Blockchain for Mexican Climate Instruments: Emissions Trading and MRV systems

MEDIO AMBIENTE
SECRETARÍA DE MEDIO AMBIENTE Y RECURSOS NATURALES

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

of the Federal Republic of Germany

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List of Acronyms

ABM: National Banking Association (for its acronym in Spanish)

AI: Artificial Intelligence

AMEXCID: Mexican Agency for International Development Cooperation (for its acronym in Spanish)

AML: Anti-Money Laundering

BMU: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (for its German acronym)

CDM: Clean Development Mechanism

CO_2-eq : CO_2 Equivalent

CPU: Central Processing Unit

ETS: Emissions Trading System

EU ETS: European Union Emissions Trading System

GHG: Greenhouse Gas

GIZ: Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH

GPS: Global Positioning System:

IBM: International Business Machines Corporation

IKI: International Climate Initiative (for its acronym in German)

IoT: Internet of Things

IT: Information Technologies

KYC: Know Your Customer (or Client)

MRV: Monitoring (or Measuring), Reporting and Verification

NAMA: Nationally Appropriate Mitigation Action

NDC: Nationally Determined Contribution

PECC: Special Program on Climate Change (for its acronym in Spanish)

PoA: Proof of Authority

PoS: Proof of Stake

PoW: Proof of Work

P2P: Peer-to-Peer

RENCID: National Registry for International Development Cooperation (for its acronym in Spanish)

RENE: National Emissions Registry (for its acronym in Spanish)

SDG: Sustainable Development Goals

SIAT-PECC: Information System for Transparency of the Special Program on Climate Change (for its acronym in Spanish)

SIAT-NDC: Information System for Transparency of the Nationally Determined Contributions (for its acronym in Spanish)

SINACC: National System on Climate Change (for its acronym in Spanish)

SEMARNAT: Ministry of the Environment and Natural Resources (for its acronym in Spanish)

UN: United Nations

UNFCCC: United Nations Framework Convention on Climate Change

USD: US Dollar

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Executive summary

Climate change is one of the major challenges to humanity. Governments around the world have committed to Nationally Determined Contributions (NDC). Climate policy instruments must be rapidly implemented to limit global warming well below the 2 degrees Celsius threshold agreed to by over 190 countries in 2015 through the Paris Agreement.

Through its NDC in 2015, Mexico set a 22% greenhouse gas (GHG) reduction target for 2030, and promised to increase its mitigation target to 36% under the condition of international support.

To realize this contribution, Mexico decided to enable the trading of emission allowances and explore appropriate climate transparency systems.

This briefing paper analyzes the potential of Blockchain technology for emissions trading and systems that allow for the tracking of climate mitigation efforts and climate finance flows in Mexico. The analysis considers the environmental policy framework in Mexico as of 2018, including the overall national circumstances. In particular, the suitability of a Blockchain approach are examined for the development of (1) an Emissions Transaction Registry, (2) a system for monitoring federal and sub-national climate policies and (3) a Monitoring (or Measuring), Reporting and Verification (MRV) system for climate finance.

With respect to the development of an Emissions Transaction Registry, the analysis concludes that a Blockchain approach should be considered in order to allow for a transparent linking to other Emissions Trading Systems (ETS). Moreover, a Blockchain offers great potential for the transparent integration of offset programs in the system, since a shared ledger would address the problem of double counting.

Applying a Blockchain approach to a system for monitoring federal and sub-national climate policies is, however, not recommended. In order to ensure a flawless exchange of climate relevant data between sub-national and federal authorities, a conventional data management system appears to be more suitable.

Regarding an MRV system of climate finance, the analysis concludes that a Blockchain-based Verification Platform offers great potential to implement core principles of results-based finance and could therefore facilitate access to international climate finance. The verification of climate action claims would enable transparent MRV of a variety of climate policies. Finally, the platform gathers and verifies data and processes, and thus could serve as a valuable source for future policy planning.

The analysis also examines the institutional, financial, technological and regulatory needs and requirements to effectively prepare for the implementation of the identified use case opportunities.

Blockchain technology is not the silver bullet for climate policy instruments; every such instrument must be carefully analyzed before considering a Blockchain-based approach. However, in a world with a growing amount of data, smart solutions are required to address global problems, such as tracking the progress of climate instruments in Mexico and around the world. Here, Blockchain technology offers a promising option to manage data in a way that improves the decision-making processes of governments.

Resumen ejecutivo

El cambio climático es uno de los mayores retos de la humanidad, los gobiernos alrededor del mundo se han comprometido con sus Contribuciones Nacionalmente Determinadas (CND). Los instrumentos de política climática deben ser implementados de forma rápida para limitar el calentamiento global abajo de los dos grados centígrados, este límite fue acordado por alrededor de 190 países en el marco del Acuerdo de París en el año 2015.

Mediante su CND en el año 2015, México estableció un objetivo de reducción del 22% de los gases de efecto invernadero (GEI) para el año 2030. Además, se comprometió a incrementar su objetivo de mitigación hasta el 36%, sujeto a la condición de recibir soporte internacional.

Para lograr esta contribución, México decidió hacer uso de el comercio de derechos de emisión y explorar sistemas de transparencia climática adecuados.

Este documento analiza el potencial de la tecnología de Blockchain para el comercio de emisiones y para sistemas que permitan la trazabilidad de los esfuerzos de mitigación de GEI y de los flujos de financiamiento en México. El análisis considera el marco de política ambiental en México del año 2018, incluyendo las circunstancias nacionales generales. En particular, la idoneidad de Blockchain se examina para el desarrollo de (1) un Registro de Transacciones de Emisiones, (2) un sistema para el monitoreo federal y sub-nacional de políticas climáticas y (3) un sistema de Monitoreo (o Medición), Reporte y Verificación (MRV) para el financiamiento climático.

Respecto al desarrollo del Registro de Transacciones de Emisiones, el análisis concluye que el uso de Blockchain debe ser considerado para permitir una vinculación transparente con otros Sistemas de Comercio de Emisiones (SCE). Aún más, Blockchain ofrece un alto potencial para la integración transparente de los programas de compensaciones en el sistema, ya que un registro compartido podría abordar el problema de doble contabilidad.

Sin embargo, aplicar una tecnología de Blockchain par el monitoreo de las políticas climáticas federales y sub-nacionales, no es aconsejable. Para asegurar un perfecto intercambio de datos climáticos relevantes entre las autoridades sub-nacionales y federales, un sistema de manejo de datos convencional, parece ser más adecuado.

Respecto a un sistema de MRV para financiamiento climático, el análisis concluye que una Plataforma de Verificación de ofrece un gran potencial para implementar los principios centrales de financiamiento basado en resultados y podría así, facilitar el acceso a financiamiento climático internacional. La verificación de resultados derivados de acción climática debe habilitar sistemas transparentes d MRV de una amplia variedad de políticas climáticas. Finalmente, la plataforma reúne y verifica datos y procesos y, sirve como una fuente valiosa de información para la evaluación de las futuras políticas públicas.

El análisis también comprende las necesidades y requisitos institucionales, financieros, tecnológicos y regulatorios para prepararse de manera efectiva para la implementación de las oportunidades del estudio de caso identificado.

La tecnología de Blockchain no es una bala de plata para los instrumentos de política climática; cada uno de estos instrumentos debe ser cuidadosamente analizado antes de considerar el uso de Blockchain. Sin embargo, en un mundo con una cantidad creciente de datos, se requiere de soluciones "inteligentes" para afrontar los problemas globales, tales como, el monitoreo del progreso de los instrumentos de política en México y en el mundo. Aquí, la tecnología de Blockchain ofrece una opción promisoria para el manejo de datos de forma que se mejoren los proceso de toma de decisiones de los gobiernos.

1

Introduction

1. Introduction

This paper analyzes opportunities and challenges for applying Blockchain solutions for climate policy in Mexico. The analysis was prepared in close collaboration with the Mexican Ministry of the Environment and Natural Resources (SEMARNAT) and GIZ Mexico. It builds upon the briefing paper "Blockchain Potentials and Limitations for Selected Climate Policy Instruments" (GIZ 2018).

Based on the conclusions from GIZ 2018 with regard to the potential of Blockchain technology for emissions trading, this analysis examines the suitability of using a Blockchain approach for an Emissions Transaction Registry.

In addition, the analysis examines the suitability of a Blockchain approach for setting up a cost-efficient and secure Monitoring (or Measuring), Reporting and Verification (MRV) system for greenhouse gas (GHG) emissions and climate finance. The conclusions made in this paper consider the specific circumstances of the Mexican policy framework for climate change as of 2018/2019.

This analysis is organized as follows:

Chapter 1 discusses the fundamentals of Blockchain technology. Further information, especially on the key features and challenges of Blockchains, is provided by GIZ 2018.

Chapter 2 provides a brief overview of four popular Blockchain platforms. The overview assists the understanding of the subsequent analysis of climate instruments and their suitability for a Blockchain application in Mexico.

Chapter 3 describes specific aspects of Blockchain networks and introduces corresponding evaluation criteria in order to determine the suitability of Blockchain technology for climate instruments.

Chapter 4 and 5 analyze three specific climate instruments (Emissions Transaction Registry, governmental MRV systems for climate policies, and climate finance) and their potential for applying a Blockchain, considering the specific circumstances in Mexico. The analysis is based on a comparison and analysis of pros of cons regarding both Blockchain technology and conventional database solutions. Both chapters summarize the potential of Blockchain technology and conclude with respective recommendations for the concrete implementation of identified use cases.

Chapter 6 considers relevant elements for the implementation of the Blockchain-based use cases analyzed in the previous chapters.

Information and data for this analysis were gathered in close collaboration with SEMARNAT and GIZ Mexico. The study considers the specific conditions of current policy planning within SEMARNAT as identified through

- the evaluation of Mexico's legal framework (as of October 2018);
- explanatory documentation (secondary information) provided by SEMARNAT between September and October 2018; and
- a series of interviews and interactive workshops with representatives from the executive and technical levels of SEMARNAT that were conducted between October 3 and 5, 2018 in Mexico City.

2

Blockchain Fundamentals

2. Blockchain Fundamentals

A Blockchain network essentially manages a decentralized database. The concept was first described in 2009 in a cryptography blog by a person or group of persons with the pseudonym "Satoshi Nakamoto." Nakamoto proposed an innovative peer-to-peer (P2P) electronic currency called Bitcoin that would enable online payments to be transferred directly from sender to recipient without an intermediary (NAKAMOTO 2008). Although the Bitcoin currency is an interesting and innovative experiment (by January 2019 worth more than US Dollar (USD) 130 bn in value[(1)]), it was the trust-building Blockchain technology (i.e., cryptographic approach) behind it that soon began to be seen as the actual revolutionary aspect. Blockchain is to Bitcoin what the Internet is to email. It is a big electronic system based on distributed ledgers, on top of which you can build applications. Currency (Bitcoin) is just one of these applications.

Blockchain is a database that incrementally is built up by a network of participating parties who run the same software. The associated process is subject to the constraints and rules set by the underlying software they run. A Blockchain, as the name suggests, gets built up by blocks of data gradually being "chained" together. It could almost be imagined as a spreadsheet that is gradually built by chaining on new cells. A Blockchain database continues to be built and maintained as long as the software still runs. Thus, unlike a centralized database held by a single entity, it continues to function even when individual participants pull out (or go bankrupt, for example). It creates an indelible record, resistant to tampering by any individual party.

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The 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 Information Technologies (IT) infrastructure from the start since it allows for the onboarding of functionalities over time. Therefore, Blockchains may have a truly global impact on the transfer of digital values.

2.1 Key Features of Blockchains

Key features of Blockchain networks and their benefits are summarized in the table below (for further information, see p. 16ff., GIZ 2018).

Table 1. Key Features of Blockchains and their Benefits

Feature	Benefit
Shared publicly	Servers, or nodes, maintain the entries (blocks), and every node sees the transaction data in the blocks when created.
Decentralized	There is no central authority required to approve transactions and set rules – the Blockchain based workflow is decentralized.
Secure	The database is an immutable record. Posts to the ledgers cannot be revised or tampered with – not even by the operators of the database.
Trusted	The distributed nature of the network requires computer servers to reach a consensus, which allows for transactions to occur between unknown network participants.
Automated	The software that enables Blockchain-based operations prevents the entry of conflicting or double transactions into the dataset. Transactions occur automatically.

Source: Author's own work.

(1) See https://coinmarketcap.com/ (as of 01/2019)

2.2 Governance – Permissioned and Permission-less Blockchains

Generally, permission refers to how the system works. Permission-less Blockchain networks (e.g., Bitcoin and Ethereum) are open to everyone. Anyone may become a ledger node (i.e., hold a copy of the ledger) and add valid transaction entries.

In contrast, in a permissioned Blockchain network only authorized entities can hold a copy of the ledger or participate in transactions. Here, the nodes know each other, at least to a certain degree. The consensus process is either controlled by a group of known participants or by a single participant (e.g., a company or a governmental agency), which adds some degree of centralization. Permissioned Blockchains can process transactions much faster without compromising network security. The sacrifice of decentralization in favor of security and scalability is particularly attractive to networks with pre-defined stakeholders acting within specific boundaries (within one large entity or a regulated legal framework).

2.3 Key Challenges of Blockchains

The decentralized and distributed character of Blockchain networks leads to challenges that could put the overall suitability of a Blockchain approach at risk. The key challenges of today's Blockchain networks are summarized in the table below. For further information on key challenges of Blockchain technology, see p. 23ff., GIZ 2018.

Table 2. Key Challenges of Blockchain Technology

Challenge/Barrier	Description	Solution
Energy consumption	The Proof of Work consensus mechanism in permission-less Blockchains (Bitcoin, Ethereum) leads to high energy consumption.	Alternative ways of finding consensus already exist (e.g., Proof of Stake).
Scalability	Permission-less Blockchains are currently not able to scale up their performance capacities due to their now inefficient consensus protocols.	Scalability is a far smaller issue within permissioned Blockchains. Other ways to improve scalability involve off-chain transactions or second layer solutions.
Lack of maturity and proven experience	Companies introducing Blockchain to decentralize certain economic relationships do not have the means to market the technology.	Enhanced academic and industry research on Blockchain-related topics such as latency, throughput, size and bandwidth, versioning, hard forks and multiple forks can support mainstream adoption.
Rubbish in, rubbish out	Blockchains do not verify whether incoming data is correct or not; they just verify if the data was introduced along the protocol rules.	A clear link to the data source via personal identification means could increase accountability (and thus quality) of data input.
Data privacy/rights	The nature of Blockchain networks as an immutable record inherently contradicts the "right to be forgotten," which is a legal right in many jurisdictions.	Management of data, especially personal data, needs to be analyzed carefully before storing it on a Blockchain system.

Source: Author's own work.

3

Overview of Blockchain Platforms

3. Overview of Blockchain Platforms

The Blockchain networks Bitcoin, Ethereum and EOS are three of the most popular platforms with market capitalizations of 68, 17 and 3 billion USD, respectively(2). The fourth network, Hyperledger Fabric, uses permissioned nodes to build Blockchains and functions without economic incentives in its design (i.e., cryptocurrencies).

BITCOIN:(3) First described in 2008 in the White Paper of Satoshi Nakamoto (NAKAMOTO 2008) and started in January 2009, Bitcoin is the incubator of Blockchain technology. As the first and oldest decentralized cryptocurrency, it is still seen as a role model for many other Blockchain projects. Bitcoin offers a protocol to transfer ownership of a token from one party to another. The determination of ownership does not require trusted third parties. Bitcoin also offers the possibility to manage and represent real-world assets. For this purpose, the Bitcoin scripting language allows the storage of small amounts of metadata on its Blockchain, which can be used to represent asset manipulation instructions. For example, the confirmation of the creation of 100 emission allowances can be encoded in a Bitcoin transaction. A Bitcoin transaction could also be used to transact a given number of emission allowances. The allowances would be credited to the respective Bitcoin address. Such Bitcoin transactions are also referred to as "colored coins." They can, for example, create a Bitcoin transaction that encodes the sending of 50 units of an asset from one address to a new address, and so on.

The script language is purposefully not Turing complete(4) with no loops. It is transmitted within a Bitcoin transaction. Calling a computer Turing complete means that it can execute any algorithm. The real-world value of such a colored coin is provided only through the promise of its issuer. The token issuer is therefore responsible for the link between colored coin and real-world asset. The limitations of Bitcoin's scripting language do not allow for the application of complex smart contracts that could, for example, determine the amount or characteristics of colored coins. Bitcoin's objective was to create a currency system without a central authority. Its protocol is therefore focused on (and limited to) the transactions of Bitcoins by the network's participants. While the protocol's relatively simple language has proven to be very secure, it also limits usability for purposes other than Bitcoin transactions.

ETHEREUM:(5) The first real distributed computing platform that enables the execution of smart contracts was provided by Ethereum in 2014. These are contracts that run exactly as programmed without any possibility of downtime, censorship, fraud or third-party interference. The following explanations assume that the open source code of Ethereum provides for a permissioned private version of the Ethereum Blockchain(6).

Ethereum currently uses a "Proof of Work" (PoW) consensus. With its "Casper/Serenity" release, the network plans to switch from hardware mining to virtual mining ("Proof of Stake" [PoS]); see p. 12f., GIZ 2018. If successfully executed, this switch will fundamentally change the Ethereum network and drastically lower its power consumption. The change of consensus mechanism will not come over night – although initially announced for 2018, the update is now expected to be fully implemented by 2020(7).

However, due to the permissioned character of the underlying piloting considerations, it is assumed that the applied consensus mechanism will be "Proof of Authority" (PoA), where a pre-selected node validates the transaction and state of the network. PoA only uses a fraction of energy compared to PoW.

HYPERLEDGER:(8) Hyperledger is an open-source project founded in 2015 through a collaborative effort of the Linux Foundation and several companies, such as International Business Machines Corporation (IBM) and

(2) See https://coinmarketcap.com/ (as of 01/2019)

(3) Transactions within the Bitcoin network can be monitored in real-time here: https://www.blockchain.com/es/explorer

(4) Turing complete is a term used in computability theory to describe abstract machines, usually called automata. Such an automaton is Turing complete if it can be used to emulate a system of rules, states and transitions.

(5) See https://ethereum.org/

(6) This can, for example, happen via a "fork" of Ethereum. A respective modification could be to require validators for permission to join the network. A well-known example of that kind is Quorum, an Ethereum fork by US bank JP Morgan with private access to an Ethereum clone; see https://www.jpmorgan.com/country/US/EN/Quorum

(7) See https://cryptobriefing.com/ethereum-casper-update-eth-mining/ (as of 10/2018)

(8) See https://www.hyperledger.org/

Intel, to support the implementation of Blockchain technology for global business transactions (CACHIN 2016). To address the needs of global business transactions, Hyperledger offers a permissioned Blockchain with an integrated security infrastructure for authentication and authorization.

Hyperledger is an open platform that aims to share the framework, codes and underlying technology. It is not restricted to the underlying technology of a cryptocurrency but rather applicable to all sorts of ideas that make confidential, secure transactions possible. Closely related to Hyperledger is the **Hyperledger Fabric**, which enables the running of smart contracts and implements related technologies (CACHIN 2016). An ecosystem for tokens can be developed with Fabric using chaincode, the Hyperledger term for smart contracts.

The platform is built on a modular architecture that allows for adjustments and implementation of further functions. From a technological point of view, Hyperledger aims to be, through its modular approach, as flexible as possible, which in turn attracts many different industries. The Hyperledger Fabric distinguishes between two kinds of peers: a validating peer, which is a network node responsible for maintenance, transaction validation and consensus; and a non-validating peer, which is a node functioning as a proxy that connects clients to validating peers. Fabric enables the development of a native currency or a digital token. Hyperledger benefits from the strong support (and influence?) of big technology companies like IBM and Intel. However, building applications on Hyperledger Fabric may be costlier through these companies, especially when using their related services (e.g., maintaining a full node, customer services, etc.).

EOS:[9] The EOS platform is an open-source Blockchain operating system with a focus on bringing smart contracts (decentralized applications) to the masses.[10] Its mainnet started operations in 2017. EOS introduces a Blockchain architecture designed to enable vertical and horizontal scaling of decentralized applications (the "EOSIO Software"). This is achieved through an operating-system-like construct upon which applications can be built. The software provides accounts, authentication, databases, asynchronous communication and the scheduling of applications across multiple Central Processing Unit (CPU) cores and/or clusters. The resulting technology is a Blockchain architecture that has the potential to scale to millions of transactions per second, eliminates user fees and allows for quick and easy deployment of decentralized applications[11].

Although the EOSIO Software can be used to create both private and public Blockchains, permissions are an optional feature of the permission-less Blockchain. The EOS network offers a built-in authentication system. User accounts, complete with different permission levels and their own locally secured user data, come as a feature of the EOS network. Recovery for stolen accounts is baked into the system with various methods of proving identity and restoring access to compromised accounts.

LEGAL CONSIDERATIONS: Independently of the Blockchain network, it should be noted that national legislation may require that relevant data be physically stored within the jurisdiction where the Blockchain network effectively operates. Is it required that Blockchain network nodes be physically placed within a specific jurisdiction? This could be challenging, for example, in cases where computing power and network capacity are provided via cloud servers. In this case, servers are very likely outside a particular jurisdiction. Such considerations may be relevant when a Blockchain network handles sensitive data, such as medical records.

(9) See https://eos.io/

(10) The vision of EOS is that everyday users will be able to run dapps (decentralized applications) from mobile devices with no specialized knowledge – just as they currently do with apps downloaded from any app store.

(11) See https://eos.io/faq as of 10/2018

4

Blockchain and Climate Policy within Mexico

4. Blockchain and Climate Policy within Mexico

In order to inform the Mexican Government about the potential applications and implications of Blockchain technology for climate policy making, the following chapter analyzes the technology's potential for three key areas of today's climate economics:

- an Emissions Transaction Registry;
- a governmental monitoring system for tracking climate mitigation efforts; and
- a system that supports the MRV of climate finance.

All the above-mentioned instruments involve multiple players at international (i.e., donors, recipients and loan lenders) and national levels (i.e., government and private sector organizations). These actors require trustable systems to ensure certainty over their investments, not only from the economic side of the transaction but also regarding the environmental effects. The Blockchain technology may provide the architecture for such trustable systems (see p. 51f., Conclusion of GIZ 2018).

These three specific instruments form the backbone of Mexico's climate policy framework and represent some of the most common challenges associated with the implementation of climate instruments in developing countries, including the lack of transparency and the difficulty of administering tracking systems.

The assessment methodology and its results could serve as a starting point for other jurisdictions dealing with similar issues.

4.1 General Evaluation Criteria for Climate Policy

Blockchain technology enables the transparent transaction of digital values by tokenizing (representing) real-world assets. Therefore, it may support the operation of completely new markets (e.g., via tokenization of real-world assets) and economic interactions, and provide infrastructure for the Internet of Things (IoT/machine-to-machine communication).

To determine whether Blockchain technology is the right tool to solve a particular problem, focus should be on the Blockchain-specific governance approach. If Blockchain technology is not the only solution to a given problem, it is very likely that a centralized database can solve the problem more efficiently.

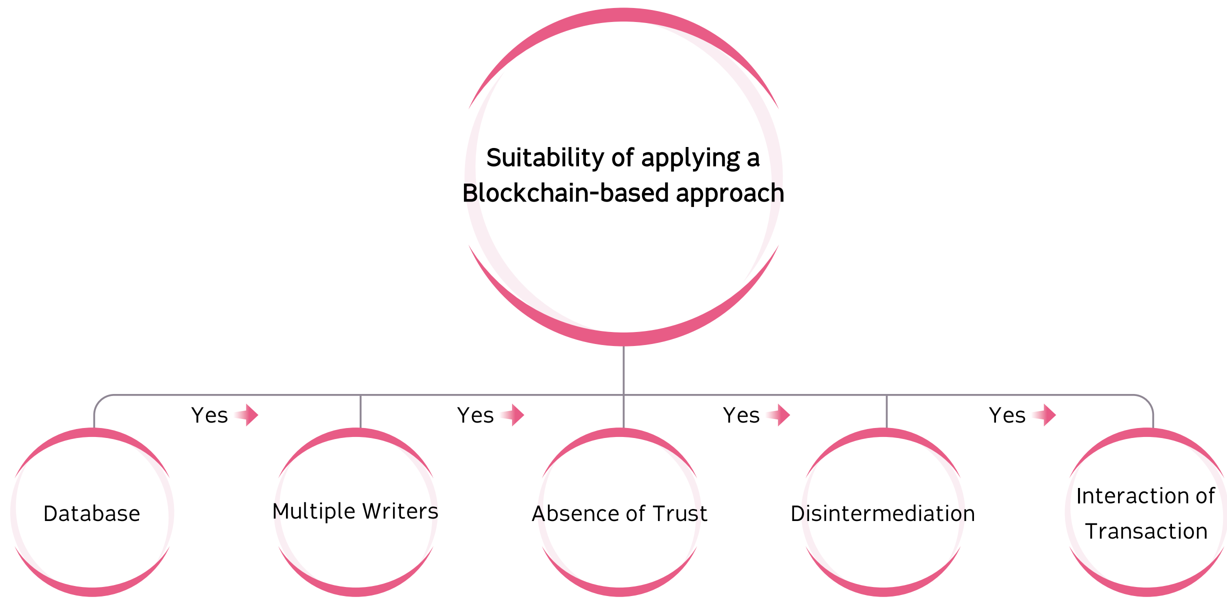
If Blockchain technology is not the only solution to a given problem, it is very likely that a centralized database can solve the problem more efficiently.

Blockchain technology is not a silver bullet for climate policy instruments; this section provides orientation on the different features to consider when analyzing the potentials of Blockchain for climate policy. Generally speaking and as a simple rule of thumb, Blockchain should only be pursued if other conventional approaches have failed to deliver the expected benefits, or if Blockchain can offer higher quality benefits at comparable or lower cost (p. 71, CLI 2018). The core features (and benefits) of Blockchain technology generally point to suitable use of climate issued cases in need of:

- **Disintermediation:** Cutting out trusted third parties could increase overall efficiencies, especially in cases where the underlying problem is not centralized in nature.
- **Cross jurisdiction:** Where it might not be possible to find or create a trusted third party, or it may be too inefficient to go through a trusted third party.
- **Reporting and compliance applications:** Reporting, especially with regards to regulatory compliance, can be moved from time-discrete (e.g., annual) reporting to a continuous consensus process through permission-less or public permissioned Blockchains (p. 18, BORN 2018).

In a subsequent step, Blockchain approaches should be examined against the existing or planned infrastructure/architecture. The figure below proposes a checklist[12] against which a climate policy instruments can be examined:

Figure 1. Suitability for Blockchain-based approaches



Source: Author's own work.

1. **Database:** Does the selected climate instrument involve a (relational) database? Multiple databases?
2. **Multiple Writers:** Does the case involve more than one entity/participant who is generating the transactions that modify the database? If the writers all mutually trust each other (i.e., no participant is malicious now or in the future), a database with shared writing access is likely the better solution.
3. **Absence of Trust:** Does the user accept modification to the joint state of the shared database by another user without further proof?
4. **Disintermediation:**[13] Is there a valid reason/need for removing trusted intermediaries (the "middleman")?
5. **Interaction of Transaction:** Are transactions dependent on one another? Transaction interaction is required by all kinds of database systems, particularly in multi-user systems involving the exchange of assets or goods. If transactions do not interact with one another, it is more effective to use a "master/slave" database, in which one "master" node acts as the champion of validation and approval for a certain subset of transactions that "slave" nodes carry out. If transactions do rely on one another, determining how to distribute corresponding transactions among master nodes becomes quite difficult, resulting in the need for something like a Blockchain to alter the collective state of the database.

(12) The checklist is based on in-depth exchanges with IT developers and a comprehensive desk review. For further documentation, please see Wüst and Gervais in "Do you need a Blockchain?" 2018, https://eprint.iacr.org/2017/375.pdf; Greenspan in "Avoiding the pointless blockchain project" 2015, https://www.multichain.com/blog/2015/11/avoiding-pointless-blockchain-project/; and Wesley in "Building It Better: A Simple Guide to Blockchain Use Cases" 2018, https://blockchainatberkeley.blog/building-it-better-a-simple-guide-to-blockchain-use-cases-de494a8f5b60

(13) Blockchains operate without a central "gatekeeper" that verifies transactions and authenticates their respective sources. Instead, the definition of "transaction" is extended to include a proof of authorization (digital signature) and a proof of validity (state check). Transaction can therefore be independently verified/validated by every node (which also maintains a copy of the whole database).

4.2 Assessment of Selected Blockchain Platforms for Climate Instruments

The evaluation of the usability of a specific Blockchain platform depends on the characteristics of the respective climate instrument. Criteria such as programmability, operating costs, security, documentation, usability and trustability should be checked carefully before developing instruments on a Blockchain.

The Blockchain networks identified in Chapter 2 have been assessed in GIZ 2018 (p. 29f.) against the criteria mentioned above. The assessment concluded that Ethereum and Hyperledger appear to be the most suitable Blockchain platforms for climate instruments. The assessment, however, was not exhaustive, meaning that other platforms may be appropriate for the deployment of climate instruments.

4.3 Blockchain Attributes Applicable for Selected Climate Instruments

4.3.1 Token Generation

The ability to create, send and receive tokens is a common feature required by all of the analyzed climate instruments. The generation of such token is enabled by smart contracts. Smart contracts are deterministic exchange mechanisms controlled by digital means that can carry out the direct transaction of value between untrusted agents (SZABO, 1997).

LEGAL CONSIDERATIONS: The generation of tokens may be subject to specific regulations from financial authorities – Anti-Money Laundering (AML)/Know Your Customer (or Client) (KYC). Most financial regulation nowadays requires the implementation of customer screening processes. These processes protect against accidentally onboarding high-risk customers. Ensuring that individuals can provide legitimate proofs of identity such as government-issued passports or driver's licenses is a common practice towards building a legal and trustworthy ecosystem in the Blockchain space.

Mexico's Law to Regulate Financial Technology Companies, enacted in March 2018, includes a chapter on operations with "virtual assets," commonly known as cryptocurrencies. This chapter defines virtual assets as representations of value electronically registered and utilized by the public as a means of payment for all types of legal transactions, which may only be transferred electronically.

In addition, Mexico has enacted a law extending the application of its money laundering laws to virtual assets, thereby requiring financial institutions that provide services related to such assets to report transactions exceeding certain amounts.

Mexico's central bank, the Bank of Mexico, is granted broad powers under the Law to regulate virtual assets, including specifying those virtual assets that financial companies are allowed to operate within the country; defining their particular characteristics; establishing the conditions and restrictions applicable to transactions with such assets; and authorizing financial companies to perform transactions with virtual assets(14). The level of governance will determine the role of tokens issued by governmental programs. The question here will be whether SEMARNAT will be clustered as "financial institution" when overseeing the issuance tokens related to climate instruments. If that is the case, then SEMARNAT would have to establish mechanisms to comply with AML/KYC requirements(15).

(14) More information on current legislative statutes (07/2018) can be retrieved from The Law Library of Congress. See http://www.loc.gov/law/help/cryptocurrency/cryptocurrency-world-survey.pdf

(15) The lack of fincancial safeguards (such as AML/KYC) led to a series of fraudulent incidents in the European ETS between 2009 and 2012. Since 2016 financial safeguards are fully applicable within the EU ETS; see https://ec.europa.eu/clima/policies/ets/oversight_en

[i] See http://www.cofemersimir.gob.mx/portales/resumen/46117#

4.3.2 Efficiency in MRV frameworks

Monitoring and reporting of verified GHG emissions can take months or even years. MRV processes are still very manual and require significant human skills (from technical and financial auditors). This results in high administrative costs, which increase climate action costs. Governments, project developers, emitters or financial entities can automate processes by writing them into a smart contract.

MRV systems (for tracking climate mitigation efforts) could benefit from automated processes. When the input conditions of the smart contract trigger a pre-defined event – for example, the generation of wind energy – the produced electricity can immediately be calculated against carbon levels on the grid, and a respective carbon reduction can be determined and issued.

Smart contracts may also support the development of new automated climate finance instruments. Input conditions of a smart contract (e.g., in case of climate risk insurance) caused by natural disasters like draughts, flooding or hurricanes can automatically trigger the claims process. Measurable parameters of the event, such as wind speed, location of a hurricane or days of rain, can be recorded onto the Blockchain. Depending on the smart contract's complexity, as the parameters cross certain pre-agreed thresholds, the claims process is immediately triggered, and the financial payout can be automatically delivered.

Input conditions of a smart contract (e.g., in case of climate risk insurance) caused by natural disasters like draughts, flooding or hurricanes can automatically trigger the claims process.

Not only does the smart contract reduce the administrative costs associated with fulfilling such policies, but – due to the distributed nature of the smart contracts on the Blockchain – all stakeholders and regulatory bodies trust in the transparency of the process. Any Blockchain platform under consideration should therefore be able to execute smart contract functions.

Conclusion: Considering the benefits of smart contracts, **it should be ensured that the selected Blockchain platform allows for the execution of smart contract functions.**

4.3.3 Centralized Governance for Authority Overseeing

A permissioned Blockchain is meant to be implemented among participants that are pre-approved by a designated authority. User profile maintenance (for approval or cancellation of participation) is controlled by this access-control layer.

The control layer also removes the need for the energy intensive PoW mechanism and increases the flexibility in terms of overall governance and energy efficiency.

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Some doubt whether **a permissioned Blockchain** still deserves to be associated with the overall features of Blockchain technology, namely decentralization. Numerous **critics** argue that a permissioned Blockchain is **"just" a special type of a database**. Blockchain is not really "just a database"; a key difference is that no database permits every participant to routinely enforce system rules on demanded changes. This is what permissioned Blockchains do. Records in permissioned Blockchains can only be altered when the changes are performed in accordance with the system rules. For example, if the system rules say that the record can only be changed with a particular digital signature, then the latter requirement is necessary in order to change the data. In a conventional database, the administrator can simply modify that record. But on a permissioned Blockchain, it is impossible to change the record without a digital signature.

A centralized database can always be programmed like a Blockchain and behave as such. However, by choosing Blockchain technology, by design, it is the decentralization that is acquired and that makes it **highly secure** and more resilient against accidental failures (no single point of failure/attack). Data remains reliably available even if a large portion of the network is offline. **Colluding** participants find it much **harder to act in ways that benefit them at the expense of other participants** through, for example, censoring, disrupting, blacklisting, restricting, seizing or freezing transactions, or preventing users from participating in the network (BORN 2018).

5

Potential of Blockchain for Emissions Trading Systems

5. Potential of Blockchain for Emissions Trading Systems

The features of Blockchain technology provide suitable elements of future Emissions Trading Systems – especially when taking into account the complexity of this policy instrument.

The table below gives an overview of the current challenges of Emissions Trading and the associated potential for Blockchain technology. For further information, see p. 32ff., GIZ 2018.

Table 3. Blockchain Potential for ETS Design Elements

ETS Element	Challenge	Potential for Blockchain
Scope	Currently limited scope, with only big industrial emitters covered due to high transaction costs	Enhanced scope possible due to lower transaction cost enabled by Blockchain-based automatization of ETS processes
Emissions Cap	Emission caps are the outcome of political decisions that may negatively affect long-term planning.	Embedding allocation rules and allowance amounts on a transparent Blockchain protocol may strengthen the frameworks of ETS.
Distribution of Allowances	Distribution of allowances via auctioning is not transparent – this could become a problem for linked ETS.	Blockchain-based auctioning could serve as gateway or a joint layer for a network of connected national auctioning platforms.
Offset Policies	Risk of double counting	A Blockchain registry jointly run by countries would ensure that generated offsets are coded into the Blockchain and reconciled with national registries.
Trading Mechanism	White-collar crimes like securities fraud, insider trading, money laundering, transfer mispricing and Internet crimes	Risks may be minimized on permissioned Blockchains (with shared ledgers).

Source: Author's own work.

A crucial tool for any Emissions Trading System is an Emissions Transaction Registry. The chapter concludes with an evaluation of the suitability of applying Blockchain when developing an Emissions Transaction Registry. An Emissions Transaction Registry forms the administrative backbone of an ETS. These systems establish markets where limits are set on the type and amount of GHG industrial/economic sectors are allowed to release. An equal number of (digital) allowances to release GHG are created and distributed to the ETS participants at the beginning of a previously defined period. Companies with a surplus of allowances can sell their shares to companies that have more emissions than allowances. In order to manage the transactions (allocation, transfer, surrender, cancellation) of digital allowances, an Emissions Transaction Registry has to be set up, similar to a banking system.

The registry is an IT database that assigns a unique serial number to each unit of an allowance and tracks those serial numbers from their issuance onward.

The registry is an IT database that assigns a unique serial number to each unit of an allowance and tracks those serial numbers from their issuance onward. This includes information on who has been issued allowances, who holds those allowances as well as other units, and when and from where units are surrendered or cancelled. Market participants (emitting companies, financial markets, etc.) sign up for the registry and create an account where their units are stored.

The potential for tokenization in an Emissions Transaction Registry is obviously very high. The digital allowance of emitting a specific amount of GHG already constitutes the representation of a real-world value (here the right to pollute).

The potential for tokenization in an Emissions Transaction Registry is obviously very high. The digital allowance of emitting a specific amount of GHG already constitutes the representation of a real-world value (here the right to pollute). A token may represent:

- the allowance to emit one ton of CO_2-eq (CO_2 equivalent);
- the verified emission of one ton CO_2-eq; or
- the verified reduction of one ton CO_2-eq.

5.1 Emissions Transaction Registry in Mexico

Mexico intends to start a pilot phase of emissions trading. The pilot will run for three years, before transitioning to an Emissions Trading System. The pilot phase's main objective is for all stakeholders to familiarize themselves with how an ETS works. The ETS definitions are based on the General Law on Climate Change and the proposal for the regulatory framework of the pilot phase.[i]

The legal framework provides for the determination of

- the scope of the ETS;
- the total cap on emissions during the pilot phase;
- the distribution of allowances;
- the use of offsets;
- provisions about the trading mechanism; and
- monitoring, reporting and verification procedures.

The regulatory framework is close to completion and expected to enter into force in 2020. From 2017 to 2018, interested participants learned about the principles of emissions trading through a series of trainings as well as through a 10-month simulation of an emissions trading sponsored by PMR. The simulation allowed for simulating trading activities, including the virtual pricing-in of carbon costs into production and return-on-investment calculations of modernization efforts.

Apart from establishing the legal framework and building capacities within the future regulated entities, the Mexican Government is analyzing options for setting up the technological infrastructure for operating the ETS, particularly the Emissions Trading Registry. One of these options is the use of Blockchain technology for its future Emissions Trading Registry. In the following, the suitability of this option will be analyzed in more detail.

5.1.1 Suitability of Blockchain Technology for an Emissions Transaction Registry in Mexico

The evaluation follows the checklist criteria from 4.1 above.

Does the Emissions Transaction Registry involve a database?

Yes! An Emissions Transaction Registry is an online database that records serialized carbon units (e.g., allowances, offset units, etc.) and any other information specific to the carbon unit required by policy. It also enables the transfer of units between multiple account holders on the registry, so-called "internal transfers," and provides for the transfer of units to another registry, referred to as "external transfers" (p. XII "Emissions Trading Registries" in WORLD BANK 2016).

Does the registry involve multiple writers?

Yes! Emission Transaction Registries do involve various participants with different backgrounds (emitters, government, auditors, financial institutions). By adding transactions into the registry, these multiple writers constantly modify the database.

Is there absence of trust in a registry environment?

Yes! Emission Transaction Registries need to work along pre-defined rules. These rules need to be enforced if necessary. Entries in the registry do have legal consequences – for example, they can disclose ownership rights. Modifications to the emissions transaction database are not based on trust; the economic and political incentives of the database's users are too different. In addition, non-compliance of entities covered by the ETS may lead to severe consequences. Any Emissions Transaction Registry has to perform its tasks based on common rules and in such way that its users can rely on the accuracy of the database's content without having to trust its direct counterpart.

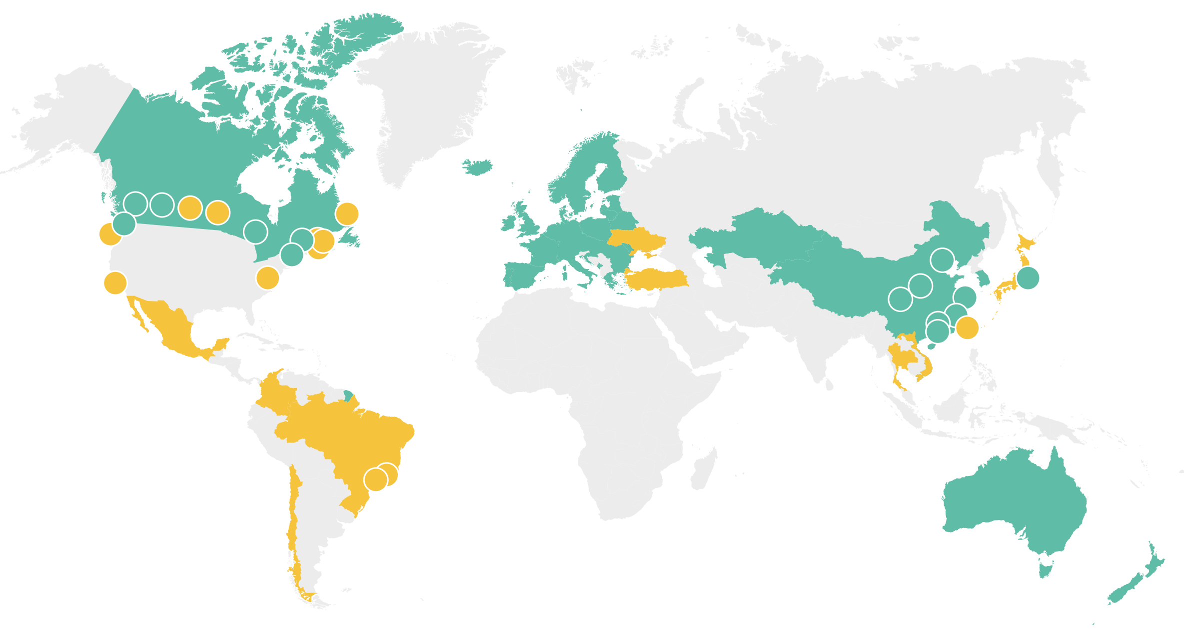
Any Emissions Transaction Registry has to perform its tasks based on common rules and in such way that its users can rely on the accuracy of the database's content without having to trust its direct counterpart.

Is there a valid reason for removing the "middleman" (disintermediation)?

The "middleman" in the case of an Emissions Transaction Registry is the intermediary that runs the registry on a technical level. Blockchain technology could be implemented to provide for the technical means of transferring allowances and offsetting credits between different accounts. However, Blockchain technology and its decentralized architecture do not outweigh the conventional centralized database approaches of today's ETS registries. Moreover, the intended effects of any Emissions Trading System may only be achieved if the system is governed by a strong oversight authority. The allocation of allowances, the opening and closing of ETS registry accounts or the recognition of offset credits are, first of all, sovereign tasks of the government. On a decentralized Blockchain network, these tasks would be more complex than on a conventional centralized database. On the other hand, there are some significant advantages of decentralized processes within an Emissions Transaction Registry. The generation of allowances and offset units via pre-defined smart contracts could add a significant level of transparency into the ETS process and facilitate the linking with other systems or programs.

The allocation of allowances, the opening and closing of ETS registry accounts or the recognition of offset credits are, first of all, sovereign tasks of the government. On a decentralized Blockchain network, these tasks would be more complex than on a conventional centralized database.

Figure 2. Emission trading systems (green: implemented/yellow: in preparation)



Source: World Bank 2018[16]

(16) See https://carbonpricingdashboard.worldbank.org/map_data (as of 10/2018)

The growing number of Emissions Trading Systems (see map above) as well as the 2015 agreed framework for cooperative approaches of the Paris Agreement (which serves as guidance for the international transfer of mitigation outcomes)[17] are strong signs that ETS linking will increase in the future.

As already indicated, Blockchain technology should only be pursued if other conventional approaches have failed to deliver the expected benefits, or if it can offer higher quality benefits at comparable or lower cost. That is particularly relevant for the role of the middleman. So far, conventional registry approaches have served their purpose. All current ETS registry approaches have in common that their operations are centralized (via a designated Registry Administrator) and only occur within their system boundaries. Whether the nationally administered and centralized governance structures seamlessly link with other systems and programs remains to be seen. In any case, the decentralized elements show strong benefits with respect to linking of Emissions Trading Systems[18]. The following table lists both advantages and disadvantages of a centralized and a decentralized registry architecture.

Figure 3. Centralized and decentralized registries – benefits and disadvantages

Advantageous | Neutral | Disadvantageous

	Allowances/Offset Units	Account Management
Centralized Executed by Registry Administration	Allowances/offset units are reflected via database entries by Registry Administrator. (Advantageous)	Accounts are managed by Registry Administrator; he also provides associated services (e.g., lost password, hotline, etc.). (Advantageous)
	Changes (e.g., reflecting allocation/surrendering) to database are possible at all times – the supply power is centralized. (Neutral)	
	Use of data beyond ETS is relatively limited – this increases complexities for linking system with other systems/ programs outside the registry boundaries (avoidance of double counting of allowances/offset units). (Disadvantageous)	
Decentralized Executed by smart contract and network protocol	High interoperability since fungible/non-fungible token approach may offer efficiency gains through increased interaction of data with other databases (linking). (Advantageous)	Management of private keys for allowances/offset ledger not trivial (e.g., lost private keys cannot be recovered without considering pre-defined additional security measures). (Disadvantageous)
	Allowances/offset units are reflected via tokens within a smart contract – once the total amount of allowances/offset units is generated, any later adjustment will mean a new setup of the underlying smart contract. (Neutral)	

Source: Author's own work.

The benefits and advantages of both centralized and decentralized registry systems are relatively balanced. The centralized approach is well in line with governmental core tasks such as allocation of allowances and management/supervision of registry accounts. When it comes to the transaction data itself (allowances, offset units or verified emissions), it is the tokenization of units related to the ETS that promise new and enhanced capabilities, including increased interoperability.

However, ETS data may be used for more than exchanging emission quotas. Linking ETS data to GHG inventories via **a hybrid approach** combining a permissioned Blockchain (token transaction) and a centralized layer (account management) can automate processes, lower transaction costs of ETS entities and facilitate international linking to other market-based systems. The following section 4.1.2 contains a description of such a hybrid approach using an analogy to crypto exchanges, a real-world use case from the financial sector.

(17) See Article 6.2 of the Paris Agreement

(18) See, for example, Macinante et al. in "Networked Carbon Markets: Permission-less Innovation with Distributed Ledgers?" 2017, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2997099

ETS data may be used for more than exchanging emission quotas. Linking ETS data to GHG inventories via a hybrid approach combining a permissioned Blockchain (token transaction) and a centralized layer (account management) can automate processes, lower transaction costs of ETS entities and facilitate international linking to other market-based systems.

Interaction of transaction required within registry?

Yes! Transactions within an Emissions Transaction Registry depend on each other. Allowances and offset units, for example, are both eligible for achieving compliance in an ETS. However, such compliance needs to respect the pre-defined limits to offset use. Hence, allowances and units depend on their relative interaction when being surrendered. Interaction of transactions are also foreseen in cases where an Emissions Transaction Registry holds units representing emissions that would have to be neutralized by dedicated allowances.

5.1.2 A Hybrid Approach – The Crypto Exchange Analogy

The comparison of centralized versus decentralized registry approaches above revealed that both sides have their benefits and disadvantages. To take advantage of the best features from each approach, a hybrid approach is proposed.

Ownership of cryptocurrencies is expressed via access to the private key of the dedicated cryptocurrency/token (e.g., Bitcoin, Ether, Litecoin, etc.). Private keys are managed by so-called "**online wallets**." Wallets can be downloaded online and installed on a desktop or smart phone. These wallets hold the information to the ledger entry where the crypto-coin is saved. Only the owner of the private key can change the entry of the ledger. Generally, there is no way to recover a private key once it is lost. Decentralized networks by definition do not have dedicated hotline services. Decentralization comes with a high level of self-responsibility.

Platforms like Kraken[19] or Coinbase,[20] where cryptocurrencies can be bought and sold, offer their customers accounts (user name and password access) on their exchanges to buy, sell or simply hold cryptocurrencies like Bitcoin or Ether. In these cases, the private keys to the respective coins (tokens) are stored on their (Kraken or Coinbase) servers. In technical terms, it is the platform that has access to the private keys of the respective tokens. Every account holder at Kraken or Coinbase can withdraw token from the platform. The benefits of these centralized exchanges are their positive user experiences, including forgotten password services and the fact that most of them are insured against hacks and loss of private keys.

The business approach of crypto exchanges could well serve as a blueprint for the architecture of future Emissions Transaction Registries.

(19) See www.kraken.com
(20) See www.coinbase.com

The business approach of crypto exchanges could well serve as a blueprint for the architecture of future Emissions Transaction Registries. It would combine the best from both sides, centralized and decentralized(21). Allocation of allowances, acknowledgement of offset units and registry account management would be managed on the centralized database (Transaction Layer). The generation and distribution of tokens (with different characteristics) on dedicated administrative wallets happens on a permissioned Blockchain (Blockchain/Settlement Layer).

The Governing Layer needs to ensure that the amount of allowances, offset units and emission units correspond to the total amount of tokens generated on the Blockchain Layer. In the case of national trading activities, transfers may only need to be recorded on the Transaction Layer within the centralized database. In situations where allowances or offset units are outside the boundaries of the ETS, the respective units have to be effectively marked as booked-out on the Transaction Layer, and the token needs to be withdrawn from the registry platform (e.g., the Blockchain/Settlement Layer).

The advantage of this hybrid model is that the capabilities of the Blockchain Layer may be gradually and subsequently enhanced by the respective development of the underlying smart contract (rules setting, fixation of token specifications, etc.). The majority of ETS activities will take place on the centralized Transaction Layer. The initial question regarding the need for eliminating the middleman can therefore not be answered with a simple yes or no. The middleman is required to ensure the proper functioning of the account system as well as to maintain flexibility with regard to ETS events like allocation of allowances or acknowledgment of offset units.

5.1.3 Evaluation Result: Emissions Transaction Registry

The evaluation concluded that the application of Blockchain technology for the setup of an Emissions Transaction Registry is a suitable approach. Based on a hybrid approach, it is suggested that Blockchain technology (permissioned Blockchain) be applied for the generation of different tokens that represent

- a fixed amount of emission allowances;
- a dynamic number of offset units (to represent emission reductions outside covered ETS entities; further rules to be determined); and
- verified emissions of ETS entities.

These tokens will be held in dedicated administrative wallets (on the Blockchain/Settlement Layer). They are linked to companies' accounts on the centralized Transaction Layer.

For more detailed considerations of the registry use case on a Blockchain, see annex 2.

(21) It has to be mentioned here that the assumptions of the hybrid approach may be more relevant for activities on the Ethereum Blockchain. The Hyperledger approach may not need specific a centralized layer for account management.

6

Potentials of Blockchain for Tracking Climate Mitigation Efforts and Climate Finance Flows

6. Potentials of Blockchain for Tracking Climate Mitigation Efforts and Climate Finance Flows

Within the context of climate change, the term MRV stands for the monitoring/measuring, reporting and verification of GHG. MRV is the process of collecting monitored data and collating it in line with standardized or non-standardized approaches to report progress on emissions reductions, the impact of a given measure or policy, or climate finance flows. MRV systems are an essential element of climate policy, as they provide transparency to stakeholders on the status quo and support ambition raising. For the purpose of this paper, we distinguish between three types of MRV systems (adopted from WRI 2016):

- MRV of **GHG emissions**, conducted at national, organizational and/or facility level to understand an entity's emissions profile and report it in the form of an emissions inventory.
- MRV of **mitigation actions** (e.g., policies and projects) to assess their GHG effects and sustainable development (non-GHG) impacts as well as to monitor their implementation. This type of MRV focuses on estimating the change in GHG emissions or other non-GHG variables.
- MRV of **support** (e.g., climate finance, technology transfer and capacity building) to track provision and receipt of climate support, monitor results achieved and assess impact.

This chapter analyzes the potential of Blockchain technology for all three types of MRV, with sections 6.1 and 6.2 focusing on MRV systems for GHG and climate policies, and section 6.3 focusing on MRV systems for climate finance.

6.1 Blockchain and MRV of Emissions and Mitigation Actions

The identification of challenges and the associated potentials for a Blockchain approach in the context of MRV of emissions and mitigation actions are summarized in the table below. For further information, see p. 41ff., GIZ 2018.

Table 4. Blockchain Potential for MRV of Emissions and Mitigation Action

Challenge	Potential for Blockchain
Lack of transparency	Greater transparency of how the data is collected and reported and how the combination of parameters leads to the determination of GHG reductions through the use of shared ledgers displaying relevant MRV parameters.
Costly and impractical	Coupling the benefits of a decentralized database with smart contract applications and IoT can help automate processes, thus lowering transaction costs and reducing complexity.
Time consuming	Blockchain technology and decision making via smart contracts makes IoT more attractive; verification can become a rolling approach where data is checked automatically or in real time.
Limited exchange of MRV frameworks (data silos)	Storage of MRV raw (primary) data on a Blockchain (following a joint protocol) could lay the ground for connecting MRV frameworks and end the era of data silos.

Source: Author's own work.

6.2 Governmental Monitoring System for Climate Policies

Objective: The objective of the monitoring system is to ensure that the planning, implementation and execution of climate policies for mitigation and adaptation take place at the community, sub-national and federal level as required by the respective laws. The system also provides an overview of the state of current Nationally Determined Contribution (NDC) implementation.

Characterization: The monitoring of climate policies involves compiling data to track the development and progress of such policies at the community, sub-national and federal level. The federal government may also use some information (policies/measures with highest GHG mitigation performance) for reporting obligations under the United Nations Framework Convention on Climate Change's (UNFCCC) transparency framework.

Potential for tokenization: A governmental system for monitoring climate policies shows some potential for tokenization. Progress of mitigation policies, for example, can be expressed in tokens representing verified reductions of GHG emissions. These tokens can be used as a standardized vehicle for information at all applicable governmental levels.

6.2.1 Governmental System for Monitoring Climate Policies – Mexico's SIAT-NDC

As indicated at the beginning of this chapter, the concrete evaluation of the suitability focuses on an MRV system for climate policies in Mexico. The evaluation considers the current situation of relevant information flows between the competent agencies on the federal and sub-national levels within the Mexican Government. SEMARNAT is the competent authority that provides information regarding Mexico's progress related to its NDC under the Paris Agreement and the UNFCCC. SEMARNAT manages, on a federal level, the registration of GHG emissions (or reductions) that occur in the context of the following mitigation frameworks:

- Future Emissions Trading System
- National Emissions Registry (RENE)
- Nationally Appropriate Mitigation Actions (NAMAs)
- Clean Development Mechanism (CDM) until 2020

SEMARNAT developed the Special Program on Climate Change (PECC) to identify climate-related goals on a federal level. To track the progress regarding the program, the government developed an electronic tracking tool, the Information System for Transparency of the Special Program on Climate Change (SIAT-PECC), which provides information on the implementing authorities and the status of every climate action. According to SEMARNAT, a similar tracking tool could be used for tracking NDC progress. To achieve a comprehensive monitoring and reporting of climate actions, SEMARNAT is working on the Information System for Transparency of the Nationally Determined Contributions (SIAT-NDC), an NDC progress tracking tool that integrates sub-national and federal GHG and policy reporting.

Although several Mexican states have established their own MRV systems to track progress on emissions reductions at a sub-national level, common formats or standards remain largely absent. Increased collaboration is therefore envisaged by both federal and sub-national agencies. In that context, SIAT-NDC should eventually serve as the common registry to inform the federal and sub-national government departments on GHG emissions. The approach will be introduced to the National System on Climate Change (SINACC), a commission that brings together representatives from all Mexican states and the federal government. The objective of this examination is to identify plausible niches where applications of Blockchain may be suitable and reasonable. While SIAT-NDC will also include adaptation measures, the following examination only focuses on the mitigation side.

6.2.2 Suitability of Blockchain Technology for SIAT-NDC

The evaluation of the suitability of applying Blockchain technology to SIAT-NDC follows the checklist criteria from section 3.1 above.

Does SIAT-NDC involve a database?

Yes! SIAT-NDC involves a database where information on mitigation policies and their associated outcomes are registered. The policy outcome can be expressed in GHG reductions or in other indicators (e.g., number of studies, meetings, etc.). Currently, it is up to the responsible (sub-national or federal) authority to define corresponding reporting procedures.

Does SIAT-NDC involve multiple writers?

Yes! SIAT-NDC involves multiple writers. Although all writers may be associated with the public sector, they modify the dedicated database while executing sovereign powers. As such, the right to write by representatives from sub-national governments is not supervised or guided by the federal government. Both writing levels operate on the same hierarchy and will have to respect each other's entries.

Is there absence of trust in a sub-national/federal MRV environment?

No! It is unclear whether "trust" is the appropriate term for this evaluation point. However, the acting participants are operating on the same "side" – the public sector. In the context of this examination, it does not make a difference whether the sub-national government has leeway in designing GHG mitigation policies, including its associated monitoring and reporting procedures. Both actors in question operate under a framework of sub-national, national and, eventually, constitutional laws. This situation does not require trust since it is (on all levels) regulated by legislative (and executive) guidance. This guidance fosters a trustworthy environment.

Is there a valid reason for removing the "middleman" (disintermediation)?

No! A middleman or intermediate could be mandated to manage the SIAT-NDC tool. This does not have to be a private company, as it can be delegated to a governmental authority under the supervision of an oversight board. In fact, SINACC could be the appropriate and legitimate institution to mandate a respective middleman to run SIAT-NDC.

Interaction of transaction required within SIAT-NDC?

No! Transactions or better database entries within SIAT-NDC would not depend on each other. As indicated above, sub-national and national authorities are acting on the same hierarchy where no actor may modify the entry of the other one. A transaction dependence could be assumed in cases where data entries would be linked to specific claims or even sanctions – for example, if SIAT-NDC would provide the basis for an incentive mechanism[22]. However, the objective of SIAT-NDC is not "incentivizing" mitigation actions,[23] but to provide for a national transparency mechanism to enable the communication of relevant mitigation outcomes internally and externally – for example, to the UNFCCC.

6.2.3 Evaluation Result: SIAT-NDC

The evaluation concluded that SIAT-NDC, in its current form and context as a tool for monitoring and reporting of climate relevant data, would not benefit from a Blockchain-based architecture. In order to ensure a flawless exchange of climate relevant data between sub-national and federal governments, a conventional data management system appears to be more suitable. The features associated with Blockchain would not improve overall reporting. An increase in the credibility of governmental data can be achieved through internal or external audits and evaluations, if the government finds it necessary.

SIAT-NDC, in its current form and context as a tool for monitoring and reporting of climate relevant data, would not benefit from a Blockchain-based architecture.

(22) Reason for incentivizing specific database entries would be, for example, the aim to inspire a race to the top among different sub-national states in terms of promoting specific policies or technologies.

(23) Another objective of SIAT-NDC is to provide for a reporting tool as required by law. In addition, an incentive mechanism could lead to unfair competition, due to considerable differences between the sub-national states in Mexico (income, population, cultural, geographical, among others).

6.3 Blockchain and MRV of Climate Finance

Climate finance is understood as the flow of international and national public and private funds towards activities that reduce or mitigate GHG emissions or help communities adapt to the impacts of climate change. Climate finance will also play an important role in helping developing countries meet the United Nations (UN) Sustainable Development Goals (SDG) by 2030. The distribution and tracking of global development and humanitarian aid funds remain complex, opaque and hugely inefficient. Transfers can take weeks to arrive and associated losses are not uncommon.

The identification of challenges as well as the associated potentials for Blockchain approaches in the context of MRV of climate finance are summarized as follows:

Table 5. Blockchain Potential for MRV of Climate Finance

Challenge	Potential for Blockchain
Lack of transparency due to weak infrastructure, capacity limitations and cash-based systems	Functions of a smart contract can be displayed in code on the Blockchain for all network participants to check. This way, every participant can clearly anticipate the agreed funding processes.
Many intermediaries, high costs and risk of corruption	Maintaining a shared ledger facilitates the corresponding requirements of bookkeeping and accounting for climate finance. It may decrease the number of intermediates and associated transaction costs, and decrease risks of corruption.
Overlap of different donors	Overall tracking of international funding, including a clear reference to participating donors, could be enabled by executing funding decisions along pre-defined conditions recorded on distributed ledgers.
Limited possibilities to link payments to concrete results	Blockchain-based tokenization can improve results-based payments systems, where a token may represent the verified reduction of a specific amount of GHG emissions or another tangible sustainable development claim.

Source: Author's own work.

Within the Mexican context, in order to maintain some level of oversight, the National Registry for International Development Cooperation (RENCID) was created. Led by the Mexican Agency for International Development Cooperation (AMEXCID), RENCID monitors finance flows for international cooperation. Other climate-finance-related MRV mechanisms do not yet exist in Mexico. In 2017, GIZ started working alongside the National Banking Association (ABM) to develop an MRV system for climate finance flows in private banks and establish a green portfolio.

SEMARNAT is in charge of overseeing the "Climate Change Fund" (Fondo de Cambio Climático). It strengthened its management structure during 2017-2018 in order to start rolling out activities in 2019.

6.3.1 MRV System for Climate Finance (and Climate Policies)

Objective: A system that supports the MRV of climate finance has multiple objectives. On the one hand, it aims to strengthen transparency, accountability and trust between the donating and receiving entities. On the other, it assesses the deployment and general use of climate finance. In strengthening efficiency and effectiveness, a climate finance MRV system improves the overall understanding of the scale, distribution and use of both public and private support. It shows who profits from financial support and identifies gaps in regional and sectoral support, for example. It also helps monitor and evaluate trends and progress in climate-related investment.

Characterization: MRV of climate finance is very complex due to the multitude of actors, the proliferation of funds and the financing mechanisms used to channel funding. To ensure use of an appropriate evaluation instrument, the MRV system follows the principles of results-based finance. Broadly defined, results-based finance is a financing modality under which funds are disbursed by an investor or donor to a recipient after a pre-agreed set of results, with achievement of these results subject to independent verification (see p. 1 in "Results-based climate finance in practice," WORLD BANK 2017).

Potential for tokenization: The potential for tokenization of results-based finance is high. In the context of climate finance, a token may represent a monetary claim that would, for example, increase transparency in cross-border transactions. A great opportunity for tokenization may be seen in results-based payment systems, where a token may represent the verified reduction of a specific amount of GHG emissions or another tangible sustainable development target.

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This way, tokenization would not only serve the purpose of providing a tool for results-based finance but would also become the fundament of a dynamic and domestic MRV framework for climate policies.

The access to and the disbursement of climate finance will be facilitated if the intended outcome can be verified. It is therefore proposed to analyze the Blockchain's suitability for an MRV climate finance system that allows for the verification of climate action claims (mitigation and adaptation). This approach supports for the integration of many potential projects. Moreover, the generated data also helps to inform future policy planning.

6.3.2 Verification Platform for Climate Action and Results-Based Finance in Mexico

In the context of financial flows for climate action, verification and validation elements are crucial. They form the fundament of relations between donors and recipients. Unlike government-led monitoring and reporting processes on climate policies and GHG emissions, climate finance is based on verified results-based outcomes. The need for verified outcomes evolves between governments, or between the government and private sector activities and/or multi-lateral entities. Government-led MRV usually lacks formal verification processes.

In the Mexican case, monitoring and reporting of climate-relevant data is limited to quality checks that, for example, identify common errors such as typos or examine extremely high or low values; it should be noted that domestic verification processes in Mexico (for the private sector) were only introduced in 2017. By the end of 2018, about nine verification organizations, including private companies and universities, were registered.

The subsequent discussion on Blockchain application to an MRV of climate finance at national level is based on the assumption that SEMARNAT or another competent authority provide for the use of a decentralized platform for verified climate action claims. Could the platform integrate workflows reflected in SIAT-NDC or RENCID? The data platform architecture could also be set up as a stand-alone tool.

However, the application needs to allow flexibility so that climate action claims can be formulated in conjunction with self-determined verification procedures. A claim may be a specific activity as such (e.g., deployment of a solar heating device) or the outcome of an activity (e.g., the reduction of GHG)[24]. Consequently, the proposed Verification Platform for Climate Action and Result-Based Finance would provide for an infrastructure application rather than for a concrete use case. The platform could support the MRV of various climate policy instruments (e.g., sustainable land and forest management, low carbon technologies, etc.) and facilitate access to international climate finance.

(24) See, for example, https://www.einnews.com/pr_news/461648903/south-pole-ixo-foundation-and-gold-standard-develop-blockchain-application-for-carbon-credit-tokenization

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The final packaging of the claim and its verification are represented in a token, which will be generated every time the pre-defined conditions (claim description and verification procedures) have been fulfilled. The token would have an assigned value based on the quality of its claim and its selected verification level. All token would be stored on the shared ledger – the verification platform. The platform and its accumulated token base provide for a pool of verified data that can be used for policy planning and improvement.

Legal considerations: The verification platform needs to ensure that the accessible data of each token is limited to general information (region, methodology used, general performance indicators) since every token may also carry personalized data (e.g., ownership information, GPS data, etc.).

The tool for creating and verifying claims should be open to all possible stakeholders from the public (sub-national and federal) and private sector (e.g., tool operation could be based on a public private partnership model).

A Blockchain based and tokenized data verification platform would serve various objectives, including:

- awareness raising about the monetary role of a verified climate data bases;
- access to NDC financing (including conditional NDCs);
- the development of best practice approaches for verifying climate action;
- support for the efforts of SEMARNAT to standardize its programs/projects;
- capacity building on MRV for the public and private sector; and
- the generation of data for analyzing and improving policy planning.

6.3.3 Suitability of Blockchain Technology for a Verification Platform

A Verification Platform for climate action and results-based finance could help standardize results-based climate finance. Applying Blockchain technology to climate action claims is expected to facilitate access to climate finance on a national and project level. The suitability of Blockchain technology follows the checklist criteria from above.

Does the Verification Platform involve a database?

Yes! The Verification Platform involves a database. The database stores information about the climate action claims as well as the associated verification processes. The platform will also be the gateway for exchanging the token.

Does the Verification Platform involve multiple writers?

Yes! The platform involves multiple writers. The right to write and modify will be executed by various stakeholders coming from different angles (project developers, auditors, financial institutions, government). In fact, the integrity of such Verification Platforms would require different writers to ensure objective verification of climate action claims.

Is there absence of trust within the climate finance environment?

Yes! The realization of climate action can prove complex. From the perspective of a donating entity, it is crucial to receive credible evidence that its financial contribution led to the intended impact. The motivation for allocating climate finance is linked to the goal of achieving the intended impact. Impact has to be created and formulated so that it can be used beyond the trusted participants of a project activity. In other words, proof of impact needs to be objective; it cannot be based on subjective trust. The climate finance environment would therefore benefit from a trust-less Verification Platform.

Proof of impact needs to be objective; it cannot be based on subjective trust. The climate finance environment would therefore benefit from a trust-less Verification Platform.

Is there a valid reason for removing the "middleman" (disintermediation)?

Yes! The platform is a tool to accommodate various approaches of implementing and verifying climate action. The tool itself should provide for an open data pool that offers access to relevant stakeholders. A core objective of the Verification Platform is to generate data for improved policy planning. This data should be managed jointly by the platform community, rather than by a centralized data management company. The protocol rules of the Verification Platform ensure that climate action claims are only verified once the conditions are met. This approach is also seen as more credible to climate finance donors than assigning the content management to a middleman.

Interaction of transaction required on the Verification Platform for climate finance?

Yes! The transactions of the Verification Platform require interaction. The data entries may (or may not) lead to the creation of a token. Token forwarded to a specific wallet environment will expose information that in turn may trigger execution of further transactions.

6.3.4 Evaluation Result: Verification Platform

The MRV of climate finance could be facilitated and supported by the use of a decentralized platform that enables the verification of climate action claims. These verified claims may be traded/exchanged, for example, in the context of results-based finance in international climate finance. In addition, a shared ledger that gathers all tokens with verified climate action claims serves as a valuable source for data that can be used for future policy planning.

Annex 3 contains information about the configurations and costs of developing a verification project on the Ethereum Blockchain.

7

Pre-Conditions for Implementing Identified Use Cases Using Blockchain Technology

7. Pre-Conditions for Implementing Identified Use Cases Using Blockchain Technology

The analysis for applying Blockchain solutions for climate policy instruments in Mexico revealed a great potential for using the technology for emissions trading as well as for tracking climate finance and climate policy outcomes. The identified instruments for a Blockchain-based approach are an Emissions Transaction Registry and a Verification Platform for Climate Action Claims.

The implementation of both use cases requires the involvement of various stakeholders from the public and private sectors. Their roles need to be carefully analyzed and should be reflected accordingly in the architecture of the respective Blockchain network. Specific pre-conditions may have to be met with the tokenization of emission allowances and verified climate action claims. These tokens may represent digital assets of a specific value. Consequently, financial market provision may apply.

The table below provides a general overview of the institutional and regulatory needs for implementing both approaches on a Blockchain.

Table 6. Overview of Institutional and Regulatory needs for Blockchain Implementation in an Emissions Transaction Registry and a Verification Platform

	Emissions Transaction Registry	Verification Platform
Institutional needs (public sector involvement)	Federal government (environment, industry, IT, finance)	Federal government, sub-national government, communities, academia
Institutional needs (private sector involvement)	Industry and business associations, financial associations, Mexican Blockchain Association[25]	Verification and auditing companies, industry and business associations, financial associations, Mexican Blockchain Association
Regulatory needs related to tokenization activities	Fintech Law Mexico: Ley para Regular las Instituciones de Tecnología Financiera o Ley FinTech, March 9, 2018[26] AML-Law Mexico: Ley Federal para la Prevención e Identificación de Operaciones con Recursos de Procedencia Ilícita Article 17(XVI), Nota de vigencia, D.O.F., October 17, 2012[27]	

Source: Author's own work.

Considerations on the IT requirements for two Blockchain platforms are provided in annex 1. Workflow considerations are discussed in annex 2 (Emissions Transaction Registry) and annex 4 (Verification Platform). Information on the financial needs for the development of an Emissions Transaction Registry is provided in annex 3.

Annex 5 contains a high-level road map for developing a Verification Platform for Climate Action Claims.

(25) In November 2018 the Mexican tech companies Bitso, Volabit, BIVA, GBM, Lvna Capital, ConsenSys and Exponent Capital founded the first Blockchain Association in Mexico. See https://www.forbes.com.mx/nace-la-primera-asociacion-de-blockchain-en-mexico/

(26) Fintech Law Mexico is available at https://perma.cc/SB6N-RQY7

(27) AML-Law Mexico is available at https://perma.cc/4UVN-GM98

8

Conclusion

8. Conclusion

The development of a Blockchain-based Emissions Transaction Registry for Mexico has the potential to facilitate the integration of national as well as international offset programs and may support the linking to other Emissions Trading Systems.

Regarding tracking climate finance and climate action, the analysis identified a Blockchain-based Verification Platform for Climate Action Claims as an appropriate use case. Such a platform can facilitate access to international climate finance since it integrates principles of results-based finance. Moreover, the platform also provides a tool for the sub-national and the federal Government of Mexico to monitor and analyze their climate policies.

The analysis also revealed that Blockchain is part of an ecosystem of digital technologies including big data, IoT and artificial intelligence (AI). In many cases, the combined use of these digital technologies can unlock new, more accurate ways to measure, report and verify climate outcomes at lower transaction costs. Successful Blockchain use cases, especially in the MRV context, will also depend on the readiness of these new technologies.

However, the Blockchain technology is still in its early days. The governance of Blockchain networks needs to be further explored. Integrating the modern means of communication technology for scaling up the effectiveness of climate instruments will be necessary to achieve Mexico's NDC. Decentralizing climate processes (e.g., in emissions trading or in tracking climate mitigation efforts and climate finance) can bring a new level of trust to the complex world of growing climate data.

This development does not come overnight. The analysis shows that designing climate instruments on a Blockchain is a complex endeavor. Building a Blockchain-based infrastructure for MRV systems therefore appears to be an efficient way to gain experiences. It allows for a broad piloting and testing of a variety of climate instruments. Such processes need to be planned carefully and should consider all relevant stakeholders from the beginning.

9

Annex

Annex 1. IT Requirements for Ethereum and hyperledger

Technical considerations	Public Ethereum	Private Ethereum (Quorum)	Hyperledger (Fabric) [1]
Transactions per second of network	20[2]	2,100[3]	100,000[4]
CPU (recommended)	CPU: CPU Intel Core 4th Gen Series or above	See Public Ethereum	Reference to Ubuntu Linux 14.04/16.04 LTS
Memory (recommended)	4 GB or above	See Public Ethereum	2 GB
Storage (recommended)	512 GB or 1 TB SSD[5] or above	See Public Ethereum	25 GB and more
Internet connection (recommended)	50 Mbps or above	50 Mbps or above	50 Mbps or above

(28) IT requirements for Hyperledger (Fabric) applications are difficult to estimate (workload depends on number of transactions, throughput/latency requirements of the network, etc.). The information provided is based on the capacities required by Ubuntu Linux 14.04/16.04 LTS, which is the recommended operating system by the Linux Foundation.

(29) See Ploom, T. et al. p. 39 in Blockchain Technology, Einführung für Business und IT Manager. Berlin. 2017.

(30) See Baliga, A. et al. 2018. "Performance Evaluation of the Quorum Blockchain Platform." Available at: https://www.researchgate.net/publication/327570196_Performance_Evaluation_of_the_Quorum_Blockchain_Platform

(31) See Ploom, T. et al. p. 39 in Blockchain Technology, Einführung für Business und IT Manager. Berlin. 2017.

(32) HDD is not recommended, as it is too slow and has limited multi-tasking capability. An SDD is 10 times faster than an HDD.

Annex 2. Considerations for a Registry Use Case on a Blockchain

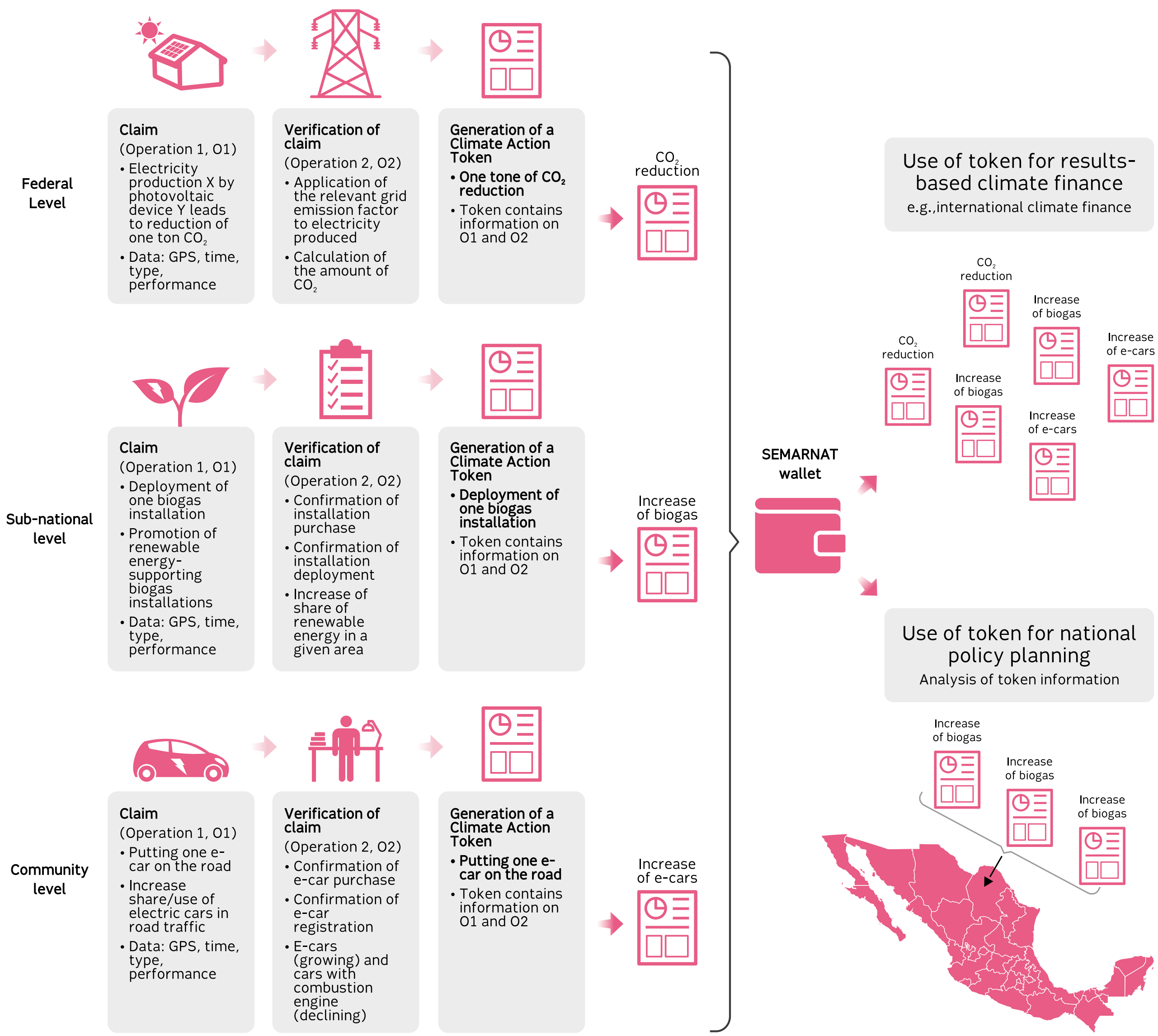
Preparation of ETS 3-Year Pilot Phase	Digital Requirements	Digital Tasks
Calculation of total cap for 2019 - 2021 = total amount of allowances	Generation of 810 Million **green token**	
Mexico: 270 Million x 3 = 810 Million allowances that are divided into allowances for: 70% = free allocation to companies 10% = new entrance reserve 10% = general reserve 10% = auctioning	Characteristics of green token: fungible, unique ID Administrative wallets: 70% = transferred to allocation wallet 10% = new entrance reserve wallet 10% = general reserve wallet 10% = auctioning wallet Characteristics of wallets: Send receive function for green token	AUTHORITY transfers **green token** to dedicated administrative wallets
	Generation of (high/unlimited amount) **red token**. One red token represents the verified emission of one ton CO_2-eq. Characteristics of red token: non-fungible (after first transfer), unique ID Characteristics of emissions wallet: Send receive function for red token	AUTHORITY transfers **red token** to emissions wallet
ETS allows for the use of offsets in the amount equivalent to 10% of capped emissions.	Generation of 81 Million **yellow token**. One yellow token represents one approved offset credit. AUTHORITY allocates yellow token to project developers (details of token and wallet to be defined).	AUTHORITY transfers **yellow token** to offset wallet.
Providing all 350 ETS companies with accounts in an Emissions Transaction Registry	Creation of 350 ETS Company Wallets Characteristics of ETS Company Wallet: Send/receive function for green token and yellow token Holding and Compliance Account (sub-sections of wallet) Receive-on-Compliance Account-only function: red token	AUTHORITY to release requirements for opening and maintaining ETS accounts (ID verification, AML/KYC if applicable)

ETS Revolving Tasks in Pilot Phase	Registry Tasks
October 2019: Individual allocation of allowances for the year 2019. Each of the 350 ETS companies receives allowances for the year 2019. *Steel Company A receives 60,000 (3 x 20,000) total allowances to cover emissions for whole pilot phase – the actual allowance allocations are split in three slots multiplied by 20,000.* ***January 2019:** Steel Company A starts monitoring emissions for 2019.*	*No relation*
***October 2019:** Steel Company A receives 20,000 allowances.*	*AUTHORITY transfers 20,000 **green token** from allocation wallet (administrative) to Holding Account in Company Wallet of Steel Company A.*
***January 2020:** Steel Company A starts monitoring emissions for 2020.*	*No relation*
***October 2020:** Steel Company A receives 20,000 allowances.*	*AUTHORITY transfers 20,000 **green token** from allocation wallet (administrative) to Holding Account in Company Wallet of Steel Company A.*
***March – June 2020:** Steel Company A submits its first monitoring report for verified emissions 2019 = 18,000 tons of CO_2-eq.*	*Authority transfers 18,000 **red token** to Compliance Account in Company Wallet of Steel Company A.*
***January 2021:** Steel Company A starts monitoring emissions for* 2021.	*No relation*
***July 2021:** Steel Company A surrenders allowances in the amount of its emissions in 2020, hence 18,000 allowances.* *Steel Company A can transfer up to 1,800 offset credits to fulfill part of its compliance obligation.*	*Steel Company A transfers 18,000 **green token** from its Holding Account to the Compliance Account. The 18,000 **red token** have now been "neutralized."* *Once the neutralization is concluded, the Compliance Account is "sealed" for the corresponding year. The AUTHORITY will be informed that Steel Company A is compliant.* *Steel Company A can also use up to 10% of its compliance using **yellow token** to offset wallet.*

Annex 3. IT Cost Considerations for a Blockchain-Based Registry

No.	Option	Consequence	Costs (roughly, only development)	Timeframe (roughly)	Remarks
1	Development on Ethereum - development of ERC20 token	Non-binding offers Swiss Developer, Zug	0.2 Million USD	2-3 months	Decentralized app based on open Ethereum source code, private version. Note: Cost estimates are very rough. Development works iteratively and in steps (with small steps towards a minimum viable product and then adding of functions and features successively).
2	Development on Ethereum - development of ERC20 token	Mexican Ethereum Developer, Mexico City	No detailed price information – further input required! Generally, token creation starts at 1000 USD plus wallet setting, keys management and constant tech support (crucial!)	n/a	Biggest issue: Wallet management and basic training for use of wallets (for admins, ETS companies, and PoA nodes). Hiring Ethereum developers is probably more economical than Hyperledger. Note: Consideration of ready-made solutions for permissioned Blockchains can significantly reduce in-house time and money!
3	Development on Hyperledger	Brazilian Hyperledger Developer, Sao Paolo	Development of main business network and chain-code (token): 40,000 USD plus legacy system integration, external devices, off-chain interfaces like web portals or mobile apps.	n/a	Each network participant needs a medium cloud instance for peers (for Amazon Web Service, it is 200 USD/month).

Annex 4. Considerations for a Climate Finance Use Case (Verification Platform)



Annex 5. Roadmap for the Development of a Blockchain-Based Verification Platform

Activities	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Months 7-12
Feasibility study to identify appropriate pilot cases for the Verification Platform, including 1. Analysis of climate action programs (e.g., subsidy schemes) on the federal, sub-national and community level; 2. Determination of respective/appropriate verification methods; and 3. Identification of three pilot cases based on national priorities and feasibility study components 1) and 2) above.							
Finalization of arrangements with relevant stakeholders of identified pilot cases							
Implementation of the required hardware configuration (e.g., oracles)							
Digitizing the formulation of • climate action claims and • verification methods/processes using ixo protocol or similar.							
Validation of Verification Platform with stakeholders (claims and verification)							
Implementation of improvements/validation outcomes; including "fine tuning" of operational model. Model needs to "onboard" "project owner," originating service, verification services, Blockchain coding and maintenance							
Capacity building/training of stakeholders/communication							
Start of pilot case(s) with real-time verification of climate action claims							

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Bibliography

Bibliography

BORN, Robin in "Distributed Ledger Technology for Climate Action Assessment," Climate-KiC, 2018.

CACHIN, Christian. "Architecture of the Hyperledger Blockchain Fabric," IBM Research, 2016, Zurich. Available at: https://www.zurich.ibm.com/dccl/papers/cachin_dccl.pdf.

CLIMATE LEDGER INITIATIVE. "Navigating Blockchain and Climate Action – an Overview" (CLI 2018), 2018, Available at: https://www.climateledger.org/resources/CLI_Report-December2018.pdf.

GALEN, Doug et al. "Blockchain for Social Impact – Moving beyond the Hype," Stanford Graduate School of Business, 2018, Available at: https://www.gsb.stanford.edu/sites/gsb/files/publication-pdf/study-blockchain-impact-moving-beyond-hype.pdf.

GIZ. "Blockchain Potentials and Limitations for Selected Climate Policy Instruments," 2018.

NAKAMOTO, Satoshi. "Bitcoin: A Peer-to-peer Electronic Cash System," 2008, Available at: https://bitcoin.org/bitcoin.pdf.

SINGH, Neelam; FINNEGAN, Jared; LEVIN, Kelly. "MRV 101: Understanding Measurement, Reporting, and Verification of Climate Change Mitigation,"World Resources Institute, Working Paper, WRI 2016, Available at: https ://wriorg.s3.amazonaws.com/s3fs-public/MRV_101_0.pdf?_ga=2.162051772.145580224.1544481986-1565746195.1544481986.

WORLD BANK GROUP. "Emissions Trading Registries: Guidance on Regulation, Development and Administration," 2016, Available at: http://documents.worldbank.org/curated/en/780741476303872666/Emissions-trading-registries-guidance-on-regulation-development-and-administration.

WORLD BANK GROUP. "Results-based climate finance in practice: delivering climate finance for low-carbon development," 2017, Available at: http://documents.worldbank.org/curated/en/410371494873772578/Results-based-climate-finance-in-practice-delivering-climate-finance-for-low-carbon-development.

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