Blockchain and Smart Contract for Peer-to-Peer Energy Trading Platform: Legal Obstacles and Regulatory Solutions

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Abstract

This paper discusses the implications of smart contracts in energy trading for the protection of consumer and individual rights. It examines the legal risks and regulatory solutions for a peer-to-peer energy trading platform (P2P-ETP) in creating a sustainable energy ecosystem. Part I discusses the conceptual framework of P2P-ETP, which enables consumers to become energy ‘producers' and traders. Smart technologies—smart contracts, smart meters, and distributed ledger technology (DLT) platforms, are the main components of this platform. The study examines the legal basis for these components. Part II analyses the legal uncertainty of the smart contract, such as its enforceability, and the inadequate protection for consumers and their individual rights through price manipulation, violation of rights to privacy, and data breaches. Part III discusses the potential policy implementations and the principles behind a legal and regulatory framework for establishing a trusted peer-to-peer energy trading platform.

Keywords: Peer-to-peer; energy trading; sustainability; tokenisation; smart technologies; blockchain

I. Introduction

Smart technology is the inspiration of the Fourth Industrial Revolution; it simultaneously embodies the concept of the shared economy and consumer awareness. Environmental and research evidence on this type of economy shows that consumer awareness of energy usage helps lower carbon emissions. However, as the most recent industrial revolution demonstrated, consumer confidence in smart technology is low because of legal uncertainties regarding smart algorithmic contracts and the unfamiliarity of their impact on privacy. Societal priorities are shifting towards a more sustainable ecosystem, and smart technologies, such as smart contracts, have been claimed to empower consumers and encourage energy efficiency through peer-to-peer energy trading. Research into the application of smart contracts within energy trading shows the risks of third-party influence through market manipulation, violation of privacy rights, and potential misuse of data. This paper discusses the implications of smart contracts in energy trading for the protection of the individual rights of consumers. Part I shall discuss the conceptual framework of P2P-ETP, which enables consumers to become energy 'producers' and traders. Part II will analyse the legal uncertainty of the smart contract, such as its enforceability, and the inadequate protection for consumer rights through price manipulation, violation of rights to privacy, and data breaches. Part III discusses the potential policy implementations and the principles behind a legal and regulatory framework for a peer-to-peer energy trading platform.

II. Peer-to-Peer Energy Trading

i. Smart Technology

Smart technology is described as the marriage between enhanced data processing and internet-based communication to facilitate effortless access to information and enable control over complex systems in both physical and digital spaces.[1] Peer-to-Peer Energy Trading Platform ('P2P-ETP') is a system that encompasses the technologies of smart grids, smart meters and blockchain-based smart contracts. Thus, P2P-ETPs correspond directly with the growth of smart cities[2] as envisioned by the United Nation's New Urban Agenda[3] which coincides with the United Kingdom's focus on developing sustainable cities.[4] Smart grids allow access to detailed information on electricity production (with renewable energy appliances) and consumption to improve the reliability of the service, reduce costs, and introduce renewable energy sources into a nation's energy portfolio.[5] The purpose of a smart grid is to ensure that consumers can establish real-time situational awareness over vast stretches of energy systems and their production and consumption. In doing so, these smart technologies collect, aggregate, and report detailed energy production and consumption data from individual households.[6]

Smart grids rely on the installation of smart meters to achieve these goals of greater consumer awareness and participation- producing, consuming and trading energy. Therefore, it is necessary to identify all the necessary components of the P2P-ETP network to understand how smart technologies, such as smart contract, can assist with greater consumer protection in the promising P2P-ETP industry. Traditional energy trading is mostly unilateral, as it flows from producers to consumers through a centralised grid. P2P-ETP disrupts this model by promoting multi-directional trading

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[1] J. Forbush 'Regulating the Use and Sharing of Energy Consumption Data: Assessing California's SB 1476 Smart Meter Privacy Statute' (2011) 75 Alb. L. Rev. 341.

[2] 'Smart Cities Background Paper' (Department for Business, Innovation and Skills 2013) <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/246019/bis-13-1209-smart-cities-background-paper-digital.pdf> accessed 13 March 2020.

[3] United Nations, 'Transforming Our World: The 2030 Agenda For Sustainable Development' (United Nations General Assembly 2015) <https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E> accessed 13 March 2020.

[4] 'Smarter London Together' (Greater London Authority 2018) <https://www.london.gov.uk/sites/default/files/smarter_london_together_v1.66_-_published.pdf> accessed 13 March 2020.

[5] A. Brown, and others, 'Initiative, Smart Grid Issues in State law and Regulations' (2010).

[6] Elias Leake Quinn, 'Smart Metering And Privacy: Existing Laws And Competing Policies' [2009] SSRN Electronic Journal.

without a central body transmitting energy unilaterally.[7] Hence, it removes the role of a monopolist grid. This is because of the peer-to-peer aspect, which relies on a decentralised system. Within this decentralised system, smart contracts serve as the digital medium and form a reliable and secure foundation for peer-to-peer energy trading.[8]

Smart meters are the initial step towards smart electricity grids and lay the foundation for further implementation of renewable energy production and consumption.[9] Smart meters are communication devices, similar to a messaging service, which correspond to the electricity usage of in-house appliances of the consumer and external providers. Smart meters provide a detailed breakdown of usage, including peak consumption and other relevant energy regulatory data.[10] A crucial difference between smart meters and traditional meters is the smart meter's ability to communicate immediately with the household and energy providers- who may also be the consumer if renewable energy appliances are installed in the household. Traditional meters only give current usage of the household, and an accurate breakdown of usage is inaccessible to the individual consumer. Conversely, smart meters can communicate usage to consumers and other parties, such as utility companies, in real time.[11] In P2P-ETP applications, smart meters are vital to the tracking, trading, and allocation of energy of the participants in the network. Energy trading will operate through the P2P network, with transactions verified through blockchain-based smart contracts.

These contracts will operate on blockchain, a distributed ledger technology, which shall serve as the infrastructure of the platform. It uses cryptographic security

[7] Ning Wang and others, 'Peer-To-Peer Energy Trading Among Microgrids with Multidimensional Willingness' (2018) 11 Energies.
[8] Ibid.
[9] N. King and P. Jessen, 'Smart Metering Systems and Data Sharing: Why Getting a Smart Meter Should Also Mean Getting Strong Information Privacy Controls to Manage Data Sharing' (2014) 22(3) International Journal of Law and Information Technology.
[10] K. Doran, 'Climate Change and The Future of Energy: Privacy and Smart Grid: When Progress and Privacy Collide' (2011) 41 The University of Toledo L Rev 909-23, 910.
[11] N. King and P. Jessen, 'Smart Metering Systems and Data Sharing: Why Getting a Smart Meter Should Also Mean Getting Strong Information Privacy Controls to Manage Data Sharing' (2014) 22(3) International Journal of Law and Information Technology.

combined with a consensus mechanism[12] so that the transaction activities are transparent and immutable. The decentralised nature of the technology enables each meter (or node on the blockchain) to have access to the record of the transactions on the platform. The nodes represent energy consumers that operate on the same chain and detail all transactions via the copy that each consumer possesses.[13] Consumers can be either consumers or prosumers, based on their specific keys. Within the P2P-ETP ecosystem, users interact with the blockchain via private or public keys depending on the accessibility of the chain itself. Private keys give access solely to the individual's personal transactions, while public keys create access to the network transactions. The dual system works as an 'asymmetric cryptography[14]', which brings authentication and integrity to the dealings on the network.[15] Each block is identified by its cryptographic lock and references the block that came before it[16]. This creates the immutability of the technology, as the data, and prior blocks cannot be deleted, only copied, and more information added to the following blocks. Blockchain blends several existing technologies alongside P2P networking. As outlined earlier, these include public and private keys, which are protected through cryptography, and consensus mechanisms that create a highly resilient and immutable ledger.[17] The networks are not centrally managed but operate collectively[18]. However, because of the personal data stored on the P2P-ETP, it is submitted that a private chain, with a central operator, would likely to be required. It is envisaged that, in the future with more advanced automated technology, no central operator would be required to manage P2P-ETPs. The transition towards a truly decentralised peer-to-peer network would initially need to integrate the current regulatory systems[19] with smart technologies.

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[12] J. Wu and Nguyen Khoi Tran, 'Application of Block Chain Technology in Sustainable Energy Systems: An Overview' (2018) MDPI Sustainability Journal.
[13] Ibid.
[14] Ibid.
[15] Ibid.
[16] Primavera De Filippi and Aaron Wright, '*Blockchain and the Law: The Rule of Code*' (Harvard University Press 2018)
[17] K. Christidis and M. Devetsikiotis, 'Blockchains and Smart Contracts for the Internet of Things' (2016) 4(-) IEEE Access.
[18] Primavera De Filippi and Aaron Wright, '*Blockchain and the Law: The Rule of Code'* (Harvard University Press 2018)
[19] J. Wu and Nguyen Khoi Tran, 'Application of Block Chain Technology in Sustainable Energy Systems: An Overview' (2018) MDPI Sustainability Journal

Case studies show that the chief advantage of implementing P2P-ETP systems is the merging of communicative-metering infrastructures, such as smart meters and the decentralised computing aspect of energy trading.[20] The technologies operate through physical and digital media to facilitate the new energy trading model. As discussed, energy trading would run on the P2P system to facilitate bilateral transactions between consumers and those producing energy. Therefore, the P2P-ETP system is self-organised and is able execute transactions i.e. delivery of energy versus payment in an automated manner. The P2P-ETP system for energy trading follows five consistent criteria.[21] First, the transactions will be handled chronologically. Second, the specially designed smart meters measure the energy surplus after gauging the energy usage of the household. Third, tokens are used to represent the energy produced ('tokenisation'), which can be stored in a personal digital wallet and connected to the smart meter. Fourth, the energy tokens can be traded on the platform. Lastly, users of the grid can filter and indicate preferred price ranges and the amount of energy desired for specific times. After the energy token has been traded and utilises, it will disappear upon use.

The model of a shared economy requires the partnership of private, governmental, and public networks to facilitate access rather than ownership. It relies on the concept of a social contract among the participating parties.[22] In the interest of vulnerable and low-income consumers, those who may fail to gain access to such a system that requires significant immediate financial investment, government offices or an independently regulated controller should handle the maintenance and control of the physical infrastructure. Finally, billing and transactions within the P2P-ETP system require accountable coordination, relying on the data gathered by smart meters and facilitated through smart contacts. Accountability in the P2P-ETP system is established through its transparency and immutability. When transaction information is entered into the shared blockchain network, it would be difficult to manipulate or change the information. This technology increases the resilience of the power system

[20] Ibid.
[21] Ning Wang and others, 'Peer-To-Peer Energy Trading Among Microgrids with Multidimensional Willingness' (2018) 11 Energies.
[22] Ibid.

itself, whereby each peer in the network would retain a copy for records and billing to ensure mutual accountability.

According to the United Kingdom Government Office for Science, effective governance and regulation are vital to the success of implementing DLT. [23] It also brings to light the need for proper legal frameworks for regulating the technology in the interest of consumer protection. As of January 2020, the United Kingdom has implemented a deadline for energy companies to become users of data communications companies and to take all reasonable measures to introduce smart meters to their domestic and small business consumers[24]. The deadline for nine major energy suppliers in the United Kingdom to become data communication companies (DCC) is 31 March 2020[25]. This will benefit consumers and producers by enforcing trust and transparency. To achieve this, a viable option for exploration is the application of automated smart contracts for transactions.

ii. Smart Contracts

A smart contract is described as a digital agreement which executes automated instructions and utilizes immutable technology, such as DLT, to ensure validity and accountability.[26] A basic smart contract process on the P2P-ETP has three steps. First, parties must agree upon a transaction for energy. Second, once the requirements are met for the transaction to proceed, the first 'block' unlocks and distributes energy via the encoded instructions. Third, if these requirements are not met, the block will remain locked and nothing is distributed. Smart contracts have been known for the trading of

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[23] Government Office for Science 'Distributed Ledger Technology: Beyond blockchain. A report by the UK Government Chief Scientific Adviser' (2016)
[24] Ofgem, 'Statutory Consultation On The Post-2020 Smart Meter Rollout Reporting Requirements' (2019) <http://Statutory Consultation on the Post-2020 Smart Meter Rollout Reporting Requirements> accessed 24 February 2020.
[25] Office of Gas and Electricity Markets, 'Ofgem Orders Nine Energy Suppliers To Become DCC Users' (2020) <https://www.ofgem.gov.uk/publications-and-updates/ofgem-orders-nine-energy-suppliers-become-dcc-users> accessed 13 March 2020.
[26] Florian Möslein, 'Legal Boundaries Of Blockchain Technologies: Smart Contracts As Self-Help' <https://www.law.ox.ac.uk/business-law-blog/blog/2019/01/legal-boundaries-blockchain-technologies-smart-contracts-self-help> accessed 13 March 2020.

crypto-currencies such as Bitcoin and Ethereum. In the proposed P2P-ETP, smart contracts shall be used to trade units of energy represented by tokens ('tokenisation'). These tokens will be stored on digital wallets as dematerialised certificates representing the energy commodity on the P2P-ETP to be traded with the smart contracts.

Digital wallets are software applications that facilitate the storing and safe-keeping of these energy tokens[27]. These tokens are subsequently assigned value based on the context of trading and stored within the digital wallet of the consumer. For example, a single token can represent one kilowatt, or an hour of power, and consumers can use these tokens to trade energy[28] along smart grids via the smart meters installed in their households.

To execute a smart contract, the parties must negotiate terms until a 'meeting of minds'[29] occurs, and the parties enter a legally binding contract. After this relationship is established, the smart contract is subsequently encoded to contain the requirements and instructions following the agreed upon terms and conditions of the legal contract. If an energy consumer does not pay, as required by their contractual obligations, the smart contract will not transfer the energy to that consumer. This scenario demonstrates the use of software to manage contractual performance without human interpretation or intervention.[30] However, the performance instructions of the smart contract are not specifically written in standard legal prose or layman language but outlined and executed in a coded programming language stored on the blockchain. Unlike traditional contracts, a smart contract applies a command-oriented language designed for computer automation and comprehension, and it is not written in an accessible language that can be read by an attorney without the specific IT skills. The command-oriented language is derived from the code behind the smart contracts

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[27] Adam J. Levitin, 'Pandora's Digital Box: The Promise And Perils Of Digital Wallets' (2018) 166 University of Pennsylvania Law Review.
[28] Merlinda Andoni and others, 'Blockchain Technology In The Energy Sector: A Systematic Review Of Challenges And Opportunities' (2019) 100 Renewable and Sustainable Energy Reviews.
[29] (1893) 1 QB 256
[30] Primavera De Filippi and Aaron Wright, '*Blockchain and the Law: The Rule of Code*' (Harvard University Press 2018)

themselves. Typically, smart contracts on the blockchain are coded in programming-based languages such as C++ and JavaScript.[31] This requires specialised knowledge of computer languages and programming to integrate the operation of a smart contact on the P2P-ETP fully. Computer languages function as executable clauses, and conditions that must be satisfied before delivering the tokens and the units of energy to the intended energy consumer or producer. Therefore, while anyone literate can read traditional contracts, only those who can read specific coding languages can read smart contracts. This is the main disparity between traditional contracts, drafted for comprehension by people, and automated smart contracts, executed and written in a computer-oriented language.[32]

The contractual terms in the smart contract are confirmed prior to the trading of energy through a traditional contract negotiation. However, the act of energy trading will be through automation with smart contracts. Therefore, it is necessary to consider the contract law issues around smart contracts prior to the automated implementation. Smart contracts execute legal agreements and create digital commercial arrangements.[33] However, they are not themselves legally enforceable because of the decentralised nature of the blockchain, where no single party controls it. Therefore, their autonomous nature makes smart contracts potentially riskier than traditional legal agreements in terms of consumer protection. To make a smart contract legally enforceable, it is feasible to have a hybrid system of contracts. For example, context-sensitive legal prose, such as good faith or warranties, can be governed by traditional written contracts and more time-dependent actions, such as payment dates, can be governed by smart contracts.[34]

This hybrid system of contract is achievable as most coding programmes allow clauses, also known as DocStrings, to explain the purpose of the code. DocStrings exist between the lines of code to allow the programmer or readers to understand the

[31] '9 Key Tools And Technologies To Develop And Test Blockchain Applications' (*Coinspeaker*, 2019) <https://www.coinspeaker.com/tools-technologies-blockchain-applications/> accessed 29 June 2019.
[32] N. Szabo, 'Nick Szabo's Essays, Papers, and Concise Tutorials' (1994) Humuvanl.
[33] Primavera De Filippi and Aaron Wright, '*Blockchain and the Law: The Rule of Code'* (Harvard University Press 2018).
[34] Ibid.

functions of the program. Smart contracts operate on similar coding platforms backed by typical computer programming. DocStrings allows for written explanations for the functions of the code in the interest of applying them alongside traditional legal contracts. This system creates the foundation for a hybrid styled smart contract that accommodates both smart contract developers and lawyers. Consequently, in the P2P-ETP models with encoding of smart contracts, the contractual agreements between the parties would be enforced through the transparency of the automated smart contract, and they would be legally protected through the necessary statute and legislation of the traditional contract. Therefore, when parties are in dispute, they may either renegotiate or seek traditional legal routes, such as a court ordered compensation, to resolve the dispute. Judge Steven Morris QC specified in Armstrong DLW GmbH v. Winnington Networks Ltd[35] that tradable carbon emission credits constitute an intangible property[36] in English law. This forms the legal basis for trading 'tokenised energy' as an intangible property via smart contracts on P2P-ETP.

iii. Benefits of the P2P Model

There are numerous academic assessments of the potential beneficial and negative attributes of P2P-ETPs, which promotes sustainability[37] by removing the intermediaries and allowing consumers to trade energy on their own terms. The P2P-ETP satisfies many of the United Nations Sustainable Development Goals (SDGs) for the 2030 Agenda for Sustainable Development.[38] Most notably, SDGs 7 and 13 through the promotion of renewable energy trading for affordable and clean energy to combat carbon emissions and climate impact, and SDG 9 and 11 for innovating industry and infrastructure through sustainable urban development.[39] These goals also reflect in the Third Energy Package for the European Union (EU) and the Smart Meter Act 2018 in the United Kingdom. The legislation encourages allocating

[35] [2012] EWHC 10 (Ch) 156.
[36] Re Celtic Extraction Ltd (In Liquidation) [2001] Ch 475.
[37] Ibid.
[38] United Nations General Assembly, 'Transforming Our World: The 2030 Agenda For Sustainable Development' (2015) <https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E> accessed 23 June 2019.
[39] Ibid.

government investment into infrastructure and incentivising consumer energy awareness. The P2P-ETP system itself is vital for sustainable application as it impacts the physical functioning of the domestic energy sector. Smart grids and P2P-ETP systems encourage consumers to create their own renewable energy, such as solar energy, using installed solar panels.[40] Smart meters, which can track and observe the exact amount of energy produced and spent and on which activities, would promote greater consumer consciousness while ensuring control over the energy they directly produce, consume and trade.[41]

Smart contracts, working in tandem with these technologies, operate as an accountability measure to fight against the potential consequences of depleting common resources. In a situation of shared resources, self-interest leads to the depletion and eventual destruction of the collective; in this scenario, the collective are connected energy consumers. In the past, this situation in the energy sector highlighted the contribution of excessive energy consumption to severe carbon emissions. However, theoretically, consumers are unable to track their direct consumption and therefore may not be aware of their consumption levels The introduction of smart contracts to the P2P-ETP system will empower consumers through collective interest and culpability by regulating their own energy consumption.[42] The contributions of scientists worldwide[43] has resulted in the rise of environmentalism which has significantly contributed to consumers' desire for responsible energy consumption.

To empower consumers, it must be acknowledged that energy consumers are unique individuals with different preferences in terms of environmental concerns, financial burdens, and level of trust towards emerging technology. Therefore, smart contracts introduce a market mechanism suited to individual consumers' concerns within their control. P2P-ETP systems enable such consumer empowerment by using smart

[40] Rafael Leal-Arcas, Feja Lesniewska and Filippos Proedrou, 'Smart Grids In The European Union: Assessing Energy Security, Regulation & Social And Ethical Considerations' (2018) 42 Columbia Journal of European Law.
[41] Ibid.
[42] Ibid.
[43] William J Ripple and others, 'World Scientists' Warning Of A Climate Emergency' [2019] BioScience.

contracts to facilitate bilateral energy transactions within specific demand periods. Consumers are given the ability to negotiate price dynamics through supply and demand models. In embedding smart contracts within P2P-ETPs, the pricing would be flexible and automated based on pre-set conditions and demand. Consumers would be able to personalise their own ceiling cap for purchasing, and therefore, avoid potential overcharge or overconsumption of energy. This dynamic style would assist the energy consumer's ability to negotiate in conjunction with complex tariff structures. Consequently, by enabling energy trading throughout a period of fluctuating pricing, demand at peak times would be lowered as energy will be purchased at will by the individual consumer prior to use or when necessary.[44]

As a result of these dynamics, P2P-ETP facilitates management of energy supply through this shared economy model for energy with smart grids and smart meters[45]. Energy consumers can actively manage their household energy usage and cost through the accessibility of their data[46]. Research on this application is outlined in the cost-benefit analysis issued by the UK Government. The real-time awareness of usage and cost will encourage consumers to reduce demand and contribute to lower energy bills.[47] A real-world example of this structure is the Brooklyn Microgrid Project[48] in the United States, where participants generate their own energy and resell to consumers who need it, at a cheaper rate.[49]

Several P2P-ETP projects are being tested worldwide.[50] For example, in the United Kingdom, Piclo was established as a collaboration between the technology company

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[44] Claire Henly, 'Energizing the Future with Blockchain' [2018] The Energy Bar Association Energy Law Journal.

[45] Hilary E. Brown, Siddharth Suryanarayanan and Gerald T. Heydt, 'Some Characteristics Of Emerging Distribution Systems Considering The Smart Grid Initiative' (2010) 23 The Electricity Journal.

[46] Sonia McNeil, 'Privacy and the Modern Grid' (2011) 25(1) Harvard Journal of Law and Technology.

[47] Department of Business, Energy and Industrial Strategy, 'Smart Meter Roll-Out Cost-Benefit Analysis' (2016).

[48] Merlinda Andoni and others, 'Blockchain Technology In The Energy Sector: A Systematic Review Of Challenges And Opportunities' (2019) 100 Renewable and Sustainable Energy Reviews.

[49] Brooklyn Microgrid, 'BMG 101 | Brooklyn Microgrid | Community Powered Energy' (2019) <https://www.brooklyn.energy/bmg-101> accessed 29 June 2019.

[50] T. Morstyn, and others, 'Using Peer-to-Peer Energy-Trading Platforms to Incentivize

Open Utility[51] and the renewable energy supplier Good Energy.[52] Piclo's system matches consumption preference to generators depending on locality and demand, while providing consumers with data analytics through smart meters.[53] This is an example of P2P-ETPs integrating data, pricing and consumer preference information, to match demand based on consumer selection. While these systems are being rolled out slowly, limited research is currently available on the impact of smart contracts and P2P-ETPs.

While these examples are still new, they demonstrate that the support P2P-ETPs have to engage consumers in a more dynamic energy market. Feedback of energy consumption is especially useful for consumers, as it has been shown to change behaviours dramatically. Darby[54] and Fischer[55] noted that energy feedback could reduce energy consumption by 10%.[56] The European Smart Metering Industry Group (ESMIG), after a review of 100 beta-testing pilots and 460 samples over 450,000 consumers, suggested savings from around 5-6% without real-time readings compared to an average of 8.7% with available readings.[57] Further trials in the EU resulted in similar data.[58] As a direct result, the amount paid towards energy bills will be lower for consumers and households. The cost for suppliers and utility companies will also be positively affected as traditional meters allow for a simple record of energy consumption and require manual reading, such as meter visits on-site or consumers sending in meter readings from their household. The labour necessary for these checks and balances would no longer be required for meter readings and updates. Conclusively, the Early Learning Project found in its report in 2015—on behalf of the

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Prosumers to Form Federated Power Plants,' (2018) Nature Energy, vol. 3, no. 2, pp. 94–101.

[51] 'Piclo.Energy' (*Piclo.uk*, 2019) <https://piclo.uk> accessed 29 June 2019.

[52] Ibid.

[53] Ibid.

[54] S. Darby, 'The Effectiveness of Feedback on Energy Consumption' (2006) Environmental Change Institute, University of Oxford.

[55] Corinna Fischer, 'Feedback On Household Electricity Consumption: A Tool For Saving Energy?' (2008) 1 Energy Efficiency.

[56] Ibid.

[57] European Smart Metering Industry Group 'The potential of smart meter enabled programs to increase energy and systems efficiency' (2011).

[58] CER11080a, Commission for Energy Regulation 'Electricity Smart metering Customer Behaviour Trials (CBT) Findings Report' (2011) < https://www.cru.ie/wp-content/uploads/2011/07/cer11080ai.pdf> accessed on 2 February 2019.

United Kingdom Department of Energy and Climate Change—that consumers with smart meters were better able to budget for expenditure as a result of the real-time meter, and therefore, were more satisfied than those with traditional ones.[59] Within the energy market's proliferating smart technologies, the implementation of DLT is already being considered for the next step for smart meters, grids[60], and eventually a cohesive P2P-ETP.

III. Legal Obstacles

i. Limitation of smart contracts in P2P Trading

Smart contracts are computer-based software. The regulatory challenge is to embed smart contracts into the current contract law framework.[61] Otherwise, the creation of a separate regulatory legislation will become a necessity in the future legal structure of P2P-ETPs.

i) Black box smart contracts

While it is not written entirely in a programmed-coded format, the form of expression in smart contracts differs greatly from traditional contracts.[62] An understanding of computer languages is necessary to draft, understand and implement the code within them. While the code facilitating the smart contacts might be correct, unspecified directions for the instructions or requirements can result in unintentional consequences and in liabilities to either party. A notable issue with smart contracts is

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[59] Department of Energy and Climate Change 'Smart Metering Early Learning Project: Domestic Energy Consumption Analysis' (2015) <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/407568/8_Synthesis_FINAL_25feb15.pdf> accessed 9 January 2019.

[60] Enterpriseinnovation.net, 'Global Data: Blockchain is the missing link to transform the electric power industry'(*Enterprise Innovation | Asia's Premier Business and Technology Publication*, 31 December 2018) <https://www.enterpriseinnovation.net/article/globaldata-blockchain-missing-link-transform-electric-power-industry-751371248> accessed 2 February 2019.

[61] Jake Goldenfein and Andrea Leiter, 'Legal Engineering On the Blockchain: 'Smart Contracts' as Legal Conduct' (2018) 29 Law and Critique.

[62] Guido Governatori and others, 'On Legal Contracts, Imperative And Declarative Smart Contracts, And Blockchain Systems' (2018) 26 Artificial Intelligence and Law.

rooted in the fixed format and protection of what has been previously agreed and programmed into the code.[63] While this is helpful for accountability, it can lead to potential issues in consumer protection and contractual liability if smart contracts are recognised as legally enforceable contracts. Should they be recognised as legal contracts, it would be difficult to verify that they are appropriately coded and protected.[64] Consumers and businesses would have to rely on the qualifications of those drafting the computer language behind them and ensure that they are legally enforceable.[65] On P2P-ETPs, smart contracts are considered to function as purposed by the developer.[66] Thus, the smart contract, if not properly executed and functioning, can result in malfunctions. For example, an attack on the distributed autonomous organisation (DAO) led to over 60 million US dollars being moved into an incorrect account.[67] This resulted in a legal controversy regarding the automation and ownership of these tokenised funds on the blockchain. To avoid this risk with P2P-ETP systems, an established and accredited standard for trustworthy professionals on the back end of the technology is necessary. Consumer contracts must be clearly and unambiguously understood[68] of what they are binding to; therefore, the development of smart contracts as legal contracts would create a hurdle for those who are not technologically inclined. Trust in a contract that an average person cannot read or understand opens a technological Pandora Box of litigation and misunderstanding.

ii) Systemic risk due to errors in coding

A systematic chain reaction stemming from errors would severely impact both parties involved with the contract.[69] For example, an error in the contract's application and

[63] Guido Governatori and others, 'On Legal Contracts, Imperative And Declarative Smart Contracts, And Blockchain Systems' (2018) 26 Artificial Intelligence and Law.
[64] Ibid.
[65] Institute of International Finance, 'Getting Smart: Contracts On The Blockchain' (Institute of International Finance 2016).
[66] Maher Alharby and Aad van Moorsel, 'A Systematic Mapping Study On Current Research Topics In Smart Contracts' (2017) 9 International Journal of Computer Science and Information Technology.
[67] Fan Zhang and others, 'Town Crier' [2016] Proceedings of the 2016 ACM SIGSAC Conference on Computer and Communications Security - CCS'16.
[68] WRM Group Ltd v Wood (1998) CLC 189.
[69] Jake Goldenfein and Andrea Leiter, 'Legal Engineering On The Blockchain: ‘Smart Contracts’ As Legal Conduct' (2018) 29 Law and Critique.

execution would create a crisis of time-restricted consequences. The contract's intricate system of immutability to editing and retracting on the blockchain would be a negative characteristic. There is a risk of using niche languages with smart contract coding, as even if there is an error within the code of the smart contract, the programme itself could potentially still run without indication of error.[70] However, it would then run incorrectly. For example, errors in the execution of smart contracts could lead to incorrect billing, malfunctions between transactions, and loss of potential or purchased energy units. This is avoidable once all codified terms and clauses of smart contracts perform as intended, relying on the guarantee that the contract is coded correctly. Smart contacts rely on the trust of the computer programmers behind them. This trust also depends on the resilience to tampering once adequately coded. Due to the difficulty of changing the underlying blockchain code, the narrow opportunities for anyone to access or change the contract without preceding agreed arrangements can also represent a risk of errors in coding.[71]

Blockchain technology and smart contracts should assist consumers in understanding the risks and terms better before agreeing.[72] Trust can be reinforced by requiring the consumer to digitally check mark terms and clauses indicating acceptance, or being able to track how long someone spends on a page to guarantee that the consumer has properly read all the terms and conditions. It is also symbiotically beneficial to companies, such as the controllers of the private blockchain network, that rely on consumer acknowledgement for their legal protection. Clauses should be drafted in the traditional contract to include legal accountability through the consumer protection legislation for any breach or errors in service.

Consumer knowledge, trust, and understanding are vital to the contractual agreements between consumers and energy producers. However, 60% of domestic consumers within the United Kingdom, who are on default tariffs, are not currently

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[70] Christian Chessman, 'A Source Of Error: Computer Code, Criminal Defendants, And The Constitution' (2017) 105 California Law Review.

[71] Alharby M and Moorsel AV, 'Blockchain Based Smart Contracts: A Systematic Mapping Study' (2017) Computer Science & Information Technology (CS & IT) accessed 06 November 2018.

[72] Jake Goldenfein and Andrea Leiter, 'Legal Engineering On The Blockchain: 'Smart Contracts' As Legal Conduct' (2018) 29 Law and Critique.

benefitting from this model.[73] This indicates that most domestic consumers in the energy market fail to meet their needs. An example of this is demonstrated by OVO Energy in January 2020, where consumers were extraordinarily overcharged and issued incorrect energy usage information.[74] It is submitted that the implementation of P2P-ETPs would ensure greater consumer protection and company compliance through transparency and accountability. P2P-ETPs would enable consumers to access their own energy data (produced, consumed, purchased, stored in the custody of the wallet, and traded) and avoid a disaster billing system. The platform can also ensure a cap on energy expenditure based on the amount of energy produced and used within the household. With the collected data from smart meters, consumers would know the precise amount of energy produced[75] and used while utilising smart contracts for their legal protection and billing.[76]

The P2P-ETP smart contact trading for energy detailed above is exemplified through a cyclical ecosystem. Smart meters are applied as the medium to regulate energy consumption and production. As discussed, the consumer has agreed to energy tariffs and contracts, and the smart contract enforces accountability and price arrangement. When the terms and conditions of trading have been agreed, the information is encoded into the smart contract as an automated system. To avoid overbilling, a cap can be introduced into the smart contract transaction to ensure that the consumer does not consume or pay for more than stipulated. Options for additional purchases may be presented if the consumer is reaching close to their limit. The consumer can use the smart meter to enforce their smart contract with the energy company. The smart meter requires no direct regulation and functions autonomously using the data from the smart meter, ensuring that the consumer is receiving the agreed amount of energy. In turn, the smart contract also ensures that the energy company is receiving

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[73] The Office of Gas and Electricity Markets, Draft Forward Work Programme 2018-2019 (2018).

[74] 'Ovo Energy To Pay £8.9M For Overcharging Customers' (*BBC News*, 2020) <https://www.bbc.co.uk/news/business-51292695> accessed 24 February 2020.

[75] L. Benichou, 'AXA Launches Ethereum Smart Contract Insurance Product for Flight Delays' (Trustnodes, June 18 2018) < https://www.trustnodes.com/2018/06/18/axa-launches-ethereum-smart-contract-insurance-product-flight-delays> accessed on December 4 2018.

[76] F. Zhang, and others, 'Town crier: An authenticated data feed for smart contracts,' in Proceedings of the 2016 ACM SIGSAC Conference on Computer and Communications Security, CCS '16, pp. 270-282 (2016).

payment at the specified time and date, as agreed in the hybrid contract. This limits the potential of energy being cut off during colder times of the year and protects vulnerable consumers from sudden heating cuts. Therefore, this example of a smart contract in the P2P-ETP would not require any additional regulation outside of traditional contract law and application, as it utilises pre-determined conditions in a traditional contract as protection.

ii. Consumer protection

Consumers are empowered through P2P-ETPs by having more control over their energy usage. Technological infrastructure should be regulated in the interest of consumers. The P2P-ETPs infrastructure includes Smart Meter, Smart Contracts, and Smart Grids. Currently, the Energy Act 2011, Electricity Act 1989, the Gas Act. Specifically, for P2P-ETPs, the Renewable Energy Directive also states that the infrastructure of smart technology and regulatory instruments should embed consumer protection. The Directive indicates that an applicable regulatory framework should be established to empower renewables for self-consumers (consumers and prosumers) without disproportionate burdens.[77] Thus, the foundation for consumer protection, while consuming and generating energy, has been enshrined in this legislation for the encouragement of P2P-ETPs. Discussions throughout this paper indicate that smart contract obligations on the P2P-ETP can be regulated through traditional contract law via hybrid contractual arrangements. Other legislative measures can also be applied to blockchain-based smart contracts depending on the legal recognition of smart contract. Furthermore, the transparent model also raises legal issues around security, individual privacy, and data protection.[78]

i) Smart contracts as Software

P2P-ETP systems are an amalgamation of multiple smart technologies. Smart contracts, as discussed, operate as the functioning medium for billing and financial

[77] Renewable Energy Directive, Section 66.
[78] N. King and P. Jenssen, 'For privacy's sake: Consumer "opt-outs" for smart meters' (2014) 30(5) Computer Law and Security Review.

transactions. However, they may not be legally enforceable because they comprise of code. Therefore, smart contracts can be considered software as digital content under the Consumer Rights Act 2015. Digital content is data produced and supplied in digital form.[79] Therefore, P2P-ETPs can be considered the devices on which smart contracts—the digital content in this context—operate. Smart contracts are enforced by the blockchain, which is also considered a 'digital good'; therefore, consumer protection against software and product liability in P2P-ETP systems can fall under the Consumer Rights Act 2015. Other legislative measures can be applied to smart contracts on the blockchain. For example, the Digital Economy Act 2017 Part 6 Section 113 states that Schedule 9 extends to the Banking Act 2009 Part 5, which oversees the Bank of England's inter-bank payment system,[80] to connect to other payment systems. The Act 2017 makes consequential provisions to facilitate digital transactions. Therefore, digital transactions are not a new activity that needs to be regulated and monitored outside of existing legislation.

ii) Software and product liability

With reference to the potential dangers discussed above with flaws and vulnerabilities[81] within coded products, there is a precedent for large-scale software being susceptible to failures.[82] Failures tend to be costly, and many dangerous malfunctions have led to products and services being recalled. However, potential flaws within software are an inevitable reality,[83] and it has even been argued that strict product liability regulation would result in stifling the creative and entrepreneurial spirit

[79] Consumer Rights Act 2015, Part 1 Chapter 1 Section 2 (9)
[80] 'The Bank Of England's Oversight Of Interbank Payment Systems Under The Banking Act 2009' (The Bank of England 2009) <https://www.bankofengland.co.uk/-/media/boe/files/news/2009/september/the-boes-oversight-of-interbank-payment-systems-under-the-banking-act-2009> accessed 25 February 2020.
[81] 'Whatsapp Voice Calls Used To Inject Israeli Spyware On Phones | Financial Times' (*Ft.com*, 2019) <https://www.ft.com/content/4da1117e-756c-11e9-be7d-6d846537acab> accessed 29 June 2019.
[82] Shuai Wang, Chengyu Zhang and Zhendong Su, 'Detecting Nondeterministic Payment Bugs In Ethereum Smart Contracts' (2019) 3 Proceedings of the ACM on Programming Languages.
[83] Jonathan G. Rohr, 'Smart Contracts and Traditional Contract Law, or: The Law of the Vending Machine.' (2019) 67 CLEV. ST. L. REV. 71.

of software development.[84] Arguments against regulation include the high cost of meeting a specified standard could potentially drive smaller software companies out of business, and thus, create an unfair monopoly[85] to the point of delaying or stifling innovation.[86] From this perspective, software liability and redress are still developing areas of law for consumer protection with regard to defence and obligation[87].

Software failure on the P2P-ETP can cause losses to consumers due to resulted blackout or billing errors. Thus far, there is no clear legal standard of care for consumers applied to software developers.[88] Hence, a universal standard is necessary to demonstrate software liability.[89] This standard must establish that no reasonable software developer would commit such an act.[90] Software development is a subjective field in terms of creation and application; however, a line must be drawn between the proper function of software and the unreasonable failure in delivering that function.

The United Kingdom's case of *The Software Incubator Ltd v Computer Associates Ltd*[91] extended the meaning of software supplied electronically under the term 'goods' within The Commercial Agents Regulations 1993.[92] This case features the argument that if a company produces and distributes software (goods) through commercial agents, they must pay compensation to the commercial agents upon the termination of agency agreements.[93] This is specific to English law and can be applied even if the controller operates internationally. Therefore, applying this to the application of smart contracts, that is a digital software provided electronically, there is a strong argument

[84] Ibid.
[85] Ibid.
[86] Ning Wang and others, 'Peer-To-Peer Energy Trading Among Microgrids with Multidimensional Willingness' (2018) 11 Energies.
[87] Carol Dick and Aaron Praktiknjo, 'Blockchain Technology And Electricity Wholesale Markets: Expert Insights On Potentials And Challenges For OTC Trading In Europe' (2019) 12 Energies.
[88] Ibid.
[89] Horst Treiblmaier, 'Toward More Rigorous Blockchain Research: Recommendations For Writing Blockchain Case Studies' (2019) 2 Frontiers in Blockchain.
[90] Ibid.
[91] (2016) EWCA Civ 518.
[92] The Commercial Agents (Council Directive) Regulations 1993/3053.
[93] Horst Treiblmaier, 'Toward More Rigorous Blockchain Research: Recommendations For Writing Blockchain Case Studies' (2019) 2 Frontiers in Blockchain.

for software liability to be considered under the same scope as a digital good failing to produce its intended function.

An opposing argument states that software should be treated like electricity, which itself is specifically covered by the Directive in Article 2 and the Consumer Protection Act 1987 in Section 1(2), and that software is essentially compiled from the energy that is material in the scientific sense. However, this is a dated argument, as modern definitions of software have placed it as a product of the information age. The case of St Albans City and District Council v. International Computers Ltd [1996] [94] emphasised that software should be classified as a product versus electricity and enables redress under standard consumer protection legislation.

iii. Consumer Rights and P2P-ETP

Software being a commercial good and product is also covered under Part 1 and Part 3 of the Consumer Rights Act 2015 with regard to faults in digital content or products. The Act defines digital content as, 'data which are produced and supplied in digital form'[95] and was assumed from the Consumer Rights Directive (2011/83/EU). However, this would be difficult to apply to smart contracts within the P2P-ETP system because of the context and nature of the software. On P2P-ETP, the smart contract operates as a facilitator for transactions instead of a purchased product. The product being purchased is energy and not the smart contract itself. Therefore, under the Consumer Rights Act 2015, it is difficult to separate the smart contract, because of its facilitating nature, from the entire P2P-ETP itself.

This issue is substantial with regard to consumer protection if trading goes wrong due to the smart contract. In this situation, the question is if a consumer would be able to obtain legal redress against the smart contract designer or the platform provider. It can be interpreted that smart contracts are part and parcel of the P2P-ETP network, and therefore, the standards under the Consumer Rights Act 2015 could apply. The code operating the smart contract is the mechanism that controls the automation of billing

[94] 4 All ER 481
[95] Consumer Rights Act 2015 Part 1 Chapter 1 Section 2 (9).

and transactions. The parties involved in the transactions on the P2P-ETP are consumers and the smart grid operator. This analysis considers traditional contract law concerning the contractual relationship between consumers and the smart grid operator that maintains the infrastructure physically and digitally. As previously discussed, the Act recognises the consumer's rights in situations of digital content, where it is either supplied for free in conjunction with paid goods services or digital content that is inaccessible without payment. [96]

In this case, the digital content is a part of the overall contract for such goods and services, and the prescribed standards will apply. Therefore, assuming the definition of digital content in the 2015 Act applies to smart contracts, the designers of the smart contracts would be held to the standard set out in the legislation.[97] These requirements include that the digital content is an appropriate fit for the intended purpose, is free from minor defects, and is safe and durable.[98] However, Section 38 of Part 3 of the 2015 Act also enforces that unless expressed in the contractual agreement, there are no further requirements in addition to the above. Finally, the Act also provides additional[99] remedies in situations of digital content, such as being able to claim damages in specific circumstances. Because of the ambiguity of software liability, as discussed earlier in this paper, the definition of smart contracts as a good or product would have to be handled on a case-by-case basis. This highlights a legal risk with smart contracts operating on P2P-ETP.

i) Consumer Protection Act

Consumer protection legislation has a long history of regulating consumer rights in commercial aspects. In the past, the Consumer Protection Act 1987, following the EC Directive (85/374/EEC), enshrined the concept of product liability as part of the law of the United Kingdom for over a decade. The effect of the Directive and the Act is to create liability, even without a fault on the part of the producer of a defective product,

[96] The Consumer Rights Act 2015, Section 33(3).
[97] The Consumer Rights Act 2015 Part 3, Sections 34, 35, 36.
[98] Ibid.
[99] The Consumer Rights Act 2015 Part 3 Section 42 (6).

which causes death, personal injury, or any loss or damage to property, including land.

Consumers are at the heart of the P2P-ETP's purpose, and consumer rights include the right to information and the right to fair and responsible marketing.[100] These are to encourage responsible and informed consumer choices and behaviour.[101] When an energy supplier agrees to supply gas or electricity, it is a legally binding contract covered by the Consumer Rights Act 2015. For consumer benefit, it is necessary to have features for metering and informative billing of energy consumption.[102] This is to make consumers aware of and provide them competitively priced individual meters that accurately reflect the energy data that they engage with (production, consumption, trading, and ownership). The smart metering system, in the P2P-ETP model, communicates with other energy suppliers or network operators and they use systems that allow collection, measurement and analysis of energy for grid management and billing purposes.

In the European Union, smart meters are being rolled out as a result of legislation–the Third Energy Package.[103] This led to the establishment of the Agency for the Co-operation of Energy Regulators (ACER), which is an EU body with a legal personality to monitor developments in European energy markets.[104] The Third Energy Package states that member states should replace at least 80% of the traditional meters with smart meters by 2020.[105] To accomplish this, the EU has a directive that requires member states to provide citizens with smart meters.[106] In the United Kingdom, this promise is regulated by the Electricity and Gas (Internal Markets) Regulations 2011. The legislative push for smart meters is fuelled by governmental targets for reducing

[100] Ibid.
[101] Ibid.
[102] Directive 2006/32/EC, Article 13 (1).
[103] Directive 2009/72/EC, Article 9.
[104] Regulation 713/2009.
[105] Directive 2009/72/EC.
[106] Directive 2006/32 EC.

greenhouse gas emissions by increasing renewable energy[107] and infrastructure for future P2P-ETPs.

ii) EU: P2P-ETPs and renewable energy

Early energy legislation in the European Union did not consider P2P-ETP's high regulatory burdens. As of December 2018, the European Union places consumers at the centre of the energy market transition, with a clear and concise right to produce their own renewable energy. The Renewable Energy Directive[108] defined P2P-ETP systems as the bartering of renewable energy between market consumers through pre-determined, automated conditioned contracts.[109] Understanding and defining P2P-ETPs is the first step in creating legislation, which allows consumers to regulate their systems and benefit from consumer protection mechanisms. Section 72 of the Renewable Energy Directive[110] enforces valid consumer protection in situations of energy trading on P2P-ETP, where energy consumers and communities participate in the self-consumption of renewable energy. This section specifically states that consumers shall maintain their rights, including those involving contractual agreements with suppliers of their choice.[111] Therefore, according to this recent legislation, consumer protection in the European Union for P2P-ETPs, within relevant reason, would fall under traditional consumer contract law. The nature of smart contracts running on DLT is still young. Therefore, a case-by-case assessment is necessary to establish an accurate jurisdictional legislation to apply for consumer protection, especially in situations of applying contract law for consumer litigation in circumstances of service failure or error.

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[107] House of Commons: Energy and Climate Change Committee 'The energy revolution and future challenges for UK energy and climate change policy — Third Report of Session 2016–17 — HC 705' (2016) <https://publications.parliament.uk/pa/cm201617/cmselect/cmenergy/705/705.pdf> accessed on 15 January 2019.
[108] Directive (EU) 2018/2001.
[109] Directive (EU) 2018/2001, Section 18.
[110] Directive (EU) 2018/2001.
[111] Directive (EU) 2018/2001, Section 72

IV. Infrastructure

i) Privacy and Data protection

The EU's General Data Protection Regulation (GDPR) expanded the scope of the European Union's data protection to encompass the powers of those determining the purpose and means of processing personal data[112], data controllers[113], and the parties collecting and processing[114] the data for the controller.[115] It is irrelevant if the processing of actual data occurs in that location.[116] Consequently, as P2P-ETPs fall under the definition of a data controller by determining the means and purpose of processing energy data of consumers within the EU, it is subject to the GDPR. Once the data is related to the offering of goods or services, regulatory bodies can track the trading or usage behaviour of consumers within the EU.[117] However, for the application of EU data protection law, the data stored on the blockchain must meet the criteria of personal data under Article 4 (1).[118] This criterion requires the data to be related to a natural person.[119] This also coincides with Article 2 (a) of the Data Protection Directive 95/46, and thus, it can be applied to smart technologies affecting identifiable individuals operating on P2P-ETPs.[120] While smart contracts running on DLT will typically be encrypted, and consequently, can only be accessed with specific keys and authorised parties, this will not remove the personal data from the scope of data protection legislation.[121]

The levels of encryption are used as a measure for determining the level of data security needed to meet the protection requirements. Energy consumption data in the

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[112] General Data Protection Regulation 2016/679 Article 4 (1)
[113] General Data Protection Regulation 2016/679 Article 4 (7)
[114] General Data Protection Regulation 2016/679 Article 4 (2)
[115] General Data Protection Regulation 2016/679 Article 4 (8)
[116] General Data Protection Regulation 2016/679 Article 3 Para 1.
[117] General Data Protection Regulation 2016/679 Article 3 Para 1.
[118] General Data Protection Regulation 2016/679.
[119] General Data Protection Regulation 2016/679 Article 4 (1).
[120] M. Berberich and M. Steiner, 'Practitioner's Corner · Blockchain Technology and The GDPR – How to Reconcile Privacy and Distributed Ledgers?' (2016) 2 European Data Protection Law Review.
[121] General Data Protection Regulation 2016/679 Article 32.

past did not raise many privacy concerns, as traditional electric meters previously required a physical assessment to gauge output.[122] Traditional meters recorded usage over extended periods and were not specific to appliance or activity. In addition, in traditional business models for energy data, utility companies did not have the means to share energy consumption data with third parties. With the digitisation of energy data on P2P-ETPs, it is much easier to acquire and transfer data from smart meters[123]. This raises issues around lack of transactional privacy and data privacy of P2P-ETP.[124] In DLT systems, all transactions are publicly available to be viewed if allowed by pre-determined parameters within the terms and conditions and the security level of the network, especially if on the public chain network. This lack of privacy could limit the adoption of P2P-ETPs, as individual consumers usually consider their data and financial transactions as personal and confidential. However, privacy-preserving smart contracts can encrypt the code to ensure that only participants in the transaction can access the content on the chain.[125]

Information privacy is a major concern with regard to DLT, and therefore, P2P-ETPs. The primary purpose of using smart meter data is to ensure that consumers can take advantage of the opportunity to access their households' energy data (i.e. production and usage) and make smarter choices to conserve and trade energy while potentially saving money on their energy bills.[126] Access to more detailed energy-use information, increased control over households' energy use and costs, the ability to transfer data to others, and personal involvement in energy conservation are all potential benefits to consumers with access to P2P-ETPs. These considerations justify treating

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122 'Guide to Energy Meters' (*OVO Energy*, 2012) <https://www.ovoenergy.com/guides/energy-guides/energy-meters.html> accessed 2 February 2019.

123 N. King and P. Jessen, 'Smart Metering Systems and Data Sharing: Why Getting a Smart Meter Should Also Mean Getting Strong Information Privacy Controls to Manage Data Sharing' (2014) 22(3) International Journal of Law and Information Technology.

124 D. Wright, and others 'Sorting outsmarts surveillance' (2010) 26(4) Computer Law & Security Review.

125 S. Zhou and M. Brown, 'Smart meter deployment in Europe: A comparative case study on the impacts of national policy schemes' (2016) 144 Journal of Cleaner Production.

126 Ibid.

consumers' access to smart meter data as a primary purpose of P2P-ETP.[127] However, there are privacy risks in terms of transferring such important data to third parties. For example, energy usage patterns and profiles based on smart meter data can be used for many secondary purposes. Such purposes include generating targeted and personalised advertising in online and mobile frameworks.[128] Under the Data Protection Act 2018, it is an offence to disclose personal data without consent.[129] It would be necessary to include such consents in the traditional contractual terms and obligations prior to enabling P2P-ETPs access to household data.

Another risk in terms of data sharing on a transparent model of P2P-ETP is the fear of individual data tracking. Consumer interest includes an individual's legal right to be free of unreasonable surveillance,[130] intrusions into their homes and personal lives.[131] There is potential to apply data-mining technologies to energy usage data produced by P2P-ETPs and use the information for primary and secondary commercial purposes, including many purposes that have not yet been identified in the evolving digital economy.[132] Parties involved with data sharing with P2P-ETPs include direct consumers, energy suppliers, and potentially third parties.[133] Third parties would include energy service management companies with whom the consumer's energy data has been shared, or markets that rely on consumer data for product advertising and profiling. Data sharing on P2P-ETP may be carried out by the consumer or their

[127] N. King and P. Jessen, 'Smart Metering Systems and Data Sharing: Why Getting a Smart Meter Should Also Mean Getting Strong Information Privacy Controls to Manage Data Sharing' (2014) 22(3) International Journal of Law and Information Technology.
[128] European Data Protection Supervisor, 'Opinion of the European Data Protection Supervisor on the Commission Recommendation on preparations for the Roll-out of Smart Metering Systems' <https://edps.europa.eu/sites/edp/files/publication/12-06-08_smart_metering_en.pdf> accessed on January 15th 2019.
[129] Data Protection Act 2018, Section 170 (1).
[130] N. King and P. Jenssen, 'For privacy's sake: Consumer "opt-outs" for smart meters' (2014) 30(5) Computer Law and Security Review.
[131] D. Wright, and others 'Sorting outsmart surveillance' (2010) 26(4) Computer Law & Security Review.
[132] O. Tene and J. Polonetsky, 'Privacy in the Age of Big Data a Time for Big Decisions' (2012) 63 (Online) Stanford Law Review.
[133] N. King and P. Jessen, 'Smart Metering Systems and Data Sharing: Why Getting a Smart Meter Should Also Mean Getting Strong Information Privacy Controls to Manage Data Sharing' (2014) 22(3) International Journal of Law and Information Technology.

energy supplier. Data that could potentially be shared by third parties include the amount of automated transfers of smart meter data.[134]

Data sharing is often necessary to achieve the benefits of P2P-ETPs, and that data can trickle down to secondary purposes. For example, energy companies may utilise the consumer's smart meter data with a third-party advertising company to earn advertising revenue.[135] These distinctions about parties and purposes of sharing are the foundation of the transparent and accountable model of P2P-ETP. An example can be taken from the United States, where significant progress has been made for consumer privacy concerns with regard to smart meter data. The US Department of Energy enacted a task force[136] specifically focused on addressing the issue.[137] Currently, their key responsibility is to craft a voluntary smart grid code of conduct specific to privacy.[138] Another development is the construction of a voluntary 'smart grid privacy seal program[139]' aimed at companies that utilise consumer energy data.[140] Policy and legislation play major roles in assisting consumer protection while implementing smart technologies in everyday life. For example, in the United Kingdom, consumer protection for privacy and personal data is included in the suppliers'

[134] Department for Business, Energy and Industrial Strategy, 'Smart Metering Implementation Programme: Consultation on maximising interoperability for SMETS1 meters, including draft legal text' <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/700382/SMETS1_maximising_interoperability_enrolment_mandate_consultation_.pdf> accessed on January 28 2019.

[135] N. King and P. Jessen, 'Smart metering systems and data sharing: why getting a smart meter should also mean getting strong information privacy controls to manage data sharing' (2014) 22(3) International Journal of Law and Information Technology.

[136] Energy Independence and Security Act of 2007.

[137] United States Department of energy, 'Voluntary Code of Conduct Final Concepts and Principles' (*Energygov*, January 2015) <https://www.energy.gov/sites/prod/files/2015/01/f19/VCC%20Concepts%20and%20Principles%202015_01_08%20FINAL.pdf> accessed 3 January 2019.

[138] A. Carson, 'Stakeholders Aim to Craft Smart Grid Privacy Code of Conduct' (*The Privacy Advisor*, 27 February 2013) <https://iapp.org/news/a/2013-02-27-stakeholders-aim-to-craft-smart-grid-privacy-code-of-conduct/> accessed 1 February 2019.

[139] N. King and P. Jenssen, 'For privacy's sake: Consumer "opt-outs" for smart meters' (2014) 30(5) Computer Law and Security Review.

[140] Trustarccom, 'Privacy Risk Summit Preview: Privacy by Design for IoT' (*TrustArc Blog*, 26 May 2016) <https://www.trustarc.com/blog/2016/05/23/privacy-risk-summit-preview-privacy-design-iot/> accessed 2 February 2019.

licensing terms.[141] Under these terms, a P2P-ETP supplier may collect monthly meter readings for billing and regulation purposes without the need for consumer consent. Furthermore, it would be possible to collect daily meter readings with an option for opting out at the consumer's consent, or half-hourly meter readings solely with consumer consent for opting in.[142] Balancing consumers fundamental human rights to privacy and data protection with the beneficial interests of society and the environment is an obvious challenge. However, with P2P-ETP's smart metering systems, accountable smart contracts, and legislative protection, it is becoming a realistic objective.[143] The European Court of Justice delivered a preliminary ruling[144] in 2010, where they assessed the validity of the Data Retention Directive.[145] In light of Article 7 of the Charter of Fundamental Rights,[146] the issue was whether the service provider could retain the data of registered users and if the Directive adequately met the requirement of personal data protection.[147] It was held that the retention of data for a particular purpose of the Directive was of general public interest. This can prove to be problematic to consumer privacy, as P2P-ETPs utilise and store consumer energy usage. This data is particularly sensitive, as it can be used to track consumer habits and lifestyles.[148] However, Article 52(1) of the Directive states that the application of the principle of proportionality should be enforced, and only data that is necessary for general interest should be retained.[149] Operating this against Articles 7 and 8 emphasises that it is possible to balance installing P2P-ETPs with adequate consumer privacy; however, in the spirit of the EU's principle of proportionality, consumers should

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141 Ofgem, 'Licence guide: smart metering' (*Ofgemgovuk*, 16 November 2017) <https://www.ofgem.gov.uk/system/files/docs/2017/11/smart_metering.pdf> accessed 24 January 2019.

142 Department for Business, Energy and Industrial Strategy, 'Smart Metering Implementation Programme : Consultation on maximising interoperability for SMETS1 meters, including draft legal text' <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/700382/SMETS1_maximising_interoperability_enrolment_mandate_consultation_.pdf> accessed on January 28 2019).

143 D.Wright, and others 'Sorting outsmarts surveillance' (2010) 26(4) Computer Law & Security Review.

144 Joined Cases C-293/12 and C-594/12.

145 Directive 2006/24/EC.

146 Charter of Fundamental Rights of the European Union.

147 The Charter of Fundamental Rights of the European Union, Article 8.

148 N. King and P. Jenssen, 'For privacy's sake: Consumer "opt-outs" for smart meters' (2014) 30(5) Computer Law and Security Review.

149 The Charter of Fundamental Rights of the European Union Article 52(1).

not be penalised with excessive opting-out fees in order to exercise their fundamental right to privacy.[150]

This ruling should be considered in the context of the United Kingdom's laws, as the United Kingdom is not exempt from complying with the provisions of the Charter of Human Rights.[151] Further legislation is required to address privacy concerns surrounding data sharing and retention. In this context, smart contracts deal with the financial and energy trading aspects of P2P-ETPs, and therefore, will contain and hold consumers' data on the underlying blockchain. Hence, it is reasonable to apply the previous analysis of data retention to P2P-ETPs, as their function in this model facilitates the exchange of data. Therefore, consumers are protected by overarching principles within the EU for their right to privacy when trading energy and recording energy usage. However, these rights are also subject to general interest and potential future regulations for third-party commercial uses.

ii) Security

The security of the infrastructure is vital to the trust consumers need to operate on a P2P based platform. As previously discussed, the security of P2P-ETPs is embedded in the strength of the DLT coding behind it. In the past, the lack of secure technology in smart meters has led to hacking of consumer devices. These attacks have resulted in hackers controlling their billing, tracking their electronics, and even causing fires[152] and explosions.[153] Once a hacker gains access to the meter and the software, the consequences have been dire. In 2013, a town of near 40,000 consumers in the south of Germany almost lost all power, water, and gas.[154] This situation was a test of the

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[150] N. King and P. Jenssen, 'For privacy's sake: Consumer "opt-outs" for smart meters' (2014) 30(5) Computer Law and Security Review.
[151] C-411/10, C-493/10.
[152] CBC, 'SaskPower To Remove 105,000 Smart Meters Following Fires' (2014) <https://www.cbc.ca/news/canada/saskatchewan/saskpower-to-remove-105-000-smart-meters-following-fires-1.2723046> accessed 22 March 2019.
[153] A. Hern, 'Smart Electricity Meters Can Be Dangerously Insecure, Warns Expert' *The Guardian* (2016) <https://www.theguardian.com/technology/2016/dec/29/smart-electricity-meters-dangerously-insecure-hackers> accessed 22 March 2019.
[154] C. Steitz and Harro H. Ten Wolde, 'Smart' Technology Could Make Utilities More Vulnerable To Hackers' (*Thomson Reuters*, 2014) <https://www.reuters.com/article/us-

system's security but highlighted a gap in the encryption protection for retail market devices. A report from the University of Cambridge stated that smart meters raised certain serious security issues.[155] These issues included fraud through manipulated meter readings, threats of power outages through cyber-attacks, and other misuses of private customer data.[156] A cyber-attack that can shut down a household's access to heat can be detrimental during winter in the United Kingdom. The Office for National Statistics reported 50,100 excess deaths[157] in England and Wales in 2017-2018 due to weak health and freezing temperatures.[158] Therefore, the issue with cyber security is more than merely privacy and encompasses consumer safety.

P2P-ETP systems carry a greater guarantee of security because of the nature of DLT underpinning them. The data involved in energy trading can be used to track individual movements and the time spent in their households. Therefore, it is possible for this data to be considered useful by police in criminal or civil cases in verifying individual locations and activities. This information might require search warrants in the same vein for personal cellular devices. Data ownership and its use in the exercising of police powers were demonstrated in *Business Energy Solutions Ltd and others v. Crown Court at Preston,*[159] where it was found that data can be covered under the scope of search warrants, and within reasonable practicality of the case's context, the data can be copied, and the copies kept.[160] This is typically applicable to corporate

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utilities-cybersecurity/smart-technology-could-make-utilities-more-vulnerable-to-hackers-idUSKBN0FK1SZ20140716> accessed 22 March 2019.

[155] Economic and Social Research Council, 'Smart Metering And Electricity Demand: Technology, Economics And International Experience' (Economic and Social Research Council 2018) <https://www.eprg.group.cam.ac.uk/wp-content/uploads/2014/01/binder2.pdf> accessed 22 March 2019.

[156] C. Steitz and H. Ten Wolde, 'Smart' Technology Could Make Utilities More Vulnerable To Hackers' (*Thomson Reuters*, 2014) <https://www.reuters.com/article/us-utilities-cybersecurity/smart-technology-could-make-utilities-more-vulnerable-to-hackers-idUSKBN0FK1SZ20140716> accessed 22 March 2019.

[157] M. Bennett, 'Excess Winter Mortality In England And Wales: 2017 To 2018 (Provisional) And 2016 To 2017 (Final)' (Office for National Statistics 2018) <https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/bulletins/excesswintermortalityinenglandandwales/2017to2018provisionaland2016to2017final> accessed 22 March 2019.

[158] D. Campbell, 'Excess Winter Deaths In England And Wales Highest Since 1976' *The Guardian* (2018) <https://www.theguardian.com/society/2018/nov/30/excess-winter-deaths-in-england-and-wales-highest-since-1976> accessed 22 March 2019.

[159] [2018] EWHC 1534 (Admin)

[160] Criminal Justice and Police Act 2001 Section 53: 'the duty to 'return' seized property'

and commercial civil cases where data from a business is a source within an investigation. A more reasonable approach of the law for consumers is necessary if comparing data on P2P-ETP smart meters to those on an individual's cellular device. In this scenario, the data would be regarded with the same privacy considerations. While the United Kingdom does not have specific legislation requiring a warrant for such data searches, current legislation states that it would only occur if there were reasonable grounds.[161] Therefore, the P2P-ETP systems do not fall outside the applicable legislation for security and privacy surrounding data. Furthermore, an energy consumer can lose the access key to the system. In such situations, fail-safe measures should be in place to accommodate consumers in the same way that individuals retrieve lost bank details. Some institutions employ verification via secure, encrypted text messages, or email verifications. Because P2P-ETPs are digitally based, this is the most reliable system of key or password retrieval.

V. Recommendations

i) Standardisation and Certification

One possible recommendation to ensure a stable P2P-ETP network would be a collective consortium of those consuming energy, known as consumers, and those consuming while also producing energy, known as prosumers. The P2P-ETP facilitates contracts among consumers, prosumers and the central operator, as discussed earlier. Therefore, consumers can form trading coalitions to fulfil a more trustworthy system. Coalition forming is envisaged as being highly automated, undertaken by P2P-ETP users based on preferences and information from connected consumers.[162] Several mechanisms for forming trading coalitions are possible, including bilateral contract networks.[163] One option for standardisation is to have a set range during periods of peak demands.[164] For example, pricing during the evenings where a majority of users would be in their households after work. A ceiling and floor

[161] Police and Criminal Evidence Act 1984
[162] Woongsup Lee and others, 'Direct Electricity Trading In Smart Grid: A Coalitional Game Analysis' (2014) 32 IEEE Journal on Selected Areas in Communications.
[163] Ibid.
[164] Ibid.

cap should be implemented to deter pricing out more vulnerable consumers. This ensures the protection of the P2P-ETP market against price discrimination or manipulation. With multiple consumers and households on one P2P-ETP, trading between parties would be held in a controlled and certified environment.

As discussed earlier, smart meters are replacing traditional energy meters in households across the United Kingdom. These meters serve as certified nodes on the P2P-ETP's DLT and serve as a physical transmitter for this information. As smart meters are already being encouraged and rolled out across the United Kingdom and the European Union, they are affecting consumer confidence and interest in reviewing energy consumption.[165] Smart technologies on P2P-ETP create a trustworthy arrangement for consumers to track and monitor their energy consumption for billing and carbon emissions. Therefore, proper standardisation, regulation, and certification are the first necessities to increase consumer trust in P2P-ETPs. Another possible regulatory initiative would be for the P2P-ETP controller to invest in specific safeguards for their liabilities to the consumers operating on the system itself. In the event of a system failure or error, the controller can produce and send energy to affected households as a backup system. The controller can also establish warranty clauses in traditional contracts to ensure that consumers are aware of each individual step possible for compensation.

Finally, the controller can ensure the functioning capabilities of the technology behind the P2P-ETP system by enlisting certified coders. A regulatory body can oversee the certification of smart contracts and blockchain developers to ensure a standardised level of training and ability before implementation. These examples encourage greater consumer trust, which is vital to the success of implementing P2P-ETPs.

ii) Trust system

[165] Economic and Social Research Council, 'Smart Metering And Electricity Demand: Technology, Economics And International Experience' (Economic and Social Research Council 2018) <https://www.eprg.group.cam.ac.uk/wp-content/uploads/2014/01/binder2.pdf> accessed 22 March 2019.

Consumer trust in P2P-ETPs relies on the social collective's confidence in smart technology. To increase consumer trust, the European Consumer Organisation[166] recommended the creation of transparent mechanisms to track the delivery of renewable energy.[167] Following the recommendations of a standardised consortium of P2P-ETP traders in the prior section, P2P-ETPs have four critical roles in facilitating energy transactions: helping consumers identify complementary preferences of types of energy and amount, establishing prices for transactions, accountability through smart contract automation, and providing legally binding contract clauses for coordinating services to execute transactions.

P2P-ETPs are emerging in economic and social shifts to greater decentralised energy systems. Smart contracts, once appropriately coded, should be compatible with the United Kingdom and the European Union's contract laws. While specific energy legislation would depend heavily on the design and construction of P2P-ETP networks, private DLT and blockchain-based smart contracts should be designed to comply with the existing legal structures aimed at protecting consumers.

VI. Conclusion

This paper discusses the potential benefits and shortcomings of implementing P2P-ETPs for energy trading in the interest of consumer protection, specifically for the United Kingdom. The P2P-ETP ecosystem would allow new market models to emerge for self-sustained energy trading. P2P-ETPs can facilitate energy trading for renewables, tracking time, and location of energy production, storage, and consumption. 'Green Tariffs'[168] have been introduced in the European Union and the United States for retail supply contracts to certify the percentage of renewable sources for consumer interest. This benefit would translate into greater consumer responsibility toward energy consumption and lower carbon emissions by promoting renewable energy use.

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[166] BEUC, ' Ensuring Consumer Protection in the Platform Economy - Position Paper' (The European Consumer Organisation 2018) <https://www.beuc.eu/publications/beuc-x-2018-080_ensuring_consumer_protection_in_the_platform_economy.pdf> accessed 29 June 2019.
[167] Ibid.
[168] Leila Dagher, Lori Bird and Jenny Heeter, 'Residential Green Power Demand In The United States' (2017) 114 Renewable Energy.

However, consumers take potential risks including legal uncertainty of smart contract, violations of privacy right and data protection, pricing manipulation, and systemic failure due to coding failure of smart contracts. It is submitted that smart contracts alone cannot be legally binding and a hybrid system including a traditional contract should continue to be used to mitigate the risk of legal uncertainty. Trust and cooperative groups serve as links between consumers through smart contracts and communication via P2P devices such as smart meters. As technology progresses, the law must be adaptable. With adequate legislation and coordination, P2P-ETPs can open the gates for consumers to produce, consumer and share (through trading) energy with greater knowledge, accountability, awareness, and protection than the traditionally established energy market arrangement.

While the P2P-ETP system is still in its early stages, stability is essential for smaller-scale community projects, such as the Brooklyn Energy Trading Project.[169] It is suggested that, to maintain consumer trust, these smaller-scale projects should be operated and maintained by an independent body through public funding or yearly consumer payments.

[169] 'Brooklyn Microgrid | Community Powered Energy' (Brooklyn Microgrid, 2019) <https://www.brooklyn.energy/> accessed 29 June 2019.

BIBLIOGRAPHY

CASE LAW

- Armstrong DLW GmbH v Winnington Networks Ltd
- Business Energy Solutions Ltd and others v Crown Court at Preston [2018] 2018] EWHC 1534 (Admin)
- Carlill v Carbolic Smoke Ball Company [1892] EWCA Civ 1
- Court of Appeal (Civil Division). Computer Associates UK Ltd v The Software Incubator Ltd [2018] EWCA Civ 518 (19 March 2018).
- Joined Cases C-293/12 and 594/12 Digital Rights Ireland ltd and Seitlinger and others
- N. S. (C-411/10) v Secretary of State for the Home Department and M. E. and Others (C-493/10) v Refugee Applications Commissioner and Minister for Justice, Equality and Law Reform.
- Re Celtic Extraction Ltd (In Liquidation) [2001] Ch 475.
- St Albans City and District Council v International Computers Ltd [1996] 4 All ER 481
- WRM Group Ltd v Wood (1998) CLC 189.

LEGISLATION

- Consumer Rights Act 2015
- Criminal Justice and Police Act 2001
- Data Protection Act 2018
- Directive (EU) 2006/32 EC
- Directive (EU) 2006/32/EC
- Directive (EU) 2009/72/EC
- Directive (EU) 2018/2001
- Directive (EU) 2006/24/EC
- General Data Protection Regulation 2016/679
- Police and Criminal Evidence Act 1984
- Regulation 713/2009.
- Renewable Energy Directive (EU) 2018/2001/EU
- The Charter of Fundamental Rights of the European Union

- The Commercial Agents (Council Directive) Regulations 1993/3053
- UNITED STATES: Energy Independence and Security Act of 2007

JOURNALS

- A. Brown, and others, ‘Initiative, Smart Grid Issues in State law and Regulations’ (2010)
- A. Carson, 'Stakeholders Aim to Craft Smart Grid Privacy Code of Conduct' (*The Privacy Advisor*, 27 February 2013) <https://iapp.org/news/a/2013-02-27-stakeholders-aim-to-craft-smart-grid-privacy-code-of-conduct/> accessed 1 February 2019.
- Alharby M, and Moorsel A, 'A Systematic Mapping Study On Current Research Topics In Smart Contracts' (2017) 9 International Journal of Computer Science and Information Technology
- Andoni M and others, 'Blockchain Technology In The Energy Sector: A Systematic Review Of Challenges And Opportunities' (2019) 100 Renewable and Sustainable Energy Reviews
- Brown H, Suryanarayanan S, and Heydt G, 'Some Characteristics Of Emerging Distribution Systems Considering The Smart Grid Initiative' (2010) 23 The Electricity Journal
- C. Fischer ‘Feedback on household energy consumption: a tool for saving energy?’ (2008) <10.1007/s12053-008-9009-7> accessed on 18 January 2019.
- Cartwright P, 'Understanding and Protecting Vulnerable Financial Consumers' (2014) 38 Journal of Consumer Policy <https://link.springer.com/article/10.1007/s10603-014-9278-9> accessed 5 January 2019
- Chessman C, 'A Source Of Error: Computer Code, Criminal Defendants, And The Constitution' (2017) 105 California Law Review
- D. Wright, and others ‘Sorting outsmart surveillance' (2010) 26(4)Computer Law & Security Review < https://doi.org/10.1016/j.clsr.2010.05.007> accessed 20 January 2019.

- Dagher L, L BirdJ Heeter, 'Residential Green Power Demand In The United States' (2017) 114 Renewable Energy
- Dick CA Praktiknjo, 'Blockchain Technology And Electricity Wholesale Markets: Expert Insights On Potentials And Challenges For OTC Trading In Europe' (2019) 12 Energies
- Energy Systems: An Overview' (2018) MDPI Sustainability Journal.
- Fischer, C. (2008). Feedback on household electricity consumption: a tool for saving energy?. *Energy Efficiency*, 1(1), pp.79-104.
- Goldenfein J, and Leiter A, 'Legal Engineering On The Blockchain: 'Smart Contracts' As Legal Conduct' (2018) 29 Law and Critique
- Governatori G and others, 'On Legal Contracts, Imperative And Declarative Smart Contracts, And Blockchain Systems' (2018) 26 Artificial Intelligence and Law
- Henly C, 'Energizing the Future with Blockchain' [2018] The Energy Bar Association Energy Law Journal <https://www.eba-net.org/assets/1/6/14-197-232-Blockchain_%5BFINAL%5D.pdf> accessed 19 June 2019.
- Henly C, 'ENERGIZING THE FUTURE WITH BLOCKCHAIN' [2018] The Energy Bar Association Energy Law Journal <https://www.eba-net.org/assets/1/6/14-197-232-Blockchain_%5BFINAL%5D.pdf>
- J. Forbush 'Regulating the Use and Sharing of Energy Consumption Data: Assessing California's SB 1476 Smart Meter Privacy Statute' (2011) 75 Alb. L. Rev. 341.
- J. Hsiao, "Smart" Contract on the Blockchain-Paradigm Shift for Contract Law?' (2017) 14(10) US-China Law Review
- J. Wu and Nguyen Khoi Tran, 'Application of Block Chain Technology in Sustainable Energy Systems: An Overview' (2018) MDPI Sustainability Journal.
- K. Christidis and M. Devetsikiotis, 'Blockchains and Smart Contracts for the Internet of Things' (2016) 4(-) IEEE Access.
- K. Doran, 'Climate Change and The Future of Energy: Privacy and Smart Grid: When Progress and Privacy Collide' (2011) 41 The University of Toledo L Rev 909-23, 910.
- King N, and Jessen P, 'Smart Metering Systems And Data Sharing: Why Getting A Smart Meter Should Also Mean Getting Strong Information Privacy

Controls To Manage Data Sharing' (2014) 22 International Journal of Law and Information Technology

- Leal-Arcas R, Lesniewska F, and Proedrou F, 'Smart Grids In The European Union: Assessing Energy Security, Regulation & Social And Ethical Considerations' (2018) 42 Columbia Journal of European Law
- Lee W and others, 'Direct Electricity Trading In Smart Grid: A Coalitional Game Analysis' (2014) 32 IEEE Journal on Selected Areas in Communications
- Levitin A, 'Pandora's Digital Box: The Promise And Perils Of Digital Wallets' (2018) 166 University of Pennsylvania Law Review
- M. Berberich and M. Steiner, 'Practitioner's Corner · Blockchain Technology and The GDPR – How to Reconcile Privacy and Distributed Ledgers?' (2016) 2 European Data Protection Law Review <https://edpl.lexxion.eu/article/EDPL/2016/3/21> accessed 7 November 2019.
- N. King and P. Jenssen, 'For privacy's sake: Consumer "opt-outs" for smart meters' (2014) 30(5) Computer Law and Security Review <10.1016/j.clsr.2014.07.001> accessed 11 January 2019.
- N. Szabo, 'Nick Szabo's Essays, Papers, and Concise Tutorials' (Humuvanl, 1994)
- O. Tene and J. Polonetsky, 'Privacy in the Age of Big Data a Time for Big Decisions' (2012) 63 (Online) Stanford Law Review <https://www.stanfordlawreview.org/online/privacy-paradox-privacy-and-big-data/>accessed 20 December 2018.
- Quinn E, 'Smart Metering And Privacy: Existing Laws And Competing Policies' [2009] SSRN Electronic Journal
- Ripple W and others, 'World Scientists’ Warning Of A Climate Emergency' [2019] BioScience
- Risteska Stojkoska B, and Trivodaliev K, 'A Review Of Internet Of Things For Smart Home: Challenges And Solutions' (2017) 140 Journal of Cleaner Production
- S. Darby, ‘The Effectiveness of Feedback on Energy Consumption’ (2006) Environmental Change Institute, University of Oxford. <https://www.eci.ox.ac.uk/research/energy/downloads/smart-metering-report.pdf> accessed on 18 January 2019.

- S. Zhou and M. Brown, ‘Smart meter deployment in Europe: A comparative case study on the impacts of national policy schemes’ (2016) 144 Journal of Cleaner Production < http://dx.doi.org/10.1016/j.jclepro.2016.12.031> accessed 11 January 2019.
- Sonia McNeil, ‘Privacy and the Modern Grid’ (2011) 25(1) Harvard Journal of Law and Technology.
- T. Morstyn, and others, ‘Using peer-to-peer energy-trading platforms to incentivize prosumers to form federated power plants,' (2018) Nature Energy, vol. 3, no. 2, pp. 94–101 <http://www.nature.com/articles/s41560-017-0075-y > accessed on 29 June 2019
- Wang N and others, 'Peer-To-Peer Energy Trading Among Microgrids With Multidimensional Willingness' (2018) 11 Energies
- Zhang F and others, 'Town Crier' [2016] Proceedings of the 2016 ACM SIGSAC Conference on Computer and Communications Security - CCS'16

BOOKS

- Primavera De Filippi and Aaron Wright, ‘*Blockchain and the Law: The Rule of Code*’ (Harvard University Press 2018)
- Treiblmaier H, 'Toward More Rigorous Blockchain Research: Recommendations For Writing Blockchain Case Studies' (2019) 2 Frontiers in Blockchain

REPORTS

- 'Smart Cities Background Paper' (Department for Business, Innovation and Skills 2013) <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/246019/bis-13-1209-smart-cities-background-paper-digital.pdf> accessed 13 March 2020
- 'Smarter London Together' (Greater London Authority 2018) <https://www.london.gov.uk/sites/default/files/smarter_london_together_v1.66_-_published.pdf> accessed 13 March 2020

- 'The Bank Of England’S Oversight Of Interbank Payment Systems Under The Banking Act 2009' (The Bank of England 2009) <https://www.bankofengland.co.uk/-/media/boe/files/news/2009/september/the-boes-oversight-of-interbank-payment-systems-under-the-banking-act-2009> accessed 25 February 2020
- BEUC, 'Ensuring Consumer Protection in the Platform Economy – Position Paper’ (The European Consumer Organisation 2018) <https://www.beuc.eu/publications/beuc-x-2018-080_ensuring_consumer_protection_in_the_platform_economy.pdf> accessed 29 June 2019
- CER11080a, Commission for Energy Regulation ‘Electricity Smart metering Customer Behaviour Trials (CBT) Findings Report’ (2011) < https://www.cru.ie/wp-content/uploads/2011/07/cer11080ai.pdf> accessed on 2 February 2019.
- Department for Business, Energy and Industrial Strategy, ‘Smart Metering Implementation Programme : Consultation on maximising interoperability for SMETS1 meters, including draft legal text’ < https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/700382/SMETS1_maximising_interoperability_enrolment_mandate_consultation_.pdf> accessed on January 28 2019.)
- Department of Business, Energy and Industrial Strategy ‘Smart meter Roll-Out Cost-Benefit Analysis (2016) <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/567167/OFFSEN_2016_smart_meters_cost-benefit-update_Part_I_FINAL_VERSION.PDF> accessed 9 January.
- Department of Energy and Climate Change ‘Smart Metering Early Learning Project: Domestic Energy Consumption Analysis’ (2015)< https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/407568/8_Synthesis_FINAL_25feb15.pdf> accessed 9 January 2019.
- Economic and Social Research Council, ‘Smart Metering And Electricity Demand: Technology, Economics And International Experience’ (Economic

and Social Research Council 2018) <https://www.eprg.group.cam.ac.uk/wp-content/uploads/2014/01/binder2.pdf> accessed 22 March 2019

- European Commission, Directorate-General for Energy, 'Communication From the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions United In Delivering The Energy Union And Climate Action - Setting The Foundations For A Successful Clean Energy Transition' (2019)
- European Data Protection Supervisor, 'Opinion of the European Data Protection Supervisor on the Commission Recommendation on preparations for the Roll-out of Smart Metering Systems' < https://edps.europa.eu/sites/edp/files/publication/12-06-08_smart_metering_en.pdf> accessed on January 15th 2019
- European Smart Metering Industry Group 'The potential of smart meter enabled programs to increase energy and systems efficiency' (2011) < https://esmig.eu/sites/default/files/2011.10.12_empower_demand_report_final.pdf> accessed on 1 February 2019.
- House of Commons: Energy and Climate Change Committee 'The energy revolution and future challenges for UK energy and climate change policy — Third Report of Session 2016–17 — HC 705' (2016) <https://publications.parliament.uk/pa/cm201617/cmselect/cmenergy/705/705.pdf> accessed on 15 January 2019.
- Institute of International Finance, 'Getting Smart: Contracts On The Blockchain' (Institute of International Finance 2016).
- Ofgem, 'Licence guide: smart metering' (*Ofgemgovuk*, 16 November 2017) <https://www.ofgem.gov.uk/system/files/docs/2017/11/smart_metering.pdf> a ccessed 24 January 2019.
- Ofgem, 'Statutory Consultation On The Post-2020 Smart Meter Rollout Reporting Requirements' (2019) <http://Statutory Consultation on the Post-2020 Smart Meter Rollout Reporting Requirements> accessed 24 February 2020
- The Office of Gas and Electricity Markets, Draft Forward Work Programme 2018-2019 (2018)

- United Nations Conference on Trade and Development: Guidelines for Consumer Protection UNCT AD/DITC/CPLP/MISC/2016/1 <https://unctad.org/en/PublicationsLibrary/ditccplpmisc2016d1_en.pdf> accessed on January 24 2019.
- United Nations General Assembly, 'Transforming Our World: The 2030 Agenda For Sustainable Development' (United Nations 2015) <https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E> accessed 23 June 2019
- United Nations, 'Transforming Our World: The 2030 Agenda For Sustainable Development' (United Nations General Assembly 2015) <https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E> accessed 13 March 2020
- United States Department of energy, 'Voluntary Code of Conduct Final Concepts and Principles' (*Energygov*, January 2015) <https://www.energy.gov/sites/prod/files/2015/01/f19/VCC%20Concepts%20and%20Principles%202015_01_08%20FINAL.pdf> accessed 3 January 2019
- Wang S, Zhang C, and Su Z, 'Detecting Nondeterministic Payment Bugs In Ethereum Smart Contracts' (2019) 3 Proceedings of the ACM on Programming Languages

WEBSITES

- '9 Key Tools And Technologies To Develop And Test Blockchain Applications' (*Coinspeaker*, 2019) <https://www.coinspeaker.com/tools-technologies-blockchain-applications/> accessed 29 June 2019
- 'A New Coalition Looks To Accelerate The Pace Of Blockchain In The Energy Sector' (*Greentechmedia.com*, 2019) <https://www.greentechmedia.com/ articles/read/bringing-blockchain-technology-to-the-grid#gs.wuvVMW8> accessed 29 June 2019
- 'BMG 101 | Brooklyn Microgrid | Community Powered Energy' (*Brooklyn Microgrid*, 2019) <https://www.brooklyn.energy/bmg-101> accessed 29 June 2019

- 'Brooklyn Microgrid | Community Powered Energy' (*Brooklyn Microgrid*, 2019) <https://www.brooklyn.energy/> accessed 29 June 2019
- 'Exercise: Simple Solidity Smart Contract For Ethereum Blockchain | Codementor' (*Codementor.io*, 2019) <https://www.codementor.io/rogargon/exercise-simple-solidity-smart-contract-for-ethereum-blockchain-m736khtby> accessed 29 June 2019
- 'Ovo Energy To Pay £8.9M For Overcharging Customers' (*BBC News*, 2020) <https://www.bbc.co.uk/news/business-51292695> accessed 24 February 2020
- 'Piclo.Energy' (*Piclo.uk*, 2019) <https://piclo.uk> accessed 29 June 2019
- 'The Law Applicable To Smart Contracts, Or Much Ado About Nothing?' (*Oxford Law Faculty*, 2019) <https://www.law.ox.ac.uk/business-law-blog/blog/2019/01/law-applicable-smart-contracts-or-much-ado-about-nothing> accessed 29 June 2019
- 'Whatsapp Voice Calls Used To Inject Israeli Spyware On Phones | Financial Times' (*Ft.com*, 2019) <https://www.ft.com/content/4da1117e-756c-11e9-be7d-6d846537acab> accessed 29 June 2019
- A. Hern, 'Smart Electricity Meters Can Be Dangerously Insecure, Warns Expert' *The Guardian* (2016) <https://www.theguardian.com/technology/2016/dec/29/smart-electricity-meters-dangerously-insecure-hackers> accessed 22 March 2019.
- C. Steitz and Harro H. Ten Wolde, 'Smart' Technology Could Make Utilities More Vulnerable To Hackers' (*Thomson Reuters*, 2014) <https://www.reuters.com/article/us-utilities-cybersecurity/smart-technology-could-make-utilities-more-vulnerable-to-hackers-idUSKBN0FK1SZ20140716> accessed 22 March 2019.
- CBC, 'SaskPower To Remove 105,000 Smart Meters Following Fires' (2014) <https://www.cbc.ca/news/canada/saskatchewan/saskpower-to-remove-105-000-smart-meters-following-fires-1.2723046> accessed 22 March 2019.
- Coin Idol, 'Blockchain and Smart Contracts Definitions in Italy In 2019' (*Coinidol.com*, 2019) <https://coinidol.com/smart-contracts-definitions/> accessed 22 March 2019.

- D. Campbell, 'Excess Winter Deaths In England And Wales Highest Since 1976' *The Guardian* (2018) <https://www.theguardian.com/society/2018/nov/30/excess-winter-deaths-in-england-and-wales-highest-since-1976> accessed 22 March 2019.
- Enterpriseinnovation.net, 'Global Data: Blockchain is the missing link to transform electric power industry'(*Enterprise Innovation | Asia's Premier Business and Technology Publication*, 31 December 2018) <https://www.enterpriseinnovation.net/article/globaldata-blockchain-missing-link-transform-electric-power-industry-751371248> accessed 2 February 2019
- L. Benichou, 'AXA Launches Ethereum Smart Contract Insurance Product for Flight Delays' (Trustnodes, June 18 2018) < https://www.trustnodes.com/2018/06/18/axa-launches-ethereum-smart-contract-insurance-product-flight-delays> accessed on December 4 2018
- M. Bennett, 'Excess Winter Mortality In England And Wales: 2017 To 2018 (Provisional) And 2016 To 2017 (Final)' (Office for National Statistics 2018) <https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/bulletins/excesswintermortalityinenglandandwales/2017to2018provisionaland2016to2017final> accessed 22 March 2019.
- Möslein F, 'Legal Boundaries Of Blockchain Technologies: Smart Contracts As Self-Help' <https://www.law.ox.ac.uk/business-law-blog/blog/2019/01/legal-boundaries-blockchain-technologies-smart-contracts-self-help> accessed 13 March 2020
- Office of Gas and Electricity Markets, 'Ofgem Orders Nine Energy Suppliers To Become DCC Users' (2020) <https://www.ofgem.gov.uk/publications-and-updates/ofgem-orders-nine-energy-suppliers-become-dcc-users> accessed 13 March 2020
- Ofgem (2019). *Statutory Consultation on the Post-2020 Smart Meter Rollout Reporting Requirements*. [online] Available at: http://Statutory Consultation on the Post-2020 Smart Meter Rollout Reporting Requirements [Accessed 24 Feb. 2020].

- Ovoenergy.com, 'Guide to energy meters' (*Ovoenergy.com*, 2012) <https://www.ovoenergy.com/guides/energy-guides/energy-meters.html> accessed 2 February 2019.
- Trustarccom, 'Privacy Risk Summit Preview: Privacy by Design for IoT' (*TrustArc Blog*, 26 May 2016) <https://www.trustarc.com/blog/2016/05/23/privacy-risk-summit-preview-privacy-design-iot/> accessed 2 February 2019.