Leveraging Blockchain Technology for Innovative Climate Finance under the Green Climate Fund

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Earth System Governance

APRIL 2020

CITATION

This paper can be cited as: Schulz, Karsten and Marian Feist. 2020. *Leveraging Blockchain Technology for Innovative Climate Finance under the Green Climate Fund.* Earth System Governance Working Paper No. 39. Utrecht: Earth System Governance Project.

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ABSTRACT

The rapid development of digital technologies such as blockchain and distributed ledger-based systems holds transformative potential for the financial sector. Promising applications include asset management as well as peer-to-peer networks for the transparent exchange of data and information. International climate finance stands to benefit in particular ways from these new opportunities in financial technology. Distributed ledger technologies could be leveraged to support climate action, for example by facilitating transparent and standardized transactions, or by enabling more efficient monitoring and accreditation processes. In view of these promising opportunities, we focus our inquiry on the case of the Green Climate Fund to explore how distributed ledger technologies can be used for innovative climate finance. Based on our analysis of different digital system models and potential use cases, we then discuss some of the technical and political challenges that may arise, for example with regard to standards and safeguards, governance processes, country ownership, and further capitalization. Our findings show that distributed ledger-based systems could benefit the work of the fund in key areas such as multi-stakeholder coordination and impact assessment. However, our analysis also points to the concrete limitations of technology driven solutions. Digital technologies are not a standalone solution to persistent resource allocation and governance challenges in international climate finance, especially because the design and deployment of these digital systems is inherently political.

Keywords: Blockchain; Distributed Ledger Technology; Climate Finance; Green Climate Fund; FinTech

SERIES FOREWORD

This working paper was written as part of the Earth System Governance Project — a global research alliance, the largest social science research network in the area of governance and global environmental change. Earth system governance is defined in this Project as the system of formal and informal rules, rule-making systems, and actor-networks at all levels of human society (from local to global) that are set up to steer societies towards preventing, mitigating and adapting to environmental change and earth system transformation, within the normative context of Sustainable Development.

Based on this general notion, the Earth System Governance Project advances the 2018 Science and Implementation Plan that is organized around five research lenses and four contextual conditions, which are brought together in a research framework. The Science Plan emphasizes four key conditions that characterize the context within which earth system governance research takes place: (a) the numerous political, technological and socio-economic *transformations* that are shaping and being shaped by governance processes; (b) the increasing and multifaceted *inequalities* across and within countries and socio-economic groups; (c) the tremendous as well as contested impact of human beings on the entire planet and the changing human-nature relationship captured by the notion of the *Anthropocene*; and (d) the opportunities and challenges offered by the *diversity* and pluralism of human societies in knowledge, culture and identities in addressing sustainability challenges in the contemporary world. In addition, the 2018 Science and Implementation Plan present five interconnected research lenses that constitute the central element of the Earth System Governance research framework: *architecture and agency*; *democracy and power*, *justice and allocation*, *anticipation and imagination* and *adaptiveness and reflexivity*.

The Earth System Governance Project is designed as the nodal point within the global change research programmes to guide, organize and evaluate research on these questions. The Project is implemented through a Global Alliance of Earth System Governance Research Centres, a network of lead faculty members and research fellows, a global conference series, and various research projects undertaken at multiple levels (see www.earthsystemgovernance.org).

Earth System Governance Working Papers are peer-reviewed online publications that broadly address questions raised by the Project's Science and Implementation Plan. The series is open to all colleagues who seek to contribute to this research agenda, and submissions are welcome at any time at ipo@earthsystemgovernance.org. The Earth System Governance Project does not assume the copyright for working papers, and we expect that most working papers will eventually find their way into scientific journals or become chapters in edited volumes compiled by the Project and its members.

Comments on this working paper, as well as on the other activities of the Earth System Governance Project, are highly welcome. We believe that understanding earth system governance is only feasible through joint effort of colleagues from various backgrounds and from all regions of the world. We look forward to your response.

The Scientific Steering Committee
Earth System Governance Project

Gustav Thungren
Managing Director, Earth System Governance Project

1. INTRODUCTION

The advent of the Anthropocene and the looming climate crisis have sparked vivid debates about the future of the human species, based on the growing realization that human activities have shifted the Earth system toward a critical "no-analogue state" (Crutzen and Steffen 2003: 253). Responding to this fundamental shift in the Earth system arguably requires an equally fundamental shift in our understanding of the complex interactions between the environment, society and technology. Scholars in the fields of environmental politics and Earth system governance have thus pointed out that governance in the Anthropocene should be predicated on environmental reflexivity, the effective rethinking of dominant institutions, and the fundamental transformation of behavioral patterns that degrade the environment and endanger social cohesion (Biermann and Lövbrand 2019; Dryzek and Pickering 2019). Simultaneously, societies need to seize the opportunities and minimize the risks of accelerating global digitalization.[1] The ubiquitous application of digital technologies creates new interdependencies and fundamentally impacts all aspects of society, including ethics, politics, law, business, finance, security, labor markets, and environmental sustainability, thus requiring new forms of cooperation (United Nations 2019a).

Technological change driven by digitalization may, on the one hand, provide unprecedented opportunities for the advancement of human welfare and help accelerate progress towards achieving the SDGs and the Paris Agreement on climate change (United Nations 2018; WBGU 2019). On the other hand, there is the imminent risk that unregulated digitalization may create entirely new challenges, or further exacerbate existing ones. Unchecked digitalization processes may, for example, lead to the fundamental disruption of political, legal or financial systems. Digitalization may also negatively affect sustainability goals due to the increase in energy demand caused by the large-scale application of digital technologies (De Vries 2018; Mora et al 2018; United Nations 2019b).[2] Nonetheless, there is a surprising dearth of research at the intersection of global environmental politics and technological change, specifically on the ways in which particular technological forms are reshaping human behavior and interactions. More targeted research is urgently needed to maximize potential benefits and minimize the risks of digital transformations for both humans and the Earth System as a whole.

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[1] *Digitalization* "generally refers to how different political, social and economic domains are restructured around the broad use of digital technologies, often leading to new business models, services of employment as well as in interaction and engagement," while *digital transformation* is defined as "the application of digital technologies to fundamentally impact all aspects of business and society" (United Nations 2019c).

[2] *Disintermediation* in the economic sphere can be defined as "a process that provides a user or end consumer with direct access to a product, service, or information that would otherwise require a mediator such as a wholesaler, lawyer, or salesperson" (United Nations 2019b: 12). In the social and political domains, in particular, disintermediation refers to a process that directly links individuals to each other in digital peer-to-peer networks and reduces or eliminates the influence of governments and other regulatory bodies. Disintermediation can be both beneficial and risky, depending on the specific context.

We contribute to addressing this research gap by examining the role of blockchain and distributed ledger technology (DLT) for innovative digital financing of the SDGs, and Goal 13 (Climate Action) in particular. Blockchain and DLT, as the underlying technological infrastructures for cryptocurrencies such as Bitcoin and Ethereum, have attracted considerable attention for at least a decade. They can be described as "a novel and fast-evolving approach to recording and sharing data across multiple data stores (or ledgers) [which] allows for transactions and data to be recorded, shared, and synchronized across a distributed network of different network participants" (Natarajan et al 2017: 7). Blockchain, in particular, is a specific type of DLT and can be used as a general-purpose tool for creating decentralized and secure peer-to-peer applications in digital networks, for example with the aim to expedite payments, to create new financial instruments, or to organize the transparent exchange of data and information (De Filippi and Wright 2018).

Depending on the design of the digital system, DLTs may facilitate more inclusive processes in our societies and offer promising solutions for common concerns in international climate finance such as ensuring accountability and transparency. However, DLTs may also fundamentally disrupt the capacity of governments or governance regimes to supervise and regulate economic activities due to the disintermediation of established institutional processes, for example by cutting out traditional intermediaries such as large financial institutions, legal authorities, or governments (De Filippi and Wright 2018). Mitigating the potential risks of DLTs therefore requires a thorough investigation of specific digital systems. DLT system design has distinct governance implications, since it determines, for example, how the technology can be embedded in societal processes, or how recipients can be linked to funding sources.

In this paper, we specifically focus our inquiry on the Green Climate Fund (GCF) due to its role as a key actor in international climate finance. As the largest dedicated climate fund in terms of money pledged, currently US$ 19.9 billion after the recent first round of replenishment, the GCF plays a fundamental role in mobilizing climate finance to achieve SDG 13 and meet the goals of the Paris Agreement (GCF 2019b; Schalatek and Watson 2019: 3).[3] Nonetheless, the challenge to efficiently manage funds in multilateral climate finance remains, and the GCF is no exception to this problem. Direct access to GCF funding is only granted based on complex bureaucratic procedures for the accreditation of implementing partners. To become accredited entities under the GCF, partners have to demonstrate that they can implement fiduciary standards, environmental and social safeguards, the Monitoring and Accountability Framework, the Gender Policy and Action Plan, as well as the Indigenous Peoples Policy (Amerasinghe et al 2019: 50). Successfully completing this complex accreditation process and demonstrating compliance with social, ecological and fiduciary standards presents a considerable burden for many entities in recipient countries, with real consequences for the ownership and approval of climate change projects (Amerasinghe et al 2019: 51).

[3] The overall figure of US$ 19.9 billion should be treated with caution due to some pledges that have not yet been received as well as exchange rate fluctuations.

Considering these pertinent challenges, we aim to explore how DLTs could be used to support adequate, effective and accountable climate finance under the GCF. We then discuss political and technical challenges that may arise, for example with regard to GCF standards and safeguards, country ownership, further capitalization, and scalability. We conclude our investigation by identifying key recommendations for innovative climate finance under the GCF.

2. DLTS FOR INNOVATIVE CLIMATE FINANCE

The question of how DLTs can be leveraged for 'social good' is increasingly attracting the attention of policy makers, lawyers, tech developers, business leaders and practitioners in the fields of sustainable development and humanitarian action (Al-Saqaf and Seidler 2017; Kewell et al 2017; Kshetri 2017; Reinsberg 2019; Zwitter and Boisse-Despiaux 2018). New actor coalitions and technology networks with a focus on DLT innovations are emerging in the private sector, in academia, and under the umbrella of the UN. Examples include innovation and research hubs such as the European Union Blockchain Observatory and Forum, the Stanford Center for Blockchain Research, the Oxford Internet Institute, as well as the UN Climate Chain Coalition and Secretary-General's Task Force on Digital Financing of the Sustainable Development Goals.

In the field of digital financial technology, or 'FinTech', the focus rests primarily on how financial services can be delivered through digital infrastructures. It needs to be better understood how the conversion from analog to digital technologies in financial functions may result in systemic changes to financial systems, for example through the disintermediation of the banking and capital market sectors, or due to the shifting roles of regulatory and supervisory bodies, with important implications for governance (Paech 2017; Reijers et al 2016; United Nations 2019c). Actors in the private sector, ranging from large corporations and banks to smaller businesses and start-up companies, are now actively involved in research and development activities centered on DLTs. The overall aim is to benefit from newly emerging business opportunities, and to avoid being 'disrupted' by technological innovation. At the same time, it is evident that FinTech innovations based on DLTs will also affect climate finance in the near future. International climate finance, aimed at supporting developing countries' responses to climate change, stands to benefit in particular ways from these new technological possibilities. Emerging DLTs hold the possibility to facilitate innovative forms of climate finance by enabling decentralized forms of cooperation between stakeholders, and by fostering trust based on transparent, automated and standardized transactions. Nonetheless, realizing the full potential of DLTs requires a sound knowledge of the ways in which these new digital tools may be used to mobilize, allocate and monitor financing flows under the GCF (United Nations 2019c).

2.1 Blockchain and Distributed Ledger Technologies: General Capabilities and Governance Implications

Answering the question of how blockchain and DLTs can be used for innovative climate finance under the GCF requires a closer look at the design, capabilities and governance implications of these nascent technologies. Although there are large overlaps between technology clusters, it has been emphasized that the technical terms 'blockchain' and 'DLT' are not necessarily interchangeable. As Natarajan et al (2017: 7) point out, it is important to keep in mind that "not all distributed ledgers necessarily employ blockchain technology." The term blockchain generally refers to a specific type of data structure that stores and transmits data in a growing list of data packages called 'blocks'. Each block contains a unique code called 'hash' that sets it apart from every other block, as well as a timestamp and transaction data for verification. These blocks are then linked to each other in a digital 'chain' or peer-to-peer network in a linear and chronological order. Blockchains employ cryptographic signing and algorithmic methods to record and synchronize data across the network in a public, immutable and decentralized manner, meaning that blockchains are largely resistant to fraud or the malicious modification of data since an unchangeable distributed ledger of records is created in the process. Digital copies of the distributed ledger are replicated, shared, and synchronized between all nodes in the network. This makes a blockchain transparent and secure by design, since any given block that has been added to the blockchain cannot be altered retroactively without the alteration of all subsequent blocks, which requires consensus of the network majority. As decentralized databases, blockchains can be used to store a registry of assets and transactions, whereas the term 'asset' may refer to not only money but also to ownership rights, custodianship, contracts, goods, and even personal information (Zwitter and Boisse-Despiaux 2018).

While the complex technical details of different applications are certainly beyond the scope of this article, it will suffice to say that some DLTs use only certain parts of blockchain technology such as the distributed ledger (Paech 2017). Compared to a truly decentralized and public blockchain such as the infrastructure underlying the cryptocurrency Bitcoin, where participants in the peer-to-peer network are taking decisions which directly affect the network's overall structure and design, DLTs may only be decentralized in terms of the technological infrastructure. The overall design and organization of the network could still follow proprietary or commercial principles, for example if the respective DLT is developed by private companies or banks to facilitate certain types of financial transactions

Since the technical terms 'blockchain' and 'DLT' are often used indiscriminately, we consider it necessary to define blockchain as a particular *type* of DLT. We then differentiate the underlying DLT system along the lines of (1) *public-permissionless* ledgers, (2) *public-permissioned* ledgers, (3) *private-permissionless* ledgers, and (4) *private-permissioned* ledgers, resulting in at least four distinct DLT system models (see Table 1).[4]

Table 1. DLT System Models

DLT Architecture	1. Public-permissionless	2. Public-permissioned	3.Private-permissionless	4.Private-permissioned
System	Transaction or data history publicly visible Every node in the network has permission to verify and add transactions	Transaction or data history publicly visible Nodes have to gain special permission to verify and add transactions	Transaction or data history not publicly visible Every node in the network has permission to verify and add transactions	Transaction or data history not publicly visible Nodes have to gain special permission to verify and add transactions
Trust	Distributed (Peer-to-Peer) ◦ Open Exchange	Distributed (Intermediary) ◦ Restricted Exchange	Distributed (Intermediary) ◦ Restricted Exchange	Centralized (Intermediary) ◦ Restricted Exchange
Governance	Fully Distributed	Hybrid: Partly Distributed	Hybrid: Partly Distributed	Fully Centralized
Token Required	Yes	Yes	No	No
Example	Bitcoin, Ethereum	Ripple	LTO Network	Hyperledger Fabric

[4]This overall distinction still remains an oversimplification of highly complex technical processes, since "there are other permutations of permissioning (such as a permissioning of the node infrastructure or participants in a consensus protocol) that may also achieve similar ends" (Blockchain Bundesverband 2018, 25).

The first system model (public-permissionless) describes a system where the transaction or data history is publicly visible and every node in the network has permission to verify and add transactions to the blockchain. Bitcoin is a prominent example. The data or transaction history is also publicly visible in the second system model (public-permissioned), but nodes in the network have to gain special permission to verify and add transactions. The network maintainer can even appoint privileged parties. Ripple, which is a payment settling, currency exchange and remittance system intended for banks and payment networks is an example for such a model. Ripple uses a distributed consensus ledger (XRP) instead of the classic blockchain. The third model (private-permissionless) refers to a network where anyone can verify or add transactions, but only a specific group of pre-approved nodes is able to view the respective data or transaction history. One example is the LTO Network, a platform to run trustless workflows, targeting multinationals and governments. LTO uses a hybrid blockchain with a private layer for data sharing and process automation, and a public layer which acts as an immutable digital notary. The fourth system model (private-permissioned) can be described as a private consortium ledger. Only pre-approved nodes have permission to view the data or transaction history, as well as to verify and add data or transactions. Use cases include Hyperledger Fabric, a private permissioned blockchain backed by IBM, innovative supply chain management systems, or banking consortia.

These four different system models clearly illustrate that the effective use of DLTs for climate finance will not only depend on general technological capabilities and the actors involved in DLT implementation or regulation, but also on initial **design choices**. In order to explore specific fields of application for DLTs in the context of the GCF, initial design choices are of crucial importance, as they may create path dependencies or lock-ins, with concrete governance implications. For example, permissionless systems allow participants to collaborate with any other party on a case-by-case basis, whereas permissioned systems such as consortium blockchains are less flexible and only allow for interactions between pre-approved members (nodes). Design choices also influence whether the DLT network is based on notions of openness, cooperation and transparency, or on proprietary and commercial principles. This specific design choice is also tightly linked to questions of legal regulation, since it needs to be ensured that the benefits of data-driven innovation are balanced with concerns about privacy, ethics, sustainability, and basic human rights.

Therefore, it is important to be cognizant that the design of DLT systems is inherently **political**. DLT design choices seriously affect the lives of users because of the various effects that digital products have on people's behavior, attitudes, and needs (Werbach 2018). In other words, DLT system design encourages certain forms of social interaction and human behavior by defining specific rules for users interacting through the network. This political dimension clearly situates discussions about DLT design within wider debates about the **governance** *of* and *through* emerging technologies (see, for example Epstein et al 2016; Kuhlmann et al 2019). One of the key insights that can be gleaned from ongoing debates about the governance of emerging technologies is that DLTs are neither a panacea nor a standalone solution for key political issues in climate finance. In their current state of development, DLTs should rather be seen as versatile tools that can be used to address clearly defined operational and interorganizational problems. According to the Gartner 'Hype Cycle' for

Blockchain Business, a well-known graphic representation of the maturity and relevance of DLTs for solving problems and exploiting new opportunities, DLTs are expected to reach their full potential over the next five to ten years (Gartner 2018a). Gartner predicts that "blockchain's business value-add will grow to slightly over $360 billion by 2026, then surge to more than $3.1 trillion by 2030" (Gartner 2018b). Some of the most promising applications for DLTs include financial transactions, asset and supply chain management, energy markets, decentralized peer-to-peer networks for the exchange and storage of data, as well as social service provision and digital identities (GIZ 2019; Zwitter and Herman 2018). Public sector and non-governmental organizations are currently exploring the potential of DLTs in several areas. These include democratic participation, public procurement, taxation, education, and the establishment of digital asset markets, especially in regulated areas such as insurance, utilities, healthcare, and natural resource management (Gartner 2019; GIZ 2019).

In addition, DLTs are a means to foster accountability and transparency by augmenting existing organizational processes and institutions to address fraud, counterfeit issues, or corruption, with important implications for the operation of carbon markets and the measuring, reporting, and verification of emissions and their reductions (Aggarwal and Floridi 2019; Chen 2018). Automated compliance mechanisms based on DLTs and 'smart contracts' could even disrupt the regulatory provisions of the current climate regime within a decade by connecting databases of high interoperability to funding sources, and by linking "renewable energy and carbon accounting, reporting, and tracking on a micro- and macro-economic level" (Marke 2018: 272). In view of these promising developments, the subsequent section will take a closer look at the potential of DLTs for addressing salient issues in the context of the GCF.

2.2 Leveraging DLTs Under the Green Climate Fund

International climate finance, especially under the GCF, refers to the sourcing, managing, and allocation of funds to support developing countries in their efforts to mitigate climate change and adapt to its effects. The reasoning behind international climate finance ranges from normative to strategic. From a normative perspective, international climate finance can be seen as a response to the double inequality of climate change: those countries that have contributed least to global warming are often the most vulnerable, and lack the necessary resources to adapt (Barrett 2013; Gough 2011). From a strategic perspective, international climate finance has been described as a means to correct market failures, secure support from developing countries in negotiations under the UNFCCC, and manage climate effects before catastrophic events may occur that would also affect contributing countries (Kotchen and Martinez-Diaz 2017; Salisbury and Khvatsky 2018; Skovgaard 2012). While COP 15 in Copenhagen is widely regarded as a severe political failure, one of its few tangible outcomes was the commitment of developed countries to jointly mobilize US$ 100 billion per annum by 2020 in additional climate finance from both public and private sources (Bäckstrand and Lövbrand 2016; Bodansky 2010). It is worth noting that the figure of US$ 100 billion has been criticized as being insufficient to finance a global transition to clean energy and to meet the adaptation needs of the world's most vulnerable countries (Abadie et al 2013; Moser et al 2019; UNEP 2016). The measuring and tracking of climate finance flows presents a considerable challenge as well, and still depends on politically controversial definitions (Clapp et al 2012; Donner et al 2016; Hall 2017; Roberts and Weikmans 2017).

The idea for a dedicated fund to manage climate finance flows was concretized at COP 15 in Copenhagen, and the GCF was formally established at COP 16 in Cancún in 2010. The GCF was meant to serve as a major, albeit not the exclusive, channel for the US$ 100 billion annually (UNFCCC 2010). According to its governing instrument, the fund's key mission is to "promote a paradigm shift towards low emission and climate-resilient pathways" (UNFCCC 2011). This can be seen as a prime example of so called constructive ambiguity: the wording agreed at the COP was kept rather vague, and the technical details of the fund's institutional and operational design had to be negotiated during a post agreement process. The fund's operationalization took at least until just before COP 21 in 2015, when the GCF approved its first set of funding proposals. Some fundamental governance questions, however, such as decision-making in the absence of consensus remained pertinent until mid-2019 (Feist 2018; GCF 2019c: 5).

The main decision-making body in this regard is the GCF's board, which also takes operational and strategic decisions, for instance concerning the approval of funding proposals. The GCF board consists of twenty-four members in total, with equal representation from developed and developing countries. The board generally decides by consensus, although a voting mechanism for decision-making in the absence of consensus has been established recently.[5] Before funding proposals can be put before the board for approval, they are submitted by accredited entities, such as private or development banks. The GCF's secretariat based in Songdo, South Korea, is the entity tasked with conducting the fund's daily operations, including the preparation of decision documents for board meetings, or accepting and managing applications for accreditation and funding proposals. As of 2019, the GCF has approved 124 projects worth about US$ 5.6 billion in total (GCF 2019a).

[5] Decisions to be taken by the GCF board were substantial for the fund's design. For example, the board was tasked with striking a balance between mitigation and adaptation finance while the exact meaning of such a balance had been left undefined (Schalatek 2014, XXII). The board later decided to interpret it as a 50:50 split.

It should be noted that the GCF is not the first funding mechanism of its kind. The Adaptation Fund and the Global Environment Facility, for example, had been established before. Yet, a certain degree of innovativeness has been attributed to the GCF since its inception. Particularly from the perspective of developing countries, the GCF was meant to depart from business as usual in international climate finance. As one developing country board member stated at the eighth GCF board meeting in Bridgetown, Barbados: "We're not compiling practices from different institutions here. We're going to do business in a new way, and in a way that GCF is mandated to do."[6] Mobilizing innovative technologies such as DLTs to facilitate the work of the GCF will thus depend on the identification of promising use cases and supportive networks such as the Climate Chain Coalition to provide economic and policy incentives for technology uptake and implementation.

2.3 DLT Applications and Their Use Potential

In order to facilitate the ongoing debate about climate finance under the GCF, we introduced four basic types of DLT systems that range from public and permissionless DLT systems to private and permissioned solutions, with very specific legal, technical, and governance implications (see Table 1). These four types can serve as a first orientation for decision-makers and the wider climate finance community to consider how different DLT systems may benefit the work of the fund. DLTs are linked to several of the fund's key distinguishing features, as well as to crucial points in the GCF governance process (see Table 2). In the remainder of this section, we examine five key issue areas where DLTs could be leveraged to support the work of the GCF: (1) accountability and trust, (2) accessibility and the required institutional capacity, (3) country ownership, (4) impact assessment, and (5) scalability.

It should be noted, however, that we do not perceive DLTs as the ideal solution for all existing GCF governance challenges, nor do we wish to argue that DLTs are necessarily aligned with the political agenda and priorities of the fund. The operations of the GCF are very much embedded in a political process that will not be fundamentally changed through the incremental implementation of technical fixes. Instead, we aim to illustrate how DLTs could help alleviate a number of pertinent governance challenges in international climate finance due to their basic technical features.

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[6] Recording of day 2 of the 8th GCF board meeting, held in Bridgetown, Barbados, from October 14-16, 2014.

Table 2. Relevant GCF Governance Challenges

Governance Challenge	Specific Issues	DLT Solution	Example
Accountability and Trust	Ensuring the transparent and effective use of financial resources	Enabling transparent, secure and standardized transactions	European Blockchain Services Infrastructure (European Commission)
Accessibility and Capacity	Establishing efficient accreditation and approval processes	Facilitating peer-to-peer data exchange based on clear standards and safeguards	Adaptation Ledger (United Kingdom) Treum (United States)
Country Ownership	Ensuring the effective involvement of relevant institutions and stakeholders	Automating the direct disbursement of funds to authorized recipients	Building Blocks (World Food Programme) Forus.io 'Kindpakket' (The Netherlands)
Impact Assessment	Ensuring the effective and efficient monitoring of GCF activities by the Independent Evaluation Unit	Standardized, transparent and efficient measuring, reporting and verification (MRV) of climate action	The Climate Chain (France) BFLO™ (United States)
Scalability	Mobilizing institutional investors at scale via the Private Sector Facility to fund climate action	Connecting to the private sector via interoperable databases and registries to facilitate investments	ClimateTrade™ (Spain) Blockchain for Climate Foundation (Canada)

Considering the key issue of *accountability and trust* means to discuss how DLTs can be used to facilitate accountability and trust between parties, since it is a common concern in climate finance to ensure that financial resources are used in a transparent and accountable manner (UNFCCC 2015, Art. 13). At the GCF, this is ensured through a number of fiduciary principles, standards, and safeguards that need to be met before funding can be disbursed, for example during the accreditation and project approval process. While developed countries held diverse views during the negotiations with regard to how extensive these requirements should be, it was clear to developing countries that the conditionality of standards and contributions could potentially neglect the historic responsibility for climate change and the urgency of action. Here, the core opportunity of DLTs is that "[u]nrelated parties can reach agreement and coordinate their activities without needing to know or trust one another, and without requiring a central coordinating authority" (Aggarwal and Floridi 2019: 16). Transparency is a key element under the Paris Agreement (van Asselt et al. 2016; Jacoby et al. 2017). As certain DLT systems provide a decentralized, public register of transactions, these systems have the potential to make financial flows and the use of resources fully transparent to all parties (Retamal et al. 2018: 39). Thus, while much still depends on the institutional and political context, DLT systems offer the opportunity to facilitate trust and accountability based on transparent and standardized transactions.

Concerning *access to funding*, the capacity to submit funding proposals and to handle them at the GCF secretariat has been a bottleneck since the inception of the fund. Even the process of getting accredited to submit proposals is an administrative burden, especially for developing countries, a challenge which has been frequently emphasized during negotiations. So-called readiness support and fast tracked accreditation were among the measures to counter this problem. Nonetheless, it has been proposed in light of these pertinent governance challenges that DLT systems could help to ease administrative burdens associated with accreditation and project procedures (Paz Neves and Aleixo Para 2018: 44f). Mature DLT products are already available and demonstrate that DLT systems hold the potential to facilitate transparent and traceable transactions in climate finance based on clear standards and safeguards (Baumann 2019). Ensuring transparency with regard to the use of funds has also been a key concern of developed countries in the negotiation process. The transparency that DLTs provide – and the standardized interactions that they facilitate – may help to address these concerns directly, ultimately allowing for easier access to funding. Beyond the disbursement of funds, DLTs could potentially be used for the administrative easing of international standard setting and enforcement in general (GIZ 2019). The political and technical implications of these proposals will be discussed in the following section.

Besides transparency and accountability, *country ownership* has been one of the key priorities since the establishment of the GCF. As a financial mechanism under the UNFCCC, the GCF employs a country-driven approach and has made country ownership one of its six investment criteria (Eco 2019). Ownership is assessed by considering a funding proposal's alignment with the recipient country's nationally determined contributions or national development strategies, and by considering whether relevant stakeholders have been consulted (GCF 2018). In addition, National Designated Authorities (NDAs) in recipient countries must provide a letter of no objection for a funding proposal to be approved. This means that enabling access to funding via a DLT system could, on the one hand, contradict the principle of country ownership as the direct disbursement of funds would necessitate less involvement from national governments or financial institutions. On the other hand, one may argue that the direct disbursement of funds through a DLT system is fully in line with the principle of country ownership, namely, to ensure that those who are directly affected by climate change have control over the financial means to take action. Independent of the perspective that one may adopt, these examples show that DLTs are not a panacea for pertinent problems of governance and resource allocation, despite their potential to facilitate efficient and transparent transactions and information exchange.

Another interesting area for DLT application in GCF projects is *impact assessment*. This includes questions such as: Are mitigation projects effectively reducing GHG emissions? Are adaptation actions making communities less vulnerable? Various DLT tools are currently piloted to answer these and similar questions in the context of the UNFCCC process, for example by building the next generation of interoperable GHG registries and tracking mitigation outcomes, or by automating and enhancing standardized measuring, reporting and verification processes in climate change projects (Fuessler et al 2019). These use cases show that DLTs could support, and ultimately enhance regular impact assessments conducted by the GCF's Independent Evaluation Unit (UNFCCC 2011: 15).

Lastly, *scalability* constitutes a challenge not only for the GCF, but for climate finance in general. Scalability refers to the scalability of technological and institutional systems on the one hand, and the potential to upscale the total amount of funding available for climate action on the other. The extent to which international climate finance should originate from public or private sources has been the cause for much debate in the global climate negotiations. Developing countries generally favor public over private funding to ensure that adaptation projects with potentially low returns on investment are ultimately realized. The need for adaptation finance alone is expected to be around US$ 140-300 billion per year by 2030, with projected available funding only reaching US$ 25 billion (UNEP 2016). However, while it is likely that the total amount of funding available for climate action will be insufficient without further involvement of the private sector, climate finance requirements under the UNFCCC are often misaligned with the realities of private sector investments (Pauw et al 2016). The GCF has thus established a Private Sector Facility, and as of January 2020 about 38 percent of total GCF funding are channeled into private sector projects or activities (GCF 2019a). DLT solutions might further enhance private sector involvement in climate finance by (a) improving the visibility of investment opportunities, (b) increasing investor flexibility for direct investments in small-scale projects, and (c) facilitating secure accreditation and transparent information exchange among GCF entities and partners (Salisbury and Khvatsky 2018). This could be done by setting up interoperable databases and registries for the secure peer-to-peer exchange and storage of data or digital assets, primarily to facilitate private sector investment in climate change projects (Baumann 2019). DLTs could also foster synergies across organizations, given that the GCF Board has been tasked to consider the complementarity of the GCF with other climate finance mechanisms.

3. POLITICAL CHALLENGES AND TECHNICAL LIMITATIONS FOR DLTS

Having explored the potential of DLTs to address common issues in international climate finance, we now turn to assessing the key political challenges and technical limitations associated with these novel technologies, and especially for their use in the context of the GCF. From a technical and capacity perspective, the implementation of DLTs may be challenging in some instances, especially if digital infrastructure and electricity requirements in recipient countries are not met. This means that the effectiveness of DLTs will depend on "the strength of a country's (digital) infrastructure — the Internet, distributed and cloud computing, electricity supply, and digitized data, all of which power the blockchain, as well as the technological literacy of its population" (Aggarwal and Floridi 2019: 17). The latter problem of technological literacy also touches on a variety of key debates in fields such as political science, science and technology studies and development studies, most notably those revolving around so called "digital divides" (see Andreasson 2015). The term digital divides generally refers to stark demographic and geographical differences concerning the availability, adoption and use of digital technologies. It may also include different cultural perceptions of digitalization. Taken together, these factors play an important role with regard to technology access, and may lead to specific situations in which the implementation of DLTs could widen existing inequalities within or among societies, especially in recipient countries. Differences in technological skills and literacy have to be carefully considered to guarantee that digitalization does not negatively impact social cohesion. Another potential barrier for the inclusive use of DLTs in climate finance is the current shortage of specialists (e.g., coders), together with developer competition and a relatively low interest in climate action within these communities (EIT Climate-KIC 2018). The deployment of DLTs will thus require initial investments in infrastructure, technical expertise, and research or pilot projects to ensure that standardized DLT systems are implemented for the benefit of all GCF entities and partners.

The high energy demand of DLTs is often seen as another crucial challenge for the sustainable and inclusive use of these emerging technologies. Recent studies show, for example, that the energy demand for blockchain applications such as Bitcoin could lead to a significant increase in carbon emissions (Mora et al 2018). It is estimated that Bitcoin alone uses the same amount of energy per year as Ireland or Austria, depending on the concrete circumstances of its application (De Vries, 2018). This is certainly a problem for Bitcoin. However, it is a widely held belief in the technical community that the energy problem of DLTs is primarily associated with the logical mechanism which is used by the ledger to confirm the claims of users. While Bitcoin uses a 'proof-of-work' logic, the efficiency of DLTs can improve considerably once alternative 'proof-of-stake' or 'proof-of-authority' mechanisms are introduced (for more information, see Chen 2018). Yet, since the number of digital devices and the amount of data that is created on a daily basis are steadily increasing, together with a rising demand for computational power, it should be kept in mind that the Internet itself, as a key driver of digitalization, will require more and more energy over time. As Chen (2018: 76) points out, "the Internet consumed 200-300 TWh of electricity in 2017 [...] To put this into a broader perspective, the Internet is now comparable to aviation as a source of carbon emissions." As long as relevant innovations such as quantum computing are still under development, and as long as related promises of exponentially higher computational power and technological sustainability have not materialized, the key question remains how the energy demand of digitalization processes can be met sustainably. This does not mean to imply that energy demand should be a reason to stop the development of DLTs altogether, or that DLTs are an unsustainable technology per se. DLTs are simply one aspect of digitization processes on a global scale, and hold significant potential to increase energy efficiency, to accelerate climate action, and to support transitions toward sustainable energy systems (Marke 2018).

If and how this potential can be realized will crucially depend on the design of specific DLT systems and the political choices that are made along the way. This also includes the effective adaptation of institutional structures and organizational processes to minimize potentially harmful effects. Due to the inherent dynamism of innovation, it is still difficult to predict how exactly DLTs will affect, or even disrupt existing institutional structures and processes, since DLT systems differ considerably with regard to their legal, technical, and governance implications. In public and permissionless systems, decision making power may shift away from centralized institutions such as governments, or for example in the case of community-based and decentralized energy systems, from large energy providers and corporations. In proprietary and commercially oriented systems, there might be strong economic incentives to focus on DLT applications that are less relevant for climate finance. Other types of DLT systems that combine public or private with permissioned or permissionless infrastructures may strengthen the role and capacity of public institutions. All of these use cases certainly imply a power shift to DLT developers and specialists.

Policy incentives and system design will also play a crucial role for further GCF capitalization. One of the main benefits of DLT for climate finance is that the technology can reduce the overall costs of developing new green finance products, reduce information asymmetry between actors, and improve certification systems (EIT Climate-KIC 2018). Nonetheless, there are a number of obstacles for the uptake of DLTs in climate finance, especially for private sector entities, such as the general uncertainty attributed to climate finance business models and the related prospect of minimal risk-adjusted returns, especially in adaptation finance. The reluctance among decision makers in the private sector to engage with DLT solutions may also stem from a negative image of DLT as an immature technology, together with a general lack of industry-specific knowledge (trends, problems, rules of the game) among developers or project partners to create real value-adding solutions (EIT Climate-KIC 2018).

Deploying DLTs to reduce the need for conventional accountability measures in climate finance is another promising field of application, but deploying the technology to this end might be problematic for several reasons. Since DLTs can be used to disintermediate processes, to create transparency in interactions, and to facilitate 'trust-free' interactions between participants based on immutable records, DLTs have been heralded as tools to address problems related to trust, accountability, and ultimately legitimacy under the GCF (Reutemann 2018). This means that the control which developed countries legitimately exert through conventional standards and board oversight would be reduced. Developed countries would, however, likely be reluctant to give up that control, particularly if they consider engagement with the GCF to be in their strategic interest. Quite ironically, some of the most significant benefits of DLTs may also constitute political obstacles for their implementation.

However, governments and organizations may not only be reluctant to implement DLT systems because of oversight issues or cost-benefit calculations, depending on the outcome of such analyses for specific use cases. Implementing DLTs also raises ethical and legal issues, as well as issues of data security. Creating an immutable record of activities and collecting large amounts of sensitive data might provide incentives for criminal behavior and requires precautionary measures, especially since the immutability of ledgers makes it extremely difficult to retrospectively alter or remove (false) information once it has been entered into the system. Within the European Union, there is an ongoing discussion among legal scholars whether a decentralized DLT system can in principle be compliant with regulations such as the 2016 General Data Protection Regulation, especially when considering an individual right to erasure ('right to be forgotten') enshrined in Article 17 (Finck 2018). Creating transparency and accountability also means constraining the scope for the pursuit of vested interests, and may thus be resisted under certain circumstances (Aggarwal and Floridi 2019).

Despite promises of decentralization, disintermediation and democratization, there is also the real possibility that DLTs may support a push towards centralized control, depending on the design of the system and the political context for its implementation. The deployment of DLTs thus requires clear **ethical and design principles** to ensure the security, inclusivity, and legal compatibility of the system. This includes the complex question of whether it would be desirable to disintermediate traditional processes related to, for example legal oversight, standardization or public administration, provided there are choices involved at all, and the process is not disruptive.

Lastly, it is evident that the aforementioned technical and political challenges will directly affect the scalability of DLTs. Generic predictions about the scalability of DLT solutions are nevertheless hard to make. Prospects depend on specific cost-benefit calculations as well as a number of other factors such as the technical aspects of the system model, contextual factors such as the political and cultural preferences of users, or the concrete effects of existing digital divides, especially between developed and developing countries.[7]

4. CONCLUSION

In this paper, we discuss how the Green Climate Fund (GCF) may leverage emerging distributed ledger technologies (DLTs) for innovative climate finance and service provision. On the one hand, our findings show that digital technologies offer great potential to support the work of the GCF in key areas such as MRV, international standard setting, and multi-stakeholder coordination. On the other hand, we illustrate why emerging digital technologies do not provide a silver-bullet solution for existing GCF governance challenges. In their current state of development, DLTs should rather be seen as digital multi-purpose tools that can be used to address some of the organizational and operational challenges the GCF is currently facing. First, the capability of DLTs to facilitate secure, immutable and standardized transactions speaks to the need to ensure transparency and accountability for GCF funding. Second, in the same wake, DLTs could reduce the need for administratively burdensome processes to access funds, which directly addresses the problem of limited institutional capacity, especially in developing countries. Third, DLTs could enhance country ownership by giving recipient countries more direct control over funding. Fourth, DLTs can provide a decentralized and transparent register that holds great potential for MRV or impact assessment. Finally, improved information and ease

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[7] For a more in-depth discussion of DLT scalability, see for example EIT Climate-KIC 2018. What can be said in more general terms is that different DLT solutions might involve trade-offs between decentralization, security, and scalability.

of accessibility might ultimately incentivize more private investment, thereby allowing the GCF to scale-up more easily.

However, based on our analysis of existing use cases and system models, we find that DLTs do not necessarily solve pertinent **governance** issues. Many problems in international climate finance are normative or political. These problems cannot simply be done away with through technical solutions. Especially the frequent claim that blockchain is a 'trustless' technology is questionable and warrants further investigation. DLTs can certainly be used to facilitate trust between actors in climate finance, but emerging technologies neither generate trust out of thin air, nor do they solve existing problems of resource **allocation**. Depending on the design of the digital system, DLTs could even disrupt established relations of trust and negatively affect the capacity of governments and governance regimes to regulate economic activities. This means that DLTs are not entirely 'trust-free' technologies. They remain connected to existing governance arrangements, and may either facilitate or disrupt institutional processes.

Harnessing the positive effects of DLTs will thus require targeted economic and policy incentives to support digital innovation in line with the recommendation of the UN Secretary-General's High-level Panel on Digital Cooperation, namely to test new approaches "on a small scale before being rolled out widely—through, for example, pilot zones, regulatory sandboxes or trial periods" (United Nations 2019a: 14). The identification of transdisciplinary research and development projects which can be brought to scale and contribute to finding solutions for clearly defined problems should be made a priority in this regard. Careful **anticipation** and foresight will be needed, together with the development of clear ethical, legal and design principles to avoid situations where DLTs may endanger social cohesion. Disintermediation has complex consequences across multiple domains (social, legal, political, financial, economic) and should not be regarded as an end in itself. Additional research will be necessary to better understand the context specific consequences of disintermediation for climate finance and governance systems.

Our analysis further shows that technical infrastructure and skill requirements present noteworthy challenges for DLT deployment, particularly in developing countries, and that the carbon footprint and energy consumption of DLTs can be considerable. While this might present a challenge, DLTs will reach maturity within the next five to ten years, and it is expected that technological **sustainability** will improve as a result of ongoing innovation. DLTs are simply one facet of global digitization, and are equally capable of increasing energy efficiency, accelerating climate action, and supporting transitions toward sustainable and more decentralized energy systems.

Lastly, it should be emphasized that DLTs develop in a highly dynamic fashion. DLTs are hardly an isolated technological trend, and it will be crucial to monitor their increased maturation together with other technological developments in fields such as artificial intelligence, the emerging internet of things and services, or big data analytics. As pointed out by digital innovation experts, international organizations or businesses may "ignore the trend at their peril," and thus risk being disrupted, for better or worse, with yet unforeseen consequences for global sustainability and environmental governance (Gartner 2018b). What might be needed at this point, beyond inflated expectations and pessimistic scenarios, is a more analytical approach to DLTs in both the public and private sector, together with structured research and development informed by deliberate experimentation.

Acknowledgements

We thank the anonymous ESG reviewers for their insightful comments and for providing valuable feedback on previous drafts of this paper. This research has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 691060.

REFERENCES

Abadie, Luis, Ibon Galarraga, and Dirk Rübbelke. 2013. *An Analysis of the Causes of the Mitigation Bias in International Climate Finance.* Mitigation and Adaptation Strategies for Global Change 18 (7): 943-955.

Amerasinghe, Niranjali Manel, Joe Thwaites, and Caitlin Smith. 2019. *Key Policy Issues in the Green Climate Fund*. Washington, DC: World Resources Institute.

Aggarwal, Nikita, and Luciano Floridi. 2019. *The Opportunities and Challenges of Blockchain in the Fight against Government Corruption. In 19th General Activity Report (2018) of the Council of Europe Group of States against Corruption (GRECO),* adopted by GRECO 82 (18-22 March 2019), 16-19. Strasbourg: Council of Europe.

Al-Saqaf, Walid, and Nicolas Seidler. 2017. *Blockchain Technology for Social Impact: Opportunities and Challenges Ahead*. Journal of Cyber Policy 2 (3): 338-354.

Andreasson, Kim. 2015. *Digital Divides: The New Challenges and Opportunities of E-Inclusion*. Boca Raton: CRC Press.

Bäckstrand, Karin, and Eva Lövbrand. 2016. *The Road to Paris: Contending Climate Governance Discourses in the Post-Copenhagen Era.* Journal of Environmental Policy & Planning: 1-19. DOI: 10.1080/1523908X.2016.1150777.

Barrett, Sam. 2013. *Local Level Climate Justice? Adaptation Finance and Vulnerability Reduction.* Global Environmental Change 23 (6): 1819-1829.

Baumann, Tom. 2019. *2019 Assessment Report of the Climate Chain Coalition Membership.* Available online at: https://bit.ly/2Sep6w2, last accessed January 19, 2020.

Biermann, Frank, and Eva Lövbrand. 2019. Encountering the "Anthropocene": Setting the Scene. In *Anthropocene Encounters: New Directions in Green Political Thinking*, edited by Frank Biermann and Eva Lövbrand, 1-22. Cambridge, UK: Cambridge University Press.

Blockchain Bundesverband. 2018. *Self-sovereign Identity. A Position Paper on Blockchain Enabled Identity and the Road Ahead.* Berlin: Blockchain Bundesverband.

Bodansky, Daniel. 2010. *The Copenhagen Climate Conference: A Postmortem.* American Journal of International Law 104 (2): 230-240.

Bowman, Megan, and Stephen Minas. 2019. *Resilience Through Interlinkage: The Green Climate Fund and Climate Finance Governance.* Climate Policy 19 (3): 342-353.

Chen, Delton. 2018. *Utility of the Blockchain for Climate Mitigation.* Journal of the British Blockchain Association 1 (1): 75-80.

Clapp, Christa, Jane Ellis, Julia Benn, and Jan Corfee-Morlot. 2012. *Tracking Climate Finance: What and How?* Paris: OECD/IEA.

Crutzen, Paul J., and Will Steffen. 2003. *How Long Have We Been in the Anthropocene Era?* Climatic Change 61 (3): 251-257.

De Filippi, Primavera, and Aaron Wright. 2018. *Blockchain and the Law: The Rule of Code.* Cambridge, MA: Harvard University Press.

De Vries, Alex. 2018. *Bitcoin's Growing Energy Problem*. Joule 2 (5): 801-805.

Donner, Simon, Milind Kandlikar, and Sophie Webber. 2016. *Measuring and Tracking the Flow of Climate Change Adaptation Aid to the Developing World.* Environmental Research Letters 11 (5): 1-9.

Dryzek, John S., and Jonathan Pickering. 2019. *The Politics of the Anthropocene*. Oxford, UK: Oxford University Press.

Dutch Blockchain Research Agenda. 2018. *Dutch Digital Delta*. Available online at: https://bit.ly/2RwKrAM, last accessed January 19, 2020.

Eco Ltd. 2019. *GCF Insight: Enhancing Country Ownership.* Available online at:

https://bit.ly/3aFZIrM, last accessed 21 January 2020.

EIT Climate-KIC. 2018. *Distributed Ledger Technology for Climate Action Assessment.* Zurich: Climate-KIC.

Epstein, Dmitry, Christian Katzenbach, and Francesca Musiani. 2016. *Doing internet Governance: How Science and Technology Studies Inform the Study of Internet Governance.* Internet Policy Review 5 (3): 3-14.

Feist, Marian. 2018. *A Crisis of Confidence at the Green Climate Fund?* Available online at: https://bit.ly/2KEO3zt, last accessed 21 January 2020.

Finck, Michèle. 2018. *Blockchains and Data Protection in the European Union.* Eur. Data Prot. L. Rev. 4: 17.

Fuessler, Juerg, Owen Hewlett, Sven Braden, Marion Verles, Rachel Chi Kiu Mok, Susan David Carevic, and Madeleine Guyer. 2019. *Navigating Blockchain and Climate Action: 2019 State and Trends.* Zurich: Climate Ledger Initiative.

Gartner. 2019. *How Governments Can Unlock Blockchain's Potential.* Available online at: https://gtnr.it/2Xb9fni, last accessed January 19, 2020.

Gartner. 2018a. *The Reality of Blockchain.* Available online at: https://gtnr.it/2LsRSY2, last accessed January 19, 2020.

Gartner. 2018b. *The CIO's Guide to Blockchain.* Available online at: https://gtnr.it/2X9wT3V, last accessed January 19, 2020.

GCF. 2018. *Investment criteria indicators.* GCF/B.20/Inf.14.

GCF. 2019a. *Portfolio Dashboard.* Available online at: https://bit.ly/2HXeDDw, last accessed January 19, 2020.

GCF. 2019b. *Resource Mobilization*. Available online at: https://bit.ly/2ZZl2SL, last accessed January 19, 2020.

GCF. 2019c. *Decisions of the Board – Twenty-third Meeting of the Board*, 6–8 July 2019. GCF/B.23/23.

GIZ. 2019. *Blockchain Potentials and Limitations for Selected Climate Policy Instruments.* Bonn and Eschborn: GIZ.

Gough, Ian. 2011. Climate Change, *Double Injustice and Social Policy: A Case Study of the United Kingdom*. Geneva: UNRISD.

Hall, Nina. 2017. *What Is Adaptation to Climate Change? Epistemic Ambiguity in the Climate Finance System.* International Environmental Agreements 17 (1): 37-53.

Jacoby, Henry, Y.-H. Henry Chen, and Brian Flannery. 2017. *Transparency in the Paris Agreement.* Cambridge, MA:MIT Joint Program on the Science and Policy of Global Change.

Kewell, Beth, Richard Adams, and Glenn Parry. 2017. *Blockchain for Good?* Strategic Change 26 (5): 429-437.

Kotchen, Matthew, and Leonardo Martinez-Diaz. 2017. *Memo to the President. Support for Green Climate Fund Puts America First.* Available online at: https://bit.ly/320W4UK, last accessed January 19, 2020.

Kshetri, Nir. 2017. *Will Blockchain Emerge as a Tool to Break the Poverty Chain in the Global South?* Third World Quarterly 38 (8): 1710-1732.

Kuhlmann, Stefan, Peter Stegmaier, and Kornelia Konrad. 2019. *The Tentative Governance of Emerging Science and Technology—A Conceptual Introduction.* Research Policy 48 (5): 1091-1097.

Marke, Alastair. 2018. *Blockchain for Better Green Finance Law Enforcement (Interlude V).* In Transforming Climate Finance and Green Investment with Blockchains, edited by Alastair Marke, 271-272. Cambridge, MA: Academic Press.

Mora, Camilo, Randi L. Rollins, Katie Taladay, Michael B. Kantar, Mason K. Chock, Mio Shimada, and Erik C. Franklin. 2018. *Bitcoin Emissions Alone Could Push Global Warming*

Above 2°C. Nature Climate Change 8 (11): 931-933.

Moser, Susanne C., Julia A. Ekstrom, Julia Kim, and Samantha Heitsch. 2019. *Adaptation Finance Archetypes: Local Governments' Persistent Challenges of Funding Adaptation to Climate Change and Ways to Overcome Them*. Ecology and Society 24 (2): 28.

Natarajan, Harish, Solvej Krause, and Helen Gradstein. 2017*. Distributed Ledger Technology (DLT) and Blockchain.* World Bank FinTech Note No. 1. Washington, DC: The World Bank.

Paech, Philipp. 2017. *The Governance of Blockchain Financial* Networks. The Modern Law Review 80 (6): 1073-1110.

Pauw, Pieter, Richard Klein, Pier Vellinga, and Frank Biermann. 2016. *Private Finance for Adaptation: Do Private Realities Meet Public Ambitions?* Climatic Change 134 (4): 489-503.

Paz Neves, Leonarda, and Gabriel Aleixo Para. 2018. *Blockchain Contributions for the Climate Finance. Introducing a Debate.* Available online at: https://bit.ly/2FI6oaW, last accessed January 19, 2020.

Reijers, Wessel, Fiachra O'Brolcháin, and Paul Haynes. 2016. *Governance in Blockchain Technologies & Social Contract Theories.* Ledger 1: 134-151.

Reinsberg, Bernhard. 2019. *Blockchain Technology and the Governance of Foreign Aid*. Journal of Institutional Economics 15 (3): 413-429.

Retemal, Cristián, Iván Razo-Zapata, and Gustavo Arciniegas López. 2018. *Accounting for Climate Finance.* In *Navigating Blockchain and Climate Action: An Overview*, edited by Juerg Fuessler, 39-44. Zurich: Climate Ledger Initiative.

Reutemann, Tim. 2018. *Disintermediating the Green Climate Fund.* In *Transforming Climate Finance and Green Investment with Blockchains*, edited by Alastair Marke, 153-163. Cambridge, MA: Academic Press.

Roberts, J. Timmons, and Romain Weikmans. 2019. *The International Climate Finance Accounting Muddle: Is There Hope on the Horizon?* Climate and Development 11 (2): 97-111.

Salisbury, Neil, and Jenya Khvatsky. 2018. *Using Smart Algorithms, Machine Learning, and Blockchain Technology to Streamline and Accelerate Dealflow in Climate Finance.* In *Transforming Climate Finance and Green Investment with Blockchains*, edited by Alastair Marke, 179-188. Cambridge, MA: Academic Press.

Schalatek, Liane. 2014. *Post-Bali: It's Crunch Time!* Available online at: https://bit.ly/2KHO2uQ, last accessed January 19, 2020.

Schalatek, Liane, and Charlene Watson. 2019. *The Green Climate Fund.* Available online at: https://bit.ly/2REWNZo, last accessed January 19, 2020.

Skovgaard, Jakob. 2012. *Learning About Climate Change. Finance Ministries in International Climate Change Politics*. Global Environmental Politics 12 (4): 1-8.

United Nations. 2019a. *Report of the UN Secretary-General's High-level Panel on Digital Cooperation: The Age of Digital Interdependence*. New York: United Nations.

United Nations. 2019b. *UN Secretary-General's Task Force on Digital Financing of the Sustainable Development Goals.* Framework Document. New York: United Nations.

United Nations. 2019c. *UN Secretary-General's Task Force on Digital Financing of the Sustainable Development Goals.* Glossary of Terms. New York: United Nations.

United Nations. 2018. *UN Secretary-General's Strategy on New Technologies.* New York: United Nations.

UNEP. 2016. *The Adaptation Finance Gap Report.* Nairobi: United Nations Environment Programme.

UNFCCC. 2015. Paris Agreement: FCCC/CP/2015/L.9/Rev.1.

UNFCCC. 2011. *Governing Instrument for the Green Climate Fund.* Annex to Decision 3/CP.17 Presented in FCCC/CP/2011/9/Add.1.

UNFCCC. 2010. *Report of the Conference of the Parties on Its Fifteenth Session*, Held in Copenhagen from 7 to 19 December 2009. FCCC/CP/2009/11/Add.1.

van Asselt, Hasso, Romain Weikmans, J. Timmons Roberts, and Achala Abeysinghe 2016. *Transparency of Action and Support under the Paris Agreement.* Oxford: European Capacity Building Initiative.

WBGU. 2019. *Towards Our Common Digital Future: Summary.* Berlin: WBGU.

Werbach, Kevin. 2018. *The Blockchain and the New Architecture of Trust.* London and Cambridge, MA: MIT Press.

Zwitter, Andrej, and Mathilde Boisse-Despiaux. 2018. Blockchain for Humanitarian Action and Development Aid. *Journal of International Humanitarian Action* 3 (1): 16.

Zwitter, Andrej, and Joost Herman. 2018. *Blockchain for Sustainable Development Goals: #Blockchain4SDGs* - Report 2018. Leeuwarden: University of Groningen.

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20. Cadman, Tim. 2012. EVALUATING THE QUALITY OF GLOBAL GOVERNANCE: A THEORETICAL AND ANALYTICAL APPROACH.

21.Biermann, Frank. 2012. GREENING THE UNITED NATIONS CHARTER. WORLD POLITICS IN THE ANTHROPOCENE.

22. Mayer, Benoît. 2012. ENVIRONMENTAL MIGRATION IN ASIA AND THE PACIFIC. COULD WE HANG OUT SOMETIME?

23. Schaffrin, André. 2012. WHO PAYS FOR CLIMATE MITIGATION: AN EMPIRICAL INVESTIGATION ON THE SOCIAL IMPACT OF CLIMATE CHANGE.

24. Laguna-Celis, Jorge. 2012. IDEAS FOR A SUSTAINABLE DEVELOPMENT OUTLOOK.

25. Asselt, Harro van, and Fariborz Zelli. 2012. CONNECT THE DOTS MANAGING THE FRAGMENTATION OF GLOBAL CLIMATE GOVERNANCE

26. Biermann, Frank 2012. CURTAIN DOWN AND NOTHING SETTLED. GLOBAL SUSTAINABILITY GOVERNANCE AFTER THE "RIO+20" EARTH SUMMIT

27. Baber, Walter F., and Robert V. Bartlett, 2013. JURISTIC DEMOCRACY: A DELIBERATIVE COMMON LAW STRATEGY FOR EARTH SYSTEM GOVERNANCE.

28. Schmeier, Susanne, Andrea K. Gerlak and Sabine Schulze. 2013. WHO GOVERNS INTERNATIONALLY SHARED WATERCOURSES? CLEARING THE MUDDY WATERS OF INTERNATIONAL RIVER BASIN ORGANIZATIONS.

29. Mattor, Katherine, Michele Betsill, Ch'aska Huayhuaca, Heidi Huber-Stearns, Theresa Jedd, Faith Sternlieb, Patrick Bixler, Antony Cheng, and Matthew Luizza. 2013. TRANSDISCIPLINARY RESEARCH ON ENVIRONMENTAL GOVERNANCE: A VIEW FROM THE TRENCHES.

30. Kemp, Luke. 2014. REALPOLITIK AND REFORM AT RIO+20: THE POLITICS OF REFORMING THE UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP).

31. Kavya Michael and Vamsi Vakulabharanam. 2014. CLASS AND CLIMATE CHANGE IN POST-REFORM INDIA.

32. Adenle, Ademola A., Casey Stevens, and Peter Bridgewater. 2015. STAKEHOLDER VISIONS FOR BIODIVERSITY CONSERVATION IN DEVELOPING COUNTRIES: AN ANALYSIS OF INTERVIEW RESPONSES FROM COP11

33. Schulz, Karsten and Rapti Siriwardane. 2015. DEPOLITICISED AND TECHNOCRATIC? NORMATIVITY AND THE POLITICS OF TRANSFORMATIVE ADAPTATION.

34. Patterson, James, Karsten Schulz, Joost Vervoort, Carolina Adler, Margot Hurlbert, Sandra van der Hel, Andreas Schmidt, Aliyu Barau, Pedi Obani, Mahendra Sethi, Nina Hissen, Mark Tebboth, Karen Anderton, Susanne Börner, and Oscar Widerberg. 2015. 'TRANSFORMATIONS TOWARDS SUSTAINABILITY' EMERGING APPROACHES, CRITICAL REFLECTIONS, AND A RESEARCH AGENDA.

35. Skovgaard, Jakob, and Jacqueline Gallant. 2015. NATIONAL DELEGATIONS TO UNFCCC CONFERENCES OF THE PARTIES: WHO PARTICIPATES?

36. Blumstein, Sabine. 2016. MANAGING ADAPTATION: INTERNATIONAL DONORS' INFLUENCE ON INTERNATIONAL RIVER BASIN ORGANIZATIONS IN SOUTHERN AFRICA?

37. Rabitz, Florian. 2017. MANAGING GENETIC RESOURCES: INTERNATIONAL REGIMES, PROBLEM STRUCTURES, NATIONAL IMPLEMENTATION.

38. Biermann, F., Kalfagianni, A., 2018. PLANETARY JUSTICE. A RESEARCH FRAMEWORK.