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RESEARCH ARTICLE

Analyzing the Sustainability of 28 "Blockchain for Good" Projects via Affordances and Constraints

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ABSTRACT
Proponents of "Blockchain for Good"—that is, blockchain efforts seeking to enable a range of benefits to humans and the environment—have suggested that the technology can support sustainability. However, while previous research has addressed aspects of the sustainability *affordances* of Blockchain for Good projects, the *constraints* that these projects impose have not faced equal consideration. Furthermore, the theoretical concepts of sustainability "problems" and "solutions" implicit in these projects have not been made clear. In this exploratory study, we evaluate the sustainability of 28 Blockchain for Good projects that use cryptocurrencies or tradable tokens with regard to the UN sustainability goals. These projects span a range of goals, such as decentralized renewable energy trading, supply chain tracking, transparent charity, and fairer voting. Nevertheless, despite their admirable goals, we find that current Blockchain for Good projects are unlikely to contribute to a sustainable future due to technical limitations and a conceptual framing that favors the status quo rather than transformative change.

1. Introduction

Distributed ledger technology (DLT), also called blockchain technology, has been hailed as a potentially disruptive innovation, possibly on par with the digital computer and the Internet (Giaglis & Kypriotaki, 2014). But, blockchain systems have also been criticized for wasting energy (de Vries, 2018) and fueling criminal activities, among other shortcomings. One use of this technology is to handle financial transactions in a decentralized manner, such as with the cryptocurrency Bitcoin. Like blockchain technology in general, cryptocurrencies remain divisive, meeting continued hype and critical backlash. After the large drop in cryptocurrency markets in early 2018, commentators have suggested that the cryptocurrency era is coming to an end, e.g., (Crowhurst, 2018). However, others remain hopeful that the technology will not only survive but become central to many facets of modern civilization. e.g., (McCauley, 2019).

Among the thousands of blockchain-based initiatives that have been deployed (CoinLore, 2019), only a subset may be considered "Blockchain for Good". However, how to define the boundaries of this subset is tricky. Adams, Kewell, and Parry (2018), one of the first papers to discuss Blockchain for Good explicitly, as well as a more recent paper by Bartoletti, Cimoli, Pompianu, and Serusi (2018), both operationalize that term in part via the United Nations Sustainable Development Goals (SDGs). While we disagree with this precise characterization (that is, something can be good without being sustainable, and sustainable without being good), we nevertheless agree that these two domains are closely linked. In large part, this is because of the breadth of the SDGs, which address seventeen disparate domains, including

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environmentally-related topics such as “Climate Action” and “Life Below Water,” but also a wide range of social goals including “Gender Equality,” “Quality Education,” and “Peace, Justice and Strong Institutions.”

Although Bitcoin itself remains to be proven as a practical money form, its implementation has created a new conversation around how the nature of money and the underlying blockchain mechanisms that support it reconfigure social relationships (Swartz, 2018). As social, political and power relationships often figure prominently in development projects, both cryptocurrency and blockchain have captured the imagination and sparked the ire of the development community(e.g., (Crandall, 2019)).

The cashlessness of bitcoin overlaps with a parallel strategy of addressing poverty with comparatively lightweight banking that services such as Dwolla, PayPal, and M-Pesa have attempted to address: Purely digital transfers of value promise to reduce reliance on physical cash and the associated overhead of theft, fraud, transport and decay that disproportionately affect the poor (Maurer, 2015). Additionally, the insight that data associated with transparent transactions at the “bottom of the pyramid" creates, offers the hope of analysis into services geared specifically toward supporting new goods and services for the poor. The ability for blockchains to self-adjudicate independently of a trusted authority (apart from the algorithm itself) enable them to bypass state and corporate control. To the degree that such control appears to be inhibiting development, blockchains offer the promise for working around societal structures (Future of Money Research Collaborative, Nelms, Maurer, Swartz, & Mainwaring, 2018).

These transactions don’t have to be limited to currency, they can include cell phone air time, votes, digital rights, etc.—an insight not lost on many of the Blockchain for Good project we discuss below. Blockchains have even been developed to support entirely new kinds of governance (e.g., the DAO (Dupont, 2018)) that have sparked the possibility of democratic reforms within non-representative communities.

In this exploratory paper we evaluate the sustainability of 28 projects that seek to use cryptocurrencies (or other valuable tokens stored on a blockchain) in ways that have been identified as “Blockchain for Good” in the development context. We do this from a holistic sustainability perspective, which encompasses not just environmental but also social (Busse et al., 2012) and economic aspects of sustainability as operationalized through the SDGs, as well as the internal sustainability of the projects. We should note that, given the distinction between “Good” and “Sustainable”, while we evaluated the projects against sustainability goals, these are not necessarily standards to which the projects held themselves. The sustainability-focused analysis nevertheless engages with an important domain, even if the projects didn’t consider their own work in that light. Evaluating the sustainability of **any** sociotechnical system is relevant to the future of humanity. In particular, evaluating the sustainability of a system that is being perceived as “for good” is particularly relevant, because the degree to which a system is “for good” depends on many different factors, including its effects across a range of types of good that it might do. The impacts of human-made climate change are growing more severe, and we risk irreversible damage to societies and nature (Intergovernmental Panel on Climate Change, 2014). Further, the broad nature of the SDGs includes a wide array of other critical objectives. If blockchain efforts are effective at addressing these objectives, the technology would be highly relevant, as problems of sustainability become ever more pressing.

A critical aspect of the work described here is this: while previous researchers have presented potential sustainability ‘affordances’ of blockchain tokens (e.g., (Kewell, Adams, & Parry, 2017)), the corresponding concept of ‘constraints’ has been neglected. The idea of affordances can be generalized to “…the perceived or actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used…”. (p.968) Kaptelinin and Nardi (2012), and constraints as “the limitations that shape what solution designs are practical." (p.1) Billingsley (2016) We seek to address both of these topics in this paper. Furthermore, we draw out the theoretical assumptions on which these projects build and connect them to competing conceptions of sustainability.

Many technologically oriented academic disciplines, including many computing-related subfields, have a tendency to suggest technological solutions to sustainability issues, and therefore to align themselves with approaches that reaffirm the status quo, or require modest reform rather than radical reconfigurations of society. Such tendencies have been critiqued in various computing subfields. For example Brynjarsdóttir et al. (2012) argue that a large part of human-computer interaction (HCI) follows a "modernist agenda," and criticize the emphasis on using technologies for persuading individuals to behave in a more sustainable manner as not being transformative enough. Many other voices critique technosolutionism as well (e.g., (Lindtner, Bardzell, & Bardzell, 2016)).

In addition, a recent blog post from the ACM Future of Computing Academy suggested that "Papers and proposals ... are typically already flush with anticipated positive impacts." (Hecht et al., 2018) The post explicitly flags novel blockchain projects as an instance where significant negative externalities may not be addressed. By considering both the affordances and constraints of the various blockchain systems we reviewed, we hope to provide a more thorough assessment than the platforms' design teams themselves might have done.

This work makes two key contributions to the ITD literature. First the framework described here makes a theoretical contribution by providing a novel way to conceptualize research at the juncture of ITD, sustainability, and blockchain. By clarifying that there are implicit theories of solutions and problems, affordances *and* constraints, we provide specific analytical tools to guide future work in this domain. Second the paper provides an empirical contribution by critiquing the sustainability implications of a range of blockchain projects via that framework.

Beyond these contributions to the research literature, we hope that the paper also makes a contribution via its broader impact on society. This paper examines a genre of technology usage that is intended to serve the public good, but that, from a broader perspective, may not actually do so. In this way, this work seeks to support designers and technologists wishing to do pro-social work, helping them avoid efforts that may be confounded by broader constraints they may not have considered, and redirect their labor toward activities more consistent with the outcomes they seek.

2. Related Work

2.1. Sustainable Development

Sustainability and sustainable development are concepts that are often highly contested, e.g. (Hopwood, Mellor, & O'Brien, 2005). The perceived sustainability of a technological artefact largely depends on the framework of sustainability that is employed and the socio-technical context in which it is deployed.

In much computing work, sustainability has tended to be used synonymously with environmental sustainability (see e.g. (DiSalvo, Sengers, & Brynjarsdóttir, 2010)). This can be contrasted with the view taken by the UN, where social, economic and environmental sustainability are equally important and interrelated, and must always be considered together (UN General Assembly, 2015). The latter approach is openly anthropocentric: sustaining the environment is a means to meet human needs. This conceptualization of sustainability stems from the original definition of sustainable development made by the Brundtland Commission, as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). In this context, sustainability and sustainable development are closely interconnected: social and economic sustainability require social and economic development, because many human needs are currently not met (Holden, Linnerud, & Banister, 2014).

In this study, we aim to take a holistic approach to sustainability, in the spirit of the UN and the Brundtland Commission. An evaluation of sustainability that does not take human needs or welfare into account risks becoming meaningless, since humans are integral to the current global context (e.g., (Shove, 2010)). In many cases where green technology attempts to regulate the environmental impact of another activity, the most effective method would be to prevent the activity entirely. For example, a purely green system for regulating the use of fuel in cars would simply prevent the engine from starting. In not taking this 'hard line' approach, there is an implicit balancing of human needs (or wants) with the environment.

However, the UN's Sustainable Development Goals (SDGs) have been criticized on many accounts, including for not fully recognizing that there are environmental limits (Holden, Linnerud, Banister, Schwanitz, & Wierling, 2017), and for being difficult to measure and quantify (Swain, 2018). Nevertheless, the 17 overarching goals can be useful for the type of exploratory research into the sustainability of blockchain projects conducted in this study.

Sustainability can also be thought of simply as a system's ability to persist over time (Tainter, 2006). In addition to considering the sustainability of blockchain projects in relation to society and the environment, it is useful to consider this type of internal sustainability. In order to be effectively "for good", blockchain projects must not only contribute positively toward sustainable development, but also be able to continue their operations. This is especially relevant for blockchain systems since, as we discuss below, their internal sustainability has been called into question.

In order to make sense of the many interpretations of sustainability, Hopwood et al. (2005) present a framework for placing all sustainability conceptions into one of three categories: status quo, reform, and transformation. This model aims to show that conceptions of sustainability are not only different in minor technical details, but that they can be connected to political interests and ideologies. Status quo approaches imply that sustainability goals can be reached without fundamental change to the structure of society and the economy. Instead of social change, technological improvement is often seen as sufficient to overcome sustainability problems. Growth is seen as fundamentally unproblematic, and 'hard limits' to natural resources are generally not seen as an issue. Reform approaches see the solutions in increased knowledge and a shift in ideals and individual behaviors. Lifestyles may have to change dramatically to reach sustainable outcomes, but this can be done without challenging existing power structures. Again, technological change is viewed as important, but government action and market reform are seen as necessary to put green technology in place. Unlike status quo approaches, increased growth and consumption is seen as problematic. Transformation approaches consider the problems of sustainability to be rooted in the economic and power structures of contemporary society. In this view, technology cannot solve issues of sustainability unless it fundamentally challenges the core social structures that make society unsustainable.

The political dimensions of sustainability affect both how sustainability is framed as a problem, and what solutions are deemed fitting. This can be thought of in terms of *theories of the problem* and/or *theories of the solution* (Majchrzak, Markus, & Wareham, 2016). Any assertion that a technology promotes sustainability contains an implicit or explicit theory of both what the fundamental obstacles to sustainability are (theory of the problem), and how the technology is supposed to overcome them (theory of the solution). A critical evaluation of such assertions needs to consider whether the problem to be solved is an actual and relevant obstacle to sustainability. If the technology does not attack a real bottleneck to sustainable development, its positive sustainability effects will be negligible in practice. If the technology is attacking a relevant sustainability problem, it becomes relevant to ask if it is effective at solving it, and what assumptions about behavioral and social change must be true for the solution to work.

We seek to use this framework to make explicit the theoretical assumptions by which a blockchain project becomes sustainable or unsustainable, and if these assumptions fit into a status quo, reform, or transformation view of sustainability.

2.2. Affordances and Constraints

Both affordances (e.g., (Kaptelinin & Nardi, 2012; Kaur et al., 2018; Norman, 2002)) and constraints (e.g., (Billingsley, 2016; Biskjaer, Dalsgaard, & Halskov, 2014; Ullmer, Ishii, & Jacob, 2005)) are key analytical tools used within various computing communities. However, to date, "Blockchain for Good" projects have focused primarily on affordances, rather than considering constraints. For example, in their overview of "Blockchain for Good" projects, Adams et al. (2018) use an approach described by Seidel, Recker, and Vom Brocke (2013), which presents a framework for identifying functional affordances that "assist organizations in establishing environmentally sustainable work practices" (p.4). Adams et al. (2018) use this framework to identify affordances of blockchain projects that can be used to promote sustainable development. However, determining whether a technology can be used to further sustainability goals is different from evaluating the overall sustainability of the technology for such use. A sustainability evaluation would also have to take into account how the technology constrains actors in reaching sustainability goals. Neither Seidel et al. (2013) nor Adams et al. (2018) take the constraints perspective into account. The research presented here seeks to address that shortcoming.

2.3. Blockchain and Cryptocurrencies

Blockchain platforms, as with many other aspects of IT Chipidza and Leidner (2019), have significant implications for the development domain. Kshetri and Voas argue that blockchain "has a much higher value proposition for the developing world than for the developed world" (p.1) Kshetri and Voas (2018). Over the past several years, the ITD community has begun to explore opportunities and challenges of blockchain for development. Fir example, Diniz, Siqueira, and van Heck (2019) offers a taxonomy of digital community currencies (DCCs), examining the design and execution of DCCs, including two blockchain-based DCCs. In addition, in their analysis of how Zambia has used micro-firms to stabilize their entrepreneurial sectors, Tang and Konde (2019) recognize blockchain as a rapidly emerging domain. Zambrano (2017) analyzes the future of blockchain technology in developing countries to foster their economies and human development, and how these information and communication technologies are often easier to use, more efficient, and more sustainable than other alternatives. Cheesman (2017) discusses the impacts of blockchains and other distributed ledger technologies through the data, power, and futurity they address, explaining the range of problems that this technology is solving, and is speculating to solve. And Coppi and Fast (2019) delve into the complexities of implementing distributed ledger technologies for humanitarian purposes, drawing upon potential use cases and expert opinions on the topic to come to the conclusion that they more positively than negatively impact the humanitarian sector. This emerging discussion around blockchain technology in the context of development motivates our work, which seeks to understand the affordances and constraints of a range of blockchain-based efforts.

However, the trade-offs of blockchain have not been as fully explored as blockchain's potential promise. ICTs in general are well-understood to be a "double-edged sword". For example, Qureshi (2019) discusses the paradox between the benefits that ICTs can offer sustainable development initiatives, while at the same time acknowledging the substantial resource footprint of those ICTs. The energy costs of blockchain are known to be problematic (e.g., (Vincent, 2019)). However, given that ICTs in general and blockchain-based systems are having a growing influence on development, we believe it is important to examine both the sustainability affordances and constraints of blockchain systems. Many of the specific blockchain technology projects discussed in this paper address development-related issues; as such, understanding both the benefits and drawbacks of these systems are critical to understanding what likely outcomes of their deployment are.

To provide a bit of technical background about blockchain that is relevant to this paper: blockchains may be either *public* or *permissioned* (also called *private)*. In a public blockchain network, anyone can create a node (copy of the ledger) and there is no need for a central authority to decide who gets to add data to the ledger. Instead, consensus on what data to add is achieved through algorithms, such as Proof-of-Work (PoW) or Proof-of-Stake (PoS), which make it difficult for anyone to manipulate the blockchain without controlling over 50% of computational power (PoW) or over 50% of all tokens on the blockchain (PoS). In a permissioned blockchain, valid nodes are selected by some trusted authority, which means that PoW or PoS is not necessary. There are also hybrid systems that integrate one or more permissioned blockchains with a public blockchain.

In this paper, we limit ourselves to the study of cryptocurrencies and other valuable or tradable tokens on a blockchain. These are associated with public blockchains, for which we see two major characteristics. The first is that, while public blockchains can have purposes other than creating cryptocurrencies, they need valuable blockchain tokens in order for the standard consensus mechanisms of PoW and PoS to make sense. The second is that trust in the value of blockchain tokens is predicated on decentralized consensus algorithms. If there were a central authority that had control over the network, trust would reside in the organization rather than in the blockchain implementation.

As mentioned above, an often-repeated problem with public blockchains is the high energy costs of Proof-of-Work mechanisms. As of August 2018, Bitcoin alone has been estimated to consume 0.33% of global energy, comparable to the entire country of Austria, and a single Bitcoin transaction has an estimated carbon footprint of 455 kg of CO2 (Digiconomist, 2018).

The main alternative to Proof-of-Work is Proof-of-Stake (PoS). It is seen by many as the future of blockchains, reducing the computational resources required for consensus making to a minimum. However, Proof-of-Stake may not be able to perform one of the fundamental functions of PoW: ensuring that supporting more than one version of the blockchain is costly. When incentives are not aligned towards supporting one version, consensus is at risk.

This raises the question of why cryptocurrencies are valuable in the first place, which is a contested topic. Critics argue that a currency must be backed either by assets or by a state or financial institution to be valuable, and that cryptocurrencies are fundamentally worthless. That they have a price at all can be explained by speculation (Cheah & Fry, 2015) with consumer transactions making up a small fraction of transactions (Yermack, 2015). A counter-argument to this is that Bitcoin and other cryptocurrencies offer something that other methods of transaction do not, in that they can provide pseudo-anonymity and avoid state regulation due to their decentralized nature. However, this could mean that cryptocurrencies are mainly useful for “drug dealing, money laundering, crim2crim payments, gambling, attempts to hire hitmen, etc.” (Weaver, 2018). There is empirical evidence of the co-evolution of Bitcoin with darknet markets (Janze, 2017).

Another critique of public blockchains is that, contrary to how they are often described, they are not ‘decentralized’ in absolute terms. There is a trend of centralization in Bitcoin (Beikverdi & Song, 2015). Developers have decision-making power, without being elected (Gervais, Karame, Capkun, & Capkun, 2014). Bitcoin is supposed to be governed by its technical infrastructure (“code is law”) (Lessig, 2009), but there is an invisible technocratic power structure, where developers play a key role (De Filippi & Loveluck, 2016). Unless explicitly organized otherwise, public blockchains will likely exhibit the same patterns.

2.4. Three Sustainability Dilemmas for Blockchain

Added together, these criticisms suggest three major dilemmas related to the sustainability of public blockchains and cryptocurrencies.

(1) **Energy cost vs. security**. If a public blockchain uses Proof-of-Work as a consensus mechanism, security is proportional to computational costs. The main contending mechanism, Proof-of-Stake, may not be secure—and whether or not a secure Proof-of-Stake system is possible is contested. Today, a high energy expenditure effectively means a high carbon footprint, working against SDG 13 "Climate Action" (UN General Assembly, 2015). If total sustainable energy production has 'hard limits' at any given time, it also competes with SDG 7 "Affordable and Clean Energy". If, on the other hand, the security of the blockchain is weakened, its internal sustainability is threatened. Furthermore, if blockchains replace centralized institutions, SDG 16 "Peace, Justice and Strong Institutions" would be threatened if security measures are weak, allowing attacks and corruption.

(2) **Value proposition vs. state regulation**. A possible value proposition of cryptocurrencies is that they are decentralized, pseudo-anonymous and hard to regulate by state actors. If these are the only value propositions, relative to other currencies, their value might be dependent on criminal activities. If that is the case, even 'good' uses of the currencies, or the public blockchains they support, would constrain human societies to a path where the cryptocurrencies allow a significant amount of economic activities beyond the grasp of state power. Regulating cryptocurrencies to prevent harmful activities could undermine their value, and thus usefulness as currency. Reducing the reach of the state may be seen as ideologically attractive for some, but it can also stand in opposition to SDG 16 "Peace, Justice and Strong Institutions," which includes reducing "illicit financial and arms flows" and combating organized crime. It would also oppose SDG 10 "Reduced Inequality" which includes "improved regulation and monitoring of global financial markets" as a way to combat inequalities. On the other hand, if the value of cryptocurrencies falls substantially their internal sustainability is threatened. Cryptocurrencies with an unclear value proposition stand in opposition to SDG 1 "No Poverty" which includes the reduction of exposure to economic shocks.

(3) **Decentralization and democratic transparency**. Although there does not appear to be a 'true' dilemma in choosing between decentralization and democratic transparency, there is tension between the two. Democratic transparency may require formal institutions and accountability, which could require central responsible authorities and official representatives. At the same time, internal tendencies towards centralization in public blockchains, independent of their democratic transparency, is a problem of its own. Tendencies towards centralization is a risk to the internal sustainability of public blockchains and cryptocurrencies, as decentralization is one of their defining features, underpinning the reliability of the ledger and value of the tokens. To the extent that such cryptocurrencies become important social institutions, SDG 16 "Peace, Justice and Strong Institutions" is threatened both by a lack of democratic transparency and by centralization, as the latter makes public blockchains vulnerable. In addition to this, in PoW systems rewards are distributed proportionally to computing power, providing a mechanism by which the rich can grow richer by accumulating PoW mining technology. This stands in opposition to SDG 10 "Reduced Inequalities".

2.5. Blockchain for Good?

The idea that blockchain technology can be used to further sustainability goals has been suggested by both researchers and practitioners in the blockchain community. For example, a 2017 Nature article (Chapron, 2017) suggests that the fundamental inability of existing governments to achieve sustainable development comes from a propensity for corruption. Therefore, blockchain technology, offering more trustworthy modes of governance, is necessary to avoid environmental and economic crises. Elsden et al. (2018) suggest that distributed and algorithmic governance is "the most ambitious and radical of blockchain applications" (p.7). Two organizations called "Blockchain for Good" have appeared (Blockchain for Good, 2016; Blockchain for Good (B4G) project, 2016), and there are several other organizations and initiatives in the same spirit, promoting the use of blockchain technology to serve humanity in novel ways (e.g. (Blockchain for Social Impact, 2019; European Commission, 2019)). Researchers from one of the "Blockchain for Good" organizations have published a scholarly article detailing the theoretical underpinnings of what Blockchain for Good would be (Kewell et al., 2017) and a book chapter listing a number of potential Blockchain for Good projects (Adams et al., 2018). However, they do not address the various sustainability-related constraints that accompany blockchain technologies. The existence of the Blockchain for Good community indicates a belief that each of the constraints has a solution: the problems with current blockchain implementations are momentary setbacks, or wrinkles to be ironed out. But is this mindset realistic? That is, **can cryptocurrencies and other valuable blockchain tokens promote sustainable development?**

3. Method

To explore this domain, we first constructed a list of 60 "Blockchain for Good" projects that have been identified in scientific articles or web media outlets, or described themselves as such. The main source of such projects has been Adams et al. (2018) directly or indirectly referenced from that article, supplemented by the list of projects on the corresponding "Blockchain for Good" website (Blockchain for Good (B4G) project, 2016). A Google search for "Blockchain for Good" yielded additional projects, including via reports on projects in a number of web media articles (Accenture, 2019; Alejandro, 2016; Good, 2017). We acknowledge that our search strategy may have missed applications that potentially fit this category but are not labeled as such, or post-dated our search in early-mid 2018. Our intent has not been to map all existing "Blockchain for Good" projects, nor to provide a representative random sample, but to construct a diverse sample of projects allowing for an exploratory typology. We excluded projects that were only suggested in an abstract form, and not in active development by any organization or group of developers.

The analysis of the projects is based on descriptions of the projects taken from their websites, technical 'white papers,' or similar documents. The blockchain community is typically quite thorough in its presentation of white papers, including considerable technical detail, and hence we believe white papers offer a sound basis on which to evaluate the nature of blockchain projects. However, we acknowledge that they may seek to present projects in the most positive light. Nevertheless, if there are sustainability issues in the white papers, it is likely they will exist in the implementations as well.

Because some projects lacked enough information in the white papers, we also constructed a web-survey to gain additional knowledge. Despite significant effort to contact project staff, though, out of 60 projects contacted, we received full survey responses from only four projects.

Table 1.: Projects

Project	Platform	Sources	Summary	SDGs
Curecoin	Native token	Curecoin (2018a, 2018b)	Focuses on medical domain; has contributed 47 petaflop of processing to computational biology via Folding@Home	3.3; 3.b
Gridcoin	Native token	Gridcoin (2019a, 2019b)	Open source cryptocurrency for "data-driven analysis and scientific discovery"	3.3; 3.b; 7.2; 7.b
BioCoin	Native token	BioCoin (2017, 2018)	A cryptocurrency that "contribute[s] to the sustainable development of the planet in accordance with the principles of a green economy."	2.3; 2.4; 2.a
Eco-Coins.ee	N/A	EcoCoins (2017)	Aims to provide cryptocurrency rewards for everyday sustainable actions	12.5; 12.8, 13.3
Energi-Token	Ethereum	EnergiToken (2017, 2018)	A blockchain solution that rewards and incentivizes consumers for a range of energy-saving behaviors	12.2; 12.8; 13.3
SolarCoin	Native token	SolarCoin (2019a, 2019b, 2019c)	Aims to incentivize a solar-powered planet through rewarding generators of solar energy with the first energy-referenced currency	7.2; 7.a; 7.b
Power-Ledger	Ethereum	PowerLedger (2018, 2019)	Aims to provide access to low-cost, renewable electricity, and to support an economy based off exchanges for electricity	7.1; 7.2; 7.a; 7.b
ixo Protocol	Ethereum	ixo Foundation (2018a, 2018b)	Combines blockchain with Web 3.0 standards to allow the collection and verification of high quality data about sustainable development	All
Earth Token	Ethereum	impactChoice (2017, 2018)	Supports exchange in the natural asset marketplace, and can be used for projects such as waste to energy, wind farms, solar projects, carbon sequestration and avoided emissions	7.1; 7.2; 7.3; 7.a; 7.b; 12.2; 12.4; 12.5; 12.6; 12.7
Seratio	N/A	Centre for Citizenship Enterprise and Governance (2018, 2019)	An Ethereum token that is able to capture information about both financial and non-financial value transactions simultaneously, and record this on the blockchain.	1.4; 8.3; 11.a
Restart Energy	Ethereum	Restart Energy (2015, 2017)	Provides tradable green certificates stored in a blockchain; supports direct peer-to-peer trading	7.2; 7.a; 12.2; 12.8; 13.b
Bitland	Bitcoin	Bitland (2016, 2019)	An international project to strengthen property rights, by making the land registration process "accessible, transparent, and free from government corruption."	9.1; 9.3; 9.a; 16.3; 16.5; 16.6
Swedish Land Registry	Native token	Swedish Land Registry (2017, 2018)	Digitizes land titles and store them in a blockchain; resides in a stable state with strong property rights	16.6

Project	Platform	Sources	Summary	SDGs
MediBloc	Ethereum	MediBloc (2017a, 2017b)	Aims to make patient medical data more accessible, while using private/public key encryption to make sure that only the right people and organizations can access it	3.5; 3.7; 3.8
Docademic	Ethereum	Docademic (2016, 2018)	Single globally-sourced healthcare platform with an associated suite of services to enable a high level of access and medical advancement	3.5; 3.7; 3.8
AidCoin	Ethereum	AidCoin (2019a, 2019b)	Connects the non-profit community while allowing full transparency and traceability of donations	All
Alice.si	Ethereum	Alice.si (2017, 2019)	A network that brings together social organizations, donors, grant-makers and impact investors to identify and scale effective social projects	All
BitMari	Neo Blockchain	BitMari (2018a, 2018b)	Utilizes Blockchain technology to facilitate the remittance of money to Africa	All
GiveTrack	Bitcoin	GiveTrack (2018a, 2018b)	Aims to bridge the gap between an innovative technology and its practical applications for non-profits and humanitarian work in the developing world	All
Ambrosus	Ethereum	Ambrosus (2017a, 2017b)	Aims to be a hybrid blockchain, "ensuring the origin, quality, compliance and proper handling of items tracked by the network."	9.2; 9.5; 12.2; 12.3; 12.5
OriginTrail	Ethereum	OriginTrail (2013, 2017)	Built to support other blockchain implementations with its own valuable token to incentivize data processing and storage	9.2; 9.5; 12.2; 12.3; 12.5
Humaniq	Ethereum	Humaniq (2017a, 2017b)	Aims to shift emerging economies into the cryptoeconomy using blockchain technology combined with biometrics and a focus on mobile technology	9.1; 9.3; 9.a
BolivarCoin	Native token	BolivarCoin (2015a, 2015b)	Use their own cryptocurrency as a way to increase financial inclusion, and allow for cheap remittances	9.1; 9.3; 9.a
Agora	Bitcoin	Agora (2017a, 2017b)	A Swiss based voting technology company that focuses on building a blockchain based voting system for governments and institutions	16.5; 16.6; 16.7
followmy-vote.com	BitShares	followmy-vote.com (2014, 2018)	Aims to host verified and transparent elections within an end-to-end voting system powered by blockchain technology	16.5; 16.6; 16.7
Colony	Ethereum	Colony (2019a, 2019b)	Allows 'peer-to-peer' organizations' to be built, using principles inspired by market principles	16.5; 16.6; 16.7
Handshake	Ethereum	Handshake (2017, 2018)	Seeks to build a system for storing and managing labor contracts; allows for a censorship resistant way for workers to raise complaints	16.5; 16.6
CarbonCoin	Native token	CarbonCoin (2018a, 2018b)	Represents a variant of cryptocurrency that hopes to work towards sustainability goals without using incentive structures or tokenized impact	12.2; 13.b; 15.1; 15.2

The difficulty of communicating with the project architects, while not particularly surprising, foregrounds the challenge of achieving meaningful transparency and democratic governance which we elaborate on below. Deanonymized survey results are presented with Human Ethics Committee and participant permission. After excluding projects that still did not have enough data for meaningful analysis, 28 remained. (Note: of these 28 projects, 25 remained active as of November 25, 2019. According to the Wayback Machine (Internet Archive, 2019), three projects (BioCoin, 2017; EcoCoins, 2017; Handshake, 2018) have disappeared from the Internet since this analysis was conducted.) Table 1 provides a brief summary of each project.

We then sorted these 28 projects into 12 categories, similar to how Diniz et al. (2019) sorted a selection of digital community currency platforms into groups. For each of these 12 categories, we identified implicit and explicit theories of the problem, solution and conceptions of sustainability according to the *status quo, reform, and transformation* framework. Then, we identified ways in which the projects handle the three 'sustainability dilemmas' outlined in the previous section: *energy costs vs. security*, *value proposition vs. state regulation*, and *decentralization and democratic transparency*.

4. Results

The general results of our analysis can be summarized as follows:

- All of the projects in this study operate primarily within a status quo path of sustainable development. Technical development, growth, and increased production are promoted, rather than approaches that challenge people's lifestyles or power structures. Where a change in lifestyle is the goal, market incentives are seen as the solution.
- None of the projects offer alternatives to Proof-of-Work and Proof-of-Stake as methods of ensuring consensus. Instead, they build upon one or the other, and the apparent dilemma between energy expenditure and security remains unresolved.
- In general, the value propositions of the projects rely on the notion that 'traditional' cryptocurrencies like Bitcoin are fundamentally sound. Their selling point is not a completely alternative value proposition but a 'sustainable edge' in relation to Bitcoin and its competitors. If cryptocurrencies without such an edge are not viable, then neither are these. The potential exceptions are projects that connect their currency to a service platform, where the tokens are required to use the platform, creating a viable source of demand and value.
- Issues of democratic transparency are rarely discussed, although some projects show ambitions to have democratic control and accountability. However, the democracy of these projects seems to rely on the goodwill of the developers, not on formalized democratic power. It is not made clear how the institutions behind the projects are to be held accountable and made transparent. The transparency and immutability of blockchains is talked about in absolute terms, with little critical examination.
- None of the projects included engages with the problem of centralization tendencies in blockchains in a novel way. However, by using Proof-of-Stake, the issue of control going to a few large mining pools is removed, although this may open them up to the potential vulnerabilities of PoS.
- Almost all of the projects rely on trusted data from external sources, which means that the trustlessness and decentralization provided by the blockchain is incremental rather than absolute.

In the following sections, each of the 12 categories of projects is presented and discussed in more detail. Table 2 provides a brief summary of each category.

Table 2.: Categories

Category	Projects	Affordances	Theory of Problem/ Solution	Level of Change	Energy Cost vs. Security	Value Proposition vs. State Regulation	Decentralization and Democratic Transparency
Useful mining	Curecoin, Gridcoin	Considerable computer capacity	(P) Lack of research; (S) Increase incentives to do more research.	Status Quo: More research adds value, but still encourages energy use.	Both projects based on PoS, but still high energy use from computing for research.	(VP) Use computational processing to add value to society rather than for security; (SR) Difficult to regulate.	Decentralized to a point (has voting system), but institutional governance unclear.
Rewards & Loyalty Programs	BioCoin, Ecocoins, EnergiToken, SolarCoin, PowerLedger	Open, secure tracking; Tradable tokens	(P) Economic incentives do not align with sustainable practices; (S) Use ethical incentives, instead of economic ones.	Status Quo: Encourages more sustainable behaviour, but there are both operational & opportunity costs.	All projects use either PoS or PoW (except Ecocoins, which plans to use PoW in future). PoS vs. PoW problems remain.	(VP) SolarCoin, Ecocoins, BioCoin act as cryptocurrencies; BioCoin is also a loyalty program; (SR) Finacial regulation of non-participant transactions may limit growth; (VP) EnergiToken & PowerLedger need tokens to participate - may increase demand; (SR) Less of an issue.	Trustlessness more problematic with dependency on verifying external data to operate.While Powerledger & SolarCoin have democratic institutions providing a voice, none provide formal democratic decision-making.
Tokenized Impact	ixo Protocol, Earth Token, Seratio, Restart Energy	Tradable tokens	(P) Lack of trustworthy social impact data; (S) Data rendered trustworthy via blockchain, but neglects issues of choice/evaluation.	Status Quo: Embeds ethical, as well as financial, value.	All projects use either PoS or PoW; PoS vs. PoW problems remain.	(VP) Tokens have value for social good, but these are largely symbolic & lack market value; (SR) Less of an issue.	Trustlessness more problematic with dependency on verifying external data to operate.Democratic transparency largely neglected.
Energy Trading	PowerLedger, EnergiToken, Restart Energy	Decentralized trading	(P) Current energy market is: too centralized, opaque, lacks competition, and lacks incentives to conserve; (S) Platform that directly connects energy providers with consumers, independent of size.	Status Quo.	All projects use either PoS or PoW; PoS vs. PoW problems remain.	(VP) Decentralization & deregulation will avoid favouring large producers; (SR) In practice, energy markets heavily deregulated, making large providers potentially dominant, even monopolistic.	Trustlessness unlikely to help, given importance of energy sector. Decentralized operation may not prevent private platform ownership controlling market and suppressing democratic transparency.

Category	Projects	Affordances	Theory of Problem/ Solution	Level of Change	Energy Cost vs. Security	Value Proposition vs. State Regulation	Decentralization and Democratic Transparency
Land Registry	Bitland, Swedish Land Registry	Open, secure tracking	(P) For Bitland, corrupt governments cannot be trusted to manage property rights; (S) Data rendered trustworthy via blockchain [but still requires government property data].	Status Quo: For Bitland, running blockchain systems in countries with unstable infrastructure may be infeasible. For SLR, blockchain value added may be minor.	Both projects use PoW; PoS vs. PoW problems remain.	(VP) For Bitland, less corrpution with property rights; (SR) But government involvement still required; (VP) For SLR, increased efficiency & accuracy; (SR) Less of an issue.	Trustlessness more problematic with dependency on verifying external data to operate.Democratic transparency largely neglected.
Health Records	MediBloc, Docademic	Open, secure tracking	(P) Health data difficult to access across borders, including medical research; (S) Provide a secure, more widely accessible platform.	Status Quo	Both projects use PoW; PoS vs. PoW problems remain.	(VP) Secure, trusted access to medical data within & across borders; (SR) Market role unlikely given natural monopoly - must be state run.	Highly centralized, monopolistic control - likely by government. Democratic transparency not guaranteed.
Transparent Charity	AidCoin, Alice.si, BitMari, GiveTrack	Open, secure tracking; Cryptocurrency	(P) Lack of transparency & trust in charity financial activity constrains donations; (S) Provide a trusted, transparent & accessible account of financial transactions.	Status Quo: Eventually cryptocurrency has to re-enter currency-based market to become usable.	All projects use either PoS or PoW; PoS vs. PoW problems remain.	(VP) Donations made via cryptocurrency & encouraged by transparent, secure & accessible platform; (SR) Regulation around auditing still required, limiting value of blockchain.	Trustlessness more problematic with dependency on verifying external data to operate.Democratic transparency not guaranteed.
Supply Chain Tracking	Ambrosus, OriginTrail	Open, secure tracking	(P) Lack of transparency & trust with origins of consumer goods; (S) Provide trusted, transparent account of supply chain origins.	Status Quo: Trusted ethical sourcing important to consumers.	Both projects use PoW; PoS vs. PoW problems remain.	(VP) Will encourage sustainable sourcing and decrease misleading marketing through transparency, though verification could be expensive; (SR) Quality of data & platform difficult to regulate; open to greenwashing.	Trustlessness more problematic with dependency on verifying external data to operate. Democratic transparency not guaranteed.

Category	Projects	Affordances	Theory of Problem/ Solution	Level of Change	Energy Cost vs. Security	Value Proposition vs. State Regulation	Decentralization and Democratic Transparency
Financial Inclusion & Remittances	Humaniq, BolivarCoin	Cryptocurrency	(P) Difficult & costly for many to engage in financial activity (including international remittances) safely; (S) Trade on unregulated cryptocurrency exchanges to avoid expensive service fees.	Status Quo: Enabling freer flow of currency across borders, but increasing risk as well.	Both projects use PoW; PoS vs. PoW problems remain.	(VP) Avoiding service costs makes financial activity across borders more accessible, but only where cryptocurrency viable; (SR) The VP depends on lack of regulation, which increases risk of criminal activity.	Cryptocurrencies voluntary and likely to be more attractive to poorer nations. Democratic transparency at risk as regulatory bodies uninvolved.
Voting & Open Organizations	Agora, followmyvote .com, Colony	Decentralized, open, secure communication	(P) Large public & private bodies need effective, democratic communication and decision-making(S) Provide trusted, transparent mechanism that enables democratic participation.	Status Quo: Alternative approach to member engagement, including voting, though there is a risk with cryptocurrency market engagement.	All projects use either PoS or PoW; PoS vs. PoW problems remain.	(VP) Agora & followmyvote use blockchains for 'free and fair' elections, with reduced costs, at a national level; (SR) Corrupt states least likely to adopt/regulate; (VP) Colony creates 'peer-to-peer' organizations to break down hierarchy-based problems; (SR) regulation market-based using smart contracts.	Decentralized participation, but under the auspices of a centralized authority;Transparent democracy provided at a technical level, but unclear how easily members could engage with it.
Labor Contracts	Handshake	Smart contracts	(P) Contractual issues between employer & employees(S) Provide transparency over content, alterations and enforcement of contracts.	Status Quo: Though widespread adoption (as a regulatory requirement) could have some reforming capability.	The project uses PoW; PoS vs. PoW problems remain.	(VP) Smart contracts improve contractual management for all parties; (SR) Smart contracts enable easier regulation enforcement, but do not guarantee it; voluntary adoption by employers may be unlikely.	Employee perspective decentralized, but employer still has centralized control; there is trust in recorded data, but necessarily in the actions that follow. Democratic transparency is key, but unclear how easily members could engage with it.
Funding Social Good	CarbonCoin	Cryptocurrency	(P) Need for funding for sustainability initiatives; (S) Investment in cryptocurrency will ensure rising value for funding purposes.	Status Quo: Based on assumption that tokens will rise in value - but no clear argument to support this.	The project uses PoW. PoS vs. PoW problems remain.	(VP) Uses transaction fees around cryptocurrency investment to fund initiatives, though very competitive market (and so relies on sustainability incentive); (SR) Cryptocurrency market largely unregulated and risky.	Trust depends heavily on business model around wealth generation, which appears doubtful at this stage. Decentralization and democratic transparency are not helpful features.

4.1. Useful Mining

The projects in this category are concerned with connecting the process of 'mining' cryptocurrency to computations that are not merely arbitrary Proofs-of-Work but help provide useful scientific knowledge. When users devote their computers to mining these currencies, they are also participating in a distributed computing network that solves mathematical and scientific problems, such as protein folding.

Two main projects fell into this category: Curecoin (Curecoin, 2018a, 2018b) and Gridcoin (Gridcoin, 2019a, 2019b). Both of these platforms seek to incentivize distributed computing for research. Curecoin focuses primarily in the medical domain. It is currently in public deployment and has been brought to bear in a variety of domains, including contributing 47 petaflops of processing power to computational biology research through the Folding@Home project. GridCoin focuses more broadly on "data-driven analysis and scientific discovery". It is an open source cryptocurrency used on the platform BOINC, a volunteer computing grid that combines the processing power of individual computers used for over 30 scientific projects, such as tackling problems in clean energy and public health. (Gridcoin, 2019b).

The common idea behind GridCoin and CureCoin is to 'hitch' the costly PoW process of cryptocurrencies to useful computing work. If successful, this would serve two sustainability ends. First, increased mining effort would translate into more scientific findings, which could further sustainability goals, for example by assisting in the development of new medicines (SDG 3 "Good Health and Well-being"). Second, individuals and organizations would be incentivized to use underutilized computational capacity for scientific ends, which could mean a more efficient use of resources.

There is a tension between these two ends, in that the first seeks to alleviate the perceived 'wastefulness' of PoW while the second seeks to incentivize more intensive use of computer resources. From a hard limits perspective on sustainability, total energy consumption needs to be reduced. Replacing regular PoW with 'useful' mining does not reduce energy consumption, even if it makes it have more value. While promoting decentralized computing in this manner seeks to utilize underused material resources ("Idle Processing Potential" as Gridcoin calls it) it is simultaneously promoting increased energy usage. If there are hard limits to sustainable energy usage at a given level of technology, it is not a given that devoting more of those limited energy resources to computationally-intensive scientific research is the best way to meet human needs. In defining the problem as a lack of research and the solution as increased positive incentives, the projects fall squarely into a 'status quo' conception of sustainable development.

The conceptual success of these projects hinges on their ability to replace PoW with a scientifically useful mining process. So far, this has not been accomplished. Instead, the verification of useful data happens on top of PoS systems. By using PoS, the projects avoid the energy cost problems of PoW, but may expose themselves to potential security vulnerabilities. Furthermore, by incentivizing increased energy usage, they replace the energy consumption problem of PoW with a different energy problem, as discussed above.

These projects incentivize miners to contribute processing power and storage for use by research projects that rely on distributed computer networks. These projects incentivize miners with newly minted cryptocurrency (or credits that they can convert to currency) according to how much computing power they provide (and in the case of CureCoin, for contributing to security of the blockchain). These cryptocurrencies can then theoretically be exchanged for goods and services. The value proposition of these projects can therefore be seen as building on the basic value proposition of cryptocurrencies, incentivizing people to support a particular cryptocurrency because it supports scientific research for "good" causes. If critics are right in that cryptocurrencies can only work as currency because they avoid state regulation and allow speculation, these projects offer no remedy to these concerns.

In their current implementations, CureCoin and GridCoin require that the scientific computations are verified by a trusted authority. This goes against the idea of trustlessness and decentralization that is a core selling point of cryptocurrencies, and may therefore undermine their value proposition and internal sustainability.

4.2. Rewards and Loyalty Programs

Projects in this category seek to incentivize sustainable action by producers and consumers. All of the projects we have included in this category are concerned with energy or environmental sustainability, and create incentives via rewards in cryptocurrency tokens for behaviors that promote sustainability.

There were five projects that fell into this category: BioCoin (BioCoin, 2017, 2018), EcoCoins.ee (EcoCoins, 2017), EnergiToken (EnergiToken, 2017, 2018), SolarCoin (SolarCoin, 2019a, 2019b, 2019c), and PowerLedger (PowerLedger, 2018, 2019). BioCoin is a peercoin fork cryptocurrency acting as a loyalty program for "socially responsible businesses that support organic agriculture, local farms, responsible attitude to the environment, contribute to the sustainable development of the planet in accordance with the principles of a green economy." (p.1) (BioCoin, 2018) EcoCoins aims to provide cryptocurrency rewards for everyday sustainable actions. EnergiToken is a blockchain solution in current deployment that rewards and incentivizes consumers for a range of energy-saving behaviors, such as using public transport and buying energy-efficient appliances. SolarCoin aims to incentivize a solar-powered planet through rewarding generators of solar energy with the first energy-referenced currency. Power Ledger aims to provide individuals and communities with access to low-cost, reliable, and renewable electricity, and to support an economy where households that generate electricity can trade with their neighbors and get a fair return.

All of these projects work from the idea that changing consumer behavior and incentivizing green production are keys to environmental sustainability. They are generally not concerned with reducing unsustainable actions, but with increasing what is deemed sustainable. This makes them largely compatible with a status quo conception of sustainable development, where the solution is more 'good' rather than less 'bad'. One exception is that EnergiToken notes that reducing total energy consumption is as important as increasing the availability of green production (EnergiToken, 2017). Their solution is to positively incentivize lowered energy consumption within their network.

The theory of the problem behind these projects is that economic incentives do not align with sustainable environmental practices. However, in order to work, they rely on users voluntarily subjecting themselves to these economic incentives, and paying the costs necessary to fund the rewards programs. Rather than using economic incentives to promote sustainable practices, the projects presume a willingness to behave sustainably on the part of participants. Otherwise, a self-interested rational economic actor would choose Bitcoin over Solarcoin, or an energy trading platform with the lowest prices over one that rewards green producers. If actors are not narrowly self-interested, but ready to promote sustainability anyway, then the assumption of misaligned incentives as the core problem is weakened.

To function as incentives, the tokens that users are rewarded with must be valuable. The projects in this category have value propositions that are quite different from one another. SolarCoin and EcoCoins.ee present the same value propositions as Bitcoin, in that each can function as a currency because it is scarce in supply and allows for anonymous ownership, while avoiding government intervention and intermediaries such as banks (SolarCoin survey response). BioCoin has the potential to present another value proposition, because it works as a loyalty program. Businesses that accept the currency could form a sort of protected market, if the currency circulates among these businesses and their customers. EnergiToken and PowerLedger have a more concrete value proposition, because users need their tokens to participate in their energy trading platforms. As long as these platforms provide a service that is attractive to users, there will be a demand for their respective tokens.

PowerLedger and SolarCoin are the two projects in this category that seem to work towards internally democratic institutions. PowerLedger has explicit plans to become a fully decentralized network, run by its users. SolarCoin tries to ground its decision-making in its user community (SolarCoin survey response). However, thus far, users in all projects seem to lack formal decision-making power and the internal democracy is based on the goodwill of the developers. Compared to a project like Bitcoin, the ability for users to 'vote with their feet' and create forks of the blockchain is impaired, because leavers would lose all of the organizational infrastructure that is not contained in the blockchain, such as the provision of smart meters.

4.3. Tokenized Impact

There were four projects that fell into this category: The ixo Protocol (ixo Foundation, 2018a, 2018b), Earth Token (impactChoice, 2017, 2018), Seratio (Centre for Citizenship Enterprise and Governance, 2018, 2019), and Restart Energy (Restart Energy, 2015, 2017). The projects in this category take a slightly different approach to incentivizing sustainable practices, compared to the rewards systems discussed above. The idea behind the ixo Protocol, Earth Token, and Seratio projects is to create tradable blockchain tokens that represent various social goods. By giving these social goods a market value, the projects hope to incentivize users to produce more of them. Earth Token supports exchange in the natural asset marketplace, and can be used for projects such as waste to energy, windfarms, solar projects, carbon sequestration and avoided emissions. Seratio is an Ethereum token based on the philosophy of transacting intangible value. It is able to capture information about both financial and non-financial value transactions simultaneously, and record this on the blockchain. Similarly, Restart Energy provides tradable green certificates stored in a blockchain. These tokens represent positive social "impact". The company's decentralized energy trading platform supports direct peer-to-peer trading. Customers can also access intelligent wifi meters and watt prediction tools on the platform. The company has a franchise model with over 300 franchise business partners.

Tokenized impact or value-embedded tokens take the model of carbon emission rights and green certificate trading, and tries to apply it to social goods in general. Applying this idea to its fullest extent would be nothing less than the commodification of all aspects of social life.

The implicit theories of the problem and solution build on the idea that markets are a good solution to any problem, if only market externalities are given a price. This solution, generally supported by mainstream economics, can be contrasted with the idea that it is the spread of markets that allows natural resources to be overexploited (O'Neill, 2013). The tokenized impact projects start from the assumption that carbon trading and similar schemes are successful solutions, but this is not an uncontroversial position. Critics of carbon trading argue that such systems are protective of the status quo by design and have failed to push societies toward fossil free economies (Reyes & Gilbertson, 2010).

An implicit theory of the problem behind these projects is that there is a lack of trustworthy data on social impact. Framing the problem as lack of information is also compatible with a 'status quo' conception of sustainability. An alternative framing of the problem would be that actors with the power to enact change refuse to do so (or are limited in their power to do so), in spite of overwhelming data - for example regarding which industries have the most negative impact on the environment.

In order for tokenized impact to work, the tokens must have value. This problem is similar to the problem of value for cryptocurrencies, except that these tokens are not intended to be currency, but commodities. One take on this is that the tokens are inherently valuable because they represent a social good, such as a reduction in carbon emissions (see (Centre for Citizenship Enterprise and Governance, 2018)). However, making a tradable token that is said to represent a social good does not give that token market value. There must be effective demand. Therefore, the idea is that institutions with an interest in sustainability or other social values can buy these tokens as a way to support the production of social goods. Unlike the rewards programs, these systems explicitly rely on external actors that are ready to incentivize social impact and put ‘real’ money behind it. This could solve the problem of initial demand, but in doing so raises a set of new questions.

While institutional actors like governments, Non-Governmental Organizations (NGOs), companies with Corporate Social Responsibility (CSR) programs, or individuals, can create demand for these tokens, why would there be a market to re-sell them? Why would anyone want to buy impact that has already been paid for by someone else, instead of paying for new impact? Buying and selling impact at a profit seems pointless and unlikely, because the final buyer has no clear reason to pay a premium for impact that has already been financed, instead of buying new impact. In this sense, impact in general is very different from something like carbon emission rights, which are useful to the final owner, whereas impact tokens only have symbolic meaning. Using computer power to maintain a market of tradable tokens seems wasteful, in light of this.

Blockchain technology is supposed to guarantee that the social impact is real, and prevent double counting. However, as with the rewards systems above, any data on the blockchain is only as reliable as the data that went into it. This would require an immense machinery of auditing and control instances, and if such an apparatus can be trusted to provide correct information in the first place, trustworthiness might not be significantly increased by having it stored in a blockchain. The issue of democratic transparency - how users can understand and trust the institutions and processes that produce the data - is seemingly neglected.

4.4. Energy Trading

There were three projects in this category: PowerLedger (2018, 2019), Restart Energy (2015, 2017), and EnergiToken (2017, 2018).[1] These projects aim to be decentralized energy trading platforms, lowering the barriers of entry for “prosumers” of electricity to produce renewable energy and sell their surplus. This is supposed to incentivize more widespread adoption of renewable energy, and make it easier for consumers to buy renewable energy at an affordable price. By removing the middlemen, and allowing for peer-to-peer trading, small-scale producers can demand higher prices, and consumers can buy renewable energy at lower prices. On top of these systems, they use crypto tokens to incentivize sustainable practices, as has been outlined in the previous sections.

EnergiToken puts forward four central problems with today’s energy market: it is too centralized, opaque, lacks competition, and lacks incentives to use less energy. Except for the last point, which EnergiToken is unique to make in this context, the other two projects frame the problem in a similar way. Essentially, in energy markets controlled by large monopolies, small producers of renewable energy are kept out. The intended role of blockchain technology is to decentralize the market, increase transparency and make use of cryptocurrency mechanisms to create new incentives.

This form of solution is similar to the idea of the ‘Sharing Economy’. Spare resources, in this case the potential renewable energy production of households and businesses, are put into use

[1]PowerLedger and EnergiToken were also included in the “Rewards and Loyalty Programs” subsection above.

via a central platform which connects producers and consumers. This is supposed to increase the efficiency of resource use, because previously underutilized resources are now available to the wider public. PowerLedger (2018, 2019) makes this comparison explicit, comparing their network to Uber and AirBnB.

However, the concept of the Sharing Economy has been criticized (e.g., (Martin, 2016)), and some of the critique is applicable here as well. While decentralization and openness are frequently used keywords in these projects, their explicit intent is also to become the single dominant energy trading platform in the world. While trading within such a platform could be 'free' and deregulated, the platform itself is a potential monopoly. Although PowerLedger expresses the intention to become an energy system "owned by the people of the world" (p.1) it, and its competitors, are currently privately owned. There is a risk that widespread adoption of such a platform, without ensuring that it becomes more democratically controlled, leads to a private monopoly situation.

Part of the reason that these projects base themselves on blockchain technology may be that these projects involve valuable blockchain tokens as integral parts of their infrastructure. This serves two obvious potential reasons: allowing for tokens to be used for incentive programs (see above) or as a method of financing the project via ICOs. If state cooperation is required anyway, incentive programs can be accomplished by centralized means. Accessibility to ICO financing is not a sufficient reason to run a system using blockchain technology.

The use of blockchain technology is supposed to allow for decentralization, but this type of project will necessarily require management by some trusted authority. It is inconceivable that something as vital as an energy network can be allowed to run without the oversight of a responsible authority. The trustlessness provided by a blockchain seems unnecessary in this context.

4.5. Land Registry

This category includes two projects: Bitland (2016, 2019) and the Swedish Land Registry (2017, 2018). The idea behind these projects is to digitize land titles and store them in a blockchain. This is supposed to make ownership information both easy to access and securely stored. For Bitland, this is an international project to strengthen property rights, by making the land registration process "accessible, transparent, and free from government corruption." (p.2) For the Swedish Land Registry, the security of property rights is less of an issue, because the project resides in a stable state with strong property rights.

Both projects require a centralized and trusted authority to set up and maintain the service. In the case of the Swedish Land Registry, this is an organization that answers to the Swedish government. In the case of Bitland, it becomes more complicated, because part of their problem theory is that corrupt governments cannot be trusted to manage property rights on their own. Therefore, it is the Bitland organization that sets up the blockchain infrastructure. From then on, the intention seems to be to build a public blockchain infrastructure with its own native cryptocurrency. However, the system will still need cooperation from trusted officials from the government, to make sure that the land titles registered in the blockchain match legal titles.

The Bitland system runs into a common blockchain problem, in that the trustworthiness of external data can not be guaranteed by blockchain technology. In this case, it is unclear how blockchain technology can increase the overall reliability of the system. Furthermore, it is questionable whether it is feasible to have a public blockchain for this type of project.

For Sweden, digitization of property rights may increase efficiency and security incrementally, but whether or not a permissioned blockchain is the best database solution for this purpose is debatable, and beyond the scope of this article. In any case, such a system does not seem to produce any significant sustainability affordances or constraints, as property rights institutions are already functioning.

Running blockchains in countries with unstable infrastructures may not be feasible in the first place. In addition, we expect that a government is unlikely to accept land titles from a blockchain outside of its control; however, if the blockchain is under the government's control, the blockchain may have difficulty avoiding corruption.

4.6. Health Records

This category includes two projects: MediBloc (2017a, 2017b) and Docademic (2016, 2018) These projects aim to make patient medical data more accessible, while using private/public key encryption to make sure that only the right people and organizations can access it. This could improve global healthcare, by removing the need to request and transfer patient files between different care providers, and by potentially allowing researchers direct access to anonymized medical data.

The basic idea appears sound, and there are many competitors vying to become the dominant platform in this field. MediBloc and Docamedic are both examples of commercial actors in this scene, using hybrid blockchain technology with Ethereum-based cryptocurrency tokens. In Estonia (Einaste, 2018), a state-owned blockchain solution has also been implemented, using a permissioned blockchain.

Given that a permissioned blockchain (or any system using private/public key encryption) is enough to provide the basic functionality, one must ask what the need is for public blockchains and cryptocurrency in this case. Given the pseudo-anonymous nature of public blockchains, and the sensitivity of personal medical information, it seems like a bad fit. The answer seems to be that these services want to connect the storage of medical data to a wider platform of medical-related services.

The storage of medical data using blockchain technology could be considered a natural monopoly, because using several networks at once defeats the purpose of reducing 'data silos'. Meaningful competition is unlikely to be possible, which means that market solutions are unlikely to benefit end users. On the contrary, privately monopolized control of essential medical data services can be severely harmful to end users, and to health related sustainability goals.

Unlike some energy trading platforms such as PowerLedger (2019), there is no explicit intent to become an open and decentralized network, controlled by no one but its users. Until they show intent of democratization, they should be regarded as are private interests that seek to monopolize medical services, by 'forcing' all who use their medical data system into a privately owned platform, which is also used to sell other services, such as medical artificial intelligence.

4.7. Transparent Charity

There were four projects in this category: AidCoin (2019a), Alice.si (2019), BitMari (2018a), and GiveTrack (2018b). The idea behind these projects is that blockchain technology can increase the transparency of how charities use their funds, which will encourage more efficient usage and increase trust from givers, resulting in more donations. There is also the idea that unregulated international transfers of cryptocurrency are cheaper, and will therefore lead to a more efficient use of donated resources.

A major obstacle for these projects is that they rely heavily on trusted authorities to verify that funds are used as reported. The blockchain can not, by itself, track how resources are used in the real world. One advantage these projects have is that donations are made in the form of cryptocurrency, which can be tracked on the blockchain. However, as soon as the cryptocurrency is converted into another currency, or used to buy goods and services, the system must somehow gather trusted data from the real world on where the funds end up. As long as the particular cryptocurrency is not in widespread use, aid organizations will have to convert the currency into something else in order to use it.

Since these organizations will need to make use of traditional auditing measures, it is unclear whether or not blockchain technology solves any significant real problem. If auditing processes, smart meters or other sources of external data can be relied on to enter correct information into the blockchain, why would they not be trusted to maintain correct records without using a distributed ledger?

In the case that the external data can not be trusted, it is possible that the blockchain branding creates a sense of false security. This sense of security could be exploited by less honest aid organizations.

As with green-washing, the pioneers of transparent charity may have honest intentions, but this does not prevent copycats from misusing the trust that pioneers have established. This problem is discussed further in the section on supply chain tracking. The idea that cryptocurrencies can be used for international money transfers is discussed in the section on financial inclusion and remittances, below.

4.8. Supply Chain Tracking

There were two projects in this category: Ambrosus (2017a, 2017b) and OriginTrail (2013, 2017). These projects aim to increase the reliability, transparency and efficiency of industrial quality assurance, by tracking supply chains in blockchains.

In a UK study (PricewaterhouseCoopers, 2008), cost was the main barrier for consumers to buy ethically sourced products, and confusion and trust the second largest. Blockchain supply chain tracking promises to improve both. Cost is to be reduced by replacing labor intensive auditing processes with automated transparency on the blockchain. Confusion is to be reduced by giving consumers direct insight into how their goods and services have been produced, instead of having to navigate hundreds of different ethical brands and markings, some of which may mean very little. By reducing confusion and giving more direct access to information, trust can be increased.

This sounds very promising, but there are a number of issues to consider. Regarding cost, the implicit theory of the problem is that ethical and green goods cost more because it is expensive to verify ethical production. However, it is unlikely that ethical and green production can ever be as cheap as its competitors. The main reasons to produce unethically and unsustainably must be that it is cheaper – lower wages, fewer regulations, access to a wider variety of inputs and so on. Furthermore, for this type of system to achieve transparency, it must track all goods involved at all stages. This is a much more ambitious project than traditional auditing processes, and requires a complex infrastructure of tracking technology, which is likely to be costly. Whether or not it is strictly cheaper than traditional ethical labelling remains to be seen. As always, the blockchain can only be as trustworthy as the data that is entered into it, and making that data trustworthy is still a significant cost.

Furthermore, as with any guarantee of sourcing, consumers must be able to tell the difference between a genuine and a "green-washed" label. A recurring problem with blockchain technology is that it requires a genuine understanding of the technology for it to provide the intended transparency and trust. Consumers themselves can only fully determine the reliability of sourcing if they understand the complex process of blockchain supply tracking.

Traditional ethical or green labels face an issue of trust, not least because of green-washing, where less strict labels compete with stricter ones (Atkinson, 2014). Supply chain tracking systems face a similar problem, where copycats may use the blockchain brand to gain the trust of consumers. Instead of wondering which ethical label to trust, consumers may have to ask which supply chain tracking platform to trust.

Supply chain tracking will only be relevant to the extent that involved companies want to take part. From a business perspective, achieving total transparency might not be attractive. There is a potential tension here, between businesses that want to increase their knowledge about their suppliers, for quality assurance and ethical reasons, and businesses that want to hide this information because they know it will hurt their brand.

4.9. Financial Inclusion and Remittances

There were two projects in this category: Humaniq (2017a, 2017b) and BolivarCoin (2015a, 2015b). These projects intend to use cryptocurrencies as a way to increase financial inclusion, and allow for cheap remittances. While there are a number of services that provide wallets and accessible transfers of Bitcoin and other cryptocurrencies, Humaniq and BolivarCoin both provide their own currencies to fill this function. In any case, these services rely on the continued function of cryptocurrencies, with all the constraints this carries, as outlined above. Using cryptocurrencies for remittances produces additional problems.

The first apparent problem is that of exchange rates. Traditional remittances between countries require currency exchange, unless the countries share the same currency. Crypto-remittances avoid expensive currency exchange services, and costly international money transfers, by trading on unregulated cryptocurrency exchanges. However, in a remittance situation, money tends to move in one way more than the other, typically from labor importing countries to labor exporting countries. If the remittances are made in cryptocurrencies, this would mean that these currencies primarily flow towards the labor exporting countries, pushing down the exchange rate of the cryptocurrency for the local currency. Over time, the value of remittances, in local currency, will fall. To prevent this, there must be a counteracting flow of the same cryptocurrencies. In other words, people must use these currencies to buy goods and services from abroad at the same rate as the remittances flow in. This is an unlikely scenario, unless cryptocurrencies become widely accepted in international trade of all types of goods.

The second problem is that these type of remittances may be cheap in large part because they are unregulated. A large part of the cost of international transfers is connected to regulation (Crosman, 2016). Part of this regulation is necessary to combat tax evasion, money laundering and criminal activities. Complete removal of such regulation would therefore be in conflict with several sustainability goals. If cryptocurrencies were regulated, transfers would cost more as well. On the other hand, a significant part of the cost of transfers is the cash-and-paper nature of transactions (Crosman, 2016), indicating that digitization of transactions can reduce costs. But doing so within the framework of unregulated cryptocurrencies does not appear to be a sustainable solution.

The Humaniq project tries to fix some of the apparent problems with regular cryptocurrencies, such as the tendency for the rich to get richer via mining or minting. Intended as a cryptocurrency adapted to the needs of poor people, it limits the amount that any one person can mint, promoting an equal distribution of assets. However, this does not address the question of whether cryptocurrencies are viable as stable currencies in the first place. Given the volatile nature of crypto-assets, it seems unwise for poor people to use them as currency. Furthermore, the equalising effects of Humaniq depends on it being widely adopted, even among those who would effectively be losing in relative wealth by its equalization of assets.

Given that cryptocurrencies are voluntary, this would require a great deal of idealism on part of the richer half of the world. If Humaniq only attracts the poor, and is only used among them, then its redistributive effects will only be among the same poor.

4.10. Voting and Open Organizations

There were three projects in this category: Agora (2017a, 2017b), followmyvote.com (2014, 2018), and Colony (2019a, 2019b). Projects in this category use blockchains to enable voting and decentralized organizations. Agora and followmyvote focus on building a blockchain-based voting system that can be used in national elections. The purpose of Colony is to allow 'peer-to-peer organizations' to be built, using principles inspired by market principles. Agora and followmyvote require cooperation with states in order to make the elections on the platform official. Trusted authorities are required to establish identities, lists of eligible voters and candidates or options. As with all blockchains, the data on the ledger can only be trusted insofar as the data that is entered is correct in the first place.

One of the proposed sustainability affordances of blockchain voting is that it can guarantee free and fair elections. However, in cases where the government is corrupt or does not want free and fair elections, application of this technology is not likely to help. Such governments are not likely to agree to these systems in the first place, and if they are, their required input of external data could be misused. In case the system was implemented, and then abused, international observers would potentially have better proof due to increased transparency. However, one must note that international observers are already often able to point out that elections have been unfair, but their critique may be avoided or ignored by the government (Hyde & Kelley, 2011). If, however, one believes that election fraud is more common that what observers have shown, then these solutions could prove useful.

Regarding the open organizations of Colony, it is beyond the scope of this article to evaluate how well such organizations can function. There are potential sustainability affordances, if such organizations allow for a more democratic and equal society. However, it should be noted that the way this project intends to break down hierarchies is to replace it with a market-inspired system where "smart contracts distribute ownership according to the value each individual contributes" (Colony, 2019a). In other words, the democratic principle of one person one vote is replaced by a meritocratic model of influence. Since Colony relies on public blockchain technology, it is susceptible to the sustainability constraints of such blockchains and cryptocurrencies. Running a similar model using permissioned blockchains would possibly defeat the purpose of open organizations.

Digitized voting can reduce costs and possibly improve transparency where the state is already willing to take a path of improving democracy. In this case, blockchain based systems could be a way to make digitized voting more secure and transparent. However, public blockchains using either proof-of-work or proof-of-stake models of consensus are potentially vulnerable to attacks, making them unsuitable for such high-stakes systems. Since these systems require trusted authorities, in government and in the form of active independent observers, it is not clear why a permissioned blockchain or equivalent distributed database system can not be used. By using public or hybrid blockchains, Agora and followmyvote become dependent on using cryptocurrency tokens. Connecting elections to potentially volatile cryptocurrency markets puts the stability of these systems at risk.

Blockchain technology can provide technical transparency, but as has been discussed above, this is not necessarily the same as democratic transparency. The transparency of a system is limited by people's understanding of the system, and resources used to monitor activities in it. Such transparency could be achieved, but this requires trusted institutions that can monitor and explain what happens on the blockchain to the general populace. In the case of countries with lacking democratic institutions, this could be a problem. As with supply chain tracking, there is the risk that dishonest governments use the blockchain brand to legitimize dysfunctional systems. For people in general, telling the difference between a good and a bad blockchain voting system would be difficult, and people would have to rely on some trusted authority, like the government, academics or international observers to know if they can trust the system. Without an educated and engaged citizenry, technical solutions will arguably have little effect.

4.11. Labor Contracts

There was one project in this category: Handshake (2017, 2018). This project seeks to build a system for storing and managing labor contracts, using blockchain technology. When stored in the blockchain, contracts can not be altered, and workers, employers, agents, lawyers and authorities will have access to the same text. Furthermore, the blockchain allows for a censorship resistant way for workers to raise complaints against employers or agents. In this way, workers' legal and contractual rights can be protected. This could be especially important for migrant workers who are often tricked and exploited by employers.

There are a number of issues with this concept, regarding to how the theory of the solution reflects on the theory of the problem. For example, the whitepaper claims that the platform "removes trust required" (p.6) between employers and government agencies and between government agencies and recruitment agencies (Handshake, 2017) Whether or not employers live up to their end of such a contract can not be enforced by blockchain technology or smart contracts. For example, how would the system know what the actual working conditions are or the number of hours worked? Resolving such matters relies on the experience and testimony of workers, and involves a great deal of trust.

Regarding the core functionality of the system, the whitepaper states that "... employment contract processes and terms are subject to corruption, fraud, forgery, and delays resulting in exploitative work environments for international migrant workers." (p.7) (Handshake, 2017) In other words, the problem theory is that the problems in the contract process result in exploitative work environments. However, fraud in the contract process is arguably a symptom, not a cause. The core problem situation is that the workers in question are highly vulnerable on the labor market, and easily exploited by both recruitment agencies and employers. This indicates that labor is in high supply, and jobs are relatively scarce, allowing employers and agencies to set the conditions. In this situation, what are the incentives for "shady" employers or agencies to agree to this system or use it honestly? As long as employers have access to a large number of desperate workers, there is little need to attract workers by being ethical. For Handshake, there are employers that are "[c]ommitted to recruit migrant workers ethically but [have] no system to track recruiting process." (p.8) (Handshake, 2017) The system depends on the goodwill of employers.

One interesting aspect of the system is that it will have a reputation system that allows for workers to rate agencies and employers. This could be useful, assuming that workers have the ability to deny work because of an employers' bad reputation. Workers may know of the risks of particular employers or agencies, and still be economically compelled to work for them. But even in that case, a reputation system could allow some workers to avoid the worst employers. A public/private key system could increase the reliability of ratings, by making sure that they come from existing workers and not made up identities or employers. However, a secure rating system does not require the full set of blockchain features. In particular, the use of public blockchain technology puts the system at risk, given the potential for attacks and the debatable viability of cryptocurrency economies.

In order for a system like this to have any impact, cooperation with the government is necessary, and Handshake seem to recognize this. Like with land registry and voting, if the government is corrupt, blockchain will have a limited impact on the reliability of the system. If the government is not willing to protect the rights of workers, storing contracts in the blockchain will have little to no effect. While the system claims to remove the need for trust, the need for external data means that it requires trust, and only a limited formal part of the labor-employer relationship can be ‘objectively’ stored in the blockchain. Also, the issue of technical vs. democratic transparency is relevant: how are migrant workers supposed to know what blockchain system to trust? The peer-to-peer transparency of blockchain systems presumes a high level of technical knowledge among users.

4.12. Currency to Fund Social Good

There was one project in this category: CarbonCoin (2018a, 2018b). This project represents a variant of cryptocurrency that hopes to work towards sustainability goals without using incentive structures or tokenized impact. Instead, the idea is that the constantly rising value of the currency will be used to fund the planting of trees. The intended model has changed over time. In one version, an amount of tokens would be held in a trust, and gradually sold off to finance tree planting as its market value increased. In another version, transaction fees would go to a fund for tree planting efforts. The promise behind CarbonCoin is that 90% of transaction fees are used to plant trees.

The core assumption behind this project is that cryptocurrencies can generate wealth, and that Bitcoin proved that “money is not an issue”. However, as has been discussed in the section on cryptocurrencies, it is doubtful that Bitcoin has proved any such thing. Unlike Ethereum or other platforms, CarbonCoin tokens have no other use than as a currency.

While the developers agree that speculation and criminal darkweb activity was essential to produce the initial demand for Bitcoin, they believe that cryptocurrencies can survive without such dependencies. However, no clear theory of alternative value or demand is presented. Given the large number of cryptocurrencies available, the only reason to adopt CarbonCoin would be if users were willing to pay a ‘tax’ on every transaction that goes towards planting trees. If people are willing to do so, it can be accomplished without a cryptocurrency. The assumption that CarbonCoin can create wealth is entirely baseless: a currency can only transfer wealth, not create it.

A project such as this required that the trust or fund in charge of planting trees is a reliable organization. At the time of creation, the commitment to planting trees appeared to be little more than a promise. As of now, the system having largely gone off the Internet, it is unfortunately unlikely to engender trust.

5. Conclusions

The concept of “Blockchain for Good” in a sustainable development context is based on an assumption that the apparent problems with blockchain technology, including cryptocurrencies, can be overcome by novel implementations. Numerous blockchain initiatives have sought to address these concerns and make meaningful contributions to development. In this paper, we do not mean to question the motives of the people undertaking these efforts; rather, we applaud them for engaging with this critically important domain. However, this overview of 28 projects has not found evidence that the central worries surrounding cryptocurrencies and other tradable blockchain tokens have been overcome in this context. Issues regarding energy consumption, security, criminal usage, lack of democratic transparency and tendencies towards centralization still remain. Not only are these projects vulnerable to many of the same critiques as Bitcoin, but the logic by which they purport to promote sustainable development can be contested on several accounts.

This is not proof that cryptocurrencies can not be used for ‘good’. This study has been an exploratory overview, not an exhaustive analysis, and only a non-representative subset of projects have been evaluated. The results also say little about the concept of “Blockchain for Good” outside cryptocurrencies, except to the extent that public blockchains depend on cryptocurrencies to function. Another significant limitation is that our data consists largely of the developers’ published intents, not of observations of the implementations in practice.

Although the included projects are not a statistically representative sample of ‘for good’ cryptocurrencies, it is interesting to note that all of the projects fit into a conservative conception of sustainable development, which may protect a market-focused status quo rather than challenge it. As Crouch (2012) notes, “...normal market relationships between producers and customers are not equipped to cope with issues of long-term sustainability” (p. 365) given the interests in maximizing gains now as opposed to the uncertainties of the future. This may be a general tendency for all technological solutions to sustainability problems, or it could be that blockchain technology in particular does not easily lend itself toward reformist or transformative change. However, as suggested by (Scott, 2016), it could also be because the blockchain community has right-wing libertarian ideological tendencies. But if that is the case, one must ask if that is because the potential affordances of blockchain technology are especially attractive for this community. For example, abstract decentralization is not considered universally ‘good’ across the ideological spectrum.

In this paper, we have argued that discussions about the sustainability of technologies need to take a holistic sustainability perspective, be aware of different conceptions of sustainability, and place at least as much weight on constraints as on affordances. We hope to have demonstrated that such an approach is possible and urge future researchers to take these factors into consideration. Blockchain practitioners who wish to promote sustainable development would also be well served by viewing their own projects through different lenses of sustainability. For blockchain-based platforms to be effective in the development context, developers of these systems must be sensitive to this critical set of concerns.If commonly held conceptions about sustainability are not critically evaluated, there is a risk that well-meaning efforts will produce counter-productive or even dangerous results. Blockchain technologies propose to transform the ways in which people interact with many computational systems, both financially and otherwise; while the urge to harness this new technology for good is admirable, it is not clear that blockchain lends itself to sustainability initiatives any more than any other general purpose technology.

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