Blockchain and Smart Contracts in the Energy Industry: A European Perspective

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BLOCKCHAIN AND SMART CONTRACTS IN THE ENERGY INDUSTRY: A EUROPEAN PERSPECTIVE

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1. Introduction

Even for an energy lawyer – in Europe or elsewhere – blockchain technology is hard to ignore these days. It is clearly one of those potentially very disruptive technologies that raise high expectations across both renewable and fossil energy industries.

Some dream that blockchain, in combination with smart contracts, can be an answer to some if not all the most pressing questions of the energy transition. This may in particular include ensuring security of supply in the light of highly volatile renewable electricity sources. The most radical scenarios anticipate that blockchain will do nothing less than reshape the energy industry entirely and turn electricity markets as we know them into decentralized structures, where utility providers are superfluous and electricity is traded directly among peers. In the oil and gas sector, blockchain can possibly lead to significant cost and time savings for example in commodity trading.

Of course this raises questions as to the technical feasibility of such visions. For a lawyer, a key question is how blockchain applications fit into the relevant legal frameworks.

This article will discuss to what extent blockchain and smart contracts in the energy sector are compatible with the law of the European Union (EU). To this end, a brief introduction will provide the technical basics of blockchain, smart contracts and Ethereum, a platform for blockchain applications, before examples of use in the energy industry will be outlined. The legal issues of blockchain and smart contracts arising under EU law will then be analyzed, focusing on EU energy law, contract law, consumer protection law, data protection law and financial markets regulation.

We will argue that the EU's legal framework, whilst accommodating for some blockchain applications already, still provides obstacles for the implementation of true peer-to-peer electricity trading between consumers. But obstacles can be overcome – if dealt with properly.

2. Blockchain, Smart Contracts and Ethereum in a Nutshell

Blockchain is frequently associated, if not equated, with Bitcoin. Indeed, the digital currency envisaged by Satoshi Nakamoto is the first application of the blockchain technology,[1] but it is by far not the only one.

Blockchain is conceptually a distributed, decentralized ledger that enables direct peer-to-peer electronic transfers of value without the need for an intermediary.[2] Put simply, blockchain is a form of record-keeping, [3] a digital database, but unlike traditional databases, the information

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[1] See Satoshi Nakamoto, "Bitcoin: A Peer-to-Peer Electronic Cash System" (2008), https://bitcoin.org/bitcoin.pdf.

[2] Alan Cohn, Travis West and Chelsea Parker, "Smart after all: Blockchain, Smart Contracts, Parametric Insurance, and Smart Energy Grids" 1 Geo. L. Tech. Rev. 273 (2017) at 277; see also Bernard Marr, "A Complete Beginner's Guide to Blockchain" (2017), https://www.forbes.com/sites/bernardmarr/2017/01/24/a-complete-beginners-guide-to-blockchain/#7df4d3a36e60.

[3] Adam J. Sulkowski, "Blockchain, Law, and Business Supply Chains: The Need for Governance and Legal Frameworks to achieve Sustainability" (2018), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3205452.

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it contains is not stored centrally. Rather, participants of the blockchain, "nodes", store identical copies of the database, making a central authority controlling the data superfluous.

Each user of the blockchain has an account which it can access by using a private key, similar to a password, and each account has a (pseudonymized) public key to identify it to other users. Every time a transaction is made, such as the transfer of a certain amount of a digital currency from one user to another, a new block is created and verified by "miners" in accordance with a consensus protocol. The block is then added to the already existing blocks and broadcasted to the other nodes, who will then append it to their local copies – hence the name blockchain.[4]

"Proof-of-Work", the consensus protocol used by Bitcoin[5] and other cryptocurrencies, ensures that mining does not come without cost, in order to safeguard the blockchain from malicious actors.[6] To create a new block, miners have to solve a mathematical problem, a "hash puzzle". The miner who solves the problem first creates the new block and receives bitcoin as a reward, thus incentivizing miners to invest significant resources in order to provide the computing power to solve the problem, which, in turn, demonstrates their integrity.[7]

The downside is, however, that Proof-of-Work consumes – and wastes – high amounts of energy, as all miners invest computing power to solve the puzzle, but only one of them will succeed by creating a new block.[8] Exact figures on power consumption from cryptocurrencies are difficult to come by. For bitcoin alone, estimates were in the range of 2.55 GW in mid 2018, which would translate into 22 TWh annually, or about the consumption of Ireland.[9] But maybe this contributes to blockchain's appeal to the energy industry .

The idea underlying blockchain is, in essence, to remove the necessity of trust from value transactions between people who do not know each other.[10] In a blockchain based system, they do not need to trust each other, as the technology is "tamper-evident" and records transactions in an irreversible way. This is because each block is marked with a timestamp and a hash that is also reflected in the next block, keeping the blocks in the right order und linking them in an immutable sequence which makes it, at least in theory, impossible to modify an existing transaction. Tampering with the information contained in a block would become apparent immediately.[11] A decentralized system, blockchain further removes the need to rely on trusted third parties, such as financial institutions, and hopes are high that this will decrease transaction costs.[12]

These essential features are shared by Bitcoin and other *public* or *permissionless* blockchains, allowing anyone to become a user, node or miner. By contrast, *private* or *permissioned* blockchains are not open to everyone and differ significantly from the blockchain originally envisaged by Nakamoto. Broadly speaking, they come in the form of either consortium blockchains, where only a number of pre-selected, trusted nodes control the consensus process; or fully private blockchains, where write permissions are in the hand of one,

[4] See further Jean Bacon et al., "Blockchain Demystified", Queen Mary University of London, School of Law, Legal Studies Research Paper No. 268/2017 (2017), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3091218.
[5] Nakamoto, *supra* note 1.
[6] Bacon et al., *supra* note 4, at 13.
[7] Bacon et al., *supra* note 4, at 14.
[8] Bacon et al., *supra* note 4, at 14.
[9] "The Economist explains: Why bitcoin uses so much energy", The Economist (2018), https://www.economist.com/the-economist-explains/2018/07/09/why-bitcoin-uses-so-much-energy.
[10] Nakamoto, *supra* note 1.
[11] Bacon et al., *supra* note 4, at 6 et seq.
[12] Nakamoto, *supra* note 1.

centralized organization.[13] This reduces the need for resource-intensive mining, making the blockchain cheaper and faster to operate.[14]

Coupled with smart contracts, blockchain may have the potential to revolutionize not only the financial sector, but the energy sector as well. The concept of smart contracts, first described by Nick Szabo long before the emergence of blockchain technology, denotes “a set of promises, specified in digital form, including protocols within which the parties perform on these promises”.[15] In their simplest form, for instance, they are used to transfer assets to a buyer once payment is made — comparable to a vending machine.[16] When combined with blockchain, the rules set out in smart contracts must be fulfilled for a change of state to be triggered within the blockchain.[17] This is the idea behind Ethereum, a platform that provides a blockchain with an integrated “Turing-complete” programming language, meaning that it is suitable for any smart contract or transaction that can be defined mathematically.[18] Ethereum and similar platforms thus allow running smart contracts far more complex than the vending machine prototype.

3. Applications of Blockchain and Smart Contracts in the energy industry

Often referred to as the “internet of value”, the blockchain was invented to send value, usually expressed in a digital currency, anywhere in the world.[19] Energy, on the other hand, is physical. As a technology that moves and stores data, blockchain itself cannot generate, store, transport and deliver energy, or replace electrical grids.[20]

Still, energy digitalization opens up a vast range of possible applications for both blockchain technology and smart contracts. They can be as simple as a vending machine and involve smart meters that only release energy to residential consumers once they transferred money to the electricity supplier, an idea developed by the South African start-up Bankymoon.[21] The technology is further able to track the provenance of the electricity produced and provide end consumers with information about their electricity mix, even where the electricity is traded with the help of an intermediary utility provider.[22]

More revolutionary, the use of blockchain and smart contracts can facilitate the operation of peer-to-peer electricity distribution networks, potentially making utility providers superfluous or at least less and less relevant in their traditional role as energy suppliers.

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[13] Vitalik Buterin, “On Public and Private Blockchains” (2015), https://blog.ethereum.org/2015/08/07/on-public-and-private-blockchains/.

[14] Bacon et al., *supra* note 4, at 19 et seq.

[15] Nick Szabo, “Smart Contracts: Building Blocks for Digital Markets” (1996), http://www.fon.hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh.net/smart_contracts_2.html.

[16] Max Raskin, “The Law and Legality of Smart Contracts” 1 Geo. L. Tech. Rev. 305 (2017) at 306.

[17] Florian Glatz, “Blockchain – A New Foundational Technology in Law?”, in Markus Hartung/Micha-Manuel Bues/Gernot Halbleib, *Legal Tech* (2018), at 279.

[18] Vitalik Buterin, “A Next-Generation Smart Contract and Decentralized Application Platform”, https://github.com/ethereum/wiki/wiki/White-Paper; on the functioning of Ethereum see further Gavin Wood, “Ethereum: A Secure Decentralised Generalised Transaction Ledger” (2014), http://gavwood.com/paper.pdf.

[19] Bernard Marr, “A Complete Beginner’s Guide to Blockchain” (2017), *supra* note 2.

[20] See also Philipp Overkamp and Charlotte Schings, “Blockchain im Strom- und Verkehrssektor” EnZW 3 (2019), at 4.

[21] See http://bankymoon.co.za/.

[22] This approach is pursued by a public utility company in Wuppertal, Germany, see https://wsw-talmarkt.de/. See further Christian Buchmüller, “Plattformökonomie und Blockchain-Technologie – Neue Impulse für die Peer-to-Peer-Lieferung von Ökostrom?” EWeRK 2018, 117, 118.

Probably the most famous example is the Brooklyn Microgrid, allowing owners of rooftop solar panels in Brooklyn, New York City, to sell any electricity produced in excess of their needs directly to their neighbors.[23] While smart meters track the electricity produced and consumed, an Ethereum-based Blockchain records the smart contracts, enabling automatic peer-to-peer transactions.[24] Similar pilot projects have been launched all over the world, such as Power Ledger in Australia, SOLshare in Bangladesh, OneUp in the Netherlands and Conjoule in Germany.[25]

While regulatory law may impose obstacles too high for true peer-to-peer electricity transactions between energy consumers and energy generators to overcome (see section 4 below), blockchain can also be implemented on the wholesale energy market. Energy trading in Europe is currently characterized by a multitude of actors, and energy is sold and purchased through trading platforms and brokers.[26] Blockchain, it is hoped, can facilitate peer-to-peer wholesale trading of energy, bypassing third parties and thus leading to savings in transaction costs.[27] Major European energy trading companies are already participating in the Enerchain project, testing peer-to-peer electricity and gas trading.[28]Blockchain can perhaps also contribute to grid stability. As energy generation is becoming more and more decentral in many countries due to the rise of solar panels and wind power plants, the blockchain technology can possibly help to automatically coordinate feeding-in electricity from numerous small power plants.[29] What is more, blockchain can conceptually be used to facilitate the integration of decentral energy storages in order to balance the high volatility of renewable power.[30]

The e-mobility sector might equally benefit from blockchain technology and smart contracts.[31] The Ethereum based platform Share&Charge, developed by the German energy company Innogy and the start-up Slock.it, brings together electric car drivers and charging station owners and enables direct transactions between them.[32] A mobile phone app enables electric car drivers to find the nearest charging station and to pay the owner of the charging station automatically with a digital currency on the basis of a smart contract operated by a blockchain.

In a similar manner, blockchain applications are emerging on the oil and gas markets. To facilitate the trade in crude oil and other commodities, a consortium venture of major oil companies, energy trading firms and banks launched the blockchain based platform Vakt in

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[23] See https://www.brooklyn.energy/; Diane Cardwell, "Solar Experiment Lets Neighbors Trade Energy Among Themselves" (2017) New York Times, https://www.nytimes.com/2017/03/13/business/energy-environment/brooklyn-solar-grid-energy-trading.html.
[24] Elizabeth Woyke, "Blockchain Is Helping to Build a New Kind of Energy Grid" (2017), MIT Technology Review, https://www.technologyreview.com/s/604227/blockchain-is-helping-to-build-a-new-kind-of-energy-grid/.
[25] See https://www.powerledger.io; https://www.me-solshare.com/; https://www.oneup.company/ and http://conjoule.de.
[26] See generally Michael Merz, "Potential of the Blockchain Technology in Energy Trading", in Daniel Burgwinkel et al., *Blockchain technology introduction for business and IT managers* (2016).
[27] Michael Merz, "Enerchain Project Overview and Key Insights" (2018), https://ponton.de/downloads/enerchain/EnerchainKeyInsights_2018-03-29_final.pdf; Jules Besnainou, "Diving into blockchain use cases: Wholesale energy trading" (2017), https://www.cleantech.com/diving-into-blockchain-use-cases-wholesale-energy-trading/.
[28] Merz, *supra* note 27; Enerchain, "Press Release: European Energy Trading Firms test peer-to-peer trading over the Blockchain" (2017) https://enerchain.ponton.de/index.php/21-enerchain-p2p-trading-project.
[29] Philipp Overkamp, "Regulierungsrecht & Blockchain" (2018), https://www.juwiss.de/17-2018/.
[30] This was tested by the European transmission system operator TenneT in a pilot project, see https://www.tennet.eu/news/detail/europes-first-blockchain-project-to-stabilize-the-power-grid-launches-tennet-and-sonnen-expect-res/.
[31] See generally Overkamp and Schings, *supra* note 20.
[32] See https://shareandcharge.com/.

2018.[33] Digitizing and centralizing post-trade processes that used to require physical documents to be shared between the parties of a deal,[34] it is one of many initiatives that seek to establish paperless commodity trade and electronic bills of lading.[35] On the gas market, the BTL Interbit platform uses the blockchain technology and smart contracts to speed up the otherwise burdensome reconciliation processes.[36]

These examples show the potential blockchain has in the energy industry, but, upon closer look, also reveal the technology's limitations when it comes to peer-to-peer trading of a physical good, rather than a digital currency. The trading platform Enerchain, for instance, is based on a private, permissioned blockchain, with a "Proof-of-Authority" consensus mechanism. It is less energy-intensive and operates faster than "Proof-of-Work" Protocols, as new transactions and blocks are verified by an internal authority.[37] The Brooklyn Microgrid, too, operates on a permissioned blockchain, and the electricity traded through the virtual Microgrid is physically transferred through the existing distribution network.[38] While these applications carry the "Blockchain" label, their technology deviates from the Bitcoin prototype and the idea of value transactions in trustless environments free from centralized authorities.

4. Legal issues of Blockchain-based solutions in the European Union

In the context of the energy transition, European energy markets are increasingly shifting away from energy generated centrally from fossil fuels to energy generated in a multitude of places from renewable sources.[39] Consequently, the energy industry is faced with unprecedented challenges, such as ensuring security of energy supply and grid stability in the light of highly volatile renewable sources. Moreover, the key actors may no longer be limited to system and meter operators, commercial plant operators and energy companies, as more and more energy consumers are generating energy themselves, turning them into so-called prosumers.[40] In the light of the ever-growing demand for renewables and volatile oil and gas prices, the fossil fuel industries, on the other hand, are not able to simply rely on traditional business models anymore to keep their profit margins up.[41] Digitalization is seen as a necessary means to address these challenges, and blockchain-enabled solutions as described above may facilitate and speed up this process.

Besides technical growing pains, such as the extremely high energy consumption of the blockchain technology, its low transaction speed and security concerns, this raises the question to what extent blockchain based applications in the energy sector fit into the European legal framework, namely EU energy, contract, consumer protection, data protection

[33] Yogita Khatri, "Blockchain Oil Trading Platform Backed by Shell and BP is Now Live", Coindesk (2018), https://www.coindesk.com/blockchain-oil-trading-platform-backed-by-shell-and-bp-is-now-live.
[34] Julia Payne, "Blockchain platform goes live for North Sea crude oil trading", Reuters (2018), https://www.reuters.com/article/us-blockchain-oil-trading/blockchain-platform-goes-live-for-north-sea-crude-oil-trading-idUSKCN1NY0X6.
[35] See further Dentons, "Blockchain in the energy sector: evolving business models and law", International Energy Law Review 233 (2018), at 247 et seq.
[36] BTL, "Powered by Blockchain", http://btl.co/download/BTL_Powered_by_Blockchain.pdf.
[37] Carsten Kloth, "Energiegroßhandel: Blockchain-Projekt Enerchain auf der Zielgeraden" (2018), https://bizz-energy.com/energiegrosshandel_blockchain_projekt_enerchain_auf_der_zielgeraden.
[38] See Exergy, "Business Whitepaper" (2018), https://exergy.energy/wp-content/uploads/2018/04/Exergy-BIZWhitepaper-v10.pdf, at 11 and 16.
[39] Saskia Lavrijssen and Arturo Carrillo Parra, "Radical Prosumer Innovations in the Electricity Sector and the Impact on Prosumer Regulation" 9 Sustainability 1207 (2017), at 1.
[40] *Id.*; Matthias Lang, "Prosumer Legislation in Germany", in Martha M. Roggenkamp and Catherine Banet (eds.), *European Energy Law Report XII* (2018), at 135-136.
[41] See Robin Goswami, "Now is the Time for Digitalization in the Oil & Gas Industry", Infosys, https://www.infosys.com/insights/industry-stories/Pages/time-for-digitalization-in-the-oil-and-gas-industry.aspx.

and financial markets law. This will be discussed in the following sections, with a particular focus on blockchain enabled peer-to-peer energy trading between consumers and on the wholesale level.

4.1 Energy law

4.1.1 Basics of EU energy law and policy

The EU and its member states share their legislative competence for energy law. This means that both the EU and the member states can adopt legally binding acts in this area, but member states can only exercise their competence to the extent that the EU has not exercised its competence.[42] National energy law is thus significantly shaped by EU regulations and directives, however without this area of law being fully harmonized.

The internal market, an area without internal frontiers in which the free movement of goods, persons, services and capital is ensured, lies at the heart of EU energy law and policy, which has been aiming to establish an open, liberalized internal energy market since the 1990s.[43] But the establishment of the internal market is no longer the only driver: the EU further aims to ensure the functioning of the energy market, security of supply, and to promote energy efficiency, energy saving, the development of new and renewable forms of energy as well as the interconnection of energy networks.[44] Against this background, a multitude of EU regulations and directives in force regulate the electricity and natural gas markets in particular.

To address the challenges posed by the energy transition and to promote the establishment of the Energy Union, a fully-integrated internal energy market where energy can flow freely without any technical or regulatory barriers, the European Commission launched its latest legislative initiative "Clean Energy for All Europeans" in winter 2016. The so-called Winter Package, whose implications for blockchain technology will be examined below,[45] contains a range of proposals for amendments of existing directives with the main goals of putting energy efficiency first, achieving global leadership in renewable energies and providing a fair deal for consumers.[46] The proposals have led to the adoption of new legislative acts, including a new Renewable Energy Directive[47] and a new Energy Efficiency Directive[48]. However, some of these proposals are still pending within the EU's ordinary decision-making procedure at the time of writing.

Although EU legislation currently in force addresses certain issues arising in the context of energy digitalization, such as smart metering,[49] the use of blockchain or smart contracts is neither regulated specifically for the energy sector nor on a general level. As a policy tool,

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[42] See Articles 4(2)(i), 2(2) and 194 of the Treaty on the Functioning of the European Union (TFEU).
[43] See Article 26(2) TFEU; Jörg Gundel, "Europäisches Energierecht", in Wolfgang Danner and Christian Theobald, *Energierecht* (98. Supplementat, 2018), at paras. 7 et seq.
[44] See Article 194 TFEU.
[45] See section 4.1.3.
[46] European Commission, Press release "Clean Energy for All Europeans – unlocking Europe's growth potential" (2016), http://europa.eu/rapid/press-release_IP-16-4009_en.htm.
[47] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources, OJ L 328, 21.12.2012.
[48] Directive (EU) 2018/2002 of the European Parliament and of the Council of 11 December 2018 amending Directive 2012/27/EU on energy efficiency, OJ L 328, 21.12.2018.
[49] See, in particular, Article 9(2) of Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC, OJ L 315/1, 14.11.2012; and Article 3(11) of Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC, OJ L 211/55, 14.8.2009.

however, the European Commission has launched the EU Blockchain Observatory and Forum in order to map key initiatives, monitor developments and inspire common actions in February 2018.[50]

4.1.2 Current regulatory issues of blockchain-based peer-to-peer electricity transactions

At present, it seems that true peer-to-peer electricity grids, allowing electricity trading between prosumers without any intermediary, are facing regulatory constraints in EU member states.

To begin with, prosumers who sell the electricity generated by their renewable power plants in excess of their needs to their neighbors are likely to be qualified as "suppliers" within the meaning of the EU Electricity Directive as currently in force.[51] This entails a range of different obligations relating to the terms and conditions of energy supply contracts, billing and information on the energy mix to be made available to consumers.[52] While it is possible to put the relevant requirements either into a smart contract's code or to include them in a framework agreement which could serve as the basis of a smart contract,[53] this increases the burden for prosumers. Furthermore, the current European and national rules on the change of supplier were not drafted with blockchain-based peer-to-peer electricity grids in mind.[54] They require supplier changes to be effected within three weeks at the most,[55] but suppliers are supposed to change within minutes in "Brooklyn" inspired blockchain networks.[56]

Moreover, prosumers trading electricity directly with their neighbors are often obliged to contribute to grid balancing. In Germany, for example, it is argued that energy producers who sell electricity to end consumers may be responsible for managing their own balancing group, which includes submitting demand forecasts to the network operators – an obligation clearly not practicable for most owners of rooftop solar panels.[57] In other countries, prosumers are required to obtain suppliers' licenses and to fulfil universal service obligations in order to sell electricity to household customers, which usually proves impossible in practice.[58] Further constraints may be imposed where prosumers want to benefit from national renewable energy support schemes.[59]

Therefore, under the current regulatory framework, blockchain-based peer-to-peer electricity transactions between prosumers appear to be viable in EU member states only if an external service provider fulfils all of the often burdensome obligations on behalf of the participating

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[50] European Commission, "EU Blockchain Observatory and Forum" (2018), https://ec.europa.eu/digital-single-market/en/eu-blockchain-observatory-and-forum.
[51] Directive 2009/72/EC; see also Lavrijssen and Carrillo Parra, *supra* note 39, at 7.
[52] See Article 3(9) and Annex I of Directive 2009/72/EC and Article 10 of Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency; on the German implementation see further Boris Scholtka and Friedrich Kneuper, "Lokale Energiemärkte auf Basis der Blockchain-Technologie" 17 IR (2019) at 19.
[53] Boris Scholtka and Jule Martin, "Blockchain – Ein neues Modell für den Strommarkt der Zukunft?" RdE 113 (2017) at 117.
[54] See also Overkamp and Schings, *supra* note 20, at 4.
[55] See Article 3(5) of Directive 2009/72/EC and § 20a(2) of the German Energy Industry Act (Energiewirtschaftsgesetz).
[56] Scholtka and Martin, *supra* note 53, at 117.
[57] PwC, "Blockchain – an opportunity for energy producers and consumers?" (2016), https://www.pwc.com/gx/en/industries/assets/pwc-blockchain-opportunity-for-energy-producers-and-consumers.pdf, at 30; Buchmüller, *supra* note 22, at 120; Overkamp and Schings, *supra* note 20, at 5.
[58] See Anna Butenko, "Sharing Energy: Dealing with Regulatory Disconnection in Dutch Energy Law" 4 EJRR 701 (2016) at 708, on Dutch energy law.
[59] For Germany see Buchmüller, *supra* note 22, at 121 et seq.

prosumers, which, in turn, removes one of the key features of the blockchain: the possibility of trade without an intermediary.[60]

4.1.3 The "Winter Package" proposals – a way forward?

Considering these demanding and sometimes diverging regulatory requirements in the EU member states, the question arises whether the Winter Package may ease the burden for blockchain-based peer-to-peer electricity transactions, making them possible even without an intermediary operator.[61]

In support of the growing role of prosumers, the Commission's proposal for a recast of the Electricity Directive introduces the concept of "local energy communities" and provides that member states shall ensure that final customers are entitled to generate, store, consume *and sell* self-generated electricity in all organized markets, either individually or through aggregators, without being subject to disproportionately burdensome procedures and charges that are not cost reflective, turning them into "active customers".[62]

In a similar fashion, the recast of the Renewable Energy Directive of 11 December 2018 defines a "renewables self-consumer" as "a final customer operating within its premises located within confined boundaries or, where permitted by a Member State, within other premises, who generates renewable electricity for its own consumption, and who may store or sell self-generated renewable electricity, provided that … those activities do not constitute its primary commercial or professional activity".[63] More importantly, the directive contains a definition of "peer to peer trading" of renewable energy, including "the sale of renewable energy between market participants by means of a contract with pre-determined conditions governing the automated execution and settlement of the transaction … directly between market participants".[64] The referral to contracts governing the automated execution and settlement seems to point towards smart contracts.

An exemption of (smaller) prosumers from the suppliers' obligations currently existing under the Electricity Directive as outlined above was implied in the Commission's original proposal of a Renewable Energy Directive Recast.[65] It provided that renewable self-consumers are not considered as energy suppliers under EU or national laws in relation to the electricity they feed into the grid where such electricity does not exceed certain thresholds.[66] While this would have facilitated blockchain-based peer-to-peer electricity trading, the provision did not survive the legislative process.

Rather, article 21 of the new Directive now provides that member states shall ensure that consumers are entitled to become renewables self-consumers, which includes the right to sell their excess electricity through peer-to-peer trading arrangements without being subject to discriminatory or disproportionate procedures and charges, and to network charges that are

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[60] *Id.* at 121.
[61] Cf. also Buchmüller, *supra* note 22, at 120.
[62] European Commission, "Proposal for a Directive of the European Parliament and of the Council on common rules for the internal market in electricity" COM(2016) 864 final/2, Arts. 2(6) and (7), 15, 16; on the concept of "active customers" see also Lea Diestelmeier and Dirk Kuiken, "Legal Framework for Prosumers in the Netherlands" ", in Martha M. Roggenkamp and Catherine Banet (eds.), *European Energy Law Report XII* (2018), at 151, 165.
[63] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast), OJ L 328/82, 21.12.2018, Article 2(14).
[64] *Id.* Article 2(18).
[65] See also Lavrijssen and Carrillo Parra, *supra* note 39, at 14.
[66] European Commission, "Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (recast)", COM(2016) 767 final/2, Article 21(1)(c).

not cost-reflective. They shall further be entitled to maintain their rights and obligations as final consumers and to receive remuneration, including through support schemes, for the electricity that they feed into the grid, that reflects the market value of that electricity and which may take into account its long-term value to the grid, the environment and society. Member states are called upon to address unjustified regulatory barriers to renewables self-consumption.

While these rules certainly try to alleviate the existing regulatory hurdles for true peer-to-peer trading of electricity, their actual impact will depend largely on their transposition into national law. Unlike under the European Commission's initial proposal, prosumers may be considered "suppliers", and it is open to the Member States' interpretation to what extent, if any, national energy regulation in place imposes "disproportionate procedures" or "unjustified regulatory barriers", so the national regulatory frameworks for blockchain based peer-to-peer transactions are likely to remain somewhat heterogeneous.

4.2 Contract law

Legal issues also arise in the area of contract law. The attraction of smart contracts lies in their automatic performance and enforcement of legal obligations.[67] To use the example of an electricity microgrid: Where both electricity is transferred to the consumer and payment is made to the solar panel owner in an automatic and unstoppable manner, neither the solar panel owner nor their neighbor will need to enforce their energy supply contract by other means, such as litigation. In other words, "there is no room to bring an action for breach when breach is impossible".[68] While some speculate that this innovation, in combination with blockchain technology, will make contract law obsolete altogether in the long term, it seems more likely that, on the contrary, the emergence of smart contracts will present lawyers and their clients with novel challenges.[69]

To start with, it is not undisputed whether smart contracts are actually contracts in the legal sense, or whether they are merely automated computer protocols that execute obligations contained in a given contract on the basis of the conditions stipulated therein and agreed outside of the computer code.[70] Although this depends, to some extent, on the definition of a "contract" under the relevant jurisdiction, it seems safe to say that if legally binding agreements can be expressed in whatever language the parties choose, this includes computer code.[71]

Even if smart contracts *per se* did not qualify as contracts in the legal sense, it is beyond doubt that contract law applies to the underlying legal contract and that smart contracts as expressed in computer code have to comply with the applicable laws.[72] Easy as that may sound, the details can be challenging. Computer code is not for everyone to read. How can lawyers actually find out what the smart contract actually says or does? As difficult as a complex contract document may be to read, lawyers usually manage to understand it. Maybe with some differing interpretations. Contracts hidden in computer code are taking the challenge to a new

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[67] Tom Braegelmann and Markus Kaulartz, "Smart Contracts for Modern Lawyers", in Markus Hartung/Micha-Manuel Bues/Gernot Halbleib, *Legal Tech* (2018), at 283.
[68] Kevin Werbach and Nicolas Cornell, "Contracts Ex Machina" 67 Duke Law Journal 313 (2017) at 327. at 332.
[69] See generally Werbach and Cornell, *supra* note 68.
[70] For the former view see Werbach and Cornell, *supra* note 68; for the latter view see Olivier Hari/Ulysse Pasquier, "Blockchain and distributed ledger technology (DLT): academic overview of the technical and legal framework and challenges for lawyers" I.B.L.J. 423 (2018) at 443-444. Braegelmann and Kaulartz, *supra* note 67, argue that some, yet not all smart contracts are contracts in the legal sense.
[71] Werbach and Cornell, *supra* note 68, at 342; Markus Kaulartz, "Rechtliche Grenzen bei der Gestaltung von Smart Contracts", DSRITB 1023 (2016) at 1028-1029.
[72] Braegelmann and Kaulartz, *supra* note 67, at 287.

level: Can you actually translate the computer code back to text that can be read by humans? Into which language? Would this really be feasible in practice? Do you need experts to explain it to a lawyer or a judge? Is such legal review really a viable option for a contract that you bought for 99 cents in the app store?

While smart contracts, due to their self-executing nature, may provide more reliability to the contracting parties than traditional contracts, their main feature might turn into their main bug where things go wrong. What if, for example, it turns out that the agreement expressed in a smart contract is the result of fraud or duress, if its content is illegal under the applicable laws, or if the agreement was entered into by mistake of one of the parties? Or what if unforeseen events lead to unexpected behavior of the smart contract? In the absence of any technical way to reverse a transaction made through a blockchain-based smart contract, the contracting parties will have to put exceptions and conditions into the smart contract's code. In practice, however, it is virtually (and really) impossible to anticipate each and every eventuality already at the outset.[73] Moreover, smart contracts are only as smart as the person who programs them, and problems are likely to arise where errors in the computer code lead to unintended reactions. This is essentially what happened in the context of the "DAO hack", the most prominent example of things going terribly wrong in a blockchain-based solution as yet. It involved the theft of more than $ 50 million worth of Ether, Ethereum's cryptocurrency, as a result of a bug in the code of the smart contract that ran the Decentralized Autonomous Organization, a company built entirely on the blockchain.[74] If and when smart electricity supply contracts become a reality, coders will thus have to cooperate with lawyers in order to ensure not only a legally sound design of the contract, but also a reasonably bulletproof contract code.

4.3 Consumer protection law

Where such smart contracts are concluded between prosumers, lawyers will further have to consider to what extent, if any, consumer protection law applies – an area of contract law extremely developed in the EU. The EU's extensive consumer legislation includes, inter alia, provisions on unfair contract terms,[75] comprehensive information requirements and cooling-off periods with withdrawal rights for consumers as parties of "distance contracts" concluded without the simultaneous physical presence of the parties[76].

In the context of peer-to-peer electricity trading, the first question to ask is whether the smart contracts at issue are concluded between traders and consumers, as EU consumer law does not apply to C2C transactions. Although Article 21(2)(c) of the draft recast of the Renewable Energy Directive[77] provides that renewables self-consumers shall maintain their rights (and obligations) as final consumers, this does not rule out the possibility that prosumers are considered suppliers or traders where they sell their excess electricity, as the EU's classification of traders and consumers is situational rather than static in nature.[78] Where a

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[73] Werbach and Cornell, *supra* note 68, at 335, 369.
[74] Nathaniel Popper, "A Hacking of More than $50 Million Dashes Hopes in the World of Virtual Currency" (2016) New York Times, https://www.nytimes.com/2016/06/18/business/dealbook/hacker-may-have-removed-more-than-50-million-from-experimental-cybercurrency-project.html?_r=2.
[75] Council Directive 93/13/EEC of 5 April 1993 on unfair terms in consumer contracts, OJ L 95, 21.4.1993.
[76] Directive 2011/83/EU of the European Parliament and of the Council of 25 October 2011 on consumer rights, amending Council Directive 93/13/EEC and Directive 1999/44/EC of the European Parliament and of the Council and repealing Council Directive 85/577/EEC and Directive 97/7/EC of the European Parliament and of the Council, OJ L 304/64, 22.11.2011; for the definition of "distance contracts" see Article 2(7).
[77] *Supra* note 63.
[78] Christian Alexander, "BGB § 13 Verbraucher", in Beate Gsell et al. (eds.), *beck-online. Großkommentar* (2018), at paras. 87 et seq. Under Article 2(2) of Directive 2011/83/EU, a trader is

smart contract is to be classified as a consumer contract within the meaning of EU consumer protection law, requirements for contractual terms can be complied with, in principle, by programming the contract code accordingly. However, the concepts of cooling-off periods and information requirements as included in the Consumer Rights Directive, do not, for obvious reasons, appear to be suitable for self-executing, often automatically concluded smart contracts.

The second question to ask is thus whether all consumer protection regulation applies to smart consumer contracts. Generally, it is argued that the legal position of a consumer under a smart contract should be the same as under a traditional contract,[79] and feared that smart B2C contracts not granting consumers a right of withdrawal, for instance, violate consumer protection law[80]. On the other hand, certain types of contracts are already exempted from the substantive scope of consumer protection law, as its application to them would be futile. Most notably, it can be argued that the Consumer Rights Directive does not apply to smart contracts at all, as contracts "concluded by means of automatic vending machines or automated commercial premises" are exempt from its scope.[81] Although blockchain based smart contracts as discussed in the energy sector are neither vending machines nor concluded on "premises", they are, too, characterized by an automated exchange of goods or services, making cooling-off periods and information requirements rather preposterous. This is different, of course, in relation to framework contracts that energy consumers and prosumers may enter into before they start trading electricity through smart contracts.

In order to remove remaining uncertainty, however, the EU Commission may need to launch a comprehensive legislative reform that encompasses not only the energy and the financial sectors to ensure that the consumer protection framework accommodates for smart contracts.

4.4 Data protection law

Even more uncertainty as to the legality of blockchain based smart contracts arises in the context of EU data protection law, in particular the EU's General Data Protection Regulation (GDPR)[82]. It aims to provide a high level of consistent and homogenous protection of personal data across the EU, with severe fines for non-compliance.[83] While it only entered into force recently in May 2018, the GDPR was designed for centralized methods of data collection, storage and processing rather than for decentralized, distributed ledger technologies, which poses a multitude of problems when applied to blockchain.[84]

Due to the GDPR's broad territorial scope, the legal issues arising do not only affect blockchains in the EU, but also international blockchains.[85] According to Article 3 GDPR, it applies to data processors and controllers established in the EU as well as controllers and

defined as "any natural person or any legal person, irrespective of whether privately or publicly owned, who is acting, including through any other person acting in his name or on his behalf, for purposes relating to his trade, business, craft or profession in relation to contracts covered by this Directive".

79 Martin von Haller Grønbæk, "Blockchain 2.0, smart contracts and challenges" (2016), https://www.twobirds.com/en/news/articles/2016/uk/blockchain-2-0--smart-contracts-and-challenges.

80 Bacon et al., *supra* note 4, at 32.

81 Article 3(3)(l) of Directive 2011/83/EU.

82 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), OJ L 119, 4.5.2016.

83 See recitals 9-11 and Article 83 GDPR.

84 Michèle Finck, "Blockchains and Data Protection in the European Union" 1 EDPL 18 (2018).

85 See further *id.*, at 27-28.

processors who process personal data of EU data subjects where such processing is related to the offering of goods or services in the EU or the monitoring of behavior within the EU.

Although the GDPR's material scope is limited to the protection of "personal data", it is likely that it applies to the majority of blockchain applications that involve natural persons due to the extensive interpretation of this notion. "Personal data" is defined as "any information relating to an identified or identifiable natural person", i.e. a person who can be directly or indirectly identified (Article 4(1) GDPR). This is not limited to data that is blatantly personal, such as the name or the date of birth of a person, but encompasses all sorts of information that can somehow be linked to a natural person, even where it is pseudonymized.[86] To give a prominent example, dynamic IP addresses, which can only be traced back to a natural person with the help of additional information, are classified as personal data, and it is not required that all the information needed to identify that person must be in the hands of one entity.[87] Against this background, not only transactional data that is linked to a natural person and stored on the blockchain qualifies as personal data. Furthermore, the pseudonymized public key is likely to constitute personal data where it belongs to a natural person, as it is technically possible to identify this person.[88]

The existence of personal data entails a range of different rights under the GDPR that seem to be generally incompatible with blockchain technology. To name but a few, data subjects have the right to access their personal data and to information relating to the data processing (Article 15 GDPR), the right to rectification of inaccurate personal data (Article 16 GDPR) and the right to erasure of personal data ("right to be forgotten", Article 17 GDPR). Blockchain, on the other hand, is characterized as an immutable ledger, to which data can only be amended, but not changed or deleted.[89]

Besides, it is problematic against whom a data subject would enforce these rights, in other words, who is the "data controller" within the meaning of the GDPR in a blockchain based system? It seems that this depends largely on the type of blockchain used, but is still surrounded by uncertainty. Under Article 4(7) GDPR, a controller is the natural or legal person or entity "which, alone or jointly with others, determines the purposes and means of the processing of personal data". While in a centralized, fully private blockchain, the platform operator is likely to be the one who determines these purposes and means,[90] the answer is less clear regarding public, permissionless blockchains. The predominant opinion seems to be that each node qualifies as a data controller with respect to all of the data stored on the blockchain, so in order to make a successful request under Articles 15-17 GDPR, a data subject would have to identify and contact each and every node, which appears to be virtually impossible in practice.[91] Others differentiate in accordance with the level of control granted to individual nodes and consider any user who sends personal data to the blockchain to be data controller with respect to this data.[92] In any case, however, as it is technically impossible to comply with requests on the basis of the GDPR, data subjects will in the vast majority of cases not be able to enforce their rights, making blockchain generally incompatible with this part of the GDPR.

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[86] Recital 26 GDPR.
[87] Patric Breyer v Bundesrepublik Deutschland, European Court of Justice, Case C-582/14, ECLI:EU:C:2016:779, at paras. 31 et seq.
[88] Bacon et al., *supra* note 4, at 40-41; Finck, *supra* note 84, at 22-25.
[89] See further Finck, *supra* note 84, at 28 et seq.
[90] Bacon et al., *supra* note 4, at 41 et seq.; Finck, *supra* note 84, at 26-27.
[91] See, for example, Finck, *supra* note 84, at 26, 28 et seq.; Markus Köhler and Ingwert Müller-Boysen, "Blockchain und smart contracts – Energieversorgung ohne Energieversorger?", 3 ZNER 203 (2018) at 207; Mario Martini and Quirin Weinzierl, "Die Blockchain-Technologie und das Recht auf Vergessenwerden" NVwZ 1251 (2017) at 1253, 1255.
[92] Bacon et al., *supra* note 4, at 43 et seq.

Several approaches are discussed as potential solutions. Firstly, it may be possible to interpret the provisions of the GDPR in a way that they are not at odds with blockchain technology. It is argued that the right to rectification under Article 16 allows "providing a supplementary statement", so data stored on a blockchain could potentially be amended by adding new blocks as a means of rectification; and the right to erasure under Article 17(2) is subject to the "available technology", which might permit to take the technical limitations of blockchain into account.[93]

Secondly, compliance could be ensured by technical modifications to the blockchain, i.e. by storing personal transactional data "off-chain", so that it can be modified retroactively.[94] Other suggestions relate to limiting blockchain applications to private ones that are governed by rules providing how each party is allowed to process any personal data submitted to the blockchain and by introducing trusted third parties to validate transactions[95] — begging the question whether blockchain can add any other substantial benefits if one of its core features, the independence from a trusted third party, is removed.

Specifically in relation to peer-to-peer electricity trading it is suggested to design blockchain applications in a way that they do not process any personal data through the implementation of a Zero-Knowledge-Proof procedure.[96] This technology aims to enable transactions without making any of the parties identifiable: the blockchain only shows that a transaction was made in accordance with the rules of the blockchain, but it does not show which public keys were involved or which value was transferred.[97] Peer-to-peer electricity trading, it is argued, is comparable to shopping anonymously in supermarkets: electricity producers are only interested in *someone* buying the electricity and paying for it, whereas the identity of the purchaser is not relevant to them, which is why Zero-Knowledge-Proof technology is considered suitable in this context.[98] This might indeed avoid the classification of public keys, which cannot, unlike transactional data, be stored off-chain, as personal data. However, it may raise other problems if things go wrong. If, for example, due to a technical fault electricity is not delivered to the purchaser – bearing in mind that electricity as a physical good has to be transferred through physical grids – purchasers have an interest in proving that they paid the producer appropriately, but Zero-Knowledge-Proof technology removes the transparency otherwise provided by the blockchain. From a legal point of view, Zero-Knowledge-Proof would further have to be regarded as meeting the high standards of the GDPR in relation to encryption.[99]

Therefore, EU data protection law seems to presently pose major obstacles to blockchain applications, especially where they operate publicly. Even if they can be overcome either by blockchain-friendly interpretation of the relevant provisions or, more likely, by technical solutions, legal uncertainty remains and may well slow down the implementation of blockchain and smart contracts in the energy sector. It remains to be seen whether the EU will adapt its data protection law accordingly. So far, neither the draft proposal for a new ePrivacy Regulation[100], which would add to the GDPR as lex specialis, nor the Commission's proposal

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[93] Finck, *supra* note 84, at 29-30.
[94] *Id.* at 29 et seq.
[95] Christopher Kuner et al., "Blockchain versus data protection" 8(2) International Data Privacy Law 103 (2018) at 104.
[96] Köhler and Müller-Boysen, *supra* note 91, at 208.
[97] Martini and Weinzierl, *supra* note 91, at 1256; for more details on Zero-Knowledge-Proof technologies see George Samman, "The Trend Towards Blockchain Privacy: Zero Knowledge Proofs" (2016), https://www.coindesk.com/trend-towards-blockchain-privacy-zero-knowledge-proofs.
[98] Köhler and Müller-Boysen, *supra* note 91, at 207-208.
[99] See also Finck, *supra* note 84, at 32.
[100] European Commission, Proposal for a Regulation of the European Parliament and of the Council concerning the respect for private life and the protection of personal data in electronic communications and repealing Directive 2002/58/EC, COM(2017) 10 final.

for a recast of the Electricity Directive[101], which includes general data protection provisions and references to the GDPR relating to data protection in smart metering systems, seem to offer more certainty for blockchain applications.

4.5 Financial markets regulation

Especially in relation to blockchain based applications on wholesale electricity markets, lawyers may have to check whether they have to comply with the EU's financial market regulation. The Directive on Markets in Financial Instruments ("MiFID II") contains authorization requirements for the provision of investment services, which include, inter alia, trading of options, futures, swaps, forwards and other derivative contracts relating to commodities that must or may be settled in cash, as well as options, futures, swaps and any other derivative contracts relating to commodities that can be physically settled, provided that they are traded on a regulated market.[102] MiFID II might thus become relevant where blockchain is implemented on wholesale energy markets. In relation to peer-to-peer electricity trading between prosumers and consumers, it is discussed whether MiFID II has to be complied with where a virtual currency, such as Bitcoin or Ether is used.[103] However, it is questionable whether virtual currencies qualify as financial instruments within the meaning of the directive.[104] In any case, the use of a virtual currency as a means of payment alone does not trigger the obligations under the directive.[105]

On the wholesale market level, the Regulation on Wholesale Energy Market Integrity and Transparency ("REMIT")[106] is also likely to apply to blockchain based applications. It prohibits insider trading and market manipulation, and contains extensive reporting obligations. Under both REMIT and MiFID II, a crucial question to consider in peer-to-peer systems is who will be responsible for ensuring compliance. Although it is argued that this will often not be possible for individual energy suppliers, making a platform operator necessary,[107] the blockchain enabled wholesale energy trading tool Enerchain, for instance, relies on true peer-to-peer transactions and requires each participant to report trades in accordance with REMIT[108].

5. Conclusion

Blockchain and smart contracts can be applied in the energy sector in various different forms, and their compatibility with EU law depends largely on the design in question. It is thus crucial for lawyers to define what is actually meant by "blockchain" when analyzing the legality of blockchain based applications. Ironically, many applications marketed as "blockchain based" in the energy industry do not necessarily promote innovations which would otherwise not be possible to implement.

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[101] *Supra* note 62.
[102] 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 (recast), OJ L 173/349, 12.6.2014.
[103] See Scholtka and Martin, *supra* note 53, at 118.
[104] The Berlin Court of Appeal (Kammergericht), for instance, has recently denied that Bitcoins are financial instruments within the meaning of the German implementation act of the directive, see judgment of 25 September 2018, (4) 161 Ss 28/18, ECLI:DE:KG:2018:0925.4.35.18.00; see further Robby Houben, "Bitcoin: there are two sides to every coin" I.C.C.L.R. 155 (2015) at 162.
[105] Scholtka and Martin, *supra* note 53, at 118; German Federal Financial Supervisory Authority (BaFin), "Virtual Currency (VC)", https://www.bafin.de/EN/Aufsicht/FinTech/VirtualCurrency/virtual_currency_node_en.html.
[106] Regulation (EU) No 1227/2011 of the European Parliament and of the Council of 25 October 2011 on wholesale energy market integrity and transparency, OJ L 326/1, 8.12.2011.
[107] PwC, *supra* note 57, at 31.
[108] Merz, *supra* note 27.

While private blockchains operating with the help of intermediaries are easier to fit into the legal frameworks of the EU and its member states, they usually lack core features of the blockchain prototype. By contrast, public blockchains enabling genuine peer-to-peer transactions among prosumers face regulatory constraints, especially in the areas of EU energy and data protection law. For proponents of the blockchain technology and its applications in the energy sector, the Winter Package legislative proposals, as they currently stand, may come as a disappointment. Although they certainly address peer-to-peer electricity trading, they hardly solve the regulatory problems associated with blockchain and smart contracts.

Blockchain and smart contracts are playing a role in the energy industry. This role is very likely to increase. It is not yet clear how that role will develop, and which business model will ultimately drive change in a commercially successful way. But one thing is clear: It will require some further thinking from smart energy industry players, computer people, and lawyers to make it work.

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