Compendium of Papers & Presentations

CONFERENCE
ON
CREATION OF ECO-SYSTEM USING
BLOCK CHAIN TECHNOLOGY

FOR RENEWABLE ENERGY, DISTRIBUTED ENERGY GENERATION & SUPPLY

Organized by

UP ELECTRICITY REGULATORY COMMISSION

ON

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Papers

List of Papers

List of Presentations

UP ELECTRICITY REGULATORY COMMISSION

Message from Energy Minister

यह जानकर अत्यंत हर्ष हुआ है कि उत्तर प्रदेश विद्युत नियाम आयोग द्वारा दिनांक 10 अक्टूबर, 2018 को "Creation of Eco System using Block Chain Technology for Renewable Energy, Distributed Energy Generation & Supply" विषय पर सक संगोष्ठी का आयोजन किया जा रहा है, जिसमें अनेक विषय विशेषज्ञों सहित कई प्रदेशों के विद्युत नियामक आयोगों के पदाधिकारियों द्वारा भी प्रतिभाग किया जायेगा।

इस अवसर पर विषय के विशेषज्ञों तथा अन्य प्रतिभागियों द्वारा जो महत्वपूर्ण प्रस्तुतीकरण होगा, उसका संकलन एक पुस्तिका के रूप में प्रकाशित भी किया जायेगा।

'ब्लॉक चेन' एक अत्याधुनिक तकनीक है, जिसका अनेक क्षेत्रों में उपयोग प्रारम्भ हो चुका है। देश और प्रदेश में ऊर्जा के संयोजनों एवं उपभोक्ताओं की बढ़ती हुई संख्या को देखते हुए भविष्य में इस तकनीक की विकेन्द्रीकृत नवीकरणीय ऊर्जा के उत्पादन एवं वितरण को एक सूत्र में बांधने में महत्वपूर्ण भूमिका सम्भावित है। इसका वृहद लाभ विशेष रूप से ग्रामीण उपभोक्ताओं को मिलेगा।

मैं इस अवसर पर पुस्तिका के प्रकाशन एवं संगोष्ठी के आयोजन के लिये उत्तर प्रदेश विद्युत नियामक आयोग को हार्दिक शुभकामानाएँ और बधाई देता हूँ।

¼Jhdkur 'kek½

ऊर्जा मंत्री, उत्तर प्रदेश

UP ELECTRICITY REGULATORY COMMISSION

Message from Chairman

The biggest challenge and accomplishment for a regulator is to move towards deregulation, UP Electricity Regulatory Commission is also taking a baby step in pursuit of deregulation by conducting a workshop on "Creation of Eco System using Block Chain Technology for Renewable Energy Distributed Energy Generation & Supply".

It was a parlance in Indian Power Sector in 1970s that power sector in India suffers from 2/3 syndrome i.e. what ever energy is generated, only 2/3rd of it is consumed; whatever energy is consumed, only 2/3rd of it is billed and whatever energy is billed, only 2/3rd of it is getting paid for. Since then scenario of power sector in India has undergone significant change as PLFs of Indian thermal power plants have increased and efficiencies have been brought in the metering, billing and revenue collection activities. Still a look at statistics reveals that even now the distribution cost is around 70% to 75% of generation cost, which is not an acceptable situation. With around 85% power procurement stranded in long term power purchase agreement and only around 4000 MW power available at exchange, there is little scope for dynamic generation pricing with sensitivity for demand variation. Nevertheless, under existing framework, there is little scope for further optimizing the power purchase cost.

In this backdrop, efficiencies can be brought in only through dynamic location based pricing responding to market signals, wherein distributed energy sources viz small solar panels, smart devices, EVs & other consumers of varying demand interact with each other and energy trading takes place in a localized grid through blockchain technology, which will not only enable direct consumer engagement with the decentralized grid but with the support of local ancillary reserves, it will flatten the hyperlocal demand curve along with efficient billing and settlement amongst the peer groups connected through this local grid, while promoting the use of renewable energy and efficient transaction of RE attributes among the local players. It will also, to a certain extent, solve the problems associated with quick ramping up and ramping down of large generators in response to highly inverted demand curve of a gigantic grid by superimposing an efficient hyperlocal demand response curve, which is significantly efficient as it is sensitive to dynamic local based pricing and has a reduced network cost and dynamic in nature. It can open possibilities ranging from peer-to-peer exchange to creating a energy ecosystem. Decentralizing the electricity market would make distributed energy resources of large number of prosumers available for power trade based on block chain technology within a peer-to-peer market of their mini grid. Utilities, prosumers and consumers can benefit from the numerous advantages of the block chain including real time trustworthy transaction records,lower transaction costs, network transparency and much more.

The introduction of blockchain technology will not only bring in transparency and efficiency in the power system; it will also help the regulator in looking at real time transactions rather than trailing accounts, which hardly help regulator in taking market based efficient decisions. The ability to support a globally connected network of energy transfer, where smart devices will be able to securely send and receive data while autonomously reacting to market signals, is a reality some believe still 5-10 years away, but it is also my conviction that it has enormous potential and also that in order to effectively regulate Blockchain, policy makers should first invest in understanding it. It is with this view, that UP Electricity Regulatory Commission has made this avant-garde attempt of conducting this workshop

I envisage this workshop as a genuine precursor to gradual adoption of blockchain technology in power sector in the state, which is likely to leapfrog in the coming decade. With this sprit, I welcome all the participants in this workshop and urge to let us put our minds together and synergise our energies for seamless and quick adoption of this technology.

(Raj Pratap Singh)
Chairman

UP ELECTRICITY REGULATORY COMMISSION

Message from Member Shri S. K. Agarwal

It gives me immense pleasure that UP Electricity Regulatory Commission is conducting a workshop on "Creation of Eco System using Block Chain Technology for Renewable Energy Distributed Energy Generation & Supply". This is, no doubt, the first small step in this direction but it has enormous potential to be harnessed in the coming future.

Electric power systems around the world are rapidly changing. For over a century, these systems have relied largely on centralized, fossil fuel plants to generate electricity with gigantic grids to deliver it to end users. Utilities had a straightforward objective: provide electricity with high reliability and at low costs. But, with new push on renewable energy these systems have to face extreme volatility of wind and solar power and when coupled with high share of electric vehicles (EVs) & self-generation getting fed into the grid, grids are likely to face acute strain. Further complicating the matter, customers are installing their own equipment-from solar panels to batteries and smart appliances-to control their production and consumption of electricity.

It is in this backdrop, that the policy makers & innovators are peddling a putative solution viz application of blockchain technology in power sector, which can be utilized for facilitating peer-to-peer transactions that bypass a central utility or retail energy provider. Further, blockchain technology can be utilized to track the production of clean energy, facilitating secure & easier payment gateway for charging EVs, raising funds to deploy clean energy, managing customer appliances etc.. Although most blockchain ventures aim to replace today's centralized power system with decentralized energy trading, but in coming years, these ventures are most likely to achieve commercial traction while working within the existing system and partnering with incumbents such as utilities.

Since the electric power sector is highly regulated, policymakers will play a crucial role in determining how much of blockchain's potential can be realized and technical standards are to be developed. It is in this backdrop, that this workshop assumes critical significance and participants are welcome to start a meaningful dialogue on the subject, which has potential to transform our future in general and that of power sector, in particular. With this objective in mind, I welcome all the participants to make this workshop a success and have this appreciation that a good beginning is half work done.

(Shri S. K. Agarwal)
Member

UP ELECTRICITY REGULATORY COMMISSION

Message from Member Shri K K Sharma

It gives me immense satisfaction that UP Electricity Regulatory Commission has taken a lead and is conducting a workshop on "Creation of Eco System using Block Chain Technology for Renewable Energy Distributed Energy Generation & Supply". I wish this workshop a colossal success.

The ability to support a connected network of energy transfer, where smart devices will be able to securely send and receive data while autonomously reacting to market signals under the blockchain technology domain may take some time to fructify in reality but its likely footprints in the lives of future generation cannot be lost sight of. Alongside the rollout of smart meters and continued development of demand side response measures, new digital peer-to-peer platforms are starting to emerge that cut out the middle man and seamlessly connect green energy producers directly with those wanting it. Blockchain technology is likely to consist of complex web of multiple transactions, which will not only balance the geographical mismatch between supply and demand but will also address it with utmost security and trust supported by IOT.

As a regulator, it is my endeavour to be abreast of the issues arising in the application of blockchain technology in power sector specially for renewable energy power so that meaningful regulations may be cast keeping in view the technical and security concerns. With this objective in mind, I welcome all the participants in the workshop, which will help in creating an enabling platform for pursuing the objective in future based on the "take away" of this workshop.

(K K Sharma)
Member

Business Model for Increasing Metering Billing and Collection in Rural Areas using Blockchain

Profile

Dr. Sugata Gangopadhyay is an associate professor at the Department of Computer Science and Engineering of Indian Institute of Technology Roorkee. Dr. Gangopadhyay did PhD from Indian Institute of Technology Kharagpur in 1998, and has worked in BITS Pilani, IIT Kharagpur, ISI Chennai center apart from being in IIT Roorkee from the year 2004. His research interests are cryptographic Boolean function and stream cipher cryptanalysis. Dr. Gangopadhyay has coordinated many successful international projects in cryptography and information security.

Abstract

We introduce blockchain technology starting from a level which is accessible to a wider audience than the community of computer scientists and engineers. We discuss how the relevance of blockchain technology is being realized beyond its initial single case application to electronic currencies such as bitcoin. The application of private-permissioned blockchains in highlighted, and a business model is proposed for increased electricity metering billing and collection in rural areas by using this technology. The applicability of blockchain in micro-grid is also discussed.

Keywords: Distributed ledger; private blockchain; hash pointer linked list; consensus; smart meter; micro-grid; renewable energy.

1. Introduction

Any discussion on blockchain invariably leads to bitcoin. At the outset it is important to mention that blockchain is not synonymous to bitcoin. Bitcoin is a type of digital money or currency among many other digital currencies. Blockchain is the technology which enables bitcoin. In this article we will discuss the basics of blockchain and then state a business model for increasing revenue in the power sector. This article is based on an excellent book by Don Tapscott (2018), lecture by Karim Lakhani (cf. reference), and a whitepaper a company called LO3 Energy which is a pioneer in the application of blockchain in power sector.

In Section 2 we provide a top level overview of blockchain and the concept of distributed ledger. Section 3 is on evolution of this concept from supporting the single use case of bitcoin to private permissioned blockchain, substitution of existing business models, and finally transforming business concepts. In the last section we state a business model of power sector revenue collection using smart metering and blockchain. We provide a view of the impact of blockchain-based business models on viability of renewable energy generation and distribution, rural empowerment, apart from evolving an efficient revenue generation process.

2. Blockchain Technology

2.1. Open distributed ledger

Ledgers are ubiquitous within and across organizations. The blockchain technology provides a way to maintain an open distributed ledger in the cyberspace which has the properties such as immutability, that is although the ledger is distributed to all over the cyberspace it is tamper-proof; the ledger is distributed to all the participants, and finally that consensus about the content of the open ledger distributed among all the participants is undisputed. All these seemingly impossible objectives are achieved by the use of cryptography, and consensus algorithms for distributed databases. A ledger is stored in a sequence of interlocked blocks of data or transactions which is called a blockchain. The technology developed for this is called the blockchain technology.

The basic problem that a blockchain addresses is that of money transfer, or in a generic sense value transfer. Success of blockchain technology is effectively leading us from the internet of information to the internet of value. The key to establishing an internet of value is to solve the problem of "double spending". A blockchain network solves precisely that problem by using available cryptographic primitives such as cryptographic hash functions, digital signatures, and consensus algorithms developed from eighties onward. For a through account of the science of blockchain we refer to Watenhofer (2017)

For example, suppose A, B, C are three participants. Suppose that in the beginning A has ¹ 50. Suppose A transfers ¹ 35 to B and makes centralized ledger entry. Subsequently, if A promises C to give her ¹ 20, in case the ledger is available to C then C will not accept the transaction, since it is clear that A does not have that money. Suppose in between B sends ¹ 20 to A and makes a ledger entry in the so far centralized ledger accessible to all. Afterwards if A makes a promise to send ¹ 20 to C, looking at the ledger C will accept the transaction. The idea of blockchain is to develop a technique to remove this centralized ledger and distributed it to all the participants securely within the framework of a consensus protocol. Following figure describes the above example.

Open ledger **Distributed Open ledger**

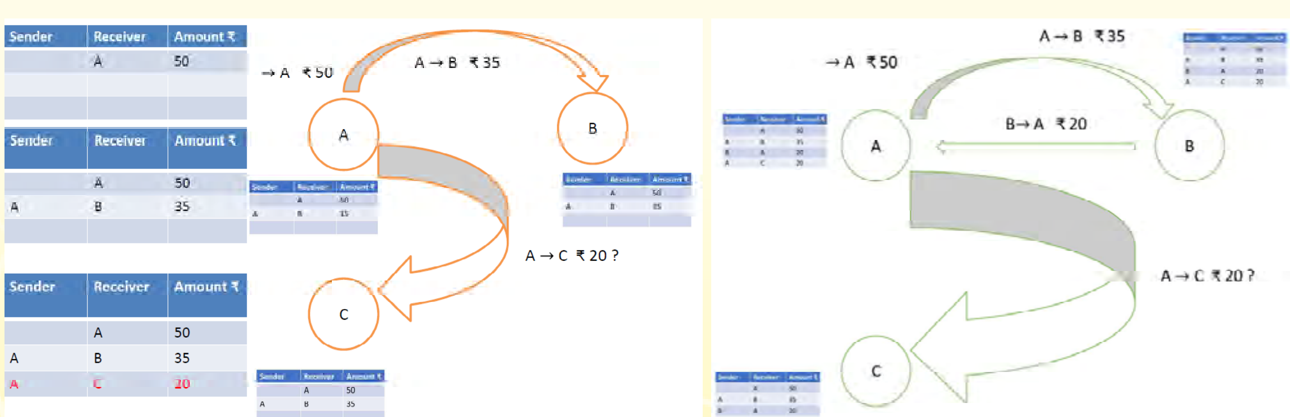

Fig. 1. Transactions using open distributed ledger.

2.2. Cryptographic hash functions

Cryptographic hash functions map messages or datasets of arbitrary lengths to strings of much smaller fixed lengths. Let M be a message and H be a cryptographic hash function. The hash value of , also known as the message digest or authentication tag of , is denoted by . Following properties are satisfied by a cryptographic hash function making it suitable for application in the blockchain technology.

- Given it is computationally infeasible to
  - find (Pre-image resistant) find such that (Second pre-image resistant)
- Given it is computationally infeasible to
  - find such that . (Collision resistant)

2.3. Blockchain

In a block chain a specified number of consecutive transactions are collected together to form each block. These blocks are interlocked with each other in a chain by using their hash values. This makes the blockchain immutable because, if data is changed in one block then the whole blockchain from that point onward has to be rehashed again which is not possible by any single individual participant or even a collective effort short of a collusion of effectively all stakeholders of the blockchain. This is due of the strong cryptographic conditions endowed by the employed cryptographic hash function. In Fig. 2 we show that if is changed then stored in will not match with a fresh hash value of modified . Thus the change will be detected. To hide the change the attacker will have to change all the hashes changed in the subsequent blocks. This is computationally infeasible due the some specific properties of a blockchain.

In public blockchains such as Bitcoin blockchain hashing is done by special nodes called *miners* who have access to high computation power. In order to put a block in the blockchain they have to solve a prespecified difficult mathematical puzzle known as proof-of-work (PoW). The miners compete among themselves to be the first to solve the proof-of-work puzzle. The miner who wins gets to hash the block and get some bitcoins as her incentive. This model has a severe drawback in several applications where the use of high computation power by miners is looked upon as a waste, and miners may not have enough incentive for mining as in the bitcoin network. Keeping this in mind other protocols are designed. For theory of blockchain we refer to Wattenhofer (2017).

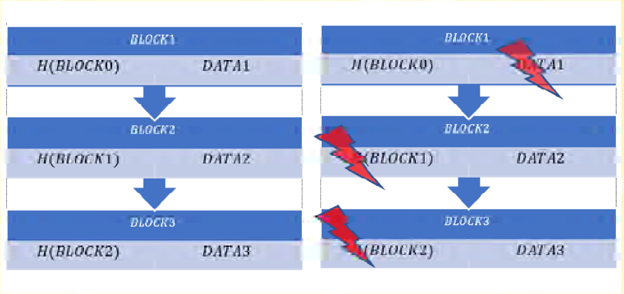

Fig. 2. Simplified representation of three consecutive blocks of a block chain.

3. Business Model

3.1. An overview of application of blockchain to business

Originally the blockchain technology had a single use application, namely, the Bitcoin network. Soon it was realized that public blockchains can be changed to private blockchains for many other potential applications. The transition of the public blockchains to private, consortium-based permissioned blockchains or so called industrial blockchains is a localization phenomenon. A private blockchain is owned and managed by an individual entity. Consortium blockchain is owned and managed by a consortium of companies. Permissioned blockchains are private or consortium blockchains, which give special permission to other verified users for specific functions. This type of blockchains are relevant for utility sectors such as power sector, and medical sector. In these blockchains miners are replaced by individuals or consortium members. PoW is replaced by an appropriate protocol, e.g., proof-of-stake.

Apart from localization, it is envisaged that the blockchain technology has the capacity of substituting peer-to-business-to-peer framework adopted by the companies such as Amazon and Uber. The trust established by a blockchain through immutability of the blocks and consensus protocol can substitute many existing businesses by a distributed market place enabled by a blockchain network. In short, blockchain has in principle the capacity of substituting any intermediary entity. Finally, the blockchain technology has the capability of transforming many business processes through smart contracts when the transactions can happen within a contract which triggers actions autonomously depending on predetermined conditions. Smart contracts can change the way the lawyers and accountants function at present.

3.2. Power Sector in Rural Area: Blockchain based business model

Most obvious challenges of power sector in rural areas are, regular meter reading, billing, collection of revenue. Integrating with renewable energy production, and to provide adequate incentive to rural households to produce renewable energy are some more recent challenges faced by our country for pursuing the path of green-energy. Development of rural micro-grid, establishment of peer-to-peer electricity exchange are other ambitious plans to make the rural sectors cost effective and resilient. Blockchain can facilitate meeting these demands by

- Integrating development of smart meters, and dedicated blockchain technology for secure storage of consumption and payment data of individual users.
- Provide access to this blockchain to the consumers /prosumers possibly through mobile applications.

A permissioned blockchain-based infrastructure will have the following benefits:

- User authentication of consumers/prosumers can be performed through Aadhar linkage automatically.
- Bill payment can be enabled through Aadhar linked mobile phones and bank accounts.
- Pre-paid mode can be deployed to address the problem of non-payment and late payment.
- Subsidies can be provided to economically backward communities/individuals through Aadhar linked blockchain infrastructure.
- Incentives can be provided to individual households based on their renewable energy contribution to the grid.
- Facilitate transition towards seamless integration of rural micro-grid to the regular grid, and monetize renewable energy generated by individuals.

4. Conclusion

It is to be noted that Blockchain technology is new and fast developing. Therefore, continued research is required to be at the cutting edge of the this enabling technology. It is important to study particular use cases in detail, and blockchain technology addressing specific use cases should be developed as proof-of-concept. These should be tested in controlled environment. Finally, ongoing research is a must to develop and sustain a secure blockchain technology.

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Blockchain in Power Generation, Transmission and Distribution

Profies

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- Spearheaded development of online B2C portal & Sunkalp Partner App (on Google Play) as tools to aggregate the industry stakeholders: Manufacturers, EPCs and customers.
- She has done extensive policy and regulatory analysis in the rooftop solar domain and published insights in industry magazines and blogs
- Awarded among the 50 Most Impactful Green Leaders, World CSR Day
- Awarded among the 50 Most Influential Solar Energy Leaders, Thought Leaders International

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Abstract

Over the coming decades, we expect the electrical grid to transform from a centralized utility-based model to one with an increasing number of decentralized resources, real-time pricing signals, and the ability to more closely match power supply and demand. One of the prominent reasons for this is because of the limited reach of the grid infrastructure in places where electricity is required. An example of this limitation is in the rural areas of India. With heavy investments of time and money required for penetration of the grid into areas with no energy access, decentralized generation and consumption becomes an attractive opportunity to exploit.

We foresee the opportunity for blockchain to play an important role in facilitating communications, transactions, and security between millions of transacting parties. In our view, blockchain will enable a decentralized energy marketplace that could significantly shift the balance of spending toward investments in distributed energy resources, while also creating a potential redistribution revenue to new market participants i.e. non utilities. Non utilities can range from individual customers to small and medium sized enterprises.

For peer- to- peer transactions to be realized, however, there would need to be an accompanying shift to smart metering and smart appliances. Such a shift is necessary in order to accurately estimate power requirements and hence, enable transactions on the blockchain network that match these requirements.

Introduction

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What is the Opportunity?

Structurally, the economies of scale of large power plants have driven investment in centralized resources (e.g., coal/gas plants). And these power plants have typically been located far away from population centers because of the pollution they produce. The power so generated is shipped across miles of transmission and distribution infrastructure to the end consumer leading to T&D and AT&C losses of as much as 25%.

We believe the modernization of energy production and consumption – driven by smart meters/ devices, energy efficiency devices, renewables, and storage – is already beginning to disrupt the traditional utility model, particularly as customers seek to engage directly in power purchase decisions via self-generation and/or energy arbitrage through storage solutions. The reason for the shift towards renewables now is external economies of scales of the Renewable Energy industry (especially, solar PV). Renewable sources of energy deal with both the problems: it is a non-polluting source of energy and hence, does not need to be located away from population centers allowing for lower losses in energy. Secondly, it is now at par and even cheaper than power purchased from the grid.

Blockchain could further the disruptive potential of these new sources of energy, eventually creating an increasingly decentralized means of energy consumption where energy users are also energy generators, transacting directly with each other in the electricity market. It could give birth or realize the concept of 'community solar' where there is absolutely no tampering with the energy that has been distributed in the community.

Further, this could potentially reduce entry barriers for becoming an electricity distribution company (with lesser investment and infrastructure requirement). The market could potentially be transformed from largely a monopoly to something between an oligopoly and monopolistic. This would also increase the supply of electricity because of the number of providers, furthering easier and cheaper access to electricity due to higher competition.

What are the Pain Points?

Line losses. Supplying power across miles of wires creates inefficiencies as voltages are stepped up and down, resulting in power losses. We estimate that 25% of total generation actually never reaches the final end user – resulting in higher cost for the consumer.

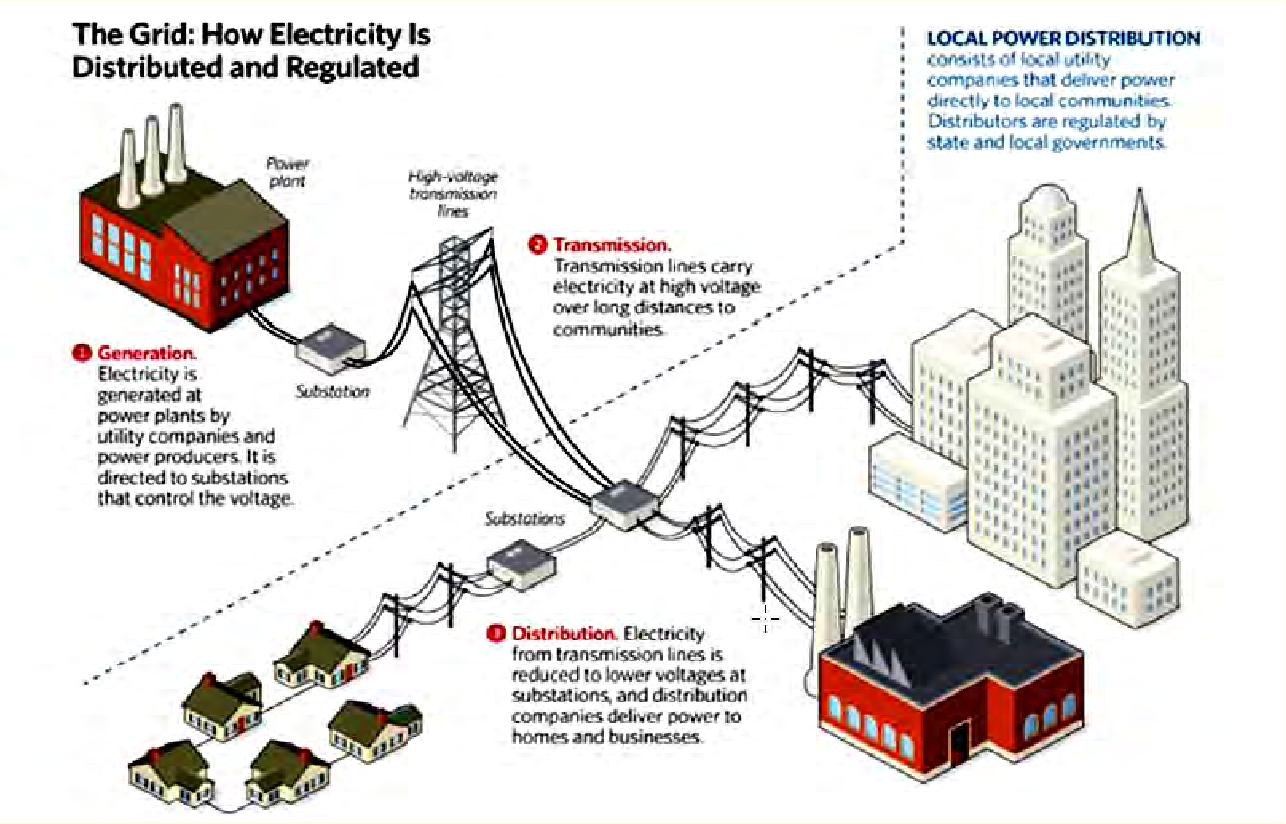
Reliability. Even if the power reaches rural areas they are the first victims of load shedding. The centralized infrastructure of the power grid leads to broad swaths of the population losing power at once.

Expensive Power Tariffs. This is by far, the biggest pain point for consumers of electricity in India with rising grid tariffs. The rural market cannot afford the electricity tariffs and hence is prone to electricity tapping and theft. A peer to peer network (combined with solar electricity) can partially solve this problem by doing both- tracking who consumes how much and by providing affordable power.

What is the current way of doing business?

The electric power grid pairs centralized production with distributed consumption. Since the advent of alternating current (AC) transformers in the late 1800's, the electrical grid has been dominated by centralized power generation and long-distance transmission infrastructure.

Distributed resources, particularly rooftop solar, effectively feed excess power back to the grid under net metering, with credits adjusted in the bills. This is a billing mechanism, used in more than 23 states, that credits customers for electricity provided to the grid from approved renewable energy generation systems. Under net metering, credits are generated at the prevailing retail utility grid rate in most cases and enable consumers to lower their traditional electricity bill; however, no direct revenue is generated. We believe that pressures to lower the rate at which net metered power is credited will continue to increase over time owing to the business lost by the DISCOMs. This sometimes is manifested in ways such as the bills don't have adjusted credits so the bills don't reduce as a result of installing solar. This further leads to consumer's trust being evaded about Solar PV technology and its use. So how can consumers become independent of these pressures?



Source: The Heritage Foundation

How does blockchain help?

Business impact: Blockchain could help create a decentralized energy marketplace. In what would be the most disruptive scenario for the electricity market, we believe the combination of blockchain and communications technology could facilitate secure transactions and payment between millions of parties, enabling a decentralized energy marketplace. Simply put, the distributed nature of blockchain could allow distributed energy users to sell power seamlessly to consumers in their vicinity in a literal localization of energy production and consumption. The potential appears real. In Brooklyn, NY a startup called Trans Active Grid has enabled this type of peer-to-peer energy sales network based on blockchain technology whereby homes with rooftop solar sell to neighbors on the same street who do not have solar installed.

Such a mechanism has only been suggested in 'Group Net-Metering' in Delhi, however, does not make use of blockchain technology and has also not been implemented yet. Realistically, this potential exists in small and localized micro-grids – residential and industrial – given that the vast majority of power generation will likely remain centralized for decades to come. Owing to the vast potential offered in India by villages that don't have electricity access, this application could have more value for India than anywhere else in the world.

We also note that significant regulatory changes would be required for blockchain to have a major disruptive impact on the traditional utility business model. On the other hand, the potential for traction could be higher in off-grid opportunities. For instance, a startup called Grid Singularity is using blockchain to explore "pay-as-you-go" solar in developing countries where grid infrastructure is less sophisticated and regulatory hurdles may be lower.

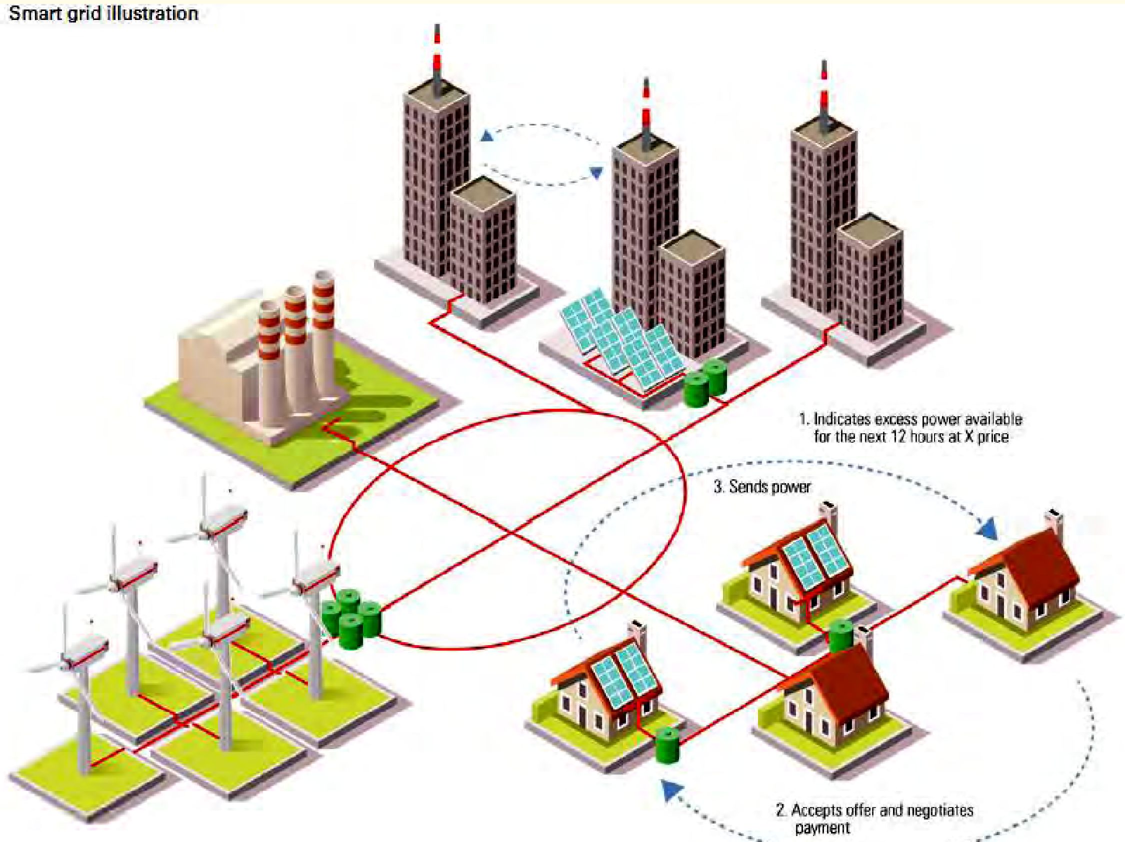
Structural impact: Blockchain drives more distributed grid infrastructure. The ability to transact in the energy markets as a localized generator would likely drive a bigger shift toward technologies that enable a distributed grid. The revolution would not only include smart blockchain networks and devices, but also Internet of Things (IoT) appliances and electric vehicles, as well as power resources like rooftop solar, energy storage, and even fuel cells. Theoretically, the more distributed the grid becomes, the more reliable and efficient it could be in matching power supply and demand – sending real-time pricing signals and reducing expenditures on costly transmission and distribution infrastructure, among other factors.

Policy impact: Blockchain could end the need for net metering. We believe the adoption rate of distributed solar has largely benefited from policies such as net and gross metering, which support the economics of going solar vs. paying for grid power. However, the longer-term outlook for net metering is not certain owing to growing opposition from utilities. We believe distributed energy producers would embrace an alternative to selling back to the grid – e.g., selling into a localized merchant market, for which blockchain could provide the distributed and secure transactional backbone to enable a decentralized marketplace.

Combining blockchain with the Internet of Things could enable the negotiation of distributed power transactions. By using distributed wireless or wireline data links in a mesh network (or another more traditional communications architecture), distributed producers could automatically broadcast information on excess power availability along with relevant duration information. Individuals/ small companies will function as mini- power trading companies. In principle, consumers could automatically respond with their power needs. Using a blockchain-based ledger, machine proxies of producers and consumers can negotiate pricing and enter into a power sale transaction based on a smart contract.

Smart contract is a digital contract between two parties who are engaging in a transaction on a blockchain network and this transaction is irreversible and incorruptible.

Smart grid illustration



Source: Goldman Sachs Global Investment Research

We believe the Smart Grid use case may offer a good example of when a public blockchain could be used to enable secure transactions between users who do not know each other. We can imagine multiple "**Smart blockchain network**" (SBN) being enabled on a local or regional basis.

Challenges to adoption

- **Regulatory**: States have laws that prohibit sales of electricity by non-utility entities. For blockchain to enable distributed energy users to transact directly in energy sales, regulation will need to evolve. This is the largest of all the hurdles.
- **Technical**: Smart blockchain network infrastructure would be required for devices and meters to transact via blockchain.
- **Physical limitations**: Blockchain enables secure transaction processing, but power will still need to be physically delivered from one node to another on the grid, which will still need to be maintained by utilities/transmission operators.
- **Costs**: Future cost reductions in distributed energy appear likely given the technology roadmaps of areas such as solar and battery storage. In addition, a reduction in required transmission and distribution investment is favorable for all-in cost considerations in the shift from centralized to distributed generation. So, when such a distributed generation begins to compete with/ take business away from traditional thermal generators, there would be a rising opposition.
- **User behavior**: While blockchain would theoretically make transactions seamless and automatic, energy consumers have traditionally not been energy generators – and they have definitely not been revenue generators. This would require a dramatic change in seller thinking about the application of energy usage/ consumption in a more widely distributed grid environment where market dynamics between buyers and consumers become increasingly transparent.
- **Security**: Blockchain would drive the potential for millions of transactions on the grid. This would imply higher risk given the sheer number of points on the smart blockchain network; however, blockchain's enhanced security and ability to register participants could potentially strengthen grid security.

Use of Block Chain technology in providing quality reliable uninterrupted power by mini grids having different generating technologies (Solar PV/Wind/ Bio Mass etc.)

Profile

Narendra Chauhan is a technology evangelist and Chief Technology officer at Bigtronics Data Lab. He having 14 years of experience into information technology. His role involves providing enterprise level Technical solutions based on Blockchain technology, open source and cloud technologies. He has immense experience in working on various roles ranging from Architecture, design,development to performance tuning. He has acquired professional certification in Oracle, IBM Big Data and Hadoop technologies. Worked as a Senior Consultant at Capgemini Pvt. Ltd. and IBM India Pvt. ltd. He worked with Capgemini for Epsilon Campaign Management and IM VEGA Transition and has handled roles ranging from architecture of systems, Development and Administration of Oracle Database on varied RDBMS implementations. Besides work, Narendra is a Cricket enthusiast and in his spare time, he plays cricket and loves watching movies.

Abstract

The Popularity of Digital Cryptocurrencies has led the foundation of Blockchain technology.

A fundamental design concept behind the formation of blockchain technology is to provide an "Un-hackable" transaction process. The technology consists of a continuously growing list of 'blocks' — each containing a data record, timestamp, or data from a transaction — on a network chain that is distributed, public and encrypted.

This design enables a system that allows for information to be digitally distributed, without being copied or vulnerable to modification by a hacker. The most famous implementation of blockchain is what enables bitcoin currency to function. But, the technology has much greater applications than just finance , process management, IOT and it will be revolutionary for the energy sector to create future Eco System using Block Chain Technology for Renewable Energy Distributed Energy Generation & Supply.

This paper will dive into the fundamentals of blockchain technology and its core components, discussing the opportunities and applications for blockchain technology within the energy industry.

How blockchain could improve and/or replace existing systems and processes relevant to electric utilities, enable peer-to-peer "transactive" energy markets, and help lead the way in enabling a resilient, distributed energy grid of the future.

This will evaluate sustainability aspects of blockchain — such as how blockchain could improve traceability for natural gas trading, and also the associated phenomenon of 'bitcoin mining' that requires a massive energy footprint.

The goal of this paper is to summarize the implementation of the Blockchain in various domains beyond its application to crypto-currency.

Overview

According to the World Economic Forum , in 2016 solar and wind energy became cheaper than fossil fuels, indicating that the battle against global warming could become a lucrative business. The same article indicates that by late 2016, 47 developing countries had updated their energy plans by raising their reusable energy consumption targets to 100 percent. At the same time, Bill Gates, Jeff Bezos, Mark Zuckerberg, Jack Ma and others invested $1 billion USD in Breakthrough Energy Ventures, a fund for emerging energy source research. The World Economic Forum article points out that many new investments in energy infrastructure today go to renewable energy. The biggest investments come from Asia, where India and China have submitted huge projects in solar energy, which became the cheapest renewable energy last year, well ahead of the original forecast. The article also says that most multinational companies have 100 percent green energy adoption targets for their operations.

Substituting the transportation systems in big cities, which used to consume about 50 percent of the total production of fossil fuels, with electrical, intelligent, clean systems can also lead to a drastic decrease in the demand of fossil fuels.

Uttar Pradesh has ample renewable energy resources. Land-based wind, the most readily available for development. Uttar Pradesh has a solar energy potential of 22300 MW which the Yogi government has decided to harness to meet the target of 10700 MW by 2022. Hence the state government is going all out to promote solar power plants by introducing various subsidies for those willing to do it. Electricity generated by these solar power plants is transferred to the grid, an interconnected network for transferring electricity from producers to consumers. This is part of the state government's decision to promote private participation in generation of electricity through solar power.

However, developing renewable resources presents a new set of technological challenges not previously faced by the grid: the location of renewable resources far from population centers, and the variability of renewable generation.

Although small penetrations of renewable generation on the grid can be smoothly integrated, accommodating more than approximately 30% electricity generation from these renewable sources will require new approaches to extending and operating the grid.

The variability of renewable resources, due to characteristic weather fluctuations, introduces uncertainty in generation output on the scale of seconds, hours and days.

These uncertainties, affect up to 70% of daytime solar capacity due to passing clouds and 100% of wind capacity on calm days for individual generation assets.

Although aggregation over large areas mitigates the variability of individual assets, there remain uncertainties in renewable generation that are greater than the relatively predictable uncertainties of a few percent in demand that the grid deals with regularly.

Greater uncertainty and variability can be dealt with by switching in fast-acting conventional reserves as needed on the basis of weather forecasts on a minute-by-minute and hourly basis; by installing large scale storage on the grid or; by long distance transmission of renewable electricity enabling access to larger pools of resources in order to balance regional and local excesses or deficits.

At present, renewable variability is handled almost exclusively by ramping conventional reserves up or down on the basis of forecasts.

However, as renewable penetration grows, storage and transmission will likely become more cost effective and necessary.

Forecasting The high variability of renewable generation, up to 100% of capacity, makes forecasting critical for maintaining the reliability of the grid. Improving the accuracy and the confidence level of forecasts is critical to the goal of reducing the conventional reserve capacity, and will result in substantial savings in capital and operating costs.

The variability of renewable energy is easily accommodated when demand and renewable supply are matched—both rising and falling together. However when demand and renewable supply move in opposite directions, the cost of accommodation can rise significantly.

For example, if the wind blows strongly overnight when demand is low (as is often the case), the renewable generation can be used only if conventional base-load generation such as coal or nuclear is curtailed, an expensive and inefficient option that may cause significant reliability issues. Alternatively, on calm days when there is no wind power, the late-afternoon peak demand must be met entirely by conventional generation resources, requiring reserves that effectively duplicate the renewable capacity.

Reducing the cost of dealing with these two cases is a major challenge facing renewable integration.

What is blockchain?

Blockchain is a distributed, digital transaction technology that permits the secure execution of smart contracts over peer-to-peer networks independently from a central authority such as banks, trading platforms or energy companies/utilities. Other participants in the network act as witnesses to each transaction carried out between a provider and a customer; these are stored permanently on a digital ledger - the blockchain - which is duplicated by every computer on the network.

Blockchain is a open "Distributed Ledger that can record transaction between two parties efficiently and in a verifiable and permanent way."

Open : Accessible to all.

Distributed or Decentralized : no single party control.

Efficient : fast and scalable.

Verifiable : everyone can check the validity of the information.

Permanent : The information is permanent.

Blockchain in detail

Each blockchain is essentially a so-called decentralised application operating on the basis of a peer-to-peer protocol and coming with the special feature that it provides distributed storage functionality for storing transaction data.

These are open-source applications which represent a contract between a network and its users and which run on a distributed register (the so-called "ledger"), such as the Bitcoin or Ethereum blockchains. What makes this type of application special is that no single organisation controls these contracts or holds a legal claim over them, but that all decisions (e.g. on protocol adaptations) are taken by consensus between the users on the basis of computer code.

In order for an application to qualify as a genuine decentralised application, both its protocol and data must be stored on a public, decentralised blockchain (to avoid a central point of failure) and validated using a decentralised verification mechanism (e.g. "proof of work").

Properly decentralised applications ensure that a reliable record can be kept of all transactions and business deals, even in the event that key websites and interfaces go offline. Also, no one can subsequently revise or erase the ledger.

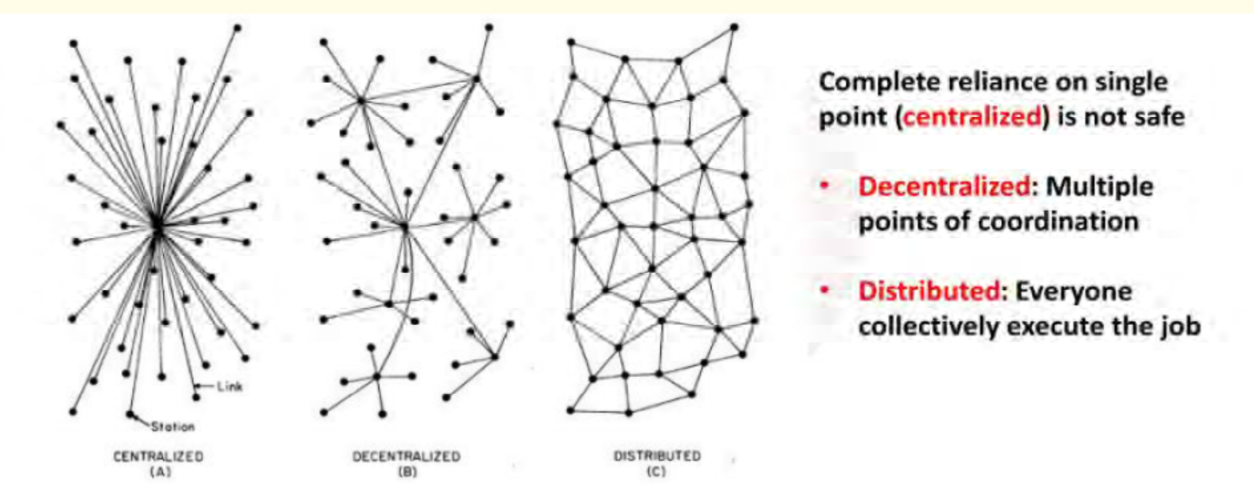
Decentralised application can be classified as follows:

- Type 1: decentralised applications that have their own blockchain

  - Examples: Bitcoin, Altcoin, Litecoin

- Type 2: decentralised applications that use the blockchain of a type 1

  - Example: Omni Protocol (a software layer built on top of the Bitcoin blockchain)



- Type 2 Apps are protocols and use their own tokens

- Type 3: decentralised applications that use the blockchain of a type 2

  - Example: the SAFE Network, which uses the Omni Protocol to issue "safecoin" tokens.

The proof-of-work and proof-of-stake concepts

The purpose of the verification process is to achieve consensus on the content of the distributed ledger.

Consensus-based verification is a decentralised (i.e. embedded on the blockchain itself) and automated process.

The following two mechanisms are most commonly used to establish consensus:

Proof of Work

The proof-of-work concept is the consensus mechanism most frequently used in conjunction with blockchain technology, and relies on so-called "miners". Each block is verified through mining before its information is stored.

The data contained in each block is verified using algorithms which attach a unique hash to each block based on the information stored in it. These hashes can be either ordinary hashes or cryptographic hashes.

The complexity of this task lies in finding a specific hash corresponding to the block's content.

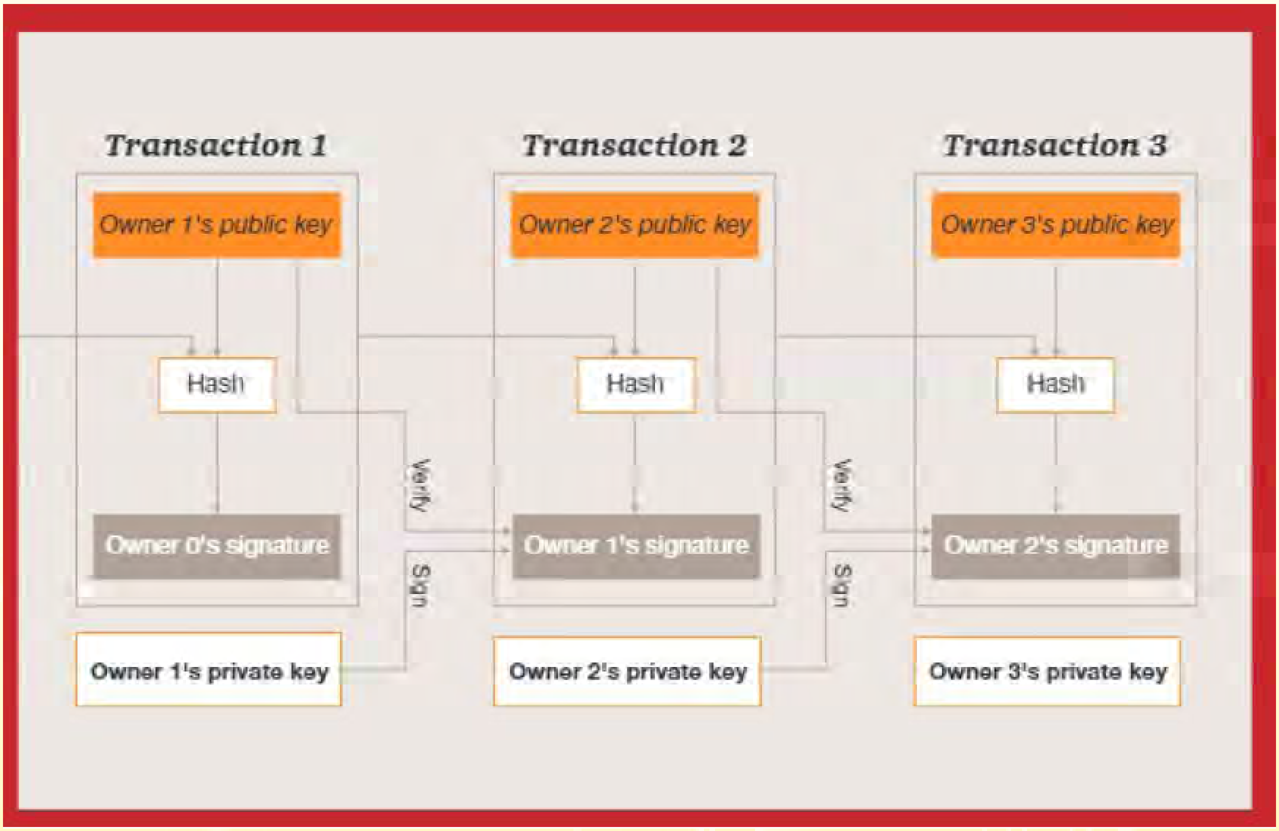
The level of complexity (difficulty) adjusts flexibly in response to the computing power available on the miners' network, so as to ensure that new blocks can be hashed at predefined intervals (Bitcoin: 10 minutes, Ethereum: 10 seconds).

Even if only a single piece of information relating to any transaction is subsequently changed, for example if the amount of a transaction is altered as a result of tampering or due to transmission errors, the algorithm applied to the block will no longer produce the correct hash.

The hashes computed for the same block, which was stored many times around the decentralised network as described above, are compared so that changed blocks can be identified and declared invalid.

The verified, correct version of a block is identified by the majority of participating computers and added to the other blocks previously verified, thereby extending the blockchain.

Once the block which contains the initial transaction is added to the blockchain and this addition



has been stored by a sufficient number of network participants,the transaction is confirmed to both parties.

The mining process can also be used to take decisions on changes to a Decentralized Applications .

Decisions made in accordance with the proof-of-work principle are taken on the basis of the amount of work the individual stakeholders have performed to verify a block.

Proof of stake

The proof-of-stake approach simplifies the mining process where a large number of tokens need to be verified. While under the proof-of-work principle, a large group of distributed users are continuously verifying the hashes of transactions through the mining process in order to update the current status of the blockchain assets, the proof-of-stake concept requires users to repeatedly prove ownership of their own share ("stake") in the underlying currency.

Where the proof-of-stake method is used, the work required to carry out the verification process is allocated between the individual members based on their stake in percent.

For example, if a user owns a 10% share of the total outstanding blockchain assets, the user will have to carry out 10% of the required mining activity. This approach reduces the complexity of the decentralised verification process and can thus deliver large savings on energy and operating costs.

What are tokens?

The term "token" may refer to several things: a token can be used to grant users access to a (de-)centralised computer application, act as a key for the execution of digital transactions or represent a currency unit (e.g. bitcoins).

Decentralized Applications tokens must be generated and distributed according to a standard algorithm or set of criteria. Tokens constitute the basis for using an application, and are also a reward for contributions by users. Yet tokens do not represent any assets, nor do they give rights to dividends or equity shares.

Although the value of a Decentralized Applications token may increase or decrease over time, it would be a misconception to think of them as a type of security.What mechanisms are used to distribute tokens?

There are three general mechanisms decentralised applications (e.g. Bitcoin, Ethereum) can use to distribute their tokens (e.g. bitcoins, ethers): mining, fundraising and development

Mining: tokens are distributed as a reward to those participants who solve certain verification operations most quickly (with consensus being established by proof of work). Bitcoinis one example of a Decentralized Applications issuing its tokens through mining.

Fundraising: tokens are distributed to those who funded the initial development of the Decentralized Applications.

Development: tokens are generated using a predefined mechanism and are available for the future development of the Decentralized Applications (with consensus being established by proof of stake).

Execution of transactions In blockchain transactions, cryptographic proof replaces the third-party intermediary. The chart below shows a peer-to-peer transaction conducted without the assistance of any third-party intermediary. In this context, it is important to distinguish between the two components of a blockchain address, namely the private key and the public key. The public key can be used to view the transaction history of a user but it cannot be used to make a transaction unless the private key is also known.

The private key is what is needed to access an account and actively execute a transaction.

The chart illustrates how Owner 1 transfers a token to Owner 2 by digitally signing a hash of the previous transaction and the public key of the next recipient (digital signature).

The transaction is then added to the blockchain. The party receiving the information/payment (Owner 2) can verify the "chain of ownership" by verifying the signatures using the public key of Owner 1 stored on the publicly accessible blockchain. What they cannot check is whether a previous owner had already used the same token prior to the current transaction ("double spending"). Double spending can be verified either by a central authority or, in the case of Bitcoin, through a verification process carried out by a decentralised authority.

How Blockchain Could Give Us a Smarter Energy Grid

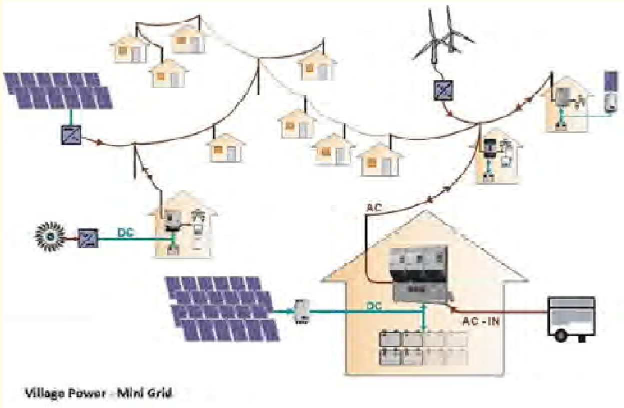
On an electricity grid, electrons generated from the sun, wind, or other renewable sources are indistinguishable from those generated by fossil fuels. To keep track of how much clean energy is produced, governments around the world have created systems based on tradable certificates.

Problem is, the way we manage these certificates "sucks," and it's holding up investment in renewable power, says energy experts.

A new system based on blockchain, the technology at the heart of Bitcoin and other digital currencies, could fix this.

Keeping track of renewable-energy certificates is one of dozens of potential applications of blockchain technology that could solve data management challenges in the electricity sector without disrupting business as usual.

In the long term, the technology could help transform the very architecture of the grid itself.



Blockchain for energy

In the transition to a new energy world - decentralised, digitised and decarbonised - several use case applications have already been developed using blockchain technology, such as automated bill payments, electrical vehicles charging and sharing, and renewable cryptocurrencies. Moving beyond bitcoin - the cryptocurrency most people associate with blockchain - the technology serves as a smart transaction platform at a systematic level that gives rise to true 'prosumers': as well as consumers, households also become producers and sellers of energy with a high degree of autonomy. Utilities and grid operators become more efficient by being able to balance supply and demand in real-time by engaging these prosumers directly. It supports renewable energy integration into the grid in a cost-effective fashion.

What can technology contribute to this global challenge?

I see several possibilities for how technology could change the energy distribution game in the near future. These include new batteries or generators capable of storing energy surplus, blockchain technology, and intelligent meters (the Internet of Things, or IoT) connected to intelligent grids and distribution networks.

For years, the energy industry has put research into long-lasting batteries that store surplus energy efficiently and in a viable, economical way. These possibilities could elevate consumers into the role of producers and eventually to "suppliers" in the existing energy distribution network.

Blockchain technology uses decentralized data storage to record digital transactions. Instead of having a central administrator, such as a traditional database (controlled by banks, governments, accountants, registries), blockchain has a network of replicated databases, synchronized over the internet and visible to anyone on the web.

The use of intelligent meters (IoT) as nodes for energy consumers and producers makes it possible to track consumption and payments. Smart contracts can initiate the transfer of funds between accounts based on usage data received from each of these meters, ensuring accuracy. Blockchain is intertwined with all of this, documenting the transactions and creating a reliable network of energy tracking.

Use cases of blockchain technology in the energy sector

After this introduction to blockchain, we can now analyze how it can be an answer to the current needs of the energy sector.

Blockchain technology may answer the crucial need of authentication of contracts and certificates addressed by the energy sector.

One of the assets of blockchain technology is database management, which is transparent and cannot be violated.This asset could be used in systems that need certifications and traceability.

In France and several other European countries, Energy Saving Certificates or "White Certificates" are one of the main tools in their policies that aim for the reduction of energy consumption.

The idea is that energy producers, suppliers or distributors (electricity, gas, fuel, heat, cold …) are pushed to promote energy efficiency actions actively.

An amount of obligations is defined in regulations over a specified period of time (obligations are distributed amongst producers according to their sales / energy deliverance). Each action indicating the amount of energy savings has to be described and filed, and can then be controlled by the authorities.

At the end of the specified period, "obliged" producers have to justify the accomplishment of their obligations, or pay penalties otherwise.

This system is quite analogous to the concept of CO2 emissions trading. Other types of certificates are also now delivered to track the production and consumption of renewable and / or recovered energy (green electricity, biomethane, etc.).

These certificates are instruments supposed to guarantee a specified amount of energy savings, emission, or renewable energy consumption has been achieved. Each certificate has to be unique and traceable, guaranteeing that the impact of the related action has not been accounted for elsewhere.

Therefore, authorities have to track the evolution of these certificates in registers. It has been noticed that authorities have a lot on their hands and sometimes lack the time to control filed actions and work on the evolution of the mechanism (corresponding regulations are often revised), in addition to managing the registers.

In the future, registers could be managed via blockchains, requiring little action from the authorities whilst being accessible to all players in the Energy sector (the State, the public, producers, consumers, emitters, …), guaranteeing the uniqueness and traceability of certificates, and even managing the certificates' trading (certificates' markets).

The benefit is for all players, since they would be able to concentrate on actions contributing to the energy transition.

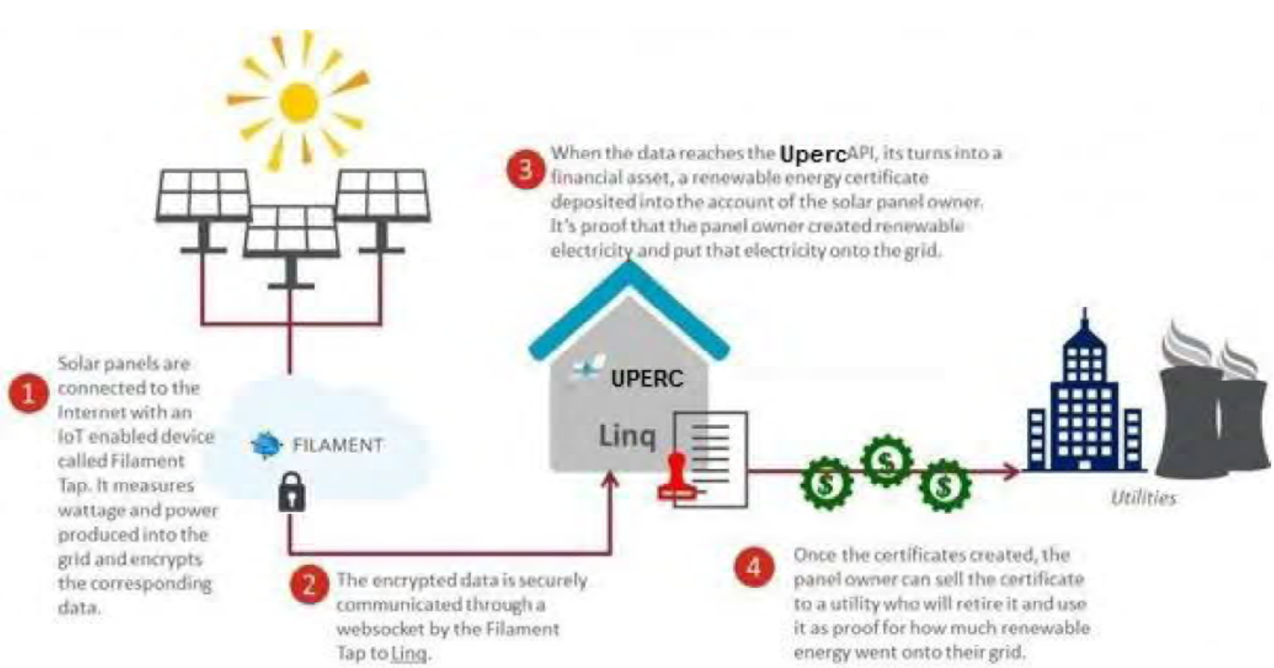
There is no denying that there is still much to be done in the field since regulation weighs heavily on any innovation.

Each country has its own national registers for the White Certificates, which meet different rules depending on the geographical location, which entails enormous costs for the utilities.

For instance, if a utility has wind turbines in Belgium, solar panels in Wallonia, and biomass in Brussels, it must have 3 different national White Certificates management registers, and as many dedicated teams and therefore the costs rocket. Blockchain would here be a perfect example of application to disintermediate all these actors, and thus reduce the risk and the costs, except that the main actor is the State, and therefore this implies to change the regulation first.

NASDAQ and its service LINQ used the authentication of the certification of solar power.

The stock exchange operator, Nasdaq, unveiled in May 2016 a service that lets solar power generators sell certificates.



In this system, the solar panels have to be connected to the Internet with technology provided by Filament, a Nevada-based blockchain start-up.

Through an API pull from NASDAQ's blockchain-based private markets platform Linq, anonymous certificates are created and can be sold to anyone who wishes to subsidize solar energy.

The solar panels are hard-wired into the IoT device through a converter which enables Linq to measure the wattage they're putting out and producing into the grid.

Blockchain technology may ease the billing process for utilities and reduce energy bills for consumers thanks to smart metering.

The electricity smart meter is the keystone between suppliers and customers of the smart grid, and concentrates all the transaction, confidence and security stakes associated with an ever more intelligent and flexible energy.

Smart meters associated with the transparency of blockchain create an environment where transactions are open and secure:

- Reduce risk of fraud / theft
- Help manage debt recovery
- Increase transparency in price changes and fees
- Improve efficiency

A smart grid network supported by blockchain technology would ensure an efficient local relationship between production and consumption of renewable energy.

Participants could publicly track their energy usage and production, and sell any unused energy to other participants. They would also have the ability to reduce their energy bills by making more informed purchasing decisions, avoiding consumption peaks or switching into a lower subscription. Smart meters and blockchain technology would ensure a simplified billing process (efficiency, transparency) and faster switching times.

A blockchain solution identifying where the energy is coming from, at what unit price and any markup passed to the consumer would result in more competitive pricing and in better integrity from public perception.

Blockchain may help the emergence of microsystems based on prosumers

In the energy sector, we are witnessing the development of prosumer characters that is to say individual consumers that are also producing energy (homes with solar panels for instance).

In that respect, blockchain technology represents an opportunity for a wider development of those behaviors by increasing the number of people who could buy and sell energy directly with a high degree of autonomy.

Indeed, as said in the previous paragraph, blockchain technology should entail major changes since it allows transactions to be carried out directly from peer to peer. No third party intermediaries are required.

In theory, we can imagine a marketplace where consumers exchange their own production without needing energy companies to organize the transactions.

It creates a shift from centralized structures (banks, trading platforms, energy companies) towards a decentralized system (peer-to-peer transactions).

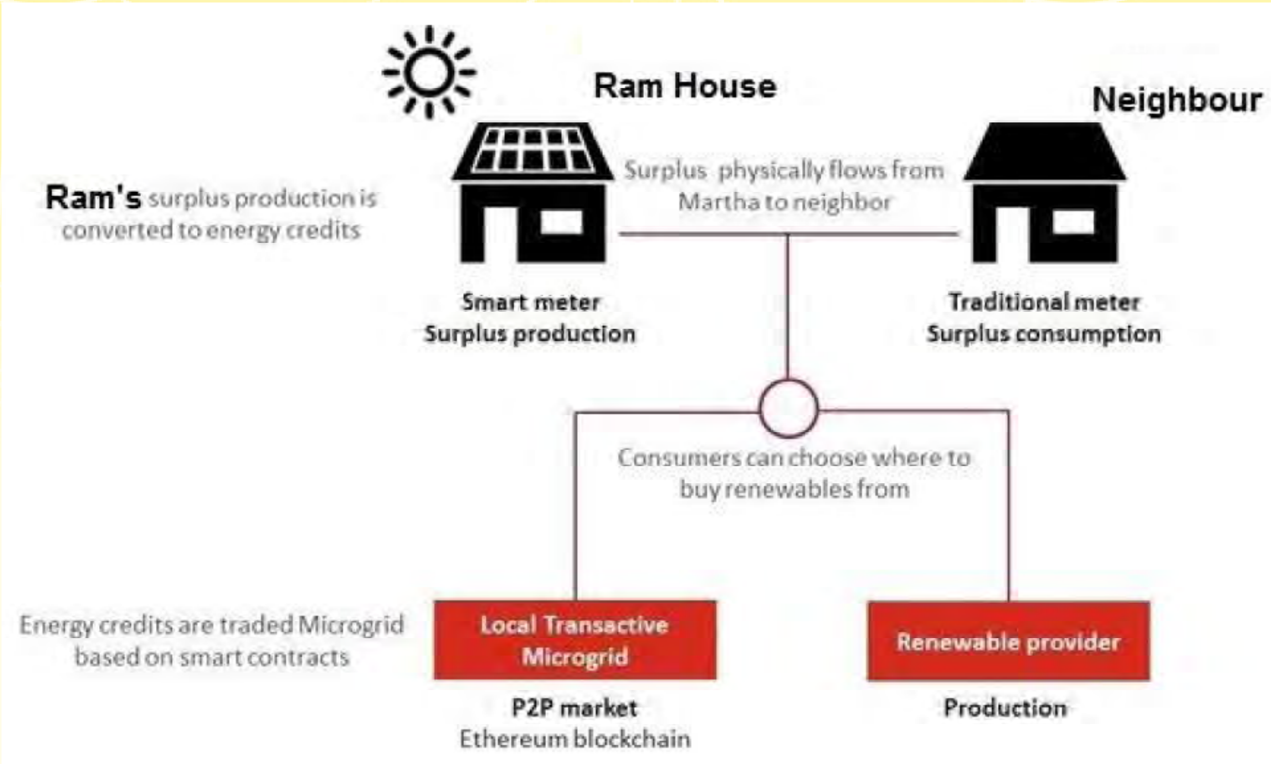
It would reduce cost and speed up processes. The system would thus become more flexible. Of course, in that model, energy companies are still needed to organize the transfer of energy.

From theory to reality: the emblematic experimentation in Brooklyn

Transactive Grid, the project of the LO3 platform and ConsenSys, has become a quite famous example of the possible application of blockchain to energy with its pilot experiment in Brooklyn, NYC (for more details: www.brooklynmicrogrid.com).

Five "producer" houses, equipped with solar panels, sell their production to five "consumer" houses, on the other side of the street since April 2016.

The objective of the experiment lies in the re-appropriation by citizens of their energy production, by the establishment of mini-grids, that is to say, mini autonomous energy communities. For this purpose, sensors record the history of the energy generation at a specific point, and immediately record it on blockchain Ethereum. Smart contracts can then govern the rules of use of this energy, and of course the tariffs of producers.



A proliferation of local decentralized and autonomous microgrids. In local communities, single persons with a single solar panel could thus participate in the end user market. Moreover, we can easily conceive a system where people with individual solar panel no longer feed their excess energy into the grid but market all their production.

List of potential use cases and associated examples. This list is not exhaustive, as blockchain technology makes it possible to increase efficiency in processes and improve transparency, so it can be considered in numerous applications.

Its use will depend on its adoption by the greater mass. At this stage, all projects remain pilots to validate the public interest.

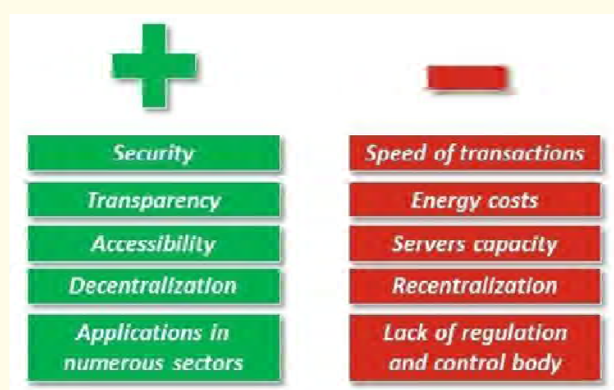
Transformations ahead

None of the energy companies currently developing blockchain applications have moved beyond the concept or pilot stage yet.

It appears that those models are difficult to put into practice. Indeed, the actual technology lacks of maturity and is complex in its development and implementation, in the energy sector in particular.

Moreover, barriers such as legal and regulatory requirements that blockchain projects must comply with are obstacles that still have to be overcome.

The legal and regulatory frameworks still have to be designed to reflect the requirements of decentralized transaction models and provide protection to energy consumers.



The development of these models is very promising. Blockchain technology is a potential game changer for the energy market and its ecosystem: users, real estate companies, municipalities.

Nevertheless, it is too early to know what role in energy markets blockchain technology is set to play.

It may be restricted to database management and transactions processing, but most likely, some wider and more disruptive future awaits.

Blockchain: A Catalyst to reshape Future Busines of Utilities

Integrating Blockchain with Grid Edge Technology will open new opportunities and will transform the present Grid from centralized, analog and fossil-fueled to more decentralized, digital and decarbonized advance Grid.

Profile

Chetan Bhatt is Senior Consultant in ZenMeter Solutions Private Limited and handles the Business Development and Bid Management activities.

He holds a bachelors' degree in Electronic and Instrumentation Engineering from UPTU and also holds Masters in Business Administration in Power Management from National Power Training Institute (NPTI-Faridabad).

He is a Desinger, Free-runner, Technology Lover and Eternal a Student who believes in the philosophy that every problem has n+1 solution.

Abstract

Highlighted throughout the paper will be the opportunities that can be explored by integrating Blockchain technology with Gride Edge Technologies.

This paper will identify and define new market entities like Aggregators of Distributed Prosumers (ADP) and Energy Storage Providers (ESP), who will be utilizing the aggregation platforms to create virtual power plants and trading systems based on Blockchain and Ethereum. These new entitites and technologies will be the catalyst and will speed up the deployment of Grid Edge Technologies and addition of more distributed energy prosumers to the grid, and will transform the present Gride from centralized, analog and fossil-fueled to more decentralized, digital and decarbonized advance Grid.

Importantly, the paper will highlight the expected Use Cases of these innovative Blockchain and Ethereum based platform viz-a-viz balancing the grid during Peak demand hours or when Grid has surplus power or during peak generation from distributed energy resources (by enabling peer energy and monetary transaction).

Finally, for an effective early adoption of this technology, it is suggested to follow the System Approach by encouraging top down strategic decisions to address the expected immediate regulatory barriers to the new market players.

Section 1

Overview-Blockchain, a Catalyst to reshape Future Business of Utilities

We soon are going to witness a rapid transition of the conventional electricity grids into a more flexible and agile advance grid due to the deployment of large scale Renewable energy resources and addition of Prosumers and Distributed Energy Resources (DER) in the grid.

The purpose of this paper is to set out and describe a Blockchain powered **platform integrated with** Grid Edge Technologies (GET) aimed **to improve the** grid management and to provide high quality reliable and uninterrupted power. The paper will identify and define new market entities like Aggregators of Distributed Prosumers (ADP) and Energy Storage Providers (ESP), who will be utilizing the platform to create virtual power plants and trading systems based on Blockchain and Ethereum.

In near future, these entities will be the catalyst in converting the current consumers to Distributed Prosumers (DP), and will be the key to provide more flexibility to the electricity grid.

Importantly, the paper will highlight the expected use cases of this innovative Blockchain and Ethereum based platform viz-a-viz during Peak demand hours or when Grid has surplus power and also peer-to-peer energy transaction during peak generation from distributed energy resources.

Finally, it is concluded and recommended that for an effective early adoption of this technology a System Approach should be followed by encouraging top down strategic decisions to address the expected immediate regulatory barriers to the new market players.

1.1. Definitions

Grid Edge Technologies (GET) The term is used to represent various hardware and software technologies that enables smart connected infrastructure to be installed at or near the "edge" of the electric grid e.g. including but not limited to Distributed Generation (DG), Energy Storage System (ESS), Demand Response (DR), Advance Metering Infrastructure, Smart Appliances and Prosumers.

Flexibility with respect to the electric grid can be described as the ability of GET to respond to the changes happening in the Grid over a sustained period.

The changes here are the altering Grid conditions like Over-Generation from the supply side or a sudden Peak in Demand from consumer side.

Prosumers[1] is a person who consumes and produces a product- electricity w.r.t energy sector.

Aggregator of Distributed Prosumers (ADP)

An entity which aggregates the GETs to form a single unit capable of responding to the altering Grid conditions by the diverse portfolio of different resources to provide relative strength of each technology.

Power Exchange[2] is a platform on which buyers and sellers come together to transact Power. It is not the market but a host to the market. Its core function is to ensure fair and transparent transactions as well as efficient dissemination of price information to its stakeholders.

1.1. Present Power System Transactions

Currently the licensees (Discom) and the Generating Companies in a State have mutual contract - which can be long term/medium term or short term- for energy transaction.

The State Load Dispatch Centre is the apex body that ensures integrated operation of the power system in a state.

The generating companies and the licensee plan and schedule their generation and power needs respectively in advance.

Table below shows the excerpts from the "*Statement of Deviation Charges*[3]" issued by the State Load Dispatch Centre for the Week-19/FY-18-19 for Utilities in Delhi.

[1]Source-Wikipedia [2]Source-IEX

[3]Source: ***Document No. F.DTL/207/2018-19/Manager***

Table 1: Excerpts of Deviation Settlement

All figure in Lacs

Sr. No.	Interstate utility	DSM amount for the current week	Net differential amount of week 12fy (16-17)	Net dsm amount for the current week
1	I.P. STN	-1.37278	0.42018	-0.9526
2	RPH	-0.53113	0.14667	-0.38446
3	G.T.STN	-3.68792	0.3597	-3.32822
A)	IPGCL	-5.59183	0.92655	-4.66528
4	PRAGATI GT	-1.9558	0.18516	-1.77064
5	Bawana	9.08782	1.43692	10.52474
6	BTPS	34.42447	17.01831	51.44278
7	BYPL	12.1435	5.09719	17.2407
8	BRPL	-98.54097	10.08177	-88.4592
9	TPDDL	-60.44768	7.68193	-52.76574
10	NDMC	6.40241	6.83405	13.23645
11	MES	-16.96177	5.4792	-11.53385
12	N. Railways	3.66086	-	3.66086
13	EDWPCL	-	0.00000	0.00000
C)	*Regional Deviation NRPC	178.16493	-54.68981	123.47512
D)	Pool balance due to additional Deviation			
E)	Pool balance due to capping of Generator & U/D Discom	-	0.00000	0.00000

(-)ve indicates amount receivable by the Utility.
(+)ve indicates amount payable by the Utility.
*for indicating purpose not for payment.

The Generating or the Distribution companies have to pay penalties whenever they deviate from their schedule-can be due to the Overdraw (OD) or the Under-draw (UD).

Now as we can see in table BYPL for the Week 19/18-19 will be paying Rs. 17.24 Lakhs and Northern Railways will be paying 3.66 Lakhs.

If, Grid Edge Technologies integrated on a blockchain platform is deployed onto the Grid, the Overdraw and Underdraw can be controlled and reduced on real-time.

This is explained in the scenarios ahead, where **Blockchain** will provide a **distributed ledger** of computer verified energy and monetary transactions and smart auto-contracts will be carried out on **Ethereum**.

Scenario 1: Let us assume there is prediction of a sudden peak in demand for next 1 hour, Discom has an option to either buy it from the "Exchange" or "Over draw "or if GETs are available then call in the Aggregator of Distributed Prosumers (ADPs) for their services.

ADP accomplishes this in either of the two ways or combination of both-by reducing the integrated dispersed demand of the consumer or by feeding into the grid from their battery storage system.

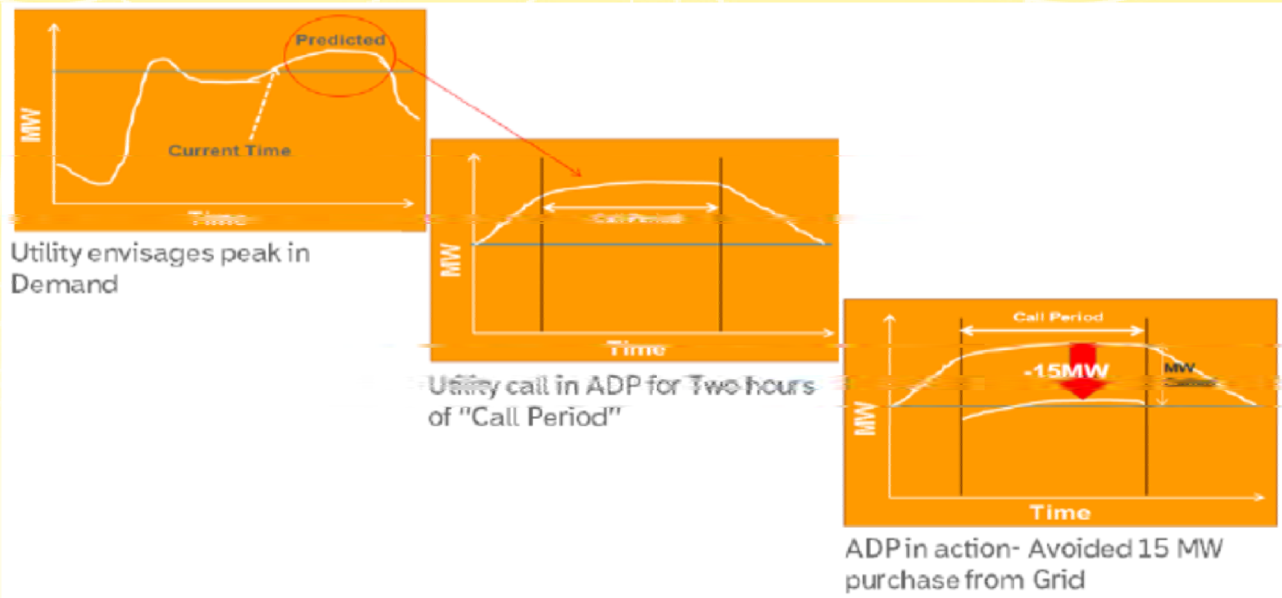


Figure 1: Peak Demand Reduction

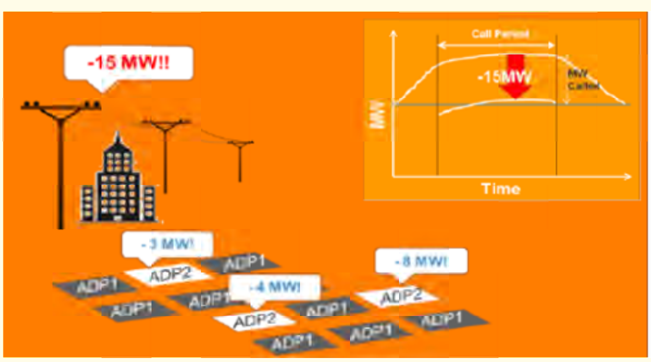


Figure 2a: Portfolio of ADPs for Demand Reduction

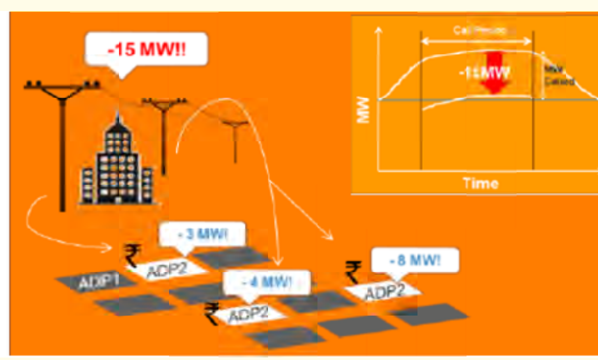


Figure 2b: Auto Distribution of Incentives

Utility floats a "smart contract" to reduce demand by 15MW from the grid for an hour on a Blockchain powered platform, it one of its region, where two ADPs (ADP1 and ADP2) operates. The ADPs evaluates their portfolios of the aggregated energy profiles and bid accordingly.

Let's say, out of the two ADP2 wins the online bid and execute the contract. On completion of the contract the result are verified on the automated platform and the settlement is carried out on the same. The incentives are then auto-distributed to the end users according to the ratio of their demand reduction achieved- as shown above 3MW, 4MW and 8MW. These monetary and the energy transactions are carried out in safe and secure platform.

Scenario 2: In this case power available with distribution companies at a particular period of time exceeds the demand by let say 15 MW, and is predicted to remain same for an hour. Utility has an option to either sell it to the "Exchange" or under-draw or call in Aggregator of Distributed Prosumers (ADPs) for their services.

The storage devices take in surplus power and release it to the grid during the peak period when the demand soars. The blockchain platform will be a powerful tool to manage the surplus power. Smart IoT metering devices integrated on this Blockchain platform will record and validate the energy and monetary transactions.

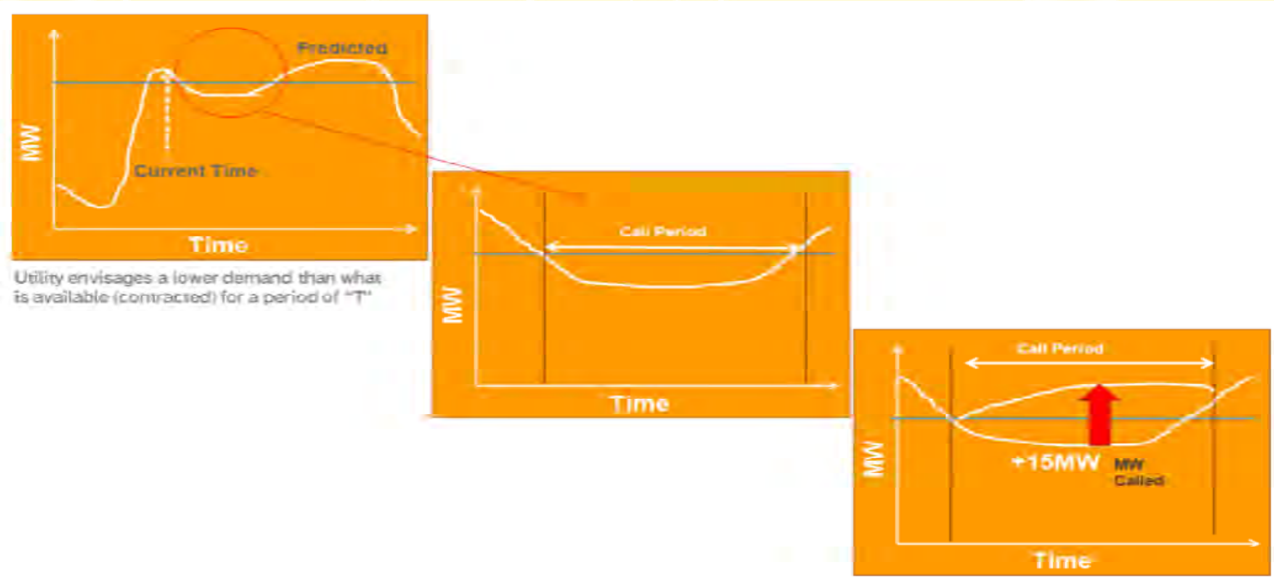


Figure 3: Demand Buildup

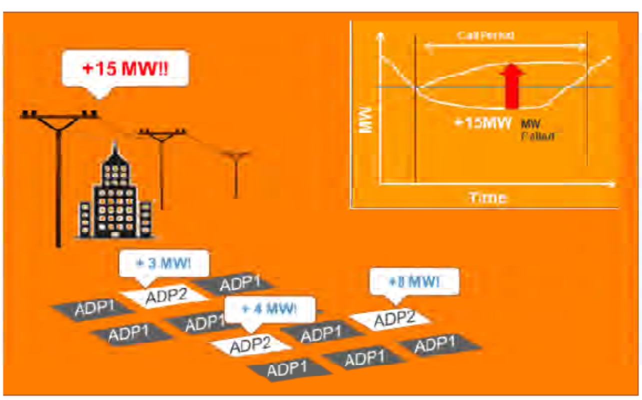


Figure 3a: Demand Portfolio of ADP

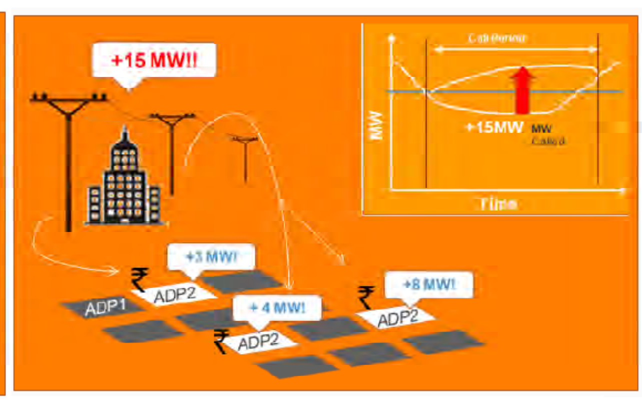


Figure 3b: Auto monetary settlement

Utility floats a “smart contract” powered by Ethereum to utilize the unused power of 15MW available in the grid for an hour on this platform, it one of its region, where two ADPs (ADP1 and ADP2) operates. The ADPs evaluates their portfolio and bid accordingly.

Let’s say out of the two, ADP2 wins the online bid and execute the contract. His portfolio contains Battery Energy Storage System with capacity of 3MW, 4MW and 8MW respectively. These system charge up during this period at certain agreed tariff as per the contract and in peak hours they supply back the consumers at regulated tariff.

Scenario 3: In this case the renewable generation is at peak but the Distribution Company already has ample power and this state is predicted to remain same for an hour. Now, the Prosumer or the Renewable generator has no option to sell their excess power, however if Grid Edge Technologies (GETs) integrated on Blockchain platform are available and if favorable policies are well in place then this excess power can be utilized more effectively and efficiently.

Enabling peer-peer energy trading from prosumer to its neighboring consumer or Prosumers to the Grid Edge Technologies (GETs) will foster the roof-top renewable energy market.

The real time verification and settling of the Energy and Monetary transactions carried on the blockchain platform will attract more and more consumers to opt for roof-top renewable installations like Solar, Micro/Mini Wind or Wind-Solar Hybrid.

The ADPs can bring in their Battery Energy Storage Systems (BESS) or EV chargers to store this excess power and the secured and reliable blockchain platform will allow Prosumers to get instant pay back from the ADPs on pre-agreed tariff.

The decentralized ledger technology (Blockchain) will hold the immutable records of all these transactions to avoid any disputes.

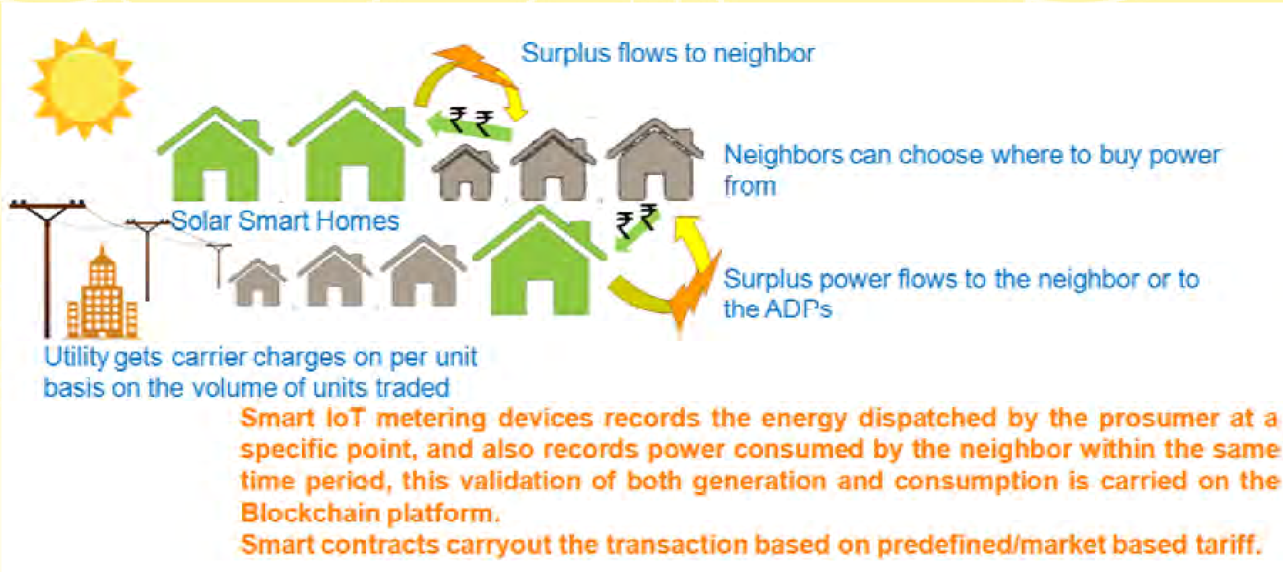


Figure 4: Peer-to-Peer Transactions on Blockchain

1.1. Conclusion and Recommendation

Follow System Approach for an effective early adoption

The Blockchain technology integrated with Grid Edge Technologies (GETs) as described in this paper are new and evolving, to reduce the technology risk, it is recommended that policies and frameworks should be well in placed before the mass deployment.

This transition from Silo Conventional Grid to Interactive Smart Grid with Blockchain enabled GETs should not be driven by market forces but by top down strategic decisions and ambitions of the government. With immediate introduction of effective policies, the transition will become smooth and the risk of unintended negative consequences can be reduced.

The regulations should be framed such that to enable Discoms/Distribution Franchises to procure services from the new market players like Aggregators of Distributed Prosumers (ADP) to address the barriers of early revenue generation faced by the new entities.

The blockchain based renewable energy networks powered with peer-to-peer transaction will accelerate the adoption and deployment of distributed generation-like Solar Rooftop, Mini and Micro windmill installations or Wind and Solar Hybrid systems

Urban and Rural mini grids, Energy Storage, Smart IoT Metering and the other Grid Edge technologies are still at nascent stages, to leverage the potentials of these technologies they need to be well knit and integrated on a Blockchain platform.

These disruptive technologies will surely change the present ecosystem and will empower the end consumers.

Blockchain for Future Energy

Profile

Prasanna Lohar: Chief Innovation Officer at DCB Bank , TOP 50 CIOs, Top 100 Innovative CIOs, Digital Leader of the Year, Top 20 BFSI Leaders, Most 50 Payment Influential, Leading Indian Blockchain & Fintech Forum , Co-Chairing at FICCI Sub-Committee on Blockchain Technology, Big Data and Analytics

Innovation is my passion. Collabaoration is my attitude. Execution is my action. Architecture is my Forte.

Currently I am working as Innovation Head & Technical Architect at DCB Bank. I am practicing Innovation Implementation & Architecture Orchestration at DCB Bank.

I have launched Global Innovation program - "DCB Bank Innovation Carnival". It will bring on Unique Experience of Innovation generation thru Hackathons & Accelerator programs in India. I have mentored more than 250 Startups during this program.

I am associated with Many Accelerators, Partners, Education institutes to practice Open innovation thru Hackathons & Innovation Programs.

I am working with various FINTECH & BLOCKCHAIN Forums in India to create a Robust Innovation Ecosystem in India.

As part of DCB's Digital & Architecture Transformation, I am closely associated with New & latest technology Assimilation, Experimentation, Innovative Customer Servicing & Engagement, Robust Architecture Implementation, Fintech & Startup Alignment, Open Innovation practices, Collaboration with other Banks on various initiatives.

At DCB I have worked as Digital Bank Head & I am Part of various deliveries like India's first Aadhaar & Biometric enabled ATM, Paperless A/c Opening - Zippi, India's first Omni-Channel Framework for Bank, Mobile banking & Mobile Apps, Internet Banking Initiative, Unified Payment Interface (UPI), Bharat Bill Payment,API Management, Switch & Cards relevant initiatives.

I have Over 17 Years of Industry Experience in Engineering and Development, Product Development, Organization Strategy & Governance, Risk Audit Compliance Management, Business Process Management, Enterprise Architecture, Mobile Apps, Digital Transformation, Fintech, E-Commerce, Payments, Platform and Product Innovation, Data Science, Machine Learning, Artificial Intelligence, Open Stack, Cloud Computing, Analytics, Big Data, IOT, BlockChain, UI-UX, Product Roadmap Strategy, Business Development

In 2017-2018, I have bagged many Leadership awards Most Influential Payment Professionals, TOP 50 CIOs, Top 100 Innovative CIOs, Digital Leader of the Year, Top 20 BFSI Leaders. I have appeared in many BFSI Conferences as Key-Note Speaker & contributed to ecosystem.

Abstract

There is more to Blockchain than moving money. In the recent days, the country has seen a dramatic increase in Blockchain adoption/ awareness and the government's openness to the technology can translate to a lenient regulatory view towards the Blockchain Technology.

Blockchain has potential to transform our lives through its benefits Viz. Faster settlement times that are user-optimized, Lower collateral requirements and counterparty risk, Improved contractual term performance, Greater transparency for regulatory reporting, Better capital optimization , Reduction of Operating Costs & Its incorruptible.

Recent trend is towards collaboration i.e. Partnerships between competitive banks, Technology companies, Fintech and regulators will bring benefits to consumers and the financial system. Collaboration among these driving force will bring on multiple innovative & cost effective use cases e.g. Clearing & Settlement , Payments , Smart Assets , Identity Management , Data Management & Data Protection , AML & KYC , Governance , Sharing Economy in Indian Banking Sector !

Blockchain for Energy : Over two-thirds of our efficiency potential is still untouched. In addition to putting the brakes on the curbing of our carbon emissions, this dormant potential means significant employment and economic markets are being overlooked. In the construction sector, for instance, 80% of EE potential remains; public building renovation in the EU alone represents a €120 billion market over the 2017-2020 periods. In France, the estimated market is around €30 billion over the next 10 years, and could create up to one million jobs by 2025. An estimated €231 billion is spent annually on energy efficiency (EE) investments - but tapping the full potential of EE will require at least four times as much investment. This finance gap is slowing down the energy transition we need.

We need financial innovation and creativity to unlock EE investments and to grasp these employment and growth opportunities.

"Could blockchain be the answer? Let's Explore"

In the transition to a new energy world - decentralised, digitised and decarbonised - several use case applications have already been developed using blockchain technology, such as automated bill payments, electrical vehicles charging and sharing, and renewable cryptocurrencies. Moving beyond bitcoin - the cryptocurrency most people associate with blockchain - the technology serves as a smart transaction platform at a systematic level that gives rise to true 'prosumers': as well as consumers, households also become producers and sellers of energy with a high degree of autonomy. Utilities and grid operators become more efficient by being able to balance supply and demand in real-time by engaging these prosumers directly. It supports renewable energy integration into the grid in a cost-effective fashion.

Concept

We can develop a microgrid project in which neighbours can buy and sell solar power from each other on a blockchain platform .This platform documents all transactions. This independent and isolated network solution offers both cleaner and more resilient energy access to its users through its embedded battery storage units.

Example: In May 2017, several companies joined forces to manage electricity grids in the Netherlands and Germany. The renewable energy company Vandebron will work with customers who own an electric vehicle to make electricity from their car batteries available to the grid in order to help the Dutch national grid operator TenneT better integrate increasing amounts of renewable energy. TenneT is using innovative IBM blockchain technology to manage this electricity grid. In the future, blockchain technology could allow millions of energy devices such as water heaters, electric vehicles, batteries and solar PV installations to transact with each other at the electric power distribution edge.

Opportunities & Usecases

The evidence suggests that targeting the risk perception of investors through a variety of instruments is successful in scaling up EE investments. The blockchain peer-to-peer model, which is built on the trust engendered by its permanent and unfalsifiable digital ledger, is a creative financial tool that can help overcome this perception of risky EE transactions.

The technology is not yet mature, but is growing fast. It might take five to 10 years before the technology reaches mainstream adoption. Yet it paves the way to acceleration of energy system decentralisation and the emergence of prosumers, where individuals can adapt their behaviours according to real-time data and a consequential increase in the overall energy system efficiency.

The total value of assets now being administered via blockchain over the world is already over $1.6 billion, and grew by a staggering 1,600% between 2013 and 2016. Over $1.4 billion was invested in blockchain-related startups in the first nine months of 2016 alone.

Road Ahead

The road is still long and the stakes are high

None of the energy companies currently developing blockchain applications have moved beyond the concept or pilot stage yet. It appears that those models are difficult to put into practice. Indeed, the actual technology lacks of maturity and is complex in its development and implementation, in the energy sector in particular.

Moreover, barriers such as legal and regulatory requirements that blockchain projects must comply with are obstacles that still have to be overcome. The legal and regulatory frameworks still have to be designed to reflect the requirements of decentralized transaction models and provide protection to energy consumers.

Blockchain technology is a potential game changer for the energy market and its ecosystem: users, real estate companies, municipalities. Nevertheless, it is too early to know what role in energy markets blockchain technology is set to play. It may be restricted to database management and transactions processing, but most likely, some wider and more disruptive future awaits.

1.0 Background

We understand that the Future Transformation will involve the combination of home grown and third-party digital products, providing personalized solutions available on demand. Organisations expanding digital transformation journey & by understanding their core strengths and weaknesses, Organisations need to look for new age technology startups that can fill the gaps they are not able to fill themselves. Collaboration is the key to deliver easier-to-use propositions to end-customers. Collaboration is the beginning of a massive change in the way, consumers and businesses deal with Finance. Consumer is embracing this unity on a greater and greater scale.

"Blockchain holds enormous potential to break down barriers that could lead to more efficiency, greater accountability, lower costs and increased remuneration for value creators. To reap these benefits, however, the technology will need to be developed responsibly within the right regulatory frameworks." (World Economic Forum: How can the creative industry benefit from BlockChain?)

Blockchain technology is unique as it cannot be implemented by just an individual bank but needs an ecosystem with an industry-wide approach. With multiple proofs of concepts being announced, the banks should work together to ensure that multiple ecosystems can operate cohesively. Collaboration will be key in the future

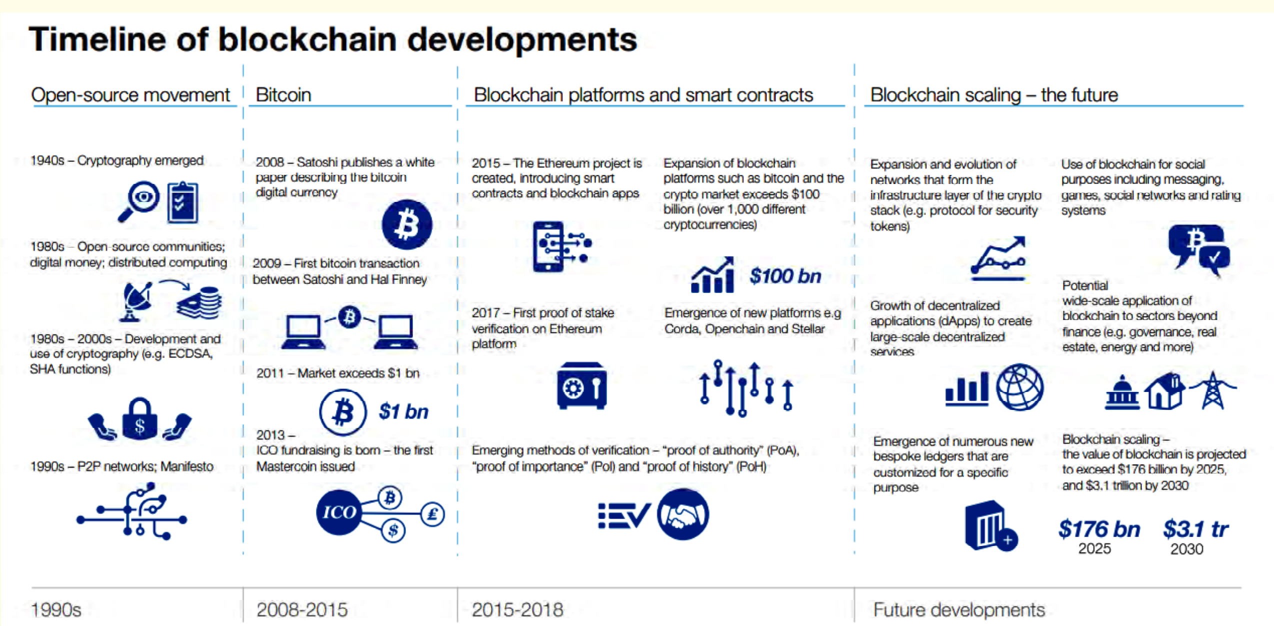
We have been increasingly hearing, reading and talking about BlockChain technology in the recent months, especially in the financial industry, where it is thought to become a game changer. It can provide additional efficiency and security, and may even completely disrupt the entire industry. Blockchain technology turns out to be of similar interest in the utilities business. Utilities and banks are alike in the way they are centralized, heavily regulated structures with complex processes. Utilities are a favourable environment for the deployment of BlockChain technology.

This Paper depicts details around adoption of Blockchain technology to mitigate current environment challenge and Usecases for Energy utilisation for the world.

2.0 Blockchain – What is it?

Blockchain and its underlying distributed ledger technology (DLT) have the potential to fundamentally transform a wide range of industries and markets. Blockchain's features can increase transparency and traceability, help to secure trust between parties, facilitate market access and improve the efficiency of transactions. The technology has clear potential, but there are also challenges to its development, including the potential for misuse and misunderstanding.

The Block Chain is the shared database technology that underlies Bitcoin and Ethereum, and it is set to disrupt many industries in the coming decade. It's already getting used in banking and payments, but most people don't realize that this same technology can be used to solve the major environmental problems we are facing today on our planet. If adopted globally, it can even help stop or reverse climate change.



Source: PwC

As permanent, tamper-proof databases that are shared by a community without a centralized owner, blockchains they are particularly interesting for environmental causes. They make it possible to track and verify transactions and interactions without a centralized authority. This can significantly increase transparency, efficiency, and accountability of environmental projects.

National governments, regulators and international standard setters will play a significant role in shaping Blockchain innovation through the domestic and global policy environment. Policymakers will need to address the challenges presented by BlockChain, but also consider its impacts on policy outcomes and programme delivery.

3.0 Blockchain – How it works?

1. Different types of blockchains use different mechanisms to "lock" the blocks in the chain and prevent altering of the data. Bitcoin operates with a "Proof of Work" approach, in which adding a block to the chain involves solving complex math problems with powerful computers in order to find the "hash" or code that will "lock" the next block in the chain. "Miners," who put in the computational work to find these hashes, are incentivized to do so because whoever finds the correct hash is paid in bitcoin for that service.

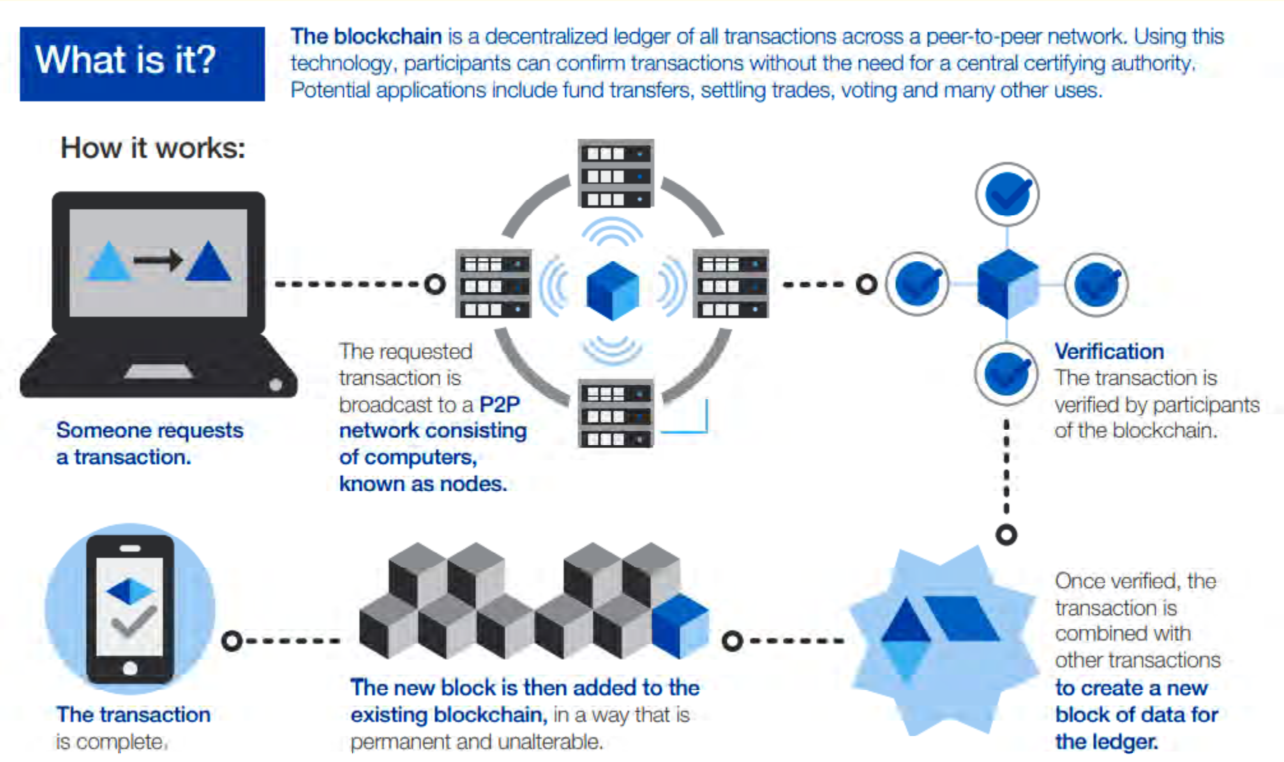
2. Finding the right hash requires significant computing power (and thus electricity). As Peck explains, "Any changes in old blocks will result in invalid hashes for all subsequent blocks." Likening hashes to keys that open locks, she notes "it's as though the design for the lock at the end of the chain depends on all the locks that came before it."

3. This makes attempts to alter prior blocks in the chain almost impossible, because that would require redoing all of the computational work for that block and all subsequent blocks. Additionally, while a would-be attacker attempted to do that with their limited resources, other players in the network would constantly be "mining" new subsequent blocks. Therefore, as long as an attacker does not control more than 50% of the whole system's computation power, they will never catch up with the rest of the players.

4. Finally, the system is structured so that the computation involved in finding the right hash gets harder over time. This keeps the rate at which blocks can be added consistent in spite of increases in computing power.

Blockchain technology's main applications are:

- **Distributed ledger:** insure traceability and certification of legal documents of all types.



- Assets transfer: peer-to-peer transactions of assets of all types, without intermediary
- Smart contracts: autonomous programs executing pre-defined actions under immutable terms

The blockchain is a public ledger that can store transaction records or any other data. It is owned by no one, with a copy of it being stored on many personal computers around the world. Anyone can use it and help run the network. This often removes the need for middlemen and allows users to interact in a peer to peer way. It can also reduce transaction costs and increase efficiency. Because it is distributed, this kind of network is difficult to take down or corrupt.

Once a data record is made, it cannot be changed and stays in the ledger forever. A new data record can be added only after it is validated by multiple computers. This makes the data trustworthy without relying on a third party. The ledger is secured with advanced cryptography, which makes it difficult to tamper with.

Platforms like Ethereum allow users to create programs, or dApps (short for decentralized apps) that run on the blockchain and have a variety of uses – not just financial applications. The programs are executed automatically, and exactly as agreed upon by all participants.

Public blockchains are transparent, meaning that high quality data is available to anyone and is consistent across the network.

The ability of blockchain to enable a decentralized and autonomous grid can explain why blockchain technology caught the attention of all energy companies in the recent times. The blockchain and the environment, what's the connection? How decentralised and peer-to-peer ecological systems can empower social activism? Eco-friendly blockchain startups can be used to solve the major environmental problems we face today. Transparency and veracity across the digital information ecosystem are some of the reasons. Forestry, energy, fisheries, organic food and mining industries can benefit from blockchain.

4.0 But why should you trust blockchain?

This is what we know until now:

- Blockchain forms an unbroken, verifiable chain of custody for whatever good or service is being exchanged and nobody can tamper with the records. Old and new transactions are both saved to the ledger.
- Blockchain maintains independence from financial institutions and national governance.
- It operates through a decentralized platform requiring no central supervision, while still remaining resistant to fraud.
- People can use blockchain as a digital signature.

4.1 Supply Chain Management

Most people want to buy products that are ethically made, but that kind of information is often unavailable and difficult to verify. A product goes through many hands before it reaches the store. It's very easy for companies to lie about how their products are made, what materials and chemicals they use, where they dump their garbage, or how fairly they treat their employees.

Blockchains can be used to track products from the manufacturer to the shelf and help prevent waste, inefficiency, fraud, and unethical practices by making supply chains more transparent. They can also help consumers be better informed of how each product was made and shipped so they can make more environmentally friendly choices.

If we tracked food, for example, this would enable buyers to purchase local produce knowing that it was actually grown locally. This would also cut down on carbon emissions due to food not having to travel long distances. Blockchains could ensure that a fish being sold at a fish market actually came from a sustainable fisherman, or verify that a bag of coffee really came from a fair trade producer.

Foodtrax is a blockchain-powered dApp being made by the Blockchain Development Company, and it aims to do just that – track food from its origin to the store shelf.

Provenace is another blockchain project that aims to make supply chains more transparent.

4.2. Recycling

With the current recycling programs, people often don't have good incentives to participate. The responsibility for running recycling programs often falls on each separate city, which results in many places not having recycling programs at all. It's also difficult to track and compare the impact of these programs.

A recycling program on the blockchain could encourage participation by giving a financial reward in the form of a cryptographic token in exchange for depositing recyclables like plastic containers, cans, or bottles. Similar setups already exist in several places around the world, in particular in Northern Europe.

It would make it easy to transparently track data like volume, cost, and profit, and to evaluate the impact of each location, company, or individual participating in the program.

Social Plastic (aka **Plastic Bank**) is a project that is turning plastic into currency by setting up collection centers in third world countries, where people can deposit used plastic in exchange for currency, services like phone charging, or items like cooking fuel. They aim to clean up the world from plastic waste while alleviating poverty. They are now working on a blockchain-powered app that will allow people to exchange plastic for cryptographic tokens.

RecycleToCoin is another blockchain dApp in development that will enable people to return their used plastic containers in exchange for a token, through automated machines in Europe and around the world.

4.3. Energy

Traditional power grids are centralized, which can create inefficiencies in energy distribution, like having unused surplus. And in parts of the world affected by natural disasters or poverty, power outages can leave people without access to electricity.

A peer to peer blockchain based energy system system would reduce the need to transmit electricity over long distances, which can result in losses along the way. It would also help reduce the need for energy storage, because such trading can move electricity locally from where it's being produced in excess to where it's needed.

Transactive Grid is a joint venture between ConsenSys and LO3 Energy that is working on a blockchain platform that solves this problem.

SunContract is a blockchain-based peer-to-peer energy trading platform for solar and other renewables.

Power plant installations are expensive and are often financed by governments of large private companies.

A blockchain-based platform could enable institutions, companies, and individuals to get returns from directly investing in renewable energy installations in their area and around the world.

EcoChain is a blockchain dApp being developed, which aims to do just that – create a platform for people to invest in renewables and get a return on their investment.

ElectricChain is another blockchain platform with several apps like SolarCoin, which aims to incentivize solar installations around the world.

4.4. Environmental Treaties

In can be difficult to track the real impact of environmental treaties, and sometimes there isn't an incentive for governments or corporations to keep their promises. Fraud and manipulation of data are also problems in this area.

Blockchain could discourage corporations and governments from back-pedalling on their environmental promises or misreporting their progress, because the technology would allow to transparently track important environmental data, and show whether commitments were met. Once the data is entered into the public blockchain, it stays there forever.

Legal document storage on the blockchain could cut down on fraud and manipulation, for example within the global carbon credits scheme. Around 979 million is spent annually on administrate this system alone. If you have an immutable record of credits bought and sold, then there is little chance of corporations and governments looking the other way when carbon credits are bribed or sold illegally.

4.5. Non-profits

When you donate to an environmental charity, it can be difficult to track where the money goes or how it is spent. Bureaucracy, corruption, and inefficiency are still common in the charity space.

Blockchain technology can ensure that money intended to be a reward for conservation, or a payment to a specific cause, does not disappear into unintended pockets through bureaucratic labyrinths. Blockchain-based money could even be released automatically to the correct parties in response to meeting specific environmental targets.

Blockchains enable funds to be transferred without bank accounts — which is beneficial to people in countries that lack banking infrastructure. This means that it's possible to send money directly to the people who need it without going through a complex web of middlemen or a centralized authority.

Bitgive and **Bithope** are two charities working with cryptocurrencies.

4.6. Carbon Tax

In the current system, the environmental impact of each product is difficult to determine, and its carbon footprint is not factored into the price. This means that there is little incentive for consumers to buy products with a low carbon footprint, and little incentive for companies to sell such products.

Tracking the carbon footprint of each product using the blockchain would protect this data from tampering, and it can be used to determine the amount of carbon tax to be charged on at the point of sale. If a product with a large carbon footprint is more expensive to buy, this would encourage buyers to buy products that are more environmentally friendly, and would therefore encourage companies to restructure their supply chains to meet the demand for such products.

A blockchain-based reputation system could also give each company and product a score based on the carbon footprint of the products they sell. This would make manufacturing more transparent, and discourage wasteful and environmentally unfriendly practices.

4.7. Changing incentives

In a world of complexity, it can be difficult for individuals or companies to see the direct effects of their actions. Therefore, the incentives for acting in an environmentally sustainable way aren't always clear, especially in the short term.

Blockchain technology can help both individuals and companies to see the real impact of their actions and incentivize them to take the actions that benefit the environment. The blockchain can be used to transparently track a variety of data like the carbon footprint of each product, the greenhouse gas or waste emissions of a factory, or a company's overall history of compliance to environmental standards. Companies and individuals can be incentivized to act in an environmentally sustainable way through the availability of information, tokenized credits being issued for taking certain actions, or blockchain-based reputation systems.

These new incentives could completely change the drivers of our economy, and benefit not only us, but the future generations living on our planet.

5.0 Blockchain for Energy

Over two-thirds of our efficiency potential is still untouched. In addition to putting the brakes on the curbing of our carbon emissions, this dormant potential means significant employment and economic markets are being overlooked. In the construction sector, for instance, 80% of EE potential remains; public building renovation in the EU alone represents a €120 billion market over the 2017-2020 periods. In France, the estimated market is around €30 billion over the next 10 years, and could create up to one million jobs by 2025. An estimated €231 billion is spent annually on energy efficiency (EE) investments - but tapping the full potential of EE will require at least four times as much investment. This finance gap is slowing down the energy transition we need.

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5.1 Concept

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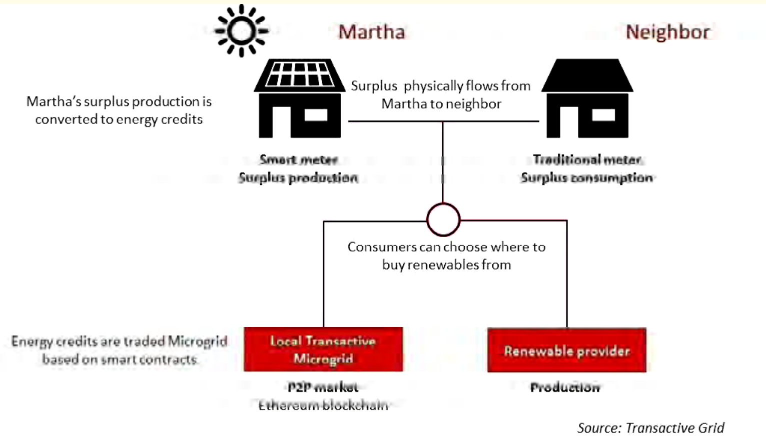


Source: Transactive Grid

and Germany. The renewable energy company Vandebron will work with customers who own an electric vehicle to make electricity from their car batteries available to the grid in order to help the Dutch national grid operator TenneT better integrate increasing amounts of renewable energy. TenneT is using innovative IBM blockchain technology to manage this electricity grid. In the future, blockchain technology could allow millions of energy devices such as water heaters, electric vehicles, batteries and solar PV installations to transact with each other at the electric power distribution edge.

5.2 Opportunities

The evidence suggests that targeting the risk perception of investors through a variety of instruments is successful in scaling up EE investments. The blockchain peer-to-peer model, which is built on the trust engendered by its permanent and unfalsifiable digital ledger, is a creative financial tool that can help overcome this perception of risky EE transactions.

The technology is not yet mature, but is growing fast. It might take five to 10 years before the technology reaches mainstream adoption. Yet it paves the way to acceleration of energy system decentralisation and the emergence of prosumers, where individuals can adapt their behaviours according to real-time data and a consequential increase in the overall energy system efficiency.

The total value of assets now being administered via blockchain over the world is already over $1.6 billion, and grew by a staggering 1,600% between 2013 and 2016. Over $1.4 billion was invested in blockchain-related startups in the first nine months of 2016 alone.

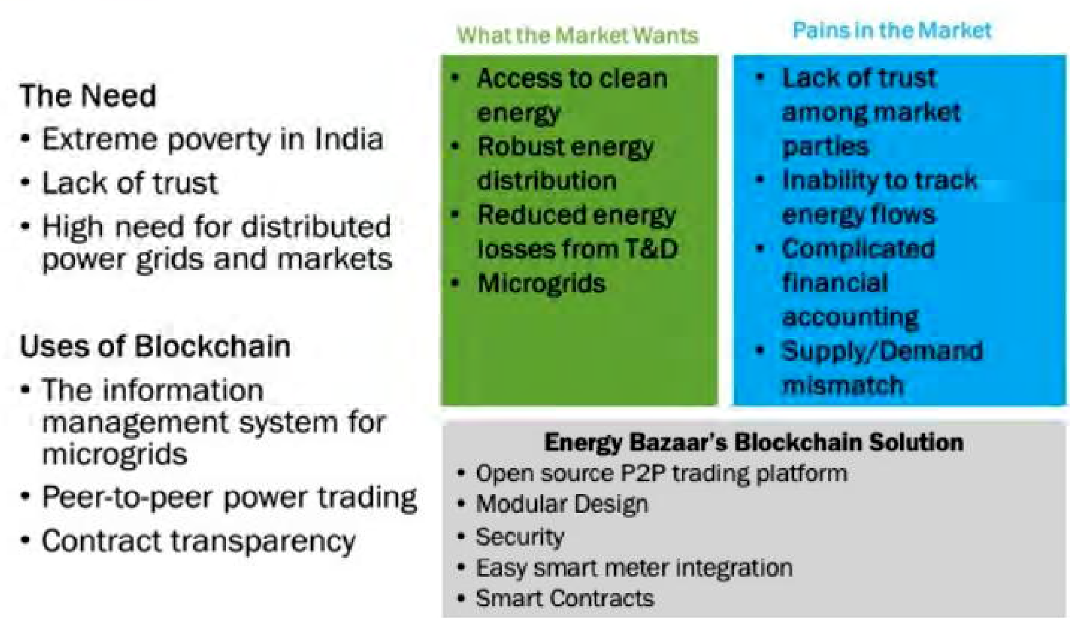
6.0 Use Cases for Energy Sector

6.1 Energy Transactions in Emerging Markets

With half of the global population growth occurring in just nine countries – mostly in emerging markets in Asia and Africa – it will be critical to create sustainable pathways for both economic and energy sector development. This will be challenging for many countries that lack the existing infrastructure needed to enable growth or have limited institutional capacity for the management of rapid development. Pathways that can support population growth and economic development while avoiding massive infrastructure investments and build-outs will be needed to sustainably meet demand.

Blockchain offers a framework for automating many fundamental institutional capacities that are generally handled by large organizations with many employees. Blockchain creates a trusted system for handling energy transactions, including billing and settlement, and can do so without the need for a central authority . For rural communities, blockchain can manage information on kWh of energy that are generated and used. The transactions can be monitored and cleared without the need for third-party auditors to control smart meters and verify data. This can drastically improve ease of use for market participants, while at the same time improving trust and creating price arbitrage opportunities.

The Energy Bazaar Example: Using Blockchain for Microgrids in India[81]

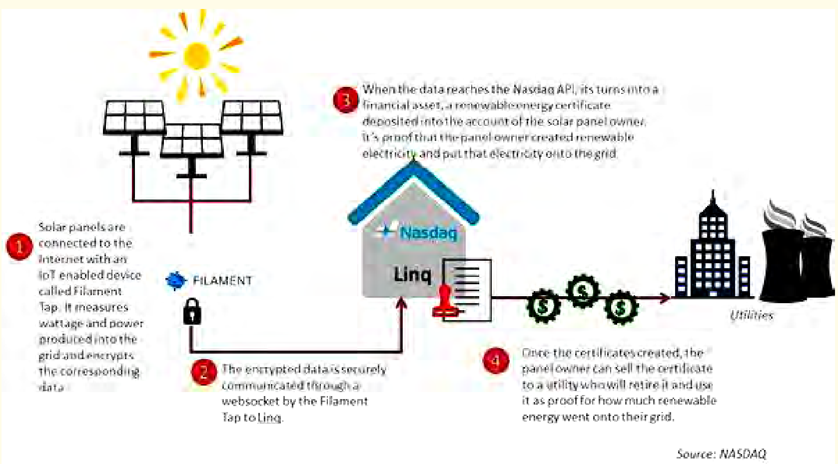


6.2 Authentication of the certification of solar power

NASDAQ and its service LINQ used the authentication of the certification of solar power

The stock exchange operator, Nasdaq, unveiled in May 2016 a service that lets solar power generators sell certificates thanks to its Linq blockchain service (for more details: http://ir.nasdaq.com/releasedetail.cfm?ReleaseID=948326).

In this system, the solar panels have to be connected to the Internet with technology provided by Filament, a Nevada-based blockchain start-up. Through an API pull from NASDAQ's blockchain-based private markets platform Linq, anonymous certificates are created and can be sold to anyone who wishes to subsidize solar energy. The solar panels are hard-wired into the IoT device through a converter which enables Linq to measure the wattage they're putting out and producing into the grid.

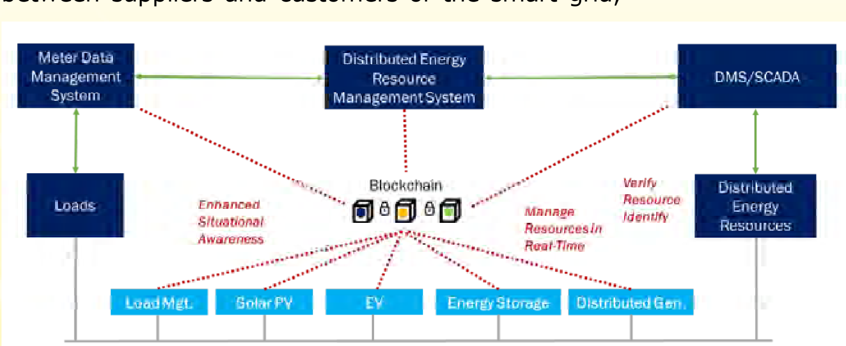


Source: NASDAQ

6.3 Smart metering

Blockchain technology may ease the billing process for utilities and reduce energy bills for consumers thanks to smart metering

The electricity smart meter is the keystone between suppliers and customers of the smart grid, and concentrates all the transaction, confidence and security stakes associated with an ever more intelligent and flexible energy.



Smart meters associated with the transparency of blockchain create an environment where transactions are open and secure:

- Reduce risk of fraud / theft
- Help manage debt recovery
- Increase transparency in price changes and fees
- Improve efficiency

A smart grid network supported by blockchain technology would ensure an efficient local relationship between production and consumption of renewable energy. Participants could publicly track their energy usage and production, and sell any unused energy to other participants. They would also have the ability to reduce their energy bills by making more informed purchasing decisions, avoiding consumption peaks or switching into a lower subscription. Smart meters and blockchain technology would ensure a simplified billing process (efficiency, transparency) and faster switching times.

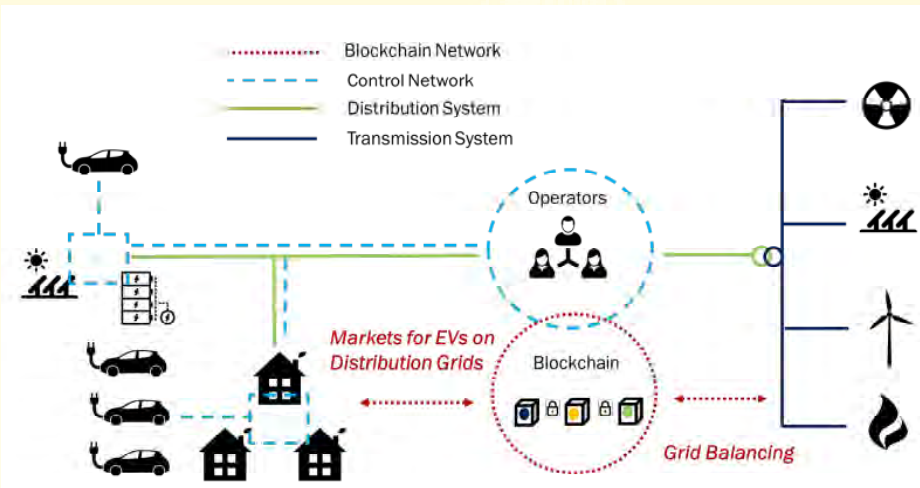
A blockchain solution identifying where the energy is coming from, at what unit price and any mark-up passed to the consumer would result in more competitive pricing and in better integrity from public perception.

6.4 BlockCharge: EV charging and billing solution

RWE and Slock.it are putting together a decentralized billing system for electric vehicle charging. It is called BlockCharge. Following the same principle that roaming for telecommunications, it would allow electric vehicles to charge anywhere (with the help of a smart plug), and to be billed for the electricity they used in a simple, common, and blockchain-based way. The EVs would interact automatically with stations and the electricity payment process would be autonomous.

The benefits of the project:

- Multiplying charging infrastructures (the use of a smart plus enables to charge a vehicle anywhere)
- Simplifying charging contracts (no need for contract anymore)
- Resolving interoperability issues
- Increasing transparency
- Simplifying the charging process by handling authentication, charging and billing



6.5 Microsystems

Blockchain may help the emergence of microsystems based on prosumers

In the energy sector, we are witnessing the development of prosumer characters that is to say individual consumers that are also producing energy (homes with solar panels for instance).

In that respect, blockchain technology represents an opportunity for a wider development of those behaviors by increasing the number of people who could buy and sell energy directly with a high degree of autonomy.

Indeed, as said in the previous paragraph, blockchain technology should entail major changes since it allows transactions to be carried out directly from peer to peer. No third party intermediaries are required. In theory, we can imagine a market place where consumers exchange their own production without needing energy companies to organize the transactions. It creates a shift from centralized structures (banks, trading platforms, energy companies) towards a decentralized system (peer-to-peer transactions). It would reduce cost and speed up processes. The system would thus become more flexible. of course, in that model, energy companies are still needed to organize the transfer of energy.

7.0 Road Ahead

The road is still long and the stakes are high

None of the energy companies currently developing blockchain applications have moved beyond the concept or pilot stage yet. It appears that those models are difficult to put into practice. Indeed, the actual technology lacks of maturity and is complex in its development and implementation, in the energy sector in particular.

Moreover, barriers such as legal and regulatory requirements that blockchain projects must comply with are obstacles that still have to be overcome. The legal and regulatory frameworks still have to be designed to reflect the requirements of decentralized transaction models and provide protection to energy consumers.

Actions that we take in the coming five to 10 years will lock us in for the next 50. The costs of inaction are rising yearly, with associated economic and humanitarian consequences. Natural disasters already cost over $500 billion a year worldwide and push an additional 26 million people into poverty every year. There are 65 million refugees in the world today, 20 million of whom exist thanks to climate change. Should countries not respect the Paris Agreement, South East Asia could become inhospitable to humans by 2100; one-fifth of the world's population lives in this region. Sea levels could also rise an estimated 2m by 2100, leading to waves of refugees as two-thirds of the world's population live in coastal areas.

Blockchain technology is a potential game changer for the energy market and its ecosystem: users, real estate companies, municipalities. Nevertheless, it is too early to know what role in energy markets blockchain technology is set to play. It may be restricted to database management and transactions processing, but most likely, some wider and more disruptive future awaits.

Blockchain has the potential beyond just a given industry. Ultimately, Blockchain is to reduce friction in existing use cases, such as improving time to settle disputes, removing physical documents and being smarter in terms of paying people. Settling and reconciling between different legal entities within a group of organisation.

8.0 Energy Consortium

It's important to have a The Forum to take stock of blockchain's impacts across the full range of government activities and public priorities. The Forum will address the benefits and risks of Blockchain for our economies and societies, begin to identify good policy and regulatory approaches, and investigate uses in specific policy areas.

Let's get together and collaborate to make "The Blockchain Energy Forum" into the Blockchain Centre of the world!

Adoption will be achieved through building trust in the economic, social and environmental potential of the token and Blockchain economy. This requires below aspects –

- Industry players who are valued for contributing to the greater good of society and with respect to the environment.
- Responsible business who demonstrate social and economic impact through developing local, regional and national capabilities and cooperation in the token and Blockchain economy.

    1) Implications on privacy and cybersecurity
    2) Using blockchain to enhance inclusiveness
    3) Using blockchain to promote green growth and sustainability
    4) Using various blockchain based solution
    5) Identification of Blockchain technology companies and provide sustainability model to nurture technology.
    6) Using blockchain to strengthen governance and enforcement practices

The Energy Consortium - Mission

To create a Blockchain Society with Government, Technology companies, Developer community, Academia, Startup, Blockchain Companies, Technology Accelerator & Investors network. Through education, advocacy and working closely with policymakers, regulatory agencies and industry, our goal is to equip our members & partners to make informed decisions regarding policies, laws and business decisions concerning the embracement of Blockchain and the tokenization of our financial futures.

We strive to create an environment in BlockChain area that fosters digital innovation, job creation & investment in the digital economy. We will achieve this through creating trust in the market for digital assets and distributed ledger technologies, eco-systems and market places in India.

The Blockchain Forum will be a key player in the process of creating a setting that will transform India into a global Blockchain destination.

The members will work harmoniously and in unison for the benefit of the individual and collective business development of International Blockchain companies.

1) Guide regulation of BlockChain, ethical cryptocurrency & tokenization by setting industry leading best practices.
2) Provide thought leadership and research on behalf of members regarding the technologies involved, and opportunities they can provide.
3) Shape relationships between key governments, and our member constituency to facilitate potential collaboration.
4) Pool the resources of our members toward priority issues and opportunities they have collectively identified.
5) Develop strategic economic cooperative ecosystems through leadership, ethics, standards and self-regulation.
6) Support the development of Blockchain professional bodies, educational standards, accreditation and professional code of conduct.
7) Propose regional, national and international strategies for the orderly bridging of the legacy and digital worlds of enterprise and finance.
8) Create a learning & certification ecosystem for developers , executives
9) Develop in-house protocols considering various use cases of Blockchain in variety of industries.
10) Research & form repository of standard use cases to pilot and practice
11) It also seeks to raise awareness of the importance of the blockchain technology among the professional and lay public, and, therefore, organizes various events and training courses. It also cooperates with the government authorities in the field of the relevant legislation.

12) To create an Ecosystem with Start-ups, Government, Students, Corporate, Accelerator Partners, Government to nurture Innovation.

13) To create Education and skill building framework. It aims to create awareness of Blockchain wave.

14) To conduct Hackathons for churning Ideas & Innovative Solutions from pool of startups & institutes with similar interests. We look forward to work with Identified Startups & Students as a part of Innovation Journey!

15) To identify & maintain use case repositories. This should help to Experiment latest Trends, Technologies & its adoption.

16) It will help us in bringing out potential business use cases.

17) It will bring a pool of potential champions from Institutes. We can look forward to incubate them.

Annexure 1: Pilot Project @ Bangkok

Residents in a Bangkok neighbourhood are trying out a renewable energy trading platform that allows them to buy and sell electricity between themselves, signalling the growing popularity of such systems as solar panels get cheaper.

The pilot project in the centre of Thailand's capital is among the world's largest peer-to-peer renewable energy trading platforms using blockchain, according to the firms involved.

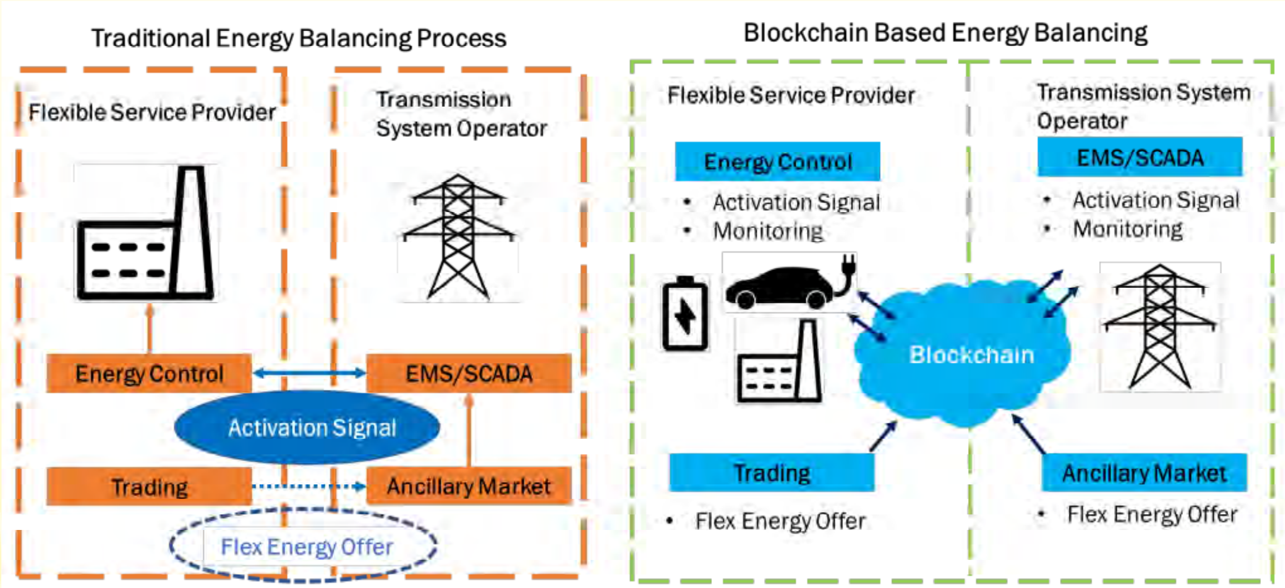
The system has a total generating capacity of 635 KW that can be traded via Bangkok city's electricity grid between a mall, a school, a dental hospital and an apartment complex.

For the pilot in Bangkok's upmarket Sukhumvit neighbourhood, electricity generated by each of the four locations will be initially used within that building. Excess energy can be sold to the others through the trading system. If there is a surplus from all four, it will be sold to the local energy storage system, and to the grid in the future, said Gloyta Nathalang, a spokeswoman for Thai renewable energy firm BCPG, which installed the meters and solar panels.

Power Ledger, an Australian firm that develops technology for the energy industry and is a partner in the project.

Commercial operations will begin soon & expecting below benefits –

- By enabling trade in renewable energy, the community meets its own energy demands, leading to lower bills for buyers, better prices for sellers, and a smaller carbon footprint for all.
- It will encourage more consumers to make the switch to renewable energy, as the cost can be offset by selling excess energy to neighbours.
- Helping it along is blockchain, the distributed ledger technology that underpins bitcoin currency, which offers a transparent way to handle complex transactions between users, producers, and even traders and utilities.
- Blockchain also saves individuals the drudgery of switching between sending power and receiving it.
- There are opportunities everywhere - not just in cities, but also in islands and remote areas where electricity supply is a challenge



The World Energy Council predicts that such decentralised energy will grow to about a fourth of the market in 2025 from 5 percent today. Neighbourhoods from New York to Melbourne are upending the way power is produced and sold, with solar panels, mini grids and smart meters that can measure when energy is consumed rather than overall consumption.

Thailand is Southeast Asia's leading developer of renewable energy, and aims to have it account for 30 percent of final energy consumption by 2036. The energy ministry has encouraged community renewable energy projects to reduce fossil fuel usage, and the regulator is drafting new rules to permit the trade of energy. The Bangkok Metropolitan Electricity Authority forecasts "peer-to-peer energy trading to become mainstream for power generation in the long run" . BCPG, in partnership with the Thai real estate developer Sansiri, plans to roll out similar energy trading systems with solar panels and blockchain for a total capacity of 2 MW by 2021.

Annexure 2 : Themes of "Blockchain Energy Consortium"

A. Functional

1) Creation of Use Case Repository
2) Use Case Validation Framework
3) Risk Management

B. Technology

1) Consensus & Protocol Mechanism Standardisation
2) Technical Challenges & Resolution
3) To oversee Evolution of Fabrics & Frameworks
4) Track various Fabrics & Platforms

C. Complience & Regulatory

1) Creating of Policy around Cryptocurrency
2) Creation of Blockchain Guidelines for Government Use Cases
3) Creation of Sandbox Environment for better governance

D. Acclerator Program

1) Execute Manage Hackathon Execution
2) Practice Open Innovation
3) Development of POC, Pilot, MVP, SCALE
4) Talent Identification Programs
5) BlockTech Graduation Program

E. Education & Academia

1) Education Curriculum creation
2) Awareness Programs / Meet-Ups
3) Skillset Building Workshops
4) To Support Blockchain Fundamental & Expert level Courses & Certifications
5) Setup of Cost effective Blockchain Lab

F. Consortium Network

1) Blockchain Companies working on Use Cases & Technology Improvements
2) Repository of MVP Ready use cases
3) Developer Network

Annexure 3: World Economic Forum Report

The World Economic Forum has just published a report on blockchain's potential to solve or assuage environmental problems.

The report identifies 65 existing or emerging environmental use cases for blockchain, which are broken down into eight main "game-changers":

1. Transparent supply chains

Blockchains record and allow shared access to each transaction completed. This transparency allows companies to fulfill any environmental or sustainable promises by demonstrating provenance. But it can also help industries manage resources to ensure sustainable practices.

2. Decentralised resource management

Decentralised platforms can collect information from energy grids and water systems. This could end any asymmetries in energy generation and clean water production, enabling better system design and management. Furthermore, a decentralized P2P utility platform would enable resource trading which could more efficiently allocate power and water with fewer intermediaries.

3. Financing

Blockchain platforms could simplify investing for retail players. This allows environmental projects to crowdsource from a larger pool, unlocking otherwise dormant capital. Moreover, a 'tokenization' of financial investments could remove the need for third parties, enabling a swifter and more efficient process. It also enables stakeholders to participate as opposed to just shareholder.

4. Circular economy incentives

By incentivizing people to recycle, blockchain systems could unlock financial value from otherwise 'waste products'. This would decrease the level of waste we produce and change our attitudes towards these products. For example, a reward token could be issued when an individual recycles plastic or batteries, which he could then spend on other products.

5. Carbon Markets

Critics of the carbon credit trading system usually point to its lack of transaction traceability, differing laws and jurisdictions, and potential for double counting. Blockchain's transparency offers solutions that solve these problems, potentially allowing a feasible carbon trading system

6. Sustainability monitoring

The transparency of blockchains enables people to monitor claims by governments and companies. Hence it encourages them to improve their performance and ensure more sustainable practices.

7. Automatic disaster preparedness and humanitarian relief

Blockchain could better connect emergency services with people and improve humanitarian relief. For example, if a community needs drinking water or another commodity. Smart contracts could enable automatic matching based on timing, location, pricing, quantity, and other community needs.

8. Earth-management platforms

New blockchain platforms could help with geospatially monitoring natural resources. For example by tracking biodiversity or an endangered species. Projects like Amazon's Earth Bank of Codes are already doing this in a collaborative but centralized manner.

The report also identifies obstacles that blockchain systems could face. These include privacy, scalability and legal issues. Right now, public blockchain systems such as Ethereum don't have the technological ability to carry out the above solutions. Their transactions per second cannot handle it.

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5) https://www.bearingpoint.com/fr-fr/blogs/blog-energie/how-blockchain-technology-could-reshape-utilities-businesses/

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8) http://www3.weforum.org/docs/WEF_Building-Blockchains.pdf

Is Blockchain Too Good To Fail? – A Proactive Prescription For Regulation

Profile

Dr. Akhilesh Chandra is a Professor of Accounting & Accounting Information Systems, and KPMG Research Fellow in the University of Akron. He has served as the Special Issues Editor of the Journal of Information Systems, and is on the Editorial board of Open Journal of Accounting. He serves on the Board of Financial Executives International (FEI) NEO Chapter and International Journal of Applied Decision Sciences. In his leadership role as the Director of The Institute for Global Business, he built a vibrant Advisory Board of Senior Executives from Fortune 100 area organizations, developed outreach programs such as the Executive Business Forums Lecture Series, China Week Keynote Speaker Series, International Tax Conference, and the Global Business Scholars program. He has helped develop and grow global partnerships with Yonsei University in Korea, Henan University in China, and The University of Delhi in India among others. In his leadership role as the Associate Director of the Center for Research & Training in Information Security & Assurance, he has organized eight symposia and workshops. Dr. Chandra is the recipient of the competitive research grant from the National Science Foundation (NSF) for a three-year period to examine life-cycle costs of earthquakes in a joint collaborative effort with Professors from Civil Engineering. His research interests include risk, control, and assurance of accounting systems and corporate governance. He is widely published in several Some of the journals in which his work is published include GeoRisk, Communications of the ACM, Journal of Information Systems, Transportation Journal, Advances in Accounting, International Journal of Accounting Information Systems, Managerial Auditing, and Decision Support Systems Journal. He holds several professional certifications from India and the US.

Abstract

I develop a framework that uses seven constructs to identify specific issues with blockchain. The framework assumes significance in the context of claimed promise in the literature of blockchain as a tamper-proof solution against error, fraud and misrepresentation. In developing and discussing each construct of the proposed framework, I argue for a cautionary note to treat blockchain as a cure all and panacea for all problems.

1. Introduction

The literature widely considers blockchain technology as the tamper-proof solution against error, fraud and misrepresentation. This claim overlooks consideration of pre-requisites that must happen to achieve blockchain's promise. In this paper, I develop a framework eight pre-requisites to implement blockchain technology (hereafter BT). Without these pre-requisites, investments in BT may never correlate with promised benefits.

The paper proceeds as follows: second section briefly describes BT and its components; third section develops and discusses the framework to identify pre-requisites for BT to have wider adoption; fourth section discusses implications of the framework for theory and practice; fifth section concludes the paper with avenues for future research.

2. Concept of Blockchain

A block is a list of transaction records. In a blockchain, block grows and is updated continuously. Virtual currency of bitcoin used blockchain as the underlying platform for its growth. Any member in the network can update and verify blocks. Hence, blockchain is a distributed, shared ledger, which is completely transparent and fixed. Transparency implies that no member in the network can hide changes to the block without full discovery and accessibility. No one member has complete control or ownership of the block unlike an entity that owns and maintains its ledger. These features of blockchain, in principle, provide impossibility for any error or fraud.

3. Issues with Blockchain

It is important to state that blockchain is a technology solution that operationalizes the concepts of immutability, transparency and un-alteration. Therefore, at least in principle, as with any tool, BT is vulnerable which becomes evident when viewed in the context of a process-view. In this section, I provide seven pre-requisites that must happen for mass scale adoption of BT across industries (see Figure 1).

3.1 Conceptual

The blockchain technology is still at an evolutionary stage in the context of common data definitions, processes, models, and operating standards. For example, various cryptocurrencies have evolved using different coding languages and standards. These differences result in varying coding practices some of which inadvertently become the source of vulnerabilities in BT.

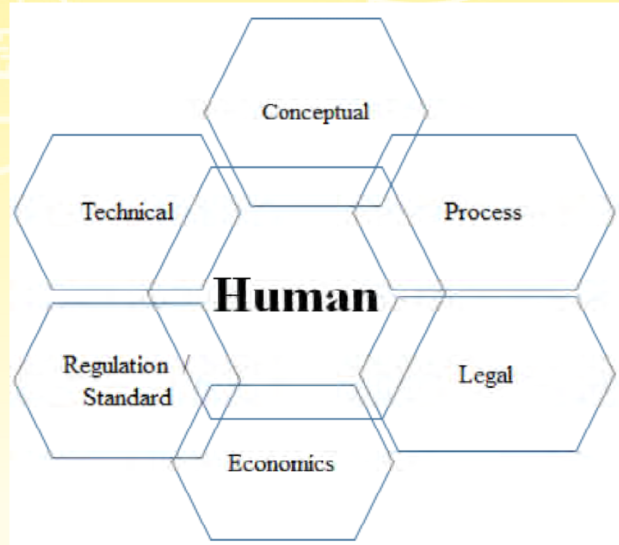

Figure 1: Framework of pre-requisites for Blockchains

Further, for effective governance of BT applications, organizations should develop appropriate KPIs, performance metrics and quantify benefits.

Given the state of evolution, the audit profession is yet to develop a common and agreed upon audit standards to provide assurance on the integrity of processes and data stored in and generated by BT.

3.2 Regulation and Standards

Across the globe, there is a lack of effective and comprehensive state regulation and industry standards to monitor and govern blockchain applications. There is a significant gap between rapid development of BT applications in practice and formulation of regulation and standards.

One reason for this gap is lack of complete understanding about blockchain technology and its effect on the economy. Progress with regulation and standards is very slow and often non-existent. The popular press makes regular reference to central banks of various nations that are trying to grasp with the reality of cryptocurrencies and ways to integrate, manage and regulate such currencies. However, practice has several non-financial applications of blockchains that are hardly in the radar of state and standard setting bodies.

Further, research suggests that the concept of blockchain stands in direct contrast to some of the regulations and standards. For example, EU's General Data Protection Regulation (GDPR) that took effect on 25th May 2018 has a 'right to be forgotten' feature to ensure privacy and protect data. This feature conflicts with 'immutability' of information inherent in blockchain where once the data is stored in a block, that data is irreversible (Žyman ius 2018; Ibanez 2018). A possible solution of 'prohibition to use' data versus outright deletion provides some compromise, but the underlying issue of going against the law is concerning.

3.3 Legal Conundrums

Legal conundrums closely follow lag in or absence of regulation and standards with respect to BT. Courts do not have a clear understanding, which may prevent proper and effective adjudication in case of disputes. Examples of issues that need legal clarity include locus, jurisdiction, and applicable law governing 'shared distributed ledgers'; absence of central administration and governance; lack of precedence; absence of any legal recognition; no uniform legal validity in different countries; Territoriality, ownership, evidence and liability issues for blockchain transactions, data/documents stored in blockchain, financial instruments issued in blockchain and smart contracts; legal interpretation for man-machine evolution with associated functionalities including AI, VR, AR, MR. Fair and effective adjudication requires a global legal framework to recognize distributed ledgers as valid regulatory registries. Resolution of these and related legal conundrums is an evolutionary process and may take some time to mature.

3.4 Technical

In its early days of evolution, blockchain provided the platform for operation of cryptocurrencies. Later, the technology evolved into non-financial applications. However, underlying technical challenges remain common across applications.

Notable technical challenges include security vulnerabilities at the design, architectural and coding phases for smart contracts deployed on their respective platforms (Luu et al. 2016). For example, reentrancy (flexibility to interrupt a program during its execution and to be called again) and overflow (inability of a program to handle too large a number) are common vulnerabilities in the coding phase and render blockchains vulnerable to hacking attacks (Thornburg 2018).

Further, data deluge in a typical blockchain network significantly deteriorates performance and efficiency with a drain on scarce resources.

Closely related to data deluge is the scalability concerns where performance (slower speed and higher cost per transaction) of BT declines with increased numbers.

Similarly, proof-of-work (PoW) to verify a transaction, arrive at a consensus and add to a block is an energy-intensive operation and unsustainable in its current state. This is especially true given the already current strain on the economics of global energy production and consumption (Holthaus 2017), and has political and social ramifications.

Also, small blockchain networks are vulnerable to double-spend or 51% attack. Bonneau (2016; 2018) showed several strategies for a hostile takeover making blockchain particularly vulnerable.

Common logic suggests that concerns about security vulnerabilities override all other considerations.

3.5 Process

A BT application would likely be one of the several applications and information systems, some of them are legacy, while others are ERP based. Experience with ERP implementations has shown that despite the goal and the promise, several of these implementations remained as silos and needed further investments in middleware and bolt-on tools to integrate and achieve connectivity. Unless addressed at the design level, BT applications could potentially face similar integration challenges, which may dampen their economic appeal.

Further, organizations should consider designing appropriate internal controls to ensure data and system integrity. Both general and application level internal controls co-exist to achieve satisfactory managerial, governance and regulatory compliance. At any point in time, organizations are required to comply with several, often-overlapping internal control frameworks such as COSO, COBIT, ISO, SOX and Lean manufacturing. Both the internal auditor and external auditor provide assurance on the integrity of internal controls. With SOX 2002, now public organizations and government entities are required to document such internal controls, which the top management must truthfully certify every year to avoid criminal prosecution. Given this industry and regulatory requirements, organizations must ensure that their BT applications are in due compliance.

3.6 Economics

Cost efficiency is a key feature of BT since it reduces the transaction and verification costs. However, a BT application is unlikely to stay as a silo in an organization. The seamless integration of a BT application with other legacy and ERP systems is likely an expensive operation. Thus, any savings in transactions could significantly dwarf in the presence of design and maintenance of enterprise system integration. Further, memories of money laundering and illegal activities associated with early days of cryptocurrency is too recent for a mass adoption of BT (Li et al. 2017).

3.7 Human

Blockchain as a technical solution needs human involvement for design, implementation, maintenance and assurance. This involvement lends to vulnerabilities since human is the weakest link in any solution. BT solution would therefore, need an appropriate blend of vulnerability management using three-pronged simultaneous strategies of Blockchain Education, Training and Awareness (BETA). Research suggests that in a man-machine solution to address any vulnerability, the human component typically shares half of the total solution. According to a HBR research, the nature of human involvement would shift from prediction-related skills to judgment-related skills (Agrawal et al. 2016). The extent of human involvement in a BT solution reduces the infallibility of blockchain.

The other side of human issue relates to privacy concerns. The transparency of distributed ledgers lends to open visibility and verification, hence a positive feature. However, Blockchains can run into conflict for those applications where such level of transparency is against the law. Examples include sensitive patient data within the purview of regulatory control (such as HIPPA in the US), financial data and government data. If applications mask relevant fields from public view and verification, then such masking compromises the transparency of blockchain and limits their functionality.

4. Implications

The preceding discussion suggests that for a successful BT application, organizations need a systematic, integrated and holistic strategy. A blend of technical, people-based and process-oriented strategy provides an ideal for organizations to address the seven pre-requisites. Since legal and regulation is outside the purview of organizations, the society and government should coordinate their efforts with various standard setting bodies to develop solutions. The distributed nature of shared ledgers implies that countries and regions internationally should pool their resources for a consensus approach to govern and monitor BT applications.

5. Conclusions

In principle, at least, blockchain hold significant promise for process and cost efficiencies, minimize error and fraud, and provide transparency and open verification. However, the concerns discussed above suggest that organizations considering adoption of BT should strategically address them for a lasting return on the investment. Some of the concerns are exogenous to the organization and need address at macroeconomic and government policy levels. We should avoid BT becoming another compliance exercise. If the experience with past technologies is any guide, then as a society, we are still very premature to label blockchain as the savior of all ills that plague our society. In this paper, I argue for a cautionary note to treat blockchain as a cure all and panacea for all problems. Let's not throw the baby out with the bathwater, just yet!

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Blockchain Technology for Renewable Energy Distributed Energy Generation : Identification and Analysis of Business Models

Profile

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Experience : In his 20 years of professional experience, Sujit K Nair has contributed towards various roles in the IT Industry. He was a Systems Engineer on Linux/Unix Operating System and early Mobile Application Stacks with teams across US and Europe. Post engineering roles; he transitioned to Product Sales and Business Management roles for Indian Subcontinent and South East Asia region. He started Rayk Labs providing Consulting and Development Services in terms of API Development, Architecture Design, SAAS Delivery, Cloud Solutions and BlockChain. Rayk Labs has also built a SAAS product called SAILS (Track & Servato) - Sales & Service Management Platform. In the spirit of Social Entrepreneurship he started CoEthix (Collaboration & Ethics) Platform. Under CoEthix, Project RedDrop365 is being developed as a platform to seamlessly work through Blood Banks, NGO's, Corporate, Educational Institutions and Donors for an efficient and effective Blood Supply Management.

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Abstract

This paper aims to identify the type of business models in the Energy Sector using Blockchain-based initiative. Blockchain-based applications within the electricity market are not only new to the energy business but also a young field within academic research.

Researchers have analysed how Blockchain technology can:

- Support the energy management of the distribution grid and within residential microgrids while integrating distributed Renewable Energy Sources (Danzi, Angjelichinoski, Stefanoviæ, & Popovski, 2017; Horta, Kofman, & Menga, 2016).

- Furthermore, Mihaylov and Van Moffaert have introduced a digital currency that allows prosumers on the smart grid to trade their produced renewable energy (Mihaylov, Razo-Zapata, Rãdulescu, & Nowé, 2016).

- Blockchain-based electricity transactions and congestion management (Tai, Sun, & Guo, 2016).

The academic research analyses how Blockchain technology can be used to solve some of the open questions and issues concerning the electricity market, it does not address business cases and opportunities. Research covers business models involving the smart grid or explores business models that encourage the flexibility of distributed energy resources. Hence, there is a research gap regarding business models based on the Blockchain within the electricity market.

The key questions answered in this paper are:

What are distributed ledger technologies and the Blockchain?

What are the existing Blockchain-based business models within the electricity market?

How do these business models affect the electricity market and the value chain?

Finally we will summarize as to how Blockchain-based business models promote green energy, increase efficiency and lower energy costs. And the three characteristics that are rooted in the business model dimensions of value proposition, value chain and value capture allow organisations to add value to customers and to lower costs at the company end.

Blockchain Technology for Renewable Energy Distributed Energy Generation: Identification and Analysis of Business Models

Currently a general literature review reveals that Blockchain within the energy market is primarily dominated by Energy Trading, P2P and Smart Contracts followed by discussion of Blockchain properties and use cases. Also, the literature is dominated by publications from Management Consultancies and non-academic institutions such as start-ups. Few journal articles actually address the technical aspects of Blockchain applications in the context of electricity trading or energy management. In contrast, non-academic publications address the topic in broader terms and less specifically than academic research. So current academic research and publications centre around energy-trading platforms based on the Blockchain, general Blockchain properties, smart contracts and digital currencies.

Blockchain–Functional Principles

Blockchain technology is a special form of a distributed database. All participants in the network share a consistent copy of the database; not having a central server is a distinct feature of distributed databases. Moreover, network participants can conduct peer-to-peer transactions, meaning that transactions, e.g., online payments, can be transferred directly from one person to another without an intermediary or central authority such as a central bank. In place of the intermediary, participants share the responsibility to verify the legibility of the transaction using a pre-agreed-upon consensus mechanism.

Figure illustrates the procedure of verifying and executing payment transactions through a bank versus a P2P network.

Blockchains enable disintermediation by building a distributed and replicated ledger among all the users of the Blockchain. This allows the participants to directly share information or initiate transactions between each other.

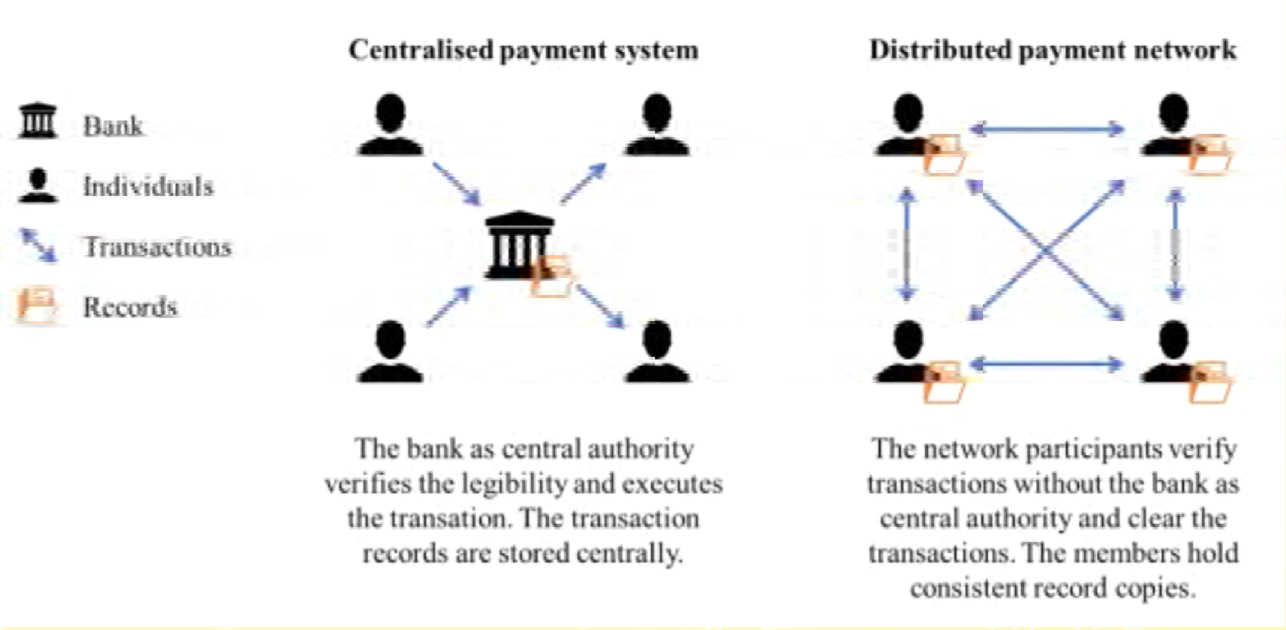
The technology uses a consensus mechanism in order to validate a transaction. This is a requirement to be able to disintermediate the transaction process from the hands of a central authority.

The blocks, which are added successively following validation, remain transparent and verifiable to the network participants. This follows from the mechanism of the distributed ledger as all network participants, or the computer systems to be precise, keep a copy of the transaction records.

The transactions are immutable as a consequence of all participants keeping a copy and thereby having proof of past transactions. However, this immutability is not absolute. If the network participants decide to change some recorded information, they need to agree to do so according to the pre-agreed-upon consensus protocol.

Development of Blockchain

Blockchain technology was first introduced as a digital payment system. More specifically, Satoshi Nakamoto5 introduced the cryptocurrency bitcoin in 2008 (Nakamoto, 2008). The initial bitcoin movement



that occurred in the years after the currency's introduction is commonly referred to as Blockchain 1.0. Expanding on Blockchain 1.0, which deals with the decentralisation of money and payments, Blockchain 2.0 encompasses the development of further applications which may benefit from decentralised infrastructures within markets. The key idea is that the decentralized transaction ledger functionality of the Blockchain could be used to register, confirm and transfer all manner of contracts and property. The use-cases move beyond crypto currency and include a broader range of application possibilities.

Use cases of Blockchain

Smart contract

By extending the usage of cryptocurrencies, the Blockchain can utilise its core function: Validating transactions if certain conditions are met (for example, validating a bitcoin payment if there is enough balance). Ethereum, an example of a Blockchain technology platform, aims to further advance in correcting the shortcomings of bitcoin, focusses on using the advantages of Blockchain such as decentralised validation methods to enable smart contracts.

Smart contracts are pre-defined and formalised agreements executed and enforced by code across all network nodes in an autonomous and decentralised manner. This is possible by specifying if-then conditions to trigger transactions. While such automation processes have existed for a long time (for example, automatic bill transfers at the end of each month), by putting the conditions on the Blockchain, its validation is not dependent on a single entity. The Blockchain also depicts the settlement of the smart contract and can assess whether the agreed terms have been met. Hence, smart contracts based on a Blockchain remove the middleman to verify contracts and enable automatic settlements based on the conditions agreed by the parties involved. By combining several conditions, a smart contract could, for example, automate the sale of a security if a certain price target is hit and directly settle the transaction in cryptocurrency.

Ownership documentation

The Blockchain is applicable to various modes of exchange: Inventory and asset registries, as well as both hard and intangible assets. The process of registering any asset as a digital asset on the Blockchain is called tokenisation. Although it is not possible to physically store tangible assets in a Blockchain, its record of ownership can be registered there. As described above, one of the main advantages of the Blockchain is that once a record is on the Blockchain, it cannot be altered, as the other nodes in the network would detect this. Hence, if ownership over an asset is registered on the Blockchain, the ownership records can only be changed with the current owner's private key.

This entails two use cases.

First, it eases the transfer of ownership. While intermediaries used to be necessary to check whether the seller of an asset was its actual owner, this is now done by the nodes of the network. The verification is furthermore completed within seconds, without any paper trail and with the possibility for instant settlement (e.g. using a cryptocurrency).

Second, it simplifies the shared ownership of physical assets. While it is easy to physically divide some assets (e.g. a 1 kg gold bar into two 0.5 kg gold bars), this is not possible with many assets that are central to today's society (e.g. a production machine or an airplane). Although the shared ownership of such assets is not new (consider a corporate shareholder), establishing shared ownership on a Blockchain brings additional advantages. Not only does it simplify the ownership transfer process as described above, it also allows combining the ownership records with Blockchain-based smart contracts. For example, a shared car ownership can be managed in such a way that the use of the car is continuously tracked and transactions are settled directly and automatically among the users of the car and the owners.

Distributed transaction records

One characteristic of the Blockchain that depicts a use case is the distributed storage of all transaction records. As every transaction is added to the block chain, every participant can monitor and back-trace all transactions. Practically no other market provides such transparency about its transactions without any additional information-sharing costs for the market participants and almost in real time. These transaction records can be utilised to improve the flows of goods. For example, a producer can track the consumption of its input factors and check their source of origin in order optimise its ordering mechanism and supply chain. A producer could also automate its billing process based on the transaction records with its customers.

Limitations of Blockchain

Although the Blockchain has many advantages and the potential to disrupt a variety of industries, the technologies also faces some limitations that might hinder or slow down wide-spread usage.

First, the wide-spread usage of the Blockchain is limited by its maximum throughput. While payment technologies such as VISA are able to process up to 47,000 transactions per second, Blockchains throughput is usually more limited. For example, bitcoin can only process a maximum of seven transactions per second. This is due to the size limit of each processed block. Although it would be technically possible to increase the size of the blocks, such updates are unpopular among large parts of the bitcoin community, especially miners. They are concerned that with increased size of the blocks, miners with limited bandwidth are disadvantaged.

Second, the decentralized approach of the Blockchain brings disadvantages as the Blockchain grows. As every full node needs to process every transaction, the inter-node traffic increases logarithmically with every added node – leading to an increase in latency as more nodes are added. Hence, the processing latency not only limits the general application opportunities of the Blockchain, but the limitation also become more apparent as a Blockchain grows.

Third, although the storage of all past transaction on the Blockchain leads to a large data size and requires large bandwidth. If the bitcoin Blockchain were to increase its throughput to 30 VISA standards, the Blockchain would grow by 1.42 PB/year. Through requiring more resources, an increase in size and bandwidth would ironically promote centralisation.

Fourth, Blockchain transactions are resource and energy-intensive. Certain estimates suggest the cost per confirmed transaction would be between USD 1.4-2.9. These costs are mostly driven by the energy-intensive mining process. Compared to the VISA network, bitcoin uses 20,000 times more energy per transaction. This is due to the decentralization that requires all node to process a transaction. Although other Blockchains such as Etherum require less energy, compared to centralized system their energy consumption is still more than 1000 times higher.

Blockchain based Business Models

An overview of the current and possible business-model archetypes:

Retailer, REC-incentive scheme, Proof-of-Green-Power procurement, OTC-trading platform, Flexibility-Trading platform, Crowd-sale/funding platform and P2P energy-trading platform.

Description of business-model archetypes and their impact on the electricity market

I) Retailer

Business model

The retailer archetype resembles the existing electricity-retail business model. The target customers are residential and commercial electricity consumers. The value proposition to the customers centres on offering a lower electricity price and generating revenue through energy arbitrage. In addition, transparency and flexibility are provided for example through having complete insight into energy charges and bill components or the option to enter and leave the energy contract without restrictions. Moreover, consumers have superior choice over the configuration of their energy mix. They can then balance their preferences regarding the energy mix and their willingness to pay.

Within the value-chain dimension, the two representative cases in USA, Drift and Grid+, differ slightly. Drift purchases energy directly from its network of independent energy generators following its supply-and-demand forecasting while Grid+ buys electricity from the wholesale market. Both sell energy to their customers and collect transmission and distribution charges for the DSO.

Technology-wise, Drift operates on a distributed ledger. Grid+ uses the Ethereum Blockchain and additionally takes advantage of a smart agent. The agent automates billing in real-time after customers make a prepayment on the digital wallet that is associated with the smart agent. In addition, the agent can control customers' connected devices such as energy storage units or smart thermostats. This way, Grid+ enables customers to shift consumption and arbitrage energy prices, thereby contributing to grid balancing. The revenue sources of the two services differ as well. Drift in fact passes on the wholesale price to the customers, who in return pay a weekly subscription fee of $1. Grid+ charges a transaction fee with a mark-up of 20%. In addition, the smart agent presumably costs a minimum of $50. Grid+ not only operates as a retailer on its own, but also licenses its soft- and hardware to interested utility companies and retailers. Even so, at the core of their business model, the operations of the two cases resemble an electricity retailer.

Implications for the electricity market

Blockchain-based retailers are innovating within the energy market on three fronts.

First, Drift is replacing the intermediary and directly sources energy from producers to sell it to customers. This gives it a competitive advantage over other retailers by taking advantage of the digitalisation trend and cutting administrative costs in response to financial pressure in the energy market. Consequently, the retailer is able to offer the commoditised product at a lower price than other retailers. Second, the option to freely adapt one's own energy mix reflects a high degree of customisation, whereas prior to this customers might have been able to choose between regular utilities or green-power retailers, but nothing in-between. Third, the retailers collect customer payments at a higher frequency than the regular monthly invoice. This way, the companies face lower risks of not having customers pay their energy bills and optimize their cash-flows.

The retailer takes advantage of or is enabled by the Blockchain technology especially in the first and the third area. On the one hand, linking a network of producers as well as consumers on a Blockchain-based platform allows the retailer to better aggregate and forecast demand as well as to track the available generation capacity of the suppliers. On the other hand, Blockchain simplifies accounting for energy transactions and automates the billing process through smart contracts. Hence, the key Blockchain characteristics which are taken advantage by the retail model of are disintermediation, transparency and distributed ledger.

II) Renewable energy certificates

Business Model

This type of Blockchain applications is meant to incentivise and reward renewable energy deployment. The target customers are solar-energy producers, prosumers, consumers as well as miners. The incentive scheme can be implemented on a global scale. The value proposition for producers and prosumers is that for each generated kWh or MWh of electricity, they get a unit of a cryptocurrency or a token (or the rewards are referred to as coins). The coins serve as proof of the renewable energy generated. In other words, they resemble RECs and provide a transparent and verified record of green energy production. Miners who process the transactions receive a 2% interest per transaction for their efforts. The recipients can use the coins to buy electricity for the same rate or can redeem them against fiat currency. Interested consumers can purchase the coins and buy a corresponding amount of electricity from the producers or prosumers. In this way, the consumer is guaranteed to procure electricity from their chosen source. The main valuechain process for issuing coins for the energy generated relies on tokenisation, which can be done in two ways. First, the incentive scheme can be implemented on say Ethereum Blockchain and tokens are hence created on the basis of smart contracts. Second, a public Blockchain similar to bitcoin can be used and coins can be issued. In other words, the latter case relies on miners, while the former case does not. This is also related to the fact that the latter project was developed to be open source. The revenue model of the first case depends on the implementation goals of the interested parties.

Implications for the electricity market

First, the coins serve as incentives for producing solar energy. In regions where no renewable-energy subsidies or similar support schemes have been implemented, the coins can minimise the pay-back time for investment in the solar PV. With this mechanism, the global deployment of renewable energy can be advanced. Second, the Blockchain-based issuing mechanism makes the intermediary redundant as the process is verifiable and the coins are directly linked to the solar energy generated. In this way, the currently complicated REC-issuing system can be simplified by tokenising the generated energy in real-time. Overall, this model is aligned with global goals to mitigate climate change by renewable energy generation through RECs.

Handling RECs on the Blockchain entails a few advantages

First, solar energy production can be tracked on the Blockchain and as a consequence RECs can be created accordingly through tokenizing generated energy. This process makes REC creation verifiable and transparent.

Second, trading RECs on the Blockchain untwisted the centralised and complex REC trading system as mentioned above. Technically every market participant who is registered on a Blockchain-based REC platform can issue, trade and buy RECs. Thus, the key Blockchain characteristics here are disintermediation, immutability, transparency, trustlessness and tokenization ability.

III) Transparency regarding Procured Energy Mix

Business Model

While RECs are certificates of renewable energy produced, they do not actually guarantee that the consumer receives green power at home. Once green power is injected into the grid, it 'mixes' with electricity generated in fossil-fuel power plants and becomes grey power. This aspect of the current energy market has not been addressed yet. GrünStromJeton (literally meaning 'green power token') offers a possible solution by estimating the share of green power in the total energy mix. The project targets prosumers and consumers but could also be deployed by retailers and utility companies to inform their customers. Currently, the system is applied on a regional scale, although it has potential to be globally applicable, if the necessary information about the energy mix is retrievable on a local level. The value proposition for the target customers is increased transparency regarding the procured energy mix. The value is delivered through tokenisation. The consumption data can either be registered by the meter operator using automated meter-reading or manually, if two readings are available. Then, either in real-time or retroactively for a given time period, the actual share and amount of green power is calculated based on a green-power index, the zip code and the meter data. For each kWh of green power, a token is issued. The tokens, called GrünStromJetons, are issued using the Ethereum Blockchain. The project runs open source and everybody can freely access the information.

Implications for the electricity market

The described transparency system can illustrate the gap between the electricity paid for or the goal of using 100% electricity from renewable energies, and the actual energy mix which reflects the standard load curve. First, this can improve the accountability of utility companies and retailers promising environmentally friendly energy. Second, conscious consumers can adapt their electricity consumption in light of the real-time energy mix, running energy-intensive appliances during a time of green-power peak production.

The main characteristic this model takes advantage of is its distributed and transparent manner. Moreover, the system tokenizes the received energy mix. However, in contrast to the above mentioned REC model, there is no such market yet for the created tokens. Therefore, this transparency system is rather a transparency and accountability tool to track the advances in energy transition strategies on a regional or local level.

IV) CrowdSale platform

Business Model

This type of business model is similar to the online crowdfunding platforms Indiegogo or Kickstarter but is focused on solar PV projects. The target customers are private investors as well as property owners who have suitable land or roof area for solar PV. The potential network size or outreach for this type of business model is the global scale, meaning that an investor in Europe can invest in a project in Australia. Investors are offered rent in exchange for investing, while property owners benefit from the potential sale of surplus electricity and lower electricity costs when consuming the generated energy themselves. The value chain is built on a platform on which property owners can suggest their solar PV projects. Interested investors can then fund the projects, which are developed once sufficient funds are collected.

Investors have shared ownership of the solar PV and get a continuous rent on the sale of surplus energy production, while property owners lease the solar PV from the investors. The companies involved provide a platform to connect the parties and act as a service provider for marketing, the arrangement of leasing agreements or power purchasing agreements, and profit distribution. The shared ownership is arranged using tokenisation through say the Ethereum Blockchain. Because of this, the crowdfunding process is oftentimes called crowdsale in this context; it is a specific type of crowdfunding in which tokens are issued. People holding tokens get either a share and/or the right to pay for services as part of the platform. In one instance, however, the platform runs on a public Blockchain on which payments can be made using bitcoin or a local currency. Even so, cross-border investment transactions are enabled on both the Ethereum-based and public platforms. Revenue sources differ between the three cases studied. One project's software is free and open source, while another case charges a transaction fee and the third one collects a commission fee on successfully funded solar PV projects and collects an annuity.

Implications for the electricity market

Crowdsale platforms decentralise financing processes within the energy market. This has four positive effects on the energy market and society. First, crowdsales make private solar PV installations more accessible to the public. Households and small commercial enterprises, who might not afford it otherwise, can profit from a lower financial barrier to solar PV. In particular, the crowdsale model helps in areas with little financing mechanisms and infrastructure in place such as in sub-Saharan Africa, which is a special focus of one of the analysed case studies (The Sun Exchange). Second, property owners are energy consumers in this arrangement and can profit from lower electricity costs. Third, individuals can invest in RES projects outside of the regular project-finance processes. Taking the three effects into account, all are relatable to the organised resource sharing trend. Essentially, individuals, communities and enterprises make their potential solar PV area available to the general public and share the financial benefits thereof. Fourth, crowdsale platforms can boost the installation of solar PV and thereby advance the attainment of climate-change-related policies and decarbonisation targets. Hence, the crowdsale platform fosters decentralisation, decarbonisation and electrification. However, a major drawback of the analysed case studies and the underlying business model is that they don't address the technological challenge of the shift in load curve. If anything, the focus on the financial model that boosts small-scale RES further contributes to the over generation during the day. The crowdsale business model benefits from Blockchain through connecting investors and recipients in a trustless network. Centrally organised financial mechanisms and project funding in the area of RES are disintermediated. Based on predefined smart contracts, the rent payments are automated and reflect the real-time energy generation on the installed solar PVs.

V) OTC trading platform

Business Model

The OTC trading platform is a distributed marketplace for OTC trading of wholesale energy. The target customers are energy producers, utility companies and retailers within the European power and gas market. The value proposition is to reduce the transaction costs for trading large volumes by making operational processes more efficient. The value chain is based on a platform which connects the trading desks of all parties. Through the platform, the market participants can initiate and physically settle power and gas trades. The trades are anonymous and only the involved parties know each other. The studied platform is set up on a Tendermint Blockchain. The plan is to integrate an energy-trading and risk-management system as well. The platform is delivered by a software company and over 30 companies have already joined the proof-of-concept platform. Among the partners are some of the biggest European energy companies: Enel, E.ON, Iberdrola, RWE, Statkraft, Statoil, Total and Vattenfall. Because the project is a cross-industry collaboration with the software company, there is no public information available regarding the software company's revenue streams.

Implications for the electricity market

Blockchain enables that all market participants can connect and share information with each other without an intermediary or broker. Here, the OTC-trading platform eliminates the broker company. The participating partners using the platform can expect to reduce their transaction costs and to potentially pass on the benefits to consumers. As a consequence of lower transaction costs, the OTC market could potentially be expanded to participants with smaller trading volumes. Following the decentralisation trend of the energy market, the OTC-trading platform takes the discussion further to decentralise energy trading processes as well.

VI) Flexibility-trading platform

Business Model

There are few cases which can be categorised as flexibility-trading platforms. Of these, one integrates flexible capacities such as household battery storage or EVs, and the other addresses demand-side responses. The target customer groups are prosumers, consumers and system operators. So far, the projects have been implemented or are in development on a regional level. The value proposition is, on the one hand, to offer remuneration for adjusting one's energy consumption. On the other hand, the platforms promise to lower electricity costs or to shorten the pay-back period for household storage systems/EVs in exchange for renting the household storage capacity to the system operator. The value chain is rooted in a (private) Blockchain-based platform that connects all the storage units and smart home appliances. Their capacity and availability is recorded on the Blockchain. Based on this, there are two options for controlling devices. First, battery systems can store electricity when demand is low and feed electricity back into the grid during peak consumption periods. Second, home appliances can shift their energy consumption between peak and off-peak hours when needed. In this way, the network of storage and home devices enables grid stabilisation and balancing. In one of the case, collaboration is engaged between a TSO and a storage manufacturer, there is no information regarding the revenue streams, as it is in the interest of and the responsibility of the TSO to balance the grid reliably. Another case concerns a start-up that received funding from the UK government to develop a demand-side-response trading platform. A potential revenue model for the start-up is to offer the solution as a platform-as-service to system operators.

Implications for the electricity market

The cases discussed integrate household devices and storage systems into the flexibility market by connecting them into a network which can be activated when needed. Again, this is enabled by the Blockchain's core characteristics as information can be updated and shared near real time. While the main beneficiary of the setup is technically the system operator, it also offers financial value to consumers. Overall, the flexibility-trading platform provides three main solutions to the electricity market. First, connecting more and more devices and storage units to the grid with the aim of integrating them into a flexibility market expands the overall available flexibility capacity. With an increasing share of intermittent renewable energy generation, the higher capacity value supports system operators in stabilising and balancing demand and supply. Second, the increased capacity increases together with the liquidity of the flexibility market, making it easier to schedule flexibility sources at short notice. Especially when conventional power plants are used for re-dispatching to stabilise the grid, the power plants cannot be shut down instantly. Here, the increase in residential demand-side flexibility shortens scheduling periods. Third, the platforms can lower the costs associated with flexibility measurements, considering that re-dispatch interventions are very costly. Thus, expanding the flexibility market to households enabled by Blockchain-connected devices provides a solution to shifting load curves due to increasing over-generation by RES.

VII) P2P energy-trading platform

P2P energy-trading platforms are at the moment the most common Blockchain-based applications within the energy market. Most cases address the local energy-trading market between prosumers and consumers.

Business Model

While the core concept of the P2P energy-trading platform is shared by all the cases using this business model, it manifests itself in four different forms. First, there are platforms which are currently operating (or in proof-of-concept) on a local level and target producers, prosumers and consumers. Second, some projects predominantly aim to offer the P2P trading marketplace as a platform-as-a-service to utility companies and retailers. Third, a few cases intend to target prosumers and consumers and to implement their platform on a global scale, in some cases using hybrid Blockchain solutions on a local and global level. Fourth, some cases incorporate two models: addressing producers, consumers and prosumers with a local P2P platform as well as utility companies and retailers with their platform-as-a-service. The value propositions are the sale of surplus electricity for prosumers; higher remuneration for renewable energy producers; lower electricity prices and increased transparency as well as flexibility over the preferred energy mix for consumers; and lower administrative costs for utility companies and retailers. The value chain unfolds on an energy-trading platform, which is implemented using an Ethereum Blockchain in almost all cases. In addition, most projects tokenise the data. As the platforms operate on top of the grid but still rely on infrastructure, compensation for transmission and distribution is collected by the platforms and provided to the system operator. Regarding the software, artificial intelligence enables energy-management services and forecasting supply and demand. Two projects deliver smart meters in addition to software. At a later stage, some projects intend to integrate other features such as storage-capacity trading. On the financing side, it can be seen that all three purely local P2P energy platforms are backed by or emerged out of corporate partnerships and projects, while the majority has launched or already successfully closed initial coin offerings. The standard revenue source is transaction fees. The platform-as-a-service solutions are offered through licensing agreements.

Implications for the electricity market

As with the mentioned OTC and flexibility-trading platform models, prosumers and consumers are connected to trade energy directly with each other. This business model has four implications for the electricity market.

First, the business model makes use of the Blockchain technology to automate processes and skip intermediaries, for example, by triggering payments and energy transactions through smart contracts. Automation and disintermediation reduce administrative costs, which lowers the barrier for communities to implement such P2P energy-trading systems. Likewise, if utility companies implement a platform-as-a-service or their own platform, they can also benefit from lower operational costs. In both cases, consumers can profit from lower electricity costs, while producers/prosumers can obtain a higher remuneration.

Second, the P2P energy-trading platform localises the energy market and consequently reduces the burden on the transmission grid, which is especially strained by large-scale, intermittent RES. This is particularly noticeable in Germany. The large wind power production but high-energy consumption in the South creates a bottleneck problem on the transmission grid. Local energy markets with integrated balancing mechanisms could therefore increase the overall grid efficiency.

Third, prosumers and consumers are empowered by participation and can experience a higher sense of belonging to a community through the sharing economy trend. This was not possible in the former top-down electricity market design. Consumers can choose between supporting their immediate neighbouring prosumers and procuring power from the utility company or retailer. By doing this, they can independently set their price preferences or negotiate the prices on the P2P platform. Within the value proposition, this builds on the analysed criteria of flexibility and transparency.

The key Blockchain characteristics that facilitate the business model of P2P energy-trading platforms are being able to build a trustless network with a distributed record and the use of smart contracts. Smart contracts execute price preferences, tokenise the energy produced and transact energy trades and payments.

Conclusion

Seven Blockchain-based business model archetypes in the electricity market have been identified: Retailers, REC-incentive scheme, Proof-of-Green-Power procurement, OTCtrading platforms, flexibility-trading platforms, crowd-sale/funding platforms and P2P energy-trading platforms. The assessment of the business models revealed the implications for the electricity market. The retailer, the REC-incentive scheme, and the OTC-trading platform are not inherently transformative but, to a certain extent, they innovate on different business model dimensions. They utilise Blockchain characteristics to disintermediate in the value chain, redesigning and automating processes to increase their efficiency and thus cut administrative costs. In addition, the Blockchain-based REC system is superior to the current REC system by making the REC issuing process verifiable and transparent. The platforms that operate in the flexibility and P2P energy-trading markets present new means of addressing the challenges and implementing the solutions that have been discussed in research and practice in terms of the electricity market. Moreover, they build on prosumers and further promote residential and small-scale commercial solar PV deployment. Blockchain-based crowd-sale/funding and OTC-trading platforms have further advanced the decentralisation of the electricity market by minimising the entry barrier into their field of application. The former has minimised individuals' need for solar PV investments and has allowed a new target customer (private investors) to participate in the electricity market. The latter has reduced trading transaction costs through disintermediation, thus disburdening smaller traders. Last, proof-of-green-power procurement is a novel transparency and accountability tool to reveal the actual share of green power in energy consumption, although there is no market for this data yet.

From a wider perspective, these Blockchain-based business models have modified and added new characteristics to the business model dimensions.

First, compared to the conventional electricity market, the target customer group has been extended by two customers: Prosumers and private investors.

Second, in terms of the value proposition, in addition to generating revenue and cutting costs for the customers, these business models have offered the attributes of transparency and flexibility.

Third, the value chain processes have been dominated by smart contracts and tokenisation, both of which go hand in hand with Blockchain technology.

Fourth, the revenue streams have not challenged current market practices, although it should be noted that a majority of case studies in the prosumer/consumer oriented business models (retail and P2P energy-trading platforms) charge transaction fees while only one case uses a subscription model.

Hereby, some cases are not intrinsically motivated to encourage energy-efficient behaviours by consumers, whereas in the case of a subscription model, the company's profit is not correlated to consumers' energy consumption.

Considering all of the above, the business models have promoted renewable energies through additional remuneration and electricity cost cutting; however, this benefit can be overshadowed if a business model's sole purpose is to one-sidedly promote RES, such as for the crowd-sale/funding platform. The good news is that through the integration of storage and the control of home devices, some P2P energy-trading platforms and flexibility-trading platforms offer an attractive solution to accelerate demand response and demand-side management. This way, the negative consequence of the RES, i.e. the shift in the load curve, can be overcome. Likewise, the increasing rate of electrification can potentially be absorbed by the higher degree of the RES. All of the business models have taken advantage of and relied on digitalisation. On the one hand, the case studies have highlighted superior user interfaces than conventional energy providers and services. On the other hand, some processes have been enabled by digitalisation in the first place, such as tokenisation and the automation of energy and payment settlements.

In sum, Blockchain-based business models promote green energy, increase efficiency and lower energy costs. Hence, the three characteristics that are rooted in the business model dimensions of value proposition, value chain and value capture allow organisations to add value to customers and to lower costs at the company end.

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Deloitte's Government & Public Services Energy practice delivers a blend of global energy market knowledge with informed local delivery to accelerate affordable, reliable access to electricity around the globe. Deloitte provides the following services to international development institutions and their host country counterparts:

- **Energy strategy and planning:** market design and development; implementation of energy sector plans and road maps
- **Regulatory, legal, and policy reform:** regulatory reform; enabling investment and private sector participation; governance structures
- **Energy sector capacity development:** training for utilities, regulators, ministries, financial institutions, and developers
- **Project development and innovative finance:** energy project design and execution; transaction structuring/derisking

Powered by blockchain Reimagining electrification in emerging markets

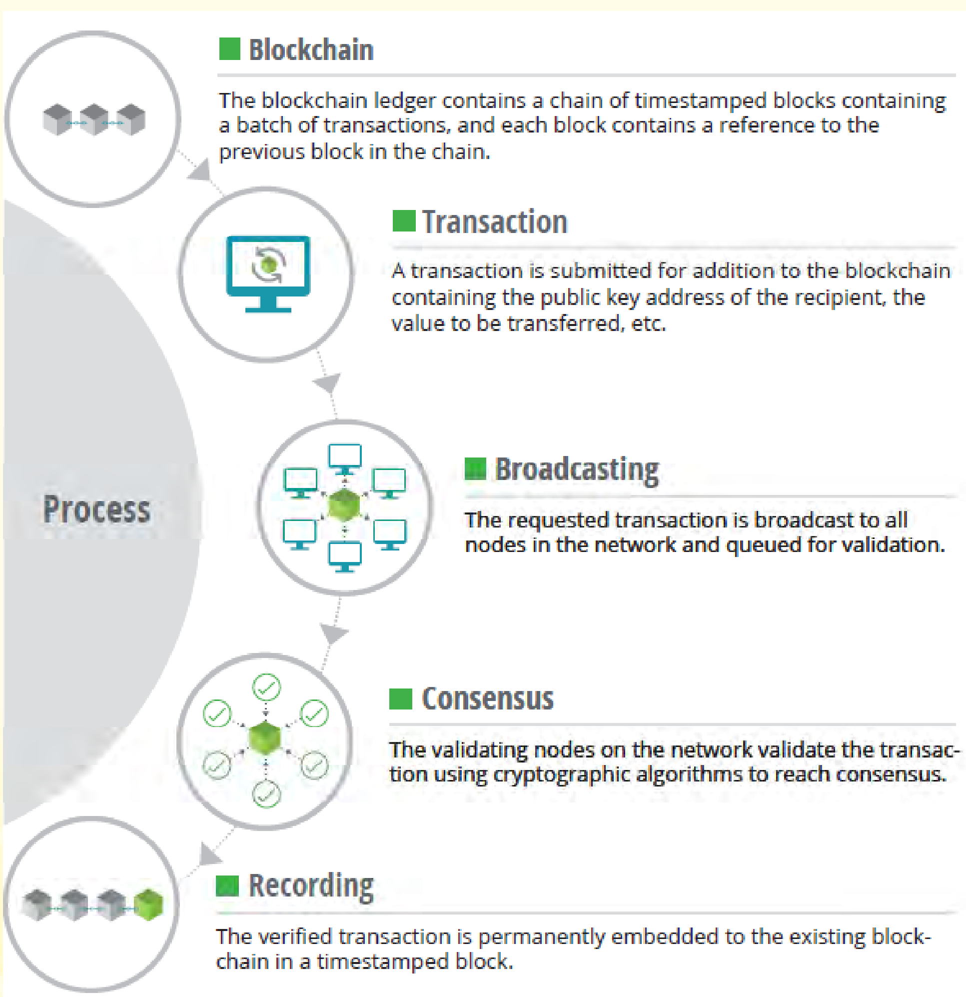
Introduction

The power sector—in its electricity sourcing, production, and delivery—pro–vides multiple opportunities to test blockchain technology. Across advanced economies, small businesses leveraging the technology are standing up microgrids in areas as dense as New York City, developing energy trading plat–forms in Tokyo and Australia, and driving supply chain efficiencies around the world.1 Larger utility companies, from the United Kingdom to Illinois, are also funding research and testing blockchain applications on their systems.2

While tokyo and New York City have extremely developed, capital-intensive transmission and distribution networks, and the utilities that serve those networks are large organizations with intricate supply chains, where is blockchain's place in the developing world's elec–trification puzzle? The two geographic areas that account for most of the global electrification deficit— sub-Saharan Africa and India, which represent 57 percent and 25 percent, respectively, of the approxi–mately 1.14 billion people worldwide without access to electricity3—present quite a contrast to Japan and the United States. Can systems that lack some of the most fundamental of physical electrical assets, such as generation plants, substations, and transmission and distribution cables, effectively leverage an ad–vanced technology such as blockchain?

Not only could emerging markets deploy block–chain technology to meet their electrification goals, but they may in fact be the *optimal markets* in

FIGURE 1



Source: Deloitte Consulting.

which to push the limits of blockchain's capabilities in the power sector. There are potential risks associated with a less traditional electrification path, but there are also possible benefits to working in an unbuilt environment—a technological "white space." For instance, revising policy and regulatory frameworks in developed markets may prove too cumbersome to create attractive opportunities for blockchain solutions;4 also, many advanced economies already have systems in place to ensure payment for service, while developing countries may lack the same struc−tures.

In emerging markets, governments and businesses can utilize blockchain to potentially advance the future of their grid—a distributed, nimble, adaptive, and transparent network—by unlocking three functionalities:

- Bridging the financing gap
- Enabling energy transactions
- Unleashing radical transparency

This article considers thought-provoking ap−plications of the technology in both advanced and emerging economies, with potential implications for meeting electrification goals in the developing world. Development institutions and their stake−holders should be encouraged by the range of possibilities, and should consider blockchain as a foundational technology to enable future business processes.

What is Blockchain?

Blockchain, at its core, is a technology that can facilitate transactions, or any transfer of value. It is a transparent and shared transaction ledger that can substitute for centralized general ledgers in most current accounting systems. Rather than developing this ledger on a typical, centrally managed database software, the database or ledger is replicated across other devices and confirmed by its participants. Each transaction is broadcast to parties subject to the transaction as it occurs, and certain devices work to build consensus about, validate, and record the transaction—after which it is irreversible (see figure 1). Due to this distributed, consensus-driven validation model, blockchain does not require intermediaries; each recorded transaction's validity is evident to all on the chain. To better understand the technical aspects of blockchain technology, please refer to *Blockchain: A technical primer*.5

How is blockchain improving access to electricity?

Electrification is an expensive process that faces both physical and financial challenges, such as the installation of power lines and costs associated with generating and transmitting power. Developers need to recoup the money they invest; countries and generators that trade power need confidence they will be paid; and regulatory bodies that oversee the sector need transparency to monitor transactions. Blockchain potentially offers approaches to address these challenges.

Bridging the financing gap

While developers and financial institutions have advanced innovative approaches to financing power projects, capital remains scarce for genera−tion assets in developing markets. The main reason for this scarcity is that developers need long-term (15–20-year) power purchase agreements (PPAs) with creditworthy off-takers before they can obtain financing. In many developing countries, the off-takers are state-owned utilities, and, unfortunately for developers, capital markets do not typically con−sider these off-takers to be sufficiently creditworthy. As a result, development bank funds and donor guarantees buttress short-term development with the goal of improving utility creditworthiness over time. One innovative approach to expanding project financing sources is to allow local or international direct retail investors to purchase future energy production (either for resale or direct consumption) in the form of energy tokens—providing discounted capital now for energy delivery once the projects have been developed.

For example, WePower, a Lithuanian firm, is using blockchain technology to sell future energy production from planned renewable generation to raise capital (see sidebar, "The cost of trust" for a further explanation of the business model).6 Developers market their future contracts through WePower's online trading platform, and receive funds from investors in exchange for energy tokens that can be traded or used to receive power later as agreed. While the concept is like that of a more traditional PPA, WePower's approach includes two innovations. First, it "distributes" the PPA by tokenizing it, avoiding reliance on the utility on whose creditworthiness financial markets traditionally price a loan. Second, it liquidates the market for electricity, llowing WePower's token purchasers to fund the project, and then sell the right to consume the electricity generated either to the end consumer or to a utility/retailer. Although initial coin offerings (ICOs) are as yet an imperfect and lightly regulated investment vehicle, one measure of WePower's traction in the market is that it raised US$ 40 million in a public ICO in February 2018,8 and it is currently exploring blockchain-enabled national-scale energy tokenization in Estonia. While WePower currently operates in Europe, its application may hold some promise for developing countries. As noted in the sidebar "The cost of trust," any tool that helps displace the centralized and opaque system that is often present in developing countries has the potential to free up capital in otherwise capital-starved markets.

Enabling energy transactions

Most emerging markets need the kind of nimble electricity grid that exists in more developed countries— for instance, one that can effectively leverage highly energy-productive regions to power less productive regions in real time (for more information on the value of this functionality, see sidebar, "Fighting variability with nimbleness"). For example, India has set highly ambitious renewable energy targets that would result in great quantities of variable renewable energy generation, but the addition may prove to be problematic for the grid in those regions in which intermittent wind and solar resources are likely to dominate. Cross-regional energy trading may alleviate the intermittency issue because it allows a region whose production has dropped to purchase power from another to cover that deficit. Blockchain can provide a smoother, more efficient environment for this type of trading through programming logic known as a "smart contract"—one that leverages consumption and production data on the shared ledger to trigger automated transactions.

Smart contracts also offer an opportunity to au–tomate the renewable energy certification process. The Indian Energy Exchange opened a market for Renewable Energy Certificates (REC) in 2015, but requires state and central agencies to participate in the accreditation, registration, and issuance of RECs—a time-consuming but necessary process. Smart contracts can not only automate this process, but also increase transaction speed, while creating an immutable record that supports REC authen–ticity and audit. In a blockchain ecosystem, state and central agencies would still govern and operate the system, but the smart contracts would facili–tate more seamless and transparent transactions. It is worth noting that for the above-mentioned use cases to apply, grid infrastructure may need to meet minimum standards; blockchain's facilitation of interregional energy trading and REC recordation may therefore better fit more advanced emerging markets such as India.

Trading automation and transparency can not only strengthen the existing grid, but may also lower operational costs generally, and particularly for isolated small or rural microgrid solutions (for an explanation about the value proposition of blockchain applications in microgrids, see sidebar, "The grid edge"). Traditionally, microgrid devel–opers often struggle to find an attractive return while providing reasonable electricity prices. Inno–vative entrepreneurs active in emerging markets are driving blockchain-based scalable solutions. Com–panies such as LO3 are testing peer-to-peer trading on a microgrid scale in neighborhoods within New York City,9 and Power Ledger is working to deploy a similar solution in India's urban areas.10 This peer-to-peer trading deploys blockchain-based smart contracts that automatically net out produc–tion and consumption across a microgrid. This type of automatic settlement between a microgrid's peer consumers and peer producers reduces the microgrid's operational costs; keeping costs down is particularly important in developing countries where profit margins are often low. Both LO3 and Power Ledger offer

THE COST OF TRUST

The problem: There are real costs and risks associated with state-owned, vertically integrated power system operators in developing countries. When developers seek capital, financiers typically charge premiums to access funding based on the risk profile of those system operators—premiums that may be prohibitively high, but are the cost of doing business in some markets. In April 2016, for instance, the Tanzania Electric Supply Company was US$300 million in arrears in payments to its suppliers.7 That is a difficult environment in which to get projects funded: When developers don't get paid, their investors don't get paid, so investors typically stop injecting capital.

Looking to blockchain: Can the power sector intermediary as institutional off-taker and capital markets be decentralized? WePower is testing this idea. Its model in a developing world context would allow retail investors to fund projects by purchasing its coin, and allow for a network of distributed holders of those coins to become direct ratepayers to the project, circumventing centralized market operators.

FIGHTING VARIABILITY WITH NIMBLENESS

The problem: Countries such as India are in the process of installing large quantities of variable renewable energy generation onto its still maturing grid. The additions add stress to existing grid operations, as unexpected dips in wind or solar production tend to require last-minute dispatch of conventional energy.

Looking to blockchain: Grids in emerging markets are often extremely regionalized. Enabling peer-to-peer energy transfer between regions to balance renewable energy ebb and flow can mitigate the stress variability causes. Smart contracts that leverage open-ledger production data offer one potential solution to help even variability and drive overall grid stability.

potentially promising new tech–nology, but after proving the concept, they will need to champion regulatory reform, whether at state or provincial-level governments, such as in New York, or even nationwide in a country such as India.[11]

Bankymoon is exploring another innovative approach in South Africa; the company is enabling pre-paid meters for isolated solar home systems or rooftop power generation.12 Installing pre-paid electric meters can ensure that suppliers recoup their capital expenses since consumers pay for what they use in advance. Further, Bankymoon enables its pre-paid meters to accept digital currency pay–ments, which allows individual donors worldwide to pre-pay for electricity usage by Bankymoon-metered schools and other social institutions. Those payments are, in turn, settled automatically through blockchain-enabled smart contracts.

THE GRID EDGE

The problem: Extending electrification to the least served has been a persistent problem in many developing countries. Smaller and less affluent populations' usage rates and ability to pay often do not allow utilities to recoup the capital-intensive costs of the additional generation, transmission, and distribution capacity required to extend the grid.

Looking to blockchain: Microgrids and solar home systems are rapidly becoming cost-effective. Solutions such as peerto-peer trading can reduce operational costs with blockchain-enabled automated settlement; prepaid meters can be built to accept cryptocurrencies, widening the rate-paying base.

Unleashing radical transparency

In emerging market power sectors, opaque rule setting, poor compliance by utilities and other market participants, and insufficient regulatory oversight can deter investment. Where regulatory oversight is effective, costs of compliance can be a hardship for market participants. Poor transpar–ency can present opportunities for corruption, one of many hidden costs that can damage a genera–tion project's profitability. Even the best-intended regulation in emerging markets can fall prey to a market's lack of standardized processes, lagging IT systems, and concerns about inappropriate in–fluence by special interests. The uncertainty often leads project developers to demand high premiums for projects to move forward; many simply do not advance.

SHINING A LIGHT

The problem: The perception of corruption, arbitrary rulemaking, and the corresponding market and black-market costs of compliance seem to be some of the most oft-cited reasons for the lack of energy sector capital investment in emerging markets.

Looking to blockchain: Open ledger technology offers a radical view of what the future of regulatory oversight could look like: open. Transparent industry data on a blockchain and smart-contract-enabled automated compliance can lower both the cost of compliance and the risk of graft, opening these markets to greater investment.

Although currently (as of mid-2018) there are no known use cases for blockchain-enabled regulatory reporting in the energy sector, financial services sector participants in Europe recently implemented a proof-of-concept called RegChain.13 RegChain helped industry participants not only reduce the administrative investment and costs associated with regulatory reporting but also improve compli–ance and increase transparency among participants, by means of capturing transactions and managing reporting requirements through smart contracts. Using RegChain, compliance procedures are auto–mated for industry members and the processes and procedures are auditable by regulators.14 Automated reporting to regulators could have broad implica–tions, but one of the most powerful could be the ability to turn developing countries' power sectors into data-rich rather than data-poor environments. Strengthening regulatory oversight while driving better real-time response to power sector challenges could benefit citizens, power market participants, and investors alike across emerging markets.

Evaluating blockchain's potential in emerging markets

WHILE BLOCKCHAIN APPEARS to have tremendous potential for developing country power markets, the technology is not necessarily appropriate for all uses. Stake–holders should keep in mind the following factors when considering developing country blockchain applications:

- **Building a consortium:** In emerging markets, developers, utilities, operators, regulators, and customers often operate in an opaque system. Most participants are not aware of others' activi–ties, with reports on energy sector transactions due only quarterly at best, or even annually. Much of blockchain's value rests in the tech–nology's ability to provide transparency while maintaining transaction security—both of which are not currently available in many developing markets. While transparency and security repre–sent a long-term net gain for all participants, that gain likely requires major short-term investment to establish the necessary level of cooperation to set up a blockchain-driven system. Building these systems, or consortia, require stakeholders throughout the entire value chain to understand local market stakeholders' positions, as well as local policies, rules, and regulations that govern the energy sector.

- **Designing with scale in mind:** While block–chain solutions may provide value at all levels within the power sector—from microgrid to regional cross-border trade—broader block–chain applications will likely have greatest impact on existing systems that are already in place. Blockchain adopters will need to decide whether to develop lower-cost local or national systems that will require future integration into a larger regional framework, or incur the sig–nificant upfront cost associated with developing a comprehensive system that will work across borders and regions immediately. The historical spread of networking innovations suggests that local and national systems may develop before cross-border regional solutions. Some markets will recognize outsized value from blockchain solutions early; others will lag. Eventually both will likely integrate into regional systems; inter–national development institutions should reflect this reality in their planning and build a vision of distributed ledger technology to support this transition.

- **A continuing need for centralized utilities:** Most countries envision a more nimble and distributed power grid, but the reality is that centralized utilities will likely continue to meet most electricity needs. Centralized utili–ties should explore how blockchain solutions can benefit them before they agree to advance IT modernization, train staff, and invest in IoT technologies required to implement blockchain. Centralized utilities are increasingly vulnerable to catastrophic cyberattacks; the December 2015 Ukrainian power grid hack provides a sobering example.[15] Designing the system with blockchain in mind can help mitigate security vulnerabilities and help provide consumer data privacy. Successful blockchain solutions could incentivize utility participation—along with that of other market stakeholders—and demonstrate the potential for utilities to streamline opera–tions and reduce costs.

- **Attracting capital:** Potential investors may be skeptical of applying a nascent technology such as blockchain in an emerging market power sector context when it has not yet found wide–spread applicability in more sophisticated power markets. That skepticism, however, is likely in–formed by the traditional notion of an optimal power market—featuring centralized adminis–trators and clearing houses dispatching power from base load assets requiring 30-year fixed investments. Forward-thinking venture capital investors, along with financial institutions with a development mandate, could re-envision this status quo and leverage the opportunity in *unbuilt* environments to test what a more de–centralized, nodal, cleaner, and networked grid might look like, and more specifically, which pilot projects might advance this vision.

What next?

These challenges notwithstanding, blockchain appears to have the potential to help overcome obstacles that keep millions of people in the dark worldwide. To get started, development practitioners can chart out an implementation road map to help so–lutions grow in scope, scale, and complexity (for more details, read *Blockchain to blockchains: Broad adoption and integration enter the realm of the possible*).16 We recommend that development institutions consider this road map to progress from use case, through proof-of-concept, to ultimately scaling blockchain solutions in their countries of interest.

Use case: As this article illustrates, blockchain power sector applications seem nascent in all markets, including emerging markets, with many more opportunities likely to come. Development institutions should engage developers, utilities, operators, regulators, and customers broadly to help understand where business challenges can be disrupted by blockchain solutions, and build an entrepreneurial environment that can deliver more impact, for lower cost, at a sustainable scale.

Proof-of-concept to pilot: As the first so–lutions reach market, the role of international development institutions could change from building local capacity and understanding to es–tablishing a sustainable enabling environment along with advancing solutions that align with de–velopment goals. Providing support through pilot tracking, collaboration on standards, and retro–spective analysis can provide early entrepreneurs with access to essential data and training to make informed decisions, as well as an understanding of the nontechnical components required to success–fully deploy a blockchain application.

Scale: If and when pilots have proven the tech–nology, it will be time to grow. Here international development institutions could be well-positioned to provide value in establishing consortia across the power sector with robust membership, leadership, funding, and governance given their penetration in emerging market power sectors.

Development partners may have different roles to play at each stage along the road map, as defined by the consortium's operating model. With their intervention, blockchain has the potential for tremendous impact on bridging the financing gap, enabling energy transactions, and unleashing radical transparency in the power sector.

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Kathleen O'dell, principal with Deloitte Consulting's Government & Public Services (GPS) Energy practice, leads a portfolio of global energy reform programs across sub-Saharan Africa, India, and Latin America. O'Dell is board member of the Council on Women in Energy & Environmental Leadership, and is Deloitte's GPS leader on energy issues for smart cities, and the gender–energy nexus.

Carol Mulholland, a specialist master in Deloitte's Government & Public Services Energy practice, works on such issues as consumer and stakeholder engagement and outreach, energy efficiency, sustainability, financing, power sector and utility reform and restructuring, and regulatory reform. Mulholland's current focus is on renewable energy in India.

Sri Sekar is an infrastructure and energy transaction expert in the economic development sphere. Sekar has led renewable energy transactions in and developed infrastructure finance strategies throughout the developing world. He is currently working on direct power purchases and mini grid projects in Vietnam and Zambia.

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CONFERENCE

ON

CREATION OF ECO-SYSTEM USING

BLOCK CHAIN TECHNOLOGY

FOR RENEWABLE ENERGY,

DISTRIBUTED ENERGY GENERATION

&

SUPPLY

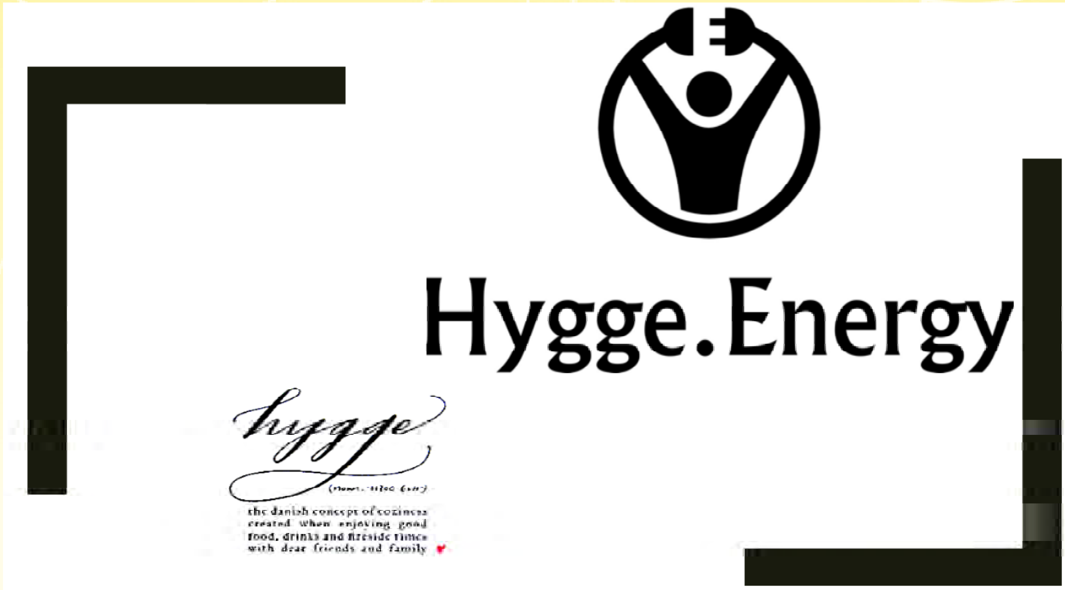
Presentations

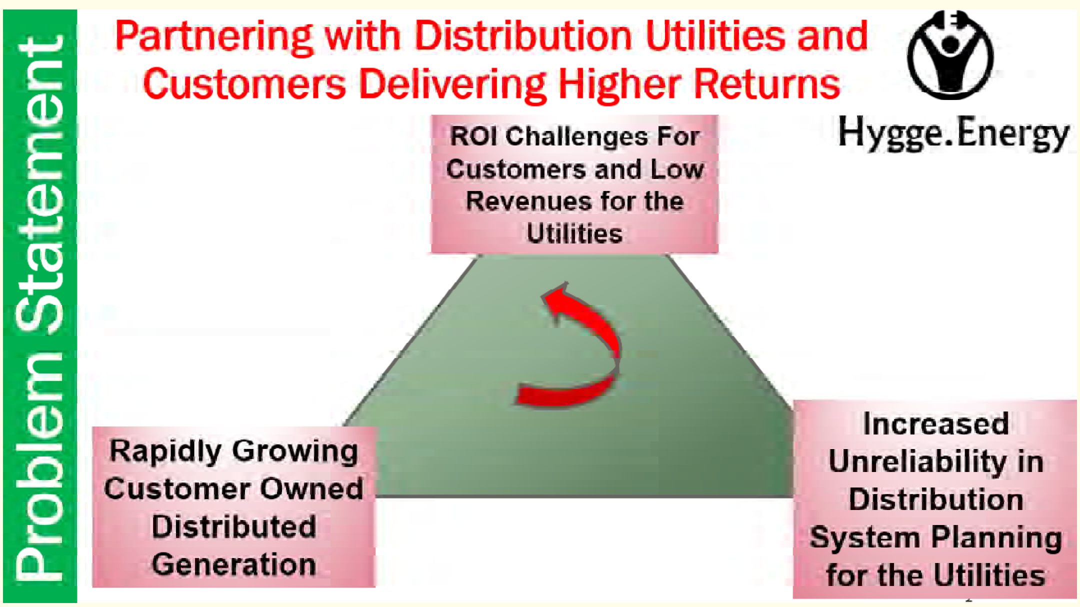
Presentation of Mr. Prateek Saxena

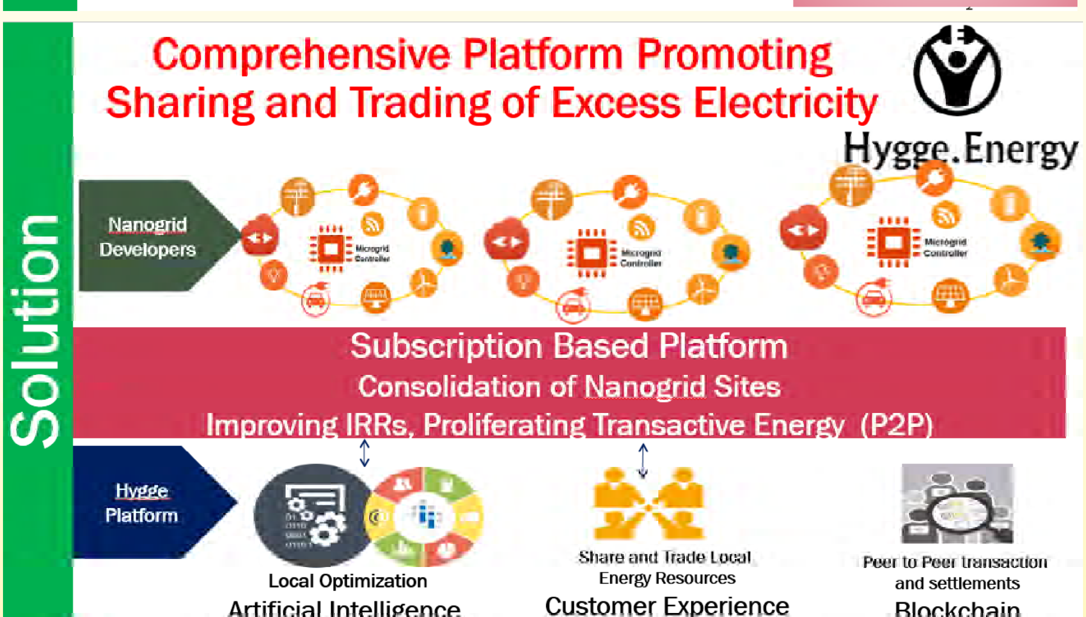
Profile

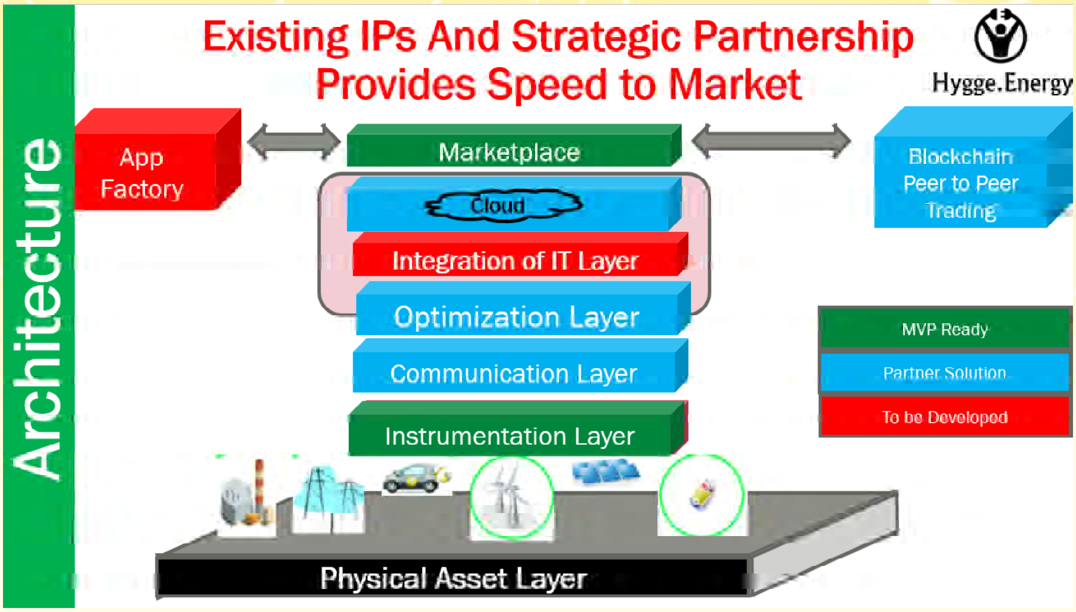
Prateek Saxena – CEO, Hygge Energy : Silicon Valley based startup offering 'Nested Microgrid As A Service' Platform by integrating block-chain based peer to peer trading platform with Microgrid Operating AI engine helping communities to share and trade electricity

- Won internal entrepreneur award and incubated within Tech Mahindra in 2015
- Recipient of top 10 Global Innovation Award by International Energy Agency in Paris, November 2016
- Top innovation award within Mahindra Group in 2017
- Awarded "Unicorn of Silicon Valley" by University of California, Berkley in April, 2018
- Head of utilities business unit for Americas for Tech Mahindra; $4.5 Billion IT and Engineering Company. (www.techmahindra.com)
- Successfully Designed and implemented Ontario Power Authority's Demand Response (DR) Portfolio that delivered 150 MW of DR capacity
- Managed Ontario's first smart meter turnkey project for Milton Hydro
- Keynote speaker at Smart City Conference, Montreal in July, 2017
- Co-chair New Energy Summit 2015 in Xi'an, China (http://www.bitcongress.com/nef2015/scientificprogram.asp)
- Speaker at SAP for Utilities Conference (https://sap-for-utilities.com)
- Invited to be part of Keynote address at SAP TechEd (http://events.sap.com/teched-global/en/home)
- Participated on Voice of America, Game Changer series on Internet of Things and Electric Vehicles (http://www.voiceamerica.com/promo/episode/86800)

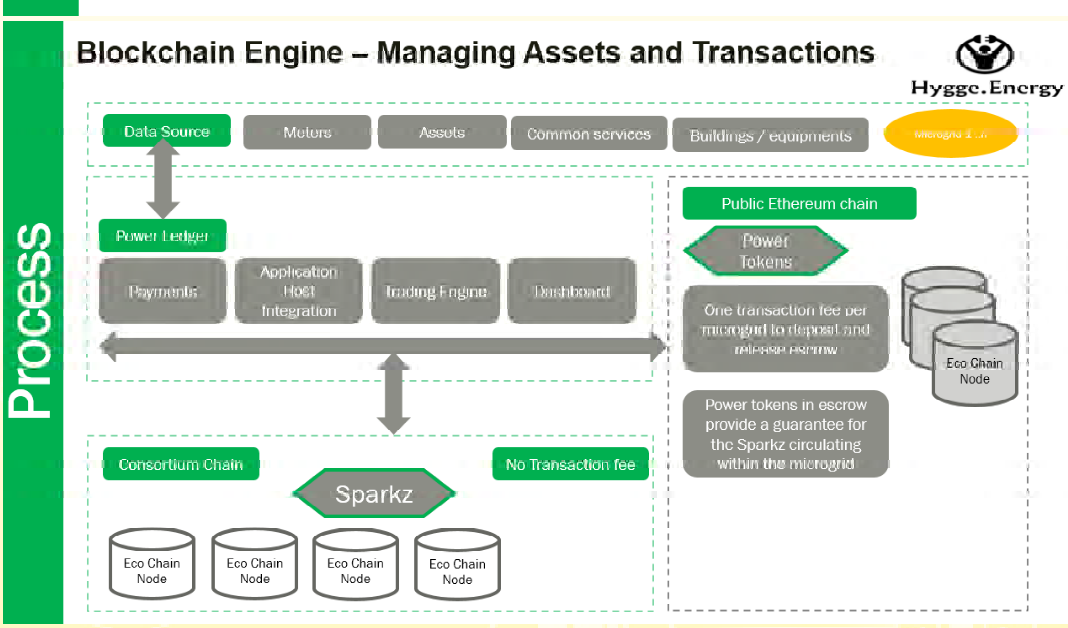

Hygge.Energy
hygge
the danish concept of coziness created when enjoying good food, drinks and fireside times with dear friends and family

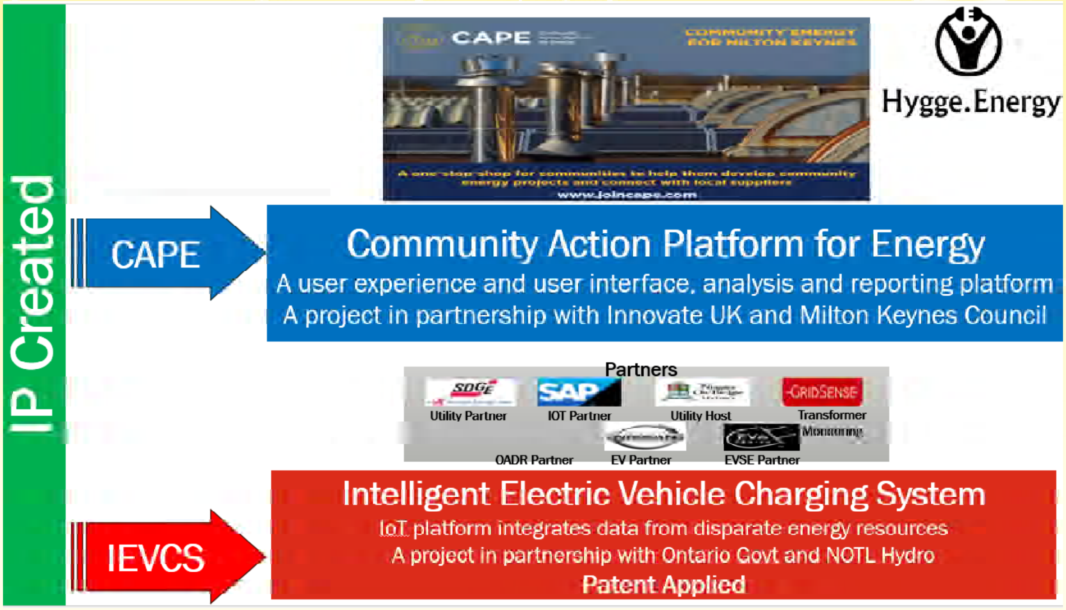

Problem Statement
Partnering with Distribution Utilities and Customers Delivering Higher Returns
Hygge.Energy
ROI Challenges For Customers and Low Revenues for the Utilities
Rapidly Growing Customer Owned Distributed Generation
Increased Unreliability in Distribution System Planning for the Utilities


Solution
Comprehensive Platform Promoting Sharing and Trading of Excess Electricity
Hygge.Energy
Nanogrid Developers
Subscription Based Platform
Consolidation of Nanogrid Sites
Improving IRRs, Proliferating Transactive Energy (P2P)
Hygge Platform
Local Optimization
Artificial Intelligence
Share and Trade Local Energy Resources
Customer Experience
Peer to Peer transaction and settlements
Blockchain

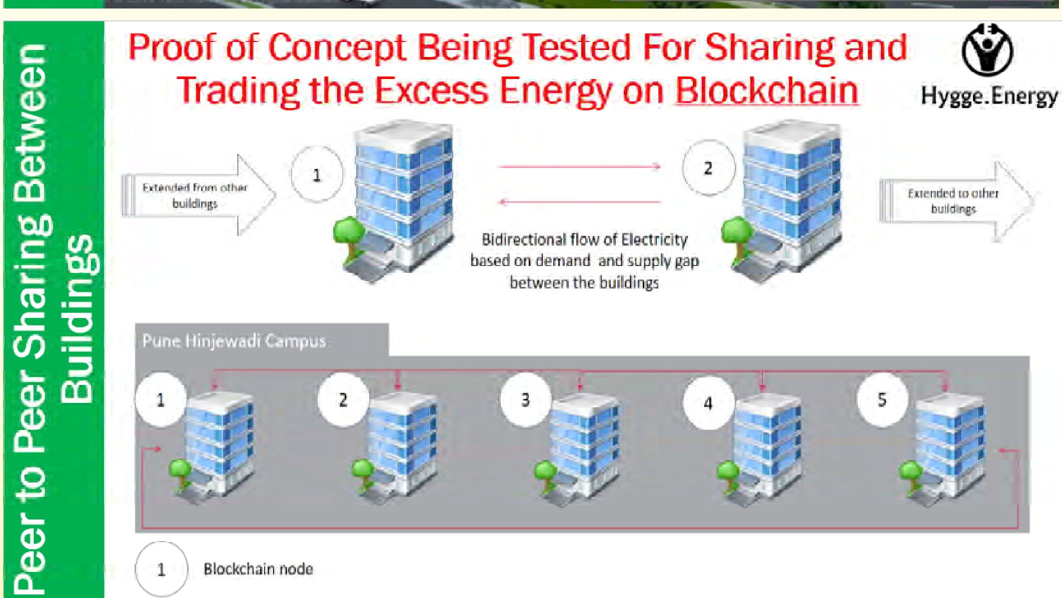

Architecture
Existing IPs And Strategic Partnership Provides Speed to Market
Hygge.Energy
App Factory
Marketplace
Blockchain Peer to Peer Trading
Cloud
Integration of IT Layer
Optimization Layer
Communication Layer
Instrumentation Layer
MVP Ready
Partner Solution
To be Developed
Physical Asset Layer

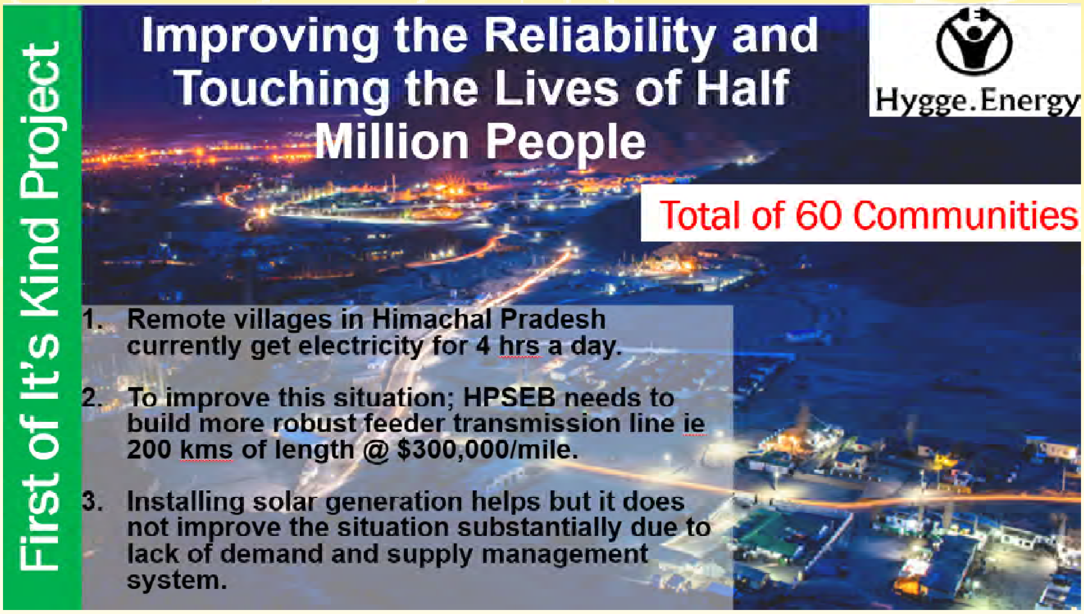

Opportunity
On The Edge Blockchain Computing Device
Hygge.Energy


Process
Blockchain Engine – Managing Assets and Transactions
Hygge.Energy
Data Source
Meters
Assets
Common services
Buildings / equipments
Power Ledger
Payments
Application Host Integration
Trading Engine
Dashboard
Public Ethereum chain
Power Tokens
One transaction fee per microgrid to deposit and release escrow
Power tokens in escrow provide a guarantee for the Sparkz circulating within the microgrid
Eco Chain Node
Consortium Chain
No Transaction fee
Sparkz
Eco Chain Node
Eco Chain Node
Eco Chain Node
Eco Chain Node


IP Created
CAPE
Hygge.Energy
CAPE
Community Action Platform for Energy
A user experience and user interface, analysis and reporting platform
A project in partnership with Innovate UK and Milton Keynes Council
Partners
SAP
Utility Partner
IOT Partner
Utility Host
GRIDSENSE
Transformer Monitoring
OADR Partner
EV Partner
EVSE Partner
IEVCS
Intelligent Electric Vehicle Charging System
IoT platform integrates data from disparate energy resources
A project in partnership with Ontario Govt and NOTL Hydro
Patent Applied


Demonstration Project
Tech Mahindra Campus
Hygge.Energy
250 kWp Solar Power Plant
Hinjewadi, Pune


Peer to Peer Sharing Between Buildings
Proof of Concept Being Tested For Sharing and Trading the Excess Energy on Blockchain
Hygge.Energy
Extended from other buildings
1
2
Bidirectional flow of Electricity based on demand and supply gap between the buildings
Extended to other buildings
Pune Hinjewadi Campus
1
2
3
4
5
1
Blockchain node


First of It's Kind Project
Improving the Reliability and Touching the Lives of Half Million People
Hygge.Energy
Total of 60 Communities
1. Remote villages in Himachal Pradesh currently get electricity for 4 hrs a day.
2. To improve this situation; HPSEB needs to build more robust feeder transmission line ie 200 kms of length @ $300,000/mile.
3. Installing solar generation helps but it does not improve the situation substantially due to lack of demand and supply management system.


Partnering With Largest Gas Stations
Gas Stations Become Distributor of Electricity in Remote India
Hygge.Energy
Solar
Battery
EV Charger
Payment Reward Gateway
Customer
Monitor and Control platform for EV charging stations
Device /Sensor Integration & Control
Energy Optimization
Asset Management
Customer Mobile App


Awards and Agreement
A Tech Mahindra spin out company, exclusively selected for the year 2015, funded and supported by the Tech Mahindra group
Intelligent Electric Vehicle Charging System (EIVCS) solution launched by Ontario Government and Niagara on the lake Hydro
IEVCS showcased at World EV Conference, Montreal by Ontario's Environment Minister, Glen Murray and Quebec Premier, Philippe Couillard
IEVCS acknowledged by International Energy Agency as top-10 global innovation
2015 to 2017
Winner of Top Mahindra Group Innovation Award 2017
Runners-up Mahindra Group Innovation Award 2015
MoU signed between Govt of Ontario and HPSEB, India for 60 Microgrid Projects
UC Berkeley awarded 'Silicon Valley Unicorn'
MoU signed between UC Berkeley and APSEB, India for 470 Microgrid Projects

Presentation of Mr. Rakesh & Mr. Upendra Bhatt

Profile

Rakesh has approx. 22 yrs of experience in the energy sector and has worked on several engagements in the power sector including mini-grid and distribution management. He has been working on energy access aspects in many countries and has formulated policies and regulations covering key aspects of access and inclusion of clean energy in the overall energy mix of the countries. Rakesh has advised various State Electricity Regulatory Commissions in determination of tariff for procurement of power from renewable energy projects. Over the last two decades he has worked closely with governments, regulators and utilities in policy development, design of regulatory frameworks as well as planning and implementation of renewable energy projects. His experience includes work in India, Pakistan, Nepal, Cambodia, Ghana, Benin, Kenya, Bhutan, Bangladesh, and Afghanistan besides 22 states in India.

Rakesh has worked on several mandates aiming to improve quality of supply and reduction in losses for the utilities. He has also worked in the mini-grid sector and has been involved in developing the first Mini-Grid Regulations in the country. He has also contributed in developing separate technical guideline for mini-grid. In the state of Uttar Pradesh Rakesh has developed Implementation Guidelines for Mini-grid, worked on the Mini-grid regulations, and development of technical guidelines for mini-grids. Currently he is working to interconnect the hitherto off-grid based mini-grid projects with grid in UP. He has been leading a project in the state where an innovative business construct based on integration of renewable energy based generation and localised power distribution management in rural area, aligned to the objectives of the Saubhagya scheme of the Government of India and the aspiration of providing 24*7 supplies to consumers. He has also been working on determination of ACoS for rural consumers in the state of Uttar Pradesh. Rakesh had developed the Renewable Energy Certificate (REC) framework and had also determined the floor and forbearance prices for RECs. He has been involved in development of more than 5000MW of utility scale solar projects and around 10MW of Roof Top Solar projects. Prior to joining Meghraj Capital Advisors Pvt Ltd, Rakesh has worked in Feedback Infra, PricewaterhouseCoopers and The Energy and Resources Institute. He has offered his advisory services to many bilateral and multilateral organisations such as GiZ, DFID, UNDP, USAID, World Bank, Asian Development Bank, African Development Bank etc.

Profile

Upendra Bhatt, Managing Director – cKinetics

Upendra Bhatt leads cKinetics, a leading Sustainability Innovation, Project development and Investments Firm.

Upendra has been engaged in infrastructure, renewable energy and resource efficiency domains with specific expertise in project development, new program design and shaping innovative market driven models for mainstreaming of technology and service interventions in the developing markets.

Upendra is the current Chair at Alliance for Energy Efficient Economy (AEEE) and also chairs of the Sustainable Business Leadership Forum. He is also a member of several Industry and Government task forces.

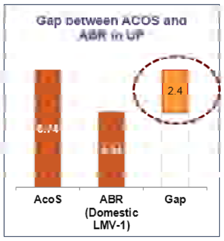
“Power for All”: pathway to frame supply resilience and customer management

October 10, 2018

Point of Arrival

Operating Landscape and continuing challenges

- After 100% village electrification focus now shifted to household. UP also focusing on universal household electrification from 71% at present*
- **Efforts to provide quality and reliable 24x7 power; however, there are few challenges****
  - **High AT&C losses** ~27.67%
  - **Gap between ACoS[1] & ABR** ~ INR 2.4 per unit
- Situation challenging in rural areas where AT&C losses are considerably high as result of long LT lines, theft, pilferage, low MBC efficiency
- Low voltage and frequent feeder trippings
- This impacts the rural economy as **productive loads** are not served optimally
- Unavailability of quality & reliable supply leads to **dissatisfaction of rural consumers**



Cracking the Conundrum

- **Complement Discoms** in meeting their 24*7 service obligations without impacting their financial viability **through decentralized generation and distribution management setup**
- Accountability on quality and reliability of supply and service to consumers, particularly **power for productive loads to enhance livelihoods**
- Intensifying customer service management to manage timely billing and collection
- Empowering last mile to ensure resilience and consumer trust
- Framing a business framework and viability construct built off significantly improved power distribution business activity in rural areas

*As on 26th Sep 2018 (Saubhagya)
** for year 2016-17 (UPPCL)
1-For rural areas this could be higher

With the Saubhagya scheme on track, there is an opportunity to frame an integrated approach for improved electricity access through reliable, affordable and resilient supply of power for the rural areas

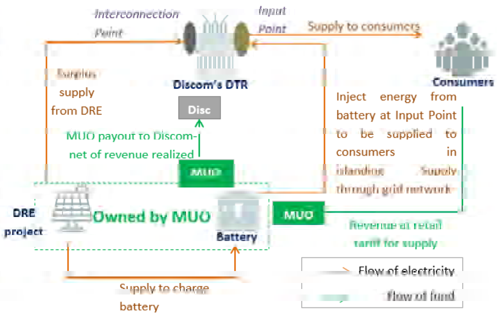
Prospective approach for an integrated and collaborative demand side management framework

DISCOM
- High AT&C losses
- High operating cost

Policy Lens
- Underserved or unserved areas with poor reliability and quality of supply as compared to Urban areas

Technical Viability
- Ability to have a clear and comprehensive coverage for all loads in an area incl. during peak hours
- High solar irradiation; Availability of land
- Adequately sized DTs – ability to cater to the load likely to emerge in a power for all situation

Financial Optics
- Investment levels
- Tariff approaches to frame viability while ensuring power to mix of domestic and commercial loads



Augmenting Discom supply with (DRE and) battery to supply under islanding mode

Design Considerations and Outcomes

- Electrically isolated area for ease of commercial accounting - cluster with ring fenced PDN to enable isolation of local grid for envisaged islanding operation during grid outage
  - Sub-station or feeder level for appropriate project sizing;
  - 24x7 power supply; brownout rather than blackout by load controlling mechanism
- System sizing and architecture should cater to all types of consumer categories with pre-agreed service levels when grid supply is not available
- Scalable model serving the needs of various players
- Framework broadly within the existing regulatory boundaries
- Balancing the perspectives and interests of various stakeholders based on risk assessment and possible mitigation measures

Consumers

- Improved quality and reliability of supply
- Support rural enterprises and productive loads
- Improved consumer service levels and consumer interaction
- Continue to receive electricity even when grid is down for improved supply

Discom

- Increase in customer base
- Enhanced customer service and improved MBC
- Definite revenue realization at Through Rate
- Avoided operation and maintenance cost
- Contribution to RPO

MUO

- Serving the productive load
- Opportunity to retain additional revenue with increase in revenue realisation compared with Through Rate
- Ease of recovery of investment in form of Through Rate
- Economies of Scale

Critical Parameters – aspects for consideration

- Technical and safety framework
  - Network and Supply SOPs
  - Operational engagement between Discom and MUO setup
- Contractual framework
  - PPA for feed-in
  - Micro-utility agreement for customer acquisition and management
- Size and scale of operation
  - Minimum sale and revenue
  - Investment levels
  - Ground capacities
- Framing buy-in from Discom staff
- Framing viability
  - Adjustment from the input rate from Discom
  - Asset fee /VGF
  - Reliability surcharge
- Revenue construct viz. Discom
  - Input Rate
  - Through Rate
  - Per Customer fee
  - Operating margin
- Performance obligations of MUO
  - Service levels and penalties
  - Metrics related to non-domestic load penetration
- Commitments from Discoms
  - Quality of power, supply hours and min. energy MUs
  - Network investments as needed

Regulatory aspects

- The business construct will not require any separate licensing
- Applicability of tariff to be charged to the consumers
  - Can the consumers be charged Mutually Agreed Tariff (MAT) or only retail tariff will be applicable
  - With the provision of 24*7 power supply can the business construct be allowed for reliability surcharge
- Banking of power and drawl mechanism
  - Energy accounting and settlement mechanism
- Sale of excess electricity to the distribution utilities @ applicable FiT
- Allow meters with load limiting feature
- Responsibility and accounting for network investment

Presentation of Er. Rajesh Vyas & Mr. Saswat S. Panda

Profile

Er. Rajesh Vyas is being Bachelor of Engineer in Electrical Power System, Chartered Engineer from IEI, Kolkata affiliated to Royal Institute of Engineer, London, started his career in 1990 as an Electrical Engineer for hydro project execution with Government of Maharashtra at Mumbai and lead team to develop and execute small hydro project in Maharashtra state. As Vice-President – Projects from 2007 to 2011 in Patni Projects, company promoted by promoters of Patni Computers, had a responsibility to give strategic advice to Patni's to venture into application of IT into smart grid project in power and energy sectors. He joined Lanco as Head - Techno-Commercial & Business Development in 2011 and from May 2018 leading POM Hydro Energy limited as COO.

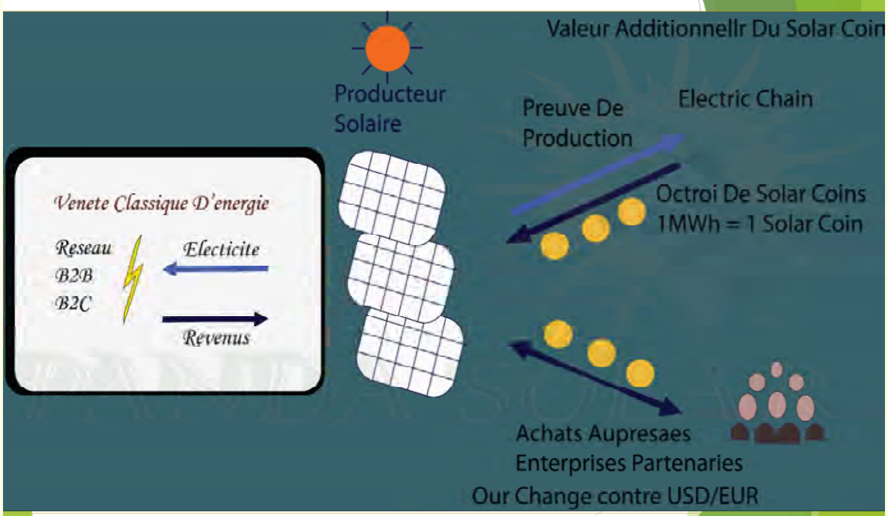
During carrier of more than 28 years got extensive exposure in development of renewable energy, application of smart grid with Patni's and in Lanco for Solar in PV, rooftop. He made potential study for application of block chain for micro grid using hybrid technology with combination of hydro, wind and for renewable energy sources. Mr. Vyas has vision - Affordable power available to all with application of block chain technology, application of fintech and creation ReneCoin like credit card in collaboration with VISA and Master card and in association with virtual money platform like PAYTM.

Profile

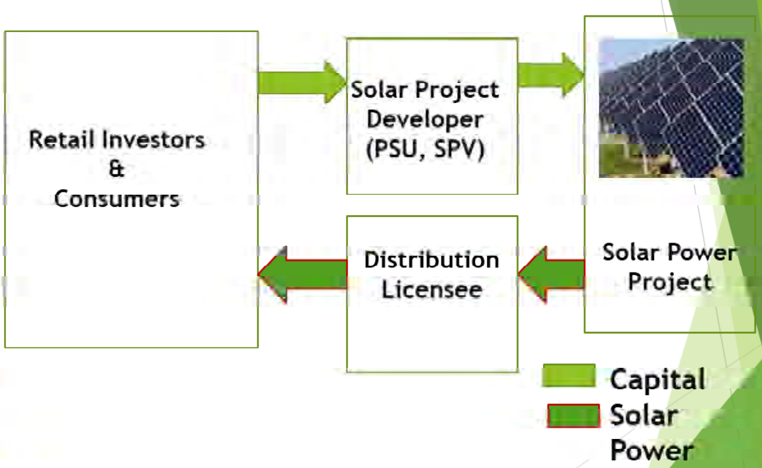
Mr. Saswat S. Panda is a technocrat with bachelors in mechanical engineering. He has around four years of Energy Industry expertise coupled with a Management Degree in Energy Infrastructure from University of Petroleum & Energy Studies, Dehradun. He started his domain expertise in energy industry research, consulting and analytics before moving into roof top solar project BD & contract management. He successfully lead into "concept to commissioning" of approx. 20 MWp of roof top projects across 80+ sites which included roof top solar projects on 2 international airports. Due to his expertise on solar technology, he was invited to deliver guest lectures at some of the prestigious institutions such as University of Petroleum & Energy Studies (Dehradun) National Power Training Institute (Nagpur), Indian Institute of Management (Amritsar) and was a contractual trainer on solar energy for Medium, Small & Micro Enterprise for 20 programs Educating more than 1,200 students in the process. For his achievement's The All India Radio invited him for radio talks which have been on air multiple times across India.

Saswat has ventured into senior management roles such as Senior Manager, COO, Solar Division Head & Business Advisory role for various organizations such as for micro grids (Horizon Power, Australia), Solar Module Manufactuing (Rise Energy, Hyderabad), Solar Charkha & Refrigiration R&D project (Hari Telematics, Bhubaneswar), Rural Solar Applications (Vivanex Energy, Odisha).

Eco-system Using Block Chain Technology For Renewable Energy Distributed Energy Generation & Supply



Basic Concept: Financing solar power through crowd funding and getting solar power as return

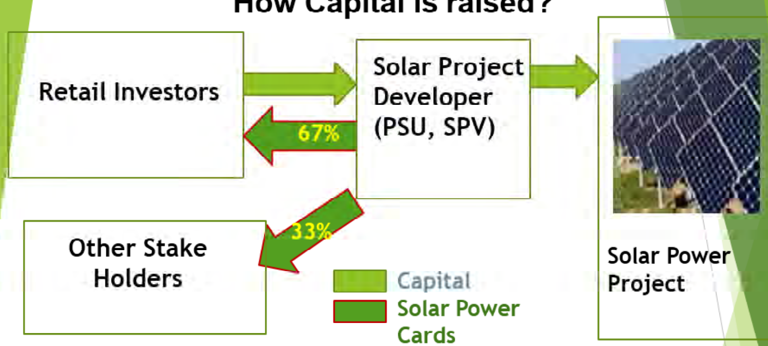


Delivery Mechanism for Virtual Net Metering; Use "Solar power" as currency

Solar Power Card" is proposed

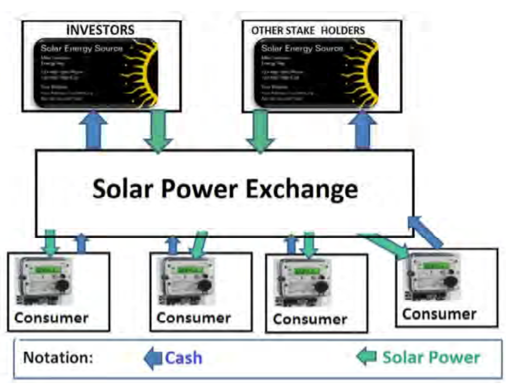
Excess energy fed into grid is converted in cryptocurrency and is digitally stored in your energy card

How Capital is raised?

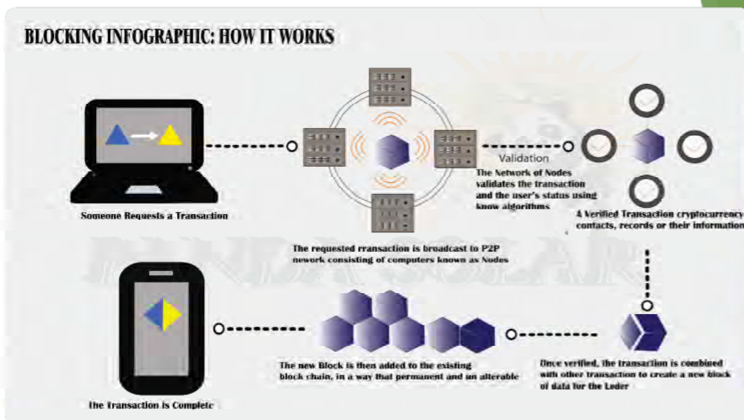


- Capital is raised from retail investors who pay cash and get solar power cards. This capital is deployed in the solar power project.

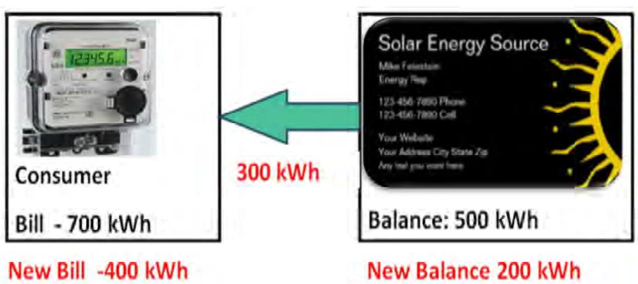
Flow of power: Concept of virtual net metering



- Generated power from the solar power plant is recharged in the solar power card every month.
- Solar card owner can transfer his balance available on the card to any consumer to set off their bill like internet banking system.

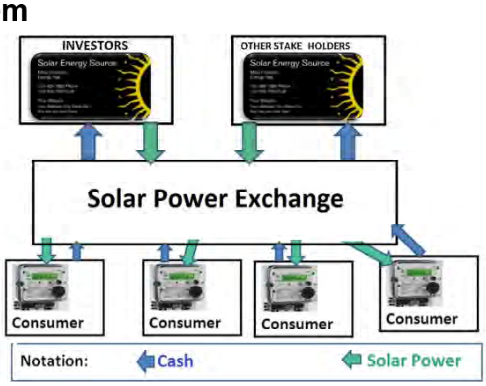


Solar Coin: Illustrative example



- Balance on Solar Power Card and on consumer's bill will get adjusted as per transaction.
- One consumer can get credit for power from multiple solar power cards.

A virtual 100% Flexible net metering system



- In the long run this will develop in a "Solar Power Exchange" where solar power card holders will sell power available with them and consumers will purchase.
- Rate of solar power will be decided by the market forces. This will be the lowest cost option for the consumers.

How much power investor will get?

- Works like lifetime prepaid card.
- Investors pay cost of solar power for 25 years upfront and get the solar power energy deductions every month in their bills.
- Pre-defined tariff

Investment basis: Rs. 1 lakh		
Rate of realisation in Rs/kWh	First Year's Return on Investment in %	Avg. RoI for 25 years in %
6	13.25	17.92
6.5	14.35	19.75
7	15.46	21.58
7.5	16.56	23.40
8	17.67	25.23

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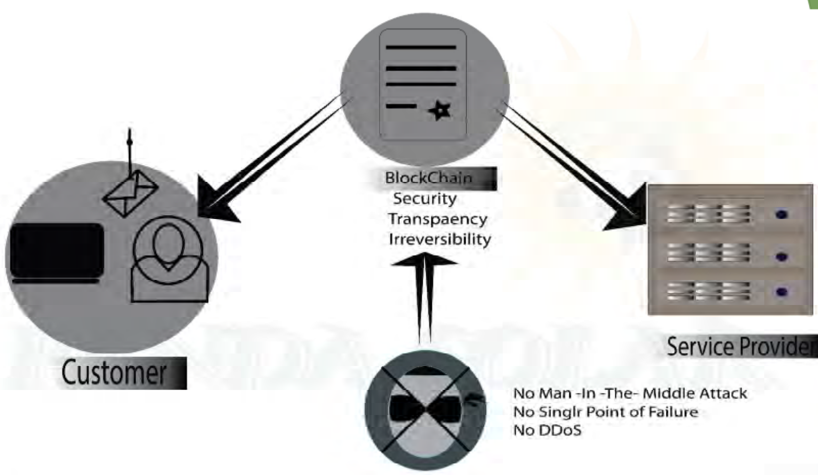
- Solar Power Companies: They can do business at will and will not be dependent on DISCOMs. This is open market for them.
- Smart Cities: Can complete solar power obligation of 10% with a single project.
- Govt. of India : Can get climate change obligation complied. Saves billions in tax rebates and subsidies.
- MSME : SMEs are most badly hit industry sector as far as power cost is concerned. They have no choice but to buy power from existing utility. Solar Coin permits them to procure cheaper solar power from open retail market.
- State Govt. : Complete target of solar power without any investment and subsidies.
- DISCOM: Puncturing grid at so many location in rooftop is not convenient. Centralised plant is better. Better control on management of grid. Low overheads.
- Consumers: Consumers truly get the choice of getting their own solar power or purchase from retail market. At present retail consumers have no choice.
- Solar Coin can kill the corruption in the system and will result in lowest possible cost of solar power.



Insert working model, technical stuff from Bitcoin

Hidden Benefits of Solar Coin

Solar power companies have to win bids and sell power to DISCOMs. Many companies may shut down this business or will get in financial trouble because of unreasonable bidding or huge overheads.

- Solar Coin permits solar power companies to do business at will. They can setup solar power projects and sell the power in retail through solar power exchange or sell the solar power cards.
- For Smart Cities, this is a practicable solution.
- Perfect substitution for rooftop solar with many advantages.
- Market forces decide the tariff increases transparency.
- Everybody can contribute to development of solar power.
- 100% flexibility and liquidity for investors.

Solar Coin: How Project Developer benefits?

1. Equity that will fetch profits for the life of the project. Mutual funds are suitable seed capital fund source.
2. Administrative expenses are negligible.
3. All profits from the project development are booked upfront.
4. Capital is raised in the form of prepaid cards from investors.
5. Lowest cost offers are expected from EPC companies as capital cost for the projects are paid upfront. Additional margins of 5 to 10% are possible.
6. Additional margins are possible with use of solar trackers.
7. Recovery of payments or non purchase of power are mitigated as off takers are the investors
8. Project developer can earn operating profits through O & M activity.
9. Can book additional profit by taking depreciation benefit

Solar Coin: Project Developer; current issues?

1. With current level of aggressive bidding for PPA, business is unviable for most project developers (PD).
2. If PD don't win bids for long time, financial situation will push for closure or bankruptcy
3. Even if a PD wins bid and start selling power under PPA, realisation of payments from the DISCOMs is a big issue.
4. Even though solar power gets highest evacuation priority in all agreements, sometimes DISCOMs make default and refuse to purchase power when they are power surplus. Such defaults by Rajasthan and Tamilnadu are reported.
5. Companies who have solar panel manufacturing capacity can utilise it 100% as they can use their own panels for such projects.

Solar Coin takes care of all these issues

Virtual Net Metering
Where Lies Innovation?

The innovation is primarily replacing thousands of small solar rooftop systems with single utility scale project. E.g. 20000 systems of 5 kW can be replaced by a single 100 MW solar power plant. Innovation uses "Solar Power" as currency:

The Advantages:

- 40% Saving in Capital.
- 20 to 40% excess power generation.
- Levallised cost of power is half that of rooftop scheme. Retail financing at lower CAPEX.
- People without disposable rooftop can participate.
- Smart Cities can use credit of project to seek matching grant of 500 crores from Govt. of India.
- Zero investment from Smart Cities / Governments.
- Win-Win for all stakeholders.

Other Advantages

1. Solar power depreciates (module degradation) at 0.5% per year while monetary currency, rupee, depreciates at more than 5%. Hence solar power is a secured from inflation
2. As all returns are in solar power (irrespective of tariff changes) there is no effect of FAC.
3. Returns to DISCOMs are fixed in % of solar power and hence they are assured of minimum profit, irrespective of dynamics of interest rates and forex rates.
4. Its easy to understand for investors that for investment of say Rs. 1 lakh upfront, how much power they are going to get in lifetime. Assurance to investor for definite quantity of solar power is easy

How Solar Coin can be promoted?

- Because of advantage with returns on investment of more than 15%, investors will jump in.
- Raising capital will be easier
- Additional investments in "Solar Power Cards" are possible with following measures.
  - All new constructions costing over Rs. 25 lakhs will be made mandatory to purchase at least one Solar power cards.
  - All new projects will have provision of Solar power cards while budgeting.
  - All industries, municipal corporations, organisations can be asked to procure some fixed percentage of their power consumption through Solar power cards. It is possible to get a village, city or organisation to run on 100% solar power in true sense. Assam industrial area can have such option.
  - M.P.s and MLAs can use LAD funds to buy few Solar power cards to support the charitable organisations of their interest.
  - Corporates can donate cards or transfer solar coins

There can be many ideas to make this program a big success.

Scalability

- **Solar power generation is uniform in a location.**
- **Generation prediction is 95% accurate.**
- **Generation guarantee insurance is available.**
- **Solar Coin can be extended to other renewable energy sources like Wind.**

Presentation of Mr. Martand Shardul & Ms. Rhythima

Profile

Martand Shardul is a Computer Engineer by training and an alumnus of the Global Masters in Development Practice program. He is one of the Founding Members of the Leadership Committee for the Students and Alumni Advisory Council (SAAC) which is hosted at the MDP Secretariat, Columbia University. In 2012, he started working with the global Lighting a Billion Lives (LaBL) initiative of The Energy and Resources Institute (TERI), New Delhi. As part of the initiative, he has steered implementation of energy access projects in remotest corners of India, and has contributed to the DFID-TERI Clean Energy Partnership for market value chain creation in rural India. He is associated with the Alliance of CSOs for Clean Energy Access (ACCESS). As pat the Capacity Building Hub for UN's Sustainable Energy for All (SE4All), he has contributed to the review of SE4All Country Action Agenda/ Investment Prospectus of several Sub-Saharan African countries. He is an avid advocate for inclusion of grassroots institutions and youth in the SDG agenda. During the historic Rio+20 Summit, he played an instrumental role by driving attention of leaders towards energy access issues of the poor people. In 2016, he received TERI's highest award, the "Roll of Honor" from Shri Jayant Sinha, Hon'ble Minister of State for Civil Aviation, Govt. of India, for facilitating the activities of the Sustainable Energy for All initiative. Also, in 2017, the UN Environment included his name in their directory of young change makers - #Faces4Change2017.

Profile

Rhythima works as a PhD in ETH Zurich in Switzerland. She is trained as double masters in Computer Science and Policy Analysis from TU Delft, where she was selected as the "best graduate of the faculty for 2017". She finished her bachelors in 2015 with achieving one of the highest Technical Awards of the institute for consecutive 2 years. She also served as co-leader for different international academic communities and organisations e.g. the System Dynamic Society energy chpaters, etc. Currently, she also works as the co-founder of Energy Bazaar, which is a startup aiming to decentralize energy market and allowing peer to peer energy connection, and accelerate renewable energy transition. She has published multiple international conference and journal papers on topic of data science methods for governance, open data policies and cyber-security methods. She has been speaker at Vienna for Engerati Event (European Energy Events Network), and different events and panel discussions on blockchain in Netherlands and Switzerland.

Leveraging blockchain technology for scale-up of DRE in Uttar Pradesh

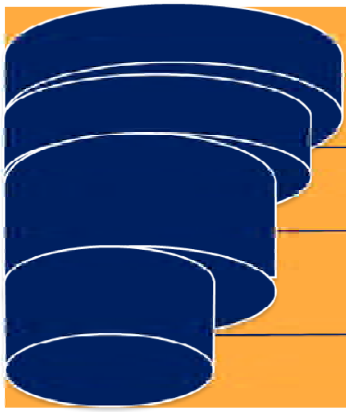
Martand Shardul, TERI

Rhythima Shinde, Energy Bazaar

The Energy and Resources Institute

Energy Bazaar

Status Quo: Access to Electricity in Uttar Pradesh(UP)



Expanding consumer base

71% of the households are already electrified and government targets electrification of remaining before 2019

Enhanced priority for DRE systems

Among early states to legitimize Mini Grid (RE Generation and Supply) Regulations, 2016

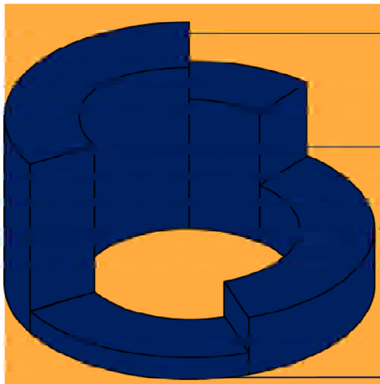
Reliable power supply a goal

Partnership of central and state governments for 24X7 Power for All

Financial health of DISCOMs

The state government is undertaking major steps to improve financial health of the DISCOMs

Status Quo: Access to Electricity in Uttar Pradesh(UP)



1. Existing minigrids are facing competition from expanding grid: Both investors and project developers are in troubled waters

2. Demand remains unfulfilled: Domestic consumers in rural areas still do not get 24x7 power supply

3. Metering, billing and revenue collection is a perennial issue in rural areas

4. Identifying faults and defaulters is a costly business in rural areas where domestic consumers do not have deep pockets

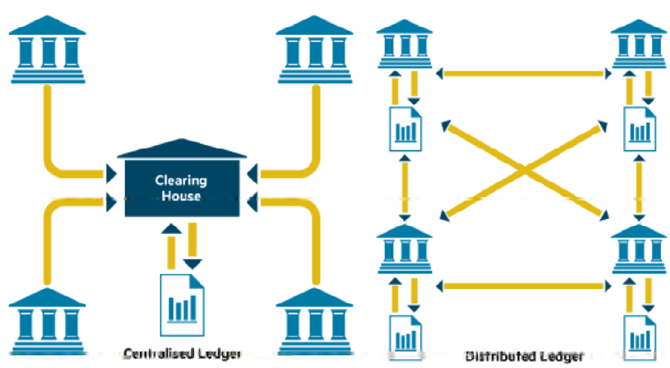
Scale-up of DRE: Is blockchain the channel

Optimist:

1. Will DRE systems remain relevant even if the grid network becomes operational in the region
2. Can we expect a transition? From DRE for basic access to DRE for enhanced RE electricity capacity
3. Is it possible to streamline metering, billing and revenue collection by leveraging social interactions?
4. Will consumers become 'Prosumers'

teri
The Energy and Resources Institute

What is Blockchain



FT graphic. Source: Santander InnoVentures, Oliver Wyman & Anthemis Partners

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Blockchain and Decentralized Energy Market

…..helps the decentralisation of electricity generation by **establishing decentralised markets**

…..can be used in **transactions of value**, where parties can be anonymous

…..allows for a **distributed accounting** of every kWh of energy that is generated and used, without the possibility of altering the numbers by attacks on the system

…..supports the use of **smart contracts**; the appropriate fees in the system can be executed automatically, **reducing administrative costs**

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Blockchain for DRE: Insights from Energy Bazaar

Energy Bazaar is a solutions provider for decentralized energy exchanges of the future

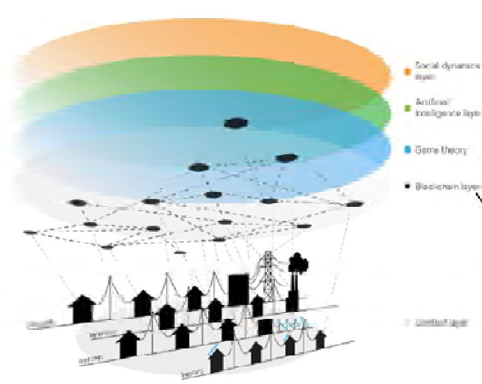
Spindle Accelerator (top 5), Netherlands
Blockchain for Social Impact Hackathon, Global
COP23 Hack4Climate Hackathon, Germany

Research Grant from TUDelft
Project advisors from:
India Energy Exchange Board
TU Delft Researchers (PhDs)

The Spindle | TUDelft Global Initiative | Hack4Climate | IEX

Further details: https://www.energybazaar.org/partners

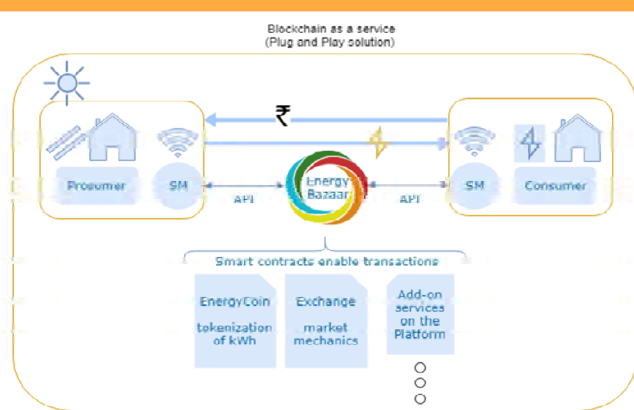
Insights from Energy Bazaar



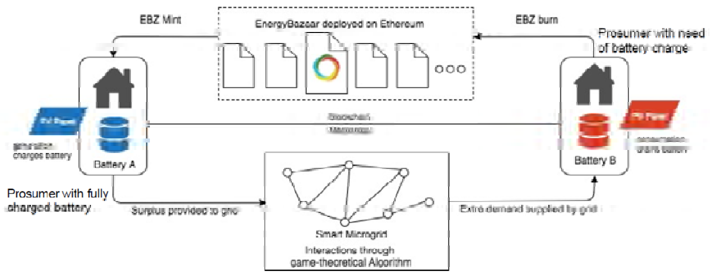
Multi-layer solution

- Social dynamics modelling
- Predictive price optimization
- Grid stabilization
- Trusted and private Peer-to-peer energy exchange

Insights from Energy Bazaar Model



Technology: Proof of Concept



[Link for complete working video](http://bit.ly/energy-bazaar-video) (http://bit.ly/energy-bazaar-video)

The Energy and Resources Institute

Scale-up of DRE: Is blockchain the channel

1.	2.	3.	4.
Will DRE systems remain relevant even if the grid network becomes operational in the region	Can we expect a transition? From DRE for basic access to DRE for enhanced RE electricity capacity	Is it possible to streamline metering, billing and revenue collection by leveraging social interactions?	Will consumers become 'Prosumers'
New business opportunities: Energy harvesting through blockchain	Blockchain based energy trading among peer groups and between generators can instigate interest in RE among small investors	Complex multi-layer algorithms set the system tamper proof while the system keeps evolving as social interactions evolve	Bi-directional transaction of energy coins via smart contract

The Energy and Resources Institute

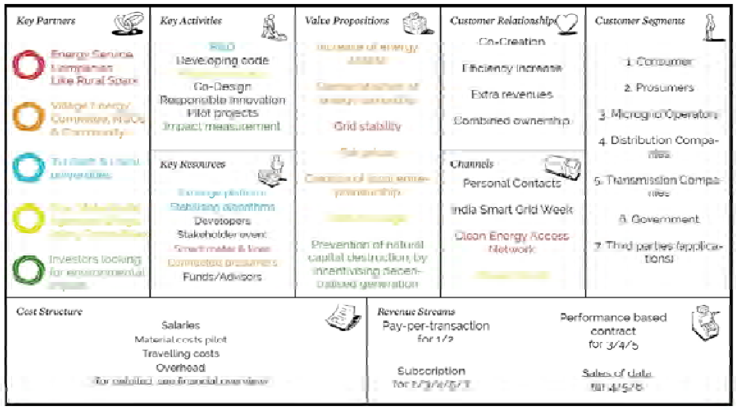
Energy Bazaar

The Way forward

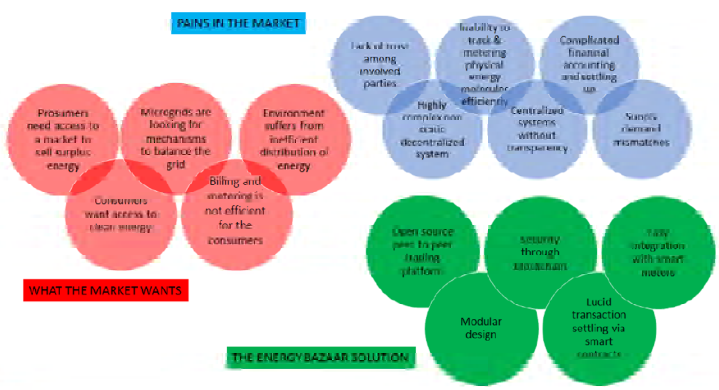
The Energy and Resources Institute

Energy Bazaar

How: Responsible Innovation



Business Value Proposition



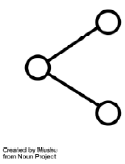
Policy Implications

….removes the barrier of a lack of trust, by installing **a neutral platform between entities** such as consumers, prosumers, microgrid operators and DISCOMs.

…. creates **flexibility** by removing the inflexible contracts i.e. Power Purchase Agreements (PPA)

….improves **information accessibility** about the dynamics of the system, helps to **detect energy theft**, leading to a **more resilient system.**

Societal Implication



Clean Energy Access

Efficiency

Ownership

Entrepreneurial opportunity

Education - Entertainment - Health - Comfort - Convenience - Productivity

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Challenges ahead

- Scaling up
  - Hardware integration across varying loads and sources
  - Dealing with the duck curve
- In decentralized grids,
  - Supply cannot be as per demand always (Storage constraints)
  - Issues of quick ramp up- or down-production when needed

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Presentation of Dr. V.S.K.V. Harish

Profile

Dr. V.S.K.V. Harish is currently working as an Assistant Professor at Pandit Deendayal Petroleum University, Gandhinagar. Prior to this, he worked as a Post-Doctoral Fellow at TERI School of Advanced Studies, New Delhi under the Netherlands government sponsored collaborative project titled "Developing and implementing smart grids for India" with Eindhoven University of Technology as partner. An Electrical and Electronics graduate, Dr. Harish received his Ph.D. from the Indian Institute of Technology Roorkee in 2017 and masters with Gold Medal from Jadavpur University in 2012.

He was nominated for the prestigious YOUNG ENERGY RESEARCHER AWARD - 2018 at World Sustainable Energy Days, one of Europe's largest annual conferences supported by the European Commission. He is also the recipient of international travel award from the Department of Science and Technology, Govt of India in 2014 and 2018 and from Soft Computing Research Society, India in 2017.

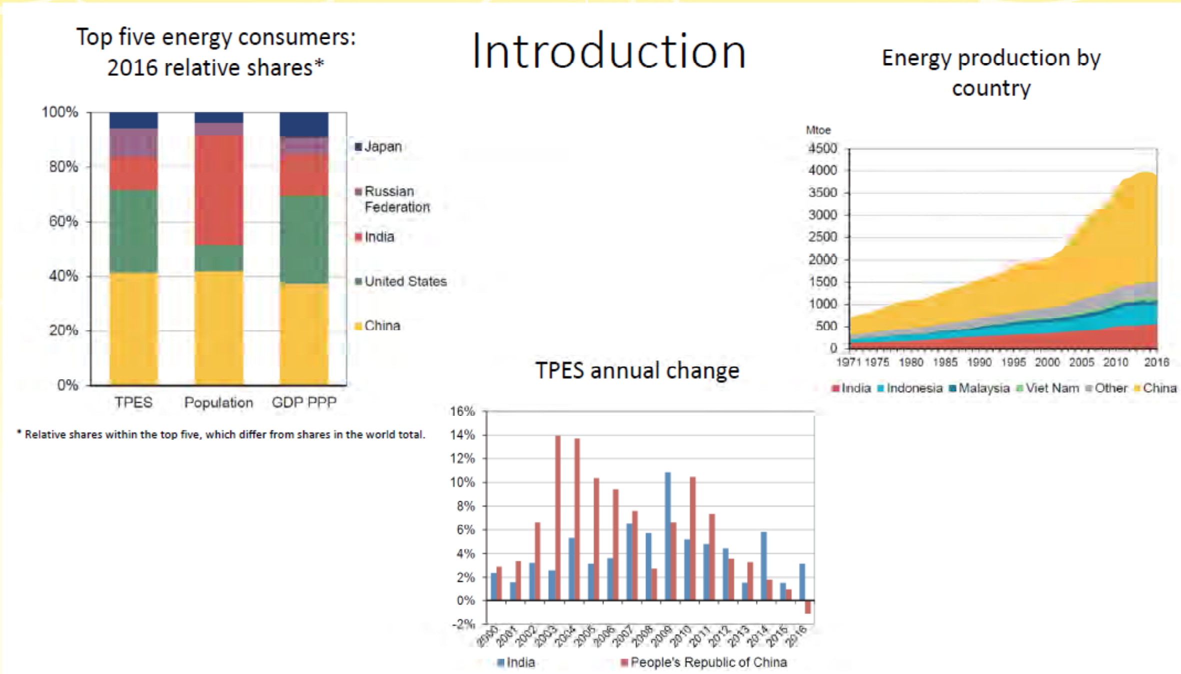
He has publications in journals of international repute and presented his works in several conferences organized by ASHRAE, ELSEVIER, and IEEE in India and abroad. He has one BOOK publication on Green Buildings with Elsevier which is scheduled to be released by Dec 2018. His research interests lie in building energy systems, micogrids and rural electrification.

Abstract

India has made proficient progress in terms of generation capacity and managing the demand; achieving lowest ever demand-supply gap both in terms of energy (0.5%) and peaking power (1.4%), as on Aug, 20181. In spite, the challenge lies in making the generated electricity/energy accessible to all (power-to-all). Renewable energy based decentralized energy systems, off-grid and on-grid based micro grids (MGs) / home-based solar products with storage are being considered as an optimistic solution to the rural electrification problems. However, a storage unit increases the cost and suffers energy loss while power transfer due to degradation of battery while charging and discharging cycles. Despite advances in electrifying rural villages, the quality of electricity service to rural households is dismal and the problem of electricity ‘access’ has not improved appreciably. Affordability of purchasing power from the grid or solar based products from the market is one prime challenge that has hampered the growth rate of rural electrification

Present work addresses such problems by developing an optimal Peer-to-Peer (P2P) electricity exchange framework among several individual rural households in a microgrid. A multi-criteria nonlinear optimization problem is formulated that aims to minimize the power transmission loss, overall energy cost in a distribution network consisting of a number of households incorporating practical constraints (e.g., power balance and battery’s operational constraints) and maximize profits. The framework enables delivering localized generated power to the households and enables the local villagers to trade their (excess) electricity for profit; thereby, creating a sustainable business model. A reliable, economically competitive and environmentally sustainable electric power system is achieved through an active P2P micro grid, thereby, addressing the issues of energy security and environmental strains.

A local marketplace is created where electricity is exchanged among the households at a price decided by the demand-supply ratio of the MG at the hour of study. Such dynamic pricing enables the developed pricing strategy to be applicable to any P2P network, regardless of the technology being used to enable P2P energy sharing i.e., BlockChain or Multi Agent System or like-wise.



Electricity sector in India

Installed capacity* of 344.69 GW as of August 2018.

Fossil energy: 81.9%, Renewable energy: 15.3%.

Demand–supplygap,July2018(CEA,2018):

- Energy:-0.5%
- Peak:-1.4%

92%villageselectrified;100%electrificationby2022(DDUGJY)(GARVDashboard,2018)

Quality and reliability

•"….connectionisnottheonlyfactor—evenduration,qualityandreliabilityareimportant."(NITIAayog,2017).

Source: CEA 2018.

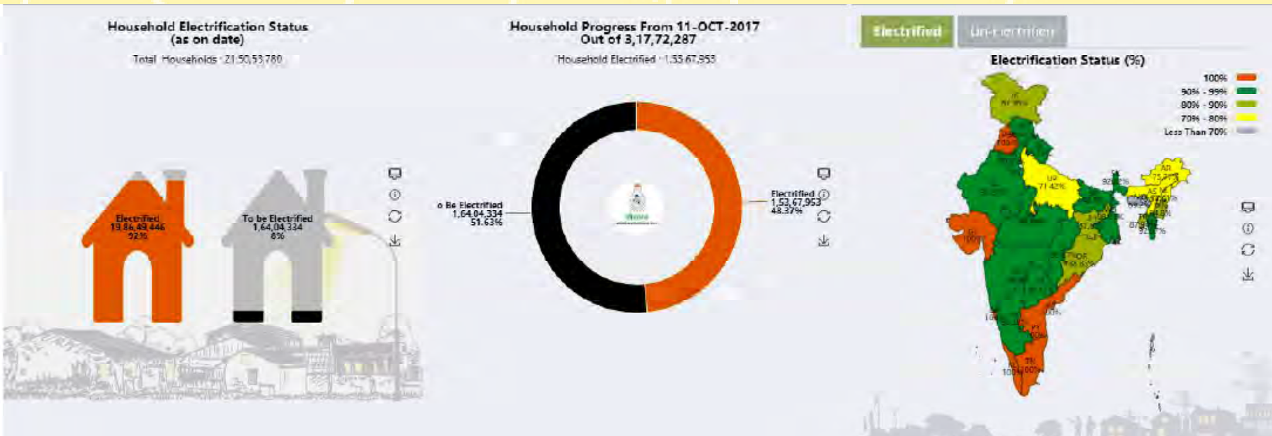
*Total installed power generation capacity is sum of utility capacity, captive power capacity and other non-utilities.

Renewable energy status in India

Solar	Biomass / Bagasse	Wind	Small Hydro	Waste to power	
21.6 GW	8.7 GW	34.1 GW	4.5 GW	0.14 GW	69.0 GW
Total Installed Grid Interactive Power Capacity as of Mar, 2018					
100 GW	10 GW	60 GW	5 GW	-	175 GW
2022 Target by GoI					
0.5 GW	0.8 GW	0.03 GW	0.2 GW	0.17 GW	1.6 GW
Total off-grid Power Capacity as of Dec, 2017					

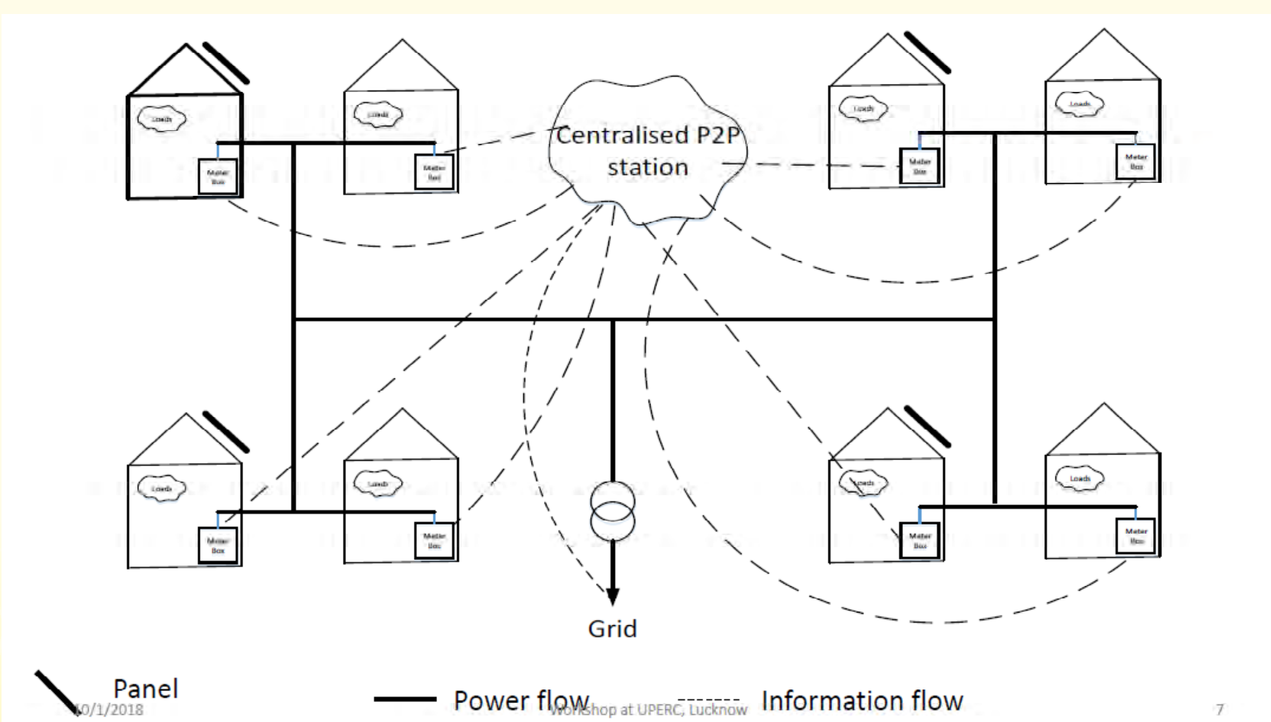
Source: CEA, 2018

Rural Electrification status India



Optimal energy management to facilitate peer to peer (P2P) sharing and trading of power for rural micro grids.

1) EnergymanagementofmultipleRuralHouseholdsunderadistributionnetwork.
    1) SchedulingstrategiesforP2Psharing,charging&dischargingofstorageunitsandinteractionwithmaingrid.
    2) MatchingRuralHousehold’spowerdemandandsupply.
2) Multi-objectiveoptimizationproblem
    1) MinimizingthepowermismatchofeveryRH.
    2) Minimizationoftotalcostofscheduling.
    3) MaximizingRHrevenuethroughP2Ptrading.

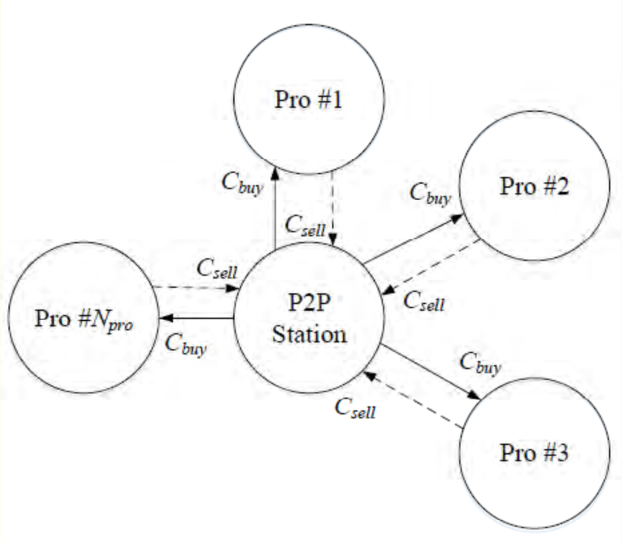


Players involved

- Prosumers:
  - Rural households with rooftop solar home based systems (SHS):
    - PV array, battery, charge controller, MPPT, converters, smart meter, electrical loads
  - Topologies:
    - DC Coupled SHS
    - AC coupled SHS
- Consumers
  - Rural households with electrical loads:
    - Electrical loads, Energy meter.
    - Electrical loads, Energy meter and batteries.
- Centralized P2P station
  - P2P pricing strategy based on Demand-Supply Ratio (DSR)
  - Shared power and cost optimization studies
  - Sharing info. on hourly buying/selling price.

Centralized P2P station

- Ensuringpowerbalancewithinmicrogrid.
- Controlthecharging/discharging activities of all batteries;
- Comm.Withindividual prosumers and consumers according to the P2 P pricing strategy and ensure the prosumers' income balance with the consumers' xpenditre.



Centralized P2P stationPricing strategy

- Underlying principles:
  - The prices should be bounded between anupper and alower limit,
  - P2P price and Demand-Supply ratio(DSR) is directly-proportional,
  - Economic balance should always be guaranteed for the P2P power sharing zone, i.e., among prosumers and consumers.

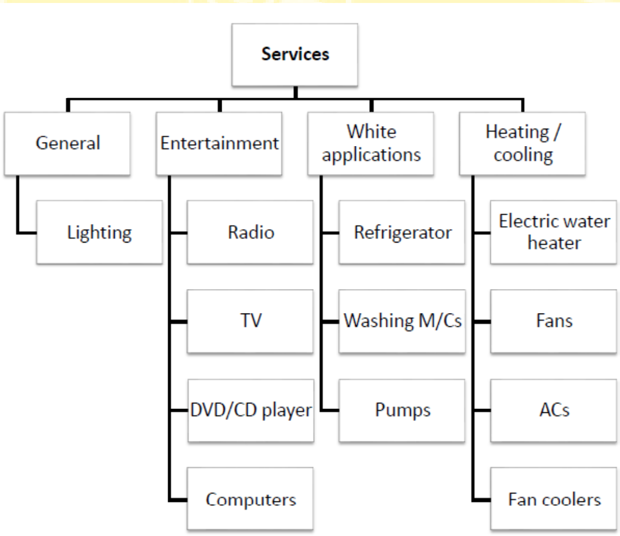
$$DSR = \left(\frac{TD}{TS}\right)_{P2P} = \left(\frac{TBP}{TSP}\right)_t = DSR(t)$$

Information exchange among all the players

Time		P2P Station	Prosumer, k	Consumer, N - k
t	Send	C_{P2P}	$P_{net}(N)$	$P_{dem}(N\text{-}N_{pro})$
$t + \Delta t$	Receive	$P_{net}(N)$	C_{P2P}	C_{P2P}

Householdloads

- Loads in rural households have been considered to be DC appliances (ratings derived from the 2015–16 Global LEAP Award winners).



Assumptions

1) Power Lines (of any topology) have been laid for direct P2P energy sharing among different RHs.

2) A local are a operator (LAO) is responsible for maintenance of the lines.

3) Decision making scheduling strategies will be developed at a centralstation operated by the LAO; and communicated to every RH.

4) All RHs in P2P network are willing to participate.

5) Only solar is taken as the renewable energy source.

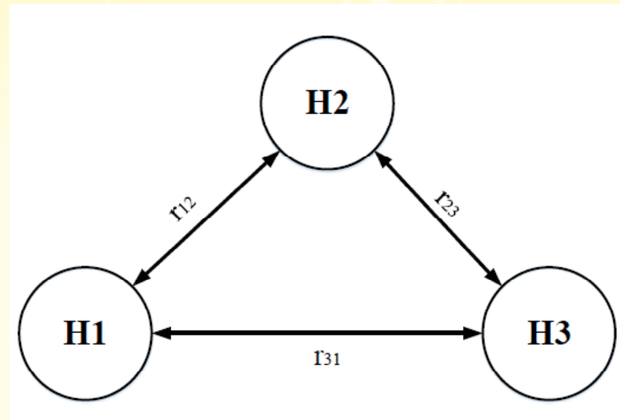
Conceptual schematic

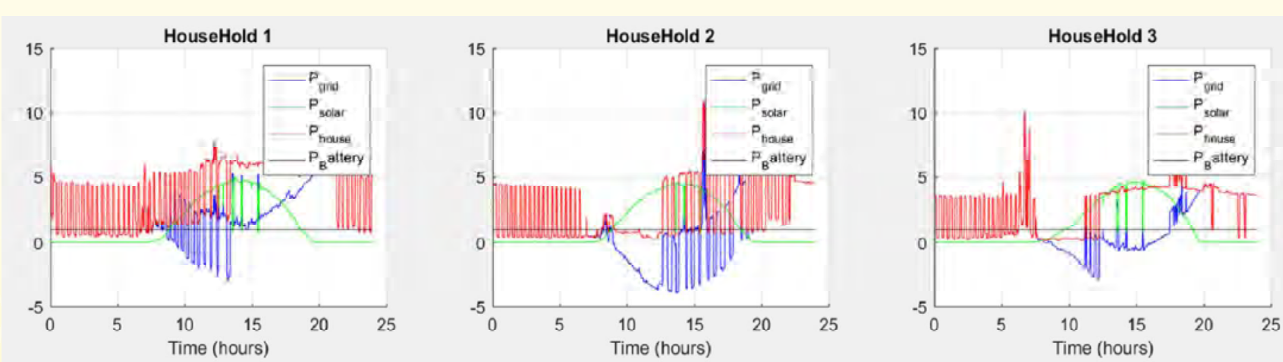
- Forillustration:

– a three house hold P2P network is considered.

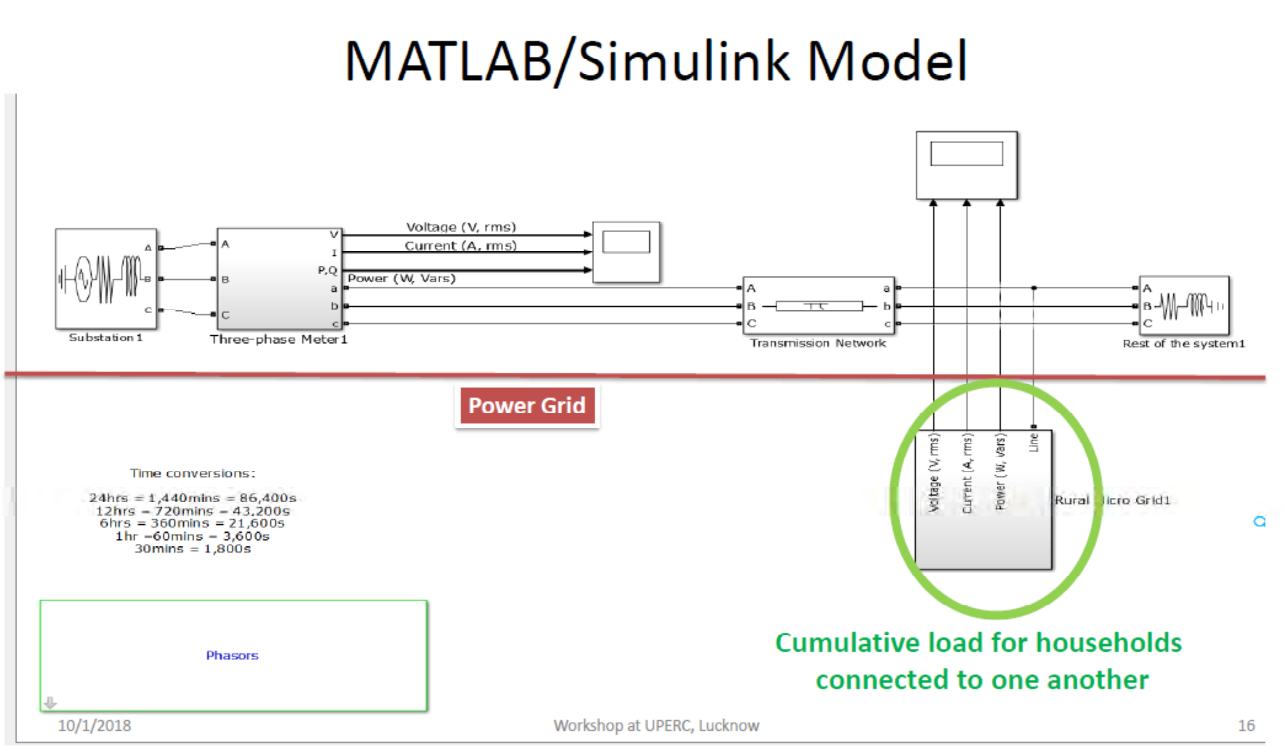
– H1, H2 and H3 are connected to each other via dedicated distribution lines of resistance r_{12}, r_{23}, r_{31}.

– r_{xy} varies with distance between x and y.

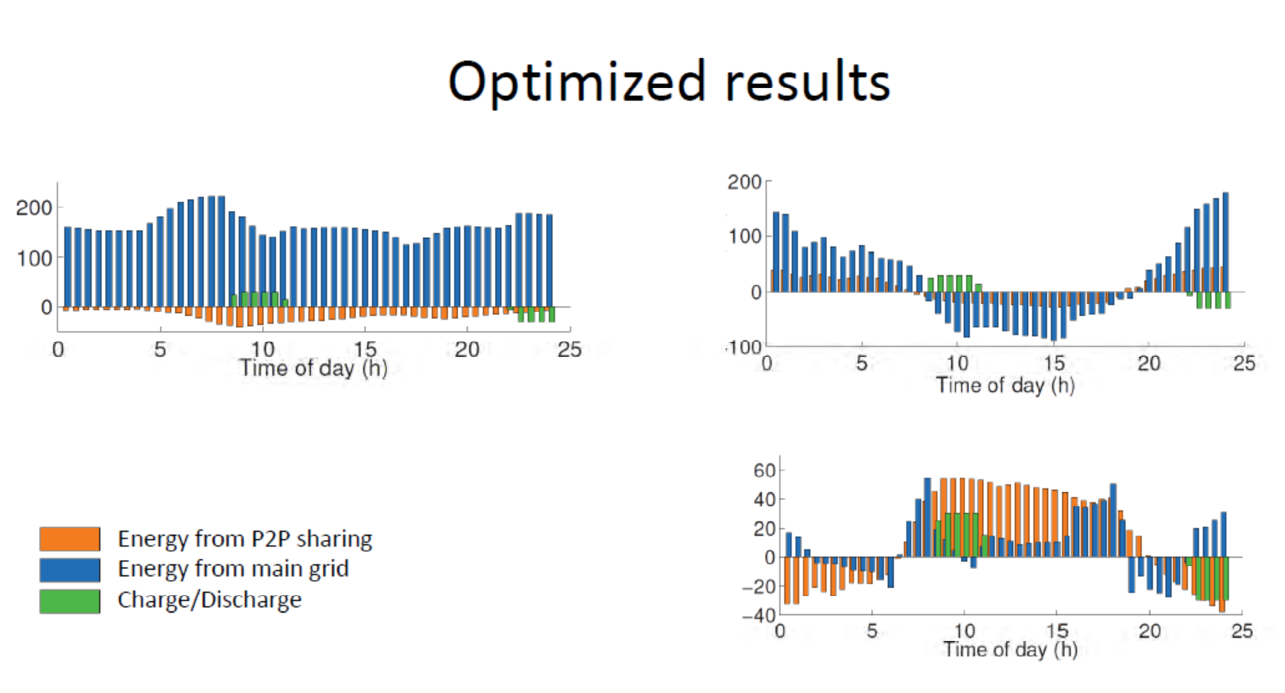




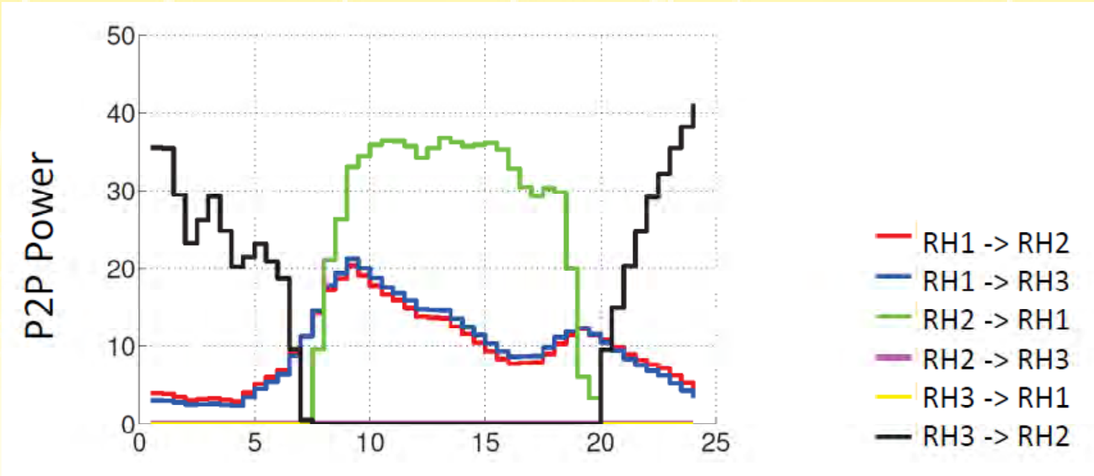
MATLAB/Simulink Model



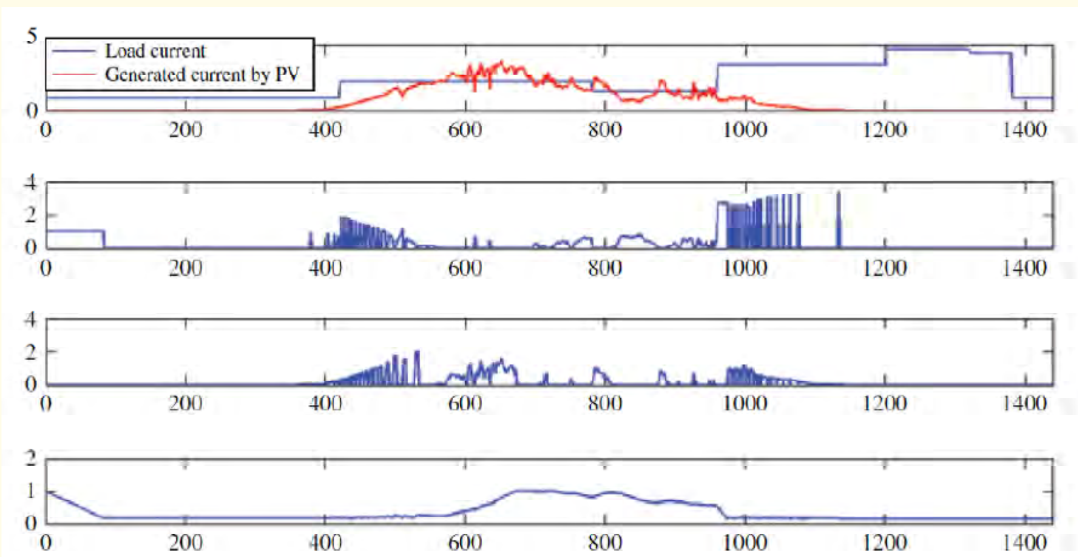
Optimized results



Optimized results



Simulation results (after P2P)



Performance Comparison

Characteristics	DISGI -P2P	ME Sol Share	Grid+	Vandebron	Okra Solar	Brooklyn MG
P2P modelling	Pro,Cons, P2P station	None	None	No	None	Pro,Cons, P2P station
Dynamic pricingstrategy	Yes	Fixed price	Yes (Ethereum)	Yes (Consensys)	Noinfo.	Yes (Ethereum)
Forecasting studies	One-hour	No	One-day	One-hour	No	One-day
Optimum power sharing	Yes	NO	No	No	NO	NO
Scalability	Yes (1mn. nodes)	Noinfo	No	Yes	No info	Yes

Control strategy	2-stage	No control	Full automation	No	None	No control
Energy Management	Decision making by players	Paymentthrough prepaid meters	Grid-interactive demand response	Prosumerbilling	Re-paymentsthroug h crowd funding	On-line tool
Third party intermedia	Centralized P2P station	Onlyfor payment	None	No	None	Full control to third party
Consumer oriented	Fully	Fully	Fully	Fully	Fully	Partial
Grid-ready	Yes	No	Yes	Yes	No	Yes

Conclusion

- Problem formulation
  - Modelling a peer to peer power sharing problem
    - Surplus status of every household
    - Power transmission loss (I2R)
    - Energy management
  - Minimization of power mismatch and transmission loss
  - Scheduling strategy for charging/ discharging of battery and P2P sharing in a DC micro grid scenario.
- P2P trading
  - Real-time P2P trading based on DSR.

Future work

- Cost model of the P2P consumer
- Revenue model of the P2P prosumer
- Performance assessment at micro level:
  - consumer willingness,
  - self-sufficiency,
  - self-consumption.

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- Menno Kardolus, Chief Executive Officer, PRE, Netherlands.
- Evan Mertens, Director of Technical Innovation, Rural Spark, Netherlands and India
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UP ELECTRICITY REGULATORY COMMISSION

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