International Journal of Global Energy Markets and Finance, 2019, Vol. 2, No. 1, 6-11
Available online at http://pubs.sciepub.com/ijgefm/2/1/2
Published by Science and Education Publishing
DOI:10.12691/ijgefm-2-1-2

Blockchain and Energy Transition: What Are the Challenges for Cities?

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Received June 09, 2019; Revised August 25, 2019; Accepted October 02, 2019

Abstract The aim of this exploratory note is to draw the first outlines of the experimental use of blockchains for energy at the local level: to what extent can blockchains impact the energy transition of cities? How can cities and their inhabitants, thanks to this technology, become a producer of energy and consume all or part of this same energy? This exploratory note provides an overview of the types of energy this technology could apply to, as well as potential uses in the territories. Multiple experiments seem to be already launched by public and private actors, for example in the sector of municipal buildings, exchanges between private actors or in the energy sector for the (electric) mobility of people. The opportunities and vigilance of blockchain technologies for communities are discussed. In addition, perspectives to establish if and when a massification of this technology at the local level could be possible are presented.

Keywords: *blockchain, technologies, energy transition*

Cite This Article: Lamia Jamel and Abdelkader Derbali, "Blockchain and Energy Transition: What Are the Challenges for Cities?" *International Journal of Global Energy Markets and Finance*, vol. 2, no. 1 (2019): 6-11. doi: 10.12691/ijgefm-2-1-2.

1. Introduction

The blockchain is a technology of storage and transmission of information, transparent, secure, and functioning without a central control body (definition of Blockchain France). By extension, a blockchain ("block chains" or transaction register) is a database that contains the history of all the exchanges made between its users since its creation. This database is secure and distributed: it is shared by its users, without intermediaries, which allows everyone to check the validity of the chain.

Instead of being stored at a central intermediary, this register of all transactions is distributed on multiple computers through a peer-to-peer network - this means allowing open access to data that it is hosted on its server. It uses cryptographic techniques: it is indelible and decentralized. Users' computers keep a record of all transactions.

It is the multitude of participants that creates a large chain and plays the role of verification (previously assured by the intermediaries, or "trusted third party") and validation. To work, the blockchain only needs the power of the computers. There are several platforms on which blockchain projects are based. In particular, the Ethereum and Hyperledger platforms are well established, which justifies to examine them more closely.

Hyperledger is an open-source initiative, which is led by the Linux Foundation in partnership with major industry players such as IBM, Cisco, Intel, JP Morgan, SAP etc. Hyperledger aims to strengthen the use of the blockchain in

different industries, and works for that with industries such as the Internet of Things, finance, supply chain management, the IT sector and other actors.

This initiative aims to standardize the use of the blockchain for business, in order to facilitate the implementation of a large-scale commercial adoption. Hyperledger is not just a platform, but rather acts as a federator for several communities of software developers who want to use this blockchain platform to build their projects. Under the term Hyperledger Fabric, a framework is offered to develop blockchain solutions specifically dedicated to private companies. This differentiates Hyperledger from platforms like Ethereum or Bitcoin virtual currency, because they are based on public blockchains that are at the service of all actors.

Thus, Hyperledger Fabric has the following features:

It's a private blockchain: to access the network, you need a right of access; Memberships are controlled and regulated by a central authority / intermediary.

Transactions are confidential: companies using a private blockchain have the flexibility and security to make transactions only visible to participants who have the correct encryption codes.

In theory, the virtual currency is not necessary for the operation: thus, one does not need a process of mining (ie it is the process by which transactions - eg Bitcoin - are secured) and of algorithms to ensure transactions.

Finally, the process is programmable: we can introduce programming logic in smart contracts, which automates business management processes across the corporate network.

It is important to clarify what the term smart contract covers because it can be confusing. In the book Blockchain Decrypted - the keys to a Blockchain France revolution, smart contracts are defined as "stand-alone programs that, once started, automatically execute pre-defined conditions. They work just like any "if-then" conditional statement ("If" condition checked "Then" consequence runs), and have three main inputs: increased speed, better efficiency, and certainty that the contract will be executed as agreed. These programs are capable of overcoming moral hazard issues, and reducing the costs of auditing, enforcement, arbitration and fraud. "

Ethereum is an open-source initiative, which was developed by the Swiss foundation Ethereum Foundation. This initiative uses its own virtual currency, called Ether. Ether is the most used virtual currency after bitcoin.

The principle of the Ethereum platform is that its blockchain is public and open to everyone. It can be seen as a virtual machine (Virtual Machine): its purpose is to provide all the services of a remote computer, like a cloud that would be distributed.

Ethereum allows its network of users to create smart contracts based on the fact that the Ethereum software is active simultaneously on thousands of decentralized computers. The program is autonomous and capable of executing (pre-) defined conditions of an upstream contract. Only one player cannot change a contract in this smart contracts system.

The concept of decentralized applications (Dapps - Decentralized applications) is key in the Ethereum platform: a decentralized application is totally open source, uses a cryptocurrency (like Ether or Bitcoin, necessary to access a Dapp) and works autonomously without an entity being able to control the currency issued and stores this data in a public and decentralized register (without a central point of coordination). A decentralized application rewards its users ("minors") with chips from its cryptocurrency for their work of validating new insertions in its public and decentralized registry.

Transactions are public and open to everyone (public blockchain) Ethereum uses the proof of stake system: this system randomly chooses the next creator of a block, taking into account factors such as for example the amount of virtual currency (cryptocurrency) that he or she owns (his stake). The creator that was chosen by this system then adds a block to the blockchain and can touch the reward, when the other users in the network have validated its approach (consensus mechanism). This stake / participation proof system is different from the proof of work system: for a user to be able to add an extra block to the blockchain in the proof of work system, he is obliged to perform a proof-of-work system. a series of expensive time and energy calculations (eg hash algorithms, solving mathematical puzzles) to validate transactions and add a block to the blockchain (his work done). The proof of work system favors users who own very powerful computers, capable of performing these calculations.

The proof of interest / participation system is, in principle, more energy efficient than the proof of work system, because in order to function it does not make use of these expensive and time-consuming calculations.

2. Applications in Energy

So far, blockchain technology has been especially attractive to the finance industry, which is already starting to use the blockchain and its ability to measure, store and certify information without the need of an outside provider, to reduce the cost and the complexity of financial transactions.

But also industries such as music, the media or even shipping believe that the blockchain would allow them to develop new applications and improve their services (for example the port of Antwerp wants to use the blockchain to make its container transport more fluid). What can the blockchain bring to local energy? Here, we will discuss the possible applications of the blockchain in the energy sector.

2.1. Transaction Management

The blockchain can be used as the main IT solution for managing energy transactions, efficiently and at a reduced cost, without the need for a traditional central control body to guarantee reliability, such as a company energy services. Each energy transaction is recorded and stored by the blockchain on all computers (nodes) that are part of its network (eg a microgrid). All participants are made aware of each transaction in real time, and their computers check each other to prevent fraud within the system. The management of energy transactions can be automated and made even more efficient and less expensive thanks to the implementation of a smart contracts system, and in a next step, with the creation of autonomous and decentralized organizations/applications (Dapps), which will no longer require human intervention.

2.2. Inquiries Possession and Asset Management

The blockchain stores and stores all energy flows and transactions in a distributed and secure manner. It can also be used to inform, for example, who has energy at a given moment, how much it has produced, sold or bought and how its asset / energy portfolio is evolving (asset management). All this is done transparently, and each stakeholder - energy service companies, distribution system operators, transmission system operators, citizens' energy collectives, local authorities through their Stadtwerke energy services, etc. - can access this tamper-proof and indelible information at any time.

Thus, it is possible to create a historical book of these records (proof of existence), which is important from a legal and legal point of view in case of conflicts. Depending on the type of blockchain set up (public or

private), the identity of network members can be either known (public) or anonymous (private).

2.3. Certification and Verification of Energy

This ability to document the blockchain opens the possibility of changing the current practices of certification and verification of energy, especially as regards the guarantees of origin or the frameworks of the emissions trading system (p. eg EU ETS). In Europe, often guarantees of origin of renewable energy are false and fraudulent guarantees, which include fossil energy and allow actors to do greenwashing. The blockchain can verify the source and type of energy at any time in an incorruptible manner (real-time audit), and create a possession history of each renewable energy certificate. This process is transparent and unchangeable, and helps ensure the management of these certificates. It can also be used to record, certify and validate emissions trading between players in such a system, an approach that is being implemented in China by IBM and the Energy Blockchain Lab.

2.4. Real-Time Monitoring and Diagnosis of Energy Consumption

The blockchain can also be used as a control and evaluation system (monitoring), and allow actors such as local authorities or citizens (through a smart meter) to make a transparent and real-time monitoring of their energy consumption. With the precise information provided by the blockchain, local authorities will be able to make a diagnosis and identify for example their energy-consuming buildings that need an energy renovation.

The blockchain could also facilitate the exchange of these data between the different actors of the energy system. With the proliferation of connected objects (Internet of Things), a development expected in the coming years, communities will be able to constantly obtain an inventory of their entire energy infrastructure (eg energy, smart grid, etc.).

A blockchain in permanent communication with these connected objects, which uses smart contracts and autonomous and decentralized applications (which have the capacity to work with predefined procedures by technicians), could in theory manage for the community its energy infrastructure without having to intervene directly.

2.5. Remuneration through an Actual or Virtual Currency

The blockchain could also be used to reform the remuneration process in energy, either through the real currency or the virtual currency (eg Bitcoin, Ether). Although the feed-in tariff or the net billing program have greatly facilitated the development of renewable energies in Europe, many observers believe that these are no longer the most efficient and flexible means of remuneration to encourage massive production and consumption of electricity. 'renewable energy. The smart contracts system could allow the implementation of an automated and flexible scheme that pays the prosumers in real time and adjusts demand at a given moment (demand response). In addition, micro-payments in energy will be possible with this system, at almost zero overhead costs and in very short intervals (eg every 15 minutes), since the presence of traditional intermediate as a Energy service or payment service company will not be required to process the cash flow and the transactions made. In a local context such as a community-citizen energy partnership, the energy provided to the community could be remunerated with a local cryptocurrency, which would be linked to the local currency. The community could profit from the mining of the local cryptocurrency and use this profit to reinvest it in the local economy and fight against fuel poverty. Although this scenario is not yet widespread in European communities, the English city of Hull has already created its own cryptocurrency (HullCoin), and reinvests the profit made with its mining in its social policy that reduces poverty in its territory . Vulnerable citizens volunteer and are paid with HullCoins, which they can then exchange for hot dishes in the local food bank.

2.6. Creating a Local / Regional Energy Market Online

Another possible application for the blockchain would be its use in a local or regional online energy market. The community could play the new role of intermediary, acting as a matchmaker and coordinator between local energy producers and its citizens. Through an online blockchain platform, the community would bring together the various local energy producers and their offerings, and could help its citizens choose an affordable energy mix.

This energy service would not only support the fight against energy poverty, but also keep the economic value of energy on the territory, since all transactions will be made at a local or regional level. In addition, small energy producers will not have to go through the wholesale market to sell their energy, but will be able to sell it directly to the citizens (Retail market). The indelibility, transparency and efficiency of the blockchain will ensure the stability of the operations of this platform.

2.7. Renewable Energy Peak Exchange in a Decentralized System

The blockchain could also allow the establishment of peer-to-peer exchange and collective self-consumption in a decentralized system. Thanks to the digital trust brought by the blockchain, members of such a system - producers as well as consumers - will be able to exchange energy manually or automatically (smart contracts) in a harmonized and secure environment, using virtual or real money. Smart contracts will control the amount of energy produced and consumed in real time. Participants in such a network would also benefit from the fact that the path traveled by the energy exchanged is shorter than in a centralized system, resulting in less waste of energy and reduced energy costs (e.g. marginal cost). Smart contracts can ensure the stability of such a system by independently managing storage, the balancing market and the balance between demand and power supply.

2.8. Compensating Its CO_2 Emissions & Being Rewarded for the Implementation of Sustainable Actions

Transforming its renewable energy produced into carbon credits and selling them on the market, or offsetting an intensive carbon activity (eg flying) - all of this could become more convenient and easy to execute and monetize (in real or virtual currency) through the blockchain. A blockchain application / platform can convert these activities quickly and automatically through a smart contracts system, in a secure and transparent way.

2.9. Facilitating the Development of Electric Mobility as a Service

Finally, the blockchain can facilitate the development of electric mobility as a service through the implementation of a reloading system simpler (one-click) and less expensive than existing solutions. In addition, she could "Uberise" and facilitate direct rental between car owners with innovative payment systems such as pay-per-use. The blockchain could also manage a massive flow of data generated by autonomous cars in dedicated exchange platforms, and also help local authorities - in cooperation with researchers - to use this data to improve the infrastructure of their urban transport.

3. Examples

It is important to note that most of the examples are still at pilot stage, experimentation - there are not really blockchain energy projects in communities yet.

Table 1. Example of blockchains

Country	Name	Initiator / Profile	Description	Induced innovation
Spain	Pylon Network Project	A European startup based in Spain, which brings together several young engineers. Has already been solicited by the giants of energy.	Pylon Network proposes to use Blockchain technology to facilitate flow knowledge for energy vendors. Their product is for renewable energy cooperatives. Combination of a smart meter (Metron) and the Blockchain to certify the flows and allow the virtual exchange of tokens (currencies / green kW production units). The renewable energy community can thus play on demand and optimize flows in real time. Pylon Network uses the Ethereum platform. Pylon coin is based on the fair coin cryptocurrency algorithm Fair coin developed by FairCoop.	• Transparency of flows • Reliability and security • Accessible to everyone • Low power server running with surplus renewable energy
Germany	Tal.Markt	The Wuppertal Stadtwerke Energie & Wasser AG (WSW) is the municipal energy supplier of the city of Wuppertal, which is located in West Germany.	The WSW has created, in cooperation with the Swiss company Elblox, the Tal.Markt blockchain platform, which establishes a local and regional market for renewable energy produced in Wuppertal. The goal is to connect local renewable energy producers with citizens, including the 5,000 wind turbines that will no longer be subsidized after 2020. Tal.Markt uses a private blockchain for these transactions, which consumes less energy than a public blockchain and also allows the WSW to manage user access to the platform. Citizens can use the platform for free, while local producers pay WSW for the right to sell their energy on Tal.Markt. In addition, for the moment only local producers with installations of at least 30 KWh can access the platform. Thus, Tal.Markt's business model is that of an online marketplace such as Amazon.	• The Tal.Markt blockchain is flexible and transparent, and allows citizens to track in real time the amount of renewable energy produced and know which local supplier it comes from. The original guarantee of renewable energy is ensured by the infallibility of the blockchain. • The service offered by the WSW not only allows it to obtain a new form of income, but also to support local producers who will no longer be able to count on the support of the German renewable energy law (Erneuerbare Energien Gesetz) after 2020.
Suisse	Power-ID	Sandro Schopfer is a researcher at the Swiss Federal Institute of Technology ETH in Zurich. Having worked for 5 years in the energy industry, he is now Professor of Information Management and is part of ETH Zurich's Bits to Energy Lab, which explores new digital technologies and its applications in the field of energy.	Power-ID is a pilot project led by ETH Zurich and funded by the Swiss Federal Energy Agency in the village of Walenstadt (population 5,000), located in the canton of St. Gallen. An energy services company - in fact, a cooperative - is also involved. The goal of this project is to create a small, local, peer-to-peer energy market between 20 prosumers and 20 consumers using the blockchain. This decentralized network relies on solar energy and storage (batteries) and aims to cover at least half of Walenstadt's energy needs. Linking local actors aims to reduce system costs for all and encourage the production and consumption of local renewable energy.	• Peer-to-peer exchange in a small decentralized network, which keeps the creation of value (the energy produced and consumed) on the territory. • The development of network costs is transparent thanks to the blockchain. • The energy services company is involved in the project, but does not assume its traditional role as intermediary, thus leaving room for the emancipation of prosumers and consumers who participate in the network instead of paying a premium on energy.

Country	Name	Initiator / Profile	Description	Induced innovation
Belgium	NRGcoin	The NRGcoin concept was developed by researchers from the Vrije Universitet Brussel (VUB), in partnership with the SME Sensing & Control Systems located in Barcelona, as part of the European Scanergy project. The Belgian start-up Enervalis, based in Limburg, now wants to market NRGcoin, first in Belgian and Dutch cities, and subsequently in other European cities. For this, Enervalis has obtained funding from the Flemish Agency for Innovation and Entrepreneurship VLAIO for a period of three years.	The idea behind NRGCoin is to respond to the inadequate (not flexible enough) subsidy of renewable energies and to encourage citizens to consume local renewable energy by remunerating them with the NRGcoin cryptocurrency. NRGcoin uses the smart contracts of the Ethereum blockchain to automatically and immovably undermine the new NRGcoins for each renewable energy KWh injected by a prosumer at the right time - when it meets the local demand - into the network. Thus, overeating is unpaid. In addition, smart contracts here are used to manage the purchase and sale of energy (not the exchange). The prosumer can sell his NRGcoins obtained on the NRGcoin currency market. In this market, you can buy NRGcoins using fiat currency (eg Euros). Thus, NRGcoins can be converted into real money if the prosumer wants to profit.	By using the Ethereum blockchain, NRGcoin is taking advantage of this blockchain (disintermediation, transparency, decentralization, reliability and indelibility). In addition, NRGcoin wants to upgrade the renewable energy facilities of these prosumers, to manage a local market that does not impact the capacity of the network and make the consumption of renewable energy produced locally cheaper.
International	SolarCoin	SolarCoin Foundation, an American foundation of volunteer scientists from around the world. ElectriCChain acts as an affiliate site of the foundation.	Launched in 2014, SolarCoin is a cryptocurrency, virtual currency, whose goal is to promote renewable energy, by allowing all solar energy producers to obtain compensation depending on the amount of energy produced. Solar power producers can claim 1 SolarCoin for 1 MWh produced and injected into the grid. Any holder of a photovoltaic installation can participate in this network. The certification of the solar origin of a MWh passes through the blockchain. The objective is to encourage the installation of 3,000 GW of photovoltaic solar panels by 2050 (against 300 GW in early 2017). The founders have decided to create 98 billion SolarCoins, to ensure the distribution of SolarCoins for 40 years.	Not very energetic. Reduces the amortization period of the solar system. An evolution desired by the initiators: The recognition of this currency by the local authorities.

4. Opportunities and Points of Vigilance for a Community

Behind the blockchain, there is no institutional organization or people identified. This raises questions of control and also of responsibility. If everything is decentralized, the power is certainly distributed, but there is no one to turn to if there is a problem. If the immediacy and irreversibility of the code makes it possible to automate contracts, it is also contrary to our legal logic: a citizen may not be subject to the rules and then be tried, challenge the law. The code executes itself. If traceability can guarantee transparency, it also questions the recording of our data. These ethical and legal issues remain open.

5. Perspectives and conclusions

It is quite complex to describe precisely the angular prospects for local communities to use the blockchain because, as we have seen, applications in energy are at the experimental or pilot stage. Moreover these initiatives sometimes can be thought exclusively "techno-centered" forgetting that the Blockchain is a means and not an end in itself.

Communities must be able to grasp it with the desire to question the current modes of governance of energy often not very conducive to take into account the motivation of citizens and other actors of the territory to want to be full-fledged players in the region. local energy. It is therefore a question of changing the mode of governance, it is under this prism that declining Blockchains projects will make sense for local energy.

The experts interviewed told us that a community should not start a blockchain project just to follow the "hype" of the blockchain, but that it should resort to using the blockchain only after making a decision reflected on the added value this technology could bring to its local energy policy, and how it could help drive systemic change in the current energy system.

Table 2. Opportunities and points of vigilance

Opportunities	Points of vigilance
• Transparent and verifiable technology. • A reliable, shared, confidential and non-refutable data pool. • Secure transactions in real time. • Reduction of transaction costs • Simplification of the management / administration of a service. • Allows easy setting up of a peer-to-peer exchange network ("Commons 3.0"). • Reduce the cost of energy bills for vulnerable consumers. • Open the door to new opportunities for compensation and local value creation.	• Trust and security not totally foolproof. • The blockchain can be energy intensive and expensive. • The capacity of the energy infrastructure to absorb a massive flow of blockchain projects. • Move our trust towards technology, and those who develop it. • Blockchain and hyper-individualization? • The complexity of the blockchain for "small" consumers. • The existence of a political and legal framework at national / European level for the deployment of the blockchain.

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