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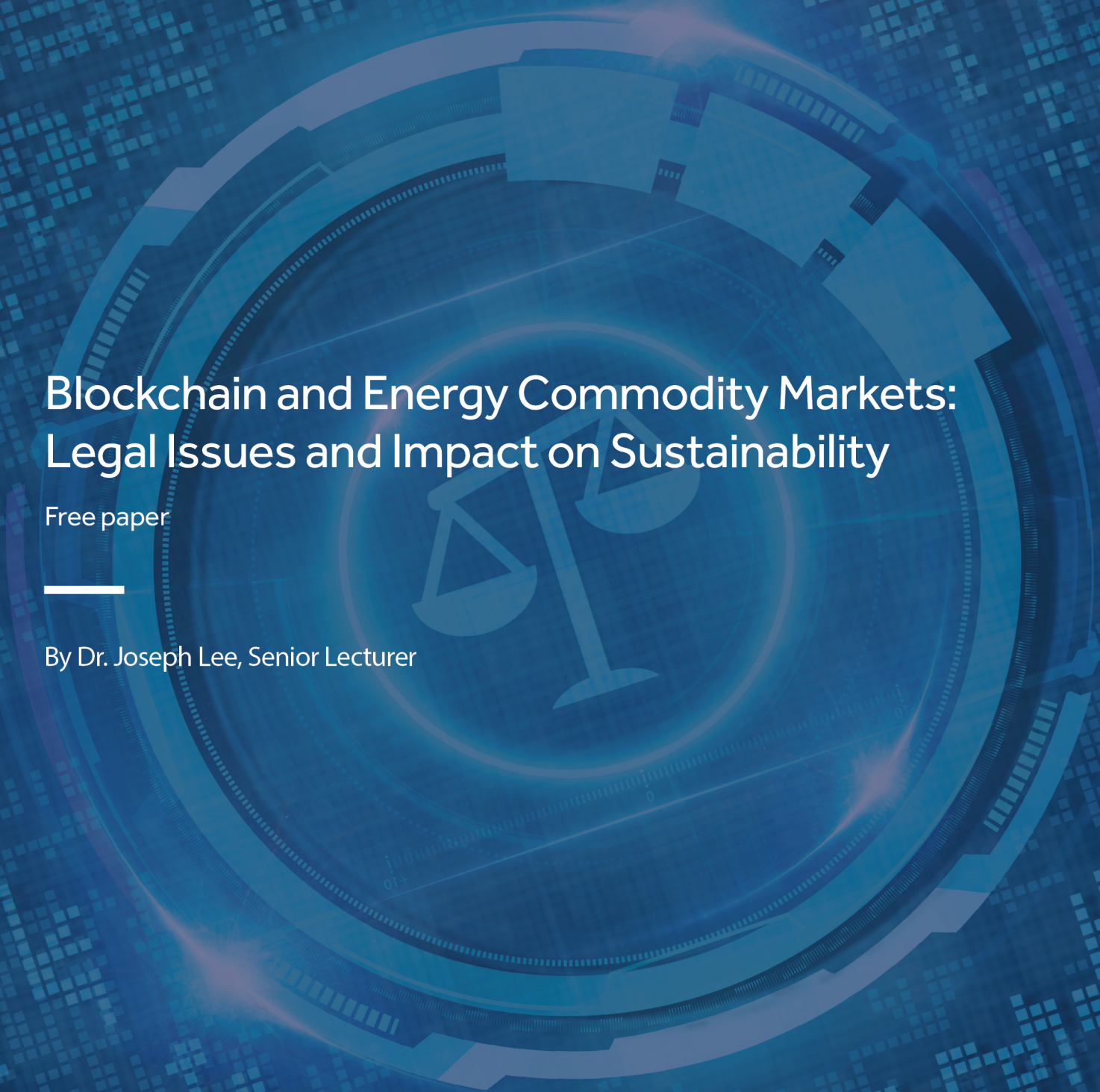

Blockchain and Energy Commodity Markets: Legal Issues and Impact on Sustainability

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Blockchain and Energy Commodity Markets: Legal Issues and Impact on Sustainability

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Abstract

In this article, we explore the application of blockchain, a type of distributed ledger technology (DLT), in the field of energy trading. Specifically, we focus on crude oil trade. We argue that the application of blockchain technology and supplementary smart contracts supports responsible sourcing in complex supply chains and helps reduce information asymmetry in both the physical trade and paper trade of energy commodities markets. In order to apply blockchain technology to the energy market, we begin with a discussion on the architecture of blockchain and the different types of blockchain that might be applied in this sector. Further to this, we examine the current oil trading markets, particularly their relevant components, as part of the discussion on blockchain application. Subsequently, we look at how the various types of blockchain may be applied to the markets and examine their advantages and disadvantages. In conclusion, we look at the legal issues that may arise from such application, the potential solutions, and the potential impact of blockchain technology on the United Nations Sustainable Developmental Goals in the future and how a green fintech application can be developed.

Keywords: Blockchain, oil trade, energy market, smart contract, sustainability, green fintech, UN sustainable development goals (SDGs), geopolitical conflicts, sanctions

Introduction

The application of blockchain technology to energy trading has become interesting and thought-provoking over the last few years.[1] It has been said that after the 'hype' of crypto-

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[1] J Lee *Crypto Finance, Law and Regulation: Governing an Emerging Ecosystem* (Routledge Abingdon 2022); 'Shell, Accenture, Amex in Blockchain Project for Sustainable Air Fuel' Ledger Insights 21 June 2022 https://www.ledgerinsights.com/shell-accenture-amex-blockchain-sustainable-aviation-fuel-saf/ accessed 21 August 2022); E Terazono 'Chevron, Total and Reliance join Blockchain-based Oil Trading Platform' Financial Times 16 January 2019 https://www.ft.com/content/9eb01af6-1964-11e9-b93e-f4351a53f1c3 accessed 21 August 2022); 'ExxonMobil, Shell Oil Consortium Trials Blockchain to Decide Joint Venture Interest' Ledger Insights 19 December 2019 https://www.ledgerinsights.com/blockchain-oil-consortium-joint-venture-afe-ballot/ (Accessed 21 August 2022); Blockchain Technology, Shell https://www.shell.com/energy-and-innovation/digitalisation/digital-technologies/blockchain.html accessed 21 August 2022; Total Energies, FlexiDAO Case Study, FlexiDAO

currency markets, the underlying blockchain technology will be developed further and applied in other areas.[2] In this article, we will discuss how the application of blockchain, a type of distributed ledger technology (DLT), in the field of energy trading will assist the energy industry with efficiency, transparency, and supply chain management.[3] We argue that *the application of blockchain technology and supplementary smart contracts supports responsible sourcing in complex supply chains and helps reduce information asymmetry in both the physical trade and paper trade of energy commodities*. To this end, we will use crude oil trade as an example. In Part I, we discuss the architecture of blockchain and the different types of blockchain that might be applied in this sector. In Part II, we examine the current oil trading markets, particularly their relevant components, as part of the discussion on blockchain application. Part III looks at how blockchain and its different types may be applied to the markets and examines the advantages and disadvantages of such application in supply chain management. In Part IV, we look at the legal issues that may arise from such application and the potential solutions. Finally, in Part V, we explore the potential future impact of blockchain technology on the United Nations Sustainable Developmental Goals (SDGs) and whether a green tech application can be developed. In closing, we summarise our findings and chart potential applications for a sustainable system of Blockchain for the Oil and Gas Industry.

PART I

What is Blockchain?

Blockchain is a collection of technologies that are distributed across a peer-to-peer network in combination with cryptography as security.[4] It is defined as '*a data structure that makes it*

https://www.flexidao.com/case-studies/total-energies accessed 21 August 2022; 'Six Next-generation Technologies that Matter for the Energy Industry' BP 6 Sep 2017 https://www.bp.com/en/global/corporate/news-and-insights/reimagining-energy/next-generation-technologies-that-matter-for-energy-industry.html accessed 21 August 2022.

[2] M Andoni, V Robu, D Flynn, S Abram, D Geach, D Jenkins, P McCallum, A Peacock 'Blockchain Technology in the Energy Sector: A Systematic Review of Challenges and Opportunities' (2019) 100 Renewable and Sustainable Energy Reviews 143-174 https://doi.org/10.1016/j.rser.2018.10.014.

[3] Ziaul Haque Munim, Srinivasan Balasubramaniyan, Mahtab Kouhizadeh, Niamat Ullah Ibne Hossain 'Assessing Blockchain Technology Adoption in the Norwegian Oil and Gas Industry Using Bayesian Best Worst Method' (2022) 28 Journal of Industrial Information Integration, https://doi.org/10.1016/j.jii.2022.100346; C Yapa, de Alwis, M Liyanage, J Ekanayake 'Survey on Blockchain for Future Smart Grids: Technical Aspects, Applications, Integration Challenges and Future Research' (2021) 7 Energy Reports 6530-6564 https://doi.org/10.1016/j.egyr.2021.09.112.

[4] G Kessler 'An Overview of Cryptography' (*Gary Kessler*, 1998) <https://www.garykessler.net/library/crypto.html> accessed 21 August 2022

possible to create a digital ledger of data and share it among networked independent parties'.[5] Thus, it can be said that blockchain technology is a digital, distributed structure that is used to record and store transactions in a secure and transparent digital ledger.[6] This structure has the additional benefit of being immutable and tamper resistant.[7]

The tamper-resistant infrastructure upon which blockchain technology is made up of comprises of hash pointer nodes. Hash Pointers store the address of data variables which allows users to not only retrieve the data, but also verify whether the data has been modified or compromised.[8] As such, users on blockchain technology trust the system to deliver a reliable outcome on the back of peer-to-peer validation built upon a collective system rather than a singular, individual controller. In recent years, blockchain technology has gained popularity through its successful application to transactions of cryptocurrencies such as Bitcoin (BTC) and Ethereum (ETH). These two cryptocurrencies use public chains as their infrastructure, and the underlying technology allows for diverse applications in different commercial and non-commercial industries.[9]

In contrast, Facebook proposed the use of a private chain in the development of its own cryptocurrency, DIEM.[10] The technology has also been applied to land registration systems to track the transfer of ownership of property through peer-to-peer verification. Furthermore, in international trade, blockchain technology has been proposed for the validation of documents such as bills of lading in cargo deliveries.[11] Blockchain has also been applied to the issuance of securities to investors within the financial sector through initial coin offerings (ICOs) and

[5] F Casino, T Dasaklis and C Patsakis 'A Systematic Literature Review of Blockchain-Based Applications: Current Status, Classification and Open Issues' (2019) 36 Telematics and Informatics 55-81 <https://doi.org/10.1016/j.tele.2018.11.006> accessed 21 August 2022.
[6] P De Filippi and A Wright *Blockchain and the Law: The Rule of Code* (Harvard University Press Boston 2018).
[7] Ibid.
[8] X Zhu and T Fan 'Research on Application of Blockchain and Identity-Based Cryptography' (IOP Conference Series: Earth and Environmental Science 2019) 252:042095 < https://iopscience.iop.org/article/10.1088/1755-1315/252/4/042095/pdf> accessed 21 August 2022.
[9] E Tan, S Mahula and J Crompvoets 'Blockchain Governance in the Public Sector: A Conceptual Framework for Public Management' (2022) 39 (1) Government Information Quarterly, Article 101625 <https://doi.org/10.1016/j.giq.2021.101625> accessed 21 August 2022.
[10] R Browne 'Facebook-backed Diem Aims to Launch Digital Currency Pilot Later this Year' (CNBC, April 20 2021) <https://www.cnbc.com/2021/04/20/facebook-backed-diem-aims-to-launch-digital-currency-pilot-in-2021.html> accessed 21 August 2022.
[11] J Lee 'Cryptoassets, Developments and the Regulatory Perimeter' in I Chiu, & G Deipenbrock (eds) *Routledge Handbook on FinTech and Law – Regulatory, Supervisory, Policy and other Legal Challenges* (Routledge Abingdon 2021); M Shope 'The Bill of Lading on the Blockchain: An Analysis of its Compatibility with International Rules on Commercial Transactions' (2021) 22 Minn. J.L. Sci. & Tech. 163 Available at: https://scholarship.law.umn.edu/mjlst/vol22/iss1/6

security token offerings (STOs). The common thread among all these applications is the benefit of the cryptographic protocol rather than any specific third-party intervention.[12] Notably, there are a few blockchain use cases in governmental initiatives and the public sector such as the Argentina DIDI which is the first self-sovereign digital identity project[13] and a public procurement platform in Chile.[14]

Another key feature of blockchain technology is the fact that it is considered tamper resistant due to its use of the so-called 'tamper-proof boxes'.[15] These serve as a log of time-stamped records, which create a sequential chain of blocks, with each block possessing the information of the previous block. Thus, the chain of blocks represents the essence of the term 'blockchain'. These blocks, as the technology currently stands, allow anyone with access to the ordered, back-linked list of blocks to read the data and understand the context of information held on the chain network.[16] As mentioned previously, the structure of the blockchain ensures that the integrity of the information stored on the blockchain reflects the sequential data agreed upon by the users of the blockchain. As such, the inherent structure reflects the tamper-resistant nature of blockchain technology as demonstrated in blockchain-based voting and decision making.[17]

How Does Blockchain Technology Work?

As outlined above, a blockchain network operates as a set of blocks that run on the same chain via the copy each block holds.[18] Therefore, it contributes to the development of a peer-to-peer network, which is the cornerstone of blockchain accountability. Users interact with a

[12] G Kessler 'An Overview of Cryptography' (*Gary Kessler*, 1998) <https://www.garykessler.net/library/crypto.html> accessed 21 August 2022

[13] World Bank *Argentina ID Case Study: The Evolution of Identification. Identification for Development (*World Bank, Washington, DC 2022*)*<https://openknowledge.worldbank.org/handle/10986/33403> accessed 21 August 2022.

[14] C Parenti, N Noori and M Janssen 'A Smart Governance Diffusion Model for Blockchain as an Anti-corruption tool in Smart Cities' (2022) 1 (1) Journal of Smart Cities and Society 71-92 < https://doi.org/10.3233/scs-210122> accessed 21 August 2022.

[15]G Kessler, 'An Overview of Cryptography' (*Gary Kessler*, 1998) <https://www.garykessler.net/library/crypto.html> accessed 21 August 2022.

[16] K Christidis and M Devetsikiotis 'Blockchains And Smart Contracts For The Internet Of Things' (2016) 4 IEEE Access < https://people.cs.pitt.edu/~mosse/courses/cs3720/blockchain-iot.pdf> accessed 21 August 2022.

[17] U Jafar, M Aziz and Z Shukur, 'Blockchain for Electronic Voting System—Review and Open Research Challenges' (2021) 21 Sensors 5874 <http://dx.doi.org/10.3390/s21175874> accessed 21 August 2022.

[18]J Lee and VM Khan 'Blockchain and Smart Contract for Peer-to-Peer Energy Trading Platform: Legal Obstacles and Regulatory Solutions' (2020) 19(4) John Marshall Review of Intellectual Property Law 283-308 < https://repository.law.uic.edu/ripl/vol19/iss4/1/> accessed 21 August 2022.

blockchain network via private or public keys depending on the accessibility of the chain itself. Private keys provide access to individuals' own transactions, and public keys create access to the network. This dual system works as a form of 'asymmetric cryptography',[19] which lends authentication and integrity to the transactions in the network.[20] Each block is identified by its cryptographic lock and references the block that came before it.[21] Blockchain blends several existing technologies, including peer-to-peer networks, public and private key cryptography, and consensus mechanisms, in order to create a highly resilient and immutable ledger.[22] They are not centrally managed and operate collectively through a peer-to-peer network comprised of a system of computers.[23] However, as they are not centrally managed, no single party needs to control access to them in the same way as the current regulatory technology. As such, it supports decentralised global value transfer systems that are both transnational and pseudonymous.[24] This decentralisation is integral in the invention of blockchain and other peer-to-peer technologies stemming from the Bitcoin White Paper.[25]

Each block on the chain is verified through a consensus mechanism, which involves the validation of the collective network to facilitate accountability and accuracy when recording transactions.[26] When new transactions are added to the end of the main blockchain with a corresponding timestamp, it ensures that the data encoded on the chain is reliable and protects the integrity of the stored data.[27] Once all the blocks are validated and a block is established on the chain, the distributed ledger cannot be altered or deleted. Further, copies of the transaction and the time stamp are stored in the corresponding computer on the collective chain.[28]

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[19] Ibid.
[20] Ibid.
[21] P De Filippi and A Wright, *Blockchain and the Law: The Rule of Code* (Harvard University Press Boston 2018).
[22] K Christidis and M Devetsikiotis 'Blockchains And Smart Contracts For The Internet Of Things' (2016) 4 IEEE Access < https://people.cs.pitt.edu/~mosse/courses/cs3720/blockchain-iot.pdf> accessed 21 August 2022.
[23] P De Filippi and A Wright, *Blockchain and the Law: The Rule of Code* (Harvard University Press Boston 2018).
[24] Ibid.
[25] S Nakamoto 'Bitcoin: A Peer-to-Peer Electronic Cash System' (*Bitcoin*, 2008) <https://bitcoin.org/bitcoin.pdf> accessed 21 August 2022.
[26] P De Filippi and A Wright, *Blockchain and the Law: The Rule of Code* (Harvard University Press Boston 2018) 33–5 (describing the blockchain as a transnational network for which national borders are largely irrelevant).
[26] Ibid 46
[27] D Oyinloye, J Teh, N Jamil and M Alawida, 'Blockchain Consensus: An Overview of Alternative Protocols' (2021) 13 (8) Symmetry 1363 < **https://doi.org/10.3390/sym13081363**> accessed 21 August 2022.
[28] M Rauchs and others, 'Distributed Ledger Technology Systems: A Conceptual Framework' (University of Cambridge Centre for Alternative Finance 2018) <https://www.jbs.cam.ac.uk/faculty-research/centres/alternative-finance/publications/distributed-ledger-technology-systems/#.YwL-InZKi5d> accessed 21 August 2022.

Types of Blockchain

The application of blockchain, however, is not a monolithic system. There are multiple models that can be applied depending on the intended use.[29] These models can be easily broken up into three categories: public chains, private chains, and hybrid chains.[30] A public chain allows any user on the network to download the software as an open-source code using an internet connection and participate in the network by adding information to the shared, distributed ledgers.[31] This information is then validated through the block network according to a consensus rule.[32] In contrast, a private chain is developed and maintained by a single entity and/or a consortium, which allows participants to input information on the shared distributed ledger.[33] The user's ability to participate in the network, input information, and access the data held on the ledger is determined through the consensus mechanism created by the network. A private chain, however, can be created to be permission-less or require specific keys that would enable authorised users to participate in the chain itself.

Hybrid blockchains are a combination of public and private chains wherein the public blockchain acts as the main chain.[34] The public blockchain is linked to a multitude of private chains through shared blocks.[35] An example of a hybrid blockchain system is found in the IBM Food Trust which allows supply chain partners to securely share tracking information related to perishable food supplies.[36] The advantage of combining private and public blockchains in this way is that it facilitates communication between multiple chains. Hybrid chains are still in developmental stages; however, the convenience of accessing a main public chain while ensuring the integrity of private chains for transactions gives the user the ability to navigate the technology in the most beneficial way unique to their own use.[37] In operating blockchain

[29] J Lee 'Cryptoassets, Developments and the Regulatory Perimeter' in I Chiu & G Deipenbrock (eds) *Routledge Handbook on FinTech and Law – Regulatory, Supervisory, Policy and other Legal Challenges* (Routledge Abingdon 2021).
[30] T Schrepel 'Collusion By Blockchain And Smart Contracts' (2019) 33 (1) Harvard Journal of Law & Technology 117-166 < https://jolt.law.harvard.edu/assets/articlePDFs/v33/03-Schrepel.pdf> accessed 21 August 2022.
[31] A Ferreira 'The Curious Case of Stablecoins—Balancing Risks And Rewards?' (2021) 24 Journal of International Economic Law 755–77 <https://doi.org/10.1093/jiel/jgab036> accessed 21 August 2022.
[32] Ibid.
[33] Ibid.
[34] J Lee *Crypto Finance, Law and Regulation: Governing an Emerging Ecosystem*, Chapter 2 (Routledge Abingdon 2022).
[35] Ibid.
[36] J Xu, S Guo, D Xie, Y Yan 'Blockchain: A new safeguard for agri-foods' (2020) 4 Artificial Intelligence in Agriculture 153-161 <https://doi.org/10.1016/j.aiia.2020.08.002> accessed 21 August 2022.
[37] Ibid.

technology in these ways, it is imperative to understand the consensus mechanisms attached to their function. The most common consensus mechanism is known as proof of work.[38]

Proof of work is the most common consensus mechanism and utilizes the application of solving puzzles to establish the credibility and integrity of data and information.[39] These calculations with proof of work are known as mining and involve a computerized system of arithmetic to generate a valid solution. Once the puzzle is solved, the solution is broadcast to other blocks to achieve consensus, which increases the validity of the presented information and provides assurance. Any change made to a block will require a new proof of work, which makes it difficult to carry out fraudulent practices. However, proof of work (POW) is computationally expensive, presenting a major disadvantage when applied to large-scale applications.[40] However, in light of this, the blockchain industry is looking into alternative methods such as proof of stake (POS). Therefore, in the context of this paper, the benefits of applying blockchain systems to energy trading markets must be assessed within the lens of blockchain technology's current application systems.

PART II

Current Trading Market

The current trading market for energy commodities is a complex industry. However, this paper shall focus on applying blockchain technology to two distinct facets: physical trade and derivatives trade.

Physical Trade

The business of physical trading of energy commodities involves diverse industries, and the transaction life cycle, including the value and supply chain, consists of several intermediaries. These include trade finance, trade facilitation, insurance, risk management, on-site inspection,

[38] Á Hajdu and D Jovanović 'SOLC-VERIFY: A Modular Verifier for Solidity Smart Contracts' (2020) Verified Software: Theories, Tools and Experiments 161-179 <https://doi.org/10.1007/978-3-030-41600-3_11> accessed 21 August 2022.
[39] A Bolfing *Cryptographic Primitives In Blockchain Technology: A Mathematical Introduction* (Oxford University Press Oxford 2020).
[40] Ibid.

verification, certification, shipping, and logistics.[41] These factors contribute to significant paperwork surrounding commodity trading and encompass both digital PDFs and physical paper records.[42] Each party involved in physical trading requires consistent and accurate verification with a unified consensus for progression at each step. Therefore, each party would be exposed to different types of data and information tracking systems spanning each unique trade. Hence, streamlining and optimization of the shipment and trading process with physical commodities has become a significant challenge with respect to the unification and accessibility of information and data across numerous jurisdictions and commodities.[43]

In terms of physical trading, there is approximately 159 litres of oil stored within a barrel and approximately 3.8 litres of crude oil can be refined and made into 1.78 litres and up to 2.54 litres of gasoline.[44] However, this is dependent upon the quality of the crude oil and a multitude of other factors.[45] Despite the consistent production of oil and gas, the market price of physical trading can fluctuate immensely as a result of consumption, supply, demand and geopolitical considerations.[46] The sectors of physical trading can be summarized into three parts: Upstream, Midstream and Downstream.

Upstream

Businesses associated with the upstream segment of the oil and gas industry are involved in the exploration, drilling and production. Companies such as Devon Energy or Occidental, are examples of firms which are focused on the upstream function in the supply chain of the oil and gas industry. Most upstream crude oil production is controlled by National Oil Companies,

[41] H Baker, G Filbeck and J Harris, *Commodities: Markets, Performance, And Strategies* (Oxford University Press Oxford 2018).
[42] Ibid.
[43] J Lee 'Embedding Cryptoassets in the Law to Transform the Financial Market: Security Token Offering in the UK' in P Maume, L Maute, M Fromberger (eds.) *Law of Crypto Assets* (Beck/Hart/Nomos Munich/Oxford/Baden-Baden 2021).
[44] BP PLC, 'Statistical Review of World Energy - Approximate Conversion Factors' BP PLC 2021 <https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-approximate-conversion-factors.pdf> accessed 21 August 2022.
[45] Statista, 'Crude Oil Products Produced from One Barrel | Statista' Statista, 2010 <https://www.statista.com/statistics/856655/products-made-of-one-barrel-of-crude-oil> accessed 21 August 2022.
[46] US Energy Information Administration, "Energy & Financial Markets – Crude oil" US Energy Information Administration <https://www.eia.gov/finance/markets/crudeoil/supply-opec.php> accessed 21 August 2022

including such as China National Petroleum Corporatio,[47] or integrated international companies such as British Petroleum or Exxon Mobil which are involved in the entire value chain of the oil business. The market for Upstream companies specifically focuses on high investment capital and are extremely technologically intensive.

Midstream

Transportation is the main function of midstream businesses, and the responsibilities include the movement of extracted raw materials to refineries to process the oil and gas. The transportation of these products require shipment through ships, tankers, pipelines and storing the raw materials.[48] Typically, oil producing countries are not the final destination, and the transportation network is crucial ingredient to ensuring that the oil and gas is refined and then transported to the necessary mediums, such as gas stations. Storage facilities are used to balance the supply and demand of the necessary refined oil and gas.

Typical transportation options include pipelines, rail, trucks and ships. Pipelines are one of the most common mediums to move crude oil from the wellhead to the gathering and processing facilities.[49] From these facilities, they are sent to refineries and then tanker loading areas. Rail shipments are a newer transportation medium and are ideal for longer distance shipping.[50] Trucks are typically used during the final steps of the transportation process to deliver refined petroleum to the requisite storage areas.[51] Finally, ships are used to transport oil when large amounts of the commodity are being shipped to other countries and some ships can carry up to 30,000 barrels on a tank barge.[52]

Downstream

[47] Wipro Limited 'Oil Custody Transfer: Blockchain Comes to The Rescue - Wipro' Wipro.com, 2019 <https://www.wipro.com/blockchain/oil-custody-transfer-blockchain-comes-to-the-rescue/> accessed 21 August 2022.
[48] Library of Congress 'Research Guides: Oil and Gas Industry: A Research Guide: Modes of Transportation' (2021) <https://guides.loc.gov/oil-and-gas-industry/midstream/modes> accessed 21 August 2022.
[49] Ibid.
[50] Ibid.
[51] Ibid.
[52] J Frittelli 'Shipping U.S. Crude Oil By Water: Vessel Flag Requirements and Safety Issues' Congressional Research Service 2014 <https://sgp.fas.org/crs/misc/R43653.pdf> accessed 21 August 2022.

Refineries are the final segment of the oil and gas supply chain and comprise of the downstream businesses.[53] These companies are responsible for removing impurities from the crude oil and converting the oil and gas for public use, such as gasoline, jet fuel, asphalt and other products for overall consumption.

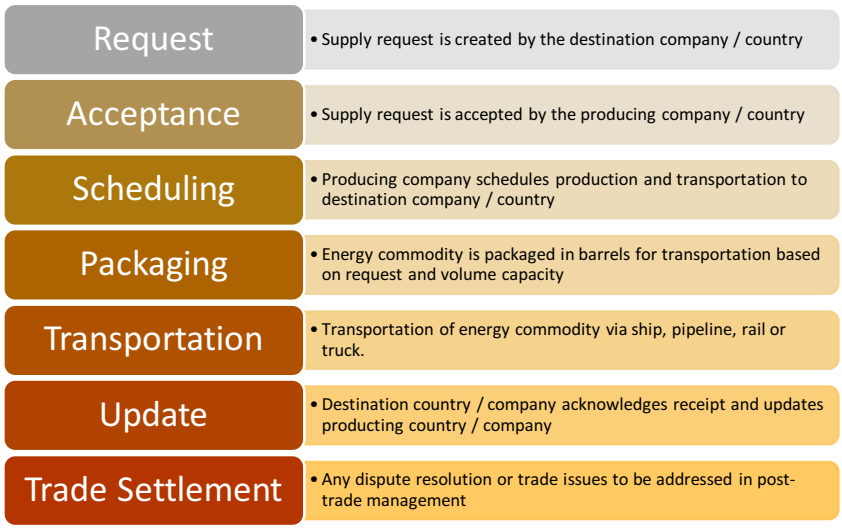

Figure 1- Breakdown of Physical Trading

The aforesaid breakdown demonstrates the cycle of the supply chain for physical oil and gas extraction, transportation, refining and trading. As such, the abundant moving parts and companies involved with the entire ecosystem of the oil and gas industry would require significant investment and overall oversight to ensure that the oil and gas commodities are appropriately handled.

Energy Derivatives Trading

With respect to energy commodities, the current trading market typically involves trading in the form of 'energy derivatives', which are contracts based on underlying assets such as petroleum and crude oil. These contracts are traded in the form of futures, swaps and options, and forwards. There are different types of oil trade depending on the requirements of the parties, and trading typically occurs on public commodity exchanges such as Intercontinental

[53] Oxford Business Group 'Major Downstream Operators Look to Expand Energy Projects in Trinidad and Tobago' Oxford Business Group 2016 <https://oxfordbusinessgroup.com/analysis/striking-balance-several-profitable-downstream-operators-are-looking-grow-and-expand-their-projects> accessed 21 August 2022.

Exchange (ICE) or the New York Mercantile Exchange (NYMEX).[54] Numerous stakeholders are involved in the energy commodity trading market, and their level of interest depends on the purpose.

For example, energy companies, energy trading companies, or even private participants who speculate in the market but do not engage in physical trading are reliant on the efficiency of the energy trading market. These parties typically have different motivations for being involved in the trading process. For example, parties may engage in oil trading for the purpose of physical delivery (physical trade), hedging against the risk of price volatility (paper trade), or making a short-term profit from market volatility (arbitrage).[55]

However, all of these different stakeholders are important elements in the market as they provide liquidity, which is vital for a successful trading market. Different contracts are used based on the terms and purpose of the contract, the degree of standardization, and the parties involved in facilitating the contracts. These differences in contracts, with respect to energy derivatives, can be broken down into two categories: options and futures contracts, which can be used for both physical and paper trade. In options trade, parties may decide to net off their positions or not exercise their rights to buy or sell depending on the market conditions. This is a less expensive way to trade in the market. However, this model can be riskier in situations where one party's decision to exercise their right to buy places the counterparty under an obligation to deliver; as a result, the risk of defaulting is inevitably higher.

Futures contracts are often used by parties who want to trade in energy commodities; in the context of this paper, we will assume the commodity to be oil, with a specific amount to be traded at a certain price and at a specified time. The parties need to pay for the specificity within this model, and thus, trading can be more expensive.[56] Additionally, futures contracts are used for physical trade and, as a result, there is also a high risk of default. However, futures are often traded on platform exchanges, which have internal rules to mitigate consequences such as credit and/or default risk. In these circumstances, when parties fail to deliver, the exchange would then act as a counterparty to deliver the oil.

[54] C Dublin 'Corre Energy set to list on Euronext Dublin' RTE. 2021 <https://www.rte.ie/news/business/2021/0906/1244891-corre-energy-dublin-listing/> accessed 21 August 2021.
[55] F Chau *Volatility Transmission Across Commodity Futures Markets* (Oxford University Press Oxford 2018).
[56] Ibid.

Another factor within these models is contracts for differences (CFD), which are often used for paper trade by parties who are not interested in the physical delivery of oil. Using CFD is a far more economical way to engage in trading.[57] Trading can take place over the counter (OTC) in which the parties can either negotiate specific terms of the contract with each other or use standardised contracts to trade without going through a centralised matching system, which is usually provided by the exchanges.[58] The involved parties can also use the multilateral trading venue provided by the exchanges to trade. These contract terms can be negotiated and drafted by the parties themselves; however, they often use standardized contracts provided by the exchanges or trade associations such as the International Swaps and Derivatives Association (ISDA).[59]

Depending on the purpose of the trade (physical or paper), the types of oil, and the location of delivery, parties will choose the types of contracts and venues for their trade, which will then determine if there are additional rules and players involved in the trade. If it is a trade on an exchange, there will be additional rules applied to their trade in terms of collateral management, margin maintenance, clearing and settlement rules, and the close-out regime. If the contract entails a physical trade, there will be a delivery of the physical product, which will involve transportation. Furthermore, commodity trade is typically a regulated sector, so relevant national regulation governing either Over-the-Counter (OTC) or exchange trade will apply. For instance, rules may require traders of an exchange to report their off-exchange, OTC trading transactions to the exchange.

At present, auditing the supply chain is an extremely time-consuming process and typically involves on-site audits and supplementary documentation.[60] This process is also quite expensive and involves numerous third-party intermediaries. The complexity of these applications in the supply chain is influenced by numerous factors within financial trade.[61]

[57] N Zengeler and U Handmann, 'Contracts For Difference: A Reinforcement Learning Approach' (2020) 13 (4) Journal of Risk and Financial Management 78 <**https://doi.org/10.3390/jrfm13040078**> accessed 21 August 2022.
[58] Ibid.
[59] M Borowicz, 'Contracts as Regulation: the ISDA Master Agreement' (2021) 16 (1) Capital Markets Law Journal 72–94 <https://doi.org/10.1093/cmlj/kmaa026> accessed 21 August 2022.
[60] R Leal-Arcas et al. 'Multilateral, Regional and Bilateral Energy Trade Governance' (2015) 6 (1) Renewable Energy Law and Policy Review 38-87 <https://www.jstor.org/stable/24324807> accessed 21 August 2022.
[61] H Sternberg, E Hofmann, and D Roeck 'The Struggle is Real: Insights from a Supply Chain Blockchain Case' (2020) 42 (1) Journal of Business Logistics 71-87 < **https://doi.org/10.1111/jbl.12240**> accessed 21 August 2022.

These factors are different layers that facilitate transactions between producers, traders, and/or consumers through business entities and third parties.[62] The complexities of this industry creates the perfect ecosystem for the introduction and integration of smart technologies.

As the number of entities increases, the complexity also increases, which makes it difficult for companies to manage the supply chain activities due to the multitude of moving parts. Therefore, it is imperative to implement a system that can streamline the process and ensure that users have a clear understanding of all the necessary factors involved in financial trade in a supply chain, which is also crucial to managing the firm's operations.[63] The complexity increases with an increase in the number of intermediaries or traders in the supply chain, and *blockchain technology can contribute to market transparency by improving visibility across the supply chain*.[64] Blockchain would contribute to the transparent and accountable integration of information using digital technology, which can ensure the provision of traceable and sustainable information in a timely manner.[65] *The application of blockchain technology and supplementary smart contracts supports responsible sourcing in complex supply chains and helps reduce information asymmetry in both the physical trade and paper trade of energy commodities.*

Paper Trade

Paper trading is typically defined as the process of trading derivatives and commodities in the OTC paper markets. It is characterized by a hypothetical trade that does not involve actual monetary exchanges. For example, an individual would only write the buy and sell orders on a piece of paper and track how the markets fluctuate in order to gain a full picture of a potential trading transaction.[66] However, this can also apply to the paper tracking of markets during monetary transactions on the trading platform. As this is more of a simulation-based practice, data gathered from the markets and physical trading can impact the types of betting and hedging that would occur during paper trading and assist seasoned and beginner traders when strategizing.

[62] Ibid.
[63] Ibid.
[64] Ibid.
[65] Ibid.
[66] S Sharma 'Market Efficiency between Indian & US Crude Oil Future Market' (2017) 122 Procedia Computer Science 1039-1046 < https://doi.org/10.1016/j.procs.2017.11.471> accessed 21 August 2022.

E-trade and Floor Trading

E-trading and floor trading can be expensive endeavours and contain a multitude of different factors, which operate separately from physical trade. A major reason for the presence of intermediaries in the transactional process is the accountability and tracking of price fluctuations, exchanges, and verification. These factors contribute to the high cost of operations.[67] However, the application of blockchain technology to these trading practices can eliminate delays, expenses, and time constraints associated with trade confirmations, payments, and supplementary third-party intermediaries.[68]

A large percentage of trading costs arise from trade record-keeping, audits, and verification of transactions. However, the introduction of blockchain technology and smart contracts would serve as a general benefit in reducing expenses related to third-party oversight and intermediaries, thereby lowering the process costs exponentially.[69] Industry-specific benefits of blockchain-based processes would reduce the need for third-party record keeping firms and ensure that verification of transactions would occur nearly instantaneously. As such, time spent on verifying information and data-transactions would eliminate excessive wait times and periods between transactions. During these transactions, a blockchain-based token representing fiat currency ie a stablecoin or a Central Bank Backed Digital Currency (CBDC) would be used for the convenience of the multitude of parties existing within the trading ecosystem. The token would be unique to the system and represent the existing market value of fiat currency, as such the trading system would be synonymous with the real-time market while maintaining a cohesive system of trading for the parties involved.

PART III

Application in Physical Trading

As described in the aforementioned areas of this paper, there are many segments to the physical trading aspect of the oil and gas industry. However, the application of blockchain technology introduces the possibility of utilizing digital tokens to track assets, transactions, and timestamps

[67] A Banerjee 'Blockchain Technology: Supply Chain Insights from ERP' (2018) 111 Advances in Computers 69-98 < https://doi.org/10.1016/bs.adcom.2018.03.007> accessed 21 August 2022.
[68] Ibid.
[69] Ibid.

across a multitude of jurisdictions.[70] A token is a unique key that allows the individual or entity to be able to carry out an accountable and transparent transaction on the blockchain itself. Within this system, the holder of the token can transfer the asset to their buyers and/or maintain a record-keeping system through pre-determined smart contract clauses.[71] For example:

> Party X sends an oil token to Party Y with a specific value. Pending acceptance by Party Y, a smart contract would be triggered, and payment would be executed upon consent. This application would then eliminate the cost related to the verification of the bill of lading and tracking of ownership of large cargoes of energy commodities in physical trading.

In recent years, the application of blockchain technology has been brought to the forefront in oil and gas trading.[72] For example, in 2017, Natixis, IBM and Trafigura were the first to launch a blockchain solution for U.S. crude oil deals using a smart-contract platform.[73] The distributive ledger technology enables buyers, sellers and their respective banks to all share information simultaneously because they are looking at the same ledger.[74] From the time an order is confirmed until its delivery and cancellation of a letter of credit, blockchain can improve the process. Another example of real-world application of blockchain technology in the oil and gas industry is Vakt, which is a London-based oil trading blockchain platform[75] backed by a group of oil and trading companies. Vakt aims to digitise the paper-based process of physical commodity trading through utilizing blockchain technology by focusing on post-

[70] H Kadry 'Blockchain Applications in Midstream Oil and Gas Industry' (2020) Paper presented at the International Petroleum Technology Conference, Dhahran, Kingdom of Saudi Arabia, January 2020 <https://doi.org/10.2523/IPTC-19937-Abstract> accessed 21 August 2022.

[71] S Global, 'Blockchain for Commodities Trading Opportunities in a Digital Age' [2018] Available at: <https://www.spglobal.com/en/research-insights/featured/blockchain-for-commodities-trading-opportunities-in-a-digital-age> accessed 21 August 2022.

[72] I Nai Fovino and others 'Blockchain in the Energy Sector, WP3 - Use cases identification and analysis' (2021) EU Science Hub https://publications.jrc.ec.europa.eu/repository/bitstream/JRC125221/JRC125221_01.pdf; Liz Hampton 'Blockchain group says pilot test shows promise for oil and gas operators' Reuters 2 June 2020 https://www.reuters.com/article/us-oil-global-blockchain-idUSKBN2392XB (Access 21 August 2022); S Brink 'How can blockchain support the energy transition?' Shell 12 Jan 2021 https://www.shell.com/energy-and-innovation/digitalisation/news-room/blockchain-building-trust-to-enable-the-energy-transition.html accessed 21 August 2022).

[73] H Kadry 'Blockchain Applications in Midstream Oil and Gas Industry' (2020) Paper presented at the International Petroleum Technology Conference, Dhahran, Kingdom of Saudi Arabia, January 2020 <https://doi.org/10.2523/IPTC-19937-Abstract> accessed 21 August 2022.

[74] Ibid.

[75] M Tesfaye 'Oil Blockchain Platform Signs Up Most North Sea Traders' (Business Insider, 2019) <https://www.businessinsider.com/vakt-blockchain-platform-signs-up-north-sea-oil-traders-2019-2> accessed 21 August 2022.

trade management processes.[76] Finally, another application of Blockchain technology is the trade finance platform called Komgo which was launched in 2018 by ING, Société Générale, ABN Amro, Shell and multiple other organisations focused on integrating banking and oil industries.[77]

One common thread among these platforms is the acknowledgement that international supply chains, with respect to the oil and gas industry, are very difficult to monitor as a result of the multiple participants and companies involved along the entire supply chain. Many of these segments meet for specific purposes and require accurate and real-time data in order to function across jurisdictions and detailed timelines. Due to the massive amounts of data involved across the several, separate and apart systems, manual reconciliation is typically required to obtain an accurate database. As a result, there are numerous middlemen involved in the micro details of the supply chain itself.[78]

These details create the ideal lacuna for Blockchain as a decentralized technology to maintain records as safe, accurate and accessible, across all the diverse players involved. Thus, it would eliminate the need for majority of the excessive intermediaries. As previous explored with tokenization representing the real-time market, through Blockchain management, efficiency would be increased in the supply chain via faster transactions and less intermediary fees.[79]

Another development which demonstrates a global shift to the wider adoption of blockchain technology in diverse industries is the GuildOne merger with Blockchain for Energy (formerly OOC).[80] This consortium's mandate is to identify, test and pilot use cases in order to improve and apply the value generated from the combination of blockchain technology within the oil and gas industry.[81]

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[76] Ibid.
[77] J Atkins 'Komgo Wins Another US$28.9Mn From Investors' Global Trade Review 2021 <https://www.gtreview.com/news/fintech/95078/> accessed 21 August 2022.
[78] The United Nations 'Transfer Pricing Issues in Extractive Industries' United Nations: Committee of Experts on International Cooperation in Tax Matters 2022 < https://www.un.org/development/desa/financing/sites/www.un.org.development.desa.financing/files/2022-06/2208552E.pdf> accessed 21 August 2022.
[79] Ibid.
[80] GuildOne 'GuildOne Conducts Industry-First AFE Ballot on Blockchain for OOC Oil and Gas Blockchain Consortium Guildone' GuildOne 2020 <https://guild1.co/2020/01/07/guildone-conducts-industry-first-afe-ballot-on-blockchain-for-ooc-oil-and-gas-blockchain-consortium/> accessed 21 August 2022.
[81] Business Wire 'Blockchain for Energy Welcomes Its Newest Member, Energy Services Giant Worley' Businesswire.com 2021<https://www.businesswire.com/news/home/20210427005064/en/Blockchain-For-Energy-Welcomes-Its-Newest-Member-Energy-Services-Giant-Worley> accessed 21 August 2022.

Mitigation of Negative Externalities

The implementation of blockchain technology into the supply chain of oil trading can ensure a more efficient management system for all stakeholders involved. Blockchain has established a reputation for assisting large scale companies with data management and record keeping across a multitude of parties. For example, Skuchain builds blockchain-based products catering to business-to-business transactions targeting the $18 trillion global trade finance market.[82] This market includes buyers, sellers, customs, third parties, banks, and logistic providers.[83] These products assist with increased traceability of commodities and ensure that corporate standards are met. Within the oil trading industry, especially in geopolitical markets, it is vital that both companies and the involved countries are aware of the source and quality of the imported commodities. As an example, countries which are subject to international sanctions would not be able to circumvent sanctions by changing ships or using non-sanctioned ports to trade oil.[84]

Further to this, the application of blockchain technology would strength corporate reputation through the provision of transparency with respect to credible data sets for price transparency, assessable data of produced oil and ensure a traceable end-to-end tracking within the supply chain.[85] However, the fundamental issue to be address when feeding real-time data into the blockchain-based platform is the veracity and legitimacy of the data being entered. This issue is coined as the 'oracle problem' wherein the information on the blockchain itself must be trusted to be a true representation of the real-world commodities.[86] Due to the complex and significantly high-level nature of commodity trading, users on the blockchain system must be able to trust the real-time data being reflected on the chain. As such, this problem can only be addressed by a unique system crafted to suit the stakeholders operating on the blockchain. This

[82] Skuchain 'Skuchain: Currency Agnostic Blockchain for Global Trade' (*Skuchain: Currency Agnostic Blockchain*) <https://www.skuchain.com/> accessed 21 August 2022.
[83] Cision PR Newswire 'Skuchain Developing Blockchain Solutions For $18 Trillion Trade Finance Market With Funding From Amino, DCG, And FBS Capital' (*Prnewswire.com*, 2016) <https://www.prnewswire.com/news-releases/skuchain-developing-blockchain-solutions-for-18-trillion-trade-finance-market-with-funding-from-amino-dcg-and-fbs-capital-300214205.html> accessed 21 August 2022.
[84] R Singh 'US Probes T&T Fuel Shipment Linked to Venezuela' *Trinidad and Tobago Guardian* (2020) <https://www.guardian.co.tt/news/us-probes-tt-fuel-shipment-linked-to-venezuela-6.2.1108194.2b869c66b6> accessed 21 August 2022.
[85] N Kshetri, *Blockchain and Supply Chain Management* (Elsevier Amsterdam 2021).
[86] G Caldarelli and J Ellul 'The Blockchain Oracle Problem in Decentralized Finance—A Multivocal Approach' (2021) 11 Applied Sciences 7572 <http://dx.doi.org/10.3390/app11167572> accessed 21 August 2022.

system would require trusted sources to feed the requisite information into the blockchain infrastructure in a timely basis to ensure that the trust and legitimacy of the system is upheld. As a result, and due to the nature of blockchain technology, there is a distinct focus on improving security, compliance, and cost reduction. As such, the supply chain application of blockchain technology in physical oil trading would assist in reducing uncertainty and risk.

Application in Energy Derivatives Trading

Price fluctuations in energy commodity trading are a common occurrence. However, in an unstable market, negative pricing can affect trading markets. For example, in the trading session of the Chicago Mercantile Exchange (CME) West Texas Intermediate (WTI) oil futures on 20 April 2020, the price collapse caused many traders and investors globally to be exposed to great risk in trading commodity futures.[87] This impacted pricing and valuation models of many derivatives. One of the largest risks that is typically unseen in the trading of commodity futures is the high storage and delivery cost for the physical commodity. This reduces the hedging functionality of commodity futures during a highly volatile market when impacted by external forces, such as the COVID-19 pandemic.[88]

However, as both exchange-listed and OTC options may take significant time to be issued in markets,[89] it is beneficial to apply blockchain technology to issue physical settlement rights via tokens. The parties involved in transportation and storage can profit from this process in a similar way to options strategies, while commodity futures traders can benefit from adequate insurance against the unexpected risk of significant expense for physical delivery. For example, utilizing smart contracts and a decentralized settlement system would enable a more flexible approach in comparison to the traditional derivatives exchanges currently being applied.[90] Additionally, premiums can be paid by the commodity itself towards transportation and storage

[87] Baker Institute 'WTI At -$37, Brent At $26! What Happened? What Comes Next? The Stories That Will Be Told…' Forbes 21 April 2020 <https://www.forbes.com/sites/thebakersinstitute/2020/04/21/april-20-wti-at37-brent-at-26-what-happened-what-comes-next-the-stories-that-will-be-told/?sh=3c1a96654d4b> accessed 21 August 2022.

[88] S Rizvi and R Itani 'Oil Market Volatility: Comparison of COVID-19 Crisis with the SARS Outbreak of 2002 and the Global Financial Crisis of 2008' (2021) 35 (1) Economic Research-Ekonomska Istraživanja 1935-1949 <https://doi.org/10.1080/1331677X.2021.1927788> accessed 21 August 2022.

[89] P Schammo 'Of standards and technology: ISDA and Technological Change in the OTC Derivatives Market' (2021) 15 (1-2) Law and Financial Markets Review 3-37 https://doi.org/10.1080/17521440.2022.2063030.

[90] A Banerjee 'Blockchain Technology: Supply Chain Insights from ERP' (2018) 111 Advances in Computers 69-98 < https://doi.org/10.1016/bs.adcom.2018.03.007> accessed 21 August 2022.

providers, which would be linked to a token value that symbolises the physical commodity itself. Therefore, this would reduce inflation that could be caused by currency over-issuance and jurisdictional complications.[91]

In other areas of trade, the application of blockchain to oil trading is mainly focused on streamlining the processes and therefore reducing the transaction costs involved. As a digital application, blockchain can be implemented as a more accessible and transparent marketplace for traders involved in multi-jurisdictional transactions. This accessibility allows for a reduction in cost, as many intermediary services for communication and record keeping would no longer be viable and cost efficient in the face of digital technology. Furthermore, blockchain technology's option for private chains allows for greater confidentiality through cryptographic technology and consensus mechanisms that gain users' trust and reinforce the integrity of transactions on an immutable distributed ledger.[92]

Alternatively, the data generated on the blockchain network can also be accessed on a public chain with the users' consent and shared with participants, including traders, investors, producers, and buyers. However, not all data will be accessible on the public chain as the private chain can be cryptographically secured between the parties involved in the trade, and this practice would make OTC trade far more attractive. Therefore, the application of blockchain technology with respect to energy commodity trading largely depends on the unique context of each system. With respect to oil trade markets, it must be designed to facilitate the needs of market participants and traders alike. For example, as in other financial market sectors, it would require the simultaneous application of smart contracts, data analytics, and artificial intelligence. The function of blockchain technology in this practice is to input information on the network in a transparent and immutable manner, depending on the consent of the parties involved, and then smart contracts would allow different sections of the trading cycle to be executed automatically.

As information is updated in real time to track the energy commodities, information is uploaded onto the system and shared across the network. Depending on their access to the different

[91]W Kaal 'Blockchain-Based Corporate Governance' (2020) 4 (1) Stanford Journal of Blockchain Law & Policy 2-28 <https://stanford-jblp.pubpub.org/pub/blockchain-corporate-governance> accessed 21 August 2022.
[92] A Lafarre and C Van der Elst 'Shareholder Voice in Complex Intermediated Proxy Systems: Blockchain Technology as A Solution?' (2021) 4 (1) Stanford Journal of Blockchain Law & Policy 29-52 < https://stanford-jblp.pubpub.org/pub/shareholder-voice-blockchain> accessed 21 August 2022.

private and public chains, participants can then have direct access to real-time information and potentially reduce the operational costs of purchasing information from third-party intermediaries that provide record keeping and transaction services.[93] Additionally, with respect to cross-border jurisdictional trading, blockchain technology can keep an immutable ledger that records the genesis of the energy commodity and provides traceability with respect to the origins of the commodity.[94] With global politics heavily influencing the international trade in oil, traders and participants would benefit from their knowledge of the source of the oil and the different trading ports by which it has been transferred. For example, Brent Crude Futures are being traded on the Synthetix trading platform as part of a decentralised finance portfolio. This traceability process can also be applied to emissions trading systems and assist with sustainable energy and green finance protocols.[95]

At present, auditing the supply chain with respect to commodity trading without the traceability function is a very time-consuming process and involves a multitude of processes and third parties.[96] For example, it involves on-site audits along with physical and digital documentation, which is to be shared with all participants on each individual system. However, with the application of blockchain technology, the effort involved in auditing these processes can be reduced significantly. Using a blockchain system that relies on RFID tags integrated with a QR code to record information on a commodity would allow the tracing of the commodity from the starting port to its destination.[97] However, RFID markers are limited in application as they are non-modifiable assets, which make tracking nearly impossible once they have been processed.[98]

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[93] Z Robertson 'Blockchain Governance: an Outsider's Perspective' (2018) Harvard Journal of Law & Technology Digest Report <http://jolt.law.harvard.edu/digest/blockchain-governance-an-outsiders-perspective> accessed 21 August 2022.

[94] S Shackelford and S Myers 'Block-By-Block: Leveraging the Power of Blockchain Technology to Build Trust and Promote Cyber Peace' (2017) 19 Yale Journal of Law and Technology 334 < https://www.yjolt.org/sites/default/files/shackelford19yjolt334_0.pdf> accessed 21 August 2022.

[95] J Lubin, M Anderson, and B Thomason 'Blockchain for Global Development' (2018) 12 (1-2) Innovations: Technology, Governance, Globalization 10-17 < https://ideas.repec.org/a/tpr/inntgg/v12y2018i1-2p10-17.html> accessed 21 August 2022.

[96] D Watton 'Internal Audit in the Oil and Gas Industry' ACCA Global 2013 Available at: <https://www.accaglobal.com/content/dam/acca/global/PFD-memberscpd/InternalAudit/Internal_audit_in_the_oil_and_gas_industry.pdf> accessed 21 August 2022.

[97] C Nolden 'Blockchain Contradictions in Energy Service and Climate Markets' (2021) in N Kumar L Gelman A Kumar S Chakrabarti (eds) *Intelligent and Reliable Engineering Systems: 11th International Conference on Intelligent Energy Management, Electronics, Electric & Thermal Power Robotics and Automation* (1st Edition, CRC Press 2021) 1-6

[98] Ibid.

However, to remedy this situation, smart contracts can be applied to project the production process in a digital token, which corresponds to the physical good for the purpose of tracking. A smart contract would be encoded with the product composition of the energy commodity and validated to ensure the integrity of the information. Specifying the required input at each stage of the transaction would ensure that it can proceed only if each specific factor has been met accordingly. Therefore, at each step of the production process, the commodity can be traced from creation to delivery. Thus, the tokenization mechanism within the smart contract would resolve any discrepancies in the commodity at different stages. Additionally, implementing a system of evidential tracing would enable the use of different factors for validation.[99] For example, volumes, weight, dates, photographs, and certificates can be recorded and uploaded to the ledger, and thus be used for the traceability and integrity of the commodity.[100] The transactions can be verified using a mass-balance approach to check if the quantity of non-certified material is controlled.

At the time of initial issuance and also in the aftermarket, blockchain technology ensures that there is an immutable transaction record, which can be properly tracked and audited; facilitates regulatory compliance, real-time reporting, and instantaneous communication between issuers and investors; ensures security of direct assets even in the absence of custodians; and help maintain consistency of data across all actors involved in the process without the need for costly and time-consuming data conciliation.[101]

PART IV

[99] 'TotalEnergies Partners with Circulor for Blockchain Plastic Traceability' Ledgers Insights 16 August 2021 https://www.ledgerinsights.com/totalenergies-partners-with-circulor-for-blockchain-plastic-traceability/ accessed 21 August 2022.

[100] B Clark and R Burstall 'Blockchain, IP and the Pharma Industry—How Distributed Ledger Technologies can Help Secure the Pharma Supply Chain' (2018) 13 (7) Journal of Intellectual Property Law & Practice 531-533 < https://blockchain.bakermckenzie.com/wp-content/uploads/sites/30/2019/01/Article6.pdf> accessed 21 August 2022.

[101] J Lee *Crypto Finance, Law and Regulation: Governing an Emerging Ecosystem, Chapter* 4 (Routledge Abingdon 2022); Accenture Consulting '*The Blockchain Benefit: Driving Freight Bill Audit and Pay Savings in Oil and Gas* (2018) <https://www.accenture.com/t20180521T235705Z__w__/us-en/_acnmedia/PDF-77/Accenture-13584-ACN-RES-Blockchain-FBAP-Brochure-2018-final.pdf> accessed 21 August 2022.

Legal Issues

Despite the benefits of applying blockchain technology and related smart technologies to energy commodity trading, several legal issues can arise.[102] However, as mentioned above, details such as the context in which the chains are designed, what they are used for, and how they are shared and accessed affect the legal issues that may arise. Specifically, when dealing with energy trading markets, legal issues can arise with cross-jurisdictional trading and disputes arising out of consumer protection and dispute resolution. The decentralised nature of blockchain technology make it a niche and developing area of law, especially when it involves trading energy commodities across multi-jurisdictional borders.

In light of these circumstances, the Dubai International Financial Centre Courts announced in December 2021 that it launched a specialised court for the digital economy to deal with disputes. The Specialised Court for the Digital Economy is to include blockchain technology and create a simplified settlement process for complex civil and commercial disputes related to the distributed ledger technology.[103] This revolutionary legal step would be a novel medium for international companies seeking a simple and up-to-date approach with dealing with smart technology and international trade with energy commodities operating on blockchain technology.

Jurisdiction of Blockchain Network

A prime advantage of distributed ledger technology is the ability to overcome problems arising from a complex patchwork of different legal systems across the globe.[104] Blockchain technology is founded upon the absence of the need to be supported by a singular law and the goal to dispense with unnecessary intermediaries because the technology is not connected to any specific legal system or jurisdictional regulation.[105]

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[102] J Lee and V Khan 'Blockchain and Smart Contract for Peer-to-Peer Energy Trading Platform: Legal Obstacles and Regulatory Solutions' (2020) 19(4) John Marshall Review of Intellectual Property Law 280-308 < https://repository.law.uic.edu/ripl/vol19/iss4/1/> accessed 21 August 2022.

[103] M Sophia 'DIFC to open special court to settle disputes related to digital economy' The National News, 14 December 2021 <https://www.thenationalnews.com/business/economy/2021/12/14/difc-opens-special-court-to-settle-disputes-related-to-digital-economy> accessed 21 August 2022.

[104] P De Filippi and A Wright *Blockchain and the Law: The Rule of Code* (Harvard University Press Boston 2018) 33–35 (describing the blockchain as a transnational network for which national borders are largely irrelevant).

[105] Ibid.

Bitcoin, the original distributed ledger technology network, functions as a payment system operating across borders without the support of any financial institution.[106] This is also a means to avoid the applicability of specific laws of jurisdictions to which these institutions are connected.[107] As the blocks of a decentralised ledger can span multiple locations around the world, it is often difficult to establish which jurisdictional laws and regulations apply to a given application. With cross-border trade, there is a risk of transactions coming within the purview of almost every jurisdiction within which the concerned block on the network is situated, which would result in an overwhelming number of laws being applied. In a public blockchain system in particular, it is vital to consider the laws and the regulations that may apply. As a result, appropriate risk management needs to be taken into consideration when building a blockchain network and the transaction system involved in trading.[108]

However, using private chains that require specific permissions can create a more sustainable and enclosed ecosystem within which a specific legal framework and data governance structure can be applied to transactions. The current exchange-based trade model based on a centralised system in which the law of the venue applies would be challenged in the face of a decentralised system such as a blockchain, particularly a trading platform built on a public chain with many different jurisdictional participants.[109] Therefore, moving trading to a public chain-based market would raise significant legality issues and legal risks. However, by utilising private chains, trading can be brought under a specific jurisdiction whose law would apply when transactions occur. Even though the physical infrastructure would be located remotely, the regulator of the sector would require a physical location to be situated in the relevant jurisdiction for further security and accountability.[110]

This is akin to a contractual agreement that would serve as the agreed law under which the contract is bound. In private systems, it would also be beneficial to agree on some form of a

[106] J Lee *Crypto Finance, Law and Regulation: Governing an Emerging Ecosystem*, Chapter 5 (Routledge Abingdon 2022); Digital Assets and Private Law, UNIDROIT, https://www.unidroit.org/work-in-progress/digital-assets-and-private-law/ accessed 21 August 2022.
[107] S Nakamoto 'Bitcoin: A Peer-to-Peer Electronic Cash System' 1 (accessed 21 August 2022) (describing Bitcoin as a peer-to-peer electronic cash system that allows online payments from one party to another without going through a financial institution)
[108] P De Filippi, M Mannan and W Reijers 'The Alegality of Blockchain Technology' (2022) 41 (3) Policy and Society 358-372 <https://doi.org/10.1093/polsoc/puac006> accessed 21 August 2022.
[109] Ibid; A Yekini *The Hague Judgments Convention and Commonwealth Model Law: A Pragmatic Perspective - Studies in Private International Law* (Bloomsbury London 2023).
[110] Ibid.

dispute resolution process. On the network, there will be trading transactions and contracts, which can be governed by the law agreed upon by the parties. Collaterals, such as cash, can be deposited in the network, and the applicable law will need to be determined.[111] Furthermore, clearing may be required by the specified market and the relevant regulatory regime. The applicable law will depend on the rules of the market and the law of the concerned jurisdiction.

Legality of Smart Contracts and the Risks

As mentioned above, a key issue with smart contracts and the infrastructure of the blockchain lies within the oracle problem. However, narrowing the necessary sources for the information stored on the blockchain eliminates a large part of the issue. As such, the participants on the blockchain would be able to rely on the information entered into the blockchain and the hybrid chain would allow individual parties to ensure the veracity of the information on a more detailed level.

Smart contracts emerged from the blockchain boom following the 2008 financial crisis. Financial corporations were looking for a way to mitigate risks and shorten settlement time following the collapse of the financial sector.[112] Explanations of smart contracts are so numerous that 'a search of the term smart contract uncovers a myriad of definitions'.[113] While a single definition has yet to be agreed upon universally, a smart contract means that '*documents containing various contracts or information that are used offline can be safely recorded online so that contract information and information can be checked at any time and place'.*[114]

To execute a smart contract, the parties must negotiate terms until a 'meeting of minds' occurs, and the parties then enter into a legally binding contract. After this relationship is established,

[111] J Lee *Crypto Finance, Law and Regulation: Governing an Emerging Ecosystem*, Chapter 4 (Routledge Abingdon 2022).
[112] K Silverberg and C French 'Getting Smart: Contracts on the Blockchain' Institute of International Finance 2016 <https://www.iif.com/Publications/ID/582/Getting-Smart-Contracts-on-the-Blockchain> accessed 21 August 2022.
[113] P Catchlove *Smart Contracts: A New Era of Contract Use* (2017) <https://ssrn.com/abstract=3090226 > accessed on 21 August 2022.
[114] S Yoo 'Blockchain Based Financial Case Analysis and its Implications' (2017) 11 (3) Asia Pacific Journal of Innovation and Entrepreneurship 312-321 < https://www.emerald.com/insight/content/doi/10.1108/APJIE-12-2017-036/full/pdf?title=blockchain-based-financial-case-analysis-and-its-implications> accessed 21 August 2022.

the smart contract is encoded to contain the requirements and instructions following the agreed-upon terms and conditions of the legal contract. If a party does not pay, as required by their contractual obligations, the smart contract is automated not to fulfil the requirements of that party due to the requisite criteria not being met for the execution of the contract. This scenario demonstrates the use of software to manage contractual performance without human interpretation or intervention. However, the performance instructions of a smart contract are not specifically written in standard legal prose or layman language, but are 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 specific IT skills. A command-oriented language is derived from the code behind smart contracts.[115]

The contractual terms in a smart contract are confirmed prior to energy trading through traditional contract negotiations.[116] However, the act of energy trading will be through automation with smart contracts. Therefore, it is necessary to consider contract law issues around smart contracts prior to automated implementation. Smart contracts execute legal agreements and create digital commercial arrangements. However, most smart contracts are not legally enforceable on their own because of the decentralised nature of the blockchain where no single party has control.[117] 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, a hybrid system of contracts should be considered.

However, since smart contracts are computer programmes, issues have been raised regarding fitting them into the current legal framework.[118] While they are not written entirely in a coded format, the form of expression in smart contracts differs greatly from that in traditional

[115] J Lee and VM Khan 'Blockchain and Smart Contract for Peer-to-Peer Energy Trading Platform: Legal Obstacles and Regulatory Solutions' (2020) 19(4) John Marshall Review of Intellectual Property Law 283-308 < https://repository.law.uic.edu/ripl/vol19/iss4/1/> accessed 21 August 2022.
[116] J Lee *Crypto Finance, Law and Regulation: Governing an Emerging Ecosystem*, Chapter 4 (Routledge Abington 2022).
[117] D Zetzsche, R Buckley, and D Arner 'The Distributed Liability of Distributed Ledgers: Legal Risks of Blockchain' (2018) 4 University of Illinois Law Review 1361-1407 < https://illinoislawrev.web.illinois.edu/wp-content/uploads/2018/10/BuckleyEtAl.pdf> accessed 21 August 2022.
[118] J Sklaro 'Smart Contracts and the Cost of Inflexibility' (2018) 166 (9) University of Pennsylvania Law Review 263-303 < https://scholarship.law.upenn.edu/cgi/viewcontent.cgi?article=1009&context=prize_papers> accessed 21 August 2022.

contracts. Consequently, they cannot be read by anyone without specialised skills. These skills are necessary to draft, understand, and implement the code within them. Smart contracts, therefore, will only be as 'smart' as the coding and the experience of the drafters behind them.[119] While the code might not be incorrect, unspecified directions for the instructions or requirements can result in unintentional consequences and result in liabilities for either party. A prominent identifiable issue with smart contracts is rooted in their fixed format and protection of what has been previously agreed upon and programmed into the code, such as the inherent self-executing nature of smart contracts. While this is positive for accountability, this will lead to massive issues in consumer protection and accountability if smart contracts are recognised as legally enforceable contracts. Should they be recognised as legal contracts, it would be difficult to verify that they were appropriately coded and protected.[120] One key drawback, however, of smart contract functionality is the fact that the '*[c]orrectness of smart contracts in this context means contracts that are functioning as intended by their developers'*.[121] Traders and participants would have to rely on the qualifications of those drafting the contracts and ensuring that they are legally sound.[122]

Therefore, a smart contract, if not properly executed and functioning, can result in catastrophic malfunctions. For example, an attack on a decentralised autonomous organisation (DAO) in 2016 led to over 60 million US dollars being moved into an incorrect account.[123] While the funds were returned to the owners after a hard-fork in the Ethereum blockchain, there is a need for a set standard for trustworthy professionals on the back end of the technology.

A failure in this area would result in a systematic chain reaction that would severely impact both parties involved in a contract.[124] For example, an error in the application and execution

[119] P Catchlove 'Smart Contracts: A New Era of Contract Use' (2017) <https://ssrn.com/abstract=3090226> accessed 21 August 2022.
[120] Ibid.
[121] M Alharby, A Aldweesh, and A Moorsel 'Blockchain-based Smart Contracts: A Systematic Mapping Study of Academic Research' (2018) *International Conference on Cloud Computing, Big Data and Blockchain (ICCBB)* 1-6 <10.1109/ICCBB.2018.8756390> accessed 21 August 2022.
[122] Institute of International Finance, 'Getting Smart: Contracts on the Blockchain' (Institute of International Finance 2016) <https://www.iif.com/Publications/ID/582/Getting-Smart-Contracts-on-the-Blockchain> accessed 21 August 2022.
[123] F Zhang, A Juels, and E Shi 'Town Crier: An Authenticated Data Feed for Smart Contracts' in Proceedings of the 2016 ACM SIGSAC Conference on Computer and Communications Security, CCS '16, 270-282 < https://doi.org/10.1145/2976749.2978326> accessed 21 August 2022.
[124] J Sklaroff 'Smart Contracts and the Cost of Inflexibility' (2018) 9 Prize Winning Papers <https://scholarship.law.upenn.edu/prize_papers/9> accessed 21 August 2022.

of a contract would create a crisis of time-restricted consequences. Therefore, the intricate system of editing and retraction in a contract would be a negative aspect.

As the digital era continues to expand, and digital technologies become more widespread, society will begin to shift away from traditional definitions of consumers and businesses and move towards a 'society of control'.[125] This means that we are turning into a more regulated society where automated consumption is becoming integrated into our ordinary operations.[126] Smart contracts are one way of ensuring accountability while creating a greater scope for monitoring behaviour and actions.[127] Essentially, smart contracts are unique in creating new tools that reduce monitoring costs and hold parties accountable in good faith[128] by not completing a transaction until the requirements are met.

Due to the degree of decentralisation, all codified terms and clauses are performed as intended once it is guaranteed that the contract is coded correctly. They are also resilient to tampering when coded adequately, and because changing the underlying blockchain code is difficult, there are very few opportunities for anyone to access or change the contract without proper agreed-upon arrangements.[129] While traditional contracts are prone to human error, smart contracts benefit both consumers and suppliers. Smart contracts are most likely to be applied in limited cases, as they cannot always ensure compliance *ex-ante*. Another issue that has been discussed is the question of which courts would hear the disputes and which laws would apply in determining the legality of a smart contract and have the power to resolve any subsequent issues.[130] In general, all rights and obligations registered in blockchain applications must rely on validity under applicable laws.[131]

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[125] G Deleuze 'Postscript on the Societies of Control' (1992) 59 October 3-7 <https://www.jstor.org/stable/778828> accessed 21 August 2022.

[126] A Marks B Bowling C Keenan 'Automatic Justice? Technology, Crime and Social Control' (2015) in R Brownsword E Scotford and K Yeung (eds), *The Oxford Handbook of Law, Regulation and Technology*, Oxford Handbooks (2017; online edn, Oxford Academic, 1 Sept. 2016) <https://doi.org/10.1093/oxfordhb/9780199680832.013.32> accessed 21 August 2022.

[127] Ibid.

[128] *Carter v Boehm* [1766] 3 Burr 1905

[129] M Alharby, A Aldweesh, and A Moorsel 'Blockchain-based Smart Contracts: A Systematic Mapping Study of Academic Research' (2018) in *International Conference on Cloud Computing, Big Data and Blockchain (ICCBB)* 1-6 <10.1109/ICCBB.2018.8756390> accessed 21 August 2022.

[130] Institute of International Finance, 'Getting Smart: Contracts on the Blockchain' (Institute of International Finance 2016) <https://www.iif.com/Publications/ID/582/Getting-Smart-Contracts-on-the-Blockchain> accessed 21 August 2022.

[131] M Haller-Gronbæk 'Blockchain 2.0, Smart Contracts and Challenges' (2016) Bird & Bird LLP White Paper <https://www.twobirds.com/-/media/pdfs/in-focus/fintech/blockchain2_0_martinvonhallergroenbaek_08_06_16.pdf> accessed 21 August 2022.

However, there is a difference between a smart contract as coded and a smart contract that is legally enforceable. To be legally enforceable, a smart contract must comply with the requirements enforced under standard contract law. For example, under California law in the jurisdiction of the United States of America, the use of electronic records in legal proceedings is recognised as enforceable. [132] Digital and electronic signatures and records carry the same legal weight and effect as paper contracts. While the law in California does not directly address the legal legitimacy of smart contracts, efforts are being made to structure the enforceability of smart contracts in general.

Traditional legal doctrines, especially those focused on regulating intermediaries, will not easily translate into these new decentralised and autonomous systems.[133] This is because the limited use of distributed ledger technology today poses a challenge to the functioning of smart contracts. Replicated ledgers are required for the functioning of a contract, and, therefore, standardisation is paramount to the success of any technological agreement.[134] Hence, the application of smart contracts has begun in very niche and localised areas that require more time-restrictive accountability, such as insurance contracts.[135] Blockchain technology can store and utilise all the information required for claims and risk assessments to automate premiums.[136] The broader adoption of blockchain technologies may ultimately rewire the development of alternative mechanisms of regulation that better account for the distinctive characteristics of Lex Cryptographia,[137] better known as the Distributive Ledger Technology Law. Therefore, applying smart contracts for legal protection between consumers and businesses is the next natural step in the rapidly changing legal landscape.

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[132] Uniform Electronic Transactions Act (Civ. Code, § 1633.1 et seq.)
[133] Institute of International Finance, 'Getting Smart: Contracts on the Blockchain' (Institute of International Finance 2016) <https://www.iif.com/Publications/ID/582/Getting-Smart-Contracts-on-the-Blockchain> accessed 21 August 2022.
[134] Ibid.
[135] L Benichou 'AXA Launches Ethereum Smart Contract Insurance Product for Flight Delays' Trustblocks June 18 2018 < https://www.trustblocks.com/2018/06/18/axa-launches-ethereum-smart-contract-insurance-product-flight-delays> accessed on 21 August 2022.; PricewaterhouseCoopers LLP, Blockchain in the Insurance Sector, 2016 <https://www.pwc.co.uk/financial-services/fintech/assets/blockchain-in-insurance.pdf > accessed 21 August 2022.
[136] V Gatteschi and others 'Blockchain and Smart Contracts for Insurance: Is the Technology Mature Enough?' Future Internet 10(2) (2018) <https://www.mdpi.com/1999-5903/10/2/20/pdf> accessed 21 August 2022.
[137] J Lee *Crypto Finance, Law and Regulation: Governing an Emerging Ecosystem*, Chapter 11 (Routledge Abingdon 2022); P De Filippi and Wright *Blockchain and the Law: The Rule of Code* (Harvard University Press Boston 2018).

Collateral Management Issues

Regardless of the aforementioned benefits of the application of blockchain technology to the trading of energy commodities, there are limitations that must be addressed in terms of management issues and potential risks. While the distributed ledger technology protects the integrity, transparency, and immutability of the data held on the chain itself, human error while recording information can be grounds for fraudulent practices and pecuniary losses. The entry of inaccurate data, such as amounts and costs, can undermine the process and destroy the trust of the participants within the system. Therefore, although blockchain technology is inherently designed to be a secure and transparent system, it can still be considered vulnerable to factors outside of its own processes.

As a safeguard to mitigate these issues, each trading transaction requires verification before being recorded on the immutable chain so as to ensure the accuracy of the figures and data. While verification can be time-consuming when considering the high volume and velocity of trading,[138] it is a necessary and unavoidable step to prevent false and/or inaccurate data from being stored and participants from being misled; further issues down the processing line can also be averted. In addition, the upfront and maintenance costs of these complex systems require massive computational power to facilitate the running of proof-of-work algorithms in the interest of cybersecurity. This can happen in cases where there are two conflicting versions of information being stored on the same blockchain; therefore, the network will automate itself to choose the longest chain.[139] The integrity of the blockchain system relies on the decentralised system and the end users involved as opposed to traditional third-party intermediaries.

Therefore, in the event of inaccurate or fraudulent transactions, it is imperative to have a system that can address dispute resolution with respect to the blockchain technology being used in these systems. Another security risk is the potential leakage of data that can occur in a blockchain system that is run on a public chain. However, a private key is typically associated with individual users and links each addition to the chain to the unique user's code and

[138] Harvard Business Review. 2020. Building a Transparent Supply Chain. [online] Available at: <https://hbr.org/2020/05/building-a-transparent-supply-chain> accessed 21 August 2022.
[139] F Casino T Dasaklis and C Patsakis 'A Systematic Literature Review of Blockchain-Based Applications: Current Status, Classification and Open issues' (2019) 36 Telematics and Informatics 55-81 < https://doi.org/10.1016/j.tele.2018.11.006> accessed 21 August 2022.

system.[140] However, if the private key is lost, then the owner of that block can lose access to the data on that block.

Moreover, errors in the smart contract code can lead to data leakage, which may make the system vulnerable to security and privacy risks. An increase in supply chain transparency with blockchain also has risks. With increased transparency, the exposure of the company to other actors increases, which can lead to the sharing of confidential information[141]. Hence, there is a risk of trade secrets and supply chain details being exposed to competitors, which can give them an unfair advantage in business. To counter this problem, a private blockchain can be used where all the participants are known and at least some are trustworthy.

Privacy

The issue of privacy and blockchain technology has been intensely debated. Many practitioners and academic commentators have claimed that blockchain technology is incompatible with privacy laws, such as the EU General Data Protection Regulation (GDPR).

As mentioned above, the original purpose of blockchain was to facilitate peer-to-peer transactions without the need for a central party. In a permission-less public blockchain system, no single party takes responsibility for the availability or security of a particular blockchain network, and all users of the system may have access to the data on the network. These attributes conflict with the thrust of privacy laws, which require the party controlling personal data of an individual to safeguard the security and privacy of that data on behalf of the individual or 'data subject'. Both a controller (the party that determines the purposes and means of processing particular personal data) and a processor (a party responsible for processing personal data on behalf of a controller, such as an outsourced service provider) have distinct obligations under GDPR, making it important to determine whether a party qualifies as a controller or a processor when processing personal data.

In a cloud computing system, those uploading personal data to the cloud environment are typically the controllers, and the operator of the cloud system is the processor. This is a key

[140] Ibid.

[141] D Zetzsche R Buckley D Arner 'The Distributed Liability of Distributed Ledgers: Legal Risks of Blockchain' (2018) 4 University of Illinois Law Review 1361-1407 < https://illinoislawrev.web.illinois.edu/wp-content/uploads/2018/10/BuckleyEtAl.pdf> accessed 21 August 2022.

area in which blockchain systems differ.[142] Many blockchain systems are operated by users in a peer-to-peer network environment, which makes it difficult to define whether users are controllers or processors. It is necessary to consider the extent to which different participants in the blockchain network are controllers based on their respective activities. Participants who submit personal data to the blockchain are more likely to be considered controllers under GDPR as they determine the details of processing, whereas blocks that only process personal data are more likely to be processors as they simply facilitate the blockchain network's operation.[143] However, this determination is not straightforward because not all blockchain systems operate in the same way, and there can be different types of participants carrying out various activities.

Despite the high level of security that blockchain systems provide to the data recorded on them, some key cybersecurity risks remain. The unique challenge to decentralised systems, particularly public blockchains, is that data input can be from any number of blocks, meaning there is a risk of tampering at each block. The benefit of using a 'tamper-proof' technology is negated if the information stored on the ledger is compromised to begin with. This type of attack is not aimed at the blockchain itself, but at external systems such as cryptocurrency wallets.[144]

There is a risk that individuals might target the data input point (rather than the ledger itself), leading to the dissemination of inaccurate information. Users operating on the blockchain would then unknowingly rely on misleading or false information. For example, a 15-year-old boy from the United Kingdom proved that such an attack is possible by developing a proof-of-concept code that allowed backdoor access to hardware wallets sold by Ledger,[145] a Paris-based company which develops security and infrastructure solutions for digital assets as well as blockchain applications. Using this approach, it would be possible to change the wallet destinations and payments. An attacker could divert payments to their own account while making it appear to be the intended destination, ensuring that the attack is undetectable to

[142] Ibid.
[143] European Parliamentary Research Service 'Blockchain and the General Data Protection Regulation can Distributed Ledgers be Squared with European Data Protection Law?' (2019) < https://www.europarl.europa.eu/RegData/etudes/STUD/2019/634445/EPRS_STU(2019)634445_EN.pdf> accessed 21 August 2022.
[144] BBC , 'Teenager hacks crypto-currency wallet' BBC News 21 March 2018) <https://www.bbc.com/news/technology-43489404> accessed 21 August 2022.
[145] Ibid.

verifying blocks. Another way data on a blockchain can be compromised is by a targeted brute force attack on certain blocks.

In the energy commodity trade, market participants are likely to be entities rather than natural persons. The risk of privacy violation is less apparent. However, privacy risk should not be neglected and such a risk become immediate if the energy trade is to be open to the consumers and can be carried out on a peer-to-peer basis.

Part V

Green Tech and United Nations Sustainable Development Goals

With the implementation of smart contracts, secure transactions are executed autonomously on the blockchain and assist with procedural streamlining. The application of blockchain technology within the energy trading market would also help bring the oil and gas industry in line with the United Nations Sustainable Development Goals (SDGs).[146] In complex procedures such as customs clearance, which involve a multitude of parties, documents, and stakeholders across jurisdictions, the application of blockchain technology would reduce excess human input through smart contracts and allow faster execution and automated regulation compliance.[147] These benefits would help reduce corruption in line with SDG 16,[148] Peace, Justice and Strong Institutions, by helping the oil and gas industry move towards a more resilient and sustainable operating system, as well as SDG 15,[149] Life on Land, through the reduction of paper processes.

It would also meet SDG 9,[150] Industry, Innovation, and Infrastructure, by contributing to the development of sustainable, resilient, and inclusive infrastructure through digital means rather than multiple, unintegrated processes. Finally, the application of blockchain would also meet

[146] The United Nations Development Programme 'The Future Is Decentralized.' The United Nations Development Programme 2018 < https://www.undp.org/publications/future-decentralised> accessed 21 August 2022
[147] Ibid.
[148] S Kumar and M Barua 'Sustainability of Operations through Disruptive Technologies in the Petroleum Supply Chain' (2022) 29(5) Benchmarking: An International Journal 1640-1676 < https://doi.org/10.1108/BIJ-02-2021-0086> accessed 21 August 2022.
[149] United Nations Conference on Trade and Development 'Harnessing Blockchain For Sustainable Development: Prospects And Challenges' (2021) < https://unctad.org/system/files/official-document/dtlstict2021d3_en.pdf> accessed 21 August 2022.
[150] Ibid.

SDG 12,[151] Responsible Consumption and Production, by increasing responsible consumption and production through sustainable management of oil commodities and the use of natural resources.[152]

With blockchain technology, the management of oil and gas trading would not only promote the functionality of the process but also gear the industry towards a more sustainable future. This is especially significant because of the prominence of the COP26 talks led by global leaders outlining the impending end of public financing for fossil fuel projects. [153] This push towards a more sustainable avenue for energy generation. Therefore, moving towards a system of operation that integrates sustainability and digitisation would be the first step towards revolutionising the energy trading market entirely.[154]

Despite its benefits, the application of blockchain technology and its impact on sustainability has been widely debated among scholars and environmental organizations.[155] This debate stems from concerns over the emissions generated from the mining of Bitcoin and other proof-of-work cryptocurrencies.[156] However, the high energy requirement does not necessarily mean that the carbon footprint would be as large as the initial estimate made during the early boom of cryptocurrencies. Implementing blockchain technology on a larger scale could eventually serve as a catalyst to push the use of renewable energy and promote compatible green technology infrastructure.[157] For example, cryptocurrencies mined in Paraguay, where the energy supply is based almost entirely on hydroelectric sources, would leave a much lower carbon footprint than cryptocurrencies mined in countries that are dependent on fossil fuels.[158]

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[151] Ibid.
[152] A Park and H Li 'The Effect Of Blockchain Technology On Supply Chain Sustainability Performances' (2021) 13 (4) Sustainability 1726 < **https://doi.org/10.3390/su13041726**> accessed 21 August 2022.
[153] L Goering and S Rodriguez 'Analysis: Push to End Oil and Gas Expansion Takes Off at COP26 but Harder on the Ground' (*Reuters*, 4 November 2021) <https://www.reuters.com/business/cop/push-end-oil-gas-expansion-takes-off-cop26-harder-ground-2021-11-04/> accessed 21 August 2022.
[154] B Marr 'How Shell Is Using Web3 And Blockchain For Sustainability And Energy Transition' Forbes 15 July 2022 https://www.forbes.com/sites/bernardmarr/2022/07/15/how-shell-is-using-web3-and-blockchain-for-sustainability-and-energy-transition/ (Accessed 21 August 2022); 'Shell, Accenture, Amex in blockchain project for sustainable air fuel' Ledger Insights 21 June 2022 https://www.ledgerinsights.com/shell-accenture-amex-blockchain-sustainable-aviation-fuel-saf/ accessed on 21 August 2022.
[155] C Stoll, L Klaaßen and U Gallersdörfer 'The Carbon Footprint of Bitcoin' (2019) 3(7) Joule 1647-1661 < https://doi.org/10.1016/j.joule.2019.05.012> accessed 21 August 2022.
[156] Ibid.
[157] World Economic Forum, 'COP26: How to Make Cryptocurrency Sustainable' (2021) < https://www.weforum.org/agenda/2021/11/how-to-make-bitcoin-and-cryptocurrency-sustainable-renewable-energy-blockchain-crypto-mining/> accessed 21 August 2022.
[158] Ibid.

In recent times, blockchain technology has been highlighted as a green technology of the future that would assist the global supply chain in becoming more accountable, transparent, and sustainable. However, applying blockchain technology to the energy commodities trading market is not a panacea for all potential environmental concerns. The implementation of distributed ledger technology can serve as the catalyst to integrate renewable energy functionality as well as assist oil and gas companies in the transition towards becoming more sustainable in the long-term future. The comparative carbon footprint of legacy banking and finance and the fact that proof of stake, as an alternative to proof of work, is increasingly more popular as a consensus mechanism demonstrates a shift in the long-term sustainable model of blockchain technology. Shifting from fossil fuels is not a short-term goal, and the stakeholders involved in many functional parts of the industry require an evolutionary approach.

Further to this, in implementing smart technology within an established field such as the energy market, it is necessary to address the need for Environmental, Social and Governance (ESG) structures.[159] Industries of the modern era require more corporate transparency and monitoring of corporate actions to ensure that what is produced and how it is produced is in line with the values of sustainable businesses.[160] As such, integrating blockchain to enforce ESG structures within supply chain management would assist the oil industry in ensuring that specific challenges within the energy market are addressed. For example, blockchain has been used to track raw materials through manufacturing, verifying that utilised materials were sourced from sustainable locations and trusted supplies in order to assist companies in focusing on reducing carbon footprints, sustainability tracking and other disclosures.[161]

This would be especially useful in circumstances where geopolitics affect the source of oil and gas or in situations where companies refuse commodities from specific supplies due to differences in values.[162] These safeguards would allow stakeholders in the energy market to source oil and gas from the most sustainable sources, ensure that they are compliant with

[159] Y Chen and U Volz 'Scaling Up Sustainable Investment Through Blockchain-Based Project Bonds' (Asian Development Bank Institute 2021) < https://www.adb.org/publications/scaling-sustainable-investment-blockchain-based-project-bonds> accessed 21 August 2022.
[160] X Liu and others 'Blockchain-Enabled ESG Reporting Framework for Sustainable Supply Chain' (2020) in S Scholz, R Howlett R Setchi *Sustainable Design and Manufacturing 2020* (1st Edition, 2020) 403-413 < https://doi.org/10.1007/978-981-15-8131-1> accessed 21 August 2022.
[161] A Park and H Li 'The Effect of Blockchain Technology on Supply Chain Sustainability Performances' (2021) 13 (4) Sustainability 1726 < **https://doi.org/10.3390/su13041726**> accessed 21 August 2022.
[162] D Pinkert, J Ton-that, and R Soopramanien 'How Blockchain can Make Supply Chains more Humane' (2019) Stanford Social Innovation Review < https://doi.org/10.48558/1BDT-AT14> accessed 21 August 2022.

production numbers against potential environmental risks and assist with the transition to renewable energy sources by tracking and tracing the supply and demand of oil within real time.

Conclusion

There are several important risk management concerns for any system wishing to adopt blockchain technology with respect to energy commodity trading. Such issues have always existed in trading and storage systems and are not unique to the introduction of blockchain technology. The key is to understand the risks inherent in the system and to ensure that they are managed and mitigated where necessary.

A crucial difficulty with this system is the structure of contractual frameworks and the associated regulations. The current market model is not designed for the decentralised world of blockchain technology. Therefore, when applying the technology to industries such as oil and gas, the major hurdle lies in pinpointing and understanding who is accountable and legally responsible. If the adoption of blockchain technology is treated no differently from any other form of outsourcing,[163] there are three potential models to consider for the energy commodity trading system.

The first is a private and/or permissioned model in which a singular party or collective group is responsible for the operation and regulation of the system. This system would be similar to the existing outsourcing model as it would be a collection of multiple private chains operating between specific parties. A neutral overseer would perform the function of a centralised hub of data for information to be shared between the participants and investors.

The second model is a public blockchain where all the stakeholders and participants on the blockchain agree on a contractual framework. Each participant would then hold specific liabilities and accountabilities towards the functionality of the public chain. An end-user licencing agreement mutually agreed by the stakeholders would outline the conditions and regulations governing the public chain.

[163] Y Zhang, R Deng, X Liu and D Zheng 'Blockchain Based Efficient and Robust Fair Payment for Outsourcing Services in Cloud Computing' (2018) 462 Information Sciences 262-277 < 10.1016/j.ins.2018.06.018> accessed 21 August 2022.

The third option is the hybrid model proposed in this study. A public blockchain would operate as the mainframe system that allocates the associated responsibility and liabilities and shares the data that is presently accounted for during transactions. However, simultaneously, there would be multiple private chains available for use, based on the type of commodity being traded and transported and restricted to the specific parties involved, in order to ensure the integrity of the system.

In conclusion, applying blockchain technology to commodity trading requires multiple layers and different approaches when considering physical trading, e-trading, and floor trading. Each system requires a unique, context-based structure that can facilitate the specific needs of all its stakeholders. There is also a need for a balance between the future of the oil and gas industry and the increasing demand for sustainable practice. Blockchain is able to facilitate such a balance and to allow the oil and gas industry to move towards a more efficient, transparent, accountable, and sustainable system of operation.

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