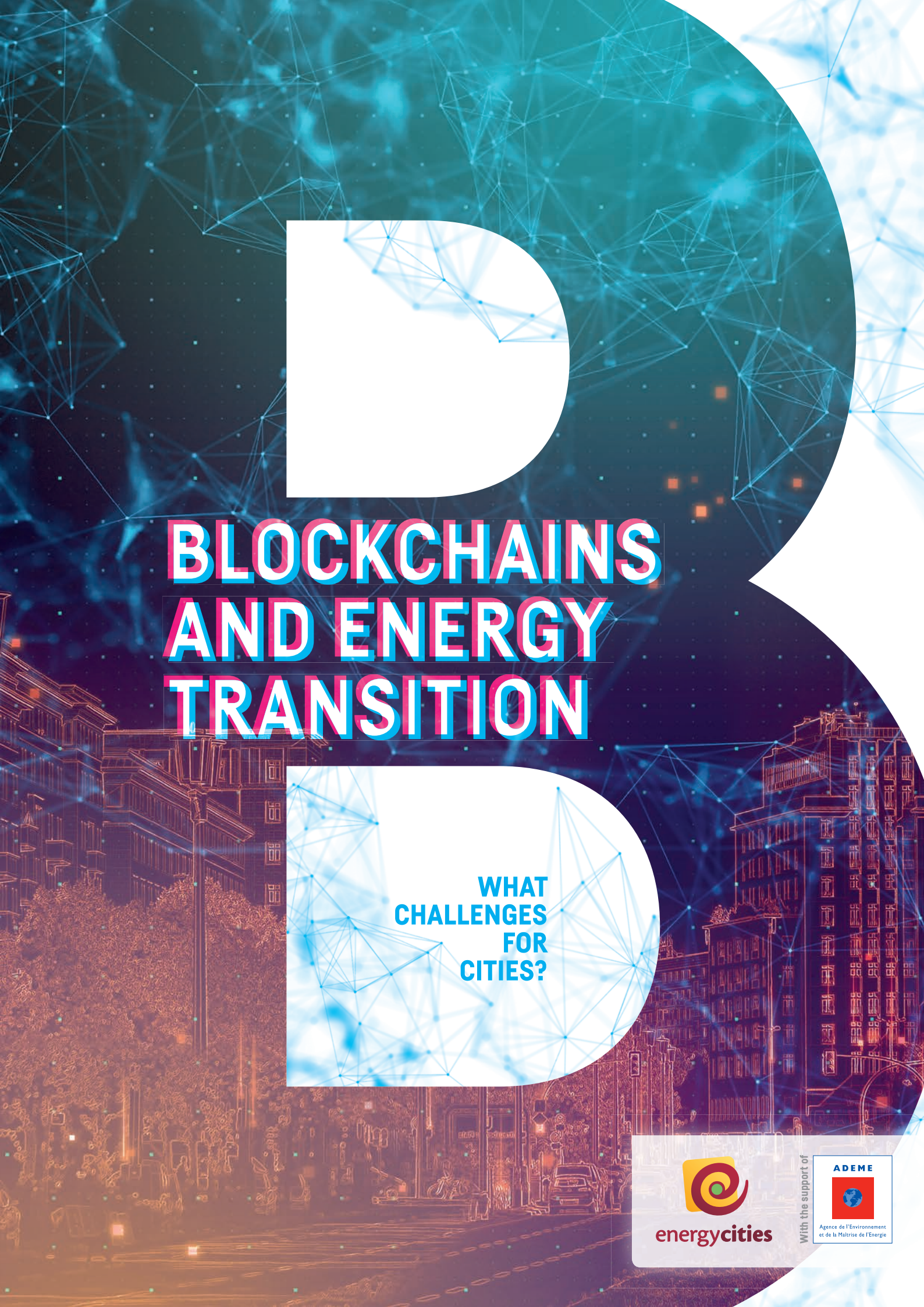

BLOCKCHAINS AND ENERGY TRANSITION

WHAT CHALLENGES FOR CITIES?

energycities

With the support of

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Agence de l'Environnement et de la Maîtrise de l'Energie

TABLE OF CONTENTS

INTRODUCTION

The objective of this exploratory note is to provide an outline of the experimental use of blockchains in the energy sector by local authorities: to what extent can blockchains influence the energy transition of cities? How could this technology help cities and their inhabitants become energy producers and use all or part of the energy produced for their own consumption?

This exploratory note describes the types of energy this technology could be applied to, as well as its potential uses at the local level. Many experiments have already been launched by public and private players, for example with regard to municipal buildings, for transactions between private players or in the energy sector for e-mobility applications.

The opportunities and potential issues of blockchain technology for local authorities will be addressed. We will also look ahead to determine whether and when mass use of this technology at the local level could be viable.

DEFINITION

Blockchain is a transparent, secure technology used for storing and transmitting data which does not require a central controlling system (definition by Blockchain France). By extension, a blockchain is a database that contains records of all the transactions that have been made by users since its creation. This transaction ledger is secure and distributed: it is shared by all users, with no intermediaries, which means everyone can verify the validity of the chain.

Instead of being stored on a central server, this ledger is distributed across many computers in a peer-to-peer network – this means users have to allow open access to the data hosted on their servers. It uses cryptographic techniques: it is indelible and decentralised. Users' computers therefore keep a log of all transactions. It is the large number of participants who create this chain and play a verification and validation role (previously played by intermediaries or "trusted third-parties"). To operate, the blockchain only needs computing power. A number of platforms are used for blockchain projects. Ethereum and Hyperledger are two widely used ones, which justifies looking at them more closely.

HYPERLEDGER

Hyperledger is an open-source initiative led by the Linux foundation in partnership with significant industrial players like IBM, Cisco, Intel, JP Morgan, SAP, etc. Hyperledger aims to reinforce the use of blockchains in different industries and has been working to that end with players operating in various sectors: the Internet of Things (IoT), finance, supply-chain management, ITC and other sectors.

This initiative aims to standardise the use of blockchain for business to mainstream its commercial adoption. Hyperledger is not just a platform; its role is somewhat more of bringing together several communities of software developers who want to use this blockchain platform to structure their projects. Hyperledger Fabric is a framework provided to develop blockchain solutions specifically designed for private businesses. This distinguishes Hyperledger from other platforms like Ethereum or the virtual currency Bitcoin, which are based on public blockchains open to all.

Hyperledger Fabric has the following features:

- **It is a private blockchain:** an access right is required to access the network; membership is controlled and regulated by a central authority/intermediary.

- Transactions are confidential: businesses using a private blockchain benefit from the flexibility and security of making their transactions visible only to those with the correct encryption keys.

- In theory, no virtual currency is necessary to operate the blockchain: no mining (i.e. the process by which transactions – e.g. Bitcoin – are secured) and no algorithms are required to secure the transactions.

- Finally, the process is programmable: a programming logic can be introduced into smart contracts, thus automating business management processing across the company network.

It is important to clarify the term 'smart contract' as it may lead to confusion. In "La Blockchain décryptée – les clés d'une révolution" published by Blockchain France, smart contracts are defined as "autonomous programs that, once started, automatically execute predefined conditions of the type "if - then" ("If" a condition is met "then" it executes). They offer three main advantages: increased speed, improved efficiency and the certainty that the contract will be executed as agreed. Such programs can overcome moral hazards and reduce verification, execution, arbitration and fraud costs".

ETHEREUM

Ethereum is an open-source initiative developed by the Swiss-based Ethereum Foundation. This initiative uses its own virtual currency called Ether. Ether is the most widely used virtual currency after Bitcoin.

The Ethereum platform is based on the principle that its blockchain is public and open to all. It can be viewed as a virtual machine designed to remotely supply all the services of a computer, like a distributed cloud.

What are Ethereum's main features?

- Ethereum allows its user network to create smart contracts based on the principle that the Ethereum software is simultaneously active across thousands of decentralised computers. The program is autonomous and executes the contract's (pre)defined conditions. With this system, the contract cannot be modified by a single player.

- The concept of decentralised application (Dapp) is key to the Ethereum platform: it is a totally decentralised open source application that uses a cryptocurrency (like Ether or Bitcoin, a precondition to access a Dapp), operates autonomously with no authority controlling the currency issued and stores data on a public, decentralised ledger (no central coordination point). Dapps reward their users ("miners") for validating new insertions in their public decentralised ledgers with tokens of their cryptocurrencies.

- **Transactions are public and open to all** (public blockchain).

- Ethereum uses the **proof-of-stake system:** the system randomly chooses which user will create the next block, based on factors like the amount of virtual currency (cryptocurrency) they possess (the stake). The user chosen by the system then adds a block to the blockchain and will be rewarded once the other users in the network have validated the new block (consensus mechanism). This proof-of-stake system differs from the **proof-of-work system:** for a user to add a block to the blockchain in a proof-of-work system, they have to perform a series of computations that are both time- and energy-consuming (e.g. hashing algorithms or solving mathematical puzzles) in order to validate the transactions and add a new block to the blockchain (once the work is done). The proof-of-work system favours users with very powerful computers capable of executing these computations.

The proof-of-stake system is by design less energy-intensive than the proof-of-work system, since no time- or energy-consuming computations are required.

CURRENT SITUATION

Everybody watches, few really understand and nobody knows exactly what the future of this new way of authenticating and securing transactions will be. Some observers, however, do not hesitate to describe blockchain technology as the "second digital revolution", on a par with the advent of the World Wide Web in the 1990s.

A raft of key international players like the UN or the European Union have even started to take an interest in it. According to the Gartner Institute's "hype cycle"[1], blockchain technology is in the peak of inflated expectations category.

At the same time, local authorities have to face fundamental changes in the energy system, namely a decentralisation of the system driven by the mass deployment of renewable energy, storage systems and smart grid solutions. The energy sector has not yet experienced its "Uber"[2] moment, but is not far from it. The challenge is to prepare local authorities to tackle these transformations and use them to improve their situation and that of their populations – notably by implementing a collective, fair self-consumption energy system with decentralised microgrids producing, consuming and sharing energy with their neighbours.

Can blockchains help local authorities tackle the fundamental changes affecting the energy system? Can they help them implement processes for producing, using and sharing their own (green) energy in decentralised microgrids, while engaging citizens? Before considering following this path and using blockchain technology in their local projects, **local authorities should ask themselves the following key questions:**

- What is the energy challenge/issue I have to face in my local area?
- How can I solve this problem?
- Why should I need a blockchain to solve this problem?
- Would it possible to solve the problem without a blockchain?
- What is the business plan for my blockchain project?
- How does my blockchain project benefit the local area and local players more than a conventional solution?
- What role am I ready to play as a local authority?
- What are the financial and energy costs of implementing a blockchain project vs. implementing the project without using blockchains?

These questions will be addressed as far as possible in the section analysing blockchain project examples. The opportunities and potential issues a local authority should consider when contemplating using blockchain technology as part of its energy policy will also be tackled, before presenting the prospects of blockchain technology in the energy transition of cities.

1 The cycle describes the various phases of public interest in a new technology / 2 A reference to Uberisation, which designates a business model in which service providers and customers are put directly, and sometimes instantaneously, into contact, using computing platforms

APPLICATIONS IN THE ENERGY SECTOR

Until recently, blockchain technology and its ability to measure, store and certify data with no need for an external service provider have been mainly used in the finance industry to reduce the cost and complexity of financial transactions.

But other sectors like the music industry, the media and even the shipping industry are considering blockchains to develop new applications and improve their services (for example, the port of Antwerp aims to use blockchains to make its container shipping services more fluid). How could blockchains benefit local energy? Below is a review of possible blockchain applications in the energy sector.

TRANSACTION PROCESSING

Blockchains can be used as the main IT solution to process energy transactions efficiently and at a reduced cost with no need for a traditional central controlling body, like an energy service company (ESCO), to guarantee the reliability of the process. Each energy transaction is recorded and stored by the blockchain on all the computers (nodes) which form its network (e.g. a microgrid). All the participants are informed of each transaction in real time and their computers control the others to prevent fraud. Transaction processing can also be automated and made even more efficient and less costly by implementing a smart contract system, and, in a future stage, using autonomous decentralised applications (Dapps) requiring no human intervention.

Examples: Sunchain, Brooklyn Microgrid, Tal.Markt, Power-ID

DOCUMENTING ASSET OWNERSHIP AND MANAGEMENT

Blockchain technology makes it possible to record and store all energy flows and transactions in a distributed and secured way. It can also be used to document at any given point in time which users have energy, how much energy they have produced, sold or bought and the evolution of their energy assets/portfolio (asset management). All this is carried out transparently and every stakeholder – ESCOs, distribution system operators (DSOs), transmission system operators (TSOs), energy community organisations, local authorities through their energy departments or Stadtwerke, etc. – has access to this indelible and forgery-proof data at any time. A record of all the transactions can therefore be created (proof of existence), which is essential from a legal and judicial point of view in case of disputes. Depending on the type of blockchain (public or private), the identity of the members is either known (public blockchain) or anonymous (private blockchain).

Examples: Gruenstromjeton, Sunchain, I-NUK

ENERGY CERTIFICATION AND VERIFICATION

This documentation capacity of blockchains could change energy certification and verification practices, especially when applied to guarantees of origin and emission trading systems (like the EU ETS). In Europe, renewable energy guarantees of origin are often false and fraudulent; they in fact include fossil energy and allow companies to indulge in greenwashing. Blockchains can verify the provenance and type of energy anytime in a tamperproof way (real-time auditing) and create a record of ownership for each renewable energy certificate. This process is transparent and cannot be altered, thus facilitating management of these certificates. It can also be used to record, certify and validate emission trading between players in the system, an approach that is being implemented in China by IBM and the Energy Blockchain Lab.

Examples: Sunchain, Pylon Network Project, I-NUK

REAL-TIME MONITORING AND ANALYSIS OF ENERGY USE

Blockchain can also be used as a control and monitoring system by local authorities or citizens to monitor their energy use in real time and transparently via a smart meter. Thanks to the specific data supplied by the blockchain, local authorities can analyse and identify their most energy-intensive buildings requiring energy retrofitting.

Blockchain could also facilitate the exchange of data between various players in an energy system. With the expected development of IoT over the next few years, local authorities will be able to obtain an ongoing diagnosis of all their energy facilities (energy producing units, smart grids, etc.).

A blockchain in permanent communication with these connected objects which uses smart contracts and Dapps (using procedures predefined by technicians) could in theory manage a local authority's energy infrastructure, with no need for direct human intervention.

Examples: DAISEE, Pylon Network Project, Gruenstromjeton

INVOICING AND ALLOCATION PROCESSES

Another blockchain application in the energy sector concerns invoicing. The capacity of the blockchain to create a distributed data transaction ledger can be used to produce a comprehensive energy, heat and water use archive. By combining a blockchain with a smart meter, local authorities would then be able to better control their energy use and their contractual relationships with their suppliers. This is due to the fact that the blockchain makes energy consumption and invoicing transparent, thus preventing suppliers from invoicing local authorities for unused energy, for example. Blockchains would also benefit citizens by giving them more leverage with their suppliers and by reducing the risk of fraudulent overbilling practices.

Blockchains can also make the allocation of network management costs more flexible and can monitor their development in real time. A blockchain using smart contracts and Dapps could be used to allocate management costs between its users according to their energy use and type of supply. Let's take the example of a decentralised network with many solar energy producers and users. A sunny day will mean virtual self-sufficiency for its users, who will only have to pay management costs for their own network. But on a sunless day, they will have to buy energy from outside the network (from the grid, for instance) and will then be required to also pay management costs for using this external network.

Examples: Gruenstromjeton, Power-ID

REMUNERATION IN A REAL OR VIRTUAL CURRENCY

Blockchains can also be used to shake up the remuneration system in the energy sector, using either a real or virtual currency (like Bitcoin or Ether). Although feed-in tariffs and net-invoicing programmes have largely contributed to the development of renewable energy in Europe, many observers consider that these remuneration methods are no longer efficient and flexible enough to encourage mass renewable energy production and consumption. Smart contracts could facilitate the implementation of an automated, flexible mechanism capable of remunerating prosumers in real time and adjusting demand when necessary (demand response). This mechanism would also make energy micro-payments possible for virtually zero overhead costs and at very short time intervals (every 15 minutes for instance), since the presence of a traditional intermediary like an energy service or payment company will no longer be required to handle cash flows and transactions. In a local context like a local authority-community energy partnership, the energy supplied to the local authority could be paid for in a local cryptocurrency linked to the local currency. The local authority could then make a profit from mining local cryptocurrency and reinvest it in the local economy or to combat fuel poverty. Although this scenario is not very common among European local authorities, the city of Hull in England e.g. has already created its own cryptocurrency (HullCoin) and reinvests all the profits from mining in its social policy to reduce poverty within its territory. Vulnerable citizens in Hull do volunteer work and are paid in HullCoins, which they can then trade for hot meals at the local food bank for example.

Examples: SolarCoin, Gruenstromjeton, NRGCoin, Brooklyn Microgrid

CREATION OF AN ON-LINE MARKETPLACE FOR LOCAL/REGIONAL ENERGY

Another possible application would be to use blockchain technology in a local or regional on-line energy marketplace. The local authority would then take on a new role, that of intermediary, by serving as a matchmaker and coordinator between local energy producers and citizens. An on-line blockchain platform managed by the local authority would list the various local energy producers and their offerings, thus helping citizens choose an affordable energy mix. This energy service would not only contribute to tackling fuel poverty, it would also help keep the economic value of energy within the local territory, since all the transactions would take place at the local or regional level. Another advantage is that small energy producers would no longer have to use wholesale markets to sell their energy, but would be able to sell directly to citizens (retail market). The indelibility, transparency and efficiency of the blockchain would guarantee the stability of the platform's transactions.

Examples: Tal.Markt, Power-ID

PEER-TO-PEER RENEWABLE ENERGY TRANSACTIONS IN A DECENTRALISED SYSTEM

Blockchains could also be used to organise peer-to-peer transactions and collective self-consumption in a decentralised system. Thanks to the digital trust provided by blockchains, such a system would enable its members – producers and consumers alike – to trade energy in a manual or automated way (smart contracts) within a harmonised and secured framework using a virtual or real currency. Smart contracts would regulate energy consumption and production in real time. Network participants would also benefit from much shorter energy transmission distances compared to a centralised system, thus reducing energy waste and costs (e.g. marginal cost). Smart contracts would guarantee the stability of the system by independently handling energy storage, the balancing market and the balance between energy supply and demand.

Examples: NRGcoin, Power-ID, Brooklyn microgrid

OFFSETTING CO2 EMISSIONS AND REWARDING THE IMPLEMENTATION OF SUSTAINABLE MEASURES

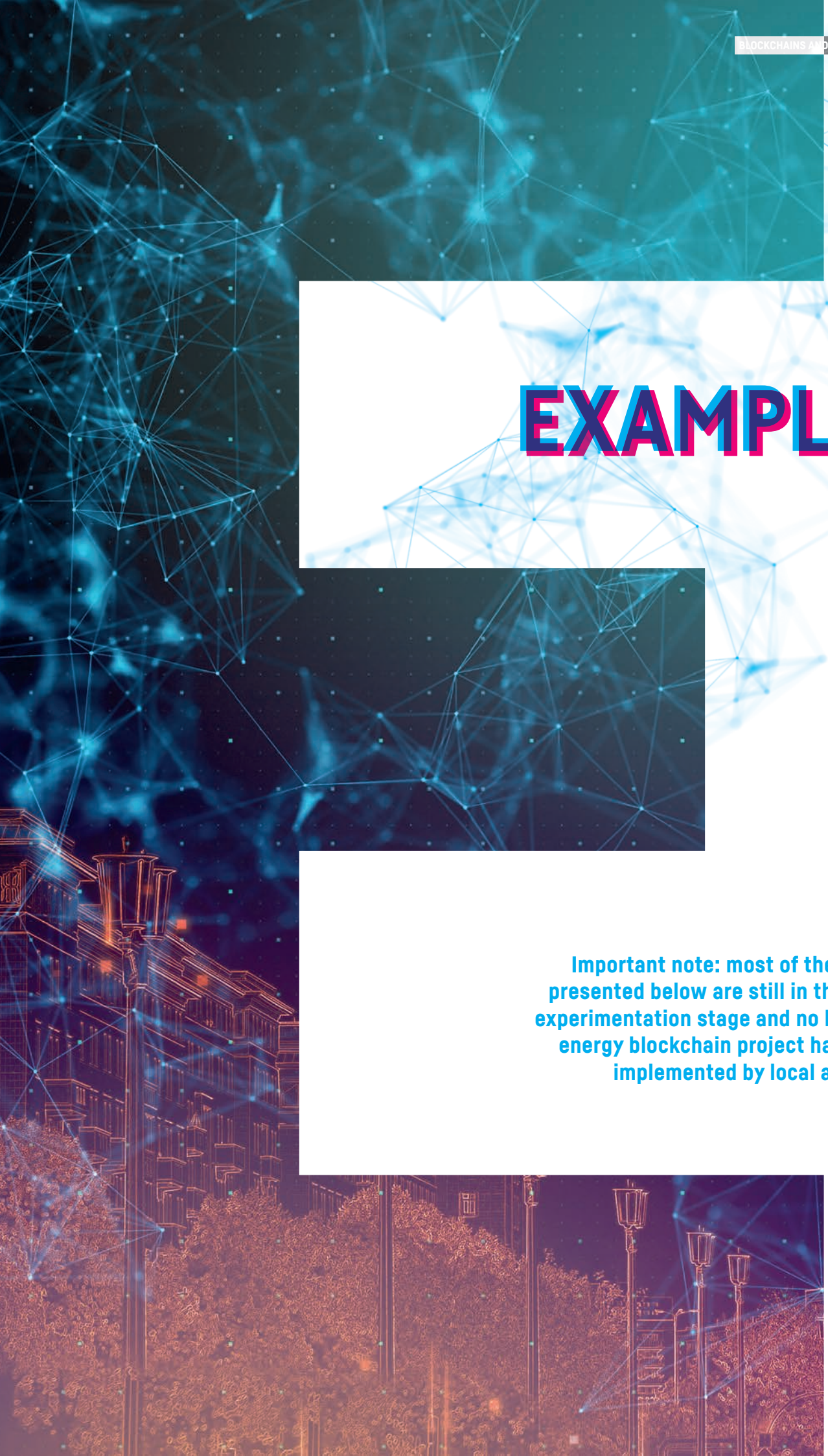
Transforming renewable energy into carbon credits and selling them on the market or offsetting a carbon intensive activity (like flying): all this can be made much more practical and easier to execute and monetise (in real or virtual currency) with blockchain technology. A blockchain application/platform can rapidly and automatically convert these activities through a smart contract system securely and transparently.

Examples: I-NUK

FACILITATING THE DEVELOPMENT OF E-MOBILITY AS A SERVICE

Finally, blockchains can facilitate the development of e-mobility as a service thanks to the implementation of a simpler (in one click) and less expensive recharging system compared to existing solutions. They could also "uberise" and facilitate direct car hire between owners thanks to innovative payment systems like pay-per-use. Blockchains could also be used to manage mass data flows generated by autonomous cars via dedicated exchange platforms and help local authorities – in partnership with researchers – use these data to improve their urban transport infrastructure.

Examples: Sunchain



EXAMPLES

Important note: most of the examples presented below are still in their pilot or experimentation stage and no large-scale energy blockchain project has yet been implemented by local authorities.

EXPERIMENTS IN THE PYRÉNÉES ORIENTALES DEPARTMENT – TECSOL

COUNTRY

France

NAME

Sunchain solution – Collective self-consumption in the Pyrénées Orientales department

INITIATOR/PROFILE

Sunchain – a TECSOL start-up

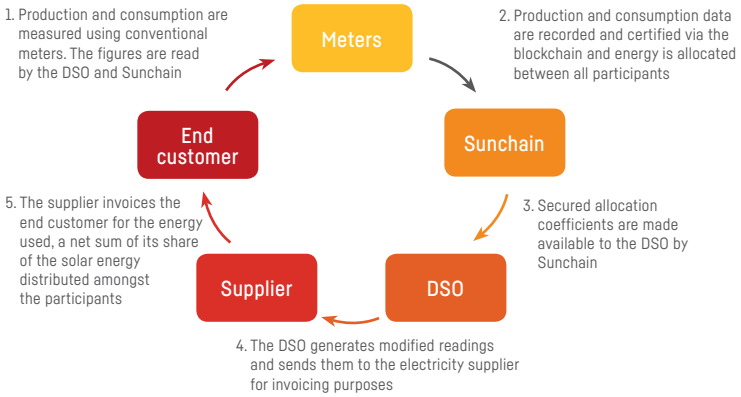
This young start-up creates virtual networks of producers and consumers using electricity meter data. Solar production and the participants' electricity use are encoded, signed and recorded in a blockchain.

Electricity allocation between the participants is automatically executed and certified based on tamperproof conditions programmed in the blockchain.

DESCRIPTION

Uses the Linux Foundation's Hyperledger Fabric open source platform. It is a "closed" blockchain with a limited number of players. This solution computes and communicates to the distribution system operator (DSO) Enedis the allocation coefficients used to distribute the energy produced between the participants in the self-consumption operation.
(see architecture below)

Sunchain Solution Architecture



Source: Sunchain

This project is covered by an experimentation agreement with Enedis

Types of applications considered:

- Solar electricity in social housing and housing developments – 1,000 flats and/or houses
- Solar electricity on close detached buildings
- Solar electricity for recharging electric vehicles (roaming)

RESULTING INNOVATION

- Certified transactions
- Traceable solar kWh and ability to invoice each housing unit for its actual share
- Automatic transfer to the DSO's software
- Automatic transfer to the DSO's software
- Facilitates the integration of solar energy into municipal buildings with various uses

FOR FURTHER INFORMATION

www.sunchain.fr

DAISEE BY MYNE

COUNTRY

France

NAME

A community energy data company in Prats-de-Mollo (1,100 inhabitants – Pyrénées Orientales)

INITIATOR/PROFILE

DAISEE
Open design programme for people who consider Energy as a Common(s).
This is not a start-up but a research community/programme led by Myne (a third place based in Lyon and an open community laboratory conducting transition research and experimentations) and Cellabz (which works on emerging technologies and aims to develop field experimentations and debunk myths about blockchain technology).

DESCRIPTION

The municipality of Prats-de-Mollo has pledged to move towards energy autonomy. In July 2017, a semi-public company (SEM), Prats'ENR owned by the municipality (60%), the municipal electricity company (20%) and a group of citizens (20%) was set up.

In order to answer a call for community energy and self-consumption projects from the Occitanie Region and ADEME, DAISEE became the SEM's R&D subsidiary.

The idea is to assist local authorities in their path towards energy self-sufficiency using blockchain technology.

The objective is to develop a distributed model that contributes to energy data management, citizen ownership and building grid governance.

In Prats-de-Mollo, DAISEE has several motivations:

- technical: communicating meters, data infrastructure and physical infrastructure
- community: diversified energy mix, encouraging citizens' participation and involvement in energy management
- scientific: setting up an experimentation framework so as to be constantly ahead of existing practice and use it as a test bed.

DAISEE's role is to:

- connect and help local players come together
- produce knowledge and know-how that will inspire other local authorities to follow suit
- above all, empower people to take action.

RESULTING INNOVATION

The community of DAISEE contributors is currently working on three aspects:

- 1 Hardware
- 2 Software (Ethereum and other technologies providing a distributed, secured and transparent system)
- 3 Network infrastructure and governance

This blockchain was designed taking local needs into account.

FOR FURTHER INFORMATION

www.daisee.org

I-NUK

COUNTRY	**France/International**
NAME	**I-NUK**
INITIATOR/PROFILE	**I-NUK** is a young French start-up which aims to shake up the carbon credit systems by creating a blockchain application enabling individuals to offset their daily carbon emissions easily and reinvest them in the construction of new solar power stations.
DESCRIPTION	I-NUK uses the Ethereum public blockchain in its application. Offsetting users' emissions requires computing their equivalent in green power. To do so, I-NUK uses a methodology that was developed by the UN and is recognised on the carbon credit markets. The I-NUK application computes in real time the carbon footprint of all sorts of daily activities, like taking a cab, having goods home-delivered, shopping or travelling by plane. In addition to this carbon offsetting activity, I-NUK also works with small solar energy producers (including local authorities) in France and abroad with installations of between 200 and 300 KWh to help them monetise their energy production. The energy produced is certified by the I-NUK blockchain in the form of carbon credits which are then sold on the market. I-NUK asks its partners for real-time access to their sensor-generated production data. At the beginning of the partnership, an I-NUK staff member visits the site to check the solar installation. Based on the data provided, I-NUK then evaluates its clients' income and certifies their energy in carbon credits. I-NUK's income is obtained through commissions, meaning I-NUK is paid a commission for each service provided (carbon certification and carbon offsetting). I-NUK is still currently being tested by its partners: the public launch is planned for April 2018.
RESULTING INNOVATION	→ The current carbon certification process used for example by the UN Framework Convention on Climate Change (UNFCCC) is considered insufficiently transparent, too bureaucratic (monitoring the installations is difficult as audits are not carried out on a regular basis) and not tangible enough. By using the Ethereum blockchain and its smart contracts (contracts whose execution is based on predefined conditions), I-NUK can guarantee a transparent, efficient, secure and automated certification process. The I-NUK blockchain permanently audits the system and publicly verifies the exactness of the certification process. → I-NUK includes the energy used by the Ethereum platform in the carbon offsetting process, thus ensuring a fully carbon neutral approach. → The I-NUK model enables small solar energy producers to obtain higher prices for the energy produced, thus contributing to the development of local clean energy.
FOR FURTHER INFORMATION	www.inuk.co

PYLON NETWORK

COUNTRY Spain

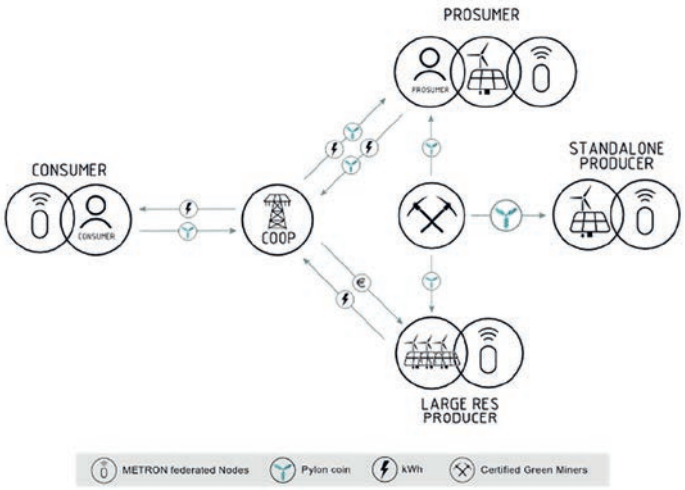
NAME Pylon Network Project

INITIATOR/PROFILE

KLENERGY TECH
A European start-up based in Spain. Has already been approached by major energy suppliers (e.g. ENGIE, ENDESA, etc.)

DESCRIPTION

Pylon Network proposes to use blockchain technology to help energy sellers have better knowledge of energy flows. Their product targets renewable energy cooperatives. Combines a smart meter (Metron) and blockchain technology to certify energy flows and enable virtual transactions using tokens (green kW production units/coins). This allows the renewable energy community to manage demand and optimise the energy flows in real time. Pylon Network uses the Ethereum platform. Pylon coin is based on the ethical Fair coin cryptocurrency algorithm developed by FairCoop.



Source Pylon white paper – Klenergy Tech

A full-scale pilot will be launched in 2018 with the Spanish basque cooperative Goiener (a member of RESCoop.eu). The project is currently sized for the Spanish market but aims to expand to other countries like the United Kingdom and Germany.

RESULTING INNOVATION

- Flow transparency
- Reliability and security
- Accessible to all
- Low energy server running on surplus renewable energy

FOR FURTHER INFORMATION www.pylon-network.org

TAL.MARKT BY WUPPERTAL STADTWERKE

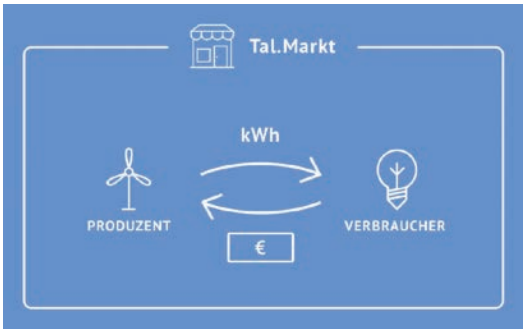
COUNTRY — **Germany**

NAME — **Tal.Markt**

INITIATOR/PROFILE — **Wuppertal Stadtwerke Energie & Wasser AG (WSW)** is the municipal energy provider supplying the city of Wuppertal, in Western Germany.

DESCRIPTION

In collaboration with the Swiss company Elbox, WSW created the blockchain platform Tal.Markt to operate a local and regional marketplace for renewable energy produced in the Wuppertal area. The objective is to connect citizens and local renewable energy producers, in particular the 5,000 wind turbines that will no longer receive subsidies after 2020.



Source : www.wsw-talmarkt.de

For these transactions, Tal.Markt uses a private blockchain. It is less energy-intensive that a public one and allows WSW to manage users' access to the platform. Citizens can use the platform for free, whereas local producers have to pay WSW a fee to sell their energy on Tal.Markt. For the time being, only local producers with a minimum capacity of 30 KWh can access the platform. Tal.Markt's business model is therefore an on-line platform marketplace like Amazon.

The Tal.Markt platform has been designed to suit the needs of the Wuppertal area, which has many medium-sized towns. With Tal.Markt, WSW aims to ensure that the value created remains at the local and regional level. WSW would also like to meet the increasing demand from Wuppertal citizens, who want to buy energy from green, sustainable and locally-rooted producers.

RESULTING INNOVATION

→ Tal.Markt's blockchain is flexible and transparent and enables citizens to monitor how much renewable energy is being produced in real time and by whom. The provenance of renewable energy is guaranteed by the infallibility of the blockchain.

→ With this service, WSW benefits from a new source of income and can support local producers, who will no longer receive subsidies under the German law on renewable energy (Erneuerbare Energien Gesetz) after 2020.

→ In the event of a shortage of renewable energy on Tal.Markt (e.g. for lack of wind or sun), WSW is responsible for securing the supply.

→ Tal.Markt also encourages investors to set up community groups of sufficient size to encourage the construction of new wind turbines or solar installations, with no support from the Erneuerbare Energien Gesetz.

FOR FURTHER INFORMATION — www.wsw-talmarkt.de/#/home

EXPERIMENTS CARRIED OUT BY STADTWERKE ENERGIEVERBUND – GRÜNSTROMJETON

COUNTRY

Germany

NAME

Grünstromjeton

INITIATOR/PROFILE

Stadtwerke Energieverbund (SEV) is a grouping of 8 Stadtwerke from the Kamen region in North Rhine-Westphalia, i.e. the municipal utility companies of the following towns: Emmerich, Hamm, Ahlen, Froendenberg, Haltern am See, Herten, Wickede, plus the Gemeinschaftsstadtwerke of Kamen, Boenen and Bergkamen. SEV only promotes locally-produced renewable electricity and targets households in particular.

DESCRIPTION

SEV is offering a new service to encourage customers to increase their renewable energy use. Any customer with a smart meter (capable of recording energy use in real time) can access this new service, which measures precisely the share of electricity produced from renewable sources in the customer's total electricity consumption.

Customers can therefore monitor their energy mix and adjust it. Customers with a high renewable share are rewarded with a cryptocurrency called Gruenstromjeton. This cryptocurrency has real value and is therefore an incentive to use more renewable energy produced within the SEV area.

The blockchain used in this model processes data transactions between consumers and SEV and also ensures rapid and efficient invoicing of the energy used. Moreover, transactions can be automatically managed via smart contracts in the blockchain ledger.

GrünstromIndex und GrünStromJeton

Uhrzeit	Grünstrom	Graustrom	Verbrauch	Grünstrom Jetons	Graustrom Jetons
10:00-11:00	60%	40%	100 Wh	60	40
13:00-14:00	20%	80%	100 Wh	20	80
16:00-17:00	100%	0%	100 Wh	100	0

Source : stromstunde.de/Thorsten Zörner

RESULTING INNOVATION

- Citizens are encouraged to increase the share of renewable energy in their energy mix; they therefore contribute to promoting renewable energy in the local area but also benefit from it themselves.
- SEV uses the blockchain to reduce transaction costs (smart contracts) as well as the costs of the invoicing process.
- The blockchain has an open source architecture, which means SEV does not have to pay licence fees.

FOR FURTHER INFORMATION

www.energieagentur.nrw/eanrw/sev_gruenstromjetons_blockchain-anwendung_macht_gruenstromverbrauch_sichtbar

EXPERIMENT CONDUCTED BY ETH ZURICH IN WALENSTADT – POWER-ID

COUNTRY

Switzerland

NAME

Power-ID

INITIATOR/PROFILE

Sandro Schopfer is a researcher at the Swiss Federal Institute of Technology ETH in Zurich. After 5 years in the energy industry, he now teaches information management and is part of ETH Zurich's Bits to Energy Lab which explores new digital technologies and their applications in the energy field.

DESCRIPTION

Power-ID is a pilot project led by ETH Zurich and financed by the Swiss Federal Energy Agency that is being tested in the village of Walenstadt (5,000 inhabitants) in the St. Gallen canton. An energy service company – in fact a cooperative – is also involved. The objective is to create a small local peer-to-peer energy marketplace of 20 prosumers and 20 consumers using blockchain technology.

This decentralised network focuses on solar energy and storage (batteries) and aims to cover at least half of Walenstadt's energy needs. Connecting local players helps reduce the system's costs for all and encourages local renewable energy production and consumption.

ETH Zurich and the energy service company have not decided yet whether they want to use a public or private blockchain for this pilot project. The stakeholders have agreed to use the Ethereum blockchain for payments.
The blockchain will fulfil three functions: ensuring payments between the players involved, serving as a matchmaker and fairly allocating network costs, taking fluctuations in energy demand and supply into account.

Network costs will be flexible and will depend on the degree of self-sufficiency achieved at a given time – when a lot of local energy has been produced (because it is a sunny day), the participants will only pay for their own network costs. However, if energy from other (local) networks has to be used, participants will also have to pay for using these external sources.

RESULTING INNOVATION

- Peer-to-peer transactions across a small decentralised network; the value generated (the energy produced and used) remains in the local area.
- Network costs are transparent thanks to the blockchain.
- The energy service company is involved in the project but does not play its traditional intermediary role, thus allowing prosumers and consumers to make their own decisions.
- Instead of paying a premium price for locally produced energy, this pilot project aims to reduce the cost of local energy and enhance its value, thus making it more attractive to citizens.
- In this pilot project, the cost of the network is determined in a bottom-up way instead of being imposed top-down by the large network operators.

FOR FURTHER INFORMATION

Project leader: Sandro Schopfer, ETH Zurich
www.im.ethz.ch/people/sschopfer.html

NRGCOIN

COUNTRY Belgium

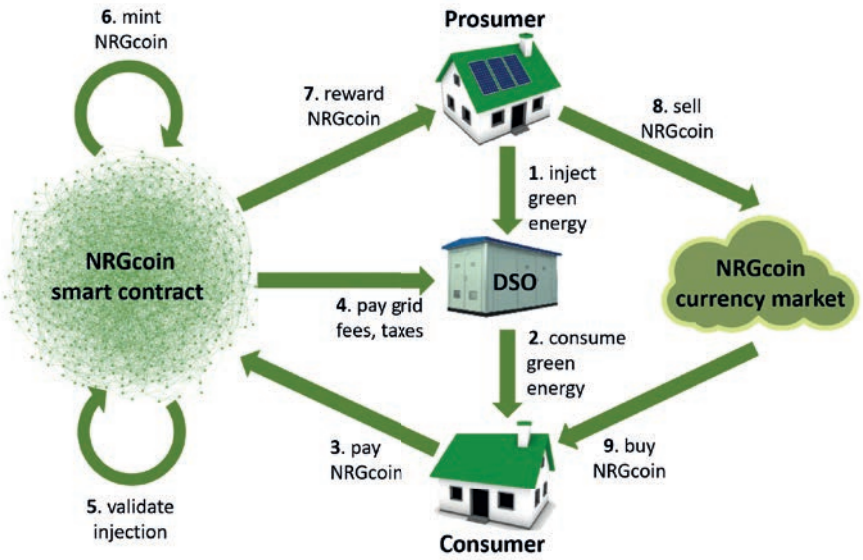
NAME NRGcoin

INITIATOR/PROFILE

The NRGcoin concept was developed by researchers at the Vrije Universitet Brussel (VUB), in partnership with the SME Sensing & Control Systems based in Barcelona as part of the European project Scanergy. The Belgian start-up Enervalis, based in Limburg, now aims to market NRGcoin, first in Belgian and Dutch cities and then in other European cities. Enervalis has already obtained a 3-year financial support from the Flemish innovation and entrepreneurship agency VLAIO to develop its project.

DESCRIPTION

The idea behind NRGCoin is to compensate for the inadequate (not flexible enough) subsidising of renewable energy and encourage citizens to use local renewable energy by paying them in a cryptocurrency called NRGcoin. Smart contracts from the Ethereum blockchain are used to automatically and immutably mine new NRGcoins for each KWh of renewable energy injected into the grid by a prosumer at the right time – when there is local demand. Oversupply is therefore not rewarded. Another feature is that smart contracts are used to manage energy sales and purchases (not the exchange of energy). Prosumers can sell their NRGcoins on the NRGcoin currency market. On this market, consumers can also buy NRGcoins with fiat money (e.g. Euros). NRGcoins can therefore be converted into real currency if the prosumer wants to cash in on their profit.



Source: NRGCoin

RESULTING INNOVATION

NRGcoin benefits from the advantages of the Ethereum blockchain (no intermediaries, transparency, decentralisation, reliability and indelibility). NRGcoin also aims to increase the value of prosumers' renewable energy installations, ensure management of a local marketplace that does not negatively impact the capacity of the network and reduce the cost of using locally-produced renewable energy.

FOR FURTHER INFORMATION www.nrgcoin.org

BROOKLYN MICROGRID

COUNTRY

United States

NAME

Brooklyn Microgrid (BMG)
Decentralised community electricity system at the scale of a neighbourhood

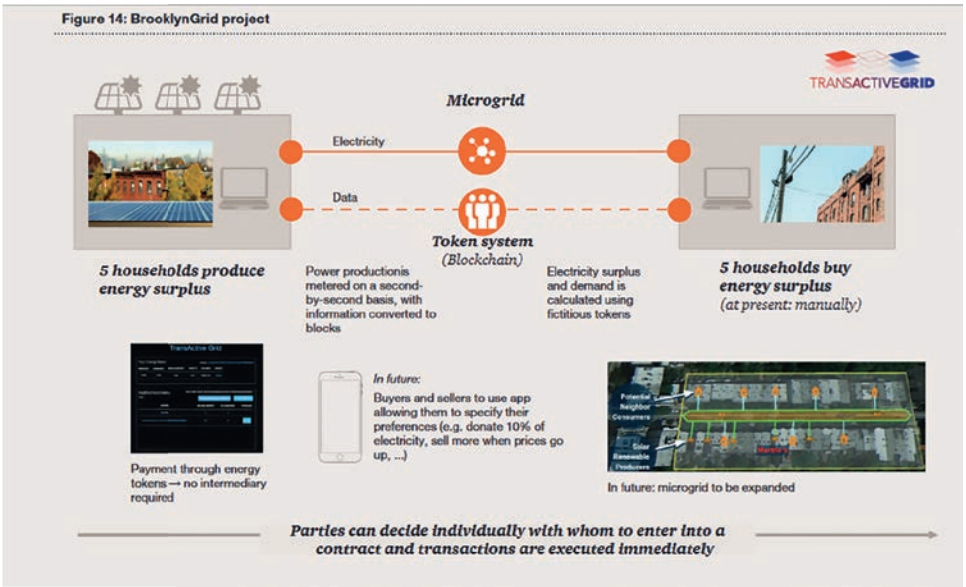
INITIATOR/PROFILE

TransactiveGrid is a joint-venture composed of Lo3 Energy, a consultancy developing decentralised systems for the energy and environmental sectors and ConsenSys, a start-up developing blockchain-based applications. Two other players also have a key role in the project: ConEdison, a local supplier with a conventional grid to which BMG is connected and CLEAResult, which proposes energy efficiency solutions to both private individuals and businesses. The project is supported by the State of New York, via the New York State Energy Research and Development Authority.

DESCRIPTION

Launched in 2016 in the Park Slope and Gowanus neighbourhoods, this microgrid was built using the Ethereum platform. Solar panels installed on the roofs of five residential buildings produce electricity, the surplus being sold to neighbours. These buildings are connected to a conventional grid and their transactions are managed and recorded via a blockchain. One of the objectives of the project is to create a local renewable energy community. 130 new households have reportedly expressed their intention to join the network.

Figure 14: BrooklynGrid project



"Source Blockchain – an opportunity for energy producers and consumers"? – PwC

RESULTING INNOVATION

- Peer to peer
- Smart contract technology and payments in a virtual currency (Ether)
- "a shared community energy marketplace", surplus electricity is exchanged with neighbours via secured transactions

FOR FURTHER INFORMATION

www.brooklynmicrogrid.com

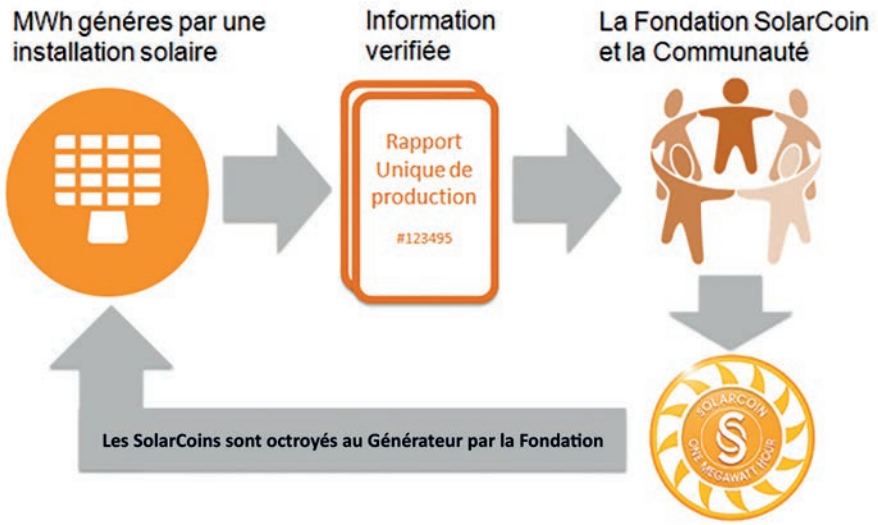
SOLARCOIN

COUNTRY International

NAME SolarCoin

INITIATOR/PROFILE SolarCoin Foundation is a US-based foundation composed of volunteer scientists from all over the world. ElectriCChain is the foundation's affiliated site.

DESCRIPTION Launched in 2014, SolarCoin is a cryptocurrency, or virtual currency, which aims to promote renewable energy by enabling all solar energy producers to be remunerated based on how much energy they produce. Solar energy producers can claim 1 SolarCoin for every 1 MWh produced and injected into the grid. Any owner of a PV installation can take part in the network. The solar origin of every MWh is certified by the blockchain. The objective is to encourage the installation of 3,000 GW of PV panels by 2050 (against 300 GW in early 2017). 98 billion SolarCoins have been created, enough to ensure their distribution for 40 years.



Source: SolarCoin

The currency symbol for SolarCoin is "§" and is abbreviated as SLR. In France, SLR is used by the French crowdfunding platform Lumo. Some energy distributors, like ekWateur, accept it as a means of payment. To obtain SolarCoins, people must produce PV electricity and be able to prove it. The Foundation verifies that the claim is valid and that the energy has actually been produced; it then transfers SolarCoins to the producer who collects them in a dedicated wallet – all these operations are recorded and visible in the blockchain. Each collected SolarCoin is therefore proof than one MWh of solar energy has been produced, which is the basis of its value as a currency. These tokens are then exchanged on a marketplace with no intermediaries, the energy price being set by the law of supply and demand.

RESULTING INNOVATION

- Uses little energy
- Helps reduce a solar installation's payback time
- Its initiators would like the currency to be recognised by local authorities

FOR FURTHER INFORMATION www.solarcoin.org

OTHER EXAMPLES

The below examples complete our panorama of current experiments applying blockchain technology to the energy sector:

THE CITY OF RIGA, the capital of Latvia, intends to use the security provided by blockchains to encourage more private investors to invest in a renewable fund which would be used to finance the renovation of private buildings.

THE CONFLUENCE DISTRICT IN LYON (FRANCE) will be the pilot site for a blockchain (deployed by Bouygues Immobilier) designed to collectively control a smart electricity distribution network and make sure that the energy produced is used on the spot. www.bouygues-immobilier-corporate.com/news-room/bouygues-immobilier-sassocie-stratumn-et-energisme-pour-deployer-une-blockchain-pour-smart

THE CITY OF COPENHAGEN AND THE DANISH ISLAND OF SAMSØ are cooperating with the Blockchain Labs for Open Collaboration start-up to test blockchain technology in their areas (implementing a decentralised network and connecting existing renewable asset infrastructure to the blockchain). www.un-bloc.com/project/energy

Wien Energie, the energy department of the **CITY OF VIENNA,** has set up a blockchain pilot project to facilitate energy trading on the wholesale market. www.coindesk.com/wien-energie-preparing-blockchain-world-energy-markets

THE INDUSTRIAL SERVICES OF SIX SWISS CITIES, including Geneva, Lausanne and Bern, will work together in 2018 to identify practical blockchain applications and implement them through pilot projects. To do so, they will use the blockchain infrastructure of the Energy Web Foundation, an organisation (members include companies like Shell, Engie, etc.) which aims to identify the various applications of blockchain technology in the energy sector.
www.ictjournal.ch/news/2017-12-01/les-services-industriels-de-six-villes-suisses-cooperent-dans-la-blockchain

THE WEPOWER START-UP, based in Gibraltar and supported by the EU CIVITAS initiative, aims to create a blockchain platform to facilitate green energy trading using a kind of cryptocurrency (tokens).
www.wepower.network

OURPOWER, the Scottish not-for-profit energy supplier will be involved in a pilot project (CEDISON) financed by the British government and aimed at exploring blockchain potential in rural and urban decentralised energy networks.
www.our-power.co.uk

OPPORTUNITIES AND POTENTIAL ISSUES FOR LOCAL AUTHORITIES

Blockchains have no institutional organisation or identified individuals behind them. This raises control and accountability issues. In a decentralised system, power is evenly distributed, but there is no one to turn to should a problem arise. Although the immediate and irreversible dimension of the code means contracts can be automatically executed, it also runs counter to our judicial logic: a citizen may decide to disobey the rules and then stand trial and contest the law. The code simply executes. Although traceability may be a guarantee of transparency, there remains the fact that our data are being recorded. These ethical and legal issues have not yet been resolved.

In view of all this, what opportunities and potential issues should a local authority interested in using blockchain solutions as part of its energy policy expect? Below is an initial analysis, partly based on the potential applications and examples described above.

OPPORTUNITIES/ADVANTAGES	POTENTIAL ISSUES
→ A transparent, verifiable technology → A reliable, shared and confidential data pool that cannot be refuted → Transactions are secured in real time	→ Not totally infallible security and trust
→ Reduced transaction costs → Simplifies the management/running of a service	→ The blockchain can be energy-intensive and expensive → Capacity of the energy infrastructure to absorb a massive flow of blockchain projects
→ Can facilitate implementation of peer-to-peer networks (“Commons 3.0”)	→ Risk of placing too much trust in the technology and those behind it → Blockchain and hyper-individualisation?
→ Reduced energy bills for vulnerable consumers	→ Complexity of the blockchain for “small” consumers
→ Opens the door to new opportunities in terms of remuneration and local added value.	→ Existence of a political and legal framework at the national/European level to roll out the blockchain → **Central question: is a blockchain always necessary? What are the costs and benefits compared to conventional solutions?**

OPPORTUNITIES/ADVANTAGES

A TRANSPARENT, VERIFIABLE TECHNOLOGY

One obvious advantage of the blockchain is not only its capacity to guarantee transparency of the transactions it handles, but also its ingenious way of verifying the transactions by conducting a permanent audit without the need for human intervention.

A RELIABLE, SHARED AND CONFIDENTIAL DATA POOL THAT CANNOT BE REFUTED

The blockchain constitutes a pool of reliable, shared and confidential data that cannot be refuted. Whenever a new block is mined, a new transaction ledger is shared with the whole network. Each transaction recorded in a ratified block can therefore be checked by the entire network. Modifying a block would require changing all its available copies in a similar way - a hugely time-consuming task.

TRANSACTIONS ARE SECURED IN REAL TIME

Blockchain technology ensures the security of all transactions in real time, and even in an automated way if smart contracts and/or decentralised autonomous applications are used.

REDUCED TRANSACTION COSTS

The Blockchains' efficiency at processing transactions results in lower transaction costs. Smart contracts and their capacity to automatically execute transactions have the potential to further improve the process, for example by ensuring a balance between energy demand and supply or by transferring surplus energy to storage.

SIMPLIFIES THE MANAGEMENT/RUNNING OF A SERVICE

Blockchains can process transactions autonomously (using predefined parameters), thus simplifying the running and management of a service. For local authorities with increasingly fewer human resources available, transferring this responsibility to the blockchain could ease the workload on staff, who would then be available for other tasks.

CAN FACILITATE THE IMPLEMENTATION OF A PEER-TO-PEER NETWORK ("COMMONS 3.0")

Another advantage of the blockchain is its capacity to facilitate the implementation of a transparent, secure, efficient and economically attractive peer-to-peer network with no need for a conventional intermediary like an energy service company.

REDUCED ENERGY BILLS FOR VULNERABLE CONSUMERS

Blockchain technology reduces transactions costs (and by extension, the cost of the entire system) and the savings made could be used to reduce the energy bills of vulnerable consumers and help tackle energy poverty.

OPENS THE DOOR TO NEW OPPORTUNITIES IN TERMS OF REMUNERATION AND LOCAL ADDED VALUE

As shown by the Tal.Markt case, blockchains can provide local authorities with new sources of income and create local value. Local authorities, through their energy department, for instance, could even become a sort of "new intermediary" by facilitating and managing peer-to-peer transactions, decentralised networks and collective self-consumption with the blockchain.

POTENTIAL ISSUES

ARE TRUST AND SECURITY REALLY INFALLIBLE?

For all that has been said, blockchain technology is not infallible. Since all users trust the same encryption key, any defect in it may jeopardise the whole network. The researchers Laurent Dehouck (ENS Rennes) and Audrey Thomas (ENSAM) have also identified a number of attacks that could potentially harm blockchain security and trust:

Examples of possible attacks that impact the security of a blockchain

"Man-in-the-middle" attacks: a "pirate" intercepts and transmits data by modifying them on the blockchain. As validity transactions are not audited, it is possible to insert invalid transactions that look like valid ones in the ledger.

"SYN-Flood" attacks: they consist in sending fast, repeated requests until the target is saturated and does not have enough power to legitimate and control the traffic.

"Sybil" attacks: an attacker hacks the blockchain network by controlling nodes. The miners associated with these nodes are his/her miners. A network of traffickers is then set up, which facilitates future attacks.

"Eclipse" attacks: they provoke the separation of the network into several groups. The users from one group cannot join those from another group and the chains continue to grow in each group. It is only after receiving a block from an unknown chain that the users will become aware of the existence of this other group and will be able to solve the problem.

Source: "Les risques des blockchains", Laurent Dehouck & Audrey Thomas

Reliability is therefore not always guaranteed: a blockchain does not "know" what is going on in the real world but depends on someone to insert this information into its network. Automatic real-time importation of data in the blockchain is not operational yet (for example a flight has been cancelled but the information has not been inserted in the application).

THE ACCOUNTABILITY ISSUE

Who should be held accountable in a decentralised, intermediary-free system? From a legal point of view, the blockchain is a governance system with no legal entity, which uses 'smart contracts' that do not fit the classic definition of a contract in terms of identification and consent. In the case of a (legal) dispute, how can it be resolved and who should be held accountable? A governance and accountability system remains to be defined to manage blockchains and the innovation they bring.

RISK OF PLACING TOO MUCH TRUST IN THE TECHNOLOGY AND THOSE BEHIND IT

The blockchain tends to make us place our trust in the technology, and more importantly, in those behind it (miners, software developers, etc.). It aims to replace traditional intermediaries (bankers, solicitors, energy service companies, etc.) but at what cost for society? Will we prefer these new intermediaries, who may moreover be important gateways for the GAFA companies (Google, Amazon, Facebook and Apple)?

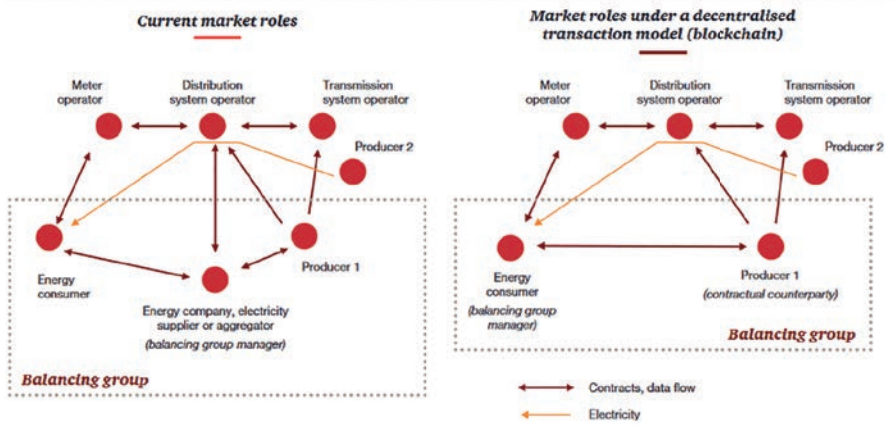
BLOCKCHAIN AND HYPER-INDIVIDUALISATION?

Michel Bauwens, the Belgian pioneer of the peer-to-peer economy, notes that blockchains are based on "a hyper-individualised vision of the world, where the collective and community no longer exist. This does not mean that blockchains cannot have other uses. For some, they reflect the increased capacity of individuals to organise themselves". Bauwens also criticises blockchain technology for its libertarian totalitarianism, as many of its defenders view it as a way to do away with States and other organisations. He also notes, however, that blockchains hold the promise of a new organisation by facilitating human self-organisation. The progressive forces advocating fairness, sustainability and social justice should therefore embrace blockchain technology and use it for collective empowerment.

TO WHAT EXTEND CAN THE NATIONAL/REGIONAL POLICY AND LEGAL FRAMEWORK HELP DEPLOY BLOCKCHAINS?

Several of the experts interviewed when preparing this note observe that blockchains are in a legal and political grey zone in Europe. Although the EU and its institutions have started to look into the blockchain question, they have not yet passed legislation on blockchains and their applications in the energy sector. The situation is much the same in many Member States. Some of the people contacted for the above case-studies however consider that this is a good thing, as innovation and experimentation is being enabled. They all agree on one point: setting up a legal and political framework favourable to the mass use of blockchain technology in the energy sector would require introducing many changes to existing legislation, as PwC noted in their blockchain study conducted at the request of the Northern-Rhine Westphalia consumer organisation (Verbraucherzentrale NRW):

Figure 15: Current market roles vs. market roles in a blockchain-based system



Source: PwC

BLOCKCHAINS ARE ENERGY- AND TIME-CONSUMING

Despite its efficiency and capacity to reduce transaction costs, blockchains remain an energy- and time-intensive technology: Ethereum, for example, uses 5 TWh/year, and each transaction costs 30 cents. Minting cryptocurrency requires high performance computers and a lot of power: according to the specialised site Digiconomist, maintaining the current Bitcoin system would require the equivalent of the power consumption of Denmark. Moreover, finding the expertise and resources needed to put together, operate and implement a public blockchain would be a significant investment for local authorities.

CAN THE ENERGY INFRASTRUCTURE ABSORB A MASSIVE FLOW OF BLOCKCHAIN PROJECTS?

Considering the previous argument about the financial and energy appetite of blockchains, it is unlikely that the existing energy infrastructure in Europe and at national level would currently be able to absorb a massive flow of blockchain projects. In Europe, the energy network is still struggling to integrate an increasing number of renewable energy and storage systems.

COMPLEXITY OF THE BLOCKCHAIN FOR "SMALL" CONSUMERS

Managing contracts with other participants and running production, storage and energy-using facilities is a too complex process for most users who have little interest in their power supply. This complexity may also limit consumers' trust in an invoicing system where the amount to be paid would no longer be based on consumption read on the meter applied to the tariff given by the energy supplier. Finally, for "small" consumers, participating in a local energy marketplace may expose them to unacceptable price risks.

IS A BLOCKCHAIN ALWAYS NECESSARY?

The last potential issue is one of the most important ones: do I really need a blockchain to implement my energy project? In principle, it is a relevant option compared to conventional solutions when multiple players have to enter data in a shared database and when they do not trust each other and when there is no trusted third-party or the third-party does not inspire enough confidence. What is the added value of using a blockchain? Several case study interviewees confirmed that theoretically, their pilot projects and experimentations could have been implemented without a blockchain. But they also noted that the blockchain had multiple advantages (see the opportunities and applications sections) that justified its usage in their experimentation.

PROSPECTS AND CONCLUSION

Describing precisely the tangible prospects of using blockchains for local authorities is quite complex, considering that their applications in the energy sector are still at an experimental or pilot stage. And some of these initiatives exclusively focus on the technological aspects, forgetting that blockchain technology is a means and not an end in itself.

Local authorities should be able to harness this technology and use it to shake up existing modes of governance in the energy sector, which are rarely designed to take into account the motivations of citizens and other local players wishing to play a full role in local energy. What is at stake here is how to change the mode of governance, and only blockchain projects delivering on this will make a meaningful contribution to local energy.

The experts interviewed indicated that local authorities should not embark on a blockchain project simply to follow the blockchain "hype", but should use this technology only after giving much thought to the added valued it could contribute to their local energy policies, and how it could help radically change the current energy system.

During the Smart City Expo World Congress in Barcelona this year, Andrew Collinge, the Greater London Authority's lead officer on the Smart City Agenda, summed up the challenge of blockchains for local authorities in the "City as a platform" panel:

Collinge noted that city leaders need to better prepare for the implications of technologies such as blockchain. He argued that while they may have a high level understanding of the technology there's typically "zero comprehension" of the impact it could have for government and the communities it serves. "That absolutely has to change," Collinge commented. "It's a matter of urgency that public services, and the leadership of those public services, is able to anticipate technology and the disrupted business models it creates; and that it can respond to that by setting out the key demands". (Source: Smart Cities Dive)

EXPERTS INTERVIEWED

CLAIRE BLAVA
CEO Blockchain Partner

ANDRÉ JOFFRE
CEO TECSOL

KIRSTEN HASBERG
Aalborg University – CPH IT University CPH – BlockchainHub Berlin – StromDAO @energydemocracy

MIHAIL MIHAYLOV
researcher at Vrije Universitet Brussel and for Enervalis (Project: NRGCoin)

TIMURS SAFIULIS
Director of Riga's energy agency

ALASTAIR MARKE
founder of the International Core Group on Blockchain Climate Finance

SOEREN HOEGEL
Strategy & Development Director, Stadtwerke Wuppertal

RIEUL TÉCHER
DAISEE core contributor – Internets of Energy: Energy as a Common – Active MYNE contributor – An open anti-disciplinary laboratory for sustainable living

AUGUSTIN ROIG & EUGENIO MOLINER
Pylon Network – first decentralised energy exchange platform running on renewable energy (Spain)

SANDRO SCHOPFER
researcher at ETH Zurich

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PROSPECTS AND CONCLUSION

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