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Clyde&Co

Study on the application of Blockchain and Smart Contracts in emerging energy markets

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List of Abbreviations

BMG – Brooklyn Microgrid

C2C – consumer-to-consumer

CNIL – Commission Nationale de l'Informatique et des Libertés (Commission on Information Technology and Liberties)

COVID-19 – Coronavirus Disease 2019

DAO – Decentralised Autonomous Organisation

DENA – Deutsche Energie-Agentur (German Energy Agency)

DEP – distributed energy prosumer

DERs – distributed energy resources

DLT – distributed ledger technology

EBRD – European Bank for Reconstruction and Development

EC – European Commission

EEA – European Economic Area

EFI – Energy Futures Initiative

EMs – emerging markets

ETS – emissions trading systems

EU – European Union

EV – Electric vehicle

GAW – Green Assets Wallet

GDPR – General Data Protection Regulation

ICO – Initial Coin Offering

IFC – International Finance Corporation

IFP – Institut Français du Pétrole (French Institute of Petroleum)

IOHK – Input Output Hong Kong

IOT – Internet of Things

IP – Internet Protocol

KEPCO – Kansai Electric Power Company

MDB – Multilateral Development Bank

MRV – measurement, reporting and verification

NFV – non-fossil value certificate

OTC – over-the-counter

P2P – peer-to-peer

PV – photovoltaic

REC – renewable energy credit

TEO – The Energy Origin

TFEU – Treaty on the Functioning of the European Union

UKJT – UK Jurisdiction Taskforce

UNDP – United Nations Development Programme

WRMHL – Wormhole (blockchain framework)

ZKP – zero-knowledge proof

Executive Summary

Smart contracts and blockchain technology have the potential to facilitate a transformation of the energy sector in emerging markets ("EMs"). In particular, they may enable a move to cleaner, more efficient and more sustainable decentralised solutions, and also help unlock unrealised economic value in natural resources and empower stakeholders and communities.

In order to harness the benefits of these enabling technologies, investment has to be leveraged appropriately and policy, legal and regulatory frameworks tailored to promote efficiencies via decentralisation.

Across the energy sector, policymakers, regulators and other industry stakeholders are faced by a series of emerging trends and challenges, which include the need for deep decarbonisation, flat or declining demand, and the integration of variable generation technologies. In addition, the COVID-19 pandemic has fast-tracked the uptake of many emerging digital technologies and highlighted the importance of robust and resilient energy supplies and emphasised the importance of localised solutions. This sits alongside the continuing momentum for sustainable development to make our economies and societies more resilient against climate and environmental shocks and risks.

Against this background, the deployment of digital smart contracts and blockchain technology presents a tremendous challenge but also a very tangible opportunity for EMs, in particular, to lead this transition.

Within energy markets, there are a number of promising, high-impact use cases – these include distributed energy resources ("DERs"), peer-to-peer ("P2P") energy trading, and carbon emissions tracking and emissions trading systems ("ETS").

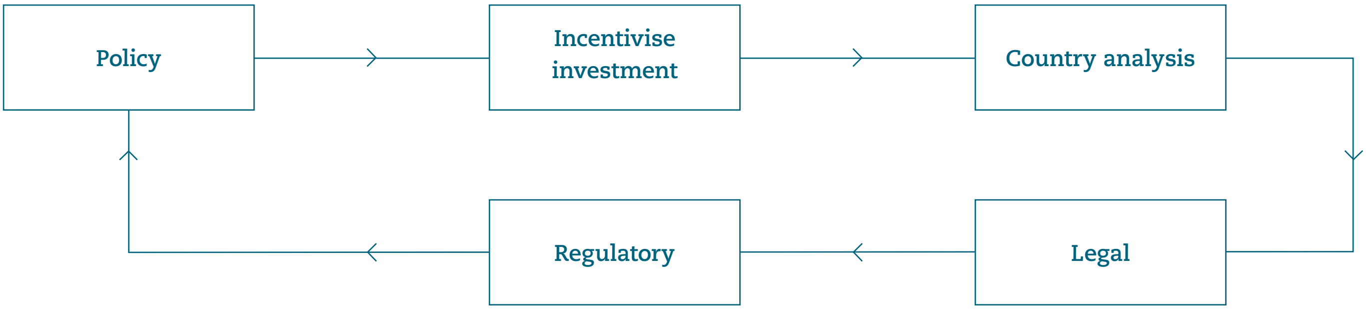
These have the potential to not only enable a more competitive marketplace, but also to facilitate growth and play a decisive role in the decarbonisation and electrification of economies.

However, technical, organisational, as well as legal and regulatory hurdles must be surmounted to facilitate blockchain adoption. This study identifies the main challenges faced in EMs, many of which highlight the conflict with existing utility business models of traditional energy generation. These include the lack of baseline digital and physical infrastructure in place to support blockchain's integration into energy systems, the lack of policy, legal and regulatory frameworks to accommodate blockchain and smart contracts in the current legal ecosystem (or lack of clarity and adaptability of existing frameworks), as well as the cost of integrating blockchain and deploying the necessary baseline infrastructure, alongside a poor investment climate in key energy technologies.

This study is concerned both with EMs but also emerging technologies. It is not an area in which clear lessons can be derived from other sectors. Rather, it is necessary to consider similar challenges where EMs have an opportunity to leapfrog some developmental stages experienced by other markets.

The study concludes that, in order to facilitate usage of blockchain for energy markets, industry stakeholders need to focus on developing:

- Policy guidelines;
- Legal and regulatory frameworks; and
- Investment and financing models, combined with incentives for technology development.



This will require constructive collaboration between diverse stakeholders ranging from technology industries through to environmental policymakers in EMs. This study concludes by making a number of key recommendations across these three areas, where the EBRD and other Multilateral Development Banks ("MDBs") can play an active role, ranging from a purely supervisory and coordinating role to acting as the driving force.

Introduction

Across the energy sector, there are a number of emerging trends and challenges currently faced by policymakers, regulators, and industry stakeholders. These include the need for deep decarbonisation to reduce greenhouse gas emissions and meet international climate change goals, flat or declining demand, the integration of variable generation technologies to address undersupply and oversupply of electricity, evolving measures of reliability, increasing consumer choice and flexibility, and the growing national and cyber security implications of electricity reliance. In addition, in the face of international crises like COVID-19, there is a pressing need to develop sustainable and resilient economies, which are often localised. Against this background, the deployment of new technologies presents a considerable challenge as well as an unprecedented opportunity for EMs, to lead this transition through innovation.

The 2015 Paris Agreement reaffirms the appetite of the entire global environmental community, and in particular EMs, to deploy new ways of generating and distributing electricity in order to meet their climate change commitments. Given the importance of the energy sector to economic stability and growth, transitioning to cleaner, more modern and efficient energy systems through technological advancement is all the more pressing and a necessary precondition to building environmentally sustainable economies. This is confirmed by the EBRD Energy Sector Strategy, which provides that technological innovation is a key pathway to driving and facilitating the integration of renewables, energy efficiency, electrification of economies and the decarbonisation of electricity.[1]

These changes present both a challenge and an opportunity for EMs to amend and modernise their laws to form a strong legal and regulatory foundation and a favourable business environment to incentivise private-sector investment.

Blockchain and other emerging technologies can be a significant factor in this transition. Blockchain-enabled smart contracts, in the form of automated contractual mechanisms, have the potential to enable a move to cleaner, more efficient and more sustainable decentralised solutions in the energy sector. Blockchain provides several benefits, which include increased decentralisation, immutability, transparency, efficiency, trust and resilience. However, it also presents a series of challenges and risks, which need to be overcome, including user trust and adoption, technology barriers (such as interoperability and scalability), cost-effectiveness, privacy and security risks, data storage and energy consumption, legal and regulatory challenges.

With particular emphasis on EMs, modern energy systems operating on blockchain and through smart contracts have the potential not only to increase process efficiency and stability, but also to ensure greater access to affordable electricity and demand flexibility on the electric grid. The ability to harness these benefits and manage the risks involved in the use of blockchain and smart contracts, in a way that instils confidence in users and investors, will necessarily determine their successful adoption in EMs.

This study provides (1) an overview of blockchain technology and smart contracts, their capabilities, as well as related challenges, (2) the opportunities that blockchain-based applications present in the energy sector and impact on EMs with specific reference to promising case studies, (3) the best practices in advanced countries and the key challenges and opportunities for EMs, and (4) the legal and regulatory barriers for application of blockchain and smart contracts in the energy markets with reference to specific use cases. Finally, the study provides practical recommendations and suggested next steps for lawmakers and other stakeholders to encourage the adoption of advanced blockchain-based applications in EMs.

1 EBRD. (2018). "Energy Sector Strategy 2019-2023" Accessible at: https://euea-energyagency.org/wp-content/uploads/2018/10/draft-energy-sector-strategy.pdf.

Overview of Blockchain Technology and Smart Contracts: Benefits and Challenges

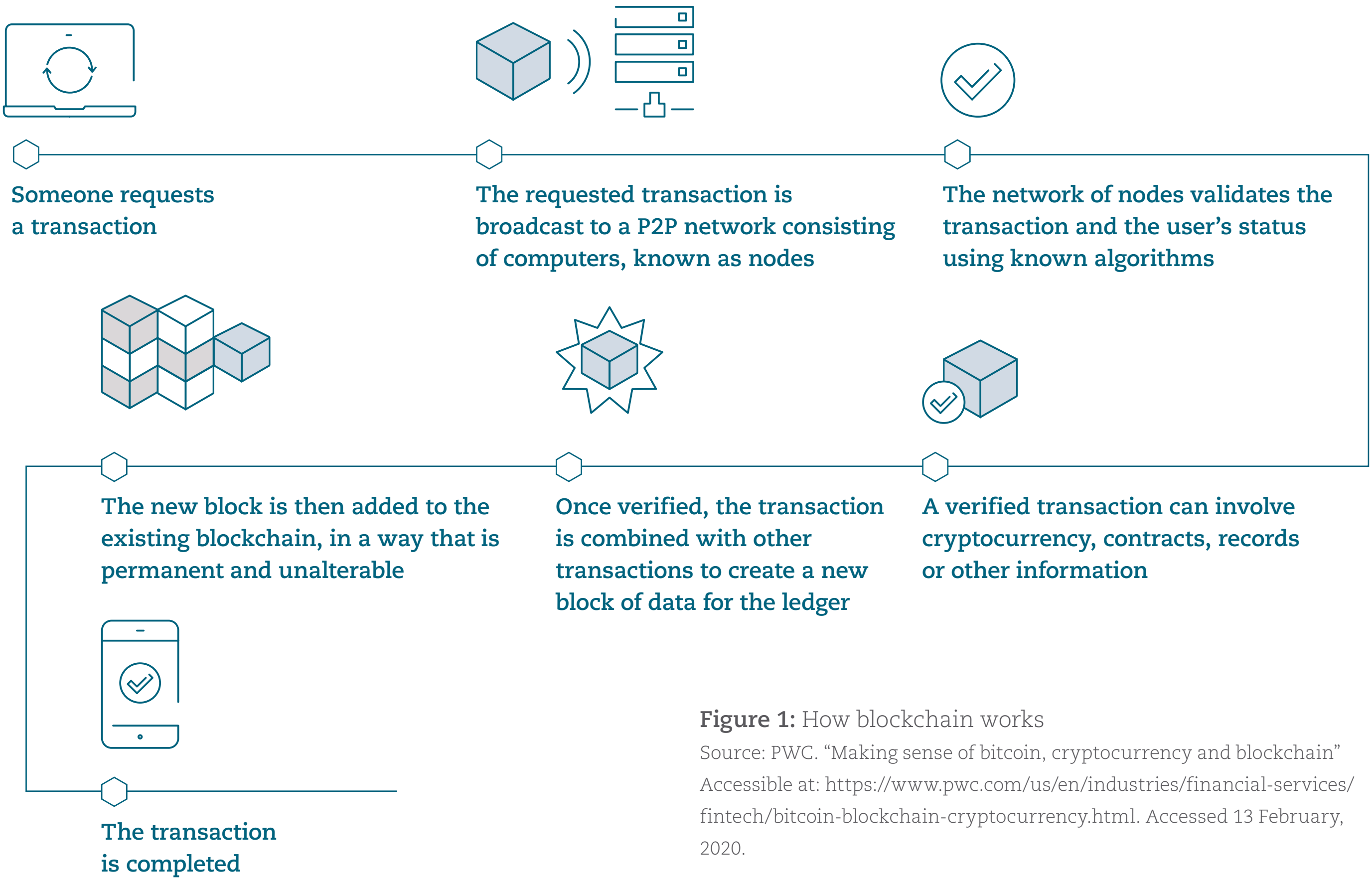


Figure 1: How blockchain works
Source: PWC. "Making sense of bitcoin, cryptocurrency and blockchain" Accessible at: https://www.pwc.com/us/en/industries/financial-services/fintech/bitcoin-blockchain-cryptocurrency.html. Accessed 13 February, 2020.

Blockchain

Overview of Key Capabilities and Characteristics

Blockchain is a digital database or decentralised electronic ledger system that verifies and stores, in a safe and cryptographically secure way, virtually any recordable information or transaction of value (whether it be money, goods, property or work) without the assistance of a centralised authority. This infrastructure can be exploited to facilitate P2P transactions, manage records, track physical assets and transfer value via smart contracts.

Broken down, blockchains store data in "blocks" and "chain" them together to form a cohesive, unbroken and immutable record of that information.

The joint operation of two features in particular makes blockchain extremely useful. First, identical copies of the particular electronic ledger are stored on and accessed from many computers or "nodes" around the world. Any attempted addition or change to the information is authenticated by the entire network of servers, and any validated change to one ledger automatically updates the others.

Second, together with this decentralised ledger system, the cryptographic technology that validates information stored and edited on the blockchain makes it extremely difficult to attack or corrupt.[2]

2 Clyde & Co. "Blockchain and the law: an uncharted landscape" Accessible at: https://www.clydeco.com/clyde/media/fileslibrary/CC010565_Blockchain_brochure_10-06-16_LOWRES.PDF. Accessed 13 February, 2020.

Private vs. Public Blockchains

There are multiple variations of blockchain, which sit within the framework of Distributed Ledger Technology ("DLT"). These range from the "pure" fully decentralised Ethereum and Bitcoin-based blockchains to various types of private and permissioned systems, a distinction which turns on the accessibility of membership and data, as well as the mechanism used to verify transactions and obtain consensus. At one end, there is a system akin to a public park, which is publicly accessible, and at the other, a private-gated park open only to residents, where information might not even be shared within the entire park but on a need-to-know basis only.

Data stored on public or permission-less networks are visible to all participants in encrypted format. These networks rely on participants to verify transactions and record data on the network, based on a selected consensus protocol referred to as "Proof of Work", which rewards participators with tokens in exchange for completing computationally complex tasks through a process known as "mining".[3] Participants in the bitcoin verification process are referred to as "miners". Other consensus-based protocols that are available for both public and private blockchains include "Proof of Stake", which involve "validators" who take a stake in the system and receive transaction fees in direct proportion to their stake by validating blocks. While Proof of Work requires high computational power and expends large amounts of energy, Proof of Stake does not.

By contrast, private or permissioned networks restrict the level of data access and transaction rights to participants, which is made possible through the operation of "trusted" nodes or system administrators that control access and rights onto the network. As with public blockchains, transactions can be verified using any one of the many consensus protocols available. Typically, they opt for mechanisms, which do not require incentives for participants, like "Proof of Authority", which uses identity as the sole verification of the authority to validate and does not require mining.

Whether a private and permissioned blockchain is more suitable in a specific case depends on the industry and company in question. One of the reasons for opting for private blockchains, alongside scalability and other factors, is that with public blockchains sensitive data has to be encrypted to ensure privacy. However, encrypted data cannot be used by smart contracts, so flexibility is limited for complex or highly "regulated" transactions. Within a private blockchain, this does not present an issue insofar as participants acquiesce in their data being shared and accessed by other members in the network. In addition, private blockchains are able to maintain data confidentiality, which also allows them to comply with regulations, something that is not possible under the conditions of anonymity (or pseudonymity) of open systems, where users are linked to a transaction only by means of their pseudonym or unique public address (i.e. a long string of numbers and letters that does not contain any identifiable information).

3 "Mining" in public blockchains like bitcoin is part of the consensus protocol referred to as "Proof of Work". Mining is the process by which transactions are added to the large distributed public ledger. It is itself connected to the incentive given to "miners" in exchange for the energy spent validating transactions and enhancing stability, security and safety on the network.

	Public/ Permission-less Blockchains	Private/ Permissioned Blockchains
Access	Anyone, fully decentralised	Single organisation, more centralised
Participation	Anonymous	Known identities
Consensus Process	Consensus mechanisms, e.g. Proof of work, proof of stake	Pre-approved participants, voting / multi-party consensus, e.g. Proof of authority
Trust	Trust embedded	Trust not embedded
Security	High security	Medium security
Transparency	High transparency	Depends on access rights
Performance	Slow transaction speed	Light, fast transaction speed
Efficiency	Low efficiency	High efficiency
Energy Efficiency	High energy consumption	Low energy consumption

Figure 2: Characteristics of Private vs. Public Blockchains

While it is possible to imagine a public blockchain in the energy sector, for instance, to operate energy transactions between network and grid users, it is likely that this will present issues related to data confidentiality.
For this reason, it may be that private blockchains are more suitable for the energy sector, given the volume of complex, highly regulated transactions involved, at least until regulations are amended to accommodate blockchain solutions in the public space. Though it should be noted, public blockchains have a number of advantages over private blockchains in this respect: they are not only considered to be more secure, but also encourage greater user participation, innovation and throughput.

Therefore, before embarking on a blockchain initiative, it will be necessary for companies, authorities and organisations to determine which blockchain system is more appropriate. As a first step, it is important that blockchain projects are gradual and start by leveraging process efficiencies in existing business models. Accordingly, it may be more appropriate to utilise private or semi-private blockchains, which are closer to relational databases currently in use in large companies, to start pilot testing the application and viability of specific use cases. Then, once successful pilot testing has taken place, investors and policymakers can switch to open-source, public blockchains with permissioned consensus protocols, in order to maximise participation, innovation, and throughput.

Overview of Key Benefits and Advantages of DLT

The key advantages for DLT relate to its distributed and immutable nature. The ledger is shared, updated with every transaction and selectively replicated among participants in near real-time. Privacy is maintained using cryptographic techniques and/or data partitioning techniques to provide participants selective visibility into the ledger, both of transactions and the identity of transacting parties.
Any data stored on the ledger is traceable and cannot be altered or deleted, without the consensus of the network, which adds an additional degree of security compared to traditional IT security systems.

The P2P network eliminates the need for third-party intermediaries, which in turn, embeds trust in the system and increases speed, lowers transaction costs, and enhances security in the network. Moreover, the distributed nature of blockchains protects the network from single points of failure, thereby increasing the resilience of the system. Finally, as a distributed and shared platform, it increases the transparency of transactions, as well as the visibility of ownership and control of assets.

Overview of Key Challenges and Risks

With all the benefits of blockchain, there also come risks and challenges that need to be overcome. These include challenges and risks of user trust, efficiency, adoption, scalability and interoperability, privacy and cyber security, data storage and energy consumption, as well as legal and regulatory challenges.

One of the most persistent problems with public blockchains revolves around efficiency, in particular, the duplication and significant resource inefficiency of Proof of Work mining. Unlike traditional distributed systems, blockchain peer nodes act independently to verify transactions, effectively doing the work of one. Each peer node in the network holds the entire transaction ledger and performs every transaction, including evaluating every line of every invoked smart contract function. There is currently research being conducted on "sharding", a process by which nodes would be responsible for only a portion of the overall data, based on a different distributed form of consensus mechanism that would decide which nodes act to verify which data, thereby eliminating duplication.[4]

From an energy efficiency and sustainability perspective, public blockchains operating on a Proof of Work system expend a lot of computational power and energy in the process of data mining, which is an issue to the extent that the type of energy resource used is fossil fuel-based, as opposed to renewable energy. Adopting different consensus mechanisms like Proof of Stake would potentially solve not only the problem of duplication, but also largely eliminate the computational power and energy costs related to this process. Alternatively, it would be possible to adopt a private or permissioned blockchain which would remove the energy consumption issue, given its reliance on alternative consensus mechanisms.

4 Hertz-Shargel, B. and Livingston, D. (2019). "Assessing Blockchain's Future in Transactive Energy", Atlantic Council Global Energy Center, p.17.

With regards to scalability, the main problem in public blockchains arises from the difficulty in managing and processing vast amounts of data which need to be validated by nodes in order to be mined into blocks. For this reason, blockchains maintain strict limits on the "block rate" (the rate at which blocks are mined), which, however, hampers the amount of transactions that can be processed at a time. By way of illustration, it is estimated that Bitcoin processes around five transactions per second and Ethereum twenty per second,[5] against Visa's average rate of two thousand per second.[6]

This is compounded by the data storage challenge, which requires that peer nodes hold a copy of the entire distributed ledger. There are technological solutions being sought that would, for example, move parts of the blockchain computations "off-chain" or "on-chain" and, in turn, reduce the computational demand on the network and the enormous energy consumption related to mining. However, reliance on off-chain computation, for instance, would not only reduce the role of smart contracts but also undermine the original proposition of blockchain as the primary application platform to the extent that a non-blockchain platform would be required to host the majority of the data and computation involved in the applications.[7] Again, one could alternatively opt for a private blockchain where scalability would not present an issue.

There is also a question of whether blockchains are fully and truly immutable, given the ability of a network to reverse or revise a blockchain through the relevant consensus process. This eliminates the level of certainty and finality associated with traditional transactions on a centralised ledger and raises a related governance problem in terms of validating transactions. It also raises an issue of cyber security in cases where there are participants in the network with malicious intent that could destabilise the system. Paradoxically, this is more of an issue for private blockchains than public blockchains, as the former are more vulnerable to external attacks than public blockchains (although they are not entirely immune either).

Finally, there are issues relating to privacy, which undermine public blockchains' main proposition of an open and transparent record of transactions across the network. While transparency is a welcome alternative to the information asymmetry between traditional platform authorities and their users, it presents risks posed by the visibility of private and sensitive data, including security risks to institutions, governments, and physical infrastructure. This is particularly applicable in energy markets given the potential impact to electricity grids.[8] To deal with this, data must therefore be encrypted on the blockchain in a way that it can be validated by the network and visible to the markets. To solve the issue of transparent privacy, there are cryptographic techniques that are being developed, which can potentially offer a way forward, but research and development are still required to make these techniques viable alternatives. Alternatively, one could opt for a private blockchain and restrict access and reader rights, which would largely eliminate privacy concerns.

Aside from the technological challenges and risks presented above, there are also substantial legal and regulatory challenges. These are addressed further below. On a practical level, there will of course also be integration challenges, although these are likely to be less pronounced in EMs, where technological infrastructure is still underdeveloped. With modern digital energy systems still lacking, integration and transition costs will be lower, depending on the level of existing systems. This, however, does not account for the costs of building the necessary physical infrastructure to support blockchain in the first place.

Smart Contracts

Main Capabilities and Benefits

The ability of blockchains to record and verify transactions in an open, reliable and transparent way provides a unique platform for the operability of smart contracts. Smart contracts are one of the tools or applications empowered by blockchain — their essential utility stems from their interoperability with and ability to run on blockchain. Smart contracts are essentially applications or pre-coded instructions written in software code that are able to automatically self-execute on the occurrence of an event.

The term "smart contract" can be something of a misnomer. There is no clear consensus as to what constitutes a smart contract. Attempts have been made to distinguish between technical smart contracts and legal smart contracts. The lack of a clearly established taxonomy can be a recipe for confusion and uncertainty.

At a broad level, a smart contract, as meant in the technical non-legal sense, shares similarities with a legal contract, in that they are both frameworks for regulating the interaction between parties. A smart contract of this nature

5 Bitcoin is a digital marketplace and payment network where "cryptocurrencies" known as bitcoins are exchanged for different fiat currencies. Ethereum is an open-source, blockchain-based, decentralised software used for its own cryptocurrency, ether.

6 Op. Cit 4, p.18.

7 Op. Cit 4, p.19.

8 Op. Cit 4, p.23.

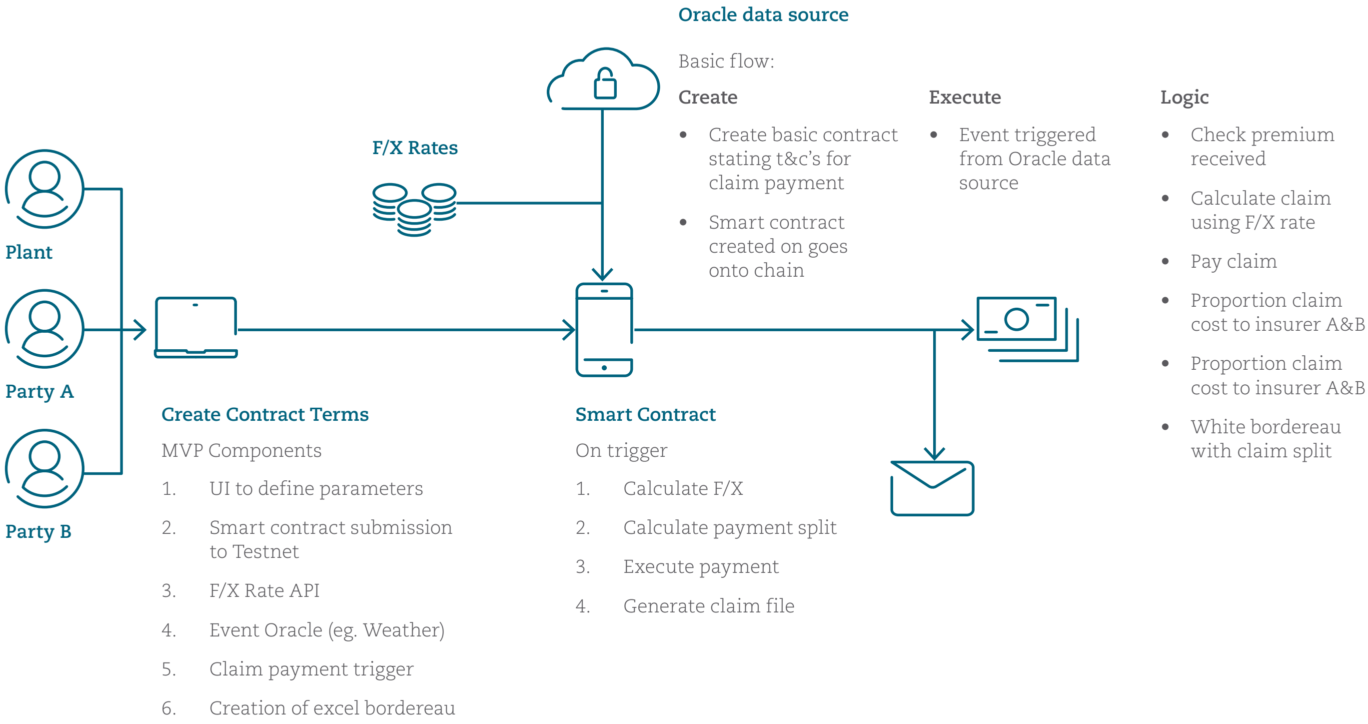


Figure 3: How a blockchain-based smart contract operates in practice

Source: Clyde & Co. "Clyde Code." 28 January, 2020. Data & Disruptive Technologies in Energy Seminar.

is, at its heart, a computer programme or coded logic that receives certain inputs and automatically executes a set of instructions to reach one of many pre-defined outcomes. It is "smart" in the sense that it is partially or fully self-executing, self-enforcing, or both. It represents the transaction between the parties and not necessarily the contract.

For example, in a basic transaction between two parties, smart contracts can automate both the performance and payment element of a contractual agreement by reference to an external set of dynamic or live conditions, such as the fluctuation of the market price of goods, the exchange rate, or even the weather. This condition can be imputed as a component in the contract terms and the smart contract can then be added onto the blockchain. Upon the occurrence of the event, which is verified by an external third party data source (or "oracle"), the smart contract can then automatically self-execute and direct payment or contractual performance to be carried out in accordance with the terms and conditions.

The extent to which the automated process-making element constitutes a contract in the legal sense will depend on a variety of factors. The analysis needs to draw a distinction between matters within the code and matters outside the code. These issues are discussed below.

Smart contracts have the potential to reduce the contracting, enforcement and compliance costs associated with related transactions.[9] It is for this reason that lawmakers in various countries are exploring ways to integrate smart contracts into the legal fabric of contract law and to ensure that the law is well adjusted to suit their application through open consultations with stakeholders and the creation of specific working groups, like the LawTech Delivery Panel in the UK.[10]

9 L. Bacon, N. Brook and G. Bazinas, Clyde & Co Clyde & Co. (2016). ""Smart Contracts": Where Law meets Technology." Accessible at: https://www.mondaq.com/uk/contracts-and-commercial-law/504854/smart-contracts-where-law-meets-technology.
10 UK Jurisdiction Taskforce (UKJT). (2019). "Legal Statement on Cryptoassets and Smart Contracts." The LawTech Delivery Panel.

One of the key advantages of smart contracts on a blockchain is that transactions are recorded accurately and consistently in a distributable and shared way that allows every node in a network to verify the accuracy of the central ledger by reference to their own copies. As stated above, this system embeds trust in the contractual relationship, enabling multiple parties to transact with each other with the certainty that a transaction will be performed as agreed. A transparent source code allows any party to access the written code online and independently verify its functionality.[11]

Finally, blockchain-based smart contracts offer not only more certainty and flexibility in the implementation of decentralised digital asset transfers, but also the capability to perform a range of functions that traditional contracts cannot, such as the automation of the performance and payment element of an agreement by reference to an external set of dynamic or live conditions, as illustrated in Figure 3 above.

In many ways, therefore, energy markets lend themselves to blockchain-based solutions. The specific use cases of blockchain and smart contracts in the energy sector are discussed further below.

Main Challenges and Risks

Although the immutability of blockchain-based smart contracts is considered a benefit, it can be a double-edged sword. Immutability presents difficulties to the extent that transactions recorded on the ledger are faulty, fraudulent or bear some form of mistake which nullifies or frustrates their intent, or which simply contain some bug in the software code of the smart contract which make it susceptible to failure. Immutability means that smart contracts cannot be reversed or retroactively amended like traditional software even after defects or vulnerabilities are found.[12]

Linked to this is the inherent limitation of smart contracts to capture the legal intent of an agreement and the inability, in a practical sense, for certain contractual terms to be fully expressed in code or executed.[13] There are a number of practical solutions to these issues, which include drawing up a traditional Master Supply Agreement expressed in natural language to govern over all smart contracts or a joint agreement that links the traditional contract to the smart contract, for instance, using the latter purely as an execution method. In addition, parties could incorporate provisions into the agreement to allow for the resolution of disputes related to the terms by an independent and neutral arbitrator.[14]

The various legal and regulatory challenges presented by blockchain-based smart contracts are explored below.

11 L. Bacon and G. Bazinas, Clyde & Co. (2017). "'Smart Contracts': The Next Big Battleground?" https://www.lexology.com/library/detail.aspx?g=91ec2f4d-0dda-47a8-a309-31e038d75e9c.

12 *Ibid.*
13 *Ibid.*
14 *Ibid.*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Promising Blockchain-Based Applications in the Energy Sector and the impact on Emerging Markets

Blockchain's ability to establish trust and support automated transactions may not only allow it to transform the energy sector but also provide an effective solution to the key challenges faced by EMs. These often include the lack of reliable and verifiable market data made difficult by the absence of financial and technical infrastructure to record and track such data, as well as the systemic lack of trust and transparency in the operation of financial systems, with other implications including a highly competitive market structure and cost of entry for new entrants.

Blockchain-based solutions typically involve a shared digital ledger of information, multiple sources and contributors of information to that ledger, and a trusted environment that does not require a centralised authority or third-party intermediary to process and verify that information. While these foundation blocks form a significant barrier for digital development in EMs, blockchain remains compelling as an enabling technology in EMs. Blockchain has the capacity to lower the verification and networking costs of participants and make the current market structure more competitive by lowering the cost of entry to new entrants.

The major advancement in this area has to do largely with the deployment of DERs, such as rooftop photovoltaic ("PV") panels, electric vehicles ("EVs"), microgrids and smart meters. These enable the formation of new business models for energy markets and trading, real-time data management, and moving carbon credits or renewable energy certificates onto the blockchain.[15]

Blockchain essentially provides the potential to decentralise traditional grid management and enact the distributed management of energy transactions without the need for a third-party intermediary. In particular, it can enable distributed management of energy demand, implementation of near real-time automated demand response event programmes, near real-time financial settlement and events validation, secure energy transactions, and scalability regarding the proportion of distributed generation within the global energy mix.

15 See Consensys, accessible at: https://consensys.net/blockchain-use-cases/energy-and-sustainability/.

In practical terms, blockchain has the ability to enable P2P energy transacting between consumers and producers. It also establishes an immutable record of provenance and chain of custody, creating transparency across supply chains in such a way that ensures products can be traced fully from source to store. This opens up an entirely new avenue for carbon emission certification and renewable energy distribution.

The impact of these technologies on EMs cannot be overstated. Blockchain-based solutions provide the opportunity to generate value in the energy sector through the enablement of a greater number of stakeholders, such as consumers acting as "prosumers".[16] The result is not only greater and cheaper access to clean energy for communities, but also greater demand flexibility on electric grids and battery storage capabilities to address the undersupply and oversupply of electricity generation respectively, as well as enhanced security of supply and energy independence for prosumers. This shift is made possible largely due to the rise of new connected technologies like blockchain that enable the tracking of energy data and the increased use of renewable power like solar and wind onto the electric grid.[17]

Distributed Energy Resources

DERs are physical and virtual assets that are typically characterised by their small capacity and connection to low and medium voltage grids, which are either behind-the-meter or connected directly to the distribution system.[18] As above, examples of DERs can include rooftop and community solar PV panels, energy storage, EVs, microgrids and smart meters. These are well-placed to provide support to communities in EMs with restricted access to the electric grid.

16 In energy, a "prosumer" is a consumer that produces and consumes energy.
17 Office of Energy Efficiency and Renewable Energy. (2017). "Consumer vs Prosumer: What's the Difference?" 11 May, 2017. US Department of Energy. Accessible at: https://www.energy.gov/eere/articles/consumer-vs-prosumer-whats-difference.
18 Energy Futures Initiative (EFI). (2018). "Promising Blockchain Applications for Energy: Separating the Signal from the Noise," p.13.

Blockchain and smart contracts enable the aggregation of individual DER entities in a power system by creating a mechanism through which these entities can share their data, signal their intention and be compensated for specific actions.[19]

In more technologically advanced use cases, microgrids running on blockchain could enable wholesale P2P trading through the use of smart contracts, where, for example, a consumer could directly purchase excess energy from a desired source (e.g. solar or wind) by transacting with a supplier of that resource.[20] In practice, a blockchain-enabled platform could be set up in such a way that when electricity prices hit a certain pre-agreed level, a sale of power could be automatically triggered between an owner of a solar PV array and a customer, with the microgrid only providing the wires.

This is particularly beneficial in EMs, where reliance on electrical utilities and energy companies for energy generation, transmission and distribution in meeting inflexible energy demand is no longer practical. Given the shifting role of consumers to prosumers, there is a significant upside to be experienced in EMs. However, this shift very much relies on the development of a greater number of customer devices at the grid-edge (e.g. smart meters, inverters, appliances, and batteries) and implies strong growth in the number of market participants that electric utilities manage in future. In addition, on the most basic level, this shift relies on the existence of baseline physical infrastructure (i.e., smart grids) that would enable the integration of such customer devices at the grid level or, alternatively, on a push towards more self-sustainable communities that can operate outside the main grid as and where needed.

Blockchain is compelling as an enabling technology in EMs in view of its ability to automate and reduce the costs of managing this growth in market participants. Through the use of smart contracts, electric utilities managing the grid from the device level can automate operational decisions and maximise efficiencies across electric grids. The various grid services that are enabled by smart, interconnected devices would be triggered, tracked and settled using blockchain-based smart contracts. The adoption of this leaner management of electric grid by utilities and system operators can reduce operational costs and unlock revenues from new services.[21] It is also expected to help meet policy mandates for implementing cleaner grids through the combined use of variable renewable supply, and responsive demand-side resources.[22]

A blockchain distributed ledger can be constructed and managed at the smart grid level. Each Distributed Energy Prosumer ("DEP") features Internet of Things ("IoT") based energy metering devices and registers the monitored data regarding the energy production or energy consumption values in blocks as part of the ledger. Thus, a DEP is modelled as a node of the P2P distributed energy network and can maintain a copy of the ledger which is automatically updated when new energy data is verified and registered.

In practice, it is possible to envision the operation of grid services at the point of production through to downstream transactions: taking the example of a consumer producing power from a solar PV array, power could be measured and recorded by a smart meter (or a smart inverter directly integrated with the array).[23] A software client on the smart meter, or oracle, could then connect to the blockchain over the internet or a home area network and submit a transaction, registering the meter read. Once validated and executed by the blockchain, the transaction would then

19 *Ibid*, p.15.

20 *Ibid*, p.15.

21 Miller, D. and Mockel, P. (2018) "Using Blockchain to Enable Cleaner, Modern Energy Systems in Emerging Markets", Chapter 8, EM Compass Note 61 in "Blockchain: Opportunities for Private Enterprises in Emerging Markets" International Finance Corporation (2019), p.2.

22 *Ibid*.

23 Smart meters deployed today only capture whole site load at the point of interconnection, net of any local energy storage or generation, so this type of envisioned submetering would require novel capabilities. Hertz-Shargel, B. and Livingston, D. (2019). "Assessing Blockchain's Future in Transactive Energy." Atlantic Council Global Energy Center, WEF. (2018). Building Blockchains for a Better Planet. Fourth Industrial Revolution for the Earth Series, p.14.

invoke a function on a smart contract, passing the oracle's identity, the kilowatt-hour value, and any other attributes of the solar production as inputs. The oracle is thus a critical part of the digital-physical interface, which determines the accuracy of physical information (such as meter reads) passed to the blockchain. The verified oracle would then invoke the smart contract function to credit the supplier's account for the production of solar power.

To better understand how this works in real-world applications, some of the more promising use cases of blockchain-based applications using smart contracts are examined below.

Promising Case Studies of Blockchain-Enabled DERs

To date, the most promising blockchain-based innovations that have been observed in this area relate to renewables, smart grid infrastructure, automation and management, EVs, energy storage and charging. With sufficient financing and technical support from MDBs and other investors in EMs, this could potentially advance the infrastructure shift for blockchain-based applications to take hold.

UK: Electron (RecorDER)

In the UK, Electron, National Grid Electricity System Operator, SP Energy Networks and UK Power Networks are collaborating on a project to create a shared register for generation and storage asset data ("RecorDER"). The project announced in June 2019 is the first step in the process of grid integration and management of DERs. RecorDER aims to create a clear view of assets connected to the energy network by integrating existing datasets in the industry.[24] It is suggested that improved visibility and availability of asset data will enable new systems that support decarbonisation and reduce the overall operating cost of the energy system. Moreover, by employing blockchain as an enabling technology, the integration layer can be deployed and hosted by collaborating parties, removing the requirement of either a large-scale infrastructure project or a central party to host the system.

France: Engie

In France, Engie is developing a smart metering solution in partnership with Ledger, a French Blockchain hardware start-up. Together they plan to develop a secured, autonomous and blockchain agnostic oracle (a hardware device that will be compatible with most blockchains). The so-called hardware oracle will measure meter data at the source of green energy production (such as wind turbines, solar panels or hydropower) and safely record it on the blockchain to be used in decentralised applications. In April 2019, Engie tested prototypes on some of its renewable infrastructures and plans to install 100,000 boxes on wind, solar and hydro farms by 2023.[25] The hardware is compatible with the Ethereum Blockchain and the Energy Web Foundation Blockchain, but the plan is for the device to be compatible and be able to connect with different blockchains and several decentralised applications at the same time. The device will include a secure element and an anti-tampering solution to ensure resilience and security of the data gathered.

Germany: Innogy MotionWerk (Share & Charge)

In Germany, MotionWerk, a start-up formed by a subsidiary of utility major RWE, developed a decentralised protocol for EV charging, transactions, and data sharing called Share & Charge. This project, allows private individuals to share and rent charging stations owned by them via a mobile phone application in a P2P way.[26] MotionWerk has already launched 1,200 stations which are connected via this application, which is based on the Ethereum blockchain that facilitates automated billing and seamless payments by integrating its stable coin as part of the payment solution. This project facilitates the availability of EV chargers, providing economic incentives for owners of private chargers to bring them online for public use.

Challenges for Blockchain-Enabled DERs in EMs

DER capabilities provide an enormous opportunity for communities in EMs to connect to microgrids and for consumers to take on an enlarged role in the production of the electricity that is consumed. DERs, however, also present a series of challenges. One of the main challenges is the lack of understanding between regulators and policymakers on the value of DERs and the role of

24 Electron. (2019). "Electron, National Grid Electricity System Operator, SP Energy Networks and UK Power Networks launch innovation project to build first blockchain-based electricity asset register in GB." 17 June, 2019. Accessible at: https://electron.net/electron-national-grid-electricity-system-operator-sp-energy-networks-and-uk-power-networks-launch-innovation-project-to-build-first-blockchain-based-electricity-asset-register-in-gb/.

25 IFP Energies Nouvelles. (2020). "Accélération de la transition énergétique grâce à la technologie des blockchains." 11 February, 2020. Accessible at: https://www.ifpenergiesnouvelles.fr/node/976.

26 See Share & Charge. Accessible at: https://shareandcharge.com/ Accessed 13 February, 2020.

prosumers. DERs are challenging many of the existing utility business models and the role and value traditional generation will continue to play.

Another challenge for DERs is that their current infrastructure is insufficient to support blockchain's integration into energy systems. This includes the needed technologies (e.g. short interval smart meters, inverters, appliances, batteries, software applications), regulations (e.g. on pricing flexibility), or business models (e.g. with incentives to build out supply resource flexibility) to create time-of-use, peak pricing, real-time pricing, or other structures that are enabled with blockchain.[27] This is particularly evident in EMs that have yet to digitalise their energy systems and adapt to best practices.

While blockchain may enable some of these technologies, many DER markets are in the early stage of development so adoption may need to be gradual in order to allow for adaptations of developing DER technologies. In this instance, the flexibility of a private blockchain, which can more easily integrate system upgrades and adapt to developments in DER markets, as well as regulatory changes, would be more suitable. Once established, moving to a public blockchain to encourage more widespread user adoption, innovation and throughput would be encouraged.

With regards to EVs, the key barrier to market adoption is clearly the availability of EV chargers. One approach to addressing this issue is public subsidies for deployment of more chargers. Another approach is to support platforms like Share & Charge which create access to affordable and reliable payment solutions for EV sharing and charging. Such platforms can achieve automated billing and incentivise the private building of EV charging infrastructure as charging stations generate a revenue stream for owners by enabling other drivers to charge EVs at their points.

While European Union ("EU") member states like Germany and France have taken the lead, EMs will need to follow suit. It is clear that MDBs and other investors will have a role to play in the financing of the needed charging infrastructure and blockchain-based applications.

RECOMMENDATION: One important step that lawmakers and policymakers should take, particularly in EMs, is to introduce new regulations and policies, which facilitate adapted, more decentralised, business models. This will support blockchain's integration into energy systems while ensuring universal access to electricity. Effective regulation in this space is usually outcome-based rather than a question of prescriptively determining the details of contractual requirements and relationships. Clarity should be provided as to overall responsibility(ies) for the effective management of distributed systems and the status of the contractual relationships. For instance, Malta's recognition of a Decentralised Autonomous Organisation ("DAO") as a distinct legal entity is innovative but likely to create confusion if adopted in a heavily regulated space. More importantly, states will likely need to subsidise the necessary smart grid and EV charging infrastructure and support innovations in the area that will allow for seamless integration in energy systems to take place and incentivise the private building of infrastructure. There is a clear role for MDBs to play in the financing part of this transition.

Advanced Energy Trading Platforms and Energy Transactions in Emerging Markets

The energy trading process still heavily relies on the manual exchange of goods, multiple interactions between entities, and third-party intermediaries to close deals and settle transactions.[28] A blockchain-based energy trading platform could help integrate current market participants and incentivise new ones (such as prosumers), while at the same time enabling, through the use of smart contracts, more types of DERs, including EVs, to receive payments for their active participation as sources of supply or as demand response.[29]

Many emerging economies lack the institutional capacity to build and sustain robust traditional energy markets. Blockchain offers a framework for automating many fundamental institutional capacities, and creates a trusted system for handling energy transactions, including billing and settlement, all without the need of a centralised authority.[30]

In addition, blockchain has the ability to facilitate platforms that connect investors with renewable electricity generating projects in developing countries. On a basic level, investors buy tokens, creating a pool of capital that is then used to fund renewable energy generation projects in different jurisdictions from a platform that records and tracks all transactions related to the project. In practice, these schemes rely largely on tokenisation and the transparency of distributed ledgers for documenting multiple, relatively small transactions between participants in different jurisdictions. Their utility in facilitating and incentivising investment in renewable power generation is therefore self-evident.

27 Op. Cit. 18, p.16.

28 Op. Cit. 18, p.20.

29 *Ibid.*

30 Op. Cit. 18, p.28.

Promising Case Studies of P2P Energy Trading Platforms

Some interesting use cases of blockchain in energy trading that serve as example innovations that could be supported and financed by MDBs in EMs are listed below. These include microgrids, consumer-centred marketplaces and P2P energy trading platforms. Platforms that incentivise investment in renewable power generation are also considered.

Germany: Ponton (Enerchain)

In Germany, Ponton has developed a project in wholesale trading called Enerchain, which allows participants in the energy wholesale markets, including new players like industrial consumers, wind and solar park operators, microgrid developers and suppliers to trade power and gas on a decentralised platform, thus avoiding intermediaries and central market platforms.[31] The proof of concept was started in May 2017 with 44 leading European energy trading companies. The participants have already been part of live trades, which were publicly executed during the ongoing project phase. In May 2019, the Enerchain 1.0 platform was launched.[32] It is the first blockchain-based distributed trading platform enabling over-the-counter ("OTC") energy trading of spot and forward contracts in the power and gas markets.

The underlying framework of the Enerchain platform ("WRMHL") is said to be process-independent, customisable to each transaction, and offers a fast and secure blockchain environment which compliments trading processes that require swift data synchronization between participants.[33] Given its trading capability within energy communities on a P2P level, the flexibility between distribution grids and wholesale delivery at the level of balancing zones, it provides a strong use case for EMs.[34]

United States: LO3 Energy (Brooklyn Microgrid and PANDO)

In the US, LO3 Energy partnered with Transactive Grid to develop a community- driven microgrid in New York, which allows a community in Brooklyn to directly use LO3's P2P blockchain platform for energy trading. The virtual, local energy marketplace, which is powered by Exergy, a blockchain platform, enables residential PV producers to directly sell excess solar electricity to neighbours or back to the grid and contribute to the local economy.[35] Smart meters track the electricity produced and consumed, while an Ethereum-based blockchain records the smart contracts, which enable automatic P2P transactions. Since the creation of the Brooklyn Microgrid in 2017, LO3 has engaged in a series of other pilot projects, including PANDO, which creates a blockchain energy marketplace for P2P community trading.[36]

Estonia: WePower

In Estonia, WePower enables financing for new renewable energy generation projects by using tradable smart contracts to establish digital power purchase agreements between parties. It is a blockchain-based green energy procurement and trading platform which brings together renewable energy generators and investors interested in supporting global green energy projects. Renewable energy produced is tokenized and subsequently traded through the platform. It can be exchanged for fiat currencies or cryptocurrencies. In 2018, WePower tokenised a year's worth of Estonian grid data (26,000 hours and 24 terawatt-hours of aggregated production and consumption data to blockchain) into 39 billion smart energy tokens.[37] Each token is essentially a digital self-settling power-purchase contract representing one kilowatt-hour of power. The tokens are tradable and can be sold into the local energy wholesale market by linking the digital contracts with power grid data on the blockchain.[38]

South Africa: Sun Exchange

In South Africa, Sun Exchange has introduced a buy-to-lease blockchain-based marketplace platform that facilitates an innovative fundraising approach and increases access to solar power for schools and businesses specifically in EMs, by enabling consumers to buy solar cells and lease them to those using electricity to profit from rental income.[39]

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31 See Enerchain, accessible at: https://enerchain.ponton.de/. Accessed 13 February, 2020.

32 Ponton. "European Energy Trading Firms to execute Trades over the Blockchain on EMART." 20 May, 2019. Accessible at: https://www.ponton.de/enerchain-1-0-is-live/.

33 See Ponton. "WRMHL", accessible at: https://www.ponton.de/products/wrmhl/. Accessed 13 February, 2020.

34 Op. Cit. 25.

35 See Brooklyn Microgrid (BMG), accessible at: https://www.brooklyn.energy/. Accessed 13 February, 2020.

36 See LO3 Energy, accessible at: https://lo3energy.com/pando/. Accessed 13 February, 2020.

37 See WePower, accessible at: https://wepower.network/tech/. Accessed 13 February, 2020.

38 Green Tech Media. (2018). "WePower Is the First Blockchain Firm to Tokenize an Entire Grid." 20 October, 2018. Accessible at: https://www.greentechmedia.com/articles/read/wepower-is-the-first-blockchain-firm-to-tokenize-an-entire-grid.

39 See The Sun Exchange, accessible at: https://thesunexchange.com/. Accessed 13 February, 2020.

Challenges for Blockchain-Based Energy Trading and Transactions in EMs

In EMs, the key challenges have to do with ensuring active consumer participation at high levels and that regulation is not too restrictive in making adoption untenable. Many countries are adopting a "wait-and-see" regulatory approach and it will be important to encourage blockchain applications and early-stage start-ups, through regulatory "sand-boxes" or other forms of incentive to spur innovation.

Renewable energy projects modelled on the Sun Exchange or WePower buy-and-let approach, which reduce the "entry level" contribution for financing solar generation assets, whilst also leveraging blockchain's capabilities to maintain a link between the individual investor's contribution and a specific asset, are excellent ways to incentivise private investment in renewable energy in EMs. They benefit both sides, by broadening the pool of available capital to invest in renewable projects, on the one hand, and providing platform and equity investors with potentially higher rates of returns in the underlying generation projects on the other. The challenge in this area is likely to be the implementation of these new models and devising an appropriate legal contractual structure to govern the relationship of the relevant parties.

Another challenge to the adoption of blockchain in energy trading platforms includes addressing liability issues. While courts are well-equipped in energy and commodity trading practices and have experience in solving disputes involving written contracts, courts and legal systems will need to adapt in order to deal with issues relating to the immutable nature of the blockchain contract, the process of dispute settlement, and a lack of technical knowledge of the platform itself.

It is clear that certain countries are already taking large strides in this direction, most notably the UK, which is currently conducting a comprehensive consultation in the context of the 13th Programme of Law Reform to ensure that English law is equipped to deal with smart contracts.[40]

RECOMMENDATION: Regulators should provide guidelines and information on the operation and usage of such platforms, as well as support to blockchain applications and early-stage start-ups through regulatory "sand-boxes" to encourage private sector investment in P2P trading platforms and renewable energy generation projects. Lawmakers in EMs should follow advanced countries as an example and initiate open consultations with stakeholders to determine the need for amendment in private contract and property law. The legal and regulatory challenges are addressed in greater detail below.

Carbon Registries and Emissions Trading Systems

Carbon tracking and registries are essential to measuring and recording carbon levels in global markets and, therefore, have an important part to play in the reduction of greenhouse gas emissions.

An ETS is a key mechanism for managing carbon levels, which establishes a mandatory cap on emissions and allocates tradeable permits to participating entities which can use them to cover their allowable emissions during a specified reporting period.[41] These are intended to put a price on carbon and incentivise companies and individuals to pursue decarbonisation.

Blockchain's core capabilities directly align with the many challenges around developing, deploying, and managing emissions tracking and trading systems. As a trusted database of transaction data, blockchain can be used to streamline the trading process, strengthen the verification process, and eliminate the need for costly centralised management.[42]

Promising Use Cases of Blockchain-Based Emissions Tracking and Carbon Registries

Some interesting use cases of blockchain in carbon emissions tracking that serve as example innovations that could be supported and financed by MDBs in EMs are listed below.

France: Engie (TEO)

In France, Engie launched The Energy Origin ("TEO") decentralised application, which leverages blockchain to bring the traceability and transparency of green energy, while also expanding the capabilities of supply-demand matching between renewable generators and corporate buyers. This is achieved through the selection of green energy based on the type of renewable energy, geographic distance from a given facility, and amount of carbon offsets.

40 Law Commission. (2017). "14 new areas of law set for reform – Law Commission." 14 December, 2017. Accessible at: https://www.lawcom.gov.uk/13th-programme-of-law-reform/.

41 Op. Cit. 18, p.23.

42 Op. Cit. 18, p.24.

The production Energy Web Chain officially launched in mid-June 2019. At the time, it was tracking roughly 17 decentralised applications running on Energy Web test networks, spanning use cases such as renewable energy certificate markets, EV charging, financial settlement for grid flexibility services from DERs, and transactive energy.[43]

Japan: KEPCO

In Japan, the Kansai Electric Power Co. ("KEPCO"), the second-largest power utility, is extending its trial of a blockchain-powered system for transacting renewable energy credits ("RECs"). KEPCO is using a blockchain-enabled renewable energy trading platform developed by Australia-based technology firm Power Ledger. In May 2019, Japan extended its programme of what the country's Ministry of Economy, Trade and Industry call non-fossil value certificates ("NFVs"). The NFVs provide energy retailers with proof that the energy under the certificate is generated from renewable energy resources. The certificates can also be used to assess which power plants are contributing the most environmental value in order to encourage investment in green industries. They can be traded, similarly to other RECs. The system uses blockchain technology's immutable and decentralised properties to track certificates across their lifecycle, reducing the potential for duplicate use. Power Ledger generates REC tokens, which are stored in a centralized KEPCO wallet.[44]

Germany: Green Assets Wallet ("GAW")

In Germany, Green Assets Wallet ("GAW") in December 2019 launched the first green bond blockchain platform, which claims to have the ability to validate the impact of green bond issues, thereby unlocking greater investment in green projects.[45] The technology is also applicable to other green debt and it plans to expand the scope beyond the current green bond focus. In particular, GAW prioritises green loans covered in 2020.[46]

Challenges of Blockchain-Based Emissions Tracking and Carbon Registries in EMs

The main challenge will be to justify to companies the switch to blockchain given the significant investments that have been made in current systems. It is estimated that nearly $1 billion is required to manage current frameworks for ETS alone, excluding the investments made by other registries to track and manage emissions data and credits.[47] Presumably, for EMs that do not have systems in place to track carbon emissions, this management cost may be negligible. However, installation costs for such frameworks for ETS will still be applicable.

A major concern is the uncertainty in how much it will cost to deploy blockchain in these cases and to implement the shift from existing systems. Finally, blockchain for international carbon tracking and registries would require consensus from a range of market stakeholders on its design, use case, support infrastructure and method of deployment, which is still lacking in some regard.

RECOMMENDATION: Quantitative research should be conducted to determine the cost-effectiveness of moving existing frameworks for ETS onto the blockchain and for deploying blockchain altogether where there are no such systems in place. It is likely that adoption may be more appropriate in certain countries to justify the industry-wide switch to blockchain than others. This will need to be examined on an individual basis for each prospective country of operation.

43 Engie. "Blockchain: TEO (The Energy Origin) App first on the Energy Web Chain." 20 September, 2019. Accessible at: https://innovation.engie.com/en/news/medias/new-energies/blockchain-teo-the-energy-origin-application-on-the-energy-web-chain/12840.

44 Power Mag. "POWER Digest [January 2020]." 1 February, 2020. Accessible at: https://www.powermag.com/power-digest-january-2020/.

45 Green Assets Wallet (2019), "The Green Assets Wallet – first blockchain for green bond impact data", accessible at: https://www.sei.org/about-sei/press-room/first-blockchain-for-green-bonds/.

46 Green Assets Wallet. "Launch of the Green Assets Wallet - the First Blockchain Platform for Validating Green Bonds and Reporting on Green Impact Goes Live". 12 December, 2019. Accessible at: https://greenassetswallet.org/news/2019/12/12/launch-of-the-green-assets-wallet.

47 Op. Cit.18, p.27.

Best Practices of Advanced Countries and Key Challenges for EMs

While it is not possible to provide a firm blueprint for the successful adoption of blockchain in EMs, it is possible to identify certain common areas and best practices in advanced countries, which, if implemented could facilitate the adoption of and incentivise the investment in blockchain. It is noteworthy that the countries where the most blockchain-enabled applications in the energy sector appear to have taken root in Europe are Germany, France, and UK.

As part of its commitment to deliver on climate change goals under the Paris Agreement, the EU has also introduced the Clean Energy for All Europeans Package ("EU Clean Energy Package"), which includes eight legislative acts that EU countries need to transpose into national law.[48]

These changes include updated rules and targets for energy performance in buildings, renewable energy, energy efficiency, governance, and electricity market design, and are intended to bring the EU a significant step towards the implementation of its long-term strategy of achieving carbon neutrality by 2050.

One can observe certain commonalities between these countries, which are quite revealing. These include a stable legal and regulatory framework for integration of new technologies like blockchain, policies in place to support and incentivise the deployment of such technologies, a general level of technological infrastructure preparedness and sophistication, receptiveness and a certain level of political will to implement this infrastructure shift and digitise traditional processes.

EMs should seek to follow the best practices outlined below in order to advance both blockchain-based applications, and achieve the infrastructure shift that will enable them to take hold.

48 European Commission. "Clean Energy for All Europeans Package." Accessible at: https://ec.europa.eu/energy/topics/energy- strategy/clean-energy-all-europeans_en. Accessed 24 May 2021.

Best Practices of Advanced Countries

Germany

In Germany, the Federal Government published a paper setting out its comprehensive blockchain strategy, in recognition of the potential of blockchain technology, and to set the legal and regulatory framework conditions for innovation.[49] It is clear that Germany is seeking to expand its leading position in digital transformation and blockchain and to create an attractive base for development of blockchain applications and for investments in scaling them up.[50]

The Federal Government's blockchain agenda includes legislative reform for electronic securities and cryptotokens, as well as advancing projects and regulatory sandboxes in various sectors. In relation to the energy sector, the Federal Government stated that preparations had already begun for piloting a blockchain-based link-up of energy facilities to a public database, which was expected to start in 2020, subject to a positive final evaluation of feasibility - we understand this is still ongoing.[51]

The Federal Government acknowledges the added value of blockchain technology in the energy sector, in terms of transparency and energy efficiency, and is examining through state-funded pilot projects and practice-oriented research the opportunity for the energy transition offered by blockchain.[52]

49 Bundesministerium fur Wirtschaft under Energie, (2019). "Blockchain Strategy of the Federal Government". Accessible at: https://www.bmwi.de/Redaktion/EN/Publikationen/Digitale-Welt/blockchain-strategy.pdf?__blob=publicationFile&v=3
50 *Ibid*, p.4.
51 Bundesministerium fur Wirtschaft und Energie, (2020). "Blockchain-basierte Erfassung und Steuerung von Energieanlagen mithilfe des Smart-Meter-Gateways: Machbarkeitsstudie und Pilotkonzept ."Accessible at: https://www.bmwi.de/Redaktion/DE/Publikationen/Studien/blockchain-smart-meter-gateway.pdf?__blob=publicationFile&v=10. Final Report concludes that linking blockchain and Smart Meter Gateway ("SMGW") technologies in order to automatically maintain a public database of energy facilities can create a safe, scalable, and interoperable basis for future decentralised models.
52 *Ibid*, p.8.

In particular, within the framework of its Smart Service Welt II initiative, it is funding and supporting energy-sector blockchain applications, which include blockchain-based virtual large-scale storage unit for operators of PV facilities through to P2P energy trading.[53] It is also commencing, in collaboration with DENA (German Energy Agency), the build-up of a Smart Contract register in the energy sector.[54]

In response to the Federal Government's blockchain strategy, the German Blockchain Association recently published an action paper outlining a number of steps related to the energy sector, which include: keeping smart meters and their interfaces open for DLT, support for open-source software and hardware (including a public tender for an Open Data Platform for electricity producers), enabling P2P electricity trading, establishing the prosumer as an independent market player and implementing requirements under the EU's Clean Energy Package (for instance, regarding P2P trading) into national law, introduction of a digital register of guarantees of origin for green energy, and an extension of sand-box initiatives.[55]

Finally, the Federal Government is exploring the state funding of environmentally sustainable blockchain applications, as well as applications contributing to the protection of the environment, the climate and nature. In short, Germany provides not only a secure legal and regulatory framework for the adoption of blockchain applications, but also a favourable business environment where investments in blockchain are encouraged and supported. Clearly, there is a strong political will from the Federal Government to implement the necessary infrastructures and provide a safe testing ground for blockchain-based applications in the energy sector.

France

Similarly, France has pioneered a legal and regulatory framework for blockchain on securities and international coin offerings ("ICOs"). As of December 2017, France became the first country to authorise the registration and transfer of unlisted securities through the use of blockchain technology. In December 2018, it adopted a decree implementing specific conditions under which unlisted securities can be registered and transferred using blockchain technology, while in April 2019 it passed a law establishing an innovative ad hoc legal framework governing ICOs and digital assets services providers.[56]

In the last few years, France has paved the way for other countries in adopting a favourable legal and regulatory framework towards blockchain and stands out in the EU as a blockchain-friendly jurisdiction.

In relation to the energy sector, in December 2018, the Grenoble Ecole de Management invited a consultation from experts on their view of the investment climate in key energy technologies.[57] While experts were divided over the future long-term role of blockchain in the French electricity sector, they acknowledged P2P energy trading and EV charging and sharing as the most promising applications of blockchain technology. They highlighted an unclear regulatory framework, high electricity consumption and technical complexity as the key barriers to increased adoption of blockchain, but also found that the future investment climate will be more favourable to new renewables, energy efficiency, smart grids and e-mobility.[58]

While there are still appreciable barriers to increased adoption in the energy sector, it is noteworthy that France has managed to already portray itself as a blockchain-friendly jurisdiction and this is largely a product of the political will and receptiveness of French Parliament to consider adaptations in its legal framework to accommodate new technologies. Moreover, open consultations in the energy sector provide clarity on the steps that need to be taken to further assist the adoption of blockchain and the indicative guidelines on how to get there.

United Kingdom

As early as December 2017, the UK Law Commission highlighted blockchain and smart contracts as a project area for its 13th Programme of Law Reform.[59] The Law Commission provided research into law reform for use of blockchain-enabled smart contracts in the British legal ecosystem in its Annual Report 2017-2018.[60]

53 *Ibid*, p.8. See also Bundesministerium fur Wirtschaft under Energie (2020). "Die Blockchain-Revolution im Stromhandel". Accessible at: https://www.digitale-technologien.de/DT/Redaktion/DE/Kurzmeldungen/Aktuelles/2020/SSW/2020_02_11_SSW_Energiepublikation_E-World.html.

54 *Ibid*, p.14.

55 Blockchain Bundesverband. (2020). "Aktionspapier desBlockchain Bundesverband e.V.", 7-9.

56 Global Legal Insights. (2019). "Blockchain & Cryptocurrency Regulation". 23 October, 2019. Accessible at: https://en.grenoble-em.com/news-energy-market-barometer-report-winter-2018.

57 GEM LAB Studies. (2019). "Energy Market Barometer Report – Winter 2018." 31 January, 2019. See https://en.grenoble-em.com/news-energy-market-barometer-report-winter-2018.

58 *Ibid*, p.1.

59 Op. Cit. 40.

60 Law Commission. (2018). "Annual Report 2017-2018 published." 19 July, 2018. Accessible at: https://www.lawcom.gov.uk/annual-report-2017-18-published/.

In the same period, the LawTech Delivery Panel was formed to provide further research and guidance on law reform in the area of smart contracts. On 18 November 2019, the LawTech Delivery Panel produced the legal statement on cryptoassets and smart contracts, under the auspices of the UK Jurisdiction Taskforce.[61] The Law Commission is currently preparing a scoping study that will analyse the current law as it applies to smart contracts, identify areas in which further work or reform may be required, and provide such advice as the Law Commission considers appropriate on options for reform.[62] It is extremely likely that, given the comments provided by the LawTech Delivery Panel on the promise of smart contracts, as well as the Law Commission's consultation process and call for evidence, we will see proposals for reform with a view to reinforcing the legal framework to accommodate smart contracts in the current ecosystem. All the same, it is the LawTech Delivery Panel's view, that "English law is fully equipped to deal not only with bilateral smart contracts but also those structured around Decentralised Autonomous Organisations (DAOs)". It is only a matter of time before this proposition is tested in national courts.

In relation to the energy sector, the UK already has the EV infrastructure in place to enable charging and sharing of electricity from households.[63] In particular, it is reported that the adoption of EVs in the UK is already at a record rate, with nearly 20,000 EV parking facilities in the UK currently in existence, and it is clear that the integration of this network with the National Grid will be largely aided by the data storage qualities that blockchain encompasses.[64]

In light of the above, the UK is underway in the establishment of a legal and regulatory framework that will support blockchain innovation and has in place the necessary smart grid and EV charging infrastructure for the integration of blockchain-enabled applications in the energy sector.

Key Challenges and Opportunities for EMs

This study has identified some of the key opportunities of EMs in using blockchain in the energy sector. These include:

– Facilitating the provision of new, cleaner methods of generating and distributing electricity in order to meet commitments to reduce greenhouse gas emissions under the Paris Agreement;

– Deploying modern digital energy systems to meet inflexible demand, and incentivising the use of renewable, distributed, and responsive energy resources that enable stakeholders to track and assess the impact of energy investments;

– Providing consumers with a greater role to play in the energy production and generation process, as well as a platform to enable consumers and communities to connect to the grid and transact between themselves in a transparent and secure way; and

– Connecting energy stakeholders with investors interested in investing in renewable energy and other blockchain-based projects.

The challenges for EMs are less pronounced and depend not only on the specific blockchain application in question but also on the specific country in which that application is to be implemented. These include:

– The lack of digital-physical infrastructure in place to support blockchain's integration into energy systems, which includes smart grid infrastructure and customer devices at the grid level (i.e. smart meters, inverters, EV chargers and batteries, and other appliances and supportive software applications);

– The lack of real understanding between regulators and policymakers on the value of DERs and on the defined role of consumers in the energy marketplace, as well as the conflict with existing utility business models of traditional energy generation;

– The lack of legal and regulatory frameworks to accommodate blockchain and smart contracts in the current legal ecosystem (or lack of clarity and adaptability of existing frameworks) and the lack of experience of legal systems in dealing with issues arising from the immutable and distributed nature of blockchain-based smart contracts, the process of dispute settlement, and a lack of technical knowledge of the blockchain platforms themselves;

– The low levels of active consumer participation and the lack of regulation that either hampers innovation or does not encourage investment;

– The cost of integrating blockchain into existing energy systems and/or deploying the necessary baseline infrastructure to support blockchain-based applications;

– The lack of capacity, awareness and readiness to incorporate blockchain technologies into the current systems, as well as the level of technological sophistication of lawmakers and policymakers; and

61 Op. Cit. 10.
62 See Law Commission. "Smart Contracts." Accessible at: https://www.lawcom.gov.uk/project/smart-contracts/. Accessed 26 April, 2021.
63 Gowling WLG. (2019). " Electric vehicle charging points: every home should have one." 14 August, 2019. Accessible at: https://gowlingwlg.com/en/insights-resources/articles/2019/electric-vehicle-charging-points-at-home/.
64 Gowling WLG. (2019). "Powering the EV industry requires blockchain to be at its heart." Lexology. 28 August, 2019. Accessible at: https://www.lexology.com/ library/detail.aspx?g=eb5d9b63-2671-45f0-b252-e9971571c544.

– The traditionally high concentration of the energy market by few large energy companies and industry players.

It is clear that EMs will need to oversee an infrastructure shift that incorporates new technologies, policies and regulations, which promote and facilitate adapted, more decentralised, business models.

In particular, while a number of EMs appear to capture some of the best practices highlighted above, such as receptiveness to emerging technologies and the necessary political will to implement technological change, some further work is required in this respect. For instance, one common shortcoming is the lack of a legal and regulatory framework aligned to blockchain and the general lack of technological infrastructure to enable the necessary adoption. Notwithstanding, it is evident that many EMs are taking large strides to adopt best practices and align themselves with EU legislation, as well as to develop the necessary physical infrastructure.

For example, Georgia and Moldova, two countries generally receptive to the use and application of blockchain technology, show a clear commitment to gradually approximate legislation to the EU Directives and Regulations on electricity, renewable energy, and energy efficiency, amongst other things. In addition, there is an interest from the respective governments to test and deploy emerging technologies like blockchain in other sectors.

The Georgian government recently started using blockchain to register land titles and validate property-related government transactions.[65] A custom-designed blockchain system has been integrated into the digital records system of NAPR, and anchored to the Bitcoin blockchain through a distributed digital timestamping service. In June 2019, the Georgian government also signed a Memorandum of Understanding with blockchain technology firm Input Output Hong Kong ("IOHK") to implement blockchain-enabled projects across business, education and government services.[66]

Similarly, Moldova has designed a measurement, reporting and verification ("MRV") system of carbon emissions as part of a low emissions capacity building programme with the UNDP.[67] In addition, the UNDP also launched the "Moldova Sustainable Green Cities" project for 2018-2022 to support the design, launching and establishment of the Green City Lab to become the leading knowledge management and networking platform and a source of innovations and expertise to catalyse sustainable low carbon green city development.[68] This includes introduction of the feasibility study on the development of EV charging infrastructure and installation of 30 EV charging stations by the end of 2020 as part of the UNDP-Ministry of Economy and Infrastructure partnership.[69] In addition, the UNDP has teamed up with Sun Exchange to help one of Moldova's largest universities to go solar by installing 15,000 square meters of rooftop solar panels.[70]

In view of the above, it is apparent that countries like Georgia and Moldova have the requisite political appetite to implement blockchain-based solutions in the energy sector. Nevertheless, there is a clear need to conduct a full and comprehensive assessment of the current digitalised systems in place and the associated costs of implementation in each of these respective EMs to evaluate the viability and cost-effectiveness of blockchain adoption.

In the first instance, MDBs and other investors should consider supporting the governments in their respective EMs in the development of national blockchain strategies, policies and initiatives to raise awareness on the potential of blockchain. In addition, there is scope for technical training from MDBs on blockchain and advanced applications in the energy sector to ensure that policymakers have the necessary technical knowhow and to instil trust in the systems. Following a comprehensive cost analysis, MDBs should consider, in direct consultation with relevant stakeholders and public-private partners, the implementation of pilot programs, for instance, to add smart grids and DER infrastructure, introduce P2P energy trading platforms or carbon registries.

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65 Forbes, "Republic of Georgia to Pilot Land Titling on Blockchain with Economist Hernando De Soto, BitFury" (2016). Accessible at: www.forbes.com/sites/laurashin/2016/04/21/republic-of-georgia-to-pilot-land-titling-on-blockchain-with-economist-hernando-de-soto-bitfury/?sh=2b5b970e44da.

66 Huillet, M. (2019). "Georgian Gov't, IOHK Partner to Develop Blockchain in Education, Ministry Services." 17 June, 2019. Accessible at: https://uk.style.yahoo.com/georgian-gov-t-iohk-partner-131300979.html.

67 United Nations Development Programme (UNDP). "Low Emissions Capacity Building Programme in the Republic of Moldova." Accessible at: https://www.md.undp.org/content/moldova/en/home/operations/projects/climate_environment_energy/proiecte-finalizate/low-emissions-capacity-building-programme-in-the-republic-of-mol.html.

68 UNDP. "Moldova Sustainable Green Cities." https://www.md.undp.org/content/moldova/en/home/projects/Moldova-Sustainable-Green-Cities.html.

69 *Ibid.*

70 UNDP (2018) "UNDP, solar currency exchange to power up Moldovan university." 7 May, 2018. Accessible at: https://www.eurasia.undp.org/content/rbec/en/home/presscenter/pressreleases/2018/undp--solar-currency-exchange-to-power-up-moldovan-university.html.

Legal & Regulatory Challenges for the Application of Blockchain and Smart Contracts in the Energy Sector

General Issues

Blockchain raises a series of legal issues and opportunities. These include, amongst others, questions around the legal status and validity of decentralised applications, jurisdiction, liability, enforceability, intellectual property and data privacy. Some of these issues are specifically raised by the energy use cases discussed above. For instance, the sharing of EV charging infrastructure on private property raises significant issues of liability and privacy. With regards to energy trading platforms, there are issues of liability and jurisdiction, due to the decentralised architecture of blockchains, involving transacting parties and nodes in several countries.[71] In energy trading platforms, there are different parties involved, including the provider of the exchange platform or marketplace that deploys the relevant smart contracts, as well as the buyer and seller of electricity that interact on the basis of smart contracts.

In addition, there are legal and regulatory challenges that are specific to energy applications and relate specifically to EVs, DERs, energy trading platforms and carbon registries in EMs. Energy regulation, particularly under EU law, is constructed around the clearly delineated roles of producers and consumers, and does not specifically cater to roles created under blockchain and other emerging technologies. Moreover, the sharing of private and sensitive data over blockchain creates data protection issues under EU law.

Jurisdictions across the world have adopted differing approaches. Some, such as Malta and Gibraltar, have taken a very detailed approach seeking to respond to the unique features of the technology. Malta has created a distinct legal status for a DAO, whereas Gibraltar has a code of conduct for using a blockchain platform.

One of the key drivers for successful regulation will be to identify the transaction or relationship which needs regulation and to focus on protecting the desired behaviours and outcomes. This can prove challenging in hierarchical organised networks.

While these issues present serious challenges to the eventual adoption of blockchain in energy markets, they may also be considered as a unique opportunity to develop legal and regulatory frameworks in EMs that will support technological innovation in the future. These are discussed in detail below.

Contract law

There are a number of complicated issues that arise under contract law. The main areas include the legal status, validity and enforceability of smart contracts under the applicable law. They also include the issues arising out of the immutable nature of blockchains, which precludes the correction of deficiencies and mistakes in smart contracts, as well as the general allocation of liability.

The utility of smart contracts lies very much in their automatic performance and enforcement of legal obligations. By way of illustration, in an electricity microgrid, the transfer of electricity to the consumer, as well as the payment to the solar panel owner, are both automatic and directly enforceable without any further means of enforcement, such as litigation.

However, this does not in and of itself mean that such automated energy supply contracts are valid, binding and enforceable contracts in the legal sense.

Basic Principles

As discussed above, there is no established taxonomy in respect of smart contracts. Attempts have been made to classify different types of smart contracts which did not lead to consensus. Thus, one must often resort to basic principles, which makes the interaction of new technology and established principles an interesting and dynamic area.

A key factor is whether there is an agreement between the parties (in writing or otherwise evidenced), whether the code constitutes the performance element (in which case it is no more than an element of a contract and does not represent the full bargain between the parties), or whether it represents the full bargain as agreed between the contracting parties. The latter is certainly possible but the intent has to be clearly established.

71 Op. Cit.18.

In the foreseeable future, and certainly within the context of smart grids and the consumer energy network, it is likely that the contractual framework will be set out in a set of traditional terms and conditions (albeit available and agreed digitally and executed by digital signatures) to which the respective parties can sign up. The smart contract layer will sit beneath this as the transaction element. As and when systems become more sophisticated, increased levels of autonomy will be delegated to the smart contracts to amend the transaction based on demand and supply factors but within the pre-agreed framework. The overarching contractual agreement will likely remain in the more traditional contractual terms. The key to success in this context is both a clear delineation and coordination between the two. Assuming that the contractual framework has been properly allocated and documented, many of the theoretical uncertainties can be resolved.

Therefore, by way of example, such a contractual framework can set out mechanisms for resolving, in full or in part, the jurisdictional uncertainties and conflicts of laws, force majeure and contract frustration events, and which party is responsible for maintaining systems and reflecting problems outside of the coded network. Further, it can help to resolve issues surrounding rules of evidence, compliance with applicable law and regulation in respect of general terms and conditions and, for example, compliance with any specific rules as to exclusionary or restrictive clauses.

The key issues to be resolved are therefore those of principle. Provided the law is broad enough to encompass computer code as a type of language in which a legally binding agreement can be expressed in, this does not present an issue. In addition, provided there is clarity as to the efficacy of digital signatures, with which the notification of contractual obligations is triggered, this provides the necessary legal framework for the operation of smart contracts.

RECOMMENDATION: Lawmakers should ensure that relevant laws are broad enough to capture agreements expressed in computer code and validated through digital signatures, but only to the extent that this is appropriate for the various types of applicable contracts. Broad principles of offer and acceptance and the fundamentals of contract law are applicable in the smart contract arena. However, the taxonomy of contract law, statutes and regulations can prove a challenge in being adapted to new technology. This is particularly applicable to P2P energy trading where contracts are concluded between consumers and prosumers. In these situations, provisions should be made in the relevant law for smart contracts to be translatable in natural language and for consumer protection provisions to be written into the smart contract, provided it is classified as a consumer contract within the meaning of EU consumer protection law. For example, how should restrictive or exclusionary language be highlighted by a consumer? It may be that a specific click-through acceptance of such terms, written into natural language, should be required. This area is considered further below.

Immutability

Another practical issue that arises with blockchain-enabled smart contracts relates to the irreversibility, or immutability, of records of transactions. This is problematic where an agreement is entered into as the result of fraud or duress, if there is some form of illegality under the applicable law or deficiency, mistake or force majeure event which renders the agreement non-performable or non-enforceable in the legal sense. It also raises data protection concerns as highlighted below.

While it is possible to include provisions in the smart contract's code to allow for some flexibility in the circumstances described above, it is virtually impossible to anticipate each and every eventuality from the outset, not to mention the difficulty of capturing the legal intent of an exception or a condition.[72] This is particularly problematic for smart electricity supply contracts, where the failure or non-enforceability of a contract could affect the provision of power in the grid.

Thus, as discussed above, in the first stages of adoption, such issues are best dealt within the contractual framework documents.

RECOMMENDATION: It is important that stakeholders, in particular software coders, lawyers and industry experts, cooperate to establish unified technological protocols and standardised smart contracts that are not only legally and technologically sound, but are also aligned to the specific needs of the energy sector. For instance, smart electricity supply contracts could be reinforced with provisions that allow reversal of transactions where there is a natural event that constitutes supply of electricity through renewables no longer feasible or for automatic performance to be halted in order for mistakes or disputes arising under the agreements to be resolved by a neutral and independent arbitrator or mediator. This is likely to require suppliers to hold an escrow of funds to cover such an eventuality and to minimise the risk of default.

72 Op. Cit. 11.

Governance, Enforceability and Accountability

One of the other key challenges associated with large-scale, decentralised blockchain-based networks, particularly those that are public, is that it is difficult to ascertain the identity of the actors, their location, and the exact scope of their actions. This can make it incredibly challenging to perform basic legal and regulatory functions, such as ascertain liability, determine the applicable law in particular situations, and carry out regulatory monitoring, or enforce rules.

The apportionment of responsibility for actions is an important part of effective governance and it is clear that the application of decentralised frameworks requires either a point of accountability for governance and liability or some form of joint and several liability by all system participants. Parties can either adopt (1) private or permissioned models where a single entity or group of entities assumes the responsibility for operating the system and reports to the regulator; or (2) public blockchain systems where an prescribed contractual framework between participants would need to be overlaid on top of the public blockchain. This reflects a "joint-venture" approach, or a single organisation that takes on the responsibility and liability of running the entire system with some kind of overseeing framework or code to guide conduct on the network.[73]

Other contractual issues that may arise include questions around legal capacity, authority, identification and verification of identity, laws on general terms and conditions, and form and public registration requirements.
These are all issues that can generally be addressed through laws that allow respectively for electronic verification of authority and approvals in practice, evidence of identification by electronic means (such as cryptographic keys), smart contracts to qualify (in whole or in part) as general terms and conditions, and records to be made and stored using DLT.[74]

If laws do not allow for the above, then lawmakers will need to consider the amendment of such laws to better facilitate the use of blockchain and smart contracts. In addition, any deficiencies or gaps in existing conflict of laws rules arising from the decentralised and disintermediated nature of DLT, for example, where existing rules only refer to the location of an intermediary, account or other record to determine the applicable law, would need to be amended.[75]

73 Salmon, J. and Myers, G. (2019). "Blockchain and Associated Legal Issues for Emerging Markets." EM Compass Note 63, January 2019, IFC.
74 Clifford Chance & EBRD. (2018). "Smart Contracts: Legal Framework and Proposed Guidelines for Lawmakers." October 2018.
75 *Ibid*, pp. 39-42.

With regards to issues of evidence, lawmakers need to consider the procedural rules regarding admissibility of evidence in court proceedings and the need for amending existing rules on the presentation of digital evidence. This should also include admissibility and status of natural language translations of smart contracts that are written in code, specifying whether this is to be considered, for evidence purposes, a matter of law or a matter of fact. In addition, with regards to the burden of proof, lawmakers should consider introducing new laws or clarifying existing laws to ensure that a smart contract arrangement, where the burden of proof would procedurally be reversed as a result of automated execution, does not result in such a reversal, if policy warrants such a conclusion.[76]

RECOMMENDATION: Overly prescriptive or detailed legislation is unlikely to be sustainable over the long term. Rather, the focus should be on identifying the building blocks of enabling the use of digital technologies. These include ensuring there is clarity as to the enforceability and use of digital signatures, methods for providing digital identity (both for legal persons and physical assets such as specific properties), and having appropriate guidelines for allowing coded arrangements to be determined by a court (most likely via expert analysis). Guidelines or rules as to the specific interpretation of standard rules of contract rules of offer and acceptance may also need to be updated.

Cross-jurisdictional concerns will arise, but it is likely that regulation will remain on a national or supra-national level. Therefore, the focus should be on enabling discussions to make the network and technical systems compliant with applicable laws and regulations. Identification of the locations of servers and physical infrastructure (for instance, utilising IoT technology) should be encouraged.

Cryptoassets

Finally, another important issue, which is more likely to fall under the purview of property law, relates to the issue and operation of cryptoassets. This area may most obviously be relevant when utilising public blockchains, although many private permissioned systems may adopt a tokenised structure. This is one of the major points of contention for regulators across the world, especially given the lack of a universally accepted definition for the term “cryptoasset” and the lack of a consistent position on how it should be regulated. This has led to considerable difficulties for stakeholders operating in different countries to use tokens in a legitimate way, given the varied approach that regulators take.

This is a particularly important point for EMs given cryptoassets’ ability to facilitate new models of capital raising or crowdfunding to fund the growth of a business or enable the investment in blockchain-based projects, like renewable energy generation projects for instance.[77] As a result, the lack of a consistent approach of regulation in respect of cryptoassets may have the unintended consequence of discouraging climate financing, which is an area where cryptoassets could potentially unlock value in.

In the UK, the UK Jurisdiction Taskforce (“UKJT”), after an extensive analysis, concluded that cryptoassets should be treated as property, since they have all the indicative features of property; namely that they are definable, identifiable by third parties, capable in their nature of assumption by third parties, and have some degree of permanence or stability.[78] This has particular relevance because if cryptoassets are capable of being property then, among other things the holder of a proprietary right over the cryptoasset may have priority over claims by creditors in an insolvency context, and may be able to create a security interest over the cryptoasset, which otherwise might not be possible.[79]

This is crucial in that it provides clarity for potential businesses or investors seeking to utilise cryptoassets for debt and equity financing. It is likely that these matters will form part of judicial decisions as well as developments in the law in the future.

RECOMMENDATION: Regulators should consider providing a clear and consistent definition of “cryptoassets” and determining whether they should qualify as property. Adopting a clear position will provide clarity in an area that is otherwise plagued with uncertainty and illegitimacy, and potentially provide the necessary impetus for businesses and investors in EMs to transact more openly using cryptoassets. Some territories, such as Gibraltar and Malta, have sought to establish a separate regime for cryptoassets and blockchain arrangements. Such an approach is fraught with risk when seeking to interface that new regime with existing structures such as in the wholesale energy markets.

76 *Ibid*, pp. 43-45.

77 See sections above that discuss this point.

78 Op. Cit. 10.

79 See Quadrant Chambers. (2020). “ Contracts Jim, but not as we know them: Cryptoassets and Smart Contracts - Jeremy Richmond.” 4 February, 2020. Accessible at: https://www.quadrantchambers.com/news/contracts-jim-not-we-know-them-cryptoassets-and-smart-contracts-jeremy-richmond.

Energy law

While legislative competence for energy law is shared by the EU and its member states, national energy law is very much dictated by EU regulations and directives. Against the background of the internal energy market and the EU energy law and policy,[80] the EU launched the EU Clean Energy Package in 2016, which led to the adoption of new legislative acts including the new Renewable Energy Directive[81] and the new Energy Efficiency Directive.[82]

While the current EU legislation in force addresses issues relating to energy digitalization, such as smart metering,[83] the use of blockchain or smart contracts are neither regulated specifically for the energy sector nor on a general level.[84] For this reason, the European Commission launched the EU Blockchain Observatory and Forum in February 2018 to monitor developments in the space and propose common actions at a policy level.[85]

Currently, P2P energy trading in microgrids between prosumers, without an external service provider to act as an intermediary, presents a number of regulatory constraints under EU law. Pursuant to the EU Electricity Directive currently in force, prosumers who sell the excess electricity generated by their renewable power plants to neighbours are likely to be qualified as "suppliers", which entails a series of obligations relating to the terms and conditions of energy supply contracts, billing and information on the energy mix to be made available to consumers.[86] While these requirements can be imported into a smart contract's code or included in a legal framework agreement that forms the basis under which the smart contract exists, this increases the burden on prosumers. Additionally, the current European and national rules on the change of supplier have not been drafted with blockchain-based P2P trading in mind, especially given the frequency of supplier changes taking place in P2P electricity grids.[87]

There are also additional obligations relating to grid balancing, obtaining of suppliers' licences, fulfilling universal service obligations in order to sell electricity to household customers, and further constraints on prosumers wishing to benefit from national renewable support schemes, which make the current regulatory framework unduly burdensome for prosumers.[88]

The "Clean Energy for All Europeans" package aims to alleviate the existing regulatory obstacles for true P2P trading of electricity to take hold. In view of the growing role of prosumers, the EU Commission's proposal under the recast Electricity Directive introduces the concept of "local energy communities" and provides that final customers are entitled to generate, store, consume and sell self-generated electricity in all organised markets, either individually or through aggregators, without being subject to disproportionately burdensome procedures and charges that are not cost reflective, turning them into "active customers".[89]

Similarly, the recast Renewable Energy Directive defines "renewables self-consumer" as a "final customer" who, operating within its premises generates, stores or sells self-generated renewable electricity.[90] It also contains a definition of "peer-to-peer trading" of renewable energy, which also seems to allow for the use of automated execution and settlement through smart contracts: "the sale of renewable energy between market participants by means of a contract with pre-determined conditions governing the automated executed and settlement of the transaction…directly between market participants".[91]

Article 21 of the new Directive provides that EU member states shall ensure that consumers are entitled to become renewables self-consumers, without being subject to disproportionate procedures and charges. Member states are called upon to address "unjustified regulatory barriers" to renewables self-consumption. It is clear, therefore, that much in the way of legal and regulatory reform lies in the hands of EU member states to enact into their national laws

80 See Article 194 Treaty on the Functioning of the European Union (TFEU) 2012/C 326/01.
81 Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources.
82 Directive (EU) 2018/2002 of the European Parliament and of the Council of 11 December 2018 amending Directive 2012/27/EU on energy efficiency.
83 See Article 9(2) of Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency.
84 Lang, M. and Muller, M. (2018). "Blockchain and Smart Contracts in the Energy Industry: A European Perspective". International Mining and Oil & Gas Law, and Investment 17B-1 (Rocky Mt. Min. L Fdn. 2019).
85 EU Blockchain Observatory and Forum. (2019). "Legal and Regulatory Framework of Blockchains and Smart Contracts."
86 See Article 3(9) and Annex I of Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and Article 10 of Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency; Op. Cit. 84, p7.
87 Op. Cit. 84, p.7.
88 *Ibid*, p.7.
89 See Arts. 2(6) and (7), 15, 16 Proposal for a Directive of the European Parliament and of the Council on common rules for the internal market in electricity; see also Lang and Muller, Op.Cit. 84, p.8.
90 See Article 2(14), Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources.
91 *Ibid*, Article 2(18).

the rights and obligations of final consumers that reflect this new role of consumers under the EU energy policy.

RECOMMENDATION: Lawmakers of EU member states should ensure that the recast EU Electricity Directive is transposed into national law. In particular, they should ensure that prosumers are considered "suppliers" and are entitled to become "renewables self-consumers" within the meaning of the EU Electricity Directive. Moreover, that national energy regulation in place does not impose "disproportionate procedures" or "unjustified regulatory barriers" to consumers selling their excess electricity through P2P trading arrangements. In order to encourage the development of "prosumers", the regulatory and legal burden should largely follow on the intermediary production and distribution companies through which the prosumers connect to the grid. National member states should be guided by the liberal interpretation of what those procedures and barriers denote and encourage the liberalisation of energy markets for consumers.

Consumer protection law

Given the conclusion of smart contracts between prosumers, consumer protection law is an area that stakeholders will need to take into account. In the context of P2P trading, the two questions to ask are whether the smart contracts at issue are concluded between traders and consumers to implicate EU consumer law and whether all consumer protection regulations apply to smart consumer contracts.

The first question poses a difficulty in that P2P energy transactions may involve two consumers, and EU consumer law does not apply to consumer-to-consumer ("C2C") transactions. This issue, however, can be overcome provided that prosumers are classified as suppliers or traders, particularly where they sell their excess electricity onto others. Where a smart contract is considered a consumer contract within the meaning of EU consumer protection law, contractual requirements can be complied with, in theory, by programming this into the contract code accordingly. These include unfair contract terms, comprehensive information requirements and cooling-off periods with withdrawal rights for consumers as parties of "distance contracts" concluded without the simultaneous physical presence of the parties.[92] However, it should be noted that concepts of cooling-off periods and information requirements do not appear to be suitable for self-executing, often automatically concluded smart contracts.[93]

The second question is one that poses greater difficulty when considering the argument that the Consumer Rights Directive does not apply to smart contracts at all, as contracts "concluded by means of automatic vending machines or automated commercial premises" are exempt from its scope.[94] While blockchain-based smart contracts are neither vending machines nor concluded on "premises", there is an element of automatic performance and execution of terms, which would make the contractual requirements under EU consumer protection law untenable.

RECOMMENDATION: Lawmakers should clarify whether P2P energy transactions are caught under EU consumer protection law and equally whether the Consumer Rights Directive applies to blockchain-based smart contracts. This may involve the need for a comprehensive legislative reform by the EU Commission encompassing the energy sector to ensure the consumer protection framework accommodates blockchain-based use cases and smart contracts.

Data protection law

Whilst blockchain can offer many benefits from a data protection perspective – for example, new forms of data management and enabling data sharing across industries – blockchain-based smart contracts also pose a multitude of problems, particularly in the context of the EU's General Data Protection Regulation ("GDPR"), which was not designed for decentralised methods of storage and DLT. The GDPR applies to blockchains in the EU as well as international blockchains to the extent that they process personal data of EU subjects in relation to the offering of goods or services in the EU or the monitoring of behaviour within the EU.[95]

It is also clear that the GDPR's material scope extends to the majority of blockchain applications given that "personal data" includes "any information relating to an identified or identifiable natural person"[96] and will naturally include dynamic IP addresses and transactional data that is linked to a natural person and stored on the blockchain, as well as an anonymised public key, as it is technically possible to identify the natural person it belongs to.[97]

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92 Op. Cit. 84, p.10.

93 *Ibid*, p.11.

94 Article 3(3)(l) of Directive 2011/83/EU of the European Parliament and of the Council of 25 October 2011 on consumer rights.

95 Article 3 General Data Protection Regulation of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data (GDPR).

96 Article 4(1) GDPR.

97 Op. Cit. 84, p.12.

The existence of personal data entails a range of different rights under the GDPR for those individuals to whom the personal data relates, which appear to be incompatible with blockchain. For instance, the right to access personal data and to information relating to the data processing (Article 15 GDPR), the right to rectification of inaccurate personal data (Article 16 GDPR), and the "right to be forgotten" (Article 17 GDPR). The tension between the "right to be forgotten" and blockchain has been one of the more contentious points of discussion over recent years.[98] This is because blockchain is an immutable and distributed ledger, to which data can only be added, but not amended or deleted, through a so-called "hard-fork" or "soft-fork". Furthermore, the overarching principles of data minimisation and purpose limitation[99] under the GDPR can be challenging to achieve with blockchain as new data is added onto the chain and stored indefinitely.

The GDPR is built on the foundation that responsibility and accountability rests with a "controller" and the controller must implement appropriate technical and organisational measures in order to demonstrate compliance with the GDPR. This, again, creates challenges for blockchains – for example, in the context of a public, permission-less blockchain it may be difficult to identify who are the "controllers" that are responsible and accountable to the relevant data subjects and against whom those data subjects may exercise their rights under the GDPR. The predominant view is that, within blockchain, each node constitutes a "controller" with respect to all of the data stored on the blockchain. It follows, that, in order to make a successful request under Articles 15-17 GDPR, a data subject would need to identify and contact each and every node, which is practically impossible. The alternate view, which was recently taken by France, is that only "active" participants, i.e. those actively inputting data into the system, and not mere "nodes" or "miners" providing verification of transactions to the platform, are responsible as "controllers".[100]

The GDPR also prohibits the transfer of personal data by a "controller" or "processor" to a third party (which includes group companies) located outside of the European Economic Area ("EEA") or which is not subject to the GDPR, unless adequate safeguards are in place. As a result, any "controllers" that are subject to the GDPR and process personal data using a blockchain will need to ensure that adequate safeguards are in place. For most non-EEA countries, the appropriate safeguard means putting in place a written contract with the third party that includes standard data protection clauses adopted by the European Commission. In a public, permission-less blockchain where all participants are unidentified, this may prove exceedingly difficult.

On the face of it, there are many challenges in creating a GDPR-compliant blockchain. Several approaches have however been discussed as potential solutions to interpret the GDPR in a way that is not at odds with blockchain technology.[101] In addition, it may be possible for technical modifications to be made to the blockchain to ensure compliance with the GDPR, such as storing the personal transaction data "off-chain" for it to be modified retroactively. However, these potentially remove the substantive proposition of blockchain as a platform that does not rely on the verification of a centralised authority and trusted third party.

For example, in relation to P2P electricity trading, it is suggested to design the blockchain applications in a way that does not require processing of any personal data, through the implementation of what is known as a zero-knowledge proof ("ZKP") procedure, which enable transactions without making any of the parties identifiable.[102] This, however, could cause further issues down the line as to responsibility and liability, where there is non-performance of the smart contract or where there is non-delivery of electricity due to a technical fault. EU data protection law, therefore, poses a number of significant obstacles to blockchain-based applications that process personal data, particularly those operating publicly, which will need to be overcome.

RECOMMENDATION: Lawmakers should clarify whether and, if so, how the GDPR applies to blockchain-based smart contracts given the intent of the technology to remove the need of a centralised authority to control and process personalised transactional data. Who is a "controller" and who a mere "processor" of data, how consent for use can be both given and evidenced. Other provisional solutions may involve blockchain-friendly interpretation of relevant provisions from lawmakers, in addition to technological developments by the industry to successfully anonymise personal data in a way that meets the requirements under the GDPR. The alternative is an expansive overhaul of EU data protection law to either exclude or expressly provide for blockchain within its scope.

98 European Parliament. (2019). "Blockchain and the General Data Protection Regulation." July 2019.
99 Article 5 GDPR.
100 Commission Nationale de l'Informatique et des Libertés (CNIL). 2018. "La Blockchain: Quelles Solutions Pour un Usage Responsible en Presence de Donneeds Personnelles." 24 September, 2018; Op. Cit. 73, p.6.
101 Op. Cit. 84, p.13.
102 *Ibid*.

Summary of Recommendations

As blockchain technologies become more widely used in support of new types of decentralised applications and platforms in EMs, lawmakers and regulators will be faced with significant challenges.

This study is concerned both with emerging markets and emergent technologies. It is not an area in which clear lessons can be derived from other sectors. Rather, it is necessary to consider similar challenges where EMs have an opportunity to leapfrog some developmental stages experienced by other markets.

In light of this framework, this study provides recommendations in three separate but overlapping areas. Each of these should be undertaken in parallel with the level of active participation from the EBRD and other MDBs required to drive change, ranging from a purely advisory and supervisory role to acting as the driving force.

Consultation / advisory > **Coordination** > **Driving force**

Policy

Energy markets are uniquely policy-driven. The prevalence of regulated structures and historically monopolistic institutions, as well as the over-arching need to enhance and protect an economy's energy infrastructure can empower top-down change. Thus, policymakers have an important role to play, which requires active encouragement as opposed to passive non-interference.

MDBs should seek to assist policymakers in:

- The development of national blockchain strategies and promotion of "sandbox" initiatives and pilot programs to spur innovation and provide a safe testing ground for new blockchain-based applications;
- The promotion of policies and initiatives to raise awareness of the potential of the technology. To include open consultations with industry stakeholders and the establishment of working groups to precisely identify the key barriers of adoption at the national level;
- Establishing unified technological protocols and standardised smart contracts aligned to the specific needs of the energy sector; and
- The provision of technical training and support to ensure understanding of these technologies by the various stakeholders.

> EXAMPLE: Policymakers should consider the implementation of pilot programs, for instance, to add smart grid and DER infrastructure, introduce P2P energy trading platforms or carbon registries. Policymakers would need to first ensure the requisite policy framework for development and private investment is in place before initiating these pilot programs.

Consultation / advisory > Coordination > **Driving force**

Legal and Regulatory

There are no intrinsic legal or regulatory barriers to implementation. Rather, there needs to be a refinement of existing frameworks, in accordance with EU policies, in order to provide a clear framework and comfort level. In particular, the GDPR framework needs to be expressly considered.

MDBs should seek to assist regional bodies and national governments in:

- The adaptation of specific national laws, harmonisation of laws and interpretations in accordance with the EU's Clean Energy Package to ensure a clear and consistent framework for adoption of blockchain-based solutions;

– The provision of regulatory guidelines on the use and operation of blockchain platforms and smart contract technologies. This study concludes that, in order to be effective quickly, such steps should move away from the use of detailed and prescriptive rules in favour of broadly stated outcome-based principles;[103]

– The formulation of such outcome-based principles or standards at which industry must operate; and

– Guidance in establishing regulatory "sand-boxes" to provide controlled environments for innovation.

EXAMPLE: Lawmakers should consider forming a specialist working group to encourage the harmonised application of trans-national rules to blockchain-based solutions, in particular of EU data protection and consumer protection law to start. The working group may find that there is a need for a comprehensive legislative reform encompassing the energy sector to ensure that the data protection and consumer protection frameworks are up to date and accommodate blockchain-based use cases and smart contracts.

Consultation / advisory > **Coordination** > **Driving force**

Investment and Finance

Running in parallel, the process of investment and finance entails the promotion of both the policy, legal and regulatory frameworks, as well as the development of the commercial basis for their execution.

MDBs should seek to provide practical guidance and assistance to regional bodies and national governments in:

– Conducting a full and comprehensive individual country analysis and research to determine the financial viability and cost-effectiveness of deploying the necessary digital-physical infrastructure and/or integrating blockchain solutions into existing infrastructure;

– Following full assessment, entering into direct consultation with relevant stakeholders and public-private partners on the implementation of initiatives to stimulate innovation and growth in the sector; and

– Providing funding or incentivising investment in the deployment of necessary baseline smart-grid infrastructure to support blockchain solutions, followed by the implementation of pilot-projects in high-impact use cases, such as DERs, P2P energy trading, and ETS.

EXAMPLE: Policymakers should consider preparing a digital "census" of existing digital-physical infrastructure and platforms to encourage investment. In addition, policymakers should consider initiating a direct consultation with relevant stakeholders, experts, and public-private partners in the energy sector to assess the commercial stumbling blocks and the current investment climate in key energy technologies.

Consultation / advisory > **Coordination** > **Driving force**

In terms of timing, these three steps should be taken in parallel in the following timeframe so that lessons can be learnt from each analysis and to avoid delay.

103 To be clear, regulation should focus on the use and operation of blockchain platforms and smart contract technologies, rather than the technologies themselves, to allow for continuous innovation.

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