Developments in Web3 for the Creative Industries

A Research Report for the Australia Council for the Arts

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Part 1: What is Web3?

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What's next...

Part 1: What is Web3?

The term 'web3' suggests a progression from web2.0, in which the internet became dominated by large platform corporations (such as Meta and Google) who derive power from advanced data capabilities that make audiences and users the product. For the creative industries, web2.0 continues to be a double-edged sword. It has created a new digital creative working class of YouTube and Spotify stars and enabled artists to promote themselves on social media. However, these opportunities are determined and constrained by the policies, algorithms, and payment terms of these corporations (Cunningham & Craig, 2019; Healy, 2022). In contrast, web3 describes an online ecosystem based on blockchain technologies (Wood, 2015), characterised by peer-to-peer transactions and users deciding who they share information with.

In this part of the report, we give a non-technical account of what blockchain technologies do and point to some useful resources for those who wish to dig deeper. We explain the key components of blockchain technology that provide the foundations for economic activity: common knowledge, automated agreements, uniqueness, and coordination. As the creative industries' uses of web3 first became dominant on the Ethereum blockchain, we refer to Ethereum for the sake of simplicity. As discussed elsewhere in this report, some creative practitioners now utilise other blockchains (including Tezos, Solana, WAX, and Flow).

1.1 Creating Common Knowledge: Blockchains

MIT Professor and founder of the Algorand blockchain, Silvio Micali, describes blockchain as a database where "you can write, I can write, and everybody can read and you have a guarantee that everybody has the same copy of the ledger that is in front of you" (in Fridman, 2021, 02:23). The result is "a common knowledge" (Micali in Fridman, 2021., 02:36).

An important part of this process is that the database – or ledger – of transactions is updated across a network of computers at the same time, with no central entity controlling that process. The events recorded on that ledger can be accepted as truthful by all because it would be incredibly difficult and expensive to rewrite (Casey & Vigna, 2018).

Events, including token transactions, occur when users interact with each other and with smart contracts (see section 1.2) (Figure 1.2). By way of a hypothetical example, let's say Alice's account has 1 Ether associated with it and Bob's has 0 Ether. If Alice sends Bob 0.5 of an Ether, the ledger will update to show that they both have 0.5 of an Ether. While this might seem like any other electronic payment, it occurs without any bank or payment service provider. Instead, the transaction relies on public-private key encryption technology, which means only the person holding the private key to an account can send a transaction from that account. Software wallets make this process reasonably straightforward. However, users need to be extremely careful to keep the private key to their wallet secure as without it they will not be able to access the tokens stored in their wallet. The support pages of MyCrypto are an excellent resource for learning more about wallets, accounts, and security for Ethereum and Ethereum-compatible blockchains (MyCrypto, n.d.).

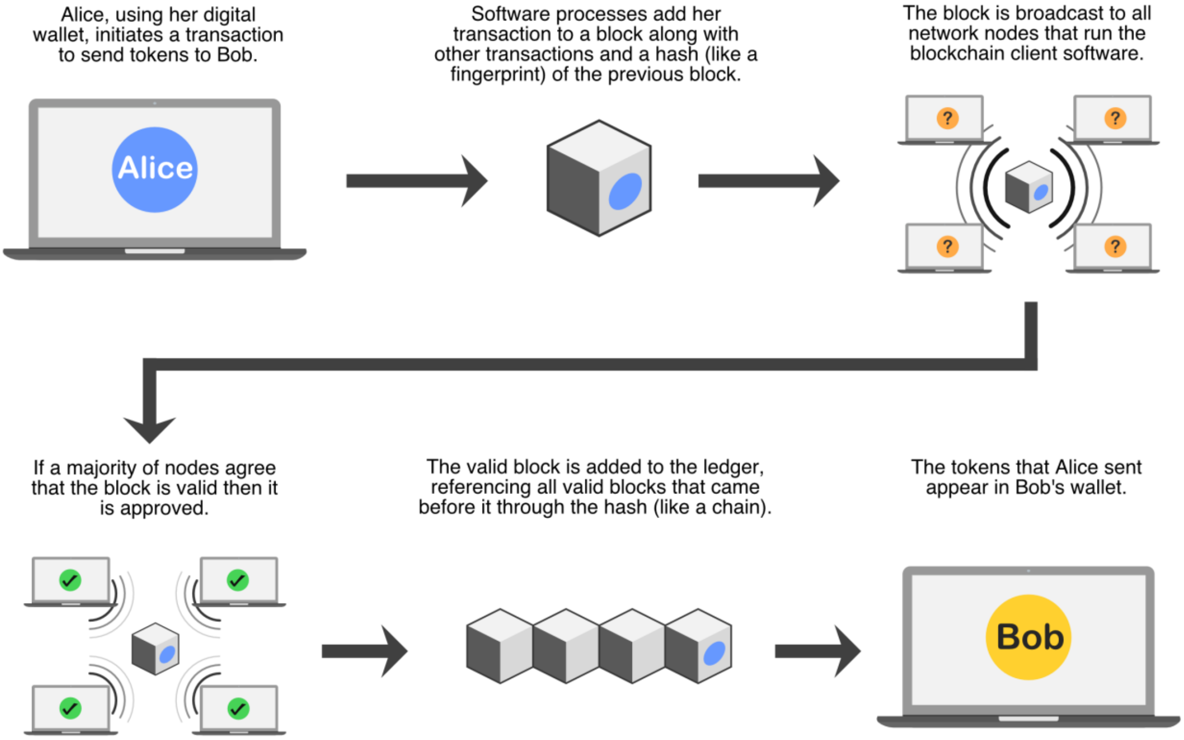

Figure 1.1: A simple depiction of a mainnet blockchain transaction.

Are blockchains secure? A necessary attribute of a functional blockchain is that it has enough people involved in running the software to make it impossible for one group to conspire and manipulate the record in their own favour. The blockchains that are most relevant to this report are Ethereum and other smart contract platforms built as 'public' blockchains, meaning that anyone with the right hardware and skills can participate in maintaining the ledger by running a node (although you do need to deposit Ether to a smart contract to participate in the process of block production. See Ethereum n.d.). As the ledger is generated and maintained by participants across the network it becomes incredibly difficult and costly to change, which makes it secure against hackers and fraud, as well as resistant to state-level censorship. Blockchains therefore enable people to coordinate in a peer-to-peer fashion with assurance that things will work as intended without requiring authorities to keep things in check (so-called trusted intermediaries).

Even though large public blockchains are in themselves very secure, crypto is a target for scammers (see Part 2 section 2.5) and many projects do not deliver on their promises to consumers (intentionally or otherwise). The risks are high because there's no one to turn to when digital assets are stolen (see Part 5 for discussion of legal considerations).

Do I need to be rich to participate? Blockchains achieve common knowledge by being costly to attack. But this does not mean you need a lot of money to participate as a user. Nor does it mean that large token holders have the ultimate decision-making power in every system.

The Ethereum blockchain has been expensive to use at times; it was a victim of its own success, attracting a high volume of transactions before it was ready. Other blockchains have emerged to compete with Ethereum and these offer faster speeds and lower transactions fees (although the trade-off can be reduced security and reliability). In response, the Ethereum ecosystem has spawned what are called 'Layer 2' technologies, which are capable of handling high volumes of transactions with low fees. Notably, Australian web3 games marketplace Immutable X has partnered with technology company Starknet to be able to process 9000 transactions a second with zero fees (it is also carbon neutral).

Will blockchains become centralised like web2.0? Censorship resistance requires a level of decentralisation and openness, but this is more nuanced than common narratives of decentralisation. There may be responsibilities that come with participation in maintaining the ledger, such as the Filecoin blockchain, where consensus is achieved as part of the process of onboarding data onto the storage providers who make up the nodes of the network. Music blockchain Audius needs its validators to handle copyright infringement take down notices. Therefore, while conversations of decentralisation are important, some parts of the blockchain ecosystem still require expertise and entities who are prepared to fulfill that need.

1.2 Automated Agreements: Smart Contracts

A smart contract is "a contract-like arrangement expressed in code" (Sills, 2019, para. 1), which executes an instruction when predetermined conditions have been met. They predate blockchains (see Szabo, 1997) but have been an essential component of blockchain use cases beyond money. An example of a smart contract in action is the Australian music platform Emanate, which records every millisecond of music that is played through the platform and then every six seconds of music played can be converted into payment in that platform's token. In this example, the smart contract contains the terms on which that payment will be made, executing the payment only when someone streams the song. Smart contracts running on a blockchain need to be invoked by information on that blockchain, or from information that is contained in data repositories that are bridged to blockchains (known as 'oracles'). In Emanate's case, the song is not stored 'on' the blockchain (Polygon within the Ethereum ecosystem in this case), but the data from the streaming platform is bridged to the smart contract.

Are smart contracts legal contracts? No, smart contracts are not legally enforceable in the way a legal contract is. However, as former Agoric software engineer Kate Sills (2019, para. 3) points out, smart contracts "are able to solve some of the fundamental social problems that have traditionally been solved by legal contracts", such as ensuring that one party does not walk away from a deal after they have received the goods from the other party.

The two major blockchain innovations discussed in this report – non-fungible tokens (NFTs) and Decentralised Autonomous Organisations (DAOs) – make use of smart contracts. We turn to these now.

1.3 Uniqueness: NFTs

A token is a transferrable asset that does not exist in physical form but is represented on a blockchain. There are fungible and non-fungible tokens. One bitcoin is the equivalent of another, like other fungible assets including money and precious metals. NFTs, or non-fungible tokens, are important for the creative industries as they can be transferred from one owner to another as unique (one of a kind or one of a series), non-interchangeable assets.

As one Australian developer we interviewed who contributed to the original NFT standard describes it:

> A dollar coin is fungible, because if I give you a dollar coin and you give me a dollar coin, neither of us are better or worse off – a dollar is a dollar. However, if I give you my pet cat and you give me your pet cat, we may not be happy, because pet cats are not completely interchangeable – they are non-fungible. (Parker, 2018, para. 4)

NFTs are token standards, which means they can be recognised and used by different applications on the same blockchain, in the same way that electronic goods need particular plugs to be compatible with a wall socket (the original ERC721 NFT standard can be viewed here). However, an NFT created on one chain is not necessarily going to work on another, just like different countries have different plugs (unless the two chains are compatible. For instance, Avalanche is compatible with Ethereum). The Mimics example in Part 3 section 3.5 of this report discusses some of the technical features of NFTs. A good technical description of the first NFT standard can also be viewed here.

Some NFTs contain the art in the token itself, in that the description of the NFT contains code that will display as an image when it interacts with a website. One example of this is POWNFT (Figure 1.2), created by Andy Parker (with design assistance from Ghostagent). The NFT is generated from the code contained in the smart contract, in this case "rendered based on the token's hash" (POWNFT, n.d. para. 5), which determines the element, its ionic charge, the colour palette and the motion of the image. Parker explains that "the element selection algorithm is inspired by natural scarcity laws, meaning some elements are more common than others" (POWNFT, n.d).[1]

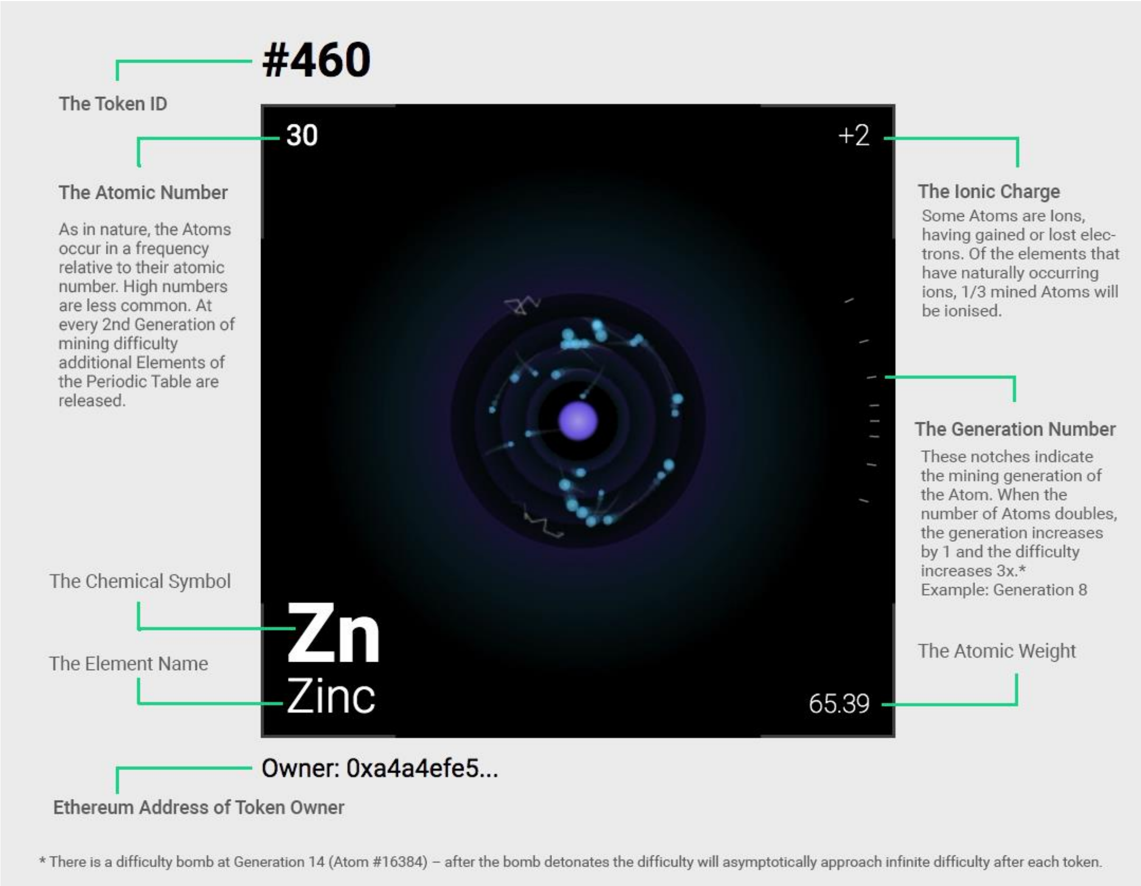

Figure 1.2: A breakdown of the POWNFT constituent parts. Image courtesy of Andy Parker

Others point to a work (such as a visual artwork, song, film, etc.) that is stored in the cloud. Many NFTs use the InterPlanetary File System (IPFS) for storage, which is a decentralised protocol for content addressing, meaning that a file can be located even if the place it is stored (for instance a server or a website) changes (see also Part 7 for a description of NFT.Storage and the decentralised storage network Filecoin).

Do I only make money from the initial sale of an NFT? It depends on your design choices. The "structurally inventive initiatives" (van Haaften-Schick & Whitaker, 2022, p. 2) that web3 technologies enable are critical for understanding their take-up and use. For example, the capacity to 'build in' resale royalties into NFTs (see Part 5) provides creative practitioners "the possibility of earning residual lifetime income from each piece of art they create" (Kugler, 2021, p. 2; van Haaften-Schick & Whitaker, 2022). In practice, this means "artists can spend more time making art rather than working or freelancing to pay the bills" (Kugler, 2021, p. 2).

Do I need to know how to code to create or buy an NFT? No. NFTs are often created ('minted') and purchased through marketplaces such as OpenSea, which provide an accessible interface that

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[1] Source code available at https://etherscan.io/address/0x9abb7bddc43fa67c76a62d8c016513827f59be1b#code

interacts with the blockchain (see DeMatteo, 2022). We discuss skills further in Parts 2 (section 2.1) and 4.

1.4 Coordination: Decentralised Autonomous Organisations

Blockchains can be useful for undertaking some of the roles and functions that are otherwise performed through organisations and firms. In Aaron Wright's (2021, p. 155) description, DAOs consist of a "network of hard to change rules that establish the standards and procedures of anyone interacting with, or taking part in, a DAO'" (see also Hassan & De Filippi, 2021). While humans set those rules and make decisions within the parameters of what is allowed, DAOs differ from other firms or community organisations in that software actors (smart contracts) do the bureaucratic work of executing decisions (Rennie, 2021a). As such, DAOs enable people to coordinate more easily by providing assurance that a decision will be enacted by the DAO software, providing governance in a permissionless organisational context (meaning anyone can come and go and remain pseudonymous). RMIT researcher Kelsie Nabben (2022, para. 6) sees the primary purpose of a DAO as aiding in the coordination of members:

> DAOs can be defined as a multi-agent system, working towards a shared objective. In these human-machine systems, computational components aid coordination (operational efficiency and/or decision-making, although that latter is less prevalent at this stage).

The Coalition of Automated Legal Applications (2021, p. 3) points out that a DAO is not "functionally equivalent to registration into a corporate entity, but the policy objectives of publicity and certainty are fully achieved". The Coalition of Automated Legal Applications (COALA) has created a Model Law to assist governments that wish to recognise DAOs as legal persons without requiring a new category within corporations law. We discuss some of the legal issues related to DAOs in Part 5.

DAOs can be set-up through DAO frameworks, which are off-the-shelf smart contracts. In recent years, developers have created a myriad of tools that enable DAOs to disperse tokens to constituents, undertake decision-making, manage wallets with multiple signatories on transactions, split income between members, track contributions by members, and pay people for their work. See Part 2 section 2.2 for some examples of creative industries DAOs.

1.5 What is the Environmental Impact of NFTs?

Artists were not the first group to raise concerns about the environmental impact of blockchain platforms; developers and researchers have been aware of the problem for some years. For instance, Ethereum founder Vitalik Buterin rejected the notion that blockchains need to be high energy consumers in 2016, stating that the dominant method used to make blockchains secure "kills trees" (Buterin, 2016, para 9). However, artists who were exploring and using NFTs were able to use their influence to amplify the issue, creating a significant social movement that changed popular discourse and spurred some blockchain developers to change course.

The key technical component involved in the environmental cost of blockchains is the 'consensus mechanism', which first appeared in cryptography and computer science research in the 1970s. In basic terms, this is the process by which a network of computers operating asynchronously come to agree on what events have occurred and in what order (achieving common knowledge as described in Part 2 section 2.1). Proof-of-work as used by the Bitcoin blockchain involves running software that performs hard computational work. Those who run this software, known as miners, earn the right to mine a new block, resulting in a new set of transactions being added to the ledger. When a new block is successfully mined, the miner is rewarded with newly minted bitcoin and transaction fees. The work required to mine a new block makes it extremely difficult and costly for an actor to try to manipulate or control the network unilaterally. The more computing power a miner has, the more likely that miner is to earn rewards. The result is that successful miners are those who can source and consume large amounts of electricity (renewable or otherwise) and who have access to the fastest hardware (known as ASICs).

However, proof-of-work is not the only consensus mechanism. Proof-of-stake, for instance, involves depositing capital (in the form of cryptocurrency) into a smart contract, which can be slashed (taken off the depositor) if they behave maliciously or fail to maintain their node. Ethereum moved from proof-of-work to proof-of-stake in September 2022, which was estimated to reduce the world's energy consumption by 0.2% (Ashraf, 2022).

Brisbane-based new media artist Michelle Brown began releasing NFTs on platforms like SuperRare, MakersPlace, and Known Origin in 2020. As she continued her web3 experimentation, she "became aware of the high-energy use of Ethereum consensus mechanisms" (interview). Michelle is a new media artist (including virtual reality), and much of her work "is actually focussed around climate action", so the environmental consequences of her use of the platform "was a big deal" (Brown, interview).

She told us:

> *The clean energy community formed in February of 2021, just before the Beeple and the big explosion of March. And there were over 3,000 artists from around the world, big name artists who had big concerns about using something that was adding to their energy footprint. We were all researching, providing resources, education around what this all meant – working out what the consensus mechanisms were, why proof-of-stake was better than proof-of-work for the energy and all the rest.* (Brown, interview)

Through her interactions on the Clean NFT Discord Channel, Brown learnt of the Tezos network, a proof-of-stake blockchain that used far less energy than Ethereum at that time. She observed the polarisation that formed around the issue and how she dealt with it:

> *There was a lot of hate going around for NFT artists because everyone had found out about the energy issues ... And I suppose our community were like, "No, we see good in it," but we want to focus on that, where that good is and promoting that.*

Figure 1.3: Strelitzia *by Michelle Brown (still image of 3D work). April 2022. On teia.art. Image courtesy of Michelle Brown.*

As the issue was picked up by the mainstream press, many NFT artists began suffering abuse and harassment. Two information and calculation tools that sparked the movement have since issued statements saying that they did not wish their websites to be used against artists. Artist Memo Atken's (2021, para. 1) website cryptoart.wtf now reads:

> CryptoArt.wtf was designed to share the best available information about the energy use and environmental impact of the growing Proof-of-Work (PoW) based CryptoArt and NFT markets. Just as we can find information regarding the ecological costs of flying, iPhones, watching Netflix, or training Artificial Intelligence models, I believe similar information should be available for CryptoArt, so that we can understand the impact of our actions, and we can make informed decisions. Unfortunately, the information on this website has been used as a tool for abuse and harassment, so I am taking the site offline.

A similar statement can be found on carbon.fyi (n.d.).

Concerns about the carbon footprint of NFTs are understandable given the current context of climate change and the need to reconsider and adjust energy use. However, there are many factors that make calculating the carbon footprint of an NFT a complicated, if not impossible, endeavour. Moreover, most studies into the environmental impact of blockchain focus on the Bitcoin blockchain, which plays a minor role in the NFT arena[2] (such studies also tend to overlook

[2] Aside from coloured coins, which are a lot like NFTs and were first proposed for the Bitcoin blockchain in 2015.

the practices of miners or look at the sources of energy that miners are using (see Carter, 2020; Rennie, 2021b)).

Understanding the carbon footprint of an NFT requires looking at the carbon footprint of the blockchain on which that NFT is minted and transferred. If there is a digital file associated with the NFT, then where that file is stored also matters. Rather than provide an estimate of the environmental cost of an NFT, we now drill down into these two areas and highlight which parts of the system use energy and why.

1.5.1 The Carbon Footprint of a Blockchain

NFTs compete for block space alongside other transactions and rely on the underlying ledger to show ownership. However, the production or transfer of an NFT does not increase the environmental footprint of the blockchain to the same degree each time.

Let's take the Ethereum blockchain as an example. NFTs as we commonly think of them originated through the creation of Ethereum standards (e.g., ERC721). During Ethereum's proof-of-work era (its entire existence prior to September 2022), it was common to read that NFTs were detrimental to the environment, such as the claim that "the amount of CO2 released when generating and storing an NFT is significantly higher than driving 100 miles" (Howell, 2022, para. 15).

However, it is not possible to calculate the environment footprint of a single NFT in this way because one NFT didn't directly translate to an increase in hash power for the Ethereum proof-of-work blockchain. The process of ordering transactions into blocks and proposing that they be added to the ledger is done by miners in a proof-of-work blockchain (or by validators/stakers in a proof-of-stake blockchain). Miners' participation is based on economic incentives. Under Ethereum's proof-of-work model (based on Bitcoin's consensus mechanism), miners would scale up their operations when it was profitable for them to do so. The algorithm was designed to deliver value by creating scarcity, so that mining a new block becomes more difficult as more computing power enters the network (the 'hashrate').

The electricity use of this system depended on the number of miners who competed to mine blocks. Under proof-of-work, we don't need more miners when transactions increase, or when gas fees are higher. An easy way to think of this is like a Melbourne tram that will run regardless of how many passengers are on it. Miners will propose blocks with or without NFTs.

There's an argument to say that congestion pushed up transaction fee prices ('gas' on proof-of-work Ethereum), which might have incentivised more miners to get involved (or the same miners to run more hardware to improve their chances of receiving mining rewards in the form of ETH). However, NFTs made up only a small portion of the total transactions, so boycotting NFTs was unlikely to lead to a reduction in miners (see Escalante-De Mattei, 2021). In addition, some NFT-related marketplaces such as Immutable X were using layer 2 solutions, which process many transactions in one transaction (or similar methods).

When Ethereum moved from proof-of-work to proof-of-stake (in September 2022), the electricity use of that network reduced by over 99% (Beekhuizen, 2021). As described above, under proof-of-stake, those who wish to participate in ordering transactions and proposing blocks must deposit Ethereum into a smart contract. Like mining, these 'validators' receive rewards for their service, but they are randomly chosen to propose blocks rather than in proportion to the amount of computational power they have expended.

1.5.2 Storing Digital Files on a Web3 Storage Provider such as Filecoin

The digital file associated with an NFT (such as an artwork or music file) can be stored in many ways, including on the owner's own device. Increasingly we are seeing NFT marketplaces offer storage solutions such as NFT.Storage, which enables developers to store NFT assets and associated metadata on the Filecoin network so that they remain accessible over time. As of 15 March 2022, NFT.Storage has passed 45 million uploads and 26,000 users.

How much energy is used to store a file on something like NFT.Storage? As Filecoin is a blockchain, it has some of the dynamics of the energy use described above, but with some subtle differences. Firstly, the Filecoin consensus model uses two consensus mechanisms to make the network secure and publicly verifiable. One of these mechanisms proves that data has been received (proof-of-replication) while the other proves that it continues to be stored (proof-of-spacetime). Filecoin participants are randomly selected by the algorithm to propose a block, creating a bundle of information (about storage) to be recorded on the ledger.

Like Bitcoin, participating in the Filecoin network requires capital and energy expenditure. In Filecoin's case, the consensus mechanism was designed so that this is done through the processes of onboarding data (sealing), through which cryptographic proofs are produced and sent to the network. Filecoin claims that the work that goes into achieving consensus in Filecoin thereby produces a positive externality rather than requiring that miners consume energy only to make the cost of attack unattractive (as is the case with Bitcoin). The second mechanism, proof-of-spacetime (PoSt, also known as proof-of-storage), uses a far lower amount of energy, and is comparable with a proof-of-stake blockchain network in its energy use (Ransil, 2021).

Filecoin uses energy for the following processes:

- The file or group of files is transported to a storage provider. Small files can be sent over the internet, but large volumes of data are delivered on hard drives by freight.
- The most energy-intensive part of the Filecoin network's process is when data is received by the storage provider and onboarded on to the network. During this set-up phase, a one-time process called sealing occurs. Sealing produces a cryptographic proof that the storage provider is in possession of the data sector, which is recorded on the Filecoin blockchain. According to Filecoin, sealing a 32 GiB sector takes five hours of compute time (Ransil, 2021).
- For redundancy purposes the data is replicated, and each copy increases the energy use.
- Once sealing has occurred, data storage continues for the term of the contract (minimum 18 months). Factors such as the energy efficiency of hard drives and hard drive configuration will affect energy use.
- Computational processes show proof-of-storage every 24 hours. These use little energy compared to the sealing process. The system is set up to independently verify that the data is stored at a location and for the length of contract that the storage provider and client agreed to. In the event where proofs are missing, storage providers are penalised.

Filecoin storage providers may use several different approaches to reduce their own carbon footprint and that of the network as a whole. For instance, they may choose to:

- install renewable energy infrastructure,
- purchase renewable energy credits,
- upgrade and optimise their hardware, or
- build their facilities in ways that use less heating and cooling.

At the time of writing, Filecoin is in the process of creating incentives that encourage Filecoin storage providers to reduce their carbon footprint and to show this using verifiable claims.

1.5.3 Wider Benefits of Blockchain for the Environment

When considering the environmental impact of blockchain, it is also important to keep in mind that the technology can enable faster, more efficient renewable energy markets. It can also provide visibility over energy use and infrastructures, assisting with carbon accounting. Currently, when companies make claims about their environmental credentials, we are asked to take their word for it. With blockchain technology (including platforms such as Energy Web (n.d.)) these claims can be verified. As the Filecoin example shows, incentives can be built into the design of protocols and applications that encourage those interacting with the blockchain to behave in an environmentally responsible manner. NFTs are an important component in that wider system, such as when used to represent renewable energy credits (such as Zero Labs, n.d.).

In summary, NFTs undoubtedly come with a carbon footprint, but that is being minimised through various developments including Ethereum’s move to proof-of-stake, and networks such as Filecoin building incentives for use of green energy. Any holistic assessment of the environmental impact of NFTs also needs to take into account how blockchains and NFTs in particular are being used to bring greater transparency to energy use, and in the development of easier, more accurate renewable energy markets.

Part 1 Summary

Blockchain technology is a means for people and machines to agree on events, including transactions and the order in which they occurred. Without blockchain technology, people need to rely on trusted third parties for many activities (such as banks that exist to maintain a record of who owns what). By enabling common knowledge, blockchain technology makes it easier for people to coordinate, and to invent new methods for coordination. NFTs are an innovation in property, in that they can be used to show proof of ownership. DAOs are an innovation in governance, whereby a group of people who are unknown to each other can coordinate to vote and impose restrictions on the actions that group members can undertake. Both of these innovations rely on smart contracts, meaning software that can be programmed on a blockchain to carry out an action when predefined conditions are met.

These technologies are very new, and we do not know how they will be deployed in the future. As the concerns around the environmental impact of proof-of-work blockchains demonstrates, these technologies may also be altered through social movements and regulatory constraints. In Part 2 we look at the innovations arising from creative uses of blockchain and how these may alter the creative industries.

Disclaimer

The contents of this report, including Part 5, are not legal advice and should not be considered as such.

References

Akten, M. (2021, March 12). CryptoArt.wtf. *CryptoArt.Wtf*. https://cryptoart.wtf/

Ashraf, A. (2002, September 16). Vitalik Buterin says Ethereum merge cut global energy usage by 0.2%, one of biggest decarbonization events ever. *CoinDesk.* https://www.coindesk.com/business/2022/09/15/vitalik-buterin-says-ethereum-merge-cut-global-energy-usage-by-02-one-of-biggest-decarbonization-events-ever/

Beekhuizen, C. (2021, May 18). Ethereum's energy usage will soon decrease by ~99.95%. *Ethereum Foundation Blog*. https://blog.ethereum.org/2021/05/18/country-power-no-more/

Buterin, V. (2016). A Proof of Stake Design Philosophy. *Medium*. https://medium.com/@VitalikButerin/a-proof-of-stake-design-philosophy-506585978d51

Carter, N. (2020, May 19). The last word on bitcoin's energy consumption. *CoinDesk*. https://www.coindesk.com/business/2020/05/19/the-last-word-on-bitcoins-energy-consumption/

Casey, M., J., & Vigna, P. (2018). The truth machine: The blockchain and the future of everything. Harper Collins Publishers.

Cunningham, S., & Craig, D. (2019). Creator governance in social media entertainment. *Social Media + Society, 5*(4), 2056305119883428. https://doi.org/10.1177/2056305119883428

DeMatteo, M. (2022, January 24). Minting your first NFT: A beginner's guide to creating an NFT. *CoinDesk*. https://www.coindesk.com/learn/minting-your-first-nft-a-beginners-guide-to-creating-an-nft/

Energy Web. (n.d.). *Energy Web*. https://www.energyweb.org/

Escalante-De Mattei, S. (2021, April 14). Should you worry about the environmental impact of your NFTs? *ARTnews*. https://www.artnews.com/art-news/news/nft-carbon-environmental-impact-1234589742/

Ethereum. (n.d.). What is Ethereum? *Ethereum*. https://ethereum.org

Fridman, L. (Host) (2021). *Lex Fridman Podcast* [Audio podcast] (No. 168). https://www.youtube.com/watch?v=zNdhgOk4-fE

Hassan, S., & De Filippi, P. (2021). Decentralized autonomous organization. *Internet Policy Review, 10*(2), 1–10.

Hesmondhalgh, D. (2012). *The cultural industries.* Sage Publications.

Howell, B. (2022), *Are NFTs bad for the environment?* The Eco Experts. https://www.theecoexperts.co.uk/blog/environmental-impact-of-nfts.

Kugler, L. (2021). Non-fungible tokens and the future of art. *Communications of the ACM, 64*(9), 19–20. https://doi.org/10.1145/3474355

MyCrypto. (n.d.). *General knowledge.* MyCrypto Knowledge Base. https://support.mycrypto.com/general-knowledge/

Parker, A. (2018, April 15). Jumping into solidity – The ERC721 Standard (Part 1). *Medium*. https://anallergytoanalogy.medium.com/jumping-into-solidity-the-erc721-standard-part-1-e25b67fc91f3

POWNFT (n.d.). *About*. https://www.pownft.com/about

Ransil, A. (2021). *Filecoin-energy-estimation*. Protocol Labs. https://github.com/redransil/filecoin-energy-estimation/blob/738d2ce0144ccc540fb051c81f308841d8a7348f/methodology/filecoin-electricity-methodology-paper.pdf

Rennie, E. (2021a, July 24). A DAO is a bureaucrat. *Medium*. https://ellierennie.medium.com/a-dao-is-a-bureaucrat-56e0e6a99782

Rennie, E. (2021b). Climate change and the legitimacy of Bitcoin (SSRN Scholarly Paper No. 3961105). https://doi.org/10.2139/ssrn.3961105

Sills, K. (2019). Smart contracts: A Libertarianism.org guide. *Libertarianism.Org*. https://www.libertarianism.org/topics/smart-contracts

Szabo, N. (1997). Formalizing and securing relationships on public networks. *First Monday, 2*(9). https://doi.org/10.5210/fm.v2i9.548

Throsby, D. (2001). *Economics and culture*. Cambridge University Press.

van Haaften-Schick, L., & Whitaker, A. (2022). From the artist's contract to the blockchain ledger: New forms of artists' funding using equity and resale royalties. *Journal of Cultural Economics*, *46*, 287–315. https://doi.org/10.1007/s10824-022-09445-8

Wood, G. (2015, October 18). *Gavin Wood "Web3: What and Why" GETD#3.* [Video] YouTube. https://www.youtube.com/watch?v=TGD7-rfdXDU

Wright, A. (2021). *The rise of decentralized autonomous organizations: Opportunities and challenges.* Stanford Journal of Blockchain Law & Policy. https://stanford-jblp.pubpub.org/pub/rise-of-daos/release/1

Zero Labs. (n.d.). *Zero Labs*. https://zerolabs.green/