Potential of the Blockchain Technology in Energy Trading

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Content

1.1 Prologue at the tennis club – August 10, 2030

Sophie and Liz are sitting in the café at their tennis club. “Hey Sophie, would you stop watching your agent the whole time and just sit back and enjoy this beautiful weather!”. “Oh sorry, my husband reprogrammed him, and now he’s been selling electricity to Sweden all week long, lots of electricity. With 230 EnerCoins last week, we’re already in second place in our town.” “Really?” Liz was amazed. “How in the world did you manage that?” Sophie: “He found out that our price was too high for Sweden because of all the roaming fees on top that make our electricity more expensive. Now he lowered the price a little and suddenly our battery is almost empty all the time. That’s how much George sells. Let’s hope the weather stays nice for a while…” “Oh yes, it’s so lovely here – and Sweden hasn’t had any wind for weeks!” Liz added. “We’ve even been considering adding more panels and a second battery. With the power prices going up and down so much, it really would be worth it. On the stock market, they call it spread trading: buying cheap in one place – and selling at a higher price in another. But, tell me, why did you name your agent ‘George’?” Sophie: “We named him after the notorious speculator George Soros, who even tried speculating against the British pound and later against the Euro – as you know, the reason why only EnerCoins are left today! Our George is in the same business, along with millions of other agents like him, but he only speculates against the weather...”

1.2 Introduction

We owe it to Bitcoin's seven years of existence, which provides us with the proof that the blockchain principle has ensured fail-safe reliability over these very seven years. At the same time, the Bitcoin network is a low-cost mechanism for data exchange and data storage – if we ignore the effort for mining. For this reason and as cost of current IT systems increase exponentially when we try to get even closer to 100% availability, it makes sense for a lot of people to step back and think about whether a radical cut in the design of software systems might be the more forward-looking solution.

The market of blockchain solutions, and start-ups that want use these solutions to solve all kinds of different problems, is becoming more and more confusing these days. We read about new developments and unexpected applications almost every day. On the other hand, it may take several years before a blockchain architecture suitable for the developments described in this chapter is available. But certainly there will be a blockchain variant someday that is accepted as a coordination mechanism in various industries and becomes part of everyday usage, without its disruptive potential having to be questioned over and over. There is a new wave of "disruption" that we can feel with the blockchain today: Business requirements normally define the starting point for the design of the IT infrastructure – i.e. the development is "top-down" – whereas with the blockchain the development is in the other direction: it is, of course, possible to make use of the blockchain to supplement existing business processes "top-down", but if these processes follow the potential of the blockchain, this opens up new windows of opportunity, as will be reported later for the energy trading business. After a while, the new business model will have adapted to the blockchain's potential to a point where the focus is no longer on the technology – its use will have become commonplace by then.

The XML (eXtensible Markup Language) standard went through a similar "bottom-up" development in the years after 1998: Visionaries in the IT industry were proclaiming XML as a future solution of B2B integration and there was an increasing number of XML conferences every year, but after a few years, people stopped thinking about whether creating new document standard meant that a new syntax was needed. Instead people simply used XML without fundamentally questioning it. Consequently, XML-centered conferences are now a rarity.

Currently, the potential uses of the blockchain in energy trading can only be described in a rudimentary way. However, energy trading is an attractive application domain as we can find an uncommon symmetry of business: today energy traders deal with other energy traders and tomorrow individuals possibly with other individuals and each kilowatt hour goes back and forth through ten or more hands. The same symmetry can be found when it comes to delivery: One may consider all market participants sitting on one copper plate in the form of the European continent's power grid and feeding power into or out of this plate. Everyone can principally trade, pay, and deliver to everyone else. By using the blockchain this symmetry of business-transactional and physical processes find its technical equivalent at the level of data communication. Taking all this together, we may find a lot of potential for a nearly perfect energy market in the future.

As mentioned, there are numerous ways of using the blockchain in industry. Nonetheless, I am convinced that – along with the likewise highly symmetrical finance sector – energy trading can benefit from it in particular. We can expect interesting developments for many years to come. 20 years ago, if an 18-year-old had asked me to recommend a field of study, I would have said "something that has to do with the Internet" Today I would say: "Something at the crossroads between energy and IT" – I hope that at the end of this chapter it will be clear that in future this could also mean "something with the blockchain".

This chapter focuses on the use of the blockchain in business. There are numerous examples of applications that could be described in detail in this context, however I would refer the reader to two books that deal with this general topic: [1] and [2]. To understand how the blockchain can contribute, it would also be interesting to understand the special market dynamics and processes of a specific industry and then consider how the blockchain can be used to fundamentally redesign its processes. However, for most of this article, we will focus on just one sector: energy trading.

The structure of this chapter follows such an approach: The initial focus is on fundamental questions of the blockchain with several practical examples, then the energy sector with its current trading and business processes will be presented, and finally these processes will be carried over step by step, as thought experiments, to the blockchain. The more likely results could come about in the next few years, the more ambitious probably in 10 to 15 years.

1.3 Value networks in B2B commerce

A company cannot function on the market as an isolated unit: On the contrary, it maintains a myriad of "interfaces" with customers, suppliers, partners, service providers, public authorities, associations, consumers and the general public. Over the past decades, the intensity of communication via these interfaces has multiplied, particularly since the turn of the millennium, when companies began using the Internet to extend, standardize and speed up communication. Around the turn of the millennium, terms like B2B commerce, B2B integration, supply chain integration, and so on, came into use [3].

Today, communication, coordination and collaboration happen online continuously. It used to be common for a manufacturer in the 1990s to receive a monthly order from an industrial customer, whereas today there could well be daily orders from that customer with hourly adjustments. A large quantity of this data is aggregated and published by the industry as a "by-product" and made available to third parties, but at the same time this data is also processed and evaluated by the companies themselves.

First and foremost, B2B integration requires standardization: If the companies of a given industry intend to exchange data, it would be extremely inefficient to have to redefine the data exchange procedure with each of the different communication partners: What data format is to be used? What are the relevant rules and roles for the business process? Which communication protocol is to be used by the partners, what aspects of data communication does the protocol cover, and what is to be handled by the partners locally?

Over ten years ago I once referred to this as the “Yin-Yang-Yong” of B2B integration. The idea here is that an efficient industry-wide integration is only possible if all the parties that need to exchange data with each other manage to agree on and standardize the aspects

- Data format (Yin),
- Business process (Yang) and
- Communication protocol (Yong)

as far as possible.

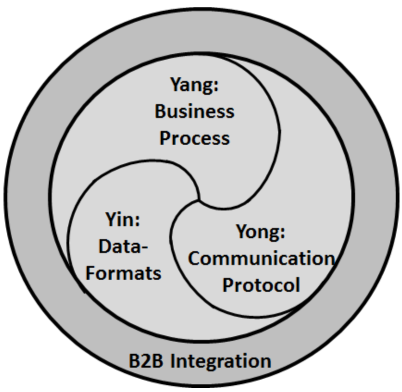

Fig. 1: The Yin-Yang-Yong of standardized data communication

In most B2B integration projects, however, a consortium agrees on the “Yin”, i.e. a unified data format, normally an XML schema with rules documented in detail. The “Yang”, i.e. the business process, is also specified in detail, including all the relevant process rules and roles. The result is a 700-page document with just one reference to the “Yong” on page 699: “FTP or E-mail may be used as the communication protocol.” But an integration standard with no “Yong” is like a three-legged stool with one leg missing! If issues of encryption, authentication, identification of participants, procedures for handling non-delivery of messages, the meaning of technical and functional acknowledgments, compatibility of electronic certificates, and very many other requirements are not clearly defined for all participants, then industry-wide integration becomes a costly undertaking in which each individually defined connection turns into a project of its own.

My personal experience with B2B integration comes from projects in different industries, including the paper industry (papiNet project), the integration of service providers with health insurance companies, as well as in the various communication processes in the energy sector (OTC and exchange related settlement processes, supplier switching processes, and so on). In all of these projects it has been confirmed that B2B integration is particularly successful when the participants continue to maintain standardization discipline not only during the initial phase of setting up an industry network, but also through years of further evolution and adaptation. The disciplining influence of a communication infrastructure that forces the participants to comply with formats, processes and protocols is particularly beneficial in such cases. Otherwise, the centrifugal forces that tempt participants to push through individual special requests are so strong that the cooperation “of many with many” is soon jeopardized.

Thus, we are approaching the blockchain technology from a less technical vantage point than is the case in many articles: When the blockchain is used as the communication and data storage infrastructure, it allows only one format across all its nodes, thereby forcing all process participants to comply with the “Yin-Yang-Yong”. This alone is a value that helps many industries save enormous integration costs – after all, the number of communication relationships increases quadratically with the number of participants (strictly speaking: N*(N-1)/2 connections for N participants). In addition, the need for central data hubs would be eliminated, allowing participants to exchange data directly, i.e. peer-to-peer. The EDA Standard in Austria (Energy Data exchange Austria, [4]) is an excellent example of such a peer-to-peer architecture. Through strict standardization of the Yin-Yang-Yong, the market participants (network operators and suppliers of electricity and gas) have managed to do without a central coordination hub.

This manner of data exchange already requires a high degree of standardization when participants of just two market roles, such as customers and suppliers, are involved. If, however, further roles are to be included, the required multilateral interoperability between all market roles can only be achieved after many years and a rocky road.

The blockchain offers several advantages regarding multilateral interoperability:

Everyone can write – everyone can read: The blockchain is a fundamentally public platform, which means that multicast communication, i.e. respectively from one sender to many receivers, is most compatible with the blockchain. Any participant can be the sender. So, the transmission of weather data from a measuring station to hundreds of recipients is as suitable for the blockchain as the broadcast of an order to interested parties in a B2B network.

“Always on”: The blockchain is fail-safe. All the dramatic messages that permeated from the bitcoin world to the public, were based on the application layer of the blockchain, that is the theft or loss of bitcoins (more precisely: of the private key required for signing a transaction) or data content in general. But that the blockchain has ever failed as a logically centralized, physically distributed persistence mechanism for even a short time, is not known. I.e., not a single platform failure after seven years!

Immutability – whatever is written in the blockchain is carved in stone. Cryptographic mechanisms are used to provide statements with a time stamp and an electronic signature. These statements may relate to ownership, contracts, account postings or other data. In any case, no participant is capable of falsifying the history written in the blockchain.

Real time: Current blockchain developments such as BigchainDB [5] or Tendermint [6] are able to confirm transactions within a second. As a result, processes that today are carried out via conventional channels such as banks or the SWIFT network can be accelerated by several orders of magnitude.

Mass data: Nowadays nobody minds watching a file grow to a few hundred gigabytes on the hard disk. Database images of complex applications can even exceed this by another 1-2 orders of magnitude. But this is not the footprint of a traditional database receiving queries of various kinds continuously. The blockchain is more like a coral reef in which only the last few millimeters represent active biomass, the rest is just a dead image of the past cast in lime, and accessed only on rare occasions to verify historical data. In the case of industrial use, the active part of the shared data would probably also be stored outside the blockchain in the database systems of the users. The blockchain approach, on the other hand, is most helpful when data is to be distributed between organizations, synchronized or archived.

Payment as a by-product Until now there has been a wide gap separating the exchange and the payment of goods or services. Since payment is not embedded in the trading process and has been a rather slow process due to the involvement of banks, it has been accepted that the settlement of payment transactions has given rise to a separate business sector of its own. But if the payment amount is documented as an entry in the blockchain in addition to the transaction data, this indicates (implicitly) that a corresponding transfer has been effected between the participants' accounts. It is important that the participants obtain blockchain-specific accounting units and that there are mechanisms to ensure that the clearing account is not overdrawn. With Bitcoin, it is the currency unit "bitcoin" in connection with the proof-of-work process for confirmation of transactions. Thus, the participants achieve consensus on the account bookings recognized as "official". It is a development goal today to efficiently embed an account-based payment mechanism into the blockchain.

Looking at the industrial applications outlined below, it is clear that there is a need for differently configured blockchains: some public, some private. Some require the identification of participants, for others this is not desired. For this reason, the following additional terms are to be defined:

- **Permissioned blockchain**: In this case, there is basic trust between the participants and the blockchain operators or "miners". Consequently, it is left to the node operators to manage the users of the blockchain in such a way that they virtually form a closed user group. In a **permissionless blockchain**, this trust does not exist (e.g. Bitcoin and Ethereum). It is always open to new, unknown participants, as all share a basic trust in the common algorithm.
- **Public / private blockchains**: A private blockchain is operated by an organization that has the exclusive privilege to write data, others have read privileges at best.

A private blockchain is suited for publishing information, i.e. for one-way, "one-to-many" communication. A public blockchain, on the other hand, is open to many who can access it for reading or writing. This could be a consortium or the public, including anonymous or pseudonymous participants.

– In public blockchains, **access control** (write or read privileges) to data of the participants is often essential, as otherwise companies would be able to view the most intimate transaction details of their competitors at any time. Closely related is the …
– **Disclosure of identities and content:** It is known that Bitcoin participants are identified by pseudonym. For various reasons, the use of pseudonyms is not purposeful for blockchains used industrially: Today participants are even forced to obtain information on their trading partners for compliance reasons (for example, to fulfill compliance requirements such as "KYC – Know Your Customer"). In addition, one might want to select or group transactions by customers. On the other hand, it is not in the interest of the participants for their transaction profile to be visible publicly (or even within the given user group). Even if identities were pseudonymous, industry experts would be able to determine who a given participant is based on a sufficient number of transactions. But it is also important for regulators to be able to establish the connection between a transaction and its actual counterparts. The MIT project Chain Anchor [7] is attempting to solve this problem by having participants use numerous anonymous public keys for transactions that are managed by a centralized administrator of identities and access rights. Nevertheless, there are still many open ends yet to be clarified before this approach to "identity management" achieves general acceptance.
– **Administrative blockchains**: One solution currently envisaged in many projects is to use an additional blockchain to manage identities and access rights for the operational blockchain. This includes the registration of authorized participants and assignment of corresponding identities, as well as allocation of one-time identities to be used by participants for transactions. Only users of the operational blockchain can access (with read privileges) the administrative blockchain and are able to decode it, whereas node operators and managers have write access to this blockchain, for example, in order to assign identities. When choosing a blockchain solution, therefore, it is important to consider whether an administrative infrastructure of this kind is already provided or whether the system is fundamentally capable of using multiple blockchains separately, so that one of them can be used for administrative purposes. Such an administrative blockchain would then be a private blockchain that the administrator maintains and the users of the operational blockchain read from.
– **Smart contracts**: Smart contracts allow the automatic execution of code on the blockchain, generally for the purpose of causing an external action in the course of a defined trigger event. This may be external calls to software applications that perform further bookings or the execution of other smart contracts. The power of a smart contract's program code can vary considerably: With Bitcoin, it is a simple

"stack-oriented" programming language that does not allow loops in the program code, so that deadlocks in the system are avoided. Other systems, such as Ethereum, consume money (in this case: Ether) when running smart contracts so that, in case of a dead loop, the execution stops when the Ether account is used up.

Another question regarding the selection of a blockchain is the degree of integration with a mechanism for payment processing. If the blockchain is intended only for data communication or synchronization of participants' applications, there are no special requirements in this regard. If, however, the participant accounts are to be used for accounting units, this can be done in two ways:

- **Explicitly:** Here, the participants define a transaction type "Payment", which includes, for example, the data fields "PayerID", "PayeeID" and "Amount", and use this transaction whenever a transfer is to be made between these accounts. However, validation of the corresponding account posting and any checks as to whether a budget is exceeded, all need to be handled at the application level of the participants.
- **Implicitly:** Here, the blockchain offers a native booking mechanism that can be used by participants in commercial transactions. Identities are already known, so only the amount has to be determined. The operator of the blockchain would then perform a validation of the payment at system level (as part of the proof-of-work mechanism) and would also maintain the account balances.

From these perspectives we can now observe a number of industrial processes in which multilateral interoperability is required, and check them as to their blockchain affinity. Here are several examples:

- **Batch tracing in the food trade sector.** Here it is conceivable that anyone who manufactures, imports or deals in food products would have to enter for each delivery a batch number in the blockchain. The essential feature in this case is that of an immutable registry. This provides all interested parties (manufacturers, suppliers, consumers, surveillance authorities, or the public) the opportunity to demonstrate that batch A was used as an input product for delivery B – subsequent manipulation is to be avoided. The dominant aspect here is that of immutability in a public blockchain. But it is also important that a company not have to disclose its trade secrets by making its customer and supplier relations transparent with regard to volumes, dates and prices. A corresponding access protection is therefore essential.
- In the **trade of used cars**, different portals and auction sites where used cars can be sold are conceivable. But if a vehicle is offered for sale on several portals, how does a buyer know whether the vehicle has not already been sold on another portal? Here, the portals could enter the sale of the vehicle in the blockchain using its unique VIN (Vehicle Identification Number). Subsequent buyers at other connected portals could then quickly recognize whether that particular car is, in fact, still

available. In this case, the blockchain serves as a kind of “registry” of sales transactions. As an added benefit, a tamper-proof entry of the vehicle’s mileage (odometer reading) could also be recorded in the blockchain. And finally, the vehicle registration authorities could be connected so that the vehicle registration certificate (based on the sales transaction) can also be entered in the blockchain. Third parties could also compile statistics indicating, for example, which vehicles were sold, when, and at what price. This example illustrates how the blockchain promotes industry-wide collaboration of many with many, but a lot of work is required in the standardization of the “Yin-Yang-Yong” to achieve multilateral interoperability.

- **The blockchain in the Internet of things**. Other traded physical objects can also be represented in the Internet of things as direct blockchain players. For an apartment that is being rented for a week, the required access code could be activated via the blockchain, once the lease has been signed (also on the blockchain) by the tenant and landlord. Activation of the access code could also occur after payment is confirmed – a common example of the use of smart contracts. This principle of “smart locks” can be generalized and applied to many other conceivable products: machines, hotel room safes, etc. Once again, there are several roles involved: the buyer, the seller and the “thing”. The outstanding feature of the required blockchain is here its use of smart contracts as a coordination mechanism.

- **Intra-organizational use**. A company could enter all transactions from its accounting journal in a private blockchain and grant employees selective access. External users such as tax consultants, accountants or auditors could also be given access. Again, there is an additional “collateral benefit” through the connection of authorized third parties. This is a typical example of a private blockchain.

- The NASDAQ used its blockchain-based system “Linq” to **issue shares** of companies and organize their trade. The first company whose shares were traded in this way, “Chain.com”, was the very company that provided the “Linq” blockchain [8].

But before we delve too deeply into the technical design of blockchains for arbitrary application scenarios, let us return to the application layer of the energy sector and take a closer look at that scenario.

1.4 B2B networks in the energy trading sector

The focus of this chapter is on the use of the blockchain in energy trading. But for what reason? Traditionally there was hardly any energy trading before the year 2000. Electricity and gas, in particular, were produced by the providers and used by the industry and consumers. Demand for energy generation was deduced from historical usage figures and short-term adaptation to unexpected usage deviations were carried out by the generators themselves based on frequency and voltage deviation measurements. However, with the liberalization of the European energy market, the previously firmly connected players involved in the energy market should have the opportunity to purchase energy supplies from alternative suppliers, which meant that consumers would be able to choose their supplier on the basis of the supplier's conditions, and likewise the supplier could choose which provider to purchase from. To achieve the required transparency, interchangeability and standardization of energy supplies, the market roles involved in the energy market had to be defined more precisely.

The new legislation initiated a transition from vertically integrated utility providers towards market mechanisms, so that today the market is characterized by large numbers of both suppliers and buyers who exchange a variety of data and perform an ever increasing number of transactions, all of which requires a high degree of standardization in the sense of the Yin-Yang-Yong. Already from this angle, there seems to be a certain fundamental need for the blockchain in this scenario. If we also take into account that energy trading is largely symmetrical and that a MWh of electricity may well be sold and resold ten times across Europe before it is actually delivered to the consumer, this seems to be a market in which the blockchain can provide some support.

So, who are the players in the energy market?

- **Generators** feed quantities of electricity and gas into the grid. Today, providers may also be smaller operators of PV plants or wind farms.

- **Suppliers** buy large quantities of energy from the providers and offer tailored products that meet special requirements of the industry or consumers.

- **Consumers** buy corresponding products from the suppliers. However, consumers can also supply energy, in which case they act as **prosumers** who not only feed electricity into the grid, but may also participate to some extent in the grid control process.

- **Traders** buy energy from generators on the wholesale market and resell it to other traders or suppliers. The wholesale energy market is a pan-European marketplace where some products are resold several times before finally reaching the consumer through a supplier.

- Physically, electricity and gas are supplied through grids operated by **transmission and distribution system operators** (TSOs / DSOs). The TSOs are interconnected horizontally across Europe and ensure the availability of the entire network in various ways, in particular by regulating the network load. One of the main objectives of a TSO is to ensure the security of supply. The distribution system operators create and operate the grid connections to the providers and consumers.

- **Energy exchanges** offer a marketplace where electricity and gas products can be traded. These marketplaces are regulated, they are monitored by national regulators, and some have a special status in that they carry out certain functional processes with network operators.

- **Clearinghouses** are usually connected to one or more exchanges and carry out the financial and physical settlement of energy transactions. In the event of a participant defaulting (as was the case, for example, in 2008 with Lehman Brothers, also on the European energy markets) the clearinghouse steps in as market participant, procuring failed deliveries or compensating defaults.

- **Brokers:** Traders are not forced to do business exclusively through the energy exchanges; on the European energy market there is also a large number of brokers offering platforms that traders can use for their transactions. Note, however, that the broker merely serves as the mediator of a bilateral contract, whereas clearinghouses act as counterparty. Of course, traders may also carry out bilateral transactions directly with each other, in which case the published prices from brokers and exchanges serve as an orientation signal for pricing.

- Another role connected with the energy market is the **index agency**; an index agency establishes the current market price for energy products, either on trading platforms or by contacting individual traders, and provides this pricing information to traders for a fee.

- **Standardization bodies** stipulate the processes of energy trading. In particular, for the European market, the EFET is to be mentioned (European Federation of Energy Traders), as well as the ENTSO-E and ENTSO-G, the TSO associations of electricity and gas, who agree on grid-relevant processes.

- Finally, there are **regulators** who monitor the energy market at the national or European level. Their technical connection covers, in particular, the reporting of transactions by the parties involved. EU directives such as REMIT and EMIR were initiated in recent years by the EU to specify the reporting of data to regulators for different transactions.

On the energy market, a variety of products is traded between generators, traders and suppliers: On the one hand, there are long-term deals covering an annual, quarterly or monthly base load (futures market); on the short-term end is the spot market, which covers mainly the following day (*day ahead*), as well as individual hours of the same day (*intraday*). On the futures market, there is a distinction between physical and financial products. With physical products, there is a delivery obligation, whereas financial products are derivatives such as options or swap transactions that are carried out by market participants generally to hedge against price fluctuations and that are financially settled. On the very short-term end (less than 15 minutes), there is the possibility of trading balancing energy which is tendered by TSOs and offered by especially suitable providers in case of need.

Viewed from a certain distance, the electricity and gas markets don't differ considerably, both being partly very liquid, whereby the electricity market is leading the trend toward more short-term transactions when compared to the gas market. For simplicity's sake we will therefore be focusing primarily on the electricity market.

1.4.1 Classical B2B processes in the electricity market

Since a large number of market participants perform the roles mentioned above, it is important that commercial processes between them are implemented uniformly.

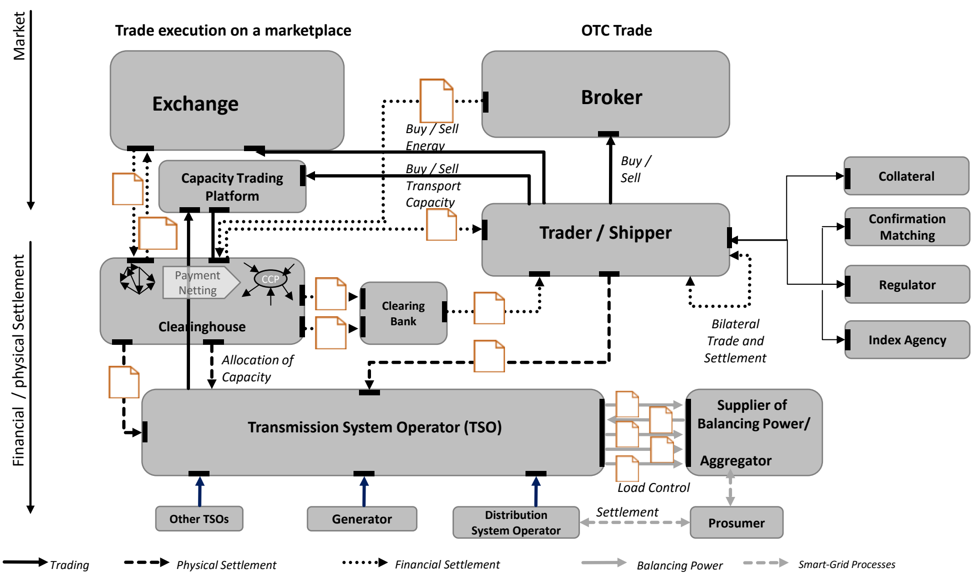

Fig. 2: Processes in the energy market

According to figure 2, during an energy transaction the following processes are essential:

– **Execution of a transaction via a trading platform:** This is the process with the least cross-platform standardization at this point, as it is implemented individually by the various platform operators. Following a transaction, both parties separately receive commercial data through a channel specific to the platform. This data is subsequently adopted into the commercial systems (also known as “Energy Trading and Risk Management” or ETRM systems)

– **Trade Confirmation:** If a transaction came about “OTC” (“over the counter” i.e. off-market), both parties bilaterally exchange the details of a transaction in order to ensure that no errors are made when having processed the data in their respective ETRM systems – there is currently no single, “leading” system that is accepted as the one source of correct data. The matching of trade data happens automatically on the basis of the eCM standards (electronic Confirmation Matching) developed by the EFET association.

– **On-Exchange clearing:** This is the processing of trades through the clearing house, mainly the financial settlement of the various transaction partners of a stock exchange has to be organized. When hundreds of trade participants trade with a large number of other market participants, there are payment obligations “from everyone to everyone”. In order to govern the resulting diversity of single transactions, the clearing house splits each single transaction into two halves, whereby it acts in the middle as a neutral, central counterparty (CCP). So a transaction S--B between the seller and the buyer turns into the transactions S--CCP and CCP--B. Here the CCP acts as a buyer on one side and seller on the other. Topologically speaking, this act of “payment netting” is basically the transformation of a fully-meshed net of contract relationships into star-shaped payment relationships in which the individual values of payment obligations between the CCP and a market participant are netted. Another function of the clearing house is to become a market participant at short notice if a participant with an payment or delivery obligation drops out. The resulting costs are socialized among the clearing participants.

– **OTC clearing:** Traders can later decide to send OTC transactions to the clearing house for processing. This is usually done in order to reduce counterparty risk. Classically, this process takes place via individually programmed interfaces between brokers and clearing houses, whereby the (clearing) brokers are commissioned by traders. It would be too laborious for traders to implement this process themselves.

– **Nominating** to the TSO. The physical counterpart of the financial settlement is the delivery of electricity. “Delivery” means that everyone who feeds electricity into the grid or receives electricity from it notifies the TSO what amount is to be expected for what period of time. This is called “scheduling” or “nomination” and initially takes place at the end of the preceding day (e.g. at 6:00 pm) and then every 15 minutes during the day of delivery (for electricity). The day of delivery is divided into 15-minute intervals so that, for instance, deliveries traded intraday are taken into account in later schedules of the same day. Traders on the wholesale market must therefore be able to reliably send up-to-date schedules. For on-exchange transactions, the clearing house in some cases takes on this task, for instance the ECC (European Commodity Clearing – the CCP of the energy exchange EEX in Leipzig). So a minor trader could avoid the process of sending schedules by trading exclusively via the connected energy exchanges. On the other hand, the clearing costs for traders are relatively high so that despite a cardinal trend towards the exchange, a large portion of commerce still takes place OTC.

– **Reporting commercial transactions to the regulator.** According to the REMIT regulation [9], traders are obligated to report their orders, trade deals and other aspects of transactions to the central agency ACER (Agency for the Cooperation of Energy Regulators[10]) by the end of the following day. For this ACER has specified the format, the reporting platforms and the communication protocol by which these reports are to be made. The most important reporting platform is the EFETnet's system eRR (electronic Regulatory Reporting).

– **Requesting balancing energy** by the TSO. If at short notice, i.e. in a time frame below 15 minutes, it becomes apparent that a grid's supply and demand diverge, the TSO requests short-term feeding-in of electricity – or in the opposite case the consumption of electricity (positive vs. negative balancing energy) Depending on the time frame we distinguish between tertiary, secondary and primary reserves: Tertiary reserves are requisitioned for 15 minutes within 5 minutes. Secondary reserves are activated on even shorter notice and with primary reserve energy, deviating network load is balanced within seconds by incorporating generators to stabilize the grid frequency at 50 Hertz. Balancing energy is tendered by the TSOs and only qualified suppliers are even approved for the procedure. The TSO therefore buys balancing energy from the supplier on the one side and on the other, bills those traders who delivered more or less energy than specified by their schedules. Such a deviation is retrospectively determined based on the respective meter readings of consumers and producers. In this way, the TSO itself becomes a market participant and carries the risk of a counterparty dropping out, since the billing of such additional costs often occurs after the end of the month.

1.4.2 Current and future developments on the electricity market

In what direction is the electricity market headed today and in the future, and why is the "Blockchain" topic now so interesting for the electricity market?

Over the years of the German "Energiewende" (energy transition), certain parameters of energy trading have changed considerably: Firstly, the proportion of renewable energies has increased dramatically, one could say Germany has become a world laboratory for renewable energies. For this reason, on Sunday May 8, 2016 a new world record was listed: Over 95% of the Germany's national electricity consumption was covered by renewable energies. So we had “sailing weather” with blue skies and favorable wind. Because it was a weekend day, the industrial consumption was correspondingly low so that at about 53 GW, the consumption load was about 12 GW lower than on a weekday. But something else was significant on that day. There was an excess of electricity, so it was traded “day ahead” at minus 12.89 EUR per MWh, rewarding buyers who took off electricity. The price for peak load that day was at minus 36.46 EUR and an hourly contract was at astonishing minus 135 EUR per MWh. So electricity is becoming increasingly available at minimal prices, this is partly due to the face that the industrial production on the basis of nuclear power and coal is not capable of appropriately reducing the production load within a few hours and is forced to find a buyer – no matter what the cost. And so on May 8, there was an overproduction of 13 GW that was sold to neighboring countries for negative prices.

Moreover, production isn’t always plannable in the short term. There have been days on which the weather deviated so strongly from the previous day’s prediction that there was a difference of over 5 GW in Germany. That is the output of 4 to 5 nuclear power plants and equals almost 10% of consumption. Due to this not entirely predictable volatility we now have situations in which balance energy represents a major part of production, but the process was never intended to handle such large quantities of power. That is why we can already see the following trends developing in the energy market:

- **Shift from a futures market to a spot market** and more to balancing energy: Why should a trader make long-term investments in energy that costs 25 or 30 Euro on the futures market when it can be acquired on short-notice (specifically intraday) for free or even cheaper? However, there may be windless nights that can only be guarded against by securing one’s supply for a sufficiently long term. But in general, because of the low marginal costs for solar and wind energy, on average the prices are sinking due to the large proportion of renewables so that a trader on the spot market can cheaply buy a large supply on short notice. For instance, the volume of the German intraday spot market has increased by over 40% from 2014 to 2015 [12].

- **Sinking Prices:** In May 2016 a provider in Dubai won a competition for the operation of a PV plant that guarantees the delivery of electricity for 2.99 USD Cent / KWh. Renewable energies, producing at low marginal costs, are also increasingly replacing the older plants (coal, nuclear, gas) on the wholesale market, as so-called aggregators, or virtual plants, combine hundreds or even thousands of small scale producers and offer them in concert reserve energy.

- **Reduced transaction volumes:** Lastly, transaction volumes are decreasing with the shift towards spot and balancing energy. Where as it used to be common for 10 to 100 MW to be traded with monthly, quarterly or yearly delivery periods, today the proportion of smaller 15 minute contracts on the EPEX spot market is increasing [12]. This is partly due to the necessity of balancing short-term fluctuations in production. Today's minimum tradeable transaction on an exchange is a 15-minute contract for the delivery of 0.1 MW of electricity.

Figure 3 shows the development of electricity prices since 2009; with increasing proximity of the delivery date (x axis) we see a decrease in prices for the annual base load contract of a given year. Also, at a constant temporal distance to the delivery date, prices decrease on a year-by-year basis. So on the whole, electricity prices on the wholesale market have decreased from over 60 Euro to 20 Euro in some cases – and this development could continue in the long term.

Fig. 3: Sinking electricity prices on the German futures market, source: ICIS [14]

So in total, we are increasingly seeing smaller amounts traded on a shorter term and at a reduced price. If the cost of transactions doesn't sink as well, trading will become a loss-making business – and precisely that is the case today for many market participants: Some trading companies are already unprofitable and many are threatening to become unprofitable, because various cost factors are not changing fundamentally:

– The **internal costs of trading** will remain high as long as there is a human factor involved: Traders themselves are highly paid, but so are legal and IT departments as well as the entire construct of front office (trade), middle office (risk management) and back office (settlement).

– Likewise, there are high **external costs**: Clearing and exchange fees, broker fees, trader admissions, index agencies and other service providers generate costs that, each in reference to a spot transaction, can be very high.

The following are examples that demonstrate the transaction volumes and values that we are confronted with in today's markets:

Tab. 1: Comparison of electricity prices

Market	Product	Volume	Total value
Future	Annual base load contract 10 MW, 30 EUR / MWh, 8,760 hours	87,600.000 MWh	2,628,000.00 EUR
Future	Monthly base load contract 10 MW, 30 EUR / MWh, 720 hours	7,200.000 MWh	216,000.00 EUR
Spot	Day-ahead, 1 MW, 30 EUR	24,000 MWh	720.00 EUR
Spot	Intraday 1 hour, 30 EUR	1.000 MWh	30.00 EUR
balancing energy	1 MW, 15 min, 100 EUR	0.250 MWh	25.00 EUR
Primary balancing power	Battery storage, 200 KW, 5 min, 300 EUR / MWh	0.017 MWh	5.00 EUR
Spot	Tradeable intraday at the EPEX spot, 0.1 MW, 15 minutes, 24 EUR / MWh	0.025 MWh	0.60 EUR

The examples above show how transaction volumes are sinking and that at some point there is a transition required from the "human factor" (future and day-ahead) to automated processes (intraday and reserve energy).

In addition to the trends discussed above, there is another factor to consider: So far we have been discussing transactions and prices on the wholesale market. Here the TSO represents the central hub of activity. However, renewable energies are fed in regionally, but their production load can't always be arbitrarily distributed, e.g. when distribution grid 1 only produces and distribution grid 2 only consumes. Depending on the region, this can lead to overload situations in the transmission network between the distribution grids.

So, a DSO should aim to cover as much local consumption as possible with local production. On a small scale, the DSO has to act like a TSO – that is, create mechanisms with which to work towards a balance between production and consumption. In short this can be summarized as *smart grid processes*. The state of technology here is that both the producing side (PV, wind, biogas) and the consuming side (industry, office buildings, hotels, private residences) intervene in load behavior, in order to balance fluctuations on the supply and the demand side (supply side/demand side management or load shifting). This is sometimes referred to as the supplying and requisitioning of *flexibility*. Production plants and consumers are quasi remote-controlled, in order to balance the local grid. Today small scale producers have their production "remote-controlled" via aggregators and are generally not involved in wholesale commerce. Rather, they are integrated in a distribution grid that has its own requirements regarding load control. While the aggregator offers the TSO balancing energy, which may come from anywhere within the control zone of the TSO or even from neighboring TSO zones, the DSO's goal is local optimization. Therefore, the producer should be able to decide whose regime to be integrated in.

But today it is hard for a producer to switch aggregators, that is, to decide freely who their transaction partner in the grid should be. Also, the rules and protocols for the connection of a producer are partly still specific to the respective aggregator. If in future however – as it is today with the wholesale market – a liberalized micro-market is established, then small-scale producers can, in principle, also sell their energy on the distribution grid to any consumer with whom they can agree on a price.

So for the even smaller transactions on the distribution grid, this requires an infrastructure with even more reduced costs. Thus flexibility can be supplied or requested, but if the charging of a battery with 10 KWh over 15 minutes at 30 EUR / KWh only costs 7.5 cents, then the transaction costs should be less than one cent. It is doubtful whether this is effectively feasible with today's infrastructure.

And so, if we shift our focus from the TSO in the year 2016 to the DSO in the year 2030 and while doing so assume a scenario in which

- the German installed output of electricity production on the basis of renewable energies is at 200 MW, which would be more than three times the consumption capacity,
- part of surplus production can be temporarily stored (e.g. with affordable battery storage systems) and can then be dispensed as comparatively inexpensive balancing energy,
- for that reason, the spot market becomes the main hub of wholesale commerce and has come within 15 minutes of the point of delivery,
- in flexibility trading, micro-transactions amounting to only a few cents are standard practice,

then we can imagine that our current IT systems are no longer appropriate for such requirements. Ever increasing real-time requirements, the necessity of keeping software systems in continuous operation and updating them at the same time, 100% availability, pressure to lower costs, along with maintaining with the primary objective of supply security all require a paradigm shift in the planning of IT infrastructures for energy trading.

If prosumers are to be able to offer transregional flexibility, then differing national implementations of processes like schedule notification are not feasible, as every small-scale producer would have an unreasonable additional effort to shoulder whenever there was a deviation from standard processes. Any adaptation effort to regional particularities would not only create usage costs, but would potentially jeopardize security of supply.

So we can summarize that in today's energy trading and adjacent processes there are cast amounts of data being moved back and forth between enormous data pools. Every connection is individual; on the European scale, the ideal of Yin-Yang-Yong mentioned above is only partially implemented, at best. Thus if we want to trade, exchange, and pay for micro-amounts of electricity at micro-prices close to real-time and with a guarantee of supply security in the future, this will really only be possible through the use of a blockchain.

1.5 Applying the blockchain in energy trading

In this section we want to take a look at how the blockchain might change energy trading. It is more a question of imagination to envision what direction this change will take, but one can imagine that these changes will happen on rather short notice, that is in the next 2-5 years, and others that would require a fundamental change in the processes practiced so far can in turn be expected to take place in 10-15 years. This is also highly dependent on how far the regulator will discover the "blockchain" concept and can implement or accelerate the standardization on the industrial side.

Hereinafter we will attempt to describe possible developments of blockchain-based energy trading, whereby we will start with short-term developments and close with the more long-term, speculative ones.

1.5.1 The blockchain in today's energy sector

Fledgling projects that use the blockchain to support transactions in the energy sector can already be found today.

In April 2016, reports spread stating that the world's first energy trading transaction using a blockchain hat taken place in Brooklyn, New York. The owner of a solar roof panel sold a few kilowatt hours to a neighbor using a smart contract of the Ethereum blockchain. This happened within the Brooklyn micro-grid (www.brooklynmicrogrid.com) which is managed by the start-up company LO3 [15].

This example shows how a smart contract may be used to initiate a delivery among neighbors, which is closer to the 2030 scenario content-wise. As a one-time transaction however, this is still a rather arbitrary process and should be understood rather as a marketing stunt of the company – generally of all those who concern themselves with the application of the blockchain in energy trading.

A different project comes from Germany: RWE, together with the company Slock.it from Saxony, uses the blockchain in the electric car sector to use a payment process that makes charging transactions at public charging stations for electric vehicles billable. For this they use an accounting unit supported by different charging providers of energy, in order to provide drivers of electric cars with a uniform payment method. RWE's system is based on the product BigchainDB developed by Ascribe in Berlin[5]. To what extent smart contracts are used for the unlocking of charging stations, is not yet determinable.

1.5.2 Scenario 2020: Evolutionary application of blockchains

In the short term we can imagine that the current, entrenched processes in the context of energy trading are supported, rather than replaced, by the blockchain (top-down approach) So the overall picture of figure 2 does not initially change, but the silo formation and individual exchange of data could be replaced by the blockchain or at least be improved by data synchronization, see figure 4.

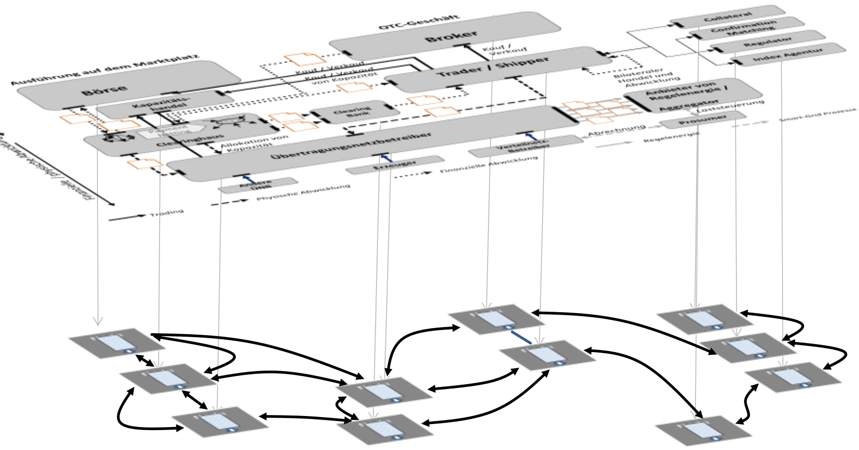

Fig. 4: Blockchain as a support for traditional energy trading processes

So a first step could be the use of blockchains as a communication channel: All the market roles are retained, traders trade with traders, brokers and exchanges are available as platforms, and grid operators receive scheduling data.

Major players in the system manage a node. This could be traders, platform operators, grid operators, IT service providers or other third parties. In any case it is likely to be a "permissioned blockchain" whose communication between nodes on the one hand (for data synchronization, horizontal in fig. 4) and between participants and nodes on the other side (vertical) is secured.

The most important effect of the blockchain in this case is standardization. Should there be only one blockchain on the entire continent, all participants would be forced to read or write data in exactly the same format – a perfect implementation of "Yin-Yang-Yong". While previously, P2P processes took place on the application level, in the age of blockchain, business processes no longer synchronize directly with each other, but rather via an adapter which maps process states and data onto the blockchain as a transport container. "Below" toward the blockchain, the adapter supports a technical interface and toward the "top", that is toward the application it supports a functional one. So the blockchain is used as a container or transport vehicle to distribute data.

Accordingly, one can imagine that for instance a trading organization who sends a schedule to the TSO writes this into the blockchain and the TSO who operates a node, reads out this data. His adapter hereby only delivers the data relevant to him, i.e., that is scheduled for his control area.

Similarly, one can imagine an exchange sending transaction data to a clearing-house or likewise a broker in the context of the aforementioned OTC clearing.

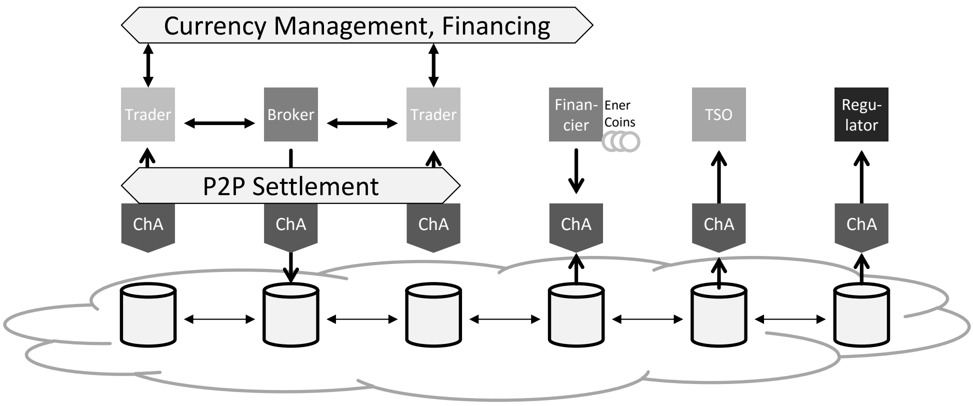

Fig. 5: Evolutionary application of blockchains

As mentioned previously, index agencies have specialized in establishing market prices for certain traded products and providing this pricing to traders. Representatives for this are Blomberg and Thomson-Reuters as the most prominent exponents or Platts and Heren as specialists in energy-related price indices. While prices for liquid products like power base load for the year 2018 are published by numerous exchanges and brokers, index agencies specialize in less liquid products like base load in Croatia. To do so, they inquire with traders – sometimes via telephone – as to the prices products were traded at. By means of averaging and smoothing functions a daily or weekly index value is created, though this value often lacks reliable interpolation points. This value is published and is available to traders and marketplaces in order to trade derivatives on that basis.

Again the following applies: Whatever is written into the blockchain can be used by various parties as a database for later transformation steps: Thus every trader is in a position to derive the index for certain products from the database, which is uniform for all participants using a standard formula. Index agencies have a reputation of being rather costly for traders, because they request data from traders and then moments later sell it back to those very traders at high prices. In the blockchain world, one can imagine that index data which has been written into the blockchain is equally accessible to other market participants. Additionally, this would be an ideal use of the immutability of the blockchain.

Regulators can also be involved as a user of the blockchain. They would simply access a node and receive transaction data in real-time – at least compared to the current 24-hour delay. This does not entail any extra effort on the part of the traders required to report. And an ambitious regulator who uses real-time software to monitor trading activity can now do this in actual real-time, not just by means of a "replay" function the following day. So if everyone who currently has to report transaction data to the regulator (traders, exchanges, brokers) writes this data into the blockchain, then there is nothing more left to do except to connect the regulator to the blockchain.

Now, what are the specific requirements for the blockchain in this evolutionary approach?

Tab. 2: Requirements for the blockchain in the evolutionary scenario

Blockchain aspect	Requirement
Availability	In the context of today's common practices, a node should be functioning again within a few minutes in case of failure, or it should be possible to connect with a substitute node within a few seconds.
Immutability	For some processes of trade, it is useful for resulting, long-term delivery obligations are unchangeably written into the blockchain. With other processes, for instance schedule notification, data loses its value after one day. Since these are additionally held in the application system, a large volume of "dead" data emerges. Here it would be useful to have a blockchain that allows for obsolete historical blocks to be disconnected or deleted.
Throughput	The system should be capable of putting through some 100 transactions per second in case of load surges, including the data required for those transactions.
Block time	Due to the evolutionary character it is sufficient for a block to be completed after as much as 30-60 seconds as current processes are considerably slower
Trustlessness	Not required, since node operators are trustworthy.
Data volume	If we use the current data volume of REMIT reporting as an estimation basis, the monthly data volume might be on the scale of terabytes.
Smart contracts.	Not required, as data exchange and synchronization are at the foreground.
Proof-of-work	Not required, rather proof-of-stake through the node operators.
Access security	Important: Transaction data from traders or certain data of a transaction must only be accessible to authorized users.
Anonymity / pseudonymity	As traders compete with one another, mutual protection from data insight and identification of other market participants is imperative. On the other hand, selected participants (TSOs,

Blockchain aspect	Requirement
	regulators) must be in a position to identify participants. Here, the aforementioned requirement of anonymization applies along with the possibility of disclosure through authorized participants.
Payment process	Not required
Currency	Not required

1.5.3 Disruptive effect on the physical settlement of commercial transactions

The evolutionary scenario does not yet assume unchanged data and processes between participants – we are following a top-down approach in which the application dominates the use of the blockchain.

If, however, we view the world from the perspective of the blockchain, then it makes much more sense to think "from the bottom up", that is to utilize inherent properties of the blockchain in order to generate an added value on the application level. As in many other sectors this added value can not only be quantitative (e.g. by accelerating processes), but also qualitative (e.g. by doing without certain market roles) by calling the roles of particular participants into question. But first, a less disruptive variant:

The fact that all users of the blockchain review all data makes a process like schedule data exchange appear somewhat obsolete in the age of the blockchain. How exactly does this work today? A trading organization that creates a schedule accesses its trade portfolio – that is, its trade transactions – every 15 minutes, filtering it by day of delivery, counterparty and TSO. Thus it receives all trade transactions whose delivery refers to the day for which a schedule is to be created. From these transactions, the trader also establishes, through netting delivery quantities at 15-minute intervals, a time line that corresponds to its net delivery into the control area of the TSO. The trader transfers this schedule to the TSO, who in turn checks whether the counterparties calculated the same result from their perspective. If this is the case, the TSO confirms the correctness to both traders. This process is repeated every 15 minutes. Similarly, production or consumption predictions are sent in this format beforehand.

From the blockchain perspective, there is a lot to simplify here. Why should the trader go to the effort of executing a data exchange process for selection and balancing every 15 minutes? Can this be done differently, with more blockchain affinity?

Here we merely have to take a look at Great Britain: The British electricity grid operator National Grid has developed the following process: As soon as two traders have completed a transaction, one of the two (the so-called ECVNA, Energy Contract Volume Notification Agent) reports the key data of the transaction to an agency of the TSO (the ECVAA, Energy Contract Volume Aggregation Agent). The same applies to all modifications or cancellations of trades. This reporting starts with forward contracts and ends with spot deals. That way, the ECVAA has access to all information about the expected load on the producing and the consuming end at the earliest possible time. With every reported transaction, this picture changes and becomes more precise in accordance with the new delivery volume. The TSO does the balancing itself and can thus derive the delivery volumes of a day, distributed over the 15-minute intervals.

If, however, traders save their commercial data in the blockchain, and the TSO is also tuned into the blockchain, then the notification process is already taken care of. Here the blockchain would help slim down a process that currently burdens the IT infrastructure of various traders with a substantial overhead of diligence and costs.

1.5.4 Disruptive effect on financial settlement

Many blockchain projects in the fintech sector deal with the impact of the blockchain on clearinghouses. There are now various clearinghouses that occupy themselves with the topic in order to better understand whether and how their existence might be threatened.

On that note, the paper by the consultancy Oliver Wyman and Euroclear is well worth reading [16]: Through the introduction of dedicated blockchains for the asset side (here: delivery obligation for electricity) and for the means of payment (Euro or a special trade currency) various service providers can be omitted from the complex mesh of financial trade, in particular the authors come to the conclusion that “no central clearing for real-time cash transactions” are necessary. In particular, concerning the role of the CCP in spot transactions, the authors write:

> “In a near real-time asset transaction settled for cash, there is no longer a need to clear the transaction centrally (as both sides have pre-trade transparency that their counterpart will be able to meet the terms of the transaction, and settlement happens almost instantly). However, transactions with a longer lifecycle (such as derivatives) still need the advantages of CCP novation to achieve netting benefits and reduced future counterparty credit risk (replacement risk)” [16, P. 13].

The role of the clearinghouse in energy trade has already been described, just like the influence of the blockchain on the physical settlement of transactions. So if an exchange, as described above, already writes its transactions into the blockchain for reasons of regulatory reporting, then they are also simultaneously available to the TSO. Thus, this part of a clearinghouse’s task (physical settlement) is already optimized elsewhere.

Concerning the financial side of the settlement – the payment netting – the star-shaped billing between the CCP and the traders is already the result of optimization – so how might the blockchain be employed here?

Since many blockchain solutions (e.g. Ethereum) are equipped with a billing unit (“Ether” in the case of Ethereum), it is no big step to integrate them into the settlement of trade transactions as well. One could hypothetically utilize a copy of the currency “Bitcoin” exclusive for energy trading, but is it really necessary to use a currency with a variable exchange rate? As long as energy trades are denominated in Euro, it is thus sufficient to use an account system in which, with every trade transaction, a payment value is also implicitly billed – similar to a Bitcoin transaction. Market participants must then stock adequate liquidity (the transaction account) so that they can subsequently execute their commercial transactions. However, since the use of the account system is considerably cheaper than conversion between fiat currencies such as the Euro or British Pound and itself, the spot market in particular would profit from this payment mechanism.

So, if a spot trade is billed instantaneously, and this billing costs no more than a few cents, then the advantage of payment netting is reversed again. For a trader, the use of the blockchain with an account system is much cheaper.

However, there is also a big disadvantage to this solution: The transaction account of every trader must be sufficient for unexpectedly large transactions, which means that the worst case defines the required liquidity. Because if in the case of such a transaction there must first be a transfer of Euros from the classical banking world to the transaction account, the delivery of energy may have already elapsed – it simply takes too long. But it is equally inefficient to continuously park an excessive amount on the transaction account of the blockchain, as this liquidity would no longer be available to the company for other transactions – the trader could use the money much more reasonably for other purposes.

At this point, one can imagine that the service of a bank for the financing of trade through the back door would come back into play (the clearinghouse by the way is also a bank). While traders today deposit securities with clearinghouses in order to secure themselves against trade partners dropping out, in the scenario of P2P payment they would use a credit line from the bank which is in turn secured by fixed assets. Nevertheless, the banking side wouldn't have to bill settlement fees for each and every trade transaction, but only for the provision of liquid assets. Additionally, this business would be a completely normal business model for banks, i.e., sector specialization might no longer be required.

Accordingly, the somewhat disruptive picture of the market roles involved appears as follows: Besides traders and market places, TSOs and regulators remain as natural monopolies which cannot be optimized out of existence wither factually or per law.

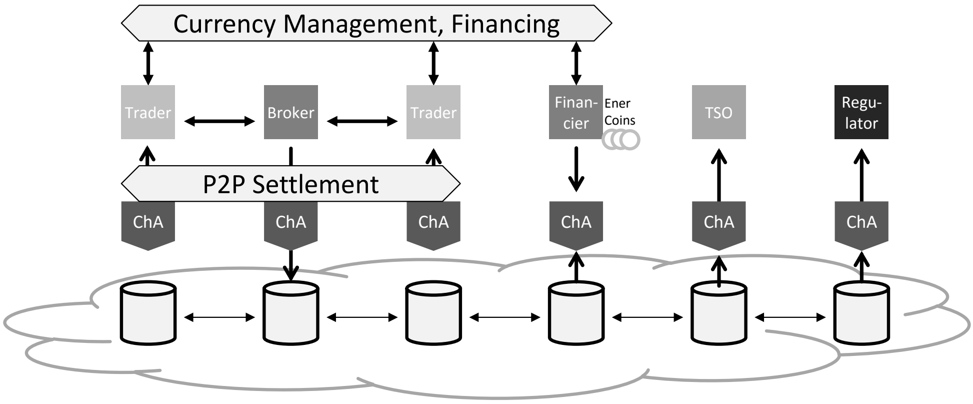

Fig. 6: From a clearinghouse to a financier

One open question still remains: How can the market participants secure themselves against the dropping out of trade partners? If the clearinghouse can no longer step in as a market participant, will all counterparties with claims against the dropped-out party also be pulled into damnation? Or will an insurance solution apply take effect in this case? These are aspects for which the blockchain community must in future find a solution which is at least as efficient as the current one.

1.5.5 Disruptive effect on peer-to-peer trading without a broker

So far we have assumed that an exchange or the trading platform of a broker naturally plays a centralized role, i.e. it was intuitively clear that trading on exchange platforms must be an inherently centralized process. This however has meanwhile been refuted! Because as of April 2016 there is the counterproof OpenBazaar (www.openbazaar.org), an open source based extension of Bitcoin which – just like Bitcoin – does without anything central. Everyone can be a trader and offer their products themselves. Whenever there are disputes between counterparties, third parties can be involved as arbitration body. The payment of goods and services is made via Bitcoin. This also means however that the disadvantages of Bitcoin (very long block time, limited transaction rate) effect OpenBazaar trade.

Since OpenBazaar consistently carries on the pseudonymity of Bitcoin, plenty of unknown traders of all sorts could be found on the first days of OpenBazaar's go-live – including vendors of illegal drugs and Nazi music – this seems to inevitably occur in connection with pseudonymity in case of unpermissioned blockchains. The OpenBazaar architecture from figure 7 should therefore be viewed as prototypical for future P2P market places:

- At the very bottom of the stack, **Bitcoin** serves as a common basis for payment transactions with its properties like persistence, accounting, data consistency between nodes, failure tolerance of nodes, etc. Alternatively, one can also imagine that the market place architecture doesn't have to be tied to any specific blockchain or blockchain technology, its technical API could for instance map onto Bitcoin according to a preset, but for other requirements (mutual trust, reduced block time) it would certainly make sense to employ a different blockchain implementation.

- **Peer-to-peer communication** The OpenBazaar network is used in order to directly exchange offers on the grid. Here the P2P protocol “Kadelia” is used which synchronizes nodes transiently, that is without using the persistence of the blockchain [17]. The advantage is in the rapid synchronization of nodes, but offers of a participant would be lost if an OpenBazaar node were to be shut off.
- **Chain adapter:** Above the technical API there is the connecting layer between the technical and the functional level. The Interface offered by the chain adapter is vertical, here in the context of the respective markets (financial trading, insurance, physical goods, crowd funding) an appropriate terminology is used. In the energy context for instance this would be product attributes such as “base load”, “delivery period” and “MWh”. In OpenBazaar it is these vertical components which implement sector-specific logic. A chain adapter would, in the sense of OpenBazaar, offer a vertical API which would in turn be used by market participants.
- **Applications of market participants** would build upon the commercial API. Typical applications here are ETRM systems and trading-front-ends of traders, for other participants it is the respective applications of clearinghouses, TSOs, regulators, etc.

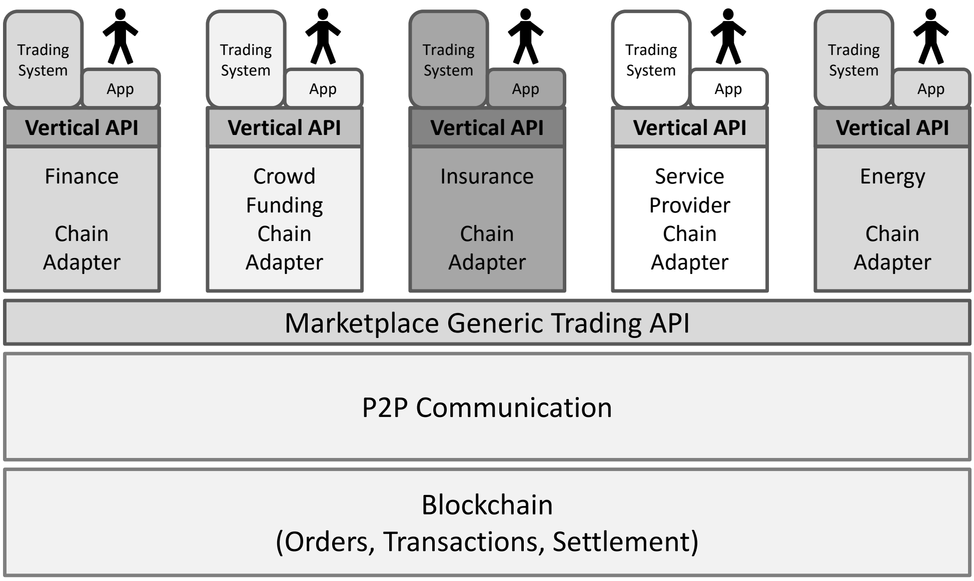

Fig. 7: Architectural model in the style of OpenBazaar

The chain adapter takes on a market-specific role, since the way application-level data formats and processes are embedded into the blockchain is defined at this level – as such, a multitude of details have to be agreed upon between the market participants before everyone involved can communicate technically. In the course of a complete standardization, the aforementioned Yin-Yang-Yong has to be implemented in the development of vertical chain adapters.

Also the Bitcoin connection of OpenBazaar may well prove too slow in the context of energy trading. While a delay up to a few hours for a secure inclusion of a transaction into a block is surely tolerable for trading goods privately, as found on, e.g., eBay, this timeframe would be far too long in the energy trading space. For energy trading the creation of an order has to be transferred to the other nodes in a fraction of a second in order to prevent traders with fast connections from gaining an advantage. The execution of a transaction must reach the other nodes with equal speed in order to prevent double billings. The protocol must insure this, since only one party can award of contract for a transaction.

In this sense OpenBazaar is here being presented as a principle and not recommended as a virtual place for energy trade transactions.

However, the community of energy traders is no longer at the very outset when it comes to establishing data formats, as various standards already exist in the sector. Special mention goes to CPML (Commodities Products Markup Language [18]), an XML standard for the structuring of data for energy trade transactions. CPML originally emerged in the course of the eCM process (electronic Confirmation Matching), in which traders mutually verify whether the data of an OTC deal of the other party match the transaction data in their own ETRM system. If this is the case on both sides, we call this a “match” – and everything is fine. Only if both parties’ data doesn’t match, an error may have occurred. In the course of the standardization of this eCM process, a pool of standard data elements for the modeling of energy transactions emerged which would “only” have to be mapped onto the blockchain (see also the Enerchain project: http://enerchain.ponton.de).

Due to the ten-year practice of the CPML standard, there is some chance that the standardization of the chain adapter could be adopted within a short time. It is therefore not unrealistic to assume that early market place projects in this area will start soon.

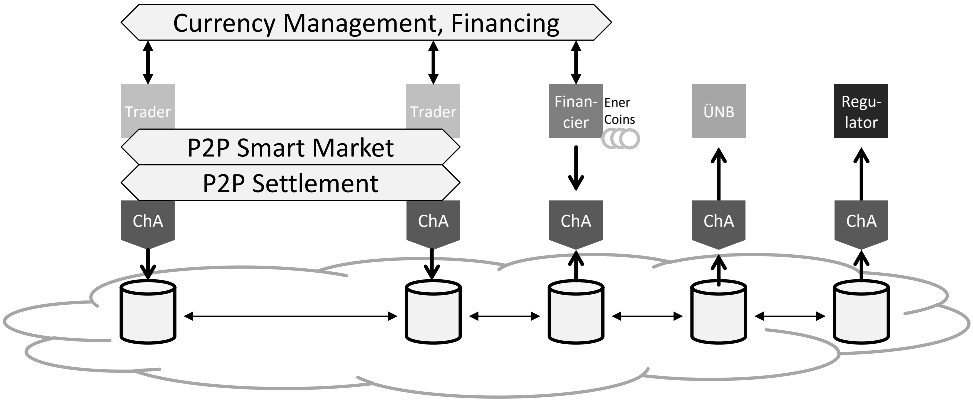

Fig. 8: OTC energy trading without a broker

One might lastly object that a P2P marketplace could never reach the speed and transaction rate of a centralized execution platform system. This is true, as for instance in high frequency trading, transactions occur in the space of a few microseconds. But is this really a requirement in energy trading? As long as a few seconds are sufficient to enter an order, display it on the trading screen of a trader and confirming the deal by clicking, we are still on safe ground for blockchain-based trading. In the long term however we can expect – as in the smart-grid scenarios mentioned above – software to make transaction decisions. But if milliseconds count here rather than seconds, then a trader sitting on the same node of the blockchain could have an advantage, as transmission time is a source of delay.

If the transaction rate of advanced execution systems doesn't have to be reached, it is nonetheless an optimization goal of energy trading to increase it for the sake of non-discrimination. It would be interesting therefore if a blockchain product offered the feature of "non-discrimination" which works without putting traders at a disadvantage based on a topologically disadvantaged node. One could for instance, in the case of a hosted blockchain, force the traders' systems to keep connecting with different nodes so that it is a matter of coincidence whether a counterparty event (e.g. an order) reaches the same node or a different one.

1.5.6 Scenario 2030: A perfect energy market

If we project the final scenario to the year 2030, what is the maximum level of optimization we can imagine? As we will see in a moment, the blockchain technology will concern us only peripherally, for two reasons: firstly, because the term "blockchain" will most likely no longer be used in 2030, just as today we don't talk about the "mobile telephone network" because of its omnipresence, and secondly, because the scenario is essentially a requirement analysis, from which the design of the blockchain for future energy trading can be derived.

Admittedly, this scenario is quite visionary, but the beauty of it is that for the foreseeable future no one can present evidence to refute it, so for the moment our thoughts can run free – please do not take prices, quantities or other quantization literally, as they may certainly end up being different in reality.

Also, the “copper plate” metaphor is not actually permissible, because the delivery of electricity to or from a distribution grid is limited by the Kirchhoff circuit laws – the market has to comply with physics. However, there could be an incentive system that encourages future producers to choose locations in the vicinity of major consumers.

We are assuming, therefore, that there is a unified grid and trading infrastructure that spans the entire European continent. Participants are the operators of large and small power plants as well as large and small energy storage providers who can deliver power, more or less reliably, to the market or alternatively to third parties depending on weather conditions. There will also be participants who offer energy conversion depending on market or transport requirements, for example: from electricity to gas and from gas to electricity. Market-distorting subsidies such as those provided through the German EEG (renewable energy law) no longer play a role in 2030, as renewable energy production no longer needs to be subsidized and the last subsidized facilities have reached the end of their eligibility period.

The investment per kilowatt of generating capacity is only 500 Euros (today it is already possible to install larger wind turbines for an investment of less than 1000 Euros per KW); in the long term, large and small plant operators will offer power at wholesale for an average of 2-4 cents / KWh, which is below the historical wholesale price in Figure 3. Battery storage costs only 100 euros / KWh [19]. Since Tesla will be producing batteries for 300 USD / KWh as of 2017, this assumption for the year 2030 is not unrealistic as further efficiency leaps can be expected. The aggregated generation capacity in Germany may be above 200 GW, only a small portion of which is typically used, the rest is available directly or indirectly as reserve capacity for exceptional situations.

However, the primary goal in 2030 is not to buy the power for heating a sauna in Finland from the owner of a solar roof in southern Italy – rather, there is an incentive to consume most of the generated power locally, in the local or regional distribution grid. For example, there could be a dynamic grid usage fee charged by the TSOs on top of the 2-4 cents / KWh as soon as the transmission goes beyond the local network, distribution grid, or TSO zone. Today these fees average out to about 6 cents / KWh. In future, there could be different charges depending on the grid level: delivery within the local grid might then cost 3 cents, within the DSO grid 5 cents, and beyond its borders perhaps 8 cents. Thus, there would be a price incentive for locally generated power to be used locally.

The participants acting on behalf of the prosumers are not people, but algorithms in the control systems of the respective producers and consumers (think of Sophie’s “energy agent” in the prologue). Just as today the control algorithm in a hybrid car determines whether generated electricity is used to charge the battery or to assist the engine, the system control software decides on a per minute basis, whether to store electricity or sell it on the grid. In the latter case, an offer is placed on the smart market, a regional market for power supply.

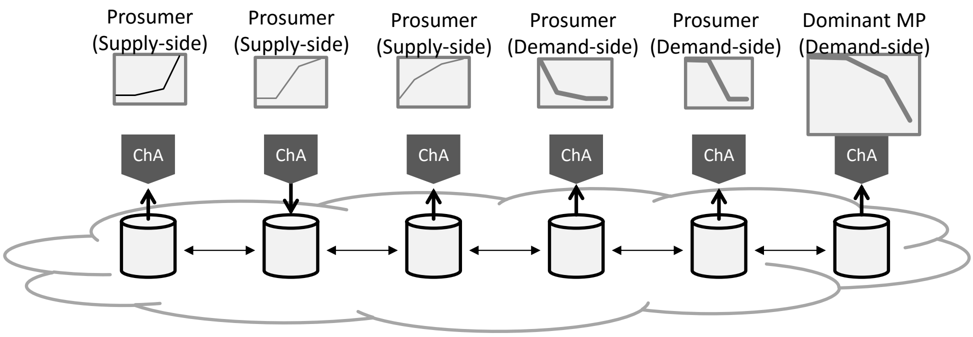

Fig. 9: Different supply and demand behavior on the smart market

Each prosumer is represented by an energy agent. The agent decides whether it makes more sense to sell generated energy, store it, consume it locally, or to obtain additional energy from the grid. The current optimization objective may change at any time based on internal or external conditions and forecasts: For example, it could be that the electric car was just connected or the stove was turned on. This would be a new situation that the prosumer's trade agent adapts to at short notice by adjusting its course of action in accordance with a preferred policy chosen by the prosumer – like when you accelerate or brake in a hybrid car.

The crucial question is: Where does the signal for the agent come from concerning whether to buy or sell, and at what price? Once again, a marketplace is required, as described above in connection with wholesale trading, but in this case it is more short-term and fully automated. The participants in this market are local energy agents from the region of the DSO, but also transregional traders. Influenced by the wind and sunshine conditions, the offers of the agents within a region vary only marginally, and the quantities traded are also quite small. The transregional traders, on the other hand, can buy or sell much larger quantities, as supply and demand can differ considerably between different regions. For example, the regions may be more or less windy or may have a more or less industrial demand.

Unlike today, where there are aggregators who pool the supply from small producers, in the 2030 scenario these small producers have emancipated themselves as independent players in the regional market. The aggregators are replaced by distributors who balance supply and demand between different regions. They stand quasi alongside the small producers in the regional market, not above them.

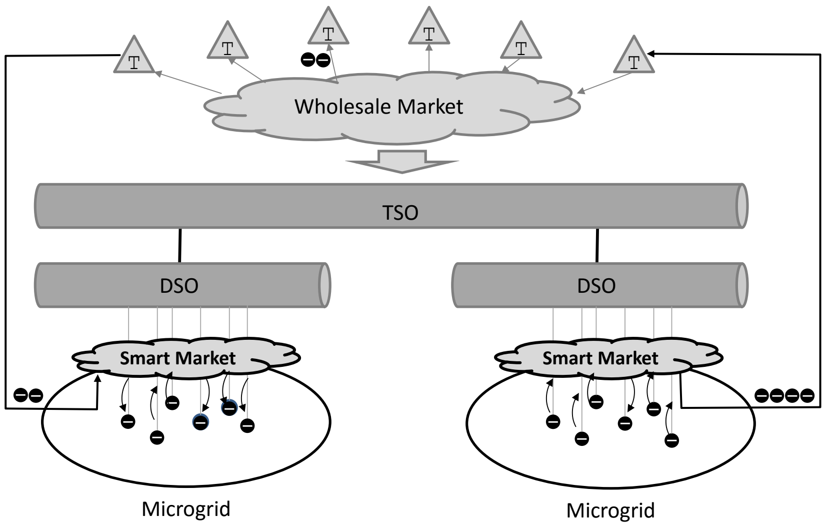

Fig. 10: Regional smart markets vs. the wholesale market

Situations with high production automatically lead to electricity prices close to zero cents / KWh, but negative rates may no longer exist in 2030 because producers can reduce system output themselves if necessary. But zero cents is realistic, since the running costs to operate generators are negligible. Power supply at minimal prices is, in turn, attractive for gas producers ("power to gas") who use it during surplus phases to produce hydrogen or methane at almost no cost. Take for example the situation on Sunday, May 8, 2016, when a surplus of 13 GW was produced within several hours, as mentioned previously. This surplus could be converted to methane and stored, and then fed into the reserve capacity of a gas power plant for use during dark, windless hours.

EnerCoin is the trading currency for electricity, and every participant involved in the trading of electricity has an EnerCoin account. Anyone who wants to purchase electricity has to use an exchange service to change euros into EnerCoins. As mentioned above, this should be possible without substantial transaction costs. The exchange can be carried out by a bank by transferring euros to the participant's EnerCoin account, or also at financial markets where EnerCoins can be exchanged directly with currencies other than the Euro. Pegging the EnerCoin 1:1 to the Euro may disappoint libertarian advocates of free cryptocurrencies, however, it is easier to evaluate variations in the price of electricity as a commodity using a currency that is firmly tied to the Euro, than to have to evaluate two prices (EnerCoins against the Euro and the price per KWh against EnerCoins). For every issue of EnerCoins, a corresponding amount in euros is virtually withdrawn from circulation, so that there is no money creation. Nevertheless, one can imagine the Central Bank using a complex calculation to determine the "money supply" in EnerCoins needed in order to provide the required liquidity for the cycle of electricity production, trading and consumption. Banks can acquire EnerCoins from the Central Bank up to the amount of the EnerCoin money supply.

If the demand for EnerCoins rises, the Central Bank can make a shift between Euro and EnerCoin by transferring a corresponding amount from their euro accounts to their EnerCoin account. The Central Bank would thus be the only instance in the EnerCoin world with the authority to change the aggregate of all EnerCoin balances. As participants in the EnerCoin market, banks provide EnerCoins to their customers for a surcharge. This is an automated process that the banks carry out for low charges as part of their regular business. Once a participant has acquired enough EnerCoins, that participant's energy agent can trade and pay for even small quantities of energy without significant transaction costs.

The transfer of a given EnerCoin amount between buyer and seller is achieved through the entry of signed postings in the blockchain. The total EnerCoin money supply is divided up among the accounts of the Central Bank, the commercial banks and the participants in the energy market.

The transaction demand for EnerCoins initially comes from the consumers and then passes to the producers in the course of the trading process. The producers then change EnerCoins back to euros through their bank. However, it is also conceivable that the roles of "bank" and "wholesaler" merge, with this participant changing the EnerCoins obtained from electricity customers back into euros.

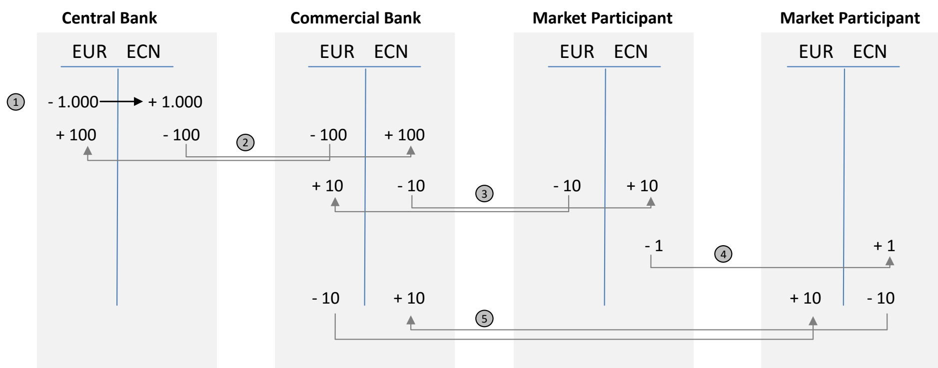

Fig. 11: The EnerCoin cycle

1. Initial formation of the EnerCoin money supply (with sporadic adjustment of the total amount as required, depending on the demand for EnerCoins)
2. Commercial banks exchange euros for EnerCoins through the Central Bank
3. Market participants exchange euros for EnerCoins, through their commercial banks, for transaction account management
4. Market participants use EnerCoins to buy electricity or receive EnerCoins from their electricity customers
5. Market participants change EnerCoins back to euros through their bank, as required

In the 2030 scenario, we can assume that the energy market outlined above is almost perfect: There is transparency concerning supply and demand, and the actions of both sides are fundamentally known to the other participants. Since the players on a local market are subject to similar conditions (prices for production and storage technology, same weather conditions), the local market price is determined by transregional parameters. To illustrate: Under normal circumstances prosumers in the Tyrol region would sell electricity to their neighbors at a daytime price of 5 cents / KWh and a nighttime price of 8 cents. A demand pull then arises due to calm winds in northern Germany, so that there is a greatly increased transregional demand. Suddenly the agents of the local PV systems in Tyrol increase their price to 25 cents at short notice, because they can now supply their solar power to Germany, rather than feeding it into batteries or to a pump storage plant. This increase is seen simultaneously among all the Tyrolean providers, because all of them use more or less the same price curves for their offers. When the market price then settles at about 15 cents, it becomes profitable for operators of gas power plants – in the medium term, i.e. within one hour – to produce electricity as well. If the calm winds then continue through the night, there is a further price increase to 55 cents / KWh. At this point, even the last CHP plant joins in, generating for its owners a profit margin of as much as 30 cents per KWh. In case of need, Norwegian hydropower plant operators and German gas power plant operators supply additional power. For the latter, this is especially attractive if they are located in the region with high demand, as the network usage fees incurred are then minimal. At 55 cents / KWh (i.e. 550 euros / MWh), the operation of a modern gas power plant could be profitable even if it only runs for one month a year.

For consumers, this means they are getting their electricity from the neighborhood at minimal cost (5-8 cents) for about six months a year – these are mainly grid usage fees, taxes and other levies. For five months, the cost of the electricity is 10-15 cents, and for one month a year they pay a “scarcity price” of 50 cents. On average, this means a price of less than 15 cents / KWh – probably a satisfactory figure for producers and consumers alike in the year 2030.

It is important to note that the traditional sale of electricity is still in place, where a consumer signs a supply contract with a supplier to receive power at a fixed price per KWh for one year, for example. This may even apply to 90% of all private and industrial customers, as they do not feed electricity into the grid.

The separation of energy trading into regional markets also involves the formation of price zones, where the market price may vary between zones. So, the price in northern Germany, with its overabundance of wind turbines, could be lower than in southern Germany where there is more energy consumption and less energy production. Further subdivision is also possible, so that there might be, for example, 30 different price zones where internal delivery is cheaper than external. Flexible grid usage charges then create the incentive to invest in energy production where consumption and prices are higher.

But why this detailed consideration of pricing in regional power grids? Regarding the use of the blockchain, the question arises as to whether the quantities produced and prices paid need to be kept secret in the described scenario of regional production. If everyone in town knows how much PV production capacity and how much battery storage Liz and Sophie have, and if the energy agents' delivery policies are all nearly identical, then the profit from the sale of electricity is no longer a secret. So if Sophie delivers a one kilowatt load throughout the entire year for an average of 6 cents, that would be just over 500 Euros. Even if it were10 times that amount, it would still be a supplementary income that no one would have to make a secret of. Perhaps the blockchain of 2030 can be kept very slim, if it omits such properties as pseudonymity and restricted access to transaction details.

In addition to the core business of energy trading, step by step other services may develop that are also traded in the EnerCoin world, so that it becomes quite normal for users to monitor not only their euro account, but also their EnerCoin account balance. Because of the 1:1 coupling to the euro, revenues and expenses can be taken over in corresponding software applications for accounting and tax purposes. This very detailed "Scenario 2030" can be elaborated in different directions:

- **Do we really need a Central Bank** to bring EnerCoins into circulation? Probably not. The task of managing the EnerCoin money supply could also be carried out by a privately held company that acts as issuer of the currency, combining the role of central bank and commercial bank. It would accumulate a huge sum of euros for issue of an equivalent amount as EnerCoins. The EnerCoin money supply would result from the exchange transactions between the issuer and the market participants; control of the money supply with regard to a specific target size would not be necessary. The issuer would need to be a trusted third party, so that market participants would be willing to use EnerCoins. In the micro-market scenario, apart from banks and wholesalers, grid operators are the only larger companies involved in energy trading activities. Perhaps they will take on further significance in future, beyond the physical transmission and distribution of electricity.
- **Are multiple issuers of EnerCoins conceivable?** This depends very much on the configuration of the blockchain. With Bitcoin, "mining" – i.e. the creation of money – is limited by cryptographic proof-of-work mechanisms, whereas the issue of EnerCoins could also be placed, with collective trust, in the hands of a group of organizations. The conditions for operating such activities would have to be clarified. Instead of mining, the blockchain used would need to provide a means of changing the money supply in a controlled and transparent way.
- **Do we need the euro as a reference currency?** Theoretically, the "EnerCoin" could be a private currency, detached from the euro. In this case, exchange of the currency would be subject to the additional risk of variable exchange rates. There is also enough literature from the Austrian School of economics that supports having a private currency competing with currencies from the national central banks, in order to discipline the latter as part of a quality competition. Further details can be found, for example, in Hayek's

"Denationalisation of Money" [20]. Alternatively, there could be multiple private currencies in competition, one of which is chosen by the transaction partners for use in the payment process. All this may be realistic and sensible from a macroeconomic vantage point, but controlling budgets and balancing exchange rates could overburden the applications and agents involved in energy trading.

- **Why not transfer the reference currency to the blockchain to begin with?** This would be the most radical variant: Simply "blockchainify" the Euro (or CHF, GBP, USD) – goods of any kind could then be traded as efficiently as described here for electricity. Presumably, this would only be accepted if the blockchain ensured the same level of pseudonymity as we know it today from Bitcoin. Moreover, it is doubtful whether blockchain technology can provide sufficient performance to bear the load of reliably processing every single transaction of the combined European economies with over 500 million inhabitants in real time.

There are many other aspects to be clarified before the 2030 scenario can materialize. In discussions with economists, for example, the question has come up as to how to deal with a market crash in the smart market. If during such phases no defined market price is available and the trading of electricity is temporarily suspended – how can uninterrupted supply be ensured? Lots and lots of questions that we can neither answer at this time, nor identify in their entirety.

If a blockchain of the future is supposed to meet the requirements outlined above, it will have to be capable of processing mass data at completely different orders of magnitude, presumably several thousand transactions per second posted Europe-wide. But if the majority of transactions occurs in subordinate, regional grids, a new requirement arises: Regional and hierarchical blockchains would need to be supported: Deliveries within a regional grid would be posted in a regional blockchain, whereas transregional deliveries would be in a higher-level blockchain. This would make it possible to process the transactions of 100,000 connections in a DSO's grid. The TSO would then read out the data from the DSOs in its control area as well as transregional data to get a real-time picture of expected deliveries. Another approach would be for the DSO to filter these details locally and only report net actual volumes to the TSO. The DSO may deal in two currencies – its own and that of the TSO?

Although regionalization may be useful in terms of the physical delivery, it could lead to "double spending" in the transfer of payment. This issue might be remedied by separating physical delivery and payment processing into two blockchains.

As said, the description above is a scenario. We still have a few years to go till 2030, but it can be quite helpful to discuss future possibilities of blockchain usage, so that we have a vision for the refinement of blockchain technologies that the developers in the relevant companies can work towards.

As a precursor to the 2030 scenario, it would be interesting to develop a kind of "midway" island model where a blockchain-based electricity marketplace can be put to the test with a limited number of participants involved. Taken literally, there are actually several islands that could be considered: The Isle of Man, for example, has 80,000 inhabitants, Ibiza 135,000, Mallorca 900,000 and Cyprus 1.1 million (both parts). With several thousand prosumers acting as market participants in these island markets, there could be a pilot of the outlined 2030 scenario on a smaller scale in perhaps five years. The movement patterns of fully automated markets could be observed well with this number of participants. In the framework of pilot projects, providers can test the development of peer-to-peer marketplaces and of the agents involved.

1.5.7 What blockchain technology is suitable for energy trading?

Now that we have considered several more or less ambitious scenarios of blockchain usage in energy trading, the question arises which of the many blockchain properties are essential in such a scenario, which are useful, and which are unnecessary. The following table lists all the different properties imaginable and their relative importance:

Tab. 3: Blockchain Properties Required for Energy Trading

Property	Importance for Energy Trading
Persistence	Essential for storage of transaction data.
Data exchange / data synchronization	Essential for processes such as the exchange of orders and transactions, nominations, useful for regulatory reporting.
Immutability	Essential if the storage of transaction data is to be secured cryptographically. Useful for regulatory reporting and to detect insider trading, e.g., around unplanned downtime
Permissioned blockchain	The blockchain is fundamentally “closed”, i.e. it is limited to the participants of traditional energy wholesale trading. For the 2030 scenario, where anyone can participate in the energy market, a public blockchain might be considered.
Proof of work / proof of stake, block formation	Essential (prerequisite for immutability), in case of a permissioned blockchain a “proof of stake” is sufficient, permission for block formation is handled through authentication of the node operators.
Availability	This is essential, the moment processes such as nomination and request of balancing energy are included, and certainly in the case of the 2030 scenario. Security of supply remains the ultimate goal in 2030.
Block time	The following characteristics are essential: The mutual exchange of transactions should occur in less than one second, the block time may be 5–10 seconds.
Throughput	For medium-term usage (trading, schedule notification) a throughput of 500 to 1000 transactions per second is required, the throughput required for the 2030 scenario can only be achieved with a hierarchical blockchain.

Property	Importance for Energy Trading
Anonymity / pseudonymity	Essential for the medium-term scenario, but with mechanisms for lifting by authorized third parties. In the 2030 scenario, anonymization may no longer be a needed.
Trustlessness	Not required, as it is assumed that all node operators are trustworthy and therefore any fraud by the operators themselves can be excluded.
Node operator = market participant?	Useful: As the number of participants increases, it becomes less and less necessary for participants to operate a full node themselves. A “core group” of 20–50 operators is probably sufficient, while the rest would access nodes remotely using something like a trading front end. In the 2030 scenario, the number of nodes could go up to a few thousand, but they would be organized hierarchically.
Smart contracts	Not required: Presumably, smart contracts are less necessary for mass transactions in a closed system than for a public, multi-purpose blockchain that supports individual transactions by its users.
Integrated payment process	Useful: The 1:1 coupling to a settlement currency would make a centralized financial management process unnecessary.
Currency	Not required: The 1:1 binding to a reference currency such as the Euro would facilitate the settlement process. A free currency with potential exchange rate fluctuation (like Bitcoin) may be difficult for participants to handle.
Creation of Money	Not required for market participants themselves (in the sense of “mining”); in the 2030 scenario, money creation is carried out by the designated banks or operators.

1.5.8 Final considerations

One question that might emerge at this point is why the topic of “smart contracts” has been touched upon so little here.

Smart contracts are a brilliant concept for “multi-purpose blockchains” which are available to consumers with various different activities – a car rental contract with the provision of an electronic key for payment, or the purchasing of a T-shirt at an online shop with automatically triggered payment and delivery. Bitcoin, as the mother of all multi-purpose blockchains, as well as, for instance, Ethereum because of its simplifications and extensions now both function as testing labs in which smart contracts can be experimented with.

It is, however, hard to understand why smart contracts would make sense in the scenarios presented here. When one considers that a contract is an individual agreement between two or more parties, then this contract entails a certain transaction effort. If the same parties often do business with one another, they will try to make life easier on themselves. This could, for instance, take place by the use of terms and conditions or framework contracts. In fact, one of the first successful standardizations of EFET is the formulation of standard framework contracts for different products in electricity and gas trading, which has simplified OTC trading with such products considerably. And if a society decides that certain rules that could be contractually agreed upon are of such universal validity that they affect all citizens, then they will be incorporated into the legal framework and no longer have to be made explicit either in framework contracts or in the contracts of single transactions.

The same goes for obligations that result from the completion of a contract: One could repeatedly incorporate the same process description in every contract and execute it automatically. A blockchain like Ethereum additionally allows for an optimization measure by saving the smart contract "off-chain", that is, data would not even encumber the blockchain, only the execution state of smart contract code. But if we limit ourselves to a domain like "energy trading", the market roles and processes are already precisely specified long-term, and for a huge number of participants a trade thus simply represents a set of transactions for which specific logic is entrenched in the IT systems involved.

In this section, it has become clear for which more or less important players on the energy market their roles may be redefined. All those who don't originally – that is physically – have electricity to offer or use it up, must ask themselves the following question: Am I an intermediary? Could those I mediate between also interact directly with each other? Is it possible that I live off of processing a non-standardized, obscure plethora of data? Or do I live off of the conversion or transfer of data? What will my role be when transparency and standardization have become normality due to the blockchain?

The keyword here is "disintermediation". Interestingly it was also a keyword in a book on "Electronic Commerce" I wrote in 1999 [3]. Fundamentally, disintermediation postulates the exclusion of intermediaries in a value chain. So far, this applies primarily to local retailers in the age of Amazon and eBay, Uber and Airbnb. But the blockchain and the scenarios mentioned above allow disintermediation to go much further. Intermediaries and service providers must also question their roles (brokers, exchanges, clearinghouses). This has a whole new quality. Whereas Uber and Airbnb, despite being intermediaries, can still attain a formidable margin, OpenBazaar leaves nothing for those who aren't buyers or sellers. On the other hand, roles often shift: The intermediary between EnerCoin and Euro will be just as necessary as the new form of clearinghouse, which acts as a financier of the single trader and embodies a trustworthy third party. And if in the final stage hundreds of thousands of prosumers trade energy in a standardized form, this in turn is a platform for hundreds of new services that we can't even imagine today.

1.6 The Enerchain project

For my company PONTON, which for many years has been conducting integration projects in energy trading as well as developing and maintaining applications for settlement processes, it is clear that the blockchain will be one of the driving forces for future processes.

But since the interface between energy trading and blockchain technology is not yet explored in detail and – as has been described extensively – plenty of standardization work is still required, we have decided to form a nucleus for this purpose: In our day-to-day business, we not only deal with all manner of electricity and gas traders, but also with market place operators of different specializations as well as grid operators. And with all of them we are involved in topics of standardization.

This nucleus "Enerchain" today consists of a first project which aims to support off-market P2P trading of energy, so basically an OpenBazaar, but optimized for energy traders.

For this, traders install a blockchain node as well as the required trading-screen over which orders can be transmitted and trades can be completed. Both are exchanged directly between the participants via the blockchain – instead of reaching for the telephone, bilateral deals happen online. On their trading screen traders can follow market activities in the blockchain: Orders are transmitted and displayed in near-real-time and the counterparty can complete an order displayed on the screen simply by clicking.

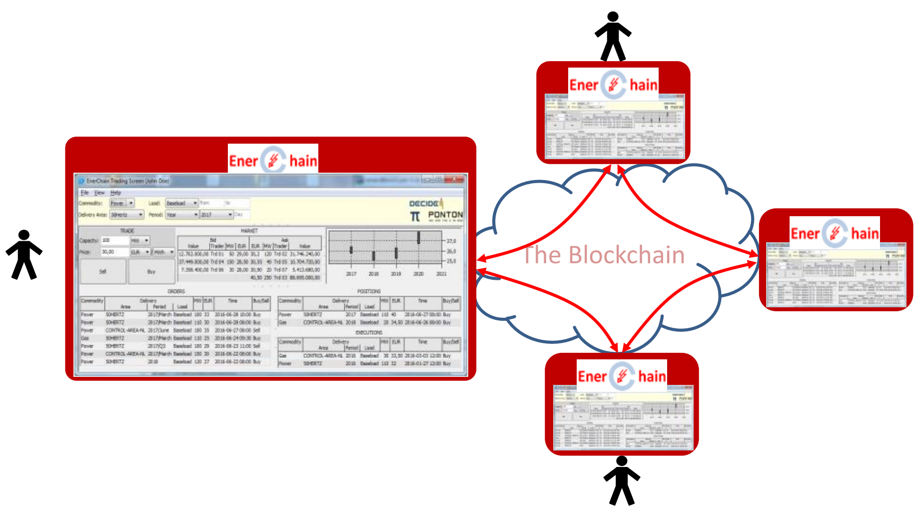

Fig. 12: Blockchain-based trading screen

As time goes on, the project then focuses on the exploration of technologies, the analysis of sector developments, and the development of new trading processes. This is done in close collaboration with companies that take on the respective market roles of future processes. In this way, the project Enerchain helps utilize the dynamic in the blockchain environment and transfer it to future energy processes.

Enerchain proceeds as a "blockchain think tank" in such a way that PONTON would analyze developments on the business or technological level, and potential processes would then be specified in detail and validated through prototypes. As a result, participants are put in a position to implement processes specific to their sector.

Further information on this can be found at http://enerchain.ponton.de.

1.7 Prospects

At this point, the blockchain is a technology with potential for energy trading. Neither has proof been given through far-reaching use that this technology will keep its promise, nor are there any fundamental reasons why it should not. It will be economic, legal and regulatory parameters that decide whether the trading and distribution of energy on the basis of blockchains make sense or not.

If the costs of an energy trade transaction are significantly lower than the internal coordination costs of today's players, if there are market-based allocation techniques that can give the right price signals to a swarm of small-scale producers, if it can be guaranteed that the requirement of security of supply is met "despite" the blockchain, and if misconduct by market participants, fraud or other forms of criminal violence can be ruled out, prevented or at least made unprofitable, then the blockchain has a chance.

In the end this is the old rivalry between "market" and "hierarchy", or between "bazaar" and "cathedral" (as described by Eric Raymond in 2001 [21]) that decides about the blockchain's permeation of the world: If the cost reduction through the use of the blockchain exceeds that achieved by the internal organization of today's market participants, then the market wins. But similarly in companies or in the coordination of traditional "incumbents" of market roles in the energy market, the blockchain along with other technologies can increase coordination efficiency. Today an exchange can also push through a large number of transactions at minimal respective costs but, like many other traditional processes of the energy market, still has considerable potential for increased performance Access to this market, however, is currently impossible or at least unprofitable for the majority of the population, due to regulatory or economic constraints.

All these observations were already made when the Internet became popular in the late '90s. The same exaggerations we heard back then ("information superhighway" etc.) are found today ("blockchain of things", "Internet of payment"). After all it took 10-15 years until the old promises were made good on and the innovative business models of the new economy could be implemented. Not until there was an economically attractive infrastructure (smartphones, affordable access, and access for a high share of the population) could we use the increasing efficiency advantages of the Internet as private persons or as companies over the past years.

But since neither Amazon, eBay, nor the railway online reservation service are “mission critical” for the commonwealth, these services could establish themselves individually. Concerning the supply of electricity, other rules apply. Here, there is a maximum demand for diligence, quality assurance, redundancy, security and availability. It is not without reason that systems in energy supply are at the very top of the German federal ministry of the interior’s list of critical infrastructures. To inform oneself about the effects of an extended, continent-wide power outage, all one has to do is read the book “Blackout” by Marc Elsberg [22].

So, if it took something like 15 years to go from a broadly available “Internet” to the “railway app”, it may well take another 15 years, maybe even 30, to reach “Scenario 2030”. Local trading in the micro-grid may currently be just as possible between people as it is to connect a solar panel to the power socket and elegantly save something like 10% of one’s power consumption. But a general marketplace that delivers power from the solar roofs of Tyrol when there is not enough wind in northern Germany not only requires the Yin-Yang-Yong of standardization in collaborative trading processes, but also international agreement on legislation and regulation.

In this context there is also the danger of blockchain-based business models developing evolutionarily rather than disruptively. As one example let’s look at the security of access to transaction data: If the hiding of transaction data limits the basic function of the blockchain too much, then its efficiency potential can’t be fully exploited. This has already been described specifically: If it is alright with the blockchain users that the amounts, prices and participants of a transaction are openly visible, because they don’t need to be secret in the context of a perfect commodity market, then the infrastructure is automatically streamlined. In any other case, the infrastructure would suffocate from the overly complex influences of the “old world”. So it is probably better to look for appropriate niches for the use of the blockchain than to expect all the developments described here to occur with the same probability.

Here at the interface between energy trading and IT, we have at least twenty very interesting years ahead of us, which will probably also be influenced by the blockchain – or whatever our technology will later be called. Initial implementations will manifest within a few years, others will take the full length of time – so let’s roll up our sleeves and see where we can begin!

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