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Exploring the governance and implementation of sustainable development initiatives through blockchain technology

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ABSTRACT

Societies at large still grapple to categorize digital space as a phenomenon. At the same time, scientists and developers are searching for innovative methods to better understand how the fundamental shifts caused by digital change will affect the future of humanity over the coming decades. Interdisciplinary governance research at the intersection of technological and environmental foresight is urgently needed to minimize the risks of technological change and explore how digitalization may support, hinder or re-shape sustainability transformations. In this article, we focus on the case of 'blockchain' or distributed-ledger technology (DLT) to investigate how recent digital technologies may support the implementation of sustainable development initiatives. Our investigation is centered on areas of public administration and governance which will most likely see an adoption of DLT over the next two decades, such as digital identity, social service provision, and innovative climate finance. To allow for a meaningful comparison of various use cases, we propose four guiding questions that can help researchers, decision-makers and practitioners to determine whether DLT might be an appropriate choice for the sustainability-related task at hand. Moreover, we illustrate how the initial design and subsequent implementation of DLTs may support more centralized or networked modes of governance.

1. Introduction

As humanity transitions to the 'digital age', we observe an increased convergence between the physical and the virtual domain. Global digitalization promises vast possibilities, while potentially creating new risks and uncertainties. Instant connectivity, omnipresent sensors, digital devices, as well as the explosive growth of personal and non-personal data raise important societal questions. How will this 'brave new world' look like? How are digital innovations affecting possible futures in complex "socio-technical-ecological systems (STES)" (Ahlborg et al., 2019)? Society at large still grapples to categorize digital space as a phenomenon, while scientists and developers are searching for innovative methods to better understand how the fundamental shifts that are brought about by digital change will affect the future of humanity over the coming decades (O'Hara & Hall, 2018).

In a recent study of futures scholarship from 1968 to present, Fergnani (2019) argues that systematic inquiries into digital change and technological futures are still relatively scarce in the field of futures studies. At the same time, there is an urgent need to further integrate interdisciplinary research on digitalization and sustainability to fill existing research gaps and investigate how digital change may support, hinder or re-shape sustainability transformations (United Nations, 2018; WBGU, 2019). Governance and foresight will be necessary to minimize the negative impacts of technological change and explore how new technologies can be utilized to address global sustainability challenges. However, the voluminous literature on the 'social constitution of technology' has

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so far only given scant attention to legal, regulatory and design choices that *precede* the introduction of novel technologies into complex systems and potentially limit the ideational space for an 'imaginary politics' of technological futures (Milkoreit, 2017; Reijers & Coeckelbergh, 2018). Emerging technologies are not simply contested tools or objects of governance but also catalysts that are influencing futuring practices to a considerable degree. Foresight, anticipation and decision-making processes are already dependent on big data analytics and are expected to become increasingly autonomous over the next few decades based on the ability of cyber-physical systems to adjust to complex situations without significant human intervention (Wagner, 2019; Zeng et al., 2019). Today's technology-related governance and design choices clearly have the potential to either broaden or narrow the scope of environmental foresight and anticipation, for example by creating path dependencies for technology implementation, or by limiting technology use and access through bias inherent to the algorithms that enable automated decision-making. Accordingly, some scholars have emphasized the need of linking foresight practices more closely to research on 'anticipatory governance' in order to investigate how potential futures and their related imaginaries are shaped by processes of anticipation and governance (Granjou et al., 2017; Vervoort & Gupta, 2018).

In view of these urgent research gaps, we argue that interdisciplinary governance research at the intersection of technological and environmental foresight is central to progress towards sustainability. In particular, we aim to provide an exploratory assessment of how blockchain technology may support, hinder and/or re-shape sustainability transformations in selected areas of sustainable development. For the overall purpose of this paper, 'blockchain' simply refers to different types of *distributed-ledger technology* (DLT, see below for a detailed definition).[1] Our inquiry is based on the premise that the anticipatory governance of emerging technologies such as DLT requires a profound understanding of the governance choices that are inherent to the basic architecture of the technology in question (De Filippi & Wright, 2018). Existing governance regimes currently face the choice to explicitly or implicitly engage with the implementation of novel technologies such as DLT and upgrade their structures, or risk being replaced ('disrupted') for better or worse, with potentially negative impacts on sustainability.

As the case studies presented in this paper illustrate, a lack of consideration and detailed planning before the implementation of technological systems can lead to considerable societal tensions and conflicts. Thus, in line with the existing blockchain research framework proposed by Risius and Spohrer (2017), we suggest that research on the governance links between technological and environmental foresight requires continuous adaptation to the inherent dynamism of complex STES. As long as DLT innovation continues apace, it will be critical for governance and foresight scholars to adopt an interdisciplinary perspective on the role of DLT in complex systems and focus on the development of relatively stable criteria for the analysis of technological change. Accordingly, our analytical approach in this paper is twofold: on the one hand, we propose four guiding questions that can help researchers, decision-makers and practitioners to determine whether DLT might be an appropriate choice for the sustainability-related task at hand. On the other hand, we suggest that anticipatory governance research can substantially contribute to effective risk management by developing unambiguous and precise ethics guidelines, normative regulation based on human rights, and common monitoring and evaluation frameworks in order to ensure that DLT implementation and design choices become a supporting factor in the collective endeavor to address global sustainability challenges and achieve the Sustainable Development Goals (SDGs).

2. Governing the implementation of sustainable development initiatives through distributed-ledger technologies

There is now increased interest among scientists, development practitioners, business leaders and policy-makers in the use of emerging technologies to confront societal challenges and achieve sustainability goals such as the SDGs. Besides big data and artificial intelligence-driven technologies, so-called 'blockchain' based solutions are said to promise a host of potential solutions. New actor coalitions and networks with a distinct focus on blockchain innovations are emerging in the private sector, in academia and under the umbrella of the United Nations (UN). Examples include innovative 'FinTech' networks such as the European Union Blockchain Observatory and Forum, research hubs at the Stanford Center for Blockchain Research, the Massachusetts Institute of Technology and the Oxford Internet Institute, as well as the UN 'Climate Chain Coalition' (CCC) with more than two hundred members. At the same time, serious concerns have been raised about the promotion of blockchain as an inherently scalable solution to pressing societal issues, especially due to problems with data privacy and the estimated environmental impacts of broad-based digitization processes which include the expansion of digital infrastructures. In view of these problems, some scholars have argued that the governance of the digital deserves as much public and scientific attention as technical questions, and that blockchain technology should not be seen as a 'silver bullet' to address deep-seated societal problems such as the growing lack of trust in democratic processes or public policy (Floridi, 2018). In other words, a more critical investigation regarding the possibilities and limitations of blockchain applications to support progress on sustainable development is warranted, especially since emerging

[1] "Distributed-ledger technology refers to a novel and fast-evolving approach to recording and sharing data across multiple data stores (or ledgers). This technology allows for transactions and data to be recorded, shared, and synchronized across a distributed network of different network participants. […] A 'blockchain' is a particular type of data structure used in some distributed ledgers which stores and transmits data in packages called 'blocks' that are connected to each other in a digital 'chain'. Blockchains employ cryptographic and algorithmic methods to record and synchronize data across a network in an immutable manner" (Natarajan et al., 2017, p. iv). Since the term blockchain is often used indiscriminately, we differentiate the underlying DLT along two main lines of (1) public or private read access, as well as (2) permissioned or permissionless write access, resulting in at least four distinct infrastructures with different implications across legal, political, commercial and technical domains. However, this distinction still remains an oversimplification of 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 achieve similar ends (Blockchain Bundesverband, 2018).

technologies are embedded in complex STES and governance structures. For the purpose of this analysis, we conceptualize governance processes in line with three interrelated 'modes' of governance (Hazenberg & Zwitter, 2017):

1) *Mode 1 governance:* traditional command and control structures, mostly embedded in the state.
2) *Mode 2 governance:* horizontal forms of governance that include private actors and can be distinguished into (a) public-private governance, (b) non-autonomous self-governance, and (c) autonomous self-governance.
3) *Mode 3 governance:* the interplay between governance structures outside and governance processes within existing network structures, characterized by changing and diverse roles of actors, and the necessity to identify new roles or adapt existing roles depending on the inherent dynamism of network clusters and policy domains.

Networked governance (mode-3 governance) is deemed particularly useful for our discussion of DLT in the context of anticipation and foresight. Networked governance assumes that within networks, a decentralized form of decision making takes place that relies on the formation of clusters of actors within the network that wield decision-making power. Within a blockchain network, such a decentralized decision-making framework is usually referred to as Decentralized Autonomous Organization (DAO).[2] Since decision making and regulation are ideally based on both, presently available information and predictions about potential developments, it is evident that futuring methods and foresight can add tremendous value to DLTs. However, a recent report on the potential use of blockchain technology to foster sustainability states that "inflated expectations around the potential of this technology often lead to misconceptions of what actually defines its essence. Clearer definitions are therefore needed in order to guide a dialogue around its potential value and applications" (Zwitter & Herman, 2018, p. 26).

3. DLT case studies

Considering the need to better understand how distributed-ledger based systems may contribute to the governance and implementation of sustainable development initiatives, we focus our investigation on areas of public administration that will most likely see an adoption of these new technologies over the next decades, such as digital identity, social service provision and innovative climate finance. It is expected that adopting DLTs in those areas will have the most far-reaching implications for the implementation of sustainability initiatives such as the SDGs. Based on empirical evidence from India and the Netherlands, we first explore the impact of governance through DLT on individual and collective privacy. In addition, we take the so-called UN 'Climate Chain Coalition' (CCC) as an example to determine under which conditions DLTs may be applied to support climate action, enhance monitoring and reporting, and support the mobilization of green finance.[3]

The three cases were selected based on their relevance for sustainable development, while each case represents a different stage of technology implementation. The Indian case has been chosen as an example for a nationwide roll-out of DLT, the Dutch case represents a local DLT pilot study, whereas the CCC case investigates an international DLT initiative that is still in its early stages. Accordingly, this article can only be exploratory in nature, aiming to highlight and summarize insights that can be gleaned from investigating ongoing national and international initiatives at the intersection of sustainability and DLT implementation.

To allow for a meaningful comparison of the selected case studies, we base our subsequent analysis on four guiding questions that have been developed by Zwitter and Boisse-Despiaux (2018) to determine if DLT might be an appropriate solution for the problem at hand. Those questions, in a slightly modified form, are the following:

1 Do the benefits of implementation outweigh the development and scaling costs of a new technology?
2 Is decentralization through distribution and built-in trust through transparency a necessary feature of the new technology?
3 Does the digital ledger, as a core of the new technology, need to be immutable?
4 Do the features of the new technology comply with legal norms, ethical principles and professional codes of conduct?

As Zwitter and Boisse-Despiaux (2018, p. 6) remark: "If the answer to any of the above questions is a NO, then Blockchain is maybe not the right technological solution […] or the solution might be unfeasible."

3.1. Case study 1: Aadhaar, India

According to the 2018 World Economic Outlook of the International Monetary Fund, the economy of India is forecasted to outpace the Chinese economy in the coming years (International Monetary Fund, 2018). Despite these positive predictions, and as for many other developing countries, the implementation and setup of a comprehensive and effective identification system continues to be a complex challenge with many intersecting problems. The Indian government started multiple national identity projects before the turn of the millennium, which all saw limited success up to 2008 (GSMA, 2017). Considering the four most popular mechanisms

[2] "Blockchains provide a platform on which to deploy and manage autonomous systems that rely on software algorithms to control access to assets and resources. On a continuum, decentralized autonomous organizations represent the most advanced state of automation, where a blockchain-based organization is run not by humans or group consensus but entirely by smart contracts, algorithms, and deterministic code" (De Filippi & Wright, 2018, p. 146).

[3] For further information on the UN Climate Chain Coalition (CCC), see: https://www.climatechaincoalition.io/. Accessed on 11 April 2020.

for identification, an estimated 40 million Indians had passports, 70 million were registered with Permanent Account Numbers (PAN) from the Income Tax Department, 220 million were registered using a 'Ration Card' which is issued by states governments to allow for the purchase of essential commodities such as wheat, and 500 million citizens possessed a voter ID issued by the Electoral Commission, which resulted in a list that was estimated to be 90–95 percent accurate (GSMA, 2017). In 2006, the Indian government started to conceive a plan for unique identification to address the distribution of public subsidies and prevent fraud, which then lead to the creation of the so-called Unique Identification Authority (UIDAI) in 2008 (Zelazny, 2012). This authority was tasked with the mission to develop and implement the necessary infrastructure in order to issue unique identity numbers to all residents of India, which should be verified securely, online, and in a cost-effective manner (Zelazny, 2012). This program was quickly regarded as one of the main references in the field with many positive aspects for other countries facing similar challenges (Gelb & Clark, 2012). It is arguably the most prominent example of a centralized top-down approach for the implementation of a digital identity worldwide. In March 2018, it was estimated that 89.2 percent of the Indian population, or 1.17 billion people were enrolled in the system (Times of India, 2018). Frequent updates on these numbers are regularly published by the UIDAI (2019).

A Unique Identity (UID) is essentially a string of twelve numbers which are issued after registration of the individuals' name, date of birth, gender, the names and UID numbers of the father/husband/guardian (optional for adult residents), the names and UID numbers of the mother/wife/guardian (optional for adult residents), the name of the introducer and UID number (in case of lack of documents), address, fingerprints, photographs and two iris scans. The system qualifies as a digital identity system and raises fundamental questions about privacy and information security that need to be addressed if DLT is to be used for achieving the SDGs, especially SDGs number 1, 2, 3 and 16 (Greenleaf, 2018). The extensive use of biometrics for identification purposes is certainly very attractive, since they are naturally unique and permanent identifiers. While humans can stop to use devices such as smartphones, wearables, or computers, relevant physiological features such as fingerprints typically remain with an individual for a lifetime, and their characteristics are virtually unchangeable. In the context of DLT systems, the use of biometrics for identification purposes is highly relevant, since biometric identification can become a fallback option if users lose their 'private keys' to access their virtual storage or 'digital wallet' (De Filippi & Wright, 2018).

Yet, precisely their natural and persistent characteristics can be highly problematic. Not only is the centralized use and storage of biometric data for individual identification completely new at this scale (Unique Identification Authority of India, 2010), experts such as Usha Ramanathan also challenge the setup of the system based on problems with the accuracy and reliability of the biometric data, the mandatory nature of the system which creates challenges for weak and sick people living in rural areas, as well as dangers for members of the transgender community (Dixon, 2017). Additionally, the underpinning 2016 Aadhaar legislation lacks appropriate provisions specifying purpose limitation for the creation, analysis and use of highly sensitive personal data, internal and external mechanisms for checks and balances, as well as sufficient measures to increase security for this centralized treasure trove containing sensitive personal data of more than one billion people (The Aadhaar Bill, 2016). The lack of detailed safeguards and institutional measures to mitigate risks created by the implementation of the new system suggest that the quick and widespread implementation of the UID happened without appropriate planning and consultation.

Public criticism ultimately led to more awareness regarding the risks associated with a new digital identity, and also to trials in front of the Indian Supreme Court. At the same time, a legal battle was fought over the question of whether privacy is a fundamental right in the Indian Constitution, which was confirmed by the Supreme Court on 24 August 2017.[4] The Court also scrutinized the Aadhaar legislation and delivered its long awaited judgment on 26 September 2018.[5] The 1448-page ruling still upholds the UID system, but defines clear limitations and additional safeguards for the use and reuse of collected data. The use of the UID is no longer mandatory for opening bank accounts, buying mobile phone SIM cards, school admissions, or for appearance in boards or common entrance examinations (Mahapatra, 2018). Nevertheless, it remains to be seen how the Indian administration will respond to the judgment in detail. The current Supreme Court ruling is certainly not the final decision about the implementation of digital identities in India, but it serves as a good example that any upgrade in technology also requires an upgrade of public governance structures, legal provisions, political imaginaries, and societal preparedness in general.

Apart from these concerns about individual privacy, the discourse on group privacy also needs be considered. Although the concept of group privacy is still multidimensional and reaching beyond the legal domain (Taylor et al., 2017), it is important to consider how the deployment of novel technologies in complex STES, such as in this case, may impact opportunities for the development of specific groups. Put differently, if methods to monitor a group change, the behavior of that group changes accordingly (Galič et al., 2017). It needs to be carefully considered how such fundamental changes in society enable the control of society (also indirectly through 'nudging'), while the group is hardly aware of the process, or not aware at all (Taylor et al., 2017). These issues and related decisions should be studied in detail and be subject to a transparent and public discussion process – particularly in democratic societies – before new systems are deployed on a larger scale.

3.2. Case study 2: Forus.io / 'Kindpakket' Project Zuidhorn, The Netherlands

It is evident that India and the Netherlands differ considerably with regard to their governance and public administration systems. In comparison to India, the Dutch public administration currently works with relatively efficient and comprehensive systems to provide proof of identity. The country even stopped carrying out a traditional census since 1971 and uses other sources such as

[4] See: Indian Supreme Court (2017), *Justice K.S. Puttaswamy (Retd) vs Union of India*, Writ Petition (Civil) W.P.(C) No. 000372/2017.

[5] See: Indian Supreme Court (2017), *Justice K.S. Puttaswamy (Retd) vs Union of India*, Writ Petition (Civil) W.P.(C) No. 000494-000494/2012.

registration with municipalities to create its national statistics (Nordholt, 2015). Approximately 15.6 billion Euros are spent annually on implementation costs for grants and subsidies, of which 1.4 billion Euros are spent by municipalities alone (Velthuijs, 2018). Considering these numbers, and despite the fundamental differences in comparison to the Indian case, the desire to make public administration more efficient unites so-called developing and developed countries. One possible way to achieve such efficiency gains is to design, develop and implement administration processes based on DLT (e.g., Blockchain, Ethereum, etc.), combined with the concept of a "self-sovereign identity" (Blockchain Bundesverband, 2018).

In the Netherlands, considerable national and international attention has been directed toward one particular case study, despite the fact that several community-based studies on the use of DLT are currently conducted in the country (Frederik, 2018). From 1 September 2017 until 31 March 2018 a pilot program to deliver child-welfare ('kindpakket') was carried out in the community of Zuidhorn in the north of the Netherlands (Velthuijs, 2018). This pilot project was conceptualized, implemented and assessed by a consortium consisting of the foundation 'Forus' which came up with the initial idea and took care of technical aspects,[6] the municipality of Zuidhorn, and the consulting agency 'Berenschot'. This bottom-up community-based pilot aimed at exploring whether DLT could be (a) operated in compliance with existing legal preconditions, (b) improve transparency, and (c) increase usability (Velthuijs, 2018). The end-result of the project was a (re-)usable open-source based platform which allows for the exchange between governments, citizens and suppliers.[7] While DLT and particularly Ethereum were used in this project, certain aspects of the interactions still had to be facilitated by governments and other central institutions. Hence, a pragmatic decision was taken to use 'traditional' databases whenever needed to test the systems in a real-world scenario. Nevertheless, the outcomes and general findings of the pilot study suggest that it is possible to continue along the envisioned implementation path as more and more large-scale projects are currently being developed in cooperation with Dutch communities. Similar community-based pilot projects are also implemented in Austria (Danube Tech), Belgium (Antwerp; Blockchain on the Move), Canada (British Columbia; TheOrgBook), Spain (Alastria), Switzerland (City of Zug; UPort and ti&m), and the United States of America (Illinois Blockchain initiative) (Blockchain Bundesverband, 2018).

All of these projects, including the Zuidhorn project, are based on the concept of a 'self-sovereign identity', which is in turn based on libertarian political imaginaries of a free, equal and capable individual. Ideally, such an identity enables individuals to be responsible for all aspects of their own identity, but without the need for an intermediary or central authority such as a national or state government to administer it. In addition, it is suggested that a 'self-sovereign identity' should be based on ten core elements: (1) existence, (2) control, (3) access, (4) transparency, (5) persistence, (6) portability, (7) consent, (8) interoperability, (9) minimization, and (10) protection (Blockchain Bundesverband, 2018). The exact details of these key elements are still being explored, as DLTs are constantly evolving. It is to be expected, however, that a tightly integrated, continuous and transferable personal data system enables people to maintain privacy and exercise control over their own identity and data. The transfer of 'raw' data is reduced considerably under the self-sovereignty model since no forms need to be filled out and there is no need to create multiple user accounts for multiple purposes. Additionally, by using 'zero-knowledge proof' mechanisms the only exchange of data concerns the credentials of a specific identity (i.e., answering specific 'yes/no' questions). This means that personal data will remain with the individual and only get verified by trusted intermediaries or the state whenever necessary, for example if a credential expires. At present, individuals typically depend on the government or large corporations such as Google or Facebook, who manage virtual identities for billions of people and keep their accounts.

Once a self-sovereign identity is set up, it may be used to apply for government funding such as child-welfare in the case of Zuidhorn (Fig. 1). The government can then determine certain criteria for individuals to become eligible. For example, child-welfare should only be available to individuals who are caretakers of children up to a certain age, live in a certain area (e.g., 'Zuidhorn'), do not have an annual income which is higher than a certain sum, etc. Generally, funding is made available via a digital platform where individuals who are administering their own identity can simply sign-up and then receive the benefits. In practice, the identity is stored in an application on a device such as a smartphone. The application is similar to Apples 'Wallet' application on iOS devices with extended features to control identity credentials, and a mechanism to enable the 'zero-knowledge proof' process.

If the registration process is successful, the beneficiary will either receive traditional currency or tokens which are similar to cryptocurrency. The benefit and, simultaneously, the challenge of a token system for social welfare is that possible use cases can be restricted (in the Zuidhorn case to what is deemed appropriate for a child such as entrance to a public swimming pool, music lessons, sport activities, book vouchers, etc.). Public authorities can then monitor in real time which services are popular with beneficiaries, and which are not.[8]

Although the Zuidhorn project was considered a success, the implementation process also highlights several challenges. When opting for the use of tokens instead of traditional currency, the token system must be managed as well. Municipalities will frequently not be able to provide all services or goods themselves. Hence, it is required to make sure that tokens can be converted into traditional currency which requires a connection to the banking system. Furthermore, while tokens make it easier to monitor and safeguard appropriate use as outlined, concerns relating to group privacy might arise, as we have already discussed in our first case study on digital identity.

Apart from these potentially contentious issues, contextual factors should be considered as well. First, organizations who are trying to adopt new technologies would be well advised to also re-evaluate existing governance processes together with relevant laws,

[6] More information is available via: https://foundation.forus.io/en/. Accessed on 11 April 2020.

[7] The code is available via: https://github.com/teamforus. Accessed on 11 April 2020.

[8] Based on a personal exchange with Forus.io members and a video conference held on 19 October 2018.

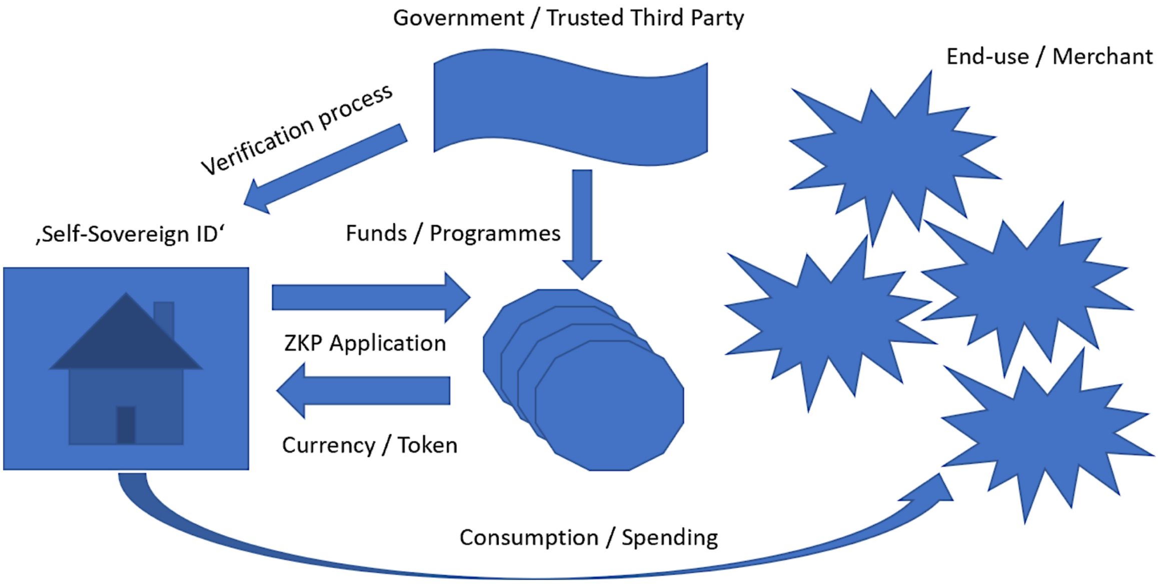

Fig. 1. Simplified Illustration of the Forus.io / Community-based Digital Identity model; ID = Identity; ZKP = Zero Knowledge Proof – not based on exchange of credentials or 'raw data', only whether results match or not; Token = coin or trade token.

policies, and procedures. Second, it might be necessary to reconsider how competences in an organization are distributed. Despite the possibility to automate certain administrative processes, technology as such cannot replace governance or politics proper. Municipalities will only reap the benefits of DLT implementation if governance structures are designed to include them, and if careful and detailed planning of the procedures takes place before the program is being rolled out. In the Netherlands, where the Zuidhorn pilot project was rolled out, a sound infrastructure was already in place and broadband/high-speed internet services were readily accessible for most communities. Thus, considering the existing 'digital divide' between developed and developing countries, adequate infrastructure is likely to be a major obstacle for local implementation. Nevertheless, the gap between developed and developing countries might not be quite as big when it comes to the availability of smart devices or smartphones.

Thus, local authorities such as municipalities have to consider which kind of technology is available to which parts of the population before decisions about implementation pathways are taken. Potentially, implementation may only be possible after investments in basic (digital) infrastructure have been made. Finally, it can be concluded that the implementation of these new technologies requires education and trust. Local system administrators are required to at least monitor the proper operation of the system and there must be mechanisms in place that back up existing users in case devices are lost or break down. There also have to be programs to educate citizens on how to use this technology, and for what purposes. Ideally, this should include thorough and inclusive public debates about political factors and the potential risks of using such a technology, for example unethical social engineering, cyber-attacks, or mass surveillance.

3.3. *Case study 3: the Climate Chain Coalition (CCC)*

During the 'One Planet Summit' on December 12, 2017 in Paris, France, a multi-stakeholder group of twelve organizations working on distributed-ledger technology held a meeting to agree to collaborate and establish an open global initiative called the Climate Chain Coalition (CCC). As of January 2020, over two hundred organizations have joined the CCC to help mobilize climate finance and enhance MRV (measurement, reporting and verification) to scale climate actions for mitigation and adaptation.[9] Member organizations also agreed on a CCC charter which outlines shared principles and values to guide the activities of the coalition. Among the core principles outlined in the charter are: (1) a strong commitment to achieve the long-term goals of the Paris Agreement, (2) a strong commitment to develop DLT innovations for climate change which simultaneously contribute to the achievement of the SDGs, (3) a strong commitment to develop DLT in the interest of cost-effectiveness, integrity, transparency, and empowering stakeholders in socio-economic systems, (4) the use of DLT to mobilize climate finance from diversified sources, and (5) a proactive strategy to identify and seek to mitigate fraudulent activities associated with the application of DLT in climate and sustainability governance.[10] These ambitious goals are certainly aligned with core ethics principles that have been actively promoted by scholars and practitioners in the fields of sustainable development and digital innovation. They also remain relatively vague, for example with regard to the empowerment of 'stakeholders in socio-economic systems.' It still remains to be seen how the application of DLT will affect social cohesion and the targeted use of climate finance to reduce inequality, improve adaptive capacities and benefit the most vulnerable

[9] Climate Chain Coalition (CCC) Webpage. https://www.climatechaincoalition.io/. Accessed on 11 April 2020.
[10] Climate Chain Coalition (CCC) Webpage: Charter. https://www.climatechaincoalition.io/charter. Accessed on 11 April 2020.

'communities' – a term that may conceal the fact that 'communities' are often characterized by strong power asymmetries, and may be less communal than commonly assumed (Schulz & Siriwardane, 2015). Existing imbalances might, therefore, be further exacerbated if the use of advanced, cutting-edge technologies is not governed by strong ethical principles.

Moreover, while actors in the field of climate research and governance are constantly working on better technological tools and models to predict the scale and impact of climate-related risks, no innovative technology is currently applied on a larger scale to improve climate budgeting and finance. Not only are there limited resources available to cope with the eminent socio-ecological, economic and health crises but, more importantly, the conventional logic of budgeting is still dominant in financing sustainable development and climate actions. Yet, innovative forms of climate finance and budgeting are urgently needed for mitigation, since large-scale investments are necessary to significantly reduce emissions (Schulz & Feist, 2020). With regard to adaptation and disaster risk reduction, budgeting is often aimed at addressing long-term crises or designed as a one-time response after a particular disaster has taken place. In practice, too many resources are spent to deal with the aftermath of disasters instead of investing in prevention measures, and the use of available resources is often neither effective nor efficient. Arguably, available resources could be used more effectively and efficiently if they are allocated based on solid and reliable data-based forecasting and are used to promote integrated as well as locally targeted disaster risk reduction, climate adaptation and resilience-building activities that are specifically focused on the needs of the most vulnerable populations.

Forecast-based financing (FBF) is now considered a cutting-edge tool of policy making that dynamically allocates resources where they are needed the most. Innovative FBF aims to avoid overlaps and gaps in the financing instruments of international development cooperation and could lead to new forms of climate finance and governance, especially in combination with solid forecasting tools and the issuance of funds via blockchain-enabled "smart contracts"[11] that are triggered by evidence-based indicators (Schulz & Feist, 2020). To date, several members of the CCC are actively involved in developing such innovative financing instruments based on DLT.

Lastly, there is another important dimension that needs to be taken into account when discussing the potential of DLT to support and enhance climate action, namely the dimension of sustainability and energy use, which has received considerable attention from both scientists (including those who are involved with the CCC) and the news media alike (Mora et al., 2018). As recent studies have shown, the aspect of energy consumption for 'traditional' implementations such as Bitcoin raises significant doubts regarding the scalability and sustainability of the technology. 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 big problem for Bitcoin. However, as mentioned earlier, it is a widely held belief in the technical community that the current energy problem 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 systems might improve considerably once 'proof-of-stake' or 'proof-of-authority' mechanisms are introduced as an alternative (Xu, 2018). The CCC is currently working on this problem as part of their charter, which states:

> "As organizations concerned about environmental integrity generally and climate change specifically, we recognize some negative effects and current challenges of many DLT applications (in particular those using the blockchain with proof of work consensus) regarding their levels of energy consumption and GHG emissions. We are transparent and forthcoming while we actively seek appropriate solutions to address these challenges."[12]

4. Limitations and possibilities of distributed-ledger technologies

The implementation of DLT in support of sustainable development certainly raises concerns about the energy consumption of traditional implementations such as the cryptocurrency Bitcoin, which started in 2009 (De Filippi & Wright, 2018). However, considering the development of other technologies in the past which became more efficient over time, it would not be surprising to see that developments such as the adoption of innovative consensus mechanisms (e.g. 'proof-of-stake' instead of 'proof-of-work') will lead to considerable efficiency gains and, in turn, reduce energy consumption. Under such circumstances the technology itself would most likely still consume significant energy resources, although efficiency gains in public administration processes combined with the potential use of energy from sustainable sources might tilt the balance in favour of DLTs. Hence, it is still too early to come to a final conclusion on this matter, and it is certainly too early to stop technological innovation because of energy concerns in particular.

Furthermore, we have shown that it is very difficult – if not impossible – to implement large-scale DLT projects for digital identities under current political, legal and technological circumstances. Essentially, the underlying question is how much meaning digital identities can have for societies in general, and how privacy-sensitive technologies using biometrics can be linked to DLT systems in order to be able to guarantee that the identity of a person is both, protected and reliably determined. As demonstrated by the Indian case study, the use of biometrics raises significant concerns since public administration processes must be adapted to technological innovation to avoid the creation of new risks. Similarly, the outcome of this case study could also be interpreted as a reminder that more scholarly attention should be given to the question of how much political, legal, historical and socio-cultural context traditional identities such as citizenship actually contain (Kochenov, 2018). While some may already dream of "cloud

[11] Smart contracts are computer protocols that facilitate the execution of services and transactions. While the term smart contract has been used for quite some time, it gained new prominence with the ascend of blockchain technology. While smart contracts simply facilitate contractual agreements automatically, blockchain technology allows to create contracts between parties that are universally verifiable, unique and tamper-proof (Szabo, 1997).

[12] Climate Chain Coalition (CCC) Webpage: Charter. https://www.climatechaincoalition.io/charter. Accessed on 11 April 2020.

communities" with truly sovereign individuals, we may still have a long way to go in order to reach this lofty goal (Orgad, 2018).

Thus, as we have illustrated in our analysis, today's DLT systems work particularly well in environments with clearly defined objectives and carefully planned processes. The case of Zuidhorn in the Netherlands shows, for example, that success and concrete outcomes are achievable if the focus of a project rests on concrete solutions for clearly defined problems, and if pragmatic implementation choices are taken along the way. Yet, the crucial question is how such a 'community-based' or bottom-up approach based on 'mode-3′ governance might be put into practice in environments that are more challenging due to a general lack of security, malfunctioning governance mechanisms, strong power imbalances, or insufficient technical infrastructure.

With regard to the four-step test that has been introduced in Section 3 of the article, our selected cases rank quite differently . First, our analysis of costs and benefits illustrates that both, Forus.io (case study 2) and the Climate Chain Coalition (case study 3) use DLTs in a way that implies considerable limitations for scalability due to increasing costs after scaling. It has to be pointed out that scaling costs remain a limiting factor for DLT-based solutions in general, especially for bottom-up initiatives with a large number of relevant stakeholders. However, depending on the specific DLT solution (Ethereum, Hyperledger Indy, Tangle, etc.) there are significant differences in costs. In the case of the Climate Chain Coalition, in particular, costs would have to be measured against funding streams that would have otherwise gone into disaster recovery and rebuilding efforts, or funds that might have been used inefficiently due to corruption and mismanagement. Yet, as the overall number of stakeholders is limited in the case of the CCC (e.g., international funding and donor organizations as well as tech companies as implementing partners), scaling costs might still be manageable. In comparison, India's UIDAI case shows quite interesting results. Being a centrally managed system, the scaling itself seems to be no major issue as 89 percent of India's population are now covered.

Second, the Indian case also points to other shortcomings of DLT since our findings show that trust and transparency are insufficiently addressed within the existing digital identity system. In cases where trust in governance and public institutions is low, a decentralized solution might be the preferable option. The Forus.io approach, for example, may remedy such issues through decentralized self-sovereign identity management based on tools such as zero-knowledge proofs and by using the ledger as a registry of data locations and data availability rather than a data repository itself. The CCC approach, by comparison, may in fact require decentralization in order to link different actors of similar legal and/or contractual status to funding and government institutions. Decentralization might then be necessary to establish a broader stakeholder alliance with a joint framework for logistics and the use of smart contracts.

Third, the question whether immutability is a key strength, or a weakness still remains unanswered as sensitive personal data is at risk in all three cases. The great advantage of immutability is that transparency upon investigation is ensured. The downside of immutability is that falsely entered data remains in the ledger, which means providing a method of redress for incorrect information is challenging. This is quite problematic with regard to identity-related data since the burden of proof clearly shifts to the identity owner and away from the host of the system. Particularly in the first case study, the question of immutability would have to be solved by establishing effective redress mechanisms for individuals. In the second case, it remains unclear whether immutability is strictly necessary. The third case shows that immutability can de facto mean that mistakes in the transfer of funds cannot be addressed immediately and need to be addressed ex-post. However, if such mistakes trigger action based on trust in the information provided, rolling back mistakes might be quite difficult vis-à-vis slow administrative procedures. The great advantage of immutability in all three cases remains that ledgers become tamper-proof, and that all changes can be traced. In short, transparency is thereby safeguarded.

Lastly, norm compliance works quite differently in all three cases since they touch upon various legal spheres. This variability of legal frameworks makes it quite hard to compare cases. What has become evident is that all cases illustrate the importance of good governance within a community to implement DLT-based bottom-up solutions. However, in cases where good governance has not been achieved, decentralization and immutability might indeed offer tangible solutions to address corruption and other governance-related problems.

Overall, it has become evident that immutability and redress remain complex aspects which are inextricably entwined. Especially with regard to the question of human rights and high standards for fair trials, one needs to be aware that immutability may have the undesired consequence of shifting the burden of proof more firmly towards the individual. This effect can make it very difficult to redress mistakes as well as faulty administrative or legal procedures. As discussed earlier, questions revolving around privacy rank high on the list of potential problems which remain to be solved. Unfortunately, considering that there is no detailed and universal legal framework, only references to Article 12 of the 1948 Universal Declaration of Human Rights and to Article 17 of the 1966 International Covenant on Civil Political Rights are possible. General Comment 16 of the Human Rights Council on Article 17 from 1988 adds little to this abstract guidance, since it is focusing on governmental surveillance using traditional 20th century means such as the interception of landline telephone calls for security purposes (HRC - UN Human Rights Committee, 1988). Nevertheless, it should be added that 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).

Furthermore, immutability and redress might result in very concrete challenges for the right to a fair trial. The 2018 decision of the United States Supreme Court on the public or private nature of historical cell phone location records shows that the discussion about the interpretation and allocation of data created in the digital sphere is far from clear.[13] In this case, Timothy Carter, who was accused of having assisted in multiple armed robberies was considered guilty in lower instances because telecommunication

[13] US Supreme Court, Timothy Ivory Carpenter v. United States of America v. United States, No. 16-402, 585 U.S.

Table 1
Four-step test for DLT-based sustainable development initiatives.

Guiding Question	Case Study 1: Aadhaar, India	Case Study 2: Forus.io The Netherlands	Case Study 3: Climate Chain Coalition
1. Do the benefits of implementation outweigh development and scaling costs?	Centrally managed system, scaling is unproblematic	Pilot study indicates that scaling costs will be a limiting factor	Costs need to be measured against otherwise mismanaged funds
2. Is decentralization through distribution and built-in trust through transparency a necessary feature?	Transparency and trust insufficiently addressed by existing governance arrangements	Pilot study shows the potential of bottom-up processes based on decentralized and self-sovereign identity management	Decentralization and transparency may be necessary to establish a standardized framework for integrated logistics and the use of smart contracts
3. Does the digital ledger, as a core feature of the new technology, need to be immutable?	Immutability shifts burden of proof to the individual; lack of redress mechanisms	Whether immutability is strictly necessary remains unclear; creates tamper-proof system	Immutability advantageous provided that effective and inclusive redress mechanisms are in place
4. Do the features of the new technology comply with legal norms, ethical principles and professional codes of conduct?	• Each case touches upon different legal spheres, which shows the importance of appropriate governance arrangements to implement bottom-up DLT solutions • Immutability and redress remain critical questions, especially with regard to human rights standards and fair trials		

operators had shared data with law enforcement that showed his mobile phone logging in to equipment needed to run their services close to the respective areas of the robberies at specific times. In a highly controversial decision with the slightest possible margin for a majority (5:4), the Supreme Court concluded that use of such data in this case infringed against Mr. Carter's right to privacy and therefore deprived him of having a fair trial. Previously, the United States government had argued that the use of such data was justified since the records were in the public domain. From a legal and anticipatory governance perspective, this case highlights the unresolved difficulties in separating the private and the public sphere when digital technologies such as DLT become the dominating infrastructure for the delivery of services.

These intersecting questions also become immediately relevant in the context of Forecast-Based Financing (FBF). The case of the CCC has shown that FBF is expected to significantly enhance community preparedness and resilience for dealing with climate-related risks. However, national and local capacities must be the main focus of research and innovation to benefit vulnerable communities. The design and implementation of FBF should be inclusive and incorporate the views of multiple stakeholders. Cooperation between funding organizations and local actors such as decision-makers, scientists, communities and development organizations is pivotal in guaranteeing ownership and ensuring responsible leadership to increase the effectiveness and sustainability of innovative FBF (Table 1).

Finally, it has to be clearly stated that the advent of DLTs should not be understood in the sense of a new panacea or 'silver bullet' that will automatically render governance processes more effective and inclusive. Despite its undeniable potential, DLT has clear limitations if the local environments and social structures surrounding it are not carefully prepared for implementation. Nonetheless, if appropriate adjustments are made in terms of prioritizing the legal, ethical and political dimensions of digital governance, especially with regard to inclusiveness, accountability and fairness, it is very likely that DLTs will significantly improve the efficiency, legitimacy and positive impact of public service provision. In this context, we have discussed four guiding questions that can support decision-making and implementation choices in digital governance. At the same time, the results of our analysis also illustrate the inherent risks of an unreflective technological utopianism that may, in turn, lead to unrealistic assumptions about the 'disruptive' or 'transformative' potential of DLTs. The current situation could, therefore, be seen as a 'window of opportunity' to use DLTs for the targeted improvement of malfunctioning, socially imbalanced or ineffective public services, financing schemes, and infrastructural systems.

5. Conclusion

As the global hype around cryptocurrencies such as Bitcoin seems to weaken, it may be just the right time to focus on other use cases for DLT (Chavez-Dreyfuss, 2018). While some believe that DLT is a solution in search of a problem (Frederik, 2018), it might be too early to come to such a drastic conclusion. At present, DLT is still developing in a dynamic relationship with other global trends such as socioenvironmental change, while new use cases for the technology are constantly being explored all over the world.[14] As we have shown for the use cases presented, the technology as such clearly holds a lot of potential, also concerning collective attempts to achieve progress on sustainable development. In this sense, deploying DLT is not simply an end in itself, but also a means to reflect on and demand improvements in areas that are crucial for the implementation of sustainability initiatives such as the SDGs. In this article, we thus respond to recent calls for more in-depth and systematic inquiries into the governance of digital change and technological futures by introducing a set of criteria that can help guide inquiries on how digital change may support, hinder or re-shape sustainability transformations.

We argue that answers to the complex question of how DLT can help societies achieve progress on sustainable development will not only depend on technological innovation but also on the cultural imaginaries as well as the societal and normative frameworks

[14] See: https://blockchan.ge/curatedexamples.html. Accessed on 11 April 2020.

that actors create in the process. Our case studies indicate that DLT indeed marks a shift away from traditional mode 1 governance as well as contemporary mode 2 governance to a mode 3 governance characterized by a network structure of actors. These actors may take on different roles depending on the subject of governance. In the context of DLT-based solutions, actors can function as authenticators, as decision-makers (within the blockchain as DAO), and as individual agents pursuing their own goals. In other words, DLT solutions have to be analyzed not only from an engineering or technological perspective, but also with a view to the social implications that new technologies and their design may tacitly introduce. Therefore, while DLT certainly presents new opportunities for cross-border activities at regional and global scales, and for actors across the multi-stakeholder spectrum to shape the digital environment in line with more sustainable development pathways, the key question remains whether there is sufficient political will and capacity to do so? Will global leaders provide the groundwork for DLT systems to become deployable at scale? Will municipal, national and international institutions be willing and able to review their existing administrative procedures and competence structures? Will the developers of DLT systems cooperate with relevant stakeholder and policy networks to overcome the challenges related to the massive energy needs of digital change? How will problems related to technology access, inclusiveness and resource allocation be addressed, especially in developing countries?

None of the potential answers to these questions hinge solely on the general capabilities of DLT as such. Governance and risk management issues will remain central in the discussion about potential technological futures, while a naive form of technological utopianism may rather obscure the profound challenges of digital and environmental change. For example, without developing solid ethics and human rights principles for the design of a DLT system, its introduction may drastically reshape the relationship between the individual and society in favor of total, immutable transparency, thus benefiting efforts of centralized control. Certain technological features such as the immutability of decentralized ledgers might also be considered problematic from a human rights perspective since they may result in serious problems for the right to privacy and the right to a fair trial. As every technological solution will inevitably have non-technological side effects that need to be taken into account, we strongly suggest to further explore the multiple links between foresight and anticipatory governance to carefully monitor technological innovation, facilitate the development of ethical and normative guidelines, support responsible research and education, and encourage collaboration between relevant stakeholders before deploying DLT systems.

As we have demonstrated in our case studies, initial design choices may have crucial implications for the modes of regulation and governance that the respective DLT system enables. DLT systems may be designed in accordance with political imaginaries that range from libertarian notions of a free, equal and capable individual to more centralized, proprietary or commercial system models, depending on the actors involved in the process. Anticipatory governance can thus play a crucial role in shifting the focus of attention towards a more detailed analysis of the legal, regulatory and design choices that precede the introduction of DLT and may have limiting effects on the 'imaginary politics' of technological futures. Moreover, DLT will only be one part of a larger multi-system architecture, whose components must be understood in terms of their complex interactions. After all, it seems more important than ever to remember that the future always includes the potential of the unthinkable. In times of combined technological architectures based on artificial intelligence, DLT and cyber-physical systems, it is now the future of 'thinking' itself that will require our careful attention.

Declaration of Competing Interest

The authors declare no competing interests.

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