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Using Blockchain to Enable Cleaner, Modern Energy Systems in Emerging Markets

Emerging markets must attract significant international financing to meet their goals for mitigating carbon pollution and increasing access to clean, affordable, reliable, and resilient energy. The authors* of this note examine how blockchain technology can—if paired with smart, interconnected devices—promote needed investments by both improving investment processes and promoting the adoption of modern energy systems and business models. Given the nascent status of both blockchain technology and blockchain applications specific to the energy sector, this note offers guidance to better assess where and how to apply blockchain technology to achieve a modern, clean, energy future including in emerging markets.

The Paris Agreement ("the Agreement")[1] on climate change indicates greater appetite by emerging markets (EMs) to deploy and track new methods of generating and delivering electricity in order to meet their commitments to reduce greenhouse gas emissions.[2] However, to tackle climate change and increase people's access to reliable, clean energy, emerging markets must mobilize trillions of dollars from various sources.[3]

Also, rather than operate centralized one-way, energy generation systems to meet inflexible demand, energy providers should use renewable, distributed, and responsive energy resources[4] that manage themselves through bi-directional[5] communication, and enable investors and other stakeholders to easily track and evaluate the impact of energy investments.

Given the opportunities and challenges involved in meeting the goals of the Agreement, and increasing people's access to affordable electricity, to improve the investment process and bolster the impact of their energy sector investments,[6] policy makers, regulators, and investors could increase the use of blockchain technology, in combination with "smart" devices, Internet of Things (IoT), and big data.

Applying Blockchain Technology to Energy Sector Investments in Emerging Markets

Blockchain's ability to establish greater trust and support more automated transactions may allow it to transform sectors and solve the pain points of emerging market investments.[7] Such investments can lend themselves to blockchain-based solutions because they typically involve a shared repository of information, multiple sources and contributors of information to that repository, minimal trust between parties, one or multiple intermediaries, and various dependencies across energy infrastructure and management.[8]

Blockchain is compelling as an enabling technology for scaling energy systems powered by renewable energy and responsive distributed energy resources. Energy sector stakeholders believe blockchain technology may in fact be the critical additional ingredient to smart IoT-enabled devices and big data that unlocks the new business models necessary for this energy sector transformation where millions (or even billions) of customer devices are being managed.[9]

Historically, electric utilities and energy companies produced value through energy generation, transmission, and distribution in order to meet inflexible energy demand

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from ratepayers. However, the opportunity to generate value in the energy sector is shifting as ratepayers become prosumers[10] and provide greater demand flexibility on electric grids.[11] For example, in order to balance electricity loads, commercial, industrial, and residential customers can now use smart, interconnected devices that can automate the powering down of their electricity-consuming systems, battery storage, and other grid services in response to variability in renewable (or conventional) generation.

This shift toward focusing on devices at the grid-edge (e.g., smart thermostats, appliances, and batteries) also implies strong growth in the number of market participants that electric utilities manage—from thousands of ratepayers today, to millions or billions of customer devices in the future. Blockchain technology offers great promise for value because it can automate and reduce the costs of managing this growth in market participants.

As electric utilities manage the grid from the device level, they can automate operational decisions and maximize efficiencies across electric grids by using smart contracts. These run on blockchain to trigger, track, and settle the various grid services that smart, interconnected devices enable. The adoption of this leaner management of electric grids by utilities and system operators is expected to reduce operational costs and unlock revenues from new services. It is also expected to help meet policy mandates for implementing cleaner grids through the combined use of variable renewable supply, and responsive demand-side resources.

To better understand how this manifests in real-world applications, consider the following blockchain applications using smart contracts. In both scenarios, the grid services provided through demand response and battery storage are tracked, and any associated compensation is settled with customers for their grid services in real time on blockchain and system operators gain confidence about these demand side resources actually delivering valuable services to the grid:

Demand response to address undersupply of electricity generation: To avoid turning on a natural gas-fired peaking power plant on a hot summer day when there is a gap between electricity supply and demand, a demand response "event" is signaled to power down smart devices based on the specifications written into the smart contracts governing them.

Battery storage to address oversupply of electricity generation: To store excess generation from wind power resources during evening hours when electricity consumption is low, a battery storage "event" notifies electric vehicles and other battery storage systems to store excess capacity, based on the specifications written into the smart contracts governing them.

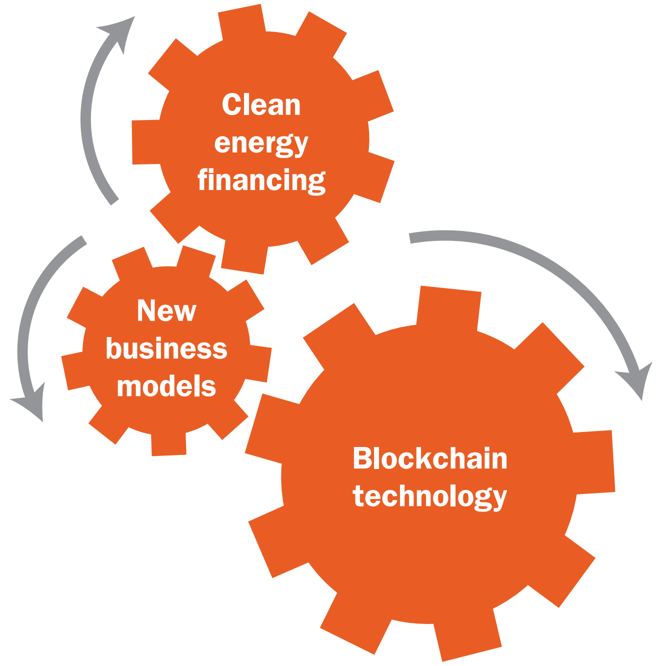

FIGURE 1 **Convergence of Opportunities**

Source: Authors

Key Blockchain Application Domains in the Energy Sector

There are many application domains for blockchain technology in the energy sector that can deliver billions of dollars in global value annually through cost reductions—driven by greater automation and disintermediation—and revenue growth. Investors should consider application domains such as the following that offer the promise of value creation across the energy sector:[12]

- **Certificate-of-origin systems for renewable energy markets:** any application that documents the provenance of renewable energy generation, issues certificates about the green attributes of each unit of renewable generation, and tracks ownership transfers between market participants for their green energy claims, and related voluntary or compliance reporting needs.
- **Utility billing systems:** any application where customers transact using cryptographic identities to manage metering, customer settlement, advanced rate implementation, or customer switching.

- **Demand response programs:** any application that conducts aggregation, real-time measurement and verification (M&V), settlement, and trading associated with participation in a given demand response event.
- **Electric vehicle charging networks:** any application that manages customers, vehicles, and charging infrastructure using cryptographic identities.
- **Transactive energy systems:** any market design where electric grids are balanced and controlled through intelligent software agents that perform grid communication and control functions for physical assets by responding to temporal and locational price signals.

Some additional applications that could deliver billions of dollars in global annual value to the energy sector include wholesale clearing and settlement, regulatory compliance, metered energy efficiency programs, grid asset procurement, and direct (energy-specific) climate finance.

Investors financing energy sector projects in emerging markets that overlap with these application domains should consider using blockchain technology to maximize private returns and broader social impacts.

The landscape of companies, consortia, and startups developing energy sector-specific blockchain platforms and applications is growing.[13] The suite of blockchain-based solutions being developed and tested now—and those coming in the future—can enhance the vision, financial transfer, project implementation, and tracking associated with emerging market investments in the energy sector. Below are a few examples of promising blockchain applications that are testing commercial viability through existing or upcoming pilots, and explanations of how these can support energy sector investments in emerging markets, which can provide a greenfield for introducing leapfrog technologies compared to existing markets:

- **LO3 Energy** builds on its existing Brooklyn Microgrid project in New York City with various products and applications such as Exergy and the Quantum Hedging System. Exergy offers a system for managing the physical characteristics and transactions for decentralized electric grids, which will help enable the adoption of transactive energy and new relationships between utilities, prosumers, and consumers—especially in cities and communities worldwide that already have independent grid edge projects. The Quantum Hedging System, which is being implemented in partnership with Direct Energy, enables enterprise customers to micro-hedge their energy purchases on an hourly basis to automate energy management and reduce costs.
- **Electron** promotes the adoption of smart grid infrastructure by developing products for energy sector market participants. Its various applications offer tools to register meters, trade demand response event actions, and coordinate distributed energy resource management—all of which help create new energy sector business models in emerging markets. Work to date has been in the United Kingdom (UK).
- **OLI** enables transactive energy systems by optimizing and automating the management of decentralized renewable generation and energy consumption with modular design. This application provides utilities with a new set of open-source hardware and software that enables a shift in their business model—thus, increasing the viability of decentralized, digital utilities. Work to date has been in Germany.
- **Share&Charge** is a decentralized protocol for electric vehicle (EV) charging, transactions, and data sharing, and was developed by MotionWerk to promote EV usage. The protocol simplifies access to EV charging stations, participation in demand response events and other grid services, and proof that electricity used to charge EVs comes from renewable generation. This application helps harmonize fragmented EV charge point markets and grid service offerings to improve the experience of existing EV owners, and increase the appeal of EVs to prospective owners. Work to date has been across Europe, and includes a pilot in the UK.
- **Slock.it** enables transactive energy systems through its "Economy of Things" technology that allows for any object to be rented, sold, or shared securely. Its applications, including Incubed Client, allow machines to operate and respond to different energy sector scenarios autonomously, which offers a solution for emerging markets to implement transactive energy systems. Work to date has been across Europe.
- **Sun Exchange** increases solar power access for schools and businesses specifically in emerging markets through an innovative fundraising approach that creates rental income for those who buy solar cells and lease them to those using electricity from successfully funded projects. This application combines aspects of crowdfunding and "as-a-service" business models to pool funding from multiple sources, and deliver solar power to solar cell lessees. This approach increases the viability of solar access by eliminating upfront cost barriers to prospective solar electricity users, and creates a long-

term revenue stream for solar cell investors. Several of these projects have been implemented in South Africa.

- **Swytch** encourages more sustainable behaviors and the broadening carbon markets by providing a financial reward for those engaging in a range of behaviors, and aggregating their collective impact. This application encourages people, companies, and other organizations to adopt sustainable behaviors—starting with renewable energy production. It also tracks the execution of any sustainable actions with an open-source oracle that acts as a distributed authority—offering a means by which to motivate and prove dispersed sustainable actions. A pilot has been carried out in Germany.
- **WePower** enables financing for new renewable energy generation projects by using tradable smart contracts to establish digital power purchase agreements (PPAs) between parties. For renewable energy projects in emerging markets, this application gives renewable energy developers greater ability upfront to secure financing, and demand for energy from buyers such as multinational corporations, cities, and universities. It also offers buyers greater liquidity with these digital PPAs. The app is expected to become available for projects in Australia, Estonia, and Spain in the last quarter of 2018.

These and other applications are setting the stage for a suite of blockchain-based solutions that will promote investments in renewable energy, demand response, EVs, transactive energy, and other application domains where blockchain plays an important role in maximizing investor value and social impacts. Accelerating and coordinating these currently-dispersed blockchain applications, is the Energy Web Foundation (EWF)—a global nonprofit based in Switzerland that is accelerating blockchain adoption in the energy sector. EWF is developing an open-source,

BOX 1: CERTIFICATE-OF-ORIGIN SYSTEMS FOR RENEWABLE ENERGY MARKETS

Renewable energy markets have experienced significant growth over the past decade and are positioned to continue expanding due to enabling policies, increasing consumer demand, technological advancements, and cost reductions.[14] However, to catalyze investments to meet the goals of the Paris Agreement and unlock access to renewable energy, the process of tracking and reporting renewable energy investments must be simplified, disintermediated, and modernized.

Currently, renewable energy markets depend on certificates-of-origin, including the guarantees of origin (GOs) used in the European Union, renewable energy certificates (RECs) used in the United States, and international renewable energy certificates (I-RECs) in about 25 countries. These certificates of origin provide detailed proof for each megawatt-hour (MWh) of renewable generation,[15] and are required because once electrons enter the shared electric grid, it is impossible to distinguish whether they were generated by renewable or fossil fuel resources.[16]

There is need to improve the operation of existing renewable energy markets, and the certificate-of-origin markets underpinning them that, for example, better enable smaller renewable energy generators and buyers to aggregate their supply and demand to gain greater market access.[17]

To achieve their Paris Agreement nationally determined contributions (NDCs),[18] emerging markets must improve their systems for tracking and reporting on their carbon emission reductions. Because renewable energy generation assets lead to carbon emission reductions when they displace polluting energy sources, countries in emerging markets want to promote renewable energy investments as part of a portfolio of options to reduce their carbon emissions. While there is a parallel opportunity to develop separate blockchain applications for carbon markets due to shared pain points,[19] investors should consider collaborating with emerging market stakeholders to determine how blockchain applications developed for certificate-of-origin systems can streamline documenting the carbon mitigation impacts of new renewable energy projects.

EWF is developing EW Origin, an open-source and blockchain-based toolkit for certificate of origin trading and tracking systems, and running tests of real-world scenarios in several countries with various energy sector market participants.[20] EW Origin can be used to build dApps that record the provenance, support direct trading, track ownership, and create reports for the green attributes of renewably generated electricity at the kilowatt-hour (kWh) level, as well as the associated avoidance of carbon dioxide emissions.

By adopting new technological tools that increase trust, simplify investment tracking, and reduce administrative costs, blockchain-based solutions like EW Origin should enable countries to leapfrog existing energy systems by encouraging more renewable energy investments.

energy sector-specific blockchain and convening an ecosystem of users, developers, and regulators to inform the development of EWF's digital infrastructure and promote the development of new energy sector applications.

Key Assessment Criteria for Blockchain-based Solutions in the Energy Sector

Emerging market investors who are planning to deploy financing in any energy sector application domain where blockchain technology provides value, should compare the viability and quality of different blockchain solutions before selecting one. Some of the criteria and associated questions for investors to use in their assessment include:

- **Technical architecture:** How is the technology stack structured—from the underlying blockchain platform to the specific applications running on the blockchain? How do applications interface with the blockchain itself? What components are executed on-chain versus off-chain?
- **Governance:** Is the blockchain public or private? What is the blockchain consensus protocol, and what are the resulting implications for throughput on the blockchain? Who are the governing and administrative bodies? What is the protocol for permissioning, system improvements, emergencies, and other actions? What controls and liabilities do users, governing bodies, and administrative bodies have? Who are the key stakeholders to engage who do not have a direct governance role, and at what junctures should this occur?
- **Features:** What are the users' key functional requirements? Does the blockchain solution meet users' business and regulatory needs?
- **Data collection and reliability:** What are the data sources? What is the methodology for sending data from these data sources to the blockchain? What data are stored on-chain versus off-chain, and how is this managed? What are the protections and processes in place to ensure data security, privacy, and reliability?
- **Throughput:** How much throughput can the blockchain solution handle? What are the gas limits and gas fees, where gas is the computational effort a given transaction needs in order to be executed on blockchain? What is the average block time? How do users pay for transactions, and how are transaction costs minimized?[21]
- **Development process:** What methods are programmers using to develop the blockchain solution? Who is managing this development process, and how transparent is it? Who owns the intellectual property, or does the solution use an open-source license? How is the solution being audited and how are any identified issues or shortcomings resolved? How is the development funded, and what (if any) funding needs remain?
- **Ecosystem:** Who are the current or potential users of the blockchain solution? Who advised on its development? How extensive and available is the community of programmers who can support and build on the particular solution?
- **Innovation:** What are the licensing rules? To what extent does the solution promote further innovations? What programming languages can be used? To what extent is the solution interoperable with others?
- **Regulatory alignment:** What are the relevant regulations? What is the extent of regulators' oversight over the solution? To what extent do regulators understand and support the solution?

Because blockchain is a nascent technology, additional assessment criteria for investors to consider will continue to emerge. Depending on the solution's maturity level, investors should also evaluate its performance and suitability, based on its existing use in the market, and consider testing through pilots before promoting or adopting a specific solution. Nevertheless, the authors of this note recommend that investors and policymakers prioritize open-source, public blockchains with permissioned consensus protocols, as these can be expected to maximize participation, innovation, and throughput.

Emerging market investors, and any regulators and market participants with whom they work, can use the key assessment criteria listed above to evaluate the suitability of applications and platforms such as EW Origin, and the Energy Web blockchain infrastructure on which it runs. They can also use these key criteria to assess other applications promoting clean energy investments that also run on the EW blockchain, or others in the fast-growing energy sector landscape.

Given the regulated nature of energy markets across the globe, regulatory support is especially critical to scaling blockchain applications. Regulators, who are still deepening their understanding of how this technology works, identifying concerns, and the regulatory oversight that may be needed—should be engaged early and often so that they can increase their understanding of particular blockchain platforms or dApps, provide input, and draw on this experience to identify best practices and regulatory implications. For example, EWF is collaborating with a national certificate-of-origin issuing body (or registry) to develop a national reference on the implementation of EW Origin that meets regulatory needs. After the target completion date of October 2019, this will serve as a freely available open-source technology "template" for use by national regulators for issuing, trading, claiming, and reporting on certificates of origin in their markets.

Both before and after running simulations or pilots, and based on existing regulations, this engagement could include proactively seeking early feedback from regulators about the platform or dApp's technical architecture, governance, and data sources. Also, to develop best practices for adopting block-chain solutions for different markets, investors should share their insights with regulators about their own blockchain assessments and pilots.

Conclusion

Investors have a tremendous opportunity with the Paris Agreement to accelerate and scale the adoption of clean, affordable, reliable, and resilient energy access in emerging markets. To tackle the challenges associated with deploying financing in emerging markets, and capture the opportunity presented as the energy sector modernizes, investors should leverage blockchain technology when they invest.

Provided that blockchain applications meet business and regulatory needs, in combination with smart devices, blockchain technology can deliver significant value across a range of energy sector application domains. Moving forward, investors and emerging market policymakers and regulators should use the assessment criteria provided above as a starting point to evaluate different blockchain solutions. Ultimately, these solutions can help unlock greater financing across the globe for democratized, decentralized, digitized, and decarbonized electric grids.

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TOP APPLICATIONS	KEY ASSESSMENT CRITERIA
• Certificates of origin • Utility billing • Demand response • Electric vehicles • Transactive energy	• Technical architecture • Governance • Features • Data collection and reliability • Throughput • Development process • Ecosystem • Innovation • Regulatory alignment

FIGURE 2 Top Applications and Key Assessment Criteria for Blockchains in the Energy Sector

Source: Authors

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Additional EM Compass Notes and reports about blockchain and its opportunities for emerging markets:

Blockchain—Opportunities for Private Enterprises in Emerging Markets (report), IFC, October 2017; *Can Blockchain Technology Address De-Risking in Emerging Markets?* (Note 38); *Blockchain in Development—Part I: A New Mechanism of "Trust"?* (Note 40); *Blockchain in Development—Part II: How It Can Impact Emerging Markets* (Note 41); *Blockchain in Financial Services in Emerging Markets—Part I: Current Trends* (Note 43); *Blockchain in Financial Services in Emerging Markets—Part II: Selected Regional Developments* (Note 44); *Beyond Fintech: Leveraging Blockchain for More Sustainable and Inclusive Supply Chains* (Note 45); *Blockchain Governance and Regulation as an Enabler for Market Creation in Emerging Markets* (Note 57).

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2 World Economic Forum (WEF). 2017. "The Future of Electricity—New Technologies Transforming the Grid Edge."

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the Parties—Twenty-first session, Paris, 30 November to 11 December 2015. Item 4(a) of the Provisional Agenda. Durban Platform for Enhanced Action (decision 1/CP.17)—Report of the Ad Hoc Working Group on the Durban Platform for Enhanced Action. Synthesis Report on the Aggregate Effect of the Intended Nationally Determined Contributions. Note by the secretariat."

4 This includes various "smart" Internet of Things (IoT)-enabled devices that can be programmed to respond to various situations that arise in a given electric grid.

5 Bi-directional flows of electricity and associated communications to/from an electric grid and grid assets (e.g., electric vehicles, batteries, and smart devices) are an important feature of promoting and managing distributed energy resources. Utilities will have to make investments to implement systems that can handle these bi-directional flows. See also: Sam Hartnett, et al. 2017. "The Decentralized Autonomous Area Agent (D3A) Market Model—A Blockchain-based Transactive Energy Implementation Framework for the 21st Century Grid." Concept Brief, Energy Web Foundation, 2017.

6 A blockchain is a decentralized database of transactions between two or more parties that are split into blocks that are validated by the entire network through encryption and added to the chain of prior transactions, where copies of the database are replicated across multiple locations (or nodes). Each block contains key details about the transactions, and each block is added as long as the block is validated by the consensus protocol used by the network. See also Niforos, Marina. 2017. "Blockchain in Development—Part II: How It Can Impact Emerging Markets." *EM Compass Note 41*, IFC.

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14 Bloomberg NEF. 2018. "New Energy Outlook 2018—BNEF's Annual Long-term Economic Analysis of the World's Power Sector Out to 2050." https://about.bnef.com/new-energy-outlook/; see also International Renewable Energy Agency (IRENA). 2018. "Global Renewable Generation Continues its Strong Growth, New IRENA Capacity Data Shows." http://www.irena.org/newsroom/pressreleases/2018/Apr/Global-Renewable-Generation-Continues-its-Strong-Growth-New-IRENA-Capacity-Data-Shows.

15 See for example "The Definitive Guide to Global Energy Attribute Certificates for Commercial, Industrial, and Institutional Buyers." Renewal Choice Energy. https://3blmedia.com/sites/www.3blmedia.com/files/other/EAC.Definitive_Guide_-_ESS.pdf

16 These data-rich certificates describe how, where, when, and who generated a given MWh. Any entity wanting to make a credible renewable energy claim for regulatory or voluntary purposes must procure these certificates, either bundled with, or separate from, their physical electricity purchases. As such, these certificates have their own markets, and serve as a de-facto consumer-driven subsidy for renewable energy because they provide an additional revenue stream for renewable energy generators.

17 Certificate of origin markets rely on third parties, outdated technologies, and multi-step processes that vary across geographies to indicate the proof of renewable generation. The resulting administrative costs, transaction costs, and other pain points, as well as the complexities of proving renewable energy generation or purchases, frustrate the current (mostly large) market participants, and discourage others from entering the market. For their renewable energy trades, certificate of origin systems should make it as easy as possible for market participants to obtain proof for their voluntary- or compliance-reporting requirements, which is based on secure, reliable generation data. The user experience associated with certificate-of-origin systems should also become more standard across markets to streamline investments for the multinational renewable energy developers and buyers who are enabling renewable energy developments across the globe.

18 Meltzer, Joshua P. 2018. "Blending Climate Funds to Finance Low-Carbon, Climate-Resilient Infrastructure." Global Economy & Development Working Paper 120, The Brookings Institution; see also: United Nations Framework Conference on Climate Change (UNFCCC). 2015. "Conference of the Parties—Twenty-first session, Paris, 30 November to 11 December 2015. Item 4(a) of the Provisional Agenda. Durban Platform for Enhanced Action (decision 1/CP.17)—Report of the Ad Hoc Working Group on the Durban Platform for Enhanced Action. Synthesis Report on the Aggregate Effect of the Intended Nationally Determined Contributions. Note by the secretariat."

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20 See Energy Web Blockchain: https://energyweb.org/blockchain/; see also *Miller, Douglas and Jens Griesing. 2018.* "Engie, Microsoft, SP Group, DBS Bank, TWL, E.ON, and Sonnen Test the First Version of EW Origin Blockchain App." Energyweb.org, April 20, 2018. https://energyweb.org/2018/04/20/engie-microsoft-sp-group-dbs-bank-twl-e-on-and-sonnen-test-the-first-version-of-ew-origin-blockchain-app/; EWF will make the full open-source EW Origin toolkit publicly available for reference and use as a template by other REC, GO, and I-REC trading and tracking systems so that application developers can build and deploy their own modernized technology services. In the context of emerging markets, which generally do not have robust renewable energy tracking systems in place, EW Origin can be used to build blockchain-based applications that reduce investors' administrative burden for tracking the impacts of their wind, solar, and other renewable energy investments. The regulators who oversee renewable energy markets can adopt and modify open-source blockchain applications such as EW Origin to deploy modern trading and tracking systems for certificates of origin that meet their markets' needs.

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