Doug Miller, *Accelerating the Development and Deployment of Blockchain Technology in the Energy Sector*, THE ENERGY WEB FOUNDATION (2017), http://resource-solutions.org/images/events/rem/presentations/2017/Miller.pdf.

88. *Id.*

operating expenses for utilities.[89] Legacy data management systems, cumbersome transaction processes, inaccurate (and often paper-based) bill delivery, and manual accounting cause credit lag for utilities and losses from unpaid bills.[90] Second, current systems are ill-equipped to provide functionalities demanded by modern electricity system users. Legacy billing platforms create roadblocks for utilities attempting to introduce sophisticated rate structures.[91] Constraints on advanced services include the technical inability of legacy platforms to nest multiple meters under a single account.[92] Lack of standardization is a third challenge. Billing systems vary dramatically between (and sometimes even within) utilities. Inconsistent data quality procedures and the lack of public universal site identification create challenges for customer data access and integration with demand response programs. Legacy billing can stall even seemingly simple processes such as switching providers, thereby making required data sharing for customer switching an onerous process.[93]

Allowing grid participants to trust a common blockchain technology could facilitate more secure, more efficient, more functional, and lower cost utility billing systems. Smart contracts could enable a variety of applications that reduce transaction costs and improve system functionality. For example, transactions between electricity users and electricity providers could execute automatically when usage and supply information met predetermined contract conditions. These conditions could be tailored to support sophisticated rate designs or integrate energy storage resources. As a decentralized network, blockchain billing platforms could allow customers direct access to, and potentially control over, their data. Customer could grant trusted third parties such as energy efficiency contractors or demand response aggregators selective access to their data. Billing systems located on open-source blockchains encourage standardization. Standardizing the management of electricity transactions across geographies would enable customers to easily switch providers and could create a more competitive market environment.

3. Current Market Optimization

Electricity and other energy markets are vast and complex. Blockchain could help lower overhead costs, increase transparency, and mitigate risks in many segments of the energy economy, from specific resources like demand response ("DR") to broader categories like wholesale energy commodity markets.

DR resources provide several benefits in the electricity sector, but structural problems are preventing their full potential from being realized. To wit, the US

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89. *Id.*

90. For one utility, SAP infrastructure and maintenance costs were quoted at 40-65MN USD per year. *Id.*

91. *Utility Billing and Customer Information Systems Software and Services Market to Reach $4 Billion by 2017*, PIKE RESEARCH FORECASTS (2012), https://www.businesswire.com/ news/home/20120802005168/en/Utility-Billing-Customer-Information-Systems-Software-Services.

92. *Blockchain and Transactive Energy: A Blockchain Breakthrough for DER and Transactive Energy?*, LAB SUMMIT, 18 (2017), https://rmi.org/wp-content/uploads/2018/01/eLab_blockchain_transactive_energy_pre-read.pdf [hereinafter *Blockchain and Transactive Energy*].

93. *Id.*

currently has approximately 37 GW of DR resources actively participating in utility or wholesale programs[94], but the potential for DR is roughly 300 GW.[95] Key barriers include high overhead costs, variable performance and evaluation frameworks, technical interoperability between systems, and lack of standardization between geographies.[96] Costs related to enrollment, measurement, and verification processes represent between 40%-50% of operating expenses and 10%-30% of gross margin for utilities and aggregators engaged in the DR market.[97] Though recent rulings have harmonized payment and performance standards for DR and supply-side resources, DR performance (i.e. energy or capacity delivered) can vary widely based on measurement and verification methodology, ambient temperatures, and participant behavior.[98] "Program economics are distorted by over-enrollment, a hedge against the probability that some loads will not respond to a given event," diminishing the value of DR programs.[99] Lack of interoperability between programs prevents large enterprises with facilities spread across multiple geographies from deploying a streamlined solution across markets.

Blockchain can address many of these problems. A blockchain can provide both DR program participants and utilities greater visibility into and confidence in data, obviating the need for complex enrollment, measurement and verification, and auditing. Smart contracts will ensure results by allowing decisions about dispatch and response to be programmed into operator and participant devices, thus removing the element of real-time human decision-making and eliminating the lag between time of service (response) and compensation. Most impactful, an open-source standard for DR systems architecture would serve as a forcing mechanism for device manufacturers to coalesce around a common set of standards. This standardization could accommodate the integration of many more IOT devices, including smaller loads that are currently excluded from participation by program economics. Expanding DR participation to this new segment of energy-using devices could tap a new global market worth an estimated $4BN per year.[100]

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94. *2018 DEMAND RESPONSE MARKET SNAPSHOT*, SEPA (2018), https://sepapower.org/resource/2018-demand-response-market-snapshot/.

95. *Assessment of Achievable Potential from Energy Efficient and Demand Response Programs in the U.S. (2010-2030)*, ELECTRIC POWER RESEARCH INSTITUTE (Jan. 2009), http://www.edisonfoundation.net/iee/Documents/EPRI_SummaryAssessmentAchievableEEPotential0109.pdf.

96. Jennifer Potter, Elizabeth Stuart, & Peter Cappers, *Barriers and Opportunities to Broader Adoption of Integrated Demand Side Management at Electric Utilities,* ELECTRICITY MARKETS & POLICY GROUP, 20 (Feb. 2018), http://eta-publications.lbl.gov/sites/default/files/barriers_and_opps_idsm_final_03222108.pdf.

97. RMI analysis based on financial statements from leading DR providers. *Blockchain and Transactive Energy*, *supra* note 92, at 21.

98. For example, PJM capacity performance. *Filed Changes: Summer Period DR and CP M&V Changes*, PJM at 9 (2017), https://www.pjm.com/-/media/committees-groups/subcommittees/drs/20170407/20170407-item-04b-drcp-mv-change-20170405-implementation-v1.ashx; Nariman Mahdavi, Julio H. Braslavsky, & Cristian Perfumo, *Mapping the Effect of Ambient Temperature on the Power Demand of Populations of Air Conditioners*, 9 IEEE TRANSACTIONS ON SMART GRID, 1540 (May 2018).

99. *Blockchain and Transactive Energy*, *supra* note 92, at 21.

100. *Utility Billing and Customer Information Systems Software and Services Market to Reach $4 Billion by 2017*, PIKE RESEARCH FORECASTS (2012), https://www.businesswire.com/news/home/20120802005168/en/Utility-Billing-Customer-Information-Systems-Software-Services.

Despite the growing complexity of wholesale commodity markets, many participants rely on legacy trading platforms, inefficient business practices, and expensive intermediaries to complete transactions. Use of legacy systems, including paper documentation, causes costly delays throughout the trade life-cycle, from price discovery to confirmation matching to auditing.[101] Contracts can be held up simply due to difficulties gathering necessary signatures. Processes that support financial transactions cost up to 7.5% of the total transaction value for financial services companies.[102] Supply chain management systems are also strained. Moving commodities between locations involves large numbers of parties engaged in complex interactions. Traders cannot establish relationships with all parties in their supply chain, and, therefore, are beholden to parties with which they have not established trust.

Blockchain can mitigate expensive inefficiencies and risks within wholesale commodity trading. Blockchain allows low-risk transactions without intermediaries dedicated exclusively to that purpose. Smart contract functionalities, including multi-signatory access and custom read and write privileges, can help counterparties to arrive at a consensus quickly, and to dramatically reduce processing times for trades. By some estimates, using blockchains can cut payment costs for settlement by 30% through added efficiencies.[103] Commodity exchanges can use blockchain to enable matching, clearing, and price discovery and reporting in a secure environment, with much better information symmetry among participants than current marketplaces. Parties can choose how to disclose information to counterparties and other market participants.

4. New Market Creation

The confluence of several trends in the power sector—accelerated adoption of DERs, flat or declining electricity sales, increasing penetration of variable renewables, decarbonization goals (state and corporate), and growing cybersecurity concerns—is placing significant stress on the traditional architecture and market mechanisms used to balance and manage electricity grids. Transactive energy—using the exchange of value as a mechanism to better manage the flow of power, particularly at the grid edge—has been proposed as a solution to some of these stresses. [104] Regulators in different markets (e.g., New York State, Belgium) are experimenting with policy changes and demonstrations to test new market mechanisms that challenge existing stakeholder roles, business models, and technical

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101. *Next Generation Energy Trading: An opportunity to optimize*, MCKINSEY & COMPANY (2013), https://www.mckinsey.com/~/media/mckinsey/dotcom/client_service/risk/working%20papers/47_energy_trading.ashx.

102. *Disaggregating FinTech: Brighter Shades of Disruption*, DELOITTE (2016), https://www2 .deloitte.com/content/dam/Deloitte/us/Documents/financial-services/us-fsi-disaggregating-fintech-brighter-shades-of-disruption.pdf.

103. Amanda Cooper, *Mercuria sees oil sector going digital with blockchain,* REUTERS (Oct. 13, 2016), https://www.reuters.com/article/us-commodities-summit-mercuria-blockchai/mercuria-sees-oil-sector-going-digital-with-blockchain-idUSKCN12D1YN.

104. *Digitalization & Energy 2017*, *supra* note 61, at 128.

approaches to grid management, while at the same time, technologists (Paul De Martini) have been evaluating new, distributed architectures for the grid.[105]

Systems necessary to support transactive energy – including a digital infrastructure capable of integrating, managing, and coordinating a more distributed electric grid; a scalable market design capable of sending the right price signals at the right time with predictable outcomes; and grid operator trust that demand-side resources can perform as consistently as traditional generation, transmission, and distribution assets – have been identified, but thus far have not emerged at scale.[106] Blockchains may remove some barriers to scalable transactive energy systems. Given their ability to protect customer data, blockchains could streamline multi-party settlement, mass customization of complex contracts, and direct bidding between devices at a local level. These elements can enable electricity consumers and producers at the grid edge to transact with each other en masse. Thanks to the combination of smart contracts, built-in cybersecurity, and immutable record keeping, blockchains could help grid operators "trust" that DERs—regardless of who owns them or where they are connected to the grid—are capable of reliably contributing important functions - including grid balancing, power quality control and grid resiliency - and that market participants will be quickly and accurately compensated for such services.[107]

5. Grid Security

In recent years cyber and physical attacks have targeted or impacted electric grids and utilities all over the world.[108] There are physical and financial risks associated with attacks against electric utilities. Electrical utilities are appealing targets because they hold valuable information and control valuable processes, and because they are often soft targets.[109]

In 2013, a still-unknown individual or group used rifles to destroy a substation (protected only by chain-link fencing) in PG&E territory; the damage took workers nearly a month to repair.[110] A similar shooting attack in central Utah cut

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105.   *See generally* Andrew M. Cuomo, *Reforming the Energy Vision (REF)*, New York State, https://rev.ny.gov/; *see also* Jeffrey Taft & Paul de Martini, *Ultra Large- Scale Power System Control Architecture: A Strategic Framework for Integrating Advanced Grid Functionality*, CISCO (Oct. 2012), https://pdfs.semanticscholar.org/c6ca/1c4bc798397ddeacc6d696655dab767f7c11.pdf.

106.   Dave Hardin & K Kaufmann*, Transactive Energy 101DERs Drive Real-Time Market Dynamics to the Distribution System – are We Ready?*, SMART ELEC. POWER ALLIANCE (Oct. 26, 2017), https://sepapower.org/knowledge/transactive-energy-101/.

107.   Cutler, et. al, *A demonstration of Blockchain-based Energy Transactions between Laboratory Test Homes,* National Renewable Energy Laboratory (2018). Fact sheet available at https://www.nrel.gov /docs/fy18osti/71535.pdf.

108.   *Cyber Threat and Vulnerability Analysis of the U.S. Electric Sector*, IDAHO NAT'L LABORATORY (Aug. 2016), https://www.energy.gov/sites/prod/files/2017/01/f34/Cyber%20Threat%20and%20Vulnerability %20Analysis%20of%20the%20U.S.%20Electric%20Sector.pdf.

109.   *Id.* at 1.

110.   Rebecca Smith*, Assault on California Power Station Raises Alarm on Potential for Terrorism*, THE WALL STREET JOURNAL (Feb. 5, 2014), https://www.wsj.com/articles/assault-on-california-power-station-raises-alarm-on-potential-for-terrorism-1391570879.

off power to 13,000 customers for one day and took six months to repair.[111] These and other events led the Federal Energy Regulatory Commission (FERC) to conduct a broader risk assessment of the U.S. grid.[112] The analysis identified 30 critical transformers substations that were particularly vulnerable.[113] In the FERC's simulation, losing nine of these substations (in various combinations) as the result of a coordinated attack would cause a nationwide blackout for an extended period of time.[114] These risks are exacerbated by the limited supply and complexity of manufacturing replacements.[115]

Digitalization has produced benefits for grid operators, utilities, and consumers alike, but wider adoption of digital technologies opens new vectors for cyber-attacks. Since the beginning of 2015, there have been several high-profile cyber-attacks against electricity systems.[116] In the Ukraine, for example, multiple cyberattacks—possibly conducted by a state actor—brought down 30 substations and took 200 MW offline, resulting in outages for 225,000 customers and forcing distribution system operators to operate in constrained manual mode for months.[117] In Ireland, the grid operator's network was breached and attackers gained access to company data.[118] In the United States, a third-party gained access to utility control systems across the country, where it may have gained the ability to cause blackouts.[119]

Blockchain can mitigate financial and physical risks of attacks against the electric grid. It is difficult to manipulate data on a blockchain, and it is easy to identify when and how attempts to manipulate data occur. Due to the strong cryptographic hashes and decentralized consensus mechanisms, blockchain attacks are costly and impractical, which effectively prevents manipulation. These features make blockchains highly resilient, and entities using blockchain-based applications can be confident in the data integrity of their systems. Further, because

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111.   Peter Behr, *Substation attack is new evidence of grid vulnerability*, E&E NEWS (Oct. 6, 2016), https://www.eenews.net/stories/1060043920.

112.   Paul Parfomak, *Physical Security of the U.S. Power Grid: High-Voltage Transformer Substations*, CONG. RES. SERV. (June 17, 2014), https://fas.org/sgp/crs/homesec/R43604.pdf.

113.   Rebecca Smith, *U.S. Risks National Blackout from small-Scale Attack*, THE WALL STREET JOURNAL (Mar. 12, 2014), https://www.wsj.com/articles/u-s-risks-national-blackout-from-small-scale-attack-139466 4965.

114.   *Parfomak*, *supra* note 112.

115.   *Id.* at 4.

116.   Jillian Ward, *Power Network Under Cyber-Attack Sees U.K. Increase Defenses,* BLOOMBERG (Jan. 8, 2015), https://www.bloomberg.com/news/articles/2015-01-09/power-grid-under-cyber-attack-every-minute-sees-u-k-up-defenses; Rebecca Kern, *Utilities Prepare Increased Cyberattacks on the Electric Grid*, BLOOMBERG NEWS (Aug. 7, 2018), https://www.bna.com/utilities-prepare-increased-n73014481471/.

117.   *Analysis of the Cyber Attack on the Ukrainian Power Grid*, ELEC. INFO. SHARING AND ANALYSIS CTR. (Mar. 16, 2016), http://www.nerc.com/pa/CI/ESISAC/Documents/E-ISAC_SANS_Ukraine_DUC_ 18Mar2016.pdf.

118.   Cathal McMahon, *EirGrid targeted by 'state sponsored' hackers leaving networks exposed to 'devious attack'*, INDEPENDENT.IE (Aug. 6, 2017), https://www.independent.ie/irish-news/news/exclusive-eirgrid-targeted-by-state-sponsored-hackers-leaving-networks-exposed-to-devious-attack-36003502.html.

119.   Rebecca Smith, *Russian Hackers Reach U.S. Utility Control Rooms, Homeland Security Officials Say*, THE WALL-STREET JOURNAL (July 23, 2017), https://www.wsj.com/articles/russian-hackers-reach-u-s-utility-control-rooms-homeland-security-officials-say-1532388110.

blockchain nodes are geographically distributed and are operated by many unrelated organizations, there is minimal risk of system downtime when compared with centralized systems.

C. Current Initiatives and Challenges

Blockchain has emerged at a time when many electricity system regulators and policymakers were already working to allow wider participation in power markets. Utilities and grid operators are researching methods to better capture the values of technologies ranging from DERs to software systems, and new regulatory efforts aim to help households and companies participate in energy markets on a more equal footing with traditional power producers and suppliers.[120]

The alignment between blockchain's capabilities and electricity system trends is reflected in the rapid growth of energy-focused blockchain companies and projects.[121] More than 150 new companies working on blockchain-based solutions in the energy space have raised over $350MM USD since January 2017, and are responsible for more than 70 pilot projects around the world.[122] Most of these startups focus on peer-to-peer applications, but applications range from tools for utilities to energy-specific cryptocurrencies.[123]

Thus far, startups and incumbent energy companies have failed to bring blockchain-and-energy applications to scale. Blockchain is very new technology. Projects face technical and regulatory hurdles, and companies are challenged to develop business models that make use of blockchain's unique features while meeting customer needs and expectations. Still, as explained below, many pilot applications demonstrate great promise, and can be used to understand the new capabilities that blockchain will soon make available to regulators and grid operators.

1. Commercial and/or Pilot Applications

Startup companies and large incumbents all over the world have initiated pilot projects to better understand and demonstrate the value of blockchain in a variety of use cases, ranging from peer-to-peer energy trading, to electric vehicle charging, to streamlining utility and market operational processes.[124] Some pilots have been successful, and larger companies including utilities are becoming more closely involved with blockchain projects.

Exciting example initiatives in the blockchain and energy space include:

- Electron: a UK-based company founded in 2015 that is building a platform for decentralized electricity and gas metering. Conducting metering using a blockchain can cut down billing settlement times,

120.   *The Future of Electricity New Technologies, supra* note 69, at 4.

121.   Lacey, *supra* note 6.

122.   *Id.*

123.   *Comprehensive Guide to Companies involved in Blockchain & Energy*, SOLAR PLAZA (Feb. 2018), http://ipci.io/wp-content/uploads/2017/12/Energy-Blockchain-Report.compressed.pdf.

124.   *Id.*

which typically take weeks to complete using current systems.[125] Electron's platform also aims to enable microtransactions in energy supply and curtailment that is open to household and device level participation. Investors and partners include the Japanese utility TEPCO, the British utility National Grid and EWF.[126]

- Origin: a decentralized application developed by EWF that provides kWh level certificate of origin (Guarantee of Origin or Renewable Energy Credit) tracking.[127] Tracking certificates of origin over a blockchain increases market transparency, integrity, and detail.[128] In 2018, EWF conducted pilot certificate of origin transactions using Origin.[129]

- Ponton: in 2016, the company developed Enerchain, a platform for wholesale energy commodity and derivative trading in Europe.[130] In 2018, dozens of market participants conducted successful tests trading on Enerchain.[131] Participants include Statoil, Engie, and Total.[132]

- Share&Charge: a European startup that provides an open blockchain platform that supports electric vehicle charging.[133] Users can register and pair charging stations with digital wallets, and drivers can pay securely for charging services using digital wallets.[134] In 2017, drivers completed the Oslo2Rome Tour, successfully paying for charging services using digital wallets during a multi-country road trip.[135] The platform will support charging paired with certificates of origin, guaranteeing that electricity used to charge cars is green. Partners include the French Utility EDF and EWF.[136]

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125.   Jason Deign, *UK Startup to Use Blockchain for Meter Registration*, GREENTECH MEDIA (Dec. 22, 2016), https://www.greentechmedia.com/articles/read/uk-startup-to-use-blockchain-for-meter-registration#gs.F_Kqrr4.

126.   Nikhilesh De, *TEPCO Invests in Blockchain Startup in Bid to Decentralize Systems*, COINDESK (Jan. 19, 2018), https://www.coindesk.com/tepco-buys-stake-uk-blockchain-startup-bid-decentralized-systems/; Ian Allison, *EDF Energy and Shell join Electron's Blockchain Energy Consortium*, INT'L BUS. TIMES (Feb. 2, 2018), https://www.ibtimes.co.uk/edf-energy-shell-join-electrons-blockchain-energy-consortium-1658271.

127.   *EW Origin*, ENERGY WEB FOUNDATION, https://energyweb.org/origin/ (last visited Oct. 15, 2018).

128.   *Id.*

129.   *Energy Web Foundation Unveils Major Blockchain Milestones at Event Horizon*, ENERGY WEB FOUNDATION (Apr. 17, 2018), https://energyweb.org/2018/04/17/energy-web-foundation-unveils-major-blockchain-milestones-at-event-horizon/.

130.   *Enerchain: P2P Energy Trading on the Wholesale Market using Advanced Blockchain-Technology*, PONTON (last visited Oct. 16, 2018), https://ponton.de/focus/blockchain/enerchain/.

131.   Michael Merz, ENERCHAIN PROJECT OVERVIEW AND KEY INSIGHTS, ENERCHAIN (May 9, 2018), https://enerchain.ponton.de/index.php/34-key-insights-report-of-the-enerchain-poc.

132.   *Enerchain*, *supra* note 130.

133.   SHARE&CHARGE, http://shareandcharge.com/ (last visited on Oct. 15, 2018).

134.   *Us Trials Blockchain Electronic Wallet for Electric Vehicle Charging*, ENGERATI (Mar. 13, 2017), https://www.engerati.com/article/us-blockchain-electronic-wallet-electric-vehicle-charging.

135.   *Oslo2Rome*, SHARE&CHARGE, http://shareandcharge.com/oslo-2-rome/ (last visited on Oct. 16, 2018).

136.   *Partners to Bring Energy, Blockchain, and E-Mobility To the Next Level,* SHARE & CHARGE (2018), http://shareandcharge.com/sharecharge-teams-up-with-ewf/.

- <u>LO3 Energy</u>: A U.S.-based company working to deploy blockchain to enable direct household-to-household exchange of electricity.[137] In 2016, they established a project in Brooklyn named the Brooklyn microgrid that allowed households and small businesses in a neighborhood to exchange RECs and similar certifications in lieu of physical electricity, with transactions settled over a blockchain-based system.[138] LO3 is now expanding into other demonstration projects, use cases, and markets (including Texas).[139] Partners include Siemens and EWF.[140]

IV. IMPLICATIONS OF BLOCKCHAIN AT THE BUSINESS AND ENERGY REGULATORY INTERFACE

A. *Legal Implications of Blockchain*

The adoption of blockchain in the energy sector and elsewhere raises several legal questions, ranging from securities issues, energy regulatory and compliance issues, and questions related to the enforceability and interpretation of smart contracts. Due to the novelty of the technology, however, most legal issues related to blockchain are still being evaluated on decades- or centuries-old tenants of statutory and common law, often on a state-by-state basis.

For instance, while blockchain technology is often used to issue "coins" or "tokens" for early-stage fundraising, the Securities and Exchange Commission (SEC) judges whether those coins and tokens constitute "securities" using the U.S. Securities Act of 1933 and the test laid out in the 1946 case *SEC v. W.J. Howey Co.*[141] It has brought dozens of enforcement actions against blockchain-based companies and digital tokens, but has failed to provide concrete industry-specific guidance or advocate for changes to current federal securities laws to account for this fundamental change in technology.[142] Similarly, the Commodity Futures Trading Commission is regulating the spot market for cryptocurrencies and has developed a process for self-certification of Bitcoin futures products contracts,[143] but has resisted calls by various members of Congress to expand its authority over

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137.   *See generally* LO3 ENERGY, https://lo3energy.com/ (last visited Oct. 15, 2018).

138.   Urszula Papajak, *Can the Brooklyn Microgrid Project Revolutionise the Energy Market?*, MEDIUM (Nov. 27, 2017), https://medium.com/thebeammagazine/can-the-brooklyn-microgrid-project-revolutionise-the-energy-market-ae2c13ec0341.

139.   *Innovations*, LO3 ENERGY, https://lo3energy.com/innovations (last visited Oct. 16, 2018).

140.   *Partners*, LO3 ENERGY, https://lo3energy.com/partners (last visited Oct. 16, 2018).

141.   Securities and Exchange Commission v. W.J. Howey Co. et al., 328 U.S. 293 (1946).

142.   Notably, SEC Chairman Jay Clayton has stated that Bitcoin is not a security. Kate Rooney, *SEC Chief says Agency won't Change Securities Laws to Cater to Cryptocurrencies*, CNBC (June 6, 2018), https://www.cnbc.com/2018/06/06/sec-chairman-clayton-says-agency-wont-change-definition-of-a-security.html. William Hinman, the Director of the Division of Corporation Finance, recently indicated in a speech that Ether (the native token of the Ethereum blockchain) would not be classified as a security, but that other crypto-tokens might qualify. Digital Asset Transactions, *When Howey Met Gary (Plastic)*: *Speech by William Hinman*, SECURITIES AND EXCHANGE COMMISSION (June 14, 2018), https://www.sec.gov/news/speech/speech-hinman-061418.

143.   CFTC Statement on Self-Certification of Bitcoin Products by CME, *CFE and Cantor Exchange*, Press Release, U.S. CFTC (Dec. 1, 2017), https://www.cftc.gov/PressRoom/PressReleases/pr7654-17.

digital assets.[144] The Financial Crimes Enforcement Network, the Federal Trade Commission, and numerous state banking regulators are bringing enforcement actions, and some are even issuing regulatory guidance, but there has been no overriding consistency to these efforts.[145] In the energy sector, the National Association of Regulated Utility Commissions (NARUC), has included an introduction to blockchain and energy session in a recent summit on rate design, but there have been no formal rules or market mechanisms specifically aimed at blockchain.[146]

1. Summary of State Blockchain Regulation

Domestically, states have led the way on blockchain regulation. Early efforts, however, have been not been groundbreaking, focusing instead on recognizing the validity of data and records recorded on the blockchain. Starting in 2017, several states began implementing, or at least considering, legislation recognizing information stored on blockchains as electronic records, and private key signatures as electronic signatures.[147] Arizona became the first state to enact such a law, redefining electronic records to include "signature[s]. . .secured through blockchain technology," and "record[s] or contract[s] that [are] secured through blockchain technology" in the context of sales, leases and documents of title.[148] In April 2018, the Arizona legislature amended the definition of "writing" and "written" in the "Corporations and Associations" title of the Arizona Revised Statutes to include blockchain technology.[149] Corporations can now use records and signatures created through blockchains as written records and electronic signatures.[150]

In 2018, the Tennessee, Wyoming, and Delaware legislatures also amended the definitions of electronic records and electronic signatures to include blockchain-based data and private key signatures.[151] Like the Arizona legislature, the

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144. *Id.*; CFTC Statement on Self-Certification of Bitcoin Products by CME, *CFE and Cantor Exchange*, Press Release, U.S. COMMODITY FUTURES TRADING COMMISSION (Dec. 1, 2017), https://www.cftc.gov/Press-Room/PressReleases/pr7654-17; Nikhilesh De, *CFTC Chair Says Regulator is 'Behind' on Blockchain*, COINDESK (July 25, 2018), https://www.coindesk.com/cftc-chair-says-regulator-is-behind-on-blockchain/; *Speech by William Hinman*, *supra* note 142.

145. *Application of FinCEN's Regulations to Persons Administering, Exchanging, or Using Virtual Currencies*, FINCEN (Mar. 18, 2013), https://www.fincen.gov/resources/statutes-regulations/guidance/application-fincens-regulations-persons-administering; Press Release, *FinCEN Fines Ripple Labs Inc. in First Civil enforcement Action Against a Virtual Currency Exchanger*, FINANCIAL CRIMES ENFORCEMENT NETWORK (May 5, 2015), https://www.fincen.gov/news/news-releases/fincen-fines-ripple-labs-inc-first-civil-enforcement-action-against-virtual; Press Release, *FTC Shuts Down Promoters of Deceptive Cryptocurrency Schemes*, FTC (Mar. 16, 2018), https://www.ftc.gov/news-events/press-releases/2018/03/ftc-shuts-down-promoters-deceptive-cryptocurrency-schemes; *see, e.g., Money Transmitter Frequently Asked Questions*, NORTH CAROLINA COMMISSIONER OF BANKS, https://www.nccob.gov/Public/financialinstitutions/mt/mtfaq.aspx.

146. Winter Committee Meetings, NARUC (Feb. 17, 2017), https://www.naruc.org/winter-policy-summit/2017/complete-agenda/rate-design/.

147. *Blockchain State Legislation*, NATIONAL CONFERENCE OF STATE LEGISLATURES, http://www.ncsl.org/research/financial-services-and-commerce/the-fundamentals-of-risk-management-and-insurance-viewed-through-the-lens-of-emerging-technology-webinar.aspx#2017Legis (last visited on Oct. 16, 2018).

148. ARIZ. REV. STAT. ANN. §§ 44-7061(A)-(B)(2017); *id.* § 44-7003(C).

149. ARIZ. REV. STAT. ANN § 10-140(53).

150. *Id.*

151. TENN. CODE ANN. § 47-10-202(a)-(b) (2018); Wyo. Stat. § 17-16-1601 (2018); 8 Del.C. § 224 (2017).

Tennessee legislature incorporated distributed ledger technology and private key signatures expressly within the definition of "electronic records" and "electronic signatures."[152] Wyoming and Delaware's laws, on the other hand, focused on corporations' use of private key signatures and blockchain-based data.[153] In Wyoming, corporations may use distributed electronic networks to create and store electronic records.[154] Moreover, shareholders may vote on corporate matters through a blockchain, using their private key signatures (referred to under the law as "network signatures") as electronic signatures.[155] Similarly, Delaware corporations may maintain corporate records and their stock ledger on a blockchain, provided the stock ledger can be "converted into clearly legible paper" records within a reasonable time period.[156]

Several other state legislatures, such as Florida, New York, Nebraska, and Ohio have introduced similar measures, but, to-date, no other states explicitly recognize private key signatures and information recorded on blockchains as electronic signatures and records.[157] In practice, however, these laws simply give legal recognition to information stored on a new kind of computer network. While the voting applications are intriguing, most consumers would probably not find these regulatory changes to drastically impact their day-to-day habits.

Various state governments are also establishing initiatives to use blockchain rather than merely sanction its use by private actors.[158] In 2016, the state of Delaware established the Delaware Blockchain Initiative, and in 2017, Illinois launched the Illinois Blockchain Initiative.[159] Both programs aim to explore the use of blockchain technology in the public and private sectors.[160] As a component of the Delaware Blockchain Initiative, the Delaware Public Archives is working with a distributed ledger and smart securities startup to store state archival records on a distributed ledger.[161] Similarly, the Illinois Blockchain Initiative included creating a task force to study how state and local governments can benefit from switching traditional recordkeeping and service delivery to a blockchain-based

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152.   TENN. CODE ANN. § 47-10-202(a)-(b) (2018).

153.   Wyo. Stat. § 17-16-1601 (2018); 8 Del.C. § 224 (2017).

154.   Wyo. Stat. § 17-16-1601 (2018).

155.   *Id.* §§ 17-16-140(xxxix), 17-16-724.

156.   8 Del.C. § 224 (2017).

157.   Florida House Bill 1357; New York Assembly Bill 8780; Nebraska Legislative Bill 695; Ohio S.B. 300.

158.   Kevin C. Desouza et al., *Blockchain and U.S. State Governments: An Initial Assessment*, BROOKINGS TECHTANK (April 17, 2018), https://www.brookings.edu/blog/techtank/2018/04/17/blockchain-and-u-s-state-governments-an-initial-assessment/. Brookings' April, 2018 study designated seven states as "actively engaged," or examining the governmental use of blockchain technologies to support government functions. *Id.*

159.   Press Release, Governor Markell Launches Delaware Blockchain Initiative, Delaware Office of the Governor, (May 2, 2016). The governor of Delaware declared "[c]ommitting State government to the use of the [distributed ledger] technology, beginning with the Public Archives project" to be one of the four key facets of the state initiative; *Blockchain in Illinois*, ILL. DEP'T OF INNOVATION & TECH., https://www2.illinois.gov/sites/doit/pages/BlockChainInitiative.aspx (last visited Jun. 27, 2018).

160.   Desouza et al., *supra* note 158.

161.   Press Release, Governor Markell Launches Delaware Blockchain Initiative, Delaware Office of the Governor (May 2, 2016).

system.[162] In May of 2018, Colorado passed a bill that will require the Governor's Office of Information Technology, the Department of State, and the Department of Regulatory Agencies to "consider using encryption techniques and blockchain tech in order to protect confidential state records from criminal, unauthorized, or inadvertent manipulation or theft."[163]

2. Confronting a Century's Worth of Energy Regulation

Beyond the simple recognition and protection of blockchain under the law, the production, transmission, and consumption of energy are among the most highly regulated forms of commerce.[164] To date, there have been no federal or state laws specifically addressing blockchain in the energy industry, which means that the blockchain use cases described above will operate against the backdrop of a century's worth of public utility regulation.

Within the energy industry, applications of blockchain technology have the potential to extract greater value from existing regulatory regimes.[165] For instance, using blockchain to improve certificates of origin will require industry buy-in and may displace legacy certificate of origin platforms, but should not require significant changes to existing statutory or regulatory regimes.[166] Similarly, applications to enhance utility or energy service provider billing systems and grid and market optimization can, for the most part, be accommodated and implemented through

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162.   Korey Clark, *The Coming Era of State Blockchain Regulation*, ST. NET CAP. J. (Feb. 2018), https://www.lexisnexis.com/communities/state-net/b/capitol-journal/archive/2018/02/09/the-coming-era-of-state-blockchain-regulation.aspx. Like Delaware, Illinois is moving cautiously. The Illinois Blockchain Task Force issued a report in January 2018 stating:

> This Task Force believes that blockchain technology and its built-in encryption can facilitate highly-secure methods for interacting with government and keeping paperless records, increasing data accuracy and providing better cybersecurity protections for Illinois residents. Though the technology still needs refinement, government has an opportunity to help shape and adopt innovative solutions.

Kevin Cucuel, *Is Blockchain Ready for State Government Use?*, STATETECH (May 30, 2018), https://statetechmagazine.com/article/2018/05/blockchain-ready-state-government-use.

163.   Marie Huillet, *Colorado Passes Bill Advocating Blockchain for Gov't Data Protection and Cyber Security*, COINTELEGRAPH (May 8, 2018), https://cointelegraph.com/news/colorado-passes-bill-advocating-blockchain-for-govt-data-protection-and-cyber-security.

164.   *Wholesale Electricity Antitrust Cases I & II*, 147 Cal. App. 4th 1293, 1301–04 (2007) (describing the wholesale electricity market as "heavily regulated" by federal and state agencies).

165.   As noted above, however, there may be other regulatory barriers in addition to energy regulation, including data privacy and consumer protection laws.

166.   For example, a state could require that renewable energy credits necessary to satisfy the state's renewable portfolio standard be certified using a blockchain-based REC tracking system. Alternatively, an existing tracking system such as PJM Interconnection L.L.C.'s Generation Attribute Tracking System (GATS) could be updated to rely on a blockchain-based platform. Energy Web Foundation and PJM recently announced a collaboration to build and evaluate a blockchain based tool for the GATS renewable energy certificate market. *See Energy Web Foundation and PJM-EIS Announce Collaboration to Build and Evaluate Blockchain-based Tool for a Major U.S. Renewable Energy Certificates Market*, ENERGY WEB (Oct. 25), https://energyweb.org/2018/10/25/energy-web-foundation-and-pjm-eis-announce-collaboration-to-build-and-evaluate-blockchain-based-tool-for-a-major-u-s-renewable-energy-certificates-market/.

new tariffs and business practices established under existing regulatory frame-works, provided utilities and other stakeholders are given adequate incentives to pursue such initiatives.[167]

Using blockchain to facilitate broader market or policy-driven objectives, however, will require policymakers to rethink existing energy regulation. For in-stance, blockchain platforms that enable peer-to-peer energy trading or integrate DERs into wholesale markets face a number of legal and regulatory hurdles, in-cluding resource size, protected franchise territories, registration requirements, and financial suitability. These hurdles are not necessarily specific to blockchain, but relate to the underlying policies and business models that were developed to support a central energy market or a relatively small number of large corporate market participants.

Within the United States, sales of electricity at retail, *i.e.*, sales to an end-use customer who consumes the electricity, are subject to state jurisdiction, and there are generally two models used by states to regulate such sales, one "deregulated" model that allows retail competition, and another model that prohibits retail com-petition.[168] At present, eighteen states allow for some form of retail competition or "retail choice."[169] In these states, customers may purchase electricity from their local distribution utility or, alternatively, purchase from a state-licensed third-party supplier. If customers elect the latter, the utility is required to deliver such power, and customers still pay the incumbent utility for associated transmission and distribution charges.[170] In states that prohibit retail competition, the local dis-tribution utility maintains the exclusive right to sell electricity at retail to all end-use customers within its designated service territory.[171] This right is granted pur-suant to statute or public service commission orders and effectively restricts any other entity from selling power to end-use customers.[172]

DERs, advanced meter infrastructure, DER management systems, and related technologies will all play a role in shifting toward a decentralized grid with more market participants, and the federal and state policies driving these technologies are likely coming with or without blockchain.[173] Blockchain has the potential to

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167. For example, while a utility may need to obtain permission from its regulator to recover the costs of a new billing system, it can likely see such approval under the existing regulatory framework. *See, e.g., Common-wealth Edison Co.*, Order on Petition for Statutory Approval of a Smart Grid Advanced Metering Infrastructure Deployment Plan, ICC Docket No. 12-0298 (Order issued June 22, 2012).

168. *An Introduction to Retail Electricity Choice in the United States,* NATIONAL RENEWABLE ENERGY LABORATORY (Aug. 2017), https://www.nrel.gov/docs/fy18osti/68993.pdf.

169. *Map of Deregulated Energy States and Markets*, ELECTRIC CHOICE (Updated 2018), https://www.elec-tricchoice.com/map-deregulated-energy-markets/ (last visited Oct. 15, 2018).

170. *Utility vs. Retail Energy Providers: Where Does My Electricity Come From?*, SMART ENERGY, https://www.smartenergy.com/utility-vs-retail-energy-providers/ (last visited Oct. 17, 2018).

171. Under both models, the utility need not actually own generation. In many states, utilities procure the power required to serve customers from third-party, independent wholesale power producers.

172. N.C. GEN. STAT. § 62-110.2 (granting each public utility the exclusive right to serve all customers within its designated service territory).

173. Diane Cardwell, *Solar Experiment Lets Neighbors Trade Energy Among Themselves*, NEW YORK TIMES (Mar. 13, 2017), https://www.nytimes.com/2017/03/13/business/energy-environment/brooklyn-solar-grid-energy-trading.html; *see also* The Beam, *Can The Brooklyn Microgrid Project Revolutionize The Energy*

accelerate DER integration, and allow for previously cost-prohibitive or operationally infeasible applications, such as platforms like the Brooklyn Microgrid.[174] However, peer-to-peer blockchain platforms that purport to cut the utility out of electric power transactions are confronted with certain obstacles. In states that prohibit retail competition, there is typically no legal means through which one end-use customer could sell physical electricity to their neighbor.[175] The right to sell power at retail belongs only to the local incumbent utility. Therefore, similar to existing net-metering arrangements, customer-generated power would need to be sold exclusively to the incumbent utility.[176] Even in states that allow retail choice, the non-utility providers that sell electricity to end-use customers must meet registration, certification, and bonding requirements.[177] Such requirements may not be suitable for peer-to-peer arrangements among residential or small commercial participants.[178]

Given the significant amount of state-by-state regulation (even in so-called deregulated states), establishing a wide-scale, peer-to-peer energy market under existing regulatory constructs would be difficult. Existing pilots are generally limited to behind-the-meter operations where power is not sold back onto the grid (i.e., tracking energy consumption and use between multiple buildings owned by the same customer), or, in the case of platforms such as the Brooklyn Microgrid, allowing participants to trade RECs or similar certifications in lieu of physical electricity.[179] These pilots have thus far failed to scale in part due to incompatibility with existing regulations, which are meant to provide some measure of consumer protection and energy security in electricity transactions.[180] Historically,

Market?, CLEAN TECHNICA (Feb. 2, 2018), https://cleantechnica.com/2018/02/02/can-brooklyn-microgrid-project-revolutionize-energy-market/.

174.	As discussed above, when paired with smart inverters and advanced meter infrastructure, blockchain can be used to track the production and consumption of electric energy between neighbors. For example, as Neighbor A generates electricity from solar arrays on Neighbor A's home, the amount of generation produced, as well as the amount of generation consumed by Neighbor A, is tracked and uploaded in real time to a blockchain network. At the same time, the amount of electric energy consumed by Neighbor B is tracked and uploaded to the blockchain. Using a smart contract, Neighbor A and Neighbor B settle for the amount of energy produced by one and sold to the other. The Beam, *supra* note 173.

175.	*An Introduction to Retail Electricity Choice*, *supra* note 168.

176.	For the purposes of this article, we refer only to the local utility. However, power could also be provided by a municipality or other governmental entity. In any event, the limitations on power sales remain the same. For an introduction to the issues associated with exclusive utility service territories, see *Pub. Serv. Co. v. Publ. Utils. Com.*, 765 P.2d 1015 (Co. Supreme Ct. 1988).

177.	*An Introduction to Retail Electricity Choice*, *supra* note 168.

178.	In New York, for example, "Electric Service Companies" are subject to a number of credit and registration requirements, along with ongoing reporting and compliance obligations. *ETIP Annual Reporting Guidance*, NY DEP'T OF PUB. SERV. (May 12, 2017), http://www3.dps.ny.gov//W/PSCWeb.nsf/All/753D3D 35C877963485257687006F39DB?OpenDocument. In Texas, non-utility entities may certify as "Retail Electric Providers" and sell electricity to end-users, but such REPs are prohibited from actually owning generation. Rather, they must purchase it from independent power producers in the wholesale markets. Public Utility Regulatory Act: Tex. Util. Code Title 2, Subtitle B § 31.002(17). Most deregulated states have constructs similar to New York and Texas.

179.	The Beam, *supra* note 173.

180.	U.S. EPA, State Climate and Energy Technical Forum, *An Overview of PUCs for State Environment and Energy Officials* at 1–2 (May 20, 2010), https://www.epa.gov/sites/production/files/2016-03/documents/background_paper.pdf.

limiting the provision of retail power to utilities or establishing credit and registration requirements applicable to retail providers was the best way to promote protection and security.[181] Ensuring consumer protection in a market where every participant can buy or sell power may require a new regulatory regime that accounts for the risks and costs of a transactive energy market. Lacking such a regulatory overhaul, the industry is there unlikely to see true applications of peer-to-peer energy trading in the near term, particularly in states that do not allow retail choice. As interest in these models grows, however, regulators will need to consider how best to accommodate them while ensuring reliability and consumer protection.[182]

3. Rethinking Utility Business Models – Utilities and Regulators will Need to Consider how Utilities Operate and Capture Value in a More Distributed Grid

Regardless of the role that blockchain plays, regulators will need to consider how the utility business model will evolve to meet the demands of an increasingly decentralized grid with high concentrations of DERs. Assuming that DER owners rely on the utility distribution infrastructure, utilities will remain responsible for ensuring a reliable flow of power and will need to be compensated for accommodating increased generation interconnected to distribution circuits and maintaining the reliability of their networks. While there has been talk of leveraging blockchain technology and peer-to-peer energy trading to effectively "cut the utility out," the value proposition for such a system is largely undefined because of the significant costs which would presumably be borne by members of the peer-to-peer marketplace to develop, operate, and maintain any distribution infrastructure required to transmit and measure the power generated. [183]

For the foreseeable future, utilities will continue to own the wires and play an important role in the pace of DER and other technological adoption. Increased DER penetration and implementing a bidirectional grid may require regulators to rethink the means through which utilities capture value. Under the existing framework, utilities are able to recover the costs associated with maintaining their systems regardless of whether increased concentrations of DERs lower customer demand for utility-provided electricity or erode the need for utilities to invest in traditional "poles and wires" infrastructure.[184] For example, net metering programs that allow DER owners to receive a one-to-one offset against their utility

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181. *Regulated vs. Deregulated Electricity Markets*, ENERGY WATCH (January 9, 2018), https://energywatch-inc.com/regulated-vs-deregulated-electricity-markets/ (last visited Oct. 17, 2018).

182. *National Grid Launches Distributed System Platform with Buffalo Niagara Medical Campus Members,* GLOBAL NEWS WIRE (June 28, 2018), https://globenewswire.com/news-release/2018/06/28/1531244/0/en/National-Grid-Launches-Distributed-System-Platform-With-Buffalo-Niagara-Medical-Campus-Members.html. Notably, some utilities have instituted transactive energy pilots to explore means to enable customers to play a larger role in energy markets. Additionally, the Arizona Corporations Commission recently opened a docket exploring the role of blockchain in facilitating a transactive energy market.

183. Ken Silverstein, *No Industry Immune To Blockchain Technology, Not Even The Electricity World*, FORBES (July 1, 2018), https://www.forbes.com/sites/kensilverstein/2018/07/01/no-industry-immune-to-blockchain-technology-not-even-the-electricity-world/#7e509f161d03.

184. Lisa Wood et al., *Recovery of Utility Fixed Costs: Utility, Consumer, Environmental, and Economist Perspectives* (June 2016), https://emp.lbl.gov/sites/all/files/lbnl-1005742.

bills may not have an adverse impact when used by small amounts of customers. Even though those net metering programs may ignore a utility's true cost of acting as the "provider of last resort."[185] At scale, however, net metering programs could erode a utility's revenue collection without reducing the utility's costs.[186] Similarly, to the extent DERs can replace the need to invest in transmission and distribution infrastructure, utilities may struggle to realize appropriate rates of return on those assets.

Against the backdrop of a changing grid, how utilities should recover their costs and achieve an acceptable return on investment, and what role they should play in the coordination and management of DERs, are open questions that are actively being considered at both the state and federal levels.[187] NARUC and other entities have written about potential new business models and the challenges such models pose for utility rate recovery.[188] Several states have participated in or encouraged utilities to institute "utility of the future" initiatives to explore new platforms and roles for incumbent utilities.[189] Other states have proposed and passed legislation allowing utilities to propose new forms of ratemaking, including rate structures that decouple the sale of electricity from utility revenue and "performance-based" rate structures that incentivize efficiency over infrastructure spending.[190] At the federal level, the FERC is in the process of considering new rules to facilitate the integration and participation of DERs in wholesale markets and to clarify the role that distribution utilities will play.[191]

Pushed by policy and commercial incentives, state and federal regulators will ultimately need to consider how best to facilitate DER growth while maintaining grid reliability and a low cost of service for all customers. Regulators will also

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185. Jeff St. John, *As California Mulls Retail Electricity Choice, Utilities Are Losing Customers in Droves*, GREENTECH MEDIA (May 17, 2017), https://www.greentechmedia.com/articles/read/california-utilities-are-losing-customers-in-droves#gs.taE8JpQ.

186. *Distributed Energy Resources Rate Design and Compensation*, NARUC, 65 (Nov. 2016), pubs.naruc.org/pub/19FDF48B-AA57-5160-DBA1-BE2E9C2F7EA0.

187. *Id.* at 159. For example, as DERs become more prevalent and there is less need for transmission infrastructure to carry power across long distances, the existing utility business model, through which the utility makes money based on capital investment, may no longer be viable.

188. *Id.* at 158–59.

189. In New York, for example, regulators have explored, through New York's "Reforming the Energy Vision" initiative, a model through which utilities would act as "distribution system platform providers." Under such a model, utilities would be responsible for maintaining the system and ensuring reliability, while third-party suppliers would provide a host of services to enable customer engagement. The goal would be for each utility to serve as the "platform" for participation in the energy markets, thereby encouraging utilities to "respond to new trends by adding value, thereby retaining customer base and the ability to raise capital on reasonable terms." Andrew M. Cuomo, *Reforming the Energy Vision (REV)*, New York State, https://rev.ny.gov/ (last visited Oct. 15, 2018).

190. *Fixed Service Utilities Distribution Rates Proposed Policy Statement*, PA PUC Docket No. M-2015-2518883; Robert Walton, *Pennsylvania Open 'Future of Utility Rates' Proceeding*, UTILITY DIVE (May 7, 2018), https://www.utilitydive.com/news/pennsylvania-opens-future-of-utility-rates-proceeding/522872/. Performance-based rate structures establish a revenue model where returns are driven by meeting goals to deliver an affordable and reliable power system, as opposed to traditional models where revenue is based on returns on large-scale capital investments.

191. Conference, *Distributed Energy Resources – Technical Considerations for the Bulk Power System*, FERC Docket No. RM18-9-000 (Apr. 2018).

need to consider how to incentivize utilities to invest in blockchain and other innovative technologies in lieu of costlier traditional "poles and wires" system upgrades. Because DERs may alleviate the need for traditional upgrades, regulators must ensure that utilities are appropriately rewarded for choosing less expensive solutions. Similarly, where appropriate, regulators should consider whether to allow utilities to earn a rate of return on investments spent on innovative pilots with a demonstrated potential value to utility customers.

B. *Legal Recognition Smart Contracts*

1. Smart Contract Mechanics

Blockchain at its core is a secure and reliable method for recording many transactions among various parties. For the energy industry, the added ability to enter into "smart contracts" shows particular promise to facilitate the use cases discussed above.[192] Smart contracts may be defined broadly: "A smart contract is an automatable and enforceable agreement. Automatable by computer, although some parts may require human input and control. Enforceable either by legal enforcement of rights and obligations or via tamper-proof execution of computer code."[193]

When two or more parties consent to the terms of a smart contract, the parties cryptographically "sign" the smart contract and deploy it to a blockchain or distributed ledger.[194] The distributed ledger and consensus mechanism are used to confirm whether contractual conditions, based on the contract coding and inputs received from on or off the blockchain, have been met.[195] If such conditions are present, the contract will automatically execute the stipulations to the parties' agreement and currency, data, or an indicia of ownership will be transferred from one account to another.[196] Payment is automatically enforced through the distributed ledger.[197] Blockchain technology provides the accuracy and security necessary for parties to use and receive payment from smart contracts without a third-party intermediary or escrow agent.[198]

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192.   Tsui S. Ng, *Blockchain and Beyond: Smart Contracts*, ABA BUSINESS LAW SECTION (Sept. 2017), https://www.americanbar.org/groups/business_law/publications/blt/2017/09/09_ng.html.

193.   Christopher Clack et al., *Smart Contract Templates: Foundations, Design Landscape and Research Directions*, RESEARCHGATE (Mar. 15, 2017), https://www.researchgate.net/publication/305779577_Smart_Contract_Templates_foundations_design_landscape_and_research_directions.

194.   Reggie O'Shields, *Smart Contracts: Legal Agreements for the Blockchain*, 21 N.C. BANKING INST. 177, 179 (2017), https://scholarship.law.unc.edu/cgi/viewcontent.cgi?referer=&httpsredir=1&article=1435&context=ncbi.

195.   *Id.*

196.   *Getting Smart: Contracts on the Blockchain*, INST. OF INT'L FIN (May 2016), https://www.iif.com/publication/research-note/getting-smart-contracts-blockchain.

197.   O'Shields, *supra* note 193.

198.   *The Future of Financial Infrastructure: An Ambitious look at how Blockchain can Reshape Financial Services,* WORLD ECON. FORUM (Aug. 2016), http://www3.weforum.org/docs/WEF_The_future_of_financial_infrastructure.pdf.

2. Overview of Existing Smart Contract Law

A traditional contract is generally understood to be "a promise or set of promises for the breach of which the law gives a remedy, or the performance of which the law in some way recognizes as a duty."[199] Over the past several decades, determining whether a contractual relationship exists relies on evaluating a handful of statutory or court-made elements, including whether there are (i) parties capable of consenting; (ii) mutual consent of those parties; (iii) a lawful object of the contract; and (iv) sufficient consideration.[200] Moreover, the parties to a contract must define their respective promises sufficiently such that a court can determine whether a party has performed its contractual duty, and if not, can provide an effective remedy.[201] While federal and state legislatures have passed laws that recognize the realities of modern e-commerce, for the most part digital contracts have been subject to traditional notions of contract law.[202]

Federal law developed to accommodate e-commerce probably applies to smart contracts residing on a blockchain, although no courts have had occasion to pass judgment on the issue. The federal ESIGN Act, enacted in 2000, allows electronic signatures to be afforded the same legal effect as traditional "wet" signatures, so long as a party has indicated its consent to be bound with an electronic indication of consent.[203] The ESIGN Act arguably affords smart contracts, private keys, and data recorded on blockchains legal protection under the definitions of electronic records and electronic signatures.[204] ESIGN defines "electronic signature" as "an electronic sound, symbol, or process, attached to or logically associated with a contract or other record and executed or adopted by a person with the intent to sign the record."[205] "Electronic record" is defined as "a contract or other record created, generated, sent, communicated, received, or stored by electronic means."[206]

In blockchain terms, a private key is a symbol attached to a smart contract or a record of a transaction recorded on a blockchain. A blockchain is a record of information recorded by electronic means. A smart contract has the fundamental components of a contract (offer, acceptance, and consideration) and is recorded by electronic means, suggesting that smart contracts could fall within the strictures of

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199. 1 CORBIN ON CONTRACTS § 1.3 (2018).

200. ASP Props. Grp v. Fard, Inc., 133 Cal. App. 4th 1257, 1268-69 (2005) (citing Cal. Civ. Code § 1550).

201. Bustamante v. Intuit, Inc., 141 Cal. App. 4th 199, 209 (2006) (quoting Ladas v. Cal. State Auto. Ass'n, 19 Cal. App. 4th 761, 770 (1993)).

202. Philip Argy et al., *The Effective Formation of Contracts by Electronic Means,* http://www.austlii.edu.au/au/journals/ANZCompuLawJl/2001/33.pdf.

203. 15 U.S.C. § 7001(a)(1) (2000). When using a website or buying an item from an online retailer, courts have determined that a party has entered into an enforceable contractual relationship if that party has constructive notice or an opportunity to review the contractual terms and has agreed to be bound by those terms (even if those terms were unread or ignored, and agreement was evidenced by a hastily checked box). Nguyen v. Barnes & Noble, Inc., No. 8:12-cv-0812-JST (RNBx), 2012 WL 3711081 (C.D. Cal. Aug. 28, 2012).

204. Patricia Fry, *Joint Statement in Response to State "Smart Contracts" Legislation,* CHAMBER OF DIGITAL COMMERCE, ELECTRONIC SIGNATURE AND RECORDS ASSOCIATION (Apr. 2018), http://esignrecords.org/wp-content/uploads/2018/04/Joint-Ltr-State-Smart-Contracts-Legislation.pdf.

205. 15 U.S.C. § 7006(5) (2000).

206. *Id.* § 7006(4).

ESIGN.[207] The Uniform Electronic Transactions Act ("UETA"), a model piece of legislation introduced around the same time at ESIGN and subsequently adopted by most states, also facilitated the entering into and storage of contracts in electronic form.[208] Under ESIGN and UETA, parties who may have never met and may be physically separated by many miles can enter into contractual relations if evidence suggests that those parties intend to be bound by a contract, have consented to doing business electronically, are participating in a system whereby an electronic signature can be paired with an underlying record of terms, and where the electronic records are retained for a period of time.[209] These are the types of transactions that smart contracts on a blockchain would facilitate.

To date, the only states to enact legislation specifically recognizing smart contracts as binding legal agreements are Arizona and Tennessee.[210] Under Arizona law, "a contract relating to a transaction may not be denied legal effect, validity or enforceability solely because that contract contains a smart contract term."[211] The law defines a "smart contract" as "an event-driven program, with state, that runs on a distributed, decentralized, shared and replicated ledger and that can take custody over and instruct transfer of assets on that ledger."[212] Similarly, Tennessee law states that "smart contracts may exist in commerce" and will not adversely impact the legal effect, validity and enforcement of contracts that contain one or more smart contracts."[213] Tennessee's definition of smart contract is nearly identical to Arizona's definition, but it is slightly more expansive.[214] Event-driven computer programs that "create and distribute electronic assets; synchronize information; or manage identity and user access to software applications" are also smart-contracts.[215]

There is some risk, however, that the Arizona and Tennessee laws are preempted under the ESIGN Act.[216] ESIGN preempts state law regarding the validity of electronic signatures and contracts that use electronic records or signatures in interstate commerce.[217] While ESIGN includes two exemptions (state law that "constitutes an enactment or adoption of the Uniform Electronic Transactions

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207.   Adam Bridgers, *Will Workplaces Be Going Off The Rails On The Blockchain?*, FISHER PHILLIPS (Mar. 31, 2017), https://www.fisherphillips.com/resources-newsletters-article-will-workplaces-be-going-off-the-rails-on-the-blockchain.

208.   Uniform Electronic Transactions Act, NATIONAL CONFERENCE OF COMMISSIONERS ON UNIFORM STATE LAWS (1999).

209.   US Electronic Signature Laws and History, https://www.docusign.com/learn/us-electronic-signature-laws-and-history; *see also* Rensel v. Centra Tech, Inc., 2018 U.S. Dist. LEXIS 100720 *31 (S.D. Fla. June 14, 2018) (finding that customers purchasing tokens via "smart contract" were not bound to arbitration because they were not required to check any boxes or click any buttons to complete their token purchase).

210.   Mike Orcutt, *States that are passing laws to govern "smart contracts" have no idea what they're doing*, MIT TECHNOLOGY REVIEW (Mar. 29, 2018), https://www.technologyreview.com/s/610718/states-that-are-passing-laws-to-govern-smart-contracts-have-no-idea-what-theyre-doing/.

211.   ARIZ. REV. STAT. ANN. § 44-7061(C).

212.   *Id*. § 44-7061(E)(2).

213.   TENN. CODE ANN. § 47-10-202(c) (2018).

214.   *Id*. § 47-10-201(2).

215.   *Id.* § 47-10-201(2)(B)-(D).

216.   ARIZ. REV. STAT. ANN. § 44-7061(E) (2017); TENN. CODE ANN. § 47-10-201 (2018).

217.   15 U.S.C. § 7001(a).

Act . . . or [law that] specifies the alternative procedures or requirements" by which electronic records and signatures are accepted), these state laws do not appear to fall within either category.[218] Therefore, these state initiatives' effect may be limited to intrastate commerce.

a. Smart Contract Formation and Interpretation Issues

When the term smart contract is discussed, lawyers need to distinguish between smart *legal* contracts and smart contract *code*.[219] Smart legal contracts are contracts that contain all the elements necessary to be a legal contract but are executed and represented by software.[220] Coders, developers, and programmers, on the other hand, often use the shorthand term "smart contract" to refer simply to "a piece of code . . . [created] to execute certain tasks if pre-defined conditions are met," regardless of whether the traditional contractual elements of offer, acceptance, intent, or consideration are also present.[221]

These semantic differences highlight a broader gulf between coders and lawyers. Because smart contracts are written largely in code, "tools will have to be developed to [help] bridge the usability gap" so that the average lawyer (or judge) can meaningfully participate in the drafting, interpretation, and enforcement of the code underlying the rights, obligations, and remedies programmed into a smart contract.[222] Drafting or encoding smart contracts is relatively straightforward when performance is predicated on a set of predictable and easily defined conditions. But not all clauses within a legal contract lend themselves to the automation and self-execution functions described above.[223] At the outset of a contractual relationship, it may be very difficult to imagine the universe of circumstances that could exist when the contract is interpreted at a later date, and even more difficult to encode all those circumstances in a smart contract. For instance, it would be difficult to encode a performance excuse clause that excuses seller from delivering energy based on circumstances beyond seller's reasonable control.[224] That determination is necessarily very context-specific, and could depend on weather, fuel supply, site control, and many other future "known unknowns."

Ontologies are one way to push smart contracts towards closer approximations of traditional written contracts. An ontology, in this context, is a "formal way of defining the structure of knowledge of a domain and the relationships between concepts."[225] Ontologies enable computers to understand common terms found in non-operational clauses such as "validly existing" or "jurisdiction."[226]

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218. *Id.* § 7002.

219. Josh Stark, *Making Sense of Blockchain Smart Contracts*, COINDESK (Jun. 4, 2016), http://www.coindesk.com/making-sense-smart-contracts.

220. *Whitepaper: Smart Contracts and Distributed Ledger – A Legal Perspective*, LINKLATERS, 4 (Aug. 2017).

221. *Id.* at 5

222. Tsui Ng., *Blockchain and Beyond: Smart Contracts*, BUSINESS LAW TODAY (Sept. 2017), https://www.americanbar.org/groups/business_law/publications/blt/2017/09/09_ng.html.

223. *Whitepaper*, *supra* note 220, at 10.

224. *Id.* at 13.

225. *Whitepaper*, *supra* note 220, at 11.

226. *Id.* at 12.

This allows them to automatically check a registry to determine whether the representation is true.[227] Therefore, smart contracts can implement contract terms that resist stable or objective definitions by reference to an outside data source. Even with the use of ontologies, whether a smart contract can truly effectuate the parties' intent, however, would depend on the accuracy of those registries.

b. Smart Contract Remedy and Enforcement Issues

Courts have historically interpreted and enforced contracts according to "a social matrix that includes custom, trade usage, prior dealings of the parties, recognition of their social and economic roles, notions of decent behavior, basic assumptions shared, but unspoken by the parties, and other factors, most especially including rules of law, in the context in which [the parties] find themselves."[228] Courts also evaluate contract formation and performance against a backdrop of practical experience and several legal and equitable remedies and defenses.[229] For instance, if a contract is otherwise clearly worded and can be said to evidence the full agreement between the parties, the parol evidence rule bars interpreting the agreement with evidence outside the four corners of the document.[230]

Because contracts are creatures of human dealing, context and relationships are significant factors in their enforcement.[231] Rather than completely reform the traditional practices of entering into and enforcing contracts, courts and legislatures have, for the most part, taken incremental, common-sense measures to adapt historical contractual principles to digital commerce.[232] Courts have rewritten or voided contracts on a post hoc basis if they find mutual mistakes of fact during negotiation, where a party lacks good faith, or because circumstances have changed such that enforcing the contract against a party would be illegal, against public policy, or unconscionable.[233] In some circumstances, a non-breaching party can choose between receiving damages or specifically enforcing the contract, as written.[234]

Smart contracts, however, challenge some of these traditional contractual enforcement remedies. For instance, traditional legal contracts are sometimes modified if the contract terms no longer reflect the commercial realities of the deal. Mistakes made in the drafting process can also be corrected through such amendments and modifications. In some cases, a court will reform (i.e., re-write) a contract to ensure that both parties get the benefits and burdens to which they originally agreed. When a smart contract is embedded in a distributed ledger, however, the ledger is considered immutable. Going back and changing the terms of a smart

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227.   *Id.* It is important to note that some legal terms do not have precise decisions and thus could not be formally represented, terms such as "good faith," for example. *Id*.

228.   1 CORBIN ON CONTRACTS § 1.3 (2018).

229.   *Remedies for Breach of Contract*, LEGALMATCH (last modified May 2, 2018), https://www.legal-match.com/law-library/article/breach-of-contract-equitable-remedies.html.

230.   Restatement (Second) of Contracts § 213.

231.   *Oglebay Norton Co. v. Armco, Inc*., 52 Ohio St. 3d 232, 235-37 (Ohio Supreme Ct. 1990).

232.   *See supra* Section IV.B.2.

233.   Restatement (Second) of Contracts § 152.

234.   *Breach of Contracts: Remedies*, USLEGAL, https://contracts.uslegal.com/breach-of-contract-remedies/ (last visited Oct. 10, 2018).

contract could be thought of as antithetical to the immutable characteristics of blockchain technology.

Finally, distributed ledger technologies raise complicated jurisdictional questions. In contractual disputes, venue may lie in the location where the deal was made or where the subject of the contract is located.[235] Digital representations of value on a distributed ledger could be said to exist in several jurisdictions at once. Should a dispute arise, or should a court of competent jurisdiction seek to attach such digital assets, it is unclear where the dispute could be resolved, under what choice of law, and where property could be attached pending resolution of a conflict.

For the earliest adoption of smart contracts, therefore, we may see very basic transactions entrusted to smart contracts under the umbrella of a traditional master agreement that incorporates traditional and equitable contract law principles. For instance, it is presently common for parties to establish a comprehensive framework for dealing with each other under the Edison Electric Institute (EEI) "Master Agreement."[236] The EEI Master Agreement can run 30 or more pages and includes many definitions and defenses that rely on context-specific concepts like "reasonable control" and "commercially reasonable manner."[237] For the purchase and sale of actual power, however, parties often use a separate, much shorter document— the EEI "Confirmation," which succinctly lists objective criteria like contract quantity, delivery point, and price.[238] Smart contracts may be better suited to Confirmation-type transactions, where the rights and obligations of each party are narrowly and specifically defined. They may not be the best instruments for establishing the rights and obligations that arise in every other facet of the business relationship, like in instances of Force Majeure, dispute resolution, or change in law.

V. CONCLUSION AND RECOMMENDATIONS

The electricity sector is moving towards decentralized resources, and blockchain could play a significant role in integrating distributed generation and load resources. Blockchain has the potential to both streamline processes under existing regulatory regimes and facilitate new business models. Wide-scale implementation of the technology is not without its challenges, however. While some of these challenges are more broadly associated with the utility's changing role in providing energy, the industry should start educating itself about blockchain now to understand how it can impact energy markets, integrate renewables, and provide greater customer choice.

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235. 12 O.S. 1752B (1971).

236. *Master Contract*, EDISON ELECTRIC INSTITUTE, http://www.eei.org/resourcesandmedia/mastercontract/Pages/default.aspx (last visited Oct. 24, 2018).

237. *Master Power Purchase & Sale Agreement*, EDISON ELECTRIC INSTITUTE (last modified Apr. 25, 2000), http://www.eei.org/Search/Pages/Results.aspx?k=master%20power%20purchase.

238. *EEI Gas Annex Confirmation Letter*, EDISON ELECTRIC INSTITUTE, http://eei.org/Search/Pages/Results.aspx?k=confirmation%20letter&r=site%3D%22http%3A%2F%2Feei%2Eorg%22.

Given the highly regulated nature of the electric power industry, state and federal policymakers will play a significant role in how much blockchain can contribute to industry-wide change. Information gathering will be critical to this process, and regulators may consider following Arizona's lead and establish proceedings to develop the technical, operational and regulatory information essential to understanding blockchain's various value propositions.[239] Similar to European efforts, regulators should also consider establishing "sandboxes" to allow industry participants to explore and experiment with potential use cases in a controlled environment.[240] Such sandboxes have allowed for proof-of-concept testing of some of the more transformative blockchain applications.[241] Allowing pilot programs to operate in controlled environments will allow startups to develop their platforms, test the value proposition of different use cases, monitor unintended consequences, and establish trust with regulators. Industry participants and grid operators should be encouraged to experiment with blockchain technology and should involve themselves in the existing efforts underway to standardize and prove out blockchain technology in the energy industry.

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239.   *Fintech Sandboxes – Update on State Approaches*, DAVIS WRIGHT TREMAINE LLP (Apr. 16, 2018), https://www.jdsupra.com/legalnews/fintech-sandboxes-update-on-state-80891/.

240.   *Ofgem Starts Blockchain Sandbox with EDF Energy and Others*, TRUSTNODES (July 7, 2017), https://www.trustnodes.com/2017/07/07/ofgem-starts-blockchain-sandbox-edf-energy-others (last visited Oct. 17, 2018).

241.   Notably, Arizona has already established a regulatory sandbox for another highly regulated industry: financial services. Arizona Becomes First State in U.S. to offer Fintech Regulatory Sandbox, Press Release, Office of Arizona Attorney General Mark Brnovich (Mar. 23, 2018), https://www.azag.gov/press-release/arizona-becomes-first-state-us-offer-fintech-regulatory-sandbox.