Blockchain Applications and the Sustainable Development Goals

Analysis of blockchain technology's potential in creating a sustainable future

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Abstract

This paper aims to assess the potential of blockchain applications in the financial, business, public and climate change sectors to contribute to the realisation of the Sustainable Development Goals (SDGs). Around two third of SDGs are found to be strongly connected with blockchain applications, especially the SDGs 8, 9, 10 and 16. This can be explained by the fact that blockchain applications, which decentralise processes, could improve the efficiency of data management, facilitate peer-to-peer models and foster innovation. The technology could also boost economic growth, improve the transparency and accountability of organisations and empower small economic actors. Through these attributes, blockchain is likely to transform the way our economy functions and contribute to the creation of sustainable societies. However, the adoption of the technology depends on its ability to overcome technical, regulatory and social challenges. This study ends with a discussion regarding the need to steer the development of blockchain towards sustainability within a digital governance framework.

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Table of content

Abstract 2
Executive Summary 6

1. About Blockchain Technology 9
1.1 Blockchain as a Distributed Ledger Technology 10
1.2 Blockchain system types and permission to access 12
1.3 Blockchain system characteristics 13
1.4 Blockchain-enabled functionalities 14
1.5 State and trends of the blockchain market 15

2. Blockchain Applications in the Financial Sector 17
2.1 Financial inclusion 18
2.2 Fundraising for start-ups 20
2.3 Securities exchange in financial markets 22
2.4 Shareholders’ proxy voting 23
2.5 Financial accounting 24

3. Blockchain Applications in the Business Sector 27
3.1 Business intelligence 28
3.2 Supply chain management 29
3.3 Marketing and advertising 32
3.4 Intellectual property 34
3.5 Insurance 36
3.6 Human resources 38

4. Blockchain Applications in the Public Sector 40
4.1 Government operations 41
4.2 Legal identity and healthcare 43
4.3 Elections 45
4.4 Land titling 47
4.5 Taxation 48

5. Blockchain Applications for Climate Change and Sustainable Societies 52
5.1 Sustainable production and consumption 53
5.2 Sustainable lifestyles 57
5.3 Institutional carbon trade 59
5.4 Individual carbon trade 61
5.5 Smart grid 63
5.6 Renewable energy 65
5.7 Philanthropy 66

6. Blockchain Adoption Challenges 68
6.1 Technical challenges 69
6.2 Regulatory challenges 72
6.3 Social challenges 73
7. Blockchain, a Tool for a Sustainable Future? 76
7.1 Blockchain implications for the SDGs 77
7.2 Blockchain's ethical crossroads 80
7.3 The need for cryptoeconomics and digital governance 81
Acknowledgments 85
References 86
Appendix 1: List of identified blockchain applications 97
Appendix 2: List of blockchain initiatives cited in this paper 100

Executive Summary

Unknown to the public until a few years ago, blockchain technology is now at the centre of every discussion on the future of the digital economy. Touted as a major disruptor across many industries, the technology's importance slowly emerged from the shadow of Bitcoin, its first well-known application. While mostly welcomed by enthusiasts for its potential benefits, blockchain also receives a fair amount of scepticism for not being as unique as usually described. Blockchain is a distributed ledger technology (DLT), a decentralised database encrypted with cryptographic protection. As such, it provides the means to vastly improve, connect and secure data collection and sharing systems.

While there is an undeniable hype over blockchain, the potential economic and social impacts of the technology are hard to overstate. The World Economic Forum (2015) estimates that by 2027, 10% of global gross domestic product (GDP) will be stored on blockchain-based platforms. Every region in the world is concerned by the spread of blockchain solutions. A survey by EY (2018a) shows that 28% of respondents expect the United States to experience the highest surge in blockchain adoption, followed by China (18%), Japan (14%) and the United Kingdom (12%).

There are already numerous experiments and technology trials around the world. A study from Moody's Investors Service in 2016 identified 25 use cases for the technology. In this paper, 24 blockchain applications are evaluated across the four sectors of finance, business, government and climate change and sustainable societies. Looking beyond market disruption, this study aims to assess the potential of each blockchain application in contributing to the SDGs (all blockchain applications listed in this study are compiled in Annex 1). For each use case studied in this paper, relevant sustainability implications and SDGs are listed in a "Sustainability Summary" box. The results of this SDG mapping are visualised in the Figure 1 below. Its main takeaways are as follows:

- The blockchain applications assessed throughout this paper present a certain connection with all 17 SDGs across four sectors. Although some SDGs are less directly related than others, overall, blockchain applications bear a strong connection to 11 of the 17 SDGs.
- Blockchain applications in the public and climate change sectors tend to complement applications in the financial and business sector in terms of SDG impact.
- While there is currently a higher number of blockchain trials in the financial and business sectors due to early technology adoption, the applications in the public and climate change sectors present more potential to positively influence the realisation of SDGs in the long-term.
- The SDGs that most strongly relate to the assessed blockchain applications are SDGs 8 (decent work and economic growth), 9 (industry, innovation and infrastructure), 10 (reduced inequalities) and 16 (peace, justice and strong institutions). This can be explained by the fact that most blockchain applications could foster economic growth and innovation, improve the transparency and accountability of organisations and empower small economic actors and vulnerable populations.
- Some SDGs that are usually seen as the responsibility of governments, such as SDGs 1 (no poverty), 2 (zero hunger) and 3 (good health and well-being), are often found to be as related to blockchain applications in the private sector as in the public sector. This is notably because blockchain facilitates the creation of peer-to-peer models in sectors that traditionally relied on intermediaries.
- One important factor to consider is that blockchain is still a nascent technology. Therefore, new applications might emerge in the future that have strong relationships with SDGs and that were not mentioned in this paper. Additionally, the assessed blockchain applications might prove to have unforeseen indirect impacts on the less connected SDGs, which are not evident as of now.

Figure 1: Blockchain SDG Mapping

Connections between SDGs and identified blockchain applications in each sector

SDG 1. No Poverty; 2. Zero Hunger; 3. Good Health and Well-being; 4. Quality Education; 5. Gender Equality; 6. Clean Water and Sanitation; 7. Affordable and Clean Energy; 8: Decent Work and Economic Growth; 9. Industry, Innovation and Infrastructure; 10. Reduced Inequalities; 11. Sustainable Cities and Communities; 12. Responsible Consumption & Production; 13. Climate Action; 14. Life Below Water; 15. Life on Land; 16. Peace, Justice and Strong Institutions; 17. Partnerships for the Goals

Blockchain disruption will touch every industry, with a business added-value that will grow to more than USD 176 billion by 2025, and USD 3.1 trillion by 2030 (Gartner, 2017). Hileman and Rauchs (2017) estimate that the sectors with the highest use cases for blockchain technologies are banking and finance (30%), government and public goods (13%), insurance (12%) and healthcare (8%). Over the next five years, blockchain technology could upend how businesses and marketplaces operate (Deloitte, 2018), while generating social impacts, mainly in the agriculture, healthcare, insurance, public, retail and utilities sectors (Carson et al., 2018).

According to the World Economic Forum (2018), the biggest global risks in 2018 in terms of likelihood are environmental risks and cybersecurity risks. Blockchain seems perfectly poised to help the world address these challenges, as it offers solutions for both types of risks. As put by Killmeyer et al. (2017), “choosing to leverage blockchain is not just a technology question—it is a decision that can transform business models and processes, and reshape the set of stakeholders and their roles.”

Overall, what appears from each use case is that blockchain could greatly improve the efficiency of processes that were designed in times before the Internet, and to fully leverage the benefits of digitisation. Although digital platforms are widely used nowadays, most data gathering and sharing systems are highly centralised. This leads to structural inefficiencies across many fields of the economy such as financial transactions, supply chain management or public identity and health records (all blockchain initiatives cited in this paper for all sectors are compiled in Annex 2). Using a distributed ledger technology such as blockchain can eliminate the need for data harmonisation and reduce (though not entirely eliminate) the role of intermediaries.

However, the use of blockchain for virtuous purposes should not be seen as a given. As with every technological breakthrough, the fundamental question that should be at the centre of the public debate is "can it serve to create a more sustainable and fair society?" After evaluating the technical, regulatory and social challenges to blockchain adoption, this paper ends with a discussion on the place of blockchain in creating a sustainable future. As put by Sangokoya and Ajoku (2018), "the Fourth Industrial Revolution has the potential, like the revolutions that went before it, to consolidate power asymmetries, increase inequalities, and advance technologies that fail to embody human-centred values."

Blockchain is likely to become a central element of this revolution, with economic and social impacts on par with the invention of the Internet. Yet, it is important to remember that technology is, by default, ethically neutral: it can be a powerful enabler but is not a solution in itself. Therefore, this revolution needs to be guided by a digital governance framework in order to ensure that blockchain technology is designed by and for people.

1. About Blockchain Technology

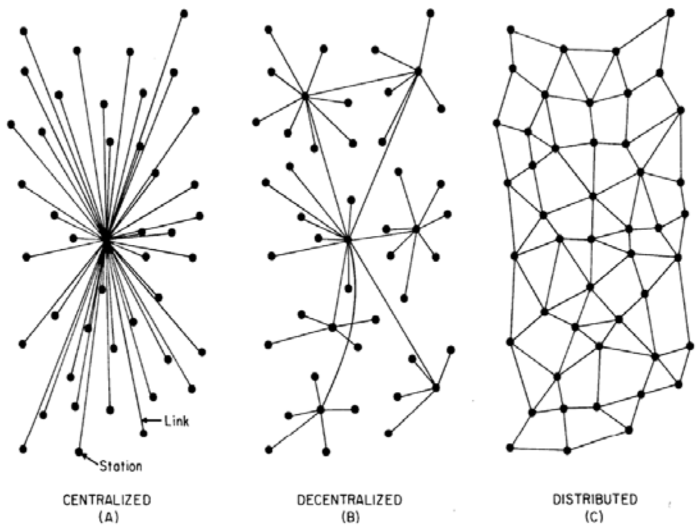
1.1 Blockchain as a Distributed Ledger Technology

The data structure used in blockchain was first proposed for time-stamping the creation of intellectual property, aiming to use cryptography to protect the property rights of creators (Haber and Stornetta, 1991). The blockchain technology gained worldwide attention following the popularity of Bitcoin, a virtual currency ("cryptocurrency"). Bitcoin was a product created in an original blockchain system invented by an unidentified person using the pseudonym "Satoshi Nakamoto", who published a white paper in 2008 and verified the first Bitcoin entry into the Bitcoin blockchain system in 2009. Throughout 2017, Bitcoin brought blockchain to the forefront of global financial and technology discussions, due to its phenomenal exchange price to fiat currency (Bitcoin reached its highest exchange rate of USD 19,783.06 for BTC 1 in 2017).

The popularity of Bitcoin and the Bitcoin blockchain system led to a common misconception that blockchain is (only) Bitcoin, a publicly accessible system specifically used for generating and trading cryptocurrency. However, Bitcoin is not the sole example of a product for which creation and transactions are possible to be performed in a blockchain system.

Blockchain is a wide-ranging and flexible type of data structure which operates under the principles of a Distributed Ledger Technology (DLT). A DLT refers to a novel and fast-evolving approach to recording and sharing data across multiple data ledgers which each have the exact same data records and are collectively maintained and controlled by a distributed network of computer servers (Figure 2).

Figure 2: Difference between centralised, decentralised and distributed networks

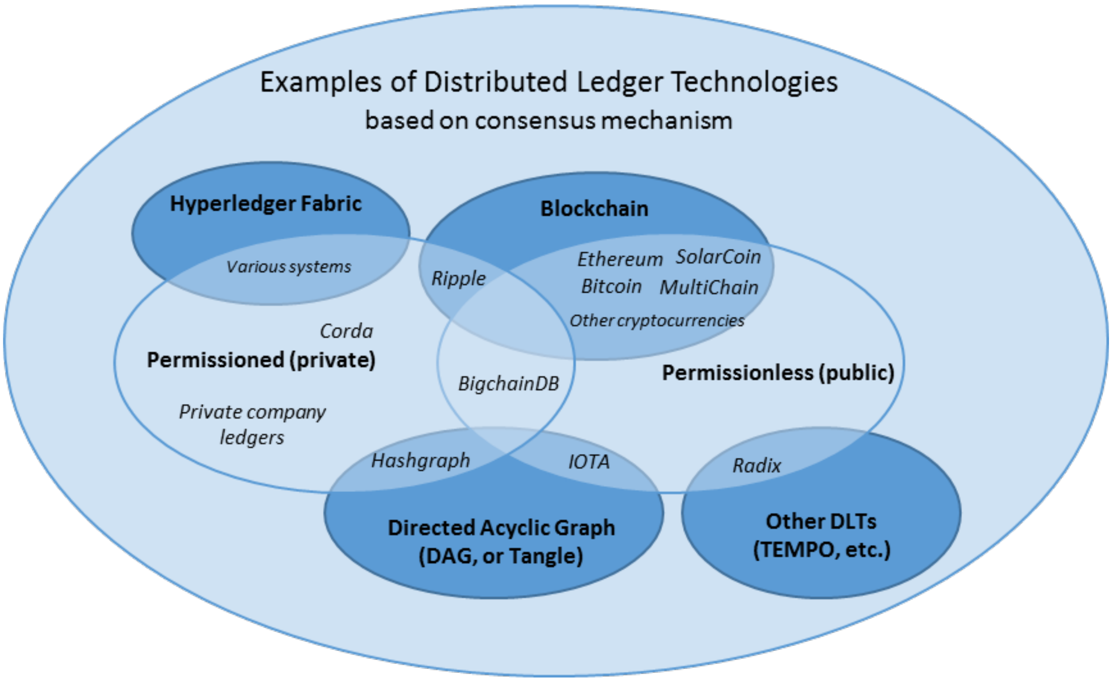


Source: Baran (1964)

A DLT has three key features: the distributed nature of the ledger, the consensus mechanism, and cryptographic mechanisms (World Bank, 2017). Within a DLT, data transactions are shared, validated and archived by different members of a network in a complementary manner. When a member of the network enters data into the system, other members validate that entry and assign a digital signature to prove its existence and validity in the network.

There are many types of DLTs aside from blockchain (Figure 3), such as Hyperledger Fabric, Directed Acrylic Graph or Tangle and TEMPO, each of these having its own subtle characteristics and functions. Indeed, the terms DLT and blockchain are widely used in an interchangeable manner without detracting from the meaning of either term. However, not all DLTs necessarily employ blockchain technology, and conversely, blockchain technology could be employed in different contexts (ibid).

Figure 3. DLT system features and examples



Source: Authors (the graphic is non-exhaustive)

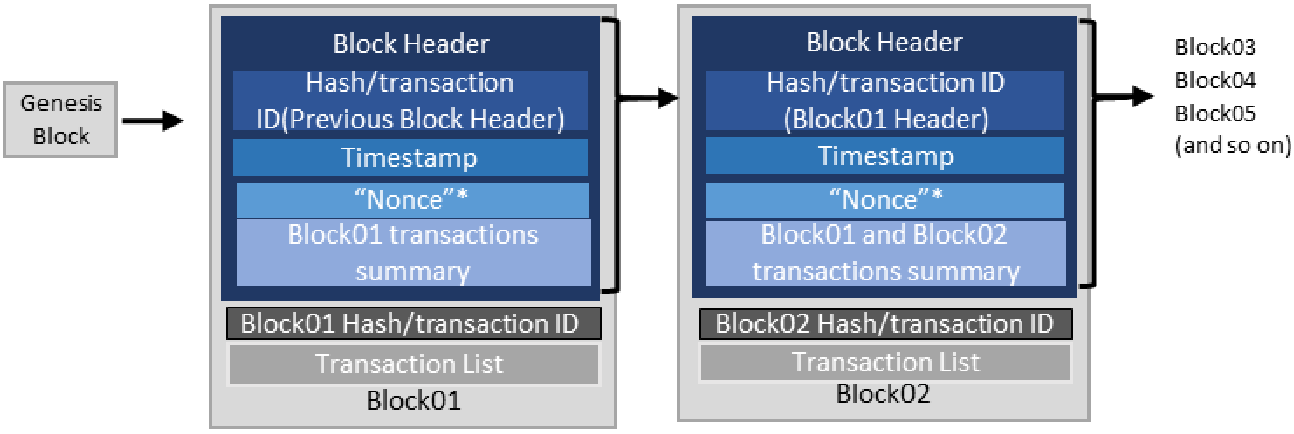
A member of a blockchain system, or a *node,* can only add a transaction that is verified by other nodes. Before a *block* can be added into a chain of blocks, or a *blockchain,* a *consensus mechanism* is needed to verify that the block meets predetermined criteria and rules of the system such as no double recording of the same data. The validation activity, called *hashing,* includes solving an assigned mathematical problem. The correct answer to this problem is called a *nonce*. Once a node finds the *nonce,* other nodes verify it, and then a cryptographed identifier, called a *hash,* is given to the transaction. A hash consists of numbers and letters. Then, a block of data consisting of this cryptographed, digital identification is created. Hashing and consensus-reaching computations are done using computer software.

After a consensus is reached, the new, identified, cryptographed, validated block can be added to the blockchain. The new block will be linked to previous blocks in the same chain, such as to blocks that contain previous transactions of the same data or asset. When a block is added to a chain, system members will be informed and own a copy of the block (not the data) in the distributed ledger accessible to them. If a block needs to be changed, another consensus mechanism is needed.

The Bitcoin blockchain has a unique consensus mechanism called *proof-of-work,* and the activity done to meet the consensus is called Bitcoin *mining.* Mining to validate a transaction involves the computation activity to solve a mathematical problem, and the miner node which solves the problem will be rewarded with Bitcoins. As a pioneer, the basic architecture of Bitcoin blockchain system became the main reference of many blockchain systems, including those covered in this report. Although the challenges associated with the Bitcoin system may not be applicable to blockchain technology as a whole, its widespread adoption and maturity compared with other blockchain systems may be valuable for future applications.

A block has two parts (Figure 4): *a header,* which includes a unique block reference identification number, the time the block was created, and a link back to the previous block; and *the content*, which usually is a validated list of digital assets and instruction statements, such as transactions made, their amounts, and the addresses of the parties to those transactions. A blockchain data ledger consists of unique blocks that each connects to individual transactions.

Figure 4: The structure of blocks building up a blockchain



Source: Adapted from U.S. National Institute of Standards and Technology (2018)

1.2 Blockchain system types and permission to access

Blockchain systems are based on a distributed management with a decentralised authority. However, blockchain offers flexibility in access and scope of 'distribution'. Each system owner can customise their blockchain based on their needs and purposes. For example, a blockchain system owner can make an eligibility criteria for access holders, create a certain level of security, and design their own management system. Based on the access to network members, a blockchain system can be accessible only within a closed network (permissioned) or accessible to the public (permissionless).

Permissioned blockchain

A 'permissioned' blockchain system maintains data that are accessible to a selected members of network with prior authorisation from the system manager. A permissioned blockchain requires participants to obtain permission from the system manager before reading or writing new data to the chain (MIT Technology Review website, 2018). This system manager can be a human operating a computer or a computer programme. Computer programmes are being developed to verify data and then pass it to a smart contract, performing as an agreed third-party within a blockchain system. If combined with artificial intelligence (AI) and the internet of things (IoT) these programmes may be able to provide qualified data to the blockchain at the right moment (Vian, 2016).

Some examples of a permissioned blockchain system are a shared ledger between multiple banks (business-to-business), internal ledger of a company group (e.g. holding company and subsidiary companies) and individual company, and business networks that requires confidentiality or regulatory compliance. According to CoinDesk, 12 banks in China deployed blockchain applications to process invoices, automatic as well as cross-border loan issuance, identity authentication, development of a digital wallet, and to explore data storage issues and streamline certificate authentication processes (Zhao, 2018). China Construction Bank reported that its platform has so far processed transactions worth a total of 1.6 billion yuan (around USD 251 million). Another example is EncrypGen Gene-Chain, a private blockchain network applied to mediate the searching, storing, sharing, buying and selling of genomic data (EncrypGen, 2018).

Permissionless blockchain

A 'permissionless' blockchain system or network can be open to anyone with the technological capability to join the network. A permissionless blockchain could be called a 'public blockchain', which some argue could potentially be compared to the internet as we know today, where organisations could exchange and retrieve information with anyone who has access to a service provider (Deloitte, 2017a).

There are many examples of permissionless, or public blockchain. The most popular product managed in a permissionless system is Bitcoin. The Bitcoin system is run by a global network of computers that compete to validate transactions, or mining, to ensure the transactions are secure and reliable through a chain of programming in exchange for Bitcoins (Reuters, 2018). The 'permissionless' system is kept secure using its own cryptographic mechanism, and network members with access to advanced computer systems share the same goal of maintaining the system's integrity. In the early days of Bitcoin, anyone with access to a basic computer system and the internet could mine. Nowadays, being a Bitcoin miner requires advanced computer systems with high data-processing capability due to the increased complexity of security measures.

1.3 Blockchain system characteristics

Decentralised

As described in the section above, blockchain is an example of a distributed ledger technology, which has by nature a decentralised system authority. Since authority is distributed among network members, the need for conventional third-party entities is minimised.

Distributed data

Blockchain systems have an inherent backup system as each block is copied to all system members once it is created.

Immutability

Once a block is created, the original data it contains cannot be altered. If an alteration is needed, it has to be created through a new block which is then linked to the original block. The original block will not be changed and will be traceable.

Traceability

Each block in the blockchain is assigned with unique identification that can be traced even if it is taken out of the system by force.

Cryptographed

Data and blocks are secured with cryptography which can be unique for each system.

Flexibility and universality

Blockchain systems can be adjusted to manage various types of data and transactions. Due to this universality, blockchain has the potential to create value and create exchange rates of various data.

Consensus-based

Blockchain systems have a strong foundation in the members' interest to protect the system security, which leads to a strong inherent validation and verification process. This characteristic is particularly basic in the Bitcoin system.

Automated

Blockchain systems can make programmes to automatically perform transactions on behalf of two or more parties, based on pre-approved criteria and conditions. This will minimise the need for conventional third-party intermediaries.

Customised access

Although principally distributed, each blockchain system can allow different access as determined by its owner. It can be public (permissionless) or private (permissioned).

1.4 Blockchain-enabled functionalities

Cryptocurrency

As a flexible data structure, blockchain can manage various types of data and turn them into valuable digital asset. Information on a single document, transaction, certificate, event, quantity, reserve, identity, product, or a group of these, covering a wide range of sectors from energy to consumer goods, can all be mutually agreed as new assets and once recorded digitally in a blockchain, they can be transacted as “cryptocurrency”. As put by Filecoin (2014), blockchain-based cryptocurrencies can organise and incentivise large networks of machines to perform computations for data validation. An older example of created value is carbon credits as a “green asset” with economic value, while the most recent and relevant to blockchain is Bitcoin. In the blockchain world, many newly-created cryptocurrencies are called “coins” and “tokens”. They can be exchanged with hard currencies and in some jurisdictions (the United States, the European Union, Japan, China, Zimbabwe, among others), can used directly like conventional money.

Smart contracts

Taking advantage of customised programmes running automated and digitised actions in real time, blockchain has been used to create “smart contracts”, a generic product type that facilitates, validates, and records transactions and agreements between multiple parties. As put by Szabo (1994), a smart contract executes the terms of a contract. Through smart contracts, many types of contractual clauses can be made partially or fully self-executing, self-enforcing or both (Deloitte, 2016). As smart contracts will reduce the time needed to make payments and settlement for all parties involved, this will minimise the need for conventional third-parties currently required to perform manual verification.

Peer-to-peer transactions

Blockchain systems emerged from an interest in making systems less decentralised and to make transactions run faster. These interests are shared by informal workers and small businesses running on an individual basis, thus there has been a growing number of new peer-to-peer businesses dealing with new commodities, goods and services.

Data accountability

A blockchain database retains the complete history of all assets and instructions executed since the very first block was created and distributes control to all system members. The mutual distrust on new transactions depending on this process, rather than on the reputation or reliability of one participant such as a bank (EY, 2017), creates a new type of trust between participants and auditors of the blockchain.

Data security

One of the strengths of a blockchain system is its digital cryptographic protocol to secure and record individual transactions, making them immutable. According to Chaprone (2017), even if someone tries to trace back the encrypted identification, they will not be allowed to access the original source and obtain the original document that generated it. This means that the original data, documents, certificates, and other assets represented in the block are kept secure for their owners and the parties that are given consent to access them. Distributed ledgers such as blockchain-based databases are also inherently harder to attack because, to be successful, a cyber-attack would have to attack each copy of the data simultaneously (EY, 2017). It also relies on a network of members with a shared interest to protect and sustain the ledger.

Fraud prevention

Each block identifier can be traced and deciphered later on to prove the data existence, together with the data reference number, creator, validator, time of consensus creation, and a link to the other block that contains information on the previous transactions on the asset. It provides for a concrete, traceable, and permanent ownership of assets. Since blockchain cannot be modified or manipulated without the consent of all involved parties, it can prevent corrupt governments or companies from evicting or seizing the assets of people unfairly.

Operational efficiency

Managing a ledger in a distributed manner reduces the risk of double-recording, cuts down on errors due to database reconciliation discrepancies, eliminates waiting time to perform a transaction, and reduces the need for intermediaries. A backup system is also embedded by distributing a copy of each block to every member of the system. These features will improve efficiency of any kind of business that involves multiple parties. In early 2018, a collaboration between blockchain technology developers and an independent research organisation announced the potential of blockchain-enabled technologies in improving mobile product delivery time by 34%, productivity by 29%, and quality by 11% (Aricent, 2018).

Strengthening IoT networks

A blockchain system can complement IoT systems, collecting real-time data and storing them in a more secure way. By directly storing encrypted data collected from IoT devices into blockchain, IoT network operators can save substantial costs and technical efforts for setting up and integrating individual IoT network for each device. The cryptographic security measures and decentralised network of blockchain can also help address security concerns surrounding IoT and improve its reliability. Imagine a future where homes are equipped with sensors connected to blockchain ("smart homes") and food delivery vehicles are equipped with temperature sensors. Micro data on air pollution, temperature, water consumption, and energy consumption behaviour by households or public transportation, also can be better managed using an IoT-blockchain system and analysed more effectively for better environmental management.

1.5 State and trends of the blockchain market

The total value of assets now being administered via blockchain globally is already over USD 1.6 billion, showing growth by 1,600% between 2013 and 2016, in which over USD 1.4 billion was invested in blockchain-related start-ups in the first nine months of 2016 alone (de T'Serclaes, 2017). The number of enterprise DLT start-ups has tripled within three years, from approximately 37 companies in 2014 to over 115 in 2017, employing an estimated number of 2,000 full-time employees (Cambridge Centre for Alternative Finance, 2017). These start-ups work as back-end infrastructure providers, application developers and operators. The first start-ups were born in North America, but Europe and the Asia-Pacific region are catching up with blockchain developments. Consequently, there has been an increasingly high demand for blockchain-related jobs (Stein, 2018) such as system developers and application programmers.

Many have foreseen the future of blockchain as the basis for an internet of value, democratising access and storage of digital assets (World Bank, 2017). It is important to note that in the information technology industry, especially software, developments take place rapidly and new brand names constantly emerge, sometimes for marketing purpose.

Some notable recent trends on blockchain systems development include enabling offline transactions, merging blockchain with IoT systems, and modifying the technology to reduce the need for data storage and energy consumption.

Some notable recent trends on blockchain systems development include enabling offline transactions, merging blockchain with IoT systems, and modifying the technology to reduce the need for data storage and energy consumption.

Blockchain technology start-ups certainly do not only work on Bitcoin, cryptocurrencies, or e-commerce or digital financial sectors. Development and applications have widened to tackle other assets and services in the conventional financial sector, various businesses, public sector, and sustainability advocacy. Examples of blockchain applications in those sectors can be found in the following chapters of this report.

2. Blockchain Applications in the Financial Sector

2.1 Financial inclusion

It is estimated that blockchain has the potential to build the foundation for the next generation of financial services infrastructure and processes (World Economic Forum, 2016). A study by Bain & Company shows that 80% of financial market participants believe that blockchain will be transformative and expect their firms to adopt it by 2020 (Olsen et al., 2017). Some experts even say that blockchain will do to the financial system what the internet did to media (Ito et al., 2017). Today's banking system is built on a wide network of intermediaries, which operates in an inefficient way (Tapscott and Tapscott, 2017)[1]. The blockchain technology hold the potential to offer substantial benefits to peer-to-peer payments.

Sustainability Summary	
Sustainability implications	■ Facilitated cross-border transfers, notably to vulnerable populations ■ Better financial inclusion and access to credit for unbanked people and small businesses through peer-to-peer lending ■ Strengthened economic development in emerging markets due to smoother transfer of capital
Blockchain functionalities	■ Peer-to-peer transactions ■ Operational efficiency ■ Cryptocurrency
SDGs	**1.** No poverty **2.** Zero hunger (incl. 2.3) **5.** Gender equality (incl. 5.A) **8.** Decent work and economic growth (incl. 8.10) **9.** Industry, innovation and infrastructure (incl. 9.3) **10.** Reduced inequalities (incl. 10.1, 10.B, 10.C)

Remittance transfer

In the current system, for any simple bank transfer from one account to another, the banks involved need to have an established financial relationship with each other. When they don't, which is usually the case, the banks need to execute the transfer through the centralised protocol of the Society for Worldwide Interbank Financial Telecommunication (SWIFT), which sends the payment order to a correspondent bank that has an established relationship with both banks. Then, the actual payment is processed through a system of intermediaries, such as banks and custodians, transfer agents, stock exchanges, traders, fund and asset managers. All of these actors also maintain a different ledgers, which need to be harmonised in order to complete the transaction.

Through the course of this process, called clearance and settlements system, every intermediary takes a fee and needs time to execute its action, which are both higher in case of a cross-border transaction. Estimates show that the average cost per transaction for a money sender is 7.68% of the amount transferred, and that 60% of B2B payments require a manual intervention (CBInsights, 2018).

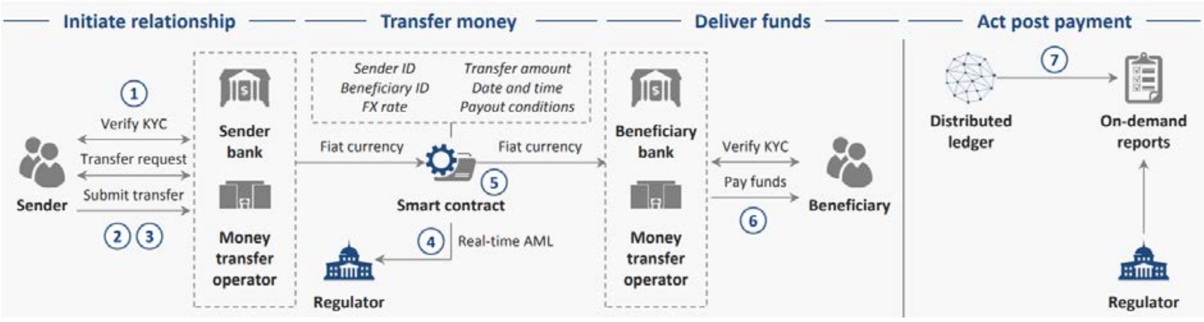
Peer-to-peer transactions

The blockchain technology could potentially replace the whole inefficient system of intermediaries (Benos et al., 2017). Every transaction processed directly through the blockchain would be registered publicly and transparently, and in a more secure way due to cryptography, reducing the risk of fraud and errors (see Figure 5). Transaction fees could also be greatly cut down. A study by Capgemini (2016) shows that consumers could

[1] There are three main reasons to this inefficiency. First, in spite of its digital appearance, the banking infrastructure mostly relies behind the scenes on outdated paper-based processes. Second, the banking system is very centralised, which makes it resistant to change and vulnerable to systems failures. Third, the system is exclusionary and denies billions of people access to basic financial tools, based on a risk-averse selection process.

save up to USD 16 billion (or USD 500 per consumer on average) in banking and insurance fees each year through blockchain-based applications. Moreover, cross-border transactions could be processed almost in real time. For example, a Bitcoin transfer on the blockchain takes between 30 minutes to a few hours (and only costs around 20 cents per transaction), compared with the 3 to 5 days required in the current banking system (Deloitte, 2017b).

Figure 5: Blockchain-based process of global payments



Source: World Economic Forum (2016)

Such faster and cheaper transactions would facilitate peer-to-peer payments, which could be pivotal in alleviating poverty and contributing to achieving income growth for the bottom 40 per cent of the population (SDG target 10.1). The technology could also reduce the transaction costs of migrant remittances (target 10.C). Additionally, it could help giving women equal rights to economic resources and access to financial services (target 5.A). On a larger scale, blockchain-based peer-to-peer transactions can facilitate economic development in emerging markets by providing a cheap and secure way to transfer money across borders. This would result in increased financial flows to the countries where the need is the greatest (target 10.B).

A few initiatives have emerged in this field For instance, BitPesa offers blockchain-based payment solutions that aim to reduce the cost of cross-border payments in Africa and the cost for small enterprises to access liquidity. Similarly, Binance, one of the biggest cryptocurrency exchanges in the world, is seeking a license to operate in Malta, with aim to become the world's first decentralised and community-owned bank (Shen, 2018).

Automated clearance and settlements systems

Another benefit from the blockchain is that a distributed ledger would circumvent the need to harmonise all the different ledgers of financial institutions for each transaction, creating near perfect records of every bank transfer across all industries. From the banks' side, the disparity or diminution of the role of intermediaries might not only translate into financial losses, it could also save money due to the reduced costs associated with those processes[2]. Overall, analysts project that blockchain will save between USD 15 to 20 billion annually in the financial services industry by 2022 (Santander and Oliver Wyman, 2015)

Several initiatives are underway to start using blockchain-based systems in banking. The blockchain service provider Ripple and the blockchain consortium R3 CEV are working with banks to create clearance and settlements systems based on permissioned blockchains, aiming to replace SWIFT (Allison, 2016). The blockchain technology from Ripple was notably put to trial from December 2017 by banks in Japan and South Korea, with aim to cut transaction costs by 30% and to achieve same-day international fund transfer (Nikkei Asian Review, 2017). Regarding peer-to-peer payments, companies such as Everex or Vio Digital already offer blockchain-based solutions to cross-border payments, trading and lending.

[2] For instance, for each transaction, banks need to carry out a costly customer verification process. According to a study by Thomson Reuters (2016), compliance to Know Your Customer (KYC) regulations and customer due diligence processes cost financial institutions on average USD 60 million, and some banks even spend up to USD 500 million a year.

Access to credit

As mentioned above, one of the reasons for the inefficiency of the current banking system is that it arbitrarily refusing access to credit to millions of people (Tapscott and Tapscott, 2017). Banks decide whether or not to grant a credit to consumers by evaluating the risks they are taking to face a default of payment. To do so, they look for consumers' credit records held by one of the few credit agencies that dominate the market such as TransUnion, Equifax and Experian. This centralised system results in a high vulnerability to data hacking and to poor global financial inclusion. According to the World Bank (2015), 38% of the world's population does not have a bank account, 3 billion are unable to obtain a credit card and 91% of the population living in developing countries experience difficulty in gaining access to credit services from traditional financial institutions.

According to a study by Cognizant (Baruri, 2016), blockchain could help the 2.5 billion unbanked people globally gain access to banking services, representing a market potential of USD 380 billion within emerging markets. Blockchain could offer a more reliable way to evaluate credit risks, improve the creditworthiness of vulnerable people and give them access to basic financial services. This would strengthen the capacity of domestic financial institutions to expand access to banking and financial services (SDG target 8.10). Moreover, blockchain could provide additional means to close the small businesses credit gap and increase the access of small-scale industries to financial services and credit (target 9.3). Blockchain could also increase agricultural productivity and incomes of small-scale food producers through access to financial services (target 2.3).

Some initiatives are exploring this area, notably regarding peer-to-peer lending. For instance, ETHLend is offering Kogia Alpha, a decentralised lending application based on the Ethereum blockchain. Its central concept revolves around using tokens as a guarantee for repayment of a loan (Valkonen, 2018). Additionally, the company Bloom is proposing a decentralised credit scoring and assessment protocol based on a blockchain. Its core function is to provide peer-to-peer identity attestation, credit registry and credit scoring services, aiming to address the current limitations to lending (Leimgruber, Meier and Backus, 2018).

2.2 Fundraising for start-ups

Sustainability Summary	
Sustainability implications	▪ Increased opportunities for start-ups due to easier and faster access to capital ▪ Improved innovation and economic growth due to more entrepreneurship
Blockchain functionalities	▪ Cryptocurrency ▪ Smart contracts ▪ Operational efficiency
SDGs	**8.** Decent work and economic growth **9.** Industry, innovation and infrastructure

The search for funding by start-ups is a critical step in their early development phase. In the traditional model, entrepreneurs need to convince venture capitalists of the value and profitability of their start-up's business model to receive funding. The motive for investors is to diversify their portfolio by investing in start-ups, which have a high-risk/high-revenue asset profile. Therefore, asset managers usually do not invest huge sums into early-stage start-ups. They delegate the investment to venture capital funds, which act as capital distributor in return for a fee. For founders, raising capital from venture capitalists is easier and allows an access to larger sums of capital than raising small amounts of money from individuals, which is logistically demanding and limited by regulations.

Access to large pools of capital

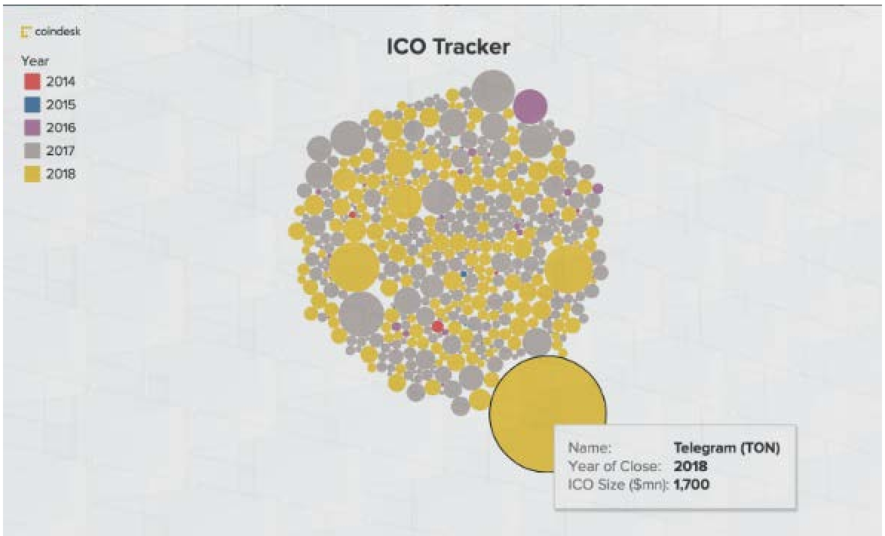
Blockchain technology presents many advantages for raising capital for start-ups. With DLT, fundraising goes through an Initial Coin Offering (ICO), the blockchain equivalent to the traditional Initial Public Offering (IPO).

With ICOs, entrepreneurs can sell tokens in exchange for a cryptocurrency like Bitcoin, and the value of the tokens is determined by the future financial success of the venture. There are several benefits to this method. First, as they happen globally and online, ICOs give companies access to a largest pool of investors. Second, ICOs make it easier to meet a start-up's funding needs in one single raise, instead of the series of small funding rounds provided by venture capitalists. It can be argued however that the progressive funding from venture capital helps entrepreneurs remain careful spenders. Third, instead of the ten years pricing of venture capital, tokens sold on the blockchain are priced on a 24-hour global market, providing immediate access to liquidity for start-ups (CBInsights, 2018).

The rise of Initial Coin Offerings

In 2017, start-ups globally raised USD 4.6 billion through ICOs on blockchain platforms, which is a sharp increase from the USD 0.2 billion raised in 2016 (Bussmann, 2018). According to the State of Blockchain report for Q1 2018 (CoinDesk, 2018), the growth of ICOs in 2018 is well-positioned to exceed its 2017 record (see Figure 6). One notable example of a company providing blockchain services for capital raising through ICOs is CoinList, a joint project between Filecoin developer Protocol Labs and start-up investment platform AngelList.

Figure 6: Global ICOs growth as of Q1 2018



Source: CoinDesk (2018)

In spite of this recent progress, it might be incorrect to presume that ICOs will replace funding through venture capital for several reasons (Crunchbase, 2018). First, ICOs are not relevant to all companies. ICOs allow the sale of tokens, not directly shares of companies, which be a hindrance for firms interested in just that. Second, unlike traditional IPOs which are heavily regulated, ICOs currently enjoy a regulatory void that might not last for long. Third, the vast amount of funding raised through ICOs up until now might not last[3]. Finally, ICOs present the risk of hacking, although the cybersecurity of the digital ledgers might improve in the future. Moreover, through the selection process, venture capitalists provide valuable expertise to entrepreneurs, allowing them to solidify their projected business model and ensure its future profitability. Therefore, rather than ICOs entirely taking over the fundraising industry, the best scenario might be to combine the traditional system of venture capital and new forms of fundraising through ICOs (Bussmann, 2018).

[3] The reason why venture capital raises smaller series of capital is because of the high risk nature of start-ups for investors. Eventually, after some start-ups will fail to provide the expected return on investment from their high-level ICO, the ICO market might adjust to the same funding patterns of venture capitalists.

2.3 Securities exchange in financial markets

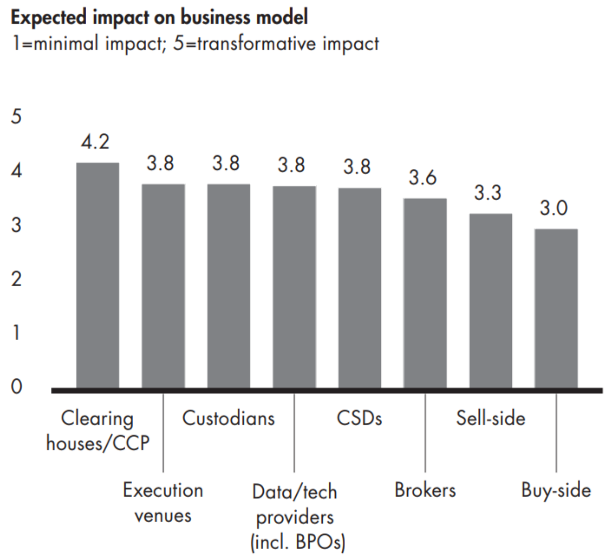
In order to trade assets like stocks, debt, and commodities, financial markets rely on a complex chain of intermediaries such as brokers, exchanges, central security depositories (CSD), clearing houses, and custodian banks. Blockchain has the potential to radically transform the securities settlement in capital markets, by offering a shared database of securities ownership that can be updated without relying on an ecosystem of intermediaries and third-parties (Chiu and Koeppl, 2018). With a distributed ledger, it could be possible to transfer the rights to an asset directly through cryptographic tokens by "tokenizing" traditional securities.

Sustainability Summary	
Sustainability implications	▪ More transparent securities depositories and transactions ▪ More stable financial markets ▪ More innovation and growth opportunity for companies due to easier access to financial products
Blockchain functionalities	▪ Operational efficiency ▪ Data accountability ▪ Data security
SDGs	**8.** Decent work and economic growth **9.** Industry, innovation and infrastructure **10.** Reduced inequalities (incl. 10.5)

Decentralised security depositories

While shares are commonly owned and registered in a central share depository, blockchain could pave the way for a decentralised share ownership. According to a report by Principles for Responsible Investment (PRI, 2018), this decentralised ownership could take form either as a single register of shares held by multiple bodies (instead of one), or by issuing shares in form of crypto tokens, held directly by their owners. In the first option, the share depository system would remain but become decentralised due to the distributed file storage, while in the second option, the crypto-equity system would make share depositories unnecessary, by allowing direct transfers between share owners. This would lead to more stable financial markets, thus improving the regulation and monitoring of global financial markets and institutions (SDG target 10.5). According to a study by Bain & Company, the financial institutions that will be the most impacted by the arrival of blockchain in the capital market are clearinghouses and custodians, while the ones to benefit from it the most are issuers and end-investors (see Figure 7).

Figure 7: Estimated business impact of blockchain on financial institutions



Source: Olsen et al. (2017)

According to Tinianow and Long (2017), such blockchain-based share ownership presents three major benefits: direct issuer-investor relations, transparent and real-time transactions and automated dividend distribution process and investor communications. Song (2018) notes however that in order to unlock its full potential in this domain, the technology needs to become scalable and attract a critical mass of market participants.

Digitised securities transfer

Several companies are already developing blockchain solutions aiming to facilitate transfer of securities through the use of smart contracts. For instance, TradeConnect is a multi-asset blockchain-based exchange platform powered by ThinkCoin. According to the company, in the past, investors have lost their assets when financial institutions have collapsed due to financial crisis, because they were unable to settle their funds. However, by using blockchain-based platforms as a near-instant settlement method instead of the usual network of intermediaries, the risk of this happening again would be substantially reduced (ThinkCoin, 2018). In the future, such platforms might not only facilitate the transfer of digital assets such as securities but might also tokenize real-world assets such as real estate or gold.

However, rather than technological innovation, policy support will be a key enabler for such transition. A major regulatory breakthrough in this regard was made by the US State of Delaware, which amended its General Corporation Law in July 2017 to allow the issuance and tracking of shares of stock by private companies incorporated in Delaware (which comprise around two-thirds of Fortune 500 companies). The amendment requires nonetheless that records of shares stored on a blockchain must be capable of being converted into 'clearly legible paper form' upon the request of a person entitled to inspect the records (Lucking, 2017).

2.4 Shareholders' proxy voting

Sustainability Summary	
Sustainability implications	▪ Better corporate governance due to transparent shareholder voting ▪ Increased participation of small shareholders in corporate decisions
Blockchain functionalities	▪ Smart contracts ▪ Data accountability ▪ Operational efficiency
SDGs	**8.** Decent work and economic growth **9.** Industry, innovation and infrastructure **16.** Peace, justice and strong institutions (incl. 16.7)

Blockchain technology presents potential for changing the way shareholders exercise proxy voting in Annual General Meetings (AGMs). Van der Elst and Lafarre (2017) note that AGMs have traditionally three major functions: the information function, the forum function and the most important one, decision-making function. However, the provisions related to AGMs often date from the 19th century and the three functions of AGMs are thus eroded nowadays[4]. The technical problems of current corporate elections have also long been denounced such as incomplete ballot distribution, disorganised vote tabulation and inexact voter lists (Kahan and Rock, 2008).

[4] For instance, the information supposed to be provided during AGMs is often disclosed long before they take place. Additionally, the forum function is often restricted by the limited time available for shareholders to discuss. Lastly, the yearly nature of AGMs hampers effective decision-making. In consequence, while AGMs were originally intended as an essential part of corporate governance, they are now seen as a superfluous and costly rubber-stamping process, leaving strategic decisions to companies' board of directors.

Decentralised voting system

A digital and decentralised voting system utilising blockchain and smart contracting would allow accurate and transparent shareholder votes. Malinova and Park (2016) even argue for a mandatory disclosure of shareholders' identity, showing that full transparency yields the highest investor welfare. The system will also benefit from lower voting costs and faster decision-making. Such system could pave the way for a renewed role of AGMs where shareholders, especially small shareholders, participate more actively in corporate governance (Wright and De Fillipi, 2015). This could contribute to ensuring responsive, inclusive, participatory and representative decision-making at all levels (SDG target 16.7). Some concrete initiatives have already emerged. For instance, Nasdaq (2016) announced that it will create a blockchain-based e-voting service in Estonia's e-Residency platform to allow shareholders of companies listed on Nasdaq's Tallinn Stock Exchange to vote in shareholder meetings. Similarly, in 2017 the Toronto Stock Exchange operator, TMX Group, is developing a blockchain-based prototype for electronic shareholder voting.

Voting risk mitigation

The most notable initiative to date concerns the Central Securities Depository (CSD) Working Group on DLT, formed in 2017. Composed of seven depositories from Russia, South Africa, Switzerland, Sweden, Chile, Argentina and the United Arab Emirates, the CSD Working Group is working with interbank co-operative SWIFT and France's SLIB to develop a distributed ledger proxy voting system embedded with the business layer of the ISO 20022 standard (SWIFT, 2018). According to the product document, such DLT-based voting system could allow to greatly mitigate four types of recurring risks in the voting process: disruption of the business process, tampering with data, compromising access to confidential data and infrastructure failure (National Settlement Depository, 2017). However, while DLT systems address trust issues, they do not remove the need of a strong governance and correct implementation. Embedding an already existing industry standard into blockchain to guide the digital voting process might be a step in the right direction. Nonetheless, blockchain-based AGM and voting systems would raise questions, such as the issue of the legal coexistence between classical and digital AGMs or the readiness of shareholders and companies to move to non-physical meetings (Lafarre and Van der Elst, 2018).

2.5 Financial accounting

Being at its core an accounting technology, it is natural that blockchain might disrupt the accounting industry. The role of accountants is to develop financial statements that register transactions in different accounts such as revenues, assets, liabilities and expenses, and summarize what happened in a company's ledger throughout a reporting period. The current system is based on double-entry bookkeeping, which revolutionized accounting by giving internal certainty over the integrity of numbers recorded in the ledgers. However, in order to gain external trust from outsiders, external auditors need to conduct audits, which are often required

Sustainability Summary	
Sustainability implications	▪ Reduced accounting fraud due to automated and time-stamped bookkeeping and audit ▪ Better accountability and corporate governance due to transparent and real-time availability of company transaction records
Blockchain functionalities	▪ Data accountability ▪ Fraud prevention ▪ Operational efficiency
SDGs	**9.** Industry, innovation and infrastructure **10.** Reduced inequalities **16.** Peace, justice and strong institutions (incl. 16.5, 16.6)

by law[5]. Such audits provide an independent opinion on the accuracy and integrity of the company's financial statements, which is notably used by investors as an indication on the financial well-being of the company and influences their decision to invest in it.

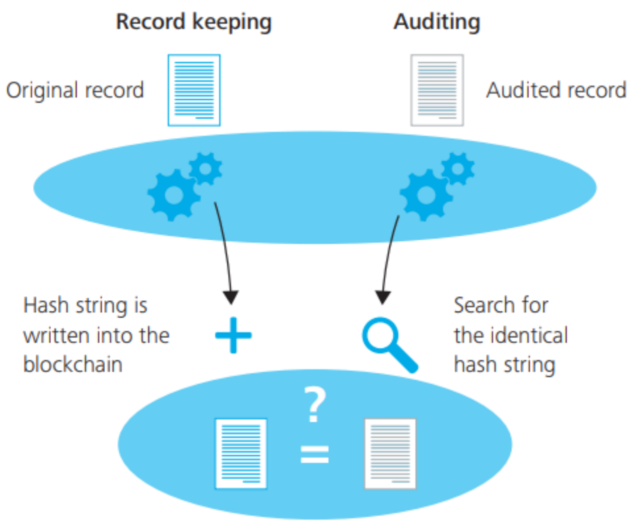
The system relies on the public trust that the auditor evaluates objectively the company's statements. However, there is an inherent flaw to this assumption: since auditors are paid by the companies they audit to conduct their evaluation, they can be tempted to conduct audits in the interest of their client and to omit to report some financial irregularities (Ronen, 2010)[6]. While accounting and audit regulations have improved in many jurisdictions since then, this inherent bias remains, causing an ethical dilemma to the whole profession.

Automated accounting and the renewed role of auditors

Blockchain technology also has the potential to automate financial reporting, which is currently manual and labour-intensive, and digitalize its process, paving the way for triple-entry accounting (Grigg, 2005). If companies switched their accounting ledger to a blockchain-based one, transactions and balances would be verifiable automatically without the use of an independent auditor, as data integrity verification is an intrinsic function of the technology (see Figure 8).

Instead of keeping separate records, companies would register their financial statements on a joint digital ledger, which verifies data entries and protects them from falsification while keeping information private through cryptography. For instance, instead of asking clients for bank statements or seeking confirmation from third parties, auditors could verify transactions on publically available blockchain ledgers (Psaila, 2017).

Figure 8: Financial accounting and audit system with blockchain



Source: Deloitte, 2016

Blockchain could reduce the costs of maintaining and reconciling ledgers, provide nearly absolute certainty over the ownership and history of assets and lead to more transactional-level accounting, which would increase the scope of the data being recorded (Institute of Chartered Accountants in England and Wales, 2017). Rather than having to navigate through complex paper trails of transactions, auditors would be able to easily

[5] Brought forth by Luca Pacioli around five hundred years ago, double-entry accounting is based on the balance sheet equation, by which the sum of all entries on the asset side must equal the sum of all entries on the liabilities side (Sangster and Scataglinibelghitar, 2010).
[6] This situation has led many accounting scandals in the past, such as the famous Enron scandal in 2001, which resulted in the bankruptcy of Enron Corporation, as well as the dissolution of the company that audited it, Arthur Andersen, then one of the five largest audit and accountancy firms in the world (Li, 2010).

verify the data by using blockchain records (Paine, 2018), which would facilitate the fight against frauds and conflicts of interests.

Since all transactions recorded on blockchain are verified as true and accurate by miners, the need for auditors to conduct manual audits in order to re-confirm these transactions would be greatly reduced (Lazanis, 2015). Some even point out that auditors might even disappear altogether for being made redundant with the use of blockchain (Ovenden, 2018). However, it seems more likely that the role of accountants and auditors would shift from developing and verifying statements to assessing the economic implications of blockchain-based financial records. They could also spend more time on controls adding a real added-value, such as complex transactions or internal control mechanisms (Deloitte, 2016).

Transparent corporate governance

The inherent transparency of blockchain also provides clear benefits for detecting and stopping corruption and misappropriation of assets, thus contributing to the reduction of corruption and bribery (SDG target 16.5) and the development of effective, accountable and transparent institutions (target 16.6). This characteristic alone might prove to be an influencing factor for corporate governance. First, the expertise needed to record companies' transactions on blockchain might lead to more diversification of a company board (Piazza, 2017). Second, using blockchain for bookkeeping means that companies' ledger will be available for access at any time by anyone who could aggregate the recorded transactions into an income statement, depending on the privacy settings of the ledger.

This will lead to real-time accounting, which means that corporate information will become more timely and accessible. Shareholders, customers and lenders will no longer need to rely on quarterly financial statements prepared by the company to access this information (Yermack, 2017). This transparency would have immediate impacts on corporate governance. Companies will need to be agile in their reactions to market fluctuations, corporate communication will have to be spontaneous, and the availability of short-term information might make room for managers to plan for long-term strategies.

Lastly, blockchain will make it much harder (or impossible) for managers to "cook the books" and for auditors to ignore ledger discrepancies. Indeed, transaction blocks on blockchain are time-stamped and therefore offer inherent protection from the practice of backdating transactions in order to change the result of financial statements, which has plagued the accounting industry for a long time. However, any system can be circumvented, and blockchain does not prevent the use of forward-dating by keeping an undisclosed parallel accounting system (Piazza, 2017).

The Big Four global accounting firms are already taking the lead in trying to embrace the technology. Deloitte made an early blockchain start back in 2014 with the development of blockchain platform Rubix, which provides enterprise-level solutions to clients. The beta product, Rubix Core, was then launched in 2016 (Prisco, 2016). KPMG and Microsoft have announced in 2017 the launch of joint blockchain nodes, designed to create and demonstrate use cases that apply blockchain technology to business processes (KPMG, 2017). More recently, PricewaterhouseCoopers (PwC) announced the launch of a blockchain auditing service with its Blockchain Validation Solution (PwC, 2018), quickly followed by Ernst & Young's Blockchain Analyzer, which will facilitate EY auditors review and analysis of transactions on blockchain (EY, 2018b).

3. Blockchain Applications in the Business Sector

3.1 Business intelligence

Blockchain technologies could constitute a breakthrough in the use of big data by corporations. Not only do they offer safety and integrity of data and transactions, they also provide a larger access to datasets, due to their global nature. These characteristics present opportunities to transform substantially business intelligence, impacting the entire business value chain from management to operations.

Sustainability Summary	
Sustainability implications	▪ Better privacy and security for data shared on cloud services ▪ Wider access to predictive analytics by small and medium enterprises
Blockchain functionalities	▪ Smart contracts ▪ Operational efficiency ▪ Data security
SDGs	**8.** Decent work and economic growth **9.** Industry, innovation and infrastructure **10.** Reduced inequalities

Decentralised cloud storage

Businesses heavily rely on cloud services to store their internal data. However, in spite of appearances, the "cloud" actually consists of someone else's computer (Floyd, 2018). Cloud storage is provided by tech giants such as Google, Microsoft or Amazon, which save users' data on centralised and remote databases, also referred to as server farms. This system presents several issues such as cost, privacy concerns and security[7]. Blockchain-based data storage could potentially replace the centralised model of cloud storage. Various solutions have emerged that leverage blockchain characteristics for this purpose: data is stored on a distributed ledger, storage providers are compensated by tokens, transactions happen through smart contracts, and data integrity is secured through cryptography. This new system doesn't remove the need for storage providers, but it decentralises the databases and the management of the data while ensuring complete privacy.

A few service providers have initiated blockchain-based data storage, the most famous being Storj and Sia, which use the spare space on people's hard drives to store and distribute data around the globe. They provide peer-to-peer data storage in a secured and decentralised way through monthly smart contracts in order to buy or rent storage space. Such blockchain applications are much cheaper than traditional cloud storage and reduce the need for server farms. Going a step further, Enigma aims to remedy to a major blockchain security issue: while data is safe when stored on blockchain, it is exposed to threats when data owners access and edit it, which happens outside of blockchain. Enigma would allow data to be accessed and edited while still in a decentralised, encrypted form (Enigma, 2015). Market incumbents will also play an important role in this emerging market. For instance, Google has announced working on blockchain-related technology to support its cloud business by developing its own DLT platform (Bloomberg, 2018).

Democratised predictive analytics

Since the beginning of the information technology revolution, businesses have been gathering and analysing data across several industries. The field of data analytics has undertaken major transformations following the introduction of computer technology and, in recent years, of machine learning and AI algorithms. Data scientists notably use predictive analytics by combining historical data and algorithms in order to predict

[7] First, it can be a costly solution for businesses that need to store a very large amount of data on cloud platforms such as Google Drive or Dropbox. Second, cloud storage poses privacy issues, as it requires to divulge potentially sensitive business information to the service providers (which can, as per their privacy terms, legally access and share this data under certain conditions). Third, centralised databases present security problems, as observed in the many data leaks in recent years, such as the Equifax data breach in 2017 that exposed the sensitive personal information of 143 million Americans (Federal trade Commission, 2017).

elements such as the evolution of market demand and such forecasting regularly guides corporate decision-making. Models are used for forecasting, hypothesis testing, scenario analysis and risk assessment, and the higher the volume of data, the greater the opportunity to refine the model (Intel, 2013). However, although predictive analytics leverage the availability of big data as much as possible, analysts still face two limitations: technological capability and accessibility (Tkatchuk, 2018)[8].

Blockchain technologies present opportunities to resolve those issues by decentralising data sets, which could make data more easily available to non-specialists and therefore make predictive analysis accessible to small and medium enterprises. Several blockchain applications already give examples of the technology potential in this field. For instance, blockchain-based Stox and Gnosis introduce the trading of event results in prediction markets, while Augur rewards users for correctly predicting the outcomes of real-world events. Developed by MIT researchers, Endor provides a blockchain-based predictive analytics suite using social physics. The tool is designed to understand queries in natural language, instead of traditional complex algorithms. With this, Endor's co-founder Professor Alex Pentland claims that "blockchain can bring predictive analytics to the masses" (Kuznetsov, 2018).

3.2 Supply chain management

The history of supply chain management intertwines with the development of globalization (Robinson, 2015)[9]. Nowadays, supply chains structures are becoming even more complex, with a high number of actors along the chain performing multiple functions. Consequently, the volume of supply chain data that companies try to gather and store keep rising up, without having the capacity to gather and analyse it in a cost-effective way. Blockchain technology could enhance supply chain efficiency, from manufacturing to transportation and retail, while reducing waste and improving compliance to drug and food safety regulations.

Sustainability Summary	
Sustainability implications	■ Reduced energy, food, water and material waste in manufacturing and transportation due to access to real-time supply chain data ■ Better compliance with drug and food safety regulations through automated quality controls
Blockchain functionalities	■ Smart contracts ■ Operational efficiency ■ Strengthened IoT networks
SDGs	**1.** No poverty (incl. 1.5) **3.** Good health and well-being **6.** Clean water and sanitation (incl. 6.3, 6.4) **8.** Decent work and economic growth (incl. 8.7, 8.8) **9.** Industry, innovation and infrastructure **12.** Responsible consumption and production (incl. 12.2, 12.3, 12.4) **16.** Peace, justice and strong institutions (incl. 16.2, 16.4)

[8] Indeed, while data is increasingly available, not all organisations have the financial and human capacity to aggregate large data sets and to make predictions out of them. In addition, the centralised nature of data sets make it difficult for non-experts to use data for analytical purposes. Moreover, a major condition for success when using predictive analytics is not only to process a huge amount of data, but to find the right questions to ask. The principal issue to overcome is how to integrate into models variables as hard as predict as human behaviour.

[9] Its roots can be found in the 1910's as segment of industrial operations aiming to improve manual loading processes. In the 1940's, mechanisation was used to enhance material handling processes and warehouse optimisation, as an answer to the logistic challenges of World War II. With the development of global trade in from the 1950's, supply chain started to encompass transportation management, as freight and road transport replaced rail. From the 1980's, the globalisation of manufacturing opened new markets while creating new logistical challenges. The use of computer applications such

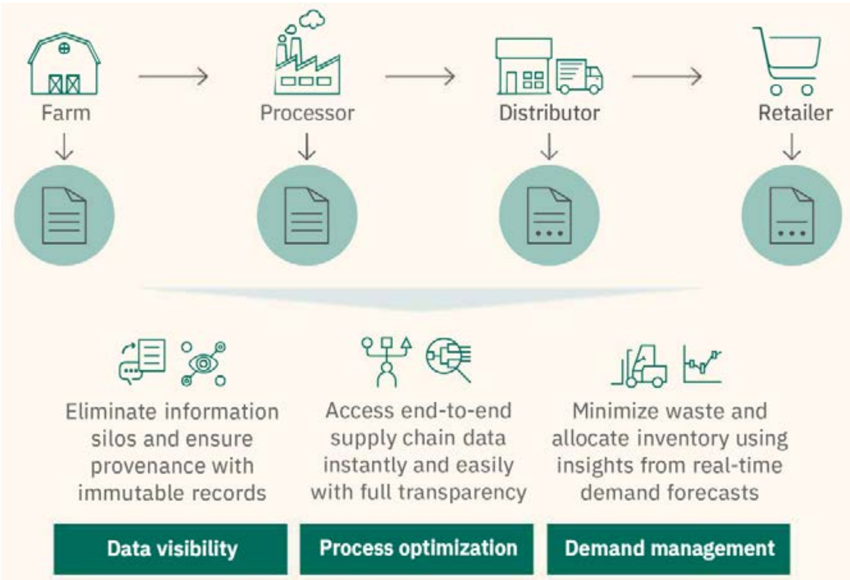
Harmonised supply chain data sharing

In the current system, each actor inside the supply chain maintains its own registry, with a different data format and data registration process. It then passes along this data to the next actor, and so on from the beginning to the end of the chain. This poses three sorts of risks. First, there is a high risk of data inconsistency, and supply chain actors often need to harmonise data sets, which takes time and money. Second, data collection and sharing systems are centralised and manual, which means that they are prone to error. Third, in case of an error, it is extremely difficult to know where the error comes from, as products change hands many times along their supply chain[10].

> With the global trade networks at stake, blockchain will help flesh out the correct pathways for goods to travel from continent to continent and from producer to end customer.
>
> Lisk (2018)

A decentralised database used across the supply chain would allow actors of different size, nationality and location to share data on a single, harmonised, immutable and confidential platform (see Figure 9 for an example in the food industry). The main advantage of such platform is that it provides a single source of truth. Each actor would register its data directly on blockchain and would be able to access the data that other actors have entered, which would greatly enhance supply chain transparency and responsiveness.

Figure 9: Supply chain benefits of using blockchain in the food industry



Source: IBM (2018)

Enhanced supply chain efficiency could enable reductions in waste of materials, energy, water and food. This would contribute to the promotion of efficient use of natural resources (SDG target 12.2), the reduction of food loss along supply chains (target 12.3) and the improvement of water-use efficiency (target 6.4).

as Enterprise Resource Planning (ERP) systems and new information and communication technologies brought by the Internet allowed companies to deal with complex networks of multiple entities across multiple countries.

[10] For instance, milk goes from farmers, to transport companies and to retailers before reaching the end consumer. All of these actors have a different record keeping method (paper-based spreadsheet, accounting software, tracking app etc.) If there is any issue with the final product such as loss, damage or delay, the retailer might turn to the transport companies, who might turn to the farmers. Whenever there are multiple actors involved at each stage of the supply chain, it becomes nearly impossible to identify the origin of issues (Buchko, 2018).

Additionally, smart contracts could allow for automatic and digital dispute resolution, by settling payments on the blockchain wherever issues have been detected.

A notable example is Wave, a blockchain-based peer-to-peer network that connects members of the supply chain (carriers, banks, forwarders, traders) and allows them to exchange documents directly. This system aims to eliminate the dependence to centralised entities in supply chain communications and reduce the number of disputes, forgeries and unnecessary risks. Similarly, Skuchain provides a blockchain-based collaborative e-commerce platform, and the Digital Supply Chain Institute (DSCI) is working on a Blockchain Return Index (BRI) to provide a standard benchmark for analysing blockchain business cases and their impact.

Automated manufacturing processes and quality controls

Blockchain could provide benefits for each step along the supply chain as well. Manufacturing, which is the field from which supply chain management first emerged, is a major area that could be impacted by blockchain solutions[11]. With a blockchain-based manufacturing management system, smart contracts would allow to detect errors as soon as they appear, and solve them automatically. The immutable characteristic of blockchain would also make it nearly impossible for negligent workers to hide their mistakes, or for fraudulent managers to manipulate the numbers (Eisenberg, 2018).

Moreover, instead of focusing on detailed quality controls, inspectors could spend more time improving manufacturing processes and inter-department coordination. This could notably improve compliance with hazardous waste and chemical regulations (SDG target 12.4), which could in turn reduce water pollution from these sources (target 6.3). Additionally, smart and automated manufacturing plants could increase safety conditions for factory workers, notably for migrants (target 8.8) and improve the resilience of the poor and those in vulnerable situations (target 1.5).

Manufacturers are already experimenting with blockchain solutions, with aim to use the technology to ensure automatic compliance with drug and food safety regulations (Guillot, 2018). Blockchain could also accompany the movement towards the robotisation of logistics for warehouse optimization. According to the International Data Corporation (2018), robots will be used in half of fulfilment centres by 2019, which will result in productivity gains of up to 30%, drive down the cost of operations and compensate for an increasing shortage of labour. With an increasing amount of data to collect, analyse and share, a decentralised database could provide the tools to ensure the efficiency of robotised logistics.

Autonomous transportation

After manufacturing, the next step on the supply chain that might be substantially impacted by blockchain is transportation. The industry is already undergoing a major disruption phase towards autonomous vehicles. The primary focus until now has been on cars, with the connected car market estimated to be USD 73 billion in 2017 and projected to reach USD 219 billion by 2025 (Markets and Markets, 2018). Blockchain solutions could act as an accelerator for this trend and help autonomous vehicles to expand to the transport of goods. With its decentralised database and real-time data offerings, the technology can improve Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2i) communications. Real-time traffic data could notably help transport companies to optimize their performance and select the shortest or safest routes (Bohl, 2017).

Automated blockchain-based payments through smart contracts could also shorten the payment delays that transportation companies are currently exposed to. Indeed, sales for these companies are usually paid out within a period of 60 to 90 days, which poses a cash flow problem for most of them (McDonald, 2018).

[11] Manufacturing traditionally involves a multitude of small empirical steps in assembly line processes, with each step building upon previous ones. As managers need to focus on their own step, they rely on inspections from quality control departments to learn issues in other steps, learning of critical errors often when they have already impacted the end product.

Blockchain could allow transportation companies to be paid instantly when the product is received, the only remaining delay being the time needed for transaction verification by miners. Companies are already experimenting with blockchain regarding data sharing for autonomous vehicles, such as the project launched by Toyota Research Institute for new mobility (Toyota, 2017) and further applications are expected to emerge for the transport of merchandises as well.

Product traceability

Blockchain technology could improve companies' capacity to track the entire lifecycle of products along the supply chain and easily verify their source. This tracking could facilitate better supply chain management, notably in terms of demand forecasting and planning, carrier contract management, customer billing and carrier payment and insurance and maintenance management (EY, 2016). Using blockchain to track products life cycle on a blockchain platform could notably help identifying and reducing illegal activities, such as human trafficking (SDG target 8.7), child trafficking (target 16.2) or illicit financial and arms flows (target 16.4).

According to the International Data Corporation (2018), by 2021, one-third of manufacturers and retailers will be tracking goods through blockchain. Additionally, by 2020, 80% of supply chain interactions are predicted to happen across cloud-based commerce networks, which could also be based on blockchain (see Section 3.1). In order to trace products, each actor simply needs to scan an RFID (radio frequency identification) chip or a QR code at each step on the supply chain. Third parties could also do the same to access detailed data on products origins.

A few companies have started providing such services. VeChain for instance uses blockchain technology in combination with smart chips to track products throughout their lifecycle. Waltonchain also combines blockchain with IoT to create a management system for supply chains. These solutions aim to offer a protection against counterfeits while improving logistics.

3.3 Marketing and advertising

As in any other sector, blockchain technology allows to cut out intermediaries and to process transactions in a quick, secure and transparent way. These characteristics could prove useful to the marketing and advertising industry, which is famously plagued by a multitude of middlemen, opacity of transactions and fraudulent behaviour.

Indeed, studies show that in 2016 half of digital advertisements were generated by bots, fraud bots were responsible for USD 7.2 billion in losses and 56% of all display advertisements spending were lost to fraudulent or unviewable inventory (Forrester, 2017). With the global cost of ad fraud estimated to increase to USD 50 billion in the next ten years, 79% of advertisers expressed concerns about transparency (Zhang, 2018).

Sustainability Summary	
Sustainability implications	▪ Customer empowerment through better control by Internet users over the data they share with companies ▪ Better customer experience due to smart and customised advertising
Blockchain functionalities	▪ Operational efficiency ▪ Data accountability ▪ Fraud prevention
SDGs	**8.** Decent work and economic growth **10.** Reduced inequalities

Smart and customised advertising

The digital revolutions has lead the major transformations in the advertising industry, forcing companies to revisit their marketing strategy and sometimes business model, notably for Media companies. The use of big data and analytics has resulted in what is called programmatic marketing. However, due to lack of transparency of the advertising ecosystem, most companies do not know who the middlemen are who process their digital ad campaign, how their advertising budget has been spent and what audience their ads reached[12].

Consequently, marketers are forced to resort to mass advertising strategies, overwhelming potential customers with ads, emails, text messages and coupons, in hopes that the right ad will somehow reach the right audience. In spite of all the data collected and used by companies through programmatic ads, the opacity of the advertising ecosystem hampers the ability of advertisers to truly get to know their customers and to be able to selectively target them with tailored advertisement. This situation, unfavourable for both sides, has led to a general sense of distrust from the general public towards digital advertising.

Using blockchain technology could reduce the need for intermediaries, improve transparency of the ad-buying and selling process, almost eradicate hidden costs and reduce frauds, while allowing companies to create trust with customers (Ghose, 2018). By running advertisement requests through a decentralised database and recording transactions in a public ledger, marketers would be able to monitor exactly where and when their ads is placed, and to properly track ad exposure and engagement. A major initiative in this regard has been launched by the Nasdaq, which is building a programmatic exchange called the New York Interactive Advertising Exchange (Nyiax) that will provide advertisers and publishers a platform to buy, sell, and re-trade premium advertising contracts on the blockchain.

Customer empowerment

Blockchain technology would give companies increased knowledge of customer preferences, allowing them to better tune their advertising strategy. In return, it would also give customers more control over the data they share. Several services already allow internet users to control their identity and transaction history, such as MetaMask. In the future, marketers might even need users' authorization to collect their data and users could charge companies for their contact information and attention (Siu, 2018).

Incidentally, the use of blockchain-based platforms in advertising would decentralise the advertising market and empower customers. This would pose a serious threat to the hegemony of social media and internet traffic giants such as Google and Facebook, which currently dominate the majority of ad traffic (Lisk, 2018)[13]. In the short-term market resistance is to be expected by those who generate profits from the opacity of the system. Therefore, in order to transform marketing, blockchain must be backed by a "supply chain-wide change in attitude towards transparency" (Malik, 2017).

[12] In addition, this myriad of intermediaries results in increased costs through hidden fees, tech taxes, charges and markups that companies need to pay, without knowing the value added by each middleman (if there is any at all). According to the aforementioned study by Forrester, for every USD 1 invested in advertising, companies receive on average only USD 0.44 in return.

[13] However, before reaching this stage, the technology needs to improve in order to match the current speed of transactions. Indeed, while ad-tech transactions are validated within milliseconds today, transactions on the blockchain take between 10 to 30 seconds to be verified by miners (Ghose, 2018).

3.4 Intellectual property

The intellectual property (IP) sector is traditionally based on the incentive theory, according to which the law protects the IP rights of creators and inventors by giving them a monopoly over their original work [14]. Blockchain potentially presents important applications for the IP sector, which is the field for which smart contracts were originally designed (Szabo, 1994). In the past, buying and reproducing a book implied some cost and time for free-riders, whereas nowadays finding and reproducing content online is an extremely fast and easy process.

Sustainability Summary	
Sustainability implications	▪ More innovation and growth for entrepreneurs and small and medium enterprises, due to better protection of IP rights through smart IP registries ▪ Control over their creative content by artists through IP rights and royalties management platforms
Blockchain functionalities	▪ Data accountability ▪ Data security ▪ Fraud prevention
SDGs	**8.** Decent work and economic growth (incl. 8.2, 8.3) **9.** Industry, innovation and infrastructure (incl. 9.B)

The digital era has led to unprecedented access to online content, yet IP laws have not yet adapted to these fast changes (Sims, 2018). Blockchain technologies could help addressing the issue of IP protection in the digital age. The technology could be used for evidence of creatorship and first use in trade, decentralised IP registries, tracking of IP rights ownership chain, IP rights management and IP agreements enforcement (Clark, 2018), which can notably be useful to inventors, artists and scientists (see Figure 10).

Figure 10: Potential uses of blockchain in IP for different user types (example of Vaultitude)

Source: Vaultitute (2018)

[14] This protection supposedly acts as a guarantee for creators that their product or idea will not be monetized by others ("free-riding"), which constitutes an incentive for innovators to keep innovating. This system relies on the registration of designs, trademarks and patents to the relevant public authority that keeps a registry for its own jurisdiction. Inventors need to register their IP in as many jurisdictions as they can if they want to fully protect their invention. In case of an IP right infringement, the only solution is often to take the matter to the courts to reach a settlement. This process involves many intermediaries, time, costs and inefficiencies.

Smart IP registries

In most countries, inventors use patents to protect the IP rights of their invention, and the rights belong to the first person to file a patent application under a "first-to-file system"[15]. Therefore, IP rights are essential for inventors, especially in competitive markets that require to be the first-mover. Indeed, some companies keep product development secret for years in order to avoid disclosure such as in the pharmaceutical industry, which makes it hard to prove its creatorship if someone else first files for a patent. Instead of maintaining centralised IP registries, IP offices could register IP rights on blockchain-based decentralised databases. By processing patent registrations with blockchain, it would be possible to substantially shorten their application time[16].

Blockchain-based smart IP registries would create an immutable record of an IP right life cycle, from registration of patents and trademarks to their first use in trade and licensing. This enhanced record would smoothen audits and due diligence exercises, which would facilitate the transfers of IP rights for merger and acquisitions. Companies would also be able to easily update their fillings, which is essential for companies that update their IP rights regularly such as IT companies modifying their IP-protected lines of code. A notable example of use of the technology for IP registries is Vaultitude, formerly IPCHAIN Database, a blockchain-based IP protection software. It allows to safely store IP rights and provides proof of authorship, defensive publications, patents and trademarks fillings and peer review and ratings mechanisms (Vaultitude, 2018).

Evidence of creatorship and IP rights management

While the IP rights of inventions are often protected by patents, others are not protected by law, such as copyrights, which are not considered as registrable IP rights under many jurisdictions. There are also many instances in which the ownership of IP rights is not clear, such as when a singer releases a song that is similar to an existing one, notably if it happens in a different country (Rhodes, 2018). Blockchain could provide a global and easily accessible tamper-proof evidence of ownership, allowing authors to register and protect previously unregistered IP rights.

The technology would be notably beneficial for small companies and freelancers. Indeed, while larger corporations employ teams of lawyers to protect their IP rights, smaller players often do not have the means to do so. It is currently very difficult for anyone uploading something on the Internet to keep track of who is using and monetising their work and to stop infringements. Conversely, it is also difficult for third parties to find who to get a license from and cumbersome to pay royalties to the authors.

By using blockchain, creators would be able to secure their IP rights while consumers would more easily find a way to pay for royalties. This would promote innovation and creativity, leading to more growth opportunities for entrepreneurs and small and medium enterprises (SDG target 8.3). On a larger scale, this would contribute to improving economic productivity through diversification and innovation (target 8.2), and notably increase innovation in developing countries (target 9.B).

Companies such as Binded and Blocknotary allow artists to record on blockchain the copyright ownership of their creative content (art or photos) and to receive a timestamped certificate of authenticity as evidence of creatorship. Similarly, KODAK has launched KODAKOne, a blockchain platform that creates an encrypted digital ledger of rights ownership for photographers. Law firms have also started to use blockchain to prove

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[15] Sometimes inventors leave their inventions IP-free in order to benefit the common good or to create a wider market for their related products. The Bitcoin blockchain itself is not patented for instance, and neither are the Internet or the World Wide Web. However, for most industries, inventions represent years of work and huge investments in research and development.

[16] For reference, according to the World Intellectual Property Organisation (2017), in 2016 a patent application to the United States Patent and Trademark Office (USPTO) and the European Patent Office took respectively 22.6 months and 23.3 months on average to complete.

ownership, existence, and integrity of IP assets. The Swiss law firm P&TS has for instance partnered with Bernstein Technologies GmbH to offers notarisation services for invention announcements based on blockchain, while keeping notarized information private. Such platforms allow authors to quickly certify their IP rights, to find across multiple sources who is using their work and to stop counterfeits and infringements by claiming licenses.

Going further, smart contracts could also be used for the IP sale and licensing. Users who want to use a certain work could look it up on the blockchain platform on which it is registered, and automatically pay licenses directly to the author through smart contracts and cryptocurrencies. For instance, EY and Microsoft have launched a solution for content rights and royalties management for the media and entertainment industry (video game company Ubisoft is testing the solution), using the Quorum blockchain protocol and Microsoft's Azure cloud infrastructure (EY, 2018c). Such platforms could facilitate micropayments for use of content, which could allow for example users to purchase licenses to download, stream or remix songs through smart contracts, giving artists better control over their creative works.

3.5 Insurance

Another major disruptive application of blockchain technologies concern the insurance industry[17]. Research shows that enhanced data analysis and risk modelling can improve insurers' knowledge of their customers and interactions with them, product development and distribution (Spencer, 2013) and feedback control process (Light, 2014).

The industry has been leveraging the benefits of big data in recent years. However, a lot of data remains untapped, such as unstructured or semi-structured information, external data sources and real-time data (IBM, 2013). Blockchain technologies could constitute a step forward for the insurance industry in harnessing data.

Sustainability Summary	
Sustainability implications	■ Wider access to insurance through micro and peer-to-peer insurance models, notably for vulnerable populations ■ Better insurance coverage with automated insurance, reducing notably climate-related risks for farmers
Blockchain functionalities	■ Smart contracts ■ Peer-to-peer transactions ■ Data accountability
SDGs	**1.** No poverty (incl. 1.3) **3.** Good health and well-being (incl. 3.8) **8.** Decent work and economic growth (incl. 8.10) **9.** Industry, innovation and infrastructure **10.** Reduced inequalities

Mainelli and von Gunten (2014) argue that blockchain might not revolutionize entirely the way insurance works, but it could support new models of insurance that facilitate deeper interactions between individuals and insurers. Overall, the changes brought by DLT could help shift the insurer's social role from a direct risk handler to an expert adviser on risk management. According to the authors, there are three ways in which the insurance industry might be impacted by blockchain: insurance automation, access to insurance and peer-to-peer insurance.

[17] Insurance companies are by nature highly dependent on data. They provide risk management mechanisms, by which the potential costs of a substantial financial loss is transferred from the client to the insurance company in exchange for a premium. Companies pool several risks together in different classes and use predictive statistical analysis to estimate their losses and revenues in each class (Mainelli and von Gunten, 2014).

Automation of insurance products

The use of smart contracts based on factual client information shared on the blockchain could facilitate the use of automatic insurance products, such as betting-like products and or hedging mechanisms. With an automatic insurance service, premiums would be paid and recorded directly on blockchain, leading to a self-administration of insurance. The example often cited would be a crop insurance, protecting farmers against the consequences of unfavourable weather conditions on their harvest. The insurance could be automated with a smart contract on blockchain, and an oracle could provide a third-party verification of the weather data.

Wider access to insurance

Blockchain technologies would allow access to an extended range of data, which was previously available only to some limited parties. In the future, valuable personal data such as digital identity, medical records and genetic data could be stored in an anonymous way on a decentralised ledger (see section 4.2).. This increased availability of personal data might in return facilitate access to insurance products to people who could not benefit from them before. Insurance coverage could be expanded through blockchain-based micro-insurance solutions.

Peer-to-peer insurance models

Blockchain could decentralise and harmonise the insurance business model, which is currently centralised and fragmented (by country, insurance company, market etc.). The technology could pave the way for more peer-to-peer and mutual insurance platforms. Insurance products, especially if automated through smart contracts, could transcend national barriers and individuals could contract with each other regardless of their insurance providers. Conversely, insurers might move away from risk pooling as main risk management model, and embrace emerging models of self-administered risk protocols.

Overall, the automation of insurance products against unpredictable events, wider access to insurance for vulnerable populations and new peer-to-peer insurance models could help countries put in place appropriate social protection systems for all (SDG target 1.3). Blockchain applications in the field of insurance could also contribute to achieving universal health coverage (target 3.8), and improving the financial institutions' capacity to expand access to insurance for all (target 8.10).

Several blockchain-based insurance initiatives have made steps in that direction. For instance, LenderBot is a micro-insurance platform developed by Deloitte, technology start-up Stratumn and insurance platform LemonWay. The participation to the platform is initiated by a contacting another individual through a chat box. The main focus is providing insurance products for high-value items such as smartphones and cameras between individuals for a short period. The terms of the insurance agreement and the payment are processed digitally in the Bitcoin blockchain (Caetano, 2016). American International Group Inc., IBM and Standard Chartered Bank also started a pilot project in 2017 by launching the first multinational, smart contract-based insurance policy using blockchain (IBM, 2017).

3.6 Human resources

With the help of blockchain technologies, human resources (HR) would be able to carry out more efficiently their tasks of recruiting and payroll, improving organisational wellbeing, employee development and institutional growth.

Sustainability Summary	
Sustainability implications	▪ More job opportunities for self-employed workers through smart recruiting and payroll procedures ▪ Better transparency from employers, employees and job-seekers
Blockchain functionalities	▪ Smart contract ▪ Data accountability ▪ Fraud prevention
SDGs	**5.** Gender equality (incl. 5.5) **8.** Decent work and economic growth (incl. 8.2, 8.5) **10.** Reduced inequalities (incl. 10.3)

Smart recruiting procedures

One of the main uses of the technology in this field would be to facilitate sourcing talents. HR professionals spend much of their time and resources in checking the accuracy and credentials and past experiences of job applicants. Indeed, studies show that 88% of recruiters have found a lie or misrepresentation on resumes and/or job applications (HireRight, 2016). Blockchain would enable the concept of "self-sovereign digital identity", by which individuals would be able to control the data available online about themselves, reducing chances of third-party organisations providing inaccurate data about a candidate or employee (Zielinski, 2017).

For instance, individuals could register their classes, credits and diploma and certifications on the blockchain, and the data could be cross-signed by universities. Blockchain service-provider Blockcerts for instance offers an open standard for creating, issuing, viewing, and verifying blockchain-based credentials and certificates. With this data available and secured, HR could conduct almost instantly its credential and resume checking process. Conversely, companies could chose to let job applicants access certain business data on blockchain, which would help them in their job search such as working hours, wages, diversity or labour turnover.

The Massachusetts Institute of Technology (MIT) is one of the first universities to have developed a digital diploma system, with a pilot programme that allows students to receive a diploma on blockchain in addition to the standard physical diploma (MIT, 2017). Additionally, the Japanese HR firm Recruit Holdings has announced a partnership with German blockchain start-up Ascribe to use blockchain technology in the HR industry in order to fight fraud in HR credentials (SIA, 2016).

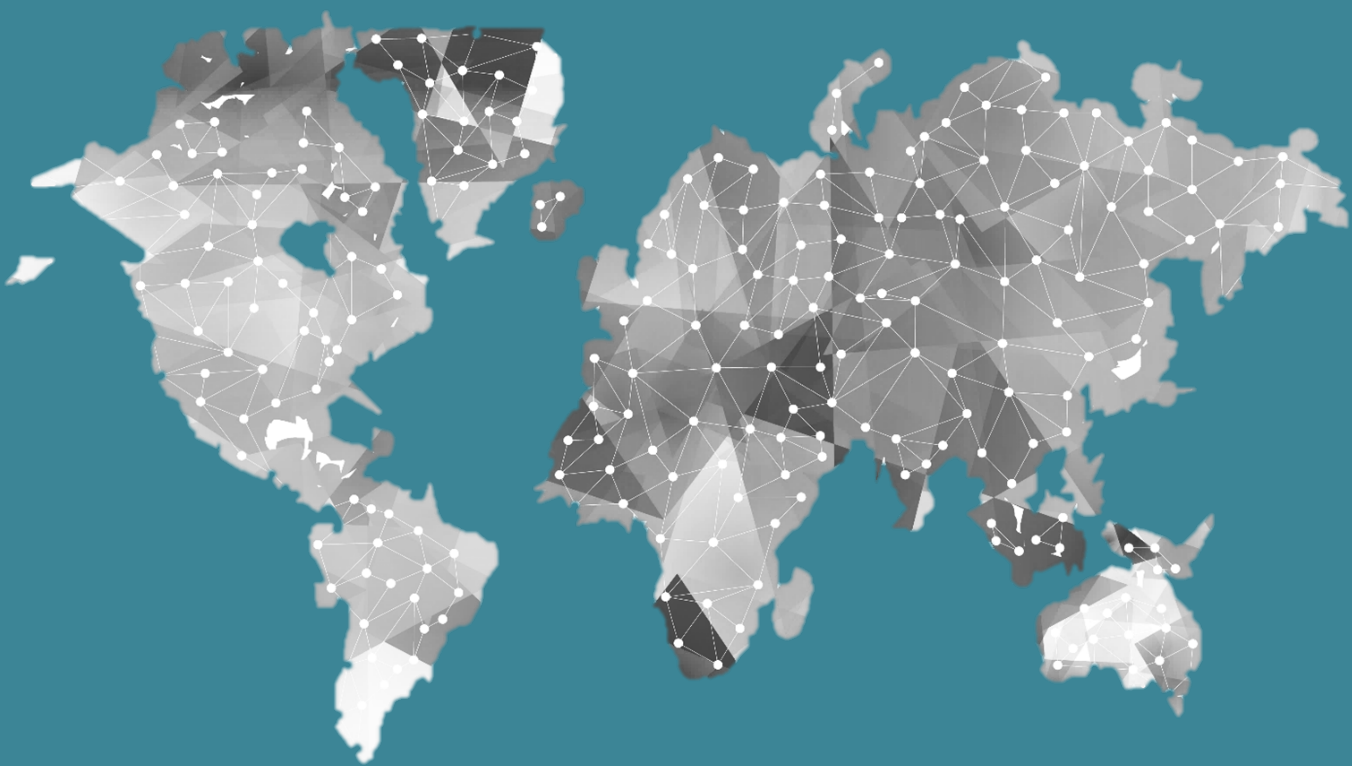
Disintermediated payroll processes

The application of blockchain technology for the payroll function is a natural extension of the general usage of DLT for more direct, faster and cheaper payments procedures (see Section 2.1). As companies in a global competitive market tend to employ international talent across borders, blockchain could help firms distribute salaries and process cross-border invoices directly, without relying on costly and lengthy third-party intervention. A more effective payroll process could reduce companies' administrative burdens, notably by facilitating data gathering for tax documentation and payments.

The use of blockchain for payrolls could also facilitate the emergence of an agile job market and decentralised workforce. With traditional vertical career paths becoming less attractive and combined with more precarious economic situations, the number of self-employed workers is expected to grow. Smart contracts could allow automatic payments for recurring sub-contractors. This could lead to increased job opportunities for freelancers, consultants and part-timers, while giving companies more recruiting flexibility (Lisk, 2018), and contributing to achieving economic productivity through diversification (SDG target 8.2). The transparency afforded by blockchain in human resources could also serve to provide full employment and decent work for all (target 8.5), and to reduce income inequalities (target 10.3). It could also serve to ensure women's full and effective participation and equal opportunities for leadership at all levels of decision-making (target 5.5).

Several companies are already using blockchain-based payroll services. For instance, San Francisco-based Bitwage uses the technology to facilitate cross-border payments through use of Bitcoins. This allows employees and contractors to be paid in the currency of their choice and within forty eight hours. The Australian company ChronoBank aims to facilitate the recruitment process for short-term jobs. The platform allows candidate to find new job postings quickly and recruiters gain access to a pool of candidates with verified records. Payments can also be processed directly on the platform.

4. Blockchain Applications in the Public Sector

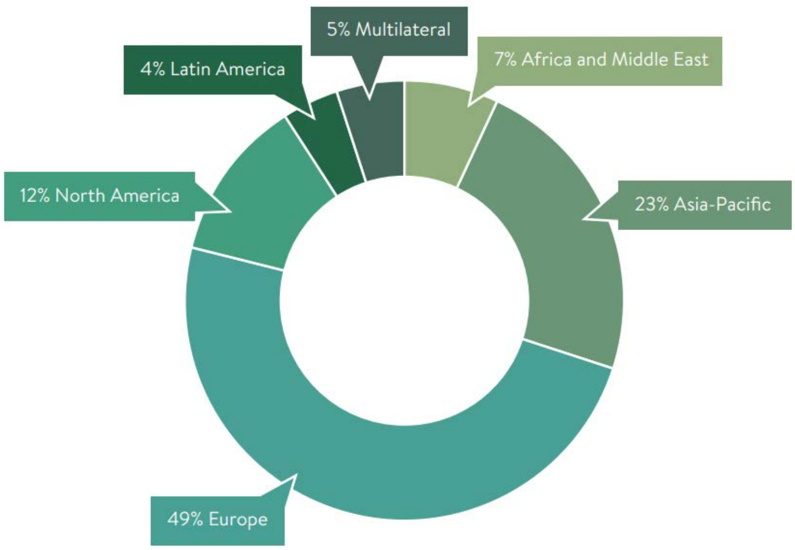


4.1 Government operations

Blockchain holds the potential to substantially improve government operations, especially in emerging markets where some public services still lack maturity[18]. According to a study by Hileman and Rauchs (2017), 77% of the 42 countries represented in the surveyed sample had multiple public institutions showing interest in blockchain and 17% are already planning to develop a national blockchain initiatives. More than 90 institutions from the public sector across 42 different countries have publicly reported exploring blockchain applications in some way. Among those, public institutions in Europe are leading the way in terms of number of blockchain-based initiatives, followed by Asia-Pacific and Northern America (see Figure 11).

Sustainability Summary	
Sustainability implications	▪ Collaborative governance and public services ▪ Greater accountability of public institutions and decisions ▪ Greater social cohesion and trust between citizens and their government
Blockchain functionalities	▪ Data accountability ▪ Fraud prevention ▪ Operational efficiency
SDGs	**8.** Decent work and economic growth **10.** Reduced inequalities (incl. 10.2) **11.** Sustainable cities and communities **16.** Peace, justice and strong institutions (incl. 16.3, 16.5, 16.6) **17.** Partnerships for the Goals (incl. 17.17)

Figure 11: Regions where public institutions have been involved in blockchain trials as of 2017



Source: Hileman and Rauchs (2017)

Collaborative public services

Blockchain could allow the creation of networked public services that provide enhanced engagement with citizens and businesses (Corydon et al., 2016). The technology could notably facilitate the integration of

[18] Governments are lagging behind compared with the private sector in the movement toward digitalization and are likely to be slower in adopting blockchain-based solutions. The technology could nonetheless help the public sector catch-up and leverage the benefits of big data. All public institutions can potentially reap the benefits of blockchain adoption: central and local governments, public agencies and central banks.

"responsive open data" in public services, allowing processes to be automated while guaranteeing a high level of trust in the integrity of the operation (Forde, 2017).

Blockchain-based public services can help to prevent fraud through greater public auditability, reduce processing costs through automation of operations, streamlining administrative processes and improve reconciliation processes[19]. For central bank specifically, improved regulatory compliance and supervision due to greater transparency and traceability can enhance network resilience (Hileman and Rauchs, 2017). According to Killmeyer et al. (2017), blockchain adoption by the public sector presents business value in three major areas: value transfer, smart contracts and bookkeeping, with a wide range of applications. Overall, decentralised and digitised public services could lead to better relationships between public authorities and citizens through more personalised public services and pave the way for new forms of collaborative governance (UK House of Lords, 2017)[20].

Collaborative public services could be instrumental in promoting the rule of law and ensuring equal access to justice (SDG target 16.3), reducing corruption and bribery (target 16.5), and developing effective, accountable and transparent institutions (target 16.6). Dynamic interactions between governments and citizens could also be used to promote public-private and civil society partnerships (target 17.17). On a broader scale, blockchain-based public services could empower and promote the social, economic and political inclusion (target 10.2).

Smart public records

Governments bear the responsibility of keeping records of important information for their citizens' life such as birth and death dates, marital status, criminal history, real-estate ownership and transactions and business licensing. Such records are usually kept in paper form or, at best, on a closed electronic database. More importantly, records are managed centrally, with each country or jurisdiction keeping a different registry. Data entry and modification often requires a lengthy application in person, and data processing is done manually and in a labour-intensive way. Additionally, the public institutions tasked with keeping records often use a unique information-management protocol, which stops other authorities from using the data.

Blockchain can not only digitalize the management of information by governments, but also facilitate the smart use of data by multiple public institutions and improve collaboration between them (Chang et al., 2017). Blockchain solutions might also lead to a decreased need for public record-keeping. Central banks in particular could beneficiate from blockchain adoption, due to its combined applications in document authentication and payments. The Bank of Thailand for instance is considering using the technology to improve regional financial connectivity and facilitate smoother cross-border financial services, aiming to reduce fraud and protect financial information (Yakubowski, 2018).

With the technology providing immutable records regardless of national boundaries, the role of governments as a guarantor of document authenticity might become superfluous. In this regards, Aragon is for instance a company providing blockchain-based services for disintermediating the creation and maintenance of organisational structures. With the goal to enable anyone anywhere in the world to become an entrepreneur, the company is stepping on a function that is traditionally held by governments.

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[19] However, there might be important obstacles to a wide blockchain adoption by public institutions. Governments tend to be risk-averse and might fear risks of militarisation of the technology. For instance, in the case of the Bitcoin blockchain, most of cryptocurrency mining is currently done in China, facilitated by the low price of electricity. As miners are required to register with the Chinese government, there is a risk that the Chinese government appropriates nodes and gains control of more than half of the network, which would block consensus between miners (Subramanian, 2018). Even if other blockchain platforms are used, similar concerns might pose barriers to blockchain adoption by public institutions.

[20] It could notably enhance public services in many sectors such as border control, customs, immigration, national security, criminal investigation, anti-terrorism, police, public safety, drug safety, food standards and public procurement. Public institutions would become able to conduct real-time monitoring of public opinion and measure the quality and impact of public services. Governments would be supported by AI and robots to treat citizens' enquiries, and the collection of data in real time would allow them to use predictive analytics to forecast and plan for public sector challenges.

The government of the United Arab Emirates (UAE) is exploring several blockchain applications involving smart records of data and transactions, such as for business registration, logistics and central bank operations. Launched in December 2016, the Dubai Blockchain Strategy aims to make Dubai the first government to execute all transactions on blockchain by 2020. Building upon this, in April 2018 the UAE have launched an "UAE Blockchain Strategy 2021", aiming to have 50% of government transactions conducted using blockchain by 2021 at the federal level. It is estimated that this technological change would contribute to saving AED11 billion annually on document transactions, 77 million hours of work, reduce the number of government documents by 389 million, and save 1.6 billion kilometres spent driving.

Another interesting initiative concerns public records of car ownership. The Danish tax Administration has been collaborating since 2017 with the payment service provider Nets, in order to launch Vehicle Wallet, a blockchain-based digital asset management tool for handling a vehicle's life cycle process. All data concerning the vehicle and its history is shared on a distributed ledger, and the smart protocol ensures that only the regulator can process transactions on the blockchain and transfer ownership of vehicles. While in the current system buyers need to trust the information disclosed by the seller and the seller needs to trust that the buyer will properly re-register the vehicle under his name, such blockchain solution automatically guarantees both parties of the integrity of data and processes (Berryhill et al, 2018).

4.2 Legal identity and healthcare

According to the World Bank's Identification for Development (ID4D) Global Dataset, an estimated 1.1 billion people worldwide cannot officially prove their identity (World Bank Group, 2017), and with a growing world population, climate refugees and mass migrations caused by regional conflicts, this number is likely to increase in the future.

Yet with the growing adoption of social identities through social media, the importance of legal identity is often underestimated. The ability of blockchain to ensure the documentation of official identity records can have important consequences for the healthcare sector and to prevent identity thefts[21].

Sustainability Summary	
Sustainability implications	■ Better access to healthcare through smart identity systems ■ Better healthcare services through decentralised electronic health records ■ Reduced identity theft through secured identification for online services
Blockchain functionalities	■ Data accountability ■ Fraud prevention ■ Operational efficiency
SDGs	**3.** Good health and well-being (incl. 3.1, 3.2, 3.3, 3.4, 3.7) **5.** Gender equality (incl. 5.6) **10.** Reduced inequalities **15.** Life on land (incl. 15.5, 15.6, 15.7) **16.** Peace, justice and strong institutions (incl. 16.9)

Access to healthcare through digital identity

Having a legal identity, characterised by the possession of official identification documents such as birth certificates, national identity cards or passports, is often a prerequisite to have access to essential services such as healthcare, education or finance (Desai, 2017). Yet, due to inefficient registration systems or

[21] However, it can be noted that identity verification using blockchain could present specific risks as well, such as decisions from institutions made by "merging profiles" (Mainelli and Gupta, 2016). For instance, credit companies combining credits records with social media data to forecast loan risks.

destruction of documentation during regional conflicts, such records are often not available to the people who need them.

According to Berkley (2017), tens of millions of children have no formal record of their existence, especially among poor and vulnerable communities. This constitutes a critical barrier to vaccination of children. The digitization of identification systems through blockchain could contribute to providing a legal identity for all, including birth registration (SDG target 16.9). This would help with reducing global maternal mortality (target 3.1) and ending preventable deaths of newborns and children under 5 years of age (target 3.2).

There are already some experiments aiming to use blockchain applications to secure legal identification. The most famous to date is ID2020 Alliance, a partnership composed of UN agencies, NGOs, companies and governments, aim to build a digital identity network on the Ethereum blockchain, that would accelerate access to digital identity for those living without identity (ID 2020 Alliance, 2017).

Small-scale initiatives also provide identity-related blockchain solutions. For instance, Civic has launched a blockchain-based identity verification product, available worldwide, with aim to create a global and decentralised identity ecosystem. Ethereum applications like uPort allow users to control their own data, identity, and reputation. Namecoin is an open-source technology providing a decentralised domain name registration database using a cryptocurrency model similar to Bitcoin. Other initiatives include UniquID, which provides Identity Access Management (IAM) services, and Shocard, providing a blockchain-based identity validation system.

Interconnected electronic health records

Due to the confidential nature of medical records, patients' health information is scattered across multiple organisations and facilities, making records non-accessible by different doctors when they need them the most[22]. This system not only costs money, but also often human lives. The reason for this inefficiency is that "electronic health records were never designed to manage multi-institutional, life time medical records" (Ekblaw et al., 2016).

Blockchain could solve the major issue of disparity of electronic health records. The cryptography characteristic of blockchain technologies could help the health sector reaping the benefits of digitization by allowing doctors to access and share patients' information in a confidential way. Blockchain-based identification would provide an additional tool in the fight to reduce deaths related to communicable diseases (SDG target 3.3) and non-communicable diseases (target 3.4). Enhanced patient data could also facilitate preventive treatments and ensure universal access to sexual and reproductive health-care services (target 3.7). Consequently, it would also enhance access to sexual and reproductive health and reproductive rights (target 5.6). One could even imagine applications of blockchain-based identification for animals, which could contribute to the protection of threatened species (target 15.5) and reduce trafficking of protected species (target 15.7).

Swan (2014) suggests that blockchain could have four main applications in healthcare. First, it could provide a global, decentralised and encoded database of legal identities that could replace non-existing or incomplete national registries and electronic health records. Such decentralised health database would not only allow doctors and other parties to access patients' medical data whenever needed (with their approval), but also provide enough data to use for preventive medicine. Second, as data on blockchain can be analyzed while remaining private, it would facilitate better health research. Third, the notary function of the technology could help patients provide evidence of important medical documents (insurance, test results, prescriptions,

[22] The city of Boston alone has for instance 26 different medical records systems used, with their own data format and language (Orcutt, 2017). According to the Office of the National Coordinator for Health Information Technology (2015), one in three individuals in the US reported experiencing one or more gaps in information exchange when seeking medical care.

treatment etc.). Lastly, blockchain could improve request for proposal (RFP) services by allowing doctors and clinics to bid for providing medical services, which would increase price transparency.

The most notable initiative in blockchain-based electronic health record is MedRec. Launched through a development agreement between IBM's Watson Health artificial intelligence unit and the U.S. Food and Drug Administration (FDA), MedRec explores the potential of blockchain technology to securely share patient data for medical purposes. The project aims to record on a blockchain data from multiple sources (electronic health records, clinical trials, genomic data, mobile devices, wearables and IoT) in order to take advantage of the accountability, traceability and transparency of the technology (Mearian, 2017).

Another initiative, DNA.Bits, enables the tagging, tracking and cross-referencing of health and genetic data on a blockchain. The technology could allow healthcare professionals to conduct pharmaceutical, medical and healthcare analyses on a large-scale and at low cost, improving the quality of medical services. Storing genetic data on blockchain-based databases could potentially enhance the access and sharing of the benefits arising from the utilisation of genetic resources (SDG target 15.6). In 2016 the Estonian Prime Minister also announced a project to store all national medical records on a blockchain-based digital platform (E-Estonia, 2016).

Preventing identity theft

Blockchain could also serve as a way to verify the identity of users of certain services, and notably help solving cases of identity thefts. A study by Javelin Strategy & Research (2017) showed that the number of identity theft victims in the United States alone has gone from 10.2 million in 2007 to 15.4 million in 2016. Fraudsters succeeded in stealing USD 16 billion from theft victims in 2016 in the US and USD 21 billion each year globally. According to the study, the most recurring identity thefts concerned cases of social security or tax-related fraud, credit card fraud, phone or utility fraud and bank fraud. Cases of digital fraud have notably increased by 40% since 2015, due to the growth of e-commerce. With fraudster increasingly moving online, blockchain could provide a safe and decentralised platform for securing people' identity in their daily life activities.

4.3 Elections

A correlated application of blockchain-based identity systems can be found in voting systems. Elections are another field of the public sector that hasn't reaped the benefits of the digital revolution. The availability of information and freedom of sharing it have greatly expanded the possible ways in which people can be governed in a democratic society. Yet, far from witnessing an emergence of self-governance or interactive governance systems, most democratic countries still rely on the old paper-based and labour-intensive voting system of representative democracy.

Sustainability Summary	
Sustainability implications	▪ Greater integrity of democratic elections through secured electronic voting systems ▪ Wider democratic participation ▪ Direct democracy and self-governance
Blockchain functionalities	▪ Data accountability ▪ Data security ▪ Fraud prevention
SDGs	**10.** Reduced inequalities (incl. 10.2) **16.** Peace, justice and strong institutions (incl. 16.3, 16.5, 16.6, 16.7) **17.** Partnerships for the Goals (incl. 17.15)

Secured electronic voting systems

While citizens in most countries have the means to access an unprecedented amount of information through the Internet, their governments still do not allow their participation to governance, or do so through antiquated paper processes[23]. Blockchain technology, with its decentralised platform and cryptographic security, might provide the solution to finally digitizing voting processes. With a blockchain-based voting system, voters would simply need to connect to voting platform from any device, prove their identity to the programme (using notably digital identity if available), access their right to vote with their own private key and finally cast their vote anonymously with their public key (Foroglou and Tsilidou, 2015).

Voter engagement and direct democracy

This secure and transparent system could reduce abstention rates by providing voting access to those who lack it, and increasing the public trust in the legitimacy of the election system, which could attract reluctant voters. More importantly, it could reduce voting fraud by taking away the power to administer elections from the central authorities, which are often lead by elected officials seeking re-election (European Parliament, 2016). While experiments might start at the organisational level in the short-term (see Section 2.5 for shareholder voting), blockchain-based voting systems could at term expand to local and then national elections.

Such blockchain-based digital voting systems could ensure the integrity of democratic elections, which would promote the rule of law at the national and international levels (SDG target 16.3), reduce corruption and bribery from public officials (target 16.5), and contribute to the creation of accountable and transparent institutions (target 16.6). Additionally, blockchain-based referendums and direct democracy practices could pave the way for responsive, inclusive, participatory and representative decision-making at all levels (target 16.7), while promoting the political inclusion of all (target 10.2). Moreover, blockchain-based elections could facilitate the emergence of multi-stakeholder partnerships necessary to establish and implement policies for poverty eradication and sustainable development (target 17.15).

Several initiatives provide blockchain-based platforms. Blockchain start-up Voatz aims to create a secure and immutable voting system enabling tamper-proof record-keeping and identity verification. Voatz has already incorporated into pilot blockchain-based voting platforms more than 70,000 voters in elections and voting-related events in multiple jurisdictions (Kuebler, 2018). Other projects, developing blockchain-based digital voting solutions include V-Initiative, nVotes (formerly AgoraVoting) and Follow My Vote.

Interestingly, the Danish political party Liberal Alliance, founded in 2007, announced in 2014 that it would use blockchain for secure electronic voting at its annual party meeting (Borchgrevink, 2014). In 2016, blockchain-based voting was used to give Colombian expatriates a voice in the peace plebiscite between the Colombian Government and FARC. With 90% of Colombian living abroad not being registered to vote in a consulate or embassy, their participation was essential to the democratic integrity of the vote. Launched by the technology NGO Democracy Earth Foundation, the blockchain platform Plebiscito Digital allowed Colombians abroad to cast symbolic votes through the platform (OECD, 2017).

[23] There are several reasons for this slow progress. First, voting systems are a highly political topic, since electoral fraud, manipulation and abstention have a critical impact on election results. Second, elections are tightly regulated in many countries, leaving limited margin for innovation. Third, for the past two decades electronic voting attempts have suffered from major cybersecurity risks and were no longer considered as a viable replacement for traditional voting systems (Lauer, 2004; Bishop and Wagner, 2007). With strong evidence of external interference in the US presidential election of 2016, enhancing the integrity of elections seems to be of paramount importance (Osgood, 2016).

4.4 Land titling

According to the World Bank Group (2016), 70% of the world's population lacks access to land titling. The weaknesses of paper-based registries, combined with the corruption of public officials and the land mafias is leaving entire parts of the population of certain countries vulnerable to land grabbing. Blockchain has the potential to create secured land registries and therefore to guarantee property rights. Even in countries with no such issues, this technology could substantially improve the efficiency of official land registry systems and save a lot of tax money.

Sustainability Summary	
Sustainability implications	▪ Reduction of land-related corruption and land-grabbing violence ▪ Better access to property ownership for vulnerable populations through decentralised land registries and smart proof of ownership
Blockchain functionalities	▪ Data accountability ▪ Data security ▪ Fraud prevention
SDGs	**1.** No poverty (incl. 1.4, 1.5) **2.** Zero hunger (incl. 2.3) **5.** Gender equality (incl. 5.A) **10.** Reduced inequalities **11.** Sustainable cities and communities (incl. 11.1, 11.2) **16.** Peace, justice and strong institutions (incl. 16.6)

Immutable land registries

A blockchain-based land registry has three main advantages: it secures the overall registry system, since the data registered cannot be corrupted; it improves the verification process by enabling public auditors to make real-time audits every few minutes, instead of usually once every year (if ever); and it reduces the costs of property rights registration by acting as an instantaneous notary service. By making land registries immutable and decentralised, blockchain could ensure ownership and control over land and other forms of property, especially for the poor and vulnerable populations (SDG target 1.4). Similarly, it could facilitate women's access to ownership and control over land (target 5.A). This would reduce the vulnerability of these populations to economic shocks, such as financial crisis (target 1.5). Ownership of land for agricultural purposes would also be facilitated, leading to increased incomes of small-scale food producers (target 2.3).

Additionally, blockchain-based land registries would reduce land-grabbing violence from land mafias and land-related corruption from public officials, contributing to the creation of transparent institutions (target 16.6). Land-related blockchain applications would also contain benefits for urban planning. It would notably contribute to ensuring access to adequate, safe and affordable housing (target 11.1), and consequently, to enhancing inclusive and sustainable urbanisation (target 11.3).

Several experiments are already in the pipeline. The Republic of Georgia is conducting since 2016 a pilot project, implemented between the National Agency of Public Registry and the Bitcoin mining company BitFury, aiming to create a private blockchain tailored for property rights registration (Shin, 2016). In Ghana, where 70% of court disputes in national courts are land-related, the government started a partnership with the start-up BenBen. The company is creating a land registry and verification platform in order to create an automated and trusted property transactions system (BigChainDB, 2017). Similarly, in India, where 66% of civil cases are property-related disputes, land records date back from the colonial era and land ownership fraud is estimated to account to 1.3% of lost GDP per year (Chandran, 2017a). To try to solve this issue, the state of Andhra Pradesh is partnering with the start-up ChromaWay and the firm Zebi to create blockchain-based land registry, having so far secured more than 1,00,000 land records through the Zebi Data platform (Sinha, 2018).

In Honduras, around 80% of the country's privately held land is either untitled or improperly titled (Chandran, 2017b). In most cases, there is no legal certainty about the official ownership of lands, so people are left vulnerable to the land mafia. Acquisitions for economic development such as mining, dams and tourism are often enforced through violence. Blockchain could therefore constitute a way to reduce corruption and violence in the country (Collindres et al., 2016). The Honduras government has launched in 2015, in collaboration with the company Fatcom, a pilot project to transfer the national land registry to a blockchain-based system. However, due to its political nature, the project is currently stalled (Kirby, 2015).

Sweden is probably the most advanced country using blockchain for land titling (Snäll, 2017). Since June 2016, Sweden's land registry authority - the Lantmäteriet - has been conducting an experiment aiming to record property transactions on blockchain. According to an estimate by the consultancy Kairos Future, this could save the Swedish taxpayer over EUR 100 million a year by eliminating paperwork, reducing fraud, and speeding up transactions (Wong, 2017). The experiment has successfully concluded two testing phases and is technically ready, according to the project's test report (Kairos Future, 2017). However obstacles, such as the legal status of digital signatures, need to be addressed before being officially launched.

Proof of land ownership

Blockchain could also be used to ascertain the existence of land titling documents. Proof of Existence (POEX) for instance provides a notary service on the Bitcoin blockchain that anonymously and securely store an online distributed proof of existence of any document. Uploaded documents are not stored on the database and are not accessible by others. It stores a cryptographic digest of the file that allows for users to later certify that the data existed at that time. This system could be used to prevent the forging or the loss of land ownership documents. It could also be used in the context of legal identity documents. Other similar initiatives include Stampery, a blockchain-based data certification platform, and Signatura, a digital signature platform.

4.5 Taxation

The ability of blockchain to provide immutable ledgers and transactions holds transformational opportunities for the way governments collect taxes and the way individual and corporate taxpayers pay them. Similarly with the other public sectors mentioned above, tax administrations in most countries still rely on antiquated paper-based and labour-intensive tax systems. Each jurisdiction keeps its own tax registry and has a different way of collecting taxes. Blockchain can potentially bring many benefits to taxation systems for tax administrations. Although technology alone cannot provide complete solutions and replace the adoption of quality tax regulations, it can bring more coordination between internal

Sustainability Summary	
Sustainability implications	▪ Reduced tax fraud and fund misappropriation ▪ Fairer taxation system due to enhanced visibility on micro-transaction ▪ Dynamic interactions between tax authorities and taxpayers
Blockchain functionalities	▪ Data accountability ▪ Data security ▪ Fraud prevention
SDGs	**8.** Decent work and economic growth (incl. 8.1, 8.2) **10.** Reduced inequalities (incl. 10.4) **11.** Sustainable cities and communities **16.** Peace, justice and strong institutions (incl. 16.5, 16,6) **17.** Partnerships for the Goals (incl. 17.1, 17.4)

departments of tax administrations[24]. In the long-term, blockchain could shift the responsibility for collecting taxes from tax authorities to the participants of the shared economy (Seco, 2018).

Overall, it can be estimated that blockchain-based taxation systems could contribute to strengthening domestic resource mobilisation and tax capacity, notably for developing economies (SDG target 17.1). Such improvements to domestic budgets could also assist developing countries in attaining long-term debt sustainability (target 17.4). Moreover, the use of blockchain for taxes could pave the way for the adoption of fiscal policies that seek to achieve greater equality (target 10.4). Smart tax collection systems could also result in fairer taxes and reduce tax avoidance, resulting in increased economic growth and productivity (targets 8.1 and 8.2). Finally, as with other public sector applications, blockchain-based taxation could help reducing corruption and bribery, and creating effective, accountable and transparent institutions (SDG targets 16.5 and 16.6), notably through decreased risks of fund misappropriation by public officials.

Digital tax collection systems

Tax administrations today are facing major challenges brought by globalisation and digitization. These factors have created a lack of nexus between value-generating activities and their relevant taxes, distorting the tax collection systems that were designed in previous eras (OECD, 2015). Indeed, large companies increasingly operate digitally and cross-border, and more SMEs enter global markets, whereas tax authorities still function within their national jurisdictions, following local regulations processes, and lack the expertise needed to deal with virtual markets (Vienna University of Economics and Business, 2017). Blockchain could provide accurate and immutable data that can be shared anonymously and in real time, which can prove valuable to tax administrations. Experts mention potential applications to most taxes, notably transactional taxes such as value-added tax (VAT), goods and services tax (GST), withholding tax, stamp duties, insurance premium taxes and transfer pricing (PwC, 2017)[25].

Smart customs declarations

A major challenge for tax administrations is the disruptions brought by global trade. Most taxes on cross-border goods depend on information declared to customs, such as the origin and destination of goods, their composition and details about buyer, seller and transporters. Not only are these declarations required to pay the necessary duties, but heir also play a major role in enforcing trade regulations such as those concerning illegal or dangerous substances (EY, 2017). However, most of this information is gathered from a wide range of jurisdictions and organisations. Blockchain could be used to make smart custom declarations through digital invoices based on encrypted data collected in real-time and in a similar format. Such decentralised custom system would enable regulators to trace back products to their exact origin and to track their evolution in the value chain. Then, with smart contracts, the technology could fully automate the collection of relevant duties.

Automated payroll and corporate taxes

A relatively straightforward application of blockchain concerns the payment of individual income taxes (or payroll taxes) and corporate taxes at the source. For income taxes, employees could pay their duties directly to tax authorities through self-executing smart contracts (see Section 3.6 for payroll applications of blockchain).

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[24] In recent years, tax administrations have been experimenting with digital tax regimes with some degree of success, such as in Estonia, India, the UAE ad the EU (Misso, 2016). However, structural and cultural issues persist and prevent the massive adoption of digitised tax solutions across countries. One of the main barriers is that tax administrations had been developing tax collection systems focused on the needs of each department, instead of systems focused on tax compliance (Ajienka, 2017).

[25] However, one main adoption challenge resides with the fact that the tax collection systems must be applied to all similar taxpayers. Small shop-keepers that keep paper records of their business activities or even individuals that do not own electronic devices might not easily adapt to a fully digital blockchain-based tax collection system. Nonetheless, this kind of technical obstacles is not insurmountable and blockchain is widely believed to have the potential to greatly improve the efficiency of tax collection systems.

Such system would not only avoid most manual errors, but would also provide a permanent proof of tax payment (Ajienka, 2017), which can be useful for employees changing employers often, notably in different countries. The same could be applied to corporate taxes, which could be paid automatically, depending on business data (revenues and transactions) recorded on blockchain (Ashurst, 2017). Automated corporate tax collection would free time for companies to spend on more complex transactions requiring added-value.

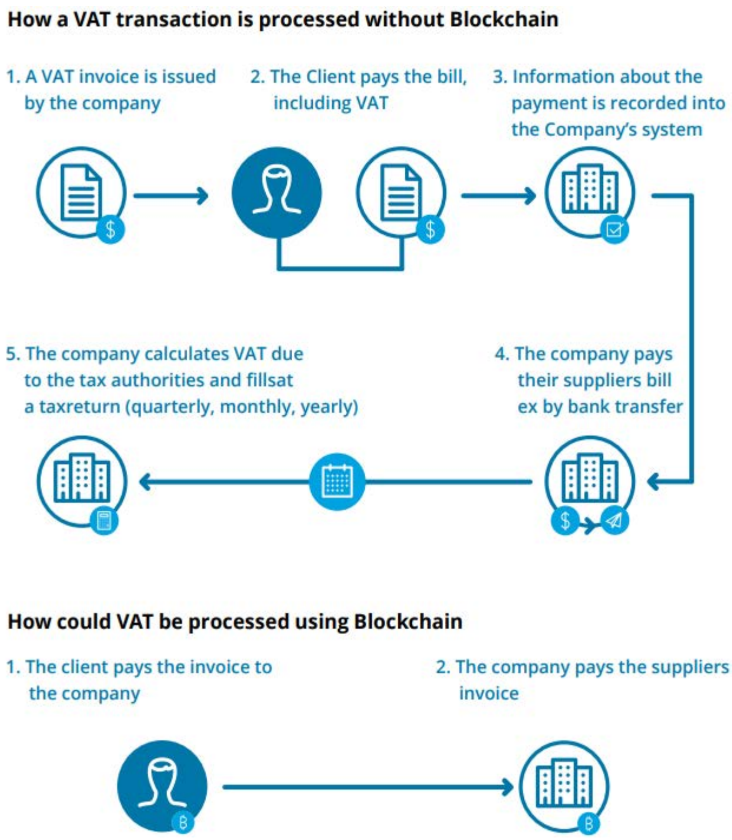
Fraud-free transfer pricing

Transfer pricing concerns rules and methods for pricing transactions within and between enterprises under common ownership or control. It allows tax authorities to adjust the taxable income of companies' intra-group transfers, notably in the case of cross-border transactions. With intra-firm trade making up for 30% of global trade, transfer pricing rules play a major role in preventing tax evasion, with a varying degree of success until now. One of the many issues is that transfer pricing heavily depends on intra-firm paper documents, data stored on private servers and corporate agreements executed manually (Deloitte, 2017c). As a result, there is a high risk of document falsification for avoiding to pay taxes. A blockchain-based distributed ledger of transactions would provide transparency to business transactions, allow corporate agreements to be self-executed through smart contracts and enable automated transfer pricing.

Decentralised collection of indirect taxes

Indirect taxes include taxes on consumption such as VAT, GST and sales taxes, but also customs duties, excise taxes, energy taxes and environmental levies. The major issue with indirect taxation is that the payment is normally triggered by a key event. Tax amount to be paid depends on the information reported by the parties involved with this event. Yet, accounting errors, negligence, lack of data and fraud cause important tax losses (EY, 2017). With the help of blockchain technology, tax administrations would be able to access immutable quality data in real-time to collect indirect taxes across different jurisdictions (see Figure 12).

Figure 12: VAT collection and payments with and without blockchain



Source: Deloitte (2017b)

In order to implement this, experts propose to create VATCoin, a cryptocurrency tied to a local currency that will be used by companies to pay indirect taxes, and which only governments would be able to convert to common currencies at the receiving end of the transaction (Ainsworth et al., 2017). This might seem extreme, but with some countries already putting their national currencies on the blockchain such as Tunisia (FT Reporter, 2016) or Senegal (Young, 2016), and others considering doing so such as the UK, Russia, Canada and China, cryptocurrency-based taxation might be closer than expected.

Reduced tax evasion

Perhaps the greatest potential of blockchain in taxation lies with its ability to detect and prevent fraud. All destination-based taxes such as VAT are susceptible to what is called missing trader fraud. It is particularly recurrent within economic regions[26]. Using blockchain for tax payments would make frauds and errors much easier to detect than in today's fragmented tax system. It would notably allow to track the details of transactions and indirect tax payments such as for VAT. This automated and transparent way of paying taxes might also generate cultural changes. While intentional fraudsters will be more easily caught, many taxpayers commit tax frauds unintentionally because they are not enough aware of their tax obligations, notably small businesses and individuals. Blockchain could enhance the visibility of micro transactions and make compliance easier for honest taxpayers (PwC, 2017).

While it might take some time to see fully blockchain-based tax systems, the EU is expected to be an early adopter, aiming to improve the efficiency of VAT collection and build trust in intergovernmental relationships (Ainsworth and Shact, 2016). Small-scale examples can be already found. For instance, the tax authority of the Chinese city of Shenzhen has started a partnership with Tencent to use blockchain platform TrustSQL in the fight against tax evasion (Sundararajan, 2018). Another initiative was conducted by Revenue Quebec in the restaurant sector. The mandatory use of Sales Recording Modules (SRMs) in 20,000 establishments, has yielded revenue gains of USD 940 million in 2015, which are expected to reach USD 2.1 billion by 2018-19. Restaurant inspections also take only 3 hours, compared with 70 hours before, allowing auditors to conduct 8,000 audits a year remotely, instead of 120 in person (Ainsworth and Alwohaibi, 2017).

Democratised tax revenue allocation

Blockchain could also facilitate taxpayers' engagement with government's budget spending to a certain level. Raupp (2018) points out that national governments' budgets are usually divided between discretionary spending programmes, such as for social security and defence, and discretionary spending programmes, which depend on government's decision. With blockchain used to collect taxes, a fixed amount would be directed to mandatory spendings, and a minimum amount to each discretionary programme. However, with blockchain-based identification, tax payment and with the help of smart contracts, taxpayers could be given the possibility of directing the rest of their due tax amount to the discretionary programme of their choice.

This could ensure direct democracy and self-governance and to enhance citizen engagement with government affairs. With taxpayers knowing the spending breakdown of their tax money, having a say in some level of spending decision, and being aware of the immutability of the technology behind the tax payment process, trust in public institutions could greatly increase.

[26] In the EU notably, the Missing Trader Intra-Community Fraud (MTIC) happens when a business makes a cross-border purchase within the EU without paying VAT, then collects VAT on an onward sale, disappearing with the VAT money instead of remitting it to the tax authorities (Europol, 2018). Due to the MTIC and other common VAT evasion and fraud, the European Union (2017) estimates that the VAT gap in the 28 Member States amounted to EUR 150 billion in 2015.

5. Blockchain Applications for Climate Change and Sustainable Societies

5.1 Sustainable production and consumption

Blockchain technology will enhance supply chain efficiency, reduce waste and enable better compliance with food safety standards (see Section 3.2), but another consequence of supply chain tracking might be found in sustainability-related applications. One of the most important impacts that blockchain might be its ability to realise sustainable production and consumption and circular economies by providing detailed and real-time data on companies and products. The ability to enhance the traceability of products could empower consumers by giving them the detailed and trustworthy information they need to choose sustainably sourced products (Cerasis, 2018).

Sustainability Summary

Sustainability implications	▪ Mainstreamed ethical consumption due to wide access to transparent products data submitted by each supply chain actor ▪ Greater consumer trust and awareness due to enhanced sustainable certification ▪ Increased fair trade practices across all industries due to empowerment of supply chain actors such as small farmers
Blockchain functionalities	▪ Data accountability ▪ Fraud prevention ▪ Strengthened IoT networks
SDGs	**2.** Zero hunger (incl. 2.4, 2.B) **8.** Decent work and economic growth (incl. 8.4) **10.** Reduced inequalities (incl. 10.1) **11.** Sustainable cities and communities (incl. 11.6) **12.** Responsible consumption and production (incl. 12.2, 12.3, 12.5, 12.6, 12.7, 12.8) **14.** Life below water **15.** Life on land **17.** Partnerships for the Goals (incl. 17.10)

Such access to product information could also pave the way for mainstreamed fair trade practices and enhanced sustainability certifications. This could in turn enable manufacturers to enhance their product stewardship, governments could use detailed products' life cycle data to improve their recycling processes and investors might grant preferential rates to sustainable suppliers.

Ethical consumer choice

The production and trade of goods can have hugely negative sustainability impacts in many fields around the world: environmental pollution, deforestation, human rights abuse etc. However, consumers are limited by the information provided by retailers regarding the origin of products and their impacts across the supply chain. Therefore, most of the time, consumers do not know the concrete impact of their daily purchases in the world. This trend is rapidly changing with the growth of ethical consumerism. According to the 2017 Ethical Consumer Markets Report, sales of ethical products have grown faster than those of ordinary products for the 14th year in a row in the UK. The report also notes that ethical spending overall has grown by 3.2% in 2016 compared with the year before and that vegetarianism increased by 30%.

This trend is notably carried by the younger generations of consumers between 16 to 35 years old, who are reportedly willing to pay a premium for ethical products (Hancock, 2017). However, in spite of this positive change, increased ethical awareness fails to translate into purchasing decisions. Indeed, the report notes that the demand for healthy food has increased by 94%, while sales of ethical food and drinks have only grown by

9.7% in the same period. This gap between demand and consumption is called the "ethical consumption gap" (Carrington et al., 2016)[27].

Blockchain offers a potential solution to remedy to this issue. By giving access to real-time, detailed and immutable data from each actor in the supply chain, the technology can give consumers the information they need to make ethical purchases. As mentioned in Section 3.2, product tracking requires recording and accessing data on a blockchain through the use of QR codes or RFID chips. By doing so, consumers will no longer have to depend on filtered data provided by companies selling the products, but will access the product specifications as inputted directly by supply chain actors. This would notably contribute to ensuring that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature (SDG target 12.8).

At the individual level, increased access to detailed data on the origin of products could enable consumers to choose products based on their environmental footprint and social impact. This would help in achieving sustainable management and efficient use of natural resources (SDG target 12.2), by notably decreasing per capita global food waste at the retail and consumer levels (target 12.3). Such data could also improve countries and cities' 3 R policies, aiming to reduce waste generation through prevention, reduction, recycling and reuse (target 12.5). At the organisational level, blockchain-based product tracking would facilitate the adoption of sustainable practices by companies (target 12.6), and pave the way for sustainable public procurement practices by governments (target 12.7).

By design, blockchain enforces the transparency, security, authenticity, and auditability necessary to make tracing the chain of custody and attributes of products possible, which in turn allows customers to derive the high-quality information needed to make more informed choices.
Provenance (2015)

The food industry is already exploring the potential of the technology. Food companies and retailers including Walmart, Nestlé, Unilever and Tyson Foods have notably started a partnership with IBM in order to explore how blockchain could be used to improve the transparency of the global food supply chain. By using a blockchain platform, all actors in the food system - growers, suppliers, processors, distributors, retailers, regulators and consumers - would gain nearly immediate access to secured information on the origins of food products and their status within their supply chain (Greenbiz, 2017).

Since 2016, WalMart even started tracking two products - a packaged produce item in the US and pork in China - using blockchain technology co-developed by IBM. With the enhanced traceability provided by blockchain, Walmart intends to tackle food safety issues (Kharif, 2017). A single receipt can now give access to detailed data on the origin of the product, the identity of its supplier, when and where it was produced and shipped, and who verified its quality. Similarly, the University of Cambridge Institute for Sustainability Leadership (2017), along with six companies and banks, and four start-ups, initiated a project that will use data gathered throughout the supply chain with blockchain to allow financial institutions to offer preferential terms or access to credit, based on the evidence of sustainability.

Although the primary application focus of experimental projects has concerned the food industry, blockchain could potentially impact all other sectors of global trade such as garments, electronic components and raw

[27] Part of this gap can be explained by the failure from of producers to identify this trend and capture its market opportunity for the past 15 years. However, consumer behaviour is also partly at fault. With limited information available to compare products in order to make an informed choice, consumers end up not making the effort to look for advanced product data and simply stick with their usual purchases.

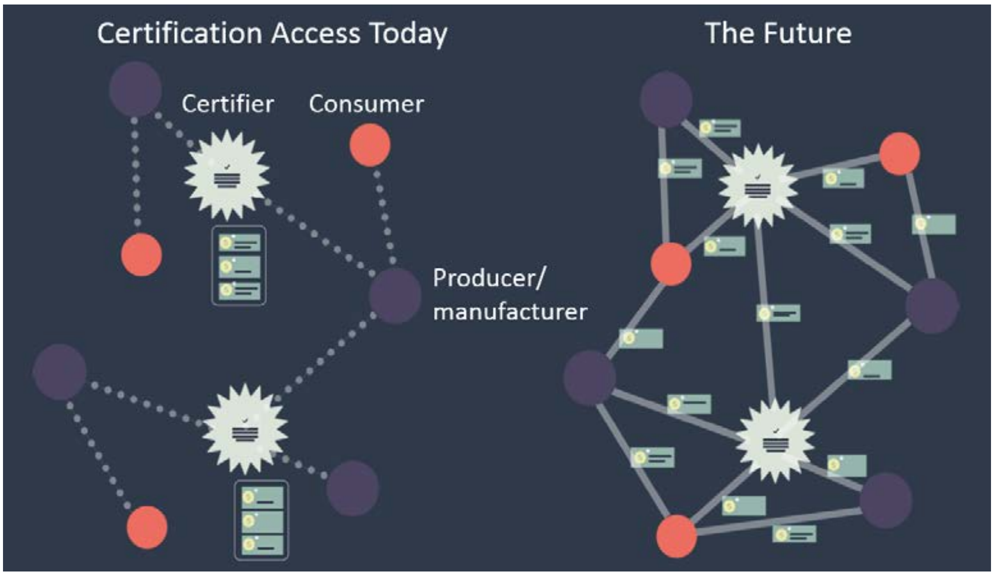
materials. Another major field of application concerns the luxury sector. The value of products in the luxury sector depends on their scarcity and authenticity. Yet such assessment is often vulnerable to manual errors and fraud. The most notable initiative in this regards is Everledger, a company providing a digital ledger that tracks and protects valuable assets, such as diamonds, throughout their lifetime journey. The authenticity of over one million diamonds have already been secured on the platform.

Sustainable certification of products

Going a step further, blockchain could also substantially improve the integrity and usefulness of sustainability-related certifications, such as those concerning fair trade or organic products. Sustainability standards and labels have been a central instrument in the development of sustainable consumption. Given the chronic lack of product information, such certification has been the most reliable guarantee regarding the sustainable performance of products. However, this system suffers from several flaws that have stopped it from gaining a mass popularity that can match the ethical consumption demand[28].

Blockchain offers a powerful solution to this situation through its decentralised nature. Relying on one centralised entity to guarantee the sustainability of products creates an inherent bias, as any third-party can be vulnerable to either bribery, social engineering or targeted hacking (Provenance, 2015). Through its decentralised data recording, blockchain enables supply chain actors, certifiers and consumers to access immutable data in real-time. While before the relationship between supply chain actors was linear (producers are audited by certifiers, who issue a certification that constitutes the only point of trust for consumers), with blockchain the fabric of trust between all parties becomes multidirectional (see Figure 13).

Figure 13: Use of blockchain for sustainability certification processes



Source: Adapted from Provenance (2015)

From the producers' side, specifically in the food sector, blockchain-based certification schemes could contribute to mainstreaming sustainable food production systems and resilient agricultural practices (SDG target 2.4) while ensuring income growth for the poorest farmer populations (target 10.1). Overall, enhanced sustainability certifications could contribute to the goal of achieving global resource efficiency in consumption,

[28] Indeed, consumers have no means of verifying the integrity of the certification, and are not aware of the quality of the labelling and audit processes. Therefore, the effectiveness of such labels relies on blind trust, which only the most environmentally-engaged consumers are ready to give. Additionally, for consumers mildly interested in making ethical purchases, current certificates are limited to a printed label on the product package and do not provide the information needed to convince hesitant customers.

production and endeavour (target 8.4), and reduce the environmental impact of cities through better waste management (target 11.6).

The best initiative to date in this regard is Provenance, a company providing a blockchain-based software enabling producers, retailers, certifiers and consumers to track the journey of goods. This solution offers a complete transparency of the supply chain by providing detailed information on the nature, quality, quantity and ownership of products, while allowing participants to remain anonymous (except for certifiers who need to identify themselves). Such blockchain-based data recording allows for sustainable certifications to reach a new level of accuracy and integrity. Standards and labels are automatically issued through smart contracts only if the product meets the requirements set in the programme and after a real-world verification by an auditor.

More uniquely, due to the public access of blockchain information by consumers, blockchain provides a "crowd-sourced scrutiny" that can complement traditional certifications schemes (Provenance, 2015). The technology was notably used to track responsibly-caught fish and key social claims down the chain to export yellowfin and skipjack tuna fish in Indonesia (Provenance, 2016). Another similar venture is Catenaut's Blockchain of Custody, a blockchain system for certifying forest management compliance.

Fair trade, or empowering the weakest link on the chain

The decentralised nature of blockchain holds the potential to majorly disrupt the current state of global trade, in which the strongest actors dominate markets and set the rules for the smaller actors who depend on them. Centralised data collection and sharing systems tend to unfairly favour the parties that have the best access to data. Small farmers notably suffer from a critical lack of access to information, which makes them vulnerable to market control by distributors and retailers.

Fair trade was intended to resolve this issue by limiting the number of intermediaries in favour of farmers, notably in the coffee industry. Yet, this solution has remained marginal, notably due to the limitations of sustainable certification systems as seen above. Blockchain provides the potential to mainstream fair trade by rebalancing the equilibrium of information and power within global trade networks. The technology can provide not only a wider access to finance (see Section 2.2) and insurance (see Section 3.5) to small farmers, but also more insight into supply chain data, giving them greater control over the product they send into the chain. The elimination of trade barriers from intermediaries could also indirectly contribute to correcting and preventing trade restrictions and distortions in world agricultural markets (SDG target 2.B), while promoting equitable multilateral trading systems (target 17.10).

Several initiatives have already emerged, aiming to use blockchain to empower actors with a weak position on the supply chain such as farmers. For instance, Agriledger provides a Distributed Cryptoledger Mobile App that enables small farmers to record transactions directly on the blockchain. On top of reducing food waste due to inefficient supply chain management, this solution aims to empower small cooperatives and help farmers retain a bigger share of their crop value.

Another interesting venture is the start-up bext360, which is using a blockchain-based transaction network, combined with AI and IoT in order to transform the supply chain of coffee. The company aims to develop kiosks, which will use smart image recognition technology to evaluate crops and products' quality, determine the identity of farmers and automatically assign a fair price to the beans. Doing so would allow coffee buyers to speed-up and automate payments to fair trade farmers while monitoring more accurately the source and quality of the coffee beans (Clancy, 2017).

5.2 Sustainable lifestyles

Sustainability Summary	
Sustainability implications	▪ More flexibility and access to sharing economy ▪ Resource efficiency through informed consumption decisions ▪ Improved working conditions
Blockchain functionalities	▪ Smart contracts ▪ Peer-to-peer transactions ▪ Strengthened IoT networks
SDGs	**3.** Good Health and Well-being (incl. 3.6) **9.** Industry, Innovation and Infrastructure (incl. 9.1) **11.** Sustainable cities and communities (incl. 11.2) **12.** Responsible consumption and production (incl. 12.2, 12.5, 12.8) **13.** Climate actions (incl. 13.3)

Lifestyles of individuals consist of various elements of daily consumption such as nutrition, housing, mobility, consumer goods, leisure, and services. Sustainable lifestyles includes reducing the impact of our lifestyles on these domains, from resource efficiency, making sustainable choices, to reducing wastes. Blockchain can help individuals understand the impact, or footprint, of the activities they choose in each domain by collecting data from equipment and movement. Being informed about the impact they are making is the first step for individuals towards making more sustainable choices in life.

Promoting sustainable lifestyle through IoT-blockchain integration

Accessibility to data that quantifies our daily activities will help us understand how we impact the environment, which can help increase public awareness and drive behaviour change towards sustainable development and lifestyles (SDG target 12.8), as well as contributing to bottom-up education of citizens on climate change and environmental issues (target 13.3). Provision of access to such data is the foundation of IoT systems[29]. Applications of IoT technologies have been growing rapidly and are globally projected to grow from USD 2.99 trillion in 2014 to USD 8.9 trillion in 2020 (Forbes, 2017). IoT technologies have been applied to various products and services. If a product or service is labelled 'smart', it most likely implies connectivity to IoT: from smart cars (automotive industry), smart homes (systems engineering), smart watches and other daily consumer electronics (consumer goods).

For example, by using IoT-enabled smart car systems on private and public transportation, drivers can access information that can help them increase efficiency of transport, such as driving behaviour that leads to inefficient fuel consumption, traffic information to avoid jams, and information on when it is time for car maintenance. In smart manufacturing, industrial companies are using the IoT to enable data analytics and communication capabilities between devices to improve productivity and efficiency by understanding data and anticipating trends. An IoT system can transmit data to the cloud or the industrial data centre, where process engineers can make necessary decisions (Intel, 2018). IoT applications are expected to grow to 50 billion connected devices by 2020 (Cisco Inc., 2017), with growth in the currently dominant daily consumer electronics as well as industrial applications. The potential is vast, and more applications to daily consumer products can mainstream sustainable consumption and lifestyles.

One of the issues that may impede further growth of IoT is systems security, as traditional centralised security models have limited utility for some IoT applications (Zahid et al., 2017). The new security system brought by

[29] By embedding equipment with sensors, meters, and connectivity to the internet, equipment and users themselves can utilise behaviour information to improve operations efficiency dynamically and adaptively, and to thus develop new products with improvements.

blockchain technologies can be a key enabler to solve the barriers in IoT security (Khan and Salah, 2017) and unlocking new applications that promotes sustainable lifestyles. The technology giant IBM has started to implement such integration; the IBM Watson IoT Platform enables IoT devices to send data to private blockchain ledgers for inclusion in shared transactions with distributed records (IBM, 2016).

Another example is IoT Layer, created by Slock.it, a decentralised network layer that improves IoT security by connecting devices to a blockchain network in order to control access. It acts as a firewall and controls all incoming and outgoing messages, requiring validation and cryptographic permission from the blockchain system before transactions can be done. Other studies also suggest the need for IoT systems to enable software self-rehabilitation methods. Blockchain has also been suggested to help address these issues. An IoT-blockchain integration can help strengthen security of three types of exchange: human to machine, machine to machine, and machine to human (see Table 1).

Table 1. Example of IoT-blockchain systems opportunities

Humans to Machine	Machine to Machine	Machine to Humans
Users share their bike or car	Autonomous car payment for parking	Autonomous car pays a human mechanic to do a service check
A public washing machine paid with an application before or after use	A manufacturing machine pays a 3D printer for creating new components	Autonomous car pays cleaning service from human
Data centre owners rent out unused data storage	An air conditioning system orders a regular cleaning solution	A computer disconnects user from the network after working hours limit has been passed

Source: Slock.it, authors

IoT technologies open the door to a potentially unlimited inter-connection between people, machines, robots, and devices. To gain more benefit from IoT for sustainability, systems security and integrity should be the priority, and blockchain technologies can aid those efforts. Experts in network systems suggest that for research in IoT networks security, particularly predictive security, real IoT datasets play a big role (Banjerhee et al. 2017). The public therefore needs to be educated about the possibility and importance of such data collection, while being assured that optimum efforts are taken to protect their privacy. Some experts recommend development of a standard for these datasets and preserve end-user privacy. Due to its distributed nature, blockchain was also suggested to help strengthen the integrity of shared datasets.

Sustainable living using IoT-blockchain integration – case study

Maria leaves home in her electric vehicle fully charged using solar-generated electricity from her and her neighbour's panel. She receives a notification on her smartphone that the smart contract payment in energy coins to her neighbour was finalised and the transaction was stored in the blockchain. As she was driving, she was notified that the junction she is taking has a high rate of traffic accidents. After passing the junction safely, the car system notified that her work car park is full and that her payment application has initiated a smart contract exchange and paid for another car park at a convenient location to both her position and her destination (Huckle et al., 2016). In the evening, she received two reminders: one from her home refrigerator system notifying that some vegetables need to be cooked before their expiry date, and one from a supermarket that is selling a cancelled food order. She approved a pre-arranged delivery to buy the food.

Sharing economy

The trend in sharing economy is famously disrupting the conventional travel and leisure industry, but a decentralised sharing economy will be further mainstreamed and made more flexible through integration with the blockchain technologies. Currently, big sharing economy companies such as Airbnb and Uber open the door to mainstream decentralised economy, but they still act as intermediaries. Blockchain innovators are experimenting with new platforms based on the same idea (Tkachuk, 2018), but enhances their efficiency using a decentralised ledger, smart contracts and, in many cases, crypto-tokens. Blocklancer, Dream, and Averspace are a few leading examples. Blocklancer and Dream consolidate providers and users in a decentralised manner for finding freelance talent. Averspace is connecting homeowners directly with potential buyers or tenants with adjustable, enforceable smart contracts.

Regarding the use of private cars, it can be more convenient to use a rental system through smart transactions, which can incentivise smart driving. In a blockchain-and-IoT-based system, car's identity can be registered on a blockchain, then the renter can electronically sign the leasing contract and store it on the blockchain, all from the driver's seat. The IoT system can also track activities – distance travelled, average speeds, hard-breaking events, for example – and potentially deliver savings on insurance, or advice about cheaper leasing options, driving routes, etc. (Hirson, 2015). If token systems are implemented, these information can incentivise more efficient driving. Blockchain systems are also being offered to address safety issues in ridesharing services by storing and verifying identities of drivers and riders on a blockchain.

The blockchain systems can also allow people to rent out their unused possessions more easily and attractively, reducing waste generation (SDG target 12.5) and improving the efficiency of use of natural resources (target 12.2). For example, Filecoin Storage Market offers networks to rent unused data storage remotely: hard drives, single disks, racks, whole data centres, every Terabyte, aiming to make data available widely and cheaply, and to repurpose wasted computational resources to useful tasks. Filecoin also aims to replace bitcoin-based consensus mechanism with an alternative, more efficient mechanism. Similarly, Golem allows people to rent out their computing power. Both networks offer tokens as means of payment and exchange.

5.3 Institutional carbon trade

"Carbon credits" is a generic term for emission reductions achieved by a climate change mitigation project implemented under carbon market mechanisms. The most common example is the Clean Development Mechanism (CDM) operated by the UNFCCC under the Kyoto Protocol, which allows countries to fund or buy carbon credits ("Certified Emission Reduction") resulting from CDM projects that reduce GHG emissions in other countries. Entities that buy carbon credits can claim the amount as their GHG emission reduction to offset their domestic emissions, thereby helping the countries where they are located meet their reduction target.

Sustainability Summary	
Sustainability implications	▪ Avoidance of double counting due to more efficient tracking and accounting of carbon credits on carbon markets ▪ Greater accountability of public institutions due to transparent carbon markets
Blockchain functionalities	▪ Data accountability ▪ Data security ▪ Operational efficiency
SDGs	**7.** Affordable and clean energy **13.** Climate action **16.** Peace, Justice and Strong Institutions (incl. 16.6) **17.** Partnerships for the Goals (incl. 17.6, 17.8)

Avoiding double counting with robust tracking

Under international climate treaties regime such as the Kyoto Protocol and the Paris Agreement, it is possible that more than one country claim the same carbon credits or reduction. Due to 'double claiming' or 'double counting' of carbon credits, the aggregate global GHG emissions reported by countries to the UNFCCC may be higher than the actual emission, leading to a lack in mitigation ambition[30]. The existing infrastructure for tracking carbon permits and carbon credits framework consists of national registries for each country and an International Transaction Log which connects them. Blockchain could serve as an advanced tool for measurement, reporting and verification (MRV) of emissions reductions or carbon credits, especially for tracking credits transfers and helping to assure there is no double counting in international accounting.

By assigning issued carbon credits into 'blocks' and storing them in a blockchain network, members can trace them at any time within the network, and members can eventually report data validated by other members of the network. Using blockchain as a technological support for carbon markets could reduce the risks of double counting of carbon credits in national and program registries, therefore contribute to the development of effective, accountable and transparent institutions (SDG target 16.6).

At the international markets level, the technology could be considered as a mechanism to increase the capacity for robust tracking, which helps robust accounting of carbon credits of countries engaging in trades as well as their capacity regarding technology and innovation (target 17.8). Blockchain in carbon markets could also enhance North-South and South-South cooperation on access to technology (target 17.6).

Some types of carbon credits can be traded in the open international market at market price without supervision or approval by countries. Similarly, the European Union (EU) Member States are given CO2 permits (called "emission allowances") that work in reverse to carbon credits; entities have a cap on CO2 emissions in terms of permits. Thus these permits are financial products, in fact CO2 permits are deemed to be services in the EU and they are subject to Value Added Tax (VAT) in all Member States (Ainsworth and Musaad, 2017). Carbon credits, or permits, therefore have financial values, and there were several cases of cybercrime attacks to steal credits from a number of national registries[31].

Blockchain can be an alternative technology for a carbon credits and carbon permits registry. Although it cannot guarantee anti-theft, the decentralised and distributed nature of blockchain can better prevent theft and offer traceability compared with the prevailing technology, making tracking easier and more robust. The technology can also help increase credibility, transparency, and auditability of carbon markets and help to address regulations without relying on a rigid technology. Both large and small emission trading systems between enterprises and/or countries can benefit from blockchain. It can reduce managerial burden by decentralising the credits management system without sacrificing the desired level of transparency, thereby encouraging enterprises to participate more actively. It should be noted that eventually, robust tracking is only one part of robust accounting to avoid double counting, and policymakers should also put in place stronger regulations and reporting measures in order to avoid double counting agreed under the Paris Agreement.

National, regional, and multilateral emission trading system

Notable developments of a blockchain-based MRV system for ETS are seen in the Americas and China. In the Americas, Canada and Chile, Colombia, Mexico and Peru (the Pacific Alliance nations), may become the first

[30] This 'double claiming' is possible due to the lack of rules under the Kyoto Protocol. Under the Paris Agreement, countries have agreed to leave this practice and avoid double counting of carbon credits in accounting for emissions and removals corresponding to their own Nationally Determined Contributions (NDCs). The Agreement also calls for a more robust accounting, including a stricter tracking of carbon credits transferred between countries, to ensure the entities who claims them at the time of reporting or NDC accounting have the right to those credits.

[31] A famous example is the hacking of the Romanian registry account of Holcim Ltd. in 2010, resulting in 1.6 million carbon credits being stolen (INTERPOL, 2013) and the hacking of the Czech registry in 2011, when 500,000 permits were stolen, leading to a loss of approximately EUR 7 million.

network of nations to implement a blockchain-based MRV system in the near future. An MRV Governance Collaboration Initiative between those countries, facilitated by the International Emission Trading Association (IETA) and ClimateCHECK, started in 2017 (IETA, 2017) to pilot test a DLT/blockchain applications within the MRV sector of the Pacific Alliance countries in 2019 (Climate Ledger Initiative, 2018). Considering the number of initiatives exploring blockchain applications to climate change governance, it can be expected that more countries will develop blockchain-based systems to track transactions of carbon credits traded by the country. If developed on an open source software, these systems can be easily scaled and adapted with different country's circumstances.

In China, the world's first blockchain-based management system made for the Chinese CER markets was announced in 2017, the same year in which the nationwide ETS started to help the country achieve its NDCs. Developed jointly by IBM and Energy Blockchain Labs, the open source system targets enterprises, allowing them to generate and trade carbon assets between each other more efficiently. The system is estimated to shorten the cycle and reduce the cost of carbon assets development by 20-30%, enabling cost-effective development of a large number of carbon assets (IBM, 2017). The next step planned by the developers is to combine the blockchain system with smart contracts, to further improve efficiency of CER quota issuing.

Within a wider scope, blockchain can also support the implementation of NDCs if facilitated by a next generation collaborative governance system and distributed rule-making (Baumann, 2017). The common concerns from the public sector on the security of a publicly accessible system can be mitigated by setting their own procedures, requirements and permits to access, similar to other information technology-based systems. If combined with IoT systems, blockchain can track carbon trading in an automated manner (Vian, 2016). In the short term, the costs and technical capacity for setting up the infrastructure and operating the system may offset its benefits, compared with implementing a more conventional human-based communication system or common, basic software. But in the long term, the blockchain offers a cost-efficient, flexible, and secure system.

5.4 Individual carbon trade

Climate change mitigation used to be seen as the responsibility of country governments. Mitigation efforts to complement reduction policies such as carbon trading between enterprises and countries have been part of common business practice in some jurisdictions. However, public awareness on the urgency of climate change mitigation has helped transitioned the view to the current campaign that every individual's action matters. Blockchain can strengthen the transparency of existing initiatives and create new initiatives, both of which can attract more people to reduce or compensate for their individual carbon emissions.

Sustainability Summary	
Sustainability implications	▪ Increased citizen's environmental awareness due to more transparent carbon footprint tracking ▪ Reduced carbon emissions through enhanced individual climate actions
Blockchain functionalities	▪ Cryptocurrency ▪ Peer-to-peer transactions ▪ Data accountability
SDGs	**11.** Sustainable cities and communities **12.** Responsible Consumption and Production (incl. 12.8) **13.** Climate action (incl. 13.3)

Carbon offsets and calculator

One of the most well-known ways to act at an individual level is offsetting carbon emissions from air trips. Individuals can donate to climate actions an amount equivalent to the cost of carbon induced by their flight (Climatecare, MyClimate, Atmosfair websites)[32]. Existing programmes run in a traditional way in which travellers calculate how much carbon their flights emit, how much they cost using a flexible price tag per tonne CO2, pay the cost via credit card or bank transfer, and receive a certificate for this payment.

In the existing framework, offsetters cannot access the flow of their donation to the selected project. Programme managers also often face delays and difficulties from managing multiple ledgers (of the web-based payment system, where different banks and credit cards often have different ledgers) and managing third-party operated electronic wallets that are used to collect the funds.

Blockchain can facilitate a unique solution using tokens and smart contract, in which programme managers and the offsetters can track their donation and better monitor how targets are met. Doing so could contribute to the education of citizens on climate change mitigation (SDG target 13.3), and increase their awareness for sustainable development and lifestyles (target 12.8).

Peer-to-peer carbon trading and cap-and-trade

Most recently, new trends in individual climate actions based on blockchain technologies are appearing, including carbon exchanges between individuals. One of the ventures for peer-to-peer carbon trading is seen from CarbonX. CarbonX invests in eligible carbon reduction projects and distributes the generated offsets as crypto-tokens through their rewards programme based on a permissioned, Ethereum blockchain. Retailers and brands participating in the programme will be able to offer the tokens to their consumers as an incentive for making climate actions, such as joining a rideshare service instead of driving their own car to work. The tokens are tracked via a mobile app and can be traded amongst consumers and exchanged within the CarbonX network for a range of goods and services, for other reward points, or for other digital currencies[33].

Another new initiative is a Climate Drops application which tracks and rewards environmentally friendly actions of its users. The blockchain-based application operated on Microsoft Azure server rewards its users with points called "Climate Drop", which corresponds to 1 kg of CO2 not emitted into the atmosphere due to the eco-friendly activities of the users. The users can exchange their points for discounts, bonuses, and other products provided by the application's partners. An interesting part of the Ukraine-based application is calling their users "Sources", emphasising that every individual creates impact on the environment and has a responsibility in protecting it.

Other ideas for peer-to-peer carbon trade floating around on the internet include a prepaid carbon credits system (Dodge, 2015) and a voluntary peer-to-peer cap-and-trade system (Sno-Caps Team, 2014). In the first idea, anyone who emits carbon will buy a certain amount of "carboncoin" for every tCO2, and deposit them in a blockchain. Later, the coins can be transferred to other parties who sequesters tCO2 such as through reforestation or industrial carbon capture and storage.

Slightly different from the pre-paid system, the voluntary cap-and-trade idea assigns a voluntary carbon emission cap to every individual and allows them to trade the allowed emissions with each other on a Bitcoin blockchain system. Actions will be incentivised by user ratings similar with the principles of Airbnb and Über.

[32] The type of climate actions in the portfolio that will benefit from the offset donations vary from distributing clean cook stoves to building wind power plants. Conscious travellers can choose between types of offset programmes: those offered by airlines and those offered by organisations running their airline-independent offset programmes.

[33] CarbonX started by making its own crypto-token called CarbonX Tokens (CxTs), intended as a future securities product, but it might switch to facilitating exchange of GOODcoins, a token created by the ZeroFootprint program following the merge between the two companies in June 2018 (PR Newswire website, 2018).

There is no need for policymakers to track and report the carbon credits in these voluntary programmes and individual actions, so the blockchain will not play a role to incentivise law enforcement. But the public demand for accountability and transparency of individual programmes will grow due to the mainstreaming of blockchain.

From the variety of new programmes, individuals will gain more opportunities and benefits from climate actions; they will be able to choose to make impacts on community development through goodwill-based carbon offset calculator systems, to make capital benefits from cryptocurrency on the crypto-tokens and crypto-coins system, and to improve public image through the ratings-based systems. Social campaigns will play a role in shaping human behaviour to maintain a healthy balance between goodwill and benefits.

5.5 Smart grid

Sustainability Summary	
Sustainability implications	▪ Improved stability of electricity grid ▪ Real-time electricity data collection ▪ Reduced energy waste through increased efficiency of energy systems
Blockchain functionalities	▪ Smart contracts ▪ Operational efficiency ▪ Strengthened IoT networks
SDGs	**7.** Affordable and Clean Energy (incl. 7.1, 7.3) **9.** Industry, innovation and infrastructure (incl. 9.1) **11.** Sustainable cities and communities **12.** Responsible consumption and production **13.** Climate action

What makes a grid smart is the technologies that enabled effective communication between utility companies in consumers through installation of sensors, IoT systems, and automation. Making a grid smart offers a number of benefits for utility companies (US DOE, 2018): increased stability of grid, quicker restoration after blackouts, enabled priority of service during emergency events, stronger monitoring of energy infrastructure, and improved grid security, among others. At the same time, a smart grid allows consumers to access information of their electricity consumption in real time through smart meters. Combined with information of dynamic pricing, consumers would be encouraged to reduce consumption during peak time in order to save money. Smart grid systems are already being implemented in some jurisdictions in the US and in the UK, and are at various levels of development in Australia, Brazil, China, the EU, Republic of Korea, and South Africa.

The use of blockchain is not a prerequisite for a smart grid system. However, it can be considered as a more advanced backbone to help utility companies in two ways: improve smart grid security and maintenance, and facilitate smoother electricity trade with independent power producers by using smart contracts.

By supporting smart grid development, blockchain could help improve efficiency of national electricity grids (SDG target 7.3) and contribute to increase access to affordable, reliable and modern energy services for all (target 7.1) including renewable energies. Additionally, reducing the dependency of remote areas on national grids would contribute to enhancing sustainable and resilient infrastructure (target 9.1).

Improved smart grid security and maintenance

Blockchain could strengthen grid management specifically by increasing security of smart grid equipment and improving efficiency of grid maintenance. Regarding security, experts and practitioners highlighted insufficiently secure protocols regulating communication between utilities, smart meters and home appliances and their high exposure to attacks by hackers (dena and ESMT, 2018). If embedded into smart grid metering systems, blockchain could potentially resolve some critical issues in hacking, due to its distributed nature in security protocol. However, the experts also note that the currently available public blockchains needs to be continuously improved in its processing time, energy consumption intensity, and compatibility with current smart metering infrastructure.

Blockchain may make smart grid systems maintenance more efficient by automatically diagnosing network emergencies and problems through monitoring of grid equipment and reconfiguring the reaction to them (Basden and Cottrell, 2017). In 2017, the first pilot project of using decentralised networked home energy storage systems and blockchain technology to stabilise the power grid formally kicked off in Germany by TenneT and sonnen (TenneT, 2018). This project focuses on stabilising a complex grid service, taking advantage of sonnen's existing network of distributed home solar power producers (see section 5.6).

In the case of Brooklyn microgrid, Siemens as the grid manager could ensure that users receive original replacement parts requested, because the system can seamlessly retrace a part's journey. This is due to the use of blockchain integrated with LO3 transactive energy platform, which created a decentralised and Web-based bookkeeping system, which saves data in a way that is inexpensive and forgery-proof (Siemens, 2018).

Another company called Grid Singularity aims to develop a decentralised energy data management and exchange platform. This platform will enable regulators, operators, investors, traders and consumers to collaborate efficiently on smart grids. The Austrian company targets developing countries to offer them a pay-as-you-go solar energy system and use blockchain to authenticate energy transactions. Samsung and IBM are also working on blockchain solutions for smart grids. Their platform ADEPT, which uses smart contracts on Ethereum can be used to decentralise an IoT network, enabling micro transactions between smart appliances on a smart grid.

Smoother electricity trade

Current grid management systems can generate datasets of electricity generated from different sources by connected power plants, which are used for purchase power agreements. However, the way these datasets are processed in the system is currently inefficient and vulnerable to both error and loss. According to Orcutt (2017a), the electricity generation datasets are sent from renewable power plant to a second party of registry provider, whom enters them into a new system and creates a certificate. Then, third party intermediaries brokers deals between buyers and sellers of these certificates, and a fourth party finally verifies the certificates after they are purchased. Combined with decision-making time, this long flow of transactions takes time and cost, which could make renewable energy and power purchase agreements less attractive to investors.

If blockchain are embedded in a smart grid system, datasets can be directly recorded on the blockchain, converted digitally to a certificate under pre-determined criteria using smart contracts, and depending on the overarching policy, can be directly verified for sales and purchase in a secured manner. The Japanese company TEPCO invested in Conjoule GmbH, a start-up company developing blockchain-based peer-to-peer energy markets in German cities (Williams, 2017), recognising its potential impact on energy industry transformation. In Estonia, an independent electricity and gas system operator Elering AS and a blockchain-based green energy trading platform WePower announced a pilot project to test a large-scale blockchain project to create energy tokens in Estonia (Prisco, 2018).

Blockchain technology will continue to redefine the energy industry, and it will no doubt continue to grow in countries where technology start-ups thrive and home solar panels have gathered popularity: Australia, Austria, Finland, Sweden, and the United States (EDF, 2017; AGL, 2017). The German utility company RWE has already started testing a blockchain system for its business in electric vehicles charging while Austria's Wien Energie is testing the technology on international gas trading.

5.6 Renewable energy

Sustainability Summary	
Sustainability implications	▪ Mainstreamed renewable energy generation by household and commercial facilities due to increased market incentives for peer-to-peer energy trading ▪ Wider dissemination of renewable energy technologies ▪ Change in consumption behaviour due to access to real-time electricity consumption data
Blockchain functionalities	▪ Cryptocurrency ▪ Peer-to-peer transactions ▪ Strengthened IoT networks
SDGs	**7.** Affordable and Clean Energy (incl. 7.1, 7.2) **9.** Industry, innovation and infrastructure (incl. 9.4) **12.** Responsible consumption and production (incl. 12.2) **13.** Climate action

Decarbonisation of the global energy system is required for a sustainable future (Institute for Global Environmental Strategies, 2018). Not only utility companies, but citizens, households and businesses are increasingly more aware of the sustainability of their energy use.

Peer-to-peer renewable electricity trading

As the use of solar panels is mainstreaming in the world, the upcoming trend will be to manage distributed grids through peer-to-peer electricity trading sourced from renewable energies. Similarly to smart grids (see section 5.5), blockchain is not a prerequisite to operating a peer-to-peer electricity trading system. A network of 'smart meters' (advanced electricity meters equipped with other types of software and systems that can measure and record electricity generation in real-time) and a central software that monitors supply and demand from all network members can be sufficient to record electricity flow between grid-connected households. Among others, sonnen in Germany is operating a system built from a household network using solar batteries (Colthorpe, 2015) while Piclo in the United Kingdom targets businesses to help them align with marketing campaigns, increase brand values, and meet sustainability goals by using renewable energy.

Nevertheless, blockchain can unlock the potential of a peer-to-peer electricity trading system in three ways: equipping it with a decentralised, fast, real-time, lower cost metering and billing system (PwC, 2016); providing economic incentive for being an electricity producer (and seller if desired); and generating a blockchain of data related to solar energy. Households will have the freedom of buying electricity from their preferred sources at a desired price and have the energy flow recorded in the blockchain. Electricity retailers can benefit from diversification of energy sources, still be able to shift peak load, and can have emergency supplies. Both households and retailers will benefit from operational cost savings as trade activities will be automated and controlled by households using smart contracts.

These benefits can help create a sharing economy network, contributing to efficient use of natural resources (SDG target 12.2). Peer-to-peer electricity trading using blockchain can notably enable wider access to energy (target 7.1), increase the share of renewable energy in the global energy mix (target 7.2), and help strengthen distributed grids anywhere in the world. Peer-to-peer networks could also facilitate the greater adoption of clean and environmentally sound technologies by industries (target 9.4) by increasing the offer of decentralised energy generation sources.

Peer-to-peer electricity trade networks have been running in a number of countries (including Australia, Germany, the Netherlands, the United Kingdom, and the United States) in the last five years, where they are managed by private companies. Among these networks, there are working examples of blockchain-based trades, such as in Brooklyn, New York, United States (Rutkin, 2016; Siemens, 2018), Allgau, Germany (LO3 Energy, 2018), and soon, Kyushu, Japan (CleanTechnica, 2018).

Solar tokens for renewable energy research and innovation

Blockchain is also being used to create crypto-tokens that can incentivise data sharing for renewable energy research and innovation. The SolarCoin initiative, for example, incentivises solar power generation by offering SolarCoin tokens to solar power producers, regardless of their location. One SolarCoin, equivalent to one megawatt-hour (MWh) of electricity from solar energy, is awarded to any interested solar electricity producer who can then convert them into hard cash. SolarCoin is affiliated with an open data initiative, called ElectriCChain, which collects non-confidential data from solar panel owners in the SolarCoin network through its public blockchain system. Those technical data will be useful to inform climate and meteorological analysis (Dabbs, 2017) as well as further development of home solar panel technologies.

In the future, operation of a fully independent peer-to-peer electricity trading network may require households to acquire a licence as well as operating a user-friendly blockchain-based IT system to fully perform as electricity prosumers. In particular, a fully independent system requires households to play a role in metering and electricity balance clearing to be able to trade by themselves. As these will present significant financial, technical, and organisational challenges for households, in the beginning of peer-to-peer electricity trading system those roles can be managed by the grid manager, as is the current practice in the sonnenCommunity in Germany.

5.7 Philanthropy

While philanthropy is playing a crucial role in alleviating poverty and helping critically vulnerable populations, the lack of transparency regarding the destination of funds is a major obstacle to an increase in the amount of donations. Although cases of misappropriation of donated funds by local governments or humanitarian organisations themselves remain a minority, the opacity of the donation process diminishes trust in charitable organisations and garners skepticism on the effectiveness of donations, in spite of good intentions (Keys, 2017). By providing a much needed transparency on the destination and use of funds, blockchain could revamp the field of philanthropy and enable an increased volume of donations.

Sustainability Summary	
Sustainability implications	▪ Direct and secured fundraising platforms enabling larger donations. ▪ Transparent donation systems, leading to a wider pool of potential donors due to increased confidence in the destination and use of funds.
Blockchain functionalities	▪ Peer-to-peer transactions ▪ Data accountability ▪ Fraud prevention
SDGs	**1.** No poverty (incl. 1.A, 1.1) **2.** Zero hunger (incl. 2.A, 2.1, 2.2) **3.** Good health and well-being (incl. 3.B, 3.3, 3.4) **4.** Quality education (incl. 4.A, 4.1) **6.** Clean water and sanitation (incl. 6.A, 6.1, 6.2) **10.** Reduced inequalities (incl. 10.B) **13.** Climate action (incl. 13.A) **17.** Partnerships for the Goals (incl. 17.3)

Direct fundraising

Blockchain could transform the field of philanthropy by creating new fundraising methods for charities. There are currently many intermediaries between donors and beneficiaries, such as banks, lawyers, NGOs and government agencies. The technology could disintermediate the transfer of money in the donation process.

According to the Charities Aid Foundation (CAF), a more direct and secure payment route for donors could not only increase the financial amount that the beneficiaries receive, it could also convince more people to donate (Davies, 2015). Blockchain could also facilitate the registration of charitable organisations, by removing the need for regulators and third-party verifications (Davies, 2016)[34]. Smart contracts could even prevent charities from spending money on activities that do not comply with their charitable purpose.

Secured and direct fundraising methods with blockchain would help with the mobilisation of additional financial resources for developing countries from multiple sources (SDG target 17.3). This could serve as a way to increase official development assistance and financial flows through co-financing (target 10.B), and to implement the pledge by developed countries to mobilise jointly USD 100 billion annually by 2020 to help developing countries' climate action (target 13.A).

New donation channels would present substantial benefits for the many fields that receive donations. For instance, they could help diversifying the sources of finance mobilised for development (SDG target 1.A), contributing to eradicate extreme poverty (target 1.1). The technology could also lead to increased investments for agriculture in developing countries (target 2.A), which could help combatting hunger and malnutrition (targets 2.1 and 2.2). In the health sector, donations facilitated by blockchain could enhance access to affordable essential medicines and vaccines (target 3.B), contributing to decrease the number of deaths related to communicable and non-communicable diseases (targets 3.3 and 3.4). Moreover, financial support for water and sanitation programmes could be boosted as well (target 6.A), which could serve to achieve universal access to safe drinking water (target 6.1) and hygiene (target 6.2). Lastly, blockchain-based donation platforms could help directing donations towards building and upgrading safe educational facilities (target 4.A), which would ensure children's primary and secondary education (target 4.1).

Decentralised donation platforms

However, the real benefit of the blockchain for philanthropy in terms of fundraising is not as much its disintermediation potential as its decentralisation potential (Davies, 2017). There is already a growing number of direct donation platforms, which allow donors to donate or lend money directly to individuals or organisations, such as GiveDirectly and Kiva, but their scope remains limited. Blockchain technology could allow to develop direct philanthropy platforms on a much wider scale, notably with the use of DAOs.

There are a few initiatives regarding the blockchain technology for charitable purposes. For instance, BitGive is the first organisation using Bitcoin for charitable donations. BitGive's flagship product, BitTrack, guarantees the transparency and trustworthiness of donations through asset tracking. Similarly, Disberse is a financial operating network for global development, built on blockchain technology. It can be used to transfer funds directly between parties for any development and humanitarian project, reducing transaction costs. Benefactory and WeiFund are also blockchain-based crowdfunding philanthropy platforms. The United Nations' World Food Programme (2017) announced that it is going to use Ethereum to make cash-based transfers for humanitarian aid faster, cheaper and more secure.

In the forestry sector, the Rainforest Foundation started accepting donations in cryptocurrencies such as BitSeeds in order to protect the rainforest and stop illegal logging. For every BitSeed created, BitSeeds, in partnership with the Rainforest Foundation, aims to plant one actual seed, with the long-term goal of planting and then protecting over 1 billion trees. Similarly, Gain Forest has built a blockchain-based payment system that transfers money directly from donors to caretakers of the Amazon forest. Its website also allows donors to pledge their money to a specific area of forest, and allows them to track the status of this area through satellite data.

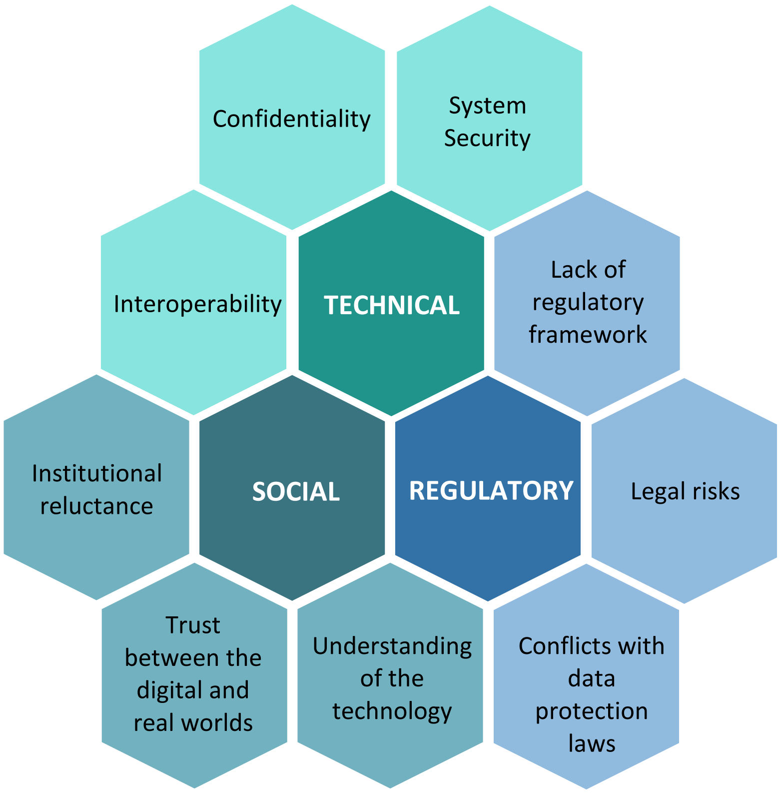
[34] Reporting from charities could also be made easier due to the increased transparency of blockchain, which could allow donors and third parties to verify how the organisation is spending its funding in real time. Additionally, enforcement could be made more efficient for regulators through blockchain-based early warning systems detecting irregularities.

6. Blockchain Adoption Challenges

In spite of the many potential applications observed in previous sections, blockchain faces many adoption challenges, as is the case with any new technology. It is just emerging from a nascent phase where a high number of early visionaries and innovative market entrants are faced with a high risk of failure. As it moves progressively into a more mature phase, blockchain will likely address most of its issues and gain more market focus.

Since, as seen above, the technology is poised to cause disruptions to most sectors of the economy, blockchain faces many different challenges. Those challenges can be classified in three groups, namely technical challenges, regulatory challenges and social challenges (see Figure 14).

Figure 14: Main challenges to blockchain adoption



According to Hileman and Rauchs (2017), the biggest challenge to blockchain adoption is the lack of regulatory framework, followed by confidentiality issues and institutional reluctance. Other challenges assessed in the same survey include technology immaturity, difficulty to build a business network, potential conflicts with data protection laws, and performance concerns. Another survey conducted by EY (2018a) broadly confirms these findings, with 61% of respondents seeing regulatory complexity as the biggest barrier to widespread blockchain adoption, followed by integration with legacy technology (51%) and a lack of general understanding of blockchain's capabilities (49%).

6.1 Technical challenges

Although blockchain presents many technological advances compared with most of the processes and solutions used in the sectors mentioned in this report, no technology is ever perfect and some technical issues remain, such as transaction speed and energy consumption, system security, confidentiality, relevance and interoperability.

Transaction speed and energy consumption

For instance, the speed of transactions is still slow compared with some current digital databases, such as the transactions validated in milliseconds in the advertising sector (see Section 3.3). Due to the need for transactions to be verified by miners, blockchain is estimated to handle on average only seven transactions per second, which is slower compared with 2000 for the Visa network (Huston, 2017). Another issue that is often raised is energy consumption. Recent reports show that Bitcoin mining consumes 33 TWh per year, which is the same as the annual electricity consumption of Denmark (Digiconomist, 2017)[35].

However, this assessment is typically confusing Bitcoin mining with blockchain technology (Carson et al., 2018). Indeed, this high level of energy intensity is likely to be specific to Bitcoin, which, as the first blockchain, suffers from structural inefficiencies in its mining process. Other cryptocurrencies and token mining are much more energy-efficient. For instance, the blockchain on which SolarCoin is based, consumes less than 0.001% of the power of bitcoin when compared on a similar scale (SolarCoin, 2018).

The misconception that blockchain is not viable at scale due to its energy consumption and transaction speed is a conflation of Bitcoin with blockchain.
Carson et al. (McKinsey, 2018)

System security

While it is often assumed that blockchain provides a perfect security by design, no security technique is foolproof, and decentralised ledgers need to be cyber-protected, as with any other technological system. Cryptography may make a database more difficult to hack, but it could still be compromised by cyber-attacks. With the potential to store so much data and process so many transactions in various fields, securing blockchain-based platforms seems to be a priority in order to pave the way for mass adoption of the technology[36].

It is important to remember that blockchain is still a new technology and therefore is continuously improving. Several examples seem to indicate some progress in improving blockchain security. For instance, the Bank of England (2018) released a Proof-of-Concept paper, which investigates how to configure a distributed ledger system to maintain privacy between participants, share data across the network, and enable a regulatory body to control transactions. The Bank of America also filed a patent application to the US Patent and Trademark Office (2018) for a patent on a blockchain-based storage system with automated data authentication.

Confidentiality

Confidentiality is also often cited as a major cause for concern regarding the use of blockchain. While the perspective to increase transparency in many areas provides great benefits, it also poses major risks regarding sensitive information. Private companies could for instance risk losing proprietary information or trade secrets,

[35] With a monthly energy consumption growth of 25%, by 2020 Bitcoin mining could be consuming the same amount of electricity every year as is currently used by the entire world (Jezard, 2017). Commentators even claim that cryptocurrencies could cost humanity its low-carbon future (Holthaus, 2017).

[36] Many options exist to ensure such protection. In its report, the Chief Scientific Adviser of the UK government recommends that if mobile devices are used to operate the system (such as for product tracking or peer-to-peer transactions), credentials and private keys should not be made visible to other applications. Additionally, ledgers should be operated through a wide network of servers to allow for resilience against network outages, and should be allowed to be taken offline if a serious network attack is suspected (Walport, 2016).

individuals could risk privacy violations and governments could risk leakage of classified data. However, confidentiality features are an adjustable parameter of blockchain systems[37].

According to the aforementioned study by Hileman and Rauchs (2017), the most widely used privacy-enhancing technique are the encryption of on-chain data (71%), and the use of pseudonymous addresses (63%) with key randomisation. Such techniques are actually rather basic, and advanced techniques such as confidential transactions, ring signatures, and zero-knowledge proofs are currently limited but on the roadmap of most blockchain developers (57%). Confidentiality is also widely safeguarded by limiting the data disclosure to specific parties, with 44% of study participants using multi-channel data diffusion models.

Not a "one size fits all" solution

Although branded as a major disruptor in many sectors, as shown throughout the course of this paper, one of the blockchain limitations is that it might not be the perfect technological solution for all situations. Many sectors could solve their specific issues through other advanced technologies such as AI, IoT, ERP systems augmented by cognitive tools, automation etc. There are many alternatives to the use of blockchain, which requires a certain capacity and investment that not all actors might have. Blockchain becomes the best solution mainly when the benefits that it provides (automation, transparency, reliability, speed etc.) are not available through other technologies (Deloitte, 2018). Not all systems that are currently 'centralised' will benefit from being 'decentralised', such as databases with sensitive data, not all systems can sustain connectivity to the internet, among others. When making the decision of whether to use a blockchain system or not, these trade-offs should be taken into account (Wüst and Gervais, 2017).

Blockchain starts to enjoy unique advantages when the network of trading partners reaches a level of complexity or scale that is difficult for today's tools to manage
Deloitte (2018)

Interoperability

The last widely cited technical challenge to blockchain adoption is its interoperability between different blockchain platforms, as well as between blockchain and legacy enterprise systems.[38] Interoperability will likely be a priority in the near future for blockchain developers, as it will be a key enabler for the mass adoption of the technology. Hileman and Rauchs (2017) show that while 70% of blockchain frameworks claim to be interoperable with other blockchain networks, this is mainly limited to the Ethereum and Bitcoin blockchains. While Ethereum is currently the largest blockchain in the world, many new ones are likely to emerge in the future, increasing the difficulty and the importance of interoperability. However, according to the same study, two-thirds of surveyed participants are members of at least one blockchain-based consortium or initiative, which can be interpreted as a first step towards mass interoperability.

[37] First, by default blockchain can be permissioned (see Section 1.1), which is likely to be the model used for commercial applications. Second, as mentioned above, the security of blockchain platforms is likely to increase in the future and therefore stored data and transactions will be more secure. Third, most blockchain applications do not require a full disclosure, so sensitive information can be hidden while fulfilling the goal of the platform.

[38] Indeed, while blockchain is often mentioned as "the blockchain", it concretely refers to a wide array of DLT solutions (see Section 1.1). Those different blockchains might not be compatible between each other and this poses a potential risk for parties that need to exchange data. Another issue concerns the compatibility between blockchain platforms and existing enterprise systems. The difficulty for companies to switch from their existing platforms to a blockchain-based one is a major hindrance to blockchain adoption, in spite of its potential benefits.

6.2 Regulatory challenges

Regulatory uncertainty poses a major barrier for even the most enthusiastic actors willing to adopt the technology. Without a clear idea of what will be permitted and restricted in the future, the use of blockchain will present some risk that many entities will not be willing to take, preferring to wait for early movers in countries that first offer blockchain regulations.

Lack of digital regulations

Classified by the majority of surveys as the greatest obstacle to blockchain adoption, the lack of regulatory frameworks can be seen as the natural barrier to a technology that, at its core, transcends artificial borders and national jurisdictions[39]. Blockchain technology provides decentralised value storage and transfer on top of access to information. This decentralised nature of the technology makes it even more difficult for traditional authorities to contain. Nonetheless, governments trying to regulate blockchain solutions are likely to face similar hurdles as they do when regulating the Internet, and therefore, future blockchain regulations could learn from the lessons of Internet regulations.

As put by the UK Parliamentary Office of Science and Technology (2001), "laws apply online in the same way as they do offline, but the international nature of the internet takes much of such content outside national jurisdiction. Although this makes policing content difficult, it also makes the internet a powerful tool for freedom of speech." The situation is similar with blockchain technology, with accrued challenges and potential freedom.

Compliance with data protection laws

Interestingly, the recent global interest in blockchain comes at a pivotal time in the history of the digital regulations. As scandals such as the Cambridge Analytica data episode revealed, the importance of privacy is increasingly acknowledged and the practice by IT companies of using personal data for commercial purposes is increasingly scrutinised. As a response, countries are adopting stricter data privacy regulations such as the EU's General Data Protection Regulation (GDPR).

There is a global call to regulate the digital world, which needs some limits to avoid abuse, in the same way that the financial industry or food processing industry are regulated (Foer, 2018). In the future, more data privacy regulations are expected to be adopted in other jurisdictions, notably in the United States. Therefore, the issue of compliance with incoming data protection laws will be critical for the successful adoption of blockchain.

Regulations might oblige blockchain service providers to set only permissioned blockchains when personal or sensitive is recorded on them. The GDPR's rules might also entail a mandatory option to modify or erase data once recorded, as a way to make the immutability of the technology comply with data subject's rights (UK House of Lords, 2017). The issue of dispute resolution might also need to be addressed. Since transactions on the blockchain can happen across borders without intermediaries, a dispute resolution framework will have to be put in place to know the jurisdiction from where legal rules will apply.

[39] The Internet is already known to be extremely difficult to regulate for as it is being a digital free space of information. Major challenges include notably the fact that the digital world evolves much faster than regulations, and that the cross-border nature of the Internet requires a global regulatory response (Samuelson, 2000). However, as the Internet is centrally managed by a handful of software companies, it is still possible for national governments to take some regulatory measures.

Regulatory options

Another major complexity when it comes to blockchain is to know which legal framework it will be subject to[40]. This confusion surrounding its applicable legal framework needs to be resolved to pave the way for mass blockchain adoption. The most efficient method envisaged to regulate a decentralised ledger system is to have direct regulations on the parameters of the codes on which the technology relies (Lessig, 2006). Experts are currently envisaging two methods for this, either through a legal code or a technical code.

The legal code approach, while the most regulator-friendly, faces major challenges due to the lack of a central legal entity. Therefore, a technical code might be the most realistic option in the short term, while a good mix of both types of regulatory codes will need to be reached in the future (Walport, 2016). Some initiatives are also trying to resolve these legal challenges, such as the Global Legal Blockchain Consortium (GLBC), a group of 40 companies, law firms, software companies, and universities that are developing standards to govern the use of blockchain technology in the business of law.

Policy dialogues

Regulatory challenges will best be addressed through dialogue between policymakers and blockchain experts. As conveyed in this report, there are many advantages to blockchain that can help implementation of policies and law enforcement as well as making policymakers' work more effective, cost-efficient, and resilient to risks. Policy dialogues can focus on differentiating cryptocurrencies and other blockchain technology applications, specific needs in standards that will not hamper but will help blockchain thrive in an ethical and sustainable way, and cybersecurity issues that blockchain technologies can help with.

One example to facilitate such dialogue is the Climate Chain Coalition, which aims to help enhancing the environmental integrity of DLT applications and other digital solutions designed for climate change issues, and to collaborate with related entities for establishment of basic standards and mitigation of fraudulent activities. As the Coalition continues to grow (as of April 2018, 56 organisations have joined) and be welcomed by the UNFCCC, its activities may lead efforts towards the realisation of a global digital governance.

6.3 Social challenges

Perhaps the most underestimated obstacle to blockchain adoption are social challenges, which are likely to make their grand entrance into the public debate very soon. As with every disruptive technology, the general public needs to learn about it, and get used to its mainstreamed applications in daily life. Public institutions and companies also need to get past experimental trials and capture the business and public service opportunities behind the technology. Additionally, it should be noted that while blockchain is sometimes branded as a "source of trust", the immutability offered by cryptography concerns the ledger system, not the data itself. Therefore, trust and intermediaries are still needed at the data-inputting phase.

Understanding blockchain

Any new technology involves a learning curve in order to assimilate and democratise it. With complex technologies such as blockchain, the curve is particularly steep. In spite of its many potential applications and

[40] As seen above, blockchain will certainly be subject to the same data privacy regulations as the Internet, since the technology allows for the exchange of data in a transparent way. However, blockchain also enables to the processing of transactions (some of which through cryptocurrencies), so it might be subject to finance and tax laws. Additionally, the technology can serve as a platform for the enforcement of smart contracts, and thus could also be subject to laws regarding civil contracts and personal liability.

benefits, the concept of a cryptographically-secured decentralised ledger complemented by smart contracts is likely not easily understandable by most people. On top of this, due to the recent global interest in the technology, many so-called ''experts'' are actually not IT professionals with the necessary qualifications to properly explain the characteristics and benefits of blockchain.

This lack of general understanding of blockchain also translates into a lack of expertise available. As a consequence, although this surge in information-sharing is a positive development, there are many misconceptions and errors being spread regarding blockchain, notably on the Internet, which is counter-productive for blockchain education[41]. The limited availability of qualified blockchain experts also naturally means that company executives and public officials do not have the necessary knowledge to fully understand the technology and its potential. A survey by PwC found that 86% of financial services executives indicate that they have not yet developed necessary blockchain skills (Smith, 2018). However, as the number of academic courses and specialisations related to blockchain is noticeably increasing in recent years, more experts might emerge in the short term. For the public, a good understanding of the technology might be achieved later.

Institutional reluctances

Blockchain is a technology that can potentially bring the power of information back to the people who own it. By sharing data in a transparent way and reducing the need for intermediaries, blockchain can empower actors that were previously in a vulnerable position compared with centralised entities. Therefore, those entities might show a certain reluctance to relinquish this power to the benefit of automated computer code and the people behind the data. Additionally, other entities might recognise the benefits of the technology but be reluctant to undertake the process to change the status quo.

The study from Hileman and Rauchs (2017) shows that reluctance to change established processes ranks third among the list of eleven blockchain adoption challenges, while the reluctance to relinquish control comes in at eight place. This means that institutions are currently more reluctant to change their established processes and business models than they are to relinquish their power over data. However, this finding might very well change in the future once more concrete applications of blockchain have emerged, and entities realise the full impact of blockchain on the balance of power between actors[42].

The fabric of trust between blockchain and the real world

One of the most common misconceptions regarding blockchain is that it is a "machine of truth". The cryptographic encryption of blocks ensures that any data recorded on blockchain cannot be altered without modifying all the other data to which its block is connected to. While not a cyber-protection in itself, this system allows easy detection of any data tampering, since the whole ledger needs to be hacked in order to change a single entry (see Section 1.4). However, this does not mean that blockchain guarantees the veracity or accuracy of the data recorded in it. What the technology does is to provide a decentralised and tamper-proof record of the data or transactions. Therefore, as with any other database, it requires participants to trust

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[41] It is important for interested governments, enterprises, and individuals to refer to resources from appropriate industrial developers and relevant industry of application when looking for technical information. This paper provides a rich list of such references.

[42] There have already been already a few blockchain projects being cancelled due to the sudden realisation of the political implications of relinquishing control over data, such as in the land titling sector (see Section 4.4). This sort of developments might happen more frequently in the future, thus in the short term blockchain adoption might need to rely on the political support from citizens' groups, NGOs, small political parties and business associations.

the party who provides the data. A trusted third party is thus still required to conduct data verifications in order to guarantee the integrity of the link between the digital record and the real world (Deloitte, 2017a)[43].

At the interface between the offline world and its digital representation, the usefulness of the technology still critically depends on trusted intermediaries to effectively bridge the "last mile" between a digital record and a physical individual, business, device, or event.
Tucker and Catalini (2018)

Rather than eliminating the need for trust, the real benefit of blockchain is to confine the need for trust to the real world, by ensuring the immutability of the digital world. Even with the help of blockchain, the relationship between digital and physical records will remain difficult to prove. Participants could very well record false or inaccurate data on decentralised ledgers, whether intentionally or not, and the technology would not be able to recognise it. For instance, regarding fraud, farmers spraying pesticides on their crops could still register their agricultural products as organic, or a corrupt government could count election votes on blockchain and still register more votes to the ruling party (Stinchcombe, 2018). Regarding errors, hospitals could record newborns on blockchain, and the person recording the data could still make a mistake in assigning a digital identity to the right physical baby (Tucker and Catalini, 2018).

The core, transformative feature of this technology is that it confronts the deep human challenge of how to intermediate trust and incentivize collective action.
Casey (2017)

The task of ensuring the veracity of data in blockchain will remain the responsibility of participants. Aside from traditional third party verifiers and auditors, specialised service providers are likely to emerge in the future to respond to this need. Artificial intelligence might also help in verifying the accuracy of data before it is recorded on blockchain. Third parties could use oracles, which are software entities that store data or perform calculations to verify data, before passing it to a smart contract (Vian, 2016).

Of course, in spite of the immutability of data once it is recorded on blockchain, the remaining issue is to know whether users will trust the technology itself. However, the decentralised nature of blockchain might gain more trust than current centralised solutions. According to Edelman Trust Barometer 2017, people in around a third (10 out of 28) of the countries surveyed reported trusting blockchain technology more than cloud technology. While DLT systems address many trust issues, they do not remove the need for strong governance and correct implementation.

[43] The point of contact between data and reality might be the greatest limit of blockchain. Nonetheless, it is important to keep in mind that, as efficient as it is, blockchain is but a tool, and it does not miraculously eliminate the necessity of basic human interactions. Blockchain is a revolutionary database because of its decentralised and encrypted nature, but it remains a database.

7. Blockchain, a Tool for a Sustainable Future?

7.1 Blockchain implications for the SDGs

Most discussions and news regarding blockchain pertain to the technology's economic impact. Yet by changing the way organisations record and share data, blockchain holds the potential to contribute to the realisation of the SDGs. The analysis of blockchain applications throughout previous sections has revealed the various SDG impacts that the technology might have across the financial, business and public sectors, as well as the climate change and sustainable societies sectors (the latter is referred solely as "climate" in this section). The connections between blockchain applications in these four sectors and the SDGs has been summarised in Table 2 below (similarly, refer to Figure 1 in the Executive Summary for the mapping of the same data)[44].

Table 2: Number of SDG-related blockchain applications identified in this paper

SDGs	Number of blockchain applications				
	Finance	Business	Public	Climate	Total
SDG 1: No Poverty	1	2	1	1	5
SDG 2: Zero Hunger	1	0	1	2	4
SDG 3: Good Health and Well-being	0	2	2	2	6
SDG 4: Quality Education	0	0	0	1	1
SDG 5: Gender Equality	1	1	2	0	4
SDG 6: Clean Water and Sanitation	0	0	0	1	1
SDG 7: Affordable and Clean Energy	0	0	0	3	3
SDG 8: Decent Work and Economic Growth	4	6	2	1	13
SDG 9: Industry, Innovation and Infrastructure	5	4	0	3	12
SDG 10: Reduced Inequalities	3	4	5	2	14
SDG 11: Sustainable Cities and Communities	0	0	3	4	7
SDG 12: Responsible Consumption & Production	0	1	0	5	6
SDG 13: Climate Action	0	0	0	6	6
SDG 14: Life Below Water	0	0	0	1	1
SDG 15: Life on Land	0	0	1	1	2
SDG 16: Peace, Justice and Strong Institutions	2	1	5	1	9
SDG 17: Partnerships for the Goals	0	0	3	3	6
Total	17	21	25	37	100

Comprehensive and complementary SDG coverage

The first observation that can be made from this SDG mapping is that all 17 SDGs will be potentially impacted by the use of blockchain. Although some SDGs will be more impacted that others, none of them is left out. If used in the right way, the technology could contribute to the creation of sustainable societies by promoting transparency and accountability in all sectors of the economy.

Another observation is that while no sector has strong connections to all SDGs, the SDG coverage of the four sectors is quite complementary. Indeed, taken all together, the evaluated blockchain applications in the four sectors bear a strong connection to 11 of the 17 SDGs. Additionally, it can be noted that the SDG coverage of blockchain usage in the private sector (finance and business) seems to be more focused than in the public and climate sectors. Indeed, SDG connections mostly overlap for finance and business, focusing notably on SDGs

[44] The SDG assessment below is based on the concrete blockchain applications studied in this paper, and does not represent a general evaluation or prediction of the relationship between blockchain and SDGs. However, such current and upcoming use cases of blockchain provide an indication on the potential of blockchain to provide a positive influence to the realisation of SDGs. It should also be noted that the Figure 1 is based the data contained is this table, but not in a strict way. Values in Figure 1 have been adjusted to facilitate visualisation and avoid an excess of data overlap.

8, 9 and 10. On the contrary, blockchain applications in the two other sectors are more versatile, reaching various SDGs such as SDGs 7, 11, 12, 13 and 16.

Quality over quantity of relationships with SDGs

Given the speed of technology adoption by the financial and business sectors, it is not a surprise that the private sector is found to have more potential blockchain applications (11) than the public sector (5). Yet, this does not mean that the technology will have a deeper impact on the realisation of SDGs in one sector than in the other. First, the public sector has been historically slower than the private sector to embrace technological disruptions. Given governments' responsibility of maintaining public services operations across entire jurisdictions, it seems only natural that blockchain adoption should be carefully planned.

Second, blockchain applications in the public sector impact noticeably more SDGs per application than in the private sector. This makes sense considering the fact that the public sector provides fundamental services that form the foundation of economic performance. For instance, better access to healthcare can have indirect impacts on a country's economic productivity, and blockchain-based elections could change its entire political regime. Overall, it can be said that positive SDG impacts in the public sector will indirectly impact further SDGs through the influence they have on the private sector by a cascade effect. This tendency has been observed in the past with the initial penetration of various information technologies, from the use of e-mails, digital signatures, registration in public facilities (governmental offices, hospitals, etc.), public service applications, to social media.

Peer-to-peer models complementing the traditional role of institutions

Some SDGs that are traditionally considered to be the responsibility of governments, such as SDGs 1 (no poverty), 2 (zero hunger) and 3 (good health and well-being) are found to be strongly related to blockchain applications in the private sector. The reason behind this is that blockchain enables many peer-to-peer models, in sectors that traditionally relied on corporate intermediaries. This is the case for instance of peer-to-peer lending, credit scoring, data storage, supply chain data exchange, insurance, carbon and electricity trading.

With its highly decentralised potential, it might be safe to assume that blockchain will facilitate the emergence of new business practices that are centred on and managed by people. This new dynamic may disrupt the traditional lines drawn between the public and private sectors in terms of accomplishment of public services. Many services controlled by companies for profit up until now may become open to more people due to the peer-to-peer sharing applications of the technology.

SDGs 8, 9, 10 and 16 appear to be the most influenced by blockchain applications

The SDGs that are found to be the most impacted by blockchain applications studied in this paper are the SDGs 8 (decent work and economic growth), 9 (industry, innovation and infrastructure), 10 (reduced inequalities) and 16 (peace, justice and strong institutions). The major impacts of blockchain on SDGs 8 and 9 can be explained by the fact that most blockchain applications can improve the economic performance of organisations in each sector. By democratising access to data and analytics, the technology can create more economic opportunities for entrepreneurs, small businesses and freelancers. Additionally, the technology can facilitate economic inclusion, innovation and growth through wider access to essential economic services such as banking and credit, healthcare, insurance, land ownership, energy etc.

Blockchain is also a catalyst for transparency and accountability, which explains its many impacts on SDGs 10 and 16. By empowering small economic actors and vulnerable populations, while giving data access to fragmented segments of the economy, blockchain holds the potential to bring people together and to reduce economic inequalities, as aimed by SDG 10. Blockchain's impact on the SDG 16 is a natural consequence of the transparency and immutability of the technology. By removing the risks of human errors and discriminatory choices, blockchain could improve the fairness of existing processes and facilitating transparent decision-making. This could enhance the accountability of current institutions in both public and private sectors.

SDGs 4, 5, 6, 14 and 15 appear to be less influenced by blockchain applications (for now)

The SDGs listed for blockchain applications in this paper are the ones that bear the strongest and most direct connection to each application of the technology. However, while most applications have only a few direct SDG impacts, they potentially have many more indirect SDG impacts that were not presented here. Indirect impacts are difficult to evaluate and require an in-depth analysis that goes beyond the scope of this study, but it is important to keep in mind the fact that such indirect impacts might provide substantial disruptions in the future. For instance, direct impacts such as financial inclusion, land ownership or access to insurance might indirectly influence SDG 1 on poverty reduction, SDG 2 on zero hunger and SDG 3 on good health and well-being. Similarly, better public services and taxation systems might indirectly impact the SDG 6 on clean water and sanitation, and SDG 4 on quality education.

Additionally, blockchain is still a nascent technology that mainly made its grand entry in the finance and business sectors. Therefore, some sectors might benefit from blockchain solutions in the future that are not referenced in this paper. This is notably the case of applications that could help to improve biodiversity conservation, as targeted by SDG 14 on life below water and SDG 15 regarding life on land. Finally, it can be noted that blockchain could also be used by countries to conduct their annual Voluntary National Reviews (VNR), in order to report their progress on SDG implementation (Hoeiberg, 2017), which might positively influence the realisation of SDGs in the long-term.

On a technical note, the study of the main blockchain functionalities relevant to each application of the technology assessed in this paper reveals further insights. As shown in Table 3 below, the blockchain functionality that appears to be relevant to the highest number of applications is data accountability, followed by operational efficiency and fraud prevention. This assessment, confirming the survey findings from Hileman and Rauchs (2017), can be explained by the fact that blockchain's most immediate benefit lies in its ability to improve the efficiency and integrity of many existing data collection and sharing processes.

Other less cited functionalities comprise data security, peer-to-peer transactions, strengthened IoT networks and (in spite of receiving the bulk of media coverage) cryptocurrency. The reason why these functionalities are not categorised as the most relevant to most blockchain applications is because they tend to pertain to new economic applications. Indeed, blockchain is likely to improve existing economic processes before facilitating the deployment of new applications, which need time to mature. Cryptocurrencies, peer-to-peer transactions and strengthened IoT networks in particular depend on the growth of new markets or the success of new disintermediated economic models. Additionally, although smart contracts and data security are an important element of the technology, they are less likely to be ranked as the main benefit of using blockchain.

Table 3: Number of blockchain features identified as most relevant in each sector

	Sector				
Blockchain functionalities	Finance	Business	Public	Climate	Total
Cryptocurrency	2	0	0	2	4
Smart contracts	2	4	0	2	8
Peer-to-peer transactions	1	1	1	4	7
Data accountability	3	4	5	4	16
Data security	1	2	3	1	7
Fraud prevention	1	3	5	2	11
Operational efficiency	5	3	2	2	12
Strengthened IoT networks	0	1	0	4	5

7.2 Blockchain's ethical crossroads

As seen throughout this paper, blockchain holds the potential to deeply impact both public and private sectors as long as the technical, regulatory and social challenges of the technology are addressed. It can even provide many benefits for sustainable societies and contribute to the realisation of the SDGs. However, by nature blockchain is not specifically designed for good. It is ethically neutral, like any tool, and its impact on the world depends on the use that is made of it by human beings. That is why it is important to bring the question of technology ethics to the public debate: how can major technological breakthroughs such as blockchain serve the common good?

From an Internet of information to an Internet of value

The Internet has democratised access to information and laid down the foundations of the digital age. At the same time, it has allowed an unprecedented amount of data about people and organisations to be freely created, shared and collected. This availability of information has led to the privatisation of data, with a few centralised collectors such as Google and Facebook providing a free service to users while harnessing and selling their data to advertisers. Although a few open source initiatives have existed for a long time, such as Wikipedia, those examples have remained marginal.

However, this centralised model, in which the power of Internet users is limited to a ''take it or leave it'' approach, is coming under the public spotlight in recent years. With a surge in data privacy, data leakage and hacks scandals, the world is increasingly becoming aware of the value of personal data. Blockchain technology represents an opportunity to improve the way in which our economy works. More importantly, it could also ensure that private data is not exploited for the sole profit of third parties, but rather used for solving global issues, such as climate change or poverty. Being a vast open source platform, blockchain could become an enabling factor in the shift from an Internet of information to an Internet of value (Gutterman, 2017).

> *Whereas the Internet revolutionised the way information is exchanged, blockchain is transforming the way we exchange value.*
> *PwC (2017)*

By decentralising the way data is stored and shared, blockchain could equilibrate the balance of power in the digital arena in favour of the owners of the data. However, the vast automation potential of the technology also poses some risks. An Internet where users share data on a decentralised open source database, which automatically determines actions through smart contracts, raises ethical questions. The current system of data storage and sharing through centralised platforms might be vulnerable to errors and frauds, but it follows rules set up by people. The question is how to ensure that the automated systems created by smart contracts' algorithms can take into account human values such as democracy or human rights.

The risk of blockchain dystopia

In spite of its potential for realising good purposes such as the SDGs or the Internet of value, blockchain also carries risks of being used for various evil purposes. This "blockchain dystopia" refers to the Red Queen hypothesis, by which criminals learn to use the technology for their harmful purposes (Blockchain for Good, 2016). The main danger is that the structural pseudonymity of blockchain could be leveraged to conduct illegal activities in complete anonymity. Law enforcement authorities would face increased difficulties if criminals, on top of hiding behind digital platforms, were protected by cryptography and decentralisation. Second, even while trying to achieve noble purposes, blockchain applications could end up monetising good intentions[45]. Additionally, even when participants are genuinely moved by selfless motivations, they are still vulnerable to blockchain-based green washing and pyramid schemes, such as what happened with Conservation Central Network's Little Green Tokens (Lang, 2015).

> *The blockchain reflects the idea expressed by Hobbes of a totalitarian sovereign in terms of rule-enforcement, coupled with Rousseau's idea of decentralised governance and Rawls's idea of equal rights and liberties for all.*
> *Reijers et al. (2016)*

Overall, blockchain can be seen as a neutral technology that holds the potential to reconfigure economic, legal, institutional, monetary and socio-political relationships. Reijers et al. (2016) argue that blockchain's characteristics relate to the philosophical concepts of direct democracy and equality. However, the technology's ethical orientation eventually depends on the incorporation of the idea of justice and common good in blockchain's algorithms and governance framework. Blockchain is likely to become a central element in the Fourth Industrial Revolution, and as such, governments, companies and civil society groups should work to ensure that the technology is used as a catalyst of accountability, fairness, trust and transparency (Sangokoya and Ajoku, 2018).

7.3 The need for cryptoeconomics and digital governance

While the need for blockchain governance to steer the technology's inherent neutrality towards the common good is apparent, the solution is less clear. In this last Section, it is important to discuss the two main governance challenges that blockchain will face in the future. First, blockchain proponents need to be wary of the risks of system re-centralisation through practices such as coin holder voting, and ensure sound governance protocols. Second, the progress of automation and the rule of algorithms raise an important question about the relationship between humans and technology and the need for digital governance in the information age.

Cryptoeconomics against blockchain plutocracy

Blockchain is without a doubt a distributed technology, but its decentralisation potential is not entirely guaranteed. Instead of relying on a central entity to verify data entry and transactions like in most current systems, blockchain relies on a consensus protocol, by which verifiers (miners) confirm the data before assigning it to a block. Bitcoin blockchain for instance is a proof-of-work, reward-based mining mechanism, functioning through a combination of cryptography and economic incentives and penalties. This economic tradeoff is an important part of the system. Miners receive Bitcoins in exchange for their mining, but need to pay a high price to afford the required computing power[46].

[45] Indeed, most of blockchain applications are based on cryptocurrencies or tokens, which function on a reward-based system. Put simply, the monetary incentive to participate to in blockchain initiatives could corrupt the not-for-profit spirit of those initiatives. While this incentive can attract many participants to contribute to a good cause, it fails to create a civil mobilisation for selfless purposes and for a greater good.

[46] This design is intentionally intended to be two-edged in order to guarantee the security of the system. Indeed, while it is theoretically possible to bypass the consensus protocol rules by gaining control of a majority of the network's hashing power (through a so-called 51% attack), it would be extremely expensive to do so due to the computing power required. For reference, as of July 2018, the cost of a 51% attack on the Bitcoin blockchain is estimated to cost around USD 7 billion in hardware and USD 5 million daily for electricity consumption (GoBitcoin, 2018).

The risk of a complete centralisation of the blockchain in the hands of one entity is therefore supposedly limited (at least in the case of Bitcoin blockchain). However, the consensus needed to create blocks still relies on miners, who can be bribed, if one follows the logic of economic incentives as the motive for miners. Besides, this economic incentive only concerns mining of data, as there is no reward for improving the quality of the governing code.

This reliance on coin holder voting practice and profit-maximising miners creates what Ethereum founder Vitalik Buterin calls the "blockchain plutocracy" (Buterin, 2018). However, getting rid entirely of miners and coin voting would be a slippery slope towards the centralisation of the system. Indeed, the alternative would be to base consensus protocols on a core developers' consensus, which poses the threat of creating systems controlled by "ivory tower intellectuals" disconnected from the day-to-day reality of users' (Buterin, 2017).

The solution for a good blockchain governance might lie in what is called cryptoeconomics. According to Stark (2017), this concept refers to "the use of incentives and cryptography to design new kinds of systems, applications, and networks". It is not a subfield of economics but an interdisciplinary area of applied cryptography that takes into account the theory of economic incentives. As blockchain depends on miners for data validation and recording, cryptoeconomics is needed to understand the role of economic incentive as an essential component of the technology.

Cryptoeconomics is about trying to reduce social trust assumptions by creating systems where we introduce explicit economic incentives for good behavior and economic penalties for bad behavior.
Buterin (2018)

Accordingly, the cryptoeconomics-based blockchain governance advocated by Buterin is based on a "multifactorial consensus" in which the final decision depends on the collective result of various mechanisms. Instead of a simple coin voting system, consensus validation would rely on different coordination flags and mechanisms such as roadmaps, consensus among core development teams, coin holder votes, user votes and established norms (Buterin, 2017). This way, blockchain would avoid the risk of becoming centrally controlled by powerful supernodes or captured by unpredictable political forces. Rather, the system would have to navigate intelligently between existing tradeoffs (Buterin, 2018). Blockchain is a nascent technology that is constantly evolving, so the governance of the technology can also be expected to evolve in the future. However, it is important to choose governance systems that prevent abuses and guarantee the respect of human values.

Digital governance against the rule of algorithms

Perhaps the biggest threat from unregulated blockchain development is that it could propel the risks currently caused by the widespread use of big data to an entirely new level[47]. However the reality is a little more complex. Organisations gather data in order notably to conduct predictive analysis, which improves organisational efficiency, as seen in Section 3.1. The problem with such use of big data is that it is growing in importance and scale, and artificial intelligence is replacing human intervention in many processes through the use of predictive algorithms and individual scoring. Blockchain can become the technology needed to mainstream such practices. While the technology can solve problems linked with human errors and biased judgements, as

[47] Governments and corporations are increasingly mining personal data, but there is a popular misconception over how they use this data. It is often imagined that organisations gather personal data as a way to look specifically into people's individual habits. Therefore, it is usually thought that this does not pose a problem as long as nobody is doing anything illegal. This data- gathering is accepted as a tradeoff: governments gather personal data but the benefit is that they can catch criminals more easily criminals, and companies collect data but can deliver personalised services in return.

seen throughout this paper, if its development is left unchecked, it can also lead to a “score society” ruled by algorithm.

Citron and Pasquale (2014) describe the many ways in which the scored society already works. Organisations use predictive analytics to assess the likelihood of an outcome based on the personal data they regularly gather. For instance, job candidates are ranked by the quality of their activities on social media, software engineers are ranked by their contributions to open source projects, and individuals’ propensity to vote for political candidates is assessed based on their cable-usage patterns. Going further, the authors cite examples of more complex behavioural scoring. For instance, credit card companies rate their consumers’ credit risk based on their purchases. Soon, one could imagine insurance companies charging insurance premiums based on the health data shared on mobile applications such as daily caloric intake.

China has recently started a controversial 'social credit' system, which rates human based on their offline and online behaviour. The exact methodology is unknown, but some examples of possible infractions were reported such as bad driving, smoking in non-smoking zones, buying too many video games and posting fake news online (Ma, 2018). This big data collection may be used for decision-making on individuals. People with bad credit may be subject to travel bans, limits to their internet connectivity, or have less opportunity to get a high-quality public services, among others. On the other hand, people with good credit would be able to get benefits such as discounts and flexibility in using public services.

> *When scoring systems have the potential to take on a life of their own, contributing to or creating the situation they claim merely to predict, it becomes a normative matter, requiring moral justification and rationale. (…) If law and due process are absent from this field, we are essentially paving the way to a new feudal order of unaccountable reputational intermediaries.*
> *Citron and Pasquale (2014)*

In many areas of daily life, individuals are being monitored and scored without knowing it, and this scoring may soon make important decisions for them, without any other basis than the behavioural likelihood determined by predictive algorithms. This precedence of individual data over personal choices poses a threat to basic human rights, and raises the fundamental question of the importance of privacy in a society where individuals are constantly monitored, evaluated and categorised in total opacity. As put by Williams (2018), “privacy isn’t the right to keep secrets: it’s the right to be an individual, not a type; the right to make a choice that’s entirely your own; the right to be private”.

Artificial intelligence can indeed rate individuals in an equal way, without discrimination. It is precisely this ability to correct the many faults of human-based systems that is attractive in autonomous technologies. This is what makes Chapron (2017) call for a cryptogovernance, which would outsource trust, law and enforcement to computer code, mentioning the fact that “the environmental crisis is growing partly because of a lack of trust — the increasing distance between multiple actors who are unknown to each other, from companies and governments to individual consumers, creates many opportunities for fraud and failed policies.”

However, one should be careful not to assume that artificial intelligence is objective by default. It is important to remember that it all depends on the complexity of its code and the inclusiveness of its protocol, which are set by humans. As seen above in Buterin’s comments, blockchain in particular could very much degenerate into a tyrannical system if it is not operated through a multifactorial protocol, based on a digital governance framework.

The time has come to start thinking about a new paradigm of law that could balance the power of blockchain technology and emerging autonomous systems in ways that promote economic growth, free speech, democratic institutions, and the protection of individual liberties.
Wright and De Fillipi (2015)

People are putting an unprecedented amount of trust in technology, providing many benefits in several areas of the economy and people's daily lives. Blockchain holds the potential to further strengthen these benefits by mainstreaming big data and establishing decentralised data ownership. However, by giving too much importance to data, societies take the risk of creating deterministic systems ruled by algorithms and shifting the power of decision from people to codes, which could constitute a modernised version of a totalitarian regime (Wright and De Fillipi, 2015).

The Fourth Revolution, driven by the progress of digital and automation technologies such as blockchain, will certainly improve the efficiency of our societies. The challenge now is to create governance frameworks ensuring that the societies of the future will enjoy the benefits of big data and automated processes while still being designed by and for people.

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References

AGL Energy Limited (2017) Press Release, 26 May 2017: AGL tests solar energy trading technology. Retrieved from: www.agl.com.au/about-agl/media-centre/asx-and-media-releases/2017/may/agl-tests-solar-energy-trading-technology

Ainsworth, R. T. and Alwohaibi, M. (2017), Blockchain, Bitcoin, and VAT in the GCC: The Missing Trader Example. Boston Univ. School of Law, Law and Economics Research Paper No. 17-05. Retrieved from: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2919056

Ainsworth, R. T. and Musaad, A. (2017), Blockchain, Bitcoin, and VAT in the GCC: The Missing Trader Example. Boston University School of Law. Retrieved from: www.bu.edu/law/files/2017/03/BLOCKCHAIN-BITCOIN-VAT-in-the-GCC.pdf

Ainsworth, R. T. and Shact, A. (2016), Blockchain Technology Might Solve VAT Fraud. Reprinted from Tax Notes Int'l, September 26, 2016, p. 1165. Retrieved from: www.law.upenn.edu/live/files/5954-83-tni-1165-september-26-2016pdf

Ainsworth, R. T., Alwohaibi, M. and Cheetham, M. (2017), VATCoin: The GCC's Cryptotaxcurrency. Boston Univ. School of Law, Law and Economics Research Paper No. 17-04. Retrieved from: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2916321

Ajienka, N. (2017), Blockchain and Tax Fraud. Article on Fintricity. Retrieved from: www.fintricity.com/blockchain-tax-fraud/

Allison, I. (2016) R3 connects 11 banks to distributed ledger using Ethereum and Microsoft Azure. International Business Times article, 20 January 2016. Retrieved from: www.ibtimes.co.uk/r3-connects-11-banks-distributed-ledger-using-ethereum-microsoft-azure-1539044

Aricent (2018), New Research Shows Blockchain Speeds Product Development for Mobile Operators. Press Release. Retrieved from: www.aricent.com/news/new-research-shows-blockchain-speeds-product-development-mobile-operators

Ashurst (2017), Tax and Blockchain. Global tax insight, Issue 3, UK. Retrieved from: www.ashurst.com/en/news-and-insights/insights/tax-and-blockchain/

Bank of England (2018), Fintech Proof of Concept. Retrieved from: www.bankofengland.co.uk/-/media/boe/files/fintech/chain.pdf?la=en&hash=CC72FA14A79CE7276C6A59654D524E0429118B4C

Baran, P. (1964), On distributed communications. Introduction to distributed communications network. The Rand Corporation. Memorandum RM-3420-PR. Retrieved from: rand.org/content/dam/rand/pubs/research_memoranda/2006/RM3420.pdf

Baruri, P. (2016) Blockchain Powered Financial Inclusion. Cognizant, presentation. Retrieved from: http://pubdocs.worldbank.org/en/710961476811913780/Session-5C-Pani-Baruri-Blockchain-Financial-Inclusion-Pani.pdf

Basden, J. and Cottrell, M. How Utilities Are Using Blockchain to Modernize the Grid, Article on Harvard Business Review, 23 March 2017. Retrieved from: https://hbr.org/2017/03/how-utilities-are-using-blockchain-to-modernize-the-grid

Baumann, T. (2017), Using blockchain to achieve climate change policy outcomes. IETA insights. Retrieved from: www.ieta.org/resources/Resources/GHG_Report/2017/Using-Blockchain-to-Achieve-Climate-Change-Policy-Outcomes-Baumann.pdf

Benos, E., Garratt, R. and Gurrola-Perez, P. (2017). The Economics of Distributed Ledger Technology for Securities Settlement. Bank of England Staff Working Paper No. 670. Retrieved from: www.bankofengland.co.uk/-/media/boe/files/working-paper/2017/the-economics-of-distributed-ledger-technology-for-securities-settlement.pdf?la=en&hash=17895E1C1FEC86D37E12E4BE63BA9D9741577FE5

Berkley, S. (2017), Immunization needs a technology boost. Nature. Retrieved from: www.nature.com/articles/d41586-017-05923-8

Berryhill, J., Bourgery, T. and Hanson, A. (2018), Blockchains Unchained: Blockchain Technology and its Use in the Public Sector, OECD Working Papers on Public Governance, No. 28, OECD Publishing, Paris. Retrieved from: http://dx.doi.org/10.1787/3c32c429-en

Bhunia, P. (2018) UAE Government launches Blockchain Strategy 2021. Open Gov Asia article. Retrieved from: www.opengovasia.com/articles/uae-government-launches-blockchain-strategy-2021

BigChainDB (2017) Blockchain Powered Land Registry in Ghana with BenBen. Article on Bog Chain, 19 May 2017. Retrieved from: blog.bigchaindb.com/blockchain-powered-land-registry-in-ghana-with-benben-a63b29afa999

Bishop, M. and Wagner, D. (2007), Risks of E-voting. November 2007/Vol. 50, No. 11 communications of the ACM. Retrieved from: https://people.eecs.berkeley.edu/~daw/papers/risks-cacm07.pdf

Blockchain for Good (2016), Blockchain for Good - Humanizing the Blockchain. White Paper. Retrieved from: https://static1.squarespace.com/static/584b0a4b37c5812f78aa6669/t/5851803a5016e172dab2b897/1481736252705/The+Blockchain+For+Good+Manifesto.pdf

Bloomberg (2018), Google Is Working on Its Own Blockchain-Related Technology. Article on Bloomberg, by Olga Kharifand Mark Bergen, on 22 March 2018. Retrieved from: www.bloomberg.com/news/articles/2018-03-21/google-is-said-to-work-on-its-own-blockchain-related-technology

Bohl, G. (2017), Improving Autonomous Driving Communication and Safety with Private Blockchains. Article on Chip Design, 26 June 2017. Retrieved from: http://eecatalog.com/chipdesign/2017/06/26/improving-autonomous-driving-communication-and-safety-with-private-blockchains/

Borchgrevink, J. (2014), Blockchain Voting Used By Danish Political Party. CCN article, 23 April 2014. Retrieved from: www.ccn.com/blockchain-voting-used-by-danish-political-party/

Buchko, S. (2018), Blockchain in Supply Chain - How One Chain Helps the Other. Article on Coin Central, 25 June 2018. Retrieved from: https://coincentral.com/blockchain-supply-chain/

Bussmann, O. (2018) Why initial coin offerings will not replace venture capital for start-ups. Financial News article, 15 February 2018. Retrieved from: www.fnlondon.com/articles/why-initial-coin-offerings-will-not-replace-venture-capital-for-start-ups-20180214

Buterin, V. (2017), Notes on Blockchain Governance. Article on Vitalik Buterin's website, 17 December 2017. Retrieved from: https://vitalik.ca/general/2017/12/17/voting.html?lipi=urn%3Ali%3Apage%3Ad_flagship3_pulse_read%3BLtaHRsihQ7qIzNq%2FqhGc2A%3D%3D

Buterin, V. (2018), Governance, Part 2: Plutocracy Is Still Bad. Article on Vitalik Buterin's website, 28 March 2018. Retrieved from: https://vitalik.ca/general/2018/03/28/plutocracy.html

Caetano, R. (2016), Unveiling the LenderBot. Article on Stratumn Thinking, 17 July 2016. Retrieved from: http://blog.stratumn.com/unveiling-the-lenderbot/

Cambridge Institute for Sustainability Leadership (2017), Blue chips and start-ups launch new fintech pilot for more sustainable supply chains at the One Planet Summit. Article on CISL, 12 December 2017.Retrieved from: www.cisl.cam.ac.uk/business-action/sustainable-finance/banking-environment-initiative/news/blue-chips-and-start-ups-launch-new-fintech-pilot

Capgemini (2016) Smart Contracts in Financial Services: Getting from Hype to Reality. Retrieved from: www.capgemini.com/consulting-de/wp-content/uploads/sites/32/2017/08/smart_contracts_paper_long_0.pdf

Carrington, M. J., Zwick, D. and Neville, B. (2016), The ideology of the ethical consumption gap. In Marketing Theory 2016, Vol. 16(1) 21–38. Retrieved from: www.gla.ac.uk/media/media_451526_en.pdf

Carson, B., Romanelli, G., Walsh, P. and Zhumaev, A. (2018), Blockchain beyond the hype: What is the strategic business value? Article by McKinsey, June 2018. Retrieved from: www.mckinsey.com/business-functions/digital-mckinsey/our-insights/blockchain-beyond-the-hype-what-is-the-strategic-business-value

Casey, M. J. (2017), Tokens for Climate Change? How We Can Rise Above ICO Mania. Article onCoinDesk, 20 September 2017. Retrieved from: www.coindesk.com/why-tokens-matter-rising-above-ico-mania/

CBInsights (2018) How Blockchain Could Disrupt Banking. Article, 8 February 2018. Retrieved from: www.cbinsights.com/research/blockchain-disrupting-banking/#securities

Cerasis (2018), The Top Supply Chain Trends that Will Impact Supply Chain Management in 2018. Retrieved from: https://cerasis.com/wp-content/uploads/2018/02/The-Top-Supply-Chain-Trends-that-Will-Impact-Supply-Chain-Management-in-2018.pdf

Chandra, R. (2017a), Indian states look to digitise land deals with blockchain. Article on Reuters, 11 August 2017. Retrieved from: https://in.reuters.com/article/india-landrights-tech/indian-states-look-to-digitise-land-deals-with-blockchain-idINKBN1AR0PA

Chandran, R. (2017b) Modernizing land records in Honduras can help stem violence, says analyst. Article on Reuters, 11 August 2017. Retrieved from: www.reuters.com/article/us-honduras-landrights-tech/modernizing-land-records-in-honduras-can-help-stem-violence-says-analyst-idUSKBN1AR151

Chapron, G. (2017), The environment needs cryptogovernance, in Nature, vol.545 (403-405) Retrieved from: www.nature.com/polopoly_fs/1.22023!/menu/main/topColumns/topLeftColumn/pdf/545403a.pdf

Chapron, Guillaume (2017), The environment needs cryptogovernance. Nature Comments, 22 May 2017. Retrieved from: www.nature.com/news/the-environment-needs-cryptogovernance-1.22023

Cheng, S., Daub, M., Domeyer, A. and Lundqvist, M. (2017), Using blockchain to improve data management in the public sector. Article on McKinsey & Company, February 2017. Retrieved from: www.mckinsey.com/business-functions/digital-mckinsey/our-insights/using-blockchain-to-improve-data-management-in-the-public-sector

Chiu, J. and Koeppl, T. (2018), Blockchain-based Settlement for Asset Trading. Queen's Economics Department Working Paper No. 1397. Retrieved from: http://qed.econ.queensu.ca/working_papers/papers/qed_wp_1397.pdf

Cisco, Inc. (2017), Cisco IoT Threat Defense: Realizing the Promise of IoT with an Architecture and Services Solution to Secure IoT Devices. Cisco, Inc. Press Release, 23 May 2017. Retrieved from: https://newsroom.cisco.com/press-release-content?type=webcontent&articleId=1847304

Citron, D. K. and Pasquale, F. A. (2014), The Scored Society: Due Process for Automated Predictions. Washington Law Review, Vol. 89, 2014, p. 1-U of Maryland Legal Studies Research Paper No. 2014-8. Retrieved from: www.datascienceassn.org/sites/default/files/The%20Scored%20Society%20-%20Due%20Process%20for%20Automated%20Predictions.pdf

Clancy, H. (2017) Can this start-up use blockchain to brew up more sustainable coffee? Article on Greenbiz, 12 April 2017. Retrieved from: www.greenbiz.com/article/can-start-up-use-blockchain-brew-more-sustainable-coffee

Clark, B. (2018), Blockchain and IP Law: A Match made in Crypto Heaven? Article on World Intellectual Property Organisation (WIPO), February 2018. Retrieved from: www.wipo.int/wipo_magazine/en/2018/01/article_0005.html

Climate Chain Coalition website (2018) http://www.climatechaincoalition.org/

Climate Ledger Initiative (2018) DLT for MRV in the Pacific Alliance. Press release, 19 April 2018. Retrieved from:

Climatecare Carbon Calculator climatecare.org/calculator/; MyClimate Calculator co2.myclimate.org/en/flight_calculators/new; Atmosfair www.atmosfair.de/en/offset/flight/, among others.

CoinDesk (2018), State of Blockchain Q1 2018. Retrieved from: www.coindesk.com/research/state-blockchain-q1-2018/?slide=1

Collindres, J. C., Regan, M. and Panting, G. P. (2016) Using Blockchain to Secure Honduran Land Titles. Fundacion Eleutera case study. Retrieved from: https://s3.amazonaws.com/ipri2016/casestudy_collindres.pdf

Corydon, B., Ganesan, V. and Lundqvist, M. (2016) Transforming government through digitization. Article on McKinsey & Company, November 2016. Retrieved from: www.mckinsey.com/industries/public-sector/our-insights/transforming-government-through-digitization

Crunchbase (2018), VCs vs. ICOs: What Model Is The Future Of Start-up Fundraising? Crunchbase news article, 8 October 2018. Retrieved from: https://news.crunchbase.com/news/vcs-vs-icos-future-start-up-fundraising/

Dabbs, A. (2017) What can blockchain do for the environment? Article on Ensia, 26 January 2017. Retrieved from: ensia.com/features/blockchain-environment-sustainability/

Davies, R. (2015) Giving Unchained: Philanthropy and the Blockchain, Giving Thought discussion paper number 4. Retrieved from: www.cafonline.org/docs/default-source/about-us-publications/givingunchained-philanthropy-and-the-blockchain.pdf?sfvrsn=4

Davies, R. (2016) Block and Tackle: Using blockchain technology to create and regulate civil society organisations. Giving Thought discussion paper number 6. Retrieved from: www.cafonline.org/docs/default-source/about-us-publications/block-amp-tackle---using-blockchain-technology-to-create-and-regulate-csos.pdf?sfvrsn=2

Davies, R. (2017), Losing the Middle but Keeping the Heart: Blockchain, DAOs and the future decentralisation of charity. Giving Thought discussion paper number 7. Retrieved from: www.cafonline.org/docs/default-source/about-us-policy-and-campaigns/losing-the-middle-keeping-the-heart--blockchain-daos-and-future-of-charity.pdf

de T'Serclaes, Philippine (2017). Blockchain could be the missing link in the renewable energy revolution. Article on We Forum, 21 September 2017. Retrieved from: www.weforum.org/agenda/2017/09/blockchain-energy-efficiency-finance/

Deloitte (2016), Blockchain Technology A game-changer in accounting? Report by Nicolai Andersen, Partner, Leader Innovation Deloitte Deutschland. © 2016 Deloitte & Touche GmbH Wirtschaftsprüfungsgesellschaft, Issued 3/2016. Retrieved from: www2.deloitte.com/content/dam/Deloitte/de/Documents/Innovation/Blockchain_A%20game-changer%20in%20accounting.pdf

Deloitte (2016), What is a blockchain? Retrieved from: www2.deloitte.com/content/dam/Deloitte/uk/Documents/Innovation/deloitte-uk-what-is-blockchain-2016.pdf

Deloitte (2017a), Blockchain & Cyber Security: Let's Discuss. Retrieved from: deloitte.com/content/dam/Deloitte/ie/Documents/Technology/IE_C_BlockchainandCyberPOV_0417.pdf

Deloitte (2017b), Blockchain in banking - While the interest is huge, challenges remain for large scale adoption. Retrieved from: www2.deloitte.com/in/en/pages/strategy/articles/blockchain-in-banking.html

Deloitte (2017c), Blockchain technology and its potential in taxes. 2017 Deloitte Poland. Retrieved from: www2.deloitte.com/content/dam/Deloitte/pl/Documents/Reports/pl_Blockchain-technology-and-its-potential-in-taxes-2017-EN.PDF

Deloitte (2018), Crunch time IV: Blockchain for Finance. A series on digital transformation in Finance. Retrieved from: www2.deloitte.com/content/dam/Deloitte/ie/Documents/Finance%20Transformation/Crunch%20Time%20IV%20Blockchain.pdf

Deloitte (2016), Blockchain technology – the benefits of smart contracts. Article on Deloitte website, 15 November 2016. Retrieved from: www2.deloitte.com/nl/nl/pages/financial-services/articles/3-blockchain-the-benefits-of-smart-contracts.html

Desai, V. (2017) Counting the uncounted: 1.1 billion people without IDs. The World Bank Blog. Retrieved at: http://blogs.worldbank.org/ic4d/counting-uncounted-11-billion-people-without-ids

dena (German Energy Agency) and ESMT (European School of Management and Technology GmbH). Vulnerabilities in smart meter infrastructure – can blockchain provide a solution? Results from a panel discussion at EventHorizon2017, February 2018. Retrieved from:https://shop.dena.de/fileadmin/denashop/media/Downloads_Dateien/esd/9236_Vulnerabilities_in_smart_meter_infrastructure_-can_blockchain_provide_a_solution.pdf

Digiconomist (2017) Bitcoin Energy Consumption Index. Retrieved from: www.digiconomist.net/bitcoin-energy-consumption

DLT for MRV in the Pacific Alliance. Article on Climate Ledger Initiative website, 12 July 2018. Retrieved from: www.climateledger.org/en/News.3.html?nid=13

Dodge, E. T. (2015), A New Model for Carbon Pricing Using Blockchain Technology. Retrieved from: www.edwardtdodge.com/2015/09/22/a-new-model-for-carbon-pricing-using-blockchain-technology

Edelman (2017), Hacking trust: 2017 Edelman trust barometer and blockchain. Retrieved from: www.edelman.com/post/hacking-trust-and-blockchain

EDF (2017), Blog article on electricity market: blogs.edf.org/energyexchange/2017/05/04/how-blockchain-could-upend-power-markets/?lipi=urn%3Ali%3Apage%3Ad_flagship3_pulse_read%3BEACuSHnjRReO66Wx9hnCkA%3D%3D

E-Estonia (2016),E-health – Estonian Digital Solutions for Europe. Retrieved from: https://e-estonia.com/e-health-estonian-digital-solutions-for-europe/

Eisenberg, A. (2018), Five Business Opportunities for Blockchain for 2018. Article on Ignite Outsourcing. Retrieved from: https://igniteoutsourcing.com/publications/blockchain-business-applications/

Ekblaw, A., Azaria, A., Halamka, J. D. and Lippman, A. (2016), A Case Study for Blockchain in Healthcare: "MedRec" prototype for electronic health records and medical research data. White Paper. MIT Media Lab, Beth Israel Deaconess Medical Center. Retrieved from: www.healthit.gov/sites/default/files/5-56-onc_blockchainchallenge_mitwhitepaper.pdf

EncrypGen website. (2018) https://encrypgen.com/

Enigma (2015), Enigma: Decentralised Computation Platform with Guaranteed Privacy. Enigma White Paper by Guy Zyskind, Oz Nathan and Alex 'Sandy' Pentland. Retrieved from: https://enigma.co/enigma_full.pdf

Ethical Consumer (2017), Ethical Consumer Markets Report 2017. Retrieved from: www.ethicalconsumer.org/researchhub/ukethicalmarket.aspx

European Parliament (2016), What if blockchain technology revolutionised voting? Retrieved from: www.europarl.europa.eu/RegData/etudes/ATAG/2016/581918/EPRS_ATA(2016)581918_EN.pdf

European Union (2017), Study and Reports on the VAT Gap in the EU-28 Member States: 2017 Final Report TAXUD/2015/CC/131. Warsaw, 18 September 2017. Retrieved from: https://ec.europa.eu/taxation_customs/sites/taxation/files/study_and_reports_on_the_vat_gap_2017.pdf

Europol (2018), MTIC (Missing Trader Intra Community) Fraud. Retrieved from: www.europol.europa.eu/crime-areas-and-trends/crime-areas/economic-crime/mtic-missing-trader-intra-community-fraud

EY (2016) Top of Mind, Digital supply chain: it's all about that data. EY publications. Retrieved from: http://www.ey.com/Publication/vwLUAssets/Digital_supply_chain_-_its_all_about_the_data/$FILE/EY-digital-supply-chain-its-all-about-that-data-final.pdf

EY (2017), How blockchain could transform the world of indirect tax. EY report by Bulk, G. and Barr, R. Retrieved from: https://betterworkingworld.ey.com/trust/how-blockchain-could-transform-the-world-of-indirect-tax

EY (2018a) Regulatory complexity is the greatest barrier to widespread blockchain adoption, while regulatory changes are the primary driver of broader integration, according to EY poll. Article on EY Newsroom, 6 June 2018. Retrieved from: www.ey.com/gl/en/newsroom/news-releases/news-regulatory-complexity-is-the-greatest-barrier-to-widespread-blockchain-adoption-while-regulatory-changes-are-the-primary-driver-of-broader-integration-according-to-ey-poll

EY (2018b), EY announces blockchain audit technology. Article on EY Newsroom, 24 April 2018. Retrieved from: www.ey.com/gl/en/newsroom/news-releases/news-ey-announces-blockchain-audit-technology

EY (2018c), EY and Microsoft launch blockchain solution for content rights and royalties management for media and entertainment industry. Article on EY, 21 June 2018. Retrieved from: https://www.ey.com/gl/en/newsroom/news-releases/news-ey-and-microsoft-launch-blockchain-solution-for-content-rights-and-royalties-management-for-media-and-entertainment-industry

Federal Trade Commission (2017), The Equifax Data Breach. Retrieved from: www.ftc.gov/equifax-data-breach

Filecoin.io (2014) Filecoin: A Cryptocurrency Operated File Storage Network. White Paper. Retrieved from: https://filecoin.io/filecoin-jul-2014.pdf

Floyd, D. (2018), Blockchain And The Cloud: How Data Storage Could Change In The Coming Years. NASDAQ article, 28 February 2018. Retrieved from: www.nasdaq.com/article/blockchain-and-the-cloud-how-data-storage-could-change-in-the-coming-years-cm927876

Foer, F. (2018), It's Time to Regulate the Internet. Article on The Atlantic, 21 March 2018. Retrieved from: www.theatlantic.com/technology/archive/2018/03/its-time-to-regulate-the-internet/556097/

Forde, B. (2017), How blockchain can help create better public services. Blockchain has the potential to cut through the hodgepodge of interfacing with government services, says MIT's Brian Forde. Article on EYQ, by Andrea Potter. Retrieved from: https://betterworkingworld.ey.com/digital/how-blockchain-can-help-create-better-public-services

Foroglou, G. and Tsilidou, A., L. (2015), Further applications of the blockchain. In 12th Student Conference on Managerial Science and Technology. DOI: 10.13140/RG.2.1.2350.8568. Retrieved from: www.researchgate.net/publication/276304843_Further_applications_of_the_blockchain

Forrester (2017) Poor-quality Ads Cost Marketers $7.4 Billion Last Year. Forrester study. Retrieved from: www.forrester.com/PoorQuality+Ads+Cost+Marketers+74+Billion+Last+Year/-/E-PRE9724

FT Reporter (2016), Tunisia is the first country to put national currency on blockchain. Article on FT Reporter, 29 November 2016. Retrieved from: http://ftreporter.com/tunisia-is-the-first-country-to-put-national-currency-on-blockchain/

Gartner (2017), Practical Blockchain: A Gartner Trend Insight Report. Published on 3 March 2017. Analysts: David Furlonger and Ray Valdes. Retrieved from: www.gartner.com/doc/3628617?refval=&pcp=mpe

Ghose, A. (2018), What Blockchain Could Mean for Marketing. harvard Business Review article, 14 May 2018. Retrieved from: https://hbr.org/2018/05/what-blockchain-could-mean-for-marketing

GoBitcoin (2018), Cost of a 51% attack. Retrieved from: https://gobitcoin.io/tools/cost-51-attack

Greenbiz (2017) Unilever, Nestle and other food giants team on blockchain. Article on Greenbiz, 29 August 2017. Retrieved from: www.greenbiz.com/article/unilever-nestle-and-other-food-giants-team-blockchain

Grigg, I. (2005), Triple Entry Accounting. Systemics, Inc. Work in progress. Retrieved from: http://iang.org/papers/triple_entry.html

Guillot, C. (2018), 4 supply chain predictions for 2018. Article on Supply Chain Dive, 8 January 2018. Retrieved from: www.supplychaindive.com/news/supply-chain-trends-cloud-blockchain-technology/514299

Gutterman, A. (2017) Blockchain Technology Has The Power to Let Us Build An Entirely New Internet. Futurism article. Retrieved from: https://futurism.com/blockchain-technology-has-the-power-to-let-us-build-an-entirely-new-internet/

Haber S. and Stornetta S. (1991) How to time-stamp a digital document, Lecture Notes in Computer Science537, 437–455 (Advances in Cryptology—CRYPT0' 90). Retrieved from: www.anf.es/pdf/Haber_Stornetta.pdf

Halloran, M. (2016). Blockchain, Mobile and the Internet of Things. Article on Samsung insights website, 17 March 2016. Retrieved from: https://insights.samsung.com/2016/03/17/block-chain-mobile-and-the-internet-of-things/

Hancock, A. (2017), Younger consumers drive shift to ethical products. Article on the Financial Times, 23 December 2017. Retrieved from: www.ft.com/content/8b08bf4c-e5a0-11e7-8b99-0191e45377ec

Hileman, Dr Garrick and Michel Rauchs. (2017) Global Blockchain Benchmarking Study. Cambridge Centre for Alternative Finance. Retrieved from: j2-capital.com/wp-content/uploads/2017/11/GLOBAL-BLOCKCHAIN.pdf

Hileman, G. and Rauchs, M. (2017) Global Blockchain Benchmarking Study. Retrieved from: https://j2-capital.com/wp-content/uploads/2017/11/GLOBAL-BLOCKCHAIN.pdf

HireRight (2016) HireRight Employment Screening Benchmark Report. Retrieved from: www.hireright.com/assets/uploads/files/HireRight2016BenchmarkingReport.pdf

Hirson, R. (2015). The future of car leasing is as easy as click sign drive. Article on Docusign.com website, 26 October 2015. Retrieved from: https://www.docusign.com/blog/the-future-of-car-leasing-is-as-easy-as-click-sign-drive/

Hoeiberg (2017), What are the potentials for using the blockchain for reporting on sustainable development? Article on Steemit, 15 November 2017. Retrieved from: https://steemit.com/blockchain/@hoeiberg/what-are-the-potentials-for-using-the-blockchain-for-reporting-on-sustainable-development

Holthaus, E. (2017), Bitcoin could cost us our clean-energy future? Grist article, 5 December 2017. Retrieved from: https://grist.org/article/bitcoin-could-cost-us-our-clean-energy-future/

Huckle, Steve, Rituparna Bhattacharya, Martin White, and Natalia Beloff. (2016) Internet of Things, Blockchain and Shared Economy Applications. Procedia Computer Science 98: 461-466. Retrieved from: http://creativecommons.org/licenses/by-nc-nd/4.0/

Huston, M. (2017), Can bitcoin's cryptographic technology help save the environment? ScienceMag article, 22 May 2017. Retrieved from: www.sciencemag.org/news/2017/05/can-bitcoin-s-cryptographic-technology-help-save-environment

IBM (2013) Analytics: The real-world use of big data in financial services How innovative banking and financial markets organisations extract value from uncertain data. Retrieved from: www-935.ibm.com/services/multimedia/Analytics_The_real_world_use_of_big_data_in_Financial_services_Mai_2013.pdf

IBM (2017), AIG, IBM, Standard Chartered Deliver First Multinational Insurance Policy Powered by Blockchain. News release by IBM on 15 June 2017. Retrieved from: https://www-03.ibm.com/press/us/en/pressrelease/52607.wss

IBM (2017), Energy-Blockchain Labs and IBM Create Carbon Credit Management Platform Using Hyperledger Fabric on the IBM Cloud: Blockchain Platform Dedicated to Green Asset Development Helping Enable a Low-Carbon Future for China, IBM News release. Retrieved from: www-03.ibm.com/press/us/en/pressrelease/51839.wss

IBM (2018), Key food supply chain benefits using blockchain. Retrieved from: www-01.ibm.com/common/ssi/cgi-bin/ssialias?htmlfid=38017038USEN

IBM (2018), Watson IoT and Blockchain: Disruptor and game changer. Retrieved from: public.dhe.ibm.com/common/ssi/ecm/ww/en/ww912350usen/watson-iot-cognitive-solutions-ww-infographic-general-ww912350usen-20180306.pdf

ID2020 Alliance (2017) Concept paper. Retrieved from: https://static1.squarespace.com/static/578015396a4963f7d4413498/t/5a5f92bcc8302548e722dff3/1519157409748/ID2020+Alliance+Doc+-+Jan+2018.pdf

IETA (2017) Press Release: IETA Comment on Canada-Pacific Alliance MRV Governance Collaboration Initiative. IETA. Retrieved from: www.ieta.org/page-18192/5473324

Institute for Global Environmental Strategies (IGES), (2018), Green Growth and Decarbonization of Energy Systems in a Changing World. Policy Report of the International Research Network for Low-Carbon Societies (LCS-RNet). Retrieved from: https://pub.iges.or.jp/pub/green-growth-and-decarbonization-energy

Institute of Chartered Accountants in England and Wales (ICAEW), (2017), Blockchain and the future of accountancy. ISBN 978-1-78363-933-5. Retrieved from: www.icaew.com/-/media/corporate/files/technical/information-technology/technology/blockchain-and-the-future-of-accountancy.ashx

Intel (2013), Predictive Analytics 101: Next-Generation Big Data Intelligence. A Crash Course on Operationalizing Predictive Analytics with Real-Time Data. Retrieved from: www.intel.com/content/dam/www/public/us/en/documents/best-practices/big-data-predictive-analytics-overview.pdf

Intel® IoT Industry Solutions for Smart Manufacturing (2018). Intel website. Retrieved from: https://www.intel.com/content/www/us/en/industrial-automation/overview.html

International Bank for Reconstruction and Development / the World Bank (2017), Distributed Ledger Technology (DLT) and Blockchain. World Bank. Retrieved from: www.worldbank.org/en/topic/financialsector/brief/blockchain-dlt

International Bank for Reconstruction and Development / the World Bank (2017), Distributed Ledger Technology (DLT) and Blockchain. World Bank. Retrieved from: www.worldbank.org/en/topic/financialsector/brief/blockchain-dlt

International Criminal Police Organisation (INTERPOL) (2013), Guide to Carbon Trading Crime. Retrieved from: www.interpol.int/Media/Files/Crime-areas/Environmental-crime/Guide-to-Carbon-Trading-Crime-2013

International Data Corporation (2018), IDC FutureScape: Worldwide Supply Chain 2018 Predictions. Retrieved from: www.idc.com/getdoc.jsp?containerId=US43146317

Ito, J., Narula, N. and Ali, R. (2017) The Blockchain Will Do to the Financial System What the Internet Did to Media. Harvard Business Review article, 9 March 2017. Retrieved from: https://hbr.org/2017/03/the-blockchain-will-do-to-banks-and-law-firms-what-the-internet-did-to-media

Jezard, A. (2017) In 2020 Bitcoin will consume more power than the world does today. World Economic Forum article, 17 December 2017. Retrieved from: www.weforum.org/agenda/2017/12/bitcoin-consume-more-power-than-world-2020?utm_content=buffera917a&utm_medium=social&utm_source=linkedin.com&utm_campaign=buffer

Kahan, M. and Rock, E. (2008), The hanging chads of corporate voting, Georgetown Law Journal96, 1227–1281. Retrieved from: https://scholarship.law.upenn.edu/cgi/viewcontent.cgi?referer=https://www.google.co.jp/&httpsredir=1&article=1163&context=faculty_scholarship

Kairos Future (2017) The Land Registry in the blockchain - testbed A development project with Lantmäteriet, Landshypotek Bank, SBAB, Telia company, ChromaWay and Kairos Future.Retrieved from: https://chromaway.com/papers/Blockchain_Landregistry_Report_2017.pdf

Keys, A. (2017), Memo from Davos: We have a trust problem. Personal responsibility and Ethereum are the solutions. Article on Medium, 20 January 2017. Retrieved from: https://media.consensys.net/memo-from-davos-we-have-a-trust-problem-personal-responsibility-and-ethereum-are-the-solutions-19d1104946d8

Khan, Minhaj Ahmad and Salah, Khaled (2018), IoT security: Review, blockchain solutions, and open challenges. Future Generation Computer Systems Volume 82, May 2018, Pages 395-411. Retrieved from: www.sciencedirect.com/science/article/pii/S0167739X17315765

Kharif, O. (2016) Wal-Mart tackles food safety with trial of Blockchain. Article on Detroit News, 19 November 2016. Retrieved from: www.detroitnews.com/story/business/2016/11/19/wal-mart-tackles-food-safety-trial-blockchain/94144568/

Killmeyer, J., White, M. and Chew, B. (2017), Will blockchain transform the public sector? Blockchain basics for government. A report from the Deloitte Center for Government Insights. Retrieved from: www2.deloitte.com/content/dam/insights/us/articles/4185_blockchain-public-sector/DUP_will-blockchain-transform-public-sector.pdf

Kirby, P. (2015) A Humble Update on the Honduras Title Project. Article on Factom, 25 December 2015. Retrieved from: www.factom.com/blog/a-humble-update-on-the-honduras-title-project

KPMG (2017), KPMG And Microsoft Announce New “Blockchain Nodes”. News release on KPMG, 15 February 2017. Retrieved from: https://home.kpmg.com/us/en/home/media/press-releases/2017/02/kpmg-and-microsoft-announce-new-blockchain-nodes.html

Kuebler, E. (2018), Making Voting, Elections Both Secure and Accessible with Blockchain Technology. Article on Bitcoin Magazine, 11 January 2018. Retrieved from: https://bitcoinmagazine.com/articles/making-voting-elections-both-secure-and-accessible-blockchain-technology/

Kuznetsov, N. (2018), Professor Alex Pentland Banks On Blockchain To Bring Predictive Analytics To The Masses. Article on Forbes, 20 February 2018. Retrieved from: www.forbes.com/sites/nikolaikuznetsov/2018/02/20/professor-alex-pentland-banks-on-blockchain-to-bring-predictive-analytics-to-the-masses/#13eae3ef2da7

Lafarre, A. and Van der Elst, C. (2018), Blockchain Technology for Corporate Governance and Shareholder Activism. European Corporate Governance Institute (ECGI) - Law Working Paper N° 390/2018. Retrieved from: www.ecgi.global/sites/default/files/working_papers/documents/finallafarrevanderelst.pdf

Lang, C. (2015) Conservation Central Network’s Little Green Tokens and Big Green Lies. Article on REDD-Monitor, 6 February 2015. Retrieved from: www.redd-monitor.org/2015/02/06/conservation-central-networks-little-green-tokens-and-big-green-lies/

Lauer, T. W. (2004), The Risk of e-Voting. Electronic Journal of e-Government Volume 2 Issue 3 2004 (177-186). Retrieved from: http://www.ejeg.com/issue/download.html?idArticle=34

Lazanis, R. (2015), How Technology Behind Bitcoin Could Transform Accounting As We Know It. Article on Techvibes, 23 January 2015. Retrieved from: https://techvibes.com/2015/01/22/how-technology-behind-bitcoin-could-transform-accounting-as-we-know-it-2015-01-22

Leimgruber, J., Meier, A. and Backus, J. (2018), Bloom Protocol Decentralised credit scoring powered by Ethereum and IPFS. Bloom white paper. Retrieved from: https://bloom.co/whitepaper.pdf

Lessig, L. (2006), Code and other laws of cyberspace, Version 2.0’, New York: Basic Books 2006. Retrieved from: http://codev2.cc/download+remix/Lessig-Codev2.pdf

Li, Y. (2010), The Case Analysis of the Scandal of Enron. International Journal of Business and Management, Vol. 5, No. 10; October 2010. Retrieved from: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.663.9418&rep=rep1&type=pdf

Light, D. (2014) The Internet of Things and Property/Casualty Insurance. Industry report, Celent. Retrieved from: https://www.celent.com/insights/877355504

Lisk (2018), Blockchain Uses in Business. Retrieved from: https://lisk.io/academy/blockchain-business/blockchain-in-business

LO3 Energy website (2018). https://lo3energy.com/

Lucking, D. (2017) Delaware Passes Law Permitting Companies to Use Blockchain Technology to Issue and Track Shares. Allen & Overy article. Retrieved from: www.allenovery.com/publications/en-gb/Pages/Delaware-Passes-Law-Permitting-Companies-to-Use-Blockchain-Technology-to-Issue-and-Track-Shares-.aspx

Ma, A. (2018) China has started ranking citizens with a creepy 'social credit' system — here's what you can do wrong, and the embarrassing, demeaning ways they can punish you. Article on Business Insider, 8 April 2018. Retrieved from: www.businessinsider.com/china-social-credit-system-punishments-and-rewards-explained-2018-4

Mainelli, M. and Gupta, V. (2016), Misplaced Trust: Distributed ledgers have a role to play in identity verifications, but there are potential pitfalls. Retrieved from: www.zyen.com/Articles/Banking%20Technology%20-%20Misplaced%20Trust%20In%20Identity%20-%20Mainelli%20and%20Gupta%202016.02.pdf

Mainelli, M. and von Gunten, C. (2014) Chain Of A Lifetime: How Blockchain Technology Might Transform Personal Insurance. Long Finance report prepared by Z/Yen Group. Retrieved from: www.longfinance.net/images/Chain_Of_A_Lifetime_December2014.pdf

Malik, A. J. (2017), Can blockchain save digital marketing from its demons? Accenture article, 5 December 2017. Retrieved from: www.accenture.com/gb-en/blogs/blogs-blockchain-save-digital-marketing

Malinova K., Park A. (2016) Market design for trading with blockchain technology. University of Toronto. Retrieved from: http://blockchain.cs.ucl.ac.uk/wp-content/uploads/2016/11/Paper_18.pdf

Markets and Markets (2018), Connected Car Market by Service (Connected Services, Safety & Security, and Autonomous Driving), Form (Embedded, Tethered, and Integrated), Network (DSRC, and Cellular), End Market, Transponder, Hardware, and Region - Global Forecast to 2025. Report by Markets and Markets. Retrieved from: www.marketsandmarkets.com/Market-Reports/connected-car-market-102580117.html

McDonald, L. (2018), MOVA's Lachlan McDonald Wants to Bring Accountability to Supply Chains. Article on Coin Central written by Steven Kuchbo, 29 April 2018. Retrieved from: https://coincentral.com/movas-lachlan-mcdonald-wants-to-bring-accountability-to-supply-chains/

Mearian, L. (2017), IBM Watson, FDA to explore blockchain for secure patient data exchange. Article on Computer World, 11 January 2017. Retrieved from: www.computerworld.com/article/3156504/healthcare-it/ibm-watson-fda-to-explore-blockchain-for-secure-patient-data-exchange.html

Misso, K. (2016), How blockchain could shape tax automation. Article on VATlive, 11 October 2016. Retrieved from: www.vatlive.com/vat-news/how-blockchain-could-shape-tax-automation/

MIT (2017), Digital Diploma Pilot Program.Retrieved from:http://web.mit.edu/registrar/records/certs/digital.html

MIT Technology Review (2018): A glossary of blockchain jargon. Retrieved from:www-technologyreview-com.cdn.ampproject.org/c/s/www.technologyreview.com/s/610885/a-glossary-of-blockchain-jargon/amp/

Moody's Investors Service (2016), Credit Strategy -- Blockchain Technology: Robust, Cost-effective Applications Key to Unlocking Blockchain's Potential Credit Benefits. Retrieved from: www.moodys.com/research/Moodys-Blockchain-can-bring-benefits-to-the-financial-industry-and--PR_352414

Munford, Monty. (2018), XYO Network Takes Blockchain Offline With Decentralised Location-Verification System. Forbes Article, 9 April 2018. Retrieved from: www.forbes.com/sites/montymunford/2018/04/09/xyo-network-takes-blockchain-offline-with-decentralised-location-verification-system/#4d0bf768537a

Nakamoto, S. (2008), Bitcoin: A Peer-to-Peer Electronic Cash System. White paper. Retrieved from: https://bitcoin.org/bitcoin.pdf

Nasdaq (2016). Nasdaq's Blockchain Technology To Transform The Republic Of Estonia's E-residency Shareholder Participation. Press release, 12 February 2016. Retrieved from: http://ir.nasdaq.com/releasedetail.cfm?releaseid=954654

National Settlement Depository (2017), General Meeting Proxy Voting On Distributed Ledger - Product Requirements v2.1. Retrieved from: www.nsd.ru/common/img/uploaded/files/gm_proxy_voting.pdf

Nikkei Asian Review (2017), Japan-South Korea blockchain payments enter trials Friday. Article on 13 December 2017.Retrieved from: https://asia.nikkei.com/Business/Deals/Japan-South-Korea-blockchain-payments-enter-trials-Friday?lipi=urn%3Ali%3Apage%3Ad_flagship3_feed%3BClu2jUQxT7SmVWzeB2cAQg%3D%3D

OECD (2015), Addressing the Tax Challenges of the Digital Economy, Action 1 - 2015 Final Report. In series: OECD/G20 Base Erosion and Profit Shifting Project. Retrieved from: www.oecd.org/ctp/addressing-the-tax-challenges-of-the-digital-economy-action-1-2015-final-report-9789264241046-en.htm

OECD (2017), Embracing Innovation in Government Global Trends. Retrieved from: /www.oecd.org/gov/innovative-government/embracing-innovation-in-government.pdf

Office of the National Coordinator for Health Information Technology (2015), 2015 Update to Congress on the Adoption of Health Information Technology. Retrieved from: https://dashboard.healthit.gov/report-to-congress/2015-update-adoption-health-information-technology-full-text.php

Olsen, T., Ford, F., Ott, J. and Zeng, J. (2017) Blockchain in Financial Markets: How to Gain an Edge. Report from Bain & Company. Retrieved from: www.bain.com/Images/BAIN_BRIEF_Blockchain_in_Financial_Markets.pdf

Orcutt, M. (2017a), How Blockchain Could Give Us a Smarter Energy Grid. Article on MIT Technology Review, 16 October 2017. Retrieved from: https://www.technologyreview.com/s/609077/how-blockchain-could-give-us-a-smarter-energy-grid/

Orcutt, M. (2017b), Who Will Build the Health-Care Blockchain? Article on MIT Technology Review, 15 September 2017. Retrieved from: www.technologyreview.com/s/608821/who-will-build-the-health-care-blockchain/

Osgood, R. (2016), The Future of Democracy: Blockchain Voting. COMP116: Information Security. Retrieved from: www.cs.tufts.edu/comp/116/archive/fall2016/rosgood.pdf

Ovenden, J. (2018), Will Blockchain Render Accountants Irrelevant? The ability to record everything accurately, may make them surplus to requirements. Article on Innovation Entreprise Channels, 26 January 2018. Retrieved from: https://channels.theinnovationenterprise.com/articles/will-blockchain-render-accountants-irrelevant

Paine, J. (2018), How Blockchain is Disrupting the Accounting Industry. Article by James Paine, Founder, West Realty Advisors, on Inc., 30 March 2018. Retrieved from: www.inc.com/james-paine/how-blockchain-is-disrupting-accounting-industry.html

Parliamentary Office of Science and Technology (2001), Regulating Internet Content. Parliamentary Copyright 2001. Retrieved from: http://researchbriefings.parliament.uk/ResearchBriefing/Summary/POST-PN-159

Pascual, A., Marchini, K. and Miller, S. (2017), 2017 Identity Fraud: Securing the Connected Life. Javelin Strategy & Research study. Retrieved from: www.javelinstrategy.com/coverage-area/2017-identity-fraud

Piazza, F. S. (2017) Bitcoin and the Blockchain as Possible Corporate Governance Tools: Strengths and Weaknesses. Penn State Journal of Law & International Affairs, Volume 5 Issue 2: Collected Works. Retrieved from: http://elibrary.law.psu.edu/cgi/viewcontent.cgi?article=1163&context=jlia

PR Newswire (2018). On UN World Environment Day CarbonX Announces Merger with Zerofootprint® Anthony Di Iorio to join as Investor. Press Release, 5 June 2018. Retrieved from: markets.businessinsider.com/news/stocks/on-un-world-environment-day-carbonx-announces-merger-with-zerofootprint-anthony-di-iorio-to-join-as-investor-1026586185

Principles for Responsible Investment (PRI), (2018), Responsible Investment and Blockchain. Retrieved from: www.unpri.org/download?ac=4522

Prisco, G. (2016) Deloitte Team Launches Custom Blockchain Solution Rubix Core. Article on Bitcoin Magazine, 19 May 2016. Retrieved from: https://bitcoinmagazine.com/articles/deloitte-team-launches-custom-blockchain-solution-rubix-core-1463687003/

Prisco, Giulio (2018) Estonia Launches Green Energy Blockchain Project. Article on Nasdaq website, 11 January 2018. Retrieved from: www.nasdaq.com/article/estonia-launched-green-energy-blockchain-project-cm904091

Provenance (2015), Blockchain: the solution for transparency in product supply chains. Provenance White paper. Retrieved from: www.provenance.org/whitepaper

Provenance (2016), From shore to plate: Tracking tuna on the blockchain. Provenance pilot blockchain technology for tracing yellowfin and skipjack tuna fish in Indonesia from catch to consumer. Provenance report. retrieved from: www.provenance.org/tracking-tuna-on-the-blockchain

Psaila, S. (2017), Blockchain: A game changer for audit processes? Article from Deloitte Malta, 22 September 2017. Retrieved from: https://www2.deloitte.com/content/dam/Deloitte/mt/Documents/audit/dt_mt_article_blockchain_gamechanger-for-audit-sandro-psaila.pdf

PwC (2016). Blockchain – an opportunity for energy producers and consumers? (PwC):www.pwc.fr/fr/assets/files/pdf/2016/12/blockchain_opportunity_for_energy_producers_and_consumers.pdf

PwC (2017), How blockchain technology could improve the tax system. PwC report, Experts in technology and tax from the private and public sectors come together to explore blockchain's potential. Retrieved from: https://info.pwc.se/hubfs/Tax_matters/Pdf-filer_Tax_matters/How-blockchain-could-improve-the-tax-system.pdf?t=1520933878531

PwC (2018), PwC Blockchain Validation Solution Innovate with confidence. Retrieved from:www.pwc.com/us/en/about-us/new-ventures/pwc-blockchain-validation-solution.html

Raupp, A. B. (2018), Tax Return 2.0: How Blockchain Technology Can Bring America's Budget Into The Future. Article on Forbes, 22 January 2018. Retrieved from: www.forbes.com/sites/forbestechcouncil/2018/01/22/tax-return-2-0-how-blockchain-technology-can-bring-americas-budget-into-the-future/#522e10867b41

Reijers, W., O'Brolcháin, F. and Haynes, P. (2016) Governance in Blockchain Technologies & Social Contract Theories. Ledger Journal, Vol 1 (2016) 134−151. Retrieved from: http://ledger.pitt.edu/ojs/index.php/ledger/article/view/62

Reuters (2017) Canada's TMX taps blockchain for shareholder voting technology. Reuters article, 7 April 2017. Retrieved from: www.reuters.com/article/cbusiness-us-tmx-grp-blockchain-idCAKBN1782BV-OCABS

Reuters (2018). Article cited in Word Economy Forum, 2 February 2018. Retrieved from: www.weforum.org/agenda/2018/03/blockchain-bitcoin-explainer-shiller-roubini/

Rhodes, D. (2018), What Opportunities Could Blockchain Create for Intellectual Property (IP)? Article on Coincentral, 6 May 2018. Retrieved from: https://coincentral.com/what-opportunities-could-blockchain-create-for-intellectual-property-ip/

Richardson, Jake. (2018) Peer-to-Peer Solar Energy Trading Trial In Japan Will Use Blockchain. Article on CleanTechnica website (July 9th, 2018). https://cleantechnica.com/2018/07/09/peer-to-peer-solar-energy-trading-trial-in-japan-will-use-blockchain-solar-power-energy-trading-trial-in-japan-using-blockchain/

Rizzo, P. (2015) Payments Firm Backs 'Crazy' Offline Bitcoin Transactions Experiment. Article on Coin Desk, 30 June 2015. Retrieved from: www.coindesk.com/netopia-internet-free-bitcoin-transactions/

Robinson, A. (2015), The Evolution and History of Supply Chain Management. Article on Cerasis, 23 January 2015. Retrieved from: https://cerasis.com/2015/01/23/history-of-supply-chain-management/

Ronen, J. (2010), Corporate Audits and How to Fix Them. Journal of Economic Perspectives, 24 (2): 189-210. DOI: 10.1257/jep.24.2.189. Retrieved from: https://pubs.aeaweb.org/doi/pdfplus/10.1257/jep.24.2.189

Rutkin, A. (2016, March 2) Blockchain-based microgrid gives power to consumers in New York. New Scientist. Retrieved from: www.newscientist.com/article/2079334-blockchain-based-microgrid-gives-power-to-consumers-in-new-york/

Samuelson, P. (2000), Five Challenges for Regulating the Global Information Society. Retrieved from: http://people.ischool.berkeley.edu/~pam/papers/5challenges_feb22_v2_final_.pdf

Sangokoya, D. and Ajoku, L. (2018), From trade unions to NGOs: we all need a say in how tech is governed. Article on the World Economic Forum, 25 April 2018. Retrieved from: www.weforum.org/agenda/2018/04/civil-society-tech-progress-fourth-industrial-revolution

Sangster, A. and Scataglinibelghitar, G. (2010), Luca Pacioli: The Father of Accounting Education. Accounting Education: an international journal, Vol. 19, No. 4, 423–438, August 2010. Retrieved from: www.researchgate.net/publication/227600560_Luca_Pacioli_The_Father_of_Accounting_Education

Santander and Oliver Wyman (2015), The Fintech 2.0 Paper: rebooting financial services. Retrieved from: http://santanderinnoventures.com/wp-content/uploads/2015/06/The-Fintech-2-0-Paper.pdf

Seco, A. (2018), Blockchain : Concepts and potential applications in the tax area. Article on the Inter-American Center of Tax Administrations. Retrieved from: www.ciat.org/blockchain-concepts-and-potential-applications-in-the-tax-area-13/?lang=en#_ftn10

Shen, M. (2018), Binance Exchange Backs First-Ever Decentralised Bank in Malta. Article on Coindesk, 12 July 2018. Retrieved from: www.coindesk.com/binance-exchange-backs-first-ever-decentralised-bank-in-malta

Shin, L. (2016) Republic Of Georgia To Pilot Land Titling On Blockchain With Economist Hernando De Soto, BitFury. Article on Forbes, 21 April 2016. Retrieved from: www.forbes.com/sites/laurashin/2016/04/21/republic-of-georgia-to-pilot-land-titling-on-blockchain-with-economist-hernando-de-soto-bitfury/#7264274544da

SIA (Staffing Industry Analysts), (2016), Japan – Recruit Technologies And Ascribe Announce Partnership To Test Blockchain Technology For The HR Industry. Article on SIA, 27 April 2016.Retrieved from:https://www2.staffingindustry.com/row/Editorial/Daily-News/Japan-Recruit-Technologies-and-Ascribe-announce-partnership-to-test-blockchain-technology-for-the-HR-industry-37728?

Siemens (2018). A Microgrid Grows in Brooklyn. Article on Siemens website, 16 February 2018. Retrieved from: https://www.siemens.com/innovation/en/home/pictures-of-the-future/energy-and-efficiency/smart-grids-and-energy-storage-microgrid-in-brooklyn.html

Sims, A. (2018), Why blockchain challenges conventional thinking about intellectual property.Article on TheConversation, 27 February 2018. Retrieved from: https://theconversation.com/why-blockchain-challenges-conventional-thinking-about-intellectual-property-91469

Sinha, S. (2018), How Andhra Pradesh Is Emerging As India's Blockchain Hub. Article on Analytics India Magazine, 17 March 2018. Retrieved from: https://analyticsindiamag.com/how-andhra-pradesh-is-emerging-as-indias-blockchain-hub/

Siu, E. (2018), The Ultimate Guide to Blockchain Digital Marketing and Cryptocurrency. Single Grain. Retrieve from: www.singlegrain.com/blockchain/how-blockchain-is-disrupting-digital-marketing/

Smith, A. M. (2018), The blockchain challenge nobody is talking about. PwC article, 15 March 2018. Retrieved from: http://usblogs.pwc.com/emerging-technology/the-blockchain-challenge

Snäll, M. (2017), Blockchain and the Land Register – A New 'Trust Machine'? Submission n.572. Retrieved from: www.conftool.com/landandpoverty2017/index.php/07-02-Sn%C3%A4ll-572_paper.pdf?page=downloadPaper&filename=07-02-Sn%C3%A4ll-572_paper.pdf&form_id=572&form_version=final

Sno-Caps Team (2014), The People's Cap-And-Trade: Proposal for U.S. Carbon Price 2014. Retrieved from: www.climatecolab.org/contests/2014/us-carbon-price/c/proposal/1305801

Solar Coin (2018), SolarCoin, A blockchain-based solar energy incentive. Retrieved from: https://solarcoin.org/sites/default/files/slr-news/2018-01/SolarCoin_Policy_Paper_FINAL.pdf

Song, W. (2018) Bullish on Blockchain: Examining Delaware's Approach to Distributed Ledger Technology in Corporate Governance Law and Beyond. Harvard Business Law Review, 3 January 2018.Retrieved from: www.hblr.org/wp-content/uploads/2018/01/Bullish-on-Blockchain-Examining-Delaware%E2%80%99s-Approach-to-Distributed-Ledger-Technology-in-Corporate-Governance-Law-and-Beyond.pdf

sonnen GmbH (2015). sonnenCommunity connects households and makes conventional electricity suppliers obsolete through self-generated power. Press release on PR Newswire website, 25 November 2015. Retrieved from: www.prnewswire.com/news-releases/sonnencommunity-connects-households-and-makes-conventional-electricity-suppliers-obsolete-through-self-generated-power-300184496.html

Spencer, R. (2013) "General Insurance in the Twenty-First Century: Meeting the Challenges." CII Thinkpiece. Retrieved from: www.cii.co.uk/media/4424789/tp94_spencer_gi_challenges_13may2013.pdf

Stark, J. (2017), Making Sense of Cryptoeconomics. Article on Coin Desk, 19 August 2017. Retrieved from: www.coindesk.com/making-sense-cryptoeconomics

Stein, S. (2018), Blockchain engineers are in demand. Article on Techcrunch, 15 February 2018. Retrieved from: techcrunch.com/2018/02/14/blockchain-engineers-are-in-demand/

Stinchcombe, K. (2018) Blockchain is not only crappy technology but a bad vision for the future. Article on Medium, 6 April 2018. Retrieved from: https://medium.com/@kaistinchcombe/decentralised-and-trustless-crypto-paradise-is-actually-a-medieval-hellhole-c1ca122efdec

Subramanian, R. (2018), State of Blockchain in Public Sector. Article on SAP, 14 March 2018. Retrieved from: https://blogs.sap.com/2018/03/14/state-of-blockchain-in-public-sector/

Sundararajan, S. (2018), Chinese City to Use Blockchain In Fight Against Tax Evasion. Article on Coin Desk, 25 may 2018. Retrieved from: www.coindesk.com/tencent-partners-with-city-authority-to-combat-tax-evasion-with-blockchain/

Swan, M. (2014), Blockchain health, remunerative health data commons and HealthCoin RFPs. Article on the Institute for Ethics and Emerging Technologies, 29 September 2014. Retrieved from: https://ieet.org/index.php/IEET2/more/swan20140929

SWIFT (2018) SWIFT and CSD community advance blockchain for post-trade. Article, 16 January 2018. Retrieved from: www.swift.com/news-events/press-releases/swift-and-csd-community-advance-blockchain-for-post-trade

Szabo (1994) Smart contracts. Retrieved from: www.fon.hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh.net/smart.contracts.html

Tapscott, A. and Tapscott, D. (2017), How Blockchain Is Changing Finance. Harvard Business Review article, 1 March 2017. Retrieved from: https://hbr.org/2017/03/how-blockchain-is-changing-finance

Tennet (2018) Europe's first blockchain project to stabilize the power grid launches: TenneT and sonnen expect results in 2018. Article from Tennet website, 2 November 2017. Retrieved from: www.tennet.eu/news/detail/europes-first-blockchain-project-to-stabilize-the-power-grid-launches-tennet-and-sonnen-expect-res/

ThinkCoin (2018), ThinkCoin white paper, version 16.2. Retrieved from: https://docsend.com/view/qgyaq2y

Thomson Reuters (2016), Know Your Customer Surveys Reveal Escalating Costs and Complexity. Retrieved from: www.thomsonreuters.com/en/press-releases/2016/may/thomson-reuters-2016-know-your-customer-surveys.html

Tinianow, A. and Long, C. (2017), Delaware Blockchain Initiative: Transforming the Foundational Infrastructure of Corporate Finance, Harvard Law School Forum on Corporate Governance and Financial Regulation: The Delaware Law Series (Mar. 16, 2017). Retrieved from: https://corpgov.law.harvard.edu/2017/03/16/delaware-blockchain-initiative-transforming-the-foundational-infrastructure-of-corporate-finance/

Tkatchuk, R. (2018), Blockchain Is The Great Equalizer For Predictive Analytics. Article on Dataconomy, 6 April 2018. Retrieved from: http://dataconomy.com/2018/04/blockchain-is-the-great-equalizer-for-predictive-analytics/

Tkatchuk, R. (2018). Blockchain Found A Shortcut To The Universal Sharing Economy. Article on Dataconomy, 14June 2018. Retrieved from: http://dataconomy.com/2018/06/blockchain-found-a-shortcut-to-the-universal-sharing-economy/

Toyota (2017), Toyota Research Institute Explores Blockchain Technology for Development of New Mobility Ecosystem. Article on Toyota corporate news, 22 May 2017. Retrieved from: http://corporatenews.pressroom.toyota.com/releases/toyota+research+institute+explores+blockchain+technology.htm

Tucker, C. and Catalini, C. (2018), What Blockchain Can't Do. Article on Harvard Business Review, 29 June 2018. Retrieved from: https://hbr.org/2018/06/what-blockchain-cant-do?utm_medium=social&utm_source=linkedin&utm_campaign=hbr

U.S. Department of Energy (DOE), Office of Electricity Delivery and Energy Reliability website. (2018). https://www.smartgrid.gov/

U.S. National Institute of Standards and Technology (2018), Blockchain Technology Overview (Draft for public comment). Retrieved from: https://csrc.nist.gov/publications/detail/nistir/8202/draft

U.S. Patent and Trademark Office (2018), United States Patent Application issued on May 31, 2018: User Authentication and Authorization for Electronic Transaction. Retrieved from:http://appft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahtml%2FPTO%2Fsearch-bool.html&r=1&f=G&l=50&co1=AND&d=PG01&s1=%22Bank+of+america%22&s2=Blockchain&OS=%22Bank+of+america%22+AND+Blockchain&RS=%22Bank+of+america%22+AND+Blockchain

UK House of Lords (2017), Distributed Ledger Technologies for Public Good: leadership, collaboration and innovation. Retrieved from: http://chrisholmes.co.uk/wp-content/uploads/2017/11/Distributed-Ledger-Technologies-for-Public-Good_leadership-collaboration-and-innovation.pdf

Valkonen, V. (2018). Beginner's Guide to ETHLend: Basic Concepts. Article on ETHLend, 24 May 2018. Retrieved from: https://blog.ethlend.io/beginners-guide-to-ethlend-basic-concepts-e968b0580d82

Van der Elst, C. and Lafarre, A. (2017), Bringing the AGM to the 21st Century: Blockchain and Smart Contracting Tech for Shareholder Involvement. European Corporate Governance Institute (ECGI) - Law Working Paper No. 358/2017. Retrieved from: https://ssrn.com/abstract=2992804

Vaultitute (2018), Vaultitude - Intellectual Property Blockchain Platform. White paper. IPCORP Ltd. 2018 Retrieved from: www.ipchaindatabase.com/assets/downloads/Vaultitude_WhitePaper.pdf

Vian, K. (2016), The blockchain climate fix. Blockchain Futures Lab. Retrieved from: blockchainfutureslab.wordpress.com/2016/06/09/the-blockchain-climate-fix/

Vienna University of Economics and Business (2017), "Blockchain: Taxation and Regulatory Challenges and Opportunities. First Meeting in the Multi-stakeholder Series. Vienna, 15-16 March,2017Room EA.0.024 (Building EA, ground floor); WU. A Background Note Prepared by the WU / NET Team. Retrieved from: www.wu.ac.at/fileadmin/wu/d/i/taxlaw/institute/WU_Global_Tax_Policy_Center/Tax___Technology/Backgrd_note_Blockchain_Technology_and_Taxation_03032017.pdf

Walport, M. (2016) Distributed Ledger Technology: beyond block chain. A report by the UK Government Chief Scientific Adviser. Retrieved from: www.gov.uk/government/uploads/system/uploads/attachment_data/file/492972/gs-16-1-distributed-ledger-technology.pdf

Williams, D. (2017) German-Japanese partnership aims for peer-to-peer energy trading hub. Decentralised Energy. Article on Decentralised Energy, 10 July 2017. Retrieved from: www.decentralised-energy.com/articles/2017/07/german-japanese-partnership-aims-for-peer-to-peer-energy-trading-hub.html

Williams, Z. (2018), Algorithms are taking over – and woe betide anyone they class as a 'deadbeat'. Article on The Guardian, 12 July 2018. Retrieved from: www.theguardian.com/world/commentisfree/2018/jul/12/algorithm-privacy-data-surveillance

Wong, J. I. (2017) Sweden's blockchain-powered land registry is inching towards reality. Article on Quartz, 3 April 2017. Retrieved from: https://qz.com/947064/sweden-is-turning-a-blockchain-powered-land-registry-into-a-reality/

World Bank (2015) The Global Findex Database 2014 Measuring Financial Inclusion around the World. Policy Research Working Paper 7255. Retrieved from: http://documents.worldbank.org/curated/en/187761468179367706/pdf/WPS7255.pdf#page=3

World Bank Group (2016), Why Land Administration Matters for Development. Report by Heider, C. and Connelly, A. Retrieved from: http://ieg.worldbankgroup.org/blog/why-land-administration-matters-development

World Bank Group (2017) Identification For Development (ID4D) Global Dataset. Accessible at: https://datacatalog.worldbank.org/dataset/identification-development-global-dataset

World Economic Forum (2015), Deep Shift Technology Tipping Points and Societal Impact. Survey Report, September 2015. Retrieved from: www3.weforum.org/docs/WEF_GAC15_Technological_Tipping_Points_report_2015.pdf

World Economic Forum (2016), The future of financial infrastructure: An ambitious look at how blockchain can reshape financial services. Retrieved from: www3.weforum.org/docs/WEF_The_future_of_financial_infrastructure.pdf

World Economic Forum (2018), The Global Risks Report 2018, 13th Edition. Retrieved from:www3.weforum.org/docs/WEF_GRR18_Report.pdf

World Food Programme (2017), Blockchain Against Hunger: Harnessing Technology In Support Of Syrian Refugees. World Food Programme news, 30 may 2017. Retrieved from: www.wfp.org/news/news-release/blockchain-against-hunger-harnessing-technology-support-syrian-refugees

World Intellectual Property Organisation (WIPO), (2017), World Intellectual Property Indicators 2017. Retrieved from: www.wipo.int/edocs/pubdocs/en/wipo_pub_941_2017.pdf

Wright, A. and De Filippi, P. (2015), Decentralised Blockchain Technology And The Rise Of Lex Cryptographia. www.intgovforum.org/cms/wks2015/uploads/proposal_background_paper/SSRN-id2580664.pdf

Wüst, Karl and Gervais, Arthur. Do you need a Blockchain? IACR Cryptology ePrint Archive 2017 (2017): 375. Retrieved from: https://eprint.iacr.org/2017/375.pdf

Yakubowski, M. (2018), Bank of Thailand Considers Blockchain for Cross-Border Payments, Fraud Reduction. Article on CoinTelegraph, 14 July 2018. Retrieved from: https://cointelegraph.com/news/bank-of-thailand-considers-blockchain-for-cross-border-payments-fraud-reduction

Yermack, D. (2017) Corporate Governance and Blockchains, Review of Finance, Volume 21, Issue 1, 1 March 2017, Pages 7–31, Retrieved from: https://doi.org/10.1093/rof/rfw074

Young, J. (2016), Senegal Introduces Cryptocurrency Based on its National Currency. Article on Coin Telegraph, 27 November 2016. Retrieved from: https://cointelegraph.com/news/senegal-introduces-cryptocurrency-based-on-its-national-currency

Zahid, J.I., Hussain, F. and Ferworn, A. (2017), Integrating Internet of Things and Blockchain: Use Cases. IEEE Internet Initiative eNewsletter, November 2017. Retrieved from: https://internetinitiative.ieee.org/newsletter/november-2017/integrating-internet-of-things-and-blockchains-use-cases

Zhang, Z. (2018), Why Blockchain Addresses Transparency Issues in Programmatic Advertising. Article on Exchange Wire by Sonja Kroll, 19 February 2018. Retrieved from: www.exchangewire.com/blog/2018/02/19/blockchain-addresses-transparency-issues-programmatic-advertising/

Zhao, Wolfie. (2018) 12 Chinese Banks Say They Deployed Blockchain in 2017. Article on CoinDesk website, 4 May 2018. Retrieved from: www.coindesk.com/12-chinese-banks-adopted-blockchain-apps-in-2017-filings-show/

Zielinski, D. (2017), Is HR Ready for Blockchain Technology? Article on Society for Human Resources Management (SHRM), 21 November 2017. Retrieved from: www.shrm.org/resourcesandtools/hr-topics/technology/pages/is-hr-ready-for-blockchain-technology.aspx

Appendix 1: List of identified blockchain applications

Blockchain Applications	Sustainability implications from blockchain use	Blockchain functionalities	SDGs	Cited SDG Targets
FINANCIAL SECTOR				
Financial inclusion	- Facilitated cross-border transfers, notably to vulnerable populations - Better financial inclusion and access to credit for unbanked people and small businesses through peer-to-peer lending - Strengthened economic development in emerging markets due to smoother transfer of capital	- Peer-to-peer transactions - Operational efficiency - Cryptocurrency	1. 2. 5. 8. 9. 10.	 2.3 5.A 8.10 9.3 10.1, 10.B, 10.C
Fundraising for start-ups	- Increased opportunities for start-ups due to easier and faster access to capital - Improved innovation and economic growth due to more entrepreneurship	- Cryptocurrency - Smart contracts - Operational efficiency	8. 9.	
Securities exchange in financial markets	- More transparent securities depositories and transactions - More stable financial markets - More innovation and growth opportunity for companies due to easier access to financial products	- Operational efficiency - Data accountability - Data security	8. 9. 10.	 10.5
Shareholders' proxy voting	- Better corporate governance due to transparent shareholder voting - Increased participation of small shareholders in corporate decisions	- Smart contracts - Data accountability - Operational efficiency	8. 9. 16.	 16.7
Financial accounting	- Reduced accounting fraud due to automated and time-stamped bookkeeping and audit - Better accountability and corporate governance due to transparent and real-time availability of company transaction records	- Data accountability - Fraud prevention - Operational efficiency	9. 10. 16.	 16.5, 16.6
BUSINESS SECTOR				
Business intelligence	- Better privacy and security for data shared on cloud services - Wider access to predictive analytics by small and medium enterprises	- Smart contracts - Operational efficiency - Data security	8. 9. 10.	
Supply chain management	- Reduced energy, food, water and material waste in manufacturing and transportation due to access to real-time supply chain data - Better compliance with drug and food safety regulations through automated quality controls	- Smart contracts - Operational efficiency - Strengthened IoT networks	1. 3. 6. 8. 9. 12. 16.	1.5 6.3, 6.4 8.7, 8.8 12.2, 12.3, 12.4 16.2, 16.4
Marketing and advertising	- Customer empowerment through better control by Internet users over the data they share with companies - Better customer experience due to smart and customised advertising	- Operational efficiency - Data accountability - Fraud prevention	8. 10.	
Intellectual property	- More innovation and growth for entrepreneurs and small and medium enterprises, due to better protection of IP rights through smart IP registries - Control over their creative content by artists through IP rights and royalties management platforms	- Data accountability - Data security - Fraud prevention	8. 9.	8.2, 8.3 9.B
Insurance	- Wider access to insurance through micro and peer-to-peer insurance models, notably for vulnerable populations - Better insurance coverage with automated insurance, reducing notably climate-related risks for farmers	- Smart contracts - Peer-to-peer transactions - Data accountability	1. 3. 8. 9. 10.	1.3 3.8 8.10

Human resources	- More job opportunities for self-employed workers through smart recruiting and payroll procedures - Better transparency from employers, employees and job-seekers	- Smart contract - Data accountability - Fraud prevention	5. 8. 10.	5.5 8.2, 8.5 10.3
PUBLIC SECTOR				
Government operations	- Collaborative governance and public services - Greater accountability of public institutions and decisions - Greater social cohesion and trust between citizens and their government	- Data accountability - Fraud prevention - Operational efficiency	8. 10. 11. 16. 17.	 10.2 16.3, 16.5, 16.6 17.17
Legal identity and healthcare	- Better access to healthcare through smart identity systems - Better healthcare services through decentralised electronic health records - Reduced identity theft through secured identification for online services	- Data accountability - Fraud prevention - Operational efficiency	1. 3. 5. 10. 15. 16.	 3.1, 3.2, 3.3, 3.4, 3.7 5.6 15.5, 15.6, 15.7 16.9
Elections	- Greater integrity of democratic elections through secured electronic voting systems - Wider democratic participation - Direct democracy and self-governance	- Data accountability - Data security - Fraud prevention	10. 16. 17.	10.2 16.3, 16.5, 16.6, 16.7 17.15
Land titling	- Reduction of land-related corruption and land-grabbing violence - Better access to property ownership for vulnerable populations through decentralised land registries and smart proof of ownership	- Data accountability - Data security - Fraud prevention	1. 2. 5. 10. 11. 16.	1.4, 1.5 2.3 5.A 11.1, 11.2 16.6
Taxation	- Reduced tax fraud and fund misappropriation - Fairer taxation system due to enhanced visibility on micro-transaction - Dynamic interactions between tax authorities and taxpayers	- Data accountability - Data security - Fraud prevention	8. 10. 11. 16. 17.	8.1, 8.2 10.4 16.5, 16. 17.1, 17.4
CLIMATE CHANGE AND SUSTAINABLE SOCIETIES				
Sustainable production and consumption	- Mainstreamed ethical consumption due to wide access to transparent products data submitted by each supply chain actor - Greater consumer trust and awareness due to enhanced sustainable certification - Increased fair trade practices across all industries due to empowerment of supply chain actors such as small farmers	- Data accountability - Fraud prevention - Strengthened IoT networks	2. 8. 10. 11. 12. 14. 15. 17.	2.4, 2.B 8.4 10.1 11.6 12.2, 12.3, 12.5, 12.6, 12.7, 12.8 17.10
Sustainable lifestyles	- More flexibility and access to sharing economy - Resource efficiency through informed consumption decisions - Improved working conditions	- Smart contracts - Peer-to-peer transactions - Strengthened IoT networks	3. 9. 11. 12. 13.	3.6 9.1 11.2 12.2, 12.5, 12.8 13.3
Institutional carbon trade	- Avoidance of double counting due to more efficient tracking and accounting of carbon credits on carbon markets - Greater accountability of public institutions due to transparent carbon markets	- Data accountability - Data security - Operational efficiency	7. 13. 16. 17.	 16.6 17.6, 17.8
Individual carbon trade	- Increased citizen's environmental awareness due to more transparent carbon footprint tracking - Reduced carbon emissions through enhanced individual climate actions	- Cryptocurrency - Peer-to-peer transactions - Data accountability	11. 12. 13.	 12.8 13.3

Smart grid	- Improved stability of electricity grid - Real-time electricity data collection - Reduced energy waste through increased efficiency of energy systems	- Smart contracts - Operational efficiency - Strengthened IoT networks	7. 9. 11. 12. 13.	7.1, 7.3 9.1
Renewable energy	- Mainstreamed renewable energy generation by household and commercial facilities due to increased market incentives for peer-to-peer energy trading - Wider dissemination of renewable energy technologies - Change in consumption behaviour due to access to real-time electricity consumption data	- Cryptocurrency - Peer-to-peer transactions - Strengthened IoT networks	7. 9. 12. 13.	7.1, 7.2 9.4 12.2
Philanthropy	- Direct and secured fundraising platforms enabling larger donations. - Transparent donation systems, leading to a wider pool of potential donors due to increased confidence in the destination and use of funds.	- Peer-to-peer transactions - Data accountability - Fraud prevention	1. 2. 3. 4. 6. 10. 13. 17.	1.A, 1.1 2.A, 2.1, 2.2 3.B, 3.3, 3.4 4.A, 4.1 6.A, 6.1, 6.2 10.B 13.A 17.3

Appendix 2: List of cited blockchain initiatives

Provider	Application Field	Use of blockchain	URL
FINANCIAL SECTOR			
BitPesa	Financial inclusion	Blockchain-based payment solutions aiming to reduce the cost of cross-border payments in Africa.	public.bitpesa.co
Binance	Financial inclusion	Blockchain-based decentralised and community-owned bank.	www.binance.com
Ripple	Financial inclusion	Blockchain service provider working to create clearance and settlements systems based on permissioned blockchains.	ripple.com
R3 CEV	Financial inclusion	Blockchain consortium working to create clearance and settlements systems based on permissioned blockchains.	www.r3.com
Everex	Financial inclusion	Blockchain solutions to cross-border payments.	www.everex.io
Vio Digital	Financial inclusion	Blockchain solutions to cross-border payments.	www.viome.io
ETHLend	Financial inclusion	Decentralised lending application.	ethlend.io
Bloom	Financial inclusion	Decentralised credit scoring and assessment protocol.	bloom.co
CoinList	Fundraising for start-ups	Blockchain services for capital raising through ICOs.	coinlist.co
ThinkCoin	Securities exchange in financial markets	Company providing TradeConnect, a blockchain-based financial asset exchange platform.	www.thinkcoin.io
Nasdaq	Shareholders' proxy voting	Blockchain-based e-voting service for shareholders of companies listed on Nasdaq's Tallinn Stock Exchange	e-resident.gov.ee
TMX Group	Shareholders' proxy voting	Blockchain-based prototype for electronic shareholder voting	N/A
CSD Working Group on DLT	Shareholders' proxy voting	Distributed ledger proxy voting system embedded with the ISO 20022 standard.	N/A
Deloitte	Financial Accounting	Rubix platform, providing enterprise-level solutions to clients.	N/A
KPMG	Financial Accounting	Blockchain nodes, demonstrating use cases of blockchain technology to business processes.	N/A
PwC	Financial Accounting	Blockchain auditing service Blockchain Validation Solution.	N/A
EY	Financial Accounting	EY Blockchain Analyzer, facilitating EY auditors review and analysis of transactions on the blockchain.	N/A
BUSINESS SECTOR			
Storj	Business intelligence	Blockchain-based peer-to-peer data storage	storj.io
Sia	Business intelligence	Blockchain-based peer-to-peer data storage	sia.tech
Enigma	Business intelligence	Blockchain-based cloud service allowing data to be accessed and edited while still in a decentralised, encrypted form.	enigma.co
Google	Business intelligence	Blockchain-related technology platform to support its cloud business.	N/A
Stox	Business intelligence	Blockchain platform for trading event results in prediction markets.	www.stox.com
Gnosis	Business intelligence	Blockchain platform for trading event results in prediction markets.	gnosis.pm
Augur	Business intelligence	Blockchain platform that rewards users for correctly predicting the outcomes of real-world events.	www.augur.net
Endor	Business intelligence	Blockchain-based predictive analytics suite using social physics.	www.endor.com
Wave	Supply chain management	Blockchain-based network that connects supply chain members and allows them to exchange documents directly.	wavebl.com
Skuchain	Supply chain management	Blockchain-based collaborative e-commerce platform.	www.skuchain.com
DSCI	Supply chain management	Provides a Blockchain Return Index (BRI) for analyzing blockchain business cases and their impact.	www.dscinstitute.org
VeChain	Supply chain management	Blockchain technology used in combination with smart chips to track products throughout their lifecycle.	www.vechain.com

Waltonchain	Supply chain management	Combines blockchain with IoT to create a management system for supply chains.	www.waltonchain.org
Nasdaq	Marketing and advertising	New York Interactive Advertising Exchange, a platform for advertisers to trade advertising on the blockchain.	www.nyiax.com
MetaMask	Marketing and advertising	Services allowing internet users to control their identity and transaction history.	metamask.io
Vaultitude	Intellectual property	Blockchain-based IP protection software.	www.ipchaindatabase.com
Binded	Intellectual property	Blockchain platform allowing artists to record the copyright ownership of their creative content.	binded.com
Blocknotary	Intellectual property	Blockchain platform allowing artists to record the copyright ownership of their creative content.	www.blocknotary.com
KODAK	Intellectual property	KODAKOne, a digital ledger of rights ownership for photographers.	kodakone.com
P&TS and Bernstein	Intellectual property	Notarisation services for invention announcements based on blockchain.	www.bernstein.io
EY and Microsoft	Intellectual property	Blockchain-based solution for content rights and royalties management.	N/A
LenderBot	Insurance	Micro-insurance platform for high-value items.	lenderbot.io
Standard Chartered Bank	Insurance	Multinational, smart contract-based insurance policy.	N/A
Blockcerts	Human resources	Blockchain-based credentials and certificates record.	www.blockcerts.org
MIT	Human resources	Pilot programme allowing students to receive a diploma on the blockchain.	N/A
Recruit Holdings and Ascribe	Human resources	Use of blockchain to fight fraud in HR credentials.	N/A
Bitwage	Human resources	Cross-border payroll payments with Bitcoins.	www.bitwage.com
ChronoBank	Human resources	Blockchain-based recruitment platform.	chronobank.io
PUBLIC SECTOR			
Bank of Thailand	Government operations	Considering using blockchain to improve regional financial connectivity and facilitate cross-border financial services.	N/A
Aragon	Government operations	Blockchain-based services for disintermediating the creation and maintenance of organisational structures.	aragon.one
UAE	Government operations	UAE Blockchain Strategy 2021, with blockchain uses for smart records, business registration and central bank operations.	N/A
Dubai	Government operations	Dubai Blockchain Strategy, aiming to execute all transactions on the blockchain by 2020.	N/A
Danish tax Administration	Government operations	Vehicle Wallet, a blockchain -tool for handling a vehicle's life cycle process.	N/A
ID2020 Alliance	Legal identity and healthcare	Partnership aiming to build a digital ID network.	id2020.org
Civic	Legal identity and healthcare	Blockchain-based identity verification product.	tokensale.civic.com
uPort	Legal identity and healthcare	Services allowing internet users to control their identity and transaction history.	www.uport.me
Namecoin	Legal identity and healthcare	Decentralised domain name registration database.	namecoin.org
UniquID	Legal identity and healthcare	Identity Access Management (IAM) services.	uniquid.com
Shocard	Legal identity and healthcare	Blockchain-based ID validation system.	shocard.com
MedRec	Legal identity and healthcare	Blockchain-based database for sharing patient data for medical purposes.	medrec.media.mit.edu/

DNA.Bits	Legal identity and healthcare	Enables the tracking of health and genetic data on a blockchain.	socialm1.wixsite.com/dnabits
Estonia	Legal identity and healthcare	Project to store all national medical records on a blockchain-based digital platform.	N/A
Voatz	Elections	Blockchain-based voting system enabling tamper-proof record-keeping and identity verification.	voatz.com
V-Initiative	Elections	Blockchain-based digital voting solutions.	www.v-initiative.org
nVotes	Elections	Blockchain-based digital voting solutions.	nvotes.com
Follow My Vote	Elections	Blockchain-based digital voting solutions.	followmyvote.com
Liberal Alliance	Elections	Use of blockchain for electronic voting at its annual party meeting.	N/A
Plebiscito Digital	Elections	Blockchain-based voting used to give Colombian expatriates a voice in the peace plebiscite.	plebiscitodigital.co
Georgia	Land titling	Pilot project on blockchain-based land titling.	bitfury.com
Ghana	Land titling	Blockchain-based land registry and verification platform.	www.benben.com.gh
Andhra Pradesh	Land titling	Blockchain-based land registry through the Zebi Data platform.	www.zebi.io
Honduras	Land titling	Pilot project to transfer the national land registry to a blockchain-based system.	www.factom.com
Sweden	Land titling	Blockchain-based land registry.	chromaway.com
Proof of Existence	Land titling	Blockchain-based notary service that stores proof of existence of any document.	poex.io
Stampery	Land titling	Blockchain-based data certification platform.	stampery.com
Signatura	Land titling	Blockchain-based digital signature platform.	signatura.co
Revenue Quebec	Taxation	Use of Sales Recording Modules (SRMs) for restaurants.	N/A
Shenzhen	Taxation	Use the blockchain platform TrustSQL against tax evasion.	trustsql.qq.com
CLIMATE CHANGE AND SUSTAINABLE SOCIETIES			
Walmart, Nestlé, Unilever and Tyson Foods	Sustainable production and consumption	Partnership with IBM to explore how blockchain could be used to improve the transparency of the global food supply chain.	N/A
Walmart	Sustainable production and consumption	Tracking of two products - a packaged produce item in the U.S. and pork in China - using blockchain technology.	N/A
Everledger	Sustainable production and consumption	Provides a digital ledger that tracks and protects valuable assets, such as diamonds.	www.everledger.io
Provenance	Sustainable production and consumption	Blockchain-based software enabling producers, retailers, certifiers and consumers to track the journey of goods.	www.provenance.org
Catenaut	Sustainable production and consumption	Blockchain of custody, a blockchain system for certifying forest management compliance.	www.catenaut.com
AgriLedger	Sustainable production and consumption	Distributed Cryptoledger Mobile App that enables small farmers to record transactions directly on the blockchain.	www.agriledger.com
bext360	Sustainable production and consumption	Blockchain-based transaction network, combined with AI and IoT in order to transform the supply chain of coffee.	www.bext360.com
Slock.it	Sustainable lifestyles	Developed IoT Layer, a decentralised network layer that improves IoT security by connecting devices to a blockchain.	https://slock.it/
Dream	Sustainable lifestyles	Consolidate service providers and users for finding freelance talent.	https://dream.ac/
Blocklancer	Sustainable lifestyles	Consolidate service providers and users for finding freelance talent.	https://blocklancer.io
Golem	Sustainable lifestyles	Allow people to rent out their computing power in exchange of tokens as means of payment.	https://golem.network/
Filecoin	Sustainable lifestyles	Allow people to rent out their computing power in exchange of tokens as means of payment.	https://filecoin.io/
Averspace	Sustainable lifestyles	Connect homeowners directly with potential buyers or tenants with adjustable, enforceable smart contracts.	https://averspace.com/

CarbonX	Individual carbon trade	Invests in carbon reduction projects and distributes the offsets as crypto-tokens through their rewards programme.	carbonx.ca/#goodcoins
Climate Drops	Individual carbon trade	Tracks environmentally friendly actions of its users and rewards them with crypto-tokens.	kt-energy.com.ua/en/projects/climate-drops/
Grid Singularity	Smart grid	Creates a platform to enable operators, investors, traders and consumers collaborate efficiently on smart grids.	https://gridsingularity.com/
ADEPT	Smart grid	Uses smart contracts on Ethereum to decentralise IoT network, enabling micro transactions between appliances on smart grid.	N/A
Piclo	Renewable energy	Help businesses meet sustainability goals by promoting renewable energy resources.	piclo.uk
SolarCoin	Renewable energy	Incentivises solar power generation by offering SolarCoin crypto-tokens to any interested solar power producer.	solarcoin.org
BitGive	Philanthropy	BitGive's flagship product, BitTrack, guarantees the transparency of donations through asset tracking.	www.bitgivefoundation.org
Disberse	Philanthropy	Blockchain-based financial operating network for global development.	www.disberse.com
Benefactory	Philanthropy	Blockchain-based crowdfunding philanthropy platform led by community organisers.	www.benefactory.cc
WeiFund	Philanthropy	Blockchain-based crowdfunding philanthropy platform.	weifund.io
World Food Programme	Philanthropy	Project to use Ethereum to make transfers for humanitarian aid faster, cheaper and more secure.	N/A
Rainforest Foundation	Philanthropy	Accepts donations in cryptocurrencies in order to protect the rainforest and stop illegal logging.	www.rainforestfoundation.org
GainForest	Philanthropy	Blockchain-based payment system that transfers money directly from donors to caretakers of the Amazon forest.	gainforest.org

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