

World Energy Insights Brief | 2018

IS BLOCKCHAIN IN ENERGY DRIVING AN EVOLUTION OR A REVOLUTION?

What are the applications of blockchain in the energy sector? What are the associated impacts of different energy blockchains and do different applications enable evolution and/or disruption of the existing market? What is the outlook for energy blockchain in enabling a successful energy transition?

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The World Energy Council is the principal impartial network of energy leaders and practitioners promoting an affordable, stable and environmentally sensitive energy system for the greatest benefit of all.

Formed in 1923, the Council is the UN accredited global energy body, representing the entire energy spectrum, with over 3,000 member organisations in over 90 countries, drawn from governments, private and state corporations, academia, NGOs and energy stakeholders. We inform global, regional and national energy strategies by hosting high-level events, including the World Energy Congress and publishing authoritative studies, and work through our extensive member network to facilitate the world's energy policy dialogue.

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ABOUT THIS INSIGHTS BRIEF

This Insights Report on energy blockchain is part of a series of publications by the World Energy Council focused on Innovation, with the aim of facilitating strategic sharing of knowledge between the Council members and the other energy stakeholders and policy shapers in a fast-paced era of disruptive changes.

www.worldenergy.org/

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Blockchain

Insights

**Anthology of
Interviews**

BLOCKCHAIN INSIGHTS: AN ANTHOLOGY OF INTERVIEWS

This Insights Report on energy blockchain is part of a series of publications by the World Energy Council focused on Innovation, with the aim of facilitating strategic sharing of knowledge between the Council members and the other energy stakeholders and policy shapers in a fast-paced era of disruptive changes.

This Insights Report has been produced by the Council in partnership with PwC, with additional support provided by the Council’s Future Energy Leaders group. It follows on from a previous joint publication by the Council and PwC, “The Developing Role of Blockchain,” issued in 2017.

The insights conveyed hereafter are underpinned by the valuable learnings from a series of 39 interviews conducted with key leaders across the energy sector hailing from around the globe. The interviewees include well-established energy incumbent players in the electricity and oil & gas industries, as well as technology providers, start-ups, regulators and think-tanks, all actively engaged within the blockchain space. The broad participation from different areas of the energy market was purposely pursued to ensure this publication could provide a reliable and relevant snapshot in time of the current state of progress of various blockchain activities within the sector.

We asked the interviewees ten questions. The two key questions posed were: How far along is blockchain, and is regulation an impediment to its progress?

Below is a list of the interviewees. We would like to take this opportunity to thank each of them for their participation.

Entities Interviewed by the World Energy Council and PwC:

General Electric	WePower	Siemens	IBM
Engie	Equinor	SP Group	Enel
TEPCO Ventures	Teri	PG&E	CPUC
Electron	DCCAE	Faraday Grid	IERC
Flexitricity	National Grid UK	Wipro	MotionWerk
Tennet	EDP	Sunrun	Verv
LO3 Energy	Rocky Mountains Institute	Freelio	Energolabs
Allgau	Hive Power	TEPCO (Trendy)	Power Ledger
Innogy Innovation Hub, Innogy	Energy Impact Partners	German Energy Agency (dena)	FutureFuel Tech
Arizona Corporation Commission	Energy Web Foundation	New Zealand Electricity Authority	

INTRODUCTION

The use of blockchain technology within the energy sector (“energy blockchain”) is emerging as a key strategy and focus area for modernisation of the industry. As a distributed ledger technology (DLT), blockchain provides a platform for the management and transaction of high-value data. Unlike other DLTs, however, blockchain is “trustless”, requiring no intermediaries and, thus, it brings the potential to catalyse the existing business processes as well as a reduction of the overhead costs and level of complexity embedded in the current energy ecosystem.

Utilising blockchain technology to optimise the existing practices of the energy sector through asset traceability applications and other behind-the-scenes technology upgrades are obvious choices for the energy sector. It will not be surprising to see such applications appear soon on the horizon. **The open question about blockchain is, can it revolutionise the way residential consumers consume and receive electricity?**

The intent of this anthology is to showcase what the different companies and participants engaging with emerging blockchain technology are aiming for and what progress has been made to date with their applications. We can also leverage their insights to gauge blockchain’s impact on the sector.

KEY INSIGHTS

Based on the 39 interviews, a clear majority (85%) of participants agreed that blockchain has not yet attained a commercially tangible impact, though it has certainly been spurring the efforts and investment of many stakeholders across the energy sector. The majority also agreed that energy blockchain has not yet led to changes in business models nor enabled a clear shift from the traditionally centralised electricity grid.

1.The term “trustless” is commonly used in describing blockchain technology, whereby there are mechanisms in place by which all parties in the system can reach a consensus on what the established truth is, without intermediaries. Power and trust is distributed (or shared) among the network’s stakeholders (e.g. developers, miners, and consumers), rather than concentrated in a single individual or entity (e.g. banks, governments, and financial institutions).

SOLUTION LOOKING FOR A PROBLEM

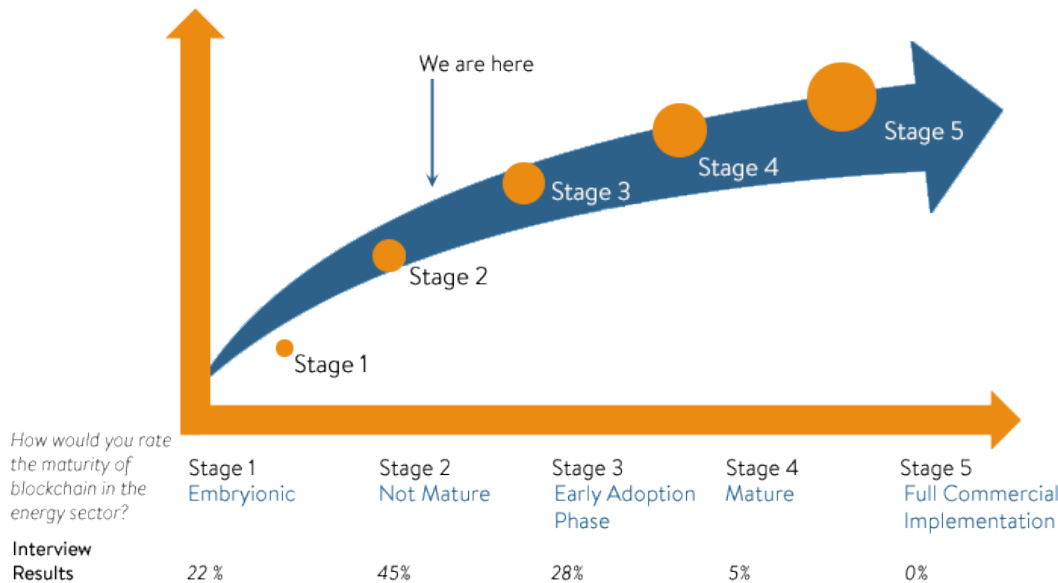
***RICHARD DOWLING,
FARADAY GRID***

**BLOCKCHAIN IN THE
ENERGY SPACE IS STILL
IN AN EMBRYONIC STATE,
COMPARABLE TO THE VERY
EARLY DAYS OF THE INTERNET
REVOLUTION**

JON CREYTS, RMI

The maturity model, Figure 1 shown below, is based on the responses gathered throughout the interview process. As can be seen, **the majority of interviewees (67%) attributed a maturity level that is reaching early adoption phase**, when considering the global developments in blockchain applications to date. This is not to suggest individual pilots are not more advanced. Rather, the model illustrates the actual, currently limited maturity of blockchain thus far in the energy sector.

Figure 1: Maturity Model



Unanimously, the interviewees agreed that while blockchain has catalysed great efforts in the innovation space from a wide number of organisations in the energy sector, **much is yet to be done to ascertain the effectiveness of the technology and its full economic/technological viability.**

We don't think that blockchain has delivered a real direct value just yet in the energy sector. However, the concept has given the industry a trigger to rethink how to trade and manage the creation and distribution within the value chain.

Audrey Lee & Chris Moris, Sunrun

There was also broad agreement among the interviewees that while blockchain technology is certainly a **very promising tool, and perhaps an accelerant for decentralisation, it is not an essential requisite for decentralisation and democratisation of energy.**

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With or without blockchain the energy system will continue to move toward decentralisation and democratisation.

Alastair Martin, Flexitricity

The energy sector is going towards decentralisation and democratisation. Blockchain is a technology enabler, but there are other macro-forces that are shifting the energy world in that direction. There are other technologies which may serve the purpose, but blockchain is well suited when we consider direct transactions between users, hence it is a strong catalyst towards decentralisation and democratisation.

May Liew, SP Group

Blockchain – Some Misconceptions to be Dispelled

Ahead of discussing some of the use cases it is worth dispelling some of the misconceptions about blockchain technology in the energy space.²

Misconceptions	Reality
Blockchain is Bitcoin	Blockchain is not Bitcoin. Bitcoin was created in 2009 and is a cryptocurrency application of blockchain, whereas blockchain technology, as the underlying protocol, has many different potential applications.
Blockchain is energy-intensive	Bitcoin is extremely energy-intensive, but there is alternative blockchain technology developed in 2017 which is not based on mining that requires significant computational power. Public and private Ethereum-based Proof-of-Authority solutions, Hyperledger and others are using a different process to reach consensus.
Blockchain is 100% tamper-free	Blockchain is not 100% tamper-free. The immutability of data on a chain has been one of the key selling points for blockchain among enthusiasts and innovators. In fact, the complete immutability of the data cannot be guaranteed entirely. Data can potentially be modified, once written. However, since this would be a rather expensive process, tamper within a blockchain isn't economically feasible.

2. https://shop.dena.de/fileadmin/denashop/media/Downloads_Dateien/esd/9165_Blockchain_in_der_Energiewende_englisch.pdf

<https://www.forbes.com/sites/forbestechcouncil/2018/03/27/11-common-myths-about-blockchain-and-cryptocurrency-you-shouldnt-believe/#30de33e6a33f>

<https://medium.com/@lmgoodman/dispelling-some-myths-about-bitcoin-from-a-bitcoin-fan-5b64f3850550>

<https://www.digitalpulse.pwc.com.au/dispelling-myths-blockchain/>

Blockchain can verify the accuracy and validity of external data	Blockchain cannot verify the accuracy or veracity of external data. It can only verify all the data entirely contained on, or generated within the blockchain itself.
Blockchain is the best database out there	Blockchain isn't necessarily better than traditional databases. It is particularly useful in a low-trust environment, where it removes the need for intermediaries and allows for participants to trade directly.
Smart contracts are legally binding	Smart, self-executing contracts, powered by blockchain platforms, require no intermediaries. However, "code is not law" and smart contracts are not legally binding without separate contractual agreements.

BLOCKCHAIN USE CASES – BEYOND THE HYPE

Attractive promises continue to be attributed to blockchain, hailed by many as the game changer that will entirely transform the energy value chain, leading to the creation of new business models and a transformation from consumers to prosumers. However, use cases beyond proof-of-concept are still very limited (at best), making it difficult to envision the highly anticipated leap from mere testing environment to the real world.

Figure 2, below, illustrates the breakdown of use cases currently in progress. As can be seen, the majority of companies interviewed, approximately 45%, are trialling Peer-to-Peer (P2P) projects aimed towards optimisation of the existing grid. Notwithstanding this notable dynamism surrounding P2P, there further exists a plethora of promising evaluations taking place in other areas of the sector, any and/or all of which, particularly given the nascent development of all the use cases, have opportunity to emerge as significant applications for blockchain.

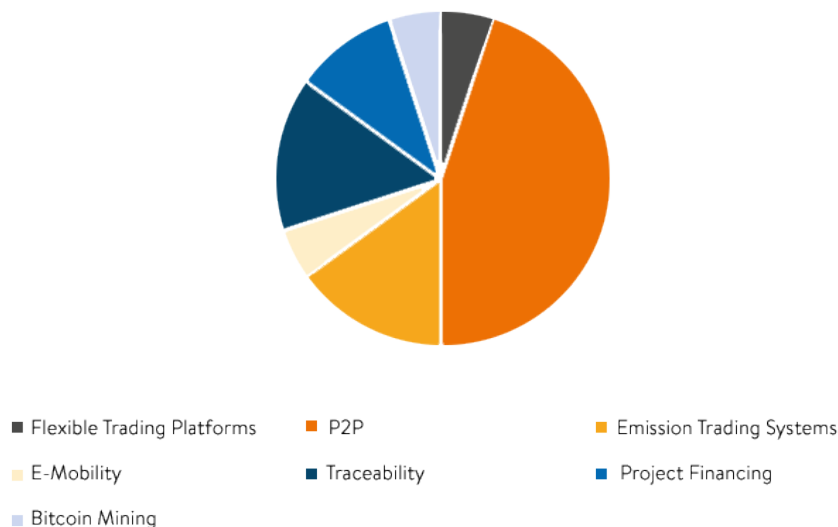


Figure 2: Different Types of Uses for Energy Blockchain

Accordingly, this section identifies **seven types of uses** of blockchain technology currently undergoing trial across the globe with varying degrees of maturity and early adoption. The follow-up to this Brief will identify and discuss in detail a number of relevant energy blockchain use cases and their potential impact on the energy ecosystem.

- FLEXIBLE TRADING PLATFORMS FOR DISTRIBUTED ENERGY RESOURCES
- EMISSIONS TRADING SYSTEMS
- SUPPLY CHAIN TRACKING
- E-MOBILITY
- TOKENISATION AND PROJECT FINANCING
- BITCOIN MINING
- PEER-TO-PEER TRADING

In addition, Faraday Grid is piloting an **alternative technology** in order to make the existing grid more robust and reliable, and to promote further inclusion of renewable energy sources across the grid.

- EMERGENT

Using Blockchain for Flexible Trading Platforms

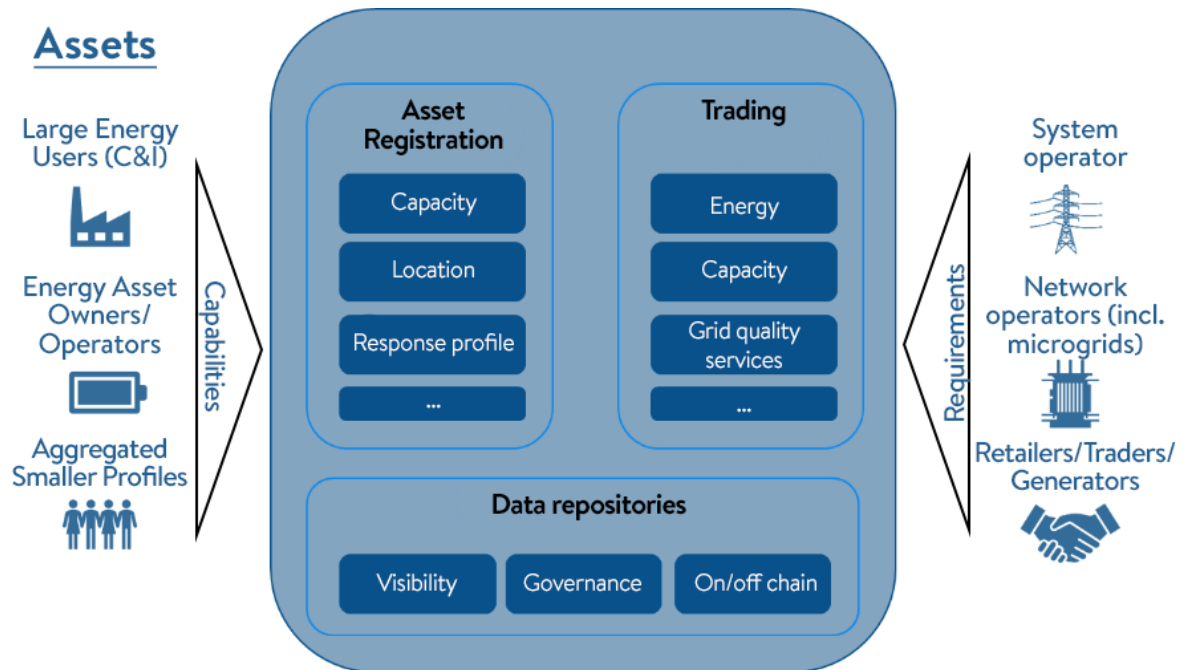
Electron, a U.K.-based start-up, has been working towards the creation of a new, **digitalised energy marketplace**, able to include smaller Distributed Energy Resources (DERs) alongside incumbent utilities, and cater for a more cost competitive, transparent and modern energy system. The Electron flexible trading platform applies blockchain technology to grid optimisation.

It (the platform) helps create visibility over billions of dollars of untapped value in grid edge assets and coordinates these assets' participation across multiple energy markets, whilst removing the requirement for a monopoly trusted intermediary.

Jon Ferris, Electron, U.K.

A requisite for this platform to be successfully implemented is the creation of an Asset Register, to provide a full map of each generating asset/device behind the meter. According to Electron, a

shared asset register would see different parties responsible for sharing their data. Blockchain, as a DLT, can allow recorded data to be available to all participants equally, thereby facilitating sharing



among multiple parties who have interest in the same information/data.

Figure 3: Electron Platform

In today's system there is already rapidly building demand for this type of platform. Thanks in no small part to policies and incentives aimed towards promoting greater renewable energy supply, over recent years there has been an increase in DER installations all over the world. These small capacity assets are connected to low and medium voltage grids and can be behind the grid or connected to the main distribution system. Surging numbers of such distributed energy assets, with their variable, weather dependent power profiles coupled with increased, likely localised electricity demand, require more interventions to manage power quality and availability in grid systems.

The inclusion of smaller, more diverse generating assets into the current energy system also requires new communication infrastructures to grant more choice and more control to the consumer over her energy choices.

Central dispatch is no longer an efficient solution to an increasingly complex problem. Moreover, data collection, storage, access permissions, and security are key challenges. [...] Democratic and inclusive marketplaces, through which thousands of smaller energy

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assets might be connected and integrated with large incumbent utilities, will optimise the costs and carbon efficiency of the energy system.

Jon Ferris, Electron, U.K.

The potential benefits of Electron's blockchain-powered flexible trading platform are attractive to several stakeholders in the energy value chain, such as system and transmission operators, distribution network operators, aggregators, traders, EV charging companies, battery management companies and energy retailers. Hence the creation of the recently announced Electron-led consortium backed by, amongst others, National Grid U.K. and Flexitricity.

One of the issues faced by the U.K. energy sector today is metering which measures the contribution of demand-response and could be potentially contaminated by unrelated factors. Sub-metering is key and would allow us to determine the correct level of energy delivery at site, but this requires appropriate information flow and validation. Blockchain technology has the potential to be able to address this issue successfully and enable us to fully optimise demand-response.

Alastair Martin, Flexitricity

With continued improvement of DER technologies, alongside the decreasing cost of storage devices, blockchain-powered DER markets could provide a quick response for market balancing.

Regulators are also expected to gain benefits from the Electron platform by having better market visibility and integrating governance processes into the platform. Electron is currently at proof-of-concept stage and estimates that it will have reached full commercial implementation in the U.K. within 18 months' time.

Blockchain for Energy Trading Systems

SP Group has developed a **blockchain-powered Renewable Energy Certificate (REC)** platform. This is one of the first global REC platforms powered by blockchain which brings together renewable originators and buyers, with the goal of integrating more renewable sources of any size into the energy system. Having an open-source, global blockchain infrastructure will encourage standardisation across geographies, thereby enabling frictionless cross-border REC transactions.

Blockchain technology can record trade certificates, providing a reliable verification process and without the need for an expensive centralised management entity. Renewable Energy Certificate systems can also be designed in a standardised manner by using a uniform set of rules enforced by the blockchain.

We believe that blockchain is the optimal technology to enable RECs transactions as it can empower buyers and sellers to achieve their sustainability goals at national and global levels. Our goal is an REC platform using blockchain technology which will enable differentiators, such as empowering buyers and sellers of any size, therefore democratizing the marketplace.

May Liew, SP Group

The SP Group RECs platform is currently in a pilot stage, on track towards first phase of commercial implementation by the end of 2018.

On the other side of the globe, Pacific Gas & Electric (PG&E) is working on a similar development. PG&E is currently developing a **blockchain application to attribute electric vehicle charging sessions** directly to on-site or grid renewables, generating a carbon credit that can be traded on an existing marketplace. Through this application, smart contracts are expected to generate carbon credits for EVs, based on a variety of factors which include: hourly grid carbon intensity, amount of on-site renewable generation, customer's tariff and charge event data. PG&E also plans to explore the feasibility of utilizing blockchain to enable customers to receive carbon credits, and then sell them in the market to companies who need to buy them to fulfil regulatory requirements³. PG&E expects to reach full commercial implementation in California within the next 3-5 years, albeit depending upon establishment of an appropriate regulatory framework.

This project would change the way the current market works by eventually replacing the centralised web-based tool that tracks assets with distributed credits/tokens as an accounting method. It would provide unique IDs for each credit generated, which would further help regulators reduce double counting/double spend in the market.

Lydia Krefta, PG&E

Blockchain for Supply Chain Tracking

Though blockchain was originally developed for sectors not involving the physical exchange of goods (i.e. banking and finance), many applications have been emerging where blockchain is used to optimise the processes behind physical exchanges. An example of this is commodity trade which involves multiple exchanges of data (at times manually) to clear and process transactions. In this area, **blockchain applications are being piloted in the oil & gas sector** through a joint-venture

³California's cap-and-trade program, launched in 2013, is one of a suite of major policies the state is using to lower its greenhouse gas emissions. The program sets a limit (cap) on the total amount of greenhouse gases that can be emitted. Companies then buy or sell (trade) permits to emit these gases, primarily carbon dioxide CO₂

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between IBM and Maersk. Their aim is to remove intermediaries, increase efficiencies across international supply and value chains, have better visibility and reduce asset loss from production to consumption. **The Global Trade Digitisation (GTD) blockchain pilot enables paperless trade by digitizing and automating document workflow.** It also allows for companies to trace assets more effectively. With \$1.8 trillion worth of goods traded across international borders annually, IBM and Maersk expect to achieve savings of ~10% through their blockchain digitised processes.

The Global Trade Digitisation (GTD) is a trade platform connecting the entire supply chain. GTD is built on an open technology stack and is underpinned by blockchain technology. It is the platform underpinning WP23 of the European Commission CORE initiative.

David Womack, IBM

Full commercial implementation of this blockchain application is expected by the end of 2018.

In the electricity sector, PG&E is also working on the development of **a blockchain application for electric utility asset management.** They intend to develop several nodes across the supply chain and digitise electric assets, tracking transactions throughout the supply chain via blockchain. Transactions can include tests, asset movement, asset changes, and asset payment. At present, the asset relies on disconnected databases that track asset movement within each company's sphere of influence. Blockchain can enable all parties to share relevant data in one single source of truth.

This project is at PoC stage and expected to be fully proven and implemented within the next 2-7 years.

Blockchain for E-mobility

E-Mobility has been on the rise with 200 million electric vehicles (EVs) expected to be in use by 2030, resulting in 11.9 billion kW of peak capacity and US\$98 billion of power consumption. At present, there is a highly fragmented EV charging market. This leads to an uncomfortable driver's experience, an increased complexity of the settlement processes of EV companies, an overload of the grid and the under-utilisation of the infrastructure.

MotionWerk, a German start-up, have developed "Share & Charge", **a blockchain application based on a decentralised, open-source protocol for EV charging.** This will enable EV users a seamless, smart and secure charging experience. Share & Charge is expected to benefit a number of stakeholders by facilitating access to all charge points for EV drivers, providing an easy integration of charge points and EVs into the network, as well as an easy payment and efficient settlement process between all parties.

It's all about people using the charging network. If blockchain holds up to its promises, the consumers will enjoy a more efficient charging process and lower costs.

Dietrich Sümmermann, MotionWerk

Currently at pilot stage, Share & Charge is expected to reach full commercial implementation and go live by mid-2019.

Blockchain for Tokenisation and Project Financing

Blockchain applications are also emerging in the context of tokenisation for project finance of renewable energy projects. Medium size assets are ill suited for traditional asset-backed securitisation and not large enough for traditional project finance. Considering these limitations, the Energy Impact Bank (EIB) has been developing a **blockchain-powered platform that enables, through tokenisation, a low cost, low friction alternative for access to broader, cheaper pools of capital** due to improved transparency and liquidity.

EIB's platform is akin to an investment bank tuned to DERs' scale and heterogeneity. [...] We are currently at PoC stage and expect to attain full commercial implementation within the next 4-8 months.

Amar Pradhan, EIB

Another financing pilot is from WePower, which has developed a platform where project developers for renewable energy generation facilities can raise capital by selling part of their future energy production directly to energy consumers or investors upfront. This is achieved via smart energy contracts that define the amount of energy to be produced in the future by an asset and the shares of equity amongst investors.

We have been developing a blockchain application to help finance more renewable energy projects by raising capital for developers during the early development/ construction stages. We involve the participation of banks, buyers and generators. Our application enables to secure capacity dispatch in advance, avoiding the need for large capacity long-term contracts, or centralised intermediary entities. Moving towards a wholesale energy market powered by blockchain is our ultimate vision.

Nick Martyniuk, WePower

WePower's solution is about to begin pilot phase in Estonia and other countries.

Blockchain for Bitcoin Mining

FutureFuel Technology, a U.K.-based start-up established in 2015, have developed two biofuel power plants that supply to the U.K. National Grid. They utilise used cooking oil, no longer fit for human consumption, and convert it into bio-fuel, which is then fed into a generator for the production of electricity to be exported into the grid. In addition, this start-up has been developing **a blockchain application to mine Bitcoin**, working towards the creation of the first entirely off-the-grid Bitcoin mine in the U.K.

Our blockchain application will allow for greater renewable energy into the U.K. market, reinforcing the move away from fossil fuels. [...] We use waste cooking oil whose provenance is fully certified, so we also provide this added environmental benefit through our bio-waste generating capacity.

Liam Ray, FutureFuel Technology

FutureFuel Technology are also aiming to explore the mining of other digital assets in the near future.

Blockchain for Peer-to-Peer Trading

Undoubtedly the area of blockchain application with the most hype surrounding it, Peer-to-Peer (P2P) trading is the final concept to be explored in this section. P2P is the “talk” of the sector -the prospects for blockchain technology to make transactive energy a reality, to upend the framework of the grid and the energy sector as we currently know it.

When conjoined with appropriate business models, **blockchain’s ability to make transactions faster, simpler, and cheaper can allow for wider participation into the energy market, down to individual households.** This is the objective of blockchain-powered peer-to-peer applications. In them, smart contracts allow a blockchain to be programmed with a set of conditions that when met automatically prompt transactions, enabling producers, consumers and prosumers all to participate into a sale process based on price, time, location and the type of energy source.

Two prominent start-ups, LO3 and Power Ledger, are extending significant effort towards the commercial implementation of the P2P business model. In the case of LO3, with its USD 6M project in collaboration with Siemens, a blockchain platform is in place to enable automated transactions over micro-grid wires between producers (mainly households with rooftop solar PVs) and consumers (households with smart meters). It should be noted, though, that this microgrid is connected to the utility’s infrastructure.

Our P2P projects are dependent on the main grid – wires and pipes that electricity flows into are a requirement. Power balancing comes from outside the LO3 application, and the main grid plays a main role. [...] Our current projects are all between the proof-of-concept and pilot stage. More than pure peer-to-peer trading, I would refer to them as peer-to-market. Not every consumer/prosumer is interested in trading to another peer. We have micro-grid communities where the prosumers trade with the grid for the energy that meets his demand and sells to the grid any excess energy that he produces.

Lawrence Orsini, LO3

In the Brooklyn Microgrid, Siemens is providing LO3 monitoring and data analytics system to forecast the trades in the micro-grid, to better forecast demand/response and pricing over a few hours span. We also enable parts of the grid to be operated in island mode to ensure the highest possible reliability and optimisation of community markets, through localised generation. Ultimately, the goal is to incentivise consumer & prosumer demand/generation according to grid capacity/overload and market situation.

Constantin Ginet, Siemens

Power Ledger has reached full commercial implementation in Australia with their P2P blockchain trading platform application, but they also have other pilot projects in South-East Asia and North America.

We wanted to create a trading platform to allow consumers to realise the value of their investment in DERs by allowing them to monetise their excess energy in much the same way as Uber and Air B&B allow people to monetise their cars and spare rooms. Blockchain technology allows for real-time payments, in a secured and transparent manner and it provides a decentralised market mechanism to aggregate individual users under a Virtual Power Plant model to participate into the wholesale market.

James Eggleston, Power Ledger

The direct involvement of retailers is a requisite for the Power Ledger P2P business model to be implemented in regulated energy markets; alternatively, embedded networks and microgrids can use the blockchain technology if they are sub-metered behind the regulated master meter.

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A London-based start-up, Verv, is currently hosting a live P2P blockchain trial in an East London estate where solar panels have been installed on the roofs of the blocks of flats. At present, due to the current structure of the U.K. electricity market, the solar energy within this estate can only be used to power communal areas. The 300+ flats are thus unable to benefit directly from the power generated by the large number of deployed panels and electricity costs in the community are continuing to rise in parallel with costs elsewhere in the U.K.

To address this issue, Verv has developed an AI-based IoT hub that can obtain a comprehensive and real-time overview of the electricity consumption of a home. This, combined with the blockchain technology, forms the basis of a P2P framework.

Thanks to advanced machine learning algorithms, which are designed to predict the supply and demand of energy, the trading of energy is fully automated by our IoT hub which ensures trading is done at optimal times to secure the best economic value for all parties involved. [...] We can provide grid balancing services based on our high-speed data sampling and in-depth knowledge of energy supply and demand.

Peter Davies, Verv

With the feed-in tariff incentives in the U.K. soon coming to an end, Verv are confident their business model, offering the promise of cheaper energy bills, will be able to provide fresh incentives to encourage new customers to embrace renewable energy sources. Verv are currently engaged with the U.K. regulator body (Ofgem), using sandbox trials to evaluate the scalability of their project, and intend to go live commercially within the year.

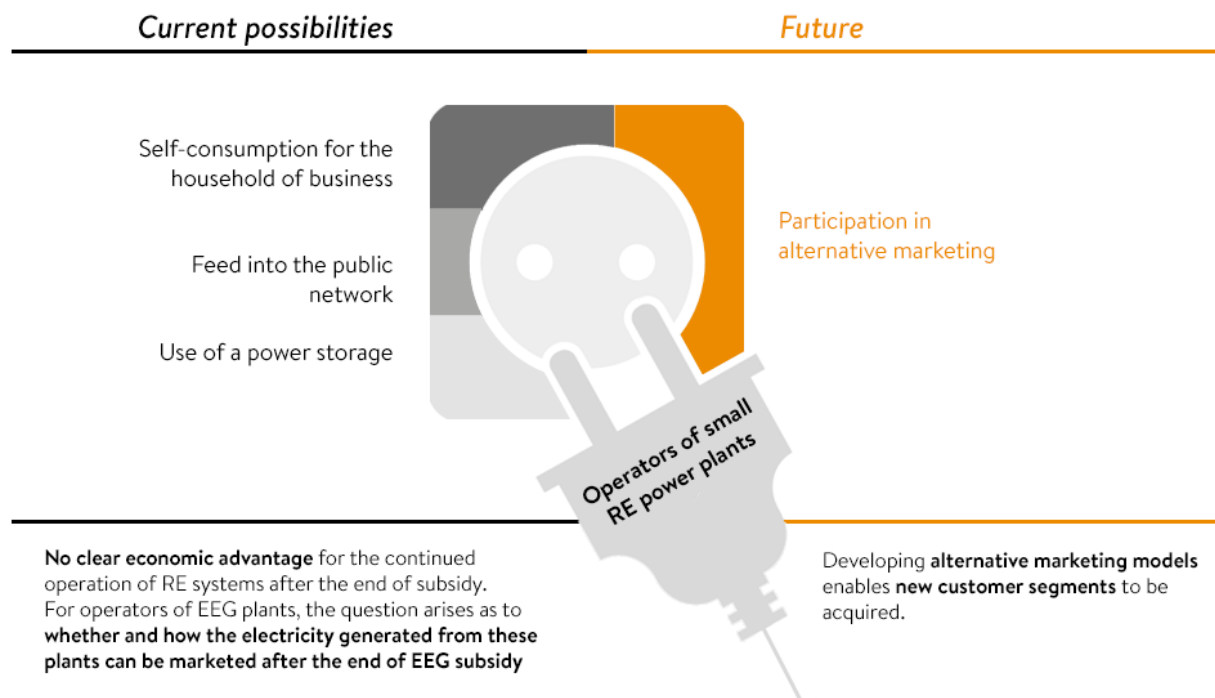
Another approach to P2P can be found in Germany, where today many utilities are considering whether they should be a pure infrastructure provider or alternatively turn into an energy service provider for their customers.

Regional utilities in Germany are facing high competition and growing challenges due to political ambitions. In Germany we expect 80% share of renewable energies in the overall power supply by 2050. Further complicating the matter, private consumer are installing more and more since 2000 their own power plants, storage stations, which can strain grids. Regional utilities can't afford being a basic energy provider, they need to become an energy service provider for their consumer. As is the case in the U.K., renewable energy subsidies will no longer be available in Germany after 2020 for households that installed their power plants in 2000. Consequently, individual DER prosumers are facing the challenge of finding new ways to commercialize the excess energy that they generate. For operators of renewable energy plants, four options exist to keep the plant in operation even after the subsidy time has reached the deadline (Figure 4):

- Feed the excess of power in the public network. Although the remuneration for this case is not yet clear, it should be based on the electricity price
- Use the excess of power for self-consumption and feed the residual electricity that can't be consumed in the public grid.
- Integration a power storage system to compensate for the time lag of power production and power consumption. Therefore, a higher self-consumption can be achieved.

Figure 4: Blockchain-based Energy Trading for Regional Utilities

There is no clear economic advantage for prosumers in the currently available options for the continued operation of RE systems after the end of subsidy. For prosumers, the question arises whether and how electricity generated from these plants can be marketed after the end of the subsidy. There is a concrete need for alternative models that will enable the trade of surplus of renewable power in a neighbourhood.



German regional utilities are embracing those challenges by developing new business models, products and services to accommodate operators of renewable energy assets. In fact, prosumers also want a service that will enable them to sell excess of power in the easiest way possible -- a need which a group of German utilities (AÜW, WSW, TWL...) are actively working together to tackle by engaging in regional P2P energy trading projects. The regulatory framework would request for each prosumer to register as an energy supply company and endorse the role and responsibility.

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The first objective is to gain experience for tomorrow's electricity market and ascertain how the ability to trade electricity is accepted by the customer. It will therefore be important to define the new role regional utilities will play in this new electricity market environment.

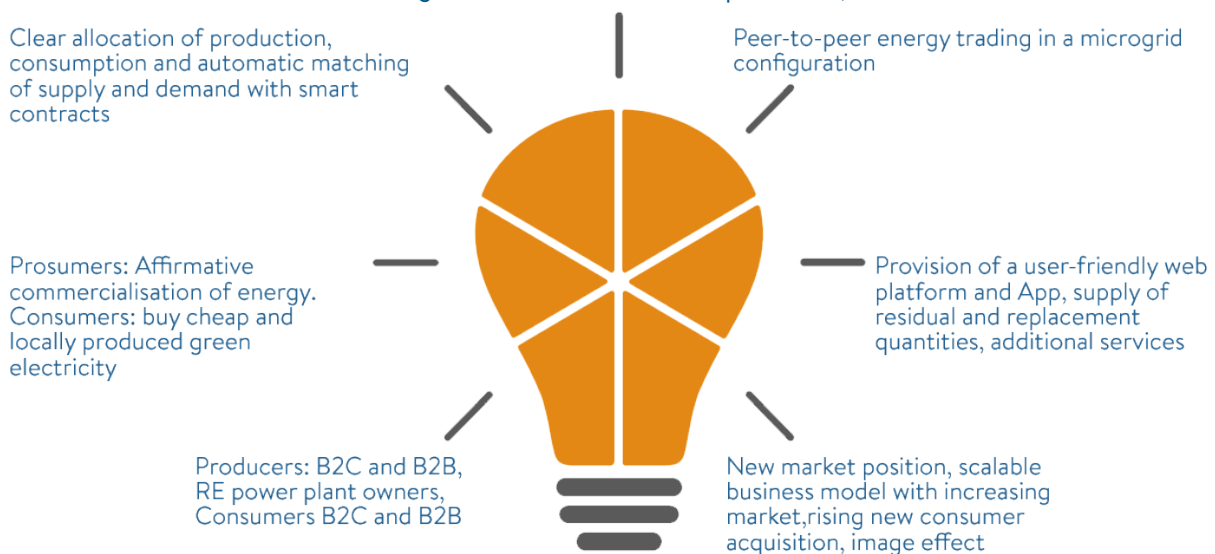
It is now conceivable that a farmer from Niedersonthofen with a large PV plant sells its surplus electricity to a tenant in Kempten, which had no opportunity to date, to support the regional green electricity production.

Michael Lucke, AUW

Regional utilities are in a good position to endorse prosumers and consumers in times of growing decentralization and digitization of the energy transition. They have direct contact to loyal customers and can offer products that directly solve their needs for security of supply and cheap greener electricity from the region. Customer needs, business model, incentive for the utility, necessary costs for the installation of the digital infrastructure, and concrete client segmentation need to be analysed profoundly and concretely to ensure the validity of the business model. This way, the regulator will recognize the benefit of the use case for the energy sector and open the way for more innovation freedom (see figure 5).

Figure 5: Blockchain-enabled Regional Utility Business Model

The business model of centralised energy production and distribution will decrease in prominence if more renewable energy for domestic consumption comes to be produced locally. In the energy market of the future, the customer will play a significantly different role than before; on the one hand because of the increasing movement towards the prosumer, on the other because of



Regional utilities step away from the traditional energy supplier and infrastructure provider model. They **become a service provider** for consumers by actively including them as an **actor of the energy transition**

technologies such as blockchain and their associated new degrees of freedom. For a regional utility, a role as an energy service provider is emerging. This function still needs to be defined, however; currently the role as a regional peer-to-peer trading platform operator remains in the background.

A successful regional utility must be able to be multi-dimensional and blockchain technology can enable this new level of choice and responsibility for regional utilities, at least in Germany (see Figure 5).

An Alternative to Blockchain – Emergent

Blockchain is not the only DLT out there, yet it may be the most well known. In order to maximise inclusion of renewable energy sources into the grid and overcome the issue of customer engagement, DLTs are being considered. The developer of an alternative, Faraday Grid, stated that *“blockchain is only operating at the edge of the grid, not within the grid, and as a result, there is a limited ability of it to be a real game changer. [...] There is a physical constraint imposed by the network itself. At a small scale, blockchain can work, but it doesn’t take account of the physical constraint of the system.”*

For Faraday Grid, scalability of blockchain is clearly an issue, and for this reason they have in fact developed the Emergent transactional platform. Emergent utilises DLT through a private chain (as opposed to blockchain) to facilitate energy transactions. It is a system of controls that balances supply and demand across the entire energy system, using price as the key operational mechanism. Chief Economist Richard Dowling further explained, *“there is a transactive layer on top of the grid, but unlike the blockchain, our system is coupled to the physics of the grid itself. Emergent is entirely integrated within the existing electricity system”*.

Emergent relies on exchangers and other enabled-devices which are physically distributed across the grid and operate independently, receiving real-time pricing signals to then enable optimal transactions between market participants. For the Emergent platform to be enabled, the deployment of Faraday Grid architecture (including Emergent-enabled exchanger hardware) is required into the physical electricity network. This approach would allow for deeper, more robust optimisation of the energy grid than the one based on blockchain, and could create interest from energy regulators, grid operators, power producers and consumers.

Emergent is now at PoC stage and the piloting phase is expected to commence at the beginning of 2019 across different geographies. According to Dowling, *“the complete system architecture developed by Faraday Grid delivers a quantum change to the energy system, equivalent to the change from the telephone system to the internet.”* Faraday Grid expects the impact of Emergent on the

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energy market to be substantial. High fidelity simulation modelling of Emergent within South Australia markets shows that energy costs for the average consumer could be improved by 78% and by 130% for prosumers.

Emergent - Faraday Grid	Blockchain
Hardware and software-based system	Software-based system, integration with third-party hardware
Peer-to-peer trading	Peer-to-peer trading
Integrates directly with physics in the Faraday Grid	Integration with third-party hardware
Single platform, no external party needed to trade. Price as key operational mechanism	Trustless system - no third-party intermediaries. Requires an additional communication layer.

CHALLENGES TO ADOPTION

Technological challenges are being actively resolved

From the interviews conducted, two challenges seem prominent above others in inhibiting full adoption of blockchain technology by the energy sector. Technological feasibility and scalability are hurdles to be sure, but the market, or rather those interviewed for this study, are confident that with time, testing and refining of the technology these will be crossed. Towards this end, the Energy Web Foundation, has assembled an ecosystem of more than 80 energy companies' affiliates and start-ups interested in blockchain applications in the energy sector. EWF builds open-source, foundational blockchain tools and technology for use in the energy sector. For instance, in response to some of the concerns raised recently about the speed and cost of transactions with blockchain platforms, **the EWF collaboration is working to speed up the number of transactions that a blockchain platform can handle as well as the cost effectiveness of the transactions.** Additionally, EWF has implemented a proof of authority consensus mechanism that requires the known companies to validate transactions, increasing the potential for regulatory integration. EWF affiliates are building blockchain applications on top of the EWF Chain, many of which are currently at Proof of Concept (PoC) or pilot stage for blockchain, e.g. certificate of origin, trading application, billing and settlement process for utilities, EV charging infrastructure, demand-response. These applications help pilot a model for a fully transactive grid and collectively may be able to help address some of the key technological challenges of blockchain in the coming months.

Unlike technological and scalability concerns **regulation and customer engagement** loom as wildcards poised to either doom the technology or allow it to transform the industry.

Consumer Apathy Remains a Challenge

Customer engagement may not be a requirement for all use cases and business models arising from the use of blockchain technology in the energy space. However, it is very much a necessity for a P2P market. **A fully scaled P2P market is dependent on residential customers becoming prosumers.** This means transforming average customers from those who normally just want to turn on the switch and have the light come on and pay a monthly electricity bill to those who will become active energy traders.

The interviewees acknowledge that a shift in customer participation might be difficult on a large scale. There is consensus that there will be early adopters such as those who want to be active in order to reduce emissions and help curb climate change. But there is also consensus on the anticipated reluctance from the majority of average residential customers who might be unwilling to

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take on new responsibilities or engage in different behaviours. For example, in the United Kingdom where residential customers can choose their electricity provider as well as the underlying tariff, **over 60% have remained in the default tariff which is £300 more expensive on an annual basis.**⁴ This begs the question of how successful can a P2P market be where customer engagement is lacking even when there is a clear financial incentive. Is it a matter of providing better customer information and transparency, or is it indicative of systemic lack of engagement and consumer inertia?

The ability to log devices is quite possible with blockchain, but the ability to engage customers and pull them in has always been elusive when you look at any large-scale mass market program focused on residential end-users; technologies dependent on customer engagement has always suffered historically to get customers involved and engaged and blockchain is no different.

Jon Creyts, RMI

The interviewees offered a host of solutions for inducing customer engagement, from sending the right price signals to making platforms more intuitive for customers to engage with. From the discussions, there emerged no silver bullet answer other than the hope customers will eventually adopt to the new platforms over time once they are easy and the appropriate incentives are in place. Jon Creyts of RMI, though, provided a particularly intriguing hypothesis: **“the way this technology emerges most quickly will have to be linked to actors that are incredibly incentivised to scale it fast. Companies like Amazon and Alibaba will need to get into this business to get us over the hurdle of engagement.”**

Mixed perspectives on regulatory constraints and enablers

A majority of interviewees agreed that some degree of regulation is warranted and should provide balance between innovation and customer protection. This viewpoint was conditioned with the speculation that there would be a push back by market participants if such regulation was to be perceived as a barrier or a hinderance to the new energy blockchain-influenced business models. Lastly, interviewees expressed confidence that regulators will intervene if at any point in time the adoption of new technologies were to put security and/or stability of supply in jeopardy.

In order to harvest this opportunity, the regulatory framework needs to change but this change isn't being triggered by blockchain, but in fact it is driven by the expansion of DERs that is being enabled by the blockchain technology. Regulators need to re-look at the energy value chain in terms of what this will be in the future.

Ravindra Balija, WIPRO

4. <https://www.ofgem.gov.uk/publications-and-updates/state-energy-market-2017>

Regulators, for their part, are unequivocal that electricity was here before blockchain and will remain after blockchain. As example, DERs, widely considered key to meeting climate change goals, have flourished in some parts of the world -California, Germany and Spain, to name a few prominent exemplars of successful DER penetration- without blockchain as platform or enabler. Nevertheless, the market points to blockchain as a conduit towards democratisation and decentralisation even beyond what the introduction of smart grid achieved for digitizing the grid.

In the mid-2000s, it may be useful to recall, smart grid was the hype of the energy market, bringing with it hope, fear and assured proclamations of the impending end to the regulated utility. Yet today smart grid is almost a legacy term, with developing countries leapfrogging this older technology for smart meters and energy storage while developed countries lay plans to replace older infrastructure with newer/smarter technology. Seen in this context, in some respects blockchain appears to be a perpetuation of a familiar technological continuum. A key difference in this instance, however, is unlike during the first phases of smart grid where regulation wasn't asked to change and only the utility had to transform and adapt, blockchain is challenging regulation to evolve as well.

RECOMMENDATIONS FOR REGULATORS AND POLICYMAKERS

The majority of those interviewed agreed that market participants have to first design a new energy blockchain enabled market before regulators could intervene. Regulation generally reacts to the market and does not create a market. However, some interviewees believe that without at least some willingness from the regulators to define preliminary parameters such as ‘what a customer is or isn’t’, the innovators cannot design a new energy blockchain enabled market. Interviewees generally recommended that regulators could consider setting parameters and/or enablers such as:

- **Defining key terms:** The consumer, prosumer and other relevant terms need to be defined by the regulators in the energy sector context so that all the energy sector stakeholders including regulators talk on the same platform. It would be complex to go ahead if businesses and regulators have different understandings.
- **Regulators must clearly state their philosophy and long-term vision:**
 - The current regulation is defined for vertically integrated utilities. Regulators need to redefine policies so that they are suitable for and do not unintentionally constrain new business models enabling transactive energy systems. Defining a transition policy is a key first step to be taken.
 - Regulators need to define how DSOs and TSOs will collaborate in the future. In a future where transactions intensify and get more complex, collaboration between all actors will become even more paramount. Starting to define future roles for stakeholders coherent with the long-term vision would go a long way.
 - As blockchain penetrates the market, regulation will change further but it will still depend heavily by the local context – size of market, nature of market, population density, volume of flows etc. In some countries regulators only regulate reliability and security of supply. In other jurisdictions sometimes in the same countries, regulators also determine tariffs and in other countries it also determines volumes. The regulators’ roles are already differentiated, depending on where they operate.
 - The final need is that regulators create a new tariff to differentiate the sources of energy based on the distance between the two and the electrical load. Several regimes can be considered, particularly regarding potential transactions across borders, making it all the more important to clear up that void. A clear and well communicated long-term stance on the direction of the rules is needed before any actual rules are implemented.

- **New Tariffs:** The immediate need is that regulators need to differentiate the tariff regarding the use of the grid. There should be a tariff for locally produced electrons versus electrons produced outside of a locally defined zone – e.g. If you transport electrons further away you pay more, if it says local, you pay less. A financial incentive is needed to support the further expansion of distributed energy resources.
- **Enabling the integration:** Regulators can establish common operating platforms and enable the integration of all assets/participants seamlessly which will be key during the initial phase of energy transition.
- **Empowering utilities:** Utilities should become enablers to the consumer. Utilities should engage with customers in transformation of production and consumption and could help in providing them the right tool to actively participate in the energy transition. Regulators need to make sure this is happening.
- **Empowering consumers and providing simplicity:** Regulators need to enable consumers to have a say in the clean energy policy. Governments need to have more discussion with the consumers. The customer should be aware that there are regulations in the system and what regulations do. Regulations need to inform consumers to enable them to have a greater role in the energy value chain. Regulators need to build trust among consumers into something which is totally new and unproven.
- **Ensuring energy security and reliability:** Regulators need to control the energy reliability and therefore some kind of regulations are needed to manage the fluctuations from DER. Governments need to encourage advanced technologies to predict the variable weather patterns and energy generations across the country. To this end regulatory standards will make sure that energy businesses are getting into technologies/businesses without jeopardizing security and reliability of energy supply.
- **Protecting the consumers and businesses:** In a P2P world the regulators should ensure that everyone is on an equal footing accessing the market and that consumers/businesses are all protected in transactions. Make sure that everyone has access and everyone is protected – this should be the mission of the regulator. There are a range of faults that could occur in the electricity system, as we already know. We need regulations as a consumer protection to ensure the reliability and security of supply.
- **Having oversight on cybersecurity:** In a decentralised market, there will be a further need for the energy regulators to have an oversight for cybersecurity. Regulators need to further develop their own knowledge in this area and create groups within their organisations that are capable of appropriate oversight; this is similar to their oversight of the physical safety of the energy system.

FUTURE OUTLOOK

Taken overall, there appears to be broad consensus that regardless of how successful blockchain applications will be, **this innovative technology is fuelling a re-thinking of the energy value chain and accelerating a transition** from energy as a commodity to energy as a service. Herein lies quite possibly the essence of blockchain's disruptive potential, whose developments we will continue to follow closely over the near future - a near future which, it must be said finally, remains almost the same as today.

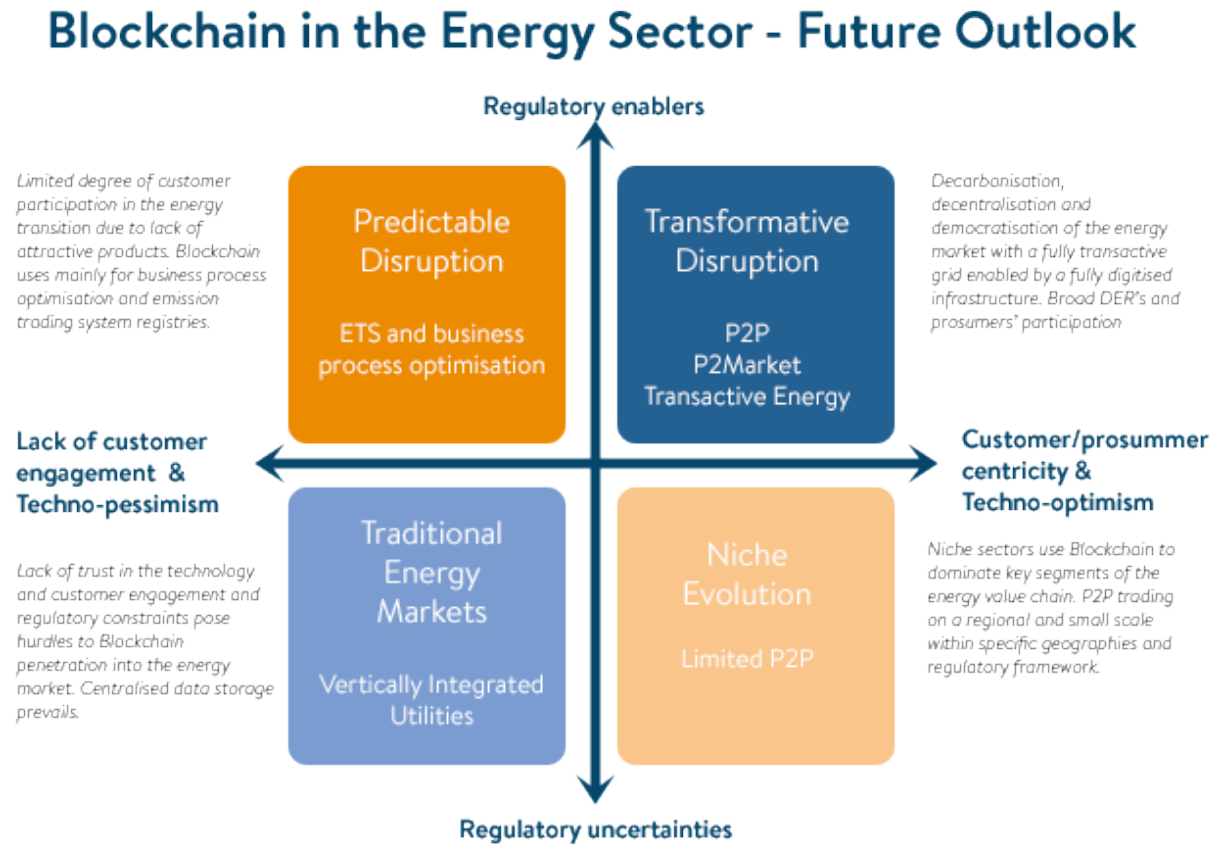
Nevertheless, whether for purpose of optimising the existing grid through asset registers and energy trading platforms or in creating a new framework through enabling transactive⁵ energy (i.e. P2P), it is now beyond doubt blockchain projects will continue to be piloted and assessed as potential game changers for the optimisation of the entire energy value chain.

The future outlook for energy blockchain is promising and uncertain. A number of possible scenarios emerge and need to be considered (see Figure 6), even at this early stage. This is partly because the technology is so new, hence it is difficult to make accurate predictions of how and when developments within any given application will come to full fruition in the market.

The intelligence gathered as a result of this work provides a means of setting the scene, so to speak, for the medium/long term outlook of energy blockchain. In the near term and without addressing the two obstacles of customer engagement and regulatory reform, a full transformative disruption may not be feasible; however, energy blockchain will continue to optimise the practices of today's energy eco-system. Figure 6 is an illustration of the potential of blockchain as an enabler provided the regulation and customer engagement concerns are met either in whole or in part. As you will note from the illustration the green box titled Transformative Disruption is only achievable if there is in place a new regulatory framework and a willingness from consumers to engage. In this scenario the existing energy ecosystem will experience the most dramatic disruption – i.e. a revolution. The other scenarios are all an evolution of the existing market place and existing practices which will all benefit from the use of blockchain technology.

5. Transactive energy is a vision of an intelligent device-enabled-grid where each device can utilise economic signals in order to optimise allocation of resources subject to the constraints of the grid. It can be applied within a localised area, e.g., microgrid, or be utilised to manage the whole power system.

Figure 6: Blockchain Enabled Scenarios



We began this effort to answer two key questions – how far along is blockchain and is regulation an impediment to its progress? The annex provides the detailed answers to these two questions from a representative sample of the interviewees.

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ANNEX 1 – COMPLETE RESPONSES FROM A REPRESENTATIVE SAMPLE OF INTERVIEWEES

Where do you see your organisation in 12 months' time, with their blockchain activity?			
Participant	Type	Response	Theme
Equinor	New market participant	We are working with 5-10 different pilots in our portfolio all in all. I would expect that between 3-5 of them will have scaled by that point and this to us represents only a step in the digitalisation of our processes. Blockchain needs to be seamlessly integrated within our processes, in the context of other technologies. The IoT is another important element around blockchain. You need to be able to connect machine to machine, to then release a flow of data away from a traditional central authority to enable full decentralisation.	Still emerging in 12 months
Hive Power	New market participant	In 12 months we hope to have concluded the first pilot, started the other 3 pilots in the pipeline and have arranged a robust financing strategy.	Still emerging in 12 months
TENNET	New market participant	We are vastly underestimating the pace of technology, we still think that new technologies: Blockchain, drones, artificial intelligence belong to the future. We do not see that it is happening today. The pain point is not the impact of the technologies, but the fact that they are much faster than we are, and we are not adapting.	Still emerging in 12 months
TEPCO Ventures	National conglomerate	We still think that in the next 12 months will be learning about business model possibilities, to subsequently design a PoC which enables market participation towards a real P2P pilot.	Still emerging in 12 months
General Electric	Multi-national conglomerate	For GE we will continue to pilot and enhance the business cases for blockchain in the energy space to explore the potential of this technology. Devices in the future would autonomously participate in the transactive energy network. Applications will help make prescriptive, optimised decisions at the device/prosumer level as well as at the network level creating a green, intelligent, distributed & collaborative platform. Blockchain technology has the potential to be the enabling technology. The technology is going through rapid evolution – an exploration journey the industry has to go through together in the coming years.	Still emerging in 12 months
Rocky Mountain Institute	Non-partisan/non-profit association	There are a lot of challenges to overcome, but blockchain is potentially a tool that can make regulators' life easier by catalysing an automated system for patrolling activities in the market. Some of the regulators' jobs could be automated by using blockchain technology, and probing market activities has the potential to be greatly simplified if regulators have enhanced permissioning. P2P transactions pose specific regulatory hurdles because in many geographies they challenge a utility franchise agreement. Regulatory support is required to address the utility/monopoly agreement as it relates to a distributed network. RMI wonders, 'How do we go to a point where individuals manage access to their energy usage data, from where we are now with a centralised entity that manages that same data? This transition needs regulatory involvement.' The regulators – how they see the position of the customer's role in the transition is also key. "In an ideal sense, blockchain could emerge faster with an 'Amazon Energy' asking you to download blockchain-enabled code to WiFi-enabled device in your own home. That device would then seamlessly connect to all energy producing, consuming, and storing devices to provide automated and secure energy efficiency and demand response."	Still emerging in 12 months
dena	Government	Pilots that are more visible and more result from those pilots. We expect more projects from Europe and more projects in general with hopefully more interesting conclusions about the projects.	Still emerging in 12 months

What are the main regulatory obstacles that you are facing and what would you expect from the regulators?			
Participant	Type	Response	Theme
Faraday Grid	Grid Operator	Doesn't view regulation as a substantial barrier; instead it believes regulators must adapt to innovation, that they cannot create value and innovation. Moreover, the company believes regulators should allow for a common protocol, establish the "rules of the game(s)" and lead discussion with incumbent utility players. Faraday Grid believes regulators can establish common operating platforms and enable the integration of all assets/participants seamlessly. That regulators have a key role to play in establishing basic standards and protocols, but not in the design of new innovations or new systems as such.	Not a barrier
National Grid	Grid Operator	Regulators are those that decide how we segment responsibilities across the energy value chain. To be able to make P2P work, we have to change responsibilities within the value chain. Regulators should not be blamed. We should be telling the regulators what we want them to do. Regulations will need to be changed and that process will take time, and it will only happen once the market has come up with a final design.	Not a barrier
Arizona Corporation Commission	Regulator	Believes blockchain is still at a stage where regulation is acting as a safeguard for consumers. At the same time, as the sector works together and identifies best practices moving forward, it will then be necessary to get regulation out of the way and let this innovation take hold.	Waiting to react
California Public Utilities Commission	Regulator	Doesn't think regulation is the biggest hurdle for blockchain in the energy space. It believes that the regulators need to support the transition of the utility business model embracing the need for blockchain application. It believes that the regulation needs to be responsive to what the market wants. By the time blockchain is ready, and the market is ready, regulation will embrace the changes and will not stand in the way as a hurdle. The Commission has rightly pointed out that a great number of DERs exist in California without the need for blockchain. In the future, with blockchain there might be more transactive energy and a greater diversification of products and services, but blockchain is not a pre-requisite for the further growth of DERs. It is, however, exciting to see that blockchain is being further developed and could make the growth of DER easier. Utilities have always been very conservative in nature, so they will move with incremental steps on blockchain engagement. The regulator's role is to create a policy vision for the future and let the market develop around it. For instance, regulators in NY and California have set forth their vision and the market are creating solutions accordingly. It is important that a regulator should not determine which technology is to go forward and which is not	Waiting to react
New Zealand Electricity Authority	Regulator	At this point doesn't see how blockchain is a necessary condition for greater participation of DER. The Authority believes there are other solutions to facilitate greater participation. A key concern they express, hence, is what will happen if some prosumers use blockchain technology and others don't? The anxiety for the Authority is that high penetration of DERs may encourage poor reliability of supply outcomes since there is not a coordinated optimised dispatch of resources, given all are using different systems.	Waiting to react
Rocky Mountain Institute	Non-partisan/non-profit association	Sees blockchain as potentially a tool that can make regulators' life easier by catalysing an automated system for patrolling activities in the market. Some of the regulators' jobs could be automated by using blockchain technology, and probing market activities has the potential to be greatly simplified if regulators have enhanced permissioning. P2P transactions pose specific regulatory hurdles because in many geographies they challenge a utility franchise agreement. Regulatory support is required to address the utility/monopoly agreement as it relates to a distributed network.	A tool for regulators for transparency & automation

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WIPRO	Energy Consultant	The regulatory framework needs to go through a change to support the use of blockchain technology that in turn underpins the use of DERs. WIPRO suggest the regulatory framework needs to change but that this change isn't being triggered by blockchain, instead it is driven by the expansion of DERs enabled by the blockchain technology	A tool for regulators for transparency & automation
Freelio	New market participant	Wants regulators and EU legislation to have the consumer defined. For example: what happens when other usable applications of Blockchain make a consumer part of a decentralised energy exchange community? The consumer must be defined. The prosumer's role must be defined. What happens when an end-user downloads an app and starts trading? The regulator should acknowledge the risks and liabilities of the new system (decentralised). If a market can be opened which is customer focussed, by way of regulators, then Freelio feels it has the chance to create a new service. However, the concern is that regulators are going to impede the growth of blockchain, which is why start-ups cannot go for different business models and stay in the regulated market business models (of established businesses). Thus, Freelio argues the reason why there is not faster growth of blockchain is because regulators cannot yet see the use of blockchain technology to empower customers. Prosumers, in their view, should have a right to buy, sell and trade renewable energy resources	Potential barrier
Sunrun	New market participant	Believes regulators should begin considering how to enable transactive energy in a manner that benefits ratepayers but also is compatible with the basic functionality of the grid. They view regulator's stance to date as having been largely at arm's length. Sunrun suggests the next couple of years will define how transactive can best be utilised, believing this technology is more efficient and the customer experience it enables, superior. The technology is in the benefit of the ratepayer but to maximise it and make it possible all the systems need to work together across organisations from individuals; 3rd party aggregators; utilities; ISOs; and to IPPs.	Barrier
FutureFuel Technology	New market participant	Its perspective is based on its business model, which is one of mining digital assets to be monetised and exchanged. Presently there are no regulations for this business model and FutureFuel is looking to regulators step in and define rules. Lack of clarity is thus a hurdle to the company, from a regulatory perspective. FutureFuel believes regulators are naturally reactive and aren't always proactive to the market. That regulators need to see the way the market evolves first and then act accordingly. The dilemma for FutureFuel, simply put, is a market for mining digital assets currently does not exist and so it is quite difficult for regulators to regulate something not in existence. Nonetheless, FutureFuel needs some indication of what the rules might be to build its business model accordingly	Barrier
Siemens	Multi-national conglomerate	Believes regulations which can cater for flexibility and ancillary services being provided even by small and mid size players to DNO's are vital. For example, Siemens believes that the fixed tariff model should be substituted by a dynamic tariff, one which allows recognition that if a consumer is in a weak part of the grid, his/her demand-response has a greater impact on grid stability. There should be tariff incentives for this type of customer.	Looking for regulatory clarity/ leadership
General Electric	Multi-national conglomerate	Believes regulation won't impede blockchain, it will be far more important to develop/ implement the right business models. Globally, the power system is undergoing a grand transformation. We see the convergence of traditional and emerging, physical and digital, large and small, all to create a new twenty-first century power network. GE believes more sustainable, intelligent and customised energy solutions will be needed within the power network, and this would include blockchain enabled solutions that can be integrated into existing networks and infrastructure. Blockchain is a solution where new business models may be more critical to facilitate growth. For this reason, GE will work with our customers, regulators and interested stakeholders as blockchain – and other innovative energy solutions – evolves.	Looking for regulatory clarity/ leadership

ANNEX 2 - INTERVIEWEE CREDITS

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