Disruptive Potential in the German Electricity System – an Economic Perspective on Blockchain

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“You can see the computer age everywhere but in the productivity statistics.”
Robert Solow (1987)

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1 MAIN FINDINGS

Within the current regulatory framework, levies, taxes and surcharges burden the disruptive potential of a public blockchain. The underlying consensus mechanisms could as well.

- The application of blockchain for peer-to-peer trading of electric power as well as the introduction of a peer-to-peer certificate trading scheme would be possible in the German electricity system.
- A fully public blockchain for peer-to-peer transactions comes with costs for maintaining the integrity, as long as proof-of-work is the underlying consensus mechanism.
- Economic feasibility of peer-to-peer trading is jeopardized by levies, taxes and surcharges from German energy policies and the regulatory framework.

The existing market structure in Germany is not fully prepared for advanced adoption but may benefit from characteristics of peer-to-peer trading if integrated successfully.

- Peer-to-peer trading does not interfere with the existing structure of the electricity supply system.
- The current structure is not prepared to handle large deployment of peer-to-peer electricity trading. Utilities must assume the risk of peer-to-peer trades and, although they cannot predict peer-to-peer trading, are still required to balance supply and demand.
- The use of existing institutions and authorities may help to eliminate shortfalls of the blockchain, mainly a costly consensus mechanism.

Energy policies and regulation should allow technologies and platforms for peer-to-peer trading to improve efficiency as well as boost innovation.

- Peer-to-peer trading allows consumers to reveal individual utility functions, which is from an economic standpoint a positive effect.
- Market participants should decide what technology to use and which platforms to establish in order to foster innovation.
- Energy policies, regulation and market organization should accept and adapt to the use of technologies and platforms to improve overall efficiency.

2 INTRODUCTION

Disrupting the electricity system, obsoleting intermediaries – the hype of blockchain provided some rather discouraging scenarios for companies in the German electricity system. The controversial discussion is fueled by the fear of many electricity suppliers and utilities that such a “disruptive” technology could cause them to lose ground in an already tough market. This is certainly exacerbated by the fact that the technology itself is complicated. Catchy keywords such as “cryptography” or “bitcoin” add mystery and obscurity for non-specialists. Paired with a complex habitat such as the German electricity market, the real impact of the blockchain is difficult to assess. As part of our energy debate series, we gathered renowned experts to discuss the implications of the blockchain technology in the electricity sector. And one thing was clear: The vivid discussion raised more questions than answers. There appears to be a great deal of uncertainty and confusion about the technology and its impact, especially in the energy world.

Some studies and white papers[1] have been recently published in an attempt to explain the features and impacts of the blockchain, which helped to make the general blockchain mechanism understandable for people outside of the tech community. Although possible applications are discussed, the focus on technical details and practical examples neglect a critical aspect: economic feasibility under the current regulatory framework. This is paramount for understanding the “disruptive” potential and possibilities for the blockchain technology. We shed light on this aspect and provide insights beyond the technology, including an economic view on various applications and the implications for the current regulatory framework.

The study at hand first describes how the German electricity market is organized, followed by a short translation of the blockchain in economic terms. Within this context, we discuss the implications for two of the most commonly discussed applications for the decentralized trading of electric power: peer-to-peer electric power transactions and peer-to-peer green certificate trading. The conclusions we draw are not limited to the blockchain technology but can be generalized for all platforms allowing peer-to-peer interaction and altered uses of transparent ledgers, i.e., with some degree of centralized entity.

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[1] E.g., PwC, Verbraucherzentrale NRW: „blockchain – Chance für Energieverbraucher?“ (in German)

3 THE ECONOMIC AND REGULATORY CHARACTERISTICS OF ELECTRIC POWER SUPPLY IN GERMANY

In electricity markets, the classic rule of economics “supply equals demand” has a whole other dimension. Supply has to equal demand in every point in time in order to keep the supply system in a stable condition. To complicate things, many individuals perceive electricity similar to a public good that is and will be available at all times. However, in reality, this is not the case; yet because of the way the supply system is currently organized, these standards and expectations are often met nevertheless. As a result, the organizational structure must rely heavily on sufficient transmission and distribution grids as well as intermediaries, who are willing to take risks on supply and demand shocks in order to reach equilibrium at all times.

The existing organizational structure was originally designed to be based on few generators with large electricity generation capacities, with (hierarchically superior) transmission and (hierarchically inferior) distribution grids to transport electricity to consumers, e.g., located in urban areas far away from generation plants. The *Energiewende* fostered incentives to invest in smaller-scale, decentralized generation units such as wind turbines and photovoltaic systems. With more than 30 % of gross electricity consumption being supplied by these renewable energy sources, a large amount of electric power is being generated in close proximity to consumption centers. Of course, these development have a tremendous impact on the German electricity supply system and the corresponding markets. We highlight three aspects, which we consider to be most relevant for the discussion at hand.

3.1 Electricity as a Good

Once generated, electric power is homogeneous in physical and economic terms.[1] Generation sources may differ due to their primary energy use, e.g., fossil fuels or wind, or as a result of technical abilities (ramping, availability)—yet in the end it all comes down to the transport of electrons.[2] In the late 19th century, establishing a transmission system that functioned, in technical terms[3], was the main objective. Once this was established, electric power was indeed a homogeneous good as it became irrespective of the primary energy source once it entered the transmission network.

Yet with rising environmental awareness, scientific advancements and increased deployment of distributed generation systems, interest in energy has risen. Value creation due to preferences for electricity from, for example, renewable energy sources or regional provision of energy has

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[1] Of course, neglecting physical phenomena such as voltage, phase angles etc.

[2] Correction: electromagnetic fields. We apologize to all technical experts and electrical engineering professors. However, for simplicity, we will continue to refer only to electrons.

[3] With respect to alternating and direct current, voltage etc.

opened the door for a newly defined understanding of electric power. As such, energy providers have started offering “regional”, “renewable” or electricity with other associated attributes. In economic terms, electric power may now be understood as a differentiable and heterogeneous good, which of course is not consistent with its physical structure. This interpretation of electric power may have massive implications regarding the structure of future markets and regulation.

3.2 The Changing Role of Consumers

Historically, consumers have predominantly relied on the supply from utility companies by buying electricity at a (fixed) retail price. However, the role of consumers has changed within the last decade. More and more, consumers are becoming “prosumers” as they produce and consume their own electricity, e.g., by installing roof-top solar photovoltaics (possibly with battery storage).

The transition of the consumer to the prosumer is being driven by several key economic and regulatory factors, including not only incentives stemming from the *Energiewende* but also technological developments accompanied by significant cost reductions. For example, decreasing capital costs in combination with fixed subsidies are causing roof-top solar photovoltaics to become cost competitive for consumers. Together with indirect financial incentives through the exemption of certain surcharges and fees, consumers may save money on their electricity costs by producing and consuming their own electricity rather than buying electricity from utility companies. Moreover, advancements in storage, measurement and control technologies as well as IT systems will make it easier for the consumer to participate in the electricity market. As such, the classic electricity consumer now becomes an electricity producer, capable of either providing itself or another consumer with renewable-based electricity. Newly introduced regulatory measures such as, e.g., the roll out of smart meters, the support scheme for small-scale CHP-power plants or subsidies for electric vehicles may further alter the behavior of consumers.

Such technical and regulatory factors overlook that the perception of electricity as a good has changed. As previously mentioned, non-monetary preferences have affected how consumers understand electricity. For example, some consumers may prefer energy independence from the centralized electricity system. In the future, electricity as a prosumer product may become increasingly attractive as it begins to play a key role in other sectors such as the transport or heating sector.

3.3 The Organizational Structure of Electric Power Supply

In order to gain a better understanding of the implications of the described decentralization of power supply, regulation, product perception and the potential role of blockchain technology in peer-to-peer trading, it is crucial to understand how electric power is currently supplied. In the following, we present – in a simplified manner – the journey of electric power, beginning with the generation of electricity in a power plant and ending with its consumption by a final consumer in Germany.

Generators have different options for selling their electric power. A generator of electricity offers its generation capability ex ante, e.g., either over the counter (OTC) or on an energy exchange. If the generator chooses to offer its electricity generation on an energy exchange[1], a clearing house connected to the energy exchange would clear and settle the trades. In doing so, the clearing house increases market efficiency, reduces transaction costs and minimizes the risk of settlement failures. Once the generator has settled a deal, the exact amount of electric power must be delivered at the time specified in the agreement.

A likely option for generators is to trade with a utility. Each utility has a balancing group to which its end consumers belong. Within this balancing group, the utility has to balance supply and demand such that total final consumption is covered at all times by the electricity either bought or self-generated by the final consumer. The utility is the balancing responsible party for its balancing group.

In most cases, the utility does not ensure that the balancing group's supply equals demand but rather a so-called "trading service provider". The trading service provider, usually an energy trading firm that has been certified by the operator on an energy exchange, manages and trades electric power on behalf of the utility. In order to do so, the utility must provide all relevant data (in particular, consumption forecasts for the final consumers) to the energy trading firm, who then procures the electric power required to meet consumption and to stabilize the balancing group.

Once the energy trading firm has bought the electric power on the wholesale market, it must inform the transmission system operator (TSO) about the trades by sending its trading schedules. The TSO verifies the schedules and calculates the implications for the transmission grid. In the case of impending grid bottlenecks, the TSO can request adjustments to the trading schedules (so-called "redispatching"). If the schedules pass the evaluations of the TSO, the corresponding trades are approved and delivery can be carried out.

At the end of the billing period, the supplier needs to know how much electric power was consumed by its final consumers. As the consumers may be connected to a large number of different distribution grid operators, and the utility does not operate the metering of all consumers, a metering point operator handles all services associated with metering. At the end of the billing period, it is the metering point operator that reads all relevant meters (often manually) and hands the metering data to the utility. The utility can thus invoice the consumed electric power to the final consumer.

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[1] Sometimes clearing houses also settle and clear OTC-trades.

This summary of the organizational structure of electric power supply in Germany should emphasize the multitude of intermediaries and agents that are involved in getting the electric power from the power plant to the final consumer: generators, utilities, energy trading firms, transmission and distribution grid operators, energy exchanges, clearing houses, metering point operators and final consumers. Each of these intermediaries and agents has a different task. Some are regulated,[1] some are in direct competition with competitors. One feature of the blockchain technology that is most often highlighted is the elimination of intermediaries. By decentrally building trust and very low transaction costs, intermediaries can become unnecessary in certain applications. Later in the study, we discuss how blockchain could impact the organizational structure of electric power supply when applied to peer-to-peer trading. But first, in the following section we briefly introduce the blockchain technology.

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[1] The grid operators are regulated as the grid is seen as a natural monopoly.

4 TRANSLATING BLOCKCHAIN TO ECONOMICS

Before diving into the economics of blockchain in power supply, it is helpful to understand the technology on its own. Although we will not go deep into the technological details, we will attempt to point out the most relevant features as well as identify key (economic) advantages and disadvantages.

At the core of a blockchain lays a ledger, wherein information (of transactions) is stored. Different blocks of information are sequentially attached to one another to form a chain, which cannot be altered.[1] This is secured by connecting the blocks with cryptography. The most interesting feature, however, lays in its decentralized organization. Everyone can keep a copy of the ledger, and additions are only possible if it is confirmed by everyone (or at least a certain majority). The "consensus mechanism" of committing a new block of information to the chain can be designed differently, e.g., proof-of-work (costly computations) or proof-of-stake, etc.

First applications of a blockchain (e.g., Bitcoin) are limited with respect to the information (e.g., "agent B gives agent C two Bitcoins") that can be (easily) stored in the chain. Newer developments (such as Ethereum) allow for more complex pieces of information to be stored, which can also include conditional transactions (e.g., "if the sun is shining, agent B gives two something to agent C, but only if…") or so-called "smart contracts". These environments are able to host complex transactions. Contrary to a public blockchain, a private blockchain is controlled by one or several institutions. These institutions may have sole permission and even alter the blocks while the ledger is still being distributed. In this case, it is generally possible to reduce or even eliminate computational work to protect the chain. As Catalinia and Gans (2016) point out, such a private blockchain hardly differs from the replicated, distributed databases already found in many applications.

In terms of economics, several characteristics of the blockchain are noteworthy. One feature of a public blockchain is the ability for anyone to verify planned transactions or attributes (such as ownership etc.), since everyone can own a copy of the ledger.[2] This verification can be done by a software protocol and does not require any intermediary, as the intermediary would simply need to check the centralized ledger. Catalinia and Gans (2016) refer to this as "costless verification". Furthermore, a blockchain constitutes a platform with all well-known shortfalls (critical mass, bringing together different sides) for getting it started. Due to high early incentives (e.g., cheap proof-of-works) these "cost of networking" are reduced (Catalini and Gans 2016). These features enable the design and start of decentralized platforms. However, there is a trade-off between the degree of decentralization and the costs for securing the blockchain: For example, commitment within the Bitcoin blockchain is ensured via mining, i.e., a competition of solving

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[1] Of course this depends on the design of the blockchain as, e.g., a hard fork, i.e., the alteration of past transaction is possible if a majority of the blockchain community approves. Also, private blockchains may be altered.

[2] Privacy may be secured by using pseudonyms.

mathematical problems with computational power. Operating and maintaining the computational hardware to solve the mathematical problems is costly. A fully decentralized blockchain (e.g., Bitcoin) with proof-of-work requires a costly commitment process to maintain the integrity of the blockchain. The costs of commitment thereby signal the integrity of the commitment. This means, the trade-off between decentralization and commitment costs cannot be (fully) resolved.

For illustration purposes, imagine a situation with a large number of nodes that hold a copy of the blockchain. In each of these nodes, the chain of transaction gets secured using computational power. With a large number of nodes, the accumulated costs of resources used for securing the blockchain (e.g., electric power for the computations) may exceed the costs related to having just one trusted intermediary. Hence, the degree of decentralization, which can also be interpreted as the additional benefit provided by the blockchain technology, depends highly on the specific application and consensus mechanism. Regarding cryptocurrencies like Bitcoin, the decentralized network is extremely valuable because it leaves out the intermediaries (i.e., central banks) and hence avoids any risk of manipulation by a central institution. Physical transaction of currencies is not necessarily required, making it easier to eliminate intermediaries. But there is room for different forms of market design: intermediaries can still be involved, granting them some sort of power within a blockchain while at the same time increasing the velocity of adding blocks and simultaneously reducing the costs for securing the blockchain (e.g., by cost-intensive proof-of-works). Other forms such as proofs by majority of nodes may also have significantly lower costs of commitment while maintaining the integrity.

To sum up, certain features of the blockchain - especially the advantages for enabling peer-to-peer trading, costless verification and reduction of network costs – could potentially have an impact. Still, trade-offs with costly commitment processes of transactions may present some economic barriers.

5 PUTTING THE PIECES TOGETHER: TWO APPLICATIONS FOR BLOCKCHAIN IN THE ELECTRICITY SYSTEM

As energy economists in Germany, we often hear the term “decentralization” being used to unify blockchain and the energy sector. Throughout the German *Energiewende*, part of the energy (or at least electricity) system has been increasingly decentralized. In order to explore the possibilities for peer-to-peer trading within this decentralized world, we examine two applications for Germany: peer-to-peer trading of electric power and peer-to-peer trading of green certificates.

5.1 Peer-to-peer Trading of Electric Power

Within the energy sector, blockchain is often used in close association with peer-to-peer trading, e.g., households making direct transactions of electric power with one another.

Structural Aspects

Say, for example, a homeowner decides to invest in a solar system (PV) because she has a southern-facing roof. Meanwhile, her neighbor would also like to buy a PV system but does not have as good of conditions for solar power generation. Put in economic terms, the neighbor has a preference for local, green electricity but she is not able to generate it herself. The consumer without the PV system therefore exhibits a willingness-to-pay for local PV electricity. However, unless the two households are directly connected, electricity has to be transmitted through the existing grid and needs to adhere to the organizational structure of electric power supply.

In this example, a platform (e.g., a blockchain application with smart contracts) has to match the supplier of electric power with heterogeneous (e.g., green, local, PV) characteristics, hereinafter called S, with the consumer with willingness-to-pay for these characteristics, hereinafter called B. Such a trade between S and B would not require a clearing house, as the nature of the blockchain would make such an intermediary obsolete. S and B agree on a price for the exchanged electricity, referred to as the “peer-to-peer contract price”. The settled trade and its schedule would then have to be sent to the TSO for verification. Now, consider the following case that represents a situation with few early-adopters of peer-to-peer trading:

Condition 1: Just a minority of consumers trade directly via peer-to-peer and the related impact on total load flows is small, and

Condition 2: Supply by these peer-to-peer trades does not cover all of B’s electricity demand.

If condition 1 holds, a TSO would not have any objections against the trade and probably verify it. If condition 1 and condition 2 both hold, B (i.e., the recipient of peer-to-peer traded electric power) requires a supplier for her residual demand. This service could be provided by a utility. As every metering point[1] can (currently) only be associated to one single balancing group[2], the question of balancing responsibility emerges. Assume S and B are associated to different balancing groups and have different utilities supplying their residual demand. Assume further that the utilities balance their balancing groups themselves[3]. A simplified illustration of the application is given in Figure 1.

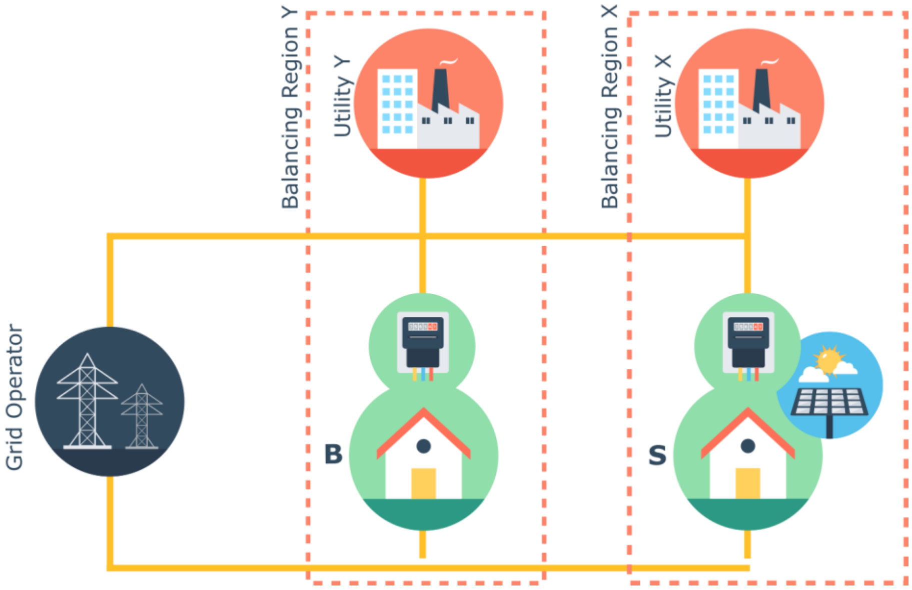

FIGURE 1: ILLUSTRATION OF THE APPLICATION SETTING. ICONS DESIGNED BY VECTORS MARKET BY FLATICON

As an example, if S sells 2 kWh of electric power to B via a peer-to-peer trade[4], and S plans to consume 4 kWh by turning on the lights or using kitchen appliances, the meter of S shows -2 kWh. This is because "behind" her meter, S consumes 4 kWh but produces 2 kWh by her PV system. At the same time, B plans to consume 4 kWh and, thus, the meter of B shows -4 kWh.

If the blockchain technology would facilitate the platform that logs all peer-to-peer trades as transactions, it would be likely that this information would be available to the utilities. Both utilities would adjust their electricity supply to this demand situation. That means, utility X has to supply 4 kWh to S in order to meet her demand of 4 kWh, and utility Y has to supply 2 kWh to B to meet her residual demand of 2 kWh (the other 2 kWh are supplied via the peer-to-peer trade between S and B). Assume in this example that everything goes as planned: Both S and B consume the expected 4 kWh of electricity, the transaction information is publicly available and both B

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[1] Metering points are the locations of the metering of electricity generation and consumption. Usually, consumers of electricity have unidirectional meters that can only track consumption from the grid. Same holds for producers of electricity, whose meters only track electricity fed-in into the grid. Prosumers, however, have bidirectional meters that track whether the prosumer is using electricity from the grid or feeding-in surplus electricity at any given point in time. As the bidirectional meter is the connection point to the grid (i.e., in front of both the PV system and all consumer appliances), electric power from the PV system is fed into the grid only if there is no running process that would directly consume the PV-generated power within the household).

[2] §4 (3) StromNZV (German regulation on electricity feed-in to and consumption from the electricity grid)

[3] I.e., the utilities do not delegate the balancing to a trading service provider. This assumption simply leaves out an intermediary and simplifies the analysis.

[4] Heterogeneous characteristics of the electric power such as, e.g., "green" and "local" are accounted for in this peer-to-peer trade.

and S act according to their contractual peer-to-peer agreements. This situation is illustrated in Figure 2.

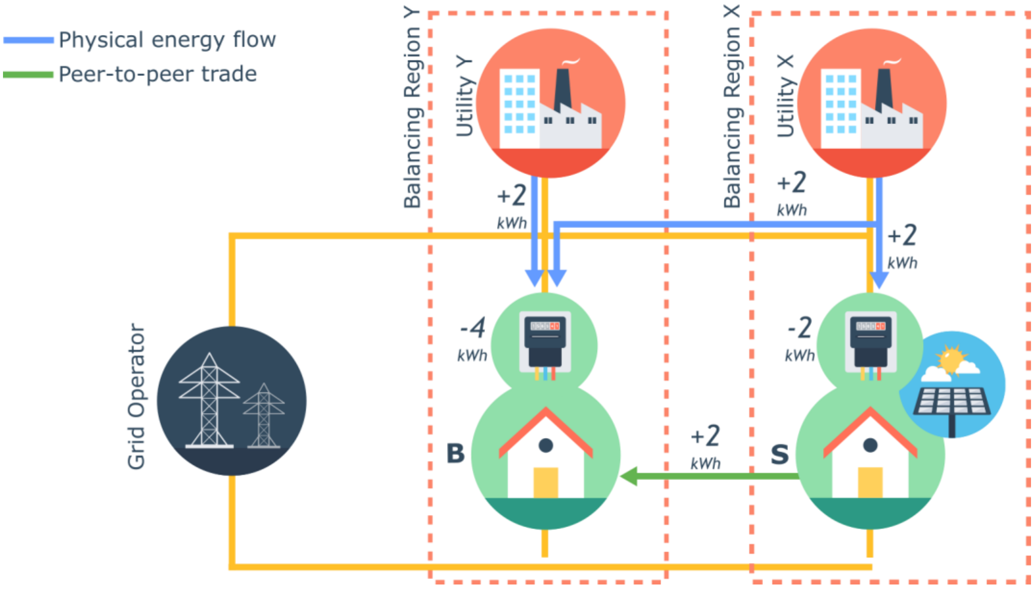

FIGURE 2: ILLUSTRATION OF THE APPLICATION SETTING WITH PHYSICAL FLOWS AND PEER-TO-PEER TRADE. ICONS DESIGNED BY VECTORS MARKET BY FLATICON

As indicated in Figure 2, one important observation is that the physical flow and the peer-to-peer trade vary from one another. As the 2 kWh generated by the PV system of S gets consumed “behind” the meter of S, 2 kWh of residual demand supplied by utility X flow from balancing group X to balancing group Y and “physically fulfill” the contract between S and B. In this case, no security of supply concerns are raised as all balancing groups are in equilibrium. It should be noted, however, that all risk associated with balancing the balancing group (including both the peer-to-peer trades and the supply of residual demand) is covered by the utility, as they are the balancing responsible party.

Now let us consider the same setting, but this time B consumes less than his expected demand and, in turn, fails to comply with the peer-to-peer trade with S. In this case, B consumes only 2 kWh instead of the expected 4 kWh (see Figure 3). By failing to comply with the peer-to-peer trade, B’s deviation leads to an oversupply in balancing group Y and the activation of balancing power by the grid operator. The grid operator is then reimbursed for the costs for this additional supply by the balancing group responsible party, i.e., utility Y.

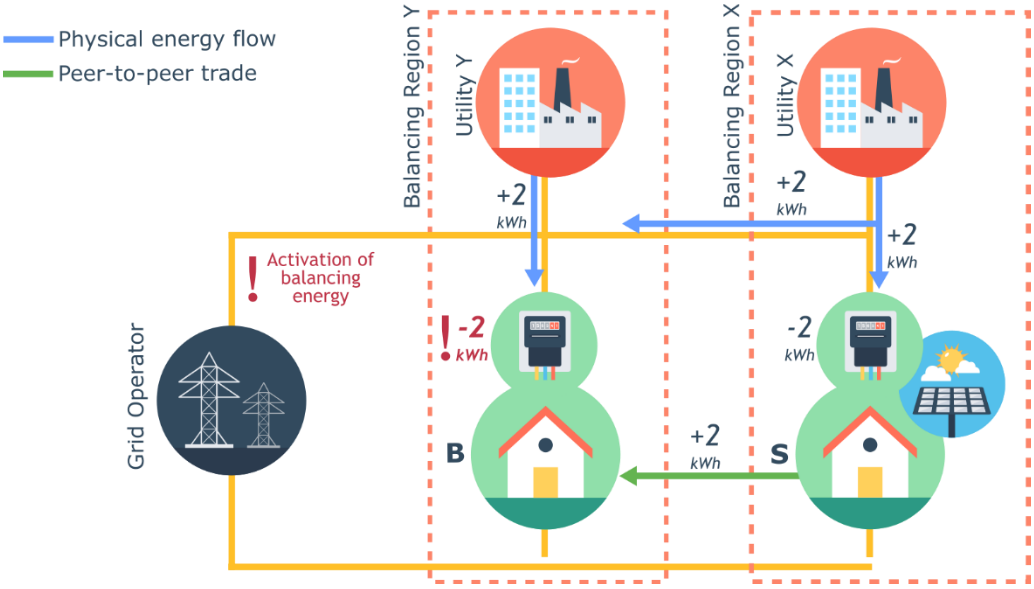

FIGURE 3: ILLUSTRATION OF THE APPLICATION SETTING, WITH B NOT COMPLYING WITH THE EXPECTED TRADE AND DEMAND. ICONS DESIGNED BY VECTORS MARKET BY FLATICON

Hence, the peer-to-peer trades result in additional risk for the balancing responsible parties and are therefore accompanied by additional costs. This externality and the related additional costs for the utility will result in higher prices for the residual supply. Nevertheless, a combination of peer-to-peer trading and residual supply by a utility is possible as long as the balancing responsible party (in our example, the utility) agrees to the peer-to-peer trading activity of B and/or S. In doing so, the utility together with B and/or S can negotiate a contract that allows for such activities and states to what degree the utility will assume the risk.

The additional risk-taking results from the fact that the consumers (usually) just have one meter or one metering point, which is accessible to only one balancing group. Consider the case in which S or B would have two metering points each – one for peer-to-peer trades and one for the residual supply. The meters for residual supply could only be accessed by their respective balancing groups, as before. However, S and B’s meters for peer-to-peer trades would then be supervised by an additional party responsible for balancing group Z. In such a scenario, the additional risk of accruing the balancing costs arising from the peer-to-peer trade would not be assumed by the utility but rather by the responsible party for the balancing group Z, who is monitoring the metering points for trades between S and B. In other words, the balancing responsible party for balancing group Z acts as a service provider to the peer-to-peer traders. By securing the fulfilment of the peer-to-peer trades, they build trust and are able to balance their balancing group.

For the sake of completeness, what happens if either Condition 1 or Condition 2 does not hold? If Condition 2 does not hold, the peer-to-peer trades satisfy all of B’s electricity demand. Thus, B requires a balancing group whose balancing responsible party is willing to take the risk associated with B’s peer-to-peer trades. In this case, the balancing cost externality on the utility vanishes, and the peer-to-peer trades would not affect the rest of the organizational structure. However, a breach of Condition 2 and Condition 1 may result in additional interactions with transmission and distribution grid operators. As soon as peer-to-peer trades significantly influence the flows in the grid, transmission and distribution grid operators have to be informed about the trades in order to maintain a secure grid operation. If a large number of peer-to-peer trades take place, given such a scenario, a new form of informational exchange would need to be established between the grid operators and the parties of peer-to-peer trading. While a new platform may impose additional costs to the system, these costs would most likely be small given technological advances in automated data exchange and evaluation.

Economic Aspects

So far, our example illustrated that peer-to-peer trades using a platform, e.g., based on the blockchain technology, are technically feasible under the current organizational structure given that Conditions 1 and 2 hold. However, a critical component must also be considered: the cost of electricity in a world with peer-to-peer trading. In fact, the current regulatory framework regarding the retail electricity price could present a key barrier for widespread adoption of peer-to-peer trading.

In Germany, a number of levies, taxes and surcharges are implicitly incorporated into the final consumer electricity price. These are intended to finance, e.g., grid maintenance and renewable energy programs and are paid by every consumer who buys electricity.[1] In the case of peer-to-peer trading of (green) electricity, it could very well be that certain levies, taxes or surcharges may not apply to and should therefore no longer be paid by the final consumer. In the example given above, the current regulatory framework would require B to pay for all levies, taxes and surcharges for every kWh consumed from the (public) grid. This includes, of course, both the residual supply from the utility as well as the electricity delivered via the peer-to-peer trade (as S and B are only connected by the public grid). Yet for the electricity delivered according to the peer-to-peer trade, the levies, taxes and surcharges would have to be added on top of the peer-to-peer contract price originally agreed upon by S and B. In other words, the levies, taxes and surcharges distort the cost of the peer-to-peer trade for B because the current regulatory framework treats electricity as a homogeneous good, i.e., irrespective of generation type or transport distance.

This holds in particular for grid charges. In Germany, grid charges vary according to the grid level of connection, metering type and utilization hours. The ordinance that regulates the grid charges[2] explicitly states: “grid charges are independent of the spatial distance between the location of the in-feed of electric energy and the location of its removal from the grid”. In other words, a peer-to-peer trade between neighbors S and B must pay the full grid charge, even though they may only use a small portion of the distribution grid. Because of the way the grid charges in Germany are designed, B will essentially be carrying the costs of the all the grid levels —from high

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[1] E.g., §17 StromNEV (German electricity network charges ordinance) and §61 EEG (German renewable energy sources act)

[2] §17 (1) StromNEV (German electricity network charges ordinance)

voltage down to the distribution level—even though the decentralized nature of the peer-to-peer trade may not require the full grid use. Of course, these grid charges are supposed to subsidize capital costs for grid expansion investments. However, peer-to-peer trades could incentivize local generation and consumption during times when bottlenecks occur in the grid, thereby reducing grid expansion requirements.[1] It could thus be argued that local generation and consumption that lead to avoided grid expansions should be subject to lower grid charges. In sum, the current regulation for grid charges does not function according to a ”cost-by-cause” principle and, with an average of 7.48 ct/kWh[2] in 2017, acts as a major barrier to the economic appeal of peer-to-peer trading.

Similar holds for the Renewable Energy Sources Act levy, another key cost component of the retail electricity price. For every kWh of electric power taken from the grid, consumers are charged a levy to subsidize the incentives for renewable energy generation (6.88 ct/kWh[3]), regardless of whether the electric power purchased was generated via e.g., green attributes in a peer-to-peer trade. Under the existing framework, S only has an incentive to sell the PV-generated electricity to B if the price is above the feed-in tariff, which is (depending on the installation date of the PV system) approximately 12 ct/kWh.[4] Hence, B would have to pay at least 12 ct/kWh and, in addition, all levies, taxes and surcharges—including the Renewable Energy Sources Act levy, even though she purchases 100 % green electricity. In total, the peer-to-peer purchase price of electric power would be roughly 20 % above the costs of a typical utility tariff.

5.2 Peer-to-peer Trading of Certificates

We have seen that peer-to-peer trades with physical delivery are facing economic barriers in terms of levies, taxes and surcharges. But if there is willingness-to-pay for heterogeneous characteristics for electric power, certificates could act as the connecting link between suppliers and consumers for the heterogeneous characteristics of electric power.

Preferences for green electricity have existed well-before blockchain entered the energy scene. Methods to somehow label green electricity in a sea of grey matter have been keeping regulators busy for decades. In fact, since 2001, the EU Commission has required that all member states certify the origin of their renewable-based generation. Some member states have chosen to implement a green certificate trading system, where producers of green electricity are actually awarded a certificate for each unit of green electricity supplied. Green certificate trading systems are implemented along with a renewable quota obligation, which requires energy suppliers (or consumers) to have a certain percentage of the electricity come from renewable sources.

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[1] Although this would require sophisticated metering and steering mechanisms within the distribution grid, which certainly is not standard today. In addition, security of supply, e.g., in times of cloudy weather conditions and related very low output from PV systems, could be maintained by generation capacities located in different areas. Hence, making grid connections necessary.

[2] BDEW Strompreisanalyse Februar 2017

[3] BDEW Strompreisanalyse Februar 2017

[4] We are not aware of any cases in which somebody opted out of the feed-in tariff and directly sold their electricity. However, we consider this to be a possibility.

Certificates earned by renewable energy generators can then be traded to generate revenue, e.g., to compensate their increased investment costs. Conventional generators, in turn, must possess a certain amount of green certificates in order to meet the quota obligation. Yet these conventional generators who possess green certificates can also attract more environmentally-aware consumers by marketing their electricity as “greener”. In other words, green certificates allow energy suppliers to offer consumers a green product (and increase their utility) without necessarily physically delivering green electricity.

Structural Aspects

Let’s return to our setting above. Once again, we have S and B who are not directly connected other than via the electric grid and who would like to exchange electricity. S is capable of generating PV electricity; B has an affinity for green electricity yet is not capable of generating it herself. Now assume that a peer-to-peer green certificate trading system exists. If S generates green electricity and feeds it into the grid, she can choose to benefit from § 21a EEG (German Renewable Energy Sources Act). This paragraph allows her to sell her electricity to anyone on the market, e.g., via a trading service provider[1]. The “green” electricity becomes “grey” once it is sold by the trading service provider. But S is compensated for this “de-greening” by receiving certificates for the heterogeneous characteristics of her generation (e.g., green and/or local). S can then sell the certificates via a peer-to-peer green certificate trading platform (see Figure 4).

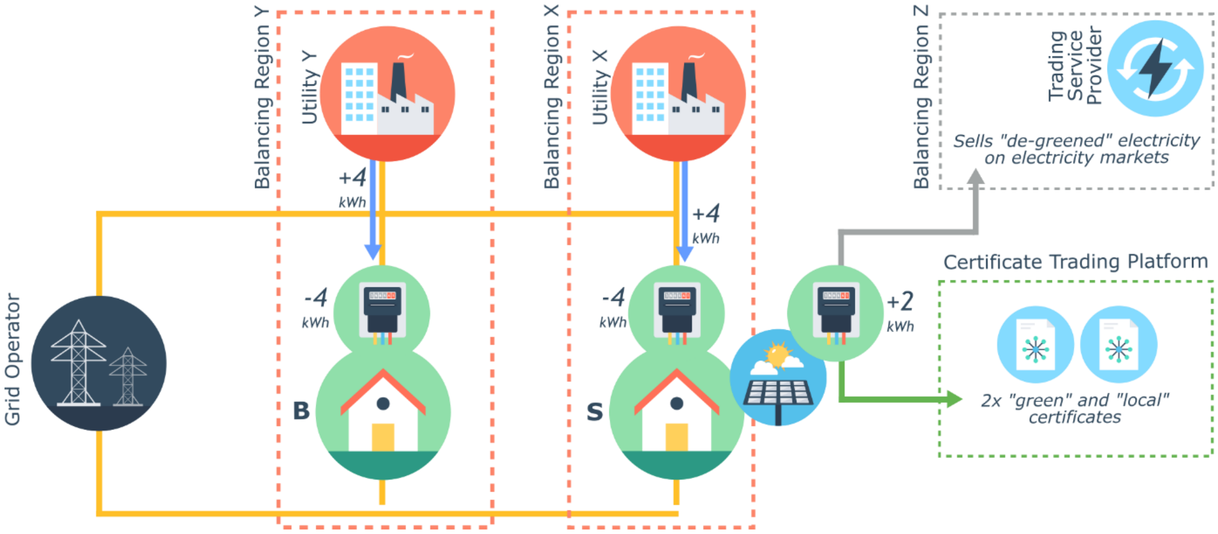

FIGURE 4: ILLUSTRATION OF THE APPLICATION SETTING WITH CERTIFICATE TRADING. ICONS DESIGNED BY VECTORS MARKET BY FLATICON

B purchases grey electricity from her utility, which is delivered via the grid, and can attach heterogeneous characteristics to this grey electric power by buying certificates over the peer-to-peer green certificate trading platform. Although we do not go into detail about the certificate

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[1] Trading service providers already offer similar services today.

trading platform presented, it is clear that such a system would hardly interfere with the existing organizational structure of electric power supply.

Economic Aspects

While peer-to-peer trading of certificates is feasible in a structural sense, again the question of economic feasibility arises. First of all, such a certificate scheme incentivizes investments in the electricity generation units possessing the heterogeneous characteristics for which consumers are willing to pay. For example, if there is a greater demand for “local” certificates than there is supply, prices for these certificates would increase and incentivize investments in distributed generation units in order to create more “local” certificates. However, national policy instruments tend to impact the economics of such trades. For example, national policy measures to subsidize renewable energy generation in Germany led to a rapid expansion of renewable generation capacities, irrespective of the consumers’ willingness-to-pay for green electricity. This results in an inefficient allocation of costs for renewable expansion between consumers with higher and lower willingness-to-pay for green electricity. In other words, not all national policies would be fully compatible with peer-to-peer certificate trading. Yet it should be noted that disclosing the willingness-to-pay by integrating peer-to-peer certificate trading with national or European policies for green electricity could reduce these economic inefficiencies.

6 DISRUPTION

The previous chapter illustrated that both peer-to-peer trading of electric power as well as peer-to-peer trading of certificates are possible under the existing organizational structure. With respect to peer-to-peer trading of electric power, changes in the supply structure only become necessary if the electricity trading volume becomes large, causing the associated risk externalities to rise. Regarding peer-to-peer trading of certificates, even with very large volumes, regulators do not have to adjust the supply structure. Yet, the costs for blockchain integrity due to the consensus mechanism as well as the current regulatory framework concerning levies, taxes and surcharges may make potential peer-to-peer trades economically less interesting.

However, the advantages of revealing the willingness-to-pay for electricity of individuals certainly exist. Insights on the willingness-to-pay for product characteristics (such as “green”) hint at the individual economic valuation of, e.g., green electricity. Among others, this could facilitate a more efficient allocation of reimbursements for renewable expansion costs among consumers. Apart from these potentials in public policy, the transparency of (potentially blockchain-enabled) peer-to-peer trading of electricity may also prove valuable. Ledgers (e.g., blockchain) could be used to comply with regulatory standards regarding transparency requirements. Furthermore, while a fully decentralized blockchain with proof-of-work may not be economical due to high costs for the commitment process, a decentralized blockchain with some elaborated, trusted organizing institution may offer other benefits. For example, such a system could eliminate major drawbacks of resourceful commitment processes while harnessing the benefits of the technology.

Regarding the disruptive potential of the technology, one has to recall the general definition of disruption. Disruption “change[s] the traditional way that an industry operates, especially in a new and effective way” (Cambridge Dictionary). Under the existing framework, neither peer-to-peer trading of electric power nor peer-to-peer trading of certificates presents a cost advantage for final pro- or consumers. The discussion on levies, taxes and surcharges in Section 5 conveys the difficulty in making peer-to-peer trading economically feasible. Furthermore, the costs for resources needed to secure the chain could exacerbate this issue. Therefore, a sudden shift towards peer-to-peer trading of electricity or certificates is not expected, nor is a disruption of the overall market structure or operation. It is important to note that this result holds not only for blockchain-based platforms but decentralized platforms in general.

Whether or not blockchain is the most efficient technology for such a platform is unclear and depends on many unforeseen factors such as, e.g., data security concerns, market structure for platform providers etc. In other words, our findings do not depend on the specific technology but rather on the existing regulatory framework. Appropriate regulatory measures are paramount for the disruptive potential and wide-spread adoption of any platform or underlying technology to take hold. Modifying the existing regulatory framework may therefore be wise if we are to benefit from the advantages of peer-to-peer trading.

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