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DECENTRALISATION AND DIGITALISATION IN THE ENERGY INDUSTRY: THE BLOCKCHAIN CASE

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‘Humanity will see an energy miracle in the next 15 years’

Bill Gates

‘Blockchain technology isn't just a more efficient way to settle securities. It will fundamentally change market structures, and maybe even the architecture of the Internet itself’

Abigail Johnson

‘Everything will be tokenized and connected by a blockchain one day’

Fred Ehrsam

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Solemn Declaration

Υπεύθυνη Δήλωση

Με ατομική μου ευθύνη και γνωρίζοντας τις κυρώσεις, που προβλέπονται από τις διατάξεις της παρ.6 του άρθρου 22 του Ν. 1599/1986, δηλώνω ότι:

«Το έργο που εκπονήθηκε και παρουσιάζεται στην υποβαλλόμενη διπλωματική εργασία είναι αποκλειστικά ατομικό δικό μου. Όποιες πληροφορίες και υλικό που περιέχονται έχουν αντληθεί από άλλες πηγές, έχουν καταλλήλως αναφερθεί στην παρούσα διπλωματική εργασία. Επιπλέον τελώ εν γνώσει ότι σε περίπτωση διαπίστωσης ότι δεν συντρέχουν όσα βεβαιώνονται από μέρους μου, μου αφαιρείται ανά πάσα στιγμή αμέσως ο τίτλος.»

On my own responsibility and being fully aware of the penalties stipulated under article 22 par. 6 of Greek Law 1599/1986, I hereby declare that:

"The intellectual work fulfilled and submitted based on the delivered master thesis is exclusive property of mine personally. Appropriate credit has been given in this diploma thesis regarding any information and material included in it that have been derived from other sources. I am also fully aware that any misrepresentation in connection with this declaration may at any time result in immediate revocation of the degree title."

ABSTRACT

Blockchain technology, or distributed ledger technology as it is often called, is an emerging technology that has attracted the attention and interest of many companies and individuals. Energy companies, financial institutions, national governments and the academic community have already started to experiment its benefits and potentials. The current sources identify Blockchain technology as disruptive and it is expected to change the whole landscape. Blockchains could bring a new, transparent and completely decentralised way for transactions among the participants, new business models and new ways of financing ideas and projects in the energy sector.

This master thesis has as target to demonstrate the current efforts to combine Blockchain technology with the energy industry. It will show the benefits and the potentials of this topic. Furthermore, it will focus on the current blockchain solutions for the energy sector by reviewing the appropriate literature and business cases. The information around some significant projects is important for the reader in order to better understand the engagement of the industry in Blockchains. My study reviews several cases, one in the USA, one in Australia with operations in Southeastern Asia, one in China, another one in Spain, one is worldwide and some in France, from which potentials and benefits for the industry are identified.

Moreover, an interview with Markos Romanos, the COO of Pylon Network, is included. Learning from professional in the industry who tries to accelerate the implementation of Blockchain technology is crucial for understanding both the benefits and the limitations.

However, there are some challenges that the projects currently face. It is necessary to address them, so that solutions can be found. The thesis ends with a discussion on the benefits and with some recommendations.

KEYWORDS

Blockchain

Energy

Technology

Commodity trading

Transactions

Energy certification

Peer-to-peer

Cryptocurrencies

Regulation

Data

Contents

INTRODUCTION

The advances on the technology sector bring more and more changes in our everyday lives, sometimes without ever being noticed. All the sectors of the economy have experienced great changes over the last 10 years due to the progression of the technology, thus affecting the way every business functions. Technology advances have changed our lives and are expected to do this in a faster and more dynamic way.

Under these circumstances, technology developments are available to everyone, not only to use them, but also to advance them. Changes are not made only by big companies, but also from anyone who may have a revolutionary idea. This has resulted in many recent developments, which have created a breakthrough and revolutions in technologies available to everyone. Such a result is the creation of the Blockchain technology in 2009. It has been described as a revolution because it changes everyday operations of businesses, banks, public sector and many more who adopt this technology.

This thesis deals with the Blockchain technology across the globe and how it can be implemented in the energy sector. Since it is a brand-new idea, the adoption of this technology has occurred in a small scale in energy, however, it is expected to grow the area of adjustment. In the first chapter, a theoretical approach of the Blockchain is presented, while in the second chapter I will describe in which cases the application of Blockchain is possible in the energy sector. Furthermore, there will be a brief presentation of some projects that deal with this technology and what their activities and goals are. Certain experiments will also be presented in this paper; while big companies such as Shell and IBM are trying to investigate which is the best way to implement it. Analysing the benefits, that can be derived from it, it is essential to understand the issue of the Blockchain in the energy sector. However, there are some changes that need to be done in the regulations for example, so that this technology can be adopted without restrictions. Finally, this paper closes with a discussion and a conclusion on the benefits from this new technology and some recommendations.

1.DESCRIPTION OF BLOCKCHAIN

The blockchain technology was created back in 2009, in order to facilitate the transactions of the cryptocurrency called Bitcoin. It was formed by Satoshi Nakamoto and its invention is considered as revolutionary and it will change the way we transact in our days; hence it is seen as both a technological and economic innovation (Macrinici et al., 2018).[1] Among different researches, the way that the Blockchain is defined is informal (Viriyasitavat et al., 2018)[2], meaning that there is no formal definition of Blockchain. Nevertheless, it is often described according to its use and the sector in which it is implemented.

Oxford dictionary defines Blockchain as "A system in which a record of transactions made in bitcoin or another cryptocurrency are maintained across several computers that are linked in a peer-to-peer network".[3]

I will use the broader definition from W. Viriyasitavat et al., Blockchain is "a technology that enables immutability, and integrity of data in which a record of transactions made in a system are maintained across several distributed nodes that are linked in a peer-to-peer network". The key characteristic of this is the absence of a central supervision. Blockchain is completely decentralized meaning that there is no central authority supervising everything; the network is distributed to its participants.

Some more definitions need to be presented in order to gain a full understanding of this new technology. First of all, peer to peer network means that peers, which are actually the computers, are connected to each other via the internet. Every document can be shared and sent on this network without the interreference of a central server.[4]

[1] Macrinici, D., Cartofeanu, C. & Shang Gao, S. (2018). Smart contract applications within blockchain technology: A systematic mapping study. Telematics and Informatics, 2337-2354

[2] Viriyasitavata, W. & Hoonsoponb, D. (2018). Blockchain characteristics and consensus in modern business processes. Journal of Industrial Information Integration

[3] Oxford Dictionary, retrieved from 'oxforddictionaries.com/definition/blockchain'

[4] Definition retrieved from techterms.com

A key definition to understand is that of a smart contract. “A “smart contract” represents a digital protocol that automatically executes predefined processes of a transaction without requiring the involvement of a third party (e.g. a bank)”.[1]

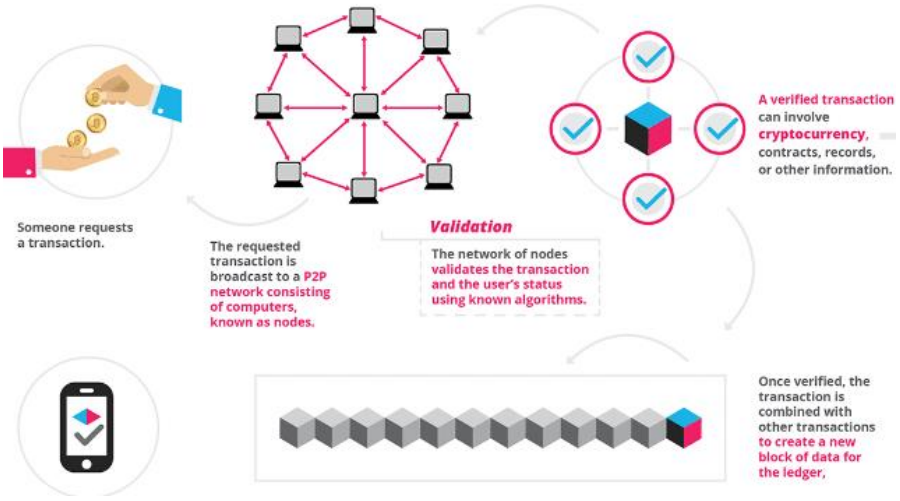
The blockchain was first invented in order to facilitate transactions made with cryptocurrency, the Bitcoin. In 2009, Satoshi Nakamoto tried to create a virtual currency, which would have no physical form and would only exist in the network. “The cryptocurrency is a medium of exchange, created and stored electronically in the blockchain, using encryption techniques to control the creation of monetary units and to verify the transfer of funds”.[2] The Bitcoin is the most famous cryptocurrency in the market. However, today there exist more than 2000 cryptocurrencies and more than 15000 markets. The total market cap exceeds the 200 billion dollars.[3]

[1] A. Von Perfall, ‘Blockchain – an opportunity for energy producers and consumers?’, PwC, 2018
[2] Definition retrieved from blockgeeks.com (Retrieved on 15/11/2018)
[3] Data retrieved from coinmarketcap.com (Retrieved on 15/11/2018)

i) How It Works

The way that this technology works is quite simple. Since it is a distributed public ledger, the platform is shared among a network. Each participant has to connect in this network via its own computer, which is called 'node'. Then, transactions can be done through this network. Let's take for example a possible Bitcoin transaction; Bitcoin was the first Blockchain ever used as well. It begins with someone's request to buy this cryptocurrency. The request is broadcasted to a peer to peer network, which is distributed among the nodes and everyone can use. Then, the network validates the user's status and the transaction. Once the transaction is verified by the network, it is stored as a block in a chain, which contains all the necessary information, for example, who bought it, from whom, which the payable amount is. A new block of data for the network has now been created, is now added to the existing blockchain and is distributed to many individual nodes. This block is unalterable and permanent meaning that no one can steal it or change it. Finally, in this step the transaction is considered complete.[1] Figure 1 illustrates a simple method of transaction in Blockchains.

Figure 1



Source: blockgeeks.com

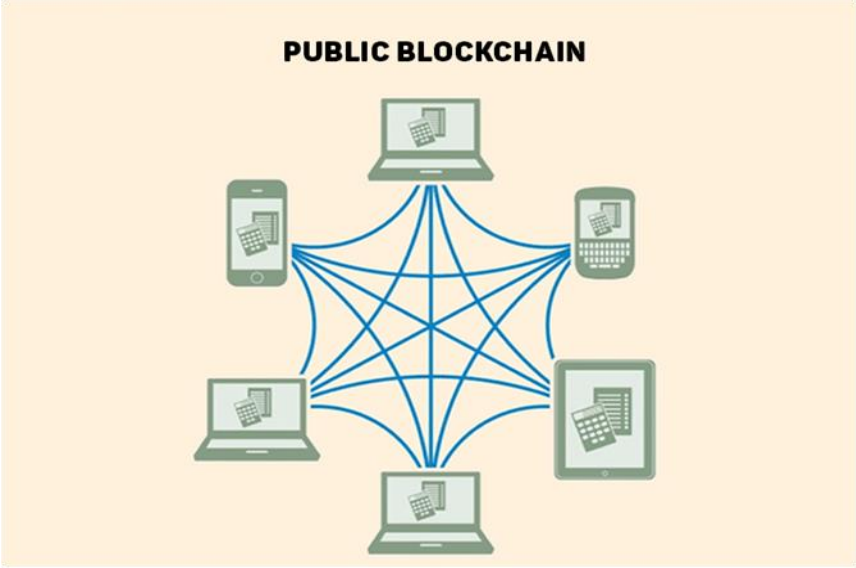
[1] 'What is Blockchain Technology? A Step-by-Step Guide for Beginners', blockgeeks.com (Retrieved on 15/11/2018)

ii) Types

Before moving on with the use cases of the Blockchain technology, it is considered necessary to describe the three key types of Blockchain technology. It is important to understand the distinction among these types.

Firstly, there is the most commonly used technology, the public Blockchain. It is often referred to as permissionless as well. Anyone can take part in this, no permission from the system operator is required in order to make transactions and validate them. Anyone can download the code and start running it on their device and participate in the consensus process, which is to determine which blocks will be added in the chain. Since there is no requirement for participation and the transactions are transparent and made anonymously, anyone is able to read them on the public block explorer. The most known Blockchain of this type is the Bitcoin and some others are Ethereum and Monero.[1] A simple network of a public Blockchain is shown in Figure 2.

Figure 2

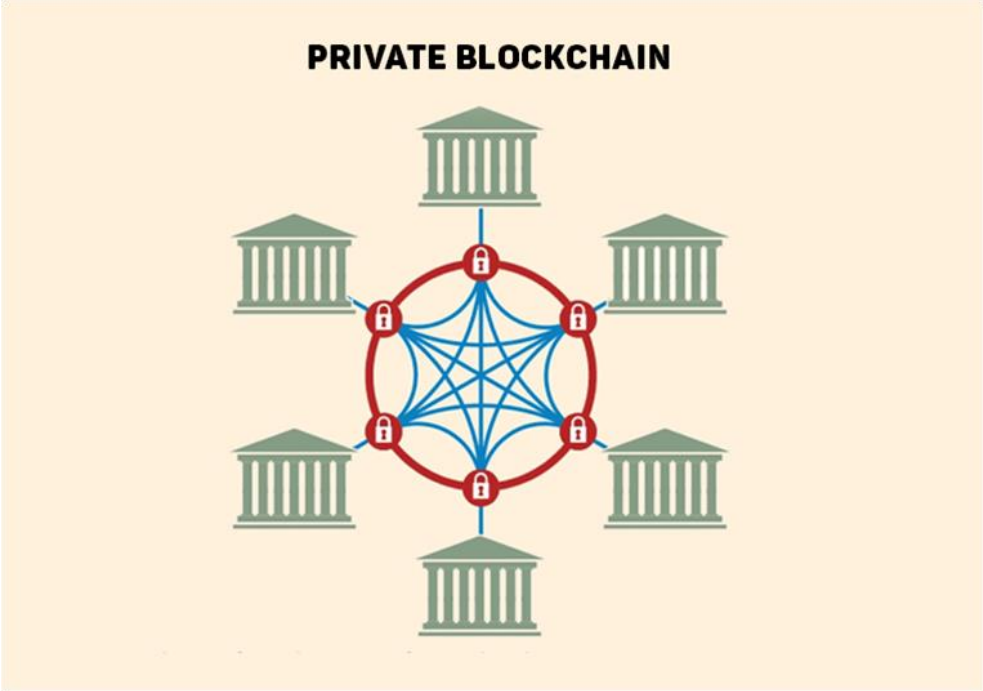


Source: blockchainsemantics.com

[1] 'Blockchains & Distributed Ledger Technologies', blockchainhub.net (Retrieved on 15/11/2018)

On the contrast, private Blockchains limit the access to a predefined list of users. Such persons must achieve the approval of the operator in order to participate in the network. In such cases, permission is restricted to a certain degree, since this platform may be held by a single company, and as a result the appropriate information and data could not go public. Some use cases of this type include governmental data security and privacy regulations. "Private blockchains are a way of taking advantage of blockchain technology by setting up groups and participants who can verify transactions internally."[1] However, there is the contradictory which says that such Blockchains contradict the nature of the system itself. Since these systems are destined to be decentralized, limiting access to participants may lead to the opposite results (Savelyev, 2017).[2] .[3] A network in a private Blockchain is shown in Figure 3.

Figure 3



Source: blockchainsemantics.com

Finally, there is the third type of Blockchain, which is the Federated or Consortium Blockchain. This type is not controlled by a single entity or company, thus federated Blockchain usually

[1] 'Blockchains & Distributed Ledger Technologies', blockchainhub.net (Retrieved on 15/11/2018)
[2] Savelyev A., 'Copyright in the blockchain era: Promises and challenges', 2017, Computer Law and Security Report
[3] 'Blockchains & Distributed Ledger Technologies', blockchainhub.net (Retrieved on 15/11/2018)

operates under a group of companies. It is more similar to the private Blockchains as regards the access to it. It is helpful to mention that such Blockchains have started to be used mostly from financial institutions, banks for instance. There can be a consortium Blockchain which is run by 15 nodes and in which everyone must verify a transaction in order to be valid. Use cases include R3 and the Energy Web Foundation which is discussed below.

iii) Characteristics

The nature of the Blockchain technology contains some key characteristics that make it different from other applications and services. It has some characteristics that make it revolutionary and transformative, depending on the sector it is used. At its core, Blockchain is just a platform, where transactions happen among the users, the nodes. However, these are the characteristics which make it different.

It is created to be decentralized and distributed. The main feature is that there is no central authority to supervise its use and its daily function. No authority is here to verify the participation of the users and to verify each action made in the network. The verifications are done by the nodes, the participants in the network, thus contributing to its function and prosperity. Each participant validates a transaction without an intermediary.[1]

The Blockchain itself builds trust among the participants. Since no one can act as they want, each user must validate transactions or actions in general in order to be valid. Transparency is guaranteed for the transactions, making it possible to perform processes close to the real time. It makes the basis for traceability of the transactions, which build trust among users about the reliability of the platform.

Another key characteristic is the consensus. It means that before any transaction becomes valid, there must be an agreement between all relevant parties. Without an agreement, the transaction is considered invalid and, thus, it cannot be added on the chain of blocks. For example, for a purchase of a Bitcoin, there must be a proof that the seller indeed owns this cryptocurrency. Consensus helps the users identify which transactions are invalid or fraudulent and keep them out of the system.

[1] Ian Pattison, "4 characteristics that set blockchain apart", IBM, 11/04/2017

However, rules concerning the consensus process can be changed based on different circumstances.

Finally, immutability of the data perfectly describes Blockchain applications. Once a transaction is recorded and stored in the chain, it cannot be changed. Someone can track each asset that is transacted and view all of its history, but they cannot undo and change it. Someone can proceed to another transaction in order to change the status of an asset, but its history remains unchanged. As I. Pattison describes it "this gives the idea of provenance of assets, which means that for any asset you can tell where it is, where it's been and what has happened throughout its life." (I. Pattison, 2017)[1]. Table 1 summarizes its characteristics.

Table 1

Characteristics	**Decentralized**	**Trust**	**Consensus**	**Immutability**
1	No intermediaries	Transparency is guaranteed	Every party must agree to verify the transaction	History of an asset cannot be changed
2	Network is distributed among the users	Smart contracts ensure the function	Rules can be changed	History of an asset can be traced back

[1] Ian Pattison, "4 characteristics that set blockchain apart", IBM, 11/04/2017

2. POSSIBLE USES IN THE ENERGY SECTOR

Back in 2016, the German Energy Agency interviewed top energy companies' executives for a survey on the Blockchain Application in the energy transition (Burger et al., 2016)[1]. The results that they derived from this survey showed that 50% of the top executives and decision-makers were either planning or were implementing pilot Blockchain projects at that moment. Furthermore, the authors saw that more than 60% of the persons interviewed were seeing further implementation in the sector and about 20% had the opinion that Blockchain technology will be a game changer in energy.

Currently there is a transformation in the energy systems due to the emerging decentralization and digitalization of the sector (Andoni et al.).[2] Thanks to their nature, Blockchains could offer a solution to the control and management of complex energy systems and microgrids as well (Konashevych, 2016).[3] Furthermore, Blockchains could offer innovative trading platforms, where the participants –either consumers and prosumers or utility companies- could make transactions, selling their excess in energy, trading on a P2P basis (Mylrea, 2017).[4]

Blockchains could be used to support and increase the local electricity production from renewable sources of energy, mainly solar generation, thus creating microgrids, where local energy is produced and consumed domestically (P. Pinson et al., 2018).[5] With the local production and consumption, the target is to reduce energy loses due to the transmission, which could result in lower electricity prices for domestic customers.

[1]Burger C., Kuhlmann A., Richard P., Weinmann J., 'Blockchain in the energy transition. A survey among decision-makers in the German energy industry.', Berlin 2016, Deutsche Energie-Agentur GmbH (dena) - German Energy Agency

[2] Andoni M., Robu V., Flynn D., Abram S., Geach D., Jenkins D., McCallum P., Peacock A., 'Blockchain technology in the energy sector: A systematic review of challenges and opportunities', 2019, Renewable and Sustainable Reports, p. 143-174

[3] Konashevych O., 'Advantages and current issues of blockchain use in microgrids', 2016

[4] Mylrea M. Gourisetti SNG. 'Blockchain for smart grid resilience: Exchanging distributed energy at speed, scale and security.' In: Proceedings of the Resilience Week (RWS) 2017, IEEE, 2017, pp. 18–23.

[5] Pinson P, Baroche T, Moret F, Sousa T, Sorin E, You S., 'The emergence of consumer-centric electricity markets.'

As regards the security of supply, Blockchain applications could create more efficient and flexible markets improving the network resilience and the security of supply, as the generation from RES is constantly increasing (Mylrea, 2017).

V. Grewal-Carr and S. Marshall, on a report published by Deloitte[1], argue that transparency and efficiency could increase in the energy markets. This will lead to improved competition as there will be more utility companies in the market and the consumer mobility will be facilitated. Consumers will now be able to switch suppliers in an instant, when they see economic benefits from these activities. Companies will be in position to alter their pricing policies and their marketing activities as well.

Moreover, Blockchains could be utilized for data storage and data sharing among the participants. The data will refer to the consumption and needs of a household. This will help companies offer better solutions to their customers and, in a microgrid, this could help prosumers choose whom they will sell their excess in electricity to.

J. Matila argues that Blockchain could enhance the efficiency and the function of smart grids, because it offers transparent solutions.[2]

Finally, M. Andoni et al. describe Blockchain as the key factor, which will give solutions to the energy trilemma. They present that, by optimizing energy processes, blockchain will contribute to cost reduction for every activity; generation, transmission, supply and consumption. Moreover, they argue that Blockchain can promote sustainability, as they encourage the adoption of renewable sources of energy and low-carbon solutions. Last, Blockchains could be a key feature for energy security, both in terms of cybersecurity and security of supply.[3]

[1] Grewal-Carr V., Marshall S., 'Blockchain Enigma. Paradox. Opportunity.' 2016, Deloitte

[2] Mattila J., 'The blockchain phenomenon-the disruptive potential of distributed consensus architectures.', 2016, Research Institute of the Finnish Economy

[3] Andoni M., Robu V., Flynn D., Abram S., Geach D., Jenkins D., McCallum P., Peacock A., 'Blockchain technology in the energy sector: A systematic review of challenges and opportunities', 2019, Renewable and Sustainable Reports, p. 143-174

i) P2P Transactions/ Decentralised energy trading

The most common use case of Blockchain is the transaction processes from peer to peer (P2P). The transactions of energy require many participants, third party entities such as brokers, banks or lawyers. In the distributed ledger, participants in the market will be able to transact with each other cutting down the middleman. This form of transactions is seen as fully decentralized, as there will be no need for intermediaries.

These transactions (direct P2P) mostly fit in microgrid communities, where the production and the consumption occur at a local level. Microgrid is 'a small network of electricity users with a local source of supply that is usually attached to a centralized national grid but is able to function independently.'[1]

Thus, microgrids form an interconnected system, which could operate in accordance with the main grid or in an island mode.

This kind of transactions directly connect the producers with the end-consumers. The nodes are connected with each other on the platform and transactions can occur directly. The consumers who need energy have access on this marketplace and the producers who wish to sell their excess in energy attend the marketplace to find potential buyers.

The Blockchain technology can now give more and better solutions to the end-consumers. Rather than buying the electricity from the main or national grid, which offers standard quantity and standardized prices, consumers can now get more personalized offers. They can ask for a specific price for example, since the producers can set their own prices. This activity creates a small marketplace, where transactions happen in a direct way.

Source: medium.com

[1] Definition retrieved from Oxford Dictionary https://www.lexico.com/en/definition/microgrid (Retrieved om 15/11/2018)

S. Lambarter et al. propose a trading environment at a local level, i.e. at a microgrid, where a flexible market is created coordinating different self-interests of the users.[1]

Every energy transaction that occurs is finally added on the chain of the network as a block (Blockchain). Every participant holds access to these blocks and are informed in real time about the transactions. These blocks, once recorded on the chain, cannot be altered or cancelled.

D. Donerer and S. Lacassagne present the need of the smart contract application.[2] Transaction processes can be done via automatic smart contract system, which require no human intervention. A consumer can ask for a specific quantity at a specific moment and a prosumer can upload his production capacity on the platform. A prosumer can also add the required price for his production. The role of the smart contract is to execute the transaction at a specific moment. The consumer pays for the electricity automatically and then the transaction is recorded on the Blockchain.

The main difference between traditional transactions and transactions made via Blockchain is the cut of the intermediary parties. There is no need for central authority to verify the transaction, no need for a bank to transfer the amount of money needed, since it is paid via platform. This results in some economic and social benefits, which will be discussed in another chapter.

[1] Lamparter S, Becher S, Fischer J-G. 'An agent-based market platform for smart grids.' In: Proceedings of the 9th International Conference Auton Agent Multi Agent Syst Industry track, IFAAMAS, 2010

[2] Donnerer D. & Lacassagne S., "Blockchains and Energy Transition", 2018, Energy Cities, ADEME.

ii) Energy Certification

Another potential use of Blockchain technology is to verify the origin of the energy produced. As D. Donnerer and S. Lacassagne note, renewable certificates are often false and fraudulent, as they include energy productions from fossil fuels or nuclear power.[1]

When energy from green sources is produced, many governments issue a green certificate for the electricity going into the national grid. However, the verification of the origin is done on a very slow pace and is often characterized by misrepresentation or dishonest (Redding, 2018).[2]

The role of Blockchain is to verify the origin in real time in a tamperproof way and create an ownership record for every renewable energy certificate. Since these certificates are recorded on the Blockchain, they cannot be altered and, as a result, their management becomes easier.

A platform built for this purpose will be a virtual notary matching the production from renewables with specific certificates. Every time a specific amount of electricity is sent into the main grid or the microgrid, the meters, which check the production, can write its unit into the Blockchain, if it is produced from renewable sources.

Fully transparent, this system can help any consumer with environmental behavior to choose from different sources of energy. The adoption of Blockchain technology for these purposes could lead to a greener and cleaner environment, helping consumers make more sustainable energy choices.

[1] Donnerer D. & Lacassagne S., "Blockchains and Energy Transition", 2018, Energy Cities, ADEME.
[2] Reading H., 'How Blockchain Can Enable Real-Time Green Energy Transactions', rtinsights.com, 26/03/2018

iii) Carbon Dioxide Allowances Certification and Trading

The concentration of the greenhouse gases is constantly on the rise and leads to the destruction of our planet and its global climate. In the purpose of combating this phenomenon and in a trial to reduce the greenhouse emissions with economic tools, the UN created a treaty to control emissions of anthropogenic carbon dioxide emissions, the Kyoto Protocol. It was signed in Kyoto, Japan in 1997 and entered into force in 2005.[1]

Many countries in order to meet their objectives that derive from their participation in the Kyoto Protocol, have established emission rights trading schemes, like the EU ETS.[2] Their objective was to create a marketplace, where companies that emit, can trade their emission rights. Companies, which emit below their allowed limits, can sell their rights to other companies which exceed their limits. It is an open market, in which prices are determined by the rules of supply and demand. Now, a ton of CO_2 costs 20€ on these marketplaces.[3]

However, these market mechanisms face tough challenges. The workload of emission certifications can be really large and difficult to carry out and there is difficulty in tracing previous transaction data (Wu and Tran, 2018).[4] Moreover, carbon asset development process requires much time, approximately one year, requires intermediaries like companies, carbon asset exchanges, regulators, and third-party verification companies.

These drawbacks as regards the efficient function of the carbon rights trading markets could be solved with Blockchain technology. Transaction data can now be stored on the chain as a block, avoiding tampering and asymmetry. W. Su and A. Huang on their book for Energy Internet propose an intelligent systematic platform, which could be effective for the validation of carbon emission rights and for the transaction processing. Furthermore, using the blockchain technology the emission status of every emitter is updated in real time, while the platform can confirm the usage of carbon emission rights of every emitter. After every successful transaction, a block is created

[1] 'What is the Kyoto Protocol?', United Nations, Climate Change
[2] EU Emissions Trading System (EU ETS), European Commission
[3] Price data retrieved from markets.businessinsider.com (Retrieved on 12/02/2019)
[4] Wu, J. and Tran, N. (2018). Application of Blockchain Technology in Sustainable Energy Systems: An Overview. Sustainability, p.13.

and added to the chain, which is then irreversible. Lastly, punishment could automatically be inflicted to every emitter who exceeds the allowed quotas.[1]

IBM and Energy Blockchain Labs are currently cooperating to create a project, which fits in this category, a brief description of which will be in a separate chapter.

iv) Business Model

Blockchain platforms are able to change the way energy companies are functioning. Business processes and operations may change, companies can easily adopt these new technologies, thus needing less time and less costs to operate. Current literature copes with several processes that could be altered with the adoption of blockchain technology and facilitated for better performance.

First of all, billing processes could be done in faster ways. Utility companies can take advantage of the disruptive technology and change billing activities for consumers and industrial use. There is potential for energy micropayments or payment platforms for several services and products, like smart meters. (Dal Canto, 2017)[2]

Blockchain platforms could serve as a marketplace in order to identify consumers' energy patterns and as a result offer specified solution for every household. This could help sales and marketing departments of companies as these practices can change in regard to everyone's energy profile and certain energy preferences. (Burger et al., 2016)[3]

Marketplaces may experience huge differences with blockchains. Blockchain-based trading platforms serve as a marketplace for commodity trading and as a result wholesale management and risk management operations may change to adopt.

[1] Su, W. and Huang, A. (2018). The Energy Internet: An Open Energy Platform to Transform Legacy Power Systems into Open Innovation and Global Economic Engines. WoodHead Publishing, p.59.
[2] Dal Canto, D. 'Blockchain: which use cases in the energy industry', CIRED2017
[3] Burger C., Kuhlmann A., Richard P., Weinmann J., 'Blockchain in the energy transition. A survey among decision-makers in the German energy industry.', Berlin 2016, Deutsche Energie-Agentur GmbH (dena) - German Energy Agency

The communication among smart devices, such as smart meters or smart home appliances can be facilitated through blockchain solutions. Smart devices such as smart meters, advanced sensors, control and energy management systems or smart home appliances can now communicate enabling faster data transmission and data storage. In general, smart grid devices can benefit from data transfer and standardization enhanced by blockchain technology; this could help TSOs as regards the grid management. (Burger et al., 2016)[1]

Grid management can also be facilitated by integrating flexible trading platforms and optimising the current resources. This will lead in better use of the network and in cheaper network updates, thus changing the tariffs for the network use.[2]

Security for transactions and data storage can benefit from blockchain enabled solutions. Companies can use cryptographic techniques and bolckchains can guarantee privacy, confidentiality and identity management. (Dal Canto, 2017)[3]

The use of smart contracts can help companies identify potential customers. This will be achieved as smart contracts can speed up the switch of energy suppliers.[4] Customers can see the offers on the platform, and they can automatically choose the most suitable and economically beneficial for them. This will lead to easily switching the suppliers, and this will enhance the competition among the companies. Increased competition means less energy tariffs for the consumers.

Blockchain holds the potential to disrupt the business models of energy companies and especially utility companies. Still this technology is far away from huge adoption, however companies and managers will find a way to use it appropriately. Companies indeed have started to experiment these potentials to use it for their better advantage. However, they must see what challenges they face and then start testing pilot projects. Finally, they will need strong collaborations with other companies to better evaluate blockchain as a business opportunity. Table 2 summarizes the business processes that could be altered.

[1] Burger C., Kuhlmann A., Richard P., Weinmann J., 'Blockchain in the energy transition. A survey among decision-makers in the German energy industry.', Berlin 2016, Deutsche Energie-Agentur GmbH (dena) - German Energy Agency

[2] Indigo Advisory Group. Blockchain in energy and utilities use cases, vendor activity, market analysis (Retrieved on 18/02/2019)

[3] Dal Canto, D. 'Blockchain: which use cases in the energy industry', CIRED2017

[4] Utility Week. Electron reveals blockchain energy platform (Retrieved on 18/02/2019)

Table 2

BUSINESS PROCESSES
Billing
Sales
Marketing
Trading
Smart grid applications
Data sharing and storage
Grid Management
Security
Competition

v) Cryptocurrency

The first introduced cryptocurrency, Bitcoin, introduced the blockchain technology as well. Blockchain platform was first used to conduct transactions in Bitcoin. Today there exist thousands of alternative cryptocurrencies worldwide, which are used for different reasons.[1] A cryptocurrency is "a digital currency in which encryption techniques are used to regulate the generation of units of currency and verify the transfer of funds, operating independently of a central bank."[2]

[1] Data retrieved from coinmarketcap.com/ (Retrieved on 15/02/2019)
[2] Definition from oxforddictionaries.com/definition/cryptocurrency (Retrieved on 15/02/2019)

The role of cryptocurrencies in the energy industry is twofold. Firstly, they are used by some companies, like Wien Energie, an Energy company based in Austria[1], which is currently accepting paying bills via cryptocurrency.

Secondly and most important, cryptocurrencies around the world are being tested and at some point, adopted to remunerate energy producers. There are some coins, like Solarcoin[2], which are used to reward the energy producers from PV panels. For every kWh which is transferred into the grid, the producers are rewarded some coins, which can be traded with other cryptocurrencies as well.

The idea behind the introduction of cryptocurrencies in energy is to promote and accelerate the electricity generation from renewable sources. Although feed-in tariffs and other incentives have forwarded the RES deployment, as D. Donnerer and S. Lacassagne argue, these methods are not any more efficient enough to persuade people to switch to RES. Blockchain could serve as a more efficient platform, which can remunerate producers in real time for their production.[3] The procedure will be carried out via smart contracts which will detect the production of any installed panel in real time.

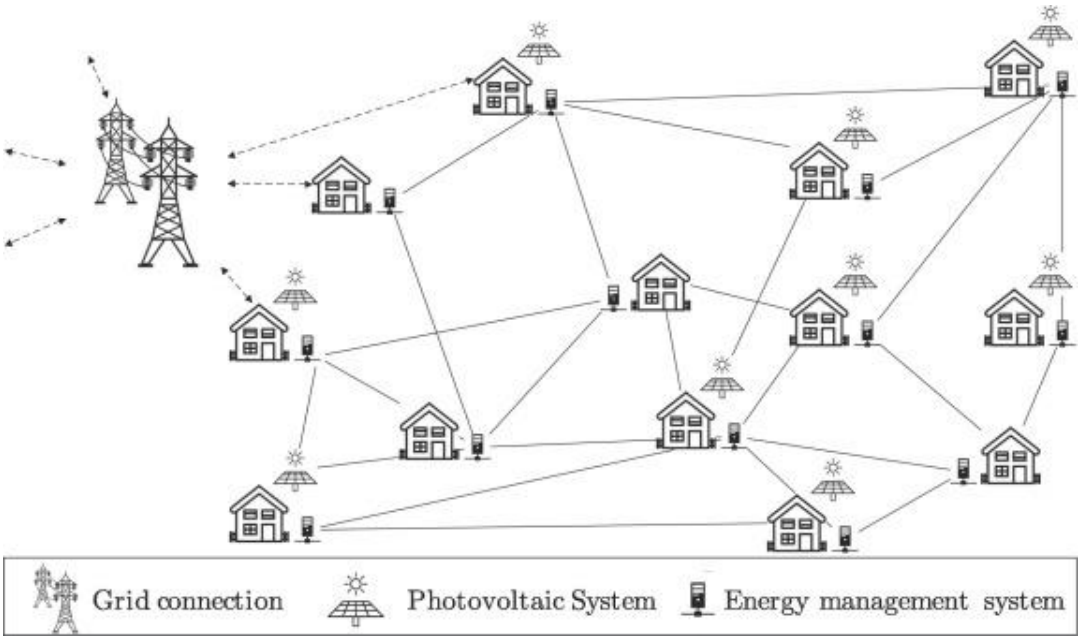
Locally, for example in a small community or a village, a local cryptocurrency linked with the national currency could be used for energy services. Then, the local authority could make a profit from mining this cryptocurrency and finally reinvest it in the local economy or to combat energy poverty.

[1] Milano A., 'Austrian Energy Group Eyes Blockchain With Vienna Test', coindesk.com 08/02/2018
[2] Data retrieved from Solarcoin.org (Retrieved on 15/02/2019)
[3] Donnerer D. & Lacassagne S., "Blockchains and Energy Transition", 2018, Energy Cities, ADEME.

3. PROJECTS

In this section the current experiments will be addressed. There have been some efforts to create a blockchain platform to facilitate energy trading among the prosumers, however, every effort is currently at an experimental phase. Up until today, there has been no large-scale development and every effort is at an initial phase. Figure 4 shows a decentralized energy network.

Figure 4



Source: science direct

i) Brooklyn Microgrid (BMG)

Brooklyn Microgrid is a P2P energy trading platform based on the Blockchain technology. It is run by Transactive Grid, which is a partnership between LO3 Energy[1], Siemens, Consensys and Centrica (Andoni et al., 2018)[2]. It is located in Park Slope and Gowanus communities in Brooklyn. Figure 5 shows the logo of Brooklyn Microgrid.

Figure 5

Source: facebook.com, Brooklyn Microgrid Official Page

The Brooklyn Microgrid project (BMG) has attracted huge attention due to the fact that this project is the first to have successfully completed P2P transactions among the participants (Mengelkamp et al., 2017)[3]. In general, it is a network consisted of Brooklyn residents, house and business owners who wish to change the way we buy and sell our energy. The aim of this network is to connect solar energy producers, who own solar panels, with people who wish to purchase energy from them.[4]

[1] LO3 Energy is an energy company created in 2012. Although it started as a think tank, it now operates in the field of disruptive technologies in the energy sector. It is developing innovations (blockchain) to revolutionize generation, storage and transactions of energy at a local level.
[2] Andoni M., Robu V., Flynn D., Abram S., Geach D., Jenkins D., McCallum P., Peacock A., 'Blockchain technology in the energy sector: A systematic review of challenges and opportunities', 2019, Renewable and Sustainable Reports, p. 143-174
[3] Mengelkamp E., Garttner J., Rock K., Kessler S., Orsini L., Weinhardt C., 'Designing microgrid energy markets: A case study: The Brooklyn Microgrid', Applied Energy, 2018, p. 870-880
[4] Info retrieved from brooklyn.energy/bmg (Retrieved on 18/02/2019)

Every resident in these district Brooklyn areas can participate in the project, either they are prosumers or consumers. If they have solar panels on their rooftops, they register as prosumers, indicating that they wish to sell their excess in energy. If they are consumers, they indicate where they wish to buy energy from. It is necessary to install a Brooklyn Microgrid smart meter system, as it is used to collect and share data in this marketplace.

Furthermore, participants can hold access to the local energy marketplace through their mobile phones once they install the Brooklyn Microgrid application. In this application, every user can check where the solar panels are installed, they can propose to add new local solar sites and, finally, they can track the energy data for the past 12 months.[1] Figure 6 illustrates the network.

Figure 6

Source: transactive microgrid

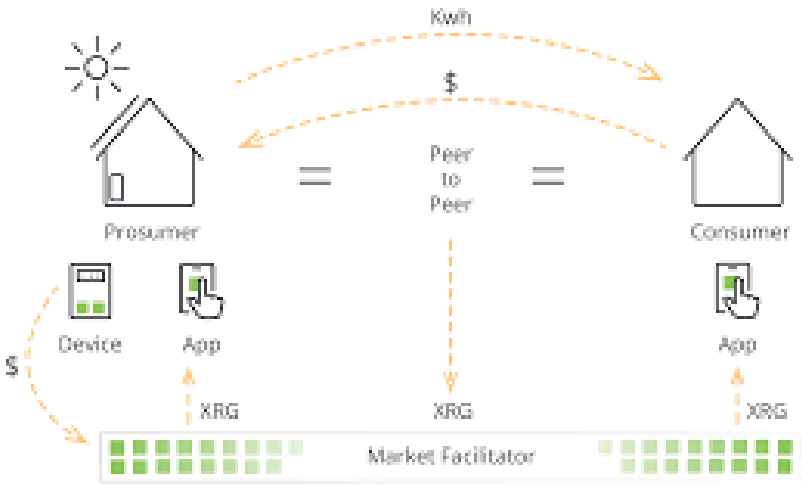
The BMG Microgrid project consists of two components: the physical microgrid and the virtual energy market platform (Mengelkamp et al., 2017)[2]. In order to act as a back-up, a physical microgrid was built and added to the existing grid. Its purpose is to secure the supply in case of

[1] Info retrieved form the official application of Brooklyn Microgrid at Google Play Store (Retrieved on 17/02/2019)
[2] Mengelkamp E., Garttner J., Rock K., Kessler S., Orsini L., Weinhardt C., 'Designing microgrid energy markets: A case study: The Brooklyn Microgrid', Applied Energy, 2018, p. 870-880

power outages of the traditional grid, since it can operate in an island mode. As E. Mengelkamp et al. describe, the microgrid operates in addition to the existing grid run by Con Edison Inc., however it only decouples in emergency situations. The virtual energy market platform is based on the Blockchain technology and is actually operating as the necessary infrastructure of the electricity market.

The virtual platform, i.e. the Blockchain on which transactions actually happen, operates on top of the infrastructure. On this platform, Brooklyn residents can send their information on electricity generation, if they are producers from PV panels, and also, they can ask to purchase the needed electricity. Besides their production data and information, the market participants need to send their own preferences as regards the electricity they wish to buy. For example, they can set price limits on their purchase or they can set the preferred energy sources. Then, the platform can operate the transactions, residents sell and buy electricity and every transaction is then recorded on the Blockchain, thus making them unalterable. Figure 7 shows the transactions' method.

Figure 7



Source: LO3 Energy

It is necessary, as mentioned before, to install the smart meters in the households which participate in the market. The significance of these meters is to collect the data and then, it is available to every participant. They help the prosumers identify their potential buyers and the consumers to choose their supplier or suppliers.[1]

[1] Info retrieved from brooklyn.energy/bmg (Retrieved on 18/02/2019)

Up until now, residents with PV panels would sell the electricity generated from them to utility companies benefiting from some reductions on their electricity bills.[1] Thanks to this project, now the residents are able to choose whether they will feed the electricity to the main grid or they will sell it to the neighboring homes. This gives them the total control of what they actually produce.

From a consumer perspective, this project gives them a real opportunity to choose their supplier, either it will be the utility company which operates in the region or their neighbors. The system that LO3 is currently creating helps consumers cut the middle man, on this occasion the utility company. Using the app on their mobile phones, Brooklyn residents can now strike deals for their needs, how many kWh they will buy, how much they will pay and to whom.[2]

The benefits derived from this system can be described as economic, social and environmental. First of all, microgrid members set their own price preferences (Antoni et al, 2018)[3] and are not charged with other fees, for example with the energy loses of the national grid. Buyers can also prioritize their sellers, setting on priority friends, families or even low-income households in order to support them. The local economy can benefit from these actions, as the profits stay within the community rather than going to the utility company (Mengelkamp et al., 2017).[4]

The BMG project intends to prove that local microgrids are sustainable (Mengelkamp et al., 2017). There can be an effective market for both renewable energy and local markets. Moreover, it shows how the market can be balanced via the Blockchain technology.

However, M. Andoni et al. address some issues that derive from the deployment of this technology in the energy sector. They argue that we need to implement large scale projects, under diverse conditions, and not small microgrids in order to identify the willingness of the consumers to participate in such markets. Furthermore, they discuss the issue of price volatility. The main grid offers standard tariffs and prices for electricity, whereas, the microgrids operate under the law of

[1] 'The Brooklyn microgrid: blockchain-enabled community power', power-technology.com (Retrieved on 18/02/2019)
[2] Bruno D., 'Brooklyn's Latest Craze: Making Your Own Electric Grid', Politico Magazine (Retrieved on 18/02/2019)
[3] Andoni M., Robu V., Flynn D., Abram S., Geach D., Jenkins D., McCallum P., Peacock A., 'Blockchain technology in the energy sector: A systematic review of challenges and opportunities', 2019, Renewable and Sustainable Reports, p. 143-174
[4] Mengelkamp E., Garttner J., Rock K., Kessler S., Orsini L., Weinhardt C., 'Designing microgrid energy markets: A case study: The Brooklyn Microgrid', Applied Energy, 2018, p. 870-880Designing microgrid energy markets A case study: The Brooklyn Microgrid

demand and supply. As a result, they may be characterized by huge price volatilities, thus affecting the most vulnerable. There must be an investigation on the protection of the elderly or the socially disadvantaged from price volatilities. M. Andoni et al. underline the social behavior of the market participants as a key factor for successful market designs and pricing mechanisms.[1]

Besides market mechanism issues, E. Mengelkamp et al. address the regulatory gaps in the deployment of this technology. They argue that, in most countries, specific regulations need to be adopted for the successful deployment, as current regulatory regimes do not cover P2P trading among the residents.

Currently, a simulated marketplace is being launched in the three parts of Brooklyn. People are testing their ability to directly purchase electricity as part of this program. LO3 company is aiming to launch the live marketplace in mid-2019.[2]

[1] Andoni M., Robu V., Flynn D., Abram S., Geach D., Jenkins D., McCallum P., Peacock A., 'Blockchain technology in the energy sector: A systematic review of challenges and opportunities', 2019, Renewable and Sustainable Reports, p. 143-174

[2] Info retrieved from brooklyn.energy/bmg (Retrieved on 18/02/2019)

ii) Pylon Network

In Spain, a project called Pylon Network is currently under way. It is developed by Klenergy, a Spanish tech startup focusing on the transition of the energy systems across the planet and the mitigation of the CO_2 emissions. Driven by the changes and the trends occurring in the energy sector, this company was created to forward the implementation of RES and play a key role in the climate change, not only in Spain but also worldwide.

Klenergy describes the energy sector as slow changing and monopolistic and sees the political unwillingness, as regards the transition, as a key factor for these problems. They see this gap in the energy transition as an opportunity to build a more democratic society, facing towards a greener planet, where every person will have access to the resources.

As a result, Klenergy built the Pylon Network Project, a platform which accelerates the energy trading between producers from solar and wind power and the end users. It is created to engage decentralized energy production, communal energy management and to facilitate the process towards energy transition.

Besides the platform, Klenergy has created smart meter as well, called Metron. Its purpose is to give free access to the data, it is based on Blockchain technology and includes its own payment system. It offers P2P transactions among the users of the networks (retailers, producers, consumers) and it is designed to be full transparent and have full privacy. The role of this smart meter is that it constitutes part of the network, contributes to the transactions, "creating an electricity and payments transactions database totally decentralized and totally transparent".[1]

The Pylon Network develops a database based on Blockchain Technology, in which every data, both production and consumption, is stored. The network aims at giving the opportunity to each participant to be an active member of it. It is achieved by allowing the data owner, either a producer or a consumer, to be in control of their own data and choose whom to share the data with.[2]

[1] Info retrieved from the official website of the network, pylon-network.org/metron (Retrieved on 10/02/2019)
[2] Pylon Network WhitePaper v.2.0, December 2018

The innovation in this system lies on the fact that the owner of the data chooses what to do with their own information, which company or user to share with, who can have a direct access to the data and, finally, who can reach them with some offer- which could be a utility company or Energy Service Company.

In this network, the data sharing scheme helps both the end users and the companies. The companies are now in position to make more personalized, more targeted and accurate offers to the clients, since they can access personal data concerning the consumption of each end-user.

The pilot partner of Pylon Network is a Basque-based retail company, Goeiner, which has agreed to be part of the experiment. The current pilot project includes 100 users from consumers, producers and large generators of Goeiner. By creating tools that focus on the interaction of the participants, the company aims at becoming more competitive as market players.

Pylon Network has tried to engage the end-consumers by their own participation. The participants share their own data, and the team of Pylon Network can analyse their consumption or their preferences in general and, then, take them into account while designing the network.

The demonstrated services of the network include a demonstrated blockchain code in real environment, energy certification, direct access to data, consumer-driven open data (consumers control their data and choose where to share it) and a mobile application.[1]

The Blockchain code includes 10000 users of the demo platform, the energy certification offers the possibility to the consumers to know and verify where their energy comes from, and, lastly, in order for the consumers to have a full knowledge of their consumption, the tools were built in a very simple way.

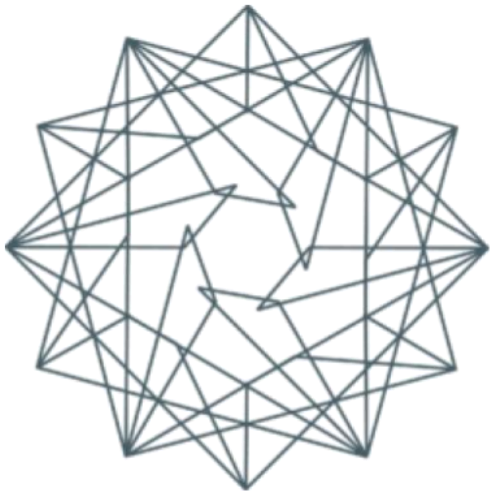
The Pylon Network is trying to play a key role in the energy transition and its team strongly believes that it can be achieved through this technology; it is facilitating the participation of the end users, by owning and sharing their data, verifying where their electricity comes from. But also, it gives the opportunity to companies to offer better services, by making more personalized offers. The use of the smart meters (metron) plays a key role for this open ecosystem. The team of Pylon Network aims at creating an open platform to achieve the decentralisation of the energy markets.

[1] Pylon Network WhitePaper v.2.0, December 2018

iii) PowerLedger (Australia)

PowerLedger was formed and operates in Australia since 2016 aiming at changing the energy landscape. Their vision includes the adoption of Blockchain technology by local communities and companies, thus creating a new environment for the industry. As their moto says “We believe in a world where blackouts are a thing of the past, where electricity is clean, affordable and available to everyone. Where sustainability and profitability go hand in hand, and consumers have the power to manage their energy costs.” In figure 8, the logo of the company is presented.

Figure 8



POWER LEDGER

Source: CoinSwitch

ENERGY TRADING

The team has created several products, which are completely commercialized, covering a wide range of disruptive technologies. The first product is mGrid, which is created for the facilitation of the selling of electricity among neighbors. This platform makes it possible for residents to trade excess in solar energy among themselves rather than putting it into the main grid. It results in residents' buying from the closest neighbors and keeping the profits in the local community.

Moreover, the platform facilitates the data storage, allowing every participant to track consumption patterns and be more energy efficient, while they can track where more energy is needed, by whom, when it is needed, and eventually manage it more easily and efficiently.

The product features include everything that is needed for peer to peer transactions, as peer to peer electricity trading platform, data storage for consumption, transactions records and detailed billing as well.

Furthermore, they produced the xGrid, which is a product for peer to peer electricity trading in the main grid. Their idea behind this project is that they wish to give access to everyone for low-carbon and low-cost energy. Since not everyone can afford solar panels or can have solar panels on their roofs, they still have the right for this kind of energy. Their platform, xGrid, gives the opportunity to companies to handle their costumers the perfect access to renewable energy, even if they do not produce it themselves. Now customers can sell their excess in energy to others in need, while companies can now hold data for prosumers and consumers, which would be too expensive to keep as customers. Finally, it ensures that the earnings from solar panels and the investment in distributed energy sources remain in the local community.

The most disruptive product is the PowerLedger VPP 2.0, with which the company is trying to solve the problems in the industry that occur from the demand shortages and the price spikes. With this product, customers can now sell frequency, capacity and ancillary services to their energy provider. What they are trying to change is the way that energy companies compensate household with solar panels for their contribution. They see that energy companies offer some standard prices which do not reflect the real value. Through this platform companies can see the customers' contribution in near real time, thus making both the compensation and the transfer of energy

quicker when there is need. Finally, through this platform, the best use of battery is determined; the platform can decide which the best application of a customer's battery will be, either frequency control or network control or demand response.

ENVIRONMENTAL COMMODITIES TRADING

Furthermore, the applications of Powerledger have expanded in carbon credits trading. They created the C6 platform where the participants, whether individuals or companies, can trade directly with each other. Individuals can be owners of solar panels or wind farms and companies could be everyone who has carbon activities. In the past, sellers faced many problems in their trying to sell their credits, mostly bureaucracy and large paperwork. This is what Powerledger is trying to improve; the time and the cost of the transactions made for this purpose. This product (C6 and C6+) runs an automate process to issue credits and accurate measurement of energy generation. Finally, the result is to create a liquid market for efficient and transparent transactions.

RENEWABLE ASSET FINANCING

Powerledger saw the lack of funding in the renewable sector and created a platform, the Asset Germination Events, to boost up investments in renewable assets. People can now invest and co-own a portion of renewable projects like electric vehicle chargers or solar farms.

The idea is to split ownership of large-scale assets into small portions, leading to less capital needed for an investment. This product aims at giving access to new funds and new sources of capital. Everyone can now buy a certain percentage of a project and then sell it, if they decide they do not wish to be part of it anymore.

The trading is done via a token, the AGE token, and it can be traded like in an exchange.

The lack of accessibility in such investments was the key reason for creating this product. Now, anyone can have access, can find several projects across the world and invest in them, via their computer.

Among the advantages and the key features of this product is the oversight of the token by the regulators and the legally enforceable rights of every shareholder. Table 2 summarizes the activities of the company.

PowerLedger Activities:

Table 2

PRODUCTS	FUNCTIONS
μGrid	Energy Trading
xGrid	Energy Trading
VPP 2.0	Energy Trading
C6 & C+	Environmental Commodities Trading
Asset Germination Events	Renewable Asset Financing

PROJECTS

Kansai, Japan.

The project in Kansai, Japan has to do with the peer to peer solar power trading. Kansai Electric Power Company uses the platform developed by PowerLedger to facilitate and promote the renewable power energy trading at a research center in Osaka City, Japan.

This trial functions as follows. There are 8 meters installed in appliances, including an EV charger, which are at the research center in Osaka. KEPCO shares the data collected from these meters and then Power Ledger gives access to their platform. KEPCO will try to facilitate and monitor energy trading between the participating meters and then examine the most suitable ways renewable energy can be traded and shared within a community. This trial will help Power Ledger commercialize its products for further deployments.

The main goal of this trial is to find out more ways communities can offset their energy costs and help producers sell their excess in energy peer to peer. Table 3 summarizes the highlights of the project.

Table 3

HIGHLIGTS			
> 70kWh Solar energy traded per week	**2** Trading algorithms executed in two-phased trial	**1,500** Energy transactions processed per week	**20%** Energy consumed from renewable resources

Source: PowerLedger

Bangkok, Thailand

Thai renewable energy business BCPG and Thai utility Metropolitan Electricity Authority started a trial by using the Power Ledger platform in a region with 700 KW solar capacity.

The aim is to test energy generated by renewables traded between an international school, apartment complex, shopping center and dental hospital in Bangkok. The trading process is run through the Blockchain platform by Power Ledger.

The Power Ledger platform monitors and visualizes for each participant the generation, consumption and trading position, and provides Statement of Use information for invoicing purposes. Table 4 shows the highlights.

Table 4

HIGHLIGTS			
2.8MWh Average solar energy generated daily	**10MWh** Average peer-to-peer energy transacted per month	**$1,500AUD** Potential monthly proceeds from peer to peer	**18%** Energy consumed within the precinct from renewable resources

Source: PowerLedger

Chiang Mai, Thailand

Power Ledger and electricity company BCPG cooperate for solar power trial at Thailand's Chiang Mai University. BCPG uses Power Ledger's peer-to-peer trading platform to study consumers' energy consumption patterns.

The aim is to study the consumers' consumption patterns by using the Power Ledger Blockchain platform. In the future, BCPG will also install a smart distribution network that connects and communicates with the University's Smart Campus Management Center through Chiang Mai University's existing information technology system. Table 5 illustrates the results of the project.

Table 5

HIGHLIGHTS			
54 New smart meters to be installed across campus	**3** Zones on PEA's network involved in the project	**2** Zones connected via private network behind the meter	**12MW** Solar capacity to be installed

Source: PowerLedger

As a conclusion, below there is a summary for the projects of PowerLedger, with information taken from their own website. Table 6 summarizes the projects and their content.

Table 6

PROJECTS	SUMMARY
Bangkok, Thailand	Peer-to-Peer solar power trading
Kansai, Japan	Peer-to-Peer solar power trading
Santa Clara, United States	Peer-to-Peer solar power trading
White Gum Valley, Australia	Discounted solar energy for artists
Kansai, Chubu, Kyushu, Japan	Trading of rooftop solar energy (Sharing Energy)
Fremantle, Australia	Peer-to-Peer solar power trading (RENew Nexus)
Wyomissing, United States	Trading of rooftop solar energy
White Gum Valley, Australia	Solar power trading for Evermore apartments
Chiang Mai, Thailand	Tracking consumer energy use habits
Vicinity's Multiple Sites, Australia	Trading solar power from shopping center rooftops

iv) Energy Blockchain Labs

"IBM Blockchain brings trust, innovation and efficiency to our carbon asset development…an important milestone for China in the era of big data.**"**

— Lin Le, Chief Executive Officer, Energy Blockchain Labs Inc.

Energy Blockchain Labs Inc (EBL) is based in China and has set up a way to close the gap in the green economy. They created a transparent platform to serve as a marketplace for carbon polluters in order to help them reach the emission quotas. They use the IBM blockchain platform in which it is built, and their challenge is to tackle climate change.

China's energy industry faces many challenges and lots of updates need to be done. China is responsible for 25% of global emissions, has inadequacies in energy market mechanisms; they do not promote the green energy production and consumption.[1]

In order to reduce emissions and promote the sustainable energy, China introduced Carbon Emission Reduction (CER) quotas. As Y. Hua and F. Dong point out, China's industry holds great potential for emission reductions and in the past few years academic achievements and pilot experiments have been introduced to improve the national carbon market (Y. Hua and F. Dong).[2]

One of these experiments belongs to Energy Blockchain Labs Inc, as they saw that blockchain technology could help reach a new level of efficiency in carbon asset trading. Their carbon asset development platform helps companies and organisations comply with the government mandated CER quotas. The key feature is that, in this trading platform, trading data becomes more traceable, transparent and visible to any participant. Moreover, EBL has turned more than 200 carbon asset development methodologies into smart contracts. In this feature, the calculation of quotas that needs to be reduced is done automatically.

[1] Retrieved from : ibm.com/case-studies/energy-blockchain-labs-inc (Accessed 18/04/2019)
[2] Y. Hua and F. Dong, "China's Carbon Market Development and Carbon Market Connection: A Literature Review", Energies 12(9):1663, 2019

EBL using the IBM blockchain technology set up a distributed ledger that records and quantifies the environmental impact of stakeholders' energy production and consumption activities. This helps participants gain better knowledge of their carbon footprint and find better chances on when to buy or sell their credits. Regulators can easily track emission reduction progress to ensure that goals are met.

The expectations are to meet the emission targets. As the technology moves on, both EBL and IBM expect the maturity of the market. They aim to bring efficient gains to the green economy, while carbon assets will move in a faster way in the blockchain technology, collaboration among the stakeholders will be promoted, as it will become easier, and errors in the market processing will be eliminated. In China, the average time for carbon asset development reach 10 months' time. Lin Le, Chief Executive Officer (CEO) of Energy Blockchain Labs, sees that blockchain technology could reduce this time about 20%-50%.

Potential long-term benefits include the channeling of funds into great green investments. Companies and organisations will find assistance and initiatives in their try for energy transition.

Lin says. "It represents an important milestone for China in the era of big data; it's key to achieving economic prosperity and allowing Chinese enterprises to generate carbon assets consistently in order to tackle global climate change."[1]

[1] Retrieved from : ibm.com/case-studies/energy-blockchain-labs-inc (Accessed 18/04/2019)

v) Experiment in the Pyrénées Orientales Department

In the Pyrénées Orientales, which is located in south France next to the borders with Spain, a startup called Sunchain has created a blockchain based platform. The concept is to collect all the data using electricity meter data and then it can be "encoded, signed and recorded in a blockchain"[1]. In cooperation with ENEDIS, the DSO in France, a subsidiary of EDF, they started an experiment to create Blockchain solutions to manage energy exchanges.

The experiment begins from the conventional meters that are installed in each participant. The meters gather data concerning both the production and the consumption. This data is then recorded on the Blockchain, which is used by Sunchain and Enedis.

Enedis can then distribute the data for consumption and production to all users of the network, and since this data includes information about the energy use, smart meters are necessary for this experimental phase.[2]

In order for the energy allocations to be successful, the Blockchain certifies the data recorded from the producers and the consumers. The responsibility of the DSO is to secure the supply, by generating modified readings in order to send them to the supplier for invoicing purposes. Finally, the supplier charges the energy used by the participants and it distributes a net sum of its share amongst the participants.[3]

The experiments show that these actions have created some innovative results. First of all, energy management is now done in a more efficient way, since every data is restored in the platform. This results in decrease in energy loses, as every participant and the DSO as well, can see in near real time both the need for energy and the consumption. As a result, the supplier performs more fair invoices, as the households are only charged for their actual use of energy and not for the loses for example.

Moreover, through smart contracts the company aims to provide the prosumers with certificates for the origin of renewable production and traceability for energy consumption as well.

[1] Donnerer D. & Lacassagne S., "Blockchains and Energy Transition", 2018, Energy Cities, ADEME.
[2] https://tecsol.blogs.com/mon_weblog/2017/07/
[3] https://www.sunchain.fr/en#autoconsocoll

In general, the experiment in the Pyrénées Orientales is a very good example on how, in a small community, self-consumption can be promoted. Through PVs installed in houses, the energy can be shared among the inhabitants. Then, the Blockchain includes every data for the production, the consumption, the origin of energy and the invoices from the supplier.

vi) Solarcoin

The projects currently testing the application of Blockchain technology in energy contain also cryptocurrencies created to promote the energy transition. 'SolarCoin is a digital asset and currency designed to support the transition from the fossil-fuel economy towards a solar-backed economy.'[1]

The idea behind this concept is to promote and accelerate electricity production from solar panels by rewarding the producers. SolarCoin Foundation awards producers from solar panels with one token per MWh produced, it is an additional reward, as it is different from any government incentives or carbon credits purchased in the markets.

Solarcoin is independent from any government or company, totally decentralised as it is based on Blockchain platforms. Like Bitcoin, it uses distributed ledger technology to create a peer to peer marketplace worldwide. These coins are held in a digital wallet and can be traded from wallet to wallet in a few minutes. The goal of the Foundation is to issue 98 billion coins in the next 30 years., currently there are 38 million circulating in the market.

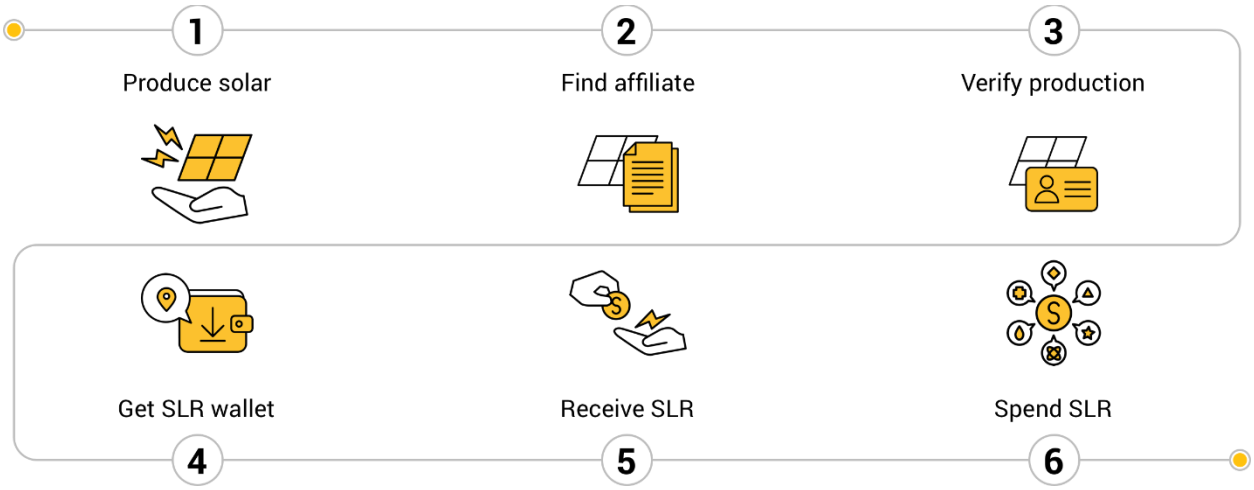
The owner of solar installations produces solar energy and then they approach an affiliate of SolarCoin Foundation to register the installations and to claim the digital coin. Then, the producer provides some verification data as regards their installations. After being accepted, the download of the e-wallet occurs and the Foundation directly issues Solarcoins to his wallet. Claimant collect

[1] Definition taken from the official website of the currency, solarcoin.org

the coins and then use it as they want, either collect them or sell them. Finally, claimant may receive Solarcoins every six months as their installations keep producing solar energy.

Solarcoin can be exchanged at online exchanges like Bittrex or Lykke for both other cryptocurrencies and fiat currencies. In the meanwhile, Solarcoins started to be accepted for payments, as other digital currencies, and the goal of the Foundation is to promote Solarcoin as a payment method for goods and services. Moreover, Solarcoin can serve as a marketing method for brands positioned as environmentally friendly. The foundation's ambition is to further develop this cryptocurrency in order to serve as the equivalent of avoided CO_2 emissions certificate. Finally, as regards the Solarcoin Blockchain platform, it can be used as a platform to store data reporting the actual solar energy production.[1] Figure 9 briefly describes how the system works.

Figure 9



Source: solarcoin.org

[1] Solarcoin Policy Paper, Solarcoin Use Cases, p.10

vii) I Nuk Application

INUK is a French startup company, which acts in the field of carbon emissions credit system. They have created an application, which can be downloaded on our smartphone devices, and its main feature is to offset our carbon emissions from our daily activities, like riding our car or having our food delivered at home.

The concept behind this innovative idea is that every gram of carbon that is emitted can be offset somewhere else on Earth with an opposite action. "Carbon offsetting means that, for every gram of carbon generated by a given activity, we compensate somewhere else."[1]

The Blockchain that is used in this application is the public Ethereum and the startup "uses a methodology that was developed by the UN and is recognised on the carbon credit markets."[2]

This application watches the carbons footprints from our activities in real time and it is, also, cooperating with some local and small solar energy producers, mainly in France. The idea is that it offers a price for an activity which omits carbon, for example, it can propose 10 cents for riding a taxi. Then this money, that the user pays, is reinvested in order to offset this emission. On most occasions, money is used to plant a tree or to fund the construction of a PV or solar panel.

Furthermore, the Blockchain used, in the application, helps the solar energy producers, who cooperate with the company, to monetise their production. It is done through carbon credits which can then be sold and traded in the markets. The Blockchain is also useful in order to provide real time data from the solar installations.

The innovation that underlies in this idea is that there can be a carbon neutral approach for every activity. Someone can pay for the emissions they produce, and the paid amount can be used in order to facilitate greener production. Moreover, transparency can be guaranteed via the Ethereum Blockchain and the smart contracts. All this procedure is public, faster and is done in a more transparent way, in opposition to the UN Framework Convention on Climate Change (UNFCCC).[3]

[1] Info retrieved from the official website of the INUK application, inuk.com/home (Retrieved on 20/11/2018)
[2] David Donnerer & Sylvie Lacassagne, "Blockchains and Energy Transition", Energy Cities, ADEME.
[3] David Donnerer & Sylvie Lacassagne, "Blockchains and Energy Transition", Energy Cities, ADEME.

Finally, the idea of decentralisation is that each participant has access to the database in order to see in real time where exactly the amount of money is spent, and which projects are financed. The beta version of this application is almost ready and will be soon launched.[1]

viii) Daisee

Prats de Mollo is a 1000 years old French village in south France, bordering with Spain. This small town/village targets to succeed in energy transition. Its plans are to go 100% self-sufficient in renewable energies by 2021.

Daisee is an open source system based in France and was co-produced by La Myne and Cellabz[2]. Their main moto is that Energy is a Commons and they are currently trying to build a self-sufficient community, where the inhabitants control the energy. La Myne is a research laboratory in Lyon, focused on the experimentation and development of sustainable research projects.

As a result, in Prats de Mollo in South France, a semipublic company was created, controlled by the Municipality, some local citizens and the Municipal Electricity Company. The main purpose of this experiment is to create the necessary conditions for a shared governance of energy by all the stakeholders.

The team is currently working on some technical issues, like the physical infrastructure and how it can be improved, on software development, providing a distributed among the residents' network, data sharing in a transparent system, and on scientific research, aiming to set up an experimentation framework to be adopted by other local authorities to use it for tests.

This experiment in Prats de Mollo is considered a total experiment on how Blockchain could be used in the energy sector. It involves all the participants of the energy network, local authorities,

[1] Info retrieved from the official website of the INUK application, inuk.com/home (Retrieved on 20/11/2018)
[2] It was a laboratory for emerging technologies, mainly Blockchain. However, it ran until 2018 and it closed. As a result, the experiment continues with the other participants.

residents, local electricity company. Their objective is to develop a distributed system, which mainly supports the energy data management, citizen ownership and grid infrastructure.

4. INTERVIEW WITH MARKOS ROMANOS

In this chapter, I present a brief interview which I had with Markos Romanos[1] via Skype. We discussed about this technology in the energy sector, what the future might be and which the problems that need to be addressed are. He gave me a full picture of his company's operations and he helped me understand some technical issues as well.

So, how did you come up with the idea and what are you currently offering in the energy sector?

We were a small group of young engineers seeing that the energy sector lacks in innovation, and we could not understand why the stakeholders keep on focusing on fossil fuels and why the sustainable technologies were not promoted as they ought to. We were seeing this gap not only from an environmental perspective, but also from a point of view to promote social and economic benefits as well. All of us were seeing that the sustainable development towards a greener environment is possible, its promotion is necessary and finally, it can be decentralised.

Currently, we are stepping on the finalization of the architecture prototype of Pylon Network. We base our efforts on our smart meter, called Klenergy Metron and we have been in close contact with some developers in order to exchange some useful ideas for further implementation. We are now using the Blockchain technology to show a disruptive way and to create a digital network for the collection and the sharing of the data. We are trying to achieve this by combining transparency with the regulations of the data protection. We strongly believe that the energy market is in real need of data and this is the basis of our job.

Finally, we have implemented a certification process of the origin of energy, which was easy for us, but has huge social and environmental impact.

Our project is an open source, designed to promote the cooperation among the actors. It belongs to the consumers and not to the stakeholders. Every consumer can put their data in our network

[1]Markos Romanos is currently the COO of the Pylon Network and his role is to facilitate international cooperations engaging with energy stakeholders and working on ways to accelerate innovation in the energy sector.

and choose how to share them. We are focused on how to provide solutions for the current situation and not in the future, we focus on now and not on the next five years.

At which phase is now the Pylon Network?

We are now at a very ambitious phase, our cooperation with Goeiner is evolving and we are heading to the commercialization phase of our project, which is expected to be a very difficult part. We have developed our code and we have managed to make the validations in a faster way, which leads in energy decrease per validation. Now, our platform can validate 1000 transactions per second, while Visa can validate up to 5000 and Bitcoin only 4. Moreover, we decreased the energy needed for every transaction to 2 mWh, while Bitcoin needs 2 kWh for every transaction.

We use our code in real energy market, we currently engage 8000 users, who are Goeiner's clients and who record their energy consumption data on our blockchain database. Working closely with the consumers and the clients helped us understand the real needs of the market and to create a valuable feedback for some future activities.

What are the next steps for your project?

We are now heading to the commercialization stage and we focus on that. This means that we will try to reach more businesses to use our idea, we will focus on marketing activities in order to engage more potential users and we will reach out our community.

From your own experience, how do you think that the stakeholders see the blockchain technology in the energy sector?

The energy sector indeed has a lot of actors, so it depends on whom you will talk with. For example, the retailers can do this, can use blockchain platforms. However, they will not do so, because they see this technology as a threat to their business model. They expect to see the competition, if someone else does it, they will do the same; but this is something unstable and non-fixed.

Furthermore, the big companies do not want to adopt themselves to such changes. They want to overcharge their consumers, they put more and more fees for the used electricity and for the national grid as well. They do not want the consumers to know what they are paying for, or to change suppliers in an easy and fast way; currently in the European market, only 5% of the end consumers change suppliers.

On the other hand, there are the medium and the small companies acting in the energy sector, which are more willing to use blockchain technologies. There are a lot of medium companies in the market, which are investing funds, or are planning on investing funds, to develop blockchain based platforms in order to facilitate their operations.

However, I can say that people do not pay attention to the changes that the energy sector undergoes. They are not too sensitive, and they cannot understand how the market functions. Moreover, they do not seem to care what they are paying for, if they can afford the bills, then they do not want to learn more; they just pay the bills. Bearing this in mind, we can say that people, cannot understand the benefits from this kind of technologies.

Finally, it is necessary to understand the politics and the lobbying behind every big change. Politicians cannot adopt these changes, because they are disruptive and as a result, they seem to be reluctant as regards the implementation. The regulation poses some serious problems, and it needs to be changed for further deployment.

How do you see that people and society face your efforts?

We have found huge support from the Goeiner's clients, who seem to find our effort really serious and with environmental and social benefits. Furthermore, energy communities and cooperatives strongly support us. While no one seems to care about the energy industry and how it works, these are teams which are really sensitive about what we are doing, and they oppose the strict regulations of the sector.

Where are you currently operating your project?

Since we are based in Spain, we are currently developing our idea in Spain with the stakeholders. However, this does not limit us and our future development plans. The European market is really attractive because of the market conditions, it is homogenized, and it offers great opportunities. It is our safe bet and we will plan to commercialize our model to other EU countries.

Since it is a global problem, we have to keep an eye in other markets as well. However, we need to find specific and attractive policies and operational environment as well. It depends on which country and which market could help us with our activities.

Furthermore, we still find interest in the British market, because of their conditions, which fit to our visions and strategy. We find it as a suitable market, because it accelerates the use of aggregators, thus enabling the distribution of data among the energy stakeholders; aggregators could play a vital role in the energy transition.

What are the current problems that this kind of technologies face?

From the early beginning we saw some problems regarding the regulations. Energy sector is highly regulated, and we need a change to make such technologies applicable to the industry. Big companies often see these projects as a threat to their business model, so they need to adjust themselves in these trends. They will try to create some blockchain applications for their own activities, which will not affect their earnings.

Furthermore, politics will play their role, as there is need for political ideas in order to accelerate new technologies. Politicians do not seem familiar with these ideas, thus affecting the need for change in the regulatory framework.

Finally, there needs to be technology progress. We need to build on the current technology infrastructure to make it more applicable. The more the actors participate in a blockchain, the heavier it becomes, so we need more expansion.

What is the strategic advantage of the Pylon Network?

The energy industry is in real need of data. However, the current data are held by certain entities, like the DSOs, who own the physical infrastructure and collect the data from the meters. We saw that this creates problems. As a result, we promote the energy sharing for the optimal use. We created a neutral, open, shared database to promote data sharing among the stakeholders.

As Pylon Network, we guarantee data neutrality by using our blockchain platform, which we created in accordance with the requirements of the energy industry. We are currently offering full transparency with full privacy of open energy data; anyone can upload their data in the platform and choose whom to share them with.

Finally, we are proud because we offer solutions to the problems of today and not of tomorrow. We build on today's needs and not on how the market will be in a few years from now.

Finally, how do you see the near future of this technology?

Blockchain application in the energy industry can offer great innovation, facilitating the cooperation among the stakeholders, like companies, DSOs, end-use consumers etc. There will be huge demand for data in the sector and companies will focus on this.

As a result, data sharing will be the key aspect in the blockchain implementation in the industry, because this is the real need.

As regards the P2P trading, I do not believe that we will see large scale development in the next 5 years due to many reasons. We will just experience this kind of trading in small local communities, villages and microgrids. However, there will be efforts for large scale implementation.

Furthermore, I expect to see experiments and development from the side of big companies, in a manner that they will make their activities more efficient and faster.

I also see a big change in the regulation, because it is needed for these projects; thus, decentralisation.

5. CHALLENGES

Despite the huge potential of the Blockchain technology, which can be identified by the investments it attracts, there are currently some drawbacks, some challenges that need to be addressed and kept in mind during each implementation.

This technology creates many questions that need to be answered before large-scale implementation and massive adoption. The current literature poses some issues, which are of high significance. There are challenges that derive as this technology goes on, especially as regards policy and regulation issues and technology issues as well.

W. Su and A. Huang describe the potential technology and regulation challenges in their book, stating that there could be limitation because of the combination of Blockchain technology and the adoption of new energies. (Su and Huang, 2018)[1]

Furthermore, they address potential policy challenges from the perspective of the regulators and of the stakeholders. Monopoly issues are also described, as it will be necessary to break the monopolies in the energy field for Blockchain technology application. (Su and Huang, 2018)[2]

M. Andoni et al, in their paper, focus on the technology issues themselves. For example, they describe the high development cost of the Blockchain technology as a key negative factor. They state that there are other problems like security risks or the regulation for data protection, which could lead in a reluctancy for huge development. Finally, the amount of energy required for a transaction on a Blockchain could be a significant problem for every participant, either a company, or a local authority, or a consumer. (Andoni et al., 2018)[3]

In another report, edited by J. Wu and N. Tran, the need for a supervision mechanism is described as a necessity in a Blockchain adoption. However, the biggest problem regards the human

[1] Su, W. and Huang, A. (2019). *The Energy Internet*. 1st ed. Woodhead Publishing, pp.60-62.
[2] Su, W. and Huang, A. (2019). *The Energy Internet*. 1st ed. Woodhead Publishing, pp.62-64.
[3] Andoni, M. (2018). Blockchain technology in the energy sector: A systematic review of challenges and opportunities. *Elsevier*, p.166.

resources. The authors state that there is a shortage in talent as regards the Blockchain development. (Wu and Tran, 2018)[1]

I) Technology Challenges

i) Scalability and Speed

The blockchain technology and its current form cannot meet the necessary requirements of a large volume of transactions, thus it is a question, up until which level this technology can be adopted. Despite the fact that, through a Blockchain, the transaction speed is significantly reduced, it is unclear whether Blockchains are mature enough for a huge number of users. What will happen when a capital, or part of it, like Brussels or Rome start using this new technology?

Blockchain technologies still need to improve, so that they will prove their resiliency for large scale developments. Large memory capacity, fast computing and faster storing speed are highly required because of the amount of transactions that will occur and the large amount of data that need to be restored.

The more participants in the Blockchain, the heavier it becomes to operate. Thus, it is crucial that, if adopted in large cities, there is a need for further development. Several current projects, such as the Energy Web Blockchain, can achieve up to thousands of transactions per second. This is a significant achievement; however it needs better performance and larger development.

The energy industry requires high transaction frequency and dispatching speed, meaning that the current blockchain technologies are far from massive adoption.

[1] J. Wu and N. Tran (2018), Application of Blockchain Technology in Sustainable Energy Systems: An Overview, p. 18

ii) Security Risks

Everything that occurs electronically must be protected from cyber-attacks. Attacks at Blockchains could be frequent, as they store huge amounts of data and are responsible for many transactions. Specifically, Blockchains will have to face many attacks especially at early stages of development, as there will be no such an experience, thus affecting both the system and the consumers. As a result, this could lead to bad publicity and fear from consumers' perspective to participate in such technology.

Furthermore, especially in public Blockchain systems, anyone can be participant, anyone can get accepted and start using it. The lack of identity validation could be a problem, since fraudulent actions could take place in.

As regards the energy industry, any breach that may occur could possibly cause significant trouble for everyone, either a consumer, or the grid itself or the platform.

However, the biggest challenge should be the protection of the data. Participation in Blockchains do not require real identifications, but they are done through email addresses for example. Strict protection measures should be taken so that no malicious user could decrypt and steal data from the system. (Andoni et al., 2018)[1]

As a crucial technology for the implementation of Blockchain technology in the energy sector, IoT technology plays a key role in this issue (Su and Huang, 2018)[2]. It helps the communication among the devices and the interaction among intelligent devices and equipment as well. If anything in IoT is attacked or damaged, it could cost immeasurable problems, loses and malfunctions as regards the platform or the grid. For example, if the information in IoT in energy blockchain is damaged, such as the wind speed or the sunlight intensity, or the home appliances status, it will cause important problems as regards the electricity transmission – which will be automatically happening.

Bitcoin, the first implemented Blockchain platform, has proved to be really resilient to cyber-attacks, however there are some reported attacks to other platforms, such as the Ethereum.

[1] Andoni, M. (2018). Blockchain technology in the energy sector: A systematic review of challenges and opportunities. *Elsevier*, p.166.
[2] Su, W. and Huang, A. (2019). *The Energy Internet*. 1st ed. Woodhead Publishing, pp.62-64.

Protection from this kind of attacks is of high importance, especially when it comes to the energy industry with the current infrastructure. Data security and personal privacy should be highly respected and protected from any serious malicious attack and should be number one priority when building the platform. At present, the creation of energy Blockchains is still in immature level, future problems are difficult to predict, however protection is the main priority.

iii) Development and operational costs

A key challenge that Blockchain in the sector could face is the high development costs. Although there will be cost savings by cutting serious intermediaries, Blockchains still have not proven to be cheaper and competitive to other already existing solutions in several markets. These solutions are already available with low costs to operate. Blockchains could possibly need whole new infrastructure, which will be costly, and will require higher operational expenses. In the energy sector, the connection of smart meters or the grid infrastructure with this technology will come at high costs, which need to break even with other benefits.[1]

The main problem in Blockchains' costs is the validation and the verification of data, as they need high hardware and energy consumed.[2] In addition, there will be high costs for data storage as the number of participants in the Blockchain will be growing and it will need bigger storage capacity.

For example, Bitcoin, the implemented Blockchain, is characterized by huge energy consumption not only for mining this cryptocurrency, but also for validating the transactions. In 2018, a total of approximately 40-80 TWh was consumed for all the Bitcoin transactions, which responds to 0.3% of total energy consumption worldwide.[3] As a result, this has created huge disapproval for this technology posing questions for its reliability. For this reason, Blockchains should be developed with huge cautiousness in order to be more efficient comparing both to the existing alternative solutions and to the current Blockchains as well.

[1] Eurelectric, 'Eurelectric launches expert discussion platform on blockchain' (01/06/2017)
[2] A. Von Perfall, 'Blockchain – an opportunity for energy producers and consumers?', PwC, 2018
[3] G. Kamiya, 'Bitcoin Energy Use: mind the gap', International Energy Agency (05/07/2019)

II) Policy Challenges

The main problems for the implementation of Blockchains will be of policy nature. The whole market will change, but as energy is an important strategic resource for a government and a country, governments must guarantee the efficient and safe function of the market, when Blockchain technology is applied. Key policy challenges will be what a government can do to change the legislative landscape, to ensure the consumer protection, and to break monopolies in the energy industry.

i) Regulation

As regards the policy challenges, the sector will face tough challenges in the regulatory sphere. The energy sector is highly regulated, regulators and policy makers set the rules that every participant has to comply with for better function of the market. Regulatory frameworks need to change in order to adopt this new kind of technology. For example, there is no regulation as regards the energy trading between prosumers and consumers, even though they will be using the main grid. Since the regulation is changed, there should be other changes, for instance, in the contracts for electricity supply. Then, there should be also a change as regards the tariffs, which are highly regulated.

Furthermore, there will be need for a supervising mechanism, which will guarantee the best and the fairest function of the technology and of the market. As Blockchains grow in a fast pace, policy makers will be in position to check exactly the points of the market, where there should be a government mechanism which will be responsible to set the relevant norms and standards.

In general, energy law and policies will change a lot the way the market will function. The current regulation does not allow huge scale implementation of Blockchain technology, however as the technology moves forward, so must do the regulation as well.

ii) Data

After the necessary changes in regulations and policies are made, there must be compliance with the consumer data protection as well. The new GDPR code of the European Union is very strict and regulatory authorities are the sole responsible for the protection of data. Consumer or commercial information between the users of the Blockchain must remain confidential, for example the agreed price between the prosumers and the consumers. Furthermore, there should be also protection of the smart contracts which will execute the transactions, because they may contain valuable information. If shared with third parties, it will be a violation of personal privacy. Finally, smart contracts should be created in accordance with data and consumer protection. Currently, if a consumer faces problem, there is central authority where to address their problems, but in a blockchain system, trust is on the platform itself and not to an authority.

iii) Stakeholders

The key concept of the Blockchain technology is the decentralisation. If applied in the energy industry, Blockchains will allow the energy trading among the participants, neighbors will exchange their surplus when necessary, P2P transactions will replace the current suppliers' activity. This will change the whole market, it will surely affect the activities of the incumbents of the market, the interests of companies operating the national grid and big energy companies in general. As a result, big companies will try to set obstacles to the implementation of new technology, by hindering the creation of energy blockchain companies for instance. The fact that in some countries the grid operation is a monopoly granted by the state is a problem that needs to be overcome. Physical monopolies or regulated monopolies will lose their interests, or part of them, if the industry adopts the Blockchains.

Breaking monopolies in the energy industry will not be an easy task, but it will accelerate the adoption of blockchain technology. It is necessary to change some kind of regulations, otherwise Blockchain in the energy sector will be nothing, will have no advantages to offer. For example, the Energy Law in China clearly states that only power grid companies can sell electricity and that the electricity must be produced in power plants. Such kind of laws need to be addressed and changed, if a government refuses to change regulations which create monopolies, the full

advantages of Blockchains cannot be seen. As a result, the breaking of these monopolies will a key problem for the implementation of Blockchain technologies.

III) Human Resources

Blockchain technology was firstly introduced 10 years ago, however it is the last years that it has attracted the interest of professionals. Therefore, there are some skills that need to be improved so that skilled professionals can be efficient. The job requirements are increasing and the industry's demands for blockchain experts are constantly on the growth. However, the supply demand ratio is 0.15%, so the supply of expert talents is insufficient. As a result, without the appropriate training and the necessary skilled workforce, there cannot be huge implementation of Blockchains in energy industry.[1]

[1] J. Wu and N. Tran (2018), Application of Blockchain Technology in Sustainable Energy Systems: An Overview, p. 18

6. DISCUSSION ON BENEFITS AND RECOMMENDATIONS

From the above, we can see the benefits, the efforts that companies put on their promising projects and the challenges for this sector.

As regards the benefits, we can identify some of them, which have already been put into practice. The transactions for example, they will be made without any third party involved. Blockchain technology will give the ability to everyone to check the real-time production, the prices and the volume of energy needed, and they will choose the suitable option where to buy from. Consumers will not base their demand in one company's supply, but rather they can choose from everyone who can produce even the least. No banks are needed to validate the transaction, no lawyers are needed for legal payments. Therefore, the supply and demand will be completely decentralised and everyone can become part of the market. As far as the CO_2 allowances are concerned, the time needed to issue one is limited, it will happen without state intervention and without all the bureaucratic procedure to check the emissions. The cryptocurrencies related to energy could serve as one more initiative to promote greener technologies and greener means of production. Worldwide, they could help in the energy transition and in the promotion of renewable sources, like solar panels, as small and local producers will find more financial benefits. Finally, business models could also benefit from blockchains as regards billing processes, trading of electricity from production companies or small producers, data management and security issues. However, companies should take into consideration many aspects of this new technology when they choose to incorporate it into their business.

Furthermore, some use cases of the Blockchain technology are described, such as the Brooklyn Microgrid, the Pylon Network and the PowerLedger. From these examples, we can conclude that the Blockchain implementation is really possible, it is tested with huge success. The Brooklyn microgrid project is the biggest and the first experiment in peer-to-peer electricity transactions and it was successful, and as a result the project is going on with significant expectations that will prove the viability of the technology in the energy industry. Several other experiments indicate that the trend is global and in the future more and more companies and individuals will engage themselves in Blockchain technologies. In addition, the fact that there are some experiments not

widely known and with only local benefits prove that there can be benefits even in small scale developments and this will give the opportunity to anyone with good ideas to create a beneficial project.

Social and environmental effects of this topic could be also addressed. As an environmental benefit of this technological breakthrough we could see the promotion of RES. Projects such as the Solarcoin are in favor of RES and as a result will pay anyone who produces from this type. Furthermore, the possibility given to everyone to choose the supplier is crucial. This will help everyone who wishes to buy their electricity produced only from renewables, this will help people with environmental sensitivity. In addition, production from renewables will be promoted as it is the only source in which initiatives could be found. As a social benefit, the most important is that in many cases electricity will be produced, traded and consumed locally, if the project concerns small cities or villages. This means that in any case, the amount of money spent for the electricity will remain in the local community. Moreover, in such a case the prices of the electricity will fall down, as both the production and the transmission will be cheaper. Especially, in small communities, the national grid will not be used and as a result no tariffs will be charged.

However, the industry faces challenges that need to overcome to create the right place. The policy challenges are the main as they are the most difficult to overcome. The reason is that policy and decision makers need to consider every aspect of the industry, consumers, companies, regulators, producers and many others involved. This means that there will always be some conflict of interests in the area and that every point of view is important to them. The necessary changes in the regulation will not be easy and they require careful preparation, that may take time depending on the country. Policy changes need to start from the peer to peer transactions. Regulators must allow the buying and selling of electricity among the consumers. There is no need for someone to cover their demand from the main grid, since they have options from their nearby neighbors. The idea to buy from someone else is the key for the complete decentralisation of the industry, and it will be the starting point for the adoption of Blockchains. The transactions do not refer only to electricity, but also include allowances and data. Blockchains could serve as a decentralised marketplace, however policy makers must allow the trading in such platforms.

To continue, data and consumer protection must be into consideration when changes are applied, because in the end, we as consumers will be the most affected. In this sector, compliance with the

current regulations is crucial. An example is the new GDPR. Customer and any other commercial information need to be confidential. This includes the smart contracts as a whole and the agreed price between two participants of the market. It is also important that smart contracts be incorporated into legal code so that compliance with laws and regulations of a country is ensured.

Moreover, governments could help by increasing the available funds on research and development (R&D). They could also try to make an experiment themselves and in this way, they will be able to engage all the stakeholders of the industry. Better cooperation between governments, businesses and educational institution would also be helpful.

As regards the technology challenges, the technology is not considered to be suitably developed yet, however, there seems to be huge potential. This is proven by the fact that huge multinational companies, like Shell, BP, Total, Engie and IBM, are currently spending funds for further research and development. The developments will not take too much time and in the next years, proper solutions will be found, and further implementation will be possible. Big companies play an important role, but also solutions can be found from the academic community and researchers as well.

With the necessary developments, security risks will not be a problem anymore, the platforms will be resistant to any possible attack or fraudulent actions. This is combined with operational costs of Blockchains. As years go by and further research is conducted, the operational cost will fall down, Blockchains will not consume as much energy as today and they will be completely operational. In this sector as well, cooperation among professionals, companies and researchers will provide useful outcomes and more and more solutions will be found with time.

The market needs professionals and academics to adopt Blockchains. As the experiments go on, we will see what the needed professions are. However, we can now tell that electrical engineers will be on top of the demand list, because they can understand the physical flow of electricity and the operation of the grid. They can perform market simulation, modelling activities to better understand how the market will function. Furthermore, the industry will need IT professionals, who can build the platform, ensure its viability and enhance its cyber protection. They will also be responsible for the further development of the technology.

Data analysts will also be important, because the whole idea of Blockchain is based on data; data collection, data analysis, data sharing. Market research analysts will be responsible for checking the operation of the market and will see where there is need for improvement or what changes are needed.

Last but not least, lobbyists or public relations professionals will also be needed. That is because they are the professionals who can promote the whole idea, who can talk to regulators, businessmen or the people to understand the technology and its benefits. Academic community will also be a key role to promote the science and the research activity around this topic.

Investments in the energy industry need time and money. A pipeline cannot be built in one single day. There is a huge preparation before every work starts. The same applies to the combination of energy sector and blockchains. Blockchain in energy is not something that will happen in several years from now; it is currently happening. Experiments are being undertaken in several countries and they are successful. With time, there will be improvement in this issue and more and more people will start to understand it and get involved. All that is needed is time and effort.

To conclude, all that the energy industry needs in order to adopt Blockchains is time. Current experiments will prove the viability of this idea and when stakeholders, regulators and consumers identify the important benefits of this technology, they will move towards it in a very fast pace. When regulators start to change the rules of the industry in favor of Blockchain adoption, then the energy industry will enter a new era completely different.

CONCLUSIONS

Due to the ongoing evolution of the technology we have seen too many changes in our everyday lives. As the technology goes on, so will the changes in every industry across the globe. As regards the energy sector, this industry has undertaken many changes due to the advancements of the technology. The introduction of the Blockchain and its engagement in the energy sector is characterized as disruptive and as a result it is expected to change many aspects of the industry leading to a new energy landscape.

The contribution of this thesis is to provide the landscape of energy and blockchain. Firstly, it described what the blockchain is and how it works. Then, it reviewed the current literature in order to provide the areas where the blockchain is implemented or experimented now. Next, some notable use cases are presented and described to provide real world projects and their future plans. The interview with Nikos Romanos was really helpful, as he gave his insights as a top employee of a company with blockchain in energy focus.

Blockchain projects face current challenges to achieve market penetration, such as legal, technological and regulatory obstacles. Future experiments will overcome such obstacles for the benefit of the market. Finally, the thesis closes with a discussion on the benefits of this issue and some recommendations to overcome the barriers.

The advancements in the technology will affect the energy industry in the years to come. The energy sector is engaging the Blockchain technology and the next years will prove that the combination is possible. Whole the energy area will change due to this technology and a new industry will be born. Moreover, the way that people face energy will also change because everyone will be affected. The next decade will be challenging and we expect to see the benefits that this technology will bring in the energy industry.

Future work, experiments, collaboration and academic research will prove the viability of this issue and its ability to be adopted in the real market.

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