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FORESIGHT Brief

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Early Warning, Emerging Issues and Futures

# Blockchain Technology and Environmental Sustainability

## Background

The Foresight Briefs are published by the United Nations Environment Programme to highlight a hotspot of environmental change, feature an emerging science topic, or discuss a contemporary environmental issue. The public is provided with the opportunity to find out what is happening to their changing environment and the consequences of everyday choices, and to think about future directions for policy. The 19th edition of UNEP's Foresight Brief explores the contributions of the disruptive features of blockchain technology to enhance environmental sustainability.

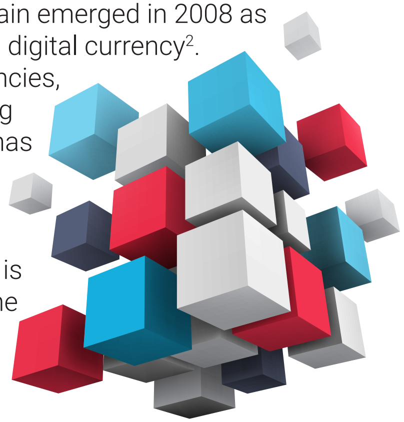
## Abstract

Blockchain technology is one of many emerging technologies that has the potential to help solve some of the environmental problems that we face today. Uses of blockchain applications for tackling environmental challenges revolve around: supply chain monitoring and tracking, innovative financial instruments, peer-to-peer trading of tokenized values, enabling decentralized systems of energy, and common-pool resources. Applications of blockchain technology could be useful when monitoring actors' compliance to Multilateral Environmental Agreements (MEAs) and progress with Sustainable Development Goals (SDGs) implementation. However, adopting the technology on a larger scale will require overcoming current and future challenges, not only in developing blockchain technology, but also in establishing various mechanisms that enhance its understanding amongst policymakers, scientists and blockchain solution developers.

## Introduction

Ever since the surge of cryptocurrency prices in 2017, most people associate blockchain with cryptocurrencies. However, over the past few years, scholars have increasingly proposed blockchain as a potential solution for sustainable development, including the environmental dimension focused on sustainability. The 2030 Agenda for Sustainable Development and the Paris Climate Agreement offers unprecedented opportunities and challenges for UN Agencies and other organizations to respond to the needs of governments and civil society. Blockchain has been seen as a promising disruptive technology that can contribute to the innovation needed to overcome some of these challenges.[1]

The concept of blockchain emerged in 2008 as decentralized encrypted digital currency[2]. Beyond the cryptocurrencies, nowadays the underlying blockchain technology has the potential to change the way institutions, people and machines interact. However, there is still uncertainty about the impact that blockchain can have. Diverse stakeholders including industries, governments,



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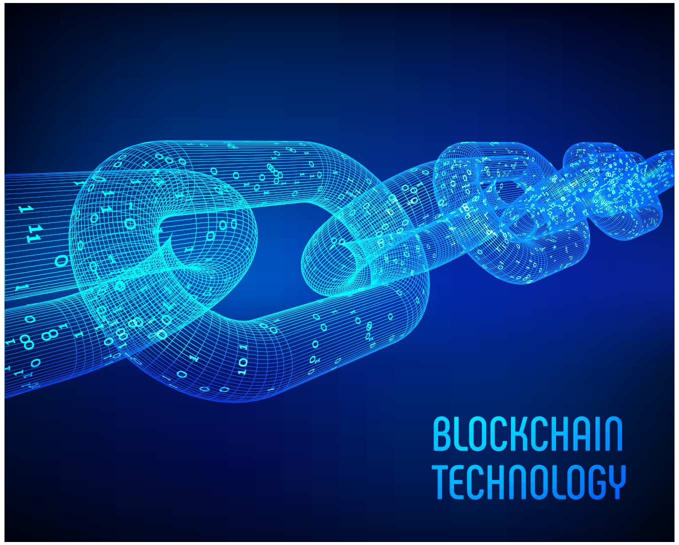


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and not for profit organizations expect that blockchain technology, together with other emergent technologies such as artificial intelligence (AI) and internet of things (IoT), will have a transformational impact across industries and amongst society (Hedenborg 2018; Gartner 2019).

This Foresight Brief explores how blockchain technology could contribute to enhancing environmental sustainability management. The brief builds upon environmental use cases to review the technology's key features, including record-keeping, transparency, value transferring, tokenized ecosystems, and cost reduction. It also considers challenges when applying blockchain technology and offers guidance for the progress of the technology's policies.

1 Note that blockchain is not a panacea for the environmental challenges we face today, but rather an enabler in some aspects that may help overcome them.
2 Bitcoin and Ether are well-known examples of digital currency.

## Importance of Blockchain

A lack of trust and confidence in rules governing the exchange and possession of resources creates challenges in maintaining ecosystems and managing natural resources (Le Sève, Mason and Nassiry 2018). Blockchain is a distributed ledger system that runs on millions of devices connected through the internet, in a distributed network (**Figure 1**). As a block of data or record is keyed into the ledger, the block's information is linked to existing blocks and so on creating a chain of blocks. Each block is assigned a unique signature per the sequence of data in that particular block. Within the distributed ledger any value such as money, land titles, electricity and even votes, can be stored and transferred in a secure manner. It is the digital medium for value as the internet was the first digital medium for information (Tapscott, D. and Tapscott, A. 2016).

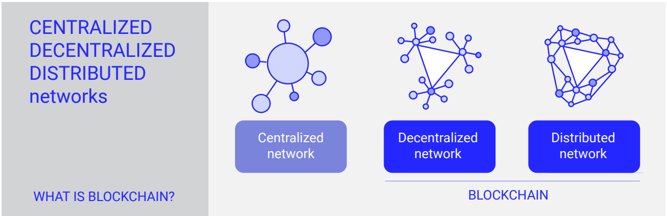


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**Figure 1:** Illustration of decentralised and distributed systems of Blockchain.

As blockchain is a shared ledger system resistant to tampering or fraud, it can provide a trusted and transparent record of transactions (Le Sève, Mason and Nassiry 2018). A transaction on blockchain is time-stamped, authenticated through smart contracts (Geiregat 2018)[3] and immutably stored without the intervention of a


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**Figure 2:** Smart Contracts Benefits

central authority. The benefit of a smart contract is to reduce transactional costs of complex manual and computational processes that involve agreements between several intermediaries and entities (Szabo 1997) (**Figure 2**). Furthermore, smart contracts enable automatic execution of the enforceable agreements between entities. These will enhance the efficiency and transparency of measuring the impact of behaviour, exchanging values, and keeping registries on the transactions in numerous industries. This also has vast implications for revolutionizing the management of the natural environment and its constituents (Jensen and Campbell 2019).

## Linking Blockchain and Environmental Management

This section discusses potential use cases for blockchain technology in global environmental issues. Based on the characteristics of the technology, blockchain-based applications can contribute to enhancing environmental management in the following five areas: 1) Record-Keeping 2) Transparency 3) Value Transferring 4) Tokenized Ecosystem and 5) Cost Reduction.

### Record Keeping

It is essential to record and manage environmental data in a secure manner. However, this is only important in some specific cases as it is also possible to store data securely without using blockchain technology. The monitoring and reporting for conventions, environmental impact assessments, and the policy development for environmental management are all based on high-quality and trusted data on the environment. Moreover, information on environmental assets must be secured since they are evidence for financial property for states, companies, and indigenous peoples. For example, land title and assets ownership information is imperative for REDD+, recording carbon trading data[4], ecosystem services and health data and payment information is important for ecosystem service (PES) policy.

The vulnerability of paper-based and centralized registration systems needs to be considered. For example, when Haiti was hit by the 2010 earthquake, the municipal buildings containing paper records such as land titles were destroyed. A blockchain-based record keeping system could potentially prevent this type of information loss. Blockchains' shared ledger system allows multiple actors to share the same view of a system's state at any point of time with an immutable source of truth (Meunier 2018). In this way blockchain can build a trusted registry for land title management. Even when natural disasters bring severe physical damage to a society, a database built as blockchain system can be safely maintained. Blockchain technology offers data management systems that removes the need for centralized record keeping. Once information is put in the chain of blocks, the data is time-stamped, authenticated, and immutably stored. This means that blockchain solutions can provide a collaborative and unalterable record-keeping platform in a decentralized fashion (Meunier 2018). The utilization of such decentralized information platforms can also help phase out existing fragmented data silos.

[3] A Smart contract could be described as hardware and/or software that initiates, controls and/or documents legally relevant acts, depending on predetermined, and digitally proven events, and through which legally binding contracts may be concluded, depending on the circumstances.

[4] Additionally, recording the global carbon budget on blockchain could prove beneficial as it would be improbable to tamper with due to the technology's cryptographic potential.

## Transparency

Transparency is a key feature of good governance and a prerequisite for accountability in the public sector and for businesses, and builds trust amongst citizens (Transparency International 2009). Transparent governance systems enable clear processes and procedures and provides easy access to public information for citizens in a timely and accurate manner (Suk Kim 2005). Transparency via information disclosure is increasingly at the heart of global environmental governance to ensure accountable, legitimate and effective governance (Gupta 2008). Blockchain solutions can provide an immutable source of data and a traceable and verifiable record of who exchanges what, and with whom (Le Sève *et al*. 2018).

For example, transparency of the supply chain for natural resources is essential not only for conservation, but also for conflict prevention and human security. While the origin of goods can be verified if the information is recorded in blockchains, it is important to note that blockchain does not track goods. Therefore, coupling blockchain technology with monitoring and tracking tools would make it possible to retrieve information on transport mechanisms, routes, and conditions at any point across the supply chain thereby making supply chain operations of a particular product more transparent. In a blockchain use case, World Wide Fund for Nature (WWF) also uses blockchain to eliminate illegal fishing in the tuna industry in partnership with ConsenSys. Supply chain information is recorded from vessel to distributor to remove room for illegal, unregulated, and unreported fishing, as well as operators who abuse human rights (WWF 2018). Another application is enabling the traceability of chemical products that in turn helps build trust amongst consumers. Environmental regulations such as Restriction of Hazardous Substances (RoHS) or Registration, Evaluation Authorization, and Restrictions of Chemicals (REACH), means that the finished product producers need to manage the whole supply chain not only from the view of cost efficiency, but also environmental regulations.

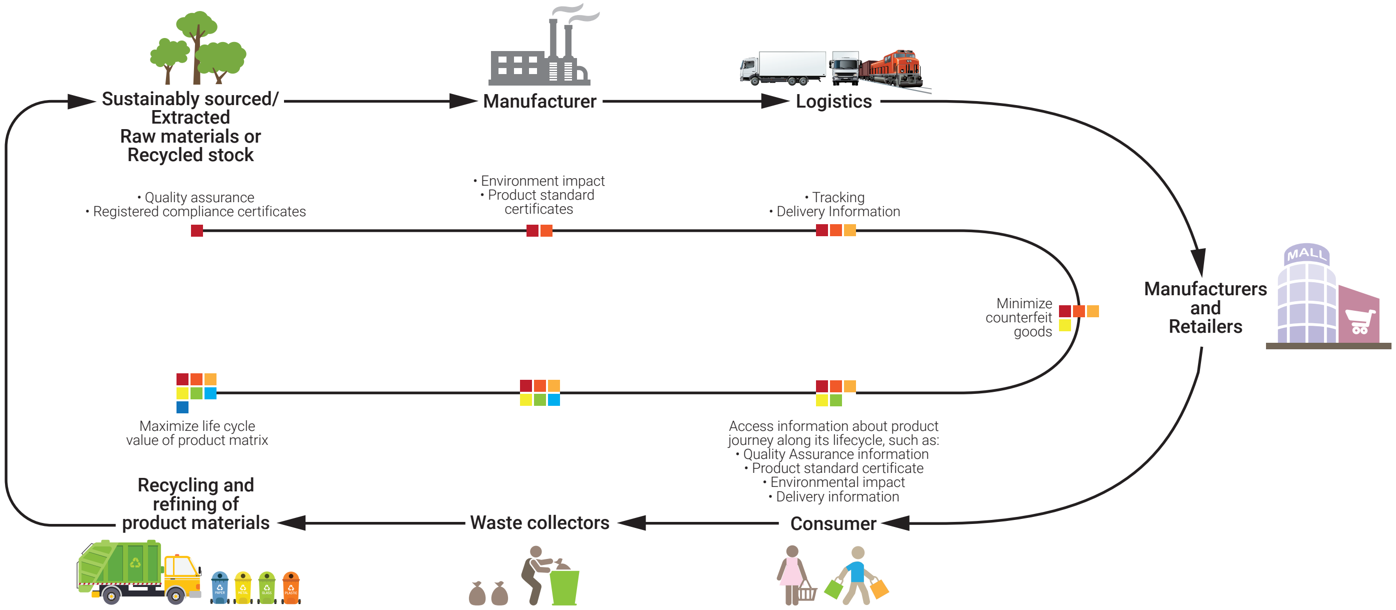


**Figure 3:** A generalized outline of what a supply chain supported by blockchain may look like

*Source: by Authors*

Blockchain technology also has the potential to improve the transparent implementation of Multilateral Environmental Agreements (MEAs) which often requires large amounts of data collection and verification. The monitoring of MEAs compliance can be transformed by leveraging the traceability of materials. The Secretariat of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is aware of the potential of blockchain-supported systems. The CITES Secretariat manages the international trade of endangered species and derived products which is currently undertaken through a lot of paper-based work. Blockchain-based systems have potential to address the risks of manipulation and errors due to the paper-based permission system with an alternative, immutable record of processed permits, in line with the CITES agreement (Busse *et al*. 2019). Blockchain could help transparently track environmental data and demonstrate the status of commitments. Similar systems could be applied to other treaty Secretariats' falling under UNEP.

Furthermore, the SDGs could serve as a common language and entry point to make heterogeneous data more interconnected in monitoring and tracking supply chains. For example, as a cross point of SDG 1 (No Poverty), SDG 12 (Sustainable Consumption and Production) and SDG 15 (Life and Land), blockchain could enhance income support for informal waste pickers who are likely to live below the poverty line and are highly exposed to contaminants and hazardous materials. The collected waste (electronic or plastic) could be transported to an independent local partner, and then delivered to corporate clients to optimizing the circular capacity of recovered materials into new products. In compensation of the recovered waste, corporates could pay a premium on the market price, which allows social enterprises to provide significant financial returns to  waste collectors. A blockchain-based tracking system can help monitor impacts of hazardous substances throughout the supply chain, segregate any contaminants, and reward tokens to waste-pickers and other intermediaries involved, leading to an increase in recycling.


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## Value Transferring

Value transfers, like cross-border payments, used to involve numerous steps and humans in its process. Similarly, carbon credit trading involves diverse entities. For example, the Clean Development Mechanism under the Kyoto Protocol can take years to verify projects, validate the transfer of credits, and involves multiple registries at national and global levels. Blockchain solutions could be leveraged to scale up peer-to-peer (P2P) value transfer without intermediaries. The decentralized shared ledger can clear and settle peer-to-peer transactions without a centralized party, as demonstrated by cryptocurrency use cases (Meunier 2018). CarbonX (by ConsenSys) is an example of value transfer. Their sourcing and recasting of carbon offsets as crypto tokens on a private blockchain, validates provenance and ensures the security and transparency of all transactions. CarbonX is the first P2P carbon credit trading platform, built on the Ethereum blockchain, that buys carbon offsets under the United Nations-backed scheme called REDD+. This certifies greenhouse gas reductions from forestry and ecosystem remediation projects around the world, and those credits are converted into a cryptocurrency, in the form of a token called CxT. These tokens are then sold on to retailers and manufacturers, who use them to incentivize consumers to make more sustainable choices.[5] There are also studies on the potential use of blockchain for the carbon market to be developed under Article 6 of the Paris Agreement (Dong *et al*. 2018). Blockchain could enhance trust amongst emission trading participants by enabling the tracking and trading of emission reduction units under the carbon offset crediting mechanisms, such as: the cooperative approach under Article 6.2; voluntary schemes; and bilateral and sub-national mechanisms. A shared ledger will address the risk of double counting of emissions reduction. It could also improve transparency in the allocation of emissions allowances to emitters in the emission trading programme under the cap and trade mechanism.

Blockchain is also compatible with Internet of Things (IoT). IoT is the mutuality through the internet of computing devices embedded in everyday objects, enabling them to reciprocate data over a network without human interaction. This would enable the transfer of environmental value in the form of virtual assets using smart contracts in P2P networks. Environmental resources can therefore be transferrable assets using IoT. These smart contracts, which are layers added to the blockchain and IoT networks are proficient at managing data-driven interactions. For example, the City of Fremantle in Australia, uses Powerledger, which is enabling energy retailers and their customers to trade energy and water resources to develop a smart city strategy (Power Ledger 2018). Power Ledger's blockchain-based system facilitates peer-to-peer renewable electricity trading by letting people sell excess solar energy directly instead of selling it to the traditional grid. Community energy micro-grids based on blockchain essentially enables localised energy trading between consumers, which is recorded in a secure and tamper-proof way (Andoni *et al*. 2019).

5 https://www.carbonx.ca/

## Tokenized Ecosystem

Sustainable behaviour at an individual level could be difficult to incentivize without a mechanism that tracks and evaluates behavioural changes. Because of technological limitations, challenges have been faced in providing verifiable and transparent management of environmental sustainability. Blockchain technology could, however, provide a solution. Tokens are often used as a digital representation of assets such as commodities, stocks, and even physical products (European Union [EU] 2019). Tokenized assets can be tracked and traded on securely maintained blockchain networks. Tokenized natural resources and rewards for consensus can incentivize participants to join the network and operate within the system. Tokenized systems also enhance the network effect that strengthens the ecosystem. Tokenized ecosystems on a blockchain are used to encourage behavioural changes for good.

Another potential application of blockchain for behavioural change could be to track, measure, and reward environmentally sustainable behaviour. For example, RecycleToCoin is a mobile app that rewards recycling of 90% of all plastic, not just polyethylene terephthalate (PET) plastic bottles, but also aluminium drinks cans and steel food cans. This data is placed in a blockchain-based data system which all stakeholders are able to access to ensure transparency. After recycling, people receive points that can be swapped for rewards like electronic gift cards or other rewards from participating partners.[6]

The tokenized economy is also applied to data collection and exchanges. Although companies generate vast amounts of data, they often find it difficult to share this data through secure and trusted means. Ocean Protocol is creating a blockchain-based ecosystem for data sharing. With tokens, Ocean Protocol encourages data exchange amongst data providers and data consumers.

6 https://www.recycling-magazine.com/2017/11/11/first-recycling-initiative-blockchain/

This protocol is primarily focused on data exchange to support artificial intelligence (AI) application development as data needs are emerging especially in the AI industry. This protocol enhances AI usage by storing metadata, linking assets and services and providing a licensing framework.It also allows users to monetize their data while preserving their privacy and control.[7]

The tokenized ecosystem is also used for democratized investment platforms through initial coin offerings (ICO), through developing cryptocurrencies in the blockchain network as a token that is linked to environmental assets or information. Since ICOs are facing stricter regulations in different countries, the blockchain community is increasingly looking into the applications of security token offerings (STOs) as an alternative way to transfer the tokenized value. As STOs are compliant with existing financial regulations, investors can buy tokenized securities (Schletz, Nassiry and Lee, 2020). STOs are gradually gaining momentum in environmental sustainability applications. For example, BBVA, a multinational Spanish bank, used blockchain to negotiate the terms of a structured green bond[8]. STOs could be applied for green bond issuance.

According to HSBC and the Sustainable Digital Finance Alliance (SDFA), the Philippines has released a framework for Security Tokens and recognises digital assets, with a push for Green investments that are motivated by climate-induced natural disasters (HSBC and SDFA 2019). There is growing interest amongst financial institutions and governments to apply blockchain technology to revolutionize funding models.

## Cost Reduction

Handling large global data sets take a lot of time to process transactions, but blockchain-based applications can be used to improve operational efficiencies.

7 https://oceanprotocol.com/

8 https://www.bbva.com/en/bbva-issues-the-first-blockchain-supported-structured-green-bond-for-mapfre/

Based on the McKinsey report (Carson *et al*. 2018), the strategic value of blockchain is primarily focused on cost reduction in the short term. Removal of intermediaries and the administrative burden of archiving can reduce the cost of data management and processing of transactions.

For example, the United Nations World Food Program (WFP) used the Ethereum Blockchain in a pilot programme called Building Blocks, to transfer cash through vouchers or pre-paid debit cards, allowing people to purchase food on their own in Jordan and Pakistan.

This initiative successfully reduced payment costs associated with cash transfers and achieved a 98% reduction in costs as P2P removes the need for verification by costly intermediaries such as banks and other institutions. Moreover, blockchain is essential in this initiative to track the ownership of assets without the need for a central authority. This could speed up transactions while lowering the chances of fraud or data mismanagement by protecting beneficiary data, controlling financial risks, and setting up assistance operations more rapidly in the wake of emergencies.[9] It should however be noted that blockchain is still a very resource-intense and computationally inefficient data structure. Operational efficiency can be gained through blockchain in limited circumstances. The challenges of blockchain are further highlighted in the next section.

To enhance effectiveness of international aid for environmental sustainability, a digital economy geared with blockchain and other emergent technologies could reduce the costs of distribution of monetary resources, enhance transparency to track funds from donors to the intended beneficiaries, and reduce the cost of multi-layered reporting through the self-auditability of blockchain technology. **Figure 4** shows a graphical representation of how the digital green economy could look.

9 https://innovation.wfp.org/project/building-blocks

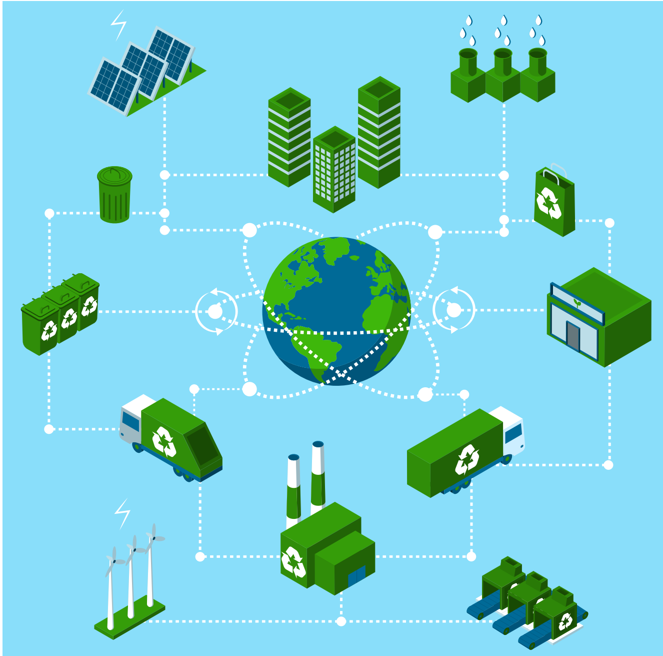
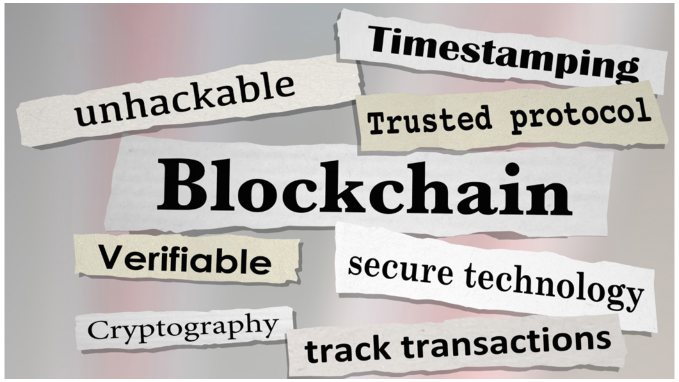


**Figure 4:** Digital Green Economy

## Challenges of the Technology

Currently, most use cases are either in concept or in a pilot phase with only a few being fully developed. The current blockchain applications for environmental purposes are centred around the themes of peer-to-peer trading of natural resources or permits, supply-chain monitoring and tracking, new financing models, and enabling of decentralized energy systems. However, challenges remain since blockchain is still at an early stage of development. Although blockchain could stimulate innovation for environmental management, the adoption of the technology on a large scale depends on successfully overcoming some of the risks involved, and experimental pairing with other emergent and existing technologies. The following are some of the challenges in blockchain technology. While this list is not exhaustive, it is illustrative of what has to be overcome.

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## Energy consumption

Creating a new block in chains requires ample energy, for example, during the validation process of a transaction through consensus mechanisms such as Proof of Work (PoW), which is the algorithm used for bitcoin (Ge *et al*. 2017).

Mining in the bitcoin network is estimated to be using over 58TWh of electricity per year, which accounts for 0.21% of the world's energy consumption and is equivalent to Switzerland's total energy consumption (Baraniuk 2019).

Large-scale mining operations are often set up in areas with lower and highly subsidized electricity prices. The power density required for undertaking mining can be extremely high especially when adding power to keep hardware cool. One of the potential solutions for this could be adopting 'green mining' where renewables are used for mining operations. There is a growing interest in green mining with USD134 million having been invested in 2018 for this purpose (Climate-KIC 2018).

The number of blockchain use cases in the environmental domain as described in this Foresight Brief are built upon alternative consensus mechanisms such as: Proof of Stake (PoS) or Proof of Authority (PoA) that consumes less energy. The Ethereum development team has been working on upgrading its protocol, called Ethereum 2.0. One of the upgrades involves adopting PoS instead of PoW. As such, consensus mechanisms are still evolving. Depending on the evolution of the consensus mechanisms, energy consumption can be curtailed when blockchains are commercially applied and scaled up. Conversely, the private and permissionless system, such as the Hyperledger Fabric, also offers no energy consumption conflicts through its reduced number of full nodes (Franke *et al*. 2020).

## Scalability

Immaturity of the technology still poses challenges for large scale applications to achieve environmental sustainability. For example, real-time matching of supply and demand will be needed if blockchain-based applications are integrated to manage energy grids. This is difficult to manage without the enhanced transaction speed when there are huge sets of data. Blockchain requires time to process transactions for maintaining an immutable network to copy all transactions to all nodes in the network. This results in challenges of transaction processing in terms of transaction speed and scale (Brody 2018). Bitcoin's network, for example, is restricted to a sustained rate of 7 transactions per second (TPS) due to the limited block sizes per the bitcoin protocol. Whereas Ethereum Blockchain, currently supports roughly 15 TPS because of a hard-coded limit on computations per block (Ge *et al*. 2017). The revolution of consensus mechanisms could potentially improve the scalability of blockchain transactions, as in the case of energy consumption.

## Interoperability

There have been several blockchain-based platforms developed although the interoperability of those platforms has not yet been resolved (EU 2019). At this early development stage of blockchain technology, platforms are showing technological diversity. The full potential of blockchain cannot be attained if platforms are not operating synergistically. For example, the energy and transport sector are two areas that are closely linked with each other. Given the accelerated adoption of e-mobility and increased demand of consumers for seamless transactions, the interoperability of infrastructure systems must be increased (Organisation for Economic Co-operation and Development [OECD] 2019). Inter-sectoral operability of platforms is essential for applying digital technology to sustainable infrastructure.

## Regulation

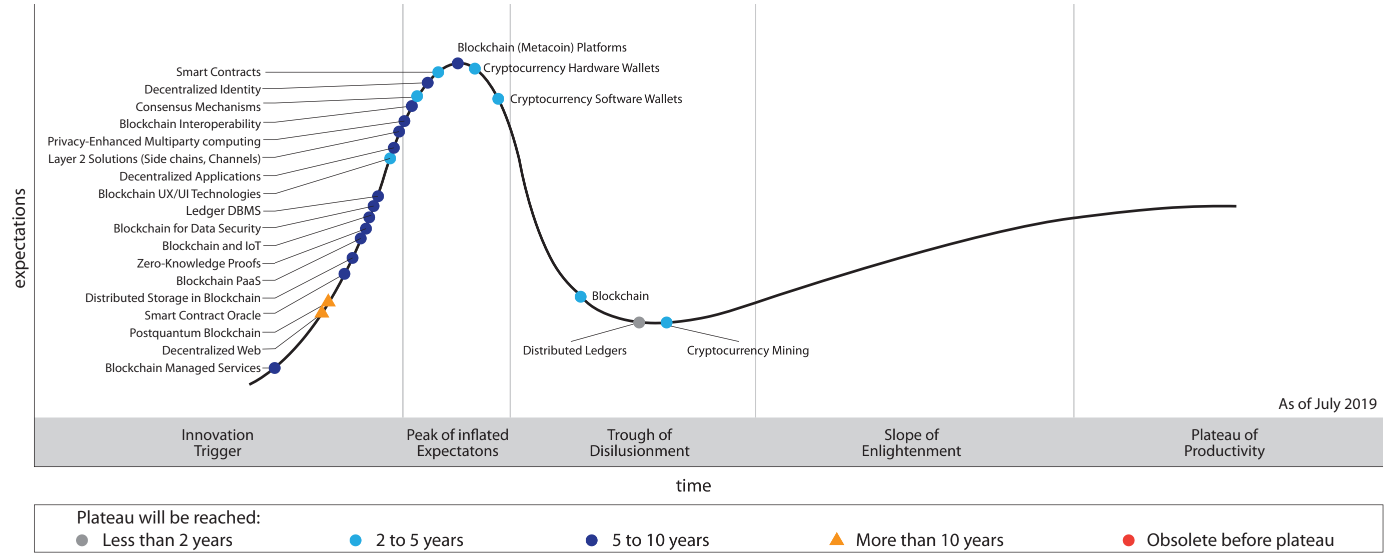
The lack of legal and regulatory support is currently impacting the development trajectory of the technology (Yeoh 2017). Blockchain use cases cannot be scaled up to commercial levels without reconciliation with regulatory concerns over several issues such as: privacy, money/value transmission, anti-money laundering, and information reporting. For example, the EU's General Data Protection and Regulation (GDPR) places strict limitations on how personal data is stored and saved. Personal data immutably-stored in blockchains could, for instance, clash with the GDPR's 'right to be forgotten' (Miliard 2018).

## Limited use cases in Global South[10]

While environmental experts are increasingly looking into the potential of innovative technologies for addressing environmental challenges, there are still a limited number of use cases of blockchain technology in the Global South. Numerous companies, non-profit organizations, and even the public sector have been testing blockchain applications for sustainability challenges encountered in developed countries. To achieve accelerated and scaled adoption of emerging technologies for social good, it is vital to examine the technology in the context of the Global South. Learning from existing early cases can help in understanding what the challenges are in using this technology within the Global South. For example, there are several initiatives in Ghana, since 2014, to explore a blockchain-based land registry system. The Government of Ghana signed a Memorandum of Understanding with IBM to accelerate the development of the registry. In the case of Georgia, an economy in transition, over

[10] The Global South consists of Small Island Developing States (SIDS), Least Developed Countries (LDCs), Landlocked Developing Countries (LLDCs), and Emerging and Transitional Economies.

1.5 million land titles were registered on their blockchain-based system in 2018 (Eder 2019). Comparing the two cases, Shang and Price (2019) suggested that advanced understanding of the technology among relevant stake-holders and scholars plays a key role in the success of blockchain-based public projects. Another important aspect of expanding use cases in the Global South is to ensure that enough volume of data and transactions be used in the blockchain. Blockchain technology does not per se solve the challenge of gathering data since it aims at managing information, data, and value (Schmidt and Sandner 2017). It is essential therefore to ensure that sufficient qualified data is available that can be used in blockchain as this still remains a challenge in the Global South. Lastly the majority of Global South countries also suffer from a digital divide (United Nations 2017)[11] that may hinder innovation in the evolution of their digital economies.




Source: by Gartner 2019

**Figure 5:** Hype Cycle for Blockchain Technologies

Overcoming the existing challenges described above could prove crucial to applying blockchain technology for environmental sustainability at a larger scale. The tech-nology is still evolving and will take some time to reach full maturity. According to the Gartner's Hype Cycle (**Figure 5**), following the inflated expectation of the technology in the 2010's, blockchain technology slid into the trough of disillusionment as it had not yet lived up to the hype, and most enterprise blockchain projects are stuck in experimentation mode (Gartner 2019). But Gartner's analysis also suggests that blockchain technology could potentially become fully scalable and technically opera-tional by the end of the 2020's, through the accumulation of innovative blockchain-based experiments and projects Moreover, for maximizing the benefits of blockchain, simultaneous development is also required in other technologies, including internet of things, artificial intelligence, and quantum computing. In addition to technological advances, building proper regulation is also key to advancing environmental sustainability with other emerging technologies. Learning from use cases and pilot projects is important for policymakers in order to be ready to fully benefit from these technologies.

## Policy Implications

Blockchains' disruptive features have been overlooked due to existing challenges. These disruptive features have resulted in the emergence of applications that demonstrates and explores the use of technology for improving our planet's environmental and social conditions. It is, however, also imperative to explore the unintended consequences associated with blockchain, especially through various foresight techniques that help build anticipatory capacity to understand and address forthcoming challenges. A shortage of professionals who are familiar with both blockchain technology and environmental issues also prevents an adequate understanding of the technology's potential for environmental sustainability among relevant stakeholders. While blockchain technology is still in its infancy stage, it is important to recognise the opportunities it can create for the betterment of our planet. In order to overcome the challenge as mentioned above and promote the application of blockchain technology for achieving our environmental objectives, the following initiatives are proposed:

- **Global-scale dialogues on blockchain technology that center around the natural environment.** Policymakers, scientists, and blockchain developers can together develop a united vision by integrating the advanced and practical understanding of blockchain merged with other emerging technologies. This will help improve environmental management operations such as; supply chain monitoring, energy transmissions, tracking emissions, carbon trading, or help to achieve Agenda 2030 and other multilateral environmental agreement targets. Through these dialogues, public and private sectors would help each other share the positive and negative implications

[11] Digital disparity between developed and developing countries based on education skills, internet connectivity, and language barriers.

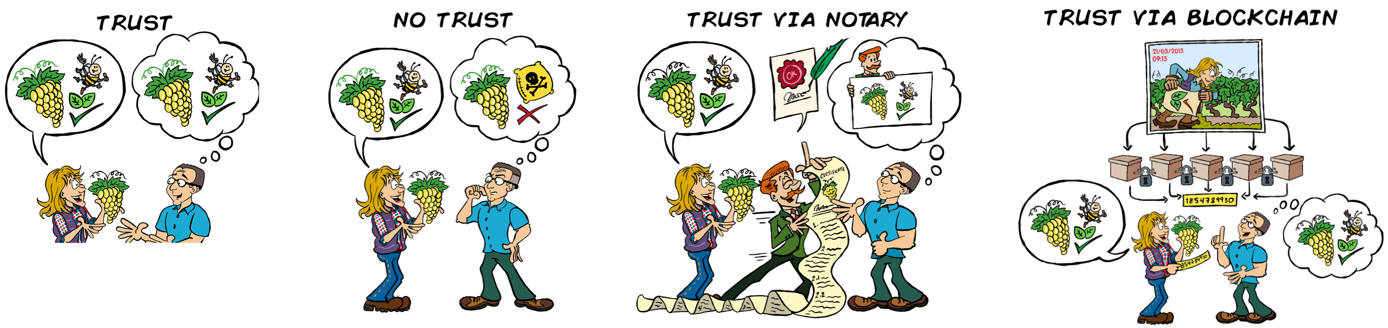
of blockchain for specific topics on environmental sustainability management. This would eventually help countries shape an enabling environment, that includes legislation, regulation, and governance for creating meaningful nature embedded blockchain applications. It is also important to take stock of results of pilot implementations and to share lessons learned.

- **Establishment of consistent legal and regulatory frameworks.** The lack of legal frameworks, standards, and regulations for governing blockchain technology is a challenge for scaling up the deployment of blockchain-based solutions. This is creating confusion amongst the blockchain community on the way to ensure compliance with existing data security and privacy laws. Policymakers need to consider whether to change existing laws to facilitate the use of decentralized models. A growing number of governments are examining the risks and potential of blockchain, which will be followed by legislation and regulations on the technology. Applying blockchain to environmental sustainability has been explored by the private sector. To support the further evolution of blockchain-based business models, it is imperative to evaluate and construct supporting policies, regulations, and laws. It is also important to create a stronger link between policy-makers and blockchain experts in domains on specific issues for mutual learning. To this end, international organizations could draw together stakeholders to support the development of policy frameworks to facilitate the creation of enabling environments for innovation through blockchain. It is also important to promote research on the governance of blockchain and on the impacts that the technology can have on society and environment.
- **Live testing of innovative technologies in controlled environments.** Countries could create controlled environments, or regulatory sandbox modes, where blockchain and other innovative technologies could be tested. These regulatory sandboxes can be beneficial in deploying new technology in a fast and scalable manner. Such a pilot interface can be leveraged to explore whether the research outcomes could be applied to the real environment. This attempt could eventually serve to enhance the understanding of various blockchains amongst stakeholders. Regulators in several countries, such as Australia and Singapore, are already providing the necessary impetus for blockchain innovation by establishing regulatory sandboxes to ease testing and piloting of blockchain projects (Cognizant 2017).
- **Establishment or improvement of national innovation centres, hubs and accelerators.** Enabling the scaling up of number of use cases and investing in understanding blockchain, and relevance as well as other emergent technologies. These innovation centres could help increase and improve the capacity of local practitioners to develop and operate local projects and integrate them into existing blockchain infrastructures whilst ensuring interoperability between them. This could be enabled through developing local prototypes or scaling up proven blockchain solutions beneficial to the natural environment; exploring and identifying specific blockchains and consensus mechanisms that can offer scalability whilst ensuring less energy consumption; and facilitating improved policies though participatory processes together with policy-makers, the private sector and local communities to help achieve equitable outcomes.

## Conclusion

Blockchains equipped with enhanced record-keeping, transparency, value transferring, tokenized ecosystems, and cost reduction shows the technology's potential to tackle global environmental challenges and help with addressing issues like climate change, energy, biodiversity conservation, water security, ocean sustainability, and air pollution. For a technology in its rudimentary stages of development, blockchain is being implemented by businesses, startups, and organizations collaboratively to address various environmental and social issues. Furthermore, the technology's applicability in scaling up environmentally-conscious blockchain based solutions could help address specific challenges. There are a few systemic challenges which limits its adoption or integration. Therefore, more technical research is required to explore and address these barriers to effectively adopt and use blockchain. Potential gains from innovative policy interventions, addressing legal and regulatory frameworks, and knowledge sharing between policymakers, scientist and blockchain practitioners present opportunities to address global environmental problems.

**A farmer and her client illustrate the benefits of blockchain technology**




... the concept of trust | ... the concept of no-trust | ... the concept of trust via the service of a Notary | ... how blockchain can contribute to create trust

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## Authors

**Lead:** Toyo Kawabata (UNEP), Minang Acharya (UNEP)

**Co-Authors:** Tsubasa Enomoto (UNEP), Sai Aashirvad Konda (Graduate Institute for International and Development Studies, Geneva).

## Reviewers

**Internal Reviewer:** Benjamin Simmons (Green Growth Knowledge Platform), Sandor Frigyik, Angeline Djampou, Virginia Gitari, Samuel Opiyo (UNEP)

**External Reviewers:** Ana Cardoso (UNEP DTU Partnership) and Marco Christian Schletz (UNEP DTU Partnership)

**UNEP Foresight Briefs Team:** Alexandre Caldas, Sandor Frigyik, Audrey Ringler, Erick Litswa, Pascil Muchesia

# Contact

unep-foresight@un.org

# Disclaimer



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