CLIMATE LEDGER INITIATIVE

NAVIGATING BLOCKCHAIN AND CLIMATE ACTION

An Overview

4 December 2018

DONORS

Swiss Agency for Development and Cooperation (SDC), the Government of Liechtenstein, EITClimate-KIC.

CLI IS OPERATED BY

INFRAS, Gold Standard, Cleantech21, LIFE Climate Foundation

WEBSITE https://climateledger.org/

Editorial Information

Concept and project management

Juerg Fuessler

Lead authors

Juerg Fuessler INFRAS | Chapters KF, 1, 2, 14

Felipe De León Consultant and Adviser to the Ministry of Environment and Energy (MINAE), Costa Rica | Chapter 3

Rachel Mok World Bank Climate Change Team | Chapter 4

Owen Hewlett Gold Standard | Chapter 5

Cristian Retamal COCOA Collaborative Innovation | Chapters 6, 7

Massamba Thioye UNFCCC Secretariat | Chapter 8

Nick Beglinger Cleantech21 and Hack4Climate | Chapter 9

Sven Braden LIFE Climate Foundation Liechtenstein | Chapters 10, 13

Christian Hübner Energy Security and Climate Change Latin America (EKLA) | Chapter 11

Marion Verles Gold Standard | Chapter 12

Madeleine Guyer INFRAS | Chapter 13

Contributing authors

Susan David Carevic World Bank Innovation and Technology Lab | Chapter 4

Florencia Sanchez Zunino World Bank Climate Change Team | Chapter 4

Iván Razo-Zapata COCOA Collaborative Innovation | Chapters 6, 7

Gustavo Arciniegas López COCOA Collaborative Innovation | Chapters 6, 7

Bianca Gichangi formerly EED Advisory Limited | Chapter 7 (Water meter use case)

Reviewers

Ximena Aristizabal GIZ Mexico

Nick Beglinger Cleantech21 and Hack4Climate

Sven Braden LIFE Climate Foundation Liechtenstein

Susan David Carevic World Bank Technology & Innovation Lab

Jeff Cohen Xpansiv Data System

Dominik Englert World Bank Climate Analytics and Advisory Services

Juerg Fuessler INFRAS

Bianca Gichangi formerly EED Advisory Limited,

Hans-Peter Gier trustwise.io AG

Madeleine Guyer INFRAS

Junaed Khan[1] UK Department for Business, Energy and Industrial Strategy (BEIS)

Seoyi Kim World Bank Climate Change Team

Felipe De León Consultant and Adviser to the Ministry of Environment and Energy (MINAE), Costa Rica

Justin Maccinante The University of Edinburgh

Rachel Mok World Bank Climate Change Team

Andrea Victoria Prada Hernandez World Bank Climate Change Team

Reece Proudfoot WWF Australia

Anshari Rahman[2] National Climate Change Secretariat, Prime Minister's Office in Singapore

Antonia Sutter Swiss Development Cooperation SDC

Massamba Thioye UNFCCC Secretariat

Marion Verles Gold Standard

Nicolás Westenenk Ministry of Energy in Chile

Coordination, editing and production

Madeleine Guyer INFRAS	Overall coordination
Sarah Leugers Gold Standard	Final editing and production
Ema Cima Gold Standard	Design

https://climateledger.org/en/Focus/Navigating-report.38.html

[1] The reviewer would like to clarify that the provided technical review input does by no means represent an endorsement by the UK government of the work's findings.

[2] The reviewer provided technical review/input of Chapter 10 of the report in his personal capacity. The inputs and opinions expressed are the reviewer's own and do not reflect the views of the Government of Singapore or represent an endorsement by the Government of Singapore of the report.

Acknowledgements

The Climate Ledger Initiative would like to sincerely thank the donors, authors, reviewers and other partners and contributors who helped to create this first report on navigating blockchain and climate action. This work also greatly benefited from the discussions and input from participants from the over 20 workshops and presentations held since early 2017 including the Cleantech21/ImpactHub in Zurich, COP and SBSTA side events in Bonn, Hack4Climate, Innovate4Climate in Frankfurt, OECD Blockchain Policy Forum, Climate Chain Coalition meetings, and meetings with governments, practitioners and developers of use cases who shared their experiences.

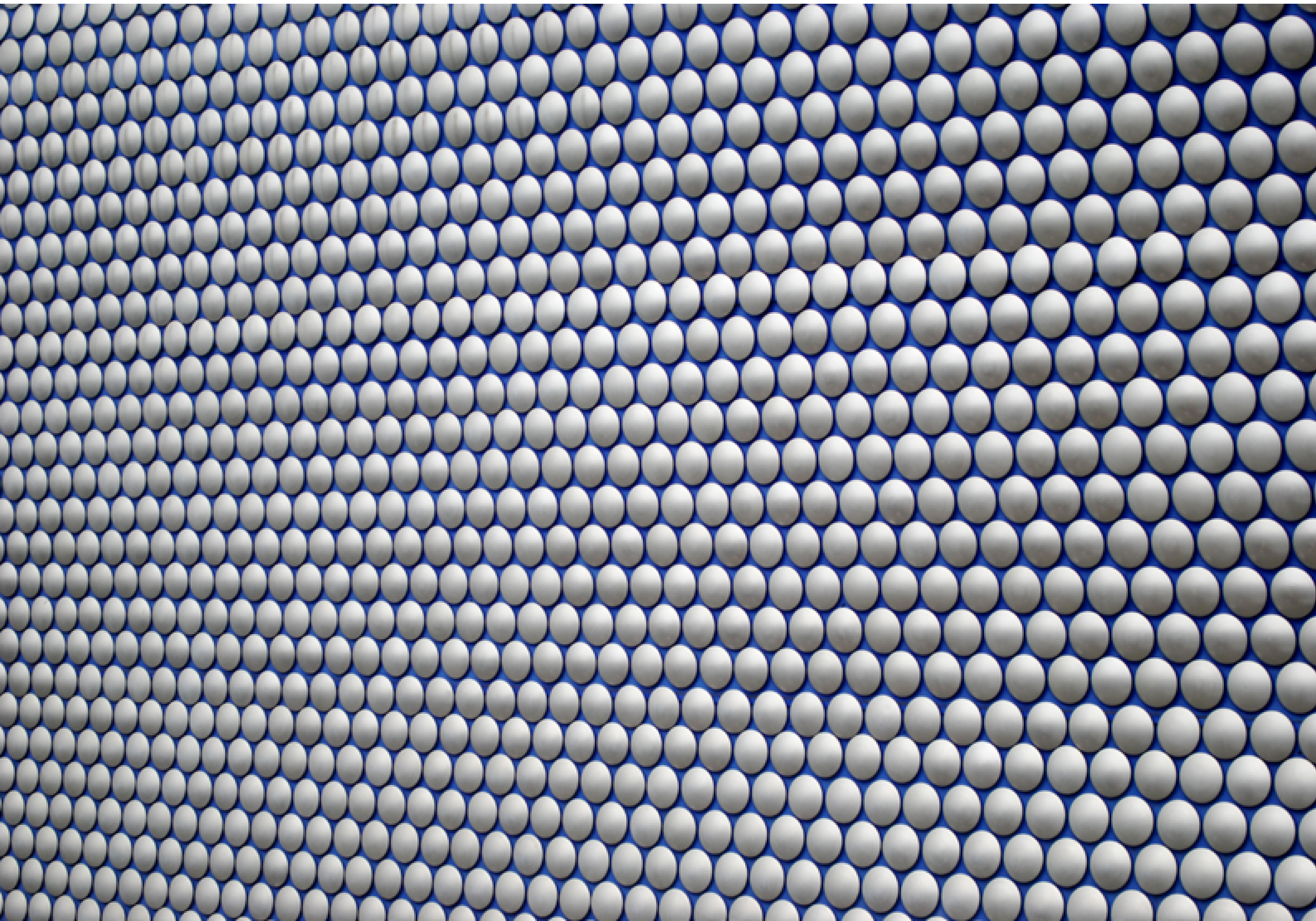


Table of Contents

Preface

This report was prepared by an international team of authors with a diverse set of experiences and insights. It is a knowledge product of the Climate Ledger Initiative (CLI) published on an annual basis to track progress according to latest research and use cases – supporting CLI's role as an international knowledge platform to accelerate climate action through blockchain based innovations.

The Climate Ledger Initiative

The mission of the Climate Ledger Initiative is to accelerate climate action in line with the Paris Climate Agreement and the Sustainable Development Goals (SDGs) through blockchain-based innovation applicable to climate change mitigation, adaptation, and finance.

The Climate Ledger Initiative has been founded by Cleantech21 and is jointly operated by Cleantech21, LIFE Climate Foundation, INFRAS Consulting, Analysis & Research and the Gold Standard Foundation.

The Climate Ledger Initiative is financially supported by the Government of Switzerland and the Government of Liechtenstein as well as by EIT Climate KIC. It maintains a platform of donors, partners and collaborators that it is constantly expanding.

For more information, in case of interest in partnerships and collaboration and for registering to our newsletter please visit https://climateledger.org/.

Juerg Fuessler
Managing Partner
INFRAS

Nick Beglinger
CEO
Cleantech21
Hack4Climate

Sven Braden
Co-Founder
LIFE Climate Foundation
Liechtenstein

Marion Verles
CEO
Gold Standard

Voices from partners and collaborators

Pio Wennubst

Ambassador, Vice-Director General
Federal Department of Foreign Affairs
Swiss Agency for Development and Cooperation (SDC)

The recently published IPCC special report highlighted that we will not achieve the 1.5°C-target without new technology. Switzerland is home to centers of excellence in climate research and technology development. Therefore, we are investigating the potential of new solutions to see how they might contribute to increased efficiency and transparency in the implementation of international climate agreements such as the Paris Agreement.

Kirsten Dunlop

CEO of Climate KIC

Climate-KIC is proud to support the Report on Navigating Blockchain and Climate Action. It will accelerate the identification of blockchain related innovation hotspots for Climate Action and will further help to develop the use-cases that will help to bring the world on a 1.5°C pathway.

Panagiotis Potolidis-Beck

Head of Division for Economic Affairs and Development, Ministry of Foreign Affairs, Liechtenstein

Decentralizing economic powers may be key for sustainable and more environmentally friendly development, despite the trends of globalization. Blockchain Technology is an important tool that enables the decentralization of powers. If applied in the right way, it can provide an important contribution to address global challenges such as climate change and poverty alleviation. I am convinced that we will see a lot of innovative and exiting approaches in that regard. And it is our call to provide for flexible but clear frameworks on Blockchain Governance.reement.

Yusuf Karacaoglu

Chief Information Technology Advisor, ITSVP and Director, Technology and Innovation Lab, World Bank Group

Distributed Ledger Technologies may provide the infrastructure needed to support tomorrow's climate markets. Courage, a willingness to experiment, and collective action from technologists partnering with diverse international communities are needed to realize its potential.

Neeraj Prasad

Practice Manager, Carbon Markets and Innovation Practice, World Bank Group

In light of the bottom-up framework embedded in the Paris Agreement, the growing diversity of climate market mechanisms and the rapidly evolving landscape of digital technology, a new architecture is needed to facilitate more liquid trading across heterogeneous systems. Blockchain and other emerging technologies have the potential to build trust and enhance the efficiency of the next generation of climate markets. The World Bank believes that open collaboration and learning-by-doing are key to further explore how disruptive approaches can support the global agenda on carbon pricing.

Martin Frick

Senior Director for Policy and Programme Coordination, UNFCCC Secretariat

The implementation of the Paris Agreement and the 2030 Agenda for Sustainable Development requires bold climate and sustainability actions, commensurate with the goals of these landmark agreements. The digital technologies, including Blockchain have a critical role to play in the profound transformation that is required at all levels, regions and sectors to ensure success. They can contribute in particular by (i) empowering climate and sustainability actors, from large corporates down to the level of individual citizens; (ii) providing them incentive to act; (iii) measuring the impact of their actions; and (iv) tracking collective progress towards the goals.

Rodolfo Lacy

Director of the Environment Directorate, Organisation for Economic Co-operation and Development (OECD)

The digital transformation presents new opportunities for driving the systemic transformation required for a low-emission, climate-resilient future. Digital technologies such as blockchain could help mobilise new sources of financing for climate change, serve as a clean energy trading platform and help overcome challenges relating to accounting, tracking and reporting of emissions reductions. This report is a welcome and timely contribution to discussions on the opportunities and challenges of using blockchain to combat climate change and implement the Paris Agreement.

Abbreviations

— AI - Artificial intelligence

— CAD - Compilation and Accounting Database

— CDM - Clean Development Mechanism

— CLI - Climate Ledger Initiative

— CTF - Common tabular format

— DLT - Distributed ledger technology

— FAO - Food and Agriculture Organization

— GHG - Greenhouse gas

— ICTU - Information for clarity, transparency and understanding

— ITL – International Transaction Log

— ITMO - Internationally transferred mitigation outcome

— IoT - Internet of things

— NDC - Nationally Determined Contribution

— MRV - Monitoring, reporting and verification

— OECD - Organisation for Economic Co-operation and Development

— SOCIT - Soil organic carbon monitoring

— TER - Technical expert review

— UN - United Nations

— UNFCCC - United National Framework Convention on Climate Change

Key findings for policy makers

Climate change is one of the most pressing existential threats to humanity. The dramatic transition to net zero emissions by mid-century will require global action on an unprecedented scale. This tremendous global challenge coincides with the emergence of the blockchain technology, or more generally Distributed Ledger Technology (DLT)[1], a new and innovative form of decentralised database providing new ways for secure exchange and storage of data and digital assets, primarily designed for peer-to-peer transaction platforms.

Blockchain technology provides a key to solving some of the critical issues that hinder effective scaling of climate action. The main benefits of blockchain technology are rooted in three main characteristics:

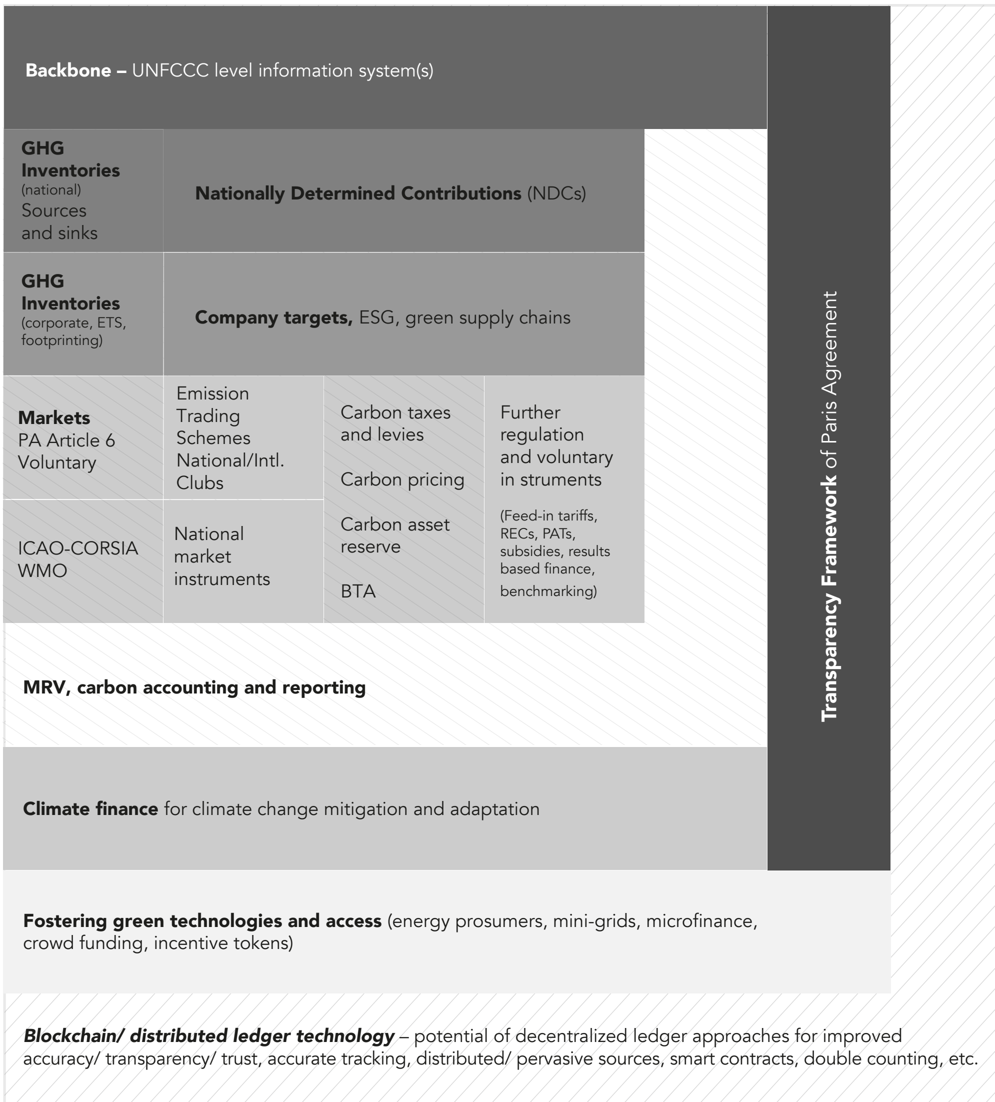
- Data records on a blockchain are immutable through a permanent ledger for increased transparency.
- Blockchain technology brings trust to peer-to-peer transactions – particularly important in the context of weak regulatory settings or under decentralised governance.
- Smart contracts – applications that can automatically execute the terms specified in a contract on a blockchain – increase efficiency and reduce transaction costs.

The potential of the technology seems boundless; however, many common climate-related applications are voluntary reward systems building on the tokenisation of climate or sustainability benefits. These rather ad-hoc, initial coin offerings (ICO) funded applications appear limited in impact and lifespan. More importantly, niche markets in voluntary climate action represent only a fraction of the lynchpin issues for effective Paris Agreement implementation.

[1] In this report, we are using the more common term «blockchain» as a simplifying placeholder for the much broader concept that includes all distributed ledger technologies, even though blockchain is only one implementation of DLT.

The key question therefore is: Where and how can blockchain technology best accelerate climate action? This report – written for governments, climate practitioners and the blockchain community – builds on an analysis of the key requirements to implement the Paris Agreement (FIGURE 1) to provide a systematic assessment of the potential of the technology to accelerate climate action. It explains how blockchain technology is currently applied in specific use cases and where further work, analysis and insights are needed to fully unleash the potential of the technology.

FIGURE 1 — Key thematic issues of the Paris Agreement to scale up climate action



Source: Climate Ledger Initiative. Abbreviations: GHG: Greenhouse gases, ETS: Emissions Trading Schemes, ESG: Environmental, Social and Governance Criteria in the Finance industry, PA: Paris Agreement, ICAO-CORSIA: The International Civil Aviation Organization's Carbon Offsetting and Reduction Scheme for International Aviation, WMO: World Maritime Organization, BTA: Border Tax Adjustments, REC: Renewable Energy Certificate, PAT: Perform Achieve Trade Scheme for Energy Efficiency in India's Industry, MRV: Measuring, Reporting and Verification.

Building on a comprehensive analysis of the needs of the Paris Agreement, the authors identify **three main areas where blockchain has the most potential to accelerate climate action:**

1 — **Next-generation registries and tracking systems**: The decentralised nature of the Paris Agreement and its governance structure requires new approaches to registries and tracking systems to handle heterogeneous rulesets for accounting and reporting and to allow for trusted, networked carbon markets (Chapters 2, 3, 4).

2 — **Digitising Measuring, Reporting and Verification (MRV)**: Blockchain is part of an ecosystem of digital technologies including remote sensors, internet of things, big data and artificial intelligence (Chapter 5). The combined use of these new technologies can unlock new, more accurate ways to measure, report and verify climate outcomes at lower transaction costs. Digitisation of MRV also allows the coding of methodologies and processes in the form of smart contracts for the automated issuance, transfer and payment of climate outcomes. Digital MRV can facilitate access to carbon markets or other results-based finance schemes for the private sector players, in particular in weaker regulatory frameworks – including for climate finance and adaptation (Chapters 6, 7). It can also transform corporate supply chains towards more transparency and accuracy on climate and sustainability impacts of goods produced and sourced (Chapter 12).

3 — **Decentralised access to clean energy and finance**: Blockchain systems emerge as the backbone of new decentralised markets for clean energy where individual "prosumers" are empowered to produce and store their own renewable energy and trade with their neighbours (Chapter 11). More generally, blockchain technology combined with new fingerprint, iris or face recognition technology allow individuals who lack identity documents or bank account to access climate finance in the form of micro credits, subsidy schemes of payments for mitigation or adaptation action (Chapter 6).

Blockchain technology is by no means the silver bullet that can put the world on track to meet a 1.5° or 2° target. There is little technology can do to solve issues such as lack of political ambition or regulatory and institutional challenges of the Paris Agreement. Work on the priority areas of innovation identified in this report remains largely early stage as governments, the UNFCCC secretariat, multilateral organisations, NGOs, private businesses and start-ups are gaining experience through use case implementation. Much research and development stands before us, including real-world testing in a wide range of use cases. Challenges like high power consumption, limited storage space, time lag and network security remain to be solved. Governance for transaction on blockchain based systems must be smartly designed and embedded in national and international regulatory systems.

As an emerging disruptive technology, blockchain's full potential cannot be forecast with certainty. This is why, in close collaboration with its network of partners, CLI will continue its work to provide an international knowledge platform on these issues and accelerate adoption of new technologies for climate action.

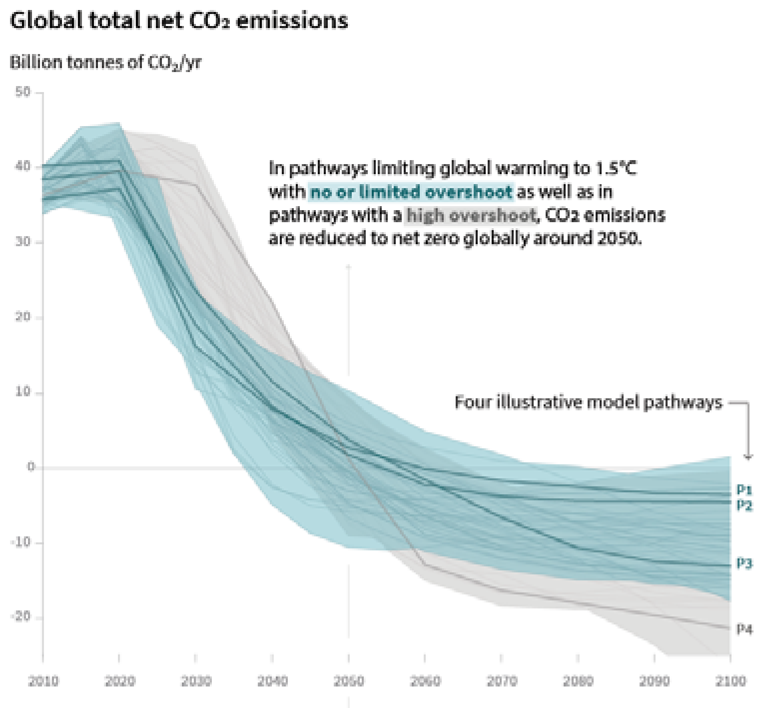
INTRODUCTION – SETTING THE SCENE

Juerg Fuessler
Managing Partner
INFRAS

Climate change is one of the most pressing existential threats to humanity. With the Paris Agreement, international climate action enters new territory. For the first time, virtually[2] all Nations agree to tackle climate change.

International action to combat climate change changes from the top-down approach of the Kyoto Protocol to an inclusive approach dominated by bottom-up country commitments.

FIGURE 2 —Emissions reductions required to keeping global warming below 1.5° – IPCC 1.5° Special Report



Limiting global warming to 1.5°C above pre-industrial levels requires rapid, large scale and ambitious greenhouse gas emissions mitigation.

Source: IPCC 2018: Global Warming of 1.5 °C. An IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways. http://www.ipcc.ch/report/sr15/

The task at hand is total net decarbonisation —a formidable challenge. Curbing temperature increase well below 2°C per the Paris Agreement[3] requires a tremendous reduction in global emissions, including the net removal of greenhouse gases from the atmosphere

2 On August 4, 2017, the Donald Trump administration delivered an official notice to the United Nations that the U.S. intends to withdraw from the Paris Agreement as soon as it is legally eligible to do so.

3 Decision 1/CP.21 Adopting the Paris Agreement mentions limited temperature increase in recital.

in the second half of the century. FIGURE 2 outlines several emission pathways in line with a 1.5°C temperature target. These can only be achieved through a deep transformation of our economies and lifestyles.

Current commitments are insufficient. The 2017 UNEP Gap Report[4] provides an analysis of countries' stated pledges to reduce greenhouse gas emission. It clearly shows the tremendous divide between what is needed and the sum of current national targets. Today's Nationally Determined Contributions (NDCs) cover only about one third of the emission reductions required to be on a least-cost pathway for the global goal to stay 'well below 2°C.'

We must reconsider our customary toolbox of instruments, policies and incentives to identify new tools that can accelerate change toward true systemic transformation. Innovative technologies, including blockchain[5], or more generally distributed ledger technology (DLT), embedded into digital ecosystems, including internet of things (IoT) and artificial intelligence (AI) together with other innovations, including remote sensors and mobile devices, can be a lever for transformational change towards net zero pathways.

As a simplified introduction, blockchain systems provide innovative ways for the exceptionally secure exchange and storage of data and digital assets. Blockchain technology uses a consensus mechanism to provide a digital, distributed ledger that is centrally accessible and immutable but does not rely on a central authority, clearing house or database to execute trusted transactions. Blockchain provides every participant a copy of the shared (distributed) ledger and a secure mechanism to keep all copies in perfect synch. Blockchain systems may also include 'smart contracts', which allow for the automated execution of rules and contracts, potentially superseding—or making redundant—many cumbersome document-based processes in business and government.

The disruptive nature of the technology has already significantly influenced the financial ('fintech'), renewable energy and health sectors. The Climate Ledger Initiative (CLI) identifies blockchain as tremendous opportunity to introduce new and potentially transformative approaches to climate action. Blockchain systems may provide the ideal backbone for new data systems and registries suited for the bottom-up architecture of the Paris Agreement. Digitised Measurement, Reporting and Verification (MRV) can catalyse automated issuance of mitigation outcomes on a trusted registry and transfers on international carbon markets, streamlining a previously labour-intensive process.

This report maps the potential of blockchain-based ecosystems through the entire landscape of what's needed to implement the Paris Agreement.

Note that for simplicity, the term "blockchain" is used to represent broader digital ledger technologies. For more details on blockchain and distributed ledger technology, including some of its challenges and risks, refer to Chapter 13.

4 https://www.unenvironment.org/resources/emissions-gap-report-2017

5 In this report, we are using the more common term «blockchain» as a simplifying placeholder for the much broader concept that includes all distributed ledger technologies, even though blockchain is only one implementation of DLT.

PART I

Blockchain for the Paris Agreement and Compliance

Measuring, reporting and transacting impact

THE PARIS AGREEMENT – A BIRD'S EYE VIEW

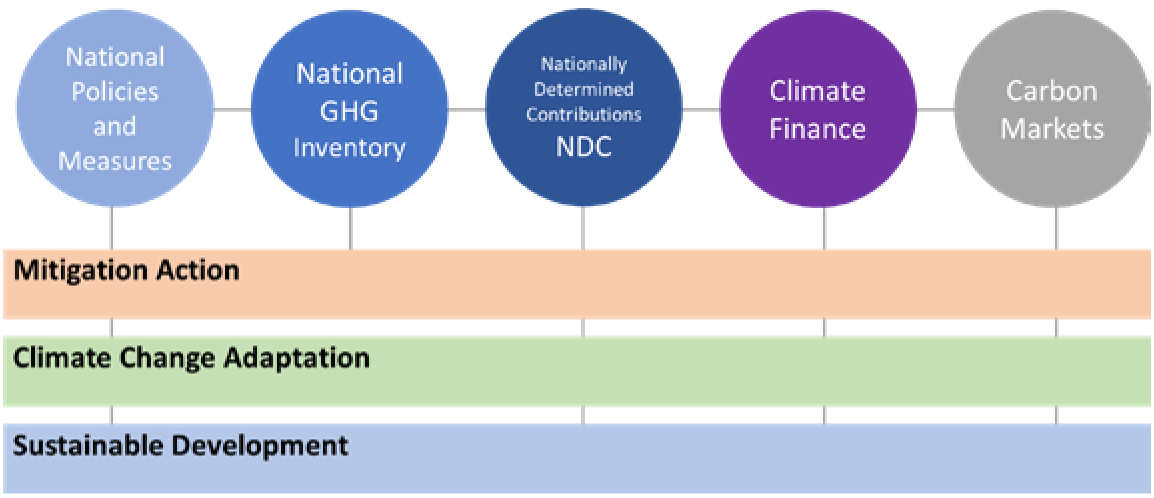
Juerg Fuessler
Managing Partner
INFRAS

2.1 Measuring, reporting and transparency: key drivers for implementation

The bottom-up nature of the Paris Agreement moves away from the centralised accounting and reporting framework of the Kyoto Protocol and allows countries to choose how to report their progress—in which metrics, form and technical protocol. With such heterogeneity, achieving transparency is even more complex. This is also true for countries' ability to track their own climate action and progress toward domestic goals. Transparent measurement and disclosure of national progress toward mitigation, finance and adaptation goals is needed to ratchet up climate ambition over time, an overall aim of the Paris Agreement.

FIGURE 3 — Paris Agreement elements and related information flows provides an overview over the main elements to implement the Paris Agreement and the activities related to mitigation action, adaptation and sustainable development. These elements are primarily components of the national system for climate action—governed by institutional entities—but may also be seen as databases to facilitate the exchange of information necessary to operationalise the Paris Agreement.

FIGURE 3 — Paris Agreement elements and related information flows



The main elements for the implementation of the Paris Agreement may also be seen as databases, sharing of data on actions, emissions, targets, transactions, payments, ownership and sustainable development benefits.

Source: CLI own analysis

Centre stage are the **Nationally Determined Contributions (NDCs)**, the targets that countries set for themselves to combat climate change and increase climate resilience. This may include information on how many emissions should be reduced over time or what percentage of renewable energy is to be achieved by a specific date, for example, by 2025 or 2030.

To evaluate progress toward NDC targets, countries must track the tonnes of greenhouse gases they emit from different sources in a **National GHG Inventory**. The **national policies and measures** describe the domestic action the country chooses to implement to meet its NDC target. Developed countries have pledged to support domestic action in developing countries with international **climate finance**. Developing countries are also encouraged to report on climate finance support received.

Countries with relatively high marginal abatement costs may enter into "cooperative approaches" with other countries under Article 6 of the Paris Agreement to use **carbon markets** to achieve part of their NDC by paying for mitigation actions in other countries. This engagement in carbon markets requires a comprehensive bookkeeping system to track international transfer of mitigation outcomes, including management of technical issues such as "transaction logs" and "corresponding adjustments" made to the issuing countries.

All these elements require comprehensive tracking and exchange of information to make climate action measurable and visible and to track contributions in a transparent, comparable and efficient manner. This forms the basis for the "global stocktake", a central element of the Paris Agreement to track progress and increase ambition levels over time.

2.2 Blockchain as a bottom-up, decentralised and trusted information system for implementing the Paris Agreement

The Paris Agreement and blockchain technology share important fundamental characteristics, as seen in TABLE 1.

TABLE 1: Shared characteristics of the Paris Agreement and blockchain technology

Needs of the Paris Agreement	Features of blockchain technology
— **Transparency**: Reporting and sharing of information as a key pillar — Party-led, decentralised, **hybrid (bottom-up and top-down) approach** — Trusted **measuring, reporting and verification (MRV)** of emissions, emission reductions, adaptation actions and progress in achieving targets — Transparent **exchange of information and review** mechanisms to enable global stocktake — Critical need to leverage **private sector contributions**	— ***Decentralised*** data system using consensus mechanism — Increased levels of **transparency**, through time-stamps and status verification in sync with all network participants — Immutable data records through **permanent ledger** for increased traceability and trust — Applicable for **small, distributed emission sources** (e.g., households, cars) — **Trust to peer-to-peer transactions** also in contexts of weaker regulatory settings — **Smart contracts** (applications that can automatically execute terms specified in a contract) to increase **efficiency** and reduce transaction costs — Rules governing the ledger **adaptable** to context, e.g., by choosing a public/permissionless or a private/permissioned consensus mechanism
Risks: **Lack in ambition levels and transparency, lack on standardised metrics**	*Risks*: **Technologies still at pilot/demonstration stage; complex, slow, (too) permanent, high power consumption**

Source: Authors own analysis

The following chapters take a closer look at where blockchain and related innovative technologies can best be deployed to tackle the challenges of implementing the Paris Agreement and to accelerate and scale up climate action.

BLOCKCHAIN SUPPORTING A HYBRID, DECENTRALISED CLIMATE TREATY

Felipe De León
Consultant and Adviser
Ministry of Environment and Energy (MINAE), Costa Rica

3.1 Supporting carbon markets through cooperative approaches

A defining feature of the Paris Agreement is its flexible cooperative approaches, as outlined in Article 6.2, allowing for the use of carbon markets for the international transfer of mitigation outcomes. To maximise potential for innovation enabled by its hybrid approach, the supporting infrastructure must be equally innovative and allow for maximum flexibility[6] while ensuring transparency and adherence to the rules established through the top-down elements.

Cooperative approaches "involve the use of internationally transferred mitigation outcomes"[7] (ITMOs) by two or more self-organising Parties collaborating through any number of cooperation arrangements, all of which "shall apply robust accounting to ensure, inter alia, the avoidance of double counting". This is further complicated by the fact that the reporting cycle for Parties is asynchronous (different Parties will report at different times) and by the fact that Parties have widely different capacities and national circumstances. Conventional information technology is ill suited to meet these challenges. Blockchain technology, on the other hand, allows robust accounting in a way that can accommodate the complexities of bottom-up governance with robust accounting based on top-down rules.

Blockchain technology, allows robust accounting in a way that can accommodate the complexities of bottom-up governance with robust accounting based on top-down rules.

In the top-down context of the Kyoto Protocol, data-related cooperation challenges have been primarily met through the International Transaction Log, which "connects registries and secretariat systems that are involved in the emissions trading mechanism defined under the

[6] On the other hand, current blockchain architectures may also be more static and require new approaches to allow for increased flexibility in their structure.

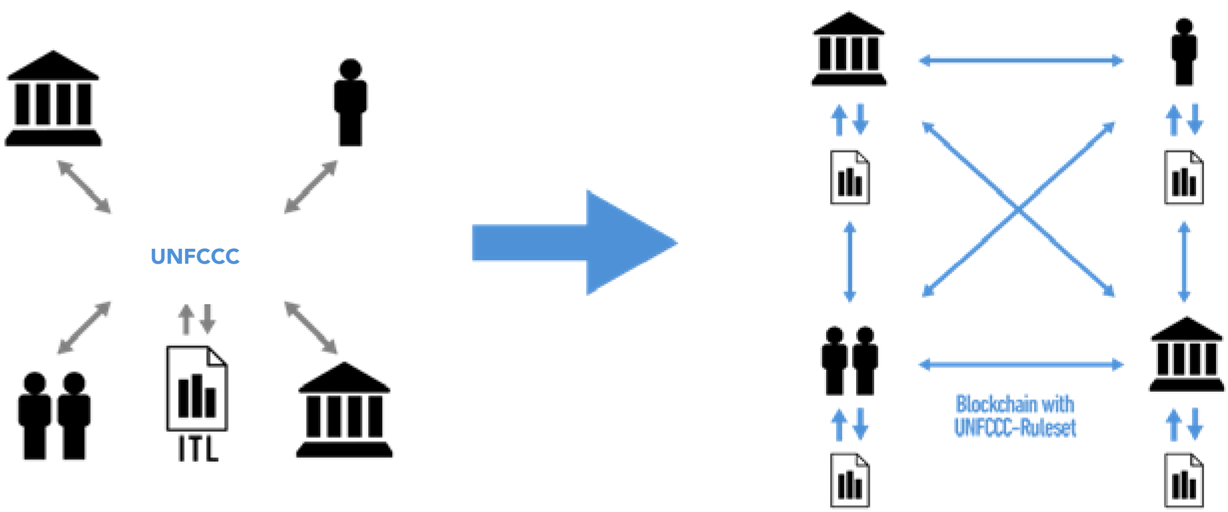
[7] United Nations Framework Convention on Climate Change. (2015) *Paris Agreement*

Kyoto Protocol"[8]. The International Transaction Log functions as the central ledger and clearing house connecting the national registries that every Annex I country is required to maintain under Kyoto. It is a generally successful system, yet its development and operation is perceived by many Parties as expensive. Further, the International Transaction Log is also quite rigid, with a 506 page Data Exchange Standard[9] and rules that must be agreed to by the designated registry administrator of every national registry, as well as a complex registry initialisation process. This rigidity is characteristic of centralised systems designed to respond to centralised needs. Such a system compromises the ability to adapt to new types of transactions it must support and the variety of national circumstances it can be deployed in.

3.2 Blockchain for flexible and robust accounting

Blockchain technology can provide both the flexibility and robust accounting to establish a framework that incorporates UNFCCC rules through which national registries can perform transactions, rather than a central system on which transactions must be registered, as seen in FIGURE 4.

FIGURE 4 — Centralised vs decentralised technology



Source: Adapted by author from Climate Ledger Initiative (formerly "#CarbonBC"), 2017: Summary for Policymakers. How can Blockchain technology contribute to Paris Agreement implementation? (© by Cleantech21)

[8] United Nations Framework Convention on Climate Change website. https://unfccc.int/process/the-kyoto-protocol/registry-systems/international-transaction-log

[9] United Nations Framework Convention on Climate Change (2013) *Data exchange standard for registry systems under the Kyoto Protocol Technical Specifications Version 1.1.11*

Importantly, there is already a practical example of the deployment of distributed ledger technology by a United Nations agency to solve real-world challenges, outlined in the inset UN World Food Program Use Case. This success story demonstrates that blockchain solutions can be deployed successfully by UN agencies, efficiently and cost-effectively within capacity- and resource-constrained conditions, which is also critical to operationalise the Paris Agreement.

USE CASE

UN World Food Program uses blockchain to distribute cash for food for refugees- The World Food Program, the world's largest humanitarian organisation, has deployed a blockchain based solution to distribute cash for food to over 100,000 Syrian refugees in Jordan through small supermarkets located in the refugee camps. The program, called Building Blocks, has been so successful it is expected to cover all 500,000 refugees in the country by the end of 2018[10]. The system allows a refugee to confirm "his identity on a traditional United Nations database, queried a family account kept on a […] blockchain by the World Food Program and [settle] his bill without opening his wallet"[11].

TABLE 2 — Challenges in Paris Agreement architecture and potential for blockchain

Challenges	Opportunities for blockchain	Remarks
Centrally accessible without centralised governance	— Traditional architecture is based on centralised information and control, particularly complex given the Paris Agreements' hybrid approach.	— Blockchain provides a single point of access without the need for a centralised authority or database.
Simple implementation in a wide variety of cooperative approaches	— Given the strong bottom-up elements of Article 6.2 and the long-term nature of Paris Agreement, solutions must be able to accommodate a variety of cooperative approaches now and in the future.	— The use of smart contracts, smart legal code and smart legal templates enables consistent application of the rules in a flexible framework.
Tracking corresponding adjustment pairs through time	— The asynchronous nature of reporting cycles under the Paris Agreement means two sides of a corresponding adjustment might occur years apart.	— The use of smart contracts can ensure that ITMOs cannot be used unless a corresponding adjustment pair is available in the system.
Embedding immutable data such as vintage or source	— The hash function provides a secure and immutable way to validate content.	

Source: Authors own analysis

10 Juskalian, Ross. (2018) *Inside the Jordan refugee camp that runs on blockchain*

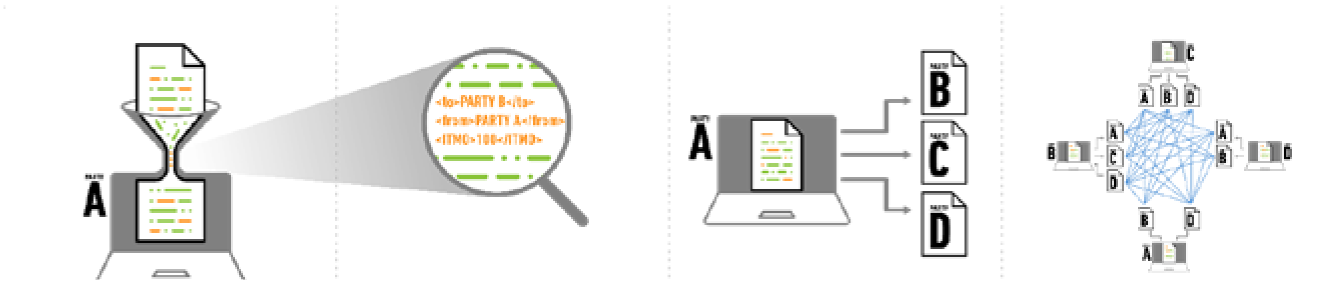
11 Ibidem

Smart contracts

Smart contracts are a key flexibility mechanism in blockchain ecosystems. A recent report commissioned by the World Bank Group found that blockchain and collaborative governance systems that enable more efficient monitoring, reporting and verification (MRV) standards can help address many of the challenges of implementing the Paris Agreement. This can be achieved "firstly, through blockchain-enabled distributed ledgers that provide transparency and robust rule implementation via smart contracts; secondly, through collaborative governance systems that enable more efficient development of MRV standards structured as holistic systems of modular, compatible and extensible methods and rules."

Smart contracts can be understood as legal contracts with at least some parts expressed through computer-automated smart legal code. While this does not preclude human input and control, a system based on smart contracts could transparently support a wide variety of cooperative approaches that suits a diversity of transaction types and relationship arrangements while automatically enforcing overarching top-down rules. Smart contracts can be developed as smart contract templates developed by standards bodies to facilitate negotiation and potentially automate contract execution through standardised smart legal code[12], as shown in FIGURE 5.

FIGURE 5 — Standardising distributed ledger (blockchain) transactions through smart contracts



Smart contracts are legal contracts with at least some parts that can be automatically executed by a computer system…

…they use a markup language, which uses tags to facilitate computer processing of the texts.

Smart contracts are legal contracts with at least some parts that can be automatically executed by a computer system…

Smart contracts are deployed to the UNFCCC-Ruleset blockchain to be immutably registered and automatically executed.

Source: Andre Kelso and author

12 Clack, Christopher D. et al. (2016) Smart Contract Templates: essential requirements and design options

3.3 Applications of blockchain in hybrid systems

Blockchain-based smart contract systems are already being applied by organisations such as Barclays, the UK banking giant. The bank used Corda, a distributed ledger platform built specifically for the financial services industry, to build a prototypefor settling over-the-counter derivatives trades based on smart contract templates.

In the climate sector, the Climate Change Directorate of the Ministry of Environment and Energy of Costa Rica is currently developing the rule set for the registries of its upcoming Costa Rican Offset Mechanism (Mecanismo Costarricense de Compensación, MCCR). As part an effort to become the world's decarbonisation laboratory and to provide a proof-of-concept for the application of blockchain in the context of the Paris Agreement, Costa Rica intends to develop an open-source blockchain registry to track the use of the national offset unit and its transactions under the Joint Crediting Mechanism with Japan, as well as any other market-based mechanisms it may engage in.

3.4 Implementing cooperative approaches on a blockchain

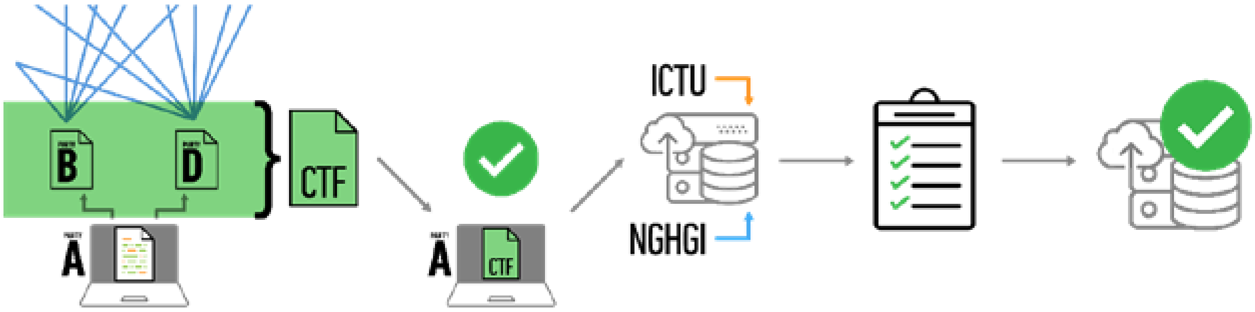
A potential arrangement for cooperative approaches under Article 6.2 would involve developing the parameters for a simple markup language and accompanying smart legal code elements for those parts of the relevant UNFCCC rules that can be automated. Automation via smart legal contracts implemented on a distributed ledger could feature elements such as:

— Embedding immutable source, vintage and environmental integrity information
— Tracking the two sides of a corresponding adjustment that occur at different times
— Ensuring that the source of a unit is properly covered in the scope of the host country's NDC before use

This markup language would then be used by the Parties when establishing their cooperative approaches and registries. By doing this, they retain full liberty in designing the terms of the relationship and other legal elements in a fully human-readable format, while ensuring that the tags trigger standardised accounting actions and/or immutably registry information on a distributed but centrally accessible ledger.

Smart contract templates could be developed under the UNFCCC to facilitate deployment of compliant national and/or regional registries, including the registry of the mechanism under Article 6.4, and to facilitate interaction with the registries of other market-based mechanisms in the United Nations system, regardless of whether or not they use blockchain for their internal functioning. A simple diagram of this arrangement is presented in FIGURE 6.

FIGURE 6 — Process for blockchain-based flexible and robust accounting in cooperative approaches



Transactions are carried out on the blockchain, which allows it to keep track of all ITMOs at all times and to pre-fill a CTF for review by the Party.	The Party reviews the pre-filled CTF and, once in agreement, submits it to the CAD.	The CAD compiles all data necessary for the TER.	The TER team carries out its review as per appropriate guidance and rules.	A "reviewed" version of all relevant documents is made public.

Source: Andre Kelso and author

Abbreviations: Compilation and Accounting Database (CAD) similar to the one used under the Kyoto Protocol[13], which would serve as a temporary collection point for all the data necessary for the Technical Expert Review (TER), potentially including the relevant National Greenhouse Gas Inventories, and information for clarity, transparency and understanding (ICTU) and would then hold a final "reviewed" version of the relevant reports and results.

Under such an arrangement a Party would connect to the blockchain through its own implementation of the smart contract templates and use these to operationalise its cooperative approaches, or market-based mechanisms, under Article 6. This would allow real-time tracking of every ITMO, automating Party and technical expert reviews, and subsequently publishing approved documents transparently to the public.

As TABLE 3 summarises, recent advances already indicate how blockchain innovations can unleash the full potential of the Paris Agreement's cooperative approaches by promoting diversity and innovation while ensuring robust enforcement of the core common rules.

TABLE 3 — Use cases for blockchain in emission reduction/transaction registries

Use case	Description	Resource
— Costa Rican Offset Mechanism (Mecanismo Costarricense de Copmensación, MCCR) open-source DLT registry	— Blockchain-based offset mechanism registry being developed as an open-source proof of concept of blockchain solutions international cooperative approaches under Article 6 of the Paris Agreement	— None available
— Noble Profits BFlow Network	— Standardised token and protocol for global sustainability reporting; developing a use-case for application to carbon markets	— https://bflow.io/

Source: Authors own analysis

13 United Nations Framework Convention on Climate Change. (2007) *Decision 19/CP.7 Modalities for accounting of assigned amounts under Article 7, paragraph 4, of the Kyoto Protocol*

NETWORKING CARBON MARKETS TO SCALE UP CLIMATE ACTION

Rachel Mok, Florencia Sanchez Zunino
World Bank Climate Change Team

Susan David Carevic
World Bank Innovation and Technology Lab

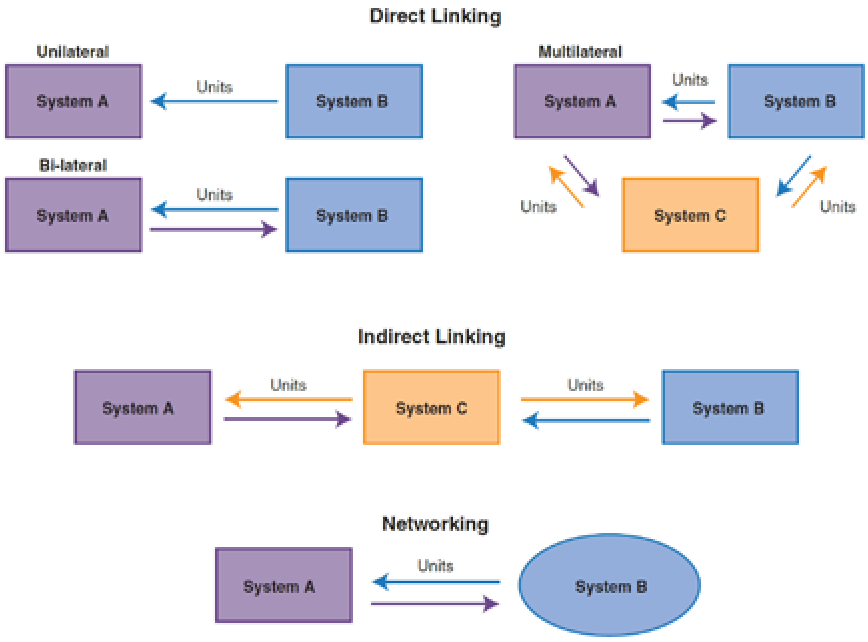
4.1 Challenges for heterogeneous post-2020 carbon markets

Carbon markets and carbon pricing offer the opportunity to increase the resources mobilised from the private sector, reduce the burden of implementing Nationally Determined Contributions (NDCs) and may support increasing global ambition. However, in the hybrid landscape of the Paris Agreement and its cooperative approaches described in Chapter 3, a multitude of heterogeneous carbon markets is growing bottom-up to be a variety of decentralised markets, linked at regional, national, and sub-national levels. To allow for scaling up, these heterogeneous and smaller markets will have to seek networking (restrictive) linking and accommodate a more diverse set of regulations, MRV systems, climate assets, metrics for mitigation outcomes, linking arrangements, and types of transactions (e.g., peer-to-peer, results-based, machine-to-machine) within and across jurisdictions (e.g., within 'carbon clubs', regional trading schemes, sectoral trading schemes), as well as greater financial flows.

Linking carbon markets can take place in several different forms, as illustrated in FIGURE 7. For direct links, such as the link between California's and Quebec's emissions trading systems (ETSs), allowances flow freely between carbon pricing systems on a one-to-one trading ratio. On the other hand, indirect links rely on a common compensation unit or offset that can be exchanged between systems, such as the use of an offset mechanism via the Clean Development Mechanism (CDM) in a national carbon pricing system. Networking, on the other hand, seeks to enable cooperation of carbon markets with less requirements to align design features. By doing so, it seeks to link schemes that have different design features, priorities and ambition, while still ensuring the environmental integrity of the trade.

Carbon markets and carbon pricing offer the opportunity to increase the resources mobilised from the private sector, reduce the burden of implementing Nationally Determined Contributions (NDCs) and may support increasing global ambition.

FIGURE 7 — Forms of linking carbon markets



Source: International Bank for Reconstruction and Development/The World Bank (2016).

The State and Trends of Carbon Pricing 2016 report suggests that comprehensive linking arrangements could reduce global costs of implementing countries' Nationally Determined Contributions (NDCs) by a third in 2030, and by half in 2050. However, to date, there have not been as many market links as might have been anticipated given these expected benefits. Of the 21 currently operating ETSs, there are only three instances of successfully concluded linking negotiations[14].

To overcome these challenges, experts are currently exploring the use of networked carbon markets, using a mix of approaches centered on key design improvements. For example, carbon assets could entail different discount rates that reflect variances in the mitigation outcomes generated from different climate assets. This can help address uncertainties on additionality and challenges of linking heterogeneous climate policies. While these proposed frameworks are still at the initial concept stage, the networked carbon markets concept is being explored and discussed in UNFCCC negotiations in context of Article 6 mechanisms, for instance, through discounting of corresponding adjustments[15].

Comprehensive linking arrangements could reduce global costs of implementing countries' Nationally Determined Contributions (NDCs) by a third in 2030, and by half in 2050

[14] Emissions Trading Worldwide Executive Summary International Carbon Action Partnership (ICAP) Status Report 2018

[15] As noted in the informal document containing the draft elements of guidance on cooperative approaches referred to in Article 6, paragraph 2, of the Paris Agreement (dated 16 March 2018), an option to safeguard overall mitigation in global emissions is to create "discounting-based" transfer of ITMOs

4.2 Role of blockchain for networking of post-2020 carbon markets

As the World Bank report Blockchain and Emerging Digital Technologies for Enhancing Post-2020 Climate Markets states, blockchain provides data sharing and transaction management elements well aligned with the requirements of carbon markets. For tradable units in carbon markets, information concerning value in terms of mitigation or data on sustainable development co-benefits can be identified as separate elements and tracked independently, while maintaining information concerning their source or identity. Blockchain technology can provide a digital mechanism for recording and tracking these separate streams of information associated with units, including when they are transacted across jurisdictional boundaries. As long as the necessary mechanism is in place to convert climate assets to a common metric for comparability, this approach ensures market and environmental integrity by precluding double counting of climate assets. Furthermore, blockchain could provide transparency and robust rule implementation via smart contracts, as these can be used to internalise governance (through standards, policy, verification, data sources and commercial terms) between two or more jurisdictions or counterparties. This can help prevent negative consequences (e.g., leakage), inhibit "bad actors" in the marketplace and ensure the environmental integrity of the market. At the same time, it can also help support transparent tracking and valuation of sustainable development co-benefits, which can serve as a lever for more ambitious climate action.

TABLE 4 — Challenges in linking and networking carbon markets and potential for blockchain

Challenges	Opportunities for blockchain
In a post-Kyoto Protocol, carbon-constrained era, climate mitigation in all its forms increasingly has financial value.	Blockchain technology can synthesise and support the transaction of all types of emission-related data (e.g., facility level, projects, programs, quantified production, and life cycle attributes) in a shared, globally accessible environment.
Article 6 could encompass the transaction of mitigation outcomes from a diversity of units, with different rules for exchange.	Smart contracts can provide the mechanism for transactions between existing market schemes[16] operating different registries[17]. Smart contracts could also execute mutually agreed-upon equivalents of mitigation outcomes, based on a common metric to value the differences between units of differences schemes, and internalise governance (e.g., standards, policy, verification, data sources and commercial terms) between two or more jurisdictions.

[16] The Kyoto Protocol took a homogeneous approach to tradable units, which by definition were all equal to one tonne CO2-equivalent GHG emission. The two most common types of tradable units in carbon markets have been allowances and credits.

[17] The term registry can refer to a GHG emissions inventory, a list of project and program information, or databases with varying levels of functionality

Countries may not have the required registry infrastructure to address double counting[18] risks in relation to climate assets.	Blockchain can support the migration to increasing level of technology sophistication and functionality requirements over time. This is important as global carbon markets span across jurisdictions with varying degrees of technological sophistication and also jurisdictions with existing infrastructure and processes. For countries without registries, an "asset wallet" could function as a registry to ease entry to markets, and smart contracts may be used to retire or expire assets according to regulation and agreements.

Source: Authors own analysis based on the report "Blockchain and Emerging Digital Technologies for Enhancing Post-2020 Climate Markets", 2018

4.3 Needs for further work and recommendations

While blockchain and other emerging technologies cannot address all challenges associated with carbon markets, these new technologies can help address double counting, improve transparency and environmental integrity, support alignment with NDCs, and help track sustainable development outcomes.

Challenges for implementing blockchain to link or network carbon markets include the lack of understanding of the technology by many stakeholders, for instance, in relation to issues of privacy of transactions, access to commercially-sensitive data, security of the digital assets, access to digital technologies (e.g., smart devices), and the costs and benefits of multiple parties to securely and directly transact without a central governance system.

Collaboration among multilateral development bank initiatives, UN organisations, Parties and technology providers is key to facilitate knowledge sharing based on experience. These institutions have vast experience in supporting the development of carbon markets and price-based mechanisms at both the domestic and international levels. Pilot markets can test research outcomes in real world environments. Such pilots should also improve stakeholder understanding of how the new technology will be embedded, implemented and operated, including interface with existing technologies.

Additionally, further research is needed to clarify how other emerging technologies, such as smart metres and other devices associated with the internet of things, big data, and artificial intelligence can complement applications of blockchain that support next generation carbon markets. Perhaps more importantly, research should test and confirm the technical, economic and legal underpinnings of the perceived advantages of blockchain applications in addressing the challenges that confront the new generation carbon markets. This can help ensure integrated, seamless implementation of emerging technologies to carbon markets[19].

18 Within the context of Corresponding Adjustments, Parties must avoid double registration, double issuance, double claiming and double use. For these purposes:
(a) Double claiming will occur when the Acquiring Party (in its capacity as Using Party) uses the ITMO towards its NDC without the Corresponding Adjustment for the Transferring Party having taken place.
(b) Double registration will occur when the same mitigation outcome [that the ITMO is meant to represent] is registered with multiple regulatory frameworks.
(c) Double issuance will occur when a double registration leads to the creation of multiple [units] representing the same mitigation outcome [of which one representation is that of an ITMO].
(d) [Double use occurs if the same ITMO is used twice to achieve a mitigation target (e.g. if the ITMO is duplicated in registries or if a Using Party uses the same ITMO in two different years to achieve its mitigation target).]

19 *"World Bank Group. 2018. Blockchain and Emerging World Bank. https://openknowledge.worldbank.org/handle/10986/29499 License: CC BY 3.0 IGO."*

MEASURING, REPORTING AND VERIFICATION OF MITIGATION ACTIVITIES

Owen Hewlett
Chief Technical Officer
Gold Standard

5.1 MRV in mitigation activities and Paris Agreement requirements

The international community enshrined the principle of measurement, reporting and verification (MRV) in the Bali Action Plan in 2007 as way to enhance climate action and increase credibility and transparency of climate impact. More recently, the Paris Agreement established the need for a universal, transparent system of MRV.

Through accurate and timely data provision, MRV provides the foundation for how to plan climate related activities, make decisions on which climate actions to finance, assess progress, allow for the issuance of units and therefore market creation, and make the efforts of all participants comparable.

The suite of digital innovations including blockchain, internet of things (IoT), and artificial intelligence can help overcome existing barriers and enhance the role of MRV. This can streamline data collection and reporting, increase and accuracy and enable better informed, quicker verification. This can then lower costs, shorten time to market, enable interoperability between carbon markets for greater market access and ultimately deliver higher returns on investment for climate action. It can also engender greater trust in results, through transparency and security and reducing the potential for error (intentional or malicious) through automation.

The suite of digital innovations can then lower costs, shorten time to market, enable interoperability between carbon markets for greater market access and ultimately deliver higher returns on investment for climate action.

What MRV entails

In the context of climate mitigation, MRV requires collecting monitored data in line with good practice, applying quality assurance and quality control (QA/QC) and using quality data to report on emissions. For credibility, this reporting is verified (audited) by independent third parties.

For example, a clean cookstove project may monitor parameters such as the hours spent cooking by the stove recipients over a period of time; a renewable energy project may measure the megawatt hours produced in a given cycle. These data have a value. Policy makers can use the data to assess which activities have the greatest impact towards climate mitigation goals and report accordingly. The data can also be used to attract results-based finance to a project activity. For example, by calculating emission reductions of a given activity according to standards set by international bodies or national authorities, carbon credits representing these emission reductions are issued and may be traded in carbon markets.

Approved methodologies such as those under the IPCC Guidance for National GHG Inventories, the Clean Development Mechanism (CDM), Verra or Gold Standard often prescribe monitoring parameters such as metrics, monitoring methods, calibration requirements, sensitivity limits or error tolerances, and sampling frequency. These are designed to standardise output (e.g., emissions reductions and subsequent carbon credit issuance) across different projects or programmes.

Other MRV approaches include company reporting of emissions, or the development of national GHG inventories for reporting to the UNFCCC and for monitoring of progress towards Nationally Determined Contributions (NDCs). An overview of the typical data collection needs in different project or programme types are provided in TABLE 5.

TABLE 5 — Mitigation activities, MRV requirements and challenges

Activity type	Key MRV requirements	Complexity	Main challenges
Improved cookstoves	— Amount of non-renewable biomass used — Distribution records — Fuel usage — Stove usage rates — Transfer of rights to carbon credits from stove owner to project developer	High	Much of the data required today relies on manual collection. As this involves tracking the performance of many small stoves distributed to individual households, collecting the data and avoiding bias in data collection is complex.
Renewable energy	— Grid emissions factor — Energy production	Low	Main data required is publicly available (grid factors) or easily checked at the point of production through metre readings. Reliability is typically high, due to grid regulation. The main challenge is to accelerate the verification process.
Transport	— Trips/journeys/distance — Fuel type/fuel used	Medium	Certain transport modes (e.g., shipping, metro) are well suited to remotely monitoring specific trips. Activities like modal shift or cycling incentives can use remote tracking, though less established.

Activity type	Key MRV requirements	Complexity	Main challenges
Agriculture, e.g., residue management, composting, reduced tillage, cover cropping, shade trees	— Farm boundaries — Farm-level activities — Soil organic carbon	High	Projects often involve a large number of farms difficult to accurately map and sample. Stratification of farms by activity can be difficult to record and monitor. Soil organic carbon monitoring can require on site sampling of results to ensure credible impact reporting.
Forests	— "Root to shoot" ratios — Tree growth — Loss and reversal — Forest inventory	Medium to high	Monitoring actual growth, alongside loss and reversal, can be expensive and impractical. Natural variation in systems makes reliable reporting difficult while opportunities to apply satellite imagery have not been fully realised.

Source: Authors own analysis

Digitising the MRV process, including the use of blockchain technologies, can significantly reduce current barriers and increase the quality and value of impact data.

1 — **Data collection:** Technology can dramatically reduce the time and cost of data collection while also improving its accuracy through enhancements like using sensors or mobile phones to capture data and IoT hubs to automate data processing, thereby removing the potential for human error. This data needs to be captured safely, securely and properly. Blockchain technology, through hashing of data entries, can provide this role.

2 — **Impact quantification and reporting:** Typically, an emission reduction is calculated from a number of data parameters including usage rates, efficiency ratios, "leakage", and others. Today, this calculation is usually done manually using complex spreadsheets. Technology could enhance the impact quantification and reporting process through blockchain-based smart contracts and cloud-based applications linked to IoT-derived data.

3 — **Verification:** Verification typically involves the review of all data collected for integrity and accuracy as well as conformity to a given methodology. Blockchain technology can enable real-time third party verification, whereby data uploaded is continuously checked and verified in real, or near-real time. Artificial intelligence can be used to inform verification by quickly comparing data with results obtained from other, similar activities to detect potential irregularities.

4 — **Issuance:** Impact data can be translated into issuance of credits to a registry. While not essential for this purpose, tokenisation using blockchain can create tradeable tokens for monetisation purposes through, for example, micro-transactions or crowd-sourcing using blockchain technology. Tokenisation can also streamline the MRV process by seamlessly connecting the impact buyer with those initiating the impact on the ground, bypassing intermediaries.

5.2 Enhanced opportunity & overcoming barriers to scale

As the Paris Agreement comes into force, there is a unique opportunity to reflect on the lessons learned concerning MRV, baseline setting and calculation of mitigation outcomes from the Kyoto Protocol era, while taking advantage of the opportunities presented by the advent of disruptive technologies.

Smart application of these technologies can help overcome the current limits to practicality and efficiency and the high costs associated with today's MRV systems, which are currently major barriers to adoption and retention. Indeed, digital MRV systems can significantly enhance climate action by mainstreaming adoption, increasing the credibility and accuracy of reporting and encouraging better comparability and decision making, as outlined in TABLE 6.

TABLE 6 — How technology can address current challenges in MRV

Challenges in MRV	Opportunities for blockchain	Remarks
Lack of trust in data, forgery	Increased confidence in, transparency and accuracy of MRV Reduced potential for human error or corruption in data collection and reporting as well as verification	A key challenge is to ensure the quality of data coming in to avoid "garbage-in, garbage-out". Transparency brought by blockchain can help increase trust in the quality of the data by making it simple to establish the origin of data and how it has been collected and verified. Blockchain alongside other technologies can achieve higher trust and integrity thanks to automated systems for collection, recording and cross-checking.
Costly, complex collection of data for individual and dispersed mitigation action	Automated collection of data through IoT, recorded and made immutable by blockchain	The automated collection, upload of data and the calculations needed to determine impact reduces the need for manual interventions in both collection and review and speeds up the process of data verification.
Costly, complex impact quantification and reporting	Smart contract and online applications in conjunction with blockchain to automate the process of impact calculation, based on automated data collection and pre-set methodological approaches	The digitisation of methodologies to calculate emission reductions will require to adapt existing methodologies to be embedded in a blockchain system in the form of smart contracts; some requirements may no longer be relevant, new requirements may be needed to ensure the appropriate use of technology.
Automated quality assurance and quality control (QA/QC)	Smart contracts on blockchain to automatically check monitoring data for plausibility and outliers	Data that does not pass the quality check may be automatically removed from issuance or switch to more conservative methodology.

Challenges in MR	Opportunities for blockchain	Remarks
Costly verification of emission reductions	Efficiency gains in verification including crowd verification and smarter, risk-based selection of what to audit and when; potential to pre-condition verification based on wider data to automate much of the process, use of blockchain's notary function[20]	This implies a gradual switch from verification of each calculation to the verification of the technology system that produces the output.
Lack of automated, accelerated learning	Automated data collection to enhance quality, integrity and standardisation of data to allow for high quality analysis of results, informing future decision making and verification	Artificial intelligence can be used to compare results from activities of a similar type and derive patterns that can be used to identify outliers. This creates the conditions for automated, risk-based verification and can help improve methodologies.

Source: Authors own analysis

5.3 | Current activities and approaches

Existing initiatives under development that relate to the MRV process are illustrated in TABLE 7. Note that to date, these have not been driven by standards schemes and hence will likely encounter adoption barriers if not resolved.

TABLE 7 — Use cases for blockchain and digitising MRV for climate mitigation

Use case	Activity Type	Description	Resources
Gold Standard 'Cookstove IQ'	Cookstoves	Online submission of data required for methodological calculation of emissions reductions	https://globalgoals.goldstandard.org/tools/

20 The current assurance process for assuring the integrity of mitigation outcomes for most tradable units requires a significant amount of manual verification by third-party, independent auditors. The "notary function" as a standard component of blockchain technology could be deployed to automate many aspects of existing verification processes. This would entail, for purposes of validation, verification, or issuances, creation of computer code logic to automatically require "proof of existence" of permits, certifications, standards, and/or other verification methods by referencing information that is publicly available on outside databases, as well as data from private sources (e.g., remote sensing, satellite imagery and encryptions, data providers, etc.) to ensure integrity of any and all digital assets.

Use case	Activity Type	Description	Resources
Nexleaf Analytics 'Stove Trace'	Cookstoves	Remote collection and upload of cookstove usage data using IoT Stove Usage Monitors and similar technology	http://nexleaf.org/cookstoves/#what-is-stovetrace
Berkeley Air Stove Usage Monitors	Cookstove	Technology-attached stove usage monitors	http://berkeleyair.com/monitoring-instruments-sales-rentals/stove-use-monitoring-system-sums/
Southpole/IXO / Goldstandard Solar MRV	Renewable energy (solar)	Blockchain enabled MRV and tokenisation	https://medium.com/ixo-blog/south-pole-ixo-foundation-and-gold-standard-develop-blockchain-application-for-carbon-credit-b80a484be3ca
FAO Tools for NFMS	Forests	Series of remote, mobile and satellite based monitoring systems for forest inventory	http://www.fao.org/redd/areas-of-work/national-forest-monitoring-system/en/
SOCIT	Agriculture	Soil organic carbon monitoring mobile app	https://www.hutton.ac.uk/news/new-soil-carbon-app-scottish-farmers
mWater	Water filter, other water	Remote/mobile monitoring of water metrics (purity or hygiene) required for water-tech emissions reductions projects	https://www.mwater.co/
Xpansiv Digital Feedstock™	Varied	Standardised format leveraging primary production data, analytics, third party certifications, cryptography and blockchain, enabling global markets to differentiate commodities based on their environmental attributes.	https://www.xpansiv.com
World Bank Innovation and Technology Lab	Varied	Blockchain lab to consider projects that can be helped with good governance and positive social outcomes in developing countries, including a pilot in SE Asia	https://blogs.worldbank.org/trade/can-blockchain-revolutionize-trade
BigChain Tool	Land use	Managing company Scope 3 emissions concerning deforestation	https://www.southpole.com/public/marketing/SPG_BigChainTool.pdf
Pacific Alliance	Waste sector	Exploring MRV systems in landfill gas project in Chile	None available

Source: Table INFRAS

USE CASE

Digital MRV in clean cooking

Image credit Berkeley Air[21]

Improved cookstoves projects, which replace conventional open fire cooking in developing countries with new, efficient equipment, represent a significant opportunity for sustainable development. Improved cookstoves reduce emissions by lowering the amount of unsustainably harvested wood fuel required for cooking and heating. Women and children can also benefit from less exposure to indoor air pollution and time saved collecting wood. As these projects involve distributing cookstoves to individual households on a large scale, often in rural areas of developing countries, they can be difficult to monitor and verify with quality data.

Several parameters must be monitored to establish the emissions benefit of a clean cookstove, including fuel type used, quantity of fuel use, and time spent cooking. Digitising the MRV process can transform the process of collecting stove usage data. 'Heating events', a critical element in calculating the actual emission reduction, have typically been monitored through periodic user survey, which is prone to human error and bias on the part of both the collector and the recipient, while also being expensive to collect and verify due to the great distances and limited access involved.

The potential of blockchain and IoT technologies to increase efficiency is clear. Digital Stove Usage Monitors (SUMs) using temperature-logging

[21] http://berkeleyair.com/monitoring-instruments-sales-rentals/stove-use-monitoring-system-sums/

sensors to automatically collect and upload usage data for emissions reduction calculations eliminate errors in data collection and dramatically increase speed, accuracy and transparency of data collection and reporting.

Digital sensors cost up to USD $300 for a 1-2 year monitoring period; roughly 25-50 are needed for a typical project; and there are additional costs associated with set up, calibration and IoT hub technology. While the technology has been widely available and costs have reduced significantly, using SUMs is still significantly more expensive than local labour to survey households. However, when used in conjunction with other cost and time savings, driven by digitally automated MRV approaches, the investment can be worthwhile.

More significant savings can be realised during verification. Automating stove usage data collection can greatly reduce or fully automate the role of the verifier, as only checking monitor calibration is required. Using artificial intelligence, results gathered can also be compared with data collected from other similar projects to assess whether the usage falls within an expected standard deviation, providing further assurance.

5.4 Needs for further work and recommendations

While there is great potential for disruption by digitising MRV, a number of issues must be resolved. Examples include:

— **Technical issues with data collection:** The example given in this chapter, Stove Usage Monitors, are not a fool-proof solution. Monitors are of varying quality, availability and cost, and they can be easily damaged or lost in the wear and tear of daily cooking. Other project types, for example, where grid connected electricity or satellite data is generated, are less challenging.

— **Costs and capacity:** While some examples of automated data collection and upload represent little change in cost, many still do. Stove Usage Monitors costs must be outweighed by the benefits. In addition, many project developers are wary of new technology, particularly where local staff need to be trained to set up and calibrate monitors. Errors or loss of data can be hugely costly and hence new practices are often viewed with suspicion.

— **Interfaces for data reporting:** While data collection can be automated, its secure upload over the "last mile", classification and storage is essential to the integrity of impact reporting. Data that cannot be accurately ascribed to a device or time period, or that is lost or damaged, can disrupt a project and lead to a loss of impact reporting and, subsequently, project finance.

— **Adaptation of methodological approaches:** To take full advantage of new technology, existing methodological approaches may need to be adapted. In some cases, this can mean a simple change in individual parameters, in others it requires a total re-write.

— **Digital MRV strategies and harmonised implementation frameworks and governance:** To integrate new approaches clear regulatory framework for implementation, greater investments in research and innovation, development and harmonisation of standards and bodies of knowledge are all required. In addition, awareness raising and capacity building for new governance and its implications for business and policy is needed to ensure all participants are able to take advantage of the approaches.

ACCOUNTING FOR CLIMATE FINANCE

Cristián Retamal, Iván Razo-Zapata and Gustavo Arciniegas López
COCOA Collaborative Innovation

6.1 Climate finance provision and barriers and requirements for accounting under the Paris Agreement

The provision of sustainable finance has evolved over decades. Intergovernmental regimes for sustainability (e.g., development, environment, and climate) have transformed the discourse on the provision of finance. Up until the 1990s, the approach of intergovernmental regimes focused on mobilising public finance from donor countries in the global North in favour of developing countries in the South. During the 1990s, this approach was transformed into schemes in which the global North assumed public responsibilities but increasingly considered private sector partnerships[22]. Today, it is clear that the involvement of the private sector is crucial to secure sufficient investments to achieve the goals of the Paris Agreement and the 2030 Agenda for Sustainable Development.

While sustainable finance has grown notably, it remains far from fulfilling its potential becoming mainstream in the financial sector at a global scale. Furthermore, while climate finance flows have been estimated at USD $410 billion from 2015 to 2016[23], global investments to address climate change in line with the Paris Agreement goals will require trillions in climate-smart portfolios. According to the Global Commission on the Economy and Climate, the world will require about USD $90 trillion over the next 15 years to replace ageing infrastructure in advanced economies and to accommodate higher growth and structural change in emerging markets and developing countries[24]. Similarly, the International Energy Agency and the International Renewable Energy Agency estimate that limiting the rise in global temperature to below 2°C by the end of the century–as the Paris Agreement stipulates–will require an average of USD $3.5 trillion investment per year until 2050 in the energy sector alone[25].

Barriers to increased mobilisation of climate finance

In the current international climate regime, the flows of climate finance traditionally suffer from heavy bureaucratic processes involving numerous stakeholders and decision steps, which sometimes have questionable legitimacy

[22] The Kyoto Protocol with its flexible mechanisms and Adaptation Fund is a good example in the climate arena of such public-private partnerships.

[23] Buchner, B., Oliver, P., Wang, X., Carswell, C., Meattle, C., Mazza, F. (2017). Global Landscape of Climate Finance 2017. Climate Policy Initiative.

[24] Global Commission on Economy and Climate. (2016). The Sustainable Infrastructure Imperative - Financing for Better Growth and Development. The New Climate Economy.

[25] IEA and IRENA. (2017). Perspectives for the Energy Transition - Investment Needs for Low-Carbon Energy Systems. OECD/IEA and IRENA.

from the public perspective since such decisions might not always represent the constituencies' desire. These processes involve definition of indicators for which data may not be available, complex monitoring, reporting and verification (MRV) schemes, as well as arduous political negotiations involving stakeholders in donor countries, fund managers, accredited intermediaries, implementing agencies, recipient governments, and local beneficiaries. In addition, climate financial resources are usually allocated without public transparency through a clear and universal system of accounting modalities for climate finance (Adaptation Watch, 2016).

In sum, such bureaucratic processes and the lack of universal transparency typically result in increased transaction costs, which constitutes a barrier to the mobilisation of climate finance, preventing the crucial engagement of private investments.

Transparency as a key element of climate finance in the Paris regime

To build trust among countries and promote effective implementation, Article 13 of the Paris Agreement considers an enhanced transparency framework. Such framework can become a cornerstone for a better understanding on climate finance flows and how its mobilisation could be optimised for fund distribution, financial services intermediation, allocation of monetary resources, and effectiveness of the climate actions supported. Blockchain-supported innovations can serve as tangible instruments to enable such a transparency framework and contribute to an accurate end-to-end tracking system on climate finance pledges at both domestic and international levels.

While high transaction costs and lack of transparency are important barriers and their mitigation or removal is conducive to fostering the flow of climate finance, it is important to note that political barriers can also limit the flow of climate finance.

6.2 The role of blockchain and its potential for climate finance

TABLE 8 summarises the challenges in climate finance and the potential role of blockchain to address them.

TABLE 8 — Challenges in climate finance and potential for blockchain

Challenges	Opportunities for blockchain	Remarks
Reconciling climate finance spending and host country attribution	Automated tracking and reporting of financial flows from donors to recipients	Smart contracts can help automate this if they are designed to analyse and report on financial transfers.
Rules for transparency framework and reporting not yet developed	Allowance for developing bottom-up systems where actors in the whole chain of climate finance flows adopt innovative blockchain approaches for best practice in reporting and transparency	This requires schemes to fully share best practices, open-source development, and open data.

Challenges	**Opportunities for blockchain**	**Remarks**
Donor and beneficiaries lack mutual trust in data, risk of forgery	Trusted transfer of financial resources Increased confidence in and accuracy of emission-relevant data on climate finance	Blockchain must able to track how fiat money and/or cryptocurrencies are spent on climate actions.
Recipients lack bank accounts	Identification mechanisms to assure digital identity of recipients on blockchain; Provision of cryptocurrency for countries with weak monetary systems	Tellers might be required to facilitate exchanges.
Reporting and transparency under Paris Agreement	Tamper-proof single point of truth that records all information on financial and technology transfers as well as non-refundable funds for technical assistance	Reporting requires defining smart contracts. Transparency relies on what must be recorded in the blockchain.
Decentralised architecture of Paris Agreement	Support for decision-making processes that do not depend on a central coordinator while still guaranteeing consistency	Mechanisms to support self-governance are required, e.g., liquid democracy.

Source: Authors own compilation

In climate finance[26], blockchain can support a transparent transfer mechanism to accelerate and improve the flow of financial resources. Transparency of financial flows in the Paris Agreement could be ensured since all accredited participants can verify the information recorded in the blockchain. In this way, such a digital mechanism can become a single version of "truth" whereby all the information regarding financial resources (and other forms of climate support, such as technology transfer and capacity-building), both received and provided, can easily be accessed and verified. Moreover, this mechanism does not depend on a centralised body or entity that could manipulate or control the flow of resources. The fast transfer of financial resources from donors to receivers can also be facilitated since blockchain consensus protocols guarantee that information regarding the transfer of those resources is validated within a few minutes. This can then be used to transfer fiat money or well-established cryptocurrencies.

Blockchain can also provide a new cryptocurrency to conduct economic transactions within the new climate economy of the Paris regime. This could be achieved by releasing a cryptocurrency (e.g., via a 'coin offering') among relevant stakeholders, such as the UNFCCC, the International Energy Agency, or another governing scheme, allowing these stakeholders to directly finance initiatives.

Blockchain-based solutions could provide the following benefits to the climate finance ecosystem:

— Reduce bureaucracy and intermediaries and corresponding transaction costs

— Prevent duplication and fragmentation of efforts in financial flows

— Avoid fraud and financial data manipulation

— Ensure that climate finance reaches beneficiaries while reducing overhead and preventing double financing

— Improve legitimacy of climate actions funded

— Avoid misreporting and backpedalling from governments and other entities in

26 We understand the climate finance arena as the ecosystem in which financing for climate actions flows from the different types of funding sources towards final beneficiaries of climate mitigation and adaptation initiatives, including all the intermediaries in such flow chain.

the climate finance landscape–multilateral development banks, corporations, and similar entities–on their climate financing commitments (Assuming that once financial resources are committed via immutable smart contracts, entities cannot influence, modify or stop the flow of those resources)

Through these improvements, an environment for private investment can be boosted, thereby expanding the mobilisation of climate finance toward the achievement of the Paris Agreement goals. Still, one has to be realistic and acknowledge that while these blockchain based improvements in transparency, trust and are important pieces of the overall puzzle. By themselves they do not automatically remove other key barriers to scaling up climate finance, such as the lack of funds available and the difficulty to identify, design and implement effective measures on the ground for both climate change mitigation and adaptation.

6.3 Current activities and approaches under development

TABLE 9 summarises several blockchain for climate finance initiatives currently under development.

TABLE 9 — Use cases for blockchain in climate finance

Use case	Description	Ressources
COCOA (The Netherlands and Chile)	Provides a decentralised digital platform that can transparently connect funding sources and benefi-ciaries, while monitoring the flow of financial and technological resources and tracking the progress of adaptation initiatives	http://cocoa-ci.org/ (Refer to Box 3 'The COCOA Initiative')
CarbonX (Canada)	Allows companies to trade carbon offsets in a pri-vate blockchain, which helps validation and keeping provenance of all transactions. It also uses the Zerofootprint and the Goodcoins programs. The former assesses the carbon impact of products and services used by customers and provided by com-panies, whereas the latter rewards customers when choosing Zerofootprint products or services.	https://www.carbonx.ca/
The Climate Chain (France)	Although the core of this French initiative is to research the benefits of blockchain to support the Paris Agreement, it also aims to facilitate trading and clearing of carbon credits via crypto-carbon curren-cies.	http://www.theclimatechain.org/
Disberse (UK and Swaziland)	Having as a main goal to improve global aid finance using blockchain, this project also tries to contrib-ute to climate finance.	http://www.disberse.com/

Use case	Description	Ressources
BNDES and KfW (Brazil)	The Brazilian Development Bank (BNDES), which has previously developed the BNDESToken to track public resources in credit operations, has also started a cooperation effort with the German de-velopment bank (KfW) to improve the transparency and efficiency of the Amazon Fund.	https://www.bndes.gov.br/

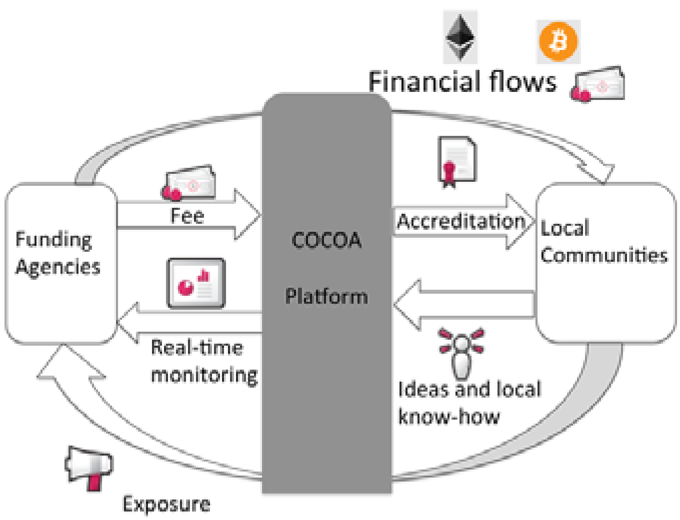
Source: Authors own compilation

DLT and blockchain have promoted the exploration of ideas and efforts encompassing aspects such as: standardisation initiatives, open source and collaborative communities (e.g., the hyperledger foundation), and research and development agendas (e.g., Blockchain4EU). Regarding climate finance, and more precisely, the flow and exchange of value in initiatives supporting climate actions, notable efforts can be observed in Brazil with the Brazilian Development Bank (BNDES) which is piloting the use of blockchain to track the operations of its Amazon Fund. Similarly, an interesting proposal in the climate finance dimension is the COCOA concept[27] 'Transforming Climate Finance and Green Investment with Blockchain', which seeks to use digital innovation to improve how resources flow towards climate initiatives.

USE CASE

The COCOA Initiative With a priority focus on climate adaptation, COCOA proposes a decentralised digital platform for organisations providing climate finance that want to transparently and safely speed up financial flows to support climate action. By using COCOA, organisations can clearly track not only the flow of financial or other resources, but also track the progress of initiatives with real-time monitoring. This should allow them to increase the number of supported initiatives, strengthen public-private partnerships, and reduce both transaction time and costs.

FIGURE 8 —
Business ecosystem of the COCOA platform



Source: Cocoa

[27] Gustavo Arciniegas, Iván Razo-Zapata, and Cristián Retamal González, COCOA—Crowd Collaboration for Climate Adaptation, in Transforming Climate Finance and Green Investment with Blockchains, Academic Press, 2018, Pages 165-177, ISBN 9780128144473.

6.4 Needs for further work

In addition to the development of proof concepts, prototypes, and pilots, adapting national and international regulations to fully support blockchain-based initiatives is a requirement for commercial availability of these digital innovations. Furthermore, capacity building for actors in the climate finance landscape on blockchain-based applications constitutes another important step. This is particularly important for governmental institutions that are accountable in the context of the Paris Agreement, which establishes a transparency framework that should address climate finance provided and mobilised by developed countries for developing countries, climate finance provided and mobilised by "other" countries for developing countries, as well as climate finance received by developing countries.[28]

Finally, while blockchain helps to increase transparency and trust in climate finance activities, there are still many factors that cannot be solved by blockchain alone. Its most important contribution lies probably in the ability of blockchain-based systems to create new levels of trust that allow far greater integration of the private sector.

[28] At the time of writing this document, the Paris Agreement Work Programme (PAWP) is being developed in the context of the UNFCCC process. The PAWP shall define the operationalization of the Enhanced Transparency Framework for action and support defined in article 13 of the Paris Agreement.

TRACKING CLIMATE ADAPTATION MEASURES AND THEIR IMPACTS

Cristián Retamal, Iván Razo-Zapata and Gustavo Arciniegas López
COCOA Collaborative Innovation

Bianca Gichangi
Formerly EED Advisory Limited

7.1 Tracking climate adaptation measures - barriers and requirements for Monitoring, Evaluation, and Learning (MEL)

Unlike climate mitigation, where global mean temperatures or greenhouse gas concentrations determine a threshold, the adaptation arena requires extensive work for both assessing climate change vulnerability and strengthening Monitoring, Evaluation, and Learning (MEL)[29] of interventions aiming to improve climate resilience. The assessment of climate risks and vulnerability as well as coherent MEL schemes are crucial requirements for decision makers at different levels (e.g., UN agencies, governments, implementing entities, and development/financing institutions in general) to design, compare, prioritise, monitor, and appraise climate adaptation interventions.

Challenges in tracking climate adaptation interventions fall into two main categories:

1— Challenges on measuring progress:

- No single common metric for adaptation initiatives
- Uncertainties and complexities linked to development
- Long-term horizons
- Specificity to local contexts

2 — Operational challenges:

- Multiple reporting requirements and lack of MEL capacities in many developing countries
- Need for indicators and comparability of measures
- Coordinating MEL and data collection across different agencies
- Financial resources required to sustain MEL within country systems

[29] Monitoring, Evaluation and Learning (MEL) is the most updated conceptual approach for tracking climate adaptation interventions. Based on the almost infinite diversity and complexity of climate impacts, the MEL approach entails a process of continuous and iterative learning.

Addressing these challenges would enhance the means for achieving the goal on adaptation set in the Paris Agreement[30]. In this sense, complementary tracking of sustainable development benefits with climate adaptation MEL schemes can provide impact investors with the confidence that their interventions will not only provide financial returns but also consider other sustainability attributes.

7.2 The role of blockchain and its potential

TABLE 10 outlines the challenges in climate change adaptation and corresponding opportunities for blockchain.

TABLE 10 — Challenges in Monitoring, Evaluation, and Learning (MEL) of climate change adaptation and potential for blockchain

Challenges	Opportunities for blockchain	Remarks
MEL of adaptation action	"Append-only" and immutable ledgers to record all information on adaptation actions, allowing for provenance on such actions from early stages	Important to clearly define the relevant information to be recorded such as that MEL (especially learning) can be achieved
Financing small-scale dispersed adaptation interventions	Fast and secure micro-donations possible with the use of crypto currencies or fiat money	More flexible with tokens/ cryptocurrencies than with fiat money as the former offer greater granularity
Results-based payments in adaptation	Smart contracts can automatically trigger payments once evidence of results/progress becomes available	Requires a priori definition of concrete rules and milestones
Changing weather conditions severely impacting fragile communities	Small scale index-based weather insurance	Requires deep understanding of relevant weather parameters

Source: Authors own compilation

Innovative approaches for climate adaptation based on Information and Communication Technologies (ICT) and using blockchain mechanisms have great potential for supporting the continuous monitoring of vulnerability reduction initiatives. To support monitoring of adaptation initiatives, mechanisms can exploit tamper-proof and data persistent (immutable) properties. This is also relevant for other functionalities, for instance, supporting the provenance/traceability of contributions, that is, who gives or receives financial resources. In this way, blockchain-based mechanisms can support recording and tracking information on climate adaptation actions, which helps to assess the impact of those actions on sustainability.

30 The Paris Agreement sets in its article 7.1 a '*global goal on adaptation of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change with a view to contributing to sustainable development and ensuring an adequate adaptation response*'.

This assessment, consequently, can help improving the mobilisation of resources to support "successful/effective" adaptation actions.

As an example, Loss & Damage (L&D) programmes using cash-based transfers as assistance mechanisms for affected individuals and families exposed to extreme climate events could be implemented through blockchain technologies, reducing transaction time and costs (e.g., for account creation, distribution mechanisms, transaction authorisation, reporting, payment of fees), thereby improving efficiency and efficacy of L&D assistance programmes. Through smart contracts and distributed accounts (e.g., on smartphones) operating on a single blockchain network, direct transfers of values between peers could be enabled. This approach can be particularly useful in countries where vulnerable communities have limited access to banking services.

Similarly, index-based climate insurance schemes where certain weather parameters can be monitored through ICT/IoT devices can combined with blockchain[31] to trigger payments through smart contracts when the index falls above or below a pre-specified threshold. This approach could enhance current initiatives building resilience not only in agriculture-based rural communities in developing countries, but also in massive business contexts, such as tourism or freight industries, which also suffer from extreme weather events.

The aforementioned applications could be developed in such a way that the blockchain transactions are visible and traceable, contributing to the transparency of the Paris Agreement and the achievement of commitments made by both governments and non-state actors.

7.3 Current activities and approaches under development

A number of approaches that aim to contribute to both climate change adaptation and mitigation are detailed in TABLE 11, most addressing management of energy and water systems. Although the approaches aim to solve several issues at once, they mostly address adaptation as a process of improving the resilience of current infrastructures.

TABLE 11 — Use cases for blockchain in climate change adaptation[32]

Use case	Description	Resources
Powerledger (Australia)	Powerledger provides a platform to support different energy applications, e.g., P2P energy trading, carbon trading, management	https://www.powerledger.io/

[31] Index-based insurance pays-out benefits based on a predetermined index for the loss of assets and investments resulting from catastrophic events, unlike traditional insurance which depends on insurance claims assessors to evaluate the damage. Examples of this approach in the climate adaptation context can be found in the agricultural sector where statistical indexes are developed before the start of the insurance scheme period, measuring deviations from normal for parameters such as temperature, rainfall, wind speed, crop yield or livestock mortality rates.

[32] Initiatives mostly aim to improve the efficiency of water and electricity systems, which contribute to build resilience and adapt to climate change.

Use case	Description	Resources
	of electric vehicles, among others. It relies on a dual token ecosystem composed of (global) POWR tokens and (local) Sparkz tokens. The former are used to access the platform (like software licences); the latter are meant to capture the value of electricity within local markets.	
NRGcoin (Belgium / The Netherlands)	NRGcoin focuses on incentivising both production and consumption of local green electricity. "Prosumers" are awarded NRGcoins only if their supply matches local demand, which reflects the real temporal value of renewable energy; they are not rewarded if their supply does not match local demand, which encourages them to self-consume their excess of electricity. NRGcoins are traded by prosumers and consumers (to pay for electricity) in a decentralised market.	https://nrgcoin.org/
KAIOTE Limited (Kenia)	KAIOTE represents IoT and blockchain-based management and billing of water consumption.	See inset Use Case.
Smart4Water Hub (UK)	This initiative aims to digitise water credits by integrating green finance, innovative technology, and water stewardship to incentivise customers based on their water resilience and efficiency and explore water trading that better reflects the right metrics and incentives for pricing water.	http://smart4.tech/

Source: Authors own analysis, EED Kenia.

Additionally, interesting work is being conducted by the Consultative Group of Experts (CGE) of the UNFCCC regarding climate change impact and vulnerability assessment through geo-information systems, which includes data-driven methods and map-based tools that can facilitate related policy making and strategy building in Hungary and South Korea. Such an approach to climate vulnerability is a first building block for a new blockchain-based architecture that could contribute to an improved tracking of climate resilience efforts.

In the insurance industry, interesting explorations in blockchain (e.g., verifying authenticity of resilience-related claims and their processing), could become an important intersection to be explored and expanded. Furthermore, the COCOA concept mentioned in chapter 6 on climate finance is currently a newly established start-up aiming to explore how blockchain can support climate adaptation by highlighting local know-how within adaptation initiatives.

USE CASE

Automated Water Meter Systems Management with blockchain in Kenya

source: EED Kenya

Water Utilities in Kenya incur heavy revenue losses each year due to Non-Revenue Water (NRW), the difference between the volume of water that a utility produces for distribution and the volume of water billed to consumers[33]. These losses are categorised as either physical losses that arise from leakages within the reticulation network and overflows at utility reservoirs, or commercial losses that arise from faulty meters, water theft in various forms, data handling errors and unbilled authorised consumption.

KAIOTE Limited, a Kenyan based IoT systems company is developing a system to enable reduction of NRW from non-physical losses at utilities and improve their efficiency and capability to cope during drought situations, which are becoming more severe due to increasing climate variability. The increased volume of water available will ensure more consistent water supply during droughts and limit the rationing done by the water services providers.

33 WASREB Impact Report (2016) Performance review of Kenya water services sector Issue Number 9.

The system involves the use of smart metres connected to an IoT network and proposed blockchain-aided online platform to manage water consumption data, automatic curtailment and reconnection, and mobile money payment facilitation for water utilities. Applying blockchain technology to the monitoring system will be highly beneficial in ensuring that consumers can track their data and are billed accurately based on what is collected by the smart metre, thereby increasing trust. The utility will rely on the data within the blockchain ledger, rather than making estimations when billing and will ensure that billing information and payments made are not tampered with to reduce fraud. A feature-phone/smart-phone app will allow consumers to monitor their water consumption.

KAIOTE is currently rolling out the first phase of this water management project as a three-month pilot with an initial phase roll out of 20-50 residential smart meters. It will be scaled up to incorporate the blockchain application within that utility and to other utilities. The current pilot utility operates over 20,000 active meters.

7.4 | Needs for further work

Tracking adaptation initiatives requires the development of advanced assessment frameworks and techniques for MEL. The integration of those assessment approaches with blockchain as well as with state-of-the-art technology such as IoT and artificial intelligence requires further exploration. Finally, the design and implementation of smart contracts that could support the allocation of resources for climate resilient development also requires deep understanding on climate finance, regulatory frameworks, and metrics on adaptation initiatives.Engaging corporations and Individuals

PART II

Blockchain for implementing climate action

ENGAGING CORPORATIONS AND INDIVIDUALS

Massamba Thioye

Manager Sustainable Development Mechanism Program

UNFCCC Secretariat

8 | Engaging corporations and individuals

The successful implementation of the Paris Agreement requires using all available drivers, including leveraging data and disruptive technologies. Climate action must expand from the remit of governmental entities to engage all of us, from those in the private sector down to the level of individual citizens.

Corporate action

A wide variety of stakeholders in a company's ecosystem can participate in climate, even outside the companies' physical boundaries. This includes policy makers, financiers, customers and suppliers along a value chain, who are all now expected to exercise their influencing power to foster behavioural changes that can bend the greenhouse gas emissions curves of companies and align them with the long-term decarbonisation goal of the Paris Agreement. As an example, for financiers, this can mean submitting a motion in annual general shareholder meetings requesting greener investment activities of an investee organisation, or setting a climate-related conditionality for a loan. Furthermore, multiple factors can drive climate actions by companies—availability of more cost-effective clean technologies, new policies or regulation or pressure from customers. While exercising tremendous catalytic power, these dynamics also make it challenging to attribute greenhouse gas emission reductions or removals to specific stakeholders. The blockchain ecosystem can help address the reliable attribution of climate contributions in corporate supply chains while avoiding any potential for double counting with national inventories (see Chapter 12).

Climate action must expand from the remit of governmental entities to engage all of us, from those in the private sector down to the level of individual citizens.

Individual action

To scale quickly, individual citizens should also be engaged as part of the solution to the climate crisis. Indeed, people all around the world are increasingly experiencing the negative impacts of climate change in greater climate fluctuations and extreme weather and the effects related to air, water and soil pollution. Collectively, the global citizenry can truly drive the transition toward a green economy if equipped with the power, capability, and incentive take meaningful climate action. Here, too, blockchain can help mobilise and manage widespread momentum.

The Paris Agreement places great emphasis on cooperation among and within countries, which requires a high degree of trust in the process. Its implementation is expected to leverage all potential climate actors and to be inclusive, with none left behind. Blockchain solutions are the building blocks of trusted cooperative platforms that can help incentivise and track climate action by a broad range of climate actors—from private sector players through to individual citizens. Part II of this report evaluates the critical role for blockchain ecosystems in the successful implementation of the Paris Agreement.

A FRESH LOOK AT CARBON PRICING: COMBINING INNOVATIVE CARBON TAXATION AND BLOCKCHAIN

Nick Beglinger
CEO and Founder
Cleantech21 and Hack4Climate

9.1 Revisiting the carbon pricing agenda based on the need for exponential climate action

Putting a price on carbon is one of the key climate action strategies to reach net-zero emissions by 2050[34]. It is estimated that explicit carbon price levels of at least USD $40-80 and USD $50-100 per tCO2e are needed by 2020 and 2030, respectively, to achieve the temperature target of the Paris Agreement[35]. While it is clear that carbon pricing might also have unintended effects for certain stakeholders, targeted policy options are available to alleviate these effects.

With currently just around 15% of global emissions covered by an *explicit* carbon price[36], and with most current price levels significantly lower than price levels that would typically lead to large scale decarbonisation[37], it is fair to argue that there is still a large potential for higher pricing ambition. Even among OECD countries, only 25% of GHG emissions are currently priced at a level of USD $30 per tCO2 or higher, a rather low price benchmark which still short of the 2020 price recommendation of USD $40-80 per tCO2 given by the High-Level of Commission on Carbon Prices[38]. Important progress has been made, but it is far from "exponential" as outlined by the Exponential Climate Action Roadmap[39]. Extrapolating from the current pace of carbon pricing development—both in terms of global coverage and price levels—a paradigm shift is necessary to make carbon pricing a key enabler for the Paris temperature target.

Two pricing instruments may be considered: taxing emissions with a carbon tax as or setting

[34] Report of the High-Level Commission on Carbon Pricing 29/05/2017 (HLCR), https://bit.ly/2fJd4fg, other activities include: Carbon Pricing Leadership Coalition (CPLC, hosted by the World Bank), We Mean Business (https://www.wemeanbusinesscoalition.org/commitment/put-a-price-on-carbon/), OECD, Effective Carbon Rates 2018, https://bit.ly/2DgIQdr,

[35] High-Level Commission on Carbon Prices, https://www.carbonpricingleadership.org/report-of-the-highlevel-commission-on-carbon-prices

[36] State & Trends of Carbon Pricing 2017 (World Bank), https://bit.ly/2PNeamT, and State & Trends of Carbon Pricing 2018 (World Bank), https://bit.ly/2MlwX75 (note: with China's ETS systems approx. 20% coverage will be reached as of 2020)

[37] 75% of all emissions covered by carbon pricing are priced below USD10, https://bit.ly/2PNeamT

[38] OECD, Effective Carbon Rates 2018, https://bit.ly/2zk0zfD

[39] https://exponentialroadmap.org/

emission caps and establishing emission trading systems (ETS), the pros and cons of which are often debated by academics and policy makers.

On the international level of the implementation of the Paris Agreement, the carbon tax instrument may have been less visible than ETS instruments and their international linking. With the cooperative approaches suggested in Article 6.2, the latter has its formal representation in the Agreement, while carbon taxes are not mentioned explicitly. Yet in some situations, a carbon tax system is more practical to implement, monitor and enforce than tradable permit-based approaches such as ETS to global climate change action; further, a tax-based system may be more transparent and offer the appropriate incentives for participationand compliance[40].

9.2 Using disruptive technology for improving climate regulation

Fortunately, the disruptive set of new technologies, particularly the "troika" of the internet of things (IoT), blockchain, and artificial intelligence (AI), can help usher in the needed paradigm shift. Blockchain technology, in particular, shows far-reaching innovation potential in the regulatory space[41]. Blockchain is fundamentally about trust, likewise many challenges inherent to mobilising climate action at scale—from the trust of people in governmental actions, to trusted information exchange between businesses[42]. Especially in regulatory contexts with no or weak central governance in place, the value of a distributed trust system becomes obvious.

TABLE 12 — Government-related blockchain use cases

Use Case	Description	Further information
Public notary	Several countries, including Sweden, are piloting blockchain-based notaries.	'Notaries turn blockchain...', https://bit.ly/2xSHHGa
Taxing	Blockchain has been specifically identified as suitable for many types of taxes, including 'transfer pricing'.	'PWC, 'How blockchain technology could improve the tax system', https://pwc.to/2Agu7gm
First official government service on blockchain	In July 2018, blockchain was used for the first time officially in the UK for food standards[43]. Several countries run major blockchain pilot projects, including Estonia, EU and US.	On emerging regulatory-related activities, https://nyti.ms/2IztYoP

Source: Authors own analysis

40 Aldy, Joseph; Ley, Eduardo; Parry, Ian. 2008. What is the Role of Carbon Taxes in Climate Change Mitigation?. PREM Notes; No. 2. World Bank, Washington, DC. Accessed 07/11/2018, https://openknowledge.worldbank.org/handle/10986/11147

41 See e.g. OECD/OPSI, 3/2018, https://bit.ly/2yCHtSL

42 IBM 2018: 'Governments organizations are using blockchain to build trust though open, transparent & collaborative networks', https://ibm.co/2JfJXdS

43 https://www.food.gov.uk/news-alerts/news/fsa-trials-first-use-of-blockchain

9.3 Tax/Dividend Schemes and potential of blockchain technology

A carbon tax scheme to highlight in respect to its fairness, simplicity and efficiency is the 'Tax/Dividend Scheme' (TDS). This approach levies a tax on greenhouse emissions and redistributes most or all income generated to the population. Such schemes have been applied in Switzerland[44] and Canada[45] and are receive increasing attention in the United States[46]. The key advantage of TDS is its simplicity and relative clarity for public communications. The "take and give-back" approach is perceived as fair and pragmatic, leaving purchasing power in the economy. Indeed, the importance of the use of revenues for public acceptability is increasingly recognised[47] and may strengthen the political viability of TDS schemes.

Furthermore, TDS can be more effectively implemented using blockchain (TABLE 13), providing the trust element vital for political feasibility. Applied in combination, TDS and blockchain offer a promising approach to price carbon in a new way—one that may well be straightforward and robust enough to represent the paradigm shift needed to lead to fast decarbonisation.

TABLE 13 — Key challenges for implementing a carbon tax and potential for blockchain application

Challenges	Potential for blockchain technology
Political feasibility	Higher trust levels due to greater transparency of distributed system – with tax and dividend transactions being publicly visible/traceable; particularly relevant in countries with weaker regulatory frameworks
International linking, carbon leakage and border tax adjustment[48]	Pricing passed on and adjusted between companies and countries, similar to supply chain blockchain use cases
Stakeholder integration	Linking to internal pricing schemes of businesses (e.g., for tax credits or other incentives)
Transaction costs	Reduced intermediaries, automated payments based on smart contracts
Fraud prevention	Distributed storage leading to higher security (e.g., against hacking/private information theft); particularly relevant in countries with weaker regulatory framework

Source: Authors own analysis

44 'Imposition of the CO2 levy on heating and process fuels, https://bit.ly/2AnrRUc

45 Exemplary source: Politico, 26/10/2018, 'Driving carbon prices northward', https://politi.co/2yOPQKP

46 Climate Leadership Council, 'Carbon Dividends Plan', https://bit.ly/2BYrvCl

47 See e.g. Nature Climate Change, 30/072018), 'Making carbon pricing work for citizens', https://www.nature.com/articles/s41558-018-0201-2

48 Border tax adjustments would account for emissions attributable to imports from nations without a carbon price. An alternative would be tariffs applied to non-taxing countries. Source: https://en.wikipedia.org/wiki/Carbon_tax

9.4 The Climate Dividend use case

Building on Tax/Dividend Schemes, a Climate Dividend[49] features:

1 — Simple levy/tax collected upstream including all greenhouse gas emissions, national/regional in scope, allowing for varying price levels internationally rather than one global price

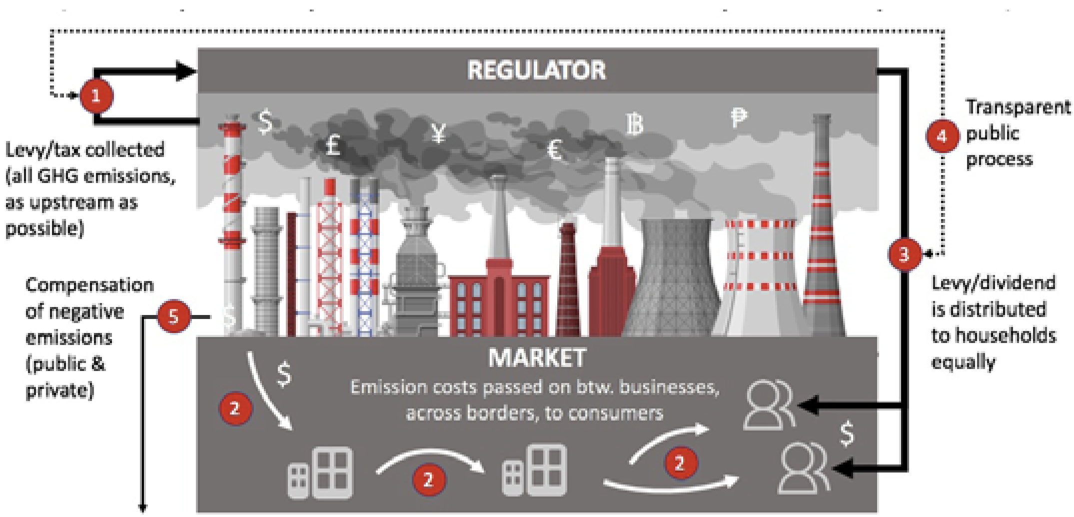
2 — Adjusted internationally across borders and value chains, reflecting different carbon price levels, including fossil fuel subsidies

3 — Redistribution of tax/levy income to all households via a dividend payment (direct pay-out or via tax rebates), allowing earmarking of up to 10% of total income to research and development activities

4 — Full transparency to all stakeholders, including emitters paying tax, adjustments, use of funds and distribution to households

5 — Further earmarking of funds for integrated negative emissions schemes, such as Carbon Capture and Storage, subject to additional government and private sector investment

FIGURE 9 — Illustration of Climate Dividend



Source: Authors own illustration

Technically, a Climate Dividend is conceived to consist of:

— A permissioned ledger solution (see Chapter 12), directed to governments for multiple national/local implementations

— A global transfer ledger, governed by all the participating national/regional governments in cooperation with UNFCCC, integrating national ledgers for allowing international adjustments and avoiding double counting.

With its advantages of simplicity and redistribution, bolstered by the trust and transparency levels offered by blockchain, the Climate Dividend promises to be worthy of further exploration.

[49] In development by the Cleantech21 foundation (www.cleantech21.org), as part of its #Hack4Climate innovation program (https://hack4climate.org/).

CROWD FINANCING FOR CLIMATE ACTION, ROLE OF TOKENISATION

Sven Braden
Co-Founder
LIFE Climate Foundation Liechtenstein

10.1 Crowd financing and how it can mobilise investments to address the Paris Agreement

Considering the insufficient climate finance pledges by industrialised nations as well as the trends of public debt and economic growth in major OECD countries, it is clear that new and innovative ways of private financing, such as crowd financing, may become crucial for the mobilisation of investment to address the goals of the Paris Agreement.

The term crowd financing refers to financial services provided by a large group of individuals, typically through online platforms. The initiator of a project communicates a concept, funding needs, timing and implementation of the project, including timing requirements for the funding. If the funding goal is not reached within that period, all prior contributions are reimbursed. Crowd financiers usually receive a good or service that originates from the project as remuneration.

Crowd financing services provide alternatives to traditional financial products and can take multiple forms, outlined in TABLE 14.

Crowd financing may lead to higher levels of financial inclusion, especially for smaller businesses in developing countries.

Blockchain technology may expand crowd financing to cover new areas related to cli-mate action, such as the generation, distribution and use of unique tokens.

TABLE 14 — Forms of crowd financing

Form	Description
Crowdfunding	Financing of a project or an enterprise through many small contributions from many people, usually through online platforms. In most cases there is a set minimum to be achieved in a predefined period. If this amount is not reached, supporters are refunded.
Crowd investing	Enables broad groups of investors to fund start-up companies and small businesses in return for equity. If the business succeeds, share value increases. (The opposite is also true.)
Crowd lending	Lending money to individuals or businesses through online services that match lenders with borrowers.

Source: Authors' own analysis

Although crowd financing activities are growing around the globe, they are yet not viewed as a realistic alternative to banks. Crowd financing may face growth limitations where it is confronted with governance challenges, especially where crowdfunding activities overlap with financial services that are covered by relevant regulatory and compliance frameworks (e.g., requirements for Know-Your-Customer and Anti-Money-Laundering provisions). These present barriers to entry, especially for smaller businesses. Nonetheless, crowd financing may lead to higher levels of financial inclusion, especially for smaller businesses in developing countries.

Blockchain technology may expand crowd financing to cover new areas related to climate action, such as the generation, distribution and use of unique tokens.

10.2 Role of blockchain and its potential for crowd financing via blockchain tokens

Crowd financing operates today in dedicated platforms such as Kickstarter and IndieGoGo, which act as trusted third party to keep the money provided by "the crowd" in escrow.

Challenges include their relatively high fees and the potential for third parties to influence the project. By using a decentralised mechanism that achieves consensus in accordance with pre-set rules enforced by a network protocol, blockchain eliminates the need, and therefore costs, for an intermediary. The risk of third parties influencing a project is also eliminated, since all transactions or financial flow happen directly peer to peer, between the investor and the project initiator.

Crowd financing using blockchain works by allowing the initiator of a project to create its own digital and fungible tokens (also referred to as "crypto-coins" or "utility tokens"). These tokens often do not represent more than the promise of a "still-to-be-developed" asset. However, the new and innovative aspect is that digital tokens enable project initiators to acquire funding from early investors, while early investors may also benefit, for example, if the digital token is listed on a trading platform and increases in value. In addition, the purchase and sale of tokens is fully transparent; donors have full read access to all token transactions.

Token generation events or Initial Coin Offerings (ICOs) have gained much attention in recent years. According to the ICO rating website, ICOdata (https://www.icodata.io/), crowd financing activities in 2017 raised up to $6 billion via ICOs on blockchains. Current data show that 2018 will exceed the raised amounts of 2017. Moreover, ICOs have already surpassed early stage funding from venture capital. Tokens or coins allocated through ICOs represent a smart share of a future project. However, since companies behind ICOs are not regulated by financial authorities, there is a high risk that lost funds (e.g.,, due to fraudulent initiatives) may never be recovered. In the course of 2017, several governments took regulative measures towards ICOs.

A promising development and a reasonable reaction towards unregulated ICOs is the classification "security tokens". Unlike utility tokens that have the potential to amount to a little more than a promise, security tokens must be backed by a tangible asset. In addition, the creation of securities (securitisation) is regulated by respective financial market provisions in most jurisdictions.

Many representatives of the financial sector expect a growing role of the securitisation of assets like venture capital funds, real estate, precious metals, currency, art, sports teams due to blockchain technology. A blockchain-based tokenisation of traditional assets can provide a wide range of benefits, including greater liquidity to asset owners, 24/7 markets, lower transactions costs, fractional ownership, automated and quicker settlement, improved compliance checks, and a broader slate of possibilities with smart security contracts[50]. These benefits may also apply for assets related to climate action.

[50] Rohit Kulkarni (November 2018) in https://www.forbes.com/sites/rkulkarni/2018/11/01/seven-ways-tokenizing-traditional-assets-will-launch-security-tokens-to-main-street-in-2019/#3f3846da4b07

TABLE 15 — Concept of security tokens on a blockchain for climate action

Tokens can represent…	…a small share in a company, for example, one m^3 wood from sustainable forests, one ton of CO2e reduction, 1 kWh of solar energy; an insurance policy against drought or flooding; the confirmation of the use of specific GHG measurement devices, the proof of the use of public transportation
Tokens can be used as…	…ownership titles, means of payment for certain services, vouchers to use specific services (public transportation) or benefits (tax reductions), digital keys for electric cars, quality certificates, or proof for earmarked payments

Tokens can be generated to fund climate action, such as the financing of specific projects, or to incentivise climate positive behaviour, such as the use of public transportation instead of individual cars. A token can also represent a concrete mitigation outcome, for example, the reduction of one ton of CO2e to offset emissions from travel or energy consumption. These approaches can facilitate results-based climate finance and mobilise action at the individual level, an often untapped demographic in terms of international climate negotiations.

10.3 Current activities and potentials around tokenisation

Recent initiatives that generate and distribute blockchain based tokens to finance climate mitigation activities are mentioned in TABLE 16.

TABLE 16 — Use cases for blockchain facilitating climate action

Use case	Description	Resources
Climate Coin	Token that equals one carbon credit and can be used to offset carbon footprints	www.climatecoin.io
CarbonX	A platform for personal carbon trading with a token called CxT, representing a carbon credit	www.carbonx.ca
Nori	Token that represents one Carbon Removal Certificate, issued for carbon that will be removed from the atmosphere by technical means	www.nori.com

Use case	Description	Resources
Earth Token	An integrated part of a natural asset exchanges and serves as a currency that aims to increase demand for environmental services like carbon mitigation	www.earth-token.com
Veridium	Transforms carbon credits into digital coins that can be traded on a decentralised exchange	www.veridium.io
IXO Foundation	Sustainable development impact measurement on blockchain	https://ixo.foundation/

Source: Authors own analysis

Another innovative approach is to enable new economic incentives or rewards for individuals or companies for the climate-friendly activities they undertake. For example, every time a car is refuelled at a gas station, or an industrial site receives new batches of fossil fuel to power its machines, a data token containing greenhouse gas (GHG) data and markers for time, location and settings could be generated and sent immediately to the data owners account on a blockchain. This could be sold against fiat currency or transferred against other values.

Such a token system could be extremely helpful, especially for GHG sources from sectors in the informal economy that are neither taxed nor monitored in any form by governments. This is not insignificant, given that a recent publication by the International Monetary Fund showed a 31.9 percent average share of informal economies within the GDPs of 158 examined countries from the period 1991 to 2015.

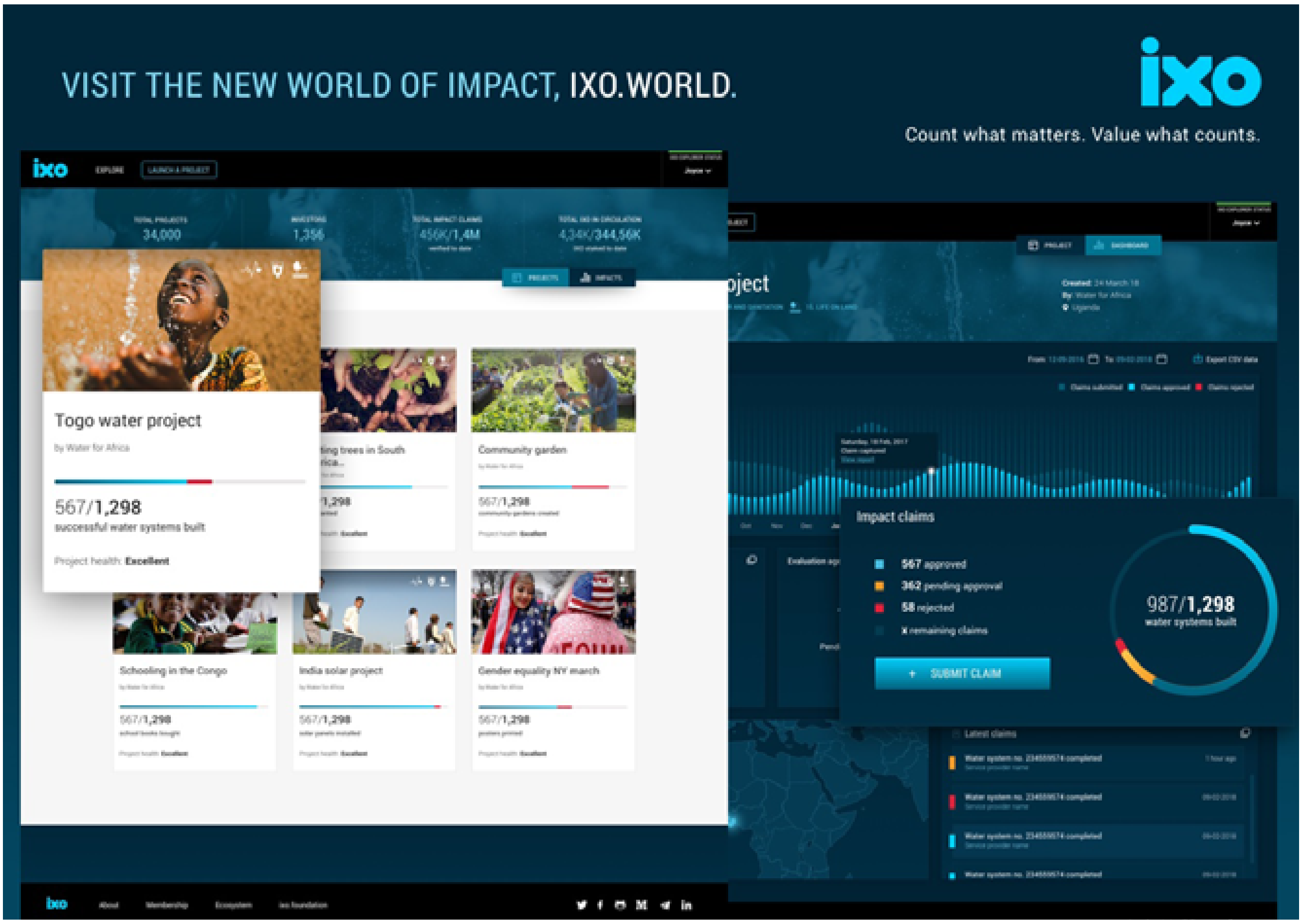
10.4 Needs for further work

The value of tokens that represent positive climate outcomes relies on blockchain-based commodification receiving legal recognition from national jurisdictions. The development of international standardisation of measurement practices and data formats would assist this rapidly evolving market. This is also critical from a technical point of view. Technology-neutral research, and international cooperation are needed to facilitate an open discussion about the potential and limitations of blockchain-based solutions for crowd financing.

The value of tokens that represent positive climate outcomes relies on blockchain-based commodification receiving legal recognition from national jurisdictions. The develop-ment of international standardisation of measurement practices and data formats would assist this rapidly evolving markets.

It remains to be seen whether initiatives as shown in Table 16 will trigger additional GHG mitigation beyond the lines of current voluntary carbon market demands. However, tokenisation for funding climate action can add liquidity to local and international carbon markets, thereby removing a current barrier and potentially expanding market access. The greatest potential of tokenisation to incentivise actors of all kinds in an environmentally desirable way lies in informal economies. Yet this requires underlying token-based incentives to be applied by a robust decentralised system with a proper mechanism design.

In addition, blockchain protocols and associated standards are to be developed open source. This would enable a common understanding of tokenisation on a global scale and could empower local economies to run regionally focused incentive schemes using an internationally "tested" source code.



Source: Image of Ixo World project marketplace https://ixo.world/

BLOCKCHAIN TECHNOLOGY AS A DRIVING FORCE FOR RENEWABLE ENERGY DEVELOPMENT

Christian Hübner

Head of Regional Programme

Energy Security and Climate Change Latin America (EKLA)

Konrad-Adenauer-Stiftung e.V., Peru

11.1 The rise of renewable energy and digitisation

Research and development of new technologies for clean energy have been growing exponentially. The share of clean energy in the overall energy supply system is steadily rising, with a clear example in the electrification of energy demand (e.g., electric vehicles, smart homes, electric appliances). This is accompanied by an increasingly digitalised and operationally decentralised energy industry.

New wind and photovoltaic parks—e.g., energy cooperatives, often local enterprises—are arising alongside even smaller scale "prosumers," households or businesses that generate, consume and store electricity simultaneously using their own wind or photovoltaic systems, leading to decentralisation of power production. This said, the extent to which such energy industry decentralisation trends will take place in heavily populated and industry intensive areas remains to be seen.

Nevertheless, this marks a definitive phase of disruption for the energy industry by increasing the efficiency of energy supply, triggering new investments, ushering in new market players while pushing out the old—and reducing GHG emissions.

11.2 The use of blockchain in renewable energy

Blockchain technology is perfectly suited for the decentralised, digitised new energy paradigm to facilitate a massive roll out of clean energy, with tremendous potential in applications related to energy trade, finance, and electric mobility, as outlined in TABLE 17.

TABLE 17 — Challenges in renewable energy promotion and potential for blockchain

Challenges	Description	Opportunities for blockchain
Energy trade	Restricted market entry: Central authorities cause high transaction costs and market barriers for new player.	Direct decentralised energy and or electricity trade between consumer, supplier or prosumer
Finance for energy infrastructure	Lack of finance for renewable energy infrastructure	Crypto currencies and token economy can change traditional financial market conditions and trigger more incentives to invest in renewable energy.
Electric mobility	Mobility sector not sufficiently connected to prosumer infrastructure	With blockchain-technology owner of electric cars, photovoltaic modules or battery stations can be directly connected.

Source: Authors own analysis

Blockchain technology is perfectly suited for the decentralised, digitised new energy paradigm to facilitate a massive roll out of clean energy, with tremendous potential in applications related to energy trade, finance, and electric mobility.

11.3 Current use cases and blockchain application

Most energy industry blockchain applications are currently related to energy trade, where the objective is to transition to decentralise direct trade, still overwhelmingly managed by centralised authorities. The major boon lies in reduced transaction costs.

The Enerchain Project by the Hamburg firm Ponton is one of the most advanced in this field. Countless large energy firms have already registered to trade directly with each other on this blockchain platform. This sort of energy trade is suitable where the aim is to supply energy products like electricity from renewable energy. The Norwegian firm Statkraft uses the platform to supply renewable energy directly, for instance. The Australian firm Powerledger offers a comparable trade infrastructure, where electricity exclusively from renewable energy is traded between individual communities.

Direct trade can also occur in smaller increments. Prosumer households that, though smart metering stations and their own storage capability, wish to participate in virtual power plants, can currently only do so with great effort. The latest blockchain uses are beginning to enable direct trade between prosumer households, local renewable energy providers, network operators, and physical and virtual storage. For instance, the German firm Conjoule has developed specially a blockchain solution which concentrates on bringing together the different participants of the renewable energy value chain on a local level (peer-to-peer). This category also includes the well-known "Brooklyn Microgrid" of the New York energy consulting firm LO3, which created an independent energy ecosystem (neighbourhood network as an alternative to the main grid), within which participants currently enjoy probably the highest degree of autonomy.

Generally, blockchain applications in energy trade rely on the existing power grid infrastructure. Therefore, for the moment, uses are mostly limited to virtual services. But in developing countries or very large areas, this infrastructure may be absent. In Bangladesh, ME SOLshare has developed a blockchain technology-based solution combined with the construction of a physical plug-and-play neighbourhood network. In this network, some households can access photovoltaic systems, which can power other households across the locally growing grid. This approach could provide a development policy model for many regions with only limited grid infrastructure.

The latest blockchain uses are beginning to enable direct trade between prosumer households, local renewable energy providers, network operators, and physical and vir-tual storage.

Financing of Renewable Energy

Tokenisation, discussed in Chapter 10, is also relevant in renewable energy financing. For example, WePower issues tokens that represent for future energy generation, which enables the financing of the corresponding plant. SolarCoin issues blockchain-based SolarCoins per kWh to a growing number of certified solar plants worldwide. SolarCoins are tradable and can be exchanged for other currencies. Resulting revenue can trigger new investments. The transparency provided by blockchain solutions is critical in the field of renewable energy, making the source of renewable energy and related climate impact known through to end users. For instance, Swytch Energy Tokens represent verified renewable energy or energy efficiency measures, which can in turn provide an incentive for further investments. Energy utilities like the Romanian Eva Energy, the New Zealand NextGen Energy and the German municipal energy company Energcity AG have already started to accept cryptocurrencies such as Bitcoins as a legitimate form of payment. MpayG goes a step further; it not only supplies cryptocurrencies as payment, but also delivers a comprehensive physical package along with it.

Electric mobility

Electric mobility represents a large proportion of electrified energy supply. The transport sector is, despite abundant regulation, still one of the main sources of global greenhouse gas emissions. Politicians therefore increasingly set their sights on funding programmes and quotas, for instance in China, one of the largest car sales markets in the world. Here, blockchain applications link up provisions for electricity storage infrastructure. The direct sale of electricity used to charge an electric car to its owner can be processed in the form of a smart phone application using blockchain.

The Share&Charge platform developed by the German start-up MotionWerk in cooperation with eMotorWerks is also using this model. Futhermore, private electricity providers and electric car owners can be brought together. The increasing fleet of electric cars may itself be valuable as virtual storage via a blockchain network. The batteries within fleets of electric cars could thereby stabilise power fluctuations and more efficient grids be used for energy storage. In addition, prosumers can connect to these grids with their own photovoltaic generation.

Source: Electric car charging station Wikimedia

TABLE 18 — Use cases for blockchain in the renewable energy sector

Use case	Description	Resources
Energchain (Germany)	Energy trading platform	https://enerchain.ponton.de/
Powerledger (Australia)	Electricity trading platform	https://www.powerledger.io/
Conjoule (Germany)	Local electricity trading platform	http://conjoule.de/de
Brooklyn Microgrid (US)	Local electricity trading platform	https://www.brooklyn.energy/
ME SOLshare (Bangladesh)	Local electricity trading platform with an physical plug and play technology	https://www.me-solshare.com/
WePower (Lithuania)	Offers tradeable smart energy contracts for finance future renewable energy plants	https://wepower.network/
SolarCoin	Global reward programme for solar electricity generation	https://solarcoin.org/
Swytch	Tracks carbon impact and rewards sustainable actions	https://swytch.io/
Eva Energy (Romania)	One of the first suppliers to initiate bill payments in crypto currency	https://www.eva-energy.ro/
Energcity AG (Germany)	Municipal energy company accepting crypto currency	https://www.enercity.de
NextGen (New Zealand)	Not for profit renewable retailer accepting crypto currency	https://nextgen.energy/
MotionWerks (Germany)	Start-up developing digital solutions to support an open, secure and decentralised mobility infrastructure	https://motionwerk.com/
eMotorWerks (US)	Working on physical solution for electro mobility	https://emotorwerks.com/
Quartier-Strom & Selber (Switzerland)	Local prosumer markets of renewable energy	https://quartier-strom.ch/
Energy web foundation	Open-source, scalable blockchain platform specifically designed for the energy sector	https://energyweb.org/
Grid+ Energy	A secure gateway to store cryptocurrencies and process payments for electricity	https://gridplus.io

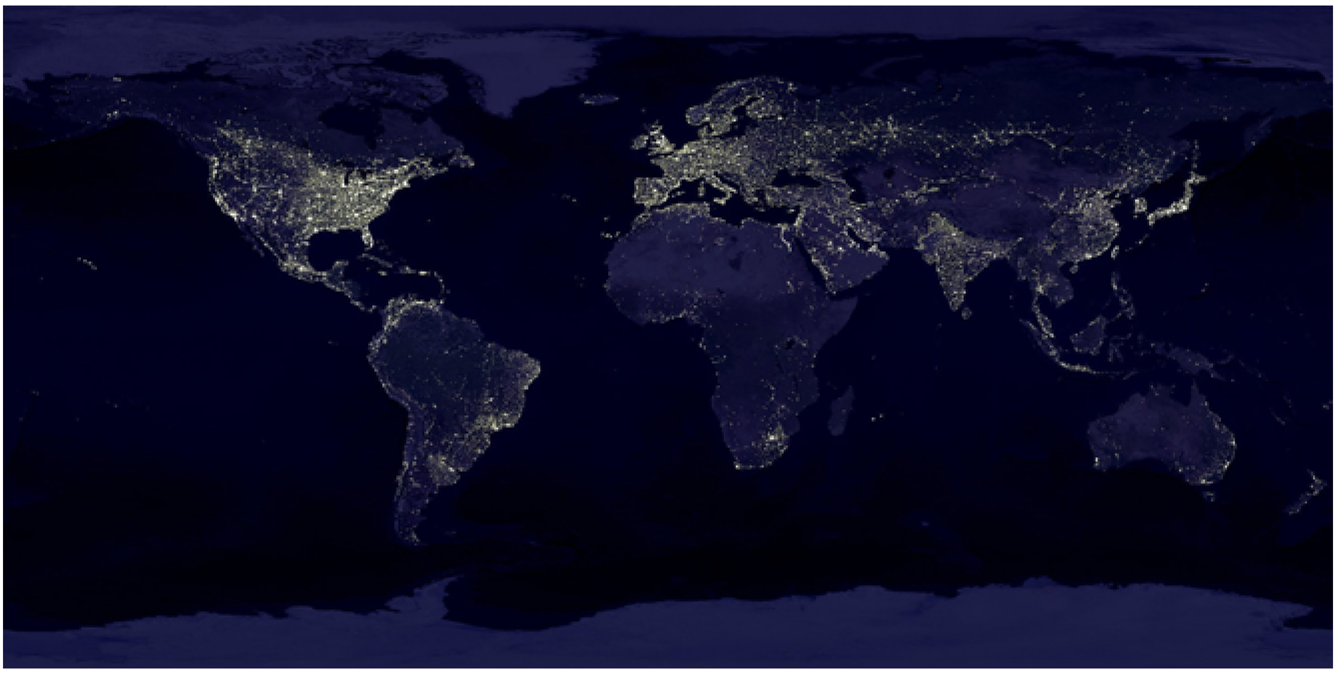
Source: Authors own analysis

11.4 Outlook

Blockchain technology effectively bridges digitalisation with the decentralisation of the global energy economy. Beyond contributions to implementation of the clean energy revolution, blockchain technologies also create possibilities for new business models. Indeed, promising decentralised solutions for renewable energy are springing up in cities within emerging markets and developing nations, where conventional electricity systems are less reliable and economic pressure to develop viable business models is even greater. It is important that those working to catalyse climate finance keep an eye on the numerous possibilities for promoting renewable energy though ties with blockchain technology.

More research and international networking is needed to connect regional approaches and share best practices and lessons learned. New pilot projects could emerge from such cooperation and, in turn, spur further impetus for effective policies.

Blockchain technology effectively bridges digitalisation with the decentralisation of the global energy economy. Beyond contributions to implementation of the clean energy revolution, blockchain technologies also create possibilities for new business models.



Source: Night image of electric grid CCO Licence

BLOCKCHAIN FOR CORPORATE CLIMATE AND SUSTAINABILITY: BETTER DATA, TRANSPARENCY AND TRACEABILITY TO DRIVE CUSTOMER TRUST

Marion Verles
Chief Executive Officer
Gold Standard

12.1 Climate and sustainability strategies, challenges and opportunities for corporates

Corporate climate action and broader sustainability strategies are on the rise: Over 85% of companies listed in the S&P 500 published a sustainability report in 2017[51]; 62% of the world's top 300 companies demonstrated commitments to the UN Agenda 2030 sustainable development goals (SDGs) in their annual reports[52]; 492 companies have made the commitment to reduce their carbon footprint in line with what science requires to stay well below 2° temperature rise[53]; there are no less than 2430 corporate initiatives listed on the global climate action NAZCA platform. Climate action is by far the most prominent area of focus of sustainability strategies with SDG 17 the most cited in companies' reports, more than double any other.

FIGURE 10 — Graphic from WBCSD Reporting matters report 2018

source: WBCSD Reporting matters report

[51] Governance and Accountability Institute, March 2018
[52] UNGSII Sustainability Commitment Report 300, December 2017
[53] Science Based Targets, October 2018

With increased adoption comes greater scrutiny. Corporate climate and sustainability strategies have had to evolve from simplistic approaches to more complex data- and science-driven strategies. This has placed greater emphasis on supply chains. Supply chain action is often cited by corporate sustainability officers as a key success criterion to deliver on ambitious climate commitments.

This mass adoption of sustainability strategies and the growth in sustainably branded products is partly driven by a shift in customers' expectations, with Generations Y and Z leading the way. Consumers increasing wish to know the origin and impacts—negative and positive—of the products they buy on the people and the planet. In fact, a 2015 survey by Nielsen found that globally 66% of respondents are ready to pay more for sustainable products. This shift in expectations comes with significant challenges, including data management, impact assessment and traceability. It also offers major growth opportunities, as sustainable brands and sustainable product lines tend to experience higher growth rates and better margins.

Blockchain has potential to tackle some of the new challenges posed by customers' growing needs for transparency through improved data management, impact quantification and verification, reporting progress, traceability of goods and business value.

Blockchain has potential to tackle some of the new challenges posed by customers' growing needs for transparency through improved data management, impact quantifica-tion and verification, reporting progress, traceability of goods and business value.

12.2 Role of blockchain in corporate sustainability

With the hype around blockchain, new risks arise. For businesses acting as intermediaries (e.g., banks, law firms, brokers, even charities), the major threat is disintermediation and loss of business model. For others, the most pressing risk is to pursue blockchain when a traditional technology would be better suited. To avoid this risk, a simple "golden rule" is that blockchain should only be pursued if conventional approaches have failed to deliver expected benefits or if it can offer higher quality benefits at comparable or lower cost.

Factors determining when to use blockchain for corporate sustainability

1 – A centralised database does not deliver the benefits needed.

2 – Stakeholders do not trust each other given diverging incentives.

3 – Significant value can be derived from allowing peer to peer transactions and disintermediating centralised functions.

4 – Data security requirements (including identification) are high.

FIGURE 11 proposes new critical challenges arising from customers' growing need for more transparency, which can be overcome by a combination of blockchain, internet of things and artificial intelligence technologies.

FIGURE 11 — Blockchain can help overcome critical new challenges posed by changing customer expectations

Source: Authors own analysis

Data management

Data issues are often cited as the most pressing challenge faced by procurement managers, who are generally responsible for supply chain issues. Their primary constraint lies in the difficulty to access and manage supplier data. Internal data management can also be problematic when multiple actors manage different data sets and are not equipped to consolidate or align their databases.

Impact quantification and verification

Even sound data does not necessarily mean impact. The most sophisticated database will not represent credible impact information unless it is connected to credible impact quantification methodologies. As a demonstration, a company purchasing and processing of milk to sell dairy products is equipped with a cutting-edge database covering all of its milk supply, including farmers, their location, volume of milk, and even greenhouse (GHG) intensity attributes of milk at farm level. Yet this would not be sufficient to credibly compute its corporate carbon footprint. Data without relevant impact quantification methodologies is meaningless. Unless the corporate can demonstrate that it is following industry best practices for quantification and communicate this in a simple and engaging manner, it will fail to satisfy its customers and broader sustainability stakeholders.

Source: image of dairy production - Gold Standard

Traceability of goods and attributes

Assuming that the aforementioned corporate has done credible carbon accounting and has built those calculations in its cutting-edge database, it must also ensure that the data and the product can be traced throughout its supply chain; from the farm to the point of purchase. While providing information on impact data on product averages is already a significant step forward; the ultimate objective is to give customers accurate information on the product origin and its full impact on the people and the planet. This can only be achieved with enhanced traceability solutions that deliver (near) real-time product data.

The ultimate objective is to give customers accurate information on the product origin and its full impact on the people and the planet

Greater business value

Emerging technologies like blockchain can help raise the level of ambition of climate strategies by turning these strategies into new value drivers. Two main expectations for driving sustainability strategies are meeting clients' expectations and enhancing the company's reputation.[54] The business case for using blockchain to overcome these challenges is clear when it comes to customer satisfaction and brand reputation built from credible, transparent impact data, as described above. In addition, the tokenisation of impact can unlock new funding opportunities for positive "externalities," or benefits delivered above and beyond the market price, that were previously not quantified or valued (See Chapter 10 for more on impact tokenisation). By using blockchain to track impact data for goods and services produced and traded, private sector players can tap into innovative results-based finance schemes in a cost-effective, secure, and transparent way. These tokens could also be bundled with products or services and transferred to customers upon payment.

TABLE 19 proposes blockchain related technology opportunities to overcome these challenges.

TABLE 19 — Blockchain potential for corporate sustainability

Challenges in corporate sustainability	Opportunities for Blockchain / AI / IoT	Remarks
Managing and automating supplier data	Data input enabled across a large network of internal and external stakeholders; automated identification of users; enhanced data security; increased data quality from IoT solutions and 'Big data'; data verification and analysis supported by AI; automated transactions based on automatic verification of sustainability data and criteria enabled by smart contracts	Especially relevant in the context of supply chains where suppliers may not necessarily trust each other but are required to share data
Quantifying impacts	Translating paper based, impact quantification methodologies into smart contracts and apps to convert dataset into a quantified impact that can be validated by the network and certified by an external third party	Helps to quantify and certify the sustainability profile of goods purchased and transacted
Reporting progress	Credible, transparent reporting via impacts stored on the blockchain to leverage data submitted by multiple actors and produce a consolidated picture of a product or a corporate sustainability profile	Responds to growing need for transparent disclosure of sustainability attributes at company- and product-level
Ensuring traceability of goods	Goods, services and their associated impacts digitised and traded on the blockchain transparently and securely	Significant existing gap in ability to translate input / production data into credible impact information to generate the full "impact profile" of a commodity
Creating business value	Tokenisation of impacts associated with goods and services to unlock monetisation opportunities	Need to properly design the ecosystem to create incentives for users to exchange and value tokens

Source: Authors own analysis

[54] Source: IMEA 2016

12.3 Selected use cases

USE CASE

WWF Tuna Fish experiment

A Blockchain Supply Chain Traceability Project implemented by WWF, Consensys, Traceable and Sea Quest Fiji is using digital technologies to strengthen supply chain management and avoid cases of illegal fishing and human rights abuse on ships. WWF representatives mention the rising expectation from customers to know the sourcing origin of their fish as well as the growing threat illegal fishing poses to marine biodiversity and worker exploitation as key drivers for this project.

The solution allows for the unique identification and traceability of fish from the point where it is caught to the point where it is sold. Using radio-frequency identification, e-tagging and scanning, fishermen can register their catch on the blockchain. From there, the blockchain captures and tracks information to the processing facility and could potentially carry on to the retail store shelf using QR codes and digital records.

Source: © WWF-Aus / Shiri Ram Yellowfin tuna being tagged with a QR code on fishing vessel. Fiji waters, December 2017.

WWF's objective with this project was to prove the technical feasibility of this digital traceability solution and demonstrate demand from customers for transparent, credible provenance information. This initial project could be taken to a next level using artificial intelligence combined with cameras to enable facial identification of workers on boats thus ensuring compliance with human rights and fishing regulations.

USE CASE

Xpansiv Digital Feedstock

San Francisco based start-up Xpansiv is pursuing the vision of a world where commodities are traded alongside their impacts. Xpansiv's platform turns production data into "Digital Feedstock", a new data format that can capture the entire sustainability profile of a commodity, from carbon intensity to associated water use and deforestation. The platform is developed on the premise that, if given a clear choice, market actors will prefer commodities with a better sustainability profile. Initially applied to the US natural gas sector with the objective to use market forces to differentiate lower carbon natural gas, the platform is geared to cover any type of commodity and any type of impact.

USE CASE

Unilever Blockchain Tea Pilot

This one-year pilot investigates whether blockchain can cut time and costs associated with tracking tea, while simultaneously delivering better quality products to consumers. This pilot is expected to contribute to Unilever's objective to increase customer trust and loyalty.
Working in consortium with a retail firm, a packaging firm and several banks, Unilever is developing a system to track and reward sustainable farming practices. Information about the produce, including quality, sustainability metrics and price, is stored on the blockchain and then assessed by actors, such as banks, who can reward farmers with preferential terms.

Unilever is developing a system to track and reward sustainable farming practices. In-formation about the produce, including quality, sustainability metrics and price, is stored on the blockchain and then assessed by actors, such as banks, who can reward farmers with preferential terms.

TABLE 20 — Use cases for blockchain and corporate climate and sustainability strategies

Use case	Description	Ressources
Bext360 and Moyee Coffee	Two platforms providing blockchain-enabled traceability of goods and quantifiable sustainability measurements. Bext360 is known for launching the first blockchain traceable coffee. Moyee coffee, the world's first "fairchain", coffee, allows customers to tip farmers directly if they enjoy the coffee.	Best360 website Fortune Article (Best360) Moyee Website
Everledger	A blockchain platform that gives physical assets an identity, proof of authenticity, existence and ownership. Initial target market is luxury goods such as diamonds.	Everledger website
IBM Food Trust	In partnership with Walmart and other food giants, IBM is rolling out a blockchain platform to maintain secure digital records and enhance the traceability of agricultural products.	Fortune Article IBM website
Unilever	Blockchain tea pilot (see above)	Supply Chain Dive Article GreenBiz Article
Walmart	Walmart is working with IBM on a food safety blockchain solution that requires all suppliers of leafy green vegetable to upload food safety data to the blockchain by September 2019 .	Techcrunch Article
WWF	Tuna Fish Experiment (see above)	WWF website
Xpansiv	DigitialFeedstock (see above)	Xpansiv website

12.4 Needs for further work, pitfalls to avoid and tips for policy makers and corporates

There is an abundance of efforts to leverage blockchain and other emerging technologies to solve traceability issues in supply chains. It is not yet clear whether these competing players are learning from each other or simply duplicating efforts.

Further, there is limited information available on the maturity and readiness of the technology, which can represent a major risk for corporates looking to engage. More work is required to develop guidance on how to assess the suitability of available technologies against a set of pre-determined user needs and real-world problems. This would benefit not only corporate users but also investors and public institutions by enabling comparison and benchmarking. Given the pace at which technology is developing, using a systematic, fast-learning approach to use-case implementation is recommended.

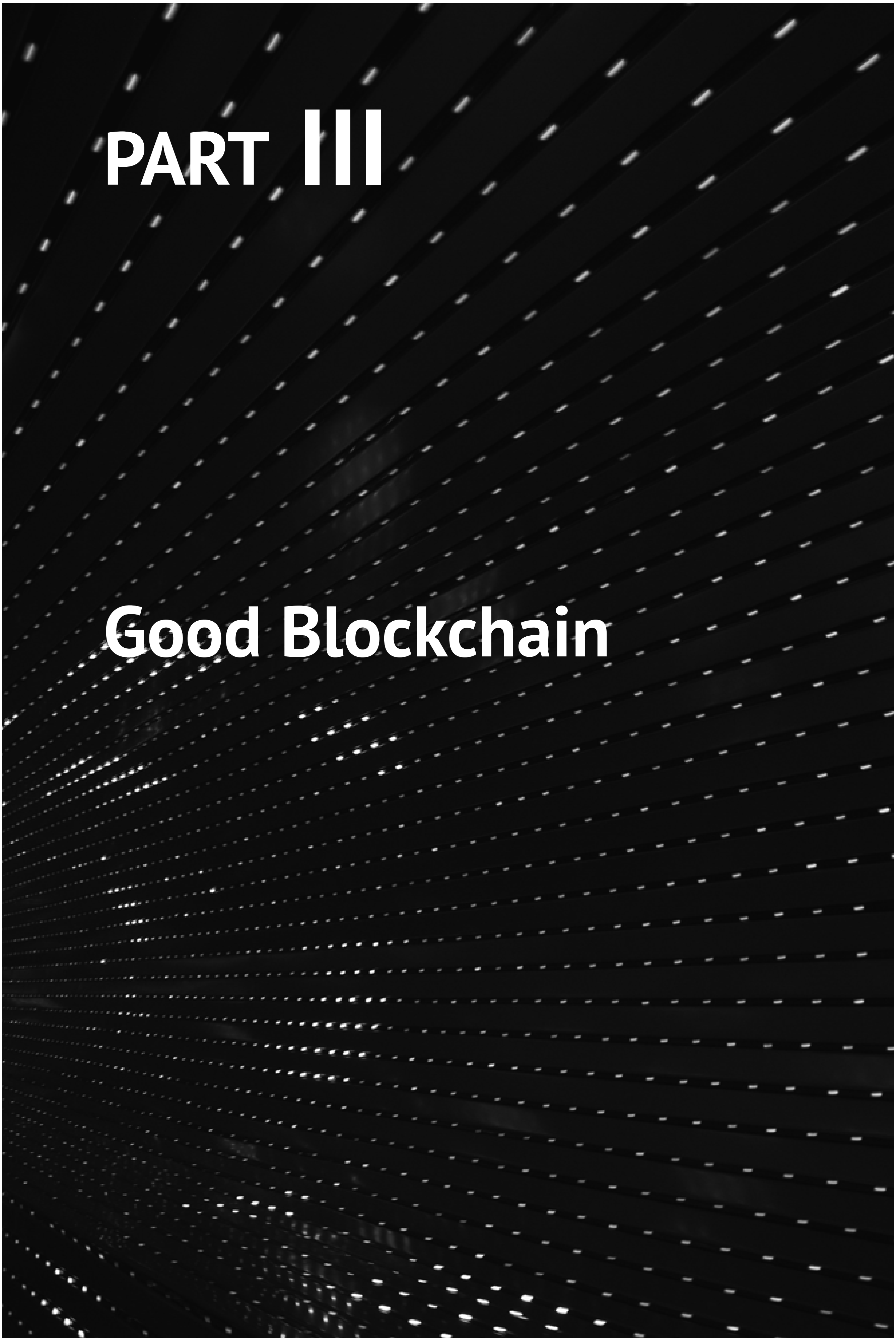
Beyond the focus on traceability, there is limited work or information available on several related issues paramount to the success of these endeavours including:

There is an abundance of efforts to leverage blockchain and other emerging technologies to solve traceability issues in supply chains

— Standardisation of best practices on matters such as input data quality, smart contracts and verification protocols

— Development of digital approaches to turn input data into credible quantified impact information usable to report on Paris Agreement related pledges or the Sustainable Development Goals

— Lack of design for impact, wherein too many technology solutions fall short because of poor design or insufficient understanding of the real-world problemsWhat blockchain technology is and how it works



PART III

Good Blockchain

WHAT BLOCKCHAIN TECHNOLOGY IS AND HOW IT WORKS

Sven Braden
Co-Founder
LIFE Climate Foundation Liechtenstein

Madeleine Guyer
Project Manager
INFRAS

13.1 Blockchain – a new kind of decentralised database

Blockchain technology, or more generally Distributed Ledger Technology (DLT) promises to restructure transaction systems worldwide. As a simplification, however, we are using the more common term "blockchain" in this report as a placeholder for the broader concept that includes all distributed ledger technologies, even though blockchain is only one implementation of DLT.

Blockchain technology provides new ways for secure exchange and storage of data and digital assets, primarily designed for peer-to-peer transaction platforms. The technology does not necessarily require high level technology infrastructure from the start since it allows for gradual build-up of functionalities over time. Therefore, blockchains may have a truly global impact on the transfer of digital values.

Blockchain technology in a nutshell

In a simplified view, the blockchain can be seen as a new kind of database system that does not follow a centralised structure like conventional databases (e.g., to track transactions of values in a bank), but dispersed over many decentralised nodes or "distributed legers". Each ledger contains a copy of the database, and each new entry into the database is to be verified decentralised by numerous entities, and, once approved by the network, stored in all the ledgers. Another key element of the blockchain technology is the cryptographic architecture that "chains" each new entry or "block" in the database to earlier entries in such a way that the entries cannot be changed anymore and that provides security and transparency over earlier entries.

More specifically, every network based on blockchain technology is run by a protocol which sets the system's rules. These rules are binding to all parties. The infrastructure of a blockchain network consists of many individual computers (termed "nodes", "validators", or "miners"). These nodes interact permanently adhering to the protocols' rules. By means of blockchain technology, transactions can be verified, validated and linked to each other, for example, by using transaction blocks—the origin of the term blockchain. This leads to a history of transactions (transactions "chained" together) shared by the whole network.

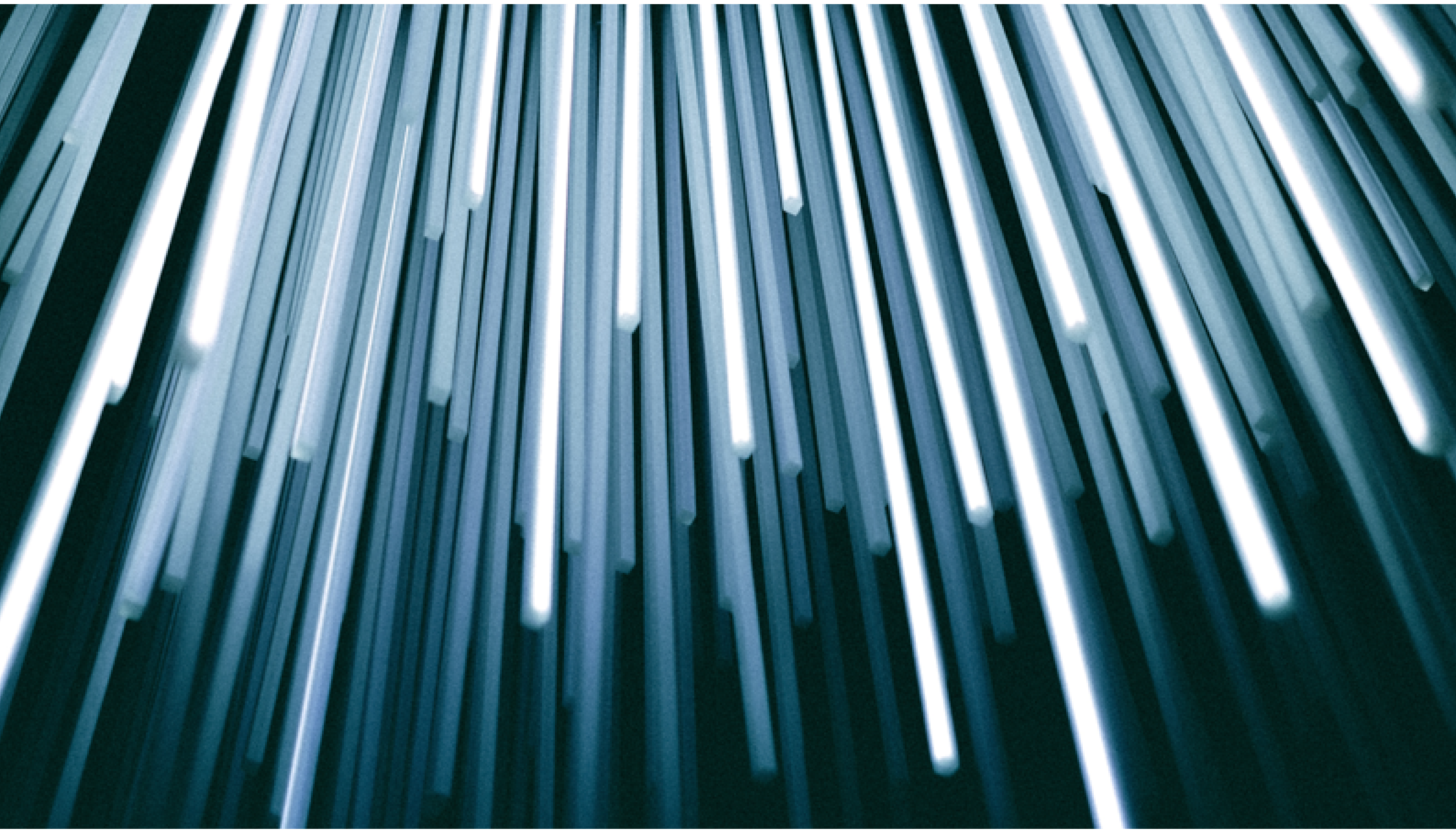
The core element of every blockchain network is powered by its consensus mechanisms and hash algorithms. Consensus mechanisms ensure that all participating computers in the network apply the same principles and functioning when working on the state of the network. provides for a common consensus is crucial for every decentralized blockchain network. The community platform 101Blockchains.com provides a comprehensive overview of consensus mechanisms currently deployed in the world of distributed ledger technology.

Consensus mechanisms ensure that all participating computers in the network apply the same principles and functioning when working on the state of the network. provides for a common consensus is crucial for every decentralized blockchain network

A hash is like the unique digital fingerprint of any imaginable set of data, regardless of its size. Technically a hash is comparable to a cross sum yet mathematically much more complex.[55] Like with the cross sum, a hash can be much shorter than the original hashed text (data).[56] It is also generally impossible to conclude from the hash back to the initial data set.

[55] A cross some is the sum of a number's individual digits - repeatedly applied. The cross sum of 8'2141 is 7. 8 + 2 + 1 + 4 + 1 = 16 which leads to 1 + 6 = 7

[56] The hash formula used by the Bitcoin network is the SHA256 algorithm which consists of 32 bits and hashes numbers as well as minuscule and capital letters: the number of hash possibilities is literally endless – one hundred quattuorvigintillion possible variations (a number with 77 zeros)



Example of hashing algorithm

For example, the hash of the phrase

"Nothing is decided until everything is decided" always has the specific hash:

9f62f85d500c8d4682c2aa9f8a00d89658be-956b3a680dfd370eb1c9bb94e445.

A change of just one minor part of the data set causes the so-called avalanche effect in the "hash mixer" and leads to a complete different hash. For example, the slightly altered phrase:

"Nothing is decided until everything´s decided" has the hash:

3f9801bc00d0a466b42c006dbbbf312ce38d1c-f515a999bb09f9b556feeb5624[57]

[57] Hash generators may be found online, e.g. http://passwordsgenerator.net/sha256-hash-generator/

Blockchain networks can be seen as cross-checking instruments. A transaction is determined by multiple parties as correct and ticked off. Hence, a transaction is only qualified as correct if the evaluating party concludes that the transaction was created in line with the applicable protocol rules. If most of the parties consider the transaction to be correct (by applying a consensus mechanism) the transaction together with a series of other transactions is merged into a cryptographic code and built into a block. This block is appended to the previous block. To be tamper-proof and work flawlessly, encryption techniques are used at the individual sections of the blockchain process. In addition, encrypted transactions or blocks of transactions are not stored in one central location but decentralised among all parties involved.

Features and advantages of blockchain technology

Unlike common data management systems, where a dataset is stored on centralised servers, blockchains and their underlying networks ensure that the data is stored on the computers of every network participant. Every participant of such a decentralised network uses the same software and runs it at the same time (via "clients"). Blockchain databases are considered to be tamper-proof, not only because the individual information blocks are encrypted and decentralised, but also because transactions can be viewed by all parties involved.

Since blockchain technology enables networks to work on an agreed set of transaction histories, it is also possible to associate these transactions to conditions that are also shared by the network. If transaction A has occurred, transaction B is automatically executed (principle of 'smart contracts'). Smart contracts are complementary mechanisms within blockchain networks that allow, for example, for the automatic coordination of decentralised suppliers and buyers or the automatic allocation of pricing tags of environmental attributes.

Complete transparency across all transactions gives stakeholders within such networks the confidence to securely conduct transactions with anonymous partners. Advantages of the blockchain technology can therefore be summarised with the term 'multilateral interoperability', which encompasses multicast communication, immutability (no forgeries possible by fraudsters), real-time tracking of transactions and faster processing of payment transactions.

Blockchain networks can be permissionless and available to the public in general or permissioned where access may be restricted or private. Some require the identification of participants, others do not. This choice is based on whether identities and contents should be disclosed or not (see Chapter 12).

13.2 Challenges – power, storage, time lag, network security

Power consumption

Blockchain technology is associated with high power consumption and the necessity of high computer capacities.[58] These associations are merely linked to patterns of a specific consensus mechanism that powered the first network

[58] See www.cleancoins.io for detailed information on energy consumption.

of its kind, the Bitcoin blockchain, which is characterised by high energy consumption.[59] The Bitcoin protocol requires fees of at least ten micro-bitcoins to process each transaction. The higher the amount of the fee, the faster the transaction is confirmed. This makes the network unattractive for microtransactions. In addition, the Bitcoin protocol applies the so-called 'proof of work' as a consensus mechanism to determine the next computer that may add its transaction block to the network. The proof of work mechanism requires the resolution of complex cryptographic tasks, which consume a high amount of energy. Although this mechanism contributes to the security and functionality of the Bitcoin network, it is highly inefficient from an energy and climate perspective.

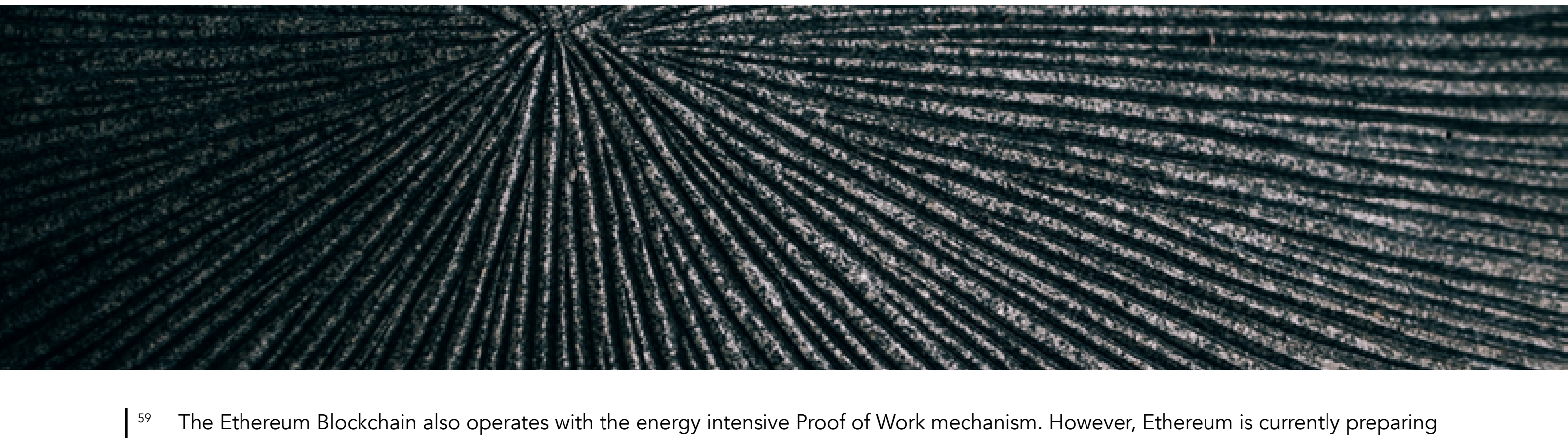
Though alternative options are being discussed, such as offset solutions for proof of work-related emissions, deployment of renewable energies at mining sites, they do not solve the need for high energy consumption of the core protocol. Moreover, the capacities required to implement such alternative options should be used to address the challenges of the ongoing energy transition, rather than helping to run a system which will, by design, grow only with an associated increase of energy demand (see for example the "difficulty adjustments" within the proof of work mechanism).

However, high power consumption is not a pre-condition for blockchain technology in general. The questions of power consumption related to blockchain networks directly relate to the way the respective blockchain protocol is designed. Factors include what consensus mechanism is applied,[60] permissioned or permissionless blockchain network, tokens/coins being mined or pre-mined or the volume of transactions/units that may be processed.

Currently, there are more than a dozen consensus mechanisms in operation that work without the need for high electricity. Hence, solutions for lower power consumption are available.

Time lag, storage and lack of scalability

Compared to centralised databases, blockchain systems tend to be slow. Depending on the blockchain architecture, the processing of a transaction may take several minutes, which is not practical, for example, for paying for groceries through a blockchain. In addition, blockchain's bottom-up network architecture may hinder scalability. With larger datasets, blockchain technology faces technological restrictions and users may therefore turn to conventional databases and store only a fraction of the database in the blockchain to maintain some of its security and transparency benefits. Scalability appears to be a technical challenge which could be solved soon via "second layer solutions" or "off-chain transactions". Moreover, in the context of distributed ledger technology, block-less network solutions with high transaction throughput and a low energy usage are already under development.[61]



59 The Ethereum Blockchain also operates with the energy intensive Proof of Work mechanism. However, Ethereum is currently preparing for a protocol change in order to switch to Proof of Stake a consensus mechanism which is more efficient in terms of energy usage.

60 At this point of time there are more than a dozen consensus mechanisms in operation that work without the need for high electricity. A comprehensive list of consensus mechanism can be found under https://101blockchains.com/consensus-algorithms-blockchain/

61 See for example IOTA, https://www.iota.org/ or Hedera's Hashgraph, https://www.hedera.com/

Overcoming challenges of power consumption and scalability – "Decentralised Consensus without Blockchain"

One of the downsides of a blockchain is that every participant (node) needs to know everything before the network can achieve consensus. That means that the speed and computing capacity of any one node may define the overall network performance. If the majority of nodes can only process about 200 transactions per second, this is the maximum capacity of the respective network, otherwise there is no consensus.[62] In opposition to blockchain networks, where the whole network validates everything, alternative network architectures only require local consensus. IOTA, an open-source project from Germany,[63] achieves such local consensus using directed acyclic graph architecture (DAG). Before initiating a transaction (e.g., a payment) every user has to first validate the transactions of its neighbouring nodes (determined by the DAG). A particular benefit of this local consensus is that it can be achieved rapidly and at low energy costs. Another way of achieving local consensus is proposed by Hedera Hashgraph,[64] a US company that enhances the concept of local consensus using a "gossip protocol". Different nodes trust each other's proposed transactions based on information that is validated on a regular basis. Although still under development, both IOTA and Hedera Hashgraph offer interesting alternatives to overcome the challenges of power consumption and scalability, currently inherent to the blockchain technology.

Network security

Attacks on blockchain networks are influential takeovers on the consensus of these networks. The bigger the blockchain network (e.g., high number of validating nodes) the more difficult it is to organise such attacks. The most common threats to blockchain networks are the "51% attack" and the "Sybil attack".

A 51% attack takes place if a malicious participant of a blockchain network combines more than 51% of the network's computing power. In other words, a malicious attacker who controls a majority of validating nodes can influence and eventually take over the consensus. This could mean approving transactions that would not be in line with the pre-defined protocol rules. For big decentralised and distributed networks like Bitcoin and Ethereum, the risk of 51% attacks are more theoretical. The resources required to launch and sustain an attack would likely be high and thus not economical feasible. Furthermore, 51% attacks should not be a risk for permissioned blockchain networks since all validating nodes are known and identifiable. However, 51% attacks can threaten smaller permission-less blockchain networks.

A Sybil attack grants undue influence to a single entity because that entity controls many pseudonyms. A Sybil attack on a blockchain network could occur if the creation and operation of validating nodes are free or extremely inexpensive. In this case a malicious entity could establish numerous nodes and influence the consensus of the overall network. Sybil attacks are the main reason for the need of sophisticated consensus mechanisms, especially in permissionless blockchain networks. These ensure that blockchain-based consensus-making requires a pre-defined economic stake from its participants to make Sybil attacks expensive and economically risky from the perspective of the attacker.

62 This limitation states a considerable obstacle for use cases that require high transaction throughput (micropayments, machine to machine communication etc).

63 See https://www.iota.org/

64 See www.hedera.com

GOVERNANCE FOR BLOCKCHAIN AND CLIMATE ACTION

Juerg Fuessler
Managing Partner
INFRAS

Governance on international, national and blockchain levels

The **international rulebook** regulates the detailed implementation of the Paris Agreement and is currently under negotiation. These rules determine what information countries must provide, in which format and how often. It determines how the bookkeeping of national inventories, Nationally Determined Contributions (NDCs) and the international transfer of mitigation outcomes, including corresponding accounting adjustments have to be carried out and the rules under which such transfers are eligible. It remains to be seen whether guidance on specific registry and data technologies such as blockchain may emerge under the Paris Agreement.

National regulation and oversight of markets may facilitate or hinder the use of blockchain systems. For instance, in many countries, the national regulation of the energy sector assumes a system of large centralised power producers and is not well suited for decentralised power generation and peer-to-peer electricity markets of "prosumers". Regulation and governance is also required to set the rules to assure the cryptographic values stored on blockchains enjoy respective recognition in the real world. A legal framework regulating key aspects of blockchains such as digital identification of participants (humans and machines) and "signatures", legal enforcement of smart contracts and the legality of crypto-currencies can help to engender trust of blockchain technologies among government entities and businesses. On the other hand, too stringent a regulation may cripple innovation in blockchain approaches. Therefore, some jurisdictions allow for regulatory "sandboxes" that allow for experimentation with blockchain approaches in different sectors within a supervised environment with trusted business partners.

The **rules and governance of blockchains themselves** defines who can access information, change protocol rules or data, mine tokens or coins, as well as setting required levels of transparency.

Importance of governance in blockchain systems

Blockchain technology tends to be developed bottom-up in a decentralised setting that does not require a centralised governance. This epitomises the vision of blockchain as a disruptive technology to decentralise much of society's social, political and economic infrastructure and eliminate unnecessary intermediaries or rigid institutions that are not fit-for-purpose for a digitally-based future. Blockchain is also a potential game changer in countries with weaker governments, as it may replace some potentially corruptible and fallible governmental processes and institutions by a decentralised yet trusted technological tool.

However, blockchain is a new technology, thus related governance systems are just emerging. Many problems with governance of blockchains to date underscore the need for robust governance for blockchain systems: Bitcoin's block size debate, Ethereum hacking and the resulting community DAO[65] crisis[66]. Furthermore, the rules and smart contracts to be embedded in a blockchain may have distributional, ethical and political consequences. Such rules may, for example, determine who gets paid for mitigation or adaptation action and who does not. Their enforcement creates winners and losers.

Existing governance systems for blockchains

Three main types of blockchain governance systems may be distinguished[67]:

1 — **Public ('permissionless') ledgers**: These are blockchains in which anyone can participate without needing permission or approval. Anyone can download code and start running a public node, validating transactions in the network and contributing to the consensus process that determines what blocks get added to the chain and defining the current state. Transactions tend to be very transparent but essentially anonymous. Most of the current consensus mechanisms in public blockchains contain the Proof of Work algorithm, which typically lead to high electricity consumption and are slower and more difficult to scale.
Examples: Bitcoin, Ethereum, Litecoin

2 — **Federated or consortium blockchains**: These operate under the leadership of a group and only allow specific nodes to participate in the verification process. The consensus process is controlled by a pre-selected set of nodes. They are faster, allow for higher scalability and provide more transaction privacy than public blockchains.
Examples: Energy Web Foundation, typically blockchains in the banking sector

3 — **Private/permissioned blockchain**: Permissions to write (and read) are kept centralised by one organisation.
Example: Company internal blockchains for database management, e.g., Hyperledger

To put it simply, the public, permissionless blockchains are truly decentralised, open to all actors and have a much larger potential to disrupt existing business models through disintermediation. However, due to current technology limitations they are slower and more difficult to scale. On the other end of the spectrum, private blockchains are easier to manage centrally, are faster and have better scalability. However, they lack what some people would call the essential decentralised features of blockchain; their private and centrally controlled nature provide its disruptive capability.

65 DAO means Decentralized Autonomous Organization, a code-based and "leaderless" investment vehicle.

66 See https://www.oii.ox.ac.uk/blog/understanding-public-blockchain-governance/ and https://medium.com/@Vlad_Zamfir/blockchain-governance-101-eea5201d7992

67 Based on https://blockchainhub.net/blockchains-and-distributed-ledger-technologies-in-general/

More experience needed

In climate action, different blockchain governance approaches may be used in different contexts. In the more open, private sector-driven field of using blockchain for implementing climate action, a more open and public approach may have greater potential, such as allowing for the emergence of crowd financing platforms or for bottom-up prosumer energy access systems in mini-grids. When it comes to the implementation of the Paris Agreement, where centralised governments are key actors, more federated blockchains, for example, run by a group of countries, might be a more feasible approach given the need to maintain a certain level of sovereignty with individual countries. However, experiences are just beginning. Only piloting and experimenting with different governance schemes for different application in climate action in the coming years may help to find the appropriate blockchain architecture in a specific context. The Climate Ledger Initiative looks forward to collaborate with a broad group of partners in this quest.