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# The Role of Blockchain in Sustainable Development Goals (SDGs)

Vilma Mattila[1], Prateek Dwivedi[2], Pratik Gauri[3], Md Ahbab[4]

5ire (Sustainable Distributed Computing)

160 City Rd, London, United Kingdom

*Email of Corresponding Author: muhammadahbab92@gmail.com*

***Abstract*: The field of sustainability is one of the areas where the efforts of the international community are scarce and deficient. Therefore, blockchain could be implemented to improve and advance in the achievement of global objectives. While the original applications of this technology focused on the financial sector, as it has evolved its uses have been extended to other areas such as the field of sustainability which this study addresses. This study presents the opportunities offered by blockchain towards UN Sustainable Development Goals (SDGs).**

***Keywords:* Sustainability; Blockchain; 5irechain; SDGs.**

## 1. INTRODUCTION

The innovations brought by the Fourth Industrial Revolution, a term first used in 2016 by Klaus Schwab (Schwab, 2017) are becoming more efficient and more accessible. In addition, technology is increasingly connected which results in the convergence of digital, physical and biological environments (Schober et al., 2013). However, if left unchecked, the Fourth Industrial Revolution could have unintended negative consequences such as accelerating resource depletion (Morrar et al., 2017). Emerging technologies such as artificial intelligence or the Internet of Things (IoT) are generating changes that affect the economy and the possibilities of future generations (Edquist et al., 2021). These innovations provide a unique opportunity to help address environmental issues and transform the way we manage our environment. The aim of this analysis is to present overviews of how one of the emerging technologies of this new industrial revolution and how blockchain could play an important role in global efforts to build sustainable environmental economies. Blockchain technology refers to a software protocol that facilitates the secure transfer of money, assets, and information over the Internet without the need for a third party such as banks or other financial institutions (Niranjanamurthy et al., 2019). Data is stored immutable in an ever-expanding list of interconnected records. Transactions are stored in blocks which are connected to other blocks created previously by including the hash of the previous block in the new one. This structure means that making a change without altering subsequent records in the chain is extremely difficult providing security to the records. Verification of transactions is accomplished when participants commit changes to each other. This decentralized consensus is designed to protect platforms from the domain of the network by an individual or a group of subjects. Two of the best-known applications of this technology are cryptocurrencies and smart contracts. Although the financial sector is the primeval application of this technology, blockchain has significant potential in other sectors offering decentralized and cleaner solutions (Leng et al., 2019). For example, it offers the potential to mitigate environmental challenges, where challenges of non-financial value and global commons prevail. The potential that this technology offers to redefine current models has generated a great deal of publicity and an inordinate expectation within society. Despite this, it is a nascent technology that presents obstacles that must be overcome including current energy consumption or legal and regulatory challenges. Ultimately, as technology matures, opportunities to harness its potential can be implemented to address climate change and support UN Sustainable Development Goals.

## 2. LITERATURE REVIEW

The supply chain involves different actors. Each one must provide complete details about the origin of the products. Today most compliance data and information are audited by trusted third parties and stored on paper or in a centralized database and these approaches are known to suffer or may suffer from many problems. The conflicts with the current method are the low integrity of the data provided by each actor, high cost and inefficiency of paper processes, problems due to human errors, data manipulation, etc. (Jamil et al., 2019). The most viable solution seems to be the use of blockchain technologies due to their multiple characteristics that would mitigate the problems mentioned. For example, an agri-food traceability system aims to record all the information related to the supply chain from before cultivation to the distribution of products. Within the framework of a centralized traceability system, members of the supply chain rely on an information monitoring center to transfer and share their information. This centralized traceability system effectively implements the exchange of information and manages traceability throughout the chain (Zhang et al., 2020). But it is a monopolistic, asymmetric and not very transparent information system which could generate trust problems due to fraud and falsification of information.

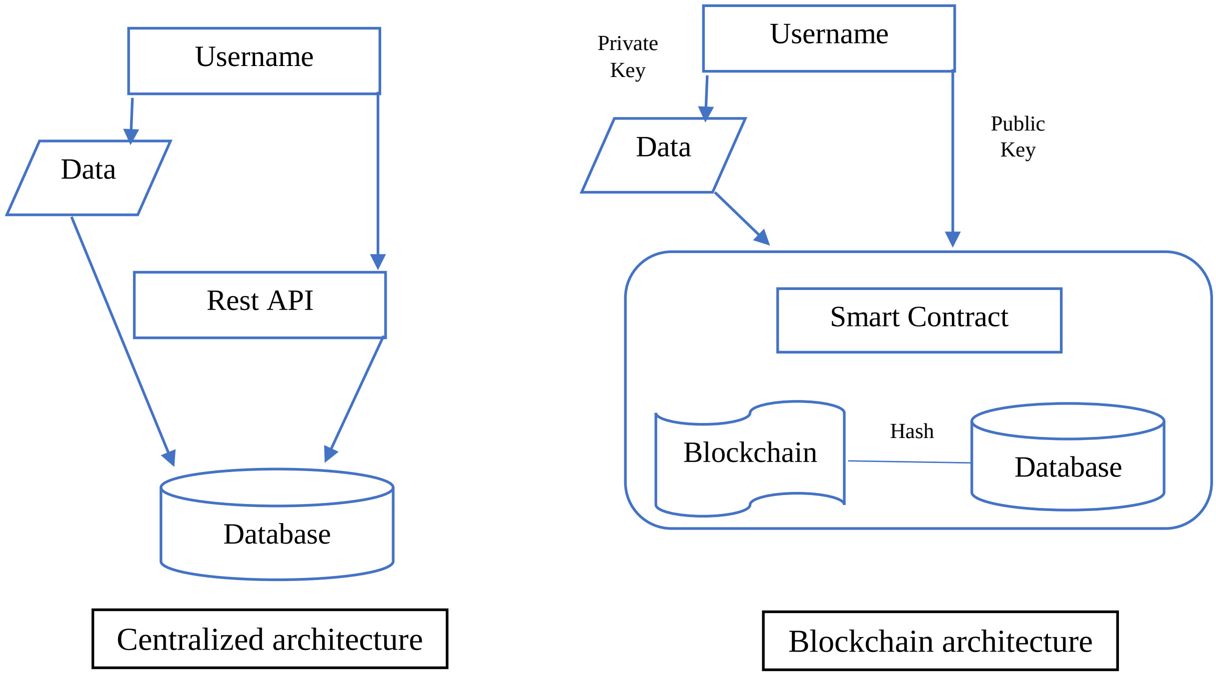


**Fig. 1: Centralized architecture versus blockchain architecture**

Blockchain, together with other technologies such as the Internet of Things (IoT) can be applied to any transaction or contract that requires a consensual verification (Hickey and O'Reilly, 2019). Likewise, through logical operators applied to smart contracts, it would allow to automatically trigger the activation of contracts or agreements between the different parties, controls or any other action that requires the prior verification and secure recording of a transaction. In addition, to automate the entire process, oracles will be required (sensors provided by a trusted third party that incorporate information into the blockchain) and with the use of APIs the end consumer will be able to access the circuit through which the product was passed. In this sense, it is important to underline that the development of 5G networks will open up new possibilities for the Internet of Things (IoT) and the possibilities of digital data capture and recording in real time. Blockchain provides a means to ensure the permanence of records and potentially to facilitate the exchange of data between disparate actors in a supply chain (Durneva et al., 2020). To carry out precise traceability, it is necessary to link the physical asset with the virtual registry which is done with RFID (radio frequency identification) or similar tags. The virtual registry is executed on the blockchain platform when a mining node generates the block, identifying the entity, and offers it to the network for validation. Since the discovery of blockchain technology, this field has seen massive growth through various innovative and technological concepts. Initially, this technology gained a negative reputation due to its association with untraceable purchases on the 'dark web' where users would use digital currencies like Bitcoin to make purchases anonymously (Rahardja et al., 2021). However, in recent years, many large companies such as IBM, JPMorgan and Barclays have invested in research and development of Blockchain technology (Abeyratne et al., 2016). Due to such interest from major organizations, and the large amount of money circulating in cryptocurrencies, entrepreneurs, innovative and creative organizations have been attracted to this new field of information technology. This rapid growth in the field has changed the perspective of many governments to see the potential of this technology over its initial relationship with illegal activities (Abeyratne et al., 2016). Corporate, industrial and government interest in Blockchain technologies has grown considerably because the applications extend far beyond the domain of cryptocurrencies. According to Swan (2018) there are four main classes of application for Blockchain technology (Swan, 2018):

1. Monetary assets (currency, payments, remittances, finance, and securities)

2. Property (land, real estate, and car title records)

3. Contracts (business agreements, licenses, registration, and intellectual property registration)

4. Identity credentials (passport, visa, driver's license and birth records).

Bitcoin is the best-known example that uses blockchain technology. However, the technology has spread to a wide range of applications beyond cryptocurrencies. The issuance and negotiation of securities, the traceability of the logistics chain, contracts, insurance operations, real-time accounting or even electoral processes are examples of applications that technology has been given. In the last decade, this technology has attracted the interest of a large number of people working in different fields of knowledge (e.g., finance, health, public services, properties, public sector etc.). This is due to the multiple advantages that technology generates including the elimination of intermediaries. As for example, some innovations related to the blockchain can be mentioned:

- *Industrial or intellectual property* allows to certify the ownership of any type of creation. For example, a musician can register the intellectual property of his work or a graphic designer can create it without having to go through a complex registration process (Ito and O'Dair, 2019).

- *Money remittances from one country to another* this type of operation is subject to high charges by the companies that carry them out (e.g., Western Union). Bitcoin (or another cryptocurrency) and blockchain can fix this at very little marginal cost (Qiu et al., 2019).

- *Registration of people* to identify them and send them services, education, health, etc. Registration is inviolable and much better than a printed document, subject to possible forgery or even loss.

- *Traceability* consists of tracking almost anything throughout your logistics chain. As an example, anyone could know where the meat of the hamburger we eat comes from, or where the cotton of the shirt we use comes from (Alves et al., 2021). This application will be described in greater depth in the following section as it is linked to Economic Sciences.

- *As Smart contracts,* blockchain works like an "oracle", giving rise to a certain action or response if certain and certain conditions are met. It is a kind of self-executing contract conditioned to a set of specifications which trigger an event or compensation if they occur. A specific example could be the automatic collection of compensation for having suffered an accident which was insured with a smart contract (Chen et al., 2021).

## 3. METHODOLOGY

The methodology used consists of searching information from academic journals indexed in Web of Science, DOAJ and Scopus. Documents in physical and digital media was used. In addition, analysis of consistent strategic model is used to analyze the attractiveness of industries in the adoption of technology and thus determine through business analysis models which are the industries in which it will have the greatest impact. The study starts with defining keywords and selecting databases. Then we established criteria for inclusion and exclusion of articles to compose the portfolio of articles which supports the research. Only articles published as of 2015 to 2021 in journals (with impact factor above 1) were considered for the portfolio. Besides of the analysis of internal and external documents such as strategic plan, operational planning, certification reports, list of performance indicators contributed to understanding the formal rules and aspects of the organization related to its process and decision making.

## 4. RESULTS AND DISCUSSION

### 4.1. Actions to address environmental challenges

One of the main challenges that humanity will face in the coming decades is to feed, provide water and energy for the 3 billion more people there will be by 2050 (Taskinsoy, 2019). In order to face this challenge, it will be necessary to change the practices of use of the land, preferences and consumer demand or ensure energy supply. Companies are facing increasing pressure from investors and consumers to address the risks that supply chains create, such as human rights violations, forced labor, new modern forms of slavery or environmental degradation, among others. In response, many companies are making public commitments — zero deforestation policies, use of recycled materials, and so on. However, supply chain processes are often complex and opaque, making it difficult to implement these commitments and showcase the achievements. High energy consumption presents one of the main issues of blockchain technology. The situation is changing as technology develops but, as the latest data show, due to the complicated validation and securing processes, bitcoin was using as much energy consumption as Switzerland (BBC News, 2019), and consumption has been growing in the recent years (see table below). This consumption generates $CO_2$ emissions that pose a threat to the environment.

**TABLE I: Environmental impact of Bitcoin (Source: United Nations Conference on Trade and Development - UNCTAD, 2021)**

| Electricity consumption by bitcoin | Year | Comparison | Source |
|---|---|---|---|
| Up to 215 kWh per transaction | 2015 | Incandescent lightbulb of 25W burning for one year | Energy Market Barometer Report by GEM |
| 300 kWh per transaction reaching 900 kWh per transaction (by 2018) | 2018 | More energy per transaction than all the world's banks put together | BBC news article |
| 22 tWh | 2015 | Annual energy consumption Ireland | Energy Market Barometer Report by GEM |
| 67.4 tWh | 2020 | Annual energy consumption of Switzerland | Cambridge Bitcoin Electricity Consumption Center |

The data that is generated throughout the supply chain can be recorded through the blockchain. In this way, full transparency would be provided due to the complete traceability of the data of the entire process. Facilitating such transparency to the consumer would help them to know how their consumption habits and purchasing decisions are affecting the environment or what are the working and living conditions around said supply chain (Francisco and Swanson, 2018). In other words, the use of blockchain tools would allow products to be tracked from origin to the point of sale, contributing to the decision-making of the final consumer or retail (Bumblauskas et al., 2020). Consequently, trust in production processes would be built by verifying supply chains and exposing dishonest or illegal practices. For example, the application of the blockchain could be used to address the global challenge of increasing illegal, unreported and unregulated fishing as a result of growing demand (Long et al., 2020). As a result, two-thirds of the fish stocks are overexploited, with forecasts prone to the rise of the trend. Blockchain technology could keep track of those species, providing transparent information about their origin. Likewise, smart contracts could support new agreements that grant specific resource rights to communities or fishers. As a consequence, by sustainably managing marine and coastal ecosystems and the fish market, and by limiting illegal, unreported and unregulated fishing, oceans, seas and marine resources would be conserved. Along these lines, a large amount of data could be collected, monitored and managed to contribute to the management of biodiversity to facilitate species conservation processes through an immutable geospatial digital record. The processing of such information would also make it possible to implement market mechanisms that protect global systems which are currently subjected to unprecedented levels of stress and whose limits have been exceeded. On the other hand, the introduction of these blockchain applications in land uses would provide security in property rights which would have implications (Konashevych and Law, 2020). In this way, the appropriation and exploitation of the resources of protected areas that lead to the extinction of species, soil degradation, etc. would be avoided. Environmental degradation represents a risk for many supply chains, as according to the CDP report, $941 trillion of global sales come from deforestation-related products (soybeans, palm oil, livestock or timber) and around 32% of those companies are experiencing business impacts due to these risks. The use of blockchain technology could help to paralyze deforestation processes resulting from the production of these goods by providing transparency in the processes of supply chains and by addressing conflicts derived from the land use (Bateman, 2015).

### 4.2. Decarbonization of the electricity sector

The electricity sector is one of the areas where the objective of reducing greenhouse gases remains despite the unstable global political conditions. Decarbonization involves the decrease in the amount of carbon in primary energy over time (Le Treut et al., 2021). However, increasing the percentage of energy generated from renewable sources can present challenges to stability and predictability. To facilitate the generation and distribution of this type of energy, a series of technologies are necessary that allow the storage of electricity. This is where the fusion of blockchain and microgrids comes into play. It should be noted that a microgrid is a group of interconnected loads and energy resources distributed within defined electrical limits that act as a single entity with respect to the grid. The uniqueness of this technology is that it can be disconnected from the main network to operate autonomously, since they are able to act while the main network is idle. In the blockchain, each block contains one or more transactions. With regard to the energy sector, the blocks can be organized in tables with details (such as the source, the destination, the amount of energy transferred, the presumed associated losses or the auxiliary services used). If any of these blocks are tampered with, the hash changes and that block is considered invalid. The figure shows the layout of the energy market based on the union of microgrids and blockchain. The most obvious peculiarity is the simplification of the structure with respect to the current model.

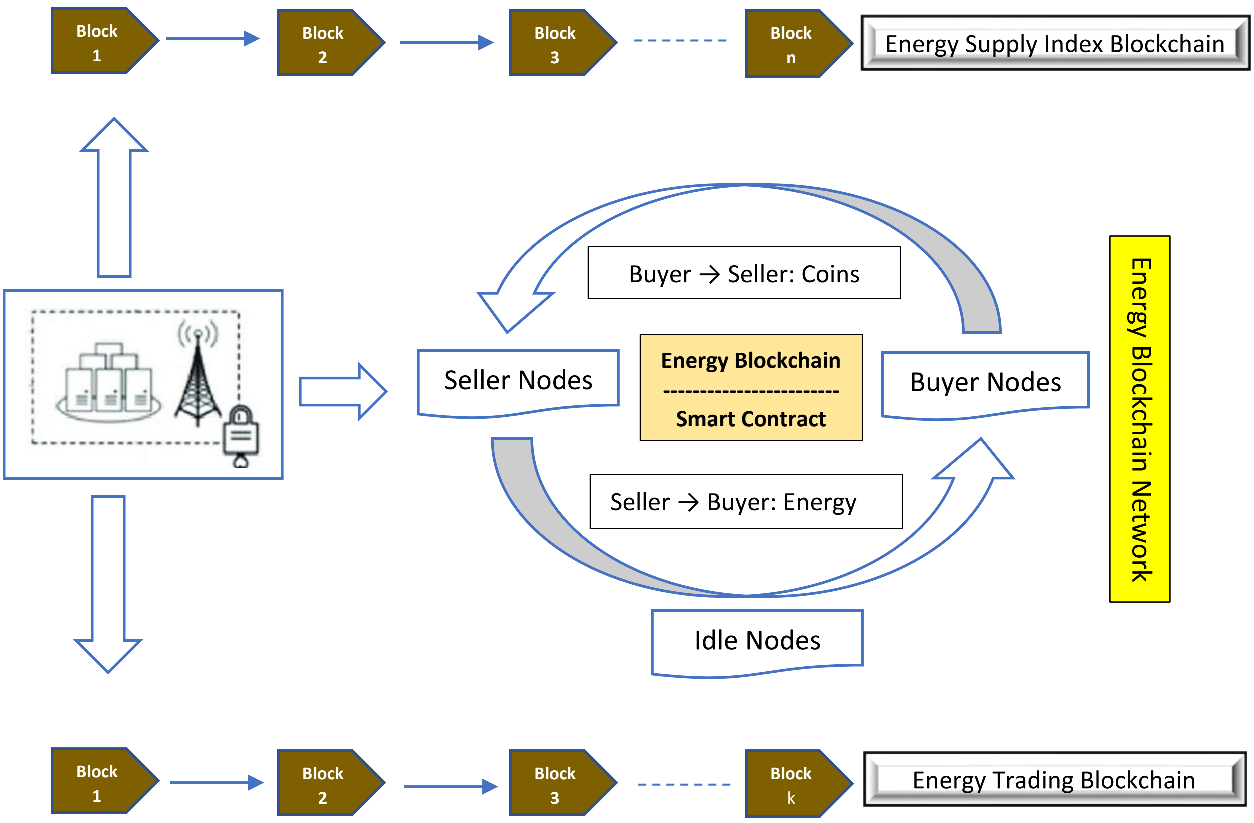


**Fig. 2: Blockchain-based energy market model**

### 4.3. The energy consumption challenge

One of the barriers concerning the implementation of the blockchain is the energy consumption that comes from its use. Many of these technologies are designed with high energy costs that threaten the global commitment. Currently, the most widely used application of the blockchain is cryptocurrencies, specifically, the most popular is bitcoin, whose mining and trading system requires such a large consumption of electricity that it is equivalent to that of many countries. The bitcoin protocol is intentionally designed to be energy intensive (Truby and science, 2018). The number of bitcoin blocks is finite and the acceptance procedure for a block occurs every ten minutes or so. The more miners that operate on the network, the more difficult it is for individuals to solve mathematical problems. So, they need to spend more time and energy. Therefore, the nature of the mining process entails high rates of energy consumption that can cause environmental damage.

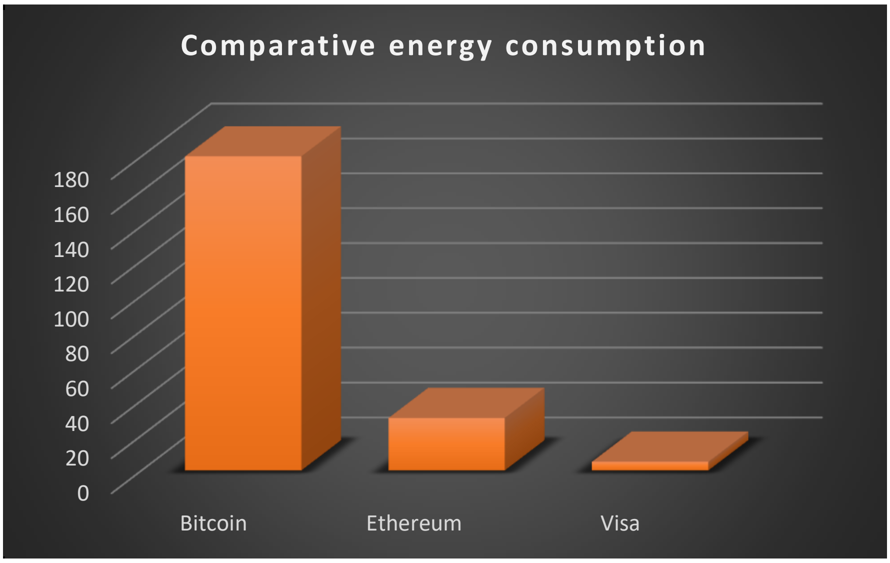


**Fig. 3: Comparative energy consumption (Estimated kWh for each transaction)**

The first generation of blockchain platforms employ a protocol called a Proof of Work (PoW) system to operate which implies that they require higher power consumption (Bentov et al., 2014). However, the second generation that includes Ethereum which consume much less power. Protocols called Proof of Importance (PoI) are also being developed which are expected to consume even less power thanks to their simplified and more accessible validation process. Consequently, there are many ways to build and operate on blockchain networks. Also, the mining process is not always necessary in all applications on the blockchain. However, understanding the impact of blockchain technology on the energy system is complex. It is important to take a big picture perspective and consider the energy impact relative to blockchain solutions, compared to existing models. For example, energy management is an area where, as discussed previously, the blockchain can incentivize the use of renewable energy and a more sustainable use of it. Implementing these solutions could support and accelerate the decarbonization of the system by assisting global efforts to reduce greenhouse gas emissions. It is therefore expected that as blockchain evolves its energy consumption will decrease and that the opportunities that the blockchain offers to mitigate climate change will exceed its energy use limitations.

### 4.4. Cases of blockchain applications to SDGs

Following are few cases of blockchain applications that contribute to the UN Sustainable Development Goals:

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| ***SDG1: No poverty*** |
| In many countries, the poor do not have official identity documentation. In 2019, the Ministry of Digital Economy and Society of Thailand embarked on the Digital ID Project to develop a nationwide digital identification platform. The goal was to use blockchain-based timestamping to authenticate and verify the digital identities of the citizens. |
| ***SDG2: Zero hunger*** |
| Blocks for transport is a supply chain digitization initiative launched by WFP to increase the efficiency of the food transport between the Port of Djibouti through the Ethiopian supply chain corridor to destination warehouses. This process aims to deploy a private blockchain between the supply chain participants from whom authorization is needed. |
| ***SDG3: Good health and well-being*** |
| The healthcare system of Cuba is working in collaboration with the Electronic Technology Software Production Company (SOFTEL) for the management and exchange of medical information between different institutions in the country using blockchain technology. In 2019, the hospital Manuel Fajardo implemented digital medical records with the support of SOFTEL. This data will be available to any health entity in the country once a centralized medical history is created at the national level. |

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| ***SDG4: Quality education*** |
| Blockcerts is an open standard for issuing, viewing and verifying blockchain-based credentials for academic certifications, workforce development and civic records. The Goal is to enable a wave of innovation that gives individuals the capacity to possess and share their own official records. |
| ***SDG5: Gender equality*** |
| VipiCash is an application that uses blockchain technology to enable secure money transfer among women so that they can have access and control over their own money. The founder, of VipiCash is working to create blockchain solutions to help empower women in humanitarian crisis situations. |
| ***SDG6: Water and sanitation for all*** |
| A multinational firm named ARUP is working with the Australian government of the State of New South Wales to build a proof-of-concept that uses blockchain technology to improve the water trading system as reliable, transparent and efficiently manageable. |
| ***SDG7: Affordable and clean energy*** |
| The power company Rosseti of the Russian Federation have implemented a pilot project called "Energy Accounting Using Blockchain Technology" to increase energy efficiency through blockchain. The project ensures transparency of the system of interactions and data exchange between electricity companies as well as consumers. |
| ***SDG8: Decent Work and Economic Growth*** |
| The Federal Tax Service of the Russian Federation launched a blockchain platform named "MasterChain" to issue interest-free loans to SMEs in 2020. The platform has been designed to rapidly process business owners' applications for interest-free loans for the payment of wages. It transfers digital values and information about them between participants and includes several services. |
| ***SDG9: Industry, innovation and infrastructure*** |
| A pilot project in Latvia involves the implementation of the cash register reform that would strengthen the supervisory capacity of the State Revenue Service by reducing unregistered cash flow and provide a proportionate financial and administrative burden for businesses to ensure compliance with the requirements set for them, thus reducing shadow economy. |
| ***SDG10: Reduced inequalities*** |
| The UNICEF Project Connect is a blockchain-based platform that aims to map every school in the world and their connectivity to help people understand what regions are lacking basic connectivity, then eliminate the digital divide, increasing opportunity for every community. |
| ***SDG11: Sustainable cities and communities*** |
| The State Railway of Thailand uses blockchain in the development of a dedicated communications system to increase the accuracy of its railway itinerary and to enhance the security of high-value parcels shipped through its logistics network. The projects of transportation and logistics ultimate goals are to deploy the blockchain technology to make cities inclusive, safe, resilient, and sustainable where opportunities are provided for all in a sustainable way. |
| ***SDG12: Responsible consumption and production*** |
| Bitcliq developed a blockchain-based e-marketplace for seafood trading. This platform allows fishers to register and post a sale for fishes and seafood on the platform. It provides a quality control service in the auction process and controls the trade agreements between the buyer and the seller with the use of blockchain. |

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| ***SDG13: Climate action*** |
| The project activities include a feasibility study and pilot testing on blockchain technology for the Kenyan tea sector. The use of blockchain supports the traceability and transparency of both production and emissions of the tea value chain. |
| ***SDG14: Below water*** |
| The Commonwealth Bank of Australia has developed a prototype platform to facilitate the protection of environmental ecosystems. The platform enables the creation of tradeable digital tokens named BioTokens representing biodiversity credits for the Biodiversity Offsets Scheme of the government of New South Wales, within an efficient blockchain-enabled marketplace. |
| ***SDG15: Life on land*** |
| Wildlife Credits is a wildlife conservation incentive payment scheme developed and piloted by Namibian community-based natural resource management organizations. They offer conservancies direct payments for wildlife sightings on their territory and for maintaining habitat. In locations where the rule of law is not upheld, payments for ecosystem services schemes can corrupt, and the payments sometimes fail to reach the addressees. This solution tackles these issues. |
| ***SDG16: Peace, justice and strong institutions*** |
| The Bank of Thailand adopted blockchain technology to minimize interbank settlement fees, and 22 banks in Thailand have come together to formalize the Thailand Blockchain Community Initiative which will streamline letters of guarantee via a shared trade finance platform. |
| ***SDG17: Partnerships for the goals*** |
| United Kingdom Aid, in collaboration with the fintech startup Disberse, launched a pilot to test whether using blockchain could solve problems of transparency, speed, efficiency and mismanagement of aid funding across the financial supply chain. Financial flows from donors represent huge sums of money but form complex networks of dependencies that are hard to understand at each level. |

**4.5. International collaboration**

- *Exchange knowledge and information and research*

Various United Nations agencies have conducted research and analysis and collected data regarding potential economic and social impacts and responses from public authorities and regulatory bodies. UNCTAD examined the impact of cutting-edge technologies including blockchains in the 2018 Technology and Innovation Report and the 2021 Technology and Innovation Report which is dedicated to the impact on inequalities. The Economic and Social Commission for Asia and the Pacific has reviewed, compiled and documented examples from Asia and the Pacific of where blockchains have had the greatest impact on development (de Villiers et al., 2021). The World Intellectual Property Organization has studied the use of blockchain technology to protect intellectual property rights.

- *Help establish guidelines, norms and standards*

There is a growing need to provide guidance, training, international standards and norms to ensure fair and responsible adoption of technology in developing countries (Pilkington et al., 2017). Some initiatives have started to address specific aspects of this issue such as the guidelines of the United Nations Center for Trade Facilitation and Electronic Transactions on the interoperability of message exchanges between blockchain-based solutions and the Technical Committee of the International Organization for Standardization which deals with the standardization of blockchain technologies and distributed ledgers.

- *Foster the ability of governments to play their role in the blockchain system*

International organizations can help developing countries build their national capacities to participate in blockchain innovation. In this regard, UNCTAD offers a number of technical cooperation and capacity-building activities that can integrate blockchain innovation such as science, technology and innovation policy reviews; rapid assessments of readiness for e-commerce; and information and technology policy reviews. The Economic Commission for Europe has an active project focused on improving transparency and traceability in the clothing and footwear sector through blockchain technology together with the International Labor Organization (Riemens et al., 2021) and the Center for International Trade is launching a pilot project in order to create a digital identity for cotton clothing by connecting it to sustainability certificates. The Economic and Social Commission for Western Asia has explored providing advice and support to governments on blockchain technology. The United Nations Industrial Development Organization has developed a methodological framework to assess the readiness of a commodity value chain to adopt blockchain technology.

- *Use blockchains in the UN system*

The UN system has recently developed projects based on blockchain technology to keep up with technological advances and apply them to concrete solutions for development, as indicated below:

a. Public records. The United Nations Human Settlements Program has implemented a system to register land ownership in a digital registry that serves as the basis for other State services such as urban planning, citizen participation and income generation

b. Supply chains. The United Nations Development Program is carrying out a pilot project in which the buyer of a chocolate bar receives an impact token as a discount for other purchases or as a donation to cocoa producers to expand plantations

c. Digital finance. The United Nations Entity for Gender Equality and the Empowerment of Women and the World Food Program have used blockchains in refugee camps to track the payment of cash aid. The project currently coordinates the delivery of food assistance to more than 100,000 refugees from the Syrian Arab Republic

d. Investment in emerging companies. UNICEF created the cryptocurrency fund to invest in startups using bitcoin or ether providing transparency as to the origin and destination of the fund and allowing UNICEF to take advantage of cryptocurrency donations (Fabian, 2018).

e. Financing of small and medium enterprises. The United Nations Industrial Development Organization uses blockchains in the Impact Investing Platform on Sustainable Development Goals, an accelerator fund to simplify financial opportunities for small and medium-sized companies moving towards the circular economy

f. Sustainability maps. In 2019, the International Trade Center explored the use of blockchain technology to improve the visualization of transparency, traceability and accountability on voluntary sustainability standards (Siddik et al., 2021). These projects contribute to the objectives of the Secretary-General's report entitled “Roadmap for digital cooperation”, which include the promotion of digital trust and security and the provision of digital public goods for a more equitable world.

The United Nations Innovation Network has created a blockchain group and the Atrium online platform to raise awareness in the United Nations system and share experiences in the implementation of blockchain applications. An underlying private permission blockchain has been created to allow the use of Remix, a smart contract development and implementation tool, and the provision of tokens through the Bounties network. Since May 2019, the United Nations Center for Trade Facilitation and Electronic Transactions has led a United Nations interagency round table entitled “Blockchains for the Sustainable Development Goals” in order to update to each agency on ongoing work regarding blockchain technology and share knowledge.

## 5. CONCLUSION

Governments and regulators in developing countries would face many challenges in designing and implementing the required institutional changes that would be needed to harness blockchain innovation for sustainable development while reducing risks. They usually have low capacity and resources to keep abreast of the developments in the technology and the innovation ecosystem. International organizations should support these governments, particularly in low- and lower-middle-income developing countries, including the least developed countries, in building their national capacities in engaging with blockchain innovation and promoting the required institutional change. The paper’s main messages are that blockchain technology can be used in many applications that could contribute to sustainable development. However, at this moment, blockchain innovation has focused on financial applications dissociated from the real economy. For most of the innovations in this field, the Goal is to profit by extracting rents through financial intermediation and speculative gains in crypto-financial assets instead of creating real value through new products and services. Such behavior, combined with the lack of regulation and the swift pace of innovation, is a receipt for financial bubbles and bursts.

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