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Blockchain in Electrical Power Distribution | Solving the evolving complex supply-demand equilibrium

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> "The energy sector has been gradually changing since the beginning of the last decade of the 20th century...[]"

Introduction

The energy sector has been gradually changing since the beginning of the last decade of the 20th century, but it was only after the nuclear disaster in March 2011 at Fukushima Daichi Nuclear Power Plant in Japan that the sector took a step forward towards sustainable energy through a rethink in the policy. Apart from this terrible accident, the implications of climate change, the increasing cognizance of power issues across the world, along with recent ICT, networks and sensors technology advancements, have set in motion a transformative relationship between energy and society.

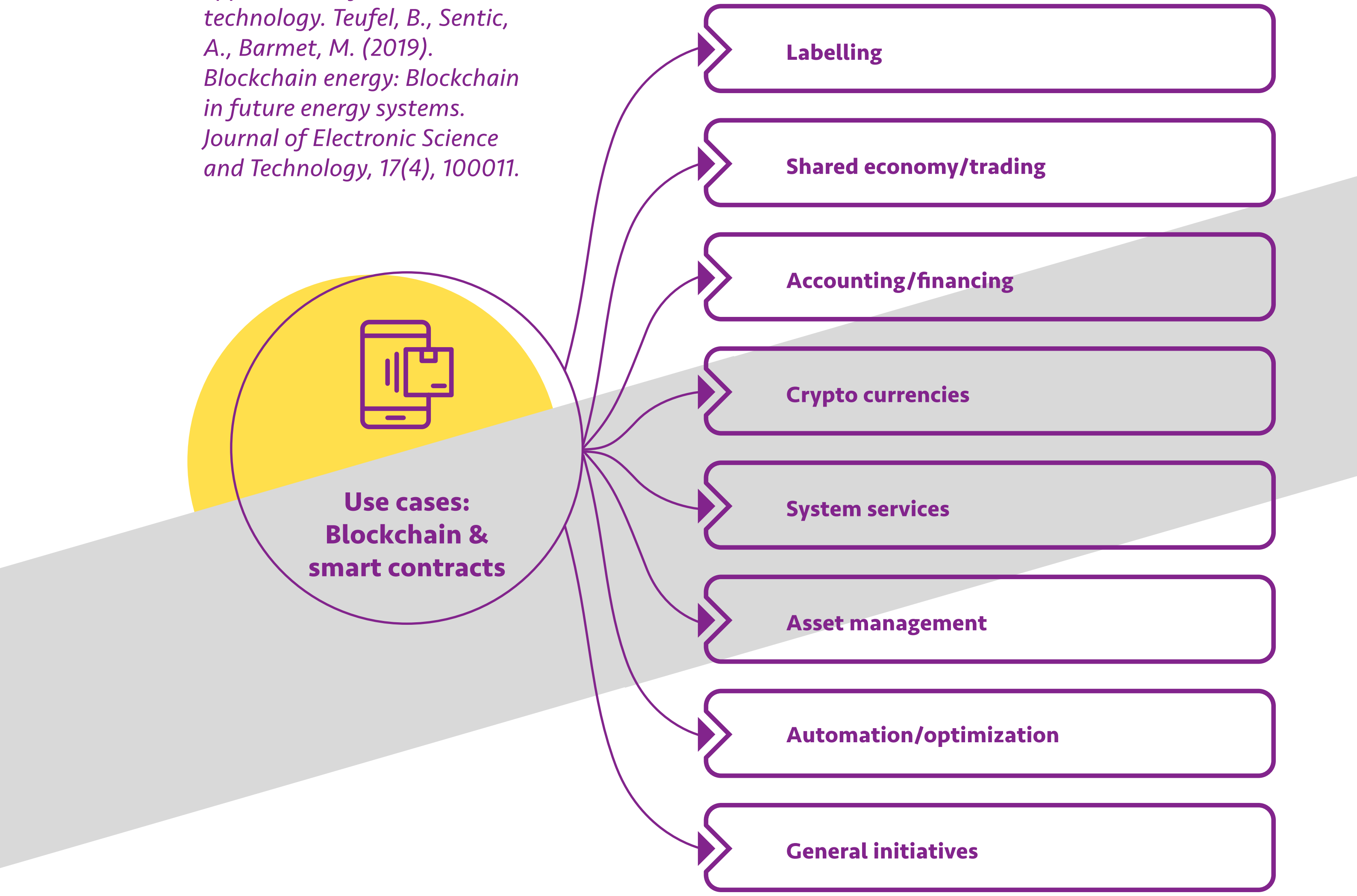
The political decision to restructure the energy systems around the world has led to major challenges from a political and social perspective, in addition to those from a technical and transformational side of things. The transition from traditional infrastructures to a smarter grid allowed a new, decentralized power generation system full of efficient possibilities, such as energy prosumers (producing and consuming energy), crowd energy, and electricity trading on a large scale. This evolution created an enormous pool of buyers and increased numbers of corresponding transactions. Intermediaries started to play a critical role in providing security and reliability, which are essential to establish a robust market.

With the advent of blockchain, which is based on a distributed ledger, where data is stored and accessible in a central place by all network participants, transparency and trust are ensured. This implies all the nodes of the network must agree on data authenticity through a complicated process, known as 'consensus mechanism'. The generated and validated blocks are linked together using a cryptographic hash fusion. Consequently, all participants can keep track of and view the blocks at any time, but they are not allowed to make changes. This ability to secure data against manipulation, promote trust between different users, and guarantee transparency without identity disclosure, is the basis for blockchain to lay the foundation for various applications in the energy sector. In addition to these characteristics, the presence of a smart contract, powered by a computer-aided transaction protocol that executes the terms of a contract, makes blockchain inevitable.

The Munich Research Centre for Energy Economics has conducted a study on the potential of blockchain technology in the energy sector. 160 professionals, operating in critical functions and strategic fields, have identified 90 distinct use cases, that can be grouped into the categories, shown in Figure 1. [1]

1. Teufel, B., Sentic, A., Barmet, M. (2019). Blockchain energy: Blockchain in future energy systems. Journal of Electronic Science and Technology, 17(4), 100011.

Figure 1 | *Categories for applications of blockchain technology. Teufel, B., Sentic, A., Barmet, M. (2019). Blockchain energy: Blockchain in future energy systems. Journal of Electronic Science and Technology, 17(4), 100011.*



SECTION 1

Four key challenges for electric utilities

The emergence of distributed energy resources

Limitations in grid

Privacy of consumer data and security of network

The authenticity of Renewable Energy Certificates (RECs)

1. The emergence of distributed energy resources

Clear and unrestricted support from governments around the globe, and dwindling costs of renewable energy systems have resulted in a drastic increase in the share of solar and wind power generation systems in the last few years. Energy generated from the above systems is expected to reach around 10 percent of the total energy supply by 2022, gradually reducing the dominance of centralized fossil fuel-based plants. [2]

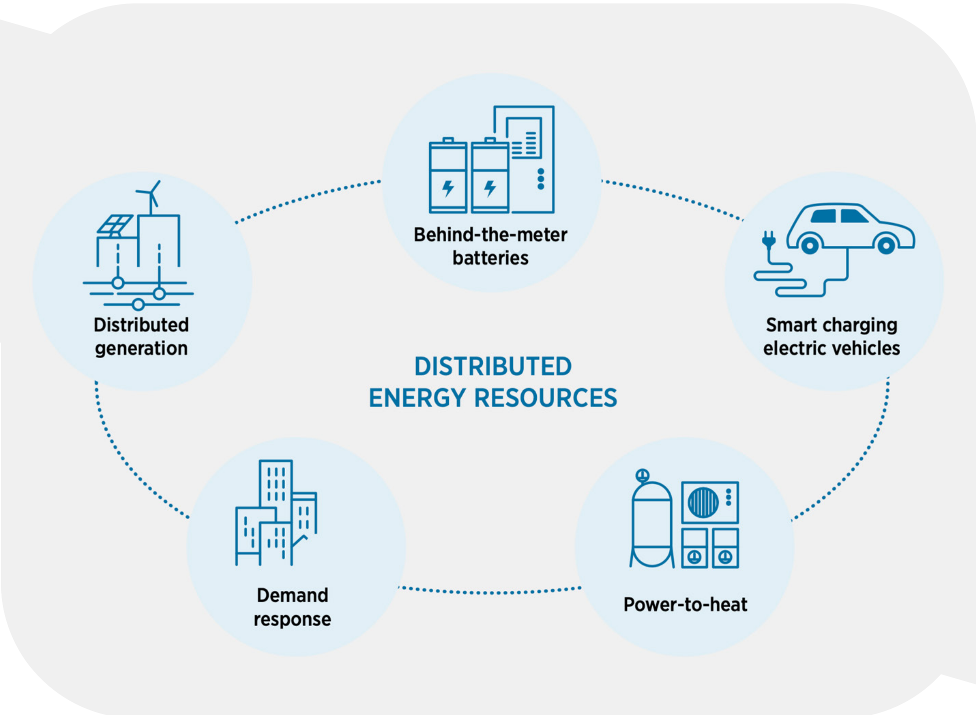


Figure 2 | *ENA. (2020). Innovation landscape brief: Peer-to-peer electricity trading. International Renewable Energy Agency.*

2. Smith, R. (2018, February). Three countries are leading the renewable energy revolution. World Economic Forum.

Energy resources that threaten the dominance of traditional centralized power generation plants include roof-top solar panels, fuel cells, batteries, micro turbines, and other small-scale energy generation units. Although a significant quantity of renewable sources is deployed on large scales, solar energy systems, in particular, are being installed in a decentralized manner in the rooftops of residential and commercial buildings.

Along with power generation systems, consumers are also installing many types of equipment to manage their power consumption, including building energy management systems. [3] These are making the work of traditional power distribution companies challenging, given they are used to operate in a centralized and top-down manner.

2. Limitations in grid

Traditionally, utilities or power distribution companies have been operating based on a centralized grid concept. However, due to the increasing customer demand for more flexible power sources, businesses aimed to manage supply by assessing more variables, like solar and wind energy. Nevertheless, limitations still occur, with power outputs highly dependent on weather conditions.

Thus, rendering the operation of the grid is even more complex.

In addition, reduction in energy systems price is increasingly empowering customers to install localized energy generation systems, including roof-top solar power plants and smart devices capable of managing electricity consumption, like on-site batteries, and energy management software, to alter their demand based on prevailing electricity rates and hence save on electricity bills. Although these systems could help the grid balance supply and demand in the long run, they add complexity to the conventional model of centralized grid management. [4]

3. Kumar, N. M., Chand, A. A., Malvoni, M., Prasad, K. A., Mamun, K. A., Islam, F., Chopra, S. S. (2020). Distributed energy resources and the application of AI, IoT, and blockchain in smart grids. Energies, 13(21), 5739.

4. Clarion Events (2012, January). The impact of smart grid and traditional generation.

In traditional power systems, power generation, transmission, and distribution have been considered separate processes. Due to various distributed generation (DG) systems in recent years, the conventional approach to power system management is also gradually changing. DGs play a vital role in the modern smart power system, but conversely, the integration with existing power networks remains a challenging process.

Distributed generation systems have both positive and negative impact on power transmission and distribution. Nevertheless, given that DGs are directly connected to the distribution network, the major problem lies on a distribution level. This is mainly due to the fact that traditional power grids have not been designed to accept the unidirectional flow of power, from transmission lines to consumer. This means the current setup of integrated distributed networks can cause voltage regulation issues, and restrictions in power handling and quality. Furthermore, with the advent of solar and wind energy plants, more concerns appear regarding supply reliability, in terms of DGs and DERs integration, associated with technical, commercial and regulatory matters. [5]

3. Privacy of consumer data and security of network

Smart meters have become ubiquitous and are being used to record information such as energy consumed, voltage levels, current, and power factors at various times of the day. These are then sent to the consumer to gain insights about their usage, and to the electricity distributor to understand their demand requirements at various intervals throughout the day. [6] The US had installed around 100 million smart meters as of year-end 2019 [7] , while the European Union, and the UK, has set a target to reach a total of 223 million smart electricity meters installation by 2024, up from 99 million as of 2018.[8]

5. Khetrapal, P. (2020). Distributed Generation: A Critical Review of Technologies, Grid Integration Issues, Growth Drivers and Potential Benefits. International Journal of Renewable Energy Development, 9(2).

6. Wikipedia. (2006, January). Smart meter.

7. Cooper, A., Shuster, M. (2021). Electric company smart meter deployments: Foundation for a smart grid (2021 update).

8. European Commission. (2019, March). Benchmarking smart metering deployment in the EU-28: Final report.

Given smart meters enable strong network connectivity, sensors, and controls to interact with the local environment, they fall into the same categories with IoT devices. This means they face potential data privacy risks, associated with wider networks. Since they are connected by default with many devices installed in any environment, like home appliances, they can allow unauthorized access from precarious networks. This can cause harm in the smart meter functionality, including the provision of energy. This makes it a two-face threat, affecting both consumers and energy suppliers, with malicious actors extracting data or compromising consumption values. [9]

4. The authenticity of Renewable Energy Certificates (RECs)

Clean energy suppliers provide RECs to utilities entities or governments to meet their state-mandated clean energy goals. Every certificate represents 1 megawatt hour of renewable energy. RECs credits have become an annual USD 3 billion market for utilities sector and companies aiming to voluntarily reduce environmental impact. [10] To ensure authenticity, each of them is given a unique identifier, which indicates the type of renewable resource from which the energy is generated, the location where a plant is located, the time stamp for power generation, and the emissions' profile. ***The tracking system is established to adhere to the following standards:***

9. Riemann, R. (2019). TechDispatch #2: Smart meters in smart homes

10. Jossi, F. (2020, April). Could blockchain make it easier to buy and sell renewable energy certificates? Energy News Network.

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