Chapter

# Leveraging Blockchain for Sustainability and Open Innovation: A Cyber-Resilient Approach toward EU Green Deal and UN Sustainable Development Goals

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## Abstract

In 2015, the United Nations (UN) member states identified 17 Sustainable Development Goals (SDGs) to be fulfilled by 2030. SDGs are an urgent global call for action to provide a blueprint for shared prosperity in a sustainable world. At a European level, in December 2019, the European Green Deal was presented, a roadmap to implement the UN 2030 agenda with a commitment to a growth strategy that will turn environmental challenges into opportunities across all policy areas. To achieve these SDGs, blockchain is one of the key enabling technologies that can help to create sustainable and secure solutions, since it is able to deliver accountability, transparency, traceability, and cyber-resilience, as well as to provide a higher operational efficiency in global partnerships. This chapter overviews the potential of blockchain to face sustainability challenges by describing several relevant applications. Finally, different open challenges and recommendations are enumerated with the aim of guiding all the stakeholders committed to the development of cyber-resilient and high-impact sustainable solutions.

**Keywords:** blockchain, distributed ledger technology (DLT), cybersecurity, smart contracts, global challenges, open innovation, sustainability, SDGs, circular economy, blockchain4SDGs

## 1. Introduction

In December 2019, the European Commission (EC) unveiled a plan to become the first climate-neutral organization worldwide by 2050. The so-called European Green Deal [1] is a roadmap for setting the sustainability and well-being of citizens at the center of policymaking and then turning climate and environmental challenges into opportunities across all policy areas. As it was created, the EU Green Deal is a commitment with sustainable development and a fundamental part of the

EC strategy to undertake the United Nations (UN) 2030 Agenda for Sustainable Development [2]. The 17 Sustainable Development Goals (SDGs) involve the three dimensions of sustainability (economic, social, and environmental) and require all the stakeholders to act in a global collaborative partnership. Such goals aim to achieve no poverty and hunger, to grant access to health services, to improve infrastructures, to reduce inequality, to fight climate change, to protect marine ecosystems, or to promote alliances between different actors to improve people's lives, among others.

Emerging technologies like the Internet of Things (IoT), 3D/4D printing, augmented reality/mixed reality/virtual reality (AR/MR/VR), cyber-physical systems (CPSs), robotics, novel human-machine interfaces (HMI), artificial intelligence (AI), big data techniques, machine learning (ML), deep learning (DL), 5G/6G connectivity, and new computing paradigms, when oriented toward SDGs, will bring a wide range of disruptive solutions in multiple fields. Nonetheless, the mentioned technologies will create ever-increasing complex systems in terms of heterogeneity, autonomy, interoperability, and scalability that will also come with additional cybersecurity risks and threats of malicious attacks.

Distributed ledger technology (DLT) represents nowadays an evolution toward the so-called Web 3.0, the Internet of Value. This new era of the Internet will include a collaborative economy among peers with crowdsourcing data sharing systems [3, 4]. A blockchain is a specific type of DLT that involves timestamped blocks of transactions linked in a chain by cryptographic hashes. Blockchain presents a decentralized architecture that provides benefits in terms of security, privacy, non-repudiation, integrity, accountability, transparency, robustness, and authentication. Moreover, it provides a high operational efficiency and eliminates the need for centralized parties and/or intermediaries. In fact, the World Economic Forum (WEF) forecasts that, by 2027, 10% of the global gross domestic product (GDP) will likely be stored on DLTs [5].

In this context, blockchain and other DLTs can enable global partnerships for open innovation and cyber-resilient applications compliant with the aims of the EU Green Deal and the UN SDGs. Thus, the contribution of this chapter is to provide a global overview of blockchain as an enabler for sustainability and open innovation. In addition, its aim is also to make the different involved stakeholders to rethink global development challenges to create cyber-resilient, decentralized, and high-impact sustainable developments.

The rest of the chapter is organized as follows. Section 2 overviews the basic concepts of blockchain. Sections 3 and 4 summarize the main principles of blockchain for sustainability and open innovation. Section 5 presents some relevant use cases of blockchain-based applications toward each of the SDGs. Section 6 summarizes the key main benefits of blockchain for SDGs and their main open challenges. Finally, Section 7 is devoted to conclusions.

## 2. Basic concepts of blockchain

A blockchain is a secured distributed ledger whose data are shared among peers [6–9]. In some blockchains like Bitcoin, decentralized miners validate every transaction (by following a consensus protocol), which allows them to solve the Byzantine Generals Problem (i.e., a situation where different parties must agree on a strategy and some of them may be corrupt, disseminate false information, or have intention to deceive). In the case of cryptocurrencies, the problem to be solved is called the double-spend problem: it must be guaranteed that the exchanged digital cash was not spent previously [6].

There are four main types of blockchains depending on who can access the stored data (private or public blockchains) and who can manage such data (permissionless or permissioned blockchains). Since a blockchain can store any kind of digital information, it could be the future of all secure transactions. Moreover, blockchain enables smart contracts, which consist of self-sufficient decentralized code that is executed autonomously according to a business logic. Furthermore, some blockchain platforms can also run decentralized applications, which are commonly called DApps [10].

Another important concept is the so-called decentralized autonomous organization (DAO), which can operate without requiring management hierarchy or a centralized authority [11]. The first DAO was launched in 2016 and raised $150 million worth of Ether (ETH) in 27 days. Nevertheless, DAOs are still very immature from the legal and security standpoints (e.g., a DAO attack due to code bugs led to a more than $50 million (ETH) theft in June 2016). Since 2016, a number of DAO initiatives have arisen (e.g., Steemit). In addition, the proliferation of DAOs is linked to the concept of decentralized autonomous society (DAS), in which citizens may be able to establish self-enforcing trade agreements without relying on centralized institutions of power and control.

It must be noted that a blockchain is not suited for every SDG-oriented application, which must fulfill the following main requirements:

- Trustworthy transactions are needed, but traditional databases do not cover the application needs.
- Data need to be updated by more than one stakeholder.
- There is a lack of trust among the entities that will update the data.
- The updaters are not willing to give the control of the database to a third party, and the involvement of intermediaries wants to be avoided when possible.
- A database could be used, but it is likely to be attacked (e.g., denial-of-service (DoS) attacks) or censored.
- Data redundancy in multiple distributed computers is needed.

Additional requirements could be involved, so several researchers have proposed more detailed decision frameworks about the use of blockchain [6, 12, 13].

It is worth mentioning that a detailed description of the different blockchain design aspects is out of the scope of this chapter, but the reader can find additional insights on the following recent works [4, 6, 8, 13].

## 3. Blockchain for sustainability

Sustainability is related to the effect that current actions will have upon the future. Such an effect can take many forms that vary depending on their nature, like the utilization of natural resources as a part of production processes, the waste management processes, the effects of competition among corporations in the same market, the enrichment of the community by creating employment, the produced pollution, the outbreak of a pandemic, or the relation with regulators. For example, if natural resources run out, then they may be no longer available (i.e., raw materials). Thus, the way in which economic, social, and environmental resources are efficiently managed is a key issue for long-term sustainability.

Recently, the EU has progressed significantly toward sustainability through the three main approaches [14]:

- Corporate social responsibility (CSR)/responsible business conduct (RBC) and new business models
- Business and human rights and the protection of human rights in general
- Sustainability and the implementation of the UN 2030 Agenda for Sustainable Development

The definition of CSR and RBC is related with ethical behavior and particularly with the relationship between a corporation and its stakeholders within a societal context, integrating social, environmental, and economic concerns into its business processes [14]. CSR/RBC can also be seen as actions under SDG 8 (decent work and economic growth).

In 2011, the UN Human Rights Council endorsed 31 Guiding Principles on Business and Human Rights (UNGPs) [14]. This approach came up as a sort of response to the perceived failure of CSR/RBC in terms of law binding and state oversight.

Recently, given the clear relationship between the three approaches (CSR/RBC, UNGPs, and the SDGs), the EC has adopted a holistic and practical approach toward sustainability irrespective of its name (i.e., CSR, RBC, business and human rights, SDG) while at the same time recognizing the target goal between the different agendas.

Within this context, blockchain is able to bring advantages toward sustainability in four main aspects: cybersecurity, accountability, transparency, and traceability:

- *Cybersecurity*. Applications for sustainability should be enabled by a robust digital infrastructure resilient to cyberattacks [15]. Cybersecurity should be implemented by design in the underlying technologies (e.g., IoT, AR, AI).
- *Accountability*. It is related to an organization (e.g., corporation or individual) acknowledgment of the impact of its actions, assuming responsibility for them. It implies to quantify the internal and external effects of the actions and report them to all the stakeholders. Such a reporting needs to be understandable, relevant, reliable, and comparable between different organizations and over time.
- *Transparency*. It implies that the external impact can be obtained from reporting by all the external stakeholders [16].
- *Traceability*. It is the ability to identify and trace assets (e.g., products, parts, processes, events, data, and materials) from their origins to production and distribution processes and, ultimately, until the end of their life cycle [17, 18]. Regarding Sustainable Supply Chain Management (SSCM), it also relates to human rights (e.g., fair trade, safety in labor, and privacy) and anti-corruption laws [18]. Therefore, it is a key organizational capability to foster sustainability. Two main categories can be considered within traceability [19]: internal (i.e., tracking and tracing assets within an organization) and external (i.e., it seeks to know the flow of information and assets between different logistics systems and processes among a number of organizations).

The importance of external traceability has been enhanced by globalization, the free movement of people and the global expansion of complex supply chain structures, combining networks of actors from multiple sectors (business, public, non-profit, and informal) in multiple locations.

## 4. Blockchain for open innovation

Open innovation, where innovative knowledge and ideas flow freely internally and externally to an organization, has become an important factor to enable sustainability [20]. To address SDGs, the EU recognizes the need for strengthening the impact of research and innovation and the use of coordinated approaches to ensure knowledge exchanges at an EU level [15]. These coordinated approaches will involve stakeholders with inter- and transdisciplinary points of view and the ability to manage jointly these development processes (SDG 17, partnerships for the goals) [21]. Although the current literature in open innovation details theoretical frameworks to guide solution development [20, 22], this development implies novel governance models that create thriving and diverse ecosystems where solutions are conceived, designed, experimented, implemented, supplied to the market, scaled up, and adopted. In that sense, one of the latest paradigms is called Open Innovation 2.0 (OI2) [23], a quadruple helix model where science, policy, industry, and society collaborate to achieve greater aims than a single entity.

Open innovation is uncertain and involves a high risk [20]. However, the lack of trust is today a major concern that withholds the cooperation and involvement of stakeholders in open innovation processes [24], especially for small- and medium-sized enterprises (SMEs). This need for orchestrating multiple stakeholders in a trusted and reliable way matches perfectly with the distributed nature of blockchain [20], which also provides the following main benefits:

- Stronger intellectual property (IP) protection. It includes responsible open-source licensing, processes of idea claiming [25], IP registries (e.g., trade secrets, patents, and trademarks), record keeping, licensing, and non-disclosure agreements (NDAs). In addition, profits (e.g., patent royalties and revenue on creative work) can be paid automatically according to predetermined agreements.

- Accurate collaboration between stakeholders modeled through smart contracts. Content can be shared among the stakeholders using smart contracts. Such smart contracts may deal with timestamping any IP disclosure or creation and automate corrective actions when unauthorized IP usage, IP infringements, and disclosure happen, acting as signed NDAs [25]. Furthermore, incentivized and rewarding mechanisms can be established (e.g., GlucoCoins to promote a global knowledge of diabetes [26]).

- Open data. It means the availability of data to all the stakeholders with a high degree of privacy (i.e., sovereignty and data ownership) and data protection.

- Regulatory compliance. It involves back-office processes mostly burdensome and inefficient to report to regulatory bodies. It also enables new open governance models.

## 5. Leveraging blockchain toward SDGs

Currently there are few examples of academic research on the use of blockchain for SDGs. For instance, the authors of [16] review recent academic and commercial "blockchain for good" applications in supply chain, innovations in governance, sharing economy, and financial inclusion. This section provides some relevant use cases of blockchain-based applications toward each of the SDGs. Such use cases are summarized in **Figure 1**.

### 5.1 SDG 1: no poverty

Access to credit and financial services (e.g., microfinance) is one of the most commonly known mechanisms to reduce poverty. For instance, crowdsourcing and crowdlending platforms can also ease financial inclusion. Blockchain can help to increase the efficiency, traceability, and transparency of these financial processes [27]. Moreover, micro-transactions and automatic funding through forecast-based financing [28] can be implemented jointly with smart contracts and big data analytics. Such models can provide more efficient funding, since no additional intermediaries are required and some procedures can be substantially simplified.

According to [29], 206.4 million people of 81 countries needed humanitarian assistance in 2018. For instance, only 6 of such countries represent 80.6 million people in need. Such a humanitarian assistance from governments and private donors reached US $28.9 billion in 2018. Nevertheless, a substantial percentage of the assistance was and is today lost due to fraud and corruption. Blockchain can be applied to provide tracking of the funds and to reduce cyberattacks. The authors of [28] highlight the need for ethical guidelines (i.e., privacy, intentional design choices, and humanitarian principles) and a common evaluation

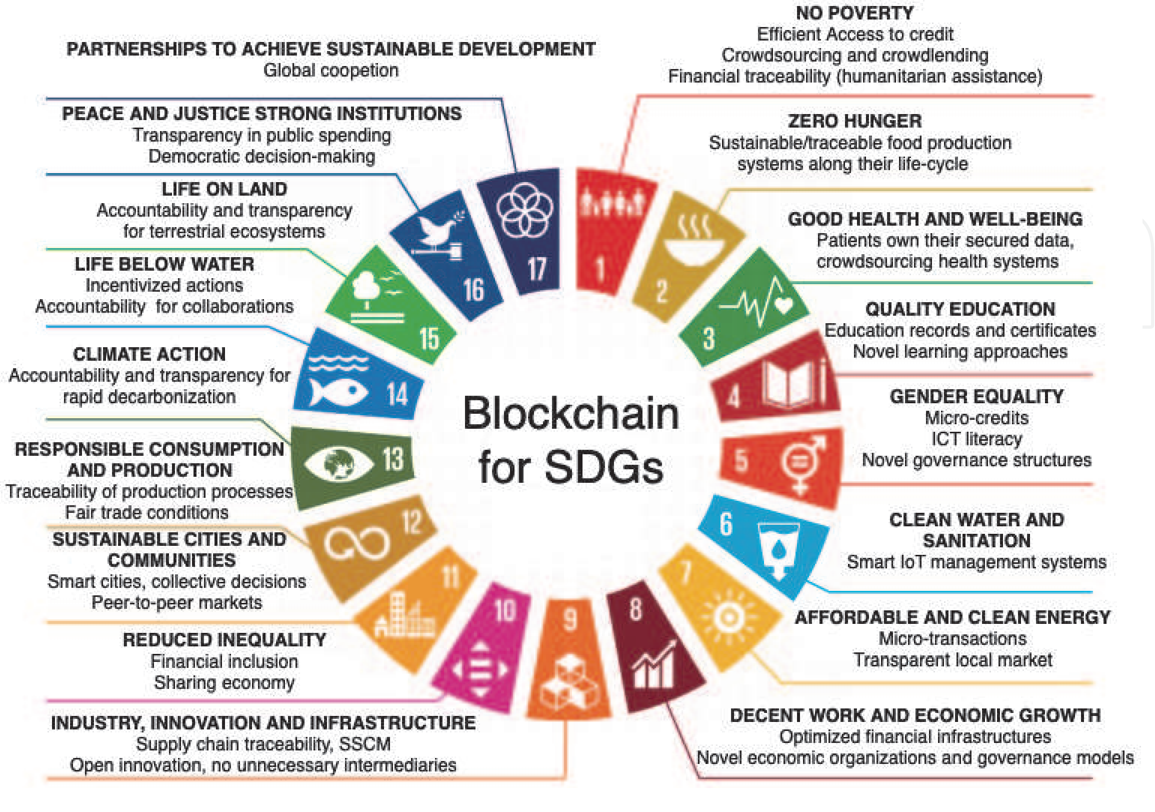


**Figure 1.**
*Blockchain4SDGs: main blockchain use cases for SDGs.*

framework of the solutions, especially as DLT developments are still in their early stages.

In 2017, the World Food Programme (WFP) [30] developed a proof of concept (PoC) in Sindh (Pakistan) named Building Blocks to evaluate blockchain for authentication and registration of transactions without financial intermediaries. Refugees have restrictions to open bank accounts and limited choices regarding the access and spending of their cash assistance. Building Blocks was also deployed with the aid of a biometric authentication system (i.e., iris scanning identification at checkout) in two refugee camps in Jordan to improve security and to ease cash transfers and the purchase of goods.

### 5.2 SDG 2: zero hunger

Sustainable food production systems along their life cycle can be guaranteed with the traceability properties of blockchain (e.g., avoid malpractice and guarantee food security).

### 5.3 SDG 3: good health and well-being

In Yue et al. [31], the authors propose a decentralized solution that enables healthcare intelligence that allows patients to control their data without compromising privacy or security.

In addition, blockchain can be used for managing data more efficiently during public health diseases. For instance, with the current rapid spread of the coronavirus disease (COVID-19) pandemic, a blockchain-based monitoring and traceability system can help to automatically identify unsafe areas by using geographic information and provide real-time information about patients (e.g., temperature, symptoms, and social distancing) for further analysis. As a result, it may keep communities from further infections and ensure (or even certify) that some locations (e.g., workplaces) are safe areas. For the implementation of such an application, cybersecurity and privacy (i.e., pseudo-anonymization) will be key issues for a successful deployment. Disease control may also depend on the ability of organizations (e.g., centers of disease control, state and local agencies, journalists, governments, hospitals, scientists) to collaborate in an effective and efficient manner. It must also be noted that richer countries are better prepared than poorer countries to identify a virus outbreak, to face infection with public health contingency plans, and to minimize the socioeconomical impact.

### 5.4 SDG 4: quality education

The authors of [32] have thoroughly reviewed the utilization of emerging technologies like blockchain, IoT, and fog and edge computing for improving education. Examples of applications include record verification [33], the management of digital copyright information [34], or the design and evaluation of novel learning approaches [35–37].

For instance, Sony Global Education [38] is an educational platform that uses Hyperledger Fabric to guarantee the authenticity of the student transcripts. Another commercial example is Learning Machine [39], a company that has created an open peer-to-peer infrastructure to issue digital records that can be easily shared and verified. The system is not only devoted to educational institutions: governments and companies can also issue blockchain-based records at scale, rooted in any blockchain they select.

### 5.5 SDG 5: gender equality

Easier access to financial services (e.g., even informal financial networks) promotes women empowerment as well as their independence. For example, hiveonline [40] is helping women through the CARE Village Savings and Loan Association (VSLA) program to get access to credits and markets with a fact-based reputation supported by blockchain. Such a financial infrastructure reduces the cost of cross-border payments and the risk of lending.

It must be noted that blockchain implies the use of Information and Communication Technologies (ICT), which can contribute to increase access to literacy. Furthermore, the inner characteristics of blockchain remove trust issues and enable the creation of new types of governance that may create equal opportunities for women leadership.

### 5.6 SDG 6: clean water and sanitation

Sustainable and efficient water management systems involve the use of sophisticated IoT architectures that optimize consumption and availability. Such architectures may be subject to security attacks (e.g., physical attacks on sensors, device cloning, data theft, DoS, jamming, or eavesdropping). Therefore, it is important to cyber-secure these systems and minimize the reliance on cloud-centered architectures that, when the server is down, may derive in the unavailability of the service. In addition, the communication between IoT devices within a decentralized architecture allows for avoiding single points of failure and enables the use of autonomous IoT transactions in a secure manner, thus guarantying tamper-proof data, visibility, and transparency in water trading [41].

### 5.7 SDG 7: affordable and clean energy

The authors of [42] study blockchain-based smart grid sustainable local energy markets. These systems enable cost-efficient micro-transactions, avoid central intermediaries, and promote reliability and equality among the different involved agents.

### 5.8 SDG 8: decent work and economic growth

Blockchain has the ability to promote economic growth by enabling free trade. For instance, it also has the potential to optimize global financial infrastructure in terms of asset transfer and operative costs.

In addition, it may ease new types of economic organization and governance (e.g., innovation-centered and governance-centered [43]). In Davidson et al. [43] the authors present an example of a self-governing organization for evaluating the contributions to projects on a network. When evaluating such an example, they introduce a wide range of perspectives to be considered, such as the problem of contractual enforcement, efficient institutions, governance, or even the constitutional characteristics of a nation.

### 5.9 SDG 9: industry, innovation, and infrastructure

The Industry 4.0 paradigm is expected to represent the next phase in the digitalization of all the sectors in the economy [8]. Supply chain traceability has been traditionally performed by wireless technologies like radio-frequency identification

(RFID) [44], which can be enhanced with additional security capabilities [45]. The next step forward is the so-called smart label [46], which adds novel features like event detection, interaction, and IoT capabilities. Such IoT solutions link cyber and physical worlds while enabling tracking and monitoring of assets and processes. Thus, blockchain goes one step further, making feasible end-to-end transparency in global supply chains. Business data can be shared rapidly between the different stakeholders across a trusted network [13]. In addition, smart contracts provide lower transaction costs by avoiding the intervention of intermediaries and third parties.

Ultimately, the ambition is to achieve Sustainable Supply Chain Management (SSCM), aiming to reduce the social and environmental impacts in global supply chains [47]. It is worth mentioning that, although research suggests that the combined use of blockchain and IoT devices will add significant value in supply chain, it will also impose some additional constraints in terms of computing power and power efficiency [6].

There are a number of supply chain projects deployed worldwide. For instance, Walmart, together with IBM, has developed a blockchain-based traceability system with Hyperledger Fabric [48]. In October 2016, they started with a PoC that tracked two items that were shipped to multiple stores. Before that, when a product had an issue (e.g., a customer became ill), it could take days to identify the batch, shipment, and vendor, and it may require to throw away a lot of the product. Through blockchain, it is possible to obtain specific data and details on the “how, where, and when” of the item within its supply chain. The shared database is able to capture attributes at the level of an individual package to take informed decisions. This functionality enables Walmart today to track a product in seconds (instead of days or sometimes weeks).

Following this approach, in August 2017, IBM announced a consortium with the food sector that included Walmart, Driscoll’s, Dole, McCormick, Nestlé, Kroger, Tyson Foods, and Unilever. This consortium, named IBM Food Trust, will further explore the potential of blockchain to boost traceability along global supply chains with more products [48].

The shipping industry can also benefit greatly from blockchain. Ocean freight and maritime transport account for over 90% of the goods shipped globally [49]. The main characteristics are high number of involved stakeholders, complex transactions (e.g., letters of credit), burdensome paperwork, and lack of transparency, traceability, and information sharing. For instance, Maersk and IBM created TradeLens, a blockchain-based solution to create a more secure and efficient global logistics and spur industry-wide innovation [50].

Additionally, several blockchain startups are also innovating in traceability. For instance, the startup Provenance [51] has created an application to engage customers in the point of sale by providing mechanisms to verify sustainability claims (i.e., no greenwashing).

As it was previously mentioned, blockchain is also able to reduce transaction costs by reducing intermediaries and thus allowing more direct payment flows. For instance, DocuSign [52] is a company that offers several applications (e.g., electronic signature, contract lifecycle management). In 2015, DocuSign collaborated with Visa in a PoC project that used a smart contract to enhance car leasing processes. In 2018, DocuSign integrated an Ethereum blockchain in their signing services. As a result, the signers of an agreement can check anytime the integrity of the contract. DocuSign is also part of the Accord Project [53], a non-profit initiative that aims to develop a technology-agnostic ecosystem with open-source tools for smart contracts.

Accurate transaction records enable the use of tools for forecasting. For instance, Augur [54] is a decentralized platform built with Ethereum smart contracts that allows users to create their own prediction markets (i.e., oracle).

Another relevant commercial solution is Storj.io [55], which is a blockchain-enabled cloud storage network where users can rent the storage space that do not use and get paid in Storj tokens or store their information on a globally distributed network.

Some startups focus on removing intermediaries from trading like OpenBazaar [56], while other companies focus on providing visibility and transparency to philanthropy [57]. Such a global foundation leverages Bitcoin and blockchain to perform and track transactions while providing an immutable record of charitable financial transactions.

In 2018, IBM was awarded a patent for its Autonomous Decentralized Peer-to-Peer Telemetry (ADEPT) environment [58]. In 2016, IBM developed jointly with Samsung a PoC using different elements of Bitcoin to create a distributed network of IoT devices. For instance, to secure transactions, it uses a mix of proof of work (PoW) and proof of stake (PoS) as consensus protocols, BitTorrent for file sharing, Telehash for messaging, and Ethereum to support smart contracts.

It is also worth mentioning that other authors focused on smart grids and supply chain management systems as substantial areas of sustainable innovation [59].

### 5.10 SDG 10: reduced inequality

Theoretically, blockchain capabilities make the technology a catalyst for enabling a sharing economy with a democratic ownership structure (e.g., fractionally own goods by every community member) while avoiding unnecessary intermediaries. Nevertheless, authors like Novak [60] evaluate the implications of blockchain for income inequality and consider that, although it has potential to have a positive impact, it may also exacerbate current wealth concentration.

### 5.11 SDG 11: sustainable cities and communities

The authors of [61] propose a systematic literature review on specific blockchain use cases proposed by the research community. They remark the great concern about the infancy stage of blockchain.

### 5.12 SDG 12: responsible consumption and production

Production patterns can be monitored by using supply chain traceability techniques.

### 5.13 SDG 13: climate action

Blockchain will likely play an important role on the urgent actions for improving the accountability and transparency of policies to limit global fossil fuel consumption and foster decarbonization. Hyperledger, as part of the Linux Foundation, has recently announced a new Special Interest Group (SIG) that will explore how blockchain can help to address the climate goals set out in the Paris Agreement [62].

### 5.14 SDG 14: life below water

The company Possible Future oriented one of its projects to the sustainable use of the oceans, preserving their life and restoring damaged coral reefs [63]. They created a game, named CryptoCorals, in which for each purchase of a virtual coral, another coral is planted. The project is developed, thanks to the collaboration of a non-governmental organization (NGO) partner, and blockchain is used to guarantee transparency, as it is one of the major concerns of potential users.

### 5.15 SDG 15: life on land

Blockchain can be used to register trustworthy data about the different terrestrial ecosystems.

### 5.16 SDG 16: peace and justice strong institutions

Blockchain can help to reduce paper-based processes, minimize fraud, create inclusive institutions, and increase accountability in public services.

A good example is Delaware Blockchain Initiative [64], which was born with the aim of creating a legal framework for DLT sharing in corporations and governments. A more ambitious approach is Aragon [65], which is a startup that aims to create worldwide decentralized organizations, including employees and contractors from developing countries.

Other initiatives focus on increasing the transparency of democratic processes and on avoiding potential frauds. An example is Follow My Vote [66], which is a cost-effective online voting platform that audits ballots in real time.

### 5.17 SDG 17: partnerships to achieve sustainable development

To strengthen the means of collaboration between stakeholders is the key for enabling open innovation and for achieving SDGs.

## 6. Blockchain benefits and challenges toward SDGs and open innovation

The following paragraphs summarize the key main benefits that blockchain will bring to SDGs and their main open challenges.

Blockchain may provide significant operational benefits, since current information systems rely on centralized databases that operate in silos. By having a single, timestamped, immutable, and unique version of the truth, transparency and simplified audits can be guaranteed.

Furthermore, re-balancing the degree of information symmetry between stakeholders will help to achieve SDGs and will enable new forms of corporate governance and decentralized corporations. A collaborative mindset (the so-called coopetition) will be necessary to find additional ways to create value.

In terms of the maturity of the technology, there are a number of open challenges related to scalability, interoperability, standardization, or even energy consumption. The process of mining public networks, especially in the case of Bitcoin [67], requires enormous amounts of electricity. Therefore, although the underlying networks can provide sustainable applications, their footprint cannot be neglected [68].

From the cybersecurity standpoint, it is essential to provide secure applications with no single point of failure that comply with the expected degree of privacy. Nonetheless, it must be noted that blockchain can be also subject to cyberattacks [6]. The evolution of quantum computers will affect the security of public-key cryptosystems and hash functions. For instance, the authors of [9] analyze how to evolve blockchain cryptography to resist attacks based on Grover's and Shor's algorithms.

## 7. Conclusions

Blockchain can be used to develop secure peer-to-peer platforms for exchanging assets without intermediaries and in a trustworthy, sustainable, accountable, and transparent way to fulfill UN SDGs and the objectives of the EU Green Deal. Although research into blockchain has significantly increased in the last few years, there are not many academic or commercial solutions with sustainability and open innovation in mind. Moreover, most of them present solutions at very early stages of development.

Blockchain has the potential to radically change many societal sectors and to foster open innovation in all types of organizations, including supply chains, or the enforcement of governance in a completely innovative way. This overview has inherent methodological limitations due to its length and high level, so only a sample selection of some of the recent solutions is presented to give an idea of the potential of blockchain. The solutions described are not meant to be representative or generalizable. Such cases are the basics for further research, having in mind how blockchain can solve many of the current cybersecurity issues. Furthermore, open challenges were mentioned as a guidance for researchers and companies for future developments.

## Abbreviations

| | |
|---|---|
| IoT | Internet of Things |
| CPS | cyber-physical system |
| CSR | corporate social responsibility |
| DLT | distributed ledger technology |
| DoS | denial of service |
| PKI | public-key cryptography |
| NGO | non-governmental organization |
| PoC | proof of concept |
| P2P | peer-to-peer |
| PoS | proof of stake |
| PoW | proof of work |
| SSCM | sustainable supply chain management |

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