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Changing power: Shifting the role of electricity consumers with blockchain technology – Policy implications for EU electricity law

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A B S T R A C T

One of the pressing legal questions of the energy transition is how to integrate *"prosumers"*, consumers who start producing electricity, in the electricity market. So far, their influence remains limited or fully absent because their role as independent market participants is barely or not facilitated as they are usually subject to regulated remuneration schemes. Blockchain technology offers changing the approach of *"integration in the market"* into *"becoming the market"* by enabling peer-to-peer transactions. Currently, transactions are facilitated by third parties, suppliers and system operators, whose main task is centrally compiling and coordinating information on loads and generation and contracting supply and distribution services. Instead, blockchain technology enables new ways of organising decentralised persons without the immediate need for one centrally connecting entity. This implies profound legal- and policy consequences. Based on information on first use cases of blockchain applications in the electricity sector, this article identifies those main policy implications for EU electricity law and thereby adds to the discussion how blockchain technology could facilitate *"prosumers"* to develop as independent market participants in the electricity sector from an energy law perspective.

1. Introduction

The energy transition towards a low-carbon society is high on the agenda of European Union (EU) policymakers and it has been acknowledged on EU level that this transition needs to be *"consumer centred"* (EU Commission, 2016a). Notably, the integration of consumers in the electricity sector through *"prosumers"* or *"aggregators"* is seen as key to the attainment of this transition. Under the heading *"putting consumers at the heart of the energy market"*, the EU Commission states that

> *"Fully integrating industrial, commercial and residential consumers into the energy system can avoid significant costs for 'backup' generation; costs which consumers would otherwise end up paying. It even allows consumers to benefit from price fluctuations and to earn money through participation in the market. Activating consumer participation is therefore a prerequisite for managing the energy transition successfully and in a cost-effective way."* (EU Commission, 2016b).

The EU Commission thus foresees empowering consumers as essential part of the energy transition (Lavrijssen, 2017). The emergence of blockchain technology possibly further advances the role of consumers by introducing the possibility of peer-to-peer (P2P) transactions in the electricity sector.[1] This would challenge the current governance structures of the sector as established by EU electricity law which are tailored to a centrally organised sector. In this article, centrally organised sector refers to an electricity sector with large remote generation mainly based on conventional sources, high-voltage transmission systems serving as *"backbones"*, low-voltage distribution systems as *"appendages"* passing on electricity to the point of final consumption, the loads (Bouffard and Kirschen, 2008; Goldthau, 2014). EU electricity law defines actors and subsequent rights and responsibilities along this conventional electricity supply chain (producers, transmission- and distribution system operators, suppliers, and consumers). The application of blockchain technology in the sector would cut through those well-defined actor definitions. The focus of this article is on exploring how blockchain technology potentially changes the role of consumers

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[1] Peer-to-peer means that users are directly interacting with each other, without an intermediating entity. Blockchain technology enables new ways of organising decentralised persons without the immediate need for one central connecting entity. Often, blockchain technology is applied for tracking transactions and therefore referred to as ledger technology. The idea and functioning of blockchain technology is further explained in Section 3 of this article.

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who have so far been at the end of the supply chain as largely passive market participants and subject to a protective legal framework.[2] Subsequently, this article aims at identifying main policy implications for a legal framework which enables blockchain technology applications in the electricity sector.

The importance of analysing the emergence of blockchain technology in the context of the electricity sector is not only given by the technical novelty of blockchain, but also by the ongoing discussion about energy law as a discipline (Heffron and Talus, 2016a). Currently, the development of energy law often takes place in what is referred to as "silo thinking", meaning that the legal development of organising the goals of security, sustainability, and market regulation in the energy sector evolve in parallel instead of in close relation (Heffron and Talus, 2016b). The EU policy aim to *place the consumers at the heart of the market* by empowering them and the emergence of blockchain technology exemplify the need to facilitate a shift in energy law from "silo thinking" towards a more holistic approach in energy law. This article thus argues that blockchain technology is a possible technical mean to facilitate the policy aim of empowering consumers in the energy transition, but this also requires the legal framework of the electricity sector to evolve by breaking the existing "silo thinking".

The urgency to further the evolution of energy law as a discipline is provided by a variety of developments of which one of them is facilitating low-carbon energy sectors (Heffron et al., 2018). A more specific example of how this development challenges the current legal framework and which is of central relevance for this article is decentralisation of the electricity sector. While the decentralisation of electricity generation on the basis of renewable energy sources (RES) and increasing electrification, for example by electric vehicles, is driven by technical sophistication and financial incentives, decentralisation in governance structures has not yet materialised in EU electricity law (Galera Rodrigo, 2016; and Lammers and Diestelmeier, 2017). Blockchain technology promises coupling the technical decentralisation of the energy transition with decentral supply and distribution structures. This article aims at exploring the idea of blockchain technology application in the electricity sector in greater detail in order to identify policy implications for the EU legal framework of the electricity sector. Therefore, this article seeks to analyse the research question *"what are policy implications of blockchain technology applications in the electricity sector for EU electricity law and the role of consumers?"* As the application of blockchain technology is only emerging in the electricity sector and regulatory questions from an energy law perspective have been barely touched upon, this article provides an explorative approach on prospective policy and legal challenges regarding blockchain technology application in the EU electricity sector. In order to answer the research question this article outlines the idea and functioning of blockchain technology in general and first use cases of blockchain applications in the electricity sector and then contrasts the emerging governance structures with current EU electricity law. Subsequently, the article deduces policy implications for a legal framework for blockchain technology in the electricity sector regarding the changing role of consumers and identifies major topics for further research which also require furthering energy law as a discipline.

This article unfolds in the following main sections: Section 2 provides the background by outlining the incumbent EU legal framework applicable to the electricity sector and by introducing the idea of smart grids, and subsequently identifying the quest for P2P transactions in decentral smart electricity systems. Section 3 describes blockchain technology, how it facilitates trust and explores first use cases in the electricity sector. Section 4 then identifies policy implications for a legal framework which enables blockchain technology applications in the electricity sector. Section 5 concludes by identifying main follow-up research questions.

2. Background

This section provides an overview of the current EU legal framework of the electricity sector with a focus on the roles and responsibilities of actors, especially consumers (Section 2.1). This section also describes the idea of smart grids which further explains the context of the emergence of blockchain technology application in the electricity sector (Section 2.2).

2.1. Outline of the current EU legal framework of the electricity sector

The current legal framework of the EU electricity sector developed along the main policy goals to ensure secure, competitive, and sustainable electricity supply.[3] Accomplishing those goals bears potential conflicts and is therefore sometimes referred to as *"energy policy trilemma"* (Oliver and Sovacool, 2017). At EU level those policy goals are enshrined in several legislations which define the main actors and their tasks in the sector (mainly the Directive concerning common rules for the internal market in electricity, (EC) No 2009/72, in the following "Electricity Directive 2009"). Additionally, the aim to foster RES materialises in binding targets of RES shares in gross final consumption and the option to establish national support schemes (Directive on the promotion of the use of energy from renewable sources, (EC) No 2009/28, in the following "RES Directive"). The next two sections outline the main governance structures and RES goals as established by EU legislation.

2.1.1. Governance structures

The governance structures of actors in the EU electricity sector are determined by the technical setting of the system and the aim to establish a liberalised EU internal electricity market. The technical setting is characterised by large remote generation based on conventional sources which serve the connected loads. EU electricity law generally affirms this setting by assigning roles and responsibilities to actors along this *"top-down"* supply chain (Lavrijssen, 2017).

With the aim to liberalise the sector and subsequent measures breaking vertically integrated utilities, companies which control the whole supply chain, the legal framework progressively unbundled potential market activities, generation and supply, from transmission and

[2] Directive (EC) No 2009/72 Concerning Common Rules for the Internal Market in Electricity and repealing Directive 2003/54/EC [2009] OJ L211/55 specifies different types of consumers. This article focuses on consumers who are connected to the distribution grid, those are typically small or medium sized enterprises and household customers. Directive (EC) No 2009/72 defines "household customers" in article 2(10) as *"a customer purchasing electricity for his own household consumption, excluding commercial or professional activities"*.

[3] Those three main objectives continuously emerged and developed in EU policy documents and subsequent legislation which is further outlined in the subsequent sections. The EU Commission reiterated those objectives in various documents in the last decades. For example Commission of the EU, Communication on Energy Roadmap 2050, COM(2011)885 final, 15.12.2011, 2; Commission of the EU, Communication on Energy 2020: A Strategy for Competitive, Sustainable, and Secure Energy, COM(2010) 639 final, 10.11.2010, 2; Commission of the EC, Communication on an Energy Policy for Europe, COM(2007) 1 final, 10.1.2007, 3–4; Commission of the EC, Green Paper on a European Strategy for Sustainable, Competitive and Secure Energy, COM(2006) 105 final, 8.3.2006, 3. Furthermore these objectives are also enshrined in primary EU law in article 194 of the Treaty on the Functioning of the European Union (TFEU) which establishes that the EU energy policy aims shall aim at the functioning of the internal energy market, ensuring security of energy supply, promoting energy efficiency and RES, and interconnection of energy networks.

distribution system operation (Arentsen and Künneke, 1996; Jamasb and Pollitt, 2005). The actors along this supply chain are producers, transmission system operators (TSO), distribution system operators (DSO), suppliers, and customers. In the course of the liberalisation process, the role of customers also changed as they were not bound to their local utility company, but were enabled to choose freely among different suppliers. However, the liberalised market setting also required a protective framework for customers who were considered to be the weaker market participant and dependent on reliable electricity supply. The Electricity Directive 2009 therefore established under article 3 the option for member states to implement public service obligations and consumer protection measures. Subsequently, the Directive establishes an obligation for DSOs to connect customers and the right for customers to be supplied by a supply company. By assigning specific roles and tasks of delineated actors EU electricity law aims to facilitate a competitive market for generation and supply and at the same time to protect consumers in the liberalised electricity market setting.

2.1.2. Renewable energy aims

Next to liberalisation efforts which progressively delineated actors in the sector along network- and market realms, the goal to establish a low-carbon electricity sector developed steadily on EU level and is mainly justified by two underlying concerns. Firstly, reducing greenhouse gas (GHG) emissions and fostering subsequent environmental benefits, and secondly, ensuring security of supply by increasing independence from fossil fuel markets and thereby tackling the challenges of unpredictable energy prices and possible geopolitical changes (Fräss-Ehrfeld, 2009).

The RES Directive establishes binding targets for each member state of the RES share in gross final consumption by 2020 (Commission of the EC, 2009).[4] Subsequently, the Directive allows for support schemes, which are broadly defined in article 2(k) as any instrument, scheme or mechanism that promotes the use of renewable energy by reducing its cost, increasing its sales price or its purchased volume. The rationale behind those measures is to reduce investment uncertainties in RES technologies. Financial incentives also encourage actors other than conventional well-established generation companies to engage in electricity generation on basis of RES. Persons who have been exclusively electricity consumers so far have begun installing small-scale generation, for example photovoltaic panels, on their premises behind the metering point (EU Commission, 2017). As they remain dependent on electricity provided by a supply company and therefore continue being consumers, they are often referred to as “prosumers”, an artificial term constructed from the words “producer” and “consumer”. As the role of prosumers in the electricity sector is the focus of this article, the remainder of this article applies the term “prosumer”, although legally speaking those actors usually remain “consumers” yet. The following section further outlines those developments and related governance challenges.

2.2. The electricity sector in flux

The above outlined efforts to liberalise the electricity sector and to reduce carbon emissions enabled and incentivised increasing amounts of small-scale generation connected to the distribution grid (decentral generation) and “prosumption” (EU Commission, 2017). Those developments not only challenge the technical setting of the electricity system as increasing amounts of bidirectional variable flows of electricity are stressing the grid capacity, but also the incumbent governance setting of the sector as consumers are not merely consumers anymore but evolve into *“prosumers”*. The following sections introduce the idea of smart grids as technical solution to those developments and identify the changing role of prosumers in smart electricity grids. This further leads to the question how to integrate prosumers in the electricity sector and to the idea of P2P transactions by means of blockchain technology.

2.2.1. Smart electricity grids

One of the main challenges of accomplishing a low-carbon electricity society by means of RES is the variable character of RES. Variability means that the availability of energy sources depends on seasons, the time of the day, and weather conditions. Since those factors do not necessarily coincide with the demand for electricity, idle peaks of high generation and peak demand at times of low generation cause energy inefficiencies (Veldman et al., 2013). Merely increasing the amount of generation of electricity from RES will thus not lead to the desired low-carbon electricity society. Equally important is using RES and the grid infrastructure efficiently (International Energy Agency, 2014). Smart electricity grids aim at to incorporating efficiency gains as core maxim for electricity grid design and system operation. In this way, smart grids constitute an alternative to the integration of decentral RES by means of costly grid extensions and balancing generation reserves (Clastres, 2011; Moura et al., 2013; Poudineh and Jamasb, 2014). The key to maintain efficiency while integrating RES is to harness flexibility in consumption and turn the current demand-driven system in a supply-driven system (Lund et al., 2015).

Harnessing demand flexibility requires a constant exchange of data on loads, generation, and grid capacities among system users and system operators. Additionally, demand flexibility can be enhanced by flexibility technologies, such as storage, including electric vehicles, or what is referred to as “smart home technologies”.[5] Smart electricity grids can thus not be captured by an exhaustive definition of technologies, but can be understood as a changing rationale in electricity system operation as the demand-side is considered as flexible and active part in the supply chain. While this is primarily a technical approach to the problem of growing amounts of variable RES at distribution grid level, the core idea of harnessing demand flexibility inevitably changes the role of consumers and therefore also implies challenges to the current governance structures as established by EU electricity law (Huhta, 2017). The following section outlines the changing role of consumers.

2.2.2. The changing role of consumers

Even though smart electricity grids are not yet implemented beyond pilot projects, first findings indicate that smart electricity grids will necessarily include a variety of actors who are not yet existent in the electricity sector (EU Commission Joint Research Centre, Institute for Energy and Transport, 2017). One of the most prominent changing actors are consumers who have been passively consuming electricity and now start engaging with electricity generation (European Commission, 2017; Schleicher-Tappeser, 2012). Not only could consumers start selling generated electricity, but, as outlined in the preceding section, they could also offer flexibilities in demand and provide balancing services for maintaining system operation which becomes increasingly valuable for integrating variable RES (Dupont et al., 2014; Kubli et al., 2018; SmartNet Project, 2016).

The potential of demand flexibility is assessed as very high across Europe.[6] However, activating this demand flexibility requires

[4] The targets for the individual member states are established in Table A of Annex I of that Directive.

[5] *“Smart home technologies (SHTs) comprise sensors, monitors, interfaces, appliances and devices networked together to enable automation as well as localised and remote control of the domestic environment. Controllable appliances and devices include heating and hot water systems (boilers, radiators), lighting, windows, curtains, garage doors, fridges, TVs, and washing machines”*. (Wilson et al., 2017).

[6] A study determines an amount of 93 GW(gigawatt) hourly average for load reduction (delaying or shedding) and 247 GW for load increase (advancing

incentives for consumers to adjust their demand according to generation and grid capacities close to real-time. Those incentives need to be established by the legal framework. Currently, consumers are mainly contracting electricity supply- and distribution services for flat-rate, location independent tariffs (Faerber et al., 2018). Electricity which is not self-consumed is remunerated according to national support schemes or compensation mechanisms:

> *"There are three different systems in EU Member States: some systems enable prosumers to feed the electricity to the grid but only if it is done for free, others offer prosumers regular compensation for their surplus electricity through a reduction in their energy bills, whilst some systems establish a financial retribution at a price of the electricity sold."* (EU Commission, 2017).

These systems do not entail any incentive to adjust demand according to the availability of variable RES and grid capacities. The contrary is the case, as the current legal framework incentivises the generation of RES which fosters stress on grid capacities, energy inefficiencies are exacerbated. Utilising variable RES thus requires flexibility technologies (e.g. storage, electric vehicles, or smart home technologies) installed at the demand-side and market structures which render the currently passive electricity consumers in active market participants (Lavrijssen, 2017; Diestelmeier and Kuiken, 2017).

With the availability and transparency of information on real-time prices, consumers could even start engaging in direct transactions (Bellekom et al., 2016; Lavrijssen, 2017). This idea is further accelerated by the emergence of blockchain technology. The following sections introduce the idea and emerging applications of blockchain applications in the electricity sector which potentially change the role of consumers towards active market participants.

3. Shifting the role of electricity consumers with blockchain technology

The prospective changing role of consumers in smart grids evoked the question how to integrate those new actors in the governance structures of the electricity sector (Gangale et al., 2013; Shandorkova et al., 2012,). Blockchain technology promises enabling consumers to evolve into independent market participants who engage in market transactions. While this would further empower consumers, this would inevitably revoke their incumbent role as established by EU electricity law. This section explains how blockchain technology could facilitate P2P transactions in the electricity sector.

The next sections depart from explaining trust as a precondition for transactions (Section 3.1), then turn to the question how blockchain technology can provide for trust by two different technology designs, namely *"permissionless"* design (Section 3.2.1) and *"permissioned"* design (Section 3.2.2). The different designs are relevant as they have implications on the role of consumers and governance structures in the electricity sector. This is further exemplified by introducing two different use cases of blockchain applications in the electricity sector (Section 3.3). The final section (Section 3.4) claims that the technology design determines the role of actors in the sector. Therefore, the governance over the technology design is crucial.

3.1. Trust as a precondition for transactions

Envisaged P2P transactions in the electricity sector are sometimes compared to developments in other sectors which have been transforming by means of the availability and transparency of information, such as most famously the car-sharing business with *"Uber"* and the vacation housing sector with *"AirBnb"* (Kolokathis and Hogan, 2018). The underlying idea of those businesses is to exploit unused capacities in housing and cars by connecting peers possessing or searching for those resources. In this context reference is often made to what is called *"sharing economy"*. In its most basic form *"sharing economy"* can be understood as follows: *"consumers granting each other temporary access to under-utilised physical assets ("idle capacity"), possibly for money."* (Frenken et al., 2015). The three key elements are thus *"user-to-user transactions"*, *"temporary access to a good"*, and *"remuneration"*.

Harnessing those unused capacities of resources by means of sharing experiences a novel revival facilitated by the online world and subsequent digital platforms. This revival is enabled by new ways of extending a trusted network as illustrated as follows:

> *"Historically, although there are some exceptions, people tended not to share with strangers or those outside their social networks. Sharing was confined to trusted individuals such as family, friends and neighbours. Today's sharing platforms facilitate sharing among people who do not know each other, and who lack friends or connections in common."* (Frenken and Schor, 2017).

This observation comes to the core of a precondition for sharing, or transacting, namely trust among the parties. The development of extended trusted networks through digital platforms is even furthered by blockchain technology by offering cryptographic ways of tracking transactions. The following sections introduce blockchain technology, how it provides for trust and potentially renders current consumers into transacting peers in the electricity sector.

3.2. Blockchain as trust-substituting technology: core components and nuances

Blockchain is a technology which can take different forms and functions in its application, usually for the purpose of tracking transactions, a ledger technology. The core component of blockchain technology relates to its verifying function of transactions by combining *"hashing"* and *"public key infrastructure"*. Hashing transforms information into a unique digit combination. Additionally, *"hash pointers"* link hashes and thereby create an interrelated data chain. The blockchain undertakes this for a large number of information pieces by compiling them into *"blocks"* and *"chaining"* the blocks via hash pointers. Public key infrastructure is the authentication of parties entering into transactions. A public and a private key are needed for encrypting and decrypting information of transactions (Bacon et al., 2017). This summarised explanation of blockchain technology remains highly limited, but it describes its core functionalities, namely ensuring data integrity and user authentication which are the core components of trust in transactions. While in the traditional settings of transactions these trust components are integrated with one central actor, an intermediating entity, blockchain technology enables users to act as verifiers in transactions. This dilutes the immediate need for a middleman facilitating transactions raising the idea that blockchain technology might compete and contest with existing companies and markets (Davidson et al., 2016).

It is important to note that there are different types of blockchain technologies. While this article does not aim at exhaustively exploring all technical differences, it is relevant to identify differences regarding the nature of assets that are transacted on the blockchain and the actors and their role in the functioning of blockchains. Both are relevant for blockchain technology application in the electricity sector.

As mentioned, blockchain technology is usually applied as a ledger technology which means it records the ownership and transaction of specific assets. Those assets can be of different nature. Assets might only exist on the blockchain (*"on-chain assets"*), which is then referred to as

(*footnote continued*)
demand to an earlier time). The study extends beyond member states of the European Union as it includes 40 countries in Europe. The study includes demand response potential from industry, tertiary sector, and residential consumers (Gils, 2014).

"pure system". This is for example the case for *"BitCoin"*, a blockchain technology-based cryptocurrency, as the coins do not represent any real-world asset. Blockchain-based ledgers can however also represent real-world objects or values, such as land, shares, or possibly electricity or electricity demand flexibility. Applying blockchain technology for off-chain assets is much more complicated *"[…] because the existence of and rights in such assets are not determined solely by the ledger"* (Reed et al., 2017). The issue of assets is further addressed in the section on blockchain use cases in the electricity sector (Section 3.3).

Next to recording different types of assets, blockchains can also differ in their governance structures. Generally, the functioning of blockchain technology involves the following three user groups: users, who engage in transactions, nodes, which store copies of the ledger, and miners who propose new blocks (Bacon et al., 2017). What distinguishes the different blockchain designs are the roles which the actors can take. The designs are usually referred to as *"permissionless"*- and *"permissioned"* blockchain. Both designs have advantages and disadvantages depending on the purpose and the setting of their application (Bacon et al., 2017; Buterin, 2015). The following two sections introduce the two different technology designs, which are then identified in the blockchain use cases in the electricity sector (Section 3.3).

3.2.1. Permissionless design

The difference in blockchain technology designs is the way how trust in transactions is facilitated. In its original and most widely known application *"BitCoin"*, the design of the technology is *"open"*. *"Open"* (or also *"permissionless"* or *"public"*) means that any user can engage in transactions, store copies of the ledger, and can propose new blocks. This design is often referred to as *"fully decentralised"* and considered to be the epitome of decentralised organisation as all information about transactions is distributed and shared among all users (Nakamoto, 2008; Buterin, 2015).

This setting provides for trust by engaging all users in the entire functioning of the blockchain and thereby internalising verification among all users. Trust in transactions is thus inherent in the design of the technology and thereby dissolves the need for verifying by central middlemen. In this way, permissionless blockchain technology design goes beyond the possibility of a central digital platform and sparks the idea of dissolving central ownership and control models by novel forms of decentral organisation. *"The blockchain turns the entire network into its source of truth. It's a mechanism […] to collectively confer legitimacy on one another. That's why it appeals to the same people who fell in love with the Internet and the Web 20 years ago: No individual or company owns it, and anyone can participate in it."* (Rosenberg, 2015).

Permissionless blockchain design thus provides for the main advantage of empowering every user to engage in the functioning of the blockchain and thereby dissolving the risk of a central entity abusing its control over transactions among the peers. However, this open design can also create challenges, such as the impossibility to reverse transactions, costly verifying processes, and threats of collusions (Buterin, 2015). These challenges are mitigated in the closed, permissioned design of blockchain technology.

3.2.2. Permissioned design

In a *"closed"* (or also *"permissioned"* or *"private"*) blockchain design not all actors are enabled to engage in all blockchain activities. Here, a trusted third party (TTP) or a limited number of determined nodes (consortium blockchain) function as the trusted node(s) for storing the ledger and updating it with new blocks (Bacon et al., 2017). This design requires some degree of trust of the users in the TTP or the predetermined nodes. Thus, permissioned blockchains do not correspond with the idea of enabling fully decentralised settings in which all users act as verifiers.

In contrast to permissionless blockchain design, the context of permissioned blockchain application needs to be a trusted environment, for example within an institution or among a small user group. Trust is thus not inherent in the design of the blockchain but also needs to be provided by external factors. This limits the original idea that the network is its own source of truth and independent of a specific individual or company. The advantage of this design is that it eliminates challenges evoked by permissionless blockchain designs as the validators (either a TTP or a limited number of nodes) are known. This allows for reversing transaction more easily, mitigating costs of validation processes as only a limited number of nodes are involved in the process, and preventing the risk of collusion (Buterin, 2015).

Permissioned blockchains rely on the role of a TTP and thereby do not empower users to the same extent as permissionless blockchain design does. Whether the advantages of permissioned blockchains outweigh the more limited extent of empowerment probably depends on the context and purpose of the respective blockchain application. The following sections introduce first use cases of blockchain application in the electricity sector with a focus on the choice of the design and the assets.

3.3. Blockchain technology in the electricity sector: first use cases

The previous sections explained how blockchain technology provides for trust in transactions via two different technology designs. Currently, trust between transacting parties in the electricity sector is facilitated by supply companies and system operators. They connect producer and consumer, and contract supply and distribution services. This section explores how the existing central model of organising transactions is challenged by blockchain applications in the electricity sector.

First reports and pilot projects explore the potential of blockchain technology for the electricity sector and, despite merely observing an initial phase of emergence, overall conclude that blockchain technology could take over several functions in the electricity sector (Verbraucherzentrale NRW, 2016; Deutsche Energieagentur GmbH and European School of Management and Technology, 2016; and Green and Newman, 2017). Overall, those reports and studies argue that blockchain promises a way for coordinating distributed persons offering or demanding electricity supply and distribution services, and thus enabling a more decentralised market setting. *"They* [blockchains] *coordinate a distributed group of people, making them actually closer to being an economy"* (Davidson et al., 2016). In that sense, blockchain potentially bears the option for the participating peers to become the market instead of being integrated in existing market settings. This relates to the idea that blockchain technology is more than a technological innovation but an alternative to existing markets and organisations, and is therefore also referred to as *"new institutional technology"* (Davidson et al., 2016). The following sections introduce two use cases of blockchain technology in the electricity sector and the respective technology design.

3.3.1. Electricity supply

As mentioned above in Section 2.2, the electricity sector is in flux of which one element is the emergence of prosumers. Surplus electricity generated by prosumers is usually compensated according to regulated remuneration schemes (see Section 2.2.2). In none of those schemes prosumers are facilitated to develop as independent market participants resulting in efficiency losses in RES utilisation. Blockchain could enable the development of prosumers as market participants by facilitating P2P electricity supply, the direct transaction between a producer and a consumer in the electricity sector. Essentially, this would extend the market realm to the current consumer level and ideally facilitate the efficient exploitation of decentral RES sources which are currently rather perceived as burdensome and not well integrated in the electricity market.

The application of blockchain as enabler of P2P supply is implemented and tested by the Australian company *"Power Ledger"*. Despite the fact that the company is based in Australia, insights in blockchain-based P2P electricity supply can serve as relevant source beyond the Australian context, for example the EU. Essentially, the company establishes a market platform especially for RES enabling decentralised transactions among producers, consumers, and those who do both (Gifford, 2016). The platform promises

> *"[…] to simply trade electricity with one another and receive payment in real-time from an automated and trustless reconciliation and settlement system. There are many other immediate benefits such as being able to select a clean energy source, trade with neighbours, receive more money for excess power, benefit from transparency of all your trades on a blockchain and very low-cost settlement costs all leading to lower power bills and improved returns for investments in distributed renewables."*[7]

The platform of *"PowerLedger"* is composed of different interrelated technology layers, which apply two different blockchain designs. One is permissionless and operates globally; this allows anyone to invest in the platform by buying market access. The other one is a permissioned blockchain (consortium design with several parties as trusted nodes), which operates as trading platform for peers. Here, the trusted nodes are so called *"application hosts"*, entities running an application on the platform (Powerledger, 2018). Powerledgers' aim is however to progress towards the public also being involved in securing the network and to enable a fully permissionless blockchain in 2019 (Powerledger, 2018). The platform applies two different tokens as assets. *"POWR"* tokens are needed to gain access to the P2P trading platform applications, the market. *"Sparkz"* are the trading currency and represent the electricity price and the local "real-world" currency. In this way, the system ensures value via *"POWR"* tokens and facilitates exchange through *"Sparkz"* (Powerledger, 2018).

The vision of the company is to enable a low-carbon electricity society by means of empowering individuals and communities (Powerledger, 2018). This vision corresponds with the view of the EU Commission aiming at *"fully integrating industrial, commercial and residential consumers into the energy system"* (see introduction). Blockchain technology might thus be a promising tool to achieve this objective. Section 4 identifies potential policy implications of blockchain-based P2P application for the EU legal framework of the electricity sector.

3.3.2. System operation

Next to P2P supply of electricity blockchain technology could also enable consumers to directly contribute to maintaining grid stability, the technical requirement to keep the system in balance. Under the current system, balancing tasks are located at the high-voltage transmission level of the system and flexibility is mainly provided by the supply side. As outlined above in Section 2.2, with increasing amounts of RES generation, system operation will increasingly need to rely on measures harnessing demand flexibility, also at the low-voltage distribution grid level (Kondziella and Bruckner, 2016). Demand flexibility can be enhanced by a larger variety of flexibility sources. However, with a larger number and variety of flexibility sources the complexity of organisation for system operation increases. Blockchain technology could enable organising decentralised flexibility sources of system users.

The idea to apply blockchain technology for harnessing demand flexibility for system operational purposes is implemented and tested by the consortium of *TenneT* (TSO), *sonnen* (a battery provider for small consumers), *Vandebron* (P2P trading platform), and *IBM* (open source blockchain provider) which launched in 2017. Jointly, the consortium started two pilot projects in the Netherlands and Germany in which electric cars and home batteries of consumers are utilised to contribute to maintaining the electricity system in balance (TenneT, 2017a). The overall rationale is to enable cost efficient integration of RES by demand flexibility instead of grid reinforcement and balancing reserves on basis of conventional energy sources. In the announcement of the projects the consortium highlights that these projects offer *"citizens the opportunity to actively participate in the energy transition."* (TenneT, 2017b).

The project applies a permissioned blockchain platform design. The reason for the choice of this design might be the determined transaction setting. The consumers provide the TSO with flexibility by means of their electric cars or their home batteries. The transaction structure is thus not P2P as consumers are not directly trading among each other, but bidirectional between the consumers and the TSO. Trust in the TSO is thus already a precondition for entering into transactions. Section 3.2.2 on permissioned blockchain designs described this as an external factor providing for trust which does not need to be substituted by blockchain technology design. Permissioned blockchain design with the TSO as TTP and a limited number of users can thus be applied.

The two cases show that blockchain technology application in the electricity sector can take various forms by means of different designs. The following section draws a preliminary conclusion on this observation regarding governance structures in the electricity sector.

3.4. Governance over technology design

This section introduced the core components of blockchain technology, its nuances, and how it is applied in first use cases in the electricity sector. The design of blockchain technology determines the role of prosumers as potential independent market participants in the electricity sector. *"In general, the idea that there is "one true way" to be blockchaining is completely wrong headed, and both categories* [permissionless and permissioned design] *have their own advantages and disadvantages."* (Buterin, 2015). This is also true for the blockchain application in the electricity sector as blockchain could fulfil several functions as the two use cases illustrate. The aim for policy makers and legislators should thus not be defining the one and only "correct" blockchain design for the electricity sector, but instead enabling governance processes which determine the blockchain design for a specific purpose in the electricity sector. The variety of options in permissionless, permissioned, or hybrid models, on- or off-chain assets makes the governance over the choice of the technology design crucial.

4. Policy implications and legal challenges of blockchain-based transactions in the electricity sector

The use cases of blockchain technology in the electricity sector illustrate that blockchain technology changes the approach from integrating prosumers in existing market structures towards enabling them to form a market. This would result in a decentralised organisation of the sector in which intermediating entities, suppliers and system operators, become increasingly nugatory and prosumers turn into independent market participants. As envisaged by the EU Commission, this promises to efficiently harness RES and to further the process towards a low-carbon society by means of integrating prosumers in this transition. The application of blockchain technology entails various nuances in the design of the technology which determine the role of prosumers and other actors in the electricity sector. The preceding section therefore concluded that governance processes which develop the design of the technology are crucial. The following sections identify the main policy implications of blockchain application in the electricity sector which would need to be specified in governance processes.

4.1. Organising decentralised responsibilities

Blockchain technology applications would still need to be installed by entities in the electricity sector. Depending on the design of the blockchain technology the entity would either be merely a platform provider or a trusted node, a TTP, in the blockchain application. However, in any case their business is not the retail and distribution of

[7] See https://powerledger.io/.

electricity, but the provision of the technology which facilitates trust and transactions between peers. Currently, technologies, trust, and transactions are integrated with intermediating actors, - the suppliers and system operators. Accordingly, the legal framework also assigns them with the related responsibilities of electricity retail and supply. Blockchain applications in the electricity sector evoke the question how to organise responsibilities for electricity supply and distribution. Who are the suppliers and system operators in blockchain applications in the electricity sector? Clearly, a blockchain-based electricity sector would not only change the role of prosumers towards active market participants, but also requires developing solutions for decentralised responsibilities of supply and system operation.

4.2. From consumers to capacities

In a decentralised blockchain-based electricity sector, the term "consumer" is not valid anymore in its current understanding. Consumers turn into system users with specific production, consumption, and flexibility profiles engaging in transactions. Every system user would thus possess a unique profile determining their commercial ability to engage in transactions. This would imply a policy shift from defining consumers as a homogenous group towards understanding them as market peers with different commercial abilities.

The current legal framework of the EU electricity sector establishes governance structures which are based on clear actor definitions along the top-down supply chain. Additionally, the liberalisation of the EU electricity sector progressively drove the ever stricter definition of actors along market- and network realms. Those actor definitions along market- and network realms dilute with the application of blockchain technology as potentially all system users could contribute to supply and system operation. A legal framework for blockchain applications in the electricity sector would thus need to refrain from a *"one-size-fits-all"* consumer definition and rather classify system users according to their flexibility capacities. Moreover, the legal framework would need to establish incentives for system users to invest in flexibility technologies (for example storage, electric vehicles, or smart home technologies) and ensure dynamic pricing systems which enable recouping investments in small-scale generation and flexibility technologies under market conditions.

4.3. Between empowerment and protection

Providing prosumers with access to data of real time prices of energy and grid tariffs and understanding them by their flexibility profile as commercially driven persons ideally results in empowering them as independent market participants. Empowerment would also imply responsibilities for self-determined market transactions and investments. While the current policy of the EU electricity sector assumes a passive role for consumers and therefore further requires a protective framework for consumers, a blockchain scenario would imply a much more self-responsible role.

The most recent legislative proposal by the EU Commission to revise the electricity market Directive 2009 acknowledges that the role of consumers is changing in the course of the energy transition. The proposal reiterates a vision

> *"[…] of an Energy Union with citizens at its core, where citizens take ownership of the energy transition, benefit from new technologies to reduce their bills, participate actively in the market, and where vulnerable consumers are protected."* (EU Commission, 2016b)

While this vision sets out ambitious aims in changing the role of consumers towards becoming active market participants, it also points out the need to maintain protective measures especially for vulnerable consumers. The challenge of a legal framework which enables consumers as active market participants, for example by blockchain technology applications, is thus striking the balance between empowering and at yet protecting consumers.

5. Conclusion

The aim of this article was to answer the following research question "*what are policy implications of blockchain technology applications in the electricity sector for EU electricity law and the role of consumers?*" Based on a first explorative approach of blockchain technology applications in the electricity sector this article identified three main policy implications which would have profound consequences for current EU electricity law. However, the variety of blockchain technology design options renders it impossible to establish *"one-size-fits-all-solutions"* in the EU legal framework of the electricity sector. Instead, this article argues, that the legal framework would need to ensure governance processes which determine the design of the technology for a specific purpose of the application. The three main policy implications identified in Section 4 would need to be subject to those governance processes. These points require further research in order to understand the policy implications of blockchain applications in the electricity sector in greater detail. Particularly, the following three main follow-up research questions are identified:

1. How could a legal framework of the electricity sector define and allocate decentralised responsibilities of electricity supply and distribution under a blockchain scenario?
2. How could a legal framework establish incentives for consumers to invest in flexibility technologies?
3. How could a legal framework strike the balance between self-responsibility and protection of consumers?

Relating these findings to the broader picture, these questions also exemplify that energy law as a discipline has to refrain from "silo thinking" as mentioned in the introduction. Instead, energy law as a discipline needs to centre around progressive issues of future energy systems which are neither organised along the "top-down" supply chain nor include actors as defined by the current legal framework. The EU policy aim to "empower consumers" in the energy transition requires also the evolution of energy law as a discipline in order to provide answers and solutions to emerging technical opportunities. An idea to further the development of energy law as a discipline is to establish and foster principles around which energy law revolves (Heffron et al., 2018). Similarly, the findings of this article propose that energy law needs to centre around progressive issues rather than an established energy system. The issues which relate to blockchain application in the electricity sector can be related to three suggested prospective principles of energy law, namely: access to modern energy services, prudent, rational, and sustainable use of natural resources, and resilience of energy systems (Heffron et al., 2018). These principles could provide guidance for answering the above identified further research questions as an academic endeavour, but also for policymakers and legislators who need to design future legal frameworks for the energy sector which need to include solutions for decentralised settings.

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