The Blockchain and the Commons: Dilemmas in the Design of Local Platforms

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ABSTRACT

This paper addresses the design dilemmas that arise when distributed ledger technologies (DLT) are to be applied in the governance of artificial material commons. DLTs, such as blockchain, are often presented as enabling technologies for self-governing communities, provided by their consensus mechanisms, transparent administration, and incentives for collaboration and cooperation. Yet, these affordances may also undermine public values such as privacy and displace human agency in governance procedures. In this paper, the conflicts regarding the governance of communities which collectively manage and produce a commons are discussed through the case of a fictional energy community. Three mechanisms are identified in this process: tracking use of and contributions to the commons; managing resources, and negotiating the underlying rule sets and user rights. Our effort is aimed at contributing to the HCI community by introducing a framework of three mechanisms and six design dilemmas that can aid in balancing conflicting values in the design of local platforms for commons-based resource management.

Author Keywords
Blockchain; commons; governance; design dilemmas; platformization; energy community.

CSS Concepts
• Human-centered computing~Interaction design theory, concepts and paradigms

INTRODUCTION

The commons consists of a wide variety of self-organized social practices that enable communities to manage resources for collective benefit in fair, inclusive, sustainable and accountable ways [52]. As a system of provisioning and governance, the commons enables participating members to collectively control the spheres of everyday life that matter to them and to make their own governing decisions [12]. There are different types of commons, which Navarro et al. [46] categorized into three: (1) natural commons (e.g. seed sharing communities, water preservation communities), (2) immaterial commons, in which knowledge and code are owned collectively and produced collaboratively (e.g. Free/Libre Open Source Software projects, open access scholarly publishing), and (3) artificial material commons, which are complex systems where peer production is applied to build some specific resource pool or system as an infrastructure. In this paper, we focus specifically on artificial material commons, which spans from hackerspaces and Fab Labs, to community infrastructures, peer-to-peer economy services, and energy communities.

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As communities grow increasingly complex, it becomes more difficult to understand all the participants' contributions to and consumption of the commons. The complex, multiple and often anonymous relationships of contemporary urban societies also preclude Ostrom's condition of clearly defined community boundaries needed for successful commons management [52, 54]. This could easily contribute to a "tragedy of the commons", in which participants reap individual benefits at the cost of collective resources, leading to the demise of the commons [36].

Distributed ledger technologies (DLT) may have some affordances to overcome this tragedy. They are well placed to play a fundamental role in registering resource production, usage, and transactions; keeping track of account balances; and managing identities and rights. In other words, they could cement technologically mediated trust between participants. Moreover, with the addition of smart contracts, distributed ledgers are set to play a role in the automated processing of data and conditional execution of transactions through algorithmic governance. Distributed ledgers can thus be understood as decentralized databases with built-in verification schemes that allow for immutable record storage and link these to automatic transactions.

Currently, blockchain is a widely discussed instantiation of this technology. Its proponents argue that blockchain enables self-organized ways to make decisions on service provision and administration [2, 13, 57]. Although much hopes are projected on the blockchain as a new tool for civic self-organization or governing the commons, we identify two significant gaps in the current discourse: First, so far we lack a critical analysis of the implications of applying blockchain for managing the commons. Whereas some of its affordances may be beneficial in the set-up of systems, others may in fact be detrimental. We are concerned about the social consequences of an uncritical application of these technologies. Technologies are not politically and ideologically neutral [47], neither are blockchain-based systems. Indeed, they present affordances that could challenge existing value sets and raise questions about ethics, privacy, and the sociopolitical implications of new forms of distributed authority [47]. To understand these positive and negative affordances better, a systematic exploration of the blockchain technology and its principles is needed. The second gap we have identified is the lack of design principles that translate the affordances into concrete guidelines for the creation of blockchain-based systems to manage an artificial material commons.

To address these gaps in design knowledge, we present a critical conceptual investigation of the affordances offered by blockchain applications to communities contributing resources to the commons. This critical and reflective examination of the affordances can be situated in the broader "digital civics" agenda, which weaves together computation and contemporary "matters of concern" such as the nature of governance, politics, and government [25]. We will structure our discussion by introducing a fictional community that uses a blockchain-based digital platform to govern a decentralized and distributed community energy system, which can be considered as an artificial material commons. Distributed energy, microgrids, and energy communities are emerging topics in the advent of new energy infrastructures, and they offer a rich space for innovative and important HCI contributions [56]. Furthermore, they serve as an excellent potential area for the implementation of blockchain [37, 44, 57, 60].

Much hype is surrounding DLT—specifically blockchain—as an "ideal tool" for governing commons. Our goal is not to investigate how this ideal can be realized, but rather to make its affordances, as well as limitations, tangible for the HCI community in the form of design dilemmas. To this end, we will first offer an overview of some foundational concepts related to the commons and blockchain-based technologies, which will be followed by the introduction of the fictional case. We will then present a set of "design dilemmas" derived from the fictional energy community that could support designers in reflecting on the set-up of a blockchain-based platform for local communities. Finally, we generalize our findings beyond energy communities to other types of artificial material commons, and we offer some initial concerns about how to design for them.

RELATED WORK

The commons and the blockchain

The Nobel laureate Elinor Ostrom is generally praised for having rescued the commons from the memory hole to which mainstream economics had consigned it [12]. Her work shows how, under certain conditions, commons can be managed in a sustainable way by local communities [52, 53]. Through extensive fieldwork, she proved that individual agents do not operate in isolation, nor are they driven solely by self-interest, as typically depicted in market economies.

Ostrom's work was mainly bounded by the mechanisms of the natural commons. It revealed how effective institutions of private governance could create *small-scale* cooperation, which is entitled as Commons 1.0 [52]. Commons 2.0 has developed over the past decades to cover the immaterial commons of knowledge and code. Here, it was shown that publicly observable reputational mechanisms could overcome the free-rider problem and generate cooperation in the production and maintenance of public goods at a *larger scale* [22]. Commons 3.0 requires a solution to the problem of cooperation in joint production *at scale* while still maintaining the benefits of commons-type decentralized governance [22]. This is where DLT and blockchain come into play.

Blockchain is a distributed database with a growing list of data records that are confirmed by the nodes participating in a network [78]. The "blocks" in blockchain store a set of transactions of digital assets [59]. The blockchain is extended by each additional block, and therefore, it represents a complete ledger of the transaction history [49]. When a transaction takes place, peer nodes validate it and the data is recorded on a public ledger. Once all nodes have approved the data, the public ledger cannot be modified or deleted [49, 78]. Zheng et al. [79] describe the key characteristics of blockchain as being *decentralized* (i.e., a transaction in the blockchain network can be conducted between any two peers without the authentication by a central agency), *persistent* (i.e., as the data is validated by nodes, falsifications are detected easily), *anonymous* (i.e., users can interact with the blockchain network with a generated address), and *auditable* (i.e., as each transaction is validated and recorded with a timestamp, the data is traceable and transparent).

These characteristics have initially supported cryptocurrencies, primarily Bitcoin. However, the worth and significance of the blockchain does not depend upon the value and prospect of Bitcoin [16]. Rather, the blockchain is better understood as a new "general purpose technology" [39] in the form of a transparent, resilient and efficient public record keeping. It can be applied to a wide variety of circumstances in which a community of players—whether in markets or commons—want reliable systems to manage their interrelationships on network platforms [13]. Because of the way it distributes consensus, the blockchain routes around many of the challenges that typically arise with distributed forms of organization—issues such as how to cooperate, scale and collectively invest in shared resources and infrastructures [50].

The use of blockchain technologies to facilitate governance processes has begun to attract the attention of social scientists [64] and some scholars have started to explore the affordances of the blockchain specifically for the governance of the immaterial commons. For instance, Rozas et al. [65] investigated the governance of Commons-Based Peer Production (CBPP) communities via blockchain. Based on their extensive comparison of blockchain properties and CBPP properties, they concluded that the blockchain has a strong potential to foster the governance of these communities. Another project is the "Backfeed", which features a blockchain-based solution supporting massive open-source cooperation without any form of centralized coordination [22, 23, 55]. Swarm City is a new decentralized sharing economy platform, in which every developer can program her own governance rules [6].

The blockchain: fundamental mechanisms and affordances

When we look at the literature, three sets of core affordances of the blockchain can be deduced, which we have labeled as *mechanisms*. This is a central term in platform studies that alludes to the ways in which technologies and user practices reciprocally shape social and economic relations [76]. Mechanisms can be understood as actualizations of technological affordances in specific use contexts, and are therefore apt for a model to critically and reflectively explore the ways in which a technology such as blockchain could contribute to the formation of artificial material commons. We discerned tracking, managing and negotiating as three important mechanisms.

First, the blockchain as a transparent, immutable database allows for the administration of transactions, rights and identities. For this reason, blockchain-based systems are particularly suited for *tracking* the resource use and how participants contribute to a shared initiative. This allows communities to provide openness about contributions on a public ledger.

Furthermore, platforms built on top of blockchains are also well suited to *managing* the day-to-day upkeep of a shared system. Indeed, such systems enable the delegation of decision-making, monitoring, and evaluating achievements according to the rules encoded in algorithms. The most prominent way to achieve this delegation is through "smart contracts": digital, computable contracts where the performance and enforcement of contractual conditions occur automatically, without the need for human intervention [51, 77]. There are a number of initiatives in this space, including widely available implementations such as Ethereum, Ripple and Mastercoin. Ethereum, for instance, builds a generalised framework that extends the capabilities of the blockchain to allow developers to write new consensus applications [50]. Smart contracts bring the ability to choose and encode a particular set of conditions linking every interaction to specific transactions (i.e., the assignment of cryptographic tokens or the allotment of micro-payments). Therefore, they enable the design of new and sophisticated incentive systems that could improve the collaboration and cooperation of commons-based communities. As such, these smart contracts could play an important role in the governance of blockchain-based digital platforms.

Lastly, there is some preliminary work on how blockchain systems may support users in *negotiating* some rules. While smart contracts automate decision-making, initiatives in blockchain-based commons governance like Backfeed and Commoncoin include the possibility of human intervention in these processes. Negotiable and transparent transactions and decision-making procedures allow the commoners to override the rules when necessary, and make it easier for communities to reach consensus with protocols such as voting. As smart contracts are pre-emptively written, these moments of intervention allow a community to deal with unexpected situations and changing community values.

HCI and blockchain

While many of the challenges related to blockchain may be perceived as technical or infrastructural, these technologies have the potential to profoundly impact human experience [27]. Blockchain being still in its infancy, Foth [29] makes a call-to-action to the HCI community to investigate the ways blockchain would be introduced and integrated into society. He invites the explorations of possible futures across a utopian–dystopian spectrum that depicts the implications of blockchain inspired scenarios. Our effort is in line with this call and aimed at challenging implicit assumptions from the blockchain discourse for governing the commons.

So far, there is a small but emerging body of research in HCI concerning blockchain. The majority of this work focuses on monetary transactions [e.g. 33, 38, 66, 67], which is typically entitled as Blockchain 1.0 [73]. Recently, Elsden et al. [27] provided a comprehensive review of blockchain application areas that move beyond money and finance, which is called Blockchain 2.0 [73]. In this emerging area, Nissen et al. [48] explored the implications of emerging and future technologies using the lens of Distributed Autonomous Organisations (DAOs) and designed the 'Geocoin' [47], a location-based platform for speculative ideating with smart contracts. Pschetz et al. [60] created a set of artifacts to engage people in debates concerning distributed energy systems that employ smart contracts. Elsden et al. [28] explored the implications of automated donations for charities, while Chiang et al. [18] designed a blockchain-based system for Mexican immigrants in the US to improve their trust in the local governments.

This paper shares the vision of using smart contracts in managing certain elements of everyday life, yet implements them to a wider context of communities and their daily transactions. In this research line, Reshef Kera et al. [62] created a design fiction scenario around a village that is managed by a drone and blockchain in order to investigate the blockchain's anticipatory governance potential. This highly fictional project provides a sound start for addressing the diffusion of blockchain into the field of justice and governance, which is entitled as "Blockchain 3.0" [73].

Blockchain 3.0 is a "world still a way off, but it is a rich horizon worth exploring" [13]. More research (preferably based on realistic scenarios) is needed in the area of governance to envision such futures. The step to the actual design and implementation of blockchain-based platforms for the governance of artificial material commons requires resolving some actions. In the rest of this paper, we will focus on some of the challenges that need to be addressed when making this move from Blockchain 2.0 to 3.0.

DESIGN DILEMMAS OF USING BLOCKCHAIN FOR COMMONS GOVERNANCE

A thought experiment

So far we have focused on the work that explored the potential of using blockchain technology for the management and governance of a commons. In this section, we will turn a critical eye and bring to light the dilemmas that could arise when setting up blockchain systems in the context of artificial material commons. In order to discuss these design dilemmas, we turn to a "thought experiment" [26], in which we imagine the case of a fictional commons with a decentralized community energy system that is managed by a local platform based on a blockchain ledger. We call our case "fictional" as it does not exist in its totality, but not because it is impossible; indeed, it is based on concrete, existing examples of projects described in HCI literature.

As we lay out our thought experiment, we point at some significant similarities and differences with other fiction-based methodologies in HCI. We find numerous points of contact with Blythe's work [8, 9], as we leverage fiction as a narrative technique to structure our argument and as a way to construct a use case that is plausible although not real (yet). Additionally, we follow Tanenbaum [69] who argued, "Situating a new technology within a narrative forces us to grapple with questions of ethics, values, social perspectives" (p. 22). On the other hand, even though we imagine a possible but not entirely real case, we do not present our work as Speculative and Critical Design [3] or as a Design Fiction [34, 70]. Although we write some fiction as part of our thought experiment, we use the narrative as a critical lens to bring certain affordances into focus, rather than presenting it as an outcome in itself. As we do so, we align with other HCI works borrowing critical methodologies from the humanities, such as discourse analysis and hermeneutics [4, 70, 71].

The use case

Researchers have already been experimenting with a coupling between energy communities and blockchain (e.g. [37, 44, 57, 60]), and the first real world demonstration projects using blockchain for logging energy transactions have already started (e.g. Brooklyn Microgrid project, PowerLedger, and GridPlus). Elements of these examples were composed to form an integrated blockchain-based platform. In our fictional system, a group of neighbors in a community are both producers and consumers of solar energy. They have installed photovoltaic cells and use blockchain as a way to create distributed networks of solar power on residential houses. Here, we would like to highlight that such an energy sharing system would not absolutely need the overhead of blockchain technology. It could also be implemented with a traditional client-server based model. Yet, using the blockchain architecture in the backend instead of another authenticated data structure would serve well to discuss the implications of designing DLTs for the governance of artificial material commons.

The three mechanisms that we have identified above will be used for a structural exploration of opportunities and challenges in the realization of such a platform. *Tracking* is a key mechanism for energy platforms. Each household has a smart meter, which accounts and registers the generated energy in the blockchain [37]. The ledger keeps track of how much energy a given household has generated and consumed. The smart meter data is represented to the residents on the local platform, which informs them about their energy usage, the self-sufficiency of the community, and the sources of their consumed energy [44].

With regard to *managing*, the smart contracts automate payments and negotiations according to predefined parameters. Instead of each residence generating and using its own energy, and each suffering the consequences of over- or under-production, the fluctuations of the supply and demand is evened out by providing energy to a common-pool and computing a distribution of energy using the algorithmic governance of blockchain [57]. In peak energy demand situations, the system uses smart contracts based on preset values to determine how power can best be distributed.

As the system transparently administers energy generation and consumption, smart contracts also support incentivization and rewarding the commoners with a "community currency". Community currencies refer to an agreement to use something else than legal tender (i.e., national money) as a medium of exchange [41]. In our scenario, the community currency is given out by the algorithm based on the smart contract or transferred from one commoner to the other. These can be spent on a range of opportunities offered by local businesses, or on trade assets such as labor, material goods, knowledge and skills with each other. A household's community currency balance can be seen at all times in the local platform.

Finally, our system also provides commoners with possibilities for *negotiating* rights and exceptions. The system offers flexibility on how much autonomy they would like to ascribe to the smart contract algorithms and provides opportunities to cancel or change the rules [1, 60].

In the remainder of this section, we will describe our exploration with regard to these three mechanisms in the context of artificial material commons governance and management. Derived from a synthesis of findings from case studies, literature on blockchain affordances, and our critical speculations on "blockchain futures", this exploration had resulted in a series of *design dilemmas* operative in each mechanism. These are potential clashes between blockchain's positive affordances for the enactment of artificial material commons and those that may undermine them.

These dilemmas are not so much binary options, but rather ends of continua. There is also no such a thing as the "right" answer in solving these dilemmas. Each local community wanting to organize a commons would have its own preferences, and different types of resources or circumstances that would call for different answers. However, in each instantiation of blockchain technology, designers and the communities they design for would need to find a balance with regard to these conflicting values in ways that suit them best. In that way, these dilemmas serve as a checklist or canvas for designers to make sure that they give these dilemmas sufficient thought in their application of blockchain technology. Table 1 gives an overview of the dilemmas we identified, which will be described in further detail below.

Mechanisms	Design dilemmas
Tracking	1. Transparency vs. Privacy
Managing	2. Economic value vs. Social value
	3. Quantified vs. Qualified values
	4. Incentivisation vs. Manipulation
	5. Private vs. Collective interests
Negotiating	6. Human vs. Algorithmic governance

Table 1. A summary of the design dilemmas operative per mechanism.

Tracking

Monitoring is an essential aspect in the management of a commons [52, 53]. A successful commons needs ways in which community members or their representatives can keep each other accountable for their use of and contributions to the commons. The mechanism of tracking could play an important role in this, as it revolves around collecting, registering and representing data from the members of the artificial material commons.

In our fictional case, there are various types of data that are being tracked. The amount of energy produced and consumed at each household is tracked via the smart meters. The number of tokens that are gained and spent are also registered at the platform. The ledger records the transactions operated via smart contracts, such as energy and token exchange. Additionally, third party software could also be attached to the energy microgrid to provide residents with extra information that might affect their energy use behavior, such as real time data on weather forecast [1] and fluctuations in the energy market [21].

Design Dilemma 1: Transparency vs. Privacy

Blockchain infrastructures can support the need for monitoring by providing full transparency of data and transactions. Transparentisation refers to the process of making the organizational processes and the associated data visible by building upon the immutability of blockchain [65]. Transparency can help to identify who contributes the most to the common goals or who uses more resources, so that the community can decide to reward/recognize the contributors and penalize excessive users or free riders. This visibility also provides an accountability for the governance rules of the commons: Each member can assess if they are treated fairly according to their contribution level, provided by the consensus-driven, publicly auditable ledger.

However, one should be wary of the limitations of this transparency. Rozas et al. [65] places this discussion into the more general one of privacy. In such scenarios, it is relatively easy for individual concerns to become visible to everyone. It has already been demonstrated that the high-resolution electricity usage information captured by the smart grid and smart metering technologies can reveal many intimate details of one's life [61]. Even if the members of a closed community are in agreement to share these details with each other, it may become problematic when third party software would be attached to their system. In addition to this issue, in our scenario, energy distribution is negotiated via smart contracts. Let us assume that there is a peak demand for energy during the night of an important sporting event [14] and the capacity of the microgrid is not sufficient to handle this demand. The energy distribution algorithm needs to reduce the amount of energy consumed by taking decisions on which households to prioritize. If a member suffers from sleep apnea which requires him to wear CPAP mask when sleeping, to what extent would he be willing to share this personal information with the whole community to get prioritization for his energy use at that moment?

To deal with stewardship and privacy concerns of the community-based data, solutions such as encrypting parts of a dataset, making data available for limited periods of time, or linking it to a specific agenda that the data associated with have been proposed [74]. However, such solutions do not apply to the communities governed by the blockchain as blockchain's records are open and immutable. Extreme transparency in the context of self-governance of commons raises the questions of: what kind of information should be permanently stored and which one should not? Also, how well are people able to understand or predict the implications of sharing their data, and formulate rules for smart contracts about their preferences [27]? The HCI community might explore further and experiment to determine the limits and how to accommodate transparency of blockchain in the daily practices of the commons-based communities.

Managing

The managing mechanism is about the rules of the smart contracts in the context of the commons. In a successful commons, the members build protocols and rules that ensure the sustainability of their resources, assign rights, obligations, and commitments and define penalties for transgression [52, 53].

Rozas and his colleagues [65] identified "tokenization" to be one of the key affordances of blockchain that would foster the self-management. Tokenization refers to the process of transforming the rights to perform an action on an asset into a transferable data element (named "token") on the blockchain [65]. In the Bitcoin blockchain, the term token is used as an abstraction of the actual coin, i.e., the cryptocurrency being transferred among users. However, the creation of tokens is inherent to how the technology is constructed. Tokenization serves as the basis for the systems where data, information, an asset, time, or anything that could have value in a particular context can be exchanged with a token [68].

In the context of our energy community, we can envision the use of tokens to granularly define the contribution level of each member to the community, propagate or revoke rights (e.g. those who produce a certain amount of energy per day gets the priority during peak shaving time), and reward certain tasks (e.g. upkeep of the system).

Design Dilemma 2: Economic Value vs. Social Value

Tokenization brings forth certain limitations, of which the first one challenges the value sets operative in a community. In a market economy, the key concern is to assess the economic value of things through a supply and demand mechanism [23]. After the industrialization, money became the primary commodity acquiring exchange value and the concept of value had become almost interchangeable with price (see [55] for a comprehensive history of value perceptions in economics). The exchanges within the commons, however, are mostly based on the agreements that the members make with each other. Without the traditional system of pricing, one can no longer rely on a universal unit of analysis that can be used to assess and compare value [55].

This situation requires the commoners to agree on the expenditure of the tokens, which might be problematic. For instance, Dyne.org created a "social wallet" for the Commonfare project, that is an API to help communities to keep track of their token collection. Every member of the Commonfare community is required to earn a minimum number of tokens by making a contribution to the community, e.g. bringing someone's order home or cleaning the communal toilets in exchange for a number of tokens. However, one of the biggest questions identified during the tests of the wallet was who determined which tasks cost which number of tokens [19].

The timebanking system, which is a community-based organization providing a framework for giving and receiving services in exchange for units of time [15], addresses this issue by valuing everyone's time equally. In a timebank community, one hour of time helping another member of the network equals one time-unit, which can then be used to buy an hour of someone else's time [17]. Therefore, a person's hour spent painting other's garden fence is as valuable as another person's hour spent giving legal counselling on filing a complaint against an employer. Shih et al. [72] had found out that timebank members struggle strongly with this ideal, because the perceived value of certified skill labor is assigned by money. Although timebanks give social recognition to civic activities and fulfill social and communal needs that demand lower levels of specialized skills, the utility of an alternative currency such as time dollars depends greatly on the values that are pegged into the universal monetary system [72].

Another way to tackle this challenge was offered by aforementioned Backfeed [22, 24, 55]. Backfeed is a generic protocol layer that sits in-between the blockchain infrastructure and the actual applications that are deployed on the blockchain. It enables assessing, comparing, and communicating the value generated by the commoners through a new consensus protocol named "Proof-of-Value" (PoV) [24]. PoV was set against the Bitcoin's Proof-of-Work (PoW) consensus algorithm—the process of verifying the transactions on the blockchain. In PoW, all computers in the network compete to solve the puzzle generated by the transaction (named "mining"). The first to solve it verifies the transaction, creates a new block on the chain, and earn a reward. PoW is driven by economic values and ultimately relies on how much computational resources have been donated to the network. PoV, on the other hand, rely on human evaluations in order to discover the value of every contribution [24].

Backfeed's PoV protocol consists of two components: a peer-to-peer evaluation system used for determining the perceived value of each contribution in a decentralized fashion, and a reputation system that allocates influence according to the value contributed and the alignment with the overall perception of value of the community [22]. By this way, Backfeed constitutes a proxy for social value of the individual actions in the commons ecosystem [24].

In our energy community, this issue plays at multiple levels. First, consensus would be needed about the value assigned to the production of units of energy. Will this value be coupled directly to prices at energy markets outside the local commons? Or will contributions be administered through a local community currency? If so, how is the value set and to what extent is it variable? Is a unit of energy consumed or produced at peak times worth more than those used at off-peak hours? And which social values should be encoded in such a local system? Would contributions to the commons as a whole, for instance in doing maintenance work, be rewarded with the same community currency, and how will the values be assigned to this? And to what extent should the community currency be applied to other social or economic services that residents offer to each other?

Each of these questions can be resolved by specific protocols, yet these also come with their problems. Such systems would require constant monitoring of everyone's actions in order to constantly update the reallocation of tokens and reputation according to the perceived value of offers and contributions. Here, questions regarding whether every action needs to be assessed and how to deal with the cumbersomeness of a constant assessment arise.

In any community that is based on commons, many value flows and transaction exists, both in terms of resources, as well as social interactions at different levels (individual, family, neighborhood). HCI community might investigate what value sets and flows look like in a particular community, and which ones are fit for tokenization as economic or social values, as well as think of systems to assign particular values and rights to particular contributions or resource usage.

Design Dilemma 3: Quantified vs. Qualified Values

The blockchain as a system favors things that can be quantified. Designed as a way to route around centralized authority and to facilitate globalized trust through cryptography, the influence of human subjectivity and relations have been minimized in blockchain technology [75]. The tokens represent a generic and measurable unit of value, imbued with the rules of the network that issued them [55].

Many blockchain applications, therefore, entail a formalization of transactions, in previously informal and unaccountable domains [27]. Creating countable representations of contributions and participation in a community through tokens, social relations are made explicit, formal, and standardized where they were before fluid, personal, and implicit. Using only accountable transactions, however, revealed to be de-valuing the forms of contribution based on altruism, idealism, and social responsibilities. For example, during the pilot experiment with their community currency design, Batterink, Kampers and van der Veer [5] had found out that the family members who would be eligible to receive tokens for informal caregiving activities strongly opposed being rewarded at all. Tallyn et al. [68] revealed that the small Bitcoin payment offered by their Bitbarista coffee machine to undertake the maintenance tasks decreased opportunities for people to contribute to a service to the group by doing chores voluntarily. Even the creators of Backfeed questioned whether introducing a formalized indicator for social value would disrupt the values of knowledge commons (such as freedom, sharing, or cooperation) by translating them into quantifiable terms [24].

Outside of blockchain applications, quantification and counting of social interactions has a longer history and has been analyzed for its effects in different contexts of application. Muller [45] illustrated that making the types of contributions that are valued in a system explicit results in people conforming their participation to these already existing categories in order to be legible to the system. While buying groceries for your elderly neighbor might add to your social status or reputation in a community normally, if it is not counted by this system, it will not be visible in its hierarchies. This makes other types of activities, however socially relevant they might be, less valuable and less favorable. This will ultimately lead to a reality in which innovation and creativity are disincentivized, because they stray from the pre-defined categories of value. Additionally, by making situations more immediately visible through quantification, they can be acted upon more quickly. This means that quantification often prioritizes short-term goals.

We must wonder which role the quantifying plays, not only in the governance of the resource, but also in the reproduction of the social relations that facilitate the sharing of the commons in the first place. Tokens can be used to incentivize participation in the commons, but we have to be wary of formalizing social relations too much. When communities start to scale up, this tendency to formalize and hierarchize is often amplified, and market logics start to play a bigger role, undermining the ideals of the commons in the long run [55].

Elsden et al. [27] emphasizes the need for considerable work to be done in unpacking the complex value transactions that blockchain can foster in a way that it reflect, embed or enact social values, especially when it comes to the management of the commons and decentralized governance. Further research in HCI will need to explore what kind of actions should be tokenized and which should be left in the domain of informal sociality, and how communities assess the desirable degree of tokenization in their governance.

Design Dilemma 4: Incentivisation vs. Manipulation

Many blockchain applications are economically and incentive driven, supported by micropayments of a native token. "Wallets" used for conducting token payments do not require validation by a human identity, which means these wallets can be held by non-human entities [60]. Therefore, smart contracts can be employed in systems that use tokens to pay for services that guarantee the performance of actions that are important to the system [68] (e.g. hosting the server for the energy distributing platform), or "modifying the behavior" of the people. Datafied systems will most likely introduce mechanisms to encourage users to temporarily use a resource or refrain from using it in order to optimize the system in realtime. In our energy community, we can easily imagine that the system would offer a certain amount of community currency to the commoners who decrease their energy usage during peak-energy hours.

Although such material gains would be important for some commoners, there is heterogeneity of motivations that drive individuals to participate in community-based sharing initiatives. For example, Bellotti et al. [7] and Hamari et al. [35] investigated the motivations for people to participate in sharing economy, and both found out that reputation is an important external motivation factor in determining participation. Correspondingly, Shih et al. [72] identified altruism and idealism to be the main motivations to join timebanks for skilled people instead of instrumental gains. Collom [20] listed altruistic, idealistic, and social motivations along with instrumental motivations for why people participate in community currency systems.

For these reasons, public recognition for positive behavior may be a more important driver than the material gains when it comes to the communities with shared ideals. This public recognition could be given through the smart contracts in the form of "reputation" points. Reputation currencies can be created by anyone according to an agreed set of rules; and anyone can gain a reputation currency simply by providing value in a recognized system of exchange [41]. Reputation could also be connected to particular privileges or rights.

Again, in our energy community, this situation could play out in many directions. Incentives may be given out by lowering the price of energy during off-peak hours. Alternatively, the commoner who decreased his energy consumption during the peak hours may receive a "master energy saver" badge in his online profile, or be recognized as such on a public screen in the community. Such an approach may even be organized in the form of a competition in which individual households or blocks compete with each other, with their collective energy use being visualized in public spaces or on the online platform (e.g. [14]). People who have saved energy during peak times may also get priority when reserving a vehicle in a car sharing system that is coupled to the grid. Extra points or rights may be earned by helping out a neighbor to insulate his house in order to become more energy-efficient, or by organizing educational meetings in a local school about energy conservation. There is almost no limit to encoding various incentives around collectively defined values into the system, rewarding commoners either symbolically, economically, or with particular privileges.

However, there may be a downside to these forms of social conditioning. To avoid judgments from their peers, users may overtly internalize the rules of the system. Earning badges or achievement may become a duty at a certain point. If a member does not have any badges, he might be seen as an outcast. Incentives, in general, give people some sense of agency, yet at the same time they can be conditioned or coerced by these systems into particular behavior and nudged to conformity with collectively set norms. These systems may thus become rather paternalistic or even oppressive.

Furthermore, as aforementioned in relation to the problems with quantification of values, rewards may also cause the efforts to shift towards the things that will be the most highly rewarded. For example, in the Bitbarista example where financial rewards were offered for maintenance of the coffee machine, there was one necessary task that did not offer a reward: emptying the drip tray. It was found out that drip tray was often left until it was overflowing since the users were waiting for the Bitbarista to offer a reward for completing this task [68].

There is a need to further understand the affordance of incentives and rewards, and explore how self-organized communities may or may not incorporate them in their governance. HCI might investigate further what the incorporation conditions might look like, and how empowering interactions might be developed around them.

Design Dilemma 5: Private vs. Collective Interests

A commons generally involves a group of people working together to achieve some shared objective. A frequent problem that can hinder collective action stems from the fact that group members may also have individual interests, which may be in conflict with the group's shared objective [58]. Which interests to prioritize under which circumstances and how a community makes a trade-off between private and collective interests are complex questions.

If we go back to our energy community, apart from managing the consumption and production of energy, the community might have also set collective goals, such as making a monthly energy donation to a local petting zoo. Let us assume that an unexpected situation like a heat wave created an extra energy need. Some of the commoners want to turn their air conditioners on, while at the same time, the alpacas at the petting zoo needs to be shaven for them to cope with the heat better. As the petting zoo was set as a collective goal, could the algorithms force the power to go out at one or more households, and thus, prioritize the collective goals above the interests of individual households? Is such a situation desirable as it enables the petting zoo to flourish in line with the collective aims or does it actually lead to a paternalistic system that limits the individual liberties? On-demand access to electricity is one of the key wishes of people when it comes to energy use [60]; however, as a society we may have to compromise this wish in the future of dwindling resources and decide how much convenience to trade in return for more sustainable infrastructures [21]. When and how to trade away personal gains for the greater good of community/society is a question to be explored further.

Negotiating

This last example also brings us to the next mechanism. If indeed the collective interest trumps private ones, how could one argue for a temporary exception, given that the rules are encoded in smart contracts? The system may give priority to the energy needs of the petting zoo, or—perhaps more likely—a nearby hospital. Yet, could an exception be made for a household hosting a visiting grandfather, who as an elderly person is prone to suffer severely from the heat wave?

The negotiating mechanism is about creating room for such exceptions and a discussion space against the rules of the system. As Ostrom [52-54] observed, successful commons need efficient conflict resolution mechanisms to maintain the commons. Commoners are usually able to abide by and regulate their behavior according to the rules they set for their communities [12]. However, as it is the case with all rules, these self-defined governance rules are also sometimes broken—either by necessity, accident, or (unfortunately) sheer malice [57]. It is therefore imperative that a blockchain-based system for the commons defines rebalancing methods and resolution mechanisms to renegotiate the rules or plea for exceptions.

Design Dilemma 6: Human vs. Algorithmic Governance

In current legal practice, the law establishes a series of rules that people must obey. Taking the risk of being held liable for any damages, everyone is free to violate these rules since legal enforcement takes place "ex-post", after the act [23]. On the other hand, as opposed to traditional contracts where parties can decide whether or not to fulfill their obligations, smart contracts cannot be breached. The rules embedded in the code would be automatically enforced according to the agreements previously negotiated by the parties involved, and therefore, the parties have no choice but to execute the contract [77].

In effect, the laws and rules coded into a smart contract (e.g. a maximum daily kW limit that one household can use from the shared energy grid), are interpreted and made to have an effect algorithmically (e.g. system detects that a household reached the limit and cuts off the electricity), irrespective of context or other mitigating circumstances (e.g. heat wave) [23]. Code is written in advance of real situations happening, i.e., "ex-ante", and therefore, can only regulate what can be expected.

This situation presents problems regarding the difficulty to define exceptions [23]. Once the code runs, edge-cases will be brutally dealt with by an algorithm that keeps ploughing on. The visit of a fragile elderly family member during a heat wave may not have been foreseen by the designers of the smart contracts of our energy community. So how can commoners rewrite the rules, rewards or their privileges?

New generation blockchain projects such as DAOStack or Aragon provide capacities to more easily upgrade the rules embedded in smart contracts over time. This increasing capacity for upgradability could help to incorporate these exceptions [65]. Another way to deal with such situations is "hard fork", a protocol that makes previously valid transactions invalid or vice-versa [30]. When their DAO was hacked, the Ethereum community almost unanimously voted to carry out a hard fork and reset many of the transactions that were previously carried out, allowing the token holders to take their ether funds back. This kind of "rewriting the history" is already outside of the mental models most people have of how currencies function, and therefore require a significant shift in viewpoint [48]. Furthermore, dealing with situations in which exceptions to the rule have to be made by means of a hard fork is like using a sledgehammer to crack a nut. It requires, in practice, a slightest exception to the rule to be evaluated and voted by the whole community. This joint decision-making might not always be feasible. Hard forks should be seen as a last resort, as they function more like implementing a new constitution and the re-evaluation of essential qualities that go with it, than like an amendment to a law.

As a possible direction to resolve this, the developers of the aforementioned Swarm City suggested a separation between decision management rights from decision control rights, similar to traditional corporations [6]. That is, owning a number of tokens allows having a voting right in the decision-making, while a board of directors (i.e., people appointed by Swarm token holders) does the day-to-day management. As this case illustrates, blockchain could be subject to both instances of centralized as well as decentralized decision making. Rozas et al. [65] argues that techno-deterministic approaches to blockchain tend to assume that hierarchies between the participants in decision-making processes vanish thanks to the disintermediation enabled by blockchain. However, these are over-reductionist accounts with regards to the distribution of power, failing to acknowledge issues such as the generation of oligarchies [65]. Yet, when to apply centralized vs. decentralized decision rights and how to transition from one to another are questions that are still unanswered for the communities [6].

The approaches to bring human agency back into algorithmically governed systems run into a number of issues. First, while exceptions can be coded into the system upon agreement from the community, during the first encounter the rules code would have been applied to the situation at hand, and the new rules will only be applicable the next time [65]. For the visiting grandfather to our energy community, the formal adaptation of a rule to give priority to elderly people may become too late.

In another approach, smart contracts can be designed to be interrupted for human voting on set times or in specific cases, which is called "off-chain governance" [63]. Again, there are limits to this shift of agency to humans. Just like commoners who would not want to be bothered to individually value "every" contribution to the commons, there is a limit to the number of such emergency calls they would want to handle. Furthermore, this situation is also problematic from the perspective of the commoners who ask for an exception. It requires a disclosure of the reason for exclusion, which may violate their right of privacy (see Dilemma 1).

In conclusion, while algorithmic decision-making is fast, the human democratic debate that is central to interpreting and implementing law should not be lost [23]. How this should be done (i.e., who is allowed to decide what kind of things under which circumstances), especially in relation to exceptions that are not recognized as such, is something to be explored further by the HCI community.

DISCUSSION AND CONCLUSION

Ostrom's foundational work already identified eight "design principles" [52] in the context of natural commons, from defining community boundaries to conflict resolution mechanisms and being embedded into the larger systems of governance. However, Ostrom's use of the word "principle" is quite prescriptive and influenced by her background in economics. We identified the lack of design principles for DLT-based community platforms as a hindering factor in their development and adoption. We offer our conceptual investigation as an initial step in that direction. Furthermore, our perspective on using the DLT to govern the commons is nuanced: on the one hand, we recognize its potential to be an enabling technology but, on the other one, we are also wary of its undiscriminated adoption. We feel that designing DLTs should be tempered with a critical outlook on their social effects.

For this reason, we addressed the conflicting design dilemmas that emerge at the crossroads of the blockchain, community platforms, and artificial material commons. Each dilemma brings forth a design spectrum that exists between two extremes. As they are inherently unsolvable, we held a "both/and" stance, acknowledging that different positions could be applicable in different contexts and that careful investigation is needed to assess their impact. This is why we cannot be as prescriptive as Ostrom had been. We can, however, provide a list of concerns stemming from our investigation.

The first one pertains having a human presence in the decision loop. Algorithmic governance where smart contracts are all automatically enforced [77] and there is no "escape button" is ultimately deterministic, with software code becoming substantially equivalent to laws. We see the urgent need for communities to have and maintain control over the rules of the system and how to renegotiate them, similarly to a legislative process that allows the amendment or cancellation of laws. This requires a community culture friendly towards negotiation, discussion and willingness to accept the self-defined rules [2]. It also requires designers to create affordances for social negotiation. This might mean embedding a "kill-switch" to the algorithms or, optimally, creating a system that halts when it detects a conflict and prompts users to discuss, confirm, or amend its rules.

Secondly, we call for more attention to the economic values underlying local platforms for the commons. Specifically, we are concerned with how these values can be made explicit and understandable. Creating an economy where certain elements (e.g. energy produced, services provided, expertise and know-how) have an intrinsic value that can be accumulated or used in transactions is not socially and politically neutral by far. The dilemma between economic and social values underlines the need for careful and critical analyses before designing such systems. Quantifying and tokenizing all contributions is likely to disrupt community relations, whereas a possible solution might lie in the creation of a transparent and understandable way of assigning monetary value.

Lastly, the same transparency should also exist with regards to human and ethical values. This point is twofold and touches upon not just the values embedded in the system, but also those informing in the process of designing for it. For what pertains the underlying values expressed by the system, we refer to the practices of Value-Sensitive Design [31, 32] and Values in Design [40], as well as other design methodologies for socially-situated value-discovery [43]. For what, instead, pertains the process of creating the system itself, we point at the need of clearly explaining the social and political implications of the system to the users. In this sense, designing one of these DLTs for the commons imply the effort of encoding desired social rules and practices into algorithmic systems.

This translation requires, at least with current technology, a high degree of technical knowledge, and therefore is unlikely that communities undertake this task on their own. Designers should act as careful enablers and translators, mindful of the long-term effects of designed-in biases in algorithms, especially when such algorithms cannot be easily understood by lay people.

These three concerns are not a conclusion of our investigation by any means, but rather a starting point. DLTs and blockchain-based systems promise to empower communities with better tools for managing common resources, and there is a pressing need for more efficient and sustainable ways of living. Nevertheless, we are wary of uncritically accepting technologies with far-reaching social consequences. In this spirit, we contribute our dilemmas and concerns with the objective of supporting further critical analyses, and we invite more attention from the HCI community to this emerging application domain.

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