energies

MDPI

Article

Blockchain Technology and Electricity Wholesale Markets: Expert Insights on Potentials and Challenges for OTC Trading in Europe

Carol Inoue Dick [1,*] and Aaron Praktiknjo [2,*]

[1] TU-Campus EUREF, TU Berlin, Torgauer Str. 12-15, 10829 Berlin, Germany
[2] Institute for Future Energy Consumer Needs and Behavior (FCN), RWTH Aachen University, Mathieustr. 10, 52074 Aachen, Germany
* Correspondence: carol.inouedick@campus.tu-berlin.de (C.I.D.); aaron.praktiknjo@rwth-aachen.de (A.P.)

Received: 20 January 2019; Accepted: 22 February 2019; Published: 2 March 2019

Abstract: In this manuscript, we investigate the adoption of blockchain for over-the-counter (OTC) electricity wholesale trading under the EU regulatory framework. Our analysis of the core legislation reveals six potential issues: (1) data immutability-related error correction, (2) personal data protection and immutability, (3) access to different data layers, (4) obligation and capacity to report, (5) identification of counterparties and (6) conflict of interest. These six issues were used as basis for a survey with experts in this field from industry and academia. The majority of our respondents indicated four major points: (i) reduction of transaction costs is the main expected benefit, (ii) the application of blockchain can be compliant with the current regulatory framework, (iii) a sandbox is the most welcome regulatory approach to reduce legal uncertainty, and (iv) the first use case to be commercially implemented is expected to be a P2P platform, ahead of a use case focused on post-trade processes. We believe that the results presented in this manuscript might serve as guidance for market participants aiming to enable the development of blockchain.

Keywords: electricity; wholesale; trading; OTC; blockchain; Europe

1. Introduction

Blockchain is often referred to as a disruptive innovation for a large variety of sectors such as the financial industry, supply chain, data management, healthcare and public sector. For further information and examples please see refs. [1–4]. The energy industry has no different expectations, especially with regards to supporting digitized and decentralized systems, aligned with the energy transition pushed by the expansion of renewables. The range of potential applications in the sector is varied and continues to expand. It includes, for instance, peer-to-peer trading both at the household level and among companies, e-mobility, issuance of green certificates, funding, and grid stability, to name but a few.

Among all of those, the use of blockchain in the electricity wholesale market is hoped to be one of the lower hanging fruits in terms of commercial maturity, see [5]. Especially in the European Union (EU), the circumstances have changed considerably over the last decades with the liberalization and deregulation of energy markets during the 1990s and 2000s, see [6,7]. However, utilities' revenues have been decreasing due to the decline of wholesale electricity prices, while costs did not develop proportionally in the same way with shrinking margins or losses as a consequence, see [8]. Against this backdrop, solutions to lower transaction costs are called for and advocates of the blockchain technology argue that this new technology could exactly provide this.

Currently, the energy industry is experimenting with the blockchain technology. In this context, especially questions touching the regulatory environment arise. Most of the academic and market

studies that have focused on the intersection between blockchain and regulation so far address aspects related to cryptocurrencies and financial securities in general. Searches on the academic portals Springer, SSRN, ScienceDirect and IEEE Xplore with the key words "blockchain" and "regulation" returned 468 items, of which 123 in the computer science discipline, 222 for the set of finance, business and economics and five for energy, covering solar panels and cryptocurrencies, energy storage, design of microgrids, household P2P trading and a general one. However, the goal of our work is to investigate the specific usage for the electricity sector, in which physical characteristics of the electric commodity have important consequences on the market functioning.

In this sense, this article aims to: (i) identify the main regulatory issues for implementation of blockchain-based electricity wholesale trading for the over-the-counter (OTC) bilateral market in the EU based on the current regulatory framework and the technology's characteristics and (ii) assess the perception of industry and academia professionals on the elements raised in point "i", including potential developments that may arise from them. A survey will support the latter task.

Figure 1 shows how the present investigation is organized. The second section following this introduction consists of a brief introduction to the electricity wholesale market in the EU and the blockchain technology, including its application for this specific scope. In Section 3, we will present the regulatory framework and the directive under investigation, namely the Regulation on Wholesale Energy Market Integrity and Transparency (REMIT), the European Market Infrastructure Regulation (EMIR), the Markets in Financial Instruments Directive (MiFID2) and the General Data Protection Regulation (GDPR). There are certainly other rules applicable to the energy wholesale market, both at European and Member States levels. These four are, however, the central ones and, therefore, this work' scope.

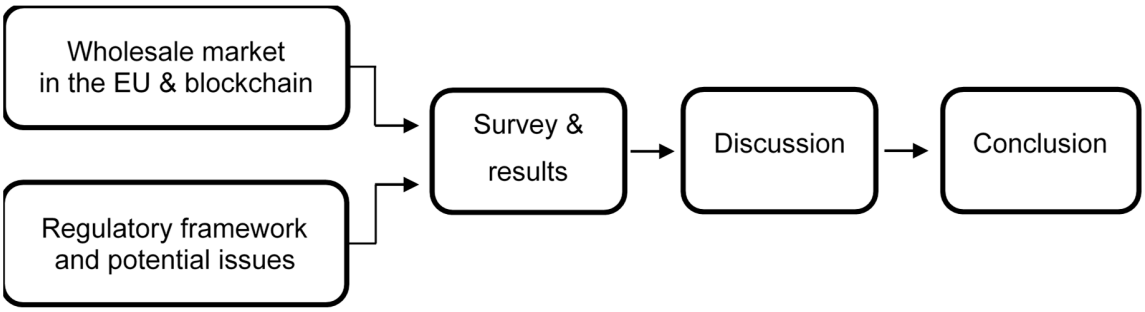

Figure 1. This article's structure.

In Section 4, we present our survey which we conducted with professionals in the sector as well as the results. These will be discussed in Section 5 to assess the previously raised hypotheses, as well as to outline the most relevant matters to which players working in the topic, mainly trading companies and regulators, should be attentive. Finally, the conclusion will summarize the main findings in Section 6.

2. The European Electricity Wholesale Market and Blockchain

2.1. OTC Bilateral

To enable a better understanding of the topic, we shortly present the basic mechanisms behind the European electricity wholesale market and behind the blockchain technology in this section. For clarity purposes, this article will use the following definitions: Trading companies and trading participants refer to stakeholders participating in the wholesale market as buyers or sellers or both. They become counterparties when entering a transaction. Market participants, market players and players are broader terms, which refer to any stakeholders involved in the wholesale market. They can be trading companies, brokers, software providers, authorities etc.

The wholesale market encompasses two types of markets: exchange and over-the-counter. The former is typically standardized and has a high level of automation, see [9], while in the

latter standardization is much lower. There are typically two OTC modalities: cleared and bilateral. Although financial authorities around the world have made efforts to increase the first, clearing also requires contracts to have a certain degree of standardization, which restrict this modality, see [10].

In OTC bilateral, often referred to as OTC only, both trading companies remain as counterparties to the deal, taking the credit risk one from another with no Central Counterparty clearing in between. This paper will specifically evaluate the bilateral OTC market for two reasons. First, it is where most transactions take place for continental Europe and it is a market that continues to grow with a total volume of 73% in the third quarter of 2017 and a 17% growth compared to the same period in 2016, see [11]. Second, it is where most of the potential efficiency gains are, once its processes are not yet as automated.

Thus, to understand the benefits of applying blockchain to bilateral OTC, it is necessary to understand a deal's life cycle, which can be separated into three main phases: pre-trade, execution and post-trade, see [9,10,12]. Figure 2 and the following paragraphs present them succinctly, as well as the potential benefits of using blockchain for each one.

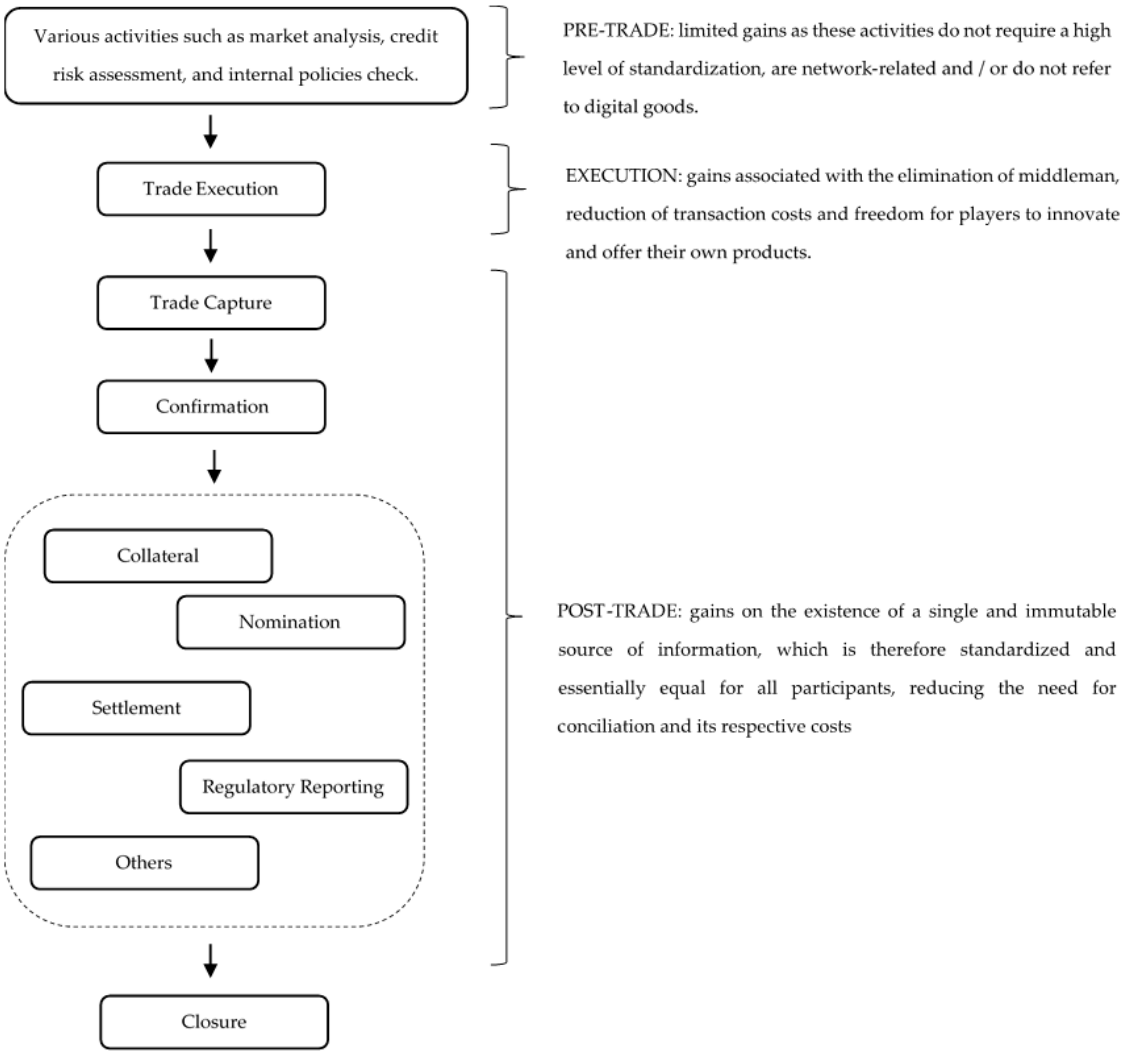

Figure 2. The OTC trade lifecycle and potential benefits from blockchain.

Pre-trade refers to activities that take place before the deal is executed, such as market analysis, counterparties evaluation and application of internal policies. Although there might be benefits transferring part of these processes to the blockchain, gains are limited, since most of the work

would continue to occur outside the DLT. Therefore, this stage is the one which presents the fewest opportunities for blockchain adoption. Arguments from [13,14] go in the same direction.

Next, the trade execution happens "when two counterparties agree to a transaction" [10] that is, both sides accept the proposed commercial terms and the orders of each become a single and binding transaction between them. In the European OTC, brokers and electronic platforms are the players gathering the necessary liquidity from buyers and sellers to move this market [12] and, for their services, they are rewarded fees that can represent a significant portion of trading companies' costs.

If blockchain allows participants to trade among themselves without a middleman, the immediate expectation is a reduction in transactions costs. A second benefit would be a greater flexibility for trading companies to create new products themselves and to anonymously test them on the blockchain. In this way, players could experiment with innovative but initially illiquid instruments and find interested counterparties without revealing the identity or strategy behind the initiator [7]. Considering a market that tends to become much more volatile in the short term, such a possibility of innovation is much appreciated.

The post-trade stage refers to a very diverse range of activities that take place after the execution and can last from days to years. It is particularly long and operational and in a simplified form comprises the following: trade capture, confirmation, collateral margining, nomination, settlement, regulatory reporting and others. A brief summary for each of these activities follows:

- Trade capture: Refers to the action taken by each part to input the deal in their own systems. This step is necessary because the platforms used for trading in the market and the internal systems for the deal administration, the Energy Trading Risk Management systems, are different as to their objectives and functionalities.
- Confirmation: Trading companies confirm with each other the transaction's material terms, such as volume, price and maturity. Although it may seem like a repetitive action, it exists because manual processes during execution and unilateral trade captures create the possibility of inconsistency between the information buyer and seller have in relation to the same transaction. Hence, confirmation is generally the earliest moment possible for risk mitigation.
- Collateral margining: In OTC bilateral this is the most common tool to mitigate risks arising from changes in the commodity's price or deterioration in counterparties' payment capacity. The risk offset only happens when resources are effectively transferred between parties, which may take some time since the calculation of mark-to-market positions involves a high volume of data and adjustments.
- Nomination: It is necessary when the instrument traded includes physical delivery. In short, it consists of submitting the scheduling for day-ahead and intraday positions per counterparty and per balancing zone to the Transmission System Operator (TSO) in charge of keeping the grid balanced. Usually both sides of one position submit their respective files.
- Settlement: It encompasses activities related to the fulfillment of financial contractual obligations between parties, such as invoice and payment. The financial settlement requires counterparties to calculate the amounts due to each other from information such as prices, volumes and taxes. This can be a complex task considering that prices may not be fixed or that the increase in the share of renewables and decentral sources brings more complexity to reconcile a high volume of data on their physical delivery.
- Regulatory reporting: Market participants must submit diverse types of reporting so regulators can monitor and protect the market from excessive risks and abusive practices. This is a resource-consuming activity as requirements are very detailed and sometimes overlapping.
- Others: Several other events may occur during the trade life cycle. This may include termination before maturity under mutual agreement or change in the counterparty due to a corporate restructuring, to name a few.

Although different from each other, these steps have in common the fact that each trading participant usually adopts procedures and systems suitable for their own management, sometimes even very manual, such as papers and spreadsheets. This generates many mismatches and the need to validate information with the counterparty. For big players, with hundreds of relationships, this might represent thousands of deals to handle per day. Thus, operational risk is high and the need for reconciliation recurrent, which consumes significant human and financial resources, both internal and external.

Efforts have been made to automate the largest possible number of activities, such as Straight Through Processing for trade capture and Electronic Confirmation Matching (eCM). However, these services are provided by third parties and are often too expensive for smaller players. In a sector like trading, characterized by network effects, this has a non-negligible effect.

Blockchain has the potential to integrate the entire trade's life cycle and reduce its costs, because it makes unnecessary to transfer data among systems and players as there is only one source which is immutable. Once the transaction is approved, it is registered in the ledger and immediately made available to the next step.

In this regard, confirmation is the one that would probably benefit the most by the adoption of blockchain. In fact, it would become virtually unnecessary [15] because when registering the transaction directly in a ledger common to all the participants, and that cannot be changed, each player can trust in the information that has and there is no need to reconfirm anything.

2.2. Blockchain

Blockchain is a Distributed Ledger Technology (DLT) that enables an immutable record of transactions. A distributed network is one, where members, known as nodes, are connected to each other and hold equal copies of the ledger containing registers of the underlying digital good(s). This contrasts with centralized and decentralized architectures, where respectively one or few central parties hold and control transactions and their records (Figure 3). A DLT is said to offer higher availability and resiliency with lower redundancy, because, in the event of any failure, it will not interrupt the network operation if sufficient nodes continue to run [13,16].

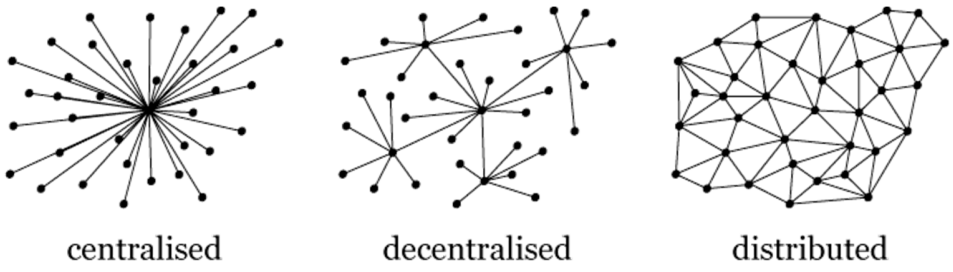

Figure 3. Network architectures, own illustration following [17].

The approval mechanisms to record a transaction in the DLT are at the very core of blockchain and there is a diversity of them. They generally consist of a validation process run by the so-called validator nodes, which can be all or some of the nodes depending on the chosen design.

Participants of the blockchain hold each a public and a private key that identify them. A member who wants to initiate a transaction sends the relevant information with its public key attached to the entire network: for example, an initiator selling energy would specify conditions such as price, volume, maturity and delivery zone, plus its public key. The order then reaches the other members, who can read all the commercial terms, but cannot identify the initiator.

In the sequence, users decide if they want to aggress the order, in this case buy the energy. Once there is a match between initiator and aggressor, the transaction is sent to the validator nodes, who verify its legitimacy by checking if both sides' public keys are registered on the blockchain and can transact with each other. This is possible because validation nodes have the list of all users' public keys.

Because a key feature of blockchain is encryption, all information exchange occurs under privacy, even at the validator node level. As private and public keys are encrypted, and because only the private key owner has reading and signature rights of the public one, validator nodes cannot know to whom each public key belongs and translate it into a readable information for upper levels in the network, for example a trader' screen. The identities are only visible to the counterparties afterwards, as they both signed it with their private keys.

Once the transaction is approved, it is added to blocks—a group of transactions—which are in turn linked to each other, forming the blockchain. Editing any of such registers is technically possible, but would require changing not only a specific transaction, but the entire chain on all copies spread across the network. Although this is theoretically possible, it is highly unlikely given that all nodes would have to agree and bear the eventual costs of processing all data again. It is such a combination of technical and economic mechanisms that makes blockchain to be called an immutable database.

When the DLT is open to anyone's participation, without any entrants' selection, it is named public. However, for many industries, some sort of gateway that allows for the identification and acceptance of new members is necessary to protect the system's integrity. These cases require a permissioned DLT, which can be: (i) private, if a single entity performs the gateway role, or (ii) consortium based, when this is done by a group of players.

The choice for a DLT type evidently implies important trade-offs to be weighted. The permissioned versions are faster, because the smaller number of players provides lower block processing time, known as latency. But fewer nodes also means less resilience. This is known as Buterin's blockchain trilemma, according to which only two of the three essential attributes—Decentralization, scalability and security, can be obtained simultaneously [17].

For this work's purposes, and in accordance with industry practices, the forthcoming chapters will refer to blockchain or DLT exclusively in its permissioned form. If a distinction between private and consortium will be necessary, this will be made explicit.

Besides the openness attribute, two types of blockchain applications are to be differentiated for the electricity wholesale trading, as they involve different stakeholders and technical solutions. One refers to trade execution. Since this is the match of seller and buyer, this application consists of a peer-to-peer trade platform and focuses on the transaction features. Because in this case the DLT is mostly replacing commercial activities, this service can eventually be understood as a new marketplace, which would certainly interest regulators from the market manipulation prevention and surveillance perspectives.

The second use case relates to post-trade services. Here, the great benefit is the standardization of information that enhances processes. As identified in [7], "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". Hence, this application concentrates on the blockchain's characteristics as a ledger and is fundamentally replacing other software providers, which, on the contrary to marketplaces, are not under wholesale trading authorities' direct supervision, although they do need to comply with stringent integrity and performance requirements.

Such division between execution and post-trade processes is not mandatory, and a solution covering both cases is possible and eventually desirable. Some practical evidence, however, ratify that players have been treating them separately, precisely indicating distinct benefits and challenges. For this reason, this work will differentiate the two use cases whenever necessary, especially when faced with regulatory issues. For further readings, please refer to [1,3,18], on which the description of blockchain in this section is based on.

3. Blockchain under the EU Regulatory Framework for OTC Bilateral Trading

In Section 3, we will present the regulatory framework and the directive under investigation, namely the Regulation on Wholesale Energy Market Integrity and Transparency (REMIT), the European Market Infrastructure Regulation (EMIR), the Markets in Financial Instruments Directive (MiFID2) and the General Data Protection Regulation (GDPR).

The main issues arising from implementation of blockchain under such rules will be discussed in the sequence. They are the result of both literature review, where indicated, and this study's own findings.

3.1. Core Regulatory Framework

Blockchain is commonly mentioned as a potential trigger for a regulatory review. However, the dynamic between innovation and regulation shows this is not so straightforward. On one hand, many of the latest regulatory changes in finance and energy markets came from the acknowledgement of the need to revise their predecessors to stay up to date with recent developments, including technological changes. On the other hand, regulators need to consider the appropriate moment to act and methods to do so, as this a path full of pitfalls. As pointed out in [19], " . . . timing is always difficult for regulators. Legislation should indeed not come too early to unnecessarily stifle innovation but also not too late to leave people and principles unprotected".

This is no different with blockchain and, hence, it should not be a surprise that the European authorities have been calling regulators to promote a "sufficiently innovation-friendly" environment, while still safeguarding important principles to preserve market stability and consumers' protection.

This means, in practice, that blockchain development shall not require *per se* the creation of a new framework and that, by principle, new solutions should ensure compliance to the existing rules. For OTC electricity trading in Europe, the core of it is given by the combination of REMIT and EMIR, to which MiFID2 and GDPR should be added when the scope includes respectively financial instruments and personal data. The next paragraphs will provide a brief description of each piece, followed by the relevant considerations for this work's scope:

- REMIT covers the power and gas markets in the EU and aims "that prices set on wholesale energy markets reflect a fair and competitive interplay between supply and demand, and that no profits can be drawn from market abuse" [20]. It is an energy regulation to be enforced by the Agency for the Cooperation of Energy Regulators (ACER).
- EMIR aims to "reduce systemic risk, increase transparency in the OTC market and preserve financial stability" [20]. It focuses on OTC derivatives because the lack of transparency on this market generate risks that are hard to identify and to prevent. As a financial regulation, it is not exclusive to the energy sector and it is under the European Securities and Markets Authority's (ESMA) surveillance.
- MiFID2, also under ESMA's umbrella, is considered one of the most complex and expensive regulatory reforms in the EU history, whose ultimate goal is to "strengthen investor protection and improve the functioning of financial markets making them more efficient, resilient and transparent" [15]. Given that in bilateral OTC participants trade mostly forward contracts, the immediate consequence is that most of this market is not subject to MiFID2 rules, see [21] for a differentiation between forward and future contracts. However, for the small portion that remains in scope (mainly swaps), the requirements are extensive.
- GDPR is the new regulation determining how to properly protect personal data in the EU. Although most information exchanged on energy trading is market-related or refer to legal persons, there are some situations where professionals participating in the energy sector are required to provide personal data., whose protection is a fundamental right in the EU. GDPR is to be enforced by Supervisory Authorities from each Member State.

Together, these four pieces form a tangle of rules and interact with each other through relations that sometimes seem complementary, sometimes overlapping and that one should consider as part of the very dynamics and complexity of the markets they propose to oversee.

The monitoring capacity of the responsible authorities is directly related to the market transparency both pre and post trade and the existence of appropriate information, which is why an important pillar is the various players' obligation to provide the relevant supervisors with an

extensive data set. This includes information about orders, irrespective of whether they were matched, transactions and aggregated positions, to name a few [22,23]. Details to be disclosed include volume, prices and who the counterparties are when this is applicable. Any error or omission shall be identified, communicated and re-transmitted [20,23–25].

While transparency is key, this does not mean authorities should have indiscriminate access to data. In fact, they should be able to see what their mandates grant them. In this sense, some authorities should only lay eyes on information concerning the Member State they supervise [23] or according to different granularities [20]. Ultimately, ACER and ESMA are the authorities with the broadest mandates. In the specific case of EMIR, trading companies must report their contracts to Trade Repositories (TR), which at their turn report to the authorities. TR are specific entities responsible for centralizing all necessary information to facilitate data collection from all OTC securities, not only commodities [20].

For REMIT and MiFID2, reporting also includes information about the natural persons who decided and executed orders, such as the login or username for REMITor passport number, social insurance number or a concatenation of some characters of the name with date of birthday for MiFID2, see [15,25]. This is where GDPR comes in, because directly associated with the personal data definition are the rights of the people to whom the information refers. GDPR's Section 3 guarantees them, among others, the "right to be forgotten", that is, to request companies in possession of their data to erase it, except if it must be collected and processed for legal purposes and the period during which they should be stored has not expired yet [24].

Beyond content, the aforementioned regulatory pieces also all impose stringent rules on formatting and layout, well-defined deadlines for reports submission—typically one business day—and terms for data storage, normally from five to ten years. While such guidelines may seem mere details at first glance, they are essential to enable effective surveillance.

To cope with such a massive amount of work, authorities require players to have robust systems that ensure reliability, integrity, and continuity. This includes maintenance rules and policies to handle access to databases and information confidentiality. The legislative texts are clear that in the case players under the direct surveillance of authorities outsource any activity, they must also ensure the third parties meet all mandatory conditions to offer the respective services and products, as in the last instance, the obligation still falls on contractors. This applies to software, which is usually bought from or jointly developed with specialized technology companies. Therefore, although the latter are not directly regulated by bodies such as ESMA and ACER, they must obey the same strict rules regarding data management.

Whilst having the integer, accurate and timely information is necessary, it is certainly not enough. That is why in the quest to monitor, prevent and punish market abuse, some market participants have a specific obligation to support authorities. ACER, for example, is emphatic about the Persons Professionally Arranging Transactions' (PPAT) responsibility under REMIT: They should not be passive, but rather active in combating market abuse. They must report any suspicious movements to the NCA "without delay" and through a report containing information such as detailed description of the event, time it occurred, markets affected, and identity of market participants involved [26]. It is worth noting that the Market Abuse Regulation of 2016 also monitors market abuse practices and has many points in common with REMIT, with the difference that the first covers financial instruments, while the latter refers specifically to physical power and gas. With regard to the PPAT function, REMIT is applicable for any instruments.

PPAT's definition reaches in several market players, also capturing brokers [26] acting in the bilateral OTC market. Under MiFID2, they will most likely be classified as an Organized Trading Facility and as such should "remain neutral" [27].

Thereby supervisory authorities impose yet additional requirements on organizational matters, which players must comply with at all times. The list is extensive and includes elements such as governance rules, fees transparency and data about shareholders and senior management. They are

also required to communicate potential conflict of interest, key people involved and shall have separate structures in cases where they are allowed to run different business within the same group.

So many organizational requirements exist to ensure that companies have, in addition to the technical conditions to provide the services they are proposing, the appropriate incentives to do so. Regulators are always looking for potential factors that may harm the market and blockchain will not escape from that.

3.2. Potential Issues with Blockchain

Throughout the research, it was noticed that some regulatory concerns depend on the blockchain's privacy: the consortium form brings, in addition to technical issues, new perspectives on governance aspects. Hence, item (f) applies specifically for such cases.

The distinction between execution layer and post-trade processes is less certain, as all issues could apply for both use cases (except for item iv, which is by definition related to post-trade). Nevertheless, considering their purpose, it is reasonable to suggest that: (i) Items (a) to (d) have a greater impact on post-trade processes as they are closely connected to blockchain's functions as a ledger; (ii) Items (e) and (f) are particularly significant to a P2P platform, because it is in the placement of orders in the market and in the match of buyers and sellers that identities' disclosure and conflict of interest offer the greatest risks to market manipulation.

(a) Data Immutability and Error Correction

Although the immutability feature is welcomed in terms of data transparency and security, it is not so valuable in cases where the single source of truth contains mistakes or outdated information.

Despite ameliorating many processes, DLT cannot eliminate all sources of errors neither avoid the necessity of adjustments as in energy trading there are still several manual inputs and interventions during a deal's cycle. In these cases, regulators are very clear on the obligation to correct the information so all stakeholders involved can properly fill their duties.

Thereupon, blockchain's tamper-proof feature makes it impossible to edit registers for the good and for the bad. Indeed, some players worry that errors could be more easily propagated and costly to revert, especially if all processes are interconnected [14]. In addition, liabilities would arise given the lack of clarity on who owns the responsibility.

(b) Personal Data Protection and Immutability

GDPR guarantees citizens the right to be forgotten, which might oppose the possibility of deleting records from the blockchain. Even if this information is encrypted and not directly readable by others, it is still considered personal data, because encryption is a form of pseudonymization, but not anonymization [28]. While the latter is an irreversible situation, the former still allows identification of the data subject if additional information is used.

Not only encrypted IDs and birth date are personal data, but also the private and public keys used by persons accessing the blockchain and potentially their IP [28]. Just as the personal data's definition, there is a certain controversy surrounding the erasing concept since such an act is subject to "taking account of available technology and the cost of implementation" [25], which leaves room for interpretation.

(c) Access to Different Data Layers

DLT could streamline operational work associated with reporting obligations and nomination by allowing regulators and TSO to become nodes and have direct connection to the ledger. As admittance should strictly follow the respective mandates, the act of granting access becomes central. It should follow two steps.

First, a methodology to identify who can see which variables should be created. If this means attaching more information to a transaction, there is a non-negligible risk of slowing down the

network performance by increasing the block size and the respective latency. As scalability is inversely proportional to the amount of data the blockchain should handle, its performance could be compromised, also decreasing the willingness to use it.

Secondly, it would be necessary to define who is entitled to have access to public and private keys and how their distribution, storage and recovery shall work. Although the blockchain architecture makes it a very secure system, one should also consider that participants still have their own access to the network, which can become the new weak spot candidate of a cyber-attack [14].

(d) Obligation and Capacity to Report

Even in the case all stakeholders are attributed with due access, reporting requirements are not automatically fulfilled: current reporting obligations include not only raw data, but processed and aggregated information, such as position reporting for MiFID2. Blockchain is a data repository, but does not manage information. It is still necessary to query data and transform it by using other tools.

The question of who is responsible for querying and completing the report remains. A very attractive option to the market would be one in which regulators assume such a role. However, this could run counter to their mandates. Besides, shifting the responsibility to authorities comes with relevant side implications. First, they will need to build capabilities and acquire new resources. Second, they would have to deal with larger risks for being the ultimate responsible for reporting. Indeed, ESMA recognizes that "use for reporting or risk management purpose may be more resource intensive and complex than anticipated. Also, the potential benefits for regulators having direct access to the data would need to be carefully weighed against the potential reputational risks" [14].

(e) Identification of Counterparties

In trading, identification of participants is a sensitive subject. On the one hand, companies must remain anonymous before entering a deal, in order to prevent market manipulation and disclosure of trading strategies. On the other hand, counterparties must always be known to each other to fulfill both internal policies and regulatory requirements, such as EMIR [29].

In the current setup, intermediaries protect and reveal participants' identities at the due time, for example for credit limit management: brokers ensure deals are displayed on the trader' screen in a differentiated way, depending on the credit limit to trade with that initiator, without, however, revealing pre-trade its identity.

In the case of blockchain, the logic and architecture of the network itself must perform such functions. As seen in Section 2.2, encryption is the element that allows this. However, there are concerns that even if encrypted identity of participants could remain officially unknown to validator nodes, it could still be deducted by linking keys with other data [30] such as pattern of records in the DLT [14] or comparison with other legal disclosed information [13].

(f) Conflict of Interest

By replacing some of the intermediaries, trading companies also eliminate some mechanisms to prevent conflicts of interest among market participants. Three possibilities deserve further exploration.

The first case is one in which the counterparties become, as a group, the marketplace operators themselves. The natural question is whether it is possible in a consortium structure to remain neutral and enforce obligations on themselves or competitors. Even if ownership is very diluted, regulators should evaluate if companies are capable to jointly influence the market or practice discriminatory behavior under the principle of the "single economic entity", see [27]. In case there are players who use blockchain to trade but are not part of the consortium, which is quite likely considering the need for liquidity and the benefit to small players, regulators might see a conflict of interest from the controllers' group towards the others.

The second situation concerns the validator nodes' role on supporting ACER with market surveillance, as they would likely be classified as PPAT under REMIT. In a blockchain consortium, they would hardly be able to comply with all related obligations, once active market monitoring and

reporting of suspicious behavior to NCA require detailed information on the counterparties involved, harming competition law. In the absence of players exercising the roles of PPAT, ACER would lose important allies, with whom it shares responsibility on identifying potential market abuse.

Finally, the third case refers to participants potentially taking on the duties of Trade Repositories, which is currently already not possible. TR carry the rather special task of centralizing records for the OTC market and keeping their integrity. Therefore, this role was designed exactly to be a third party as it mitigates potential data manipulation that could conceal systemic risks from regulators. For the same reason, there are heavy requirements to register and operate a TR and in the entire EU there are only eight of them [14]. In addition, one should remember that TR act not only in the commodities market, but also in securities in general, so that any change in this concept would impact several markets.

(g) Others

On top of the aforementioned issues, two more general topics are worth to mention. The first relates to jurisdictions: nodes hosted in different Member States may create a lack of harmonization of applicable rules, a problem that can be enlarged by doubts on who would be deemed responsible for interrupting the network operation in a situation where several should fail in order for this to happen. The second point concerns possible changes in the regulatory framework within the near future. If players believe the rules of the game can change soon, chances are they will wait for clarification before spending resources. Despite the fact that these two issues are not exclusive to the energy sector, they can be key on how blockchain will evolve in this industry.

4. Survey

In this, we present the methodology of our study: a survey which we conducted with professionals in the sector. Furthermore, we highlight the main findings stemming from our survey.

4.1. Methodology

This investigation addressed exclusively experienced professionals in the electricity wholesale market and blockchain. This population is not that large, which leads to reduced size samples and limits statistical significance. Yet, such methods are common in qualitative social sciences and considered relevant as in such an early stage of adoption of the blockchain technology, they are capable of bringing valid insights according to the scientific literature, see [31,32]. Thus, this survey is exploratory in the sense it aims to provide unprecedented insights, rather than conclusive answers, to a topic that is new and complex.

The survey was carried out by invitation only and through an online questionnaire with multiple choice closed questions. The reasons for choosing this method are mainly two. First, it allowed respondents to remain anonymous in a sector where participants, some of which are currently engaged in blockchain projects, face severe competition issues both at business and regulatory level. In contrast to an interview, an online questionnaire increases the willingness to participate because there is no traceability on the answer. Second, "this removes a major source of potential bias in the responses, and makes it easier for respondents to be honest about sensitive subjects" [33].

The questionnaire's design was based on specific techniques from Brace [33]. The set of fourteen questions was arranged in accordance with the traditional approach of starting with general questions before the specific ones, so that respondents could feel familiar with the topic throughout the questionnaire and detailed questions at the beginning would not interfere in their likelihood to answer.

The maximum number of questions each person faced was either five or nine or ten to avoid "inattention because of boredom and fatigue" [33]. The fifth question asked which blockchain use case would be the first to be commercially implemented and was a fork in the questionnaire. The answer could lead the respondent to the end of the survey or to one of the two blocks with additional four or five specific questions (Figure 4), which were derived from the issues raised in the previous section.

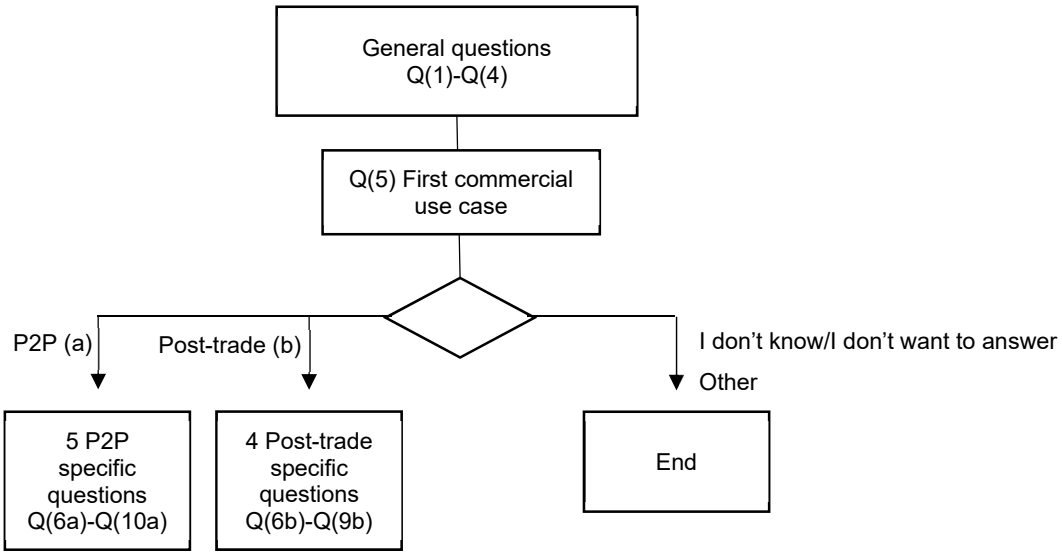

Figure 4. Flow chart to questionnaire.

The order of the questions was fixed, but the sequence of answers was randomized to avoid the bias that respondents would simply choose the first ones. The only exceptions were questions using Likert scale. Finally, alternatives "Others" and "I don't know/I don't want to answer" allowed respondents to actively contribute with a different view or to provide no answer where they would not like to, without leaving the survey. Three people, which were not included in the final sample, tested the questionnaire for reliability, validity and errors.

For more detailed characteristics of the survey, see Appendix A.

4.2. Results

This section presents the responses provided by 24 participants. The sample is characterized by professionals who work at energy companies, software developers, advisory firms, public agencies, research institutes and academia. The majority of them is based in Germany, but engaged on activities at the European level.

(1) What are the main expected benefits of blockchain for electricity wholesale market in Europe? Please select up to three options.

The alternative "reduction of transaction costs such as broker fees" was undoubtedly the most cited answer: it was selected 21 times, that is, by 87.5% of the participants, regardless the randomization function. A fairly strong signal can be extrapolated from this conclusion to the general context. Comparatively, post-trade processes received only about half of votes (Figure 5).

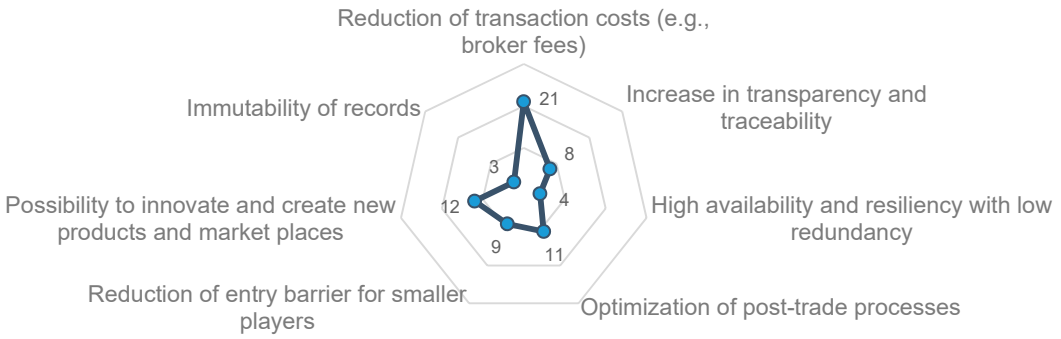

Figure 5. Main benefits.

In a second level of importance, and together with post-trade processes, respondents chose the options "possibility to innovate and create new products and marketplaces", "reduction of entry barrier for smaller players" and "increase in transparency and traceability". The three alternatives form a cluster well aligned with the changes promoted by the decentralization and digitization of energy systems. Results indicate that blockchain is expected to support these new features.

It is noteworthy that the items "High availability and resiliency with low redundancy" and "Immutability of records" appeared only three times each when they are themselves part of the very concept that differentiates DLT from centralized and decentralized structures. One possible justification may be that such benefits are common to blockchain in general, and respondents have sought to prioritize specific advantages to the wholesale market.

(2) How compliant with the current European regulatory framework for electricity wholesale market is blockchain?

Three quarters of respondents believe blockchain can be compliant with the current rules of the electricity wholesale market. For 33.3% it depends on the use case, while for 41.7% this is essentially a design issue (Figure 6). This outcome highlights the importance of having the rules of the game clear as soon as possible, so that one can develop compatible solutions from the very beginning.

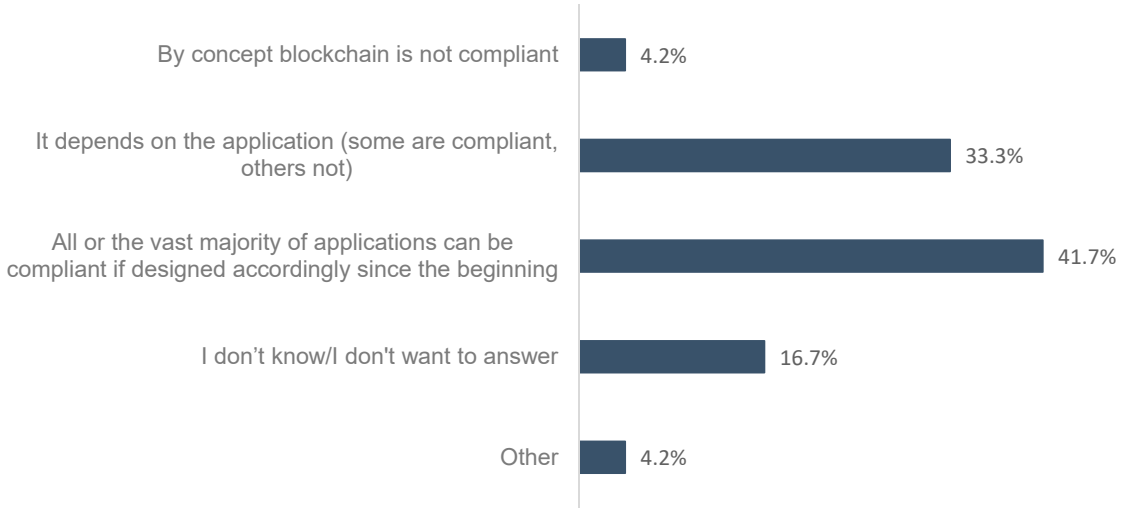

Figure 6. Compliance with regulatory framework.

The person who chose the alternative "others" mentioned that the answer to this question depends on the assessment of regulators themselves, while 16.7% did not know or did not want to comment and only one (4.2%) participant saw no limitation at all.

(3) What are the main regulatory limitations to implement blockchain for the European electricity wholesale market? Please select up to three options.

For the survey's participants, conflict of interest is the most relevant regulatory barrier. At a second level, more general issues were mentioned: uncertainty in applicable jurisdiction and potential changes in regulation (Figure 7).

The question of immutability had small relevance, which does not necessarily mean that it is unimportant. Eventually, little mention of it may be a consequence of the stage of current projects. Since there is no operational blockchain, no player is currently facing the problems caused by the immutability of data. It will certainly be interesting to evaluate how this item evolves in the agenda during the coming years, with the entry into force of GDPR being an important milestone.

Finally, it is worth noting that for this question, respondents provided 54 inputs, 20% less than for question 1. This may be an indication that the regulatory issues are quite specific and there is no need

to choose three alternatives, or that there is less clarity on this subject than on the potential benefits. Given the incipient degree of maturity of technology, the second possibility is more likely.

Respondents who chose the option "others" mentioned as additional factors MiFID II, Brexit, and lack of understanding from the regulators' side.

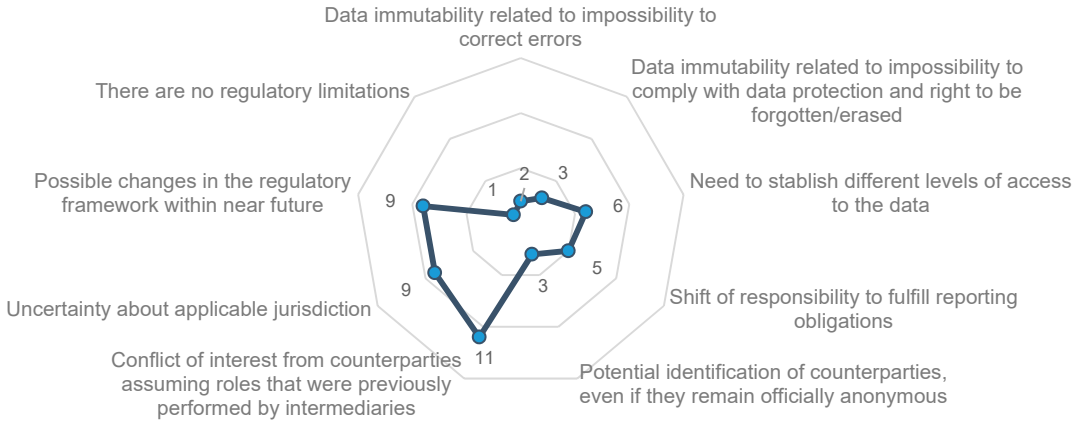

Figure 7. Main limitations.

(4) What should be the position of European regulators in relation to blockchain implementation for the electricity wholesale market?

The majority of respondents welcome a sandbox approach (Figure 8). A regulatory sandbox can be defined as a set of rules that allows innovators to test their product or business model in an environment that temporarily exempts them from following some or all legal requirements in place. Sandboxing is designed to be a tool to bring innovations to market more quickly while safeguarding public interest considerations [19]. Therefore, calling regulators for some action. This response is much in line with the results of the three previous questions. Since innovation is one of the greatest potential benefits of blockchain, it is well fitting that stakeholders support such an approach even before commercial deployment.

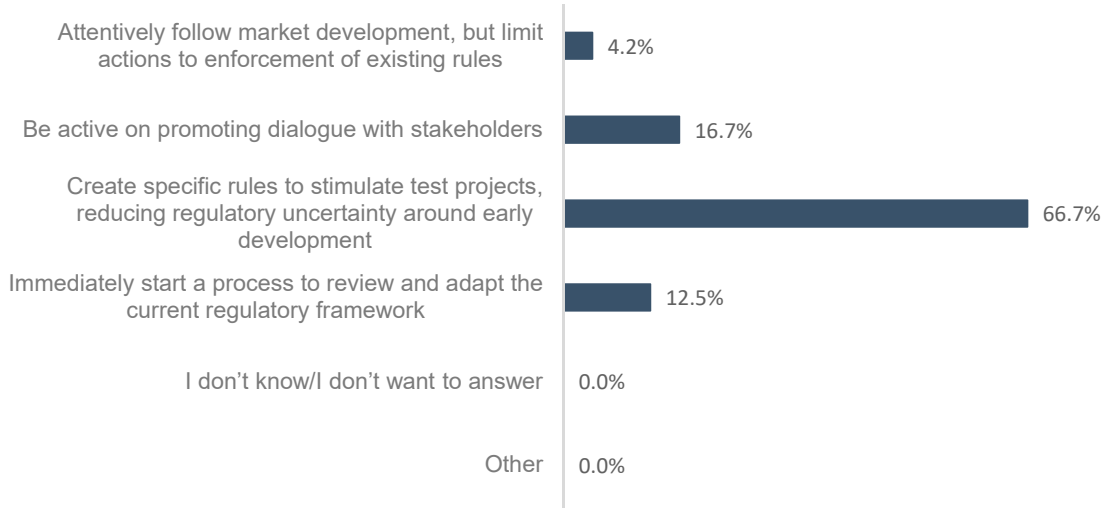

Figure 8. Position from regulators.

The results reflect well the sensitive relationship between regulators and regulated players. On the one hand, tensions are frequent. On the other hand, market participants also appreciate regulatory certainty that protects them: players want to experiment but do not want to risk breaking any rules that could significantly compromise their resources or even their business continuity.

Recent movements from the European Commission suggest that this scenario may materialize soon: the institution launched the EU Blockchain Observatory and Forum in February 2018 and announced a month after an action plan for the EU to become a global hub for FinTech, which includes a blueprint for sandbox. Although this approach is not specific to the energy trading sector, this may be the spark missing to trigger a larger movement in the industry.

(5) Which application of blockchain for the European electricity wholesale market is more likely to be commercially deployed first?

Most of the respondents believe a P2P trading platform would be the first use case one to be commercially deployed in the EU (62.5%) (Figure 9). The result also signals expectations that although conflicts of interest are the major regulatory constraint, expectation are that they can be addressed. It should be pointed out here that the indication of peer-to-peer platform as the first use case may be a reflection of the current state of maturity of the projects being developed by the market.

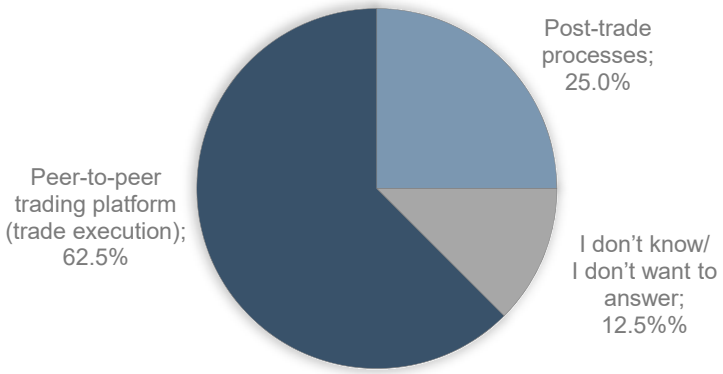

Figure 9. First commercial use case.

(6a) From now on please consider a blockchain application for peer-to-peer (trade execution) only. What are the main challenges to be overcome before commercial deployment? Please select up to three options.

According to respondents, the main challenge to be overcome is to achieve sufficient mass of participants using the new platform (Figure 10). For this, blockchain must offer something new and better compared to the existing alternatives and justify the investment from the financial perspective, which according to the previous sessions one would expect to be mainly cost-driven rather than revenue-focused. Next, come governance issues, followed by regulatory aspects along with integration with existing systems and processes.

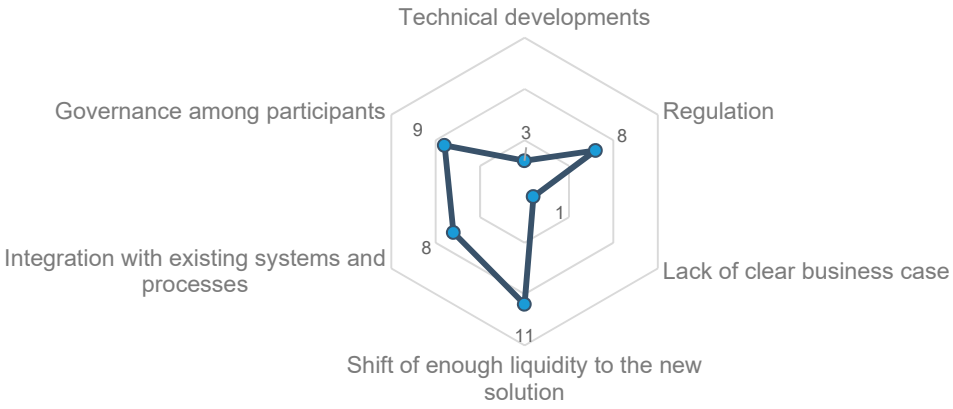

Figure 10. Challenges for P2P.

(7a) Whom do you expect to operate and manage most of the blockchain projects for electricity wholesale market in the future?

None of the respondents expect this function to be predominant performed by incumbent companies (Figure 11). All other alternatives indicate that new players and consortia are expected, which will somehow change the competition landscape.

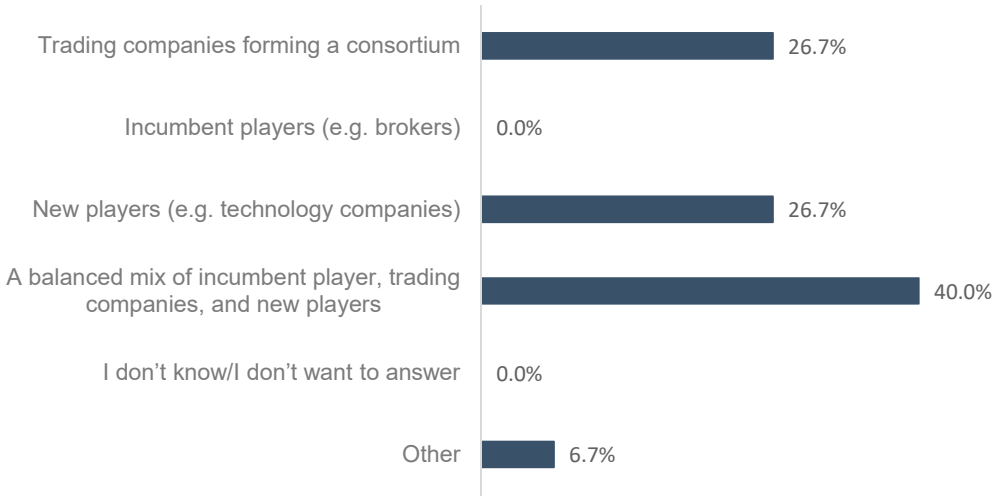

Figure 11. Operators and managers of the blockchain.

(8a) How likely is a scenario where blockchain peer-to-peer platforms would replace all or the vast majority of other marketplaces?

The answers to this question do not point in a specific direction, with responses fairly balanced between the options unlikely and likely (Figure 12).

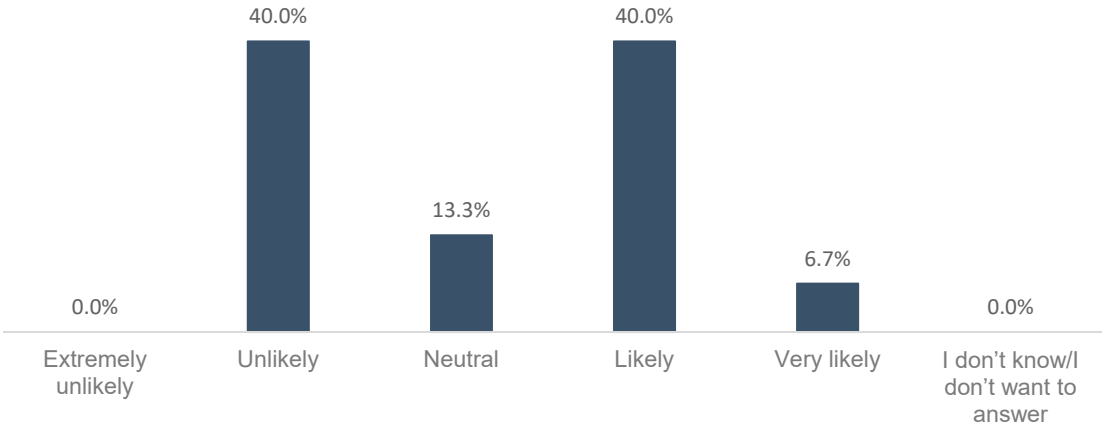

Figure 12. Likelihood to replace other marketplaces.

(9a) How much do you agree with the following? It is currently possible to remain fully anonymous in the blockchain. (Full anonymity happens when the identity of counterparties in a transaction remains officially unknown to the others, and no educated guesses are possible either.)

Opinions on this question are quite divergent, with participants taking positions and no vote for the neutral option, although two respondents chose "I don't know/I don't want to answer" (Figure 13).

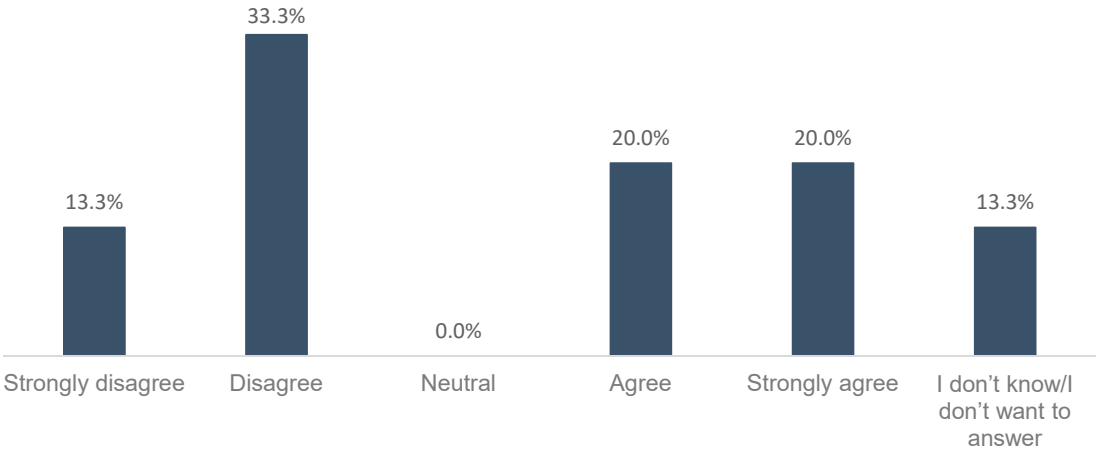

Figure 13. Anonymity.

(10a) How confident are you that a technical solution for full anonymity will be developed?

This question was posed only for participants who answered "strongly disagree" or disagree" in 9a. Even the respondents who did not believe it is currently possible to remain anonymous in the blockchain show positive expectations about future developments (Figure 14).

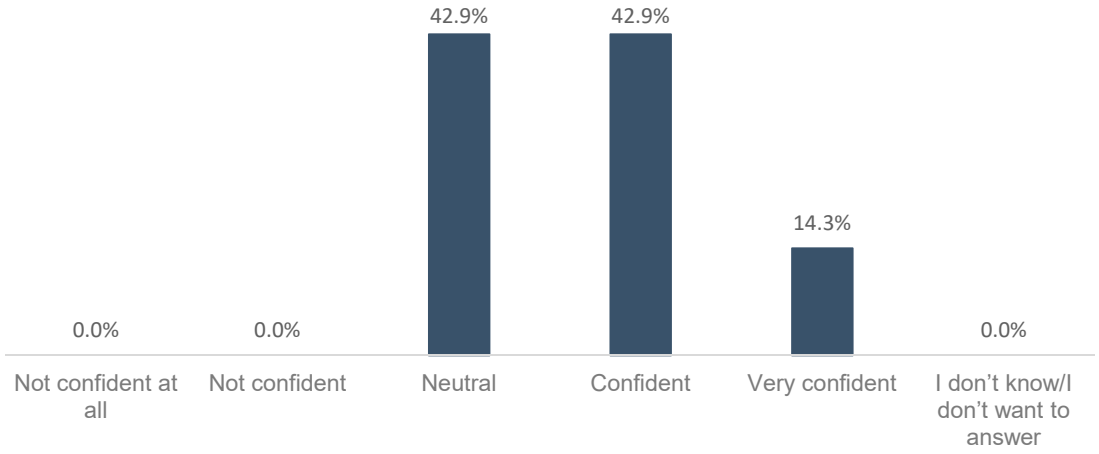

Figure 14. Solution for anonymity.

(6b) From now on please consider a blockchain application for post-trade processes only. What are the main challenges to be overcome before commercial deployment? Please select up to three options.

Regulation and integration with existing systems and processes are considered the main challenges (Figure 15). The latter is compatible with the very nature of the use case, which requires interoperability with the already stablished architecture and consequent development of future technical and industry standards.

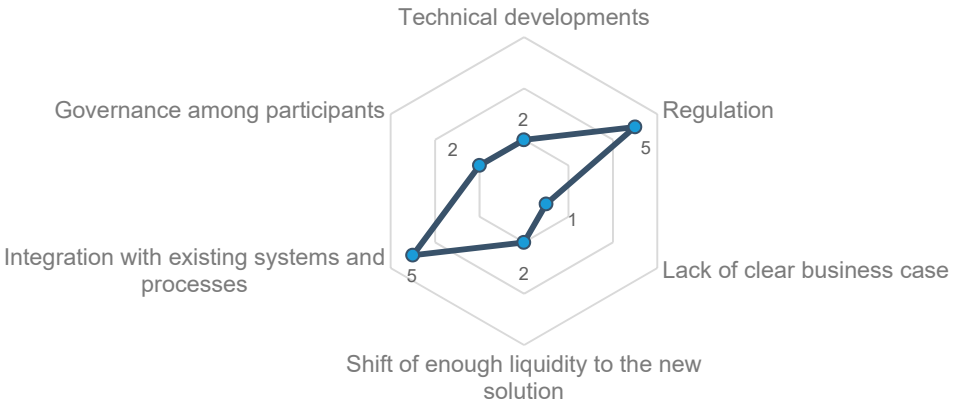

Figure 15. Challenges for post-trade processes.

(7b) Which post-trade process would benefit more from blockchain?

Respondents see more potential for the settlement, invoice and payment step instead of confirmation (Figure 16), as mentioned in Section 2.1. Indeed, this could be interesting for spot instruments, for which physical delivery is virtually instantaneous, but for which financial delivery can face a large mismatch, generating significant credit risk. This could require involvement from banks, some of which are already engaged in DLT projects.

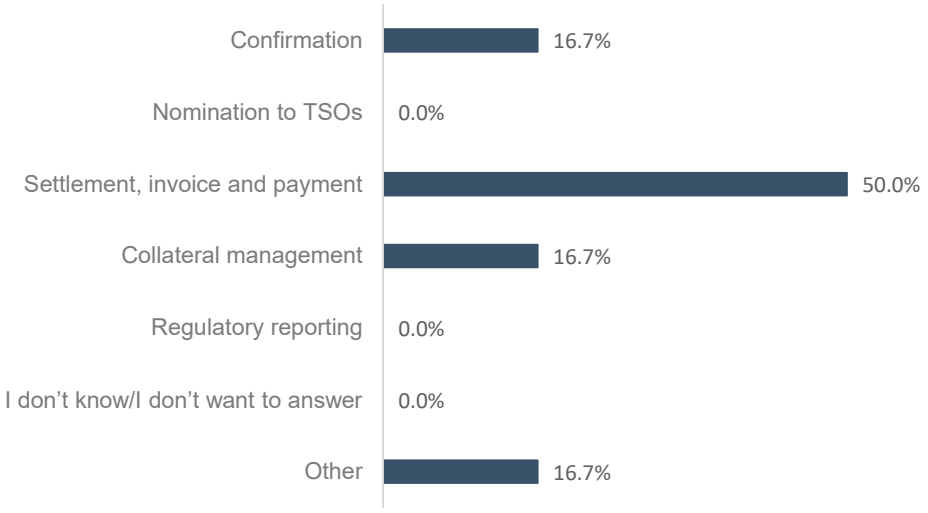

Figure 16. Most benefited post-trade process.

(8b) How likely is a scenario where regulators would directly check information on the blockchain for reporting and monitoring purpose without any action from trading participants or third parties?

Although regulatory reporting was not mentioned as a main benefit, most of the participants expect regulators to be active when querying information in the blockchain (Figure 17). This may indicate that either respondents foresee authorities will have the necessary structure to carry out such duty or a lack of knowledge about the assumptions behind such expectations.

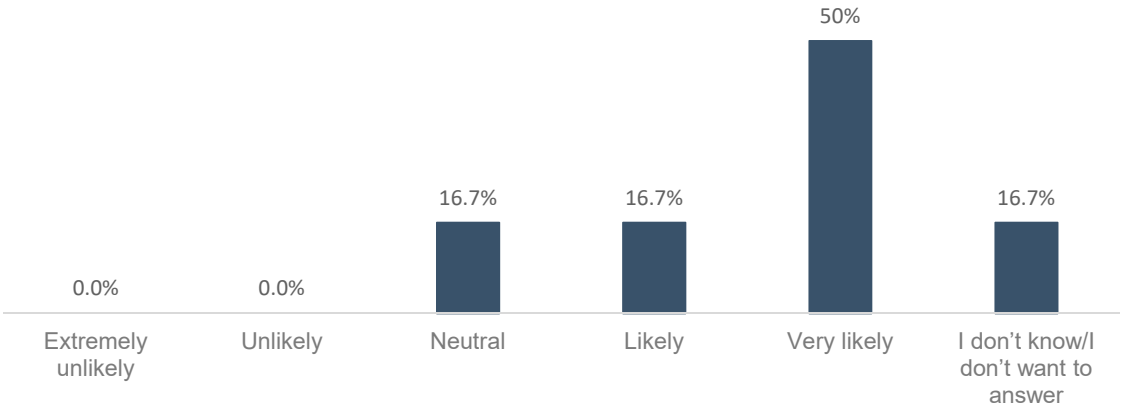

Figure 17. Regulatory reporting.

(9b) How much do you agree with the following? An editable blockchain is a prerequisite for commercial implementation of blockchain for post-trade processes (an editable blockchain is a blockchain that allows some form of change on the existing registers).

Opinions about the need to have an editable blockchain are divided and do not indicate a strong opinion (Figure 18).

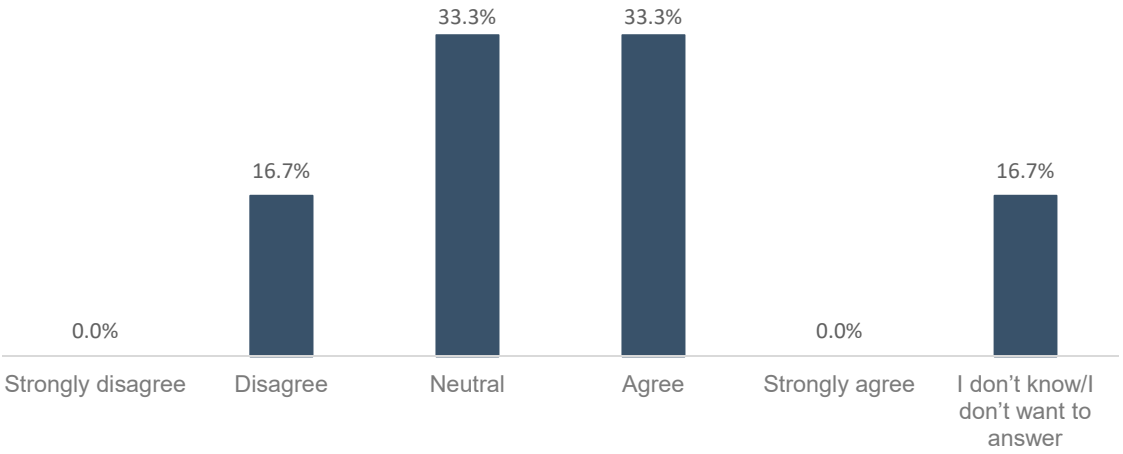

Figure 18. Editable blockchain.

5. Discussion

Due to the low number of participants who chose the post-trade application, this section will focus on the responses of the general and the specific P2P blocks. The results from the general block of questions indicates that participants have a strong view on what blockchain's main benefits for wholesale trading are. Regarding the potential regulatory issues previously identified in the literature, the respondents surprisingly do not consider them to be a blocker. However, in this regard, they would highly appreciate an environment providing legal certainty and clear conditions for the development of the business cases.

In question 1, 87.5% of respondents denoted the reduction of transaction fees as the main benefit. Despite the relatively small sample size, we believe the results to be robust, see [31] regarding the extrapolation of results from small samples to a population range according to a given confidence interval. While the margin of error for the population may still be significant, it can provide additional and important information, as in this case. Applying this method for $n = 24$ and a 95% confidence interval, this result corresponds to a range of 69.0% to 95.7% for the population. Comparatively,

post-trade shows an interval between 42.7% and 78.8% for the population, which is larger and does not necessarily point to a majority.

Such numbers indicate that a P2P platform would be the application with potential for greatest benefit and differs from ESMA, according to whom most gains are related to post-trade process. One possible explanation is the difference in scope between the two works, since ESMA's report addressed general financial securities while this work focuses exclusively on electricity [14]. From the 53 stakeholders with public answers to ESMA consultation, none precedes from energy trading companies, although some have some sort of relationship with the sector through the provision of services or because they are part of a large conglomerate. With the aforementioned sharp decline in commodity prices, it could be that fees paid to intermediaries in the power industry may weigh proportionately more on the costs of energy trading companies than on the financial industry.

The answers to questions 2–4 give an overview of how respondents consider regulatory issues. The results show that they do not see significant limitations to the initial DLT development, or that at least the existing ones can be somehow overcome. The main concerns raised—conflict of interest, uncertainty about applicable jurisdiction and short-term changes—are valid for any use case, including outside the commodity industry and send a sign to regulators, who should be aware not to become themselves the bottleneck restricting innovation. This also reinforces the point made in Section 3 that many of the challenges for blockchain deployment are not tied to technical but to governance issues. According to this perspective, technological evolutions will not suffice, and stakeholders will have to seek alternative institutional mechanisms, such as organizational innovations. It should be pointed out that some answers might reflect the development stage of existing projects. For example, little mention to topics such as immutability and levels of access in question 3 could be due to the fact that since there is no operational blockchain, no player is currently facing such problems. It will certainly be interesting to evaluate how this will evolve during the coming years.

Continuing along this line, question 4 highlights the importance of having the rules of the game clear as soon as possible: the creation of a controlled experimentation environment facilitates, before commercial deployment, the compatibility of the developed solution with the regulatory aspects, whose uncertainty was cited as a significant limitation. A sandbox approach could also benefit regulators, which could become more participative and gain more knowledge while having to create rules for experimentation.

In relation to which application would be first implemented, P2P Trading is clearly bet of the respondents (62.5%). This usage is in line with the main expected benefit (question 1), which may be an important driver to speedily validate the business model feasibility. It also signals expectations that conflicts of interest can be addressed without compromising the ability to implement the related use case.

Entering the specific questions' block, 6a shows once more that although DLT has its specific aspects, players should not neglect common challenges to any marketplace, such as justifying the decision to shift liquidity, understanding what the new platform's rules and assessing what kind of integration efforts with the existing infrastructure are necessary. In practice, this unfolds in a, often long, process of impact evaluation and approval from different hierarchical levels.

In addition, like any marketplace, blockchain only makes sense if many counterparties are using it. Therefore, the decision to migrate volumes to a new platform is not totally one-sided and involves strategy, as players need to move together while respecting competition law. Evidently, all other elements, from governance aspects that empower participants to technical features related to performance, may be the trigger for liquidity shift, in a way that they cannot be totally dissociated from the discussion.

On top of these challenges, there is also the expectation that blockchain will be operated by new players, existing players organized under a new composition or a mix of them (question 7a). For regulators, this means understanding what the consequences are and how to maintain market integrity. Authorities will have to answer a series of questions, such as these new structures'

classification. Eventually, software companies and consortia could fall under specific categories of the current regulatory framework, which might not be in their interest or capacity, for instance, an Organized Trading Facility under MiFID2.

If that is the case, it could discourage some players and hold back development. However, it might also be that regulators see the need to create new categories, able to reflect more accurately these players' functions. In any situation, it will be quite interesting to follow how regulators will see the role of software providers and consortia in the management and maintenance of a DLT-based trading platform. Consortia blockchains could entail non-negligible conflict of interests by shifting part of the functions of intermediaries to the energy trading companies who will provide services to their own competitors and to themselves, while the software suppliers could gain a more prominent place in the regulatory framework, if not eventually become directly supervised entities.

Altogether, one could expect as a natural development that players who are part of this new market will have to guarantee the same level of protection and performance as previous providers. Thus, the elimination of some intermediaries may lead to an increase in internal costs for the remaining or new companies, which could be requested to create additional structures to meet organizational requirements with the objective of avoiding conflicts of interest. There one shall balance the advantages and disadvantages and avoid the pitfall of adopting blockchain by default, when eventually other alternatives could be better suitable.

The topics of organizational structure and staff's technical qualification should also be on the authorities' agenda, even if they do not directly participate in blockchain network as nodes. These institutions should develop their own technical expertise so that they can assess the blockchain suitability to the market. In particular, ESMA and ACER will play a fundamental and resource-intensive role in the eventual adaptation of technical standards, as well as in the assessment of strategic matters related to market competition and liquidity fragmentation.

All these uncertainties may be part of the explanation of why stakeholders are still not fully convinced of DLT's ability to replace existing market places (question 8a). Indeed, it seems to be early for a strong signal when there are still many open discussions. Replacing a competitor's marketplace is not an obvious task. In addition to business aspects discussed, setting up a new platform is a resource-intensive task. It requires many hours dedicated to the establishment and test of new connectivity and registrations that can be bureaucratic, besides the learning curve to use the new tool.

It is reasonable to think that, initially, players would use the new platform in parallel with others. Moreover, even if DLT were to offer considerable advantages, it is likely that there would be several of such platforms and not just one. The question of interoperability among systems would then be a determining factor in how far blockchain can reach.

Finally, regarding the potential issue of anonymity, questions 9a and 10a should be read together. On one hand, the first question shows that, at the very least, there are still doubts about the full anonymity in the blockchain, compatible with [14]. Possible justifications may be the topic complexity or that recent solutions have not yet been fully validated and require further testing. On the other hand, overcoming this barrier can be a matter of time to understand the specifics of the industry and develop an alternative. Question 10a indicates participants have an optimistic view on this. One way or another, this item should be among the regulators' priorities if they decide to support blockchain.

6. Conclusions

One of the several possible blockchain applications for the energy industry is in the wholesale market. Because DLT has the potential to replace middlemen, maintain immutable records, and make processes more efficient, it is viewed by trading companies as an interesting alternative in a scenario where their business model faces significant challenges, particularly related to the commodity electricity and to OTC bilateral, whose value chain is long, costly and much less automated than the other existing markets.

Although a future revision of the regulatory framework could be desirable in the future, the implementation of blockchain for the electricity OTC bilateral trading should initially obey the existing rules, defined mainly by REMIT and EMIR, added by MiFID2 and GDPR in some specific aspects.

From the analysis of these legal acts, together with the understanding of the blockchain openness—the permitted form—and the two use cases, P2P and post-trade—, this study identified six potential issues that may influence the adoption of DLT for the sector in scope. They are: data immutability and error correction, personal data protection and immutability, access to different data layers, obligation and capacity to report, identification of counterparties and conflict of interest.

Based on a survey conducted exclusively with professionals working at the intersection of blockchain and electricity wholesale market, our results revealed the most important issues on the agenda, alongside expected benefits and challenges. The results point out that: (i) the most significant gains should come from reduction of transaction costs (brokers' fees); (ii) blockchain can be compliant with the current regulatory framework, depending on how it is initially designed or on the use case; and (iii) the first use case to be commercially deployed is likely to be P2P, before post-trade processes.

Regarding point (iii), respondents also raised some interesting perspectives. According to them, the biggest challenge faced is to shift liquidity to the new platform. This is a reminder that despite the constant technical focus given to blockchain, one should not underestimate issues common to the development of any new marketplace. Second, even though the view is neutral on the possibility of DLT largely replacing traditional marketplaces, one could expect different players—a mix of incumbents, software companies and consortia-running blockchain platforms in the future, which indicates that current and new structures shall coexist for some time.

If regulators need to prioritize discussions, here is an indication of which way to go. In fact, while this work' scope is the electricity OTC market for a matter of focus, the topics mapped could also be applicable to different marketplaces and commodities—especially gas—or even to other security types.

If regulatory authorities wish to take action to investigate the issues outlined in this study, a few recommendations could be useful: (i) prioritize the creation of a sandbox approach that allows live and binding trading at the European level. Ideally, it should stimulate projects to be open to all interested players that fulfill the requirements to trade in the wholesale market, also as a way of gathering liquidity; (ii) ESMA and ACER could join as blockchain nodes for regulatory reporting purposes, meaning having a hands-on approach to identify the necessary resources to fulfill such obligations, map potential pitfalls and raise lessons learned; (iii) authorities could kick-off an internal discussion to develop a formal opinion on what type of organizational structures, such as sorts of consortiums, could be seen as potentially harming market competition due to conflict of interest among participants. Similarly, they could develop an opinion on what would be the rights and obligations of participants and how they would be classified according to the applicable regulatory pieces; (iv) establish funding opportunities in the energy sector for which blockchain projects can qualify.

In terms of time expectations, the authors consider that specific business cases tackling only one step of the trade lifecycle -and that can thus focus on it, avoiding discussions applicable to other steps- could be implemented in the short term (within a year) from the technology perspective. However, from the user point of view, it doesn't seem likely that players would design a blockchain with a single purpose. Even if development would be phased, the most probable is that participants would already consider the main requirements of each step in the initial design of the blockchain, as the there is a high degree of interconnection between them. This is both to ensure regulatory compliance as to avoid double spending in the future. This could delay commercial implementation, once it considerably expands the range of subjects that need to be discussed and stakeholders to be involved. For this reason, the most likely is that the commercial application of integrated steps will happen in the mid-term (1 to 5 years), while a full blockchain for wholesale market could potentially just be established, if ever, in the long run, considering authorities would have a longer reaction time to become active actors and assume their new roles.

Finally, it is important to remember that while central, regulatory aspects are not the only ones impacting the development of a business case. There are still important technical and economic issues to be addressed, such as performance level, interoperability and costs, to name only a few. For the final decision making, they shall be considered together. The real benefits and challenges will depend on which products and processes are actually migrated to the platform and must be evaluated on a case-by-case basis.

In the end, if blockchain proves to be feasible, it might become an effective enabler of a cleaner, more efficient and intelligent energy system: one where micro transactions of energy can link wholesale and retail markets at a low cost through smart contracts that aggregate renewable and decentralized energy while maintaining the grid's reliability. Interesting times lay ahead.

Author Contributions: Conceptualization, C.I.D. and A.P.; Methodology, C.I.D. and A.P.; Validation, C.I.D. and A.P.; Formal Analysis, C.I.D.; Investigation, C.I.D.; Data Curation, C.I.D.; Writing—Original Draft Preparation, C.I.D.; Writing-Review & Editing, C.I.D. and A.P.; Visualization, C.I.D.; Supervision, A.P.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

ACER	Agency for the Cooperation of Energy Regulators
BIS	Bank for International Settlements
DLT	Distributed Ledger Technology
EMIR	European Market Infrastructure Regulation (Regulation 648/2012/EU)
ESMA	European Securities and Markets Authority
EU	European Union
GDPR	General Data Protection Regulation (Regulation 679/2016/EU)
MiFID2	Markets in Financial Instruments Directive (Directive 65/2014/EU)
NCA	National Competent Authority
OTC	Over-the-counter
P2P	Peer-to-peer
PPAT	Persons Professionally Arranging Transactions
REMIT	Regulation on Wholesale Energy Market Integrity and Transparency (Regulation 1227/2011/EU)
TR	Trading Repository
TSO	Transmission System Operator

Appendix A Characteristics of the Survey

- Period: from 19 February 2018 to 23 May 2018
- Respondents: by invitation only (e-Mail URL embedded)
- Pilot (testing): informal, with three respondents (excluded from final sample)
- Privacy: anonymous
- Close-ended questions with multiple choice
- All questions mandatory (with alternatives "Other" and "I don't know/I don't want to answer")
- Order of questions: pre-defined (general to specific)
- Order of answers: random, except for alternatives "Other" and "I don't know/I don't want to answer" and scale questions
- Scalar question: five points with radio buttons
- Length: up to ten questions, funneling at fifth question
- Multiple page: one page for general questions, another page for specific questions
- Progress indicator: yes

References

1. Tapscott, D.; Tapscott, A. *Blockchain Revolution: How the Technology behind Bitcoin Is Changing Money, Business, and the World*; Portfolio/Penguin: New York, NY, USA, 2016.
2. Nussbaum, J. Mapping the Blockchain Project Ecosystem. 2017. Available online: https://techcrunch.com/2017/10/16/mapping-the-blockchain-project-ecosystem/ (accessed on 21 April 2018).
3. Blockchain Hub. Blockchains & Distributed Ledger Technologies-Types of Blockchain. Available online: https://blockchainhub.net/blockchains-and-distributed-ledger-technologies-in-general/ (accessed on 23 March 2018).
4. IBM. *Rewire Your Industry with IBM Blockchain*; IBM: Armonk, NY, USA, 2018. Available online: https://www-03.ibm.com/press/us/en/pressrelease/52018.wss (accessed on 21 April 2018).
5. Besnainou, J. Blockchain in Energy & Industry Raises $1 Billion–and Heads into Challenging Times. 2018. Available online: https://www.cleantech.com/blockchain-in-energy-industry-raises-1-billion-and-heads-into-challenging-times/ (accessed on 6 February 2019).
6. Pollitt, M. *Electricity Liberalisation in the European Union: A Progress Report*; No. EPRG 0929; Electricity Policy Research Group, University of Cambridge: Cambridge, UK, 2009.
7. Merz, M. Potential of the Blockchain Technology in Energy Trading. 2016. Available online: https://www.ponton.de/downloads/mm/Potential-of-the-Blockchain-Technology-in-Energy-Trading_Merz_2016.en.pdf (accessed on 2 February 2018).
8. Praktiknjo, A.; Erdmann, G. Renewable Electricity and Backup Capacities: An (Un-) Resolvable Problem? *Energy J.* **2016**, *37*, 89–106. [CrossRef]
9. Economic Consulting Associates. *European Electricity Forward Markets and Hedging Products–State of Play and Elements for Monitoring*; Economic Consulting Associates: London, UK, 2015.
10. BIS. *New Developments in Clearing and Settlement Arrangements for OTC Derivatives*; Bank for International Settlements (BIS): Basel, Switzerland, 2007.
11. European Commission. *Quarterly Report on European Electricity Markets*; third quarter of 2017; European Commission, Directorate-General for Energy, Market Observatory for Energy: Brussels, Belgium, 2017; Volume 10.
12. ISDA. *OTC Commodity Derivatives Trade Processing Lifecycle Events*; International Swaps and Derivatives Association (ISDA): New York, NY, USA, 2012.
13. Santo, A.; Minowa, I.; Hosaka, G.; Hayakawa, S.; Kondo, M.; Ichiki, S.; Kaneko, Y. *Applicability of Distributed Ledger Technology to Capital Market Infrastructure*; Japan Exchange Group: Tokyo, Japan, 2016.
14. ESMA. *The Distributed Ledger Technology Applied to Securities Markets (No. ESMA50-1121423017–285)*; European Securities and Markets Authority: Paris, France, 2017.
15. ESMA. *Questions and Answers on MiFIR Data Reporting*; ESMA: Paris, France, 2017.
16. FCA. *Distributed Ledger Technology Feedback Statement on Discussion Paper 17/03*; FCA: London, UK, 2017.
17. Hagström, L.; Dahlquist, O. *Scaling Blockchain for the Energy Sector*; Uppsala University: Uppsala, Sweden, 2017.
18. Pilkington, M. *Blockchain Technology: Principles and Applications*; Research Handbook on Digital Transformations; SSRN Scholarly Paper No. ID 2662660; Xavier Olleros, F., Majlinda, Z., Elgar, E., Eds.; Social Science Research Network: Rochester, NY, USA, 2016.
19. Finck, M. *Blockchains and Data Protection in the European Union*; SSRN Scholarly Paper No. ID 3080322; Social Science Research Network: Rochester, NY, USA, 2017.
20. European Parliament and Council. *Regulation (EU) No 648/2012 of the European Parliament and of the Council of 4 July 2012 on OTC Derivatives, Central Counterparties and Trade Repositories*; European Parliament and Council: Brussels, Belgium, 2012.
21. Zweifel, P.; Praktiknjo, A.; Erdmann, G. *Energy Economics: Theory and Applications*; Springer: Berlin, Germany, 2017.
22. European Parliament and Council. *Regulation (EU) No 1227/2011 of the European Parliament and of the Council of 25 October 2011 on Wholesale Energy Market Integrity and Transparency*; European Parliament and Council: Brussels, Belgium, 2011.

23. European Parliament and Council. *Directive 2014/65/EU of the European Parliament and of the Council of 15 May 2014 on Markets in Financial Instruments and Amending Directive 2002/92/EC and Directive 2011/61/EU*; European Parliament and Council: Brussels, Belgium, 2014.
24. European Parliament and Council. *Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the Protection of Natural Persons with Regard to the Processing of Personal Data and on the Free Movement of Such Data, and Repealing Directive 95/46/EC (General Data Protection Regulation)*; European Parliament and Council: Brussels, Belgium, 2016.
25. European Commission. *Commission Implementing Regulation (EU) No 1348/2014 of 17 December 2014 on Data Reporting Implementing Article 8(2) and Article 8(6) of Regulation (EU) No 1227/2011 of the European Parliament and of the Council on Wholesale Energy Market Integrity and Transparency*; European Commission: Brussels, Belgium, 2014.
26. ACER. *ACER Guidance on the Application of REMIT*, 4th ed.; ACER: Ljubljana, Slovenia, 2016.
27. European Parliament and Council. *Regulation (EU) No 600/2014 of the European Parliament and of the Council of 15 May 2014 on Markets in Financial Instruments and Amending Regulation (EU) No 648/2012*; European Parliament and Council: Brussels, Belgium, 2014.
28. Finck, M. *Blockchain Regulation*; SSRN Scholarly Paper No. ID 3014641; Social Science Research Network: Rochester, NY, USA, 2017.
29. European Commission. *Commission Delegated Regulation (EU) No 151/2013 of 19 December 2012 Supplementing Regulation (EU) No 648/2012 of the European Parliament and of the Council on OTC Derivatives, Central Counterparties and Trade Repositories, with Regard to Regulatory Technical Standards Specifying the Data to be Published and Made Available by Trade Repositories and Operational Standards for Aggregating, Comparing and Accessing the Data*; European Commission: Brussels, Belgium, 2012.
30. Zetzsche, D.A.; Buckley, R.P.; Arner, D.W. *The Distributed Liability of Distributed Ledgers: Legal Risks of Blockchain*; SSRN Scholarly Paper No. ID 3018214; Social Science Research Network: Rochester, NY, USA, 2017.
31. Galvin, R. How many interviews are enough? Do qualitative interviews in building energy consumption research produce reliable knowledge? *J. Build. Eng.* **2015**, *1*, 2–12. [CrossRef]
32. Mason, M. Sample Size and saturation in PhD studies using qualitative interviews. *Forum Qual. Soc. Res.* **2015**. [CrossRef]
33. Brace, I. *Questionnaire Design: How to Plan, Structure and Write Survey Material for Effective Market Research*, 3rd ed.; Kogan Page Limited: London, UK, 2013.