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# Blockchain Technology: What It Means for Renewable Energy

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The goal of every invention is to change the World as we know it. Yet, very few actually succeed. The small group that has – electricity, cars, the Internet – are integral parts of daily life. And now many believe that Blockchain technology is next to be added to the list. It is most commonly associated with Bitcoin, the first cryptocurrency to gain notoriety using the technology on a global scale. But Blockchain has much more to offer than just financial assets, with potential applications in every imaginable industry. Despite these possibilities, there is an ambiguous and uncertain air surrounding Blockchain.

This paper will examine Blockchain technology with regard to its innovative potential in the renewable energy sector. It will break down the fundamental concepts of the technology and analyze the first microgrid community to successfully implement it. The components needed to integrate Blockchain into the modern electricity economy will be discussed along with the massive socioeconomic potential.

## I. What is Blockchain?

Despite all of its ambiguity, blockchain is a relatively simple technology once two key concepts are understood.

**Decentralized Network**

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The first of these is the decentralized network. Typically, the networks we encounter in our daily lives are centralized, meaning there is a single nexus that is responsible for overseeing and running operations. Straightforward examples of these networks are websites like EBay. A manufacturer wants to sell its product, so they log onto EBay where they are connected to buyers who are looking to purchase. All interactions, bartering and transactions take place on the EBay site. So, if the EBay server were to malfunction, neither party would be able to complete a transaction. This is where the power of a decentralized network becomes clear. The network that the Blockchain serves is made up of nodes that represent a computer around the globe. Because these computers are geographically dispersed, the chance of a single event damaging every node is virtually zero. If a node suddenly stops working, there are plenty of others that will pick up the slack and allow the network to function without skipping a beat. With no central point of failure, the decentralized network provides Blockchain with an amount of reliability that is unrivaled by any modern technology.

**Decentralized Concensus**

The next component of Blockchain introduces a level of accountability that is known as the decentralized consensus. In order for a transaction to be added to the Blockchain, each node in the network must agree that it occurred as presented. This takes place through a concept called proof of work. A Blockchain transaction cannot be sent to other nodes by itself. Instead it must be tagged with a piece of code that when hashed, or run in Blockchain, outputs a number starting with five zeros. It is not important to understand why it must start with five zeros, but it is important to know that there is only one unique code that will output the correct number for each transaction. As a result, this code can only be revealed through trial and error. So, each node in the network partakes in elaborate computation until finally submitting the piece of code they determine to be correct for the transaction. Only after every node in the network has independently verified that they have computed same code, the transaction is added to a block. Each block is permanently connected to the block preceding it through this unique piece of code, making the entire Blockchain interconnected. Because of this once data is added it cannot be changed or edited in any way and will remain in the same state for as long as the network exists. This creates an accurate verification method that keeps records of any transaction that has ever taken place on the network.

With this combination of security and reliability, it is easy to imagine the value that Blockchain could add to industries. As a decentralized ledger with no central point of failure that can accurately store information in a transparent way, Blockchain introduces a new level of independence that was previously impossible.

## II. The Ethereum Platform and Smart Contracts

As people began realizing the potential of Blockchain, many block-chain based platforms were created. The most successful of these is Ethereum, a generalized platform based around the idea of smart contracts. A smart contract is a piece of code that lives on the Blockchain. When a preprogrammed condition is triggered within the network, and subsequently verified by all functioning nodes, the smart contract executes its corresponding contractual clause automatically. This preprogrammed condition can be just about anything - an account amount, a temperature, a user request, etc. As long as it can be written into code, the Blockchain network can recognize it. Additionally, Ethereum gives users the ability to develop their own distributed applications (dapps) based around smart contracts. Dapps are similar to the apps we use on smartphones, except they are running on a distributed network of computers as opposed to a single device.

Think of smartcontracts as the vehicles that allow Blockchain to run without human intervention. Blockchain is profoundly different than any other technology, but it would have minimal innovative potential without the secondary invention of smartcontracts. The generalized nature of the Ethereum platform means that smart contracts can be written to trigger any kind of transaction, not just a monetary exchange. Any transaction that requires the use of a trusted third party can now be codified into the form of a smartcontract, and run on the Blockchain. This not only cuts down on transaction costs but also increases overall efficiency, individual security and reliability.

## III. Early Industry Applications

Because Blockchain is such an innovative technology, it is also a disruptive one. There is little existing legislation to guide and protect market participants. Despite this, the rush to invest in all things Blockchain is massive. Many global securities exchanges have launched their own Blockchain-based platforms and the Estonian government has even gone as far as using a Blockchain-based keyless signature to authenticate all data in its databases. But, the financial services industry was the first to truly pioneer the use of Blockchain with the introduction of Bitcoin. To clear any confusion surrounding the name, Bitcoin is to Blockchain as Kleenex is to tissues. The words can be used interchangeably in everyday conversation, but one is actually a specific brand while the other is the generic noun.

It is the first of its kind, a completely virtual medium of exchange with no intrinsic value and no connection to a central bank. The value of Bitcoin is entirely determined by the basic economic concept of supply and demand. There is a finite number of bitcoins that will ever exist, 21 million to be exact, and there are many more than 21 million individuals that would like to own some. Thus, value is created and bitcoin becomes a commodity worth trading in the financial space. In 2010, Bitcoin could be purchased at a price of just $0.08 per coin. This is a stark contrast from the highest recorded price of $17,900 per coin that the cryptocurrency reached in 2017.

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With all of this excitement and monetary value, it is important to emphasize that the profound impact of Blockchain reaches far beyond its investment potential. The ability to eliminate the need for a trusted third party is the truly revolutionary aspect of Blockchain. For centuries mankind has been faced with the inability to fully trust another person. The story of the Byzantine Generals' Problem exemplifies this issue well. A group of generals, each controlling a portion of the Byzantine army, encircle a city. The generals have two choices from here: retreat or attack. While some generals would prefer to retreat and other attack, the only thing that actually matters is that they come to a collective decision. An attack can only be successful with the full strength of the army. If only a portion of the generals attack, they will be defeated easily. To further complicate things because they are located around the city, the generals can only communicate through messengers. This is where there begins to be a problem. There is the possibility that any messenger could be a traitor. If there is but one treacherous messenger that says retreat when all others say attack, the entire army will be defeated. So, how can the generals guarantee that all of the messengers deliver their intended message?

Up until very recently, the answer to this question was that they couldn't. But with the introduction of Blockchain, this changes. Previously any message sent between generals would be written in words, which may be good for communicating, but offers little protection from deceitful messengers that would like to manipulate them. This is where Blockchain's proof of work concept comes into play. As we know any transaction or message in Blockchain cannot be sent by itself, it must be accompanied by some unique code. When a general (node) receives a message (transaction), the first step is to hash it and check that it outputs a number starting with five zeros. If the number begins with five zeros, the general knows that this is the original message sent from another node. There is only one piece of code that will achieve this result for any given transaction, so if the output is any other number the general knows that the message has been tampered with. Through proof-of-work verification, the need to trust a messenger is eliminated as there is built in verification within the message itself.

The Byzantine Generals' Problem is a perfect example of the power behind Blockchain, and there are a number of jobs aside from war messenger that could be affected by the introduction of the technology. Blockchain's unique user-identification system and incorruptible digital ledger will make it easy to legitimize transactions, potentially eliminating the need for conventional notaries. Traditional auditing, which consists of large teams analyzing a sample of transactions for consistency across ledgers, could experience a drop in human capital if transactions are managed through Blockchain. The network's decentralized computers could input, analyze and audit financial transactions continuously to maintain integrity. While lawyers will still be needed for the large majority of legal processes, litigation surrounding inheritance or document verification could become digitized to functional strictly through smart contracts. The list of potentially affected jobs goes on, but the imperative point is that Blockchain has the potential to change the employment environment of the economy.

## IV. Renewables and Blockchain: Brooklyn Microgrid Case Study

The application of Blockchain in the renewable energy sector presents many opportunities to decrease carbon emissions and further the use of non-fossil fuel energy sources. Blockchain has the ability to shift the structure of electricity generation and transmission away from large utilities towards smaller, peer-to-peer (P2P) marketplaces. The Brooklyn Microgrid Project (BMG) is the first microgrid energy market of its kind, designed and constructed by LO3 Energy in New York City. The solar power based microgrid reimagines the traditional concept of the energy grid, and focuses on offering local and affordable energy to consumers.

### What is a Microgrid?

For a complete description of Microgrids and their innovative potential, please see EcoMotion's White Paper *Creating Microgrids and PERCS: Powered Emergency Response Centers.* Microgrids represent the intersection between energy generation and consumption. They are comprised of a small network of consumers with a local source of energy supply, typically in the form of solar power. Although connected to the main grid, microgrids can "island", or disconnect and operate independently in the case of an outage. If equipped with battery storage, the microgrid's islanding life span can increase and the system can respond to demand spikes in real-time. The ability to island is the most impactful feature of microgrids, as it is invaluable to a community in the case of natural disasters or emergencies. After an increasing number of natural disasters, there has been a spike in microgrid development as communities begin to consider the importance of their energy resiliency.

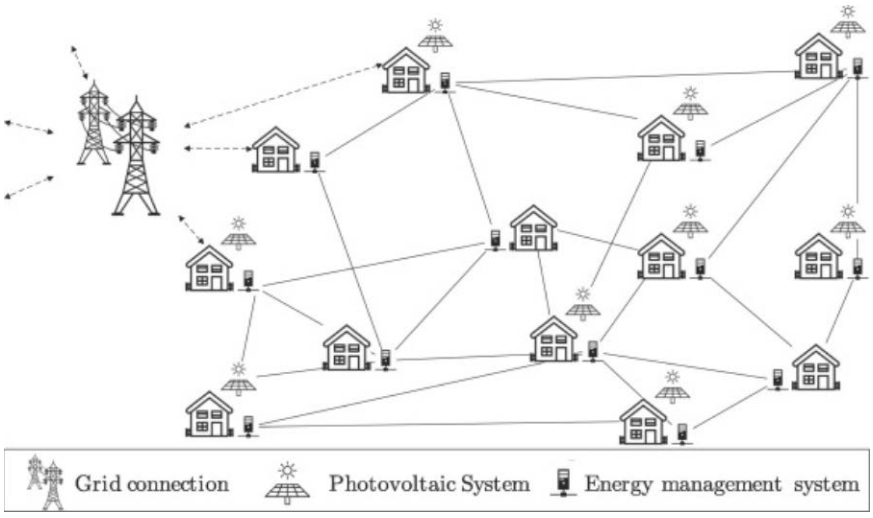
### Overview of Brooklyn Microgrid Project

With the memories of Hurricane Sandy's devastation fresh in their minds, LO3 Energy of New York was founded in 2013 to take part in the emerging distributed energy

economy. CEO Lawrence Orsini states that the company's mission has always been to make energy a product and a service that people can purchase on their own as opposed to relying on a large centralized entity. In late 2015, LO3 Energy announced an opportunity to take action on this mission through a partnership with Siemens. With a portfolio of microgrid development all over the world, Siemens provided the technical expertise and financial backing that LO3 had needed.

Together, Siemens and LO3 broke ground on the BMG in 2016. The project consists of two components: the physical microgrid and the virtual, Blockchain based energy market platform. The physical microgrid was constructed within the existing traditional grid and originally served a single neighborhood, Park Slope, which was chosen for its high concentration of solar panels. Smartmeters, placed at every participating home, are normal electricity meters equipped with dapp software and represent the nodes of the Blockchain network. Initially, smartmeters were installed at 10 homes, five with solar generation capabilities and five without. The smartmeters are multifunctional, performing all operations of a normal meter while constantly communicating and verifying with other smartmeters within the network. The infrastructure of the microgrid is 50% owned by the local community and 50% owned by LO3. Figure 1 depicts a possible design for a microgrid energy market similar to the BMG.

*Figure 1: Exemplary Microgrid Market Setup (from Mengelkamp et al., Applied Energy Vol. 210, 2018)*




The Blockchain energy-trading platform, called Exergy, can be accessed from a computer and allows local prosumers to trade energy with consumers in near real-time. App interface gives consumers the option to limit which energy sources (solar, wind, fossil fuel) they will accept as well as place ceilings on price. The software uses Blockchain to verify and monitor the energy flowing in and out of each point in the system and match buy offers with appropriate supply.

In April 2016, the first transactions took place on the BMG network between two residents on President Street. A solar power prosumer sold excess generation from his system to a house across the street that did not have any generation capacity. It is likely that this was the first P2P energy transaction to ever take place using Blockchain. From there, similar transactions continued on the network between 10 houses on President Street. With the confidence from the continued success and ease of these transactions, LO3 was able to expand the project to its modern state. Currently, the BMG serves a 10 by 10 block radius with 50 producers that are selling to over 500 households.

**Analysis**

Feedback from participants in the BMG has been overwhelmingly positive. Many residents who had previously enrolled in their utilities' 100% renewable option were thrilled to find that this system can actually guarantee the source of their electricity. If you've met anyone from Brooklyn then you know how proud they are of their borough. They love their Brooklyn lagers, Brooklyn coffeeshops and now, with the BMG, they can love their Brooklyn-generated electrons. Locally produced renewable energy means that the environmental benefits of consuming renewable power are also localized. Participating prosumers receive money for the power they generate, whereas within the traditional grid their generated energy could only be used as credits on their utility bill. This feature allows money generated within the community to be reinvested back into the local economy.

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In contrast, the BMG also revealed many obstacles that are facing distributed energy economies. After the initial transactions were successful, the project was forced to stall for months despite having 50 smartmeters installed and operational. The lag was a result of the regulatory bodies of New York State needing time to determine how participants could legally buy and sell power in this marketplace. This speaks to a problem that faces Blockchain technologies of all kinds. Because it is so new, the introduction of Blockchain into any industry will inevitably be followed by large regulatory reform. This elongates the timeframe for new ventures, placing additionally pressure on already financially fragile projects.

## V. Seven Components of Blockchain-Based Microgrids

The BMG proved to the electricity industry that Blockchain is going to have some kind of an impact, it's just unclear exactly what that will be. Since those first transactions on President Street, there has been significant investment into researching exactly what is needed to design large-scale Blockchain microgrid markets. The current accepted theory consists of seven necessary components of microgrid energy markets.

**Clearly Defined Microgrid Setup**

Because microgrids can serve different purposes, it is essential that any Blockchain microgrid have a clearly defined objective that outlines market participants and the form of energy traded. For example, the most common objectives in electricity would be to improve energy security or to increase the amount of renewables available to consumers. There must be a sufficient amount of consumption to create a need for the microgrid and there must also be enough excess production to serve demand within the system. The form of energy traded (electricity, heat, etc.) must be specified. Market participation should have a controlled enrollment that only offers access to geographically close individuals.

**Grid Connection**

There must be a minimum of one connection point between the Blockchain microgrid and the traditional electricity grid. In everyday operations, the larger grid will ensure that flows within the network satisfy existing demand and step in if generation is too low. A connection point(s) will also allow the traditional grid monitor the activity and output of the microgrid.

**Information System**

A multifunctional, Blockchain information system is critical to the proper function of these microgrid markets. It must be easily accessible to ensure that all participants have equal access to information. The system will be connected to each smartmeter in the network, record all generation and consumption and present the information to anyone with access. This will allow market participants to have complete information before engaging in a transaction.

**Market Mechanism**

The market mechanism is executed through the information system. It outlines the bidding format, including language, and payment rules that govern transactions within the network. The main purpose of the market mechanism is to efficiently match buy and sell orders, ideally in real-time. The mechanism will act as the rulebook for the information system to ensure that all transactions occur as intended.

**Pricing Mechanism**

Also implemented through the information system, the pricing mechanism aids in the allocation of supply and demand. An example of a pricing mechanism in traditional energy auctions would be individual clearing prices. In the case of this distributed energy economy, the pricing mechanism should accurately reflect scarcity in the market, increasing price when supply drops and vice versa.

**Energy Management Trading System (EMTS)**

The EMTS is arguably one of the most important features needed for distributed microgrid markets. For each market participant, the EMTS must implement a specific bidding strategy in order to ensure the energy supply is obtained. To do so, the system must have complete access to real time supply and demand information in order to predict consumption and generation. Bidding strategies will vary depending on price limits and preferences of market participants. The EMTS will also need access to individual Blockchain accounts to conduct transactions.

**Regulation**

The regulation of distributed energy markets is paramount in determining the structure of the marketplace. Legislation will dictate how Blockchain microgrid markets fit into the current energy economy along with how taxes and fees will be distributed among participants. Without the presence of regulation, it is impossible for this innovative energy-trading environment to exist.

## VI. Energy Intensity of Blockchain

The dense computation completed by nodes is essential to the security of information held within a Blockchain network. The common term for these intense calculations is mining. Like mining any precious good, the chances of finding the desired outcome in Blockchain is very small because there is only one code that will work for any given transaction. So while Blockchain may be a completely virtual technology, it takes massive amounts of energy to physically power the computers supporting it. Research predicts that the Bitcoin network alone will require the same amount of electricity as the entire nation of Ireland by 2020.

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The alarmingly large energy appetite of Blockchain has the potential to turn it from an ally of the environmental movement to a foe. This is why it is incredibly important to emphasize the energy intensity of this technology. Any entity that wishes to develop a Blockchain presence must be prepared for a substantial increase in their energy consumption. There is a very real possibility that the monetary gains made through Blockchain investment will not be enough to offset energy costs. Solar, wind and other renewables offer a solution to this problem, but if the infrastructure does not already exist, investing in these sources only makes the project more expensive. In order to make renewable energy a competitive option for Blockchain power, it must become available at a lower cost.

## VII. Conclusion

The advent of Blockchain technology has the potential to shift society towards a more decentralized future. On a smaller scale, the primary impact that Blockchain will have is placing more power in the hands of the average consumer. As seen in the BMG, distributed energy marketplaces allow local renewable energy to be integrated into the economy according to the preferences of market participants. The lack of intermediaries allows the community to actively participate and play a role in the day-to-day operations of the market. This is profoundly different from the existing structure of large, centralized utilities having complete control of the energy marketplace. And it is important to emphasize that these small but profound differences are what make Blockchain technology so groundbreaking. The numerous claims that Blockchain is going to replace traditional government and society as we know it are baseless and used as tactics to attract investors into Blockchain-based ventures. The true power of the technology lies in bringing consumer choice back to the forefront.