International Conference on Electricity Distribution

Working Group

Final Report

Blockchain, Transactive Energy and P2P Trading

Working Group 2018-6

June 2020

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Chapter 1. Introduction.

Throughout the preparation of this report, there has been a proliferation of studies and documents that extensively identified the opportunities and transformations that will occur in the energy sector as a result of the adoption of DLT technologies. The purpose of this report is not, therefore, to go deeper into these considerations but to act as an incentive to the CIRED community for the development of studies and projects to test and demonstrate those aspects that today constitute obstacles to the full exploitation of the advantages of these technologies.

The increasing amount of distributed energy resources (DER) is changing the structure of the energy system, as the location and ownership of the energy resources will be increasingly distributed. As the generation is becoming more intermittent (wind and solar), it calls for solutions to harvest flexibility also from small sources within customer premises, and new solutions for using the flexibility also to alleviate possible congestions in distribution network. Furthermore, as consumers are becoming prosumers with their own generation, solutions for their market participation and peer-to-peer trading are needed. Hence, there is a need for new market platforms and related technologies, enabling seamless co-operation of the centralized and decentralized energy resources.

It is necessary to clarify from the beginning that while P2P and transactive energy are business models, Blockchain is a technology that allows their implementation. Blockchain is suggested to be a suitable technology for transactive energy, as it provides distributed ledger and smart contracts that enable for instance secure peer-to-peer transactions and related micropayments. Blockchain is a technology that can be applied for many different purposes, most known being cryptocurrency (bitcoin). There have been pilot projects focusing on applying blockchain in energy sector, for instance for peer-to-peer trading of electricity, but breakthrough of the technology in energy sector is still to come.

The objective of this report is to investigate the opportunities and challenges related to blockchain technology in transactive energy, and role of DSOs (Distribution System Operators) in the implementation of these new technologies and marketplaces. To meet this objective, this report will study the projects, which have focused on the use of blockchain for DSOs, and find out the opportunities and challenges in the implementation of this technology.

The second chapter of this report focuses on the impacts of the blockchain on the energy sector and community energy model concept. Chapter three is focused on the challenges of these technologies , whereas chapter four illustrates the opportunities of blockchain for DSO. Chapter five presents presents what we can observe in the set of projects collected and finally, conclusions and recommendations for further actions will be drawn in the sixth chapter.

Chapter 2: “How Blockchain/P2P/Transactive energy can change the traditional energy process”

To answer the question of how Blockchain/P2P/Transactive Energy technologies can change the traditional energy business, it is necessary to evaluate two aspects: the environment and the maturity of these new solutions.

Enabling environment: the eight drivers

Fighting climate change requires technologies on the supply side (renewable generation) and on the demand side (electrification of mobility, increasing energy efficiency and reducing network losses by bringing generation closer to consumption). But supply and demand must be matched in space and time with specific matching technologies. To match them in space we must use networks and to match them in time we need an array of electric energy storage technologies and flexibility mechanisms.

The development of these technologies on the supply side, on the demand side, and as matching mechanisms has led us to a scenario that includes new situations that did not exist ten years ago:

1. Reduction of photovoltaic equipment costs and prices to customers
2. Reduction of storage costs in batteries
3. Evolution of regulation that favours customer participation and the adoption of self-production solutions
4. Deployment of Smart meters (in some countries such as Spain with 100% levels)
5. Availability of low-cost sensors for monitoring the energy performance of buildings
6. Massive availability of Internet in mobile devices
7. Deployment of high-capacity, low-latency communications infrastructures such as 5G
8. Increasing appetite of customers to new ways of engagement.

The combination of these situations creates an environment of multiplication of technological opportunities for Blockchain/P2P/Transactive Energy solutions.

Maturity of the solutions (technology+regulation+market)

But it is not enough for the environment to be broadly supportive: these solutions need to be available. And maturity can be seen as a vector of three components: technological, regulatory and market.

In terms of technological maturity, which is assessed with the TRL (Technology Readiness Level) scale, Blockchain's technologies are at a TRL8 level. This TRL8 level assumes that the technology has been demonstrated to work commercially through large-scale application. Chapter 5 "Project profiling" of this report lists more than 120 projects that demonstrate this level of technological development.

In terms of regulatory maturity, the Renewable Energy Directive (EU) 2018/2001 sets the framework for renewable energy communities. Some national regulations are admitting P2P solutions with varying degrees of scope, as in France with Law nº2017-224 and the related decree nº2017-676 and in Spain with Royal Decree 244/2019, regulating the administrative, technical and economic conditions for self-consumption of electricity. In addition, there is more needs for demand side management for balancing the demand and supply in power system with growing amount of renewable generation. For instance, in Finland in year 2018, over 70 percent of the frequency-controlled disturbance reserve procured by Fingrid was from consumption [2]. This consumption side flexibility can be aggregated, for instance, from small demand side loads, such as water heaters.

And with respect to market maturity, there is literature on the subject [1] which shows that "a positive attitude towards the environment and production transparency is the single largest predictor of openness towards P2P electricity trading where environmental attitudes are positively related to attitudes towards green technologies and transparency aspects are found to predict participation in community energy or the sharing economy".

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Chapter 3: Challenges for Blockchain/P2P

Currently, the implementation of blockchain projects in the energy sector is faced with a plethora of challenges. Some of these arise because blockchain – or more generally "distributed ledger technology" (DLT) – is a new and still immature technology. Other challenges are based on the fundamentally different governance structure (reduced role of intermediaries) that a distributed and decentralized system requires. And finally, many envisaged blockchain applications touch upon key questions in the current energy system which have emerged over the last decades independently of blockchain.

The subsequent list provides an overview of the primary challenges from various perspectives:

<u>Regulatory challenges</u>

- *Cost recognition for network operators*. As regulated undertakings, European electricity (and gas) network operators, both DSO and TSO, are subject to a cost audit by the relevant regulatory authority. A lack of cost recognition relating to blockchain can arise e.g. when network operators
    - carry out respective innovation or research projects; or when they
    - procure additional services for example in form of flexibility products.

  In both cases cost recognition across the Union may vary which is detrimental to the development of smart/flexible networks in general and blockchain applications in particular. <u>Upcoming relief</u>: Art 32 of the Directive (EU) 2019/944 explicitly mentions incentives for DSO to procure flexibility services (of course only as long as they are cost-effective)

- *Missing business model due to double charging (e.g. network tariffs).* Ideas to implement peer-to-peer trading systems or to make use of flexibility in EV or home batteries are often based on DLT. In the current regulatory framework these projects usually lack commercial viability due to the double charging of network tariffs when e.g. charging and discharging a battery via the public grid. In some cases, this double charging may be justified in substance but one could argue that in cases where such projects provide flexibility services to the system operator no double charging should occur.
  <u>Upcoming relief</u>: Art 15 of the Directive (EU) 2019/944 addresses the double charging issue at least for so-called "active customers".

- *Long lead times in key processes hinder peer-to-peer trading*. Concepts for peer-to-peer trading are based on the idea that prosumers trade energy among themselves depending

on the respective prosumer's over- or undersupply at specific points of time. Buying energy from different entities requires a change of supplier in the current regulatory framework. Lead times for supplier switching currently lie at the level of weeks, which is far too long for a successful implementation of such systems.
Upcoming relief: Art 12 of the new Electricity Directive will require shorter lead times (24h); Art 16 of the Electricity Directive introduces so-called "citizen energy communities" which might provide a more favorable regulatory framework for peer-to-peer systems.

- *Immutability of blockchain/DLT and GDPR*. Many blockchain applications in the energy sector involve the use of personal data (e.g. in the form of public keys used as addresses). The much-praised immutability of blockchain – which holds great value for transparency and auditability – has the big disadvantage that it might conflict with the GDPR's right to be forgotten.

- *Accountability and responsibility in decentralized governance systems*. Typically, (public) blockchains are distributed and decentralized IT-systems which belong to "the users". For many blockchain projects legal and technical accountability are yet to be clarified: who is responsible for maintenance? Who is held accountable if the system fails? Who is accountable for a erroneously triggered Smart Contract? …

- *Regulatory barrier for using calculated values in electricity billing*. According to Chapter 10.5 in Annex I of the Directive (EU) 2014/32 on the harmonisation of the laws of the Member States relating to the making available on the market of measuring instruments, which states: *Whether or not a measuring instrument intended for utility measurement purposes can be remotely read it shall in any case be fitted with a metrologically controlled display accessible without tools to the consumer. The reading of this display is the measurement result that serves as the basis for the price to pay.* This is a barrier for using calculated values in electricity billing. For instance, in energy community, the netting of the self-generation in community and consumption of a community member is not possible, if consequence is that billing would be based on different value than one in presented in meter display.

Technological challenges

- *DLT applications often serve as replacement for relatively new systems*. Potential applications of the technology would often constitute only an upgrade of already existing systems (e.g. reporting systems, guarantees of origin data base, etc.). Updating such existing systems can be expected in due time but are generally considered uneconomical now.

- *Spending of valuable resources, such as computational power or electricity.* Some consensus algorithms (such as PoW or PoS) employ validation mechanisms that consume computer resources and energy. Blockchain's scaling to record all energy transactions could reach the absurdity that the energy cost of recording the transaction could become significant with respect to the energy event being recorded. To reduce this effect, consensus algorithms are emerging such as proof of space or proof of storage require that validator nodes to commit hard drive space to increase their chances of producing the next block and earn its reward. These algorithms generate large datasets known as 'plots' that occupy storage space but can result in significant energy savings and does not rely on investment in expensive dedicated hardware that can quickly become obsolete. In short, these algorithms reduce operating costs in exchange for greater investment in storage capacity.

- *Lack of standardization*. The reliability of energy systems is based on a robust framework of internationally shared standards and specifications that are developed by entities with guaranteed governance systems. DLT technologies, on the other hand, evolve spontaneously so that any changes in the ruling protocols or code needs to be approved by the system nodes. It is quite common to have disagreements between developers leading to what is known as multiple system forks.

Chapter 4: Opportunities

Having seen the overview of how Blockchain/P2P/Transactive energy can change the traditional energy process and the regulatory and technological challenges, it is now time to identify where the opportunities lie. The opportunities arise because DLT and P2P technologies allow for the integration of distributed computing and logging systems with distributed systems for power generation, sharing, and use. The keyword is therefore distributed.

Below are two types of opportunities in the fields of mobility and self-consumption communities.

Blockchain applications in Smart Grids for supporting the Electric Vehicles business

The technological evolutions in automotive, autonomous systems, utilities, communication and ICTs are developing new tools that may allow to revolutionize the mobility culture.

The decentralization of economies through the implementation a blockchains paradigms can become a mainstream that can contribute to develop disruptive business models and value chains propositions. The integration of electrification and mobility business is a key innovation field of the coming years and new business models can be envisaged through the application and development of blockchains technologies.

Blockchain technologies can have lot of applications for the digitalization of a large part of the economic activities of the modern societies. The general benefits arising from their utilization are cost reductions, transparency, extension of the customer groups and new concepts of value proposition [1]. The electric vehicle business is expected to considerably expand in the coming years and reshape the transport business and the urban planning also. This prospect will bring considerable innovation in the value chain of the transport sector with the introduction of new business models and technologies [2]. It is clear that blockchain and electric vehicles business can potentially benefit from synergies that can boost the markets development and new value proposition for the customers. The exploitation of this potential requires innovation and adaptations in the electric distribution networks infrastructures. Higher flexibility and situation awareness, faults management techniques, sources and storages management are some of the critical topics that need to be addressed.

It is, therefore, proposed to discuss potential applications of blockchain technologies in the electric vehicle business and identify the technological development required in the electric networks for the exploitations of these potentials.

The starting point will be the analysis of possible business models (including vehicle to grid and vehicle to vehicle cases, impacts and new roles for DSOs, prosumers, etc.) enabled by the employment of blockchain technologies.

The expected results can be "qualitative" techno-economic evaluations of application scenarios with special focus on the impacts on the technological development of the distribution networks. Particular attention will be given to infrastructures development and to technical needs of innovative products (e.g. power electronics, storage devices) and control and protection techniques that can make the application of blockchain technologies feasible in the next years. The traditional role of DSOs is expected to change due to the introduction of new business models.

In academia there are several papers that generally mention the potential of applying blockchain to electric vehicle but they do not deeply address the specific problem (e.g. [1]-[7]).

The electricity billing seems to be the most common application but even others are appearing in literature [8]-[9].

In [10], a concept-mechanism based on decentralized blockchain system is proposed to manage battery swapping and solve the trust lacking issue. With this solution, both battery's life-cycle information and all operations histories are permanently saved in blockchain network. However several open questions are left to its real applicability. In [11] it is proposed a crowdsourcing-based methods for cyber-physical systems and realtime markets, where small-scale energy generation or energy trading is crowdsourced from distributed energy resources, electric vehicles, and shapable loads. The study is very conceptual with very initial results on the applicability of the concept and technical requirements.

The business environment is also starting to be populated by some start-ups (e.g. [14],[15]) proposing services for electric mobility based on blockchain technologies.

How blockchain can be a tool used by a legal entity to determine the rules for the allocation of the local production to each participant of a collective self-consumption project.

<u>Context</u>: The rise of collective self-consumption in France.

Collective self-consumption: "The supply of electricity among consumers and producers legally bonded by a legal entity and connected to the same LV feeder". The French law already enables collective self-consumption since 2017 (law n°2017-224 and the related decree n°2017-676).

Enedis has developed an industrial solution to facilitate the implementation of collective self-consumption projects. At the moment, some twenty collective self-consumption projects are operational in France and almost a hundred projects are under development.

In addition, the EU Clean Energy Package introduces the notion of Local Energy Communities (LECs). It aims to accelerate the energy transition by allowing consumers to engage directly in the active management of consumption and local production. Collective self-consumption is an illustration of a Local Energy Community. For example: homeowners collectively finance a photovoltaic unit to later share the production while procuring individually missing energy from a contract with an independent supplier. They take advantage of the power produced locally in a collective self-consumption lifestyle.

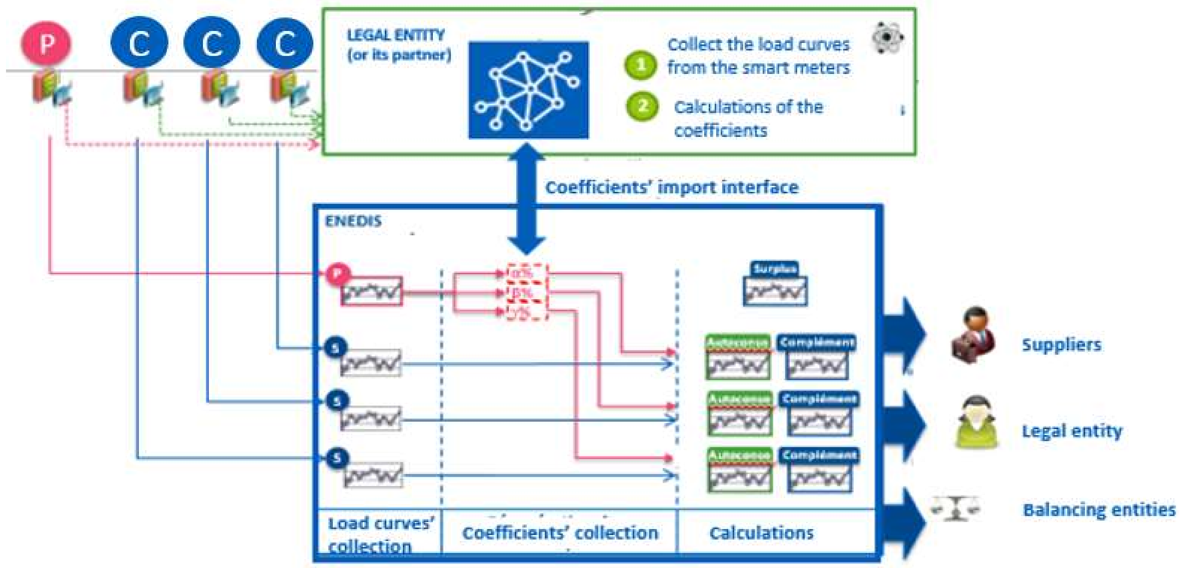
<u>Use case:</u> How blockchain can be a tool used by a legal entity to determine the rules for the allocation of the local production to each participant of a collective self-consumption project.

On one hand, the legal entity in charge of the collective self-consumption project has to determine the rules for the allocation of the local production to each participant (decree n°2017-676). In order to be able to implement these rules, a legal entity can (but it is not necessary) subcontract this role to an external partner and use blockchain technology.

In order to be compliant with the general data protection regulation and the French regulation, the participants must give their consent to the legal entity to have an access to their data in order to monitor the project. On the other hand, Enedis is in charge of providing smart meters to the consumers, and when a collective self-consumption operation has started, Enedis will make the calculations, every month, at the scale of the collective self-consumption project.

The process of those monthly calculations and the role of blockchain used by the legal entity is the following:

Step 1: Enedis collects the electricity generation injected into the grid by the local production and the electricity consumption of each participant regardless generation sourcing. These data organized into load curves are synchronous, today with an elementary step of 30 minutes.



P= Producer / C = Consumer

Step 2: In our use case, every month, the legal entity (or its partner), generates, via blockchain technology, the allocation of local production for the past month for each participant. The legal entity (or its partner) exports a file containing the coefficients generated by the blockchain and save it on a server every month, a day after the end of the month.

Step 3: A web service has been developed by Enedis to have access to this server.

According to these coefficients generated by the blockchain, Enedis calculates the share of production to be allocated to each participant. Enedis then generates the necessary data for collective self-consumption project and provides these data to different stakeholders: manager of the self-consumption operation, residual electricity suppliers, balancing entities.

The use of blockchain allows the legal entity to guarantee transparency and data security of the calculations of the coefficients.This use case including the use of blockchain to determine the rules for the allocation of the local production to each participant of a collective self-consumption project has been experimented in France in 2019.

However, the use of blockchain is not necessary to implement collective self-consumption projects, as 17 projects out of 19 in France do not use blockchain to determine the allocation of the local production to each participant.

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Chapter 5. Project profiling

This working group has identified more than 120 projects related to Blockchain/Transactive Energy/P2P trading. In view of the data collected up to the closing date of the report, we can obtain some observations, which should be considered provisional, since the continuous development of projects in these areas will make it necessary to update this analysis periodically.

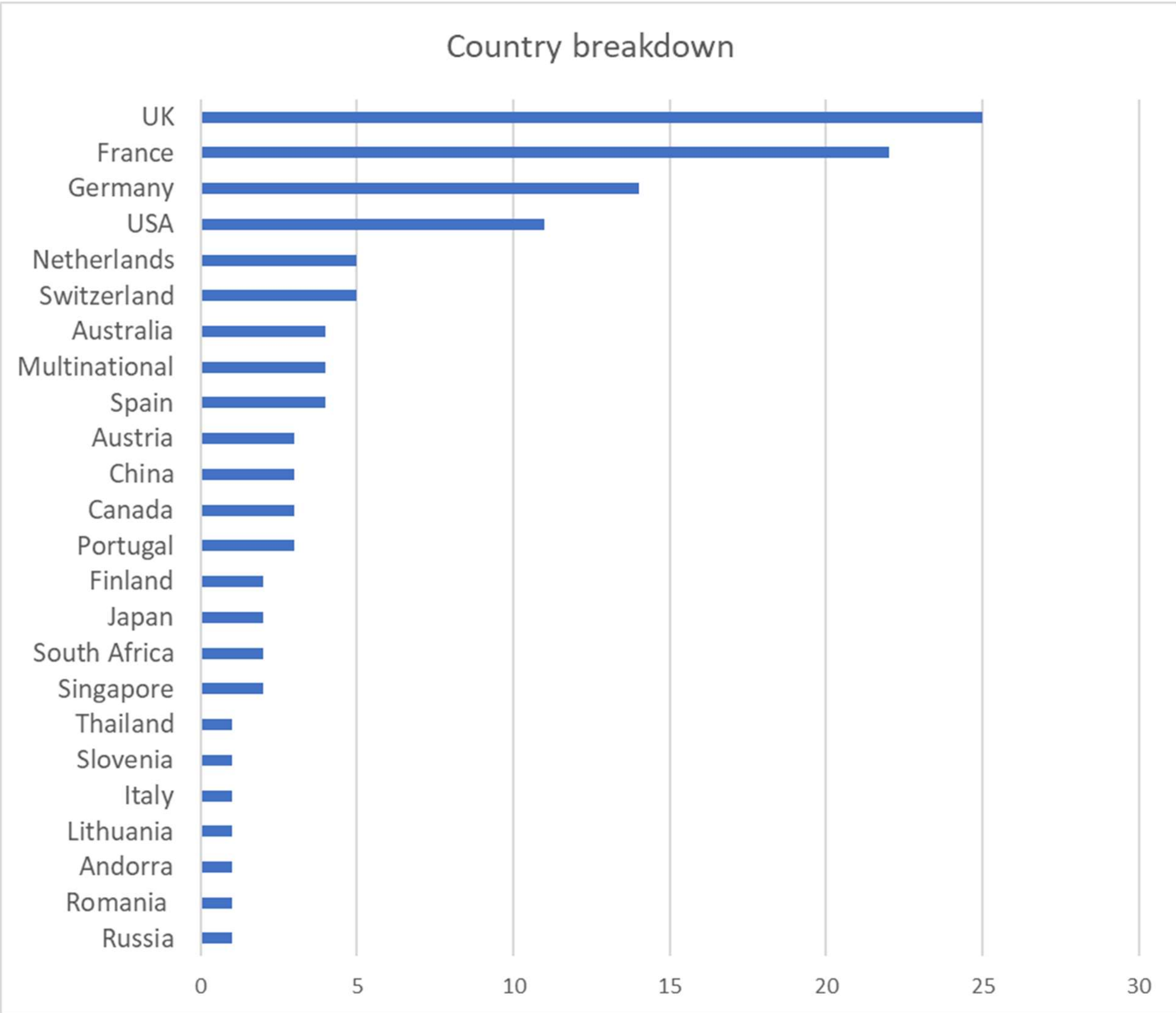

Figure 1 Breakdown of projects according to nacionality of the project leader

The need to update the data is also due to a bias in the collection of projects caused by the composition of the working group. A higher quality of the sample requires wider participation in the working group by incorporating members from other geographical areas (especially Asia).

With regard to the geographical origin of the project promoter (Figure 1), we can highlight the leadership of the United Kingdom, France, Germany and the United States. It should be noted that some multinational projects have been identified, which for practical purposes have been indicated in this report as Multinational.

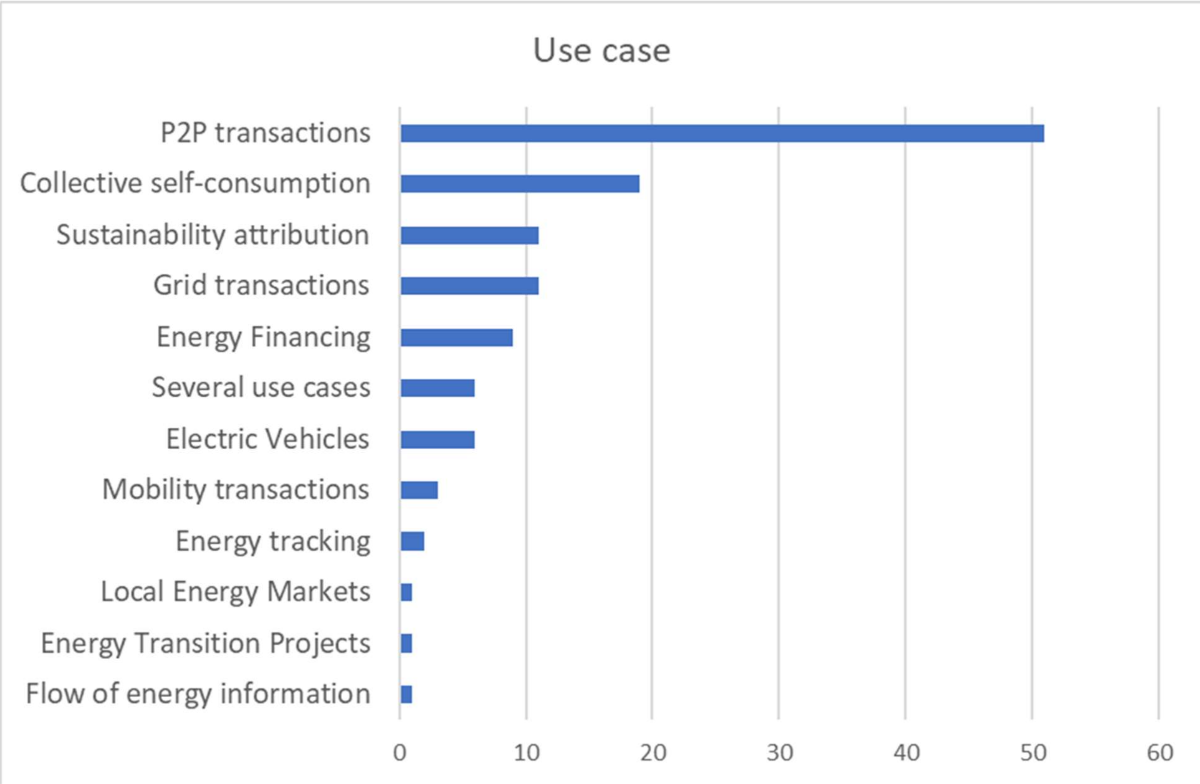

Figure 2 Breakdown of projects according to the use case tested in the project

The most frequently tested use case in the project sample is for peer to peer transactions, followed by shared self-consumption experiences (Figure 2). Some projects combine the testing of different use cases (which have been labelled "several use cases"). The third place in the ranking is for projects on the traceability of guarantees of renewable origin of the energy produced, with a number of projects equivalent to that of network transactions. With regard to mobility projects, not all of them necessarily fit into the "electric vehicles" heading, so they have been referred to as two different categories.

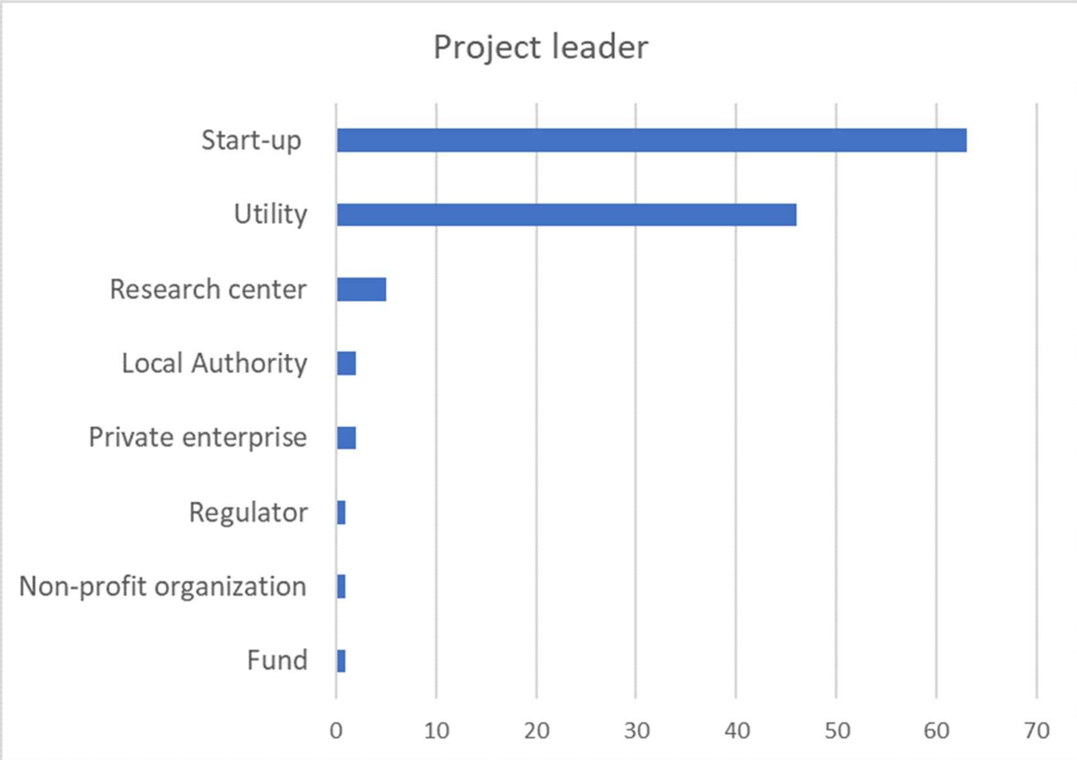

Figure 3 Project breakdown according to the type of project leader

As far as the project leader is concerned (Figure 3), there is majority of projects led by startups, followed by utilities. This might seem to be a symptom of a technology push effect over the market pull, i.e. a solution in search of a problem. It will be necessary to check whether the results of these projects actually reach the market, i.e. whether the TRL9 is accompanied by an equivalent MRL.

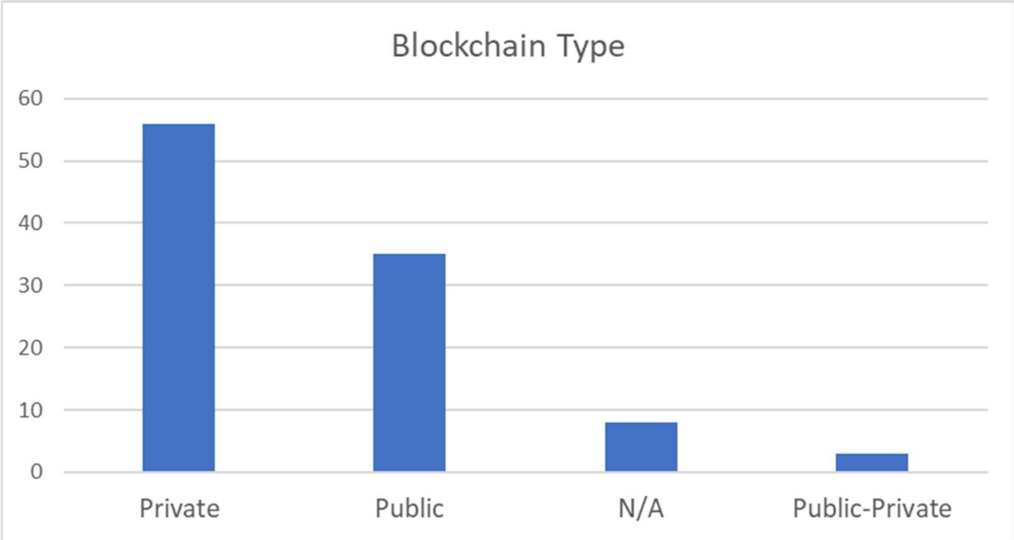

Figure 4 Project breakdown according to the Blockchain type

Most compiled projects using Blockchain use private Blockchain (Figure 4). This type of implementation has a practical objective: it can be developed at a corporate level by the project leader for greater efficiency and optimization of existing operational procedures. They allow the creation of a cooperative environment between companies of the same sector that pursue to implement a de-facto standardization that brings benefits to all its promoters. This is not a new strategy in the energy sector, which is used to the high levels of standardization required by regulated activities. In contrast, projects using public Blockchain are promoted by startups that are more faithful to the public access paradigm linked to the origins of cryptocurrency.

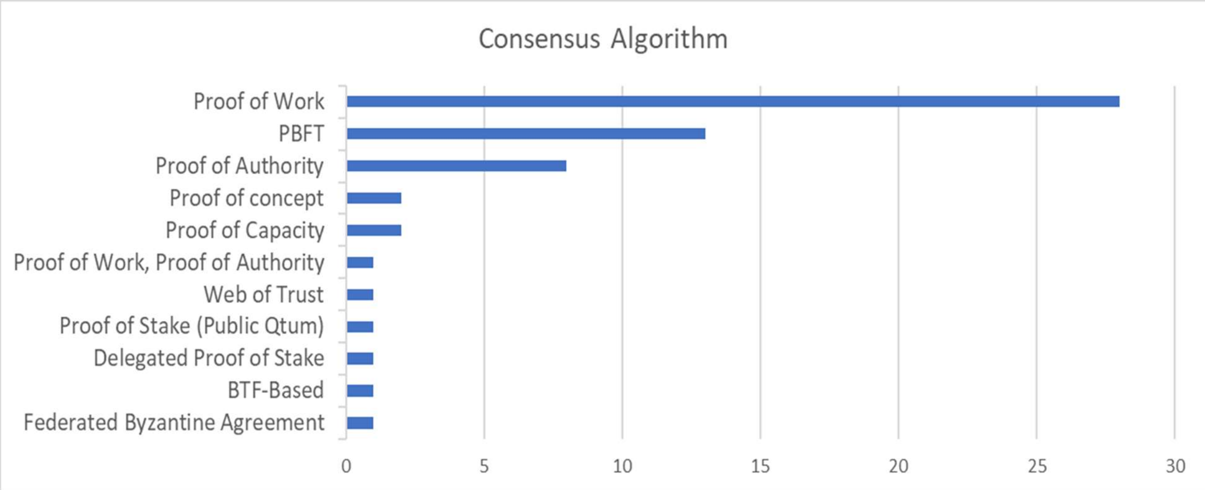

Figure 5 Blockchain project breakdown according to the consensus algorithm

Regarding the consensus algorithms (Figure 5), an overwhelming majority of two of the primitive algorithms (Proof of Work) and PBFT are observed, which are the most used in the oldest projects. On the other hand there is a great variety of other modalities in numerous projects, which evidences the phenomenon of forks characteristic of the communities of developers. This phenomenon is precisely opposite to the vocation of standardization that exists in the electricity sector and evidences a conflict.

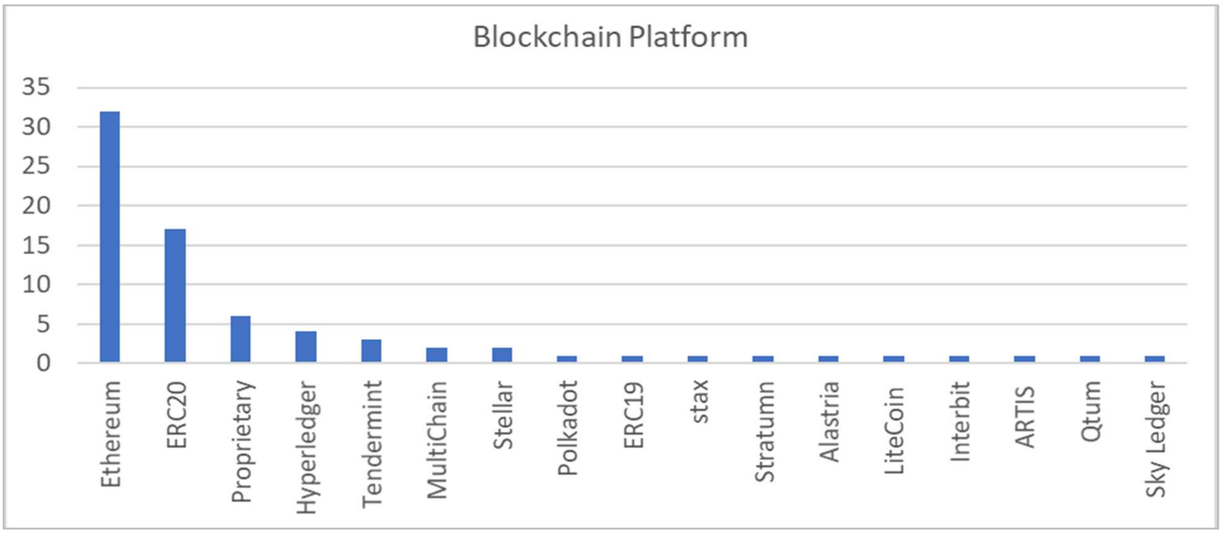

Figure 6 Breakdown of Blockchain platforms

In the case of Blockchain platforms (Figure 6) there is a clear dominance of Ethereum, followed to a lesser extent by ERC20 and an atomization of solutions (some proprietary). This profile may be a sign of a technology that is still in its infancy and where new entrants are trying to solve the drawbacks of the first platforms.

Chapter 6. Conclusions and recommendations

Conclusions

1. The high number of projects that aim to validate the use cases of peer to peer trading and energy communities shows a demand for solutions by the market on a large scale. Scalability and interoperability factors are therefore critical to avoid the proliferation of incompatible implementations in silos.

2. Not all projects developing P2P and Transactive Energy use cases have resorted to Blockchain technology. Blockchain technology was born to provide trust between agents in a transaction, but DSOs are already trusted operators by definition, so in many cases the use of Blockchain does not provide value.

3. Perhaps this trend will lead to the development of solutions that will not meet 100% of the characteristics of the original Blockchain projects and the large operators will use solutions that, guaranteeing interoperability, are not totally public.

4. The power consumption and computing resources of the older consensus algorithms do not seem to be compatible with the high number of transactions required by power systems, nor with the speed required to record records. Projects using such consensus algorithms may not be scalable or replicable in real-world operating environments.

5. The profiles of projects with different consensus algorithms and platforms are signs that Blockchain technology in the electricity sector is still in its infancy and new entrants are proliferating to try and solve the challenges of the first tested solutions.

Recommendations for the CIRED community

1. To evaluate, before launching a P2P project, to what extent the Blockchain technology is really necessary and brings value against conventional technologies (centralized database systems).

2. Advance in the standardization of consensus algorithms that favor interoperability.

3. Develop more demonstration projects to test the effective scalability of consensus algorithms with the lowest consumption of computing resources and energy.

4. Develop projects to measure the improvement of efficiency in the use of computing resources of multilayer DLT schemes.

5. Encourage controlled experimental environments (not necessarily only sandbox type) for use case testing.

6. There is an opportunity within the scope of CIRED to continuously monitor the evolution of this technology and the studies and projects that attempt to provide solutions to overcome technical barriers.

Annex I. Glossary

Aggregator: A legal person which has an agreement with an electricity customer on access to disposing of the electricity customer's flexible consumption and/or generation in the electricity market. The aggregator pools flexibility from customers and converts it for the use by TSO and DSO.

Blockchain: Decentralized, shared and secure list that record transaction from multiple participants. The records of transactions are stored in blocks which are linked each other and secured using cryptography.

Consensus Mechanism: It is a fault-tolerant mechanism that is used in computer and blockchain systems to achieve the necessary agreement on a single data value or a single state the network, among multi-agent systems.

CPO (charge point operator): Responsible for the operation and maintenance of public and semipublic charging stations. Enters into contract with electricity retailer, getting grid access (contact with DSO) and reselling electricity to MSPs that have customers at their stations.

Delegated Proof of Stake (DPoS): It is a type of algorithm by which a network aims to achieve distributed consensus. DPoS utilises distributed voting to elect delegates and witnesses that participate in the validation process. Every member votes to elect a number of witnesses to generate a block. Each witness is assigned a fixed schedule, e.g. every 2 s, to produce a block. The system relies on reputation and dishonest witnesses can be voted out of the system.

Demand-side Management: It is the modification of consumer demand for energy through various methods such as financial incentives and behavioral change through education. Usually, the goal is to encourage the consumer to use less energy during peak hours, or to move the time of energy use to off-peak times.

DSO (Distribution System Operator): It is a legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the distribution system in a given area and its interconnections with other systems to meet reasonable demand for the distribution of electricity or gas.

Energy Source Traceability: Certification process of renewable energies. Tracking the energy supplied from the point of generation to consumption to ensure that the energy comes from a certain source.

ERSE (Entidade Reguladora dos Serviços Energéticos): Energy Services Regulatory Authority. Regulation on Transmission, Distribution, Last Resort Trading, Market equity etc.

Ethereum: Major open-source, public, blockchain-based distributed computing platform featuring smart contract functionality.

EVSE (Electric Vehicle Supply Equipment): Charge point, charge station or charging pole that connects an EV to the grid. Currently maintained by CPO. Each EVSE has its EVSE ID that identifies the station and assigns charging processes.

Feed in Tariff (FiT): In Portugal, there is a regime for Small Production Units (UPP) and Self-consumption Units (UPAC) that feed to the grid. The remuneration system distinguishes between several tariff levels based on the technology used.

GO (Guarantee of Origin): A GO labels electricity from renewable sources to provide information to electricity customers on the source of their energy. The GO is standardized through the European Energy Certificate System (EECS).

Green Certificate: It is a tradable commodity proving that certain electricity is generated using renewable energy sources. One certificate represents the generation of the Megawatt hour of electricity.

Hash: Hash algorithms are used to convert data of an arbitrary length to a fixed length, thereby creating a hash. The hash value represents a checksum which is used to encrypt a message of variable size using a hash function. No two encrypted messages may be based on the same hash value, nor will the hash value provide any clues as to the message content.

Hyperlocal: Relating to or focusing on matters concerning a small community or geographical area.

ICO (Initial Coin Offering): An Initial Coin Offering is the cryptocurrency space's rough equivalent to an IPO in the mainstream investment world.

Market Rate Net Metering: The user's energy use is priced dynamically according to some function of wholesale electric prices. The users' meters are programmed remotely to calculate the value and are read remotely.

Microgrid: It is a small-scale power grid that can operate independently or collaboratively with other small power grids. Any small-scale, localized power station that has its own generation and storage resources and definable boundaries can be considered a microgrid.

MRL (Market Readiness Level): Basic scale that provides an understanding of the status of a technology according to the demand for the products and services.

MSP (Mobility service provider): Responsible for providing access to the charging stations and provide charging services to EV users. In charge of the interface used by EV user and provides tokens for authorization at charging station. Only actor who has direct contact with EV users. MSP responsible for paying CPO.

Nominated electricity market operators (NEMOs): Authorities within countries that must do the coupling of prices both for the day and intraday markets. OMIE is the NEMO in Spain and Portugal.

NSP (Navigation service provider): Offers navigation service to EV users for searching, locating and routing to charging station, showing information about charging station.

Peer-to-peer trading (P2P): It is the direct energy trading among consumers and prosumers. The peers buy or sell energy directly with each other without intermediation by conventional energy suppliers. It is developed based on the "P2P economy" concept and it is usually implemented within a local electricity distribution system.

Power purchase agreement (PPA): It is a contract between two parties, one which generates electricity (the seller) and one which is looking to purchase electricity (the buyer). The PPA defines all the commercial terms for the sale of electricity between the two parties, including when the project will begin commercial operation, schedule for delivery of electricity, penalties for under delivery, payment terms, and termination. A PPA is the principal agreement that defines the revenue and credit quality of a generating project and is thus a key instrument of project finance. There are many forms of PPA in use today and they vary according to the needs of buyer, seller, and financing counter parties.

Proof of Activity (PoAc): It is a type of algorithm by which a network aims to achieve distributed consensus. PoAc is a hybrid protocol that combines proof of work and proof of stake. Block templates that are empty of transactions are generated by miners using a traditional PoW approach. Next, the block is validated by a group consisted of a random set chosen depending on their stake in the system. Block validation is finalised when signatures are collected from all validators in the group.

Proof of Authority (PoAu): It is a type of algorithm by which a network aims to achieve distributed consensus. PoAu can be seen as a modified PoS algorithm, where validators' stake is their own identity. Network members put their trust into authorised nodes and a block is accepted if the majority of authorised nodes signs the block. Any new validators can be added to the system via voting.

Proof of Burn (PoB): It is a type of algorithm by which a network aims to achieve distributed consensus. PoB aims to replicate PoW cost for validation by charging validator nodes, who pay in coins to earn the privilege of validating blocks. Validator nodes commit coins that are 'burned' and cannot be reclaimed to increase the chance of being selected by the random selection process. Validation depends on the willingness to waste money, as a result PoB results in unnecessary wastage of resources.

Proof of Capacity (PoC) :It is a type of algorithm by which a network aims to achieve distributed consensus. PoC and other variants known as proof of space or proof of storage require validator nodes to commit hard drive space to increase their chances of producing the next block and earn its reward. PoC generates large datasets known as 'plots' that occupy storage space. PoC can result in significant energy savings and does not rely on investment in expensive ASIC hardware that can quickly become obsolete.

Proof of Elapsed Time (PoET): It is a type of algorithm by which a network aims to achieve distributed consensus. The algorithm aims to replicate a fair and random block generation process without spending valuable resources, such as coins, computational power or electricity. This is achieved by utilising new CPU instructions and a trusted execution environment. Validator nodes request a waiting time from a trusted function in a general-purpose processor. The node with the shortest wait time produces the block.

Proof of Stake (PoS): It is a type of algorithm by which a network aims to achieve distributed consensus. An algorithm proof-of-work-based uses mining, that is, the solving of computationally intensive puzzles to validate transactions and create new blocks.

Proof of Work (PoW): It is a type of algorithm by which a network aims to achieve distributed consensus. The algorithm requires some work from the service requester, usually meaning processing time by a computer.

PBFT (Practical Byzantine Fault Tolerance): It is the ability of a distributed computer network to correctly reach enough consensus despite malicious nodes in the system failing or sending out incorrect information.

Roaming (EV Roaming): It represents the possibility for the customer of an e-mobility service provider to easily access to the infrastructure of any other infrastructure operator while travelling. This access includes primarily the possibility of locating charging points, to know if they are available, to book a charging spot if possible, to be allowed to recharge and set the price of the recharge through its contract with his e-mobility service provider.

Smart Contract: It is an agreement between two or more parties that allows the transfer of whatever is being transferred (money, energy, etc.) under some predefined and customized conditions (maximum price to pay, time of the day, certified supplier, payment conditions, contract cancellation conditions…) and with a high level of automation.

Smart Meter: A smart meter is an electronic device that records consumption of electric energy and communicates the information to the electricity supplier for monitoring and billing. Smart meters typically record energy hourly or more frequently, and report at least daily. Smart meters enable two-way communication between the meter and the central system.

Transactive Energy: It refers to the economic and control techniques used to manage the flow or exchange of energy within an existing electric power system regarding economic and market based standard values of energy. It is a concept that is used to improve the efficiency of the power system, pointing towards a more interactive future for the energy industry.

TSO (Transmission System Operator): It is an entity entrusted with transporting energy in the form of natural gas or electrical power on a national or regional level, using fixed infrastructure. Due to the cost of establishing a transmission infrastructure a TSO is usually a natural monopoly, and as such is often subjected to regulations.

Vehicle-to-Grid (V2G): It is a system that enables plug-in vehicles to act as a form of distributed energy storage by providing demand-response services to the power grid. The batteries in parked vehicles can be used to let electricity flow from the car to the distribution network and back.

Annex II Further reading

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