Saving Forests with Smart Contracts

Implementing the REDD+ mechanism under the Paris Agreement with blockchain-enabled smart contracts

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List of abbreviations

CBDRRC: Common but Differentiated Responsibilities and Respective Capabilities

COP: Conference of the Parties

DLT: distributed ledger technology

FRL: forest reference level

IPCC: Intergovernmental Panel on Climate Change

MRV process: the process of monitoring, reporting and verification

NDC: nationally determined contributions

REDD+: reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries

UN: United Nations

UNFCCC: United Nations Framework Convention on Climate Change

WFR: Warsaw Framework

1. Introduction chapter

1.1 Introduction

1.1.1 Focus

This thesis researches to what extent blockchain-enabled smart contracts can promote the implementation of the REDD+ mechanism under the Paris Agreement. The REDD+ mechanism focuses on reducing emissions from deforestation and forest degradation.[1] REDD+ in full means reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries.[2] The mechanism is one of the mechanisms under the Paris Agreement concerned with the mitigation of climate change.

1.1.2 Legal/social problem

When multiple parties participate in an agreement and do not fully trust each other, blockchain serves as a tool that takes away the necessity of trust in the other (or a third) party.[3] The technology is based on a distributed network, which allows for a high level of trust among users and better monitoring of stored data.[4] Trust among the users of a blockchain network is generated by the technology itself; all transactions are recorded chronologically and inalterably and distributed among all parties. The latter means that no central party has ownership of the blockchain.[5] It follows that a single party cannot amend the entries on the blockchain. Blockchain can be used to register, confirm, and transfer any type of contract and property.[6] Blockchain technology in combination with a coded contract is able to represent an agreement between parties through so-called blockchain-enabled smart contracts. In short, smart contracts are contracts represented in code and executed by computers.[7] Legal language is in this sense translated into an executable program.[8] It is important to grasp that a smart contract is not the same as a contractual agreement. A smart contract is not the contractual agreement itself, but governs that agreement or certain elements of it.[9] This thesis focusses on the use of smart contracts that run on blockchain: blockchain-enabled smart contracts.

One might wonder what purpose blockchain-enabled smart contracts can serve with regards to the implementation of REDD+. This link is illustrated well by the ‘tragedy of the commons’. This economic theory can be applied to the fight against climate change in general.. Hardin pictured a system in which each man wants to increase his own share without a limit, the

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1 C. Voigt 2016, p. 1.

2 Ibid, p. 1-2.

3 Bits on blocks, ‘A gentle introduction to smart contracts’, *Bits on blocks*, at WWW <https://bitsonblocks.net/2016/02/01/a-gentle-introduction-to-smart-contracts/>.

4 The problem of an untrustworthy third party is commonly referred to as the ‘Byzantine Generals Problem’. More information on this problem can be found via: L. Lamport, R. Shostak & M. Pease, ‘The Byzantine Generals Problem' *AC’ Transactions on Programming Languages and Systems, 1982* Vol. 4, No. 3, p. 382-401.

5 E. Mik, ‘Smart contracts: terminology, technical limitations and real world complexity’, *Law, Innovation and Technology* 2017 Vol. 9 (2), p. 277.

6 M. Swan 2015, p. 9.

7 E. Mik, ‘Smart contracts: terminology, technical limitations and real world complexity’, *Law, Innovation and Technology* 2017 Vol. 9 (2), p. 269.

8 M. Raskin, ‘The Law and Legality of Smart Contracts’, *The Georgetown Law Technology Review*, 305, 2017, p. 309.

9 W. Mougayar, 2016, p. 65.

paradox being that the world has limits.[10] Hardin continues as follows: '*Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons*'.[11] Hardin's theory applies by analogy to the fight against climate change. When all countries combined exceed a certain amount of emissions, the consequences are grave. In this sense, the world is limited. Individually however, each country pursues its own interests, which are in the short term served by a larger amount of emissions.[12] The result is that countries collectively act contrary to the common good. The management of the commons within the sphere of climate change requires a common approach.[13] The takeaway from this illustration is that the fight against climate change is handicapped by trust-related issues and the absence of a direct common incentive in order to pursue the common good. Blockchain technology can create a common incentive, potentially countering the 'tragedy of the commons'.

Indeed, blockchain technology answers a specific flaw in the context of the international fight against climate change. Trust among participating parties, which is one of the aforementioned strengths of blockchain technology, is a weakness in international climate agreements. Countries no longer seem to question the international scientific consensus that greenhouse gases are warming up our planet. Rather the question whether governments can be trusted, is a recurring dilemma.[14] Todd Stern, the American negotiator at the Paris Agreement negotiations, pointed out that the transparency regime is the thing that will allow everyone to have confidence and trust that other countries are acting and that a transparency regime is therefore key to the deal.[15] Therefore, he argued, the United States would like to see the establishment of an international body of experts who can monitor the extent to which participating countries are complying with their pledges.[16]

Alternatively, and possibly less flawed, blockchain could take upon itself the trust-creating role that Stern envisages. Füssler argued that blockchain can help the Paris Agreement very strongly in terms of providing transparency and trust, which are key for successful implementation of the Agreement.[17] The use of blockchain-enabled smart contracts in the context of the global fight against climate change was put forward in the 23rd session of the Conference of the Parties (COP23). At the Climate Ledger Initiative side event, climate and IT experts discussed the opportunities and risks of using blockchain to promote the implementation of the Paris Agreement.[18] Gellert Paris stated that 'blockchain could contribute to greater stakeholder involvement, transparency and engagement and help bring trust and further innovative solutions

[10] G. Hardin, 'The Tragedy of the Commons', *Science* 1968 (162), p. 1244.
[11] Ibid.
[12] Current economies are often to a large extent driven by emission-related industries. The correlation is explained well by: L. Hughes & A. Herian, 'The correlation between GDP and greenhouse gas emissions' *Policy Options Politiques*, 12 September 2017, at WWW: <http://policyoptions.irpp.org/magazines/september-2017/the-correlation-between-gdp-and-greenhouse-gas-emissions/>.
[13] P.T. Stoll 2016, p. 132.
[14] C. Davenport, 'Trust and Money at Core of Crucial Paris Talks on Climate Change', *The New York Times* December 6 2015, accessed via: https://www.nytimes.com/2015/12/07/world/europe/trust-and-money-at-core-of-crucial-paris-talks-on-climate-change.html.
[15] Ibid.
[16] Ibid.
[17] M. Cuff, 'The BusinessGreen Blockchain Briefing Part Two: Electric vehicles, green supply chains and the Paris Agreement', *businessGreen,* 11 August 2017 at WWW: <https://www.businessgreen.com/bg/analysis/3015419/the-blockchain-briefing-part-two-electric-vehicles-green-supply-chains-and-the-paris-agreement>.
[18] G. Lovett, 'COP23 explores the role of blockchain in climate action', *Daily Planet*, November 2017, at WWW <https://dailyplanet.climate-kic.org/attention-role-blockchain-implementing-paris-agreement/>.

in the fight against climate change, leading to enhanced climate actions'.[19] Although the 'blockchainisation' of the Paris Agreement has been suggested in some instances, no extensive research has been done on (i) whether the use of blockchain-enabled smart contracts is actually feasible for implementing mechanisms under the Paris Agreement and (ii) to what extent such use would promote the implementation thereof.

Focussing on the use of smart contracts for the Paris Agreement in general or multiple mechanisms thereunder would be too broad. This thesis therefore merely focuses on the REDD+ mechanism. After the integration of the existing REDD+ framework in the Paris Agreement, Voigt iterates that robust UNFCCC methodologies and guarantees of support should lead to upscaled implementation of REDD+.[20] The characteristics of blockchain-enabled smart contracts could facilitate the upscaling of a mechanism that deals with deforestation and forest degradation, together accounting for ten percent of global greenhouse gas emissions.[21] The REDD+ mechanism facilitates results-based payments for reducing deforestation and restoring degraded forests. However, the paying parties within the mechanism are wary about the validity of the verified emission reductions.[22] Furthermore, concerns have been raised about the lack of transparency in transactions and preventing double-counting.[23] The possibility of using blockchain-enabled smart contracts as a tool of implementation for REDD+ was put forward at the earlier referred to COP23 as well.[24] The opportunities associated with the blockchain technology in combination with the existing problems in the implementation of REDD+ make it worthwhile to research to what extent blockchain-enabled smart contracts can promote the implementation of the REDD+ mechanism.

1.1.3 Relevance

Without successfully adapting climate policies, global warming will reach a level which leads to irreversible and fundamental changes in the climate system.[25] A radical transformation from past emission trends is necessary to avoid climate risks.[26] Compliance to arrangements aiming to fight climate change is therefore of utter importance. The objective of the Paris Agreement is to strengthen the global response to climate change, in the context of sustainable development and efforts to eradicate poverty.[27] It ties into the UNFCCC's ultimate objective to manage the global risks related to climate change.[28] The Paris Agreement aims to limit the rise in the global average temperature to a range between 1.5 ° and 2 °.[29] Unfortunately, even within this limit, the risks associated to such a rise will have a huge impact. The second goal of the Paris

[19] UNFCCC, 'Blockchain technology can boost climate action; UNFCCC recognizes potential', *UNFCCC* June 1 2017, at WWW http://newsroom.unfccc.int/climate-action/how-blockchain-technology-could-boost-climate-action/>.

[20] C. Voigt 2016, p. 7.

[21] W. Obergassel e.a., 'Phoenix from the ashes: an analysis of the Paris Agreement to the United Nations Framework Convention on Climate Change – Part 1', *Environmental Law & Management* 2015 (27), p. 251.

[22] E. Drazen & P. Graham, 'Blockchain: the missing link between climate finance and forest conservation', *Climate Advisers*, January 22 2018 at WWW: <https://www.climateadvisers.com/blockchain-the-missing-link-between-climate-finance-and-forest-conservation/>.

[23] Ibid.

[24] Presentation of Climate-KIC held by R.K. Bakkegaard at the COP 23 in Bonn, November 2017 at WWW: <https://www.climateledger.org/resources/5.pdf>.

[25] D. Klein e.a. 2017, p. 7.

[26] Ibid.

[27] Art. 2 Paris Agreement, New York, 2016, at WWW <https://unfccc.int/files/meetings/paris_nov_2015/application/pdf/paris_agreement_english_.pdf> (consulted 11 November 2017).

[28] D. Klein e.a. 2017, p. 123.

[29] Ibid, Foreword.

Agreement is therefore to increase the ability to adapt to the adverse impacts of climate change.[30] More specifically concerning REDD+, Elias utters that REDD+ is linked to many other positive social and environmental outcomes, in addition to the benefits with regards to fighting climate change.[31] REDD+ can help reducing habitat loss and illegal logging activities and promote biodiversity, improve local governance.[32] Researching a potential promotion of the implementation of the REDD+ mechanism could therefore offer multifarious advantages to society.

As pointed out earlier, blockchain technology is a tool for the public to gain trust in the regulators and to arguably implement elements of REDD+. As the public is becoming more aware of climate change, the transparency that blockchain technology provides would urge regulators to take action.[33] Transparency is a much-debated issue under the Paris Agreement. Anderson for example wondered whether the UNFCCC's Compliance Committee can really promote and ensure transparency.[34] If the answer to that question would be no, researching blockchain-enabled smart contracts as a tool for implementing provisions under the Paris Agreement would be more than worthwhile. The public as a result of the blockchain technology's inherent transparency would note a discrepancy between promises and plans and the measures being taken in practice.

A better and more reliable implementation of the REDD+ mechanism would mean that the objectives of the Paris Agreement could be achieved sooner. The debate around the possible implementation of blockchain-enabled smart contracts for the Paris Agreement transcends the REDD+ mechanism as such. The lessons learned in this thesis can namely be relevant for other mitigation mechanisms in the fight against climate change. Results-based payments illustrate this well. These payments are the conclusive piece to successful REDD+ activities. With these payments, developed countries 'buy' measured, reported and verified emissions results. Results in this thesis with regards to results-based payment are relevant by analogy for the Paris Agreement and international carbon markets in general.

1.1.4 Existing literature

There is a gap in literature on the use of blockchain-enabled smart contracts for implementing the REDD+ mechanism under the Paris Agreement. This gap stems from the missing interlinkage of three strains of literature: (i) technical and legal literature on blockchain technology describing its functioning and characteristics, (ii) (technical) literature on blockchain-enabled smart contracts, pointing out the practice, opportunities and pitfalls of blockchain-enabled smart contracts and (iii) literature on REDD+, in which the mechanism is commented on and the implementation and hurdles thereof is explained. Interlinking these three strains of literature helps to answer whether there is any truth to the often uttered adagio that blockchain could play a vital role in fighting climate change in this case within the context of REDD+.

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[30] Ibid, p. 124.

[31] P. Elias 2016, p. 391.

[32] Ibid.

[33] Research shows that in North America, Europe and Japan, more than 90 percent of the population is aware of climate change; A. Leiserowitz & P. Howe, 'Climate Change Awareness and Concern in 119 Countries', *Climate Change Communication*, 27 July 2015, at WWW <http://climatecommunication.yale.edu/publications/analysis-of-a-119-country-survey-predicts-global-climate-change-awareness/>.

[34] S. Anderson, 'Transparency and accountability in the Paris Agreement: eight questions negotiators must tackle' *International Institute for Environment and Development*, 23 October 2017, at WWW <https://www.iied.org/transparency-accountability-paris-agreement-eight-questions-climate-negotiators-must-tackle>.

Firstly, the technical literature about blockchain technology needed for this thesis is straightforward. The technical functioning of blockchain protocols can be found in many books and articles. It should be noted however that legal analysis of these technicalities is still lacking to a large extent. Mik therefore argues that is difficult to evaluate the claims concerning the potential of blockchain to change the legal landscape.[35] Mik adds that the practical deployment of blockchain-enabled smart contract raises interesting legal issues, transcending the question whether the smart contract can grasp an existing legal contract.[36] These issues are discussed in various articles and concern smart contract formation, contract performance and modification and contract enforcement, breach and remedies.[37] As stated before, these legal issues have been discussed and analysed but are yet to be applied to the implementation of REDD+.

Most of the legal literature about smarts contracts focuses on contract law.[38] Discussed use cases include digital identity, securities, mortgages and supply chain.[39] Although these use cases do not particularly relate to REDD+, literature on use cases like these is valuable by analogy. Due to the novelty of the blockchain technology, part of the literature relevant to this thesis is not necessarily written by legal scholars. For example Mougayar wrote a book called 'The Business Blockchain', which gives a good overview of the promise, practice and application of the blockchain technology.[40]

The aforementioned suggestion of using blockchain-enabled smart contracts for implementing REDD+ assume that such use is possible. Greenspan points out that the application of blockchain-enabled smart contracts may be suffering from inflated expectations.[41] A complicating factor is that it is difficult for a blockchain to retrieve information outside of the blockchain[42], because a blockchain is by its nature an isolated environment.[43] With regards to REDD+ it would for example be difficult to establish with reasonable certainty that a certain surface of forest has been conserved. Furthermore, circumstances may change between the *ex ante* drafting of a contract and the *ex post* adjudication of legal effects.[44] Parties can try to facilitate such changes by incorporating for example a *force majeur* clause. However, imprecise terms are difficult to specify in code. Moreover, smart contracts strip away the time dimension of interactions between parties, which renders it unpractical to forget about traditional contract law.[45] Mougayar however argues that smart contracts are merely limited by whoever writes

[35] E. Mik, 'Smart contracts: terminology, technical limitations and real world complexity', *Law, Innovation and Technology* 2017 Vol. 9 (2), p. 270.
[36] Ibid.
[37] See for example M. Raskin, 'The Law and Legality of Smart Contracts', *The Georgetown Law Technology Review*, 305, 2017.
[38] J.D. Hansen & C.L. Reyes, 'Legal Aspects of Smart Contract Applications', *Perkinscoie*, May 2017, p. 1, at WWW <https://www.virtualcurrencyreport.com/wp-content/uploads/sites/13/2017/05/Perkins-Coie-LLP-Legal-Aspects-of-Smart-Contracts-Applications.pdf>.
[39] Smart Contracts Alliance & Deloitte, 'Smart Contracts: 12 Use Cases for Business & Beyond', December 2016, at WWW <https://www.bloq.com/assets/smart-contracts-white-paper.pdf>.
[40] W. Mougayar 2016.
[41] G. Greenspan, 'Why Many Smart Contract Use Cases Are Simply Impossible', *Coindesk*, April 17 2016, at WWW <https://www.coindesk.com/three-smart-contract-misconceptions/>.
[42] An external source being a source outside of the blockchain. An example of such a source is the temperature in Amsterdam. This information needs to be retrieved by the parties to the blockchain.
[43] J. Slobodník, 'How Oracles connect Smart Contracts to the real world' *Medium* 2 February 2018, at WWW: <https://medium.com/bethereum/how-oracles-connect-smart-contracts-to-the-real-world-a56d3ed6a507>; E. Mik, 'Smart contracts: terminology, technical limitations and real world complexity', *Law, Innovation and Technology* 2017 Vol. 9 (2), p. 292.
[44] K. Werbach & N. Cornell, 'Contracts ex Machina', *Duke Law Journal*, 2017 Vol. 67:313, p. 367.
[45] Ibid.

them and that smart contracts are ideal for interacting with real words assets, the internet of things etcetera.[46] Mougayar adds that soon enough there will be millions of smart contracts of all sorts with logical representations of our world.[47] The discussion in literature illustrates the uncertainty of use of blockchain-enabled smart contracts in practice and emphasize a case-by-case assessment. As no research has been done about the possibilities for blockchain-enabled smart contracts for the implementation of REDD+, this thesis aims to fill this void and answer the uncertainty of the use of smart contracts.

There is a lot of legal literature about the REDD+ mechanism. Voigt's research handbook on REDD+ and Angelsen et alia's extensive analysis of the mechanism provide a lot of information on the legal functioning of the mechanism.[48] The existing literature also includes empirical findings and legal analysis of implementation issues concerning REDD+. An example thereof is the challenge to ensure the availability of funds.[49]

After going over the characteristics of blockchain-enabled smart contracts on one hand, and the characteristics of the REDD+ mechanism on the other hand, this thesis analyses the extent to which blockchain-based smart contracts can be a tool of implementation of provisions under the Paris Agreement. Consequently, again through existing literature about blockchain-enabled smart contracts as well as REDD+ implementation issues, this thesis will additionally evaluate to what extent blockchain-enabled smart contracts can improve the implementation of REDD+.

1.2 Research question and methodology

<u>Research question:</u>

To what extent can blockchain-enabled smart contracts promote the implementation of the REDD+ mechanism under the Paris Agreement?

<u>Sub questions:</u>

(i) What is the role of blockchain with regards to smart contracts?

This sub question is answered by literature review. Two strains of literature are researched. First of all, (technical) literature about the blockchain technology is necessary to point out its characteristics. Secondly, literature on blockchain-enabled smart contracts is analysed.

(ii) How can the REDD+ mechanism under the Paris Agreement be described and which problems are posed in the implementation thereof?

This sub question is answered by descriptive research. On one hand, the positive law (with regards to REDD+) will be described and clarified by doctrinal research. On the other hand, this sub question is answered by literature review and commenting on REDD+ and the problems in the implementation thereof.

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[46] W. Mougayar, *The Business Blockchain,* Hoboken: John Wiley & Sons 2016, p. 153; W. Mougayar, '9 Myths Surrounding Blockchain Smart Contracts' *Coindesk*, March 23 2016, at WWW <https://www.coindesk.com/smart-contract-myths-blockchain/>.

[47] W. Mougayar, *The Business Blockchain,* Hoboken: John Wiley & Sons 2016, p. 154.

[48] C. Voigt 2016 & A. Angelsen et alia 2012.

[49] A.G.M. La Viña & A. de Leon 2016, p. 177.

(iii) To what extent can blockchain-enabled smart contracts be a tool of implementation of the REDD+ mechanism under the Paris agreement?

This sub question is answered by analytical research. This sub question explores whether blockchain-enabled smart contracts can be a tool of implementation for REDD+.. For this purpose it is necessary to evaluate whether the characteristics of blockchain-enabled smart contracts fit within the way the REDD+ mechanism is construed.

(iv) What are the legal opportunities and pitfalls of blockchain-enabled smart contracts and what do these mean for promoting implementation of the REDD+ mechanism under the Paris Agreement?

This sub question is answered by descriptive and evaluative research. First of all, literature about blockchain-enabled smart contracts is used to identify the opportunities and pitfalls of these contracts. The third sub question establishes for which provisions under the Paris Agreement, the application of blockchain-enabled smart contracts is possible. By evaluative research, the answer to the fourth sub question identifies how the opportunities and pitfalls of blockchain-based smart contracts would affect the use of these contracts for implementing REDD+.

1.3 Roadmap of the argument

In the answer to the first sub question, blockchain technology and its role with regards to smart contracts are explained. The technical background of the blockchain technology is clarified, identifying the elements of this technology. Furthermore, the way in which the blockchain technology facilitates smart contracts is set forth and possible forms are illustrated. There are multiple ways in which smart contracts can be executed as they can be encoded on any blockchain.[50] This chapter clarifies which legal provisions qualify for being coded in a smart contract.

In the answer to the second sub question, this thesis establishes what arrangements have been made with regards to the REDD+ mechanism under the Paris Agreement. While establishing these arrangements, this chapter highlights the characteristics of those obligations and conditions. Without a clear overview of those characteristics, it is not possible to analyse whether blockchain-enabled smart contracts can be a tool of implementation. In that sense, the answers to the first and second sub questions lay the foundation for answering the third sub question. Furthermore, problems in the implementation of the REDD+ mechanism are illustrated. Pointing out these shortcomings is crucial for this thesis to research whether the implementation of REDD+ can be improved.

The answer to the third sub question analyses to what extent blockchain-enabled smart contracts can be a tool of implementation for the REDD+ mechanism. Blockchain-enabled smart contracts cannot be a tool of implementation for every kind of arrangement laid down in legal provisions. In order to promote the implementation of the REDD+ mechanism, it is necessary for blockchain-enabled smart contracts to be able to grasp the respective arrangements.

As this thesis aims to establish to what extent implementation of the REDD+ mechanism can be promoted by means of blockchain-enabled smart contracts, the answer to the fourth sub

[50] Blockgeeks, 'Smart Contracts: The Blockchain Technology That Will Replace Lawyers', *Blockgeeks*, at WWW <https://blockgeeks.com/guides/smart-contracts/>.

question evaluates whether the REDD+ mechanism benefits from implementation by means of blockchain-enabled smart contracts. For this purpose, this chapter will identify opportunities and pitfalls concerning the use of blockchain-enabled smart contracts. Once these have been established, they form the reference frame through which this chapter evaluates the use of blockchain-enabled smart contracts for implementing REDD+.

2. Blockchain-enabled smart contracts

Lately it has become difficult to miss the trend of blockchain technology. The technology has primarily attracted attention due to its facilitation of Bitcoin and other cryptocurrencies.[51] However, it is necessary to distinguish between cryptocurrencies and blockchain technology. Blockchain denotes to a category of geographically replicated, synchronised and often decentralised data logs.[52] This chapter analyses what the role of blockchain technology is with regards to smart contracts. The first part of this thesis explains blockchain technology. This thesis does not aim to explain the technical functioning of the blockchain in detail. Instead, it focuses on the legal relevance. Reasonable understanding of the technology is sufficient to understand its value for smart contracts. The explanation of blockchain-enabled smart contracts can be found in the second part of this chapter. Finally, limitations with regards to the use of blockchain-enabled smart contracts are set forth.

2.1 Blockchain technology

2.1.1 The first conceptualisation of the blockchain technology

In 2008, Nakamoto published the paper 'Bitcoin: A Peer-to-Peer Electronic Cash System', describing the first ever conceptualisation of blockchain technology as a means for Bitcoin.[53] Nakamoto points out that in current transaction systems, in which a trusted third party is needed, completely non-reversible transactions are not possible. Hence, a certain percentage of loss due to fraud has become accepted.[54] With the exception of transacting in person with physical currencies, there is still no mechanism in place that allows for transactions over a communication channel without a trusted party.[55] Nakamoto stresses that the payee can therefore not verify whether one of the previous owners double-spent the currency. Currently, this problem is resolved by using an intermediary, which checks every transaction for double-spending.[56] Bitcoin is the proposal for a purely peer-to-peer version of electronic cash.[57]

The technical solution is as follows. Bitcoin transactions are publicly announced. Participating parties agree on the order in which all transactions were received.[58] The first required element is a timestamp server, which takes a hash of a block of transactions to be timestamped, and widely publishes those.[59] The cryptographic hash is the outcome of a mathematical algorithm that is used to transform a random amount of data into a smaller amount of data: the output. Hashing thus takes a certain input and applies a mathematical transformation in order to produce

[51] S. Underwood, 'Blockchain Beyond Bitcoin', *Communications of the ACM*, Vol. 59, No. 11, November 2016, p. 15.

[52] E. Mik, 'Smart contracts: terminology, technical limitations and real world complexity', *Law, Innovation and Technology* 2017 Vol. 9 (2), p. 275.

[53] S. Nakamoto, 'Bitcoin: A Peer-to-Peer Electronic Cash System', *Bitcoin.org*, October 3, 2008, at WWW: <https://bitcoin.org/bitcoin.pdf>; Satoshi Nakamoto is the alias of an unidentified programmer, or a group of programmers

[54] Ibid, p. 1.

[55] Ibid, p. 1.

[56] Ibid, p. 2.

[57] Ibid, p. 1.

[58] Ibid, p. 2.

[59] Ibid, p. 2.

a single output: the hash. The length of that output is fixed in length, for example 256 bits.[60] Hashing needs to meet four demands: (i) it should not take a long time to compute the output from a given input, (ii) it should be very difficult to find two inputs that lead to the same output (collision resistance), (iii) the input should not be retraceable by means of the output and (iv) the output should look random.[61] Timestamping proves that the data existed at the time of being hashed and each timestamp includes the previous timestamp, in this manner adding to the chain of all timestamps.[62] That is why it is called a blockchain; there is a chain of blocks that includes all transactions that ever took place on that blockchain.

The second element of Bitcoin is a proof-of-work system.[63] The system requires the parties (the nodes) of the network to perform 'some work'. The nodes are basically the members of a blockchain network and pass around transaction and block data. In a proof-of-work system, a challenge is set, for which a response is required that leads to a value that starts with a predetermined amount of zero bits.[64] This challenge cannot be solved in any other way than parties making a huge number of attempts.[65] Once a participant has found the response that leads to the correct hash, all other participants can verify this by testing that response. The other participants can in this manner establish that the correct response has been found. Someone can effectively prove by a proof-of-work system that they have engaged in a significant amount of computational effort.[66] Satoshi envisaged the following: transactions are being timestamped by hashing them into a chain of hash-based proof of work, which forms a record (the blockchain) that cannot be changed without having to redo the proof-of-work.[67]

The steps to run the network are as follows:

1) New transactions are broadcast to all nodes.
2) Each node collects new transactions into a block.
3) Each node works on finding a difficult proof-of-work for its block.
4) When a node finds a proof-of-work, it broadcasts the block to all nodes.
5) Nodes accept the block only if all transactions in it are valid and not already spent.
6) Nodes express their acceptance of the block by working on creating the next block in the chain, using the hash of the accepted block as the previous hash.

The steps for running the Bitcoin blockchain as envisaged by Nakamoto[68]

This technology gives Bitcoin a number of unique features. Firstly, Bitcoin is decentralised; there is no central authority that determines what happens to the blockchain. All transactions are processed by the nodes. As the nodes process transactions collectively, a weak link is unable

[60] Z. Ramzan, 'Bitcoin: Cryptographic has functions', Educational video on *Khanacademy*, at WWW: <https://www.khanacademy.org/economics-finance-domain/core-finance/money-and-banking/bitcoin/v/bitcoin-cryptographic-hash-function>.

[61] Ibid.

[62] S. Nakamoto, 'Bitcoin: A Peer-to-Peer Electronic Cash System', *Bitcoin.org*, October 3, 2008, p. 2, at WWW: <https://bitcoin.org/bitcoin.pdf>.

[63] Ibid, p. 3.

[64] Ibid, p. 3.

[65] A. Rosic, 'Proof of Work vs Proof of Stake: Basic Mining Guide', *Blockgeeks* 2017, at WWW: <https://blockgeeks.com/guides/proof-of-work-vs-proof-of-stake/>.

[66] There has taken place a significant amount of computational effort because the respective user has found the correct response by trial and error. He has basically been trying out responses for the challenge until he finds the output that starts with the predetermined amount of zero bits.

[67] W. Mougayar, *The Business Blockchain*, Hoboken: John Wiley & Sons 2016, p. 65.

[68] S. Nakamoto, 'Bitcoin: A Peer-to-Peer Electronic Cash System', *Bitcoin.org*, October 3, 2008, p. 3, at WWW: https://bitcoin.org/bitcoin.pdf.

to cause a failure in the blockchain.[69] Furthermore, information that has already been stored on the blockchain, cannot be overwritten without consensus among all nodes concerning the alteration.[70] One could therefore say that Bitcoin is a democratic system. Thirdly, the longest chain within the Bitcoin blockchain serves as proof that it has been formed by the largest pool of CPU power, which makes it resilient to parties that want to attack the network. Consequently, in order to steal a Bitcoin, the entire history of the blockchain would have to be rewritten in 'broad daylight' by 'unfriendly' nodes.[71]

2.1.2 Blockchain technology as such and its relevant features

Whereas blockchain technology has probably gained most attention due to cryptocurrencies such as Bitcoin, its capabilities extend far beyond the facilitation thereof.[72] Currently, there are many other blockchain protocols being developed, allowing blockchains to interact with other technologies, such as the internet of things. It is a flexible technology, as it can be opened up for full public participation or it can be configured for more specific applications within a private context. It is sometimes argued that blockchain is the technology with the largest impact since the arrival of the Web.[73] Possible fields of application range from private securities, insurance, notary, proving existence of documents in general, decentralised storage to a decentralised internet of things.[74] This is in line with Pilkington's holistic view of blockchain technology, in which he argues that the essence of the blockchain is informational and processual, and not necessarily relating to the monetary sphere.[75] Vitalik Buterin, co-founder of Ethereum, defines blockchain technology as follows:

> *'A blockchain is a magic computer that anyone can upload programs to and leave the programs to self-execute, where the current and all previous states of every program are always publicly visible, and which carries a very strong cryptoeconomically secured guarantee that programs running on the chain will continue to execute in exactly the way that the blockchain protocol specifies.'*[76]

On a high level of abstraction, a blockchain essentially is a distributed database of records. Those records consist of all transactions or other digital events that have been executed and shared among the participating parties.[77] Those transactions or other digital events are

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69 SMU & The National CFO Institute, 'Blockchain and Smart Contracts', p. 4, at WWW: https://www.smu.edu.sg/sites/business.smu.edu.sg/files/business/Strategy_Organisation/BlockChainReport_2016_02_highres.pdf; in traditional systems that process transactions, a hack could falsify the records or make transactions unavailable temporarily.

70 M. Raskin, 'The Law and Legality of Smart Contracts', *The Georgetown Law Technology Review*, 305, 2017, p. 318; G.P. Dwyer, 'The Economics of Bitcoin and similar private digital currencies', *Journal of Financial Stability*, Vol. 17, 2015, p. 82.

71 D. Tapscott & A. Tapscott, *Blockchain Revolution: How the Technology Behind Bitcoin Is Changing Money, Business, and the World*, Penguin: New York, 2016, p. 8.

72 Risius & Spohrer, 'A Blockchain Research Framework', *Business & Information Systems Engineering*, 59(6), 2017, p. 385.

73 See e.g. ibid, p. 68.

74 M. Crosby e.a., 'BlockChain Technology: Beyond Bitcoin', *Applied Innovation Review*, Issue No. 2, June 2016, p. 13-16.

75 M. Pilkington, 'Blockchain Technology: Principles and Applications' in F. Xavier Olleros & M. Zhegu, *Research Handbook on Digital Transformations*, Cheltenham: Edward Elgar 2016, p. 9.

76 V. Buterin, 'Visions, part 1: The Value of Blockchain Technology', *Blog Ethereum*, April 13, 2015, at WWW: https://blog.ethereum.org/2015/04/13/visions-part-1-the-value-of-blockchain-technology/.

77 M. Crosby e.a., 'BlockChain Technology: Beyond Bitcoin', *Applied Innovation Review*, Issue No. 2, June 2016, p. 8.

aggregated into blocks of code and then appended onto the blockchain.[78] The blockchain is kept by a network of computers (also called nodes), at which every node keeps a complete register individually. The trust that the blockchain aims to establish is built upon cryptographic proof. The takeaway from a legal perspective is that blockchain technology is a mechanism for validating transactions without requiring an intermediary.[79] Blockchain thus solves the problem of establishing consensus among parties without the need for a centralised collection of information.[80]

2.2 Smart contracts

2.2.1 The concept of smart contracts

Szabo first proposed the concept of smart contracts in 1997.[81] He argued that many kinds of contractual clauses can be embedded in hardware and software.[82] Illustratively, he referred to a vending machine as a smart contract; 'anyone with coins can participate in an exchange with the vendor'.[83] The coins are retained and the drink supplied. Another example he set forth, related to an automobile. Szabo suggested that security protocols of a property, in this case the car, be refined in such a way to more fully embed the contractual terms that deal with that property.[84] Accordingly, an automobile could be rendered inoperable until the buyer fulfils the predefined condition.

The terminology of smart contracts is not unambiguous. Stark identifies two ways in which the term 'smart contract' is often used.[85] When referring to *smart contract code*, one means software agents.[86] The word 'contract' in this sense means that the code executes obligations and exercises certain rights, not necessarily stemming from a legal contract.[87] The second way to use the term is *smart legal contracts*, which revolves around the way in which legal contracts, or elements thereof, can be represented and executed by software.[88] The emphasis with *smart legal contracts* lies with the word 'legal'. *Smart legal contracts* therefore only relate to actual legal agreements, while *smart contract code* can relate to any type of execution. This raises the question what a legal contract is precisely. Although a universal definition of a contract has not been conceptualised in legal literature, the basic principles have been set out.[89] Peel defines a

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[78] K.E.C. Levy, 'Book-Smart, Not Street-Smart: Blockchain-Based Smart Contracts and The Social Workings of Law', *Engaging Science, Technology and Society* 2017 (3), p. 2.
[79] W. Mougayar, *The Business Blockchain*, Hoboken: John Wiley & Sons 2016, p. 66.
[80] M. Raskin, 'The Law and Legality of Smart Contracts', *The Georgetown Law Technology Review*, 305, 2017, p. 318.
[81] N. Szabo, 'The Idea of Smart Contracts' 1997, at WWW: http://www.fon.hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh.net/idea.html.
[82] Ibid.
[83] Ibid.
[84] Ibid.
[85] J. Stark, 'Making sense of blockchain smart contracts', *Coindesk,* June 4 2016, at WWW <https://www.coindesk.com/making-sense-smart-contracts/>.
[86] C.D. Clack e.a., 'Smart Contract Templates: foundations, design landscape and research directions', *Barclays Bank*, August 6, 2017, p. 2.
[87] Ibid, p. 2.
[88] J. Stark, 'Making sense of blockchain smart contracts', *Coindesk,* June 4 2016, at WWW <https://www.coindesk.com/making-sense-smart-contracts/>.
[89] E. McKendrick 2016, p. 4.

contract as 'an agreement giving rise to obligations which are enforced or recognised by law. The factor which distinguishes contractual from other legal obligations is that they are based on the agreement on the contracting parties.'[90] This thesis takes on the latter view, the one of *smart legal contracts*, with the central legal contract being the Paris Agreement.[91]

Clack stresses that the most important feature of a smart contract is its automatability.[92] After all, a smart contract would not be smart if not at least a part of it is automated.[93] Although smart contracts may seem like a revolution in contractual processes, it has been argued that they are merely technological manifestations of current contractual processes.[94] An example of a current contractual process is escrow, which suspends the execution of a contract and gives a trusted third party the authority to complete the process.[95] Another familiar process is self-help. Raskin argues that smart contracts serve as a pre-emptive form of self-help because parties will not have to address a court for the contract to execute a certain obligation.[96] While these technological manifestations of familiar contractual processes have been put forward in literature, neither fully grasps the essence of smart contracts, as both escrow and self-help are only enhancements to contractual processes.[97] It is argued that smart contracts do not distinguish themselves by simplifying enforcement, but rather by making enforcement unavoidable and hence altering the nature of the contract itself.[98] Traditional contracts in contrast are enforced in distinct phases. The wronged party must document the harm, establish the other party's responsibility, initiate legal proceedings, and ensure that the payment is made.[99]

However, this thesis should not neglect the literature suggesting that smart contracts are not contracts at all. Durkheim already held that a contract always involves facts which are beyond the parties' will.[100] Hence, a contract needs to take into account circumstances that are not necessarily a manifestation of free will. It is therefore asserted that with smart contracts, there is no possibility of uncertainty in their execution and therefore there is no compliance.[101] Strictly speaking, they are just a form of automaticity and cannot resemble an actual contract.[102] This line of argumentation, although debatable, does not prevent this thesis from exploring the possibilities of using smart contracts, as this thesis takes into account this automaticity characteristic in the fifth chapter's evaluation.

2.2.2 Blockchain-enabled smart contracts

It is important to note that a smart contract is not by its very nature stored on a blockchain. In principle, smart contracts do not need a blockchain to be executed. Smart contracts and

[90] E. Peel 2015, p. 1.

[91] Paris Agreement, New York, 2016, at WWW <https://unfccc.int/files/meetings/paris_nov_2015/application/pdf/paris_agreement_english_.pdf>.

[92] C.D. Clack e.a., 'Smart Contract Templates: foundations, design landscape and research directions', *Barclays Bank*, August 6, 2017, p. 3.

[93] Ibid, p. 3.

[94] K. Werbach & N. Cornell, 'Contracts ex Machina', *Duke Law Journal*, 2017 Vol. 67:313, p. 344.

[95] Ibid, p. 344.

[96] M. Raskin, 'The Law and Legality of Smart Contracts', *The Georgetown Law Technology Review*, 2017, p. 305.

[97] K. Werbach & N. Cornell, 'Contracts ex Machina', *Duke Law Journal*, 2017 Vol. 67:313, p. 348.

[98] Ibid, p. 348.

[99] K.E.C. Levy, 'Book-Smart, Not Street-Smart: Blockchain-Based Smart Contracts and The Social Workings of Law', *Engaging Science, Technology and Society* 2017 (3), p. 3.

[100] R.N. Bellah 1973. p. 92.

[101] Q. Dupont & B. Maurer, 'Ledgers and Law in the Blockchain', *King's Review*, June 23, 2015, p. 9.

[102] Ibid, p. 9.

blockchain technology are often talked of in the same breath, but are actually distinct technologies, albeit complementary and sometimes having an interdependent relationship.[103] That relationship is explained by the facilitating role that blockchain technology plays. The technology allows a code that both parties want to use for a contract, to be embedded in the blockchain.[104] Blockchain-enabled smart contracts thereby fulfil Szabo's vision, in which performance and enforcement of a contract, or at least a part thereof, occur automatically, without human intervention. Technically, a blockchain-enabled smart contract is an 'autonomous agent' stored in the blockchain, encoded as part of a 'creation' transaction that introduced a contract to the blockchain.[105] Raskin's legal takeaway of blockchain-enabled smart contracts is that they are agreements whose execution is automated.[106]

When terms of a smart contract on stored in the blockchain, this implicates that those terms cannot be overridden by a single party with malicious intent (as opposed to traditional systems where a third party is necessary).[107] Furthermore, parties will certainly be using the same version of the contract.[108] Blockchain thus adds its strength of decentralisation to the characteristics of smart contracts that were explained in the previous paragraph. A blockchain-enabled smart contract functions without reliance on a centralised authority.[109] Applying this knowledge to the earlier mentioned vending machine, this means that the buyer would no longer have to depend upon the seller's software, but on a 'disinterested' blockchain, which can enforce the relevant terms.[110]

2.2.3 Limitations to the reach of blockchain-enabled smart contracts

A first limitation to the use of blockchain-enabled contracts derives from the fact that its functioning is based on code. Clauses have to be susceptible to automation and self-execution in order to be coded.[111] One should therefore distinguish two aspects within legal contracts. A legal contract has (i) operational aspects and (ii) non-operational aspects. An operational aspect can be recognised by conditional logic. Upon the occurrence of a specific event, the triggering of a certain condition, a deterministic action is required.[112] Non-operational aspects do not contain such conditional logic and cannot be automated, or automation is not deemed favourable.[113] Non-operational clauses typically include open norms such as 'good faith' and 'in a commercially reasonable manner'. The distinction between operational and non-

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[103] ISDA & Linklaters, 'Whitepaper: Smart Contracts and Distributed Ledger – A Legal Perspective', August 2017, p. 8, at WWW < https://www.isda.org/a/6EKDE/smart-contracts-and-distributed-ledger-a-legal-perspective.pdf>.

[104] Ibid, p. 9.

[105] L. Luu e.a., 'Making Smart Contracts Smarter', Conference paper for the 2016 *Conference on Computer and Communications Security* 2016, p. 257.

[106] M. Raskin, 'The Law and Legality of Smart Contracts', *The Georgetown Law Technology Review*, 305, 2017, p. 309.

[107] Ibid, p. 319.

[108] ISDA & Linklaters, 'Whitepaper: Smart Contracts and Distributed Ledger – A Legal Perspective', August 2017, p. 9, at WWW < https://www.isda.org/a/6EKDE/smart-contracts-and-distributed-ledger-a-legal-perspective.pdf>.

[109] K.E.C. Levy, 'Book-Smart, Not Street-Smart: Blockchain-Based Smart Contracts and The Social Workings of Law', *Engaging Science, Technology and Society* 2017 (3), p. 2.

[110] M. Raskin, 'The Law and Legality of Smart Contracts', *The Georgetown Law Technology Review*, 305, 2017, p. 319.

[111] See e.g. Ibid, p. 10; C.D. Clack e.a., 'Smart Contract Templates: foundations, design landscape and research directions', *Barclays Bank*, August 6, 2017, p. 5.

[112] Ibid, p. 10.

[113] C.D. Clack e.a., 'Smart Contract Templates: foundations, design landscape and research directions', *Barclays Bank*, August 6, 2017, p. 5.

operational aspects of contracts can roughly be made by Boolean logic, which reduces all values to either true or false.[114] Non-operational clauses are less (or not) susceptible to being expressed in Boolean logic, which makes it difficult to grasp them in computer code. This distinction is of great interest for blockchain-enabled smart contracts being a tool of implementation for REDD+. When provisions are qualified as largely non-operational, using blockchain-enabled smart contracts proves more difficult. In this context, it should be noted that natural language is by its very nature imprecise as the meaning of the words always depend on the context. Especially legal language that can be found in lengthy clauses, with references to abstract concepts, may be more difficult to code than 'normal' natural language.

Apart from the problem of non-operational aspects, smart contracts from a legal perspective can only be arrangements aside the actual legal agreement. The right to submit a claim to court and thus have access to justice can namely not be excluded.[115] A smart contract does therefore not exhaust all rights by itself. Not considering contract law in general may result in insufficient protection of parties.[116]

2.3 Conclusion

This chapter aimed to explain the role of blockchain with regards to smart contracts. On a high level of abstraction, a blockchain is a distributed ledger of records. This ledger is maintained in a decentralised manner, as all nodes keep a register individually. Blockchain technology guarantees that records are kept in a reliable and transparent manner. Smarts contracts are automatable representations of a transaction in real life. A smart contract automates the outcome that is triggered by a predefined condition. Smart contracts in this thesis refer to a representation of an existing legal contract. However, not every provision can be coded. The application of blockchain-enabled smart contracts is therefore limited to the so-called operational elements of contracts. These limitations are relevant for (i) answering whether smart contracts can be a tool of implementation for REDD+ (chapter four) and (ii) whether such use would promote the implementation thereof (chapter five). When smart contracts run on a blockchain, the characteristics of the technology apply to the smart contract. The answer to the first sub question is therefore that blockchain-enabled smart contracts are decentralised representations of (parts of) existing legal contracts that automatically execute those parts. They create a reliable and transparent implementation that cannot be tampered with by a single party. The next chapter analyses the REDD+ mechanism under the Paris Agreement.

[114] As explained on Wikipedia: at WWW: <https://en.wikipedia.org/wiki/Boolean_algebra>.
[115] T. Kerikmäe 2016, p. 138.
[116] Ibid. p. 145.

3. The implementation of the REDD+ mechanism under the Paris Agreement

This chapter analyses the REDD+ mechanism under the Paris Agreement (hereinafter referred to as: Agreement), which is the central legal contract in this thesis. The Agreement is a legally binding document and was adopted under the overarching UNFCCC.[117] This means that the UNFCCC provisions that apply to 'related legal instruments' also apply to the Agreement.[118] The UNFCCC is an international treaty concerned with reducing greenhouse gas emissions. It sets no binding limits and contains no enforcement mechanisms.[119] It however establishes the core parameters that guide international climate action, including the Agreement negotiations.[120] The UNFCCC started developing a mechanism to combat deforestation in 2005,[121] and later expanded the focus of that mechanism to also reducing emissions from forest degradation, in addition to forest conservation, sustainable forest management and enhancing forest carbon stocks in developing countries, altogether called REDD+.[122] Between 2010 and 2015, the global forest area shrank by 3.3 million hectares annually.[123] Deforestation and forest degradation account for ten percent of global greenhouse gas emissions.[124] As forests act as sinks and sources of carbon, a reduced global forest area diminishes the forests' capability of reducing net greenhouse gas emissions.[125] REDD+ is one of the Agreements' mitigation mechanisms and is crucial towards the achievement of the Agreement's goals. The ratio of the REDD+ mechanism is that developing countries with large spans of forest area are rewarded financially for measures that reduce deforestation and thus reduce emissions.[126]

The central question in this chapter is how REDD+ under the Agreement can be described and which problems are posed in the implementation thereof. The aim thereby is to identify the obligations and conditions related to REDD+. The obligations refer to the duties that countries and paying entities have to comply with. The conditions are the events that trigger the eventual results-based payments. Precise identification is necessary to analyse whether blockchain-enabled smart contracts can be a tool of implementation for REDD+, which will be done in the next chapter. The third paragraph of this chapter analyses the current issues with regards to the implementation of REDD+. An analysis of these hurdles is a prerequisite for researching whether blockchain-enabled smart contracts can promote the implementation of REDD+.

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[117] The Paris Agreement has to be ratified as a whole by parties and is binding for its parties under international law after its entry into force on 4 November 2016, see R. Bodle & S. Oberthür 2017, p. 2; The UNFCCC was adopted on 9 may 1992 and entered into force on 21 March 1994; United Nations Framework Convention in Climate Change, at WWW: <https://unfccc.int/resource/docs/convkp/conveng.pdf>.
[118] D. Bodansky e.a. 2017, p. 212.
[119] J. Depledge 2017, p. 28; article 2 UNFCCC.
[120] Ibid, p. 28.
[121] The legal basis for conservation and enhancement of sinks and reservoirs of greenhouse gases is laid down in article 4 (1)(d) UNFCCC.
[122] REDD+ is laid down in article 5 (2) of the Paris Agreement; M.E. Recio, 'The Warsaw Framework and the Future of REDD+', *Yearbook of International Environmental Law*', 2014 Vol. 42, No. 1, p. 38.
[123] Report of the Food and Agriculture Organization of the United Nations, *Global Forest Resources Assessment 2015*, 2016, p. 3, at WWW: <http://www.fao.org/3/a-i4793e.pdf>.
[124] W. Obergassel e.a., 'Phoenix from the ashes: an analysis of the Paris Agreement to the United Nations Framework Convention on Climate Change – Part 1', *Environmental Law & Management* 2015 (27), p. 251.
[125] Ibid, p. 16.
[126] M.E. Recio, 'The Warsaw Framework and the Future of REDD+', *Yearbook of International Environmental Law*', 2014 Vol. 42, No. 1, p. 38.

3.1 Reducing Emissions from Deforestation and Degradation

The REDD+ mechanism is unique in the climate context because it wields results-based finance.[127] REDD+ rewards accomplishments, as opposed to traditional mechanisms in which financing is done upfront and therefore does not necessarily relate to actual results.[128] This paragraph first looks into the way in which REDD+ is anchored in the Agreement. This paragraph then looks into the UNFCCC decisions that govern REDD+.

3.1.1 Article 5 of the Paris Agreement

The REDD+ mechanism is laid down in article 5 of the Agreement. The article reads as follows:

> *1. Parties should take action to conserve and enhance, as appropriate, sinks and reservoirs of greenhouse gases as referred to in Article 4, paragraph 1(d), of the Convention, including forests.*
>
> *2. Parties are encouraged to take action to implement and support, including through results-based payments, the existing framework as set out in related guidance and decisions already agreed under the Convention for: policy approaches and positive incentives for activities relating to reducing emissions from deforestation and forest degradation, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries; and alternative policy approaches, such as joint mitigation and adaptation approaches for the integral and sustainable management of forests, while reaffirming the importance of incentivizing, as appropriate, non-carbon benefits associated with such approaches.*

The first paragraph is phrased as an encouragement rather than an obligation. The fact that the paragraph also states 'as appropriate', giving parties discretion with regards to the scale of REDD+ activities.[129] The second paragraph states that parties are to continue on the basis of the existing REDD+ framework. The paragraph therefore emphasises the importance of continuing with the progress that has already been made under the UNFCCC.[130] This raises the question what the existing framework exactly is. The answer is the Warsaw Framework for REDD+ (WFR).[131] The WFR sets the general criteria for developing countries to receive results-based finance after they have accomplished mitigation actions in the forest sector.[132] The WFR establishes a robust framework that fulfils the criteria to obtain facilitate results-based payments.[133] The WFR is explained in the next paragraph.

As the second paragraph of article 5 of the Agreement explicitly refers to the existing framework and REDD+, the entire framework has been anchored into the legally binding Agreement.[134] However, the legal force and therefore the material effect of specific provisions

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[127] C. Voigt & F. Ferreira, 'The Warsaw Framework for REDD+: Implications for National Implementation and Access to Results-based Finance', *Carbon and Climate Law Review* 2015 (2), p. 114.
[128] Ibid.
[129] A.G.M. La Viña & A. de Leon 2017, p. 172.
[130] Ibid, p. 173.
[131] The Warsaw Framework consists of seven decisions that were adopted at the UNFCCC COP in Warsaw in 2013.
[132] W. Obergassel e.a., 'Phoenix from the ashes: an analysis of the Paris Agreement to the United Nations Framework Convention on Climate Change – Part 1', *Environmental Law & Management* 2015 (27), p. 251.
[133] A.G.M. de la Viña e.a. 2016, p. 18; C. Voigt & F. Ferreira, 'The Warsaw Framework for REDD+: Implications for National Implementation and Access to Results-based Finance', *Carbon and Climate Law Review* 2015 (2), p. 113.
[134] M.E. Recio, 'Rainforests in the Paris Agreement: Old Wine, New Bottles', *University of Eastern Finland* 14 November 2016, at WWW: <https://www.uef.fi/en/web/cceel/blog/-/blogs/rainforests-in-the-paris-agreement-old-wine-new-bottles->.

under the Agreement depend on the use of language. Paragraph two merely encourages parties to take action within the frame of REDD+, which does not create a legal obligation for parties to actually do so. Much of the REDD+ activities therefore require further arrangements, for example between countries, in order to achieve actual implementation.

3.1.2 The Warsaw Framework and the implementation of REDD+ in practice

The WFR provides the elements required in order for REDD+ to be operational.[135] The objective to reduce emissions from deforestation and forest degradation in developing countries has been codified in Decision 1/CP.16 to the Cancún Agreements.[136] The Decision lays down four elements that REDD+ activities should comprise.[137] Parties should develop (i) a national strategy or action plan, (ii) a national forest reference level, (iii) a national forest monitoring system and (iv) a set of safeguards throughout the implementation. The REDD+ mechanism furthermore aims to guarantee transparent governance, respect for human rights, right of indigenous people and environmental integrity.[138]

Firstly, developing countries should address the drivers of deforestation and forest degradation in their national strategies or action plans.[139] The countries are furthermore requested to address land tenure issues, forest governance issues, gender considerations and the set of safeguards, ensuring full and effective participation of relevant stakeholder including local and indigenous communities.[140] In practice however, the strategies differ extensively. Countries may choose to include all aforementioned elements or single out one or several of them according to the country's interests.[141]

Secondly, the basis for measuring the impact of REDD+ activities is the national forest reference level (FRL).[142] The FRL is a requirement to apply for results-based payments. The FRL serves as a benchmark for assessing the performance of a party and is established on the grounds of average historic emissions.[143] The amount of emitted tonnes of carbon dioxide in a year below the FRL determine the performance of a party with regards to REDD+ activities in the respective year.[144] After the results are submitted, the party can request a technical assessment.[145] The fact that the FRL is established on a national level, aims to ensure that deforestation is not moved from one area in the country to the other.[146] The latter would render REDD+ activities in a country useless.

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[135] M.E. Recio, 'The Warsaw Framework and the Future of REDD+', *Yearbook of International Environmental Law*', 2014 Vol. 42, No. 1, p. 43; an overview of the decisions under the Warsaw Framework kan be found via UNFCCC, 'Warsaw Framework for REDD-plus', at WWW: <http://unfccc.int/land_use_and_climate_change/redd/items/8180.php>.
[136] Decision 1/CP.16 third chapter paragraph C, The Cancún Agreements at WWW: <http://unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf#page=2>.
[137] Decision 1/CP.16 (71), The Cancún Agreements.
[138] Cancún Agreements, Appendix 1 (2).
[139] Decision 1/CP.16 (72), The Cancún Agreements.
[140] Ibid.
[141] C. Voigt & F. Ferreira, 'The Warsaw Framework for REDD+: Implications for National Implementation and Access to Results-based Finance', *Carbon and Climate Law Review* 2015 (2), p. 118.
[142] Decision 1/CP.16 (71), The Cancún Agreements.
[143] C. Voigt & F. Ferreira, 'The Warsaw Framework for REDD+: Implications for National Implementation and Access to Results-based Finance', *Carbon and Climate Law Review* 2015 (2), p. 122.
[144] Decision 12/CP.17 (7) at WWW: <http://unfccc.int/resource/docs/2011/cop17/eng/09a02.pdf>.
[145] Decision 1/CP.16 (71), The Cancún Agreements.
[146] M.E. Recio, 'The Warsaw Framework and the Future of REDD+', *Yearbook of International Environmental Law*', 2014 Vol. 42, No. 1, p. 52.

Thirdly, national forest monitoring systems are required.[147] The monitoring systems play a crucial role in the REDD+ mechanism. The mechanism is namely based on the premise of payments for mitigation results.[148] Efforts in the context of REDD+ need to be measured, reported and verified, which is a part of the national forest monitoring systems.[149] The monitoring systems use a combination of remote sensing and ground-based forest carbon inventory approaches and should provide transparent, consistent and as far as possible accurate estimates.[150] Furthermore, the monitoring systems need to have their results available and suitable for review.[151] While keeping track of forest carbon stocks and emissions, developing countries must utilise the latest Intergovernmental Panel on Climate Change (IPCC) guidance and guidelines.[152] The monitoring systems need to be in place before a country can developed it FRL and achieve results from REDD+ activities.[153]

The set of safeguards constitute the last element.[154] UNFCCC decisions have elucidated that REDD+ activities should be consistent with safeguards, regardless of the source of funding thereof.[155] Furthermore, in order to receive results-based payments, countries should demonstrate how the safeguards are addressed and respected.[156] Seven safeguards have been laid down.[157] REDD+ activities should complement or be consistent with the objectives of national forest programmes. The national forest governance structures should be transparent and effective. There should be respect for the knowledge and right of indigenous people and full and effective participation of relevant stakeholders. REDD+ activities need to be consistent with the conservation of natural forests and biological diversity. Finally, REDD+ activities should address the risks of reversals and reduce displacement of emissions. The compliance with these seven elements is a legal obligation for parties undertaking REDD+ activities.[158]

The actual implementation of REDD+ takes place in three phases.[159] Firstly, parties should develop national strategies or actions plans and policies and measures. Secondly, parties need to implement those plans, policies and measures. Thirdly, REDD+ activities should be in place and results measured, reported and verified, allowing for results-based payments. The Agreement in conjunction with the UNFCCC decisions imply that the REDD+ mechanism can be financed through three sources: (i) assistance from foreign states, (ii) internationally transferred mitigation outcomes and thus allowing the trade in carbon credits for this purpose and (iii) domestic programmes.[160] With regards to private donors, it should be noted that the methodological guidance by the UNFCCC is not binding for them. The COP namely has no normative power with regards to entities that operate outside of its guidance and/or

[147] The modalities for the national forest monitoring systems are laid down in Decision 11/CP.19 at WWW: <http://unfccc.int/resource/docs/2013/cop19/eng/10a01.pdf#page=31>.
[148] C. Voigt & F. Ferreira, 'The Warsaw Framework for REDD+: Implications for National Implementation and Access to Results-based Finance', *Carbon and Climate Law Review* 2015 (2), p. 118.
[149] Decision 1/CP.16, The Cancún Agreements.
[150] Decision 4/CP.15 (1)(d).
[151] Ibid.
[152] Decision 11/CP.19 (2) and (3); Decision 4/CP.15 (1)(c).
[153] . Voigt & F. Ferreira, 'The Warsaw Framework for REDD+: Implications for National Implementation and Access to Results-based Finance', *Carbon and Climate Law Review* 2015 (2), p. 118.
[154] Decision 1/CP.16, Appendix 1 (2).
[155] A. Savaresi 2016, p. 133; Decision 2/CP.17 (63).
[156] Ibid; Decision 9/CP.19 (4).
[157] Appendix I (2) to Decision 1/CP.16.
[158] A. Sarafesi 2016, p. 133.
[159] Decision 1/CP.16 (73), The Cancún Agreements.
[160] M.F. Tehan, 2017, p. 20.

accountability.[161] Recio explains that bilateral co-operation and multilateral funds play a large rule in supporting REDD+ activities.[162]

3.3 Challenges to the implementation of REDD+

This paragraph identifies challenges to the implementation of REDD+ that have been discussed in literature. First of all, it makes sense to mention 'the tragedy of the commons', which is a problem that deserves consideration within the fight against climate change in general.[163] The problem was already illustrated in the introduction chapter. As every country tends to pursue its own interests, which are in the short term served by a larger amount of emissions, countries collectively tend to act contrary to the common good. Blockchain technology is apt to create a common incentive, which counters the 'tragedy of the commons'. This will be clarified in the fifth chapter.

Subsequently, the state-centricity of legal norms for jurisdictional REDD+ impedes the implementation of REDD+.[164] Jodoin and Case shed a light upon the paradox of the state-centricity, even though the private sector is very influential with regards to the success of REDD+. They argue that the private sector is a large agent of deforestation, but governments are reluctant to compensate them for lost opportunities to exploit forests through REDD+ payments. Angelsen adds that there is a lack of willingness among funding entities to fully compensate agroindustries for lost income.[165] One can think about palm oil and soy producers in this context. The private sector should therefore be more involved with REDD+. The lack of involvement of the private sector can be explained by the absence of regulatory intervention that would stimulate private activity. Jodoin and Mason-Case point out that without a compliance scheme that involves private actors, corporate social responsibility is the leading incentive for private actors to take action.[166] A risk that is currently associated with the involvement of private actors however, is that they are not bound by the UNFCCC's methodological guidance.[167] The consequence is that diverging difficult requirements and procedures apply, which raises the chances of double-counting of results and payments.[168] This thesis namely seeks improvements within the sphere of the UNFCCC. Blockchain-enabled smart contracts make it easier to involve private actors that want to finance REDD+ activities. The source of the finance does namely not matter for the payments as such. This opportunity is

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[161] C. Voigt & F. Ferreira, 'The Warsaw Framework for REDD+: Implications for National Implementation and Access to Results-based Finance', *Carbon and Climate Law Review* 2015 (2), p. 126.

[162] M.E. Recio, 'The Warsaw Framework and the Future of REDD+', *Yearbook of International Environmental Law*', 2014 Vol. 42, No. 1, p. 42; Prime examples of bilateral arrangement with regards to REDD+ are those between Norway and Brazil and Norway and Indonesia: the announcement of the extension of the partnership between Brazil and Norway can be found in a joint press statement at WWW: <https://www.regjeringen.no/contentassets/f4e0a1b87da7474ab78eb5e7d59e3477/cop21-brazil-norway-joint-press-statement-30-november-2015---nor-br-final.pdf>.

[163] G. Hardin, 'The Tragedy of the Commons', *Science* 1968 (162), p. 1244.

[164] S. Jodoin & S. Mason-Case, 'What Difference Does CBDR Make? A Socio-Legal Analysis of Differentiation in the Transitional Legal Process for REDD+', *Transnational Environmental Law* 2016 (5:2), p. 278; it should be noted that until 2020 at least, REDD+ finance comes from multiple sources that follow different rules and mechanism but also target different actors, see C. Streck & C. Parker 2012, p. 127.

[165] A. Angelsen et alia 2012, p. 48.

[166] S. Jodoin & S. Mason-Case, 'What Difference Does CBDR Make? A Socio-Legal Analysis of Differentiation in the Transitional Legal Process for REDD+', *Transnational Environmental Law* 2016 (5:2), p. 279.

[167] C. Voigt & F. Ferreira, 'The Warsaw Framework for REDD+: Implications for National Implementation and Access to Results-based Finance', *Carbon and Climate Law Review* 2015 (2), p. 126.

[168] Ibid.

discussed in the fifth chapter. Moreover, he fourth chapter will very briefly discuss the possibility of making a very automatable smart contract in combination with the internet of things, which is only possible for parties outside the UNFCCC's oversight.

Additionally, concerning the influence and involvement of the private sector in the financing of REDD+, it should be noted that the WFR strives for a high level of transparency.[169] Voigt and Ferreira point out that financing entities will not transfer funds to parties that 'provide selective, inconclusive or inconsistent information on how they address all of the safeguards'.[170] What's more, corruption levels in forestry sectors and the design and delivery of REDD+ finance pose fiduciary risks.[171] These two risks provide that transparency and accountability prove problematic in the context of REDD+. Out of the top ten recipient of REDD+ funds, nine score less 40/100 on the Transparency International's Corruption Perception Index.[172] The current design and delivery of REDD+ finance is profoundly complex, with various actors funding activities. Moreover, there is overlap and blend of the resource streams in developing countries.[173] As a consolidated database of financial flows for REDD+ activities is lacking, and many REDD+ agreements are not publicly available, transparency in this sense is lacking as well. The characteristics of blockchain technology are well-apt to improve transparency in this regard. This opportunity is discussed in the fifth chapter.

Furthermore, discrepancies between REDD+ activities at the national and subnational level can lead to difficulties with the receipt of results-based payments. The WFR adapted a centralised, national approach. This stems from Decision 1/CP.16, which refers to a *national* strategies or action plan, a *national* reference level and *national* forest monitoring systems.[174] However, developing countries are offered discretion under the WFR to develop activities at the scale and level that suit their national interests best.[175] Taking into account this room for discretion, developing countries still depend on procedures under the authority, or at least the coordination, of organisations on the national level.[176] Moreover, subnational initiatives may not even be able to obtain recognition for their results, and hence obtain results-based payments, without close coordination by the national authorities. Although this issue is relevant to the implementation of REDD+, blockchain-enabled smart contracts cannot change the approach of the WFR. Nevertheless, parties outside of the oversight of the UNFCCC are merely encouraged to take into account the UNFCCC's methodological guidance. Those parties could therefore alternatively use sophisticated smart contracts to govern their REDD+ activities.

Moreover, it is challenging to ensure that funds are actually available and flow to developing countries that undertake REDD+ activities.[177] Gizachew et alia underscore this issue and point out that a lack of performance-based payments hinders the establishment of carbon monitoring systems in developing countries.[178] Confidence in future payments for forest conservation efforts is therefore key in the implementation of REDD+. Moreover, developing countries will have to take the risk of developing REDD+ elements without having certainty that those

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169 See Decision 4/CP.15 (1)(d); Decision 11/CP.19; 1/CP.16; 12/CP.17.
170 C. Voigt & F. Ferreira, 'The Warsaw Framework for REDD+: Implications for National Implementation and Access to Results-based Finance', *Carbon and Climate Law Review* 2015 (2), p. 127.
171 P. Keenlyside e.a. 2016, p. 329.
172 Ibid, p. 331.
173 Ibid.
174 Decision 1/CP.16 (70).
175 C. Voigt & F. Ferreira, 'The Warsaw Framework for REDD+: Implications for National Implementation and Access to Results-based Finance', *Carbon and Climate Law Review* 2015 (2), p. 127.
176 Ibid.
177 A.G.M. La Viña & A. de Leon 2016, p. 177.
178 B. Gizachew e.a., 'REDD+ in Africa: contexts and challenges', *Natural Resources Forum* 2017 (41), p. 97.

elements will achieve the pre-defined results.[179] It is namely a possibility that natural hazards or institutional challenges obstruct the achievement of those goals.[180] Another point specifically related to Africa, is that proper external finance is often endangered by the struggles to demonstrate compliance with fiduciary standards and the capacity to manage substantial funds in an efficient and transparent manner.[181] The importance of large funds is furthermore caused by the fact that those funds will also have to diminish the usual wood extraction activities. The consequence thereof is that the revenue of REDD+ should exceed the costs of implementing the mechanism plus the opportunity costs associated with profits from wood extraction and forest cultivation.[182] The guaranteeing of funds can be done by means of blockchain-enabled smart contracts. The fourth and fifth chapter illustrate this.

A final challenge for properly implementing REDD+ is that a reliable system that ensures measurement, reporting and verification of the emissions from forests is a necessary condition.[183] For developing countries this often proves a difficult task. Smart contracts as such cannot help in this regards. These countries will have to comply with the UNFCCC decisions.

3.4 Conclusion

This chapter analysed the REDD+ mechanism under the Paris Agreement and identified issues in its implementation. REDD+ is one of the mitigation mechanisms under the Agreement. REDD+ wields results-based finance; developed countries and private actors pay developing countries when REDD+ activities lead to predefined accomplishments. The REDD+ mechanism is guided by the decisions underlying the WFR. The WFR comprises four elements: (i) a national strategy or action plan, (ii) a national forest reference level, (iii) a national forest monitoring system and (iv) a set of safeguards throughout the implementation. In short, the WFR offers parties a clear understanding of what constitutes mitigation results, the requirements of achieving these and how to measure, report and verify them.[184] The implementation of the mechanism is hindered by various challenges: the tragedy of the commons, state-centricity of legal norms, a lack of transparency, uncertainty about the availability of the funds and more. The next chapter will illustrate whether REDD+ as such can be implemented by blockchain-enabled smart contracts. The fifth chapter analyses whether such deployment promotes the implementation of REDD+. During the course of this analysis, the issues set out in this chapter play an important role. Some of the issues identified in this chapter can be solved (partially) by blockchain-enabled smart contracts. The table below offers an overview of the challenges identified in this chapter and already gives insight into what extent blockchain-enabled smart contracts can help.

[179] M.E. Recio, 'The Warsaw Framework and the Future of REDD+', *Yearbook of International Environmental Law*', 2014 Vol. 42, No. 1, p. 47.
[180] Ibid.
[181] B. Gizachew e.a., 'REDD+ in Africa: contexts and challenges', *Natural Resources Forum* 2017 (41), p. 97.
[182] Ibid.
[183] B. Gizachew e.a., 'REDD+ in Africa: contexts and challenges', *Natural Resources Forum* 2017 (41), p. 92.
[184] C. Voigt & F. Ferreira, 'The Warsaw Framework for REDD+: Implications for National Implementation and Access to Results-based Finance', *Carbon and Climate Law Review* 2015 (2), p. 126.

Overview of challenges and lookout to further chapters

Challenge	**Can a blockchain-enabled smart contract help?**	**Why?**	**Place of discussion in this thesis**
Tragedy of the commons	Yes	Aligning private interest with the common good; streamlining REDD+ payments	5.2.1
State-centricity of legal norms for REDD+	No	The initiative lies with the UNFCCC; smart contracts are not a source of legal norms	
Lack of involvement of private actors	Yes	Technical solutions outside oversight UNFCCC; public blockchain is open to all entities	4.2.2; 4.2.4; 5.1; 5.2.1
Transparency	Yes	Characteristic of blockchain technology	5.2.1
Centralised, national approach WFR	No	The approach as such cannot be changed;	4.2.2
Availability of funds	Yes	Tokenisation of funds on the blockchain	4.2.4; 5.2.1; 5.2.2
Reliable MRV	No	The current MRV process cannot be grasped in code	4.2.2

4. Blockchain-enabled smart contracts as a tool of implementation for the REDD+ mechanism

This chapter analyses to what extent blockchain-enabled smart contracts can be a tool of implementation for REDD+. This chapter therefore builds upon the previous two chapters. This chapter applies the knowledge about blockchain-enabled smart contracts to REDD+. Before this thesis can evaluate whether the implementation of REDD+ can be promoted by smart contracts, which will be done in the next chapter, it is necessary to analyse whether smart contracts are capable of implementing (parts of) REDD+ at all. In short, this chapter analyses whether the use of smart contracts is possible and the next chapter evaluates whether such use would improve implementation. This chapter does therefore not necessarily deal with all the implementation challenges that have been set out in the previous chapter, but analyses whether (parts of) REDD+ as such can be implemented by means of blockchain-enabled smart contracts. Nevertheless, the solutions to some of the challenges of the previous chapter already become clear during this chapter. The first paragraph in this chapter elucidates two considerations that are important for this chapter's analysis. Those considerations concern the fact that blockchain-enabled smart contracts vary in the extent that they grasp an agreement and the fact that they cannot transfer legal tender such as euros. Those considerations give a frame of reference that allows for the analysis whether REDD+ can be coded. The second paragraph analyses to what extent blockchain-enabled smart contracts can grasp the fundamentals behind REDD+ and therefore answers the sub question central in this chapter. The limitations of blockchain-enabled smart contracts that were established in the second chapter play an important role in this analysis.

4.1 Considerations for blockchain-enabled smart contracts implementing the REDD+ mechanism

4.1.1 Types of blockchain-enabled smart contracts

The second chapter iterated that legal contracts consist of so-called operational aspects and non-operational aspects. The latter do not contain conditional logic. There is conditional logic when the occurrence of a deterministic action is triggered by a predefined condition. Non-operational aspects on the other hand cannot be automated in smart contracts or automation is not deemed favourable.[185] Furthermore, there are multiple courses of action for coding a smart contract. First of all, a smart contract can be a translation of an already existing agreement. Secondly, the smart contract can be created from the start. Lastly, a contract can be drafted in natural language with the later encoding already in mind.[186] This thesis reviews the possibility of encoding the WFR, which corresponds with the first option. The diagram below illustrates the possibilities of what a smart contract can represent.[187] In the left extreme the smart contract is coding the entire existing legal contract. In the right extreme the smart contract merely comprises the payments mechanism. Due to the amount of non-operational clauses in the REDD+ mechanism,

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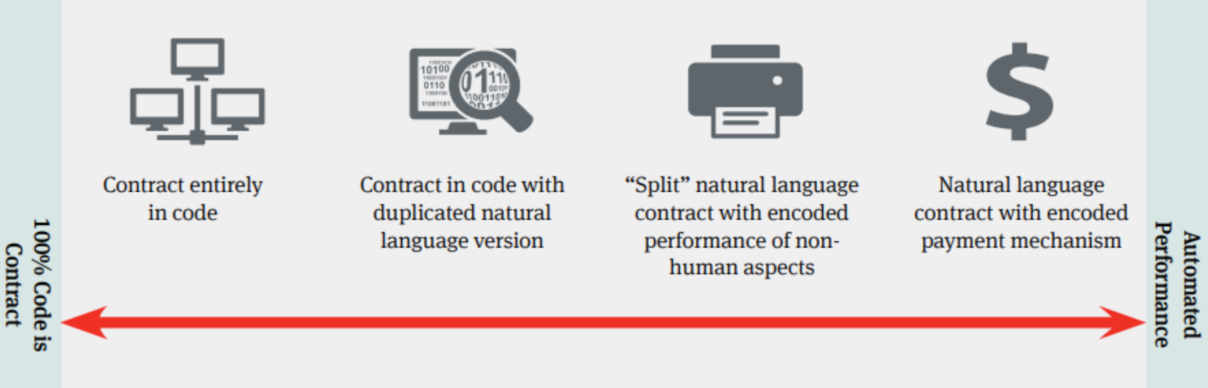
[185] C.D. Clack e.a., 'Smart Contract Templates: foundations, design landscape and research directions', *Barclays Bank*, August 6, 2017, p. 5.

[186] White paper by R3 & Norton Rose Fulbright, '*Can smart contracts be legally binding contracts?'*, *Norton Rose Fulbright* 2016, p. 12 at WWW: <http://www.nortonrosefulbright.com/files/r3-and-norton-rose-fulbright-white-paper-full-report-144581.pdf> .

[187] Ibid, p. 13

it can hardly be expected to be entirely coded. The answer to the sub question in this chapter is therefore somewhere in the middle of the diagram. These intermediate positions include the (i) case of a 'duplicated' contract, in which every clause is encoded as well as existing in natural language and (ii) the case of a 'split' contract in which non-human elements of performance have been encoded into computer code and other human obligations and for example remedial provisions exist in natural language.[188] In the latter case, the two components would work together as one.

Scale of representation by a smart contract



In order to properly govern REDD+ with blockchain-enabled smart contract, an integration with the real world is necessary. The smart contract for example needs to establish whether the predefined result has been achieved by a developing country. In other words, the triggering event needs to be computationally verifiable.[189] Three elements are required: (i) the availability of relevant data, (ii) the ability to enter such data into the smart contract and (iii) the performance (for example the amount of emissions) being able to be objectively and automatically established.[190] Communicating with the physical world is complicated for a blockchain as such. The blockchain is designed as an isolated environment, which can by its very nature only detect 'on-chain' events. 'Off-chain' events such as the outcomes of monitoring systems cannot be 'seen' by a blockchain.[191]

In practice, this constraint is circumvented by involving a third party that signs the 'unlocking script' after having verified that the event has taken place in the physical world.[192] These third party entities are often referred to as oracles. An oracle is a tool for smart contracts to interact with the 'off-chain' world by watching the blockchain and responding to the smart contract by publishing the results of a query into the smart contract.[193] It needs to be mentioned that oracles cannot create or 'think of' the desired information themselves. Oracles extract the information from external data sources, such as websites. Parties should therefore select an appropriate

[188] Ibid.
[189] E. Mik, 'Smart contracts: terminology, technical limitations and real world complexity', *Law, Innovation and Technology* 2017 Vol. 9 (2), p. 290.
[190] Ibid, p. 291-292.
[191] J. Slobodník, 'How Oracles connect Smart Contracts to the real world' *Medium* 2 February 2018, at WWW: <https://medium.com/bethereum/how-oracles-connect-smart-contracts-to-the-real-world-a56d3ed6a507>.
[192] E. Mik, 'Smart contracts: terminology, technical limitations and real world complexity', *Law, Innovation and Technology* 2017 Vol. 9 (2), p. 292.
[193] J. Weldon, 'Building an 'Oracle' for an Ethereum contract', *Medium* 10 October 2016, at WWW: <https://medium.com/@mustwin/building-an-oracle-for-an-ethereum-contract-6096d3e39551>.

oracle *and* data source.[194] A consequence is that the trustworthy nature of the blockchain is lost to a certain extent, as a result of having to depend on corruptible data sources.[195]

The data sources as such entail an additional challenge. As data sources can be compromised, it could be recommendable to create a network of independent data sources and code the smart contract in such a manner that the off-chain event needs to be validated by an *x*-amount of independent data sources. Furthermore, off-chain events can be either public and universally visible, or do not possess these characteristics.[196] The latter category confronts parties with the situation that multiple data sources come up with divergent outcomes. Applying this issue to REDD+, one can conclude that data in the sphere of climate issues are often debatable. The solution would be to appoint one responsible and trustworthy data source.

4.2.1 Tokenisation

An intrinsic characteristic of blockchain is that it is powered by tokens. For example Bitcoin and Ether are tokens. Blockchain-enabled smart contract therefore involve the transfer of crypto-tokens.[197] Funding parties and developing countries do not, at least not at this stage, use crypto-tokens for the financing of REDD+ activities. Instead, they use legal tender such as Euros or United States dollars. The question therefore is how the smart contract can transfer legal tender when it is designed to transfer crypto-tokens. There are two options to do so.

The first and closest way of getting 'automated payments' of legal tender is to not have the smart contract make the payment. Instead, the smart contract, after the triggering condition has been fulfilled, creates a bank message or a SWIFT message. This message then enters the respective bank system. The bank then determines whether it is a valid payment and if so, execute the payment. This option is straightforward but reduces the valuable characteristic of a blockchain, which can guarantee that the funds are actually available. The second option is therefore more suitable but demands a process in advance. It requires a representation of legal tender to be put onto a blockchain. The representation is the token that is driving the blockchain. An national entity in the developed country will however first need to authorise the 'tokenisation' and guarantee that the tokens are redeemable for the respective legal tender.

4.2 Coding the REDD+ mechanism under the Paris Agreement

4.2.1 Article 5 of the Paris Agreement

This thesis takes REDD+ under Paris Agreement as a starting point. It therefore makes sense to first take a look at the legal nature of article 5 of the Agreement, which lays down REDD+. The second paragraph of article 5 merely provides that parties to the Agreement are encouraged to take action to implement and support the existing REDD+ framework One can conclude that this provision does not consist of the conditional logic required for coding and can therefore be deemed non-operational. Automation by means of smart contracts is therefore not possible. This conclusion is not entirely surprising. The Agreement consists of a lot of non-operational aspects. Moreover, the second paragraph of article 5 merely anchored the already existing

[194] E. Mik, 'Smart contracts: terminology, technical limitations and real world complexity', *Law, Innovation and Technology* 2017 Vol. 9 (2), p. 292.
[195] Ibid.
[196] Ibid; an example of public and universally visible event is a stock price of an asset at a certain time. An example of the more complicated category is the temperature at a certain location at certain time. Due to the plurality and position of the respective sensors, independent data sources could provide multifarious results.
[197] E. Mik, 'Smart contracts: terminology, technical limitations and real world complexity', *Law, Innovation and Technology* 2017 Vol. 9 (2), p. 272.

REDD+ mechanism under the UNFCCC in the Agreement. In order to analyse whether the use of blockchain-enabled smart contracts is possible, this thesis therefore takes on the Warsaw Framework as point of reference. The Warsaw Framework substantiates the obligations and conditions that tie into the REDD+ mechanism.[198]

4.2.2 The Warsaw Framework

As previously highlighted, the WFR guides REDD+ activities and broadly comprises four elements: (i) a national strategy or action plan, (ii) a national forest reference level (FRL), (iii) a national forest monitoring system and (iv) a set of safeguards. This paragraph analyses to what extent blockchain-enabled smart contracts can be a tool of implementation for these elements. In the most favourable case, the smart contract would include the entire arrangement itself, govern the necessary preconditions *and* the execution of the contract.[199]

Firstly, national strategy or action plans precede REDD+ activities and eventually results-based finance.[200] These plans as such are not a condition that trigger the results-based payments and should therefore not be coded into the smart contract. Apart from that, it would be very difficult to incorporate these plans into a smart contract. The plans comprise the coordination and strengthening of existing institutional and legal arrangements concerning mitigation in the forest sector as well as identifying and launching policy reforms at national and subnational level.[201] This process is very broad and impossible to incorporate within a smart contract. Given the fact that the national strategy or actions plans are (i) not conditions that triggers results-based payments and (ii) are impossible to code, the smart contract should deal with the remaining three elements of the WFR. This does not *a priori* impede the possible use of a smart contract, as the national strategy or action plans can be considered a prequel to REDD+ activities and results-based payments. Moreover, the last paragraph already argued that it is hardly possible to code REDD+ entirely due to the quantity of non-operational elements.

Secondly, the FRL is necessary to establish the result of REDD+ activities. Results are namely established in relation to the FRL. The FRL is a quantitative source of information (tonnes of carbon dioxide per year) and can be coded into a smart contract. In practice, the smart contract will deduct the measured emissions from the FRL. The outcome of this sum establishes how much less (or more) greenhouse gases have been emitted in relation to the FRL. Under the WFR, the FRL is subject to technical assessment.[202] This technical assessment is conducted by two experts and takes into account UNFCCC guidelines and procedures and requests a synthesis report on the technical assessment process.[203] These guidelines and procedures comprise many elements. The experts should for example assess how historical data have been taken into account in the establishment of the FRL. Also, an analysis of the extent to which the information provided was transparent, complete, consistent and accurate is required.[204] Grasping the technical assessment leading to the FRL within a smart contract is therefore highly impractical and likely impossible. A smart contract can work with the FRL as such, but cannot

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[198] Voigt 2016, p. 6.
[199] R. Koulu, 'Blockchains and Online Dispute Resolution: Smart Contracts as an Alternative to Enforcement' *SCRIPTed* 2016, 40, p. 53.
[200] Decision 9/CP.19 (3).
[201] C. Voigt & F. Ferreira, 'The Warsaw Framework for REDD+: Implications for National Implementation and Access to Results-based Finance', *Carbon and Climate Law Review* 2015 (2), p. 117.
[202] The technical assessment procedure is laid down in Decision 13/CP.19 at WWW: <http://unfccc.int/resource/docs/2013/cop19/eng/10a01.pdf#page=34>.
[203] Decision 13/CP.19 (4) refers to the guidelines and procedures for the technical assessment of submissions from parties on forest reference emission levels contained in the annex.
[204] See respectively (2)(b) and (2)(c) of the Annex to Decision 13/CP.19.

replace the part of the WFR that establishes the FRL. Coding the established FRL allows the smart contract to define the results that will eventually trigger results-based payments.

The national forest monitoring systems constitute the third element of the WFR. Due to the premise of results-based payments, it is vital that emission measurements are as accurate as possible.[205] As already explained, the achievement of predefined results depends on the outcome of the FRL minus the amount of actual yearly emissions. The amount of emissions in a certain year is measured by national forest monitoring systems, which are arguably the most important element within the REDD+ mechanism.[206] A relevant factor is that monitoring systems should take into account the guidance as provided in decision 4/CP.15 and the most recent IPCC guidance and guidelines.[207] Furthermore, the systems should use a combination of remote sensing and ground-based carbon inventory approaches for estimating emissions, forest carbon stocks and forest area changes.[208] The question is whether the national monitoring systems can be linked to the blockchain-enabled smart contract properly. It is however not the monitoring systems as such that need to be coded, as the monitoring systems are a practical element of the process of monitoring, reporting and verifying (MRV process). The measurement precedes the reporting and verification.[209]

Therefore, the question is whether the MRV process can be grasped by smart contracts. A possible path is to run an oracle that reports the outcome of the verification process. In this scenario, the smart contract would play a marginal role with regards to the actual MRV process. Coding the existing MRV process proves very difficult. In existing practice, national monitoring systems can keep track of multiple elements that go beyond the assessment of emissions: forest health, biological diversity and productive, protective and socio-economic functions of forests.[210] It speaks for itself that smart contracts are not able to assess these largely qualitative elements. A further consideration is that national forest monitoring systems are required to be flexible and allow for improvement.[211] This is a complicating factor for smart contracts, which are not flexible by their nature. Sklaroff explains that computer code is simply a series of 'if-then instructions that must all be resolvable by a computer'.[212] Once a smart contract has been coded and put onto the blockchain, it is set to run toward its completion.[213] To provide for the possibility of modification, this possibility would have to be programmed into the smart contract from the very start, and providing agreed circumstances to do so. Such an exception allowing later modification would reduce the certainty of the smart contract. Especially the certainty of the smart contract is one its most important characteristics. Concluding, coding the MRV process as set out in the WFR and taking into account the IPCC guidelines proves very difficult. Parties will therefore merely have the ability to link the

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206 C. Voigt & F. Ferreira, 'The Warsaw Framework for REDD+: Implications for National Implementation and Access to Results-based Finance', *Carbon and Climate Law Review* 2015 (2), p. 119.

207 Decision 11/CP.19 (2).

208 Decision 4/CP.15 (1)(d)(i).

209 See also Handbook by the UNFCCC, *Handbook on Measurement Reporting and Verification for Developing Countries*, 2014, p. 50.

210 UN-REDD Programma, 'National Forest Monitoring Systems: Monitoring and Measurement, Reporting and Verification (M & MRV) in the context of REDD+ Activities' 2013, p. 11 at WWW: <http://www.fao.org/3/a-bc395e.pdf>.

211 Decision 11/CP.19 (4)(c) stipulates that national monitoring systems should be flexible and allow for improvement.

212 J.M. Sklaroff, 'Smart Contracts and the Cost of Inflexibility', *University of Pennsylvania Law Review* Vol. 166:263 2017, p. 291.

213 P. Catchlove 'Smart contracts: a new era of contract use', *Queensland University of Technology* 2017, p. 13.

outcome of the current MRV process to smart contracts by means of an oracle. The downside thereof is that this renders the smart contract less autonomous.

Alternatively, a more 'pure' way for a smart contract to grasp the MRV process is to directly link the smart contract to sensors that measure the emissions and forest coverage. This option is only available in the relation between developing countries and financing entities outside the UNFCCC. The previous chapter demonstrated that private actors have difficulties with getting involved in REDD+ activities. If private actors want to undertake REDD+ activities, they namely face the issue that the legal norms for jurisdictional REDD+ do not fit in well with the character of private entities. More sophisticated smart contracts in combination with the internet of things could offer a solution for private entities. Such entities are namely free to not apply the methodological guidance by the UNFCCC on REDD+.[214] Developing countries in cooperation with these entities can agree to cast aside the UNFCCC guidance and devise a smart contract that directly measures, reports and verifies REDD+ results. When a smart contract interacts with the sensors that measure the emissions and forest coverage, the smart contract needs to be linked to the internet of things.[215] This paragraph does not go into depth on how this procedure exactly works technically. From a legal perspective, the takeaway is that entities outside of the UNFCCC are free to not apply the UNFCCC methodological guidance and devise a smart contract with a high level of automatability.

Finally, this paragraph analyses whether the required set of safeguards can be grasped by a smart contract. It should be noted that the UNFCCC has adopted an extensive list of safeguards relating to REDD+ activities.[216] Savaresi points out that these safeguards are not phrased as absolute conditionalities for the funding of REDD+ activities.[217] Decision 1/CP.16 merely determines that the safeguards should be 'promoted and supported' and does not provide any specific sanctions for non-compliance.[218] However, the REDD+ framework requires that participating countries adopt a system for providing information on how the safeguards are 'addressed and respected throughout the implementation'.[219] The provision of insight therein is required in order to receive results-based payments[220], although there is no indication on how compliance is assessed, and what consequences there are in case of non-compliance.[221] A smart contract could require a document to be uploaded by the participating country, and make the upload conditional for the receiving of payments. However, due to the nature of the safeguards, a smart contract is not capable of qualitatively assessing the compliance with those safeguards. Coding the aforementioned conditionality would therefore merely implicate an easy check-off for parties and would thus not improve the REDD+ mechanism materially. On the contrary, the earlier mentioned check-off would deteriorate the status quo, as the smart contract might release payments even though the safeguards have not really been addressed and respected throughout the implementation of REDD+. The alternative is linking an oracle to the smart contract. The oracle could report the result of a review by the responsible committee with the smart contract.

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[214] C. Voigt & F. Ferreira, 'The Warsaw Framework for REDD+: Implications for National Implementation and Access to Results-based Finance', *Carbon and Climate Law Review* 2015 (2), p. 126.

[215] A broad explanation to the interaction between smart contracts and the internet of things can be found in Y. Zhang & J. Wen, 'The IoT electric business model: Using blockchain technology for the internet of things', *Peer-to-Peer Networking and Applications* 2017 Vol. 10 983-994.

[216] A. Savaresi 2016, p. 130; Decision 1/CP.16.

[217] A. Savarasi 2016, p. 130.

[218] Decision 1/CP. 16 (69).

[219] Decision 1/CP.16 (71)(d).

[220] Decision 9/CP.19 (4).

[221] A. Savaresi 2016, p. 131.

4.2.3 The possibility of a blockchain-enabled smart contract for the Warsaw Framework

Analysing whether the WFR can be coded has led to mixed outcomes for the respective four elements. This result does not form an optimal result for the deployment of blockchain-enabled smart contracts in this context. However, it should be noted that typically the operational aspects of an agreement dictate the successful performance of that agreement to completion.[222] This means that in cases in which the main process as agreed between parties goes well, the application of the non-operational aspects is not required. On the other hand, the major part of an agreement is often devoted to defining the rights and obligations of parties in the event of a complication.[223] The smart contract would not include national action or strategy plans, but would include the FRL, the MRV process and a formal (minimal) check whether safeguards have been provided. Frankly, such a smart contract would add very little value, as three off-chain events are required for the execution. Entities outside the UNFCCC could however opt for a more sophisticated smart contract with developing countries. The smart contract would then be responsible for measuring, reporting and verifying whether the predefined results have been achieved. The next paragraph researches to what extent the results-based payments can be grasped by a smart contract.

4.2.4 Results-based payments

The results-based payments are the concluding piece to (successful) REDD+ activities. The last paragraph found that for parties under UNFCCC oversight, blockchain-enabled smart contracts can add little value to the implementation of REDD+. The third chapter however established that the implementation of REDD+ faces extensive challenges concerning the financing of REDD+ activities. Possible double-payments and ensuring that funds are available are examples thereof. It is therefore worth exploring whether results-based payments can be coded. REDD+ results under the WFR have international recognition, which allows for involvement of a broad spectrum of actors interested in financing the REDD+ results.[224] The envisaged smart contract would be less complicated than a smart contract that grasps the elements of the WFR as such. Verified REDD+ results (the emission results below the FRL) can be entered into a blockchain-enabled smart contract and in that manner become fully transparent digital assets.[225]

As explained in the previous chapter, payments for REDD+ activities are linked to emission reductions, enhancements in forest coverage and forest carbon stocks. The payments are therefore results-based.[226] Voigt and Ferreira explain that four components have to be in place in order to facilitate results-based payments.[227] There has to be (i) a clear definition of the desired result, (ii) an understanding of what needs to be in place to trigger the respective payments, (iii) a set of parameters that define the level of discretion for the developing countries and (iv) a well-designed measurement, reporting and verification system.[228]

Again, taking into account the guidance of the UNFCCC, the smart contract involves a dependency on an external entity. This entity is the committee that depends the outcome of the

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[222] C.D. Clack e.a., 'Smart Contract Templates: foundations, design landscape and research directions', *Barclays Bank*, August 6, 2017, p. 5.

[223] Ibid.

[224] C. Voigt & F. Ferreira, 'The Warsaw Framework for REDD+: Implications for National Implementation and Access to Results-based Finance', *Carbon and Climate Law Review* 2015 (2), p. 126.

[225] L. Connoly e.a. 'The Missing Link: How A Distributed Ledger System Can Support Global Climate Action', *Climate Advisers*, November 2017, p. 7 at WWW: <https://www.climateadvisers.com/wp-content/uploads/2017/11/FINAL-The-Missing-Link-How-A-Distributed-Ledger-System-Can-Support-Global-Climate-Action.pdf>.

[226] Also see C. Voigt & F. Ferreira, 'The Warsaw Framework for REDD+: Implications for National Implementation and Access to Results-based Finance', *Carbon and Climate Law Review* 2015 (2), p. 116.

[227] Ibid.

[228] Ibid.

MRV process. Hence, an oracle should be coded into the smart contract that is linked to this committee. The smart contract is able to arrange the payments as such between a developed and developing country. Funds can be held in the blockchain and are transferred to the developing country by the smart contract when the triggering condition is fulfilled. The fulfilling condition would be the committee's response that the predefined results have been achieved. Results-based payments as such are apt for implementation by means of a blockchain-enabled smart contracts. The predefined result can be coded into the smart contract, as this is a quantitative form of information. The condition as well as the execution consist of conditional logic. They are so called operational aspects, deriving from consideration of precise actions to be taken by the party and relating to the performance of the contract.[229]

It is not surprising that financial arrangements can be coded, as smart contracts were originally envisaged to grasp these.[230] Admittedly, it would be too simplistic to only take into account the payments as such. Agreements between countries for the funding of REDD+ activities show several additional clauses, such as an audit clause and a clause with regards to the selection of projects and procurement.[231] These clauses cannot be grasped by a smart contract and need to exist in the existing legal agreement aside the blockchain-enabled smart contract. Returning to the beginning of this chapter, it was set forth that smart contracts have two extremes: entirely coding the legal agreement or being in natural language with an encoded payment mechanism. The smart contract arranging results-based payments would not be remote from the latter extreme. Most substantive clauses cannot be automated by a smart contract. Merely the results-based payments can be completely triggered and executed on a smart contract. Tjong Tjin Tai explains that legal rules often assume that the moment of evaluation of those rules is when they are brought to court.[232] He means that legal rules therefore often tend to use open norms, as giving an exact meaning to those terms is not required at the moment of entering into a contract. He therefore argues that legal rules can actually be simpler than ex post rulings given by a court.[233] Programmers can therefore keep the smart contract simple, but on the other hand parties have to guarantee that all parties are still fully protected by traditional contract law.[234] This does not immediately mean that the deployment of blockchain-enabled smart contracts is not useful. One could for example think of the current practical issue of guaranteeing that funds for REDD+ activities are actually available. The next chapter evaluates to what extent this use case promotes the implementation REDD+.

4.3 Conclusion

This chapter analysed to what extent blockchain-enabled smart contracts can be a tool of implementation for REDD+. Firstly, relevant to the conclusion of this chapter is that the WFR leaves little room for discretion for developing countries in setting up REDD+ activities. The

[229] C.D. Clack e.a., 'Smart Contract Templates: foundations, design landscape and research directions', *Barclays Bank*, August 6, 2017, p. 5.
[230] E. Mik, 'Smart contracts: terminology, technical limitations and real world complexity', *Law, Innovation and Technology* 2017 Vol. 9 (2), p. 290.
[231] An interesting example of an agreement between two countries is The Donation Agreement between Norway and Brazil with regards to REDD+ activities (2009-2015) at WWW: <https://www.regjeringen.no/globalassets/upload/md/vedlegg/klima/klima_skogprosjektet/donation_agreement_bndes.25.03.09.pdf>.
[232] T.F.E. Tjong Tjin Tai, 'Formalizing contract law for smart contracts', *Tilburg Private Law Working Paper Series* September 2017 No. 6, p. 7.
[233] Ibid.
[234] Ibid, p. 8

framework has provided for clear requirements that need to be in place before a country can access results-based finance under the UNFCCC. Also the MRV process has been bound by guidelines under the WFR and the most recent IPCC guidelines. One would say that this development towards more guidance makes the deployment of blockchain-enabled smart contracts for REDD+ activities easier, at least concerning translating an already existing legal agreement into a smart contract. The latter coincides with the aim of this chapter, as it aims to analyse whether blockchain-enabled smart contracts can be a tool of implementation for the REDD+ mechanism under the Paris Agreement.

Article 5 of the Agreement is not suitable for automation by means of a smart contract. The article does not contain conditional logic and merely encourages countries to undertake REDD+ activities. The answer to the sub question therefore comes down to whether the WFR can be executed by a blockchain-enabled smart contract. The four elements of the WFR can be automated partially. For parties under the UNFCCC, it would be possible to encode the FRL, the outcome of the MRV process and a formal check on safeguards. However, such a contract would be very dependent on off-chain events and would add little value. Entities outside the UNFCCC enjoy more freedom and could combine the internet of things with smart contracts to actually automate the MRV process. More interestingly, this chapter found that smart contracts can be a tool of implementation for the conclusive piece to REDD+ activities: results-based payments. The next chapter analyses to what extent these use cases can promote the implementation of the REDD+ mechanism.

5. The legal opportunities and pitfalls of blockchain-enabled smart contracts as a tool of implementation for REDD+

This chapter evaluates the legal opportunities and pitfalls of the use blockchain-enabled smart contracts for the implementation of REDD+. The first part of this chapter analyses whether the smart contract use cases concerning REDD+ found in the previous chapter, are capable of rendering the REDD+ mechanism more effective in any way. The previous chapter was more analytical rather than evaluative in the sense that it merely established use cases for blockchain-enabled smart contracts with regards to the REDD+ mechanism. The previous chapter did not extensively evaluate whether those use cases offer material benefits for the implementation of REDD+. After having established which use cases could be effective, the second part of this chapter sets out legal and practical implications of the deployment of blockchain-enabled smart contracts that has been deemed beneficial according to the previous chapter and the first paragraph of this chapter. The challenges to the implementation of REDD+ that were found in the third chapter are included in this evaluation. One can namely not adequately assess whether the implementation can be improved if one does not assess to what extent existing challenges are overcome.

5.1 Promoting the implementation of the REDD+ mechanism

The previous chapter identified three possibilities for deploying blockchain-enabled smart contracts for REDD+: (i) partially automating the WFR for parties under the oversight of the UNFCCC, (ii) automating the MRV process for parties outside of UNFCCC oversight and (iii) arranging results-based payments.

The first option does not substantially promote the implementation of REDD+. Out of the four WFR elements, only the FRL is easy to code into a smart contract. A smart contract that automates the WFR would have a high level of dependency upon external factors and would therefore necessitate multiple oracles. This raises the question what difference is made in relation to the status quo. Firstly, parties need to select and oracle *and* a data source. There is however a practical inability to ensure that the oracle as well as its data source are as trustless as the blockchain.[235] Problematic is that the benefits of blockchain technology, such as being trustless and incorruptible, are lost with ease once the smart contract requires information about off-chain events.[236] Furthermore, not all off-chain events can be represented in code and some can therefore be unreadable for computers.[237] This problem specifically applies to the set of safeguards and the extensive MRV process. It is impossible for a smart contract to code whether a developing country is implementing a safeguards sufficiently. One can conclude that blockchain-enabled smart contracts are not apt for implementing the WFR as such.

A more ambitious approach could be undertaken by parties outside of the oversight of the UNFCCC. These entities are merely *encouraged* to use the UNFCCC methodologic

[235] E. Mik, ‘Smart contracts: terminology, technical limitations and real world complexity’, *Law, Innovation and Technology* 2017 Vol. 9 (2), p. 292.
[236] Ibid.
[237] Ibid, p. 293.

guidance.[238] The UNFCCC encourages the application of its methodological guidance in order to improve the effectiveness and coordination of results based finance.[239] As this thesis focuses on the REDD+ mechanism under the Paris Agreement, it will not go into depth with regards to the regimes that apply to REDD+ outside of the UNFCCC's oversight. Moreover, Voigt and Ferreira argue that not applying the methodological guidance poses the risk of duplications with regards to the requirements for obtaining results-based payments.[240] Multifarious sets of requirements would also increase transaction costs for developing countries and increase the chances of double counting of results and payments.[241] A widespread implementation of the methodological guidance is beneficial to the eventual success of REDD+. It allows developing countries to have predictability with regards to what is expected of them.[242] This chapter does therefore not research whether the deployment of blockchain-enabled smart contracts for REDD+ activities that use very different criteria could promote the implementation of the REDD+ mechanism. Such a proposal would, for the aforementioned reasons, be self-contradictory.

The third possible deployment of blockchain-enabled smart contracts concerns results-based payments. The payments can be viewed as the conclusive piece to the WFR. Voigt and Ferreira explain that the WFR applies to REDD+ activities irrespective of the source of financing.[243] The conditionality in the smart contract that governs the payments would therefore consist of the result of the REDD+ activities expressed in a certain unit or various units.[244] An advantage of such a smart contract, as opposed to a smart contract representing the WFR, is that there is only one dependence on an off-chain event. That off-chain event is the aforementioned result of the REDD+ activities.

A blockchain-enabled smart contract arranging results-based payments can promote the implementation of the REDD+ mechanism. As already explained in the chapter about smart contracts, a smart contract does not need to be the underlying legal contracts and the contracts can therefore coexist independently. In this case, the smart contract is used as a tool for contract enforcement beside the actual legal contract. The underlying legal contract is the agreement between a developed country and a developing country. A crucial aspect of the smart contract is its utility. The smart contract facilitates the completion of a transaction in a very efficient way. In fact, parties cannot breach the conditions with regards to the results-based payments as the payments are executed remotely and in real-time by the smart contract. From a legal perspective, smart contracts have binding effects towards the existing legal contract that they support.[245] The possibility of drafting contracts without any recourse to legal language is accepted in most cases in most jurisdictions.[246] Tjong Tjin Tai adds that formal requirements for contracts are relatively rare.[247]

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[238] Decision 9/CP/19 (6) & (7).
[239] Ibid.
[240] C. Voigt & F. Ferreira, 'The Warsaw Framework for REDD+: Implications for National Implementation and Access to Results-based Finance', *Carbon and Climate Law Review* 2015 (2), p. 126.
[241] Ibid.
[242] Ibid, p. 126
[243] Ibid, p. 123.
[244] The unit would express to what extent the predefined results have been achieved. Full achievement means full payment and partial achievement means partial payment.
[245] T.F.E. Tjong Tjin Tai, 'Formalizing contract law for smart contracts', *Tilburg Private Law Working Paper Series* September 2017 No. 6, p. 2.
[246] Ibid.
[247] Ibid.

5.1 The legal opportunities and pitfalls of blockchain-enabled smart contracts

The third chapter discussed various problems associated with the implementation of REDD+. This paragraph discusses opportunities and pitfalls of blockchain-enabled smart contracts. The earlier established implementation challenges are included in this evaluation. As this thesis aims to evaluate whether blockchain-enabled smart contracts can promote the implementation of REDD+ under the Paris Agreement, it is necessary to analyse whether current issues in its implementation can be overcome.

5.2.1 Opportunities

Streamlining the REDD+ mechanism and guaranteeing the availability of funds

The third chapter set out the tragedy of the commons. The fight against climate change is hindered by self-interest, which is an integral part of human nature.[248] In the climate sphere, all countries have an individual interest to emit in relation to the common good and the collective interest. The common good that is managed by the Paris Agreement is the total permitted amount of greenhouse gases in the atmosphere. The collective interest is to limit the temperature rise. Blockchain technology has the capability to align the private interests of participating countries with the common good. This can be explained as follows. The private interest of a country to emit a high level of greenhouse gases is linked with the economic growth that stems from it. The incentive system on the blockchain-enabled smart contract should therefore ensure a reward for the respective country that is higher than the emission of greenhouse gases. In the case of blockchain-enabled smart contracts arranging results-based payments, developing countries receive payments that are deemed to outweigh the potential profit of exploiting forests. In that manner, a developing country's private interest is aligned with the common good. However, more critically, this alignment of the private interest with the common good is already at the very core of the REDD+ mechanism. REDD+ namely seeks to bring developing countries benefits for not emitting greenhouse gases. Still, arranging results-based payments by means of blockchain-enabled smart contracts ties in with the goal of solving the tragedy of the commons and therefore provides opportunity for improvement. The third chapter found that it is a challenge to ensure that funds are actually available and flow to developing countries undertaking REDD+ activities. Without confidence in future payments, developing countries are less inclined to undertake REDD+ activities. The challenge of ensuring funds can therefore undermine the REDD+ mechanism's ability to make countries strive for the common good. Blockchain-enabled smart contracts solve this issue as the very nature of blockchain ensures that the smart contract cannot be altered and that execution of the agreement cannot be influenced by neither party.[249] Moreover, as funds are publicly stored on the blockchain, developing countries can verify whether the paying entity has the funds to actually pay.

Improving the flow of finance by self-enforcement

Furthermore, blockchain-enabled smart contracts offer the opportunity to streamline the flow of finance. Streck and Parker illustrate that there can be significant delay before funds are allocated.[250] Moreover, a 2011 study found that 67% of the stakeholders disagreed with the statement that payments were disbursed in a timely manner.[251] One can conclude that the

[248] G. Hardin, 'The Tragedy of the Commons', *Science* 1968 (162), p. 1244.
[249] E. Mik, 'Smart contracts: terminology, technical limitations and real world complexity', *Law, Innovation and Technology* 2017 Vol. 9 (2), p. 277.
[250] C. Streck & C. Parker 2012, p. 123.
[251] NORDECO, 'First program evaluation for the Forest Carbon Partnership Facility (PCPF)' *Nordic Agency for Development and Ecology* 2011.

existing REDD+ mechanism struggles with disbursing finance that has already been committed.[252] Implementation by means of blockchain-enabled smart contracts would solve this issue through its automated nature of payments. Streck and Parker add that a barrier in the flow of finance is caused by the inefficiency within intermediary organisation.[253] Also this barrier would be taken away with blockchain-enabled smart contracts, as the third party disappears completely. Additionally, the implementation of REDD+ carries transaction costs. Pagiola and Bosquet explain that transaction cost comprise the costs necessary to perform a REDD+ payment, including the costs to external parties such as system administrators.[254] A somewhat obvious and very practical benefit of using blockchain-enabled smart contracts for implementing REDD+ is that costly intermediaries are not required.[255] Additionally, double spending and counting are prevented by the very nature of blockchain, which saves time and money.[256]

Enhancing transparency

The third chapter found that the finance for REDD+ activities is hindered by a lack of transparency among receiving entities. A characteristic of blockchain technology is that all of the information on the ledger is visible to all parties to the blockchain. If parties opt for a public blockchain, the public would be allowed to view all transactions that have taken place on the blockchain. The third chapter pointed out that corruption levels in forestry sectors and the design and delivery of REDD+ finance pose fiduciary risks. The third chapter also found that there is overlap and blend of the resource streams in developing countries. Blockchain-enabled smart contracts on a public blockchain could counter this issue. The blockchain demonstrates which entities have received which payments, and even the specific amounts thereof. This would for example allow journalists to address corruption, as they can in more detail demand clarification from receiving entities about what they have done with the funds. Connoly et alia explain that when a transaction audit trail is stored on a blockchain, anyone can access this audit trail. They thereby mean that the blockchain can track the confirmed results through for example a serial code.[257] Double-counting would be prevented.

The involvement of private financing entities

Ultimately, blockchain-enabled smart contracts arranging results-based payments could bring a valuable improvement with regards to the involvement of the private sector. The last chapter analysed that smart contracts could execute payments on the premise that predefined results have been fulfilled. That fulfilment is communicated to the smart contracts by an oracle. It does however not matter whether that oracle communicates the predefined result of activities under the guidance of the UNFCCC or activities that have taken place under a different regime. In other words: multiple actors that follow different regimes can be united in the same smart contract with a country that undertakes REDD+ activities. On a public blockchain it is possible

[252] C. Streck & C. Parker 2012, p. 126.
[253] Ibid, p. 123.
[254] S. Pagiola & B. Bosquet, 'Estimating the costs of REDD+ at the country level, *World Bank* 2009 at WWW: <https://www.forestcarbonpartnership.org/sites/forestcarbonpartnership.org/files/Documents/PDF/REDD-Costs-22.pdf>.
[255] IETA, 'IETA Insights: Greenhouse Gas Market Report' *IETA* No. 3 October 2017 at WWW: <https://www.ieta.org/resources/Resources/GHG_Report/2017/IETA%20Insights%203.pdf>.
[256] Ibid.
[257] 257 L. Connoly e.a. 'The Missing Link: How A Distributed Ledger System Can Support Global Climate Action', *Climate Advisers*, November 2017, p. 8 at WWW: <https://www.climateadvisers.com/wp-content/uploads/2017/11/FINAL-The-Missing-Link-How-A-Distributed-Ledger-System-Can-Support-Global-Climate-Action.pdf>.

for all entities to become a parties.[258] One could for example envision a blockchain-enabled smart contract to which multifarious paying entities are parties. If the blockchain wants to facilitate multiple financing entities, the tokens on the blockchain need to be redeemable at every respective financing entity. The UNFCCC could therefore, as coordinating entity, issue the tokens to all financing entities that have paid legal tender to them in advance. The UNFCCC could guarantee that the tokens can be redeemed with them. The third chapter found that the multitude of different regimes entails the fact that with regards to finance, double-counting of results and payments occurs regularly. As at least until 2020 REDD+ finance will come from multiple sources, the implementation of REDD+ finance would benefit from the use blockchain-enabled smart contracts.[259] Double-counting would be prevented and parties can simplify the course of action concerning payments. Voigt and Ferreira found that the broad array of differing financing sources raises the challenge of coordinating these payments.[260] Blockchain-enabled smart contracts could, for the aforementioned reasons, ease that process.

5.2.2 Pitfalls

Inability to transfer legal tender

A disadvantage to blockchain-enabled smart contracts is that it is not capable of transferring legal tender. Blockchains are powered by tokens, such as Bitcoin or Ether. However, the blockchain-enabled smart contract is asked to transfer legal tender even though it is designed to transfer crypto-tokens. The previous chapter set out two options to circumvent this. The first option is creating a bank message or SWIFT message which enters the respective banking system. However, this option would namely not guarantee that the funds are actually available, which would diminish an opportunity of the previous paragraph. The second option is to represent legal tender in the form of a token. The participating countries will need to authorise this tokenisation in advance and the paying entities or the governing entity will need to guarantee that the tokens are redeemable. The disadvantage of the latter procedure is that the automatability of the smart contract is reduced. Normally, a payment would be the last step after successful REDD+ activities. In this case however, the developing country will need to redeem the tokens for legal tender. Still, it is an improvement to the status quo as the developing country then already has obtained the redeemable tokens. Moreover, once user adoption of cryptocurrencies grows, developing countries and financing entities might agree to execute the results-based payments in the form of cryptocurrencies.[261] In that case, the automatability of results-based payments by means of blockchain-enabled smart contracts would be guaranteed.

Inflexibility of smart contracts

Secondly, blockchain is tamper-proof, as has been explained in the second chapter. With regards to smart contracts, this means that the contract cannot be stopped or modified.[262] The contract will continue irrespective of any off-chain events until the predefined expiration date has passed.[263] A blockchain-enabled smart contract being tamper-proof can also cause an issue. If a party terminates the contract with another party with regards to the payment for REDD+

[258] V. Gatteschi et alia, 'Blockchain and Smart Contracts for Insurance: Is the Technology Mature Enough?' *Future Internet* 20 February 2018, p. 5.
[259] C. Streck & C. Parker 2012, p. 127.
[260] C. Voigt & F. Ferreira, 'The Warsaw Framework for REDD+: Implications for National Implementation and Access to Results-based Finance', *Carbon and Climate Law Review* 2015 (2), p. 124.
[261] Hileman & Rauchs have done extensive research to the adoption of cryptocurrencies. The research shows that adoption is growing rapidly: G. Hileman & M. Rauchs, 'Global Cryptocurrency Benchmarking Study' *University of Cambridge* 2017.
[262] E. Mik, 'Smart contracts: terminology, technical limitations and real world complexity', *Law, Innovation and Technology* 2017 Vol. 9 (2), p. 279.
[263] Ibid.

activities for whatever reason, the smart contract will still execute the payment in case the responsible committee forwards the result of the REDD+ activities to the smart contract. The execution by the smart contract can nevertheless be eliminated in case the agreement between parties has ended. Parties can for example determine in advance that the tokens are no longer redeemable in case the agreement has ended before the transfer of those tokens. Alternatively, parties could make arrangements with the respective committee to no longer forward REDD+ activities to the smart contract once the agreement has ended. Blockchain being tamper-proof entails an additional challenge. Usually, blockchain-enabled smart contracts exclude the possibility of human intervention or modification of the smart contract once the smart contract has commenced. Mik argues that it is very difficult to ensure the absence of coding bugs in a smart contract.[264] In other words, although smart contracts protect transactions from human discretion, they pave the way for the transactions to be affected by coding bugs. The difficulty of modifying a blockchain-enabled smart contract after it has been locked into place, creates practical and legal hurdles for parties. Under traditional legal contracts, altering a contract would not pose a difficulty if both parties agree.[265] If parties for example wanted to agree upon more ambitious REDD+ activities, this would require an intermediate step before execution of the contract. The smart contract would therefore have to incorporate the possibility of modification explicitly. However, it is difficult to express in code under what circumstances and how parties can modify the terms of the smart contract.[266]

Need for knowledge about functioning of smart contracts

Over the course of multiple centuries, lawyers have gained substantial knowledge about contract law in application to a wide range of issues in the duration of the contract. This knowledge has created precedents, default rules and even statute laws in cases that these practices were democratically adopted.[267] Contracting parties therefore normally assume that the contract behaves in a manner that corresponds with traditional contracts.[268] With regards to the practice smart contracts however, there is need for knowledge about the functions of contract law that could safeguard the expectations and interest of parties. The ‘traditional’ contract law rules may namely not be implemented in smart contracts.[269] This knowledge is especially needed for ‘strong smart contracts’, in the words of Raskin.[270] He explains that ‘strong smart contracts’ have prohibitive costs when revocation and modification is required.[271] Traditional enforcers that have to deal with ‘strong smart contracts’ are helpless once the smart contract has been initiated.[272] The only remedy can be sought by parties at a traditional court, is the undoing or alteration of the smart contract in some way.[273] This is due to the fact that a ‘strong smart contract’ has (i) either already been executed or is in the course of being executed and (ii) has been set in stone after the initiation. In traditional contract law however, one could demand money damages, restitution or a specific performance. One could therefore argue that lawyers are too inexperienced with regards to smart contracts to already encode results-based payments for REDD+. In 2007, Norway pledges 2.6 billion dollars for REDD+ activities.

[264] Ibid, p. 280
[265] K. Werbach & N. Cornell, ‘Contracts ex Machina’, *Duke Law Journal*, 2017 Vol. 67:313, p. 367.
[266] Ibid.
[267] T.F.E. Tjong Tjin Tai, ‘Formalizing contract law for smart contracts’, *Tilburg Private Law Working Paper Series* September 2017 No. 6, p. 3.
[268] Ibid.
[269] Ibid.
[270] M. Raskin, ‘The Law and Legality of Smart Contracts’, *The Georgetown Law Technology Review*, 305, 2017, p. 310.
[271] Ibid.
[272] Ibid. p. 311.
[273] Ibid, p. 322.

Taking into account the height of such amounts, it can be risky to submit such payments to blockchain-enabled smart contracts, for which legal knowledge is still underdeveloped.

Knowledge gap between executing parties and forest-dependent communities

Ultimately, REDD+ activities often concern forests that are inhabited by indigenous and other forest-dependent communities.[274] The use of smart contracts for arranging results-based payments means that these communities are directly influenced by technologies to which they might not have access and in which they might lack insight. The UNFCCC has emphasized that 'the needs of local and indigenous communities should be addressed when action is taken to reduce emissions from deforestation and forest degradation in developing countries'.[275] When blockchain-enabled smart contracts are used, forest communities should be involved in order to prevent a situation of one-sided insight.

5.3 Conclusion

This chapter evaluated the opportunities and pitfalls of deploying blockchain-enabled smart contracts for the implementation of REDD+. In connection to the previous chapter, this chapter concluded that deploying blockchain-enabled smart contracts for arranging results-based payments is the only useful use case for promoting the implementation of REDD+ at this moment. The WFR can namely only partially be coded and would in that case still depend on multiple oracles. Using blockchain-enabled smart contracts to arrange results-based payments would streamline the REDD+ mechanism in the sense that trust between parties is enforced. Developing countries no longer have to worry about the availability of funds, as the funds are stored in the blockchain. Furthermore, such a smart contract would improve the flow of finance. The self-enforcing character of blockchain implicates that there is no delay in fund transfers and third party costs are cut. The smart contract would also enhance transparency, as anyone can see all the transactions that have taken place on the blockchain. Involving private financing entities becomes easier, at least with regards to payments, as multiple paying parties versus a developing country can be united in one smart contract. Such a smart contract would prevent double counting and also enhance transparency in this regard. Executing results-based payments by blockchain-enabled smart contracts is also struck by some difficulties. Parties have to circumvent the blockchain's inability to transfer legal tender and as a result lose part of its automatability. Inflexibility of smart contracts makes it difficult to make modifications to the smart contract and therefore to interact with changes in the real world. The relative novelty of the smart contract practice also implicates that more knowledge is required how to deal with smart contracts when things go wrong. In addition, the practice of smart cotnracts might entail a knowledge gap between parties and forest-dependent communities and even between programmers and parties.

[274] K. Hite 2016, p. 408.
[275] Decision 2/CP.13, considerations.

6. Conclusion

If countries collectively do not successfully adapt climate policies, global warming will reach a level that leads to irreversible and fundamental climate changes. Christine Lagarde iterated in 2017 that 'if we do not do anything about climate change now, in 50 years we will be toasted, roasted and grilled'.[276] The Paris Agreement aims to limit the rise in the global average temperature to a range between 1.5 ° and 2 °. REDD+ is one of the Agreement's mitigation mechanisms and aims to reduce emissions by reducing deforestation and forest degradation. As 10 percent of global emissions is caused by deforestation and forest degradation, successful implementation of REDD+ is crucial for achieving the Agreement's goal of limiting the rise in the global average temperature. REDD+ is however hindered in its implementation by various challenges. This thesis researched to what extent blockchain-enabled smart contracts can promote the implementation of the REDD+ mechanism under the Paris Agreement.

Firstly, this thesis described the relation between blockchain technology and smart contracts. Blockchain technology allows parties to store data collectively in a decentralised manner. There is no more need for an intermediary. Smart contracts are basically computer code that represent (part of) an existing agreement. When smart contracts run on a blockchain, they do not only represent an existing agreement, but also automatically enforce the obligations therein. Smart contracts cannot however grasp every kind of legal provision. Concepts such as 'good faith' cannot be automated. The application of blockchain-enabled smart contracts is therefore limited to the so-called operational aspects of an existing legal agreement.

Secondly, this thesis analysed the REDD+ mechanism under the Agreement and identified issues in its implementation. REDD+ under the Agreement has been defined materially under various UNFCCC decisions (the WFR). The WFR guides the implementation of REDD+ activities through four elements: (i) a national strategy or action plan, (ii) a national forest reference level, (iii) a national forest monitoring system and (iv) a set of safeguards throughout the implementation. Fulfilment thereof and achievement of the predefined results leads to results-based payments. Developed countries and other entities pay developing countries for successful REDD+ activities. The fight against climate change is however hindered by the tragedy of the commons, the availability of funds, the state-centricity of legal norms for REDD+, the lack of involvement of private actors, a lack of transparency, the centralised, national approach of the WFR and the challenge of ensuring reliable MRV.

The third sub question was to what extent blockchain-enabled smart contracts can be a tool for the implementation of REDD+. Article 5 of the Agreement refers to the existing REDD+ mechanism, which is laid down in the WFR. The four elements of the WFR can be automated partially, but automation requires various dependencies on off-chain events. The latter diminishes the distinctive qualities of blockchain technology, as the incorruptible nature thereof is lost. Blockchain-enabled smart contracts are however fully apt to facilitate results-based payments. The mechanism behind these payments is straightforward; a predefined result leads to predefined payments.

The fact that smart contracts cannot implement the WFR as such is a disappointing result, taking into account the REDD+ implementation issues and the lack of transparency in developing

[276] C. Lagarde during a panel discussing at the Future Investment Initiative in Riyadh, Saudi Arabia 2017 at WWW: <https://www.theguardian.com/environment/2017/oct/25/we-will-be-toasted-roasted-and-grilled-imf-chief-sounds-climate-change-warning>.

countries. Blockchain can namely store data with regards to emissions and forest spans in a reliable and decentralised way. The REDD+ regime needs to undergo changes before smart contracts can be of any use. One however needs to realise that such changes are to be deemed unrealistic in the foreseeable future. The WFR currently entails very guidelines for the MRV process. The verification of results includes qualitative aspects which cannot be coded, such as biological diversity.

The fifth chapter evaluated the opportunities and pitfalls of blockchain-enabled smart contract and their implication for the implementation of REDD+. Due to the conclusion that only results-based payments can be coded adequately, chapter five focused on this use case. Results-based payments implemented by means of blockchain-enabled smart contracts improve the implementation of REDD+. Four challenges that this thesis found when researching REDD+ are countered by the use of smart contracts for results-based payments. (i) the availability of funds is ensured, (ii) transparency is enhanced, (iii) private actors can be involved which also diminishes risks such as double counting and (iv) as a result of the general streamlining of results-based payments, REDD+'s capability of countering the tragedy of the commons is upscaled. On the other hand, parties have to be aware of the specific characteristics of blockchain technology: (i) legal tender cannot be transferred, (ii) modifications prove very difficult, (iii) when things go wrong, parties have to make sure that reparation is possible and (iv) the use of smart contracts entails a knowledge gap between parties and forest-dependent communities.

The main research question of this thesis was to what extent blockchain-enabled smart contracts can promote the implementation of REDD+. Weighing the opportunities and pitfalls, it is remarkable that the use of these blockchain-enabled smart contracts for results-based payments solves four important challenges in the implementation of REDD+. This would amount to a substantial improvement of current REDD+ practice. Moreover, it should be noted that three or maybe even all four of the pitfalls of the use of smart contracts are closely related with the novelty of blockchain-enabled smart contracts. This can be explained as follows: in the future, parties might want to pay with cryptocurrencies and modification of smart contracts will become easier after experience with smart contracts grows. The third and fourth pitfall will also benefit from growing experience with smart contracts. This means that even though this thesis deems the deployment of smart contracts for results-based payment already beneficial for the implementation of REDD+, the equation will favour smart contracts arranging results-based payments even more over time.

After the mainly legal analysis and evaluation in this thesis, further technical research (and experiments) with regards to the functioning of blockchain-enabled smart contracts is necessary to materialise the – according to this thesis – possible improvement of REDD+ implementation. In that sense, this thesis is limited due to its mainly legal view. The novelty of blockchain-enabled smart contracts also entails that legal literature in this regard is underdeveloped. More legal literature would allow future research on this topic to be more precise and already detect impossibilities that might at this point still be unknown. Further research could furthermore also be directed toward carbon markets. The findings of this thesis can namely by analogy be applied to carbon markets, which have similarities to the results-based payments for REDD+.

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