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"Smart contracts for decentralized business models in the electricity market: a consumer protection perspective"

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Abstract

The use of smart contracts in peer-to-peer electricity transactions is a relatively new field of application for blockchain technology. Thus, many uncertainties surround the rights and duties of prosumers, injecting the electricity they produced in excess into the grid. As a consequence, consumers see their rights possibly threatened by the use of these relatively new contractual tools. This study aims to contribute to the growing literature on smart contracting in P2P electricity trading, from a consumer perspective. First, an overview of smart contracts and blockchain technology is presented, adopting a law and economic perspective, and assessing their contribution to reducing costs in negotiating. Secondly, the electricity market is briefly detailed, with its peculiarities and challenges. Finally, the previous elements are merged to deliver a cross-field outline of smart contracts' position toward consumers. Do they provide incentives to enter the P2P electricity market model? Some final suggestions will be presented in this regard, addressing the role that both lawyers and economists can play to help blockchain applications in the energy field grow and become mainstream.

Author's declaration

I, Noemi Mauro, hereby declare and confirm that this thesis is entirely the result of my own work except where otherwise indicated. I acknowledge the supervision and guidance I have received from Professor Gomez Liguerre. This thesis is not used as part of any other examination and has not yet been published.

Table of contents

1 Introduction

Computers are crunching numbers in the basement while, on a rooftop, solar panels generate electrons, counted, and recorded on the blockchain. The electricity in excess is reinjected into the network and sold, with a bidding system, to other neighboring households, among a community remotely connected through both electricity smart grids and the internet. This is the future of energy exchanges and smart contracts are deemed to play a pivotal role in its upscale.

The focus of this work is on a peer-to-peer (P2P) market model for electricity trading among residential prosumers. This structure, also known as the «Transactive Grid» (Sabounchi & Wei, 2017), is a decentralized market architecture for the exchange of electricity that needs security and flexibility to function[1]. The present discussion hypothesizes that Ethereum blockchain and smart contract protocols represent an enabling technology for this consumer-to-consumer (C2C) model. The claim is that these technologies could support all the needs for safety and reliability required to let microgrids run and maximize energy production, balance, and exchange of electricity at a local level. In other words, this paper aims to provide an assessment of the added benefit that smart contracts bring to electricity trading through local grids, analyzing the compatibility of blockchain-based contracts and P2P energy networks from a law and economics perspective. This evaluation will be done through a progressive overview of smart contracts and blockchain, the specificities of the electricity market and considerations regarding the merging of the two, through a consumer protection perspective. In summary, the main research questions that will be addressed are: Does the existence of these smart contracts

[1] Sabounchi & Wei, 2017, p. 1 (« [T]his financial model must be reliable, scalable, secure and certifiable by all parties»).

materially change the options available to the contracting parties when it comes to electricity P2P transactions? Does it offer an added value? *Should* smart contracts be implemented and to what extent are they useful to enhance consumer welfare? How can legislation better protect prosumers engaging in P2P electricity exchanges? The structure of the paper develops as follows:

- **Chapter one** will deal with smart agreements in general, providing basic information on their nature and functioning. Transaction-cost economics will serve as a framework to evaluate the costs and benefits of these devices to determine how much of an improvement they constitute compared to traditional natural-language agreements. Behavioral insights and challenges across the legal spectrum will also be included.
- **Chapter two** touches upon the peculiarities of the energy field, detailing the functioning of smart contracts in P2P electricity trading, «also known as the *Uber* or *Airbnb* of energy» (IRENA, 2020)[2] because of the parallelism with other more famous examples of sharing economy.
- **Chapter three** elaborates on the previous two, connecting the dots and analyzing the role that lawyers and economists can cover to bring additional layers of protection to prosumers.

By highlighting potential new research fields and open questions, this analysis aims to benefit other academics and professionals. Additionally, it seeks to enable researchers to immediately acquire a summary of smart contracts' research landscape.

[2] IRENA, 2020, p. 6 («P2P electricity trading is also known as the "Uber" or "Airbnb" of energy, as it is a platform that allows local distributed energy generators to sell their electricity at the desired price to consumers willing to pay that price»). *Emphasis added in the text.*

It is important to focus especially on blockchain applications other than bitcoins, as Yli-Huumo *et al.* (2016) recall presenting their work. As an example, out of the 41 primary papers on the theme the authors analyzed back in 2016, 80% of them focused on bitcoin systems and only the remaining 20% would be dedicated to e.g., smart contracts (Yli-Huumo *et al.*, 2016, p. 1). If the objective is to produce literature that helps the evaluation of these devices assessing their potential upscale, then there is a need for more academic attention on this topic. This work intends to do so, from the more urgent than ever perspective of the energy sector. In fact, this is the element of novelty of the dissertation: merging different topics. There are existing studies, both from the academic and industrial world, on smart contracts in the energy field (Hertz-Shargel & Livingston, Atlantic Council report; Energy Future Initiatives Policy paper, 2018), analyzing electricity P2P transactions (Lu *et al.*, 2020, *Computational Intelligence*), and on these agreements and their impact on consumer protection (Poncibò, 2019), but few papers or reports discuss the combination of all these factors (PwC report, "Blockchain – an opportunity for energy producers and consumers?"), especially through the law and economics lenses.

The chosen methodology is a comparative review of the literature in the field, addressing some of the relevant books and papers found on main academic platforms such as Semantic Scholar, ResearchGate, SSRN (Social Science Research Network), IEEE Xplore or JSTOR: Journal Storage, to name a few. Two major limitations of this research are the lack of empirical testing and the need to see more advancement in the blockchain technological side in the nearby future, or else it would remain merely speculative. In fact, blockchain is currently mainly used by and primarily accessible to certified financial operators (cryptocurrency exchanges), which is to say that its central application is through virtual currencies as Bitcoin. The goal is for this technology to be readily available to the general population in the upcoming future. In this regard, it is worth mentioning that a World Economic Forum analysis predicts that by 2027, blockchain-based technology will account for almost 10% of the global GDP (World Economic Forum, Survey Report, 2015).

2 L&E approach to smart contracts

2.1 What are smart contracts?

Smart contracts are computer programs that can self-execute and self-enforce at the occurrence of specific inputs or events (Werbach & Cornell, 2017, p. 108). The possibility of using such pre-specified functions to build a system of decentralized and entrusted registries of assets and transactions appears to be one of the main achievements of the digital revolution (Clyde & Co LLP., 2021, p. 12), holding the potential for a global impact on business relationships (Hamilton, 2020). Smart contracts not only contain rules and penalties of the agreement, as any other traditional natural-language contract, but add the advantage of automated enforcement, security, and immutability of the stored data, achieved through cryptography, hashing and algorithms for proof-of-work[3], known as mining (Hamilton, 2020, pp. 8-9). Although automatization in transactions has been feasible for some time, the element of novelty in smart contracts is their distributed nature. These tools and decentralized ledger technology (DLT) often get intertwined, whereas it is fundamental to separate the two, knowing that DLT offers the platform where smart contracts can be executed (ISDA, Linklaters, 2017, p.8).

2.2 Smart contracts' enabling technology: blockchain

Smart contracts are based on blockchain technology, a network of registries located on computers that are separated one from the other but connected through the internet, where

[3] The consensus technique known as proof-of-work (PoW) protects the blockchain from some types of economic threats. It is founded on a verification procedure run by every node in the Ethereum network. The control process is called "mining". In about one year, mining on Ethereum will be replaced with proof-of-stake (PoS). To read more about the topic, refer to the source: https://ethereum.org/en/developers/docs/consensus-mechanisms/pow/.

a central registry does not exist. In this network, the data processed is encrypted and secured to provide a system that does not make mistakes, where the stored data is neither modified nor lost and where no one can access the information they do not have authorization. Blockchain is thus a structure that guarantees the users as a central authority keeping the registry would do, but where a central authority is not needed (Foti, 2017, pp. 3-13)[4]. Blockchain-based contracts automatically allow to execute a transaction and keep track of it in a block attached to the rest of the chain, with all the other transactions of an individual or object. The registry containing the list of these operations and the complementary data is not centrally kept. On the contrary, each node in the network has a copy (Foti, 2017).

Nick Szabo, a computer scientist and cryptocurrency expert, started blogging about the idea of smart contracts back in 1997 (Szabo, 1997). His vision was of a «virtual vending machine», able to equip a contractual agreement with both negative automation (to prevent interferences with the execution of the performance) and disintermediation from any possible third party (Cutts, 2019, p. 14).

2.3 Evolution of contract tools from real-world to smart

The panoramic of the progressive evolution of transactions from real-world to smart contracts offered by Cutts helps visualize the legal challenges brought by these blockchain-based agreements. The author begins with the classic example of the sale of an asset (Cutts, 2019, p. 10). The required elements are usually the presence of a seller and a buyer, who

[4] The definition and explanation have been translated from Italian to English by the author and rewritten in the author's words. The use of material in the author's own language helped the writer gain a full understanding of the concept.

agree on the exchange of a product (which implies the consensus, object, price and how the performance must take place). Additional elements are the trust that the counter-performance will occur, and that society will recognize the buyer and the seller as respectively entitled to the item and the price once the exchange has occurred. This latter is described as the «security of performance» (Cutts, 2019, p. 10), referring to the effective alteration of the identification of the party deemed qualified to oversee the relevant asset and those entitled to deal with it (Cutts, 2019, p. 10, note 68). A practical example[5] is the sale of a can of soda in a convenience store, where the consensus is reached over a price label and the material exchange of the money and the can occurs. The low-value transaction will not require the parties to put in place excessively onerous measures to secure the exchange and a certain level of risk will be automatically accepted by both seller and buyer. The next level for an agreement is the one in which the buyer has absolute reassurance of the performance, whereas the seller must rely on the counterpart's good intentions. A roadside stall provides such context of self-help, when the seller simply leaves the object of the transaction on a table, on the side of the road, without physically being present to hand it to the buyer. The latter will pass by, collect the item and, hopefully, leave the money in exchange in a box. Such a system does not provide sufficient guarantees for high-value transactions, hence the need for mutual reassurance in counter performance and the example of the vending machine (Cutts, 2019, p. 11). The mechanized delivery granted by the machine is what assures the performance of both parties, in an "If/Then" format that is the basis of smart contracts. If the buyer inserts the coin, then the can of soda will automatically be delivered, without the need for the seller to intervene but with the

[5] The description of the following examples follows what is illustrated by Cutts (2019).

guarantee that no outside interference will alter the exchange. In fact, through another example, Cutts (2019) effectively explains the difference between a vending machine-like format and digital transactions like the purchase of an online article. In this case, once the payment has been made, the download of the article is possible, unless the newspaper decides to stop or prevent access to the page. The power remains in the hands of the service provider unless a mechanism is put in place to ensure negative automation (absence of external intervention in the execution) and disintermediation (Cutts, 2019, p. 13-14 and 21). Digital transactions differ from physical ones because virtual assets face the "double spending" problem. This problem, present in real life but magnified by online exchanges, implies that digital pieces of information, once available to the counterparty, are not of exclusive possession but replicated. Hence, the need to make sure the buyer is the sole one entitled to receive the asset and the seller does not use the same money more than once. Usually, third parties such as banks are there to execute this role, creating an actual «multi-billionaire industry around trust» (Luzuriaga, 2019, p. 6). The recent distrust in central authorities keeping a record of key information in transactions and guaranteeing the exchanges between parties has exacerbated the need for tools that secure the data, grant automatization of performance of both parties and avoid intrusions in the execution (Foti, 2017, p. 11). Szabo's smart contracts are the magic formula that is supposed to address these challenges and bring agreements to a new level. These computer programs solve the need for trust, eliminating the necessity of it, and fueling economic relationships through automatization and immutability[6].

[6] Luzuriaga (2019), p. 34 (« [S]mart contracts represent a qualitative improvement in terms of the trust»).

2.4 Smart contracts and smart legal contracts. Treat to general contract law?

Another confusing element in this field is the distinction between smart contracts and smart legal contracts. The first concept resonates more with computer scientists, identified as a software agent designed to execute tasks[7] on a DLT platform according to pre-encoded instructions (ISDA, Linklaters, 2017, p. 5). The legal aspect of these computer programs becomes relevant when the encoded terms are those of a contractual agreement. There is a functional link between the two, as smart legal contracts are made of pieces of smart contract codes, where the crucial aspect is the relationship among the parties giving rise to legally enforceable rights (ISDA, Linklaters, 2017, p. 5). Smart legal contracts are therefore always based on smart pieces of code, whereas smart contracts can exist without bringing legal rights to the parties involved in the decentralized and automated operation. As there is no generally recognized definition of these smart tools (Savelyev, 2017, p. 120), the distinction seems merely meant to break down concepts to allow a deeper understanding of the subject. Nevertheless, some scholars make it the core of the discussion surrounding these blockchain-based agreements, questioning their relationship with general contract law (Savelyev, 2017, p. 122) and even predicting the «death of contract law» itself (Sklaroff, 2018, p. 274). Werbach and Cornell (2017), authors of one of the most complete publications on these smart tools, explicitly answer "yes" to the question of whether smart contracts can be interpreted as legal contracts, although they reformulate the issue as to what we mean by contract in the first place[8]. By identifying smart contracts as «agent-generated mechanisms to shift rights and obligations», the authors include them in the

[7] Possible examples of applications are the creation of cryptocurrencies or electronic voting mechanisms.

[8] Werbach & Cornell (2017), p. 126 («The first important question that smart contracts pose is: Are they actually contracts? Ultimately, we think the answer is "yes." But this question turns out to be ambiguous, requiring the answer to another question first: What do we mean by a "contract"?»).

contractual category (Werbach & Cornell, 2017, p. 126). However, some experts in the field have expressed concerns about the inconsistent methods used by various jurisdictions to control and integrate these technologies into their legal frameworks (e.g., Ruhl, 2020)[9]. More on this topic will be discussed in the following sections.

2.5 Transaction-cost economics of smart contracts

A law and economics approach to smart contracts necessitates remembering that transactions entail costs. They arise from the unbalanced spread of information between the contractors, the associated risks of the deal, opportunistic behavior and contingencies that might occur and frustrate the purpose of the agreement (Luzuriaga, 2019, p. 7). Contracts regulate human interactions[10] and aim to move resources to the highest value user (Luzuriaga, 2019, p. 7, referring to Posner, 2014, p. 124). Smart contracts represent the next level of this coordination, hence the need to address opportunism and unforeseen contingencies that might arise from these value exchanges. In this regard, it is important to examine these tools in light of the Transaction-cost economics theory (TCE). Paramount is the Coesian concept of "transaction costs" (TC), seen as the costs involved in using the market to identify more beneficial applications for certain resources and reallocate them accordingly (Coase, 1937, p. 390). A new definition was given by the Nobel laureate (2009) Williamson in developing the notion of TCE. According to him, transactions are related to governance because human exchanges must be regulated to avoid conflicts (Williamson, 1979). Governance brings lower costs than what would derive from conflicts,

[9] Ruhl (2020), p. 21 («The decisive question, therefore, is not whether smart contracts are subject to the law, but rather to which law they are subject»).

[10] Ulen (2021) defines contract law as a «facilitative area of the law», p. 287.

representing a more efficient and desirable choice for the parties (Luzuriaga, 2019, p. 7, referring to Williamson, 2005, p. 3). Hart and Holmström (1987), as well as Williamson (1985), provided an extensive overview of contractual hazards that produce TC.

2.5.1 Asset specificity and electricity

For this work, one particular element of uncertainty will be discussed, i.e., asset specificity. Remembering that the current analysis concentrates on electricity, it is useful to contextualize this particular asset and the challenges it brings in terms of costs. TCE assumes that the main element of variation in TC is asset specificity (Riordan & Williamson, 1985, p. 367)[11], where the higher the particularity of the asset, the stronger the bilateral nature of the transaction becomes. Non-convertible investments tie the parties to the initial commitment, making them want to secure future interactions, while confronted with possible contingencies that challenge the continuity of the relationship (Riordan & Williamson, 1985, p. 367). The structures to produce electricity (e.g., solar panels) are asset specific. The argument is that once installed, they cannot be converted to other purposes. Due to the variation in electricity production from these sources, prosumers would be more prone to undergo such investments if knowing that, once they produce electricity in excess, they can inject it into the grid and have strong contractual tools that ensure the payment after the auction has been cleared. In other words, consumers who were to install solar panels and connect to the local grid would gladly welcome the fact that, when wanting to sell electricity in excess, they would have secure and trustworthy means to do it (smart

[11] Riordan & Williamson (1985), p. 367 («Transaction cost economics maintains that the principal factor that is responsible for transaction cost differences among transactions is variations in asset specificity»).

contracts). They could do the entire transaction even without it, but smart contracts would represent an incentive to invest in such technologies.

These devices surely do not solve the problem of long-term commitment but prove to be the ideal contractual resource to enforce instantaneous and simply performances as P2P electricity purchases. TCE holds that «complex, bilateral contracts are invariably incomplete» (Riordan & Williamson, 1985, p. 367), whereas smart contracts demand the highest level possible of completeness for what is foreseeable. It is possible to derive that these contracts would probably fit in the framework of a master agreement, to ensure long-term interactions in a flexible environment, where basic transactions are automated with the use of blockchain-based techniques.

2.5.2 Cost-benefit analysis of smart contracts

To understand the added value that smart contracts might bring, it is necessary to identify their role in reducing (or increasing) transaction costs in contractual exchanges. On the classification of TC, Dahlman (1979) suggests dividing them among a) search and information costs; b) bargaining and decision costs; and c) policing and enforcement costs (p. 149). Williamson contributes with the useful distinction of ex-ante and ex-post TC (Luzuriaga, 2019, p. 25, referring to Williamson, 1985), particularly pertinent in the context of smart contracts. In fact, one of the claims is that they mostly anticipate costs for police of noncompliance and enforcement, shifting them to pre-contractual negotiations rather than to ex-post execution (Vatiero, 2022, p. 4). In this light, do smart contracts make parties gain or lose in terms of TC?[12] Luzuriaga (2019), for example, discusses this cost-

[12] Pivotal question that supports the analysis conducted by Luzuriaga, 2019, p. 37.

benefit analysis, assessing from an economic point of view whether the expected value and costs of drafting blockchain-based contracts justify their adoption (Luzuriaga, 2019, p. 39). The same methodology will be adopted in this paper. As reminded by the author itself, this sort of balancing requires a qualitative judgment that is highly reliant on the parties' risk preferences. Hence, the following cost-benefit overview can only aim to guide the final evaluation, which still requires a case-by-case study.

2.5.3 Advantages of smart contracts in reducing TC

I. Information and negotiation costs:

Surely, from a transaction-cost perspective, blockchain-based agreements encourage the disclosure of information before the finalization of the deal, as certain pieces of data need to be known to encode them in the algorithm under the "If/Then" clause format. In this sense, information asymmetry costs can be lowered. As for the completeness of the contract itself, legal philosophers have addressed the issue, coming to different results concerning the feasibility of a fully complete contract. Although there seems to be no perfectly comprehensive deal, a spectrum of completeness can be drafted, and some contracts can indeed be more detailed than others[13]. On this point, automated contracts running on the blockchain are as complete as their algorithmic nature allows them to be. The magnificent computational power of computer machines is strictly trapped in the 0-1 binary language, where concepts like "reasonable effort" and "good faith" do not find their coding equivalent and thus cannot be included (Luzuriaga, 2019, referring to Shavell, 2009). For this reason, information will indeed be shared, but in a most likely lengthy (and necessarily

[13] See: Shavell (2009) for the necessary incompleteness of contracts.

incomplete) drafting process, where lawyers and coders would need to find a common ground of understating to translate into machine readable terms what the parties aim to agree on.

II. *Risk-bearing:*

Similarly, the subdivision of risk among parties will be secured in unchangeable terms in the smart contract language, serving as an incentive for parties to enter the relationship, knowing ex-ante what to expect and face in terms of risk-bearing. Smart contracts themselves can operate as guarantees that the promise will indeed be kept, acting as "hostages", and fully applying the principle of *pacta sunt servanda*[14]. In this sense, they offer the parties a high degree of certainty.

III. *Search and monitoring costs:*

Opportunistic behaviors will not find a place in such algorithm-driven contracts, given that transparency and immutability are ensured through the blockchain machine (Vatiero, 2018, p. 3). Consequently, exchanges that might not have occurred due to a lack of trust, take place instead and people who do not know each other can still transact without engaging in search costs (Luzuriaga, 2019, p. 39).

IV. *Enforcement costs:*

Contracts provide mechanisms to rely upon in case of non-performance, nudging the parties into entering the contractual relationship knowing there will be remedial tools to refer to (Ulen, 2021, p. 287). Smart contracts constitute the remedy themselves, removing the necessity to depend on intermediaries for enforcement by letting the transaction occur only once both parties have fulfilled their respective duties. The cost of dependency on

[14] On the necessity for a guarantee when the contractual relationship is uncertain, see Mackaay (2011).

third-party trustees is lowered by running transactions around data feeds collected through the so-called "oracles", conveying information from the outside world to the computer and vice versa (Tjong Tjin Tai, 2018, p. 5). In this sense, the «code is law» paradigm is effectively applied and the need for judicial intervention is (theoretically) eliminated (Vatiero, 2020, p. 3, referring to Lessing, 1990). Although maybe this has never been the real problem, as the construction of a "meaningful contractual relation" between the parties, who choose how to carry on the execution of the agreement, might be more valuable in the long term than the security of automatically receiving the counter-performance. In this sense, the perspective of losing a long and fruitful contractual relationship might be a stronger (human) deterrent than any algorithmic-driven mechanism of enforcement (Luzuriaga, 2019, p. 42).

2.5.4 The reality of smart contracts and TC

It would be a misconception to believe that smart contracts create a «trustless [blockchain] environment» because they merely change the nature of the trust needed, from an external intermediary to oracles (Al-Breiki *et al.*, 2020, p. 2)[15]. This issue, with many others, could potentially undermine the overall cost-benefit analysis of such devices, as smart contracts might incur higher transaction costs than traditional contracts (Vatiero, 2020, p. 13). This is especially true for what concerns the cost of adaptation to unforeseen events, which seems excessively high in smart contracts compared to semantic ones (Luzuriaga, 2019, p. 45). Doubts are legitimately formulated on the predictability of external events even before they occur, given the impossibility of modifying these codes once written (Iredale, 2021).

[15] Al-Breiki *et al.*, 2020, p. 2 («There is a common misinterpretation about blockchain and trust, where people assume that blockchain networks are ‘‘trustless’’ environments»).

In this sense, transaction costs of negotiating would simply be anticipated at the pre-contractual stage instead of filling ex-post the gaps left strategically incomplete in semantic contracts. Moreover, as stated by Luzuriaga (2019), «much is lost in translation» when it comes to the complex exercise of programming a smart contract (p. 45).

Given that transactions need governance, expressed through contractual rules, the choice of the least costly contractual form is essential. In summary, on the topic of TC, smart contracts bring different advantages, depending on the specific application. In some scenarios, they are preferred to semantic contracts because of their automation and reduction of search, information and monitoring costs, whereas in others they do not provide the most economically efficient regulatory tool.

2.5.5 Behavioral L&E analysis of smart contracts. A consumer perspective

When addressing consumer markets, the interaction between elements of psychology and economic forces cannot be ignored[16]. For this reason, the argument for blockchain-based contracts is also supported by additional behavioral law and economics findings, which highlight that people are prone to make mistakes due to imperfect rationality and information (Bar-Gill, 2008, p. 1). Knowing these circumstances, parties will try to avoid ambiguity and tend to choose solutions that deliver more definite outcomes to overcome uncertainty. Smart contracts can be employed to provide additional help in this sense, offering a contractual tool that supports some human psychological characteristics. This is even truer in the context of a shared economy, where peer-to-peer transactions have taken over micropayments among consumers (Park & Yong, 2017, p. 4), who interact so often

[16] Bar-Gill (2012), p. 2 («[T]he design of consumer contracts can be explained as the result of the interaction between market forces and consumer psychology»).

and in such a fast-paced fashion that the need for a secured and trustless environment becomes pivotal. Indeed, electricity purchases among prosumers can be used as one such example to analyze the practical added value that smart contracts can provide, matching consumer instances and behavioral patterns.

Given the numerous biases and misconceptions in individual decision-making (Bar-Gill, 2008, p. 9)[17], it is relevant to find an ideal contract design that considers how demand and supply functions are dependent on perceived benefits and prices rather than the real ones[18]. Market solutions will not eradicate the resulting welfare costs for consumers, but designed disclosure of information could help enhance the efficiency level of the transactions (Bar-Gill, 2008, p. 43). As just mentioned, smart contracts do serve this purpose, requiring all potential ex-ante negotiations, but only for the foreseeable. Rare and unpredictable circumstances would be too expensive to encode into the agreement given their likelihood of occurring. What can and should be disclosed ex-ante, will be necessarily shared among the parties to allow for its transcription in a binary, machine-friendly language, no more modifiable once programmed. Information and search costs are hence reduced, and consumer behavioral needs are met. The need for certainty is maximized through blockchain-based contracts, whereas the criticism of the need for incompleteness based on bounded individual rationality does not hold once considered that smart contracts are as complete as it is possible to make them. What cannot be foreseen ex-ante and will thus require ex-post negotiations will be most likely dealt with traditional remedies, in front of a judge. Surely it lowers the claimed disruptive turnover in contracting promoted by smart

[17] An important difference is underlined by Bar-Grill between perfectly rational consumers and imperfectly rational ones, which lies in the way they respectively deal with imperfect information.

[18] For a detailed analysis of the way market forces and consumer psychology interact, influencing the design of consumer contracts and reducing consumer welfare, see Bar-Gill (2008).

contract enthusiasts, but the relevance of such unpredictable events is so rare in real life that their impact on contracting would cost more when trying to include them than the cost of dealing with them once they occur (Shavell, 2003, p. 10). The truth is, though, that their role in reducing consumers' welfare costs must be analyzed in the specific context of each consumer contract and market (Bar-Grill, 2012, p. 43)[19]. Hence the need to discuss the specific case of electricity P2P transactions later on in this work.

In summary, the need to account for behavioral insights in the ongoing discussion on the costs and benefits of smart contracts is because the law seeks to regulate individuals' behavior. As an obvious consequence, (smart) contractual law «must have a clear understanding of how people behave» (Ulen, 2021, p. 285).

2.6 Legal challenges of smart contracts. Gaps and cross-field approaches

Can smart contracts determine the end of traditional contract law? This issue has been mentioned in general terms, referring to the impact that the advent of blockchain-based contracts has on the law of contracts once the drafting phase becomes predominant over the executive one (Woebbeking, 2019). Nevertheless, the problem can be presented in more detail: contract law is not the only one confronted with these smart devices but also many other legal branches had the urge to make room for smart agreements. Given the multiplicity of the affected areas, an approach merely based on a legal analysis of traditional and smart contracts would not be sufficient to determine which solution would make each area of law better off in terms of efficiency. For that, a law and economics evaluation is required, through a carefully conducted cost-benefit analysis, which is what

[19] Bar-Grill, 2012, p. 43 («There are many consumer markets and many more consumer contracts. Each market is embedded in a unique historical, institutional, political, and legal context»).

scholars researching in this field are suggesting. For this paper, the question is how blockchain-based energy solutions fit into the European legal system, mainly referring to EU energy, contract, consumer, data, and financial markets laws[20].

2.6.1 Energy law

The energy sector has always been a pillar in the European Communitarian project, although it has not made it into the EU market integration scheme due to political reasons (Talus & Aalto, 2020, p. 1). Such a delicate area has obtained the status of shared competence, meaning that member states can only legislate when the EU has not intervened with binding legal acts (Lang & Muller, 2019, p. 6). The First, Second and Third Energy Packages, respectively adopted in the 90s, 2003 and 2009, progressively decoupled the gas and electricity markets, shifting state-owned enterprises to a competitive environment. The resulting panorama is highly influenced by the EU pieces of legislation, although each member state shaped its energy regulation according to its national law, determining a quite heterogeneous framework. In the long-term objective of a fully harmonized EU energy market, smart contracts and the underlying blockchain technology are not addressed, in general or in the energy sector (Lang & Muller, 2019, p. 6). Multiple questions thus arise, particularly for what concerns prosumers and their bilateral transactions in the context of energy communities. What is the legal box in which these exchanges should be classified? Who are the parties taking part in the agreement and what are the terms and conditions to comply with? Technically, prosumers are classified as suppliers according to the EU Electricity Directive (2019/944), which puts on them the burden of obligations related to

[20] A summary of these challenges can be found in Lang & Muller (2019), p. 6.

energy contracts that they need to fulfil, such as information rights to other consumers (Lang & Muller, 2019, p. 7). Moreover, what is the liability regime in case of faulty contracts or mistakes in the platform used for the exchanges? (National Energy Ombudsmen Network [NEON], Online Article). And how to conciliate the requirement on the change of energy supplier (i.e., a time framework of three weeks should be given to allow the change of supplier[21]) with the almost instant switch occurring under blockchain terms? (Lang & Muller, 2019, p. 7) These and many other riddles will require legal attention from both EU and national authorities.

2.6.2 Contract law

Regulatory hurdles also interest the field of general contract law. Briefly, the main challenges concern their nature, the role of lawyers and coders, the accuracy of the legal terms once transformed into binary language, and the inflexibility of these contracts once unforeseen events occur. Regarding their contractual nature, if legally binding agreements can be formulated through the parties' language of preference, this should safely include computer codes (Werbach & Cornell, 2017, p. 342). Even though each jurisdiction has responded to the need for blockchain regulation at a different pace and with varying degrees of reluctance,[22] they acknowledge the necessity of filling the legal gaps in this industry. Hence, the core question might be not about the legal nature of smart contracts (which seems to be present, according to many[23]), but more concerning which kind of law should

[21] Article 3(5) of Directive 2009/72/EC.
[22] Contribution by C. Poncibò, in Malena *et al.* (2022), p. 321, referring to American scholars being more willing to accept smart contracts as legally binding devices, whereas European jurisdictions (Germany, France, Italy, and Spain) are still more prone to consider it a tool to execute a semantic contract.
[23] E.g., Werbach and Cornell (2017), p. 126.

be applied (Ruhl, 2019). Referring to what is stated in the Rome I Regulation (593/2008/EC), a contract is subjected to a certain State's rules depending on the parties' residence or explicit choice of the jurisdiction they opted for. Given that smart contracts operate in a transborder digital environment, these criteria seem suitable to choose the appropriate set of rules, to then letting the algorithm run once encoded[24]. Although, if it was that easy, smart contracts would have been dedicated way less literature. In fact, a customer might decide against purchasing goods from across the border or online if they think that foreign law would make the transaction less clear or certain (Smits, 2012, referring to Lando, 2000). Hence, as the need for a Common framework for contract law becomes more and more relevant (Staudenmayer, 2002), the same could be said for smart contracts, regardless of their fit in the traditional contract law environment.

2.6.3 Data protection law

The new sharing economy giving incentives to C2C transactions determines concerns about privacy and data protection. When online platforms are not just mere intermediaries but perform acts of communication and provide additional active services (becoming Online Service Providers), it is unclear which terms they are liable for if some problems arise (NEON, Online Article). These legal gaps appear also in electricity trading among prosumers and call for immediate action[25]. In fact, the General Data Protection Regulation (GDPR) (2016/679/EC) was conceived in a world where data was kept, controlled and processed by central actors. Distributed ledger technologies such as blockchain operate on

[24] Although the concerned field of law is International Private Law, a more European-centered perspective is adopted in this paper. In this regard, more about the harmonization of European Contract law can be found in Smits (2012).

[25] For more on legal challenges on data protection posed by blockchain-based contracts see Voss (2021).

a completely different note, in which a centralized authority is not present, thus creating friction between the legal requirements imposed by law and the nature itself of the technology (CMS, 2019). Moreover, as an example of the apparent incompatibilities between blockchain-based contracts and Data regulation, Articles 16 and 17 of GDPR state the right to have erroneous personal data corrected and deleted. This is impossible at a first glance, given the immutable nature of smart contracts. A solution could be to allow for subsequent amendments, which is possible in this scenario, adding blocks with new information to the existent chain (Lang & Muller, 2019, p. 13).

2.6.4 Financial market regulation

How does the Directive on Markets in Financial Instruments 2014/65/EU ("MiFID II") interact with smart contracts and virtual currencies such as Ether or Bitcoin? Does the Regulation on Wholesale Energy Market Integrity and Transparency 1227/2011/EU ("REMIT") have anything to say on the blockchain? For wholesale energy goods, this piece of legislation provides a sector-specific ban on insider trading and market manipulation, and it becomes interesting to analyze to what extent peer-to-peer transactions shall comply. Moreover, who is responsible for ensuring compliance with such legislation? These are but a few of the issues questioning the application of smart contracts and their enabling technology in the context of financial market regulation.

2.6.5 Consumer protection

Consumers are widely considered at an EU level, with copious legislation dictating rights and duties in their interest. Unfair contractual terms, detailed information obligations, cooling-off periods, and consumers' withdrawal rights in agreements where the parties are not physically present are some of the primary provisions that are regulated (Lang & Muller, 2019, p. 10). Can smart contracts be classified as consumer contracts? Are prosumers classifiable as suppliers in practice? These are relevant questions, given that the EU consumer protection law does not apply to P2P transactions. In general, the nature and features of smart contracts challenge consumer rights from many perspectives, because whenever consumers tie themselves to immutable commitments, it is always a problem in terms of flexibility in reassessing the deal once something occurs. Among all the areas of law challenged by smart contracts, this paper will concentrate particularly on consumer protection in the electricity market. Before doing so, a brief overview of the energy sector in general and of electricity C2C deals is necessary to frame the context of the discussion.

3 Smart contract applications in electricity P2P transactions

3.1 Why the energy field and what makes it unique

The energy field offers fertile ground to inquire about the development of smart contract applications. This sector is undergoing a transition, the Digital Green Shift, based on five fundamental pillars: decentralization, digitalization, deregulation, decarbonization and democratization (European Union Blockchain Observatory & Forum, 2022, p. 4). Decentralized ledger technologies hold great potential to automate traditional energy production, transportation, and distribution along the entire supply chain. In pursuing the Digital Green Shift, it is important to recall that the energy field is unique for several reasons, and green innovation must confront sector-specific challenges because of that. The "double-externality problem" is one such example, i.e., the fact that (a) pollution is a negative externality that affects people other than actors in a market economy[26], and (b) the knowledge needed to produce (green) technology is non-rival and non-excludable (Hall & Helmers, 2010, p. 4). The non-appropriability of knowledge results in a discrepancy between private and social returns to R&D in inventions. In fact, information is costly to produce but relatively cheap to share. Welfare from innovation is reduced as a result of these two interacting factors, disincentivizing the efforts and resources put into the introduction of new environmentally-sound technologies (Hall & Helmers, 2010; OECD, 2013). Because of this issue, innovation in the energy field must carefully consider methods to solve these problems (for example, through the appropriate use of intellectual property rights). In the described context, one of the most difficult aspects of decentralization will

[26] For example, the cost incurred by a factory located near a river is not only the production cost but also the cost of the environmental impact imposed on the nearby population, affected in its farming and fishing activities because fauna and flora are killed by the polluting emissions of the industrial facility.

be ensuring stable and trustworthy information sharing among many small, distributed energy resources (DER) (European Union Blockchain Observatory & Forum, 2022, p. 5).

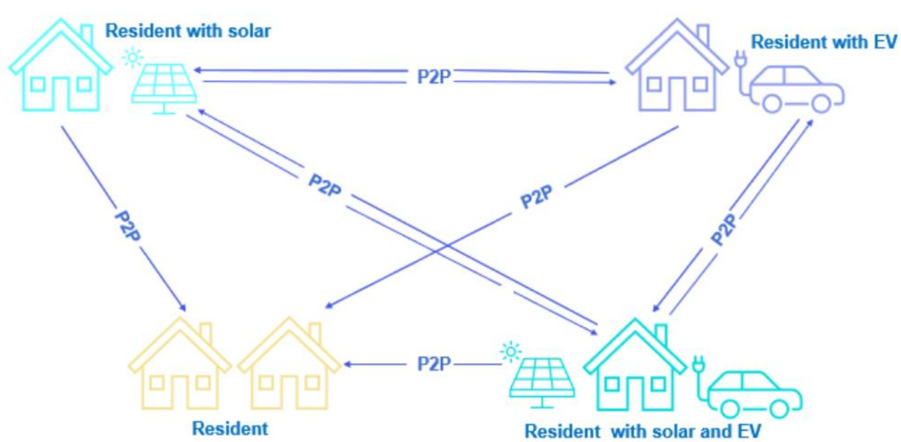
3.2 Blockchain's role in the energy transition. Contributions and challenges

Blockchain applications can play a fundamental role in this regard. The deployment of this technology in electricity exchanges follows the three phases that characterize the evolution of blockchain per se: the use of cryptocurrencies for payments of electricity bills (phase 1.0), the use of smart contracts for physical transactions (phase 2.0), and the 3.0 phase, not yet achieved, where big data and artificial intelligence will cover a pivotal role in predictive maintenance (Burger *et al.*, 2016, p. 13)[27]. In the analysis of the current phase 2.0, scarcity of reliable and verifiable market data is another of the energy field's hurdles that smart contracts can help address. It is made difficult by the lack of financial and technical infrastructure to record and track such data, as well as a structural absence of trust and clarity in financial sector operations (Clyde & Co LLP., 2021, p. 16). Blockchain can reduce participant verification and networking costs, make the current market structure more competitive by decreasing the barrier to entry for newcomers and provide an easier and quicker flow of data and a more secure way to conduct transactions. This technology can decentralize traditional grid management and implement distributed energy transactions without a third-party operator.

[27] Referring to Swan, M. (2015). Blockchain: Blueprint for a New Economy, *O'Reilly Media*, p. IX.

3.3 Uses of blockchain technology and smart contracts in the electricity sector

For what concerns the electricity sector, blockchain architectures allow for nearly real-time exchanges of electricity through smart grids, where the automated payment occurs once the required amount of energy is delivered through the grids from the producer to the purchaser. The attention of this paper is not only on what blockchain per se can do in the energy sector but specifically on what smart contracts can do for electricity transactions. Through this blockchain-based contractual application, DER entities are grouped in a power system, allowing for the exchange of data (i.e., the intention to purchase electricity and the willingness to provide it) (Clyde & Co LLP., 2021, p. 17). Blockchain works as an enabling technology for wholesale peer-to-peer trade through smart contracts in more technologically sophisticated use cases. For instance, when a consumer can directly purchase extra energy from a preferred source (e.g., solar or wind) by interacting with its supplier through a smart contract. P2P energy trading models come in a variety of configurations, including totally decentralized, partially centralized, community- or virtual-level, main grid, and autonomous microgrid models (Bagdonaité, 2022). In general, such a trading structure could be represented as follows:



Source: Bagdonaité (2022) and Liu *et al.* (2019), as used in the IRENA report (2020).

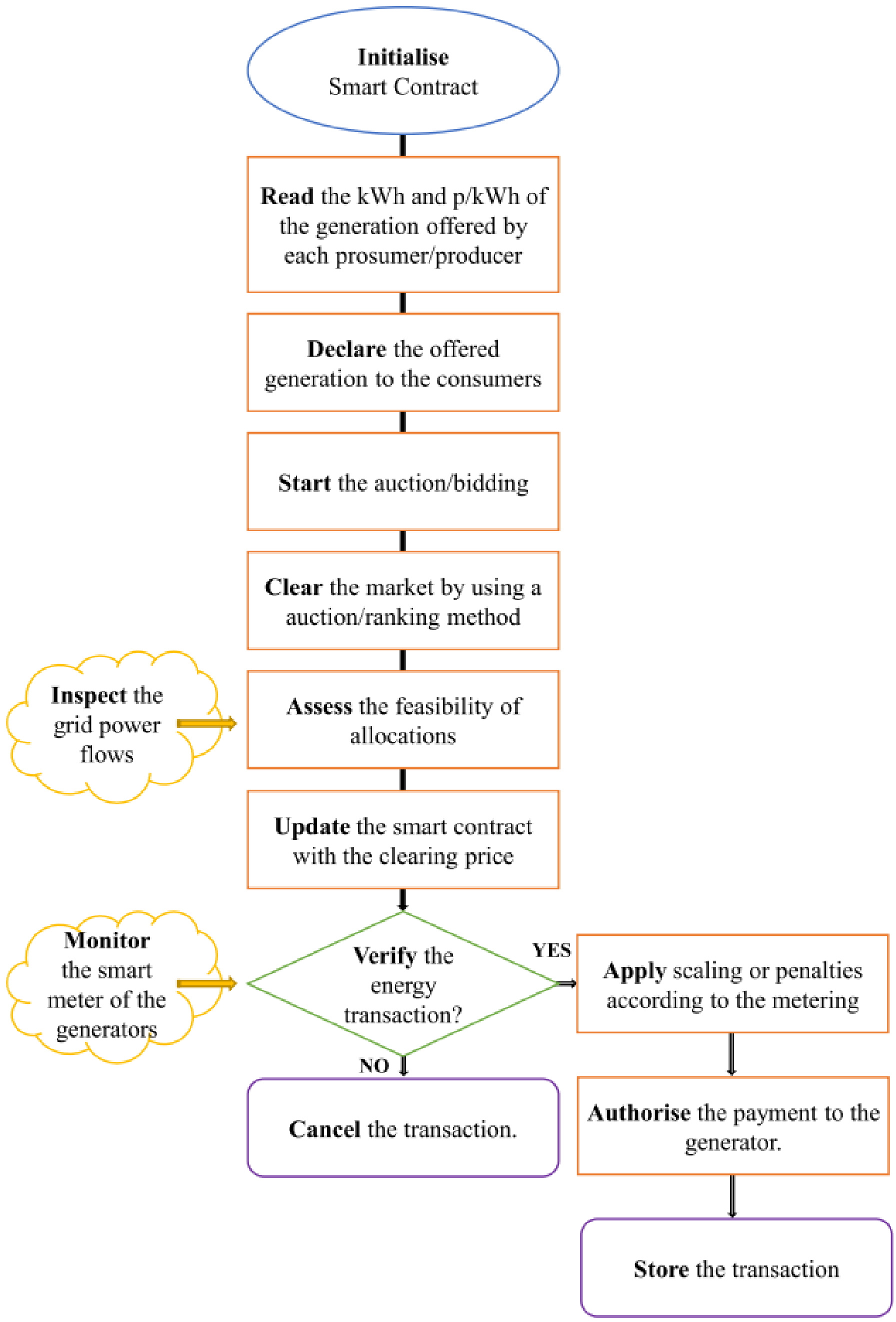
Note: the direction of the arrows indicates the directions of the money transferred and the electricity delivered.

Despite the numerous successfully operating P2P energy trading platforms all over the world, many barriers hinder the scalability of such a system. Several modifications to the current electricity market could help in this sense, and the attention to legal and economic aspects of smart contracts used for such negotiations is one aspect to pay attention. The legal framework to let it run and the economic incentives it offers are of central importance to smoothen the large-scale adoption of the electricity prosumer model.

3.4 A concrete example of a P2P electricity exchange through smart contracting

In practice, how does a smart contract operate in P2P transactions? Kirli *et al*. provide an explanation of such functioning (Kirli *et al.*, 2022, p. 6) in their work on blockchain-based contracts in the energy system. Once the smart agreement is initialized, it reads the kWh and p/kWh of electricity generated by each prosumer, to determine the amount of electricity offered for sale by each of them. The auction is then launched, where the bids are ordered through a ranking method to clear the market. The feasibility of the allocations is consequently assessed, and the smart contract is updated with the clearing price (inspection phase). Whether the transaction is verified or not (monitoring phase) determines the authorization for the final payment of the purchased electricity. The whole process concludes with the storing of the transaction into the blocks of the chain[28].

[28] Note: the description of the process is based on the following picture from Kirli *et al.* (2020). Another example of a smart contract used for P2P transactions is discussed in Hahn *et al.* (2019).



Source: Kirli *et al.* (2022), p. 6. « A sample smart contracting algorithm for P2P energy trading».

3.5 Specificities of the electricity market

While addressing the role of smart contracts in the electricity (power and capacity) market, it is worth mentioning the distinctive features it presents due to the specificity of the circulating product. Some of this market's main traits are (a) inelasticity of demand, (b) continuous request for the good and its (uneven) consumption, taking into account that production and consumption virtually coincide, (c) technical difficulties in storing it in large quantities and standardizing its range, (d) different sources of generation (hydro, nuclear, hydro, etc.), (e) homogeneity of the product, which determines a lack of brand differentiation in the classic term, (f) limitation of power grids capacity and availability of infrastructures (Gazeev *et al.*, 2015). For these reasons, energy capacity becomes a traded product in a dedicated market, and the overall framework is made even more complex by different possible market designs. The main functioning models (proceeding from a monopoly to free competition) are (i) regulated natural monopolies, (ii) retail competition in the wholesale market with different producers and buyers (i.e., distribution and retail companies), where distributors only operate in assigned territories, (iii) free markets, with competition both at the wholesale and retail levels (free competition between both consumers and producers) (Gazeev *et al.*, 2015, p. 191). These layers of complexities compound and determine the existence of ancillary markets and the widespread use of financial derivatives for electricity (Gazeev *et al.*, 2015, p. 192). The time element also plays a priority role in the final picture, with short-term markets having the scope of optimizing operational decisions and long-term markets aiming at reducing investment-related risks (ACER, 2022, p. 18).

The electricity market currently is confronted with vertiginous increases in prices reflecting the ongoing political destabilizations. Mentioning the issue of the current price inflation allows to discuss the electricity market design, and what tools to use in electricity trades, aiming for efficiency for both producers and consumers in the long run (Pototschnig *et al.*, 2022, p. 1). This section suggests a possible way to tackle today's electricity price surges with smart devices, through dynamic pricing and peer-to-peer trading.

3.6 Electricity pricing. An overview

A brief overview of electricity pricing for final users simplifies the understanding of the nuances and complexities of formulating ad-hoc policies for this field. It falls outside the scope of this paper to detail every aspect of the mechanism that defines the final price of electricity for consumers. It is sufficient to recall the existence of multiple markets for the trade of energy, transmission capacity, and flexibility, until the final real-time delivery[29]. What drives the total energy expenditure of households is a mix of several factors, which could be resumed as a combination of all the costs incurred by generators, networks, and retailers, all passed down to the final power bill[30]. Consumers pay depending on rates decided by retail companies, which can be more or less regulated. On average, electricity prices are determined by the network and wholesale costs, carbon costs, retail services and environmental schemes[31]. Generally, the main swings in final electricity bills are attributable to retail charges, although the competitive nature of this market allows final consumers to choose the plan they find more convenient among all those offered by different retailers. In addition to this flexibility of choice (aided by online platforms comparing offers, cooling-off periods, and regulated exit fees), other price-setting

[29] Four clusters can be identified, namely (A) long-term markets (forward energy markets, forward transmission markets and capacity mechanisms), (B) wholesale or spot markets (day-ahead and intraday markets), (C) Balancing markets (balancing capacity and balancing energy markets), and (D) Transmission re-dispatch "markets" (Reservation for re-dispatch and re-dispatching markets). See fsr.eui.eu/electricity-markets-in-the-eu.

[30] For a more detailed explanation of the functioning of the electricity pricing system, see: http://gs-main.panicbear.consulting/electricity-pricing/.

[31] *Ibid*.

mechanisms can help reduce the current economic burden on electricity consumers. Dynamic pricing is put forward by some experts to address the current price inflation (Pototschnig *et al.*, 2022, at "Introduction"). This kind of B2C contract, from supplier to consumer[32], benefits both parties. The former would be able to implicitly take advantage of demand response to higher prices, reducing the potential investment in generation and networks[33], whereas the latter could adjust its consumption depending on price signals.

3.7 Smart contracts' role in decentralizing the electricity network

In response to electricity price inflation, it is more urgent than ever for grid companies to develop a distribution system that is efficient, secure, and convenient for consumers, offering better electricity transactions and charge settlement tariffs and plans (Lu *et al.*, 2020, *Wiley Special Issue*, p. 1). As mentioned, smart contracts can help achieve this result, providing a distributed platform to store and secure data, with consistent verification and cryptography (*Ibid.*, Lu *et al.*, 2020). Not only retail contracts but also P2P networks can benefit from a blockchain-based electricity management system. Indeed, these devices can solve problems of trust and financial protection among prosumers. Dynamic matches through smart contracts between players in the market can add security and transparency to bilateral trading conducted under simple electronic contracts. Moreover, the automatic enforcement of the deal is granted by the self-executing code (*Ibid.*, Lu *et al.*, 2020, p. 443). Therefore, it is true that dynamic pricing can be applied even without smart contracts[34], but

[32] «Dynamic electricity supply contracts are defined as electricity supply contracts between suppliers and final customers that reflect the price variation in the spot markets, including in the day-ahead and intraday markets, at intervals at least equal to the market settlement frequency» - Article 2(15) of Directive (EU) 2019/944.

[33] See https://fsr.eui.eu/event/dynamic-pricing-in-the-electricity-retail-market/.

[34] Dynamic pricing is based on algorithms that turn big data into pricing decisions, which can be legally agreed upon through traditional contracts. The use of smart contracts brings the additional advantage of self-executing the agreement and offering a transparent and unmodifiable registry to store the data exchanged.

their use brings the execution of the electricity purchase one step forward with the advantages just mentioned. Hence, smart contracts do add benefits to consumers, and the question becomes then how to use them most *smartly*, to maximize consumers' welfare whilst offering them all the due guarantees and securities.

4 Electricity smart contracts and consumer protection

4.1 Benefits and pitfalls of smart contracts for consumer protection

Software code-based contracts and their autonomous performance are nothing new in user markets (Werbach & Cornell, 2017, p. 108)[35]. Consumers have been exposed for a while to interactions with Online Service Providers to engage in e-commerce. The use of blockchain as a platform for market exchanges has nevertheless been something revolutionary, operating similarly to other sharing economy apps but with the additional element of freedom and fairness through the consensus mechanism (Burger *et al.*, 2016, p. 12). This added benefit corroborates the argument of getting rid of power companies' centralized management as a barrier to a more sustainable era of energy generation (Burger *et al.*, 2016, p. 12). The merits of smart contracting must be confronted with the limitations and threats posed to consumers. The absence of middlemen, the uncertainty surrounding the counterpart in the agreement, together with the risks of unforeseen events modifying the expected performance, all plays a role in somehow putting consumers in a position of partial distrust toward these smart tools (Cutts, 2019, p. 40). After having analyzed smart contracts in general and their role in P2P electricity transactions, this final chapter aims to merge the information provided so far, to deliver some suggestions on how to deal with these devices in a way that promotes consumer welfare to the maximum.

In the first place, it is worth remembering that technology can undoubtedly bring about several positive changes in how consumers are safeguarded, closing the gap between consumer law and its implementation (Poncibò, 2019, p. 4). Blockchain could represent an instrument to provide more safety to consumers, in addition to lowering or even eliminating

[35] Referring to Surden (2012), describing the development of data-oriented and computable digital contracts, at 634.

the costs of justice. Overall, smart contracts could increase the effectiveness of consumer rights (Poncibò, 2019, p. 6, recalling e.g., Cutts, 2019). Nevertheless, many scholars do not miss to list the numerous downturns of these devices. Some authors do worry about the effects of contract automation on consumers' freedom and ability to exercise their consent when making purchases of products and services (Poncibò, 2019, p. 6). The main fear concerns the potential pitfalls of contract automation (especially, of general terms and conditions), anticipating that as technology develops, consumers won't be able to understand the content of the smart agreement and deliberately give their consensus.

4.2 Smart contracts use to increase consumer protection

It is inevitable that consumers will be (negatively) affected by the automated performance occurring even when a different execution or no performance at all would have been preferrable due to a change in circumstances (Savelyev, 2017, p. 120 *et ss.*). Despite that, there seems to be consensus on the benefits brought by smart contracts both to businesses and consumers (Cutts, 2019, pp. 5-7). In fact, the limitations of blockchain-based contracting might still surpass the treats to consumer rights deriving from obscure clauses and terms, boilerplates[36] that leave nothing to agree upon and confusing conditions not intelligible to the average customer. In summary, the main threats to consumers, especially with contracts on digital platforms, are a) consent, b) unequal bargaining power, c) privacy, d) confidentiality, and e) trust. Some authors, such as Rab (2020), argue that blockchain can be the answer, leveraging the playfield between the seller and consumer. According to

[36] "Boilerplate" or "miscellaneous" rules refer to the standard language that is frequently found at the end of a contract.
Source: https://www.lexology.com/library/detail.aspx?g=b6103c85-9717-446f-9b63-5509ef2ee66d.

the author, these tools help break down jurisdictional boundaries in international commerce while also fostering loyalty, security, and efficiency (Rab, 2020, "Abstract"). Blockchain, operating in a digital environment, overcomes national barriers, provides a trustworthy framework, and encourages consumers across the globe to enter negotiations even without having a clear idea of the counter party's identity.

Referring to in-house micro-generation systems for electricity[37], what are the main benefits of smart contracts (compared to semantic ones) that could be of additional incentive for prosumers to join local energy communities and sell the electricity generated in excess?

1) *Trust*: the automated nature of these contracts allows prosumers to enter the contractual relationship in the electricity network without knowing with whom they are negotiating. The performance will be executed regardless, and consumers can decide to opt for traditional systems of dispute resolution in case a rare unforeseen event happens (Rab, 2020, p. 52)[38].
2) *Self-execution*: it cuts the need for judicial intervention to enforce the deal, creating a safe environment for electricity delivery and immediate payment in response.
3) *Privacy and confidentiality*: much of the data usually needed in traditional purchases of electricity would not be required in such P2P exchanges running on blockchain devices. The secrecy of the code language is a comforting idea when it comes to communities created in big cities, where neighbors have never interacted before and maybe do not intend to do it in the nearest future. For example, smart contracts do not

[37] «A microgrid is a small-scale power source that has control systems. As a result, it can run independently and can be disconnected from the larger grid. » Source: https://www.energy.gov/articles/how-microgrids-work.
[38] See also Borgogno (2019) and Tjong Tjin Tai (2018).

require the disclosure of the seller's bank details or GPS location, referring only to the asset itself (Rab, 2020, p. 53).

4) *Tracking and control of energy networks*: smart contracts would signal which transactions to initiate, balancing demand and supply and documenting transfers of assets' ownership. The overall energy flow and business activities would be recorded into the blocks of the chain, offering a secure and accurate summary of the exchanges that have occurred (PwC rep., p. 17).
5) *Consumer empowerment*: all these advantages are supported by the fact that this technology allows prosumers to engage in the power market in ways that are far more beneficial than unilateral trading with central utilities. Low- and high-income consumers are linked and can exchange electricity, better management of decentralized resources is stimulated, and cheaper prices can be paid through the bidding system compared to fares paid to power companies (IRENA, 2020, p. 10).

Although, as seen, smart contracts could be a solution for a pro-consumer regime in a digital environment for electricity negotiations, some hurdles still require attention.

4.3 Smart contracts' detrimental effect on consumer rights

Many scholars have shown a sentiment of distrust towards the advocated benefits that smart contracts could bring to consumer rights. One major argument is that comprehension of the contract terms as they are standardized and codified in a smart contract will gradually decline (Poncibò, 2019, p. 9)[39]. Together with that, as recalled in the «Research Handbook in Data Science and Law», consumer markets systematically using data to provide more

[39] Referring to Griffin (1978), p. 158.

tailored services and products are threatening the protection of consumer rights (Mak, 2018, p. 17). Transparency and the abuse of consumer data are not the only issues in the data economy in which smart contracts operate. Schlegel (2018) sheds light on three more challenges to overcome in the blockchain-applications domain, based on the literature review and interviews he conducted for his paper (Schlegel *et al.*, 2018, p. 3484). According to the author's perspective, the main issues in the blockchain environment are 1) technical, due to the inner limitations of this technology (previously discussed when addressing smart contracts in general); 2) institutional, because some governments are not embracing the legislative duty of regulating this field (e.g., China); and 3) human given that, for consumers, something more than a "netiquette"[40] is required, due to the risks to privacy and security that blockchain poses. On this last point, the author claims that stronger behavioral practices should be promoted to arm consumers with defensive tools to interact with such devices and benefit from them while resisting possible dangers. Overall, these downturns contribute to consumers' feeling of skepticism about seeing their rights promoted and protected by smart contracts. Poncibò (2019) addresses some criticism about consumers' consent in digital transactions, focusing on the shrink of such right by smart contracts. She suggests that blockchain-based contracts represent the latest stage in a progressive annihilation of the value of contractual consent in favor of mass consumerism (Poncibò, 2019, p. 10). The question might thus be more philosophical: how much longer do we want to pretend that bargaining power in the form of manifestation of consent remains in the hands of consumers?

[40] This term is the short form for "Internet etiquette", referring to a code of conduct on the Internet. Source: https://techterms.com/definition/netiquette.

4.4 European consumer protection legislation and electricity smart contracts

Automation and immutability of smart contracts make the performance unavoidable, hence it is relevant to understand the impact that these features (together with all the others previously mentioned) have on EU consumer protection law (Forbes, 2022, p. 58). Four main areas require attention: 1) unfair contract terms, 2) the Consumer Rights Directive, 3) unfair commercial practices, and 4) defective and non-conforming goods. The analysis conducted by Forbes (2022) on this topic will be detailed from the perspective of the electricity C2C market.

1) *Unfair contract terms*: conditions in the contract that have not received mutual agreement by the parties and thus determine an imbalance in the subdivisions of rights and obligations (Forbes, 2022, p. 58). According to Article 6(1) of the Unfair Contract Terms Directive (93/13/EEC), such terms shall not be considered binding. As already seen, for what concerns smart legal contracts, the concept of "unfairness" is difficult to encode and, in any case, the performance is still enforced, regardless of how fair the coded terms prove to be. The adoption of smart contracts for electricity C2C trades would face the same limitations as any other contractual exchange on the blockchain platform. Moreover, problems arise also for those not considering smart contracts as legally valid agreements. In fact, in that case, consumers would not receive any kind of protection at all, which leaves them powerless.
2) *Consumer Rights Directive* (2011/83/EU): two major rights derive from this EU piece of legislation, namely the right to be given detailed information on the transaction and withdrawal rights. As mentioned before, this directive self-limits its area of application, excluding contracts that function according to a "vending-machine"

modus operandi[41]. Despite the possibility that smart contracts could be left out of this directive's safeguarding, blockchain-based agreements can count on a great level of "forced" information disclosure. It seems therefore that algorithms deliver in practice the same results as what the law imposes theoretically, which works in electricity trading as in similar exchanges.[42] The right of withdrawal, on the other hand, is of more difficult collocation among the smart contract's universe. How to contemplate such ex-post modification when smart contracts proceed stoically to execute the deal despite this supervened desire from one party?

3) *Unfair commercial practices* (2005/29/EC): the main problem that concerns P2P transactions of electricity is that this directive refers to B2C practices[43], proposing again the definitional issue of how to consider the prosumer's role in these exchanges. Are they acting as sellers, and thus do they have to comply with this directive or not? And even once prosumers are considered as included in this directive, struggles originate in interpreting the compatibility of their activities with aggressive advertising tactics and deceptive commercial strategies. Local peer-to-peer trading using smart meters and smart contracts is a relatively new market model, unexplored in its impact on consumers in terms of abusive attitudes of end-users acting as sellers and the protection consumers could benefit from.

4) *Defective and non-conforming goods*: the EU directive on defective products (85/374/EEC) deals with both defects and non-conformity. With the former, damages caused by the defective product are attributable to the producer; for the latter, only the

[41] See article art. 3(3)(l) of the Consumer Rights Directive.
[42] For a more detailed analysis on this point, see the author's full work (Forbes, 2022).
[43] See Article 3(1) of the Unfair Commercial Practices Directive.

seller could be held liable. The problematic legal nature of smart contracts already poses a riddle of whether there is a sale under legal terms, and thus a figure of "seller" can be identified at all. The issue is amplified by the hybrid nature of prosumers, who are consumers acting like sellers. Moreover, for those claiming that smart contracts are legally valid tools, the problem of redress for non-conformity or defects remains. It would imply referring to the judiciary for ex-post intervention, which clashes with the inner idea of smart contracts' independence from external interventions. On this last point, an additional level of complexity would be given by the inexperience on the subject that courts present. Judges across the world lack the knowledge in terms of smart contract disputes and understand even less about their contextualization in electricity negotiations.

It is worth noticing that the EU Commission is not oblivious to the threats posed to consumers by online contracts. In fact, it launched this year a «Fitness Check of EU consumer law on digital fairness», to assess whether the existing legal tools are still sufficient to offer an adequate level of consumer protection or not[44]. One relevant piece of legislation is the Directive regarding «the better enforcement and modernization of Union consumer protection rules»[45]. For example, it mentions the need to make the definition of «online marketplace» more «technologically neutral» and inclusive, together with a series of information that consumers should be provided with[46]. It becomes relevant once considering the grey area in which prosumers are acting now, surrounded by uncertainties

[44] See: https://ec.europa.eu/info/law/law-topic/consumer-protection-law/review-eu-consumer-law_en.
[45] Directive (EU) 2019/2161.
[46] *Ibid.*, points 24-29.

regarding their rights and duties. The ongoing works on this fitness check are scheduled to be finalized by the second quarter of 2024[47].

4.5 Future perspectives for the improvement of consumer welfare in P2P electricity trading. A role for lawyers and economists

Are prosumers already safeguarded enough or should there be a legislative initiative to bring forward the level of protection, particularly in the use of smart contracts, for electricity peer-to-peer transactions? After the analysis conducted, it seems that much work remains to be done in this field, not only for the electricity sector, but even at a general level for fitting smart contracts in the Energy Transition scenario. Regulatory and economic challenges are required to stimulate prosumers in entering the market, whilst providing them with more certainty regarding their rights in such operations. As an example of possible improvements in this area:

A) *Regulatory improvements*: legislators will have to keep up with the fast pace at which the energy trading environment is digitalizing, developing further a whole new set of competencies involving, e.g., the capability to dialogue across different sectors, with data scientists and energy engineers. A better regulatory environment would be created by working closely with consumer associations, which would be especially beneficial for the advancement of innovative technology like blockchain-based solutions (CEER, 2019).

B) *Economic improvements*: Article 21(4) of Directive (EU) 2018/2001 distinguished two types of self-consumers, i.e., «individual renewables self-consumers» and

[47] See: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13413-Digital-fairness-fitness-check-on-EU-consumer-law_en.

«jointly acting renewables self-consumers» (IRENA, 2020, p. 14). The former can only produce electricity for themselves, whereas the latter can also sell it to others. Investments to become an active self-consumer (the traditional concept of prosumer used so far) do not pay as much as what is obtained through self-consumption only[48]. Economists are thus asked to create support mechanisms that allow lowering prices for customers while enabling active customers to profit more from their sales (Bagdonaité, 2022).

[48] Bagdonaité (2022), see section: “Economic gains for prosumers”.

5 Conclusions, limitations, and outlook

After introducing the basic aspects of smart contracts, this work provided an overview of the transaction costs involved in operating through these blockchain-based devices. Some TC are reduced thanks to the main features of these smart agreements, whereas others are simply shifted from an ex-post to an ex-ante moment. The overall analysis, conducted through the comparison of some selected academic papers on the topic, showed that smart contracts are beneficial in certain transactions, where the negotiation is simple and can be mechanically executed in a machine-like format. For now, only this type of transaction profits from running on blockchain, whereas others, more complex deals would not receive any substantial benefit in choosing smart contracts over traditional ones.

In the second chapter, smart agreements have been contextualized in the energy field, detailing their functioning in such peculiar area. The discussion covered the practical illustration of how a smart contract for electricity P2P trading self-executes and what are the advantages that it can bring to this kind of inter-prosumer sales.

Lastly, the analysis moved on to consumer protection, building on what was developed in the previous two chapters. The leading research question, whether prosumers receive enough protection once trading electricity through smart contracts, was answered on an open note. It was observed that, in general, smart contracts would require intervention to provide more consumer guarantees.

The entire discussion was conducted with a forward-looking approach, given that, at the moment, not many energy communities adopting smart contracts are present around the world. Nevertheless, their number is increasing and blockchain applications will see more and more enthusiasts in the nearby future. The observations contained in this work are thus meant to provide useful material for future research, helping those approaching the field to gain a first glance of the still-unsolved problems to address. The limitations of this study concern the subjectivity of the practical literature consulted, as companies might inflate positive aspects of blockchain applications and minimize their downturns to stimulate the adoption of this technology. Also, the analyzed literature is not comprehensive and there might be some more relevant papers that have not been consulted and could provide insightful observations on the topic[49]. Moreover, once blockchain becomes more widespread and more prosumers will engage in P2P community transactions, the network effect typical of digital platforms will magnify the impact of this technology on consumer welfare and that will require further contextualization[50].

In general, blockchain technology is competing with existing solutions and must prove its attractiveness to users (Burger et al., 2016, "Conclusions"). To do so, it has to provide consumers with quantifiable benefits, such as reduced costs and faster time-to-use schedules. These are the main challenges to concentrate on to see the uptake of smart contracts in the next years and lawyers and economists have a decisive role in shaping the growing electricity-sharing economy. Additionally, the author of this work agrees with Cutts (2019) in remembering that, maybe, there is not a need for a trustless environment to conduct transactions, but a way for technology to interiorize values.

[49] As recalled for their work by Schlegel et al. (2018), p. 3485.
[50] *Ibid*.

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