The Practice and Potential of Blockchain Technologies for Extractive Sector Governance

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GOVLAB

Natural Resource Governance Institute

Contents

Key messages

- Blockchain technology could potentially reduce transparency challenges and information asymmetries in certain parts of the extractives value chain. However, stakeholders considering blockchain technologies need a more nuanced **understanding of problem definition, value proposition and blockchain attributes** to ensure that such interventions could positively impact extractive sector governance.
- The blockchain field currently lacks **design principles, governance best practices, and open data standards** that could ensure that the technology helps advance transparency and good governance in the extractive sector.
- Most blockchain projects are preliminary concepts or pilots, with **little demonstration of how to effectively scale up** successful experiments, especially in countries with limited resources.
- Meaningful impact evaluations or peer-reviewed publications that assess impact, including on the **implications of blockchain's emissions footprint**, are still lacking. More broadly, a **shared research agenda around blockchain** could help address questions that are particularly ripe for future research.
- Transition to a blockchain-enabled system is likely to be **smoother and faster in cases when digital records are already available** than when a government or company attempts to move from an analog system to one leveraging blockchain.
- Companies or governments using blockchain are more likely to implement it successfully when they have a firm grasp of the technology, its strengths, its weaknesses, and how it fits into the broader governance landscape. But often these **actors are often overly reliant on and empowering of blockchain technology vendors and startups**, which can lead to "lock-in", whereby the market gets stuck with an approach even though market participants may be better off with an alternative.
- The **role played by intermediaries** like financial institutions or registrars can determine the success or failure of blockchain applications.

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INTRODUCTION

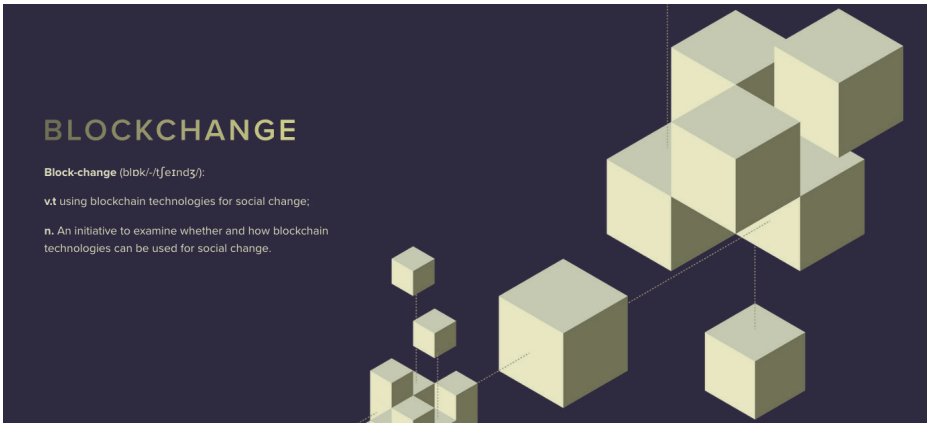
By providing new ways to identify individuals and organizations, and by recording various types of financial flows and transactions in a distributed manner, blockchain technologies have the potential to serve as a new tool to improve information disclosure. Yet, despite the earlier excitement around the use of blockchain platforms, uncertainties remain about what types of benefits the emerging technologies can actually deliver.

Important questions are being raised about whether blockchain technologies can contribute to solving governance challenges in the mining, oil and gas sectors. This report seeks to begin addressing such questions, with particular reference to current blockchain applications and transparency efforts in the extractive sector.

APPROACH

This paper summarizes extensive analysis, which commenced in mid-2018, by The Governance Lab (GovLab) at the New York University Tandon School of Engineering and the Natural Resource Governance Institute (NRGI). The research was funded by the German Federal Ministry for Economic Cooperation and Development (BMZ) through the German International Development Cooperation (GIZ). Our goal was to explore how blockchain technologies are being used, or are planned to be used, in connection with specific activities at different stages of the extractives decision chain.[1] Our study focused in particular on three activity areas: licensing and contracting, corporate registers and beneficial ownership, and commodity trading and supply chains. Through an analysis of deployed and proposed initiatives across each activity area, we aimed to unpack whether blockchain technologies could lead to changes—good or bad—in the way extractives companies operate, civil society conducts oversight and states govern the extractive sector.

We conducted our analysis through detailed desk research, a literature review (see Annex), a series of stakeholder interviews and an expert meeting in Washington, D.C. These sources supported an examination into what circumstances would enable blockchain technologies to enhance or pose risks to the governance of the mining, oil and gas sectors, with an emphasis on transparency and accountability.



More resources on Blockchain for Social Change at The GovLab's https://blockchan.ge/

1 NRGI, *The Natural Resource Charter Decision Chain* (2015),resourcegovernance.org/sites/default/files/nrgi_NRC-Decision-Chain.pdf.

DATA CHALLENGES IDENTIFIED

Transparency norms help set the foundation for improving the governance of natural resources by enabling disclosure and analysis of data to inform sound policy choices and to hold governments and companies accountable. Our research identified several data management and data use challenges associated with transparency efforts in the extractive sector that blockchain technologies could potentially impact:

- **Availability.** When data are not made publicly accessible, relevant actors' ability to share and aggregate information is constrained, which can limit efforts to ensure public accountability.
- **Accuracy.** High transaction costs associated with validating information and lack of oversight over (or trust in) the actors providing information can create challenges to ensuring that data are accurate enough to inform strong policy analysis and sectoral monitoring.
- **Alignment.** Relevant actors often generate and share data that use different standards and formats, leading to critical challenges for comparability and analysis.
- **Attainment.** Many actors in the extractives oversight and governance communities have not attained the requisite data skills to effectively monitor relevant data streams and ensure public accountability in the sector.

BLOCKCHAIN ATTRIBUTES IDENTIFIED

To inform our analysis of current practice and the potential of blockchain, we reviewed the variables and attributes that determine the design and use of blockchain technologies. Blockchain technologies incorporate different attributes in different use cases. Some of these attributes are fixed across nearly all blockchain use cases, while others are optional. In this section we provide brief definitions of key blockchain concepts, introduce blockchain's fixed attributes and then describe some key optional attributes.

Core blockchain definitions

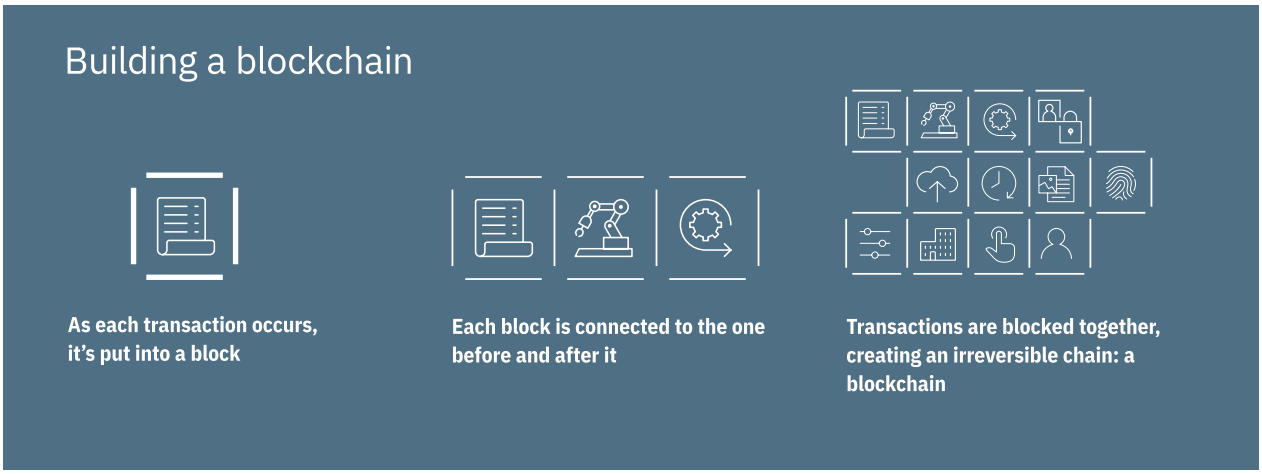
Blockchain. A system in which transactions are linked together, creating an immutable chain that logs all transactions. This irreversible log is often called the "ledger." Nodes form the infrastructure of the blockchain, so a blockchain exists on nodes.

Block. Each block represents an individual piece of information permanently stored as a unit of data. The first block of a blockchain is referred to as "genesis." Blocks are stored on "nodes" (which can be any device).

Distributed Ledger Technology (DLT). Blockchains are described as a distributed ledger technology because they record, store and replicate activities across a network of computers. As a result, no single person or entity controls a DLT.[2]

2 There are also examples of private blockchain projects from private sector initiatives. These cannot be accessed publicly and thus miss this key feature of the technology. See for example, see Wayne Vaughan. "Open vs Closed Blockchains — Let's End This Madness," *Medium*, 31 Jul 2015, medium.com/@WayneVaughan/open-vs-closed-blockchains-let-s-end-this-madness-8313e4095ead.

Figure 1. Building a blockchain[3]



Fixed blockchain attributes

Immutability. Blockchain ledgers exhibit a level of immutability not present in other database management systems. While administrators can alter databases, a blockchain-based system cannot be amended or changed. While questions increasingly arise around how immutable blockchains truly are,[4] it is generally "nearly impossible to alter information on the blockchain."[5] This immutability helps to ensure that all information is kept as "permanent legacies. If corrections are made, these will indicate how the ledger was changed, in the same way as a document including all track changes."[6]

Integrity. The distributed validation mechanisms that confirm additions to the blockchain cannot be gamed toward intentionally adding low quality or inaccurate information to the blockchain. This integrity of user information and activity is also the result of automated capturing of transaction metadata for all activity undertaken on each chain.

Resilience. The information security that blockchain offers comes from distribution of information and agency across nodes in the blockchain. Malicious attacks can strike centralized databases, but would require "an attack on every copy of the ledger simultaneously" in order to be similarly effective on a blockchain, given its distributed nature.[7]

3 IBM, *Blockchain* 101 (2018), www-01.ibm.com/common/ssi/cgi-bin/ssialias?htmlfid=45015045USEN&.
4 Christina Comben. "Are blockchains actually immutable?" *The Merkle*, 7 Apr 2018, themerkle.com/are-blockchains-actually-immutable/.
5 Raúl Zambrano. *Blockchain: Unpacking the disruptive potential of blockchain technology for human development* (International Development Research Centre, 2017), idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/56662/IDL-56662.pdf.
6 Michael Mainelli. "Blockchain will help us prove our Identities in a digital world," *Harvard Business Review*, 16 Mar 2017, hbr.org/2017/03/blockchain-will-help-us-prove-our-identities-in-a-digital-world.
7 Philip Boucher, Mihalis Kritikos and Susana Nascimento. How blockchain technology could change our lives (European Parliamentary Research Service, 2017), www.europarl.europa.eu/RegData/etudes/IDAN/2017/581948/EPRS_IDA(2017)581948_EN.pdf.

Optional blockchain attributes

Permissioned versus permissionless data contribution. The permissionless versus permissioned dichotomy hinges on who has the rights to add transactions on the chain. For permissionless ledgers (e.g., the Bitcoin blockchain), anyone has the ability to write to the blockchain, whereas permissioned ledgers enable only a restricted set of users to add transactions on the chain.

Public versus private viewing of data results. Public blockchains (e.g., Bitcoin, Ethereum) are designed so that anyone can view, browse or audit transactions. In public blockchains, the entirety of information and metadata held on a chain is available for all users to view. Even though most public blockchains store some information off-chain, with only cryptographic hashes to identify the information made publicly visible, a core set of information on all transactions will be time-stamped and available for all to view. A cryptographic hash is a fixed length string that acts as a kind of "signature" for the data provided.

On the other hand, on private blockchains (e.g., Hyperledger and various business applications), the data are not publicly accessible. These blockchains can restrict access to information to a small set of pre-approved users to such an extent that transparency cannot be reasonably attributed. As we will see in this study, few blockchain use cases led by the private sector indicate that public transparency is a key objective.

Permissioned versus permissionless data "validation." Distributed validation mechanisms ensure that information added to the ledger is consistent and that a diversity of stakeholders can monitored it. Activities recorded on the blockchain are captured, stored and open to scrutiny by other parties who have the ability to read information held on the blockchain.[8] However, the scope of who can authenticate transactions can vary. Permissioned ledgers enable only a restricted set of users to authenticate transactions.

Disintermediation level. Bitcoin, the original use case for blockchain, was developed with a particular interest in creating a disintermediated monetary system, with users transacting peer-to-peer without involving central banks.[9] Blockchains, especially public blockchains, can enable such disintermediation, but not every blockchain implementation will similarly "cut out the middle-man." A private, permissioned blockchain, for example, implemented with selected, specific nodes, would exhibit vastly lower levels of disintermediation compared to something like the Bitcoin blockchain.[10]

8 Raúl Zambrano. "Blockchain: Unpacking the disruptive potential of blockchain technology for human development," *International Development Research Centre*, August 2017, idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/56662/IDL-56662.pdf.

9 Bank of International Settlements, Cryptocurrencies: looking beyond the hype (2018), www.bis.org/publ/arpdf/ar2018e5.pdf.

10 Anna Irrera. "The Public vs Private Debate on Blockchain," *Financial News*, 1 Oct 2015, www.fnlondon.com/articles/blockchain-fintech-the-public-vs-private-debate-20151001.

Table 1. Blockchain attributes[11]

Public	Permissionless	Private	Permissionless
Who can see the result? **Everyone**	Who can write to the blockchain/ transact? **Anyone**	Who can see the result? **Select/ verified participants**	Who can write to the blockchain/ transact? **Anyone**
Example: Bitcoin, Ethereum		*Example: Monax, Multichain, Federal Byzantine Agreement*	
Public	**Permissioned**	**Private**	**Permissioned**
Who can see the result? **Everyone**	Who can write to the blockchain/ transact? **Select/ verified participants**	Who can see the result? **Select/ verified participants**	Who can write to the blockchain/ transact? **Select/ verified participants**
Example: Land titles, university degrees		*Example: Medical records, KYC, AML*	

ACTIVITY AREAS EXPLORED

Our analysis explored the current state of blockchain technologies in the following extractive sector activity areas:

Licensing and contracting. The current use of blockchain technologies was not established in extractives licensing and investor-state contracting activities. Several blockchain use cases were identified in connection with land registries (e.g., in Sweden and Georgia), but these are outside of the extractive sector and, from a governance perspective, are too dissimilar from licensing and contracting processes to be highly relevant. If blockchain applications expand in extractives licensing, considerations should include:

- whether blockchain technologies are suitable for long-term preservation of records
- what advantages (if any) blockchain approaches could bring (particularly for government and public oversight) beyond geospatial databases currently being used for extractive license cadasters
- whether smart contract approaches will be suitable for handling the many determinations that must be made in extractives licensing (e.g., whether financial and technical capacity criteria have been met or addressing the complexity of negotiated terms)

Corporate registers and beneficial ownership. Our review found several cases where corporate registers leveraged blockchain technologies (e.g., in Canada and Switzerland). In May 2016, the U.S. state of Delaware announced a blockchain initiative which would enable companies to track share ownership and transfers on a distributed ledger.[12] There are some assertions that the "transparency,

11 Provided by Karen Ottoni, Hyperledger, during Expert Meeting on July 12, 2018 in Washington, D.C.
12 Delaware Office of the Governor, "Governor Markell Launches Delaware Blockchain Initiative", May 2, 2016, www.prnewswire.com/news-releases/governor-markell-launches-delaware-blockchain-initiative-300260672.html.

immutability, and security offered by blockchain makes it ideally suited for use in record-keeping, particularly with regards to the ownership of assets."[13] However, it is also notable that momentum around the Delaware blockchain initiative has slowed considerably.[14] While none of the current use cases are specifically focused on extractives companies, their scope is broad enough that ownership information regarding mining and oil companies would likely be included. Central questions will be whether blockchain technologies can offer strong solutions regarding public transparency, and the verification of provided beneficial ownership information.

Commodity trading and supply chains. Commodity trading and supply chain management were the activity areas where blockchain technologies appeared to be gaining the most traction in the extractive sector.

At the time of writing, there were signs that three commercial consortia within the commodity trading sector were seeking to develop blockchain applications to integrate trading across oil producers, traders and financial institutions.

	Easy Trading Connect	DLT platform for U.S. crude	European gas trading
IOCs	BP, Shell, Statoil	N/A	Total, ENI
Trading Houses	Mercuria, Gunvor, Koch	Trafigura	Freepoint, Mercuria, Gasprom, Wattenfall, Petroineos, MGN Energie
Banks	ING, Societe Generale, ABN-AMRO	Natixis	N/A
Tech	Ethereu	IBM, Hyperledger	BTL, Interbit

Figure 2. Blockchain commercial consortia

A potential concern is that the private nature of these applications could counteract progress on transparency norms related to commodity trading in the "traditional" data space.

Blockchain technology is also being tested in oil and mining supply chains. S&P Global Platts is working with the Fujairah Oil Industry Zone, regional regulator FEDCom and 11 terminal operators to use blockchain for oil inventory tracking. Using the open source Hyperledger Fabric framework, terminal operators will submit data to FEDCom on individual permissioned private channels. FEDCom will then use an automatic command to calculate and send data to S&P Global Platts on a more public channel. As with the current system, FEDCom will continue to have sole access to all figures, and only approved aggregated weekly numbers will be submitted to S&P Global Platts for global distribution. In the mining sector, BHP Billiton is working with BlockApps, a ConsenSys-incubated company, to develop a blockchain web application for supply chain traceability. The system will facilitate data exchange between BHP Billiton's various vendors, including geology and shipping companies.

13 Julia de Jong, Alexander Meyer and Jeffrey Owens. "Using blockchain for transparent beneficial ownership registers," *International Tax Review*, June 2017, www.wu.ac.at/fileadmin/wu/d/i/taxlaw/institute/WU_Global_Tax_Policy_Center/Tax___Technology/feat_blockchain_beneficial_ownership_COMPLETED.pdf.

14 Karl Baker. "Delaware eases off blockchain zeal, but why?" *The News Journal*, 2 Feb 2018, www.delawareonline.com/story/news/2018/02/02/delaware-eases-off-early-blockchain-zeal-after-concerns-over-disruption-business/1082536001/.

TEN TAKEAWAYS

Our analysis of blockchain's realized and potential relevance for the governance of the extractives sector yielded ten cross-cutting takeaways that could inform future research and experimentation:

1. **Blockchain has the potential, in some situations, to reduce existing transparency challenges and information asymmetries.** However, in cases where blockchain attributes do not align with the underlying operational conditions of the sector activity, the technology could run the risk of further entrenching these information asymmetries, exacerbating transparency and governance challenges. More specifically, in sector activities where transparency norms are present or advocated for, then permissioned and private blockchain applications will not suffice.

2. **Enthusiasm is growing, but a more nuanced understanding of problem definition, value proposition and blockchain attributes is needed in order to ensure that technical interventions could have a positive governance impact in the extractive sector.** Much of the technology literature has assumed a strong belief that blockchain can address a multiplicity of governance challenges, often while disregarding the socioeconomic and political context that will inevitably influence the success or failure of any such intervention.[15]

3. **Blockchain proofs of concept and pilot projects dominate the field, with little understanding of how to effectively scale up successful experiments, especially in countries with limited resources.** While it is important to demonstrate the feasibility and potential of a blockchain project, real world applicability will only be truly tested once projects have been effectively scaled.

4. **Compelling blockchain use cases and anecdotes abound, but meaningful impact evaluations or peer-reviewed publications that assess impact are still lacking, including on the implications of blockchain's emissions footprint.** This lack of evidence reinforces questions regarding which transparency challenges blockchain would address better than alternative methods that could be more inclusive, cost efficient and environmentally sustainable.[16] At this stage of the debate, blockchain efforts should be carefully examined to determine to what extent road-tested technologies already exist for achieving the same data disclosure or data management result.[17] Many alternative data sharing technologies have, for example, proven to have a much lower emissions footprint.[18]

15 Izabella Kaminska. "Why blockchain is a belief system," *Financial Times*, 11 Jan 2018, ftalphaville.ft.com/2018/01/11/2197546/why-blockchain-is-a-belief-system/.
16 Wendy Lin, Colin McDonnell and Ben Yuan. Blockchains and electronic health records. www.fer.unizg.hr/_download/repository/blockchain_ehr.pdf.
17 Paul Nelson. *Primer on Blockchain* (USAID), www.usaid.gov/sites/default/files/documents/15396/USAID-Primer-Blockchain.pdf.
18 Wendy Lin et al, *Blockchains and electronic health records.*

5 **Moving toward a blockchain-enabled system is likely to be smoother and more rapid in cases where digital records are already available than when there is an attempt to move from an analog identification system to one leveraging blockchain.** However, the quality of digital records is also paramount, as is true with all data-driven technologies. The use of blockchain is a "garbage in; garbage out," proposition; i.e., an inaccurate or poor-quality input to the chain will affect the quality of the output.

6 **Blockchain can only be effective if the stakeholders implementing have a firm grasp of the technology, its strengths, its weaknesses and how it fits into the broader governance landscape.** This is the case for any technology considered for improving the efficiency and legitimacy of governance. As it stands, the private sector is driving uptake and development of blockchain technologies, often with an emphasis on private and permissioned approaches. Efforts should be made by all stakeholders to ensure that blockchain applications in the extractive sector align with transparency norms in the sector, and that civil society and governments have an active and appropriate role in selecting, shaping, participating in and monitoring relevant blockchain technologies.

7 **An overreliance on, and the outsized empowerment of, blockchain technology vendors and startups can lead to lock-in.** Blockchain relies on a level of interconnection among multiple data sources and stakeholders. A fragmented, rather than cooperative, approach across data points and stakeholders can lead to the creation of unnecessary silos and can minimize interoperability.

8 **The presence or absence of intermediaries, such as financial institutions or registrars, and their effectiveness can affect the success or failure of blockchain applications.** As fully decentralized systems for many blockchain use cases are unlikely to reach a critical mass of public utility and accessibility for some time, effective intermediaries can enable engagement with both intended users and any legacy systems relevant to blockchain implementation. On the other hand, the absence of trusted intermediaries, or the presence of inefficient ones, could help to incentivize the creation and use of a more decentralized approach.

9 **The extractive governance community would benefit from a shared research agenda around blockchain to address the questions that are particularly ripe for future research.** Areas in need of additional study include how to ensure compliance in the use of blockchain with existing regulatory practices and policies; optimal roles and responsibilities for different actors tasked with governing blockchain technologies; and approaches for designing fit-for-purpose blockchain initiatives given specific governance needs, objectives and constraints.

10 **The blockchain field currently lacks design principles, governance best practices and open data standards that could ensure that the technology helps advance transparency and good governance in the extractive sector.** Such principles, best practices and standards are necessary before the implementation of a more concerted approach to the use of blockchain to improve extractives governance.

DESIGN PRINCIPLES

Our analysis points towards an initial set of design principles that could act as a starting point for undertaking a more targeted approach to the use of blockchain in improving extractives governance. These design principles take the form of the acronym GENESIS, reflecting the concept of the first block in the blockchain, which is also often the initial point of failure or risk.

Table 2. Blockchain design principles

Design principle	Description
Governance	Given the potential for positive and negative impacts of an immutable ledger that can automatically take pre-defined steps when an action occurs, a transparent, accountable and participatory process for decision-making should be in place to guide the development of blockchain technologies.
Ethically sound	Blockchain implementations should take into consideration any potential positive or negative impact on the diverse rights of individuals early in the design process. Practitioners should ensure that they avoid siloed experimentation that could further jeopardize already vulnerable communities.
Not technologies, but solutions	Like many new technologies, blockchain is often treated as the proverbial hammer in search of a nail. While the tendency toward broad experimentation is a worthy aim, a clear and actionable understanding of the problem to be solved is essential both for meaningfully addressing the issue at hand, as well as contributing to a greater understanding of if, when and how blockchain can positively impact governance and social change.
Ecological footprint	Certain blockchain technologies have a massive and growing ecological footprint resulting from high levels of energy powering proof-of-work data-mining activities.[19] If blockchain is going to have a positive impact on creating social change, validation mechanisms that limit their ecological footprint may be preferable.
Synchronized with existing initiatives	Many societal challenges are neither new nor unrecognized by existing institutions. While blockchain could offer a promising option for addressing some transparency and governance challenges, new efforts should seek to be complementary rather than redundant with existing efforts.
Interoperability and open standards	The private sector drives much of the current activity around blockchain's use for governance and social change. This is to be expected given where the vast majority of blockchain-related skills, investment and capacity exist. But while vendors are an important part of the blockchain ecosystem, without whom experimentation would be impossible, government and civil society must work to avoid long-term vendor lock-in and the patenting of blockchain protocols.[20] Ensuring the interoperability of different systems, and the development of open technical standards for these systems will be key for ensuring that the public sector's use of blockchain remains flexible and problem- rather than technology-driven.
Securing first block accuracy	While blockchain's attributes of immutability and integrity ensure a level of information accuracy and consistency, the first block in the chain remains an important potential point of failure. Consistent with the aphorism "garbage in, garbage out," the quality of information held on the blockchain is only as good as what is entered in the genesis block.

19 Adam Rogers. "The Hard Math Behind Bitcoin's Global Warming Problem," *Wired*, 15 Dec 2017. www.wired.com/story/bitcoin-global-warming/

20 Matt Asay. "Why big vendors could ruin Blockchain by making it a centralized service," *TechRepublic*, 4 Apr 2017, www.techrepublic.com/article/why-big-vendors-could-ruin-blockchain-by-making-it-a-centralized-service/

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