Proceedings Paper:

Nolden, C. (2021) Blockchain contradictions in energy service and climate markets. In: Kumar, N., Gelman, L., Bar, A.K. and Chakrabarti, S., (eds.) Intelligent and Reliable Engineering Systems: 11th International Conference on Intelligent Energy Management, Electronics, Electric & Thermal Power, Robotics and Automation (IEMERA-2020). 11th International Conference on Intelligent Energy Management, Electronics, Electric & Thermal Power, Robotics and Automation (IEMERA-2020), 01-03 Oct 2020, London, UK (Virtual). CRC Press , pp. 1-6. ISBN 9781003208365

https://doi.org/10.1201/9781003208365

This is an Accepted Manuscript of a book chapter published by Routledge in Intelligent and Reliable Engineering Systems: 11th International Conference on Intelligent Energy Management, Electronics, Electric & Thermal Power, Robotics and Automation (IEMERA-2020) on 14 September 2021, available online: http://www.routledge.com/9781003208365

Blockchain Contradictions in Energy Service and Climate Markets

C. Nolden
University of Bristol Law School, UK & Environmental Change Institute, University of Oxford, UK

ABSTRACT: On paper, blockchain promises near-zero transaction cost for i) the establishment of energy demand baselines; ii) negotiation and execution of energy service contracts; iii) measuring, reporting and verifying of energy service provision relative to contractually agreed baselines; iv) capturing and trading of associated carbon emission reductions; and v) the establishment of appropriate trading platforms. It is also widely assumed that the 'invisibility' of both energy service delivery (especially in relation to energy savings) and carbon emission reductions can be overcome through provenance and 'visibility' generating capacities inherent in blockchain. Many aspects of energy service delivery and the capturing of associated carbon emission reductions, especially in relation to transaction cost minimization, also fulfil the business case for using blockchain:

- Use of a database, as the basic purpose of the blockchain is to order and record transactions
- This database must be shared among multiple users wishing to write to it to commit their own transactions
- The transactions are independent, i.e., the order of the transaction matters (e.g. the investor must pay money before the borrower pays interest on it)
- The writers do not trust each other as they may have conflicting interests; or simply have no sufficient information about each other
- There is a need for disintermediation, i.e. when no third party is suited to act as a trusted intermediary for all writers for one reason or another

Aside from fulfilling the theoretical business case, it is important to recognize the scale and scope of blockchain application in the energy sector. These, according to a recent paper by Andoni et al., range from 1) metering/billing and security; 2) cryptocurrencies, tokens and investment; 3) decentralized energy trading; 4) green certificates and carbon trading; 5) grid management; 6) IoT, smart devices, automation and asset management; 7) electric mobility; and 8) general purpose initiatives and consortia.

In practice, however, many of these attributes fail to materialize due to lack of scalability from small-scale experiments, data incompatibility and complexity. Many of these issues result from a fundamental misunderstanding of how energy systems operate, especially regarding social/technical/economic components. This paper firstly provides a transaction cost economic analysis which proves blockchain's theoretical technical potential to reduce transaction costs in energy service and climate markets and secondly juxtaposes these hypotheses with social/technical/economic systems in which this technology is embedded. By drawing on real life examples, this paper points towards limitations and issues which need to be overcome through both fundamental and applied research to establish how blockchain application in the energy sector may benefit such systems as well as individuals and businesses advocating blockchain. If blockchain's transaction cost efficiency is to be fully exploited in the ongoing energy system transformation, especially in relation to the growing importance placed on climate markets, more emphasis needs to be placed on inevitable interactions with the social/technical/economic systems in which this technology is embedded. This is necessary to ensure accountability and appropriate risk assessments before new and potentially path-dependent socio-technical infrastructures are promoted and implemented as solutions to 'problems'.

Keywords: blockchain, energy service markets, climate markets, transaction costs, socio-technical, contradiction

1 INTRODUCTION

In the energy system, an increasing number of service-based business models specialize in the provision of energy services (Steinberger, J. et al., 2009; Boza-Kiss, M. et al., 2017). These services include energy service contracts, peer-to-peer (P2P) energy trading platforms and demand and supply aggregation to offer flexibility services to local distribution systems operators (Nolden, C., 2019). Despite indications of an overall trend towards a service and performance-based economy (Lay, G. et al., 2009), the adoption of associated contracts is often hindered by high transaction costs (Sorrell, S., 2007; Steinberger, J. et al., 2009). These include search and haggling costs, bargaining costs and opportunism costs (Williamson, O., 1985; Sorrell, S., 2007; Nolden, C. and Sorrell, S., 2016).

Standardized contracts provided by trusted intermediaries and standardized methods for measurement, reporting and verification (MRV), such as the International Performance Measurement and Verification Protocol (IPMVP) for energy savings, can lower transaction costs. To create more favorable investment conditions, various organizations promote the establishment of such intermediaries and national and international investment platforms to de-risk and aggregate projects underpinned by accurate generation and consumption data (UNEP, 2011; ESMAP, 2017).

This clear emphasis on verifiable and measurable energy service delivery supports the notion that accurate generation and consumption data is essential for the viability of energy service business models (Hardy, J., 2017). Effective MRV is therefore considered essential both as a confidence building tool for assessing energy service delivery and associated benefits such as carbon emission reductions and as a means of de-risking associated contracts (ESMAP, 2017). Carbon emission reductions resulting from measured, reported and verified renewable energy generation, energy savings or flexibility services may generate additional cash flow if they are captured and certified in climate markets (Stua, M., 2017; World Bank, 2018; Yi, H. et al., 2017).

However, trust and fungibility of measured, reported and verified energy service delivery as well as associated carbon emission reductions need to increase if they are to play a greater role in energy and climate markets (UNEP, 2011; ESMAP, 2017; Stua, M., 2017; World Bank, 2018). This is supported by the UNFCCC Paris Agreement (UNFCCC, 2015: 5) which calls for 'environmental integrity, transparency, accuracy, completeness, comparability and consistency [to] ensure the avoidance of double counting' of carbon emission reductions.

According to various organizations, including the World Bank, the technical characteristics of blockchain, combined with various other emergent digital technology innovations, can help fulfil these requirements (see METRIC principles by the World Bank 2018), especially in relation to the 'invisibility' of energy demand and carbon emission reduction (Clark, J. and Knox-Hayes, J., 2011) . By focusing on energy service and climate markets, this paper indicates transaction cost reducing potential and (current) social/technical/economic limitations of blockchain application in relation to the zero-carbon energy system transformation.

2 METHODOLOGY

This study of the potentials and limitations of blockchain application in energy service and climate markets in relation to social/technical/economic systems in which the technology is embedded is the result of an ongoing study autumn 2017 and autumn 2019 of blockchain and digital technology innovation, disruption and governance in energy service and climate markets. Attendance at several conferences and invitations to workshops, including Event Horizon conference in Berlin (Germany), 2018, Smart Cities workshop in Exeter (UK), 2018, Offgrid Microgrids workshop in Belem (Brazil), 2018, Blockchain Live conference in London, 2018, Disruptive Energy for Communities workshop in Plymouth (UK), 2019, Launch of the Global Observatory on Peer-to-Peer, Community Self-Consumption and Transactive Energy Models in London (UK), 2019, and Digital Innovations in Energy Service Business Models innovation forum in Brighton (UK), 2019, provided access to expert ideas and opinions. Conversations and interviews, some of them recorded and transcribed, for example with representatives of the solar, storage and blockchain pilot in Brixton (UK), ClimateCoin and the Energy Web Foundation (EWF) provided in-depth insights into potentials and limitations of blockchain in relation to energy performance, P2P, flexibility and climate markets.

Insights from Transaction Cost Economics (Williamson, O., 1985; Sorrell, S., 2007) provide the basis for understanding the attraction of blockchain in the energy service sector, especially from a business and individual consumer perspective. The limitations of this analytical lens also highlight the shortfall of this focus on transaction efficiency to the detriment of system-wide benefits and long-term planning horizons necessary for deep low-carbon transformations. The next section provides a transaction cost economic analysis of blockchain's theoretical technical potential to reduce transaction costs for energy service delivery. The subsequent results section indicates (current) limitations with regards to the social/technical/economic systems in which this technology is embedded

3 THEORETICAL FRAMEWORK

Transaction costs, compared to production costs, are difficult to quantify as they are incurred by both the energy service provider and the client in preparing, negotiating and establishing (ex-ante) as well as in executing, monitoring and enforcing (ex-post) energy service contracts (Sorrell, S., 2007; Nolden, C. et al., 2016). These transaction costs can be subdivided into (Sorrell, S., 2007; Nolden, C. et al., 2016):

- The *search and haggling costs* associated with tendering, identifying a potential client or energy service provider, verifying their suitability, preparing and evaluating bids and selecting a preferred contracting partner
- The *bargaining costs* associated with negotiating and preparing the contract, monitoring contract performance, enforcing compliance, negotiating changes to the contract when unforeseen circumstances arise and resolving disputes
- The *opportunism costs* associated with either party acting in bad faith – for example by claiming that cost reductions derive from performance improvements when their real origin lies elsewhere

An increasing range of energy service intermediaries seek to increase the probability of contract adoption by facilitating the transaction process. Such intermediaries benefit from '*specialization economies* because their primary focus lies on energy service delivery; from *scale economies* because they deal with multiple energy service providers and clients; and *learning economies* because they carry forward lessons from one contract to another' (Nolden et al. 2016: 427). By providing these energy market services, intermediaries mainly lower *search and haggling costs* and *bargaining costs*.

To lower o*pportunism costs*, however, greater emphasis needs to be placed on transparency. According to Williamson (1985), hierarchical organizations (firms) reduce opportunism, which arises because of agents' intent and ability to exploit trust ('self-interest seeking with guile'). According to this interpretation, organizations (firms) are considered more transaction cost efficient than markets in the absence of complete market transparency At the same time, Williamson (1985) argues that contracts are always incomplete because it is not possible to fully monitor the behavior of the other party as a result of this lack of transparency.

Both concepts of *opportunism* and incomplete contracts, according Davidson et al. (2016), are being challenged by blockchain. To be precise, crypto-economic mechanisms, which enable 'a spot market exchange to carry forward indefinitely a pure promise' (Davidson, S. et al., 2016: 9) by crypto-enforcing the execution of agreed contracts through consensus, transparency and traceability, address *opportunism costs*. 'The complexity cost of writing contracts,' they continue, 'could scale linearly, and so the blockchain would lower transactions costs'. As a result, they suggest that 'all contracts would be complete and all economic transactions would be market transactions' (Davidson, S. et al., 2016: 9). This hypothesis of low transaction costs in relation to energy services suggests that the application of blockchain technology in the energy sector, especially as an MRV and accounting infrastructure facilitated by IoT and Artificial Intelligence (AI) to enhance transparency and traceability, reduces, if not eliminates, *opportunism costs*.

4 RESULTS

- Social systems

Despite blockchain's transaction efficiency, especially in relation to *opportunism costs*, the consensus mechanism underlying blockchain can entail significant negative socio-environmental consequences. Proof-of-Work (PoW) in particular is associated with centralized 'mining pools', which has led to capital concentration more skewed towards few individuals and organizations than analogue currencies. PoW, especially in the case of Bitcoin, is also very energy intense with its current electricity consumption estimated to be equivalent to Denmark with a single transaction consuming 200kWh of electricity (Andoni, M. et al., 2019). Ethereum, which thanks to its smart contracts can fully realize the potential of blockchain (GOS, 2016), also depends on a PoW consensus algorithms with associated socio-environmental consequences. EWF wants to overcome this contradiction through a Proof-of-Authority (PoA) consensus mechanism. Energy demand for transactions is significantly lowered by limiting validation to organizations that have joined EWF (EWF, 2020). However, as many of these organizations are established fossil-fuel energy generating incumbents such as E.On, Total and Engie, their desire to support transactions that might disrupt their business model is put into question.

Concentration of data in the hands of incumbents is already an issue regarding smart meters and smart meter data. Such data are supposed to enable a more service-oriented, low-carbon energy system and facilitate business model innovation around MRV automation. In the UK, however, there is no central repository for the data generated. People do not own the smart data generated in their own home and even regulators responsible for regulating commercial interests in charge of this data do not have access to it. Rather than facilitating transparent, efficient and robust accounting and recording of energy and associated carbon emission reduction data, the current socio-political environment in the UK therefore limits innovation and experimentation to incumbents and technology-driven innovators that team up with incumbents to access such data. Less technology-driven innovators or those responding to market needs and opportunities as 'outsiders', on the other hand, are excluded (Roberts, S., 2019). Supporters of PoA consensus algorithms need to ensure that this does not apply to their blockchain platforms.

- Technical systems

Most blockchain platforms inherently require a trade-off between scalability, speed and security. There appears to be an inherent dichotomy between security and the cost of guaranteeing the security: the computational resources in terms of processing power and the expended energy which inhibit scalability (Chitchyan, R. and Murkin, J. 2018). As a result, many, often successful, blockchain demonstrator projects are small-scale (Andoni, M. et al., 2019). Transaction efficiency consequently only accrue to those engaging in such trials. In fact, such bottom up innovations are often characterized by high levels trust which often neither necessitate the sharing of data with many different parties nor the immutability or transparency guaranteed by blockchain. Transaction costs are consequently low compared to more commercial P2P propositions.

Where existing ledgers and databases enable low cost and faster operations, despite less integrity and an absence of immutability and intransparency, there does not appear to be a strong business case for blockchain application. In most cases, existing ledger and database technologies are sufficient in the absence of high traceability requirements and low trust. At the same time there is a danger of P2P systems and other blockchain-based trading arrangements and platforms only benefiting those directly engaging in transactions with questionable outcomes for the wider energy system. Overall, it is also unclear what the public appetite is for P2P trading in general. Electricity and heat are generally perceived as low-involvement/low-engagement goods. Although numbers are increasing, only around 20% of UK domestic electricity customers switched suppliers in 2018 (Energy UK, 2019). If P2P energy trading was to involve any form of direct participation, it is unclear how much people would wish to engage, although it is widely understood that end-user engagement is an essential component of the zero-carbon transformation process (Eyre, N. and Killip, G., 2019).

- Economic systems

The current mismatch between blockchain's transaction cost efficiency and socio-technical realities also extends into economic systems and surrounding regulatory and political landscapes.

Blockchain's immutability is a key feature in unregulated spaces beyond political control, such as the Bitcoin blockchain. Where regulation and political legitimization are key features, such as the development of sustainable local energy systems and climate markets embedded within wider zero-carbon transformation processes, there currently do not appear to many circumstances where complete immutability is desirable. This is due to the lack of input data consistency and reliability on the one hand, and evolving political prioritization over time on the other. The ability to create a unique record, identifier and immutable timestamp, alongside the challenge of selecting the right consensus mechanism and system architecture in the first place, therefore creates other costs that might be termed *irreversibility costs*.

The production costs of developing new blockchain systems are currently high and even with an appropriate system architecture in place, there is no guarantee that the input interface regarding the identifier is immune to manipulation. While cryptographic immutability and verifiability imply that blockchain proves with certainty that the identifier of an asset existed at a particular time, nobody can verify the integrity of this data. "On the blockchain", according to Richard G. Brown, "nobody knows you're a fridge".

Regulating blockchain also requires further exploration. While permissioned ledgers are comparatively easy to regulate, permissionless distributed ledgers such as blockchain can only be regulated via legal code by focusing on businesses dealing with the tradable commodity (in this case energy generation, savings and carbon emission reductions). In theory, this enables government or the public to attain legitimate regulatory goals by determining the rules built into computer code (GOS, 2016). Such regulation, however, is still in its infancy.

5 CONCLUSION

Blockchain has great potential to help reduce transaction costs in energy service and climate markets thanks its capacity to log granular information at scales ranging from local electricity P2P markets to international carbon emission reduction registries. However, several issues remain regarding the scale and speed of transactions and blockchain's fundamental principles. Blockchain's transactional efficiency suggests that its application resembles a case of localized capitalism as opposed to democratized bartering. This might be contrary to the idea behind localizing energy systems, improving transactional efficiency and providing immutability and transparency especially when social/technical/economic systems are considered. In less contestable areas, such as in MRV, issues remain regarding data input and integrity. Contestable baselines and measurements do not lend themselves to immutable recording on the blockchain. Regarding climate markets, there appears to be more significant potential as long as the starting point is not blockchain but a mandated socio-political system that can benefit from immutable ledgers as a means of verifying carbon emission reductions. In all cases, however, the fundamental contradiction of blockchain, namely the dichotomy between the computation resources in terms of processing power required for security, and the environmental, social and economic costs of providing processing power, need to be overcome for its successful and legitimized technological application embedded within social/technical/economic systems.

REFERENCES

Andoni, M., Robu, V., Flynn, D., Abram, S., Geach, D., Jenkins, D., McCallum, P. and Peacock, A. 2019. Blockchain technology in the energy sector: A systematic review of challenges and opportunities. Renew Sustain Energy Rev, 100(2019), 143-174.

Boza-Kiss, B., Bertoldi, P. and Economidou, M. 2017. Energy Service Companies in the EU – Status review and recommendations for further market development with a focus on Energy Performance Contracting. Publications Office of the European Union, Luxembourg, Luxembourg.

CCC 2019. Climate Chain Coalition. Available https://ec94d884-4da2-402c-b98f-0cab85f86f83.filesusr.com/ugd/f69cd4_6cfcdfeb27dc4165b08c4997d54bb6ac.pdf (Accessed 6 January 2020).

Chitchyan, R. and Murkin, J. 2018. Review of Blockchain Technology and its Expectations: Case of the Energy Sector. Available at https://arxiv.org/abs/1803.03567 (Accessed 6 January 2020).

Clark, J. and Knox-Hayes, J. 2011. An Emerging Geography of Intangible Assets: Financialization in Carbon Emission Credit and Intellectual Property Markets. Georgia Institute of Technology, School of Public Policy Working Papers, Atlanta, USA.

Davidson, S., De Filippi, P. and Potts, J. 2016. Economics of Blockchain. Proceedings of Public Choice Conference, Fort Lauderdale, USA.

DAO IPCI 2018. Integral platform for climate initiatives, White Paper 5.0. Decentralized Autonomous Organization – Integral Platform for Climate Initiatives. Available https://ipci.io/wp-content/uploads/2018/06/WP_5.0-2.pdf (Accessed 6 January 2020).

Energy UK 2019. Another record year for switching. Available at https://www.energy-uk.org.uk/media-and-campaigns/press-releases/440-2019/6996-another-record-year-for-switching.html (Accessed 6 January 2020)

ESMAP 2017. Assessing and Measuring the Performance of Energy Efficiency Projects, Energy Sector Management Programme. The World Bank Group, Washington DC, USA.

EWF 2020. EW Origin. Energy Web Foundation. Available at https://energyweb.org/origin (Accessed 6 January 2020).

Eyre, N. and Killip, G. 2019. Shifting the focus: energy demand in a net-zero carbon UK. Centre for Research into Energy Demand Solutions, Oxford, UK.

GOS 2016. Distributed Leger Technology: beyond blockchain. UK Government Office for Science, London, UK.

Hardy, J. 2017. How could we buy energy in the smart future? Smart Energy GB, London, UK.

Lay, G., Schroeter, M. and Boiege, S. 2009. Service based business concepts: a typology for business to business markets. Eur Manag J, 27, 442-455.

Nolden, C., Sorrell, S. and Polzin, F. 2016. Catalysing the energy service market: The role of intermediaries. Energ Pol, 98, 420-430.

Nolden, C. and Sorrell, S. 2016. The UK market for energy service contracts. Energ Effic, 9(6), 1405-1420.

Nolden, C. 2019. Transaction cost analysis of digital innovation governance in the UK energy market. J Energ Mark, 12(2), 1-21.

Roberts, S. 2019. Why BEIS and Ofgem need smart energy data. Energise – News from the Centre for Sustainable Energy, Winter 2019, 4.

Sorrell, S. 2007. The economics of energy service contracts. Energ Pol, 35, 507-521.

Steinberger, J., van Niel, J. and Bourg, D. 2009. Profiting from negawatts: Reducing absolute consumption and emissions through a performance-based energy economy. Energ Pol, 37(1), 361-370.

Stua, M. 2017. From the Paris Agreement to a Low-Carbon Bretton Woods. Springer International Publishing, Cham, Switzerland.

UNEP 2011. Common Carbon Metric for Measuring Energy Use & Reporting Greenhouse Gas Emissions from Building Operations. United Nations Environment Programme Sustainable Buildings & Climate Initiative, Nairobi, Kenya.

UNFCCC 2015. Paris Agreement. United Nations Framework Convention on Climate Change. Available at https://unfccc.int/sites/default/files/english_paris_agreement.pdf (Accessed 6 January 2020).

Williamson, O. 1985. The Economic Institutions of Capitalism. Free Press, New York, USA.

World Bank 2018. Blockchain and Emerging Digital Technologies for Enhancing Post-2020 Climate Markets. Word Bank, Washington DC, USA.

Yi, H., Lee, S. and Kim, J. 2017. An ESCO Business Model Using CER for Buildings' Energy Retrofit. Sustainability, 9(591), 1-21.