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Blockchain solutions to unlock climate finance for increased ambition in the agriculture and land-use sectors under the Paris Agreement

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1 Introduction

The Paris Agreement (UNFCCC 2015) defines revised National Determined Contributions (NDCs) and underpinning processes that aim to limit global average temperature increase to 2ºC. UNEP's Emissions Gap Report states that current ambitions need to be tripled to achieve this goal, which implies a reduction of Greenhouse Gas (GHG) emission of 25% below 2010 levels by 2030 (UNEP 2018). The NDCs involve a mix of targets, policies and measures to mitigate emissions of greenhouse gases and also to adapt to climate change. The Paris Agreement (Article 4.3) introduced a new ambition mechanisms, which requires countries to report in successive NDCs highest possible reduction targets (ambitions) that go beyond the initial NDC. The quantification of ambitions require a clear understanding of reduction potentials in each sector (Crumpler et al. 2019). The implementation of mitigation and adaptation efforts will be monitored by the Enhanced Transparency Framework that is central element of the guidelines defined in the Paris Agreement Rulebook (see Article 13 of the Paris Agreement). The transparency centric approach adopted under the Paris Agreement rests largely on the capacity of Parties to quanitify and set targets for mitigation and adaptation activities. Operationalising the Enhanced Transparency Framework requires the development of improved reporting mechanisms, including the biennial transparency reports and a clear understanding of accounting details for each sector. Crumpler et al. (2019) present a methodology for assessing mitigation and adapatation improvements for the agriculture sector.

In addition to a clear and commonly applied assessment and accounting methodology, the reporting also needs an effective and transparent database management system and verification mechanism. One of the core accounting challenges is to avoid double counting of achieved emission reductions as many reductions are achieved by forereign investors (so-called internationally transferred mitigation outcomes, Pars Agreement Article 6.2), which means that emission reductions could be credited to the foreign investor as well as to the country. The verification step requires effective technology and robust monitoring data. This constitutes a particular challenge for agriculture and land use sectors where a large number of geographically disbursed producers operate at small scale. Greenhouse gas emissions in agriculture and land use sectors involve mainly carbon dioxide, nitrous oxides, and methane.

Finance is the major challenge for achieving the ambitious goals set out in the Paris Agreement as emission reductions of 25% from 2010 levels by 2030 require substantial investments. Innovative finance mechanisms are needed to go beyond government funding and connect emission reduction goals to private investment markets. Furthermore, current financing is particularly challenging in sectors that involve a large number of actors that are not well integrated into formal value chains and finance networks. This is particularly pertinent for the agriculture and land-use sectors.

In summary, the Paris Agreement introduces three main challenges: Finance, verification, and accounting. This paper discusses unique opportunities to address all three challenges simultanuously by employing innovative blockchain technology.

1.1 Financing options for achieving NDC targets for agriculture and land-use sectors

Meeting the targets at global and national levels that underpin the Paris Agreement will involve a series of challenges. Access to needed climate finance is often cited as a key barrier and point of dicussion in ongoing negotiations around implementation of the Agreement. Realising NDCs requires substantial investments with estimates ranging from $100 billion per annum (UNFCCC 2015) to $300 billion per annum by 2030 (UNEP 2016). While these are rough estimates, country and sector specific finance needs are difficult to quantify as most NDC priorities have not been costed (Crumpler et al. 2019). However, if considering that the overall finance gap for achieving Sustainable Development Goals (SDGs) is estimated to exceed $2.5 trillion per annum (World Bank[1]), it seems paramount to rethink financing mechanisms to effectively support emission reduction investments.

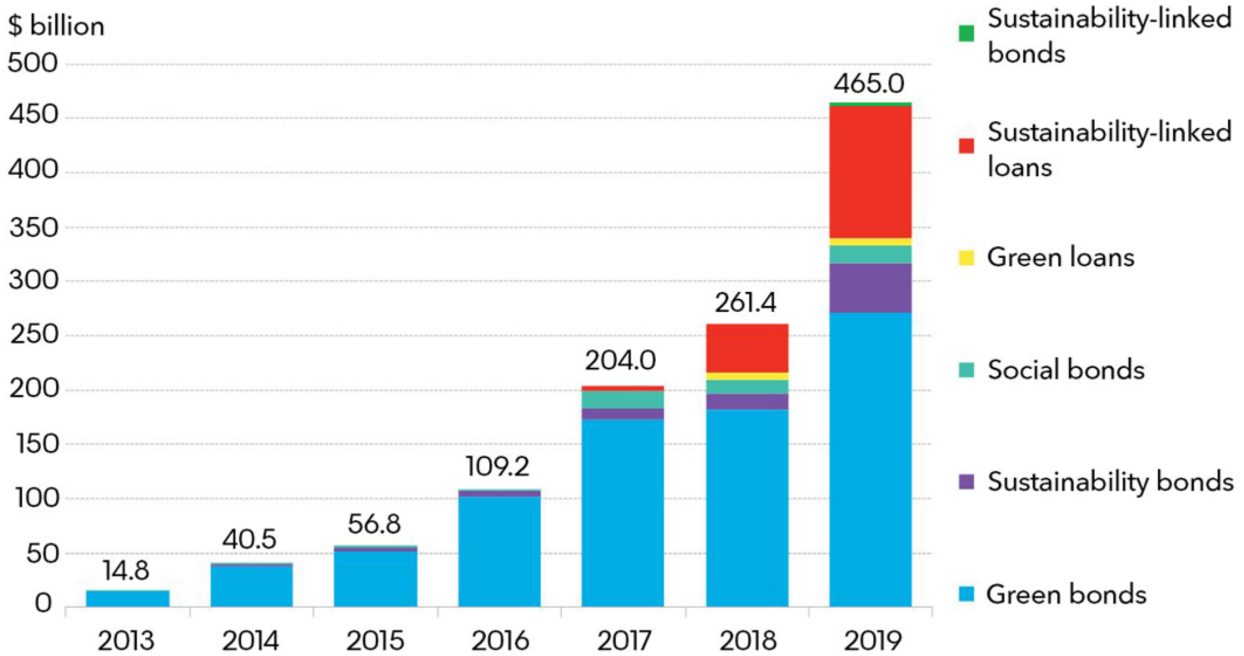

Figure 1: Global annual issuance of sustainable finance 2013-2019, $bn (Source BloombergNEF, Bloomberg L.P.)

The financing mechanisms under the UNFCCC framework are limited when compared to the scale of investment required. Current cornerstones for funding emission reductions are the GEF (Global Environment Facility, serving UNFCCC as one of five conventions) and the GCF (Global Climate Fund, established at COP 17), which provide mechanisms to select and fund eligible projects. The selection process provided by these two organisations defines a centralised solution to provide

[1] https://www.worldbank.org/en/news/speech/2018/05/15/leveraging-innovative-finance-for-realizing-the-sustainable-development-goals

incentives to governments at multiple levels. Many claim that this is insufficient (UNEP 2016) and that alternative finance mechanisms are needed to tap private investment markets and also to improve incentives for key emitters to change their behaviours and for local governments to improve their systems to account for climate action within their jurisdictions. Several alternatives have emerged as shown by Figure 1. In particular Green Bonds have experienced a substantial increase.

Bonds are a finance instrument traditionally issued by governments and companies to borrow from private and institutional investors. A bond divides a total loan amount into many small titles (the so-called "face value", e.g. $1,000) and includes typically a date (so-called "maturity date") by when the issuer pays back the face value, and an interest rate (or coupon rate), which is paid annually to the bond holder. Most bonds follow this simple design although there are also variations.

Green Bonds work in the same way but focus on providing funding for environmental improvements such as emission reduction investments. Several Green Bonds have been issues by cities, e.g. Gothenburg (2013), and is increasingly issued by local Governments around the world. Green Bonds offer investment opportunities to many investors, which defines a decentralised funding mechanism.

According to the Climate Bonds Initiative a total of $257.7 billion was issued in Green Bonds in 2019, predominantly in energy, buildings, and transport (31%, 30%, and 20%, respectively) (Climate Bonds Initiative 2020). Investments in water (9%) and waste (3 %) followed, and land use and agriculture receive only 2% of the Green Bond market. The global Green Bond market is estimated to increase to $359 billion in 2020 (https://www.climatebonds.net).

Green Bonds can also become a central element of blended finance mechanisms, as exercised for the Tropical Landscapes Finance Facility (TLFF) over $95 million, which was issued by BNP Paribas and largely covered by USAID ($70 million) as a partial guarantee. Green Bonds can also be blended with other innovative finance mechanisms, including blockchain-based mechanisms as discussed in Section 3.3.

Loans establish another core finance mechanisms for sustainability investments as shown by Figure 1. Emission reduction related loans are either provided by development banks to Governments or by private or government-owned banks to individual emittors. The loan market for sustainable development has also experienced changes. For instance, the World Bank's Program-for-Results instrument aims to support Governments' financing and leverage World Bank assistance programs. This program dispurses funding after pre-agreed milestones have been achieved.

While loans and green bonds continue to provide increasing funding for emission reducing investments, the Paris Agreement defines aforementioned internationally transferred mitigation outcomes and thereby laying the foundation for a global carbon market. Such a carbon market can define clear incentives for stimulating further emission reductions and directing investments to the most efficient emission reduction projects. Many studies have shown that such a market mechanism for tradeable quotas for emission reduction or other environmental goals (e.g. water management) can only succeed if sufficient trading volume (or investment) emerges (Smajgl et al. 2009; Smajgl 2003; Tietenberg 2006). This implies that system-wide benefits can be realised if finance mechanisms are developed compatibale with such an international carbon market and vice versa. Designing symbiotic relationships would strengthen incentives for investors, increase available investments and define stronger incentives on the ground to reduce emissions.

1.2 Transforming potential of technology

Recent technological advances started shaping a promising portfolio of highly innovative solutions that could be utilised towards achieving goals of the Paris Agreement. For instance, advances in remote sensing technologies combined with pattern recognition software to distinguish different land cover provide an effective monitoring mechanism of, for example, forest/canopy cover to audit the outcomes of actual forest related behaviour (Campos et al. 2018; Cord et al. 2017). This establishes an essential and cost-effective basis for the design of new finance instrument and a robust verification mechanism for carbon credits and NDCs.

Another new technology with potential to establish effective funding mechanisms is Blockchain technology, also known as Distributed Ledger Technology (DLT). Blockchain is perhaps best known as the underlying technology used by Bitcoin, a decentralized, peer-to-peer cryptography-based digital currency. However, the technology has a number of wider potential applications that could include systems to more accurately monitor and validate the outcomes of changes in management practices in agricultural and land-use sectors. When combined with remote sensing technologies or other technologies that can digitize high resolution data on the state and changes of biophysical systems over regular time intervals, blockchain may be able to reduce the costs associated with validation processes needed to provide investors and finance providers with certainty regarding the outcomes of changes in management practices at much lower cost than existing alternatives. Blockchain has the potential to direct finance from multiple sources directly to beneficiaries by automating traditionally complex, costly and time consuming processes including activity registration, eligibility testing, progress monitoring, and payment scheduling.

In the context of the Paris Agreement these technologies introduce potential to support advanced monitoring linked to improved transparency and more effective, decentralized incentives for emission reductions and resilient practices.

1.3 Purpose

The purpose of this report is to illustrate how blockchain technologies could be used and structured to unlock climate finance to support action to reduce emissions and associated co-benefits in the agriculture and land-use sectors that benefit small holders and stakeholders at local levels and are consistent with national priorities under the Paris Agreement. The report will highlight specific blockchain models that can be connected to existing finance sources and products ranging from grants available to Green Bonds or developed as stand-alone solutions for tapping private investment markets to finance increased ambition in the agriculture and land-use sectors.

Ultimately, the potential of blockchain technologies to provide decentralized payment structures, while delivering improvements in data transparency and measurement of impact could transform the way that climate action is supported and verified in the agriculture and land-use sectors and pave the way for more ambitious and equitable climate action.

2 Blockchain Technology

2.1 Blockchain/DLT overview

Blockchain Technology (Kakavand, Kost De Sevres, and Chilton 2016) , also known as Distributed Ledger Technology (DLT), involves three interlinked components (see also Box 1):

(1) a *network of computers* (nodes) that contribute processing resources, where each node participates with a unique public key and executes specific individual transactions (bundled in "blocks") with a corresponding private key (Nakamoto 2008);

(2) a decentralised *public ledger* database of the unalterable transactions or "blocks." A copy of this ledger exists on all nodes in the network. Transactions are updated by accountants called "miners", and the ledger is monitored by all in the network and is not centrally controlled.[14] As transactions occur and new blocks are entered, this ledger grows continuously – chains of blocks – as a result of network-wide processing (Yli-Huumo et al. 2016); and,

(3) a *consensus algorithm* (also known as a protocol) that defines how groups of nodes confirm transactions, which provides the essential security framework for the ledger (Karaindrou 2017) and the transfer of digital currency from one peer's 'wallet' into another peer's 'wallet'. (Digital 'wallets; are the equivalent to traditional bank accounts and are protected by private keys, see Box 1.) This algorithm is the key element of the cryptographic proof necessary to verify data entering the network before adding them to the next encrypted data block in the ledger.

Box 1: Glossary of Blockchain/DLT terms (Source: consensys.net)

Bitcoin: The first cryptocurrency based on the Proof of Work blockchain.

Blockchain: A consensus digital ledger comprised of unchangeable, digitally recorded data in packages called blocks. Each block is 'chained' to the next block using a cryptographic signature. This allows blockchains to act like a ledger, which can be shared with and accessed by anyone with the appropriate permissions.

Block reward: The reward given to a miner after it has successfully hashed a transaction block. Block rewards can be a mixture of coins and transaction fees. The composition depends on the policy used by the cryptocurrency in question, and whether all of the coins have already been successfully mined.

Consensus: The process used by a group consisting of peers that is responsible for maintaining distributed ledger use. The way to reach consensus on the use of the ledger's contents.

Cryptocurrency: Digital currency that is based on mathematics and uses encryption techniques to regulate the creation of units of currency as well as verifying the transfer of funds. Cryptocurrencies operate independently of a central bank.

Decentralisation: The transfer of authority and responsibility from a centralized organization, government, or party to a distributed network.

Distributed Ledger: A type of database which spreads across multiple sites, countries, or institutions. Records are stored sequentially in a continuous ledger. Distributed ledger data can be either "permissioned" or "unpermissioned" to control who can view it.

Fiat Currency: Government-issued currency. For example: US Dollars (USD), Euros (EUR), Yuan (CNY), and Yen (JPY)

Hash: A function that takes an input, and then outputs an alphanumeric string known as the "hash value" or "digital fingerprint." Each block in the blockchain contains the hash value that validated the transaction before it followed by its own hash value. Hashes confirm transactions on the blockchain.

Mining: The process by which "blocks" or transactions are verified and added to a blockchain. In order to verify a block a miner must use a computer to solve a cryptographic problem. Once the computer has solved the problem, the block is considered "mined" or verified. In the Bitcoin or Ethereum blockchain, the first computer to mine or verify the block receives bitcoin or ether, respectively.

Node: Any computer connected to the blockchain network is referred to as a node. A full node is a computer that can fully validate transactions and download the entire data of a specific blockchain. In contrast a "lightweight" or "light" node does not download all pieces of a blockchain's data and uses a different validation process.

Oracle: In a blockchain network an oracle (human or machine) helps communicate data to a smart contract which can then be used to verify an event or specific outcome.

Private blockchain: A blockchain or distributed ledger that has a closed network where participants are controlled by a single entity. A private blockchain requires a verification process for new participants. A private blockchain may also limit which individuals are able to participate in consensus of the blockchain network.

Proof of Stake: An alternative consensus protocol, in which an individual or "validator" uses their own cryptocurrency to validate transactions or blocks. Validators "stake" their cryptocurrency, such as ether, on whichever transactions they choose to validate. If the individual validates a block (group of transactions) correctly then the individual receives a reward. Typically, if a validator verifies an incorrect transaction then they lose the cryptocurrency that they staked. Proof of Stake requires a negligible amount of computing power compared to Proof of Work consensus.

Proof of Work: A protocol for establishing consensus across a system that ties mining capability to computational power. Hashing a block, which is in itself an easy computational process, now requires each miner to solve for a set, difficult variable. In effect, the process of hashing each block becomes a competition. This addition of solving for a target increases the difficulty of successfully hashing each block. For each hashed block, the overall process of hashing will have taken some time and computational effort. Thus, a hashed block is considered Proof of Work

Protocol: A set of rules that dictate how data is exchanged and transmitted. This pertains to cryptocurrency in blockchain when referring to the formal rules that outline how these actions are performed across a specific network.

Smart Contracts: Smart contracts are programs whose terms are recorded in a computer language instead of legal language. Smart contracts are automated actions that can be coded and executed once a set of conditions is met.

Stable coin: Any cryptocurrency pegged to a stable asset, like fiat or gold. It theoretically remains stable in price as it is measured against a known amount of an asset not subject to fluctuation.

Token: A Token represents an asset built on an existing blockchain (different from a coin). Tokens are designed to be unique, liquid, secure, instantly transferable, and digitally scarce.

Wallet: Used to send and receive transactions on a blockchain network. An address is an alphanumeric character string, which can also be represented as a scannable QR code.

2.2 Development of blockchain applications

Nakamoto (Nakamoto 2008) describes an innovative encryption for a ledger that establishes Bitcoin, which provides a technical solution to a cryptographic challenge (Chaum 1983). The initial goal was to create a ledger system that protects buyers and sellers by ensuring irreversibility and security of peer-to-peer transactions while preventing double-spending due to the cryptographic proof provided by multiple nodes (Nakamoto 2008). The cryptographic innovation involves digital signatures – a transformation of a character string into encrypted output using a hash algorithm – and digital timestamps to encrypt transfers from one public address to another. Each user has a unique public address and a private key that allows the user to access the assets. The decentralised system implies that users don't need to know and trust each other, referred to as a trust-less network approach (Karaindrou 2017; Pilkington 2016).

The invention of blockchain – the combination of decentralized computer networks, the public ledger and the consensus algorithm – allowed the cryptocurrency Bitcoin to be created through a software-enabled process called "mining" that can be linked to the generation of a digital coin or token. Individual or decentralized computers can mine Bitcoins, but it requires the network, through the distributed ledger, to approve this new coin or token. Importantly, for the ideas presented below, the mining algorithm can be defined to support a specific purpose.

The initial design of Bitcoin triggered a substantial surge in the creation of non-state cryptocurrencies that provide a decentralised infrastructure for transferring amounts of cryptocurrencies from one peer's digital wallet into another peer's wallet. Decentralisation provides multiple benefits (Swan 2015; Tapscott and Tapscott 2016), including improved transparency and monitoring of transactions, improved security as central actors (e.g. banks) are increasingly exposed to criminal hacks, independence from banks during financial crises, lower transaction costs, improved privacy of the internet, and improved power and control for consumers.

Another recent technological advance is the design of blockchain based platforms, such as Ethereum, NEO, and EOS, which go beyond simple currency transfers and allow users to draft contracts that involve the transfer of an agreed amount of a particular token once pre-agreed actions or conditions have been met (Swan 2015). These second-generation DLT approaches include a coding platform and a virtual machine to allow users to define so-called "smart contracts" and run made-to-order decentralised applications (Beck and Müller-Bloch 2018). Numerous and varied blockchain based applications have been developed that are increasingly predicted to facilitate substantial ramifications for a wide range of socio-economic interactions (Swan 2015; Allen et al. 2017; Pazaitisa, De Filippib, and Kostakisa 2017). Many DLT application have been developed that operate with their own "utility" tokens or cryptocurrencies used for purchasing a particular good or service. Not all crypto-currencies require a mining algorithm as many "coins" or "tokens" are pre-mined to facilitate transactions. Many merchants have started accepting crypto currencies, ranging from small cafes to online businesses. Instead of spending crypto currencies and tokens directly, they can also be converted into fiat currencies (e.g. US Dollar) and transferred to a traditional bank account. This connects the digital crypto-based economy to the fiat-based economy. A special type of pre-mined cryptocurrencies are so-called stable coins, which are fully backed by fiat currencies, previous metals, or real estate. These typically show no or little variation in value and are mainly created to facilitate transactions, such as inter-bank transfers.

Scholars are now predicting that blockchain technology will have transformative implications on the prevailing socio-economic system, including various aspects of governance (Schwab 2016; Allen et al. 2017; Atzori 2015), shifting boundary constraints for solutions developed in the fields of institutional economics, political science, and sustainability. For the purpose of this paper is is critical to emphasise that blockchain technology introduces innovative mechanisms to incentivize sustainable behaviour, including emission reducing behaviours.

3 Blockchain solutions to finance climate action in the agriculture and land-use sectors

3.1 Incentivisation, Monitoring and Decentralsation Improvements

Climate financing for agriculture is low compared to other sectors, as seen in aforementioned trend of Green Bonds. Responsible factors include the high number of actors involved in making emission-related decisions on the ground, the comparibly slow adoption of new technologies, and the challenging verification process. Hence it seems pertinant to address these challenges when discussing a new technology.

Blockchain technology provides three advantages that are relevant for addressing these specific challenges for more impactful climate finance and climate action in the agriculture and land-use sectors:

(1) The ability to directly *incentivise* the behaviour of resource users;

(2) The integration of improved *monitoring* capacity to increase transparency and establish an effective reward/penalty system and improve compliance; and,

(3) The mitigation of centralised power and related incentives that promote behaviour inconsistent with sustainable development objectives (coercion & corruption) through a *decentralized design*.

3.1.1 DIRECTLY INCENTIVISE THE BEHAVIOUR OF RESOURCE USERS

Many drivers causing emissions to increase or carbon sequestration to decline are responding to changing incentives (Costanza et al. 1997; Smajgl, Xu, et al. 2015). If, for instance, prices for a particular cash crop increase, the pressure on remaining conservation forests and wetlands also increases. External costs are difficult to introduce to this calculation (Kandulu, Connor, and MacDonald 2014; Smajgl, Toan, et al. 2015).

It is important to understand the main factors establishing incentives for individual emitters. First, emitters (individuals, households, companies, or communities) must perceive the behavioural options. Often listed as a critical behavioural barrier is the lack of awareness what options would lead to lower emissions (or even the emissions caused by the current behaviour) (Bustamante et al. 2014; Wreford, Ignaciuk, and Gruère 2017; Bohensky, Smajgl, and Brewer 2013). Second, the individual emitter must perceive the cost or payoff differences if changing the emitting behaviour. Most countries introduced taxes on fossil fuels intending to not only generate state imcome but also to incentivise emission reductions. Similar taxes or fees have been or can be introduced on a wide range of resources, e.g. water use, electricity use, or use of agrochemicals. Equally, emitters can receive subsidies for low emission options, as seen in many countries for photovoltaic or wind turbines. Third, setup costs need to be often pre-financed by the emitter, which might be the purchase of a low emission car or a more efficient heating system. Climate smart agriculture can require substantial upfront investments (McCarthy, Lipper, and Branca 2011), which establishes an important behavioural barrier in the agriculture and land use sectors. The vast majority of farmers in developing countries has poor access to formal credits and needs to revert to costly informal credit markets. This slows down uptake of new technologies or the introduction of other changes in existing practices. This is partly due to the centralised structure of loan markets. Even public funding schemes are typically centralised and require substantial transaction costs to reach a large number of geographically dispersed emitters.

Conequently, one of the most challenging aspects is to create incentives that are directly perceived by the emitter, where change is perceived actionable, and can be financed.

Blockchain technologies provide new opportunities to incentivise behaviours as software solutions can be created that reach nearly every household while providing a decentralised funding mechanism for specific changes on the ground. These decentralised mechanisms would connect directly to the individual or agency that implements climate smart initiatives without any intermediary, which implies that transaction costs are minimised and possible corruption is avoided. So far, incentive mechanisms struggled with decentralised behaviours such as transportation and heating. The main instrument changing economic incentives for behavioural change have been taxes to reach the millions of drivers and millions of households. Emission trading, widely considered more efficient and effective than taxes (Tietenberg 2006), is challenging to implement for all Greenhouse gas emitters as high tansaction costs emerge when trying to connect individual households to emissions trading schemes.

The decentralisation facilitated by many existing blockchain solutions coordinates a substantial reconfiguration of financing networks or supply chains as it automates intermediary steps that aim to cut out intermediaries. Consequently, transaction costs typically drop substantially. Transaction costs in the context of climate policies are very high if considering the high level of costs involved for the implementation of the REDD+ programme, which involves a substantial overhead at the level of central administration and in each participating member country (Angelsen 2008; Olsen and Bishop 2009).

3.1.2 INTEGRATION OF IMPROVED MONITORING CAPACITY

Monitoring is a critical aspect for ensuring compliance in institutional arrangements. Many such arrangements fail to achieve sustainable development objectives because of the lack of monitoring at the relevant scale (Ostrom 2009). A critical barrier for effective and comprehensive monitoring are the costs involved, in particular if a large number of geographically dispursed decision makers need to be monitored.

Blockchain technologies are able to integrate advances in other technologies to facilitate more effective monitoring solutions for land-use and land users, while also reducing monitoring costs and providing incentive mechanisms based on actual observation. Integrating effective monitoring solutions is critical for the effective tracking of progress towards achieving defined goals, the meaningful updating of the distributed ledger, and the design of robust smart contracts.

Recent advances in remote sensing technologies (combined with machine learning and pattern recognition software) and Internet-of-Things (IoT) solutions to distinguish different forest types provide an effective monitoring mechanism of, for example, forest/canopy cover to audit the outcomes of actual forest related behaviour (Campos et al. 2018; Cord et al. 2017). IoT data involves a wide range of different data sources and can involve for the climate context fossil fuel consumption data or power generation data.

The design and implementation of mechanisms that integrate blockchain solutions and remote sensing or IoT-based monitoring has the potential to establish an effective reward/penalty system and improve compliance among a wide variety of resource users. Such solutions can combine multiple data sources to establish a more credible database to effectvely inform, trigger, and direct investment.

mitigation of centralised power and related incentives The provision of economic incentives through centralised power structures without effective monitoring and enforcement has the tendency to involve coercion and corruption, which leads to unsustainable outcomes (Ewers and Smith 2007; Meppem 2000). Scholars argue that the decentralisation of economic incentives can circumvent power related risks (Hughes 2017; Kshetri 2017). Centralised climate finance mechanisms often employ government offices to dispurse funding, which introduces rent-seeking risks. Corruption in the context of REDD+ has been revealed in several cases, for instance in the Philipines (Mayo-Anda 2011) or in Congo (Brown 2013). Transparency International (Sabogal 2018) emphasises the relevance of community-based or decentralised monitoring for effective protection of forests.

Centralised processes are also prone to agency slack, which is based on principle-agent theory and refers to situations where independent action undertaken by agents (e.g. national or international organisations) that is contrary to the intentions of their principals (e.g. initial funding agency) (Heldt 2017). Decentralised processes can connect funding directly to the decision maker on the ground, which can diminish slack if effective monitoring mechanisms can be integrated.

Equally relevant is that centralised processes typically provide funding for solutions that are developed outside the context of individual decision makers. Decentralised processes can provide funding for specific goals without prescribing solutions, which introduces for innovation within the context of individual decision makers.

There are already examples of blockchain based technologies that are providing decentralized services and markets relevant and applicable to improving incentives for sustainable practices in agriculture and land-use. Three cases are outlined in the next section to help identify different blockchain modalities and designs that could inform climate finance options.

3.2 Blockchain examples

3.2.1 GLOBAL FOREST COIN

Deforestation is a key driver for the decline in global greenhouse gas mitigation potential (Scrieciu, 2007; Smajgl and Bohensky, 2012). Several global efforts have aimed at stabilising the extent of forests as carbon sinks or even reversing the trend in forest loss, including the UN/World Bank coordinated REDD and the REDD+ programs (Angelsen 2008). Numerous observations and evaluations highlighted that REDD involves very high transaction costs, that are due to incentives, monitoring and a centralised, multi-level governance mechanism (Angelsen 2008; Olsen and Bishop 2009).

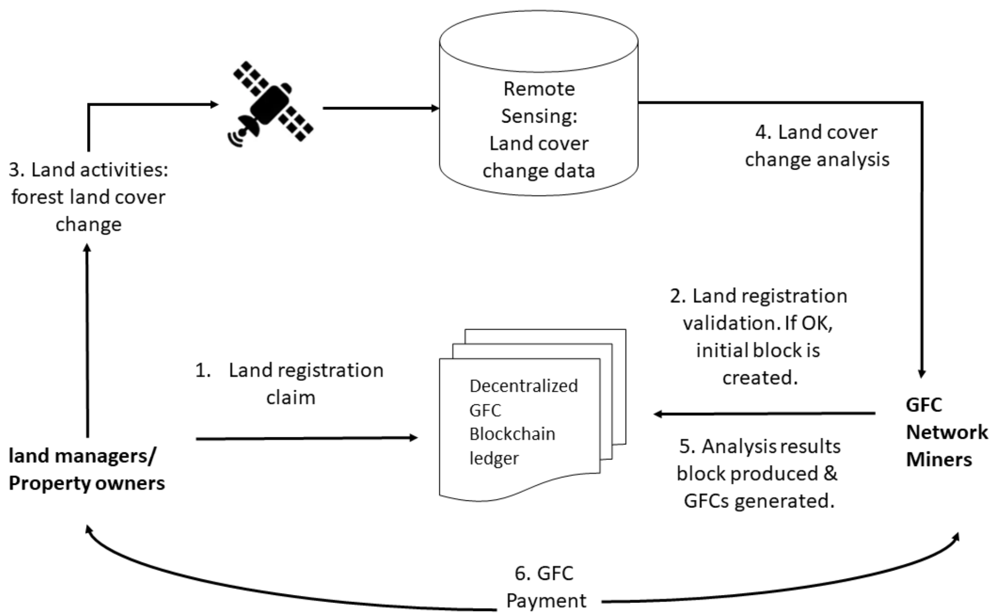

Figure 2: Conceptualisation of links in blockchain-based incentive mechanism for reforestation and avoided deforestation

As described in the previous sections, blockchain technology offers a decentralised governance mechanism coupled with new approaches to monitoring and incentivising of both monitoring staff and on-the-ground forested land managers or property owners. Smajgl (2015) and Smajgl and Schweik (2019) present a solution that involves a payment token, which they refer to as the Global Forest Coin (GFC). Figure 2 depicts the proposed blockchain based institutional and technological solution, which incorporates: (1) incentives for positive land management behaviour – the creation of a Global Forest Coin (GFC) token; (2) a mechanism to monitor behaviour using remote sensing data and analysis; and (3) a decentralized governance system via a GFC blockchain ledger. The initial blockchain technical infrastructure would need to be established with the three components described in the introduction: (1) two or more network nodes; (2) the GFC ledger; and (3) the consensus algorithm or protocol.

Once the initial technical infrastructure is established, land managers or property owners would register their land in a specifically developed client software and make a quantifiable forest land cover commitment. This would be submitted through software as a pending initial claim and a request by a land manager to participate in the Global Forest Coin blockchain program (Figure 2, Step 1). This would initiate a proof of ownership check by decentralized GFC network miners to avoid individuals establishing a claim for somebody else's land, as well as an initial baseline assessment of the property for forest cover and their proposed commitment by these same miners (Figure 2, Step 2).

Over a period of time, land managers would undertake their regular land-related activities (Figure 2, Step 3) that would, ideally, be consistent with their commitment made in Step 1. The initial commitment entry block or transaction in the GFC blockchain ledger would be monitored utilising remote sensing satellite land cover data (e.g. http://www.openforis.org). The monitoring step requires computation or landcover change analysis, which would be provided by the network of GFC miners (Figure 2, Step 4). The results of this analysis would be entered by these miners into the GFC ledger as another block in the chain of related transactions (Figure 2, Step 5). The software used by the miners to record this block would also generate tokens in the form of GFC and as a result, the miner would receive GFC payment for their efforts, as would the forest land manager or property owner if the analysis provided evidence that they were meeting their original commitment (Figure 2, Steps 5 and 6). The payment would be per ha for the previous period of one, three or six months, and could take into account the previous vegetation state as remote sensing data is continuously improving. Such a mechanism would generate regular GFC income for the land owners and would improve forests' competitiveness against cash crops. During a reforestation phase, payments per ha might be higher than during a maintenance state when additional carbon sequestration declines. The mechanism could be modified to provide higher rewards for establishing mixed species than monoculture to improve biodiversity values. The land manager would be inclined to compare per ha returns from forests with other crops, which combined with non-pecuniary motivations could make the conservation of forests competitive.

The GFC decentralised token-based mechanism would allow Governments, International Organisations, and advocacy groups to increase the incentive by buying or mining GFC and increase the price. This would allow land owners to increase their income from forests and accelerate conservation incentives on the ground.

The conceptual blockchain based approach has some clear advantages as it minimises the risk for coercion and corruption because of the decentralized design and minimises transaction costs. However, the utilization of a token as incentive would require a market for land owners to turn their earned GFC token rewards into fiat currency. Computationally, this step could be facilitated through the same software application as the initial step for registration or through one of the many existing cryptocurrencies. However, cryptocurrencies exchanges are subject to high volatility (Tapscott and Tapscott 2016). It is unlikely that risk-averse land owners will replace existing crops by forests if income prospects are highly uncertain. Equally, extremely high incentives could introduce substantial risks for food security and indirectly trigger a surge in food prices as food crops would start competing with high forest income. Third parties – Governments or international organisations – might provide the necessary interventions to stabilise GFC token prices to provide effective incentives for the desired land use change.

Deforestation could be targeted by regulatory instruments and require land owners to buy a certain amount of GFC tokens for a multi-year period and deposit them in a locked wallet. From a global perspective, this would increase the price and therefore the incentive to establish forests somewhere else, which would result in a stabilisation or even increase of global forest cover.

3.2.2 REGEN NETWORK BLOCKCHAIN

The Regen Network white paper was first published in 2017 and has since been implemented with various partners, including The Nature Conservancy. The Regen blockchain project aims to attribute economic value for natural assets such as forests. The Regen ledger builds on the widely used Tendermint consensus engine and utilises monitoring data to track changes in ecological states and reward improvements. The underpinning mechanism for rewarding investments with ecological benefits are smart contracts. The technical design combines three "core ecological protocol frameworks":

- Ecological State Protocols (ESPs): The set of algorithms and conditions that help identifying and tracking land cover change. This can be enriched by specifying habitat conditions.
- Ecological Contracts (ECs): The token-based rewarding mechanism for environmental improvements. The smart contract allows the land manager specifying proposed improvements, which will then be tracked by the ESPs and converted into token payments once goals are successfully achieved.
- Supply Protocols (SPs): In addition to environmental state changes SPs allow for adding supply chain data.

The main data sources for the tracking of environmental state changes are remonte sensing data, IoT (Internet-of-Things) sensing data, public GIS data, and data submitted by users. Ecological States are specified as carbon sequestration, grassland health, blue carbon, regenerative agriculture, and methane emissions, for which the Regen network blicchain offers specific protocols.

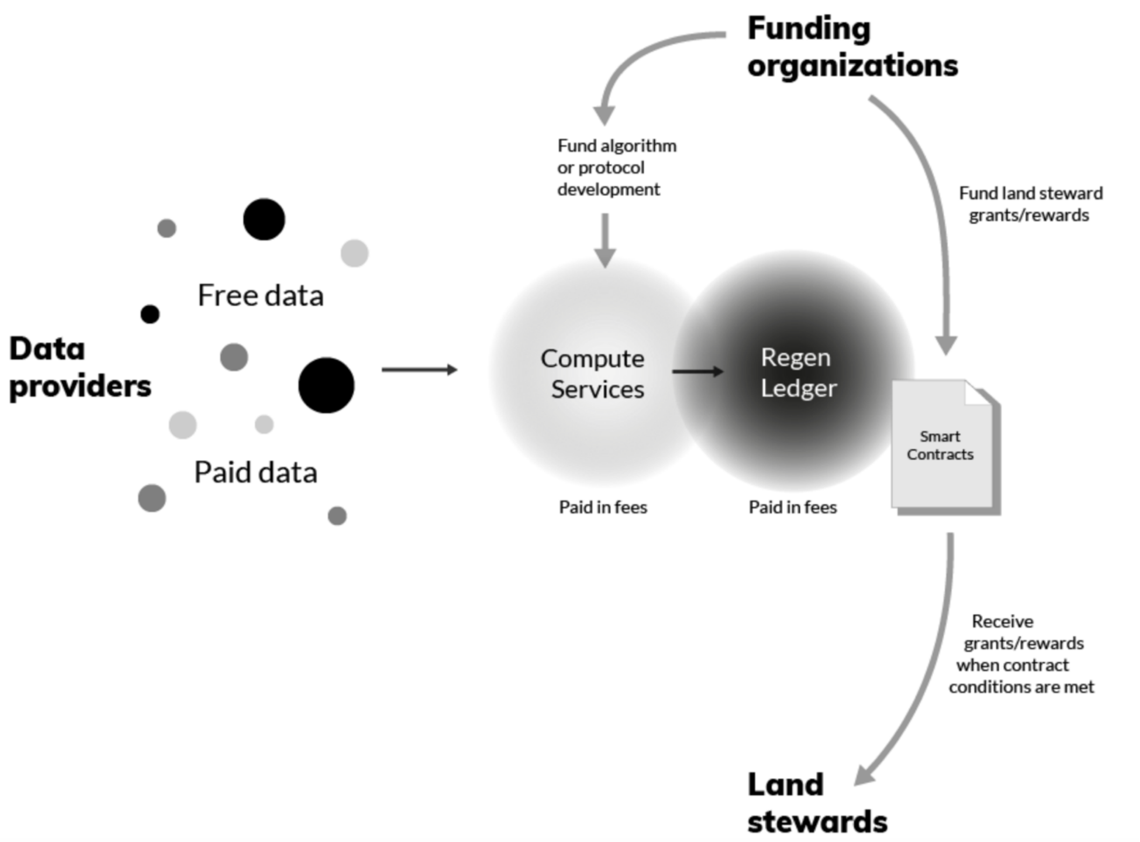

Figure 3: Regen network incentive system (Source: Booman et al 2020)

In practice, land managers sign smart contracts with the Regen network involving a specific commitment to create an environmental benefit, e.g. carbon sequestration. Then, the Regen network blockchain is utilising a combination of data to track the progress made to achieve the defined goal. Once the goal is achieved a reward is paid in form of a cryptocurrency token. Figure 3 visualises the principle flow defining the blockchain-based incentive for land managers to create environmental values. It follows a similar concept as presented for the Global Forest Coin design and involves similar advantages and disadvantages.

3.2.3 YALE OPENLAB CLIMATE PROJECT

The Yale OpenLab Climate Project developed a blockchain-based application (Open Climate Platform) to track the global carbon budget and monitors how country actions compare to national reduction targets. Monitoring and accounting define pillars 1 and 2 of the Yale OpenLab Climate project, see Figure 4.

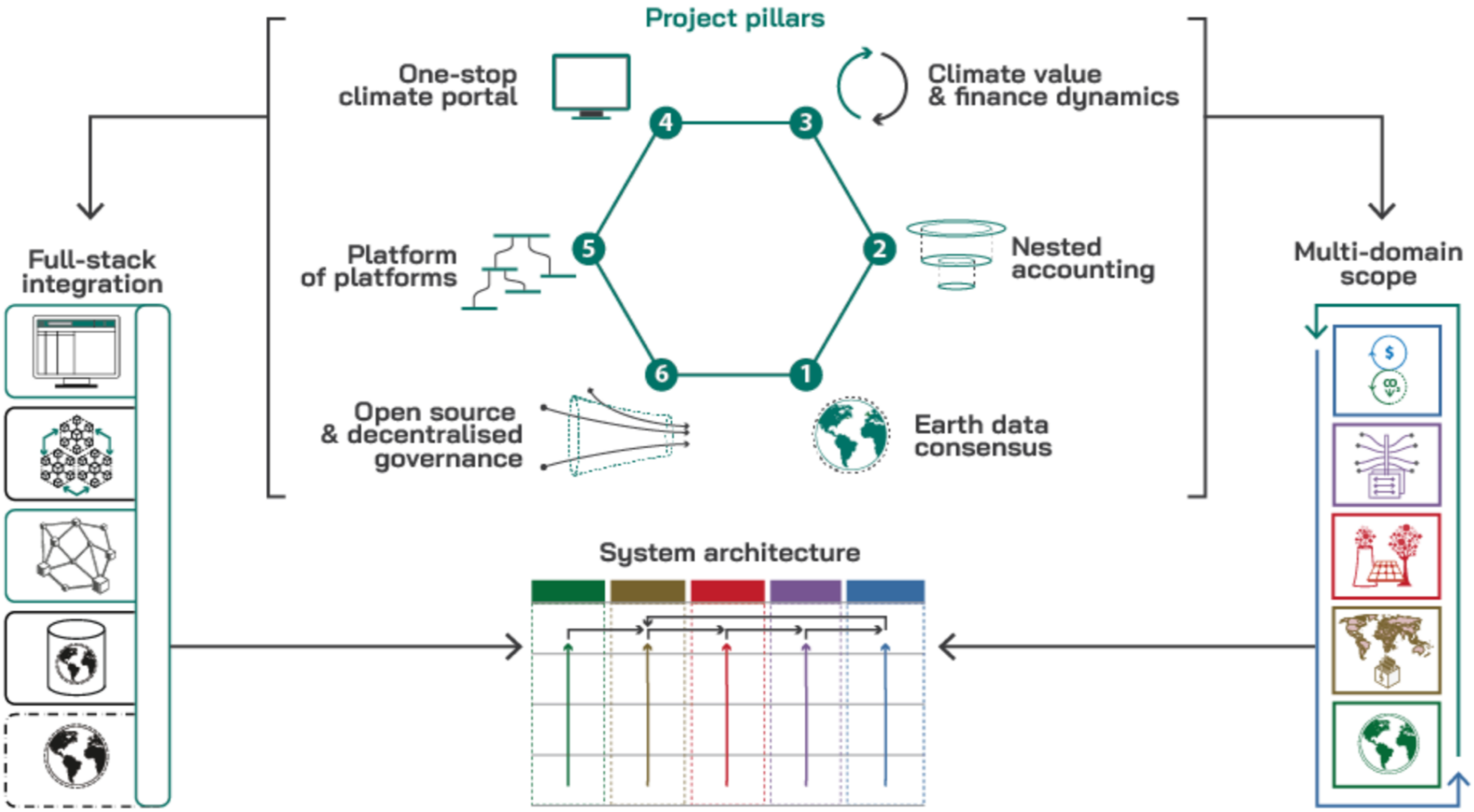

Figure 4: Yale OpenLab Climate Project components (Source: Wainstein 2019)

The third component establishes a blockchain-based finance mechanism, similar to the designs underpinning the Regen Network Blockchain and the Global Forest Coin. The finance instrument involved the the platform OpenX, which was codeveloped by the MITMedia Lab and builds on the esiting blockchain/cryptocurrency Stellar. Climate projects can be listed on OpenX to attract investors. Investment details are defined in smart contracts, which then connect to a monitoring process (IoT data such as power meter data) and then trigger payments in a cryptocurrency, which can be converted to stable coins/fiat currencies to minimise currency fluctuation related risks.

3.3 Blockchain blended finance examples

From the perspective of achieving national emission reduction targets, accounting for actual progress made, and providing effective incentives to those making decisions on the ground, it seems pertinent to discuss innovations in the context of existing finance mechanisms. Combining or blending finance mechanisms could potentially provide highly effective accounting and finance solutions.

The development of blockchain-based green bonds has recently been realised by the Spanish bank BBVA (Banco Bilbao Vizcaya Argentaria) as the issuer and the Spanish insurance company Mapfre as the private investor[2]. Mapfre invested €35 million to fund 6 sustainability focused projects at a 5-year Euro Swap rate[3]. The BBVA green bond was formally accredited Green Bond status.

In August 2018 and prior to BBVA's blockchain-based Green Bond, the world's first blockchain-based bond "Bond-I"was arranged by the World Bank through its agency IBRD (International Bank for Reconstruction and Development), which is managed by Commonwealth Bank of Australia (CBA), RBC Capital Markets, and TD Securities. This bond is issued and traded on blockchain. The first tranche was $100 million followed by a second tranche in August 2019 of $50 million. The World Bank's goal is to tap private investment markets to accelerate the achievement of Sustainable Development Goals.

Also HSBC (supported by the Sustainable Digital Finance Alliance) and UBS investigated blockchain solutions for bonds and other financial mechanisms. One of the earliest blockchain-based mechanisms banks have implemented are mechanisms to facilitate inter-bank transfers as blockchain offers very fast (near immediate), fully transparent and accountable transfers. Many of these blockchains utilise aforementioned stable coins, which are backed up by fiat currencies (e.g. USD) and do not experience any trade-related fluctuations.

In addition to connecting UNFCCC related central Government funding or Green Bonds to a climate-focused blockchain solution, Governments could also create links to other finance mechanisms, such as debt swaps or offset programs. Debt swaps define a process in which a (developing) country achieves global benefits (e.g. emission reductions) and receives in exchange a reduction of debts. Such a mechanism could be implemented with a different conversion rates to account for countries' different credit ratings.

While debt swaps define another finance mechanism between Governments, carbon offset programs are well established for private sector actors or the public. Carbon offset programs are potentially best known as payments for activities (e.g. tree planting) that offset the emissions caused by a particular service (e.g. flight). Many large companies have internal carbon offset programs to achieve carbon neutrality at the company level. Both of these additional examples, debt swaps or carbon offsets, can be blended with a blockchain solution.

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[2] https://www.bbva.com/en/blockchain-set-to-shape-future-of-green-bonds/, accessed December 2019.

[3] Currently, the rate is 1.407%. The Euro (interest rate) swap market allows parties to trade future interest payments in form of a forward contract. Technically, one side is typically defining a fixed interest rate while the other side accepts a variable interest rate, which offers a mechanism to hedge financial risks. The Euro Swap market is the financial market with the world's highest liquidity.

4 Blockchain designs to unlock climate finance for increased ambition in the agriculture and land-use sectors under the Paris Agreement

4.1 Paris Agreement and existing finance models

The Paris Agreement (2015) is an international treaty that binds ratifying countries to tackle climate change. The Agreement defines a global warming goal of "well below 2°C on pre-industrial averages". A key mechanism is that countries will need to specify progressively ambitious national goals and mitigation measures in national determined contributions (NDCs). The Paris Agreement establishes processes and reporting mechanisms that improve transparency for ongoing and planned mitigation and adaptation actions. In regards to agriculture and land-use sectors the Paris Agreement defines in Article 2 the goal to enhance 'the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production'.

Centralised finance mechanisms (e.g. GCF, GEF) dominate climate adaptation and mitigation, which involves public funding as aforementioned. Climate finance building on private investment markets are a small portion but have shown rapidly increasing growth as shown in Figure 1. This Section conceptualises financing mechanisms that could equally be developed for public or private funding. These solutions are discussed in the context of previously outlined challenges, effective incentivisation of individual decision makers and their monitoring.

4.2 Blockchain models to unlock climate finance for the agriculture and land-use sectors

Blockchain technology can be used and structured to unlock climate finance to support action to reduce emissions and associated co-benefits in the agriculture and land-use sectors that benefit small holders and stakeholders at local levels and are consistent with national priorities under the Paris Agreement. In this section, specific blockchain models will be elaborated that can better connect decentralised actors to existing finance sources and instruments to drive increased ambition in the agriculture and land-use sectors.

These models make use of some core elements of blockchain technology to provide specific functions/services:

- distributed and unalterable ledgers (or databases) – Function with respect to monitoring/transparency for agriculure and land-use actions
- risk-minimising smart contracts – Function with respect to accessing project specific financing, and decentralised power for agriculure and land-use actions

- purpose-specific mining – Function with respect to to decentralised incentives, decentralised power and accessing climate finance for agriculure and land-use actions
- transparent and effective payment transfers – Function with respect to to decentralized incentives decentralised power and accessing climate finance for agriculure and land-use actions

4.3 Model 1: Record-keeping ledger and automated payment trigger

A core advantage of blockchain technology is the immutable ledger, which can provide effective support for tracking progress in achieving defined emission reduction goals at various levels of decision making, ranging from central governments to highly disaggregated administrative units. This could support existing finance mechanisms such as centralised UNFCCC related funds (e.g. GEF, GCF) and Green Bonds. The ledger-focused support could estalish a transparent mechanism to track progress of funded emission reduction or sequestration activities. Currently, carbon offset investments are often financed by companies and accounted against their offset goal. However, the host country for the offset project is typically also accounting these improvements against their goal, which creates a double-counting problem. Blockchain solutions could provide a standardised, transparent ledger to overcome these accounting problems.

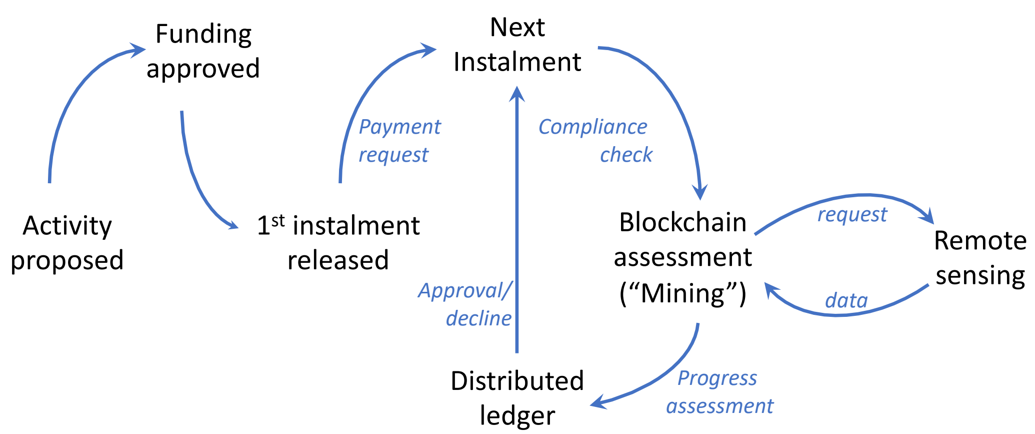

Figure 5: Blockchain-based finance approval mechanism

Theoretically, such a blockchain solution could be developed as a pure ledger design without addition incentives (Model 1a). Figure 5 visualises a possible execution process of such a blockchain-based approval process with incentives to establish an innovative finance mechanism and automated payment process (Model 1b). The initial step would be a traditional design of emission reducing activities. The proposal could either target existing central funds or be converted into Green Bonds. Such Green Bonds could be offered by the national agency to sub-national agencies (e.g. city councils). In case of centralised funding the grant would be split into multiple instalments conditional to achieving well-defined progress targets. The first instalment is released upon approval while every further instalment is dependant on the blockchain based assessment. The assessment would involve a legitimacy check by network nodes (nodes running the "mining" algorithm), which would request remote sensing data from connected databases and track the project implementation progress against defined goals. Progress is recorded in the distributed ledger and once the milestone has been achieved the next instalment would be approved. In case of Green Bonds, this mechanism could trigger the replenishment of Bonds. In the case of loans, payments could be automated based on milestones to establish an automated form of the World Bank's Program-for-Results instrument.

This design would utilise core segments of blockchain technology and provide an automated approval process, which could be categorised as an AI based solution (Artificial Intelligence). The advantage would be an increased efficiency of financing considering emission reduction achievements. However, the application would be limited to projects that would be trackable by existing monitoring mechanisms, which can include remote sensing or other monitoring technology (e.g. air quality sensors, electricity consumption meters).

4.4 Model 2: Smart contracts

The second option utilises an additional feature of blockchain technology, smart contracts. Smart contracts (see also Box 1) have first been proposed by Nick Szabo in 1994. They define contractual obligations (e.g. payments) that are automatically executed (e.g. transferred) once pre-defined conditions are met. The contractual obligations would be stored in form of code on a decentralised, distributed blockchain, which implies that the contract auto-executes. The advantage of such smart contracts is that the payee's risk to receive no or insufficient payment disappears because the payer makes the full payment before the payee starts implementing activities. However, the payee cannot access the value before fulfilling the conditions for each milestone, which eliminates risks for the investor. Many smart contract platforms exist, including Ethereum, Neo, List and Stratis. The trading of derivatives follows largely smart contract principles. The Swiss bank UBS started in 2015 working on the design of bonds as smart contracts.

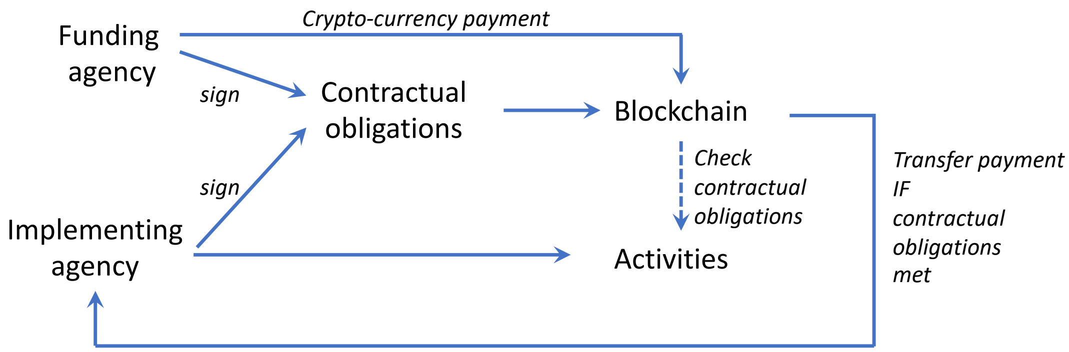

Figure 6: Smart contract blockchain

Typically smart contracts do not have access to real (or fiat) assets to complete (monetary) transfers. The rise of cryptocurrencies changed this. In other words, this model would involve cryptocurrency transactions, which implies the need for a coin or a token. This could be created as a coin within a closed system that only connects eligible entities implementing emission reducing activities. To eliminate risks, these coins could be linked to a stable coin, as used by banks for inter-bank transfers. The system could be design that all users are only dealing with fiat currencies, while the blockchain-specific coin would remain invisible.

An interesting variation of this option could be created by adding a crowd funding component. Similar to centralised authorities providing funding for activities that contribute to NDCs or sub-national emission reduction targets, smart contracts could also be offered to the public. Sub-national entities could offer such smart contracts to the public, who sign up for specific project and make payments towards achieving certain goals. Once activities are successfully implemented, the crowd funding component would be released, which would cover expenses and, thereby release the funding provided upfront for the next round of activities.

4.5 Model 3: Integrated Blockchain solution

The third option aims to fully embrace multiple features of blockchain technology, including the mining aspects of blockchains. This option would involve a similar concept as outlined for the Global Forest Coin, see Figure 2. Here a proposed emission reducing initiative is proposed and once it is registered on the ledger the network nodes utilise monitoring data to track the progress of achieving targets. Following the mining reward principle of many cryptocurrencies network nodes get rewarded as well as implementing entities. The conversion of currencies can be designed to increase financial rewards depending on the urgency.

The “Central fund” (see Figure 7) can be equally established through a GEF/GCF-type mechanism or by Green Bonds. The latter could include private investors or even crowd funding mechanisms. Assuming the national government receives a certain budget for climate mitigation through a Green Bond, projects could be proposed in an automated system that fulfil a set of pre-defined criteria. Funding would only roll out to those projects that effectively achieve their targets. In an international context with developed countries providing funds for developing countries to mitigate and adapt, such central funding could then be replenished once countries achieve specific targets.

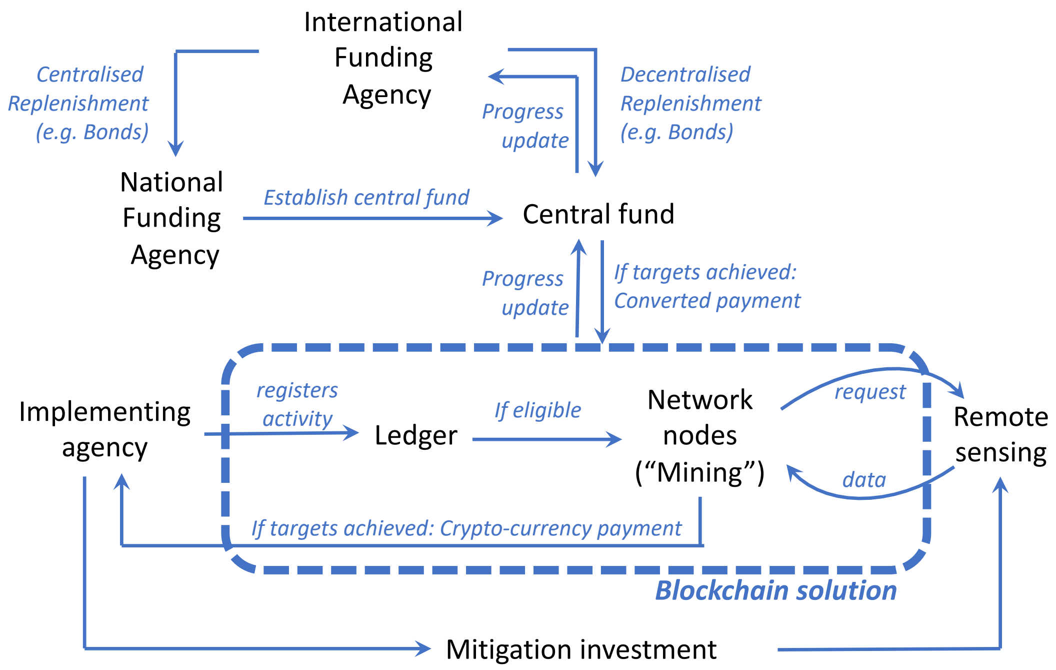

Figure 7: Blockchain based financing mechanism with international, national and sub-national agencies

Figure 7 summarises the principle connections of such a blockchain-based financing mechanism. The international agency’s fund could be directly connected to the distributed ledger and replenish national funds for sub-national activities as performance goals are met. Alternatively, this top level could be decoupled to allow for additional negotiation with individual countries. Such a non-automated design element has advantages, incl. country-specific adjustments over time, but also disadvantages, incl. high transaction costs, corruption, or slack depending on the fund-replenishing mechanism.

Variations are also possible at the lower levels. For instance, the network can be genuinely decentralised and distributed, which means that mining rewards for successfully completed monitoring (“proof-of-work”) would be paid to people unrelated to the actual emission reduction activity or the fund raising domain. Alternatively, the network could also be run by the international agency (e.g. UNFCCC), which retains all payments in a closed loop. It needs to be assessed which solution has lower transaction costs as mining rewards need to be compared with the infrastructure setup and maintanance costs of the central network.

5 Conclusion

Climate change requires drastic actions to limit global warming to well below 2°C as defined by the Paris Agreement. This will involve a substantial investment of up to $300 billion per year by 2030 (UNEP 2016). Developing innovative finance mechanisms is crucial to implement transformative solutions to reduce emissions by 26 to 28 percent below 2005 levels by 2025. Blockchain technology offers opportunities to craft innovative finance mechanisms that add to the existing portfolio of finance instruments. Several solutions offer opportunities in combining blockchain solutions with existing approaches (e.g. Green Bonds, debt swaps, carbon offset programs).

Table 1: Blockchain based models for climate finance

Model	Purpose	Key features	Application
1a) Record keeping ledger	Establish transparent database for emission related changes	Distributed ledger for actions and verified by remote sensing or IoT-based monitoring	Application domain involves aspects that can be monitored, land use change (eg. agricultural land, forests), fuel combustion, air quality, water extraction, etc.
1b) 1a plus automated payment	To provide cost-efficicent automated payment system for achieving predefined goals	Payments for achieving goals can be autmated and linked to monitoring-based ledger of model 1a.	As 1a)
2) Smart contracts	Platform for project-speific financing, including monitoring and risk-free financing	Lists individual mitigation projects for private investors to select. Financing is provided riskfree as payout only triggered if goals achieved. Also riskfree for implementing agent as funding already allocated.	Any project with clearly specified emission reduction goal, e.g. reforestation, changed feeding regime for animal production.
3) Integrated Blockchain solution	To provide an integrated blockchain solution that automates and combines database management, monitoring, verification, and payment functions	Maintains distributed ledger for goals, actions, and achievements, which are based on integrated monitoring systems (remote sensing, IoT), plus automated, milestone-based payment system.	All the above, where monitoring data is available.

The combination of decentralised ledgers and state-of-the-art monitoring (e.g. remote sensing, IoT) allows circumventing centralised, bureaucratic solutions, associated with high transaction costs and often failing to introduce effective incentives for the actual resource user (Schomers and Matzdorf 2013). This discussion paper conceptualises blockchain solutions that could provide effective climate finance and accounting mechanisms to support the Paris Agreement. Blockchain technology offers different features, which could be individually developed into effective building blocks of climate financing ranging from accounting-focused features of a distributed ledger to incentivising payments, see Table 1.

Existing solutions show that blockchain technology can provide effective financing solutions. The options presented in this discussion paper emphasise that bockchain technology can be implemented in different ways. The funds can be allocated through central funds (e.g. GCF and GEF) or by private or public investors through Green Bonds. As shown in Figure 7 these funds could be transferred onto a blockchain and finance emission mitigation investments on the ground. The blockchain would automate the entire process from testing eligibility, registration, monitoring the implementation process and facilitating the payments.

Blockchain solutions are likely to provide effective mechanisms for sectors that involve a large number of geographically dispursed emitters and resource users, which would make tradable quota mechanisms viable. Such systems could be implemented at the level of cities or other administrative units based on their specific targets and secure the required financing through the blockchain-based mechanism, as for instance defined by Figure 7.

Agricultural emissions show promising potential but is likely to meet also challenges. The easier domains are land cover changes from crops releasing more greenhouse gas emission (e.g. methane) to climate smart crops. The intensity and quantity of livestock is more challenging but monitoring is possible through other existing database systems.

However, blockchain technologies and changes in underpinning institutional arrangements can have unintended side effects that need to be analysed. First, there is always a risk for resource users misusing newly introduced economic incentives, which could lead to unsustainable outcomes. Previous assessments of economic instruments have demonstrated this effectively (e.g. Payment for Ecosystem Services, see Smajgl et al. (2015)). Therefore, it is pertinent to test the blockchain-based incentive systems. Secondly, there are sustainability related issues that will need to be addressed related to the energy costs required to maintain blockchains.

Furthermore, blockchain solutions and the automated, decentralised processes they involve are often perceived as a loss of control. This is linked to the fact that authority would be delegated to a network of decentralised financing and implementation actors. So far, political support for blockchain solutions has been volatile and often lacking to implement broader solutions. The private sector, however, has widely embraced blockchain technology with many sectors already working with applications (e.g. banking, food industry, freight sector).

The critical condition for all three options presented above (and all variations) is the availabilty of monitoring data and the ability to connect it to a blockchain solution as outlined in Figure 7. Land use change is clearly a realistic target but many other proposed activities might meet more challenges.

In synthesis, blockchain technology offers new effective mechanisms for improving institutional arrangements for climate financing and justifies increasing attention by the scientific and public policy community.

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