Decarbonising Crypto

Where do we go from here?

A state of play report October 2021

Decarbonising Crypto: Insights from stakeholder engagement

Meaningful progress on the increasingly high-profile challenge of decarbonisation in the crypto sector will be achieved only through collaboration, collective action and open, objective dialogue. Held in September 2021 by crypto wallet and Crypto Climate Accord signatory Zumo to inform the findings of this 'state of play' report, the 'Decarbonising crypto' stakeholder round-table brought together voices from across the sector to gather opinions and perspectives from solution providers, industry participants and environmental research on the following key areas of debate:

Methodology: How do we gauge cryptocurrencies' environmental impact, and how the problem is defined?

Benchmarking: Looking across and beyond sectors, how do we frame the issue and talk about it productively against the backdrop of a wider societal debate?

Collaboration: What will be required of the industry as a whole to make meaningful progress on decarbonisation, and how best does it direct its efforts in doing so?

Technology: how does ongoing technology development in the crypto space impact the discussion, now and in the future?

Roundtable participants:

Kirsteen Harrison, Environmental and Sustainability Adviser, Zumo

Doug Miller, Global Markets Lead, Energy Web (co-convener of the Crypto Climate Accord)

Michel Rauchs, Digital Assets Lead, Cambridge Centre for Alternative Finance

Alex de Vries, Digiconomist founder

Lars Jorgensen, Chief Operating Officer, TAAL Distributed Information Technologies

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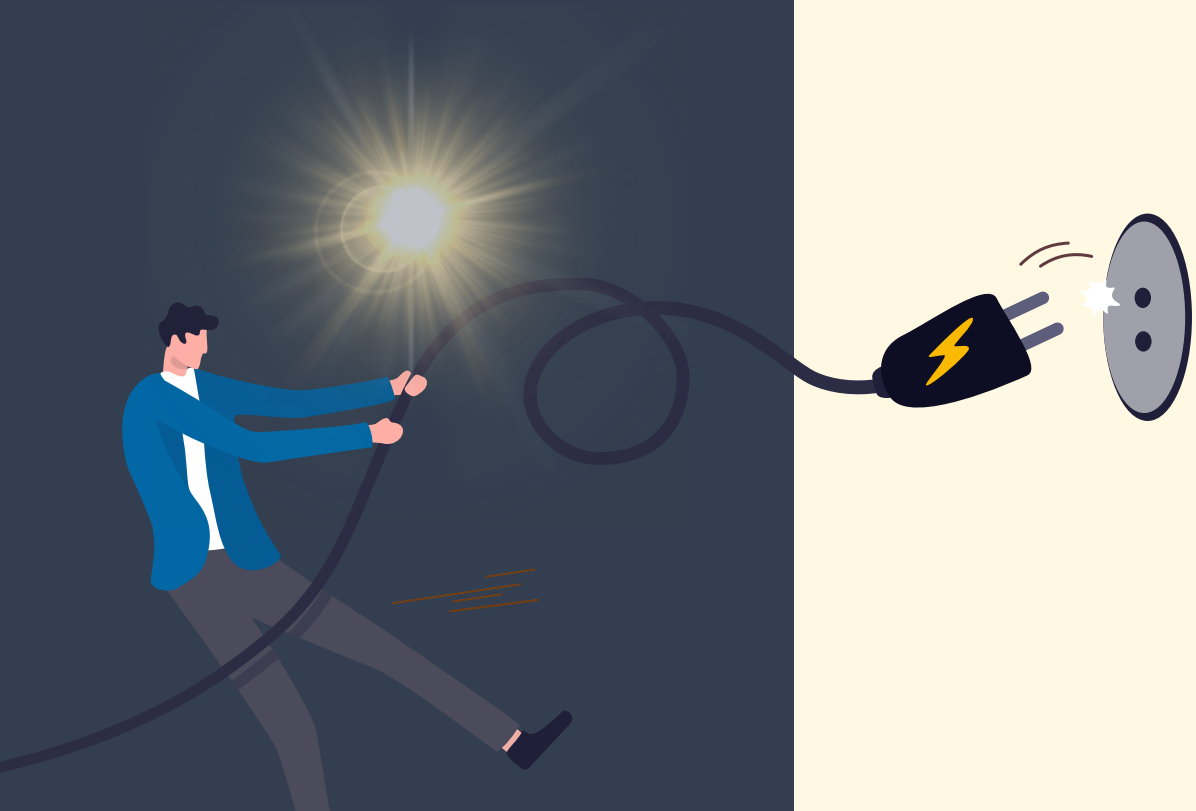

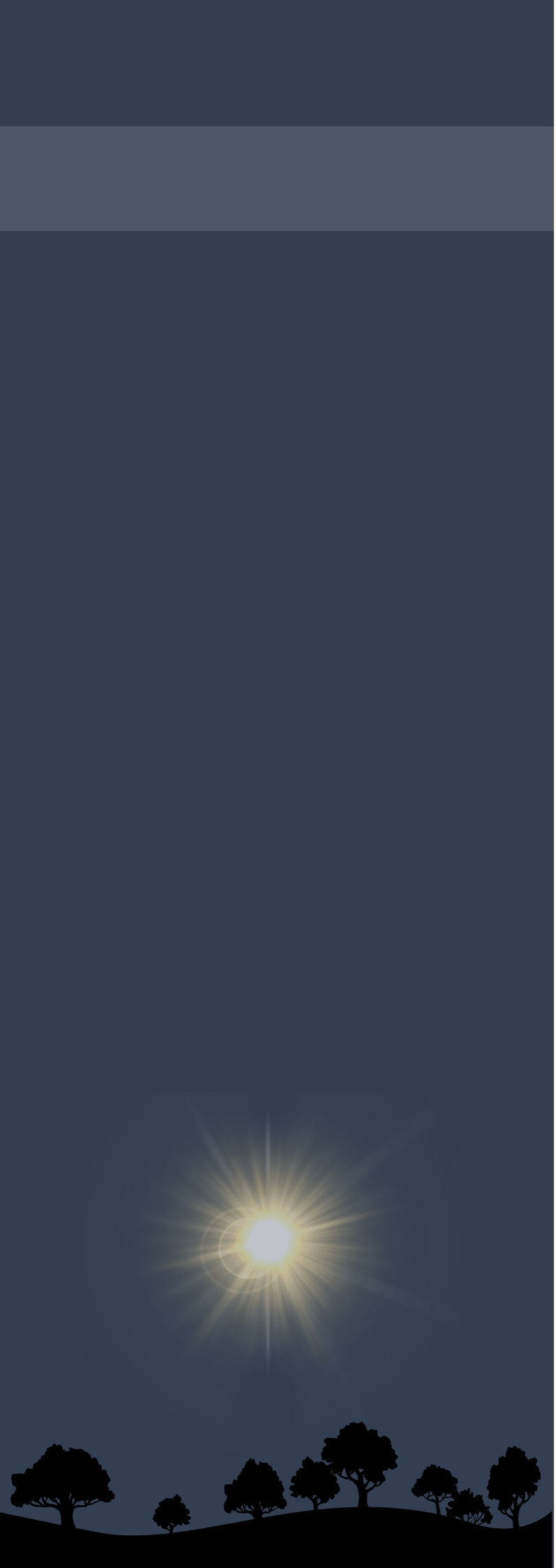

Executive summary

Decarbonising Crypto: Where do we go from here?

Clarification and contextualisation is urgently needed to inform the cryptocurrency energy consumption debate. **This report is one of the first to comprehensively deconstruct the methodologies and assumptions** quantifying the environmental impact of cryptocurrencies, offering a 'state of play' insight based on expert contributions from solution providers, industry participants and independent environmental research.

In tackling decarbonisation, **cryptocurrency has key advantages of transparency of data and defined inputs** - but must focus on making itself relatable to the public and demonstrating its utility.

Awareness and collaboration are rapidly growing on the need for decarbonisation in the crypto sector. **Cross-sector initiatives will be pivotal** and must encompass all ecosystem participants - miners, platforms and crypto holders / investors.

Greening of cryptocurrencies aligns naturally with market incentive and the advancement of the space. Environmental, Social and Governance (ESG) will feature prominently in the next stage of crypto's evolution.

The pace of technological change in the cryptocurrency ecosystem is constantly changing the complexion of the energy debate. New and planned blockchain technology will transform the way we view cryptocurrencies and their energy consumption as the space develops in application and infrastructure.

By collaborating and acting on the decarbonisation of the sector, crypto has a meaningful opportunity to convert energy requirement into renewable energy demand, **driving the growth of the global renewables market.**

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Introduction: A topical debate

"It is unequivocal that human influence has warmed the atmosphere, ocean and land." So reads the latest assessment of the Intergovernmental Panel of Climate Change (IPCC)[1]. In countries - and boardrooms - across the globe, attention is intensifying on what is increasingly termed the climate crisis.

No sector and no business operation is untouched by the reach and gravitas of this century-defining challenge. Achieving the required targets of a halving of greenhouse gas emissions globally by 2030, and net zero by 2050 at the latest, calls for meaningful, coordinated commitments and a collective effort spanning all sectors and countries.

What, then, of crypto?

Increasingly, blockchain energy consumption - and that of Bitcoin in particular - is a highly visible, not to mention emotive, issue. Yet all too often, narrowly focused headlines and deeply polarised opinion have obscured the path to open and reasoned debate.

How exactly should we be gauging the real environmental impact of cryptocurrencies? Where do we turn for our information? How do we interpret it? And ultimately, how do we move forwards on this important issue, together?

As the world looks on, the cryptocurrency sector must play its part in ensuring industry-wide decarbonisation. This report is written in the shared belief that it is time for the crypto industry to address the need for decarbonisation; that there is an urgent need for a reasoned, fact-based approach; and that this is an unprecedented opportunity for the industry as a whole to engage in debate and showcase what industry-wide decarbonisation looks like.

To that end, in September 2021 participants from across the sector gathered to participate in a round-table discussion hosted by Zumo and chaired by Energy Web, co-founder and co-convener of the Crypto Climate Accord, an industry-wide initiative focused on decarbonising the cryptocurrency and blockchain industry in record time. The aim: to spark an open and objective conversation on how the crypto sector talks about and responds to the climate crisis.

This report summarises the key outputs of these discussions, as well as providing a broad outline of the 'state of play' in the crypto sector.

It is structured as follows:

1. **In Section 1 -** We discuss the methodology behind gauging the environmental impact of cryptocurrencies, and how the problem is defined.
2. **Section 2 -** Looks at the issue of comparisons with other industries, and how progress is measured.
3. **Section 3 -** Discusses collaboration, and how the industry can work together to common goals.
4. **Finally, Section 4** - considers the role of technology, and how new technologies are impacting and will impact the sustainability conversation.

1. The IPCC Sixth Assessment Report addresses the most up-to-date physical understanding of the climate system and climate change, and humans' role within it.

1

Methodology: Defining the problem

Methodology:
Defining the problem

'Cryptocurrency is bad for the environment' is a broad and misleading statement - one that masks a much more complex reality and fails to do justice to the variety of cryptocurrencies that exist and the differing consensus mechanisms used to create them.

Today, the popular data aggregator CoinGecko tracks some 9,000 cryptocurrencies and blockchain-based tokens, many of which differ greatly in their underpinning technology and profile of energy consumption. For example: whereas a proof-of-work blockchain such as Bitcoin may have an annualised consumption of some 101 TWh, a proof-of-stake blockchain such as Tezos may have an equivalent annual consumption of just 0.00006 TWh, a difference of between six and seven orders of magnitude.

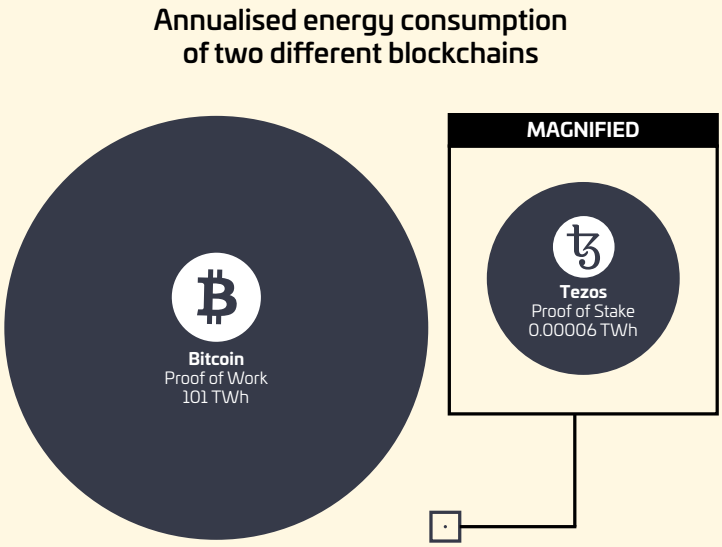


Fig 1. A sample comparison of the annualised energy consumption of two different blockchains.
Source: Cambridge Bitcoin Electricity Consumption Index, 21 September 2021/Tezos

As round-table participants pointed out, when we are talking about 'the energy consumption of crypto', we are really talking primarily about proof-of-work blockchains, as this is the particular system of consensus that results in the highest energy consumption figures.

Nevertheless, the Crypto Climate Accord (CCA) sets an industry-wide objective to decarbonize all crypto miners, exchanges, and investments across all blockchain networks, from the most energy efficient to the most energy intensive.

While proof of work allows for decentralised, secured peer-to-peer transactions without the need for a trusted third party, it does so by requiring members of a network to expend effort - and therefore energy - solving an arbitrary mathematical puzzle. For security, this is an energy-intensive process by design, and any number of members (miners) are able to join the network.

"Probably one of the main reasons we are having this discussion in the first place is the focus on proof of work based blockchains. It's always important to keep in mind that when we're talking about carbon intensive systems, we typically don't mean all cryptocurrencies"

Alex de Vries, Digiconomist

Why Bitcoin?

If proof of work blockchains are where we must focus if we wish to make the biggest contribution in mitigating climate impact, why does Bitcoin (BTC) capture so much of the popular narrative?

A large part of this must be attributed to the fact that Bitcoin is the highest valued and most established blockchain network - both acting as the 'gateway to crypto' in the public eye and also accounting for the lion's share of energy usage. In both market capitalisation and annual energy consumption, Bitcoin far outstrips any other proof of work cryptocurrency.

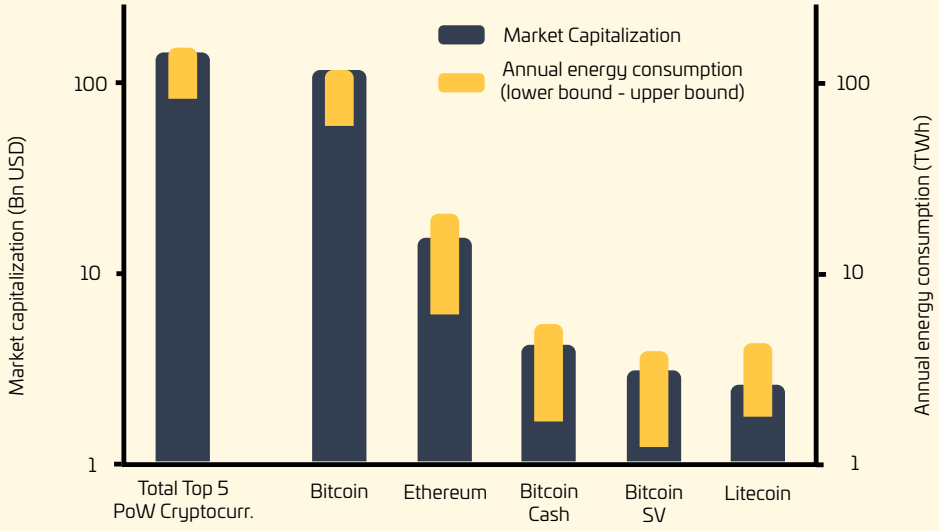


Fig.2 Market capitalisation and annual energy consumption for the five highest valued proof of work cryptocurrencies (note the logarithmic scale on the y-axis)
Source: The Energy Consumption of Blockchain Technology (Sedlmeir, Buhl, Fridgen, Keller, 2020)

As the digital asset with the largest footprint, it is therefore a good place to start in questioning the range of underlying assumptions we make in determining the environmental implications of the highest energy-using cryptocurrencies.

Quantifying environmental impact: approaches and methodology

There is currently no standard universally applied methodology to calculate the electricity consumption or carbon footprint of cryptocurrencies. Different methodologies apply different assumptions, which can vary significantly in their modelling and perspective of the problem, though we have good-quality sources available and the nonprofit RMI is publishing specific guidance for the sector in this area in support of the CCA (with an expected release date during the second half of October 2021).

To take Bitcoin as our continuing point of reference, the two commonly referenced approaches are the per transaction model, which expresses environmental cost in terms of the blockchain transaction; and the 'mined now' model, which calculates the environmental cost per bitcoin mined over the most recent period. The 'mined now' model is the methodology used by the Green Bitcoin Project.

In addition to these approaches, Zumo has developed a 'mined since genesis' model, which calculates electricity consumption based on bitcoin mining but averaged out over the entire period since the genesis (first) block. This aims to factor in and average out the unknown of when a particular Bitcoin was mined, and therefore the energy consumption associated with it at the point of its creation.

Zumo also uses a 'share of the BTC network' method to calculate the electricity consumption attributable to Zumo as a share of the usage of the whole BTC network at a specific 'snapshot' date.

These models will be made publicly available by Zumo in the early part of next year following testing as part of our net zero strategy.

> **"Whatever method is used, it's important to clearly state assumptions and data sources and be transparent about those all the way through the process."**
>
> Kirsteen Harrison, Environmental and Sustainability Adviser, Zumo

Methodology	Source	Typical Result	Pros	Cons	Best Used For
Transaction model	Digiconomist	1.78161 MWh/ transaction	Easy to calculate. Allows comparisons with other payment methods.	Attributes all electricity use to the transaction rather than block reward. Results in a skewed figure as transactions do not drive electricity consumption (see discussion later in chapter).	Illustrative purposes
Mined now model	Green Bitcoin Project	270 MWh/BTC	Reflects energy cost of mining BTC in 2021	100% focused on newly generated supply - does not factor in the utility of securing the network for all existing BTC holders	Investors, holders of crypto. Miners.
Mined since genesis model	Zumo, calculated using data from the Cambridge Bitcoin Electricity Consumption Index	17 MWh/BTC	Reflects energy cost of mining one BTC averaged 2009 - 2021	Not appropriate for miners, who should be focused on electricity costs today (not averaged)	Investors, holders of crypto. Wallets, exchanges and payment platforms.
Share of BTC network model	Zumo, calculated using data from the Cambridge Bitcoin Electricity Consumption Index	Variable according to network usage.	Gives a 'snapshot in time' and reflects actual energy use of the BTC network. Includes all energy consumption (no need to split further into transactions, block reward and securing network)	Not suitable for individual investors or holders of crypto. Fluctuates over time.	Wallets, exchanges and payment platforms.

Fig 3. Table comparing various methodologies for visualising / attributing BTC electricity consumption

We welcome comments on these methodologies, in the knowledge that there may also be other methodologies published or in development of which we are unaware.

Carbon footprint vs electricity usage

If there is one commonality in all of the methodologies described above, it is that they all rely on electricity consumption data.

This is because of the clear line of sight we can draw in the crypto sector between the electricity consumed in mining, and the cryptocurrency supply generated, secured and transacted on-chain as a result. Whereas other sectors may have more complex supply chains and indirect impacts to consider in calculating their carbon footprint, one of the greatest advantages we have in decarbonising crypto (albeit a double-edged sword in terms of public perception) is the visibility and clarity of the sole inputs: electricity and mining equipment.

Here, we have access to relatively good quality data on electricity usage - more so than other sectors - based off the network hashrate (or total computational power being used in the mining process). Despite the fact that different models show noticeable differences in the electricity consumption of the BTC network depending on the assumptions made[2], the data that we have within the crypto sector is still fairly robust and transparent when compared to many other sectors - particularly when averaged out over longer time frames to counteract the significant fluctuations observed over short time periods.

An additional layer of uncertainty is added, however, when the carbon footprint is calculated from the electricity consumption of the BTC network. For one thing, there is a lack of readily available data on the renewable electricity usage of Bitcoin/proof-of-work networks, and available sources may differ significantly in their estimations - although by all accounts the renewable share of BTC electricity consumption is higher than the global average (figure 4).

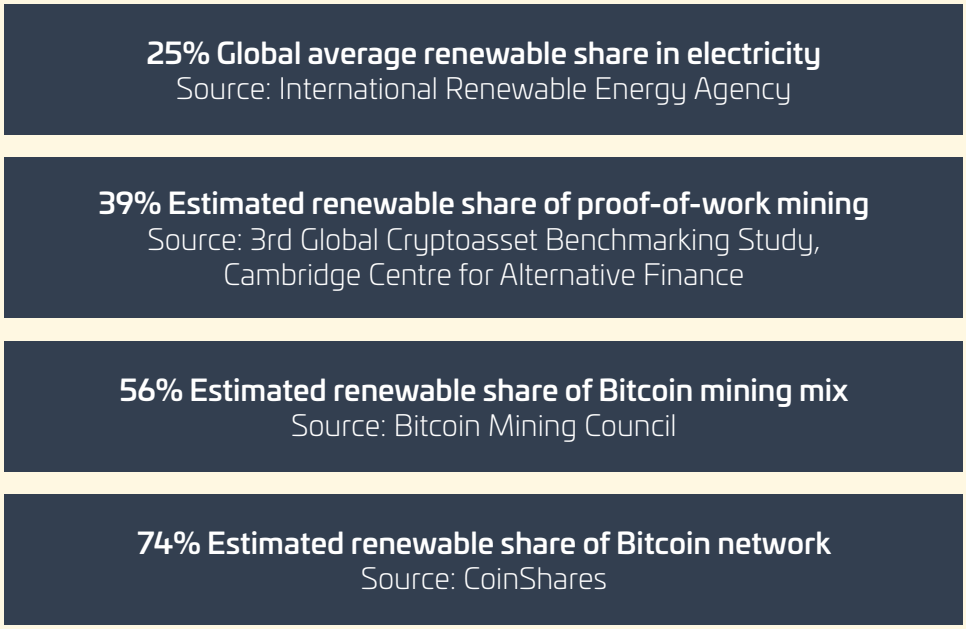


Fig. 4 The renewable component of Bitcoin electricity usage according to various sources and compared against the global average[3]

2. We might compare and contrast, for instance, the methodologies employed by Digiconomist and the Cambridge Bitcoin Electricity Consumption Index
3. Note: The illustration is to demonstrate the difficulties of quantification among varying sources, as opposed to a statement on the accuracy of any of these estimates. Best benchmarks will come from independently researched and verified sources.

Added to this we have the difficulty of tracking a decentralised network. With mining operations distributed worldwide, it is difficult to know with any certainty where the totality of Bitcoin mining takes place (although both the Cambridge and Digiconomist models show the approximate hashrate in various geographical locations to give an approximate global breakdown). What we do know is that the carbon intensity of the grid will vary significantly among these individual locations, and that the precise geography and blend of the mining electricity mix is constantly changing, both seasonally and in reaction to market/macro events. The most cited example of this is China, where the renewable mix has traditionally varied significantly between dry and wet seasons, and a large part of the infrastructure has since relocated altogether due to government-led clampdowns on mining operations.[4]

For our purposes, what is useful to note is that each country has a 'grid intensity factor'[5] which is used to calculate carbon footprint of the electricity grid - this depends on the energy sources used in that country and the intensity factor will be much higher in a grid that relies heavily on fossil fuels than one which has a high proportion of renewables. These 'grid intensity factors' are readily available and often used to calculate the carbon footprint - however, as stated above there are significant regional variations in renewable supply and the grid intensity factor does not account for such regional variations, instead giving an average for the entire country.

Ultimately, there are pros and cons of using total electricity consumption vs carbon footprint as a measure of environmental impact. However, it should be recognised that another layer of uncertainty is added when calculating the carbon footprint of the electricity usage, and again it is important to state assumptions.

Approaches to compensating for electricity usage vs carbon footprint

As the need to transition to net zero becomes increasingly urgent, many players in the crypto ecosystem are seeking to reduce their carbon footprint. Miners can of course reduce (and even eliminate) their carbon footprint by using renewable sources of electricity, but for platforms, users and investors, we essentially have two options available in order to reduce our own carbon footprint as far as possible. The decentralised nature of the network means that it works very differently from traditional supply chains in most other sectors, where businesses generally have a greater degree of control. In the crypto sector, we therefore need to approach this slightly differently to take accountability for the entire mining network.

One option to simplify the carbon accounting process is to purchase energy attribute certificates (EACs) equal to the estimated energy use associated with a given crypto holding or transaction to decarbonize the estimated electricity use associated with the underlying crypto mining, where EACs each represent one megawatt-hour of electricity generated with renewables and serve as the standard accounting instrument to support any legitimate renewable energy claims. This method is being used by Zumo for a CCA showcase being implemented in partnership with Energy Web using Zero, a public renewable energy search engine for tokenized EACs. The other method involves calculating the carbon footprint using electricity use data, and purchasing verified carbon offsets, which presents challenges due to differences in the carbon intensity of different electric grids and not knowing in which specific geography a given cryptocurrency was mined.

Transactions vs mining

Quantification aside, another focus of discussion in the decarbonisation debate is whether we should be viewing the issue through the lens of transactions or through the lens of mining.

While on-chain transactions are of course inseparable from mining from an energy consumption perspective - the mining of blocks includes and encompasses the verification of transactions - there is a clear nuance in the emphasis we choose to place.

4. Cf. https://www.jbs.cam.ac.uk/insight/2021/new-data-reveals-timeline-of-chinas-bitcoin-mining-exodus/
5. Cf. https://www.carbonfootprint.com/international_electricity_factors.html

Consider, for instance, the difference between two Bitcoin holders A and B. Bitcoin holder A holds 0.1 BTC and buys and sells that value several times over the year. Bitcoin holder B holds 100 BTC but does not transact at all.

Viewed purely through the lens of transactions, we might say holder A has incurred an environmental cost every time they transact their Bitcoin holdings, and that holder B has incurred none at all. But in fact holder B is responsible for the electricity consumption required to mine 100 BTC, and holder A responsible only for 0.1 BTC (or at worst the total value of BTC they have transacted in the given period). Looking only at the transaction activity skews the picture.

The point is that, in the case of Bitcoin at least, the bulk of energy consumption (and therefore the environmental impact) comes from the mining process and proof-of-work consensus mechanism, and not the transactions contained within it. We can draw this conclusion as the vast proportion of miner revenue (approximately 90% in recent times[6]) comes from the block reward, not transaction fees. It is therefore the mining of bitcoin itself (the block reward) and not the processing of transactions that incentivises miners and therefore drives electricity consumption. Blocks (and therefore transactions) will continue to be processed every 10 minutes or thereabouts regardless of the number of miners and therefore electricity consumption. For this reason, it would seem to make more sense to quantify and mitigate impact viewed through the lens of Bitcoin mined (which is where the main environmental cost is currently incurred), and not per transaction.

Of course, this is only true because the energy consumption of Bitcoin and proof-of-work blockchains is bound up in the proof of work mechanism: it should be noted that the 'per transaction' methodology may well be more appropriate for other cryptocurrencies, where the transaction fees make up a higher proportion of rewards, and transactions are more instrumental in driving the total energy consumption of the system.

Finding the constants

The other potential advantage of placing the emphasis on mining as opposed to transactions is that mining is the constant in the equation. As a round-table participant pointed out, with Bitcoin 'a train departs every 10 minutes. It doesn't matter if it has passengers or not.' That is to say, blocks are being mined at fixed intervals, at a specific energy cost, regardless of the transactions contained within those blocks. With BTC, there is a certain number of transactions per block, but in other cases there could be many more transactions in a single block. The energy cost is determined by the block, not the quantity of transactions contained within it.

> "It doesn't take more energy to mine a block with a million transactions than a block with one transaction."
>
> Lars Jorgensen, Chief Operating Officer, TAAL Distributed Information Technologies

6. Cf. https://argoblockchain.com/explaining-the-bitcoin-block-reward/ It is important to note that this is stated as the case at the current time. As block rewards reduce over time in line with the Bitcoin halvening schedule, the balance may shift gradually in favour of transactions, though this will depend on the evolution of BTC value.

The very fact that the mining part of the process is constant in terms of its fixed block schedule and algorithmically determined miner rewards is also appealing from a benchmarking and reporting perspective. It makes it easier to model the problem and to demonstrate progress over time. This is particularly useful when it comes to considerations of corporate governance, and how the crypto sector aligns itself with the reporting requirements and due diligence of corporate and institutional investors.

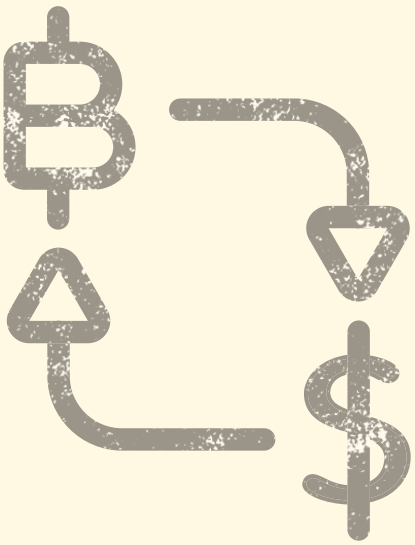
> **"We talked to our customers and they're mostly focusing on mining because this gives constant, quantifiable consumption on a per BTC basis... and so it's much easier to calculate and to prove to an investor or an ESG committee [than transactions]."**
>
> Sergey Shayakhmetov, Co-Founder, Green Bitcoin Project

What counts as a transaction anyway?

Finally, there is a certain level of complexity involved in defining the scope of what is meant by transactions. Individual, on-chain transactions, where a single transaction is recorded on the blockchain, is a simple flow to follow. However, as emerged from the round-table discussion, these days the scenario is rarely so simple.

The rise of custodial solutions, where users' funds are held by intermediaries, has obscured the link between the end user and on-chain records. On the one hand, custodians such as exchanges may batch transactions in such as way that makes individual transactions more difficult to decipher; on the other, private intermediaries can facilitate transfers of value on their internal books without ever touching the blockchain - and there is not necessarily any great transparency to the mechanisms underpinning this. These 'off-chain' transactions are a whole category unto themselves that is not addressed by looking at on-chain activity.

One example cited was that of a very large fintech that allows its users to gain crypto exposure through its app. In this particular case, the user is twice removed from the underlying asset. When a user buys cryptocurrency via the app, they are buying the 'beneficial right' to buy, sell or transfer that cryptocurrency. They do not own the asset or control the method by which it is transacted. In turn, the fintech platform in question is not in this particular scenario the ultimate custodian of the cryptocurrency either: it too partners with other crypto exchanges from which it procures the cryptocurrency it needs to serve its customer base. This raises interesting questions on what exactly is happening transactionally speaking when a customer raises a buy/sell order, and where the responsibility lies for offsetting the environmental impact given an increasingly complex network of intermediaries.



"The question is also, what assets are you actually providing or making available to users?... Everybody treats crypto as one thing, but actually we're talking about completely different forms of crypto and each form has a completely different relationship with the underlying system, and as a result the energy footprint that comes from it."

Michel Rauchs, Digital Assets Lead, Cambridge Centre for Alternative Finance

As the cryptocurrency ecosystem becomes more complex, and diverse in the touchpoints that give access to it, so too will the models required to adequately assess its environmental impact.

While this methodology section has aimed to give a broad introductory overview to the main considerations required to appraise cryptocurrencies and their environmental impact, the work is ongoing and continues to evolve, not least with the forthcoming report from the RMI that will provide further guidance on measuring the carbon footprint of proof-of-work cryptocurrencies.

2 Benchmarking: Framing the issue

2 Benchmarking: Framing the issue

Moving on from our discussion of methodology, it is equally important to consider how a shared understanding of the problem at hand can best be crystallised into action and response: demonstrating progress in decarbonisation of the industry; communicating in a way that people can understand; and offering considered perspectives on how the crypto industry relates to wider societal debate on the need to decarbonise.

From a benchmarking perspective, it is worth considering two key areas: first, the way in which the crypto sector approaches and communicates its reporting; and second, the way in which comparisons are made between the crypto industry and other sectors of the global economy.

Transparency

Looking ahead at the crypto industry's journey towards decarbonisation, it is clear from discussion that ongoing benchmarking and reporting must be transparent, accessible and cognizant of operating constraints.

As we noted earlier in this report, it is a fairly unique property of Bitcoin that the direct link between electricity consumption and the Bitcoin network is so clear, and the data so readily available. Although the electricity consumption of Bitcoin is indeed significant, electricity and mining equipment are the only inputs. There are very few other sectors that have such a simple ecosystem (although as the ecosystem matures so too will its complexity). In contrast, the environmental impact of most other industries extends well down the supply chain and is not restricted to direct impacts or electricity usage. This relative simplicity gives rise to a highly visible electricity usage within the BTC network - and must play a part in why Bitcoin has attracted so much public attention. In response, we must be equally open and transparent in the actions we as an industry take to mitigate environmental cost.

The University of Cambridge and the Digiconomist, both of which were represented in our round-table, publish freely the data associated with Bitcoin energy consumption, and the assumptions underlying it. As more and more industry participants start to publish their methodologies for assessing environmental impact - and the actions they are taking to address it - it will be vital that this is clearly and publicly documented in the spirit of transparency that has defined the development of the blockchain space.

> "I think it's important to be transparent... with the lack of standards, the most important thing is to be transparent about what you're doing. That's just the way to go."
>
> Alex de Vries, Digiconomist

Relatability

Perhaps one of the biggest challenges of the cryptocurrency sustainability conversation is how to make sense of it for the average person outside of the crypto ecosystem.

As was clear from the round table discussion, one of the biggest issues in speaking about cryptocurrency and its energy consumption is the difficulty of what to compare it to. As a still young and disruptive industry, crypto has no direct counterpart. It is yet to be normalised and form part of daily life for the average citizen. This means there is a sense of the industry still catching up with itself: nascent utility not yet publicly appreciated so much as more visible and easily digested metrics such as energy consumption. This is particularly the case given the uncontextualised interpretation of Bitcoin energy consumption, often comparing the energy usage of Bitcoin to that of countries, widely published in the press.

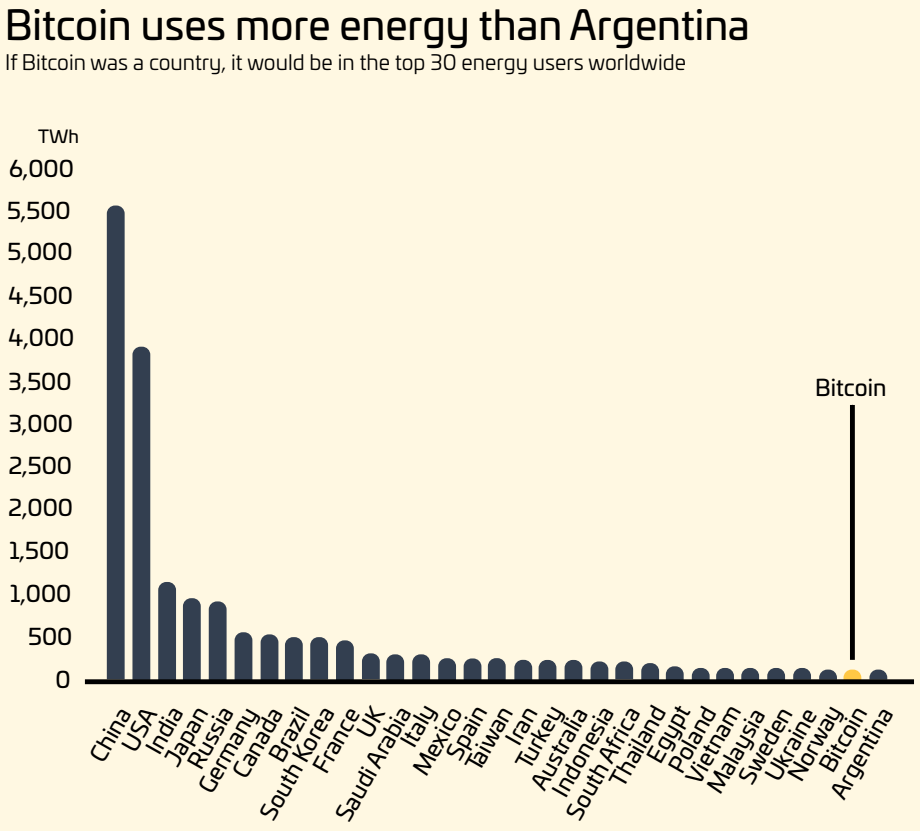


Fig. 5 Example media coverage of Bitcoin energy consumption
Source: BBC

Progress in public perception will rely on transparency, contextualisation and information, coupled with evidence of coordinated action in terms of decarbonisation.

Notably, this also means framing the issue in a productive way that everyone can understand.

As one round table participant pointed out, we can develop all the methodologies we want, but we must make it instantly accessible and relatable if it is to have a meaningful impact - even through something as simple as a visualisation of an energy star rating.

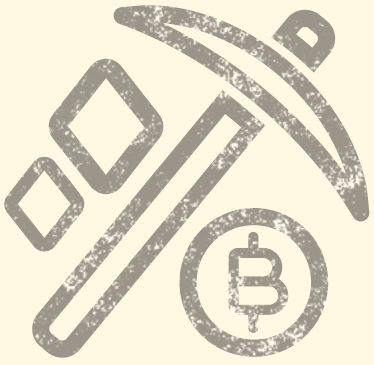
> **"There needs to be some kind of transparency in whatever measures we take and however we present it... if we all come up with our fantastic own best measure, which is maybe not comparable to anything, then the question is if we have achieved anything. So how could we make this a bit more consumer friendly? Perhaps you notice an Energy Star rating - how much did it take to mine this block, how much to mine this transaction or over a period of time. How can we prove it, how can we make it transparent and verifiable also to others?"**
>
> Lars Jorgensen, Chief Operating Officer, TAAL Distributed Information Technologies

The limits of reporting

Transparency, contextualisation and accessibility aside, there must also be an understanding of the limitations of what can be shown.

Round-table discussion left it clear that the best possible tracking of the issue would come from granular, per Bitcoin line data for every miner. However, there was an equally pragmatic appreciation that such data is almost impossible to come by: because of the inherently decentralised nature of the network, because mining operations frequently relocate by season or due to geopolitical events; and because a significant portion of mining is located in geographies and jurisdictions where expecting verified and accurate reporting would be unfeasible. However, organisations such as Energy Web are working to advance the CCA by developing a green hashrate solution that uses blockchain technology to both streamline renewable energy procurement by miners and verify green credentials of miners.

To put it into context, the Bitcoin Mining Council's estimation of renewables mix displayed in figure 4 above is based on a survey of 32% of the global network[7] - demonstrating the present difficulty of getting direct energy reporting from all network participants.



7. Source: https://bitcoinminingcouncil.com/wp-content/uploads/2021/07/2021.07.01-Mining-Council-Press-Release-Q2.pdf

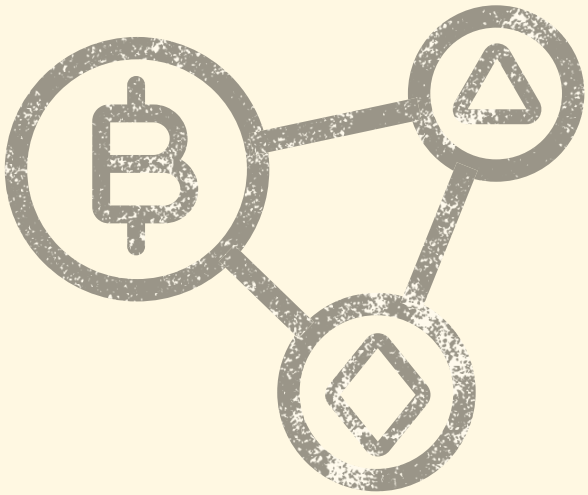
"To link [location-specific mining] data together with the electricity consumption estimate that we have, you need to have more granularity in order to get the right carbon intensity data that you want to put into those models. And the problem with granularity of course is that you get into confidentiality issues and privacy issues and all of that. So, the only truly verifiable method would be if you really kept track of every single mining farm and had access to the underlying parameters and verifiable credentials there, which I don't really see happening at any point in the future."

Michel Rauchs, Digital Assets Lead, Cambridge Centre for Alternative Finance

As we aim to build up a fuller picture of what is going on in cryptocurrency networks, this is why cross-industry initiatives such as the Crypto Climate Accord have such an important role to play in formulating an effective, coordinated response and open-source solutions. But it must also be accepted that there is a limitation - as for any sector - in the extent of data that can be collected and reported.

Bitcoin comparisons

As we have already noted, there is no shortage of circulating comparisons that aim to provide a perspective on Bitcoin's energy consumption. The question is: what constitutes a sensible benchmark, and what contextualising factors do we need to take into account? Here there are important points to be made about utility, equivalency and how crypto is to be regarded in comparison to other sectors such as the financial sector.



Exploring utility

To date, mainstream reporting has focused on an isolated illustration of energy consumption most commonly benchmarked against the energy usage of various world countries.

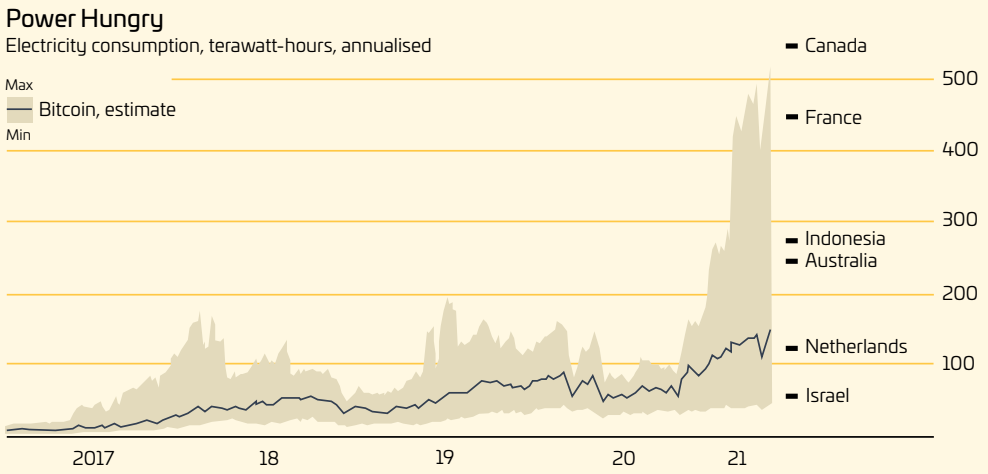


Fig 6. A graph showing the electricity consumption of Bitcoin over time as against various world countries
Source: Economist/Cambridge Bitcoin Electricity Consumption Index

The very nature of these comparisons suggests that there is a deficit in the publicly appreciated value that cryptocurrency networks provide: after all, we would not expect a similar illustration depicting the energy consumption of everyday consumables such as groceries, transportation, or even the entertainment industry.

This is where contextualisations of utility come into the picture. As the round-table agreed, it is not just a question of quantifying the energy consumption of a given network, it is about determining the value that is given in return, both to individuals and to society at large. And as participants were quick to point out, this quickly becomes a significant leveller when viewed through the lens of providing an alternative financial system, or the blockchain infrastructure to extract real-world value.

> **"I think sometimes it needs to be split a little bit between the infrastructure part, and what it is you can do with this infrastructure. And what value does that represent for society and for each individual person in the society?"**
>
> Lars Jorgensen, Chief Operating Officer, TAAL Distributed Information Technologies

We must remember, proof of work is energy intensive by design because that is what secures and enables an entirely new system of value storage and exchange. If we wish to influence public perceptions about Bitcoin power consumption and cryptocurrency in general, we must do a better job at communicating what it is the world gets in return.

The part vs the whole

Moving on to look at the benchmarking issue from a sector perspective, there are questions as to the equivalency of the comparisons that have been made in public forums.

We know that, in terms of electricity usage, Bitcoin has very easily accessible, relatively high-quality data available in the public domain. This encompasses the sum of its environmental impact, and the fact that there is such a comprehensive and transparent metric of account is both Bitcoin's advantage and disadvantage.

> **"The quality of data that we have [for crypto] - is much better than [data that exists] for many other sectors ... it is a challenge in many ways when you're trying to compare with something else because we might have a reasonable, accurate estimate for cryptocurrencies, but in all honesty, if you look at traditional finance, good luck coming up with a good number there, it can vary by orders of magnitude."**
>
> Alex de Vries, Digiconomist

This has led to problems of comparison and equivalency when the totality of Bitcoin environmental impact is set against a selected slice or cross-section of the emissions of another sector. As an example, in the figure below the totality of Bitcoin energy consumption is contrasted with, as an example, the global cash system, which isolates and abstracts a single component (cash payment) from its wider environmental impact within the surrounding banking system.

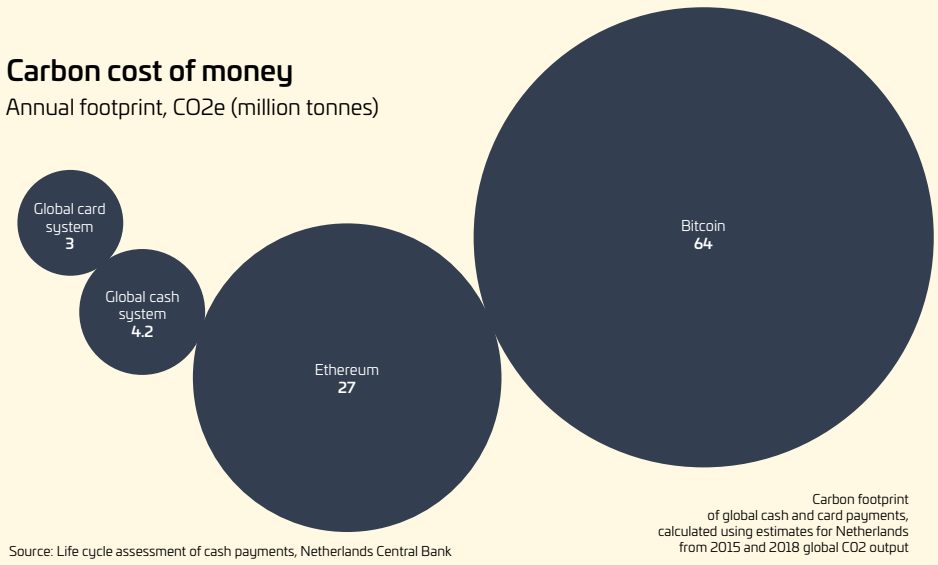


Fig 7. Bitcoin and Ethereum carbon footprint contrasted against the carbon footprint of the global cash and card systems
Source: Life cycle assessment of cash payments, Netherlands Central Bank

Hidden environmental cost

This is a significant point because, in the nearest comparable sector of traditional finance, we are only beginning to scratch the surface of what the true climate impacts might be - most of which do not come from direct emissions attributed to the finance sector itself.

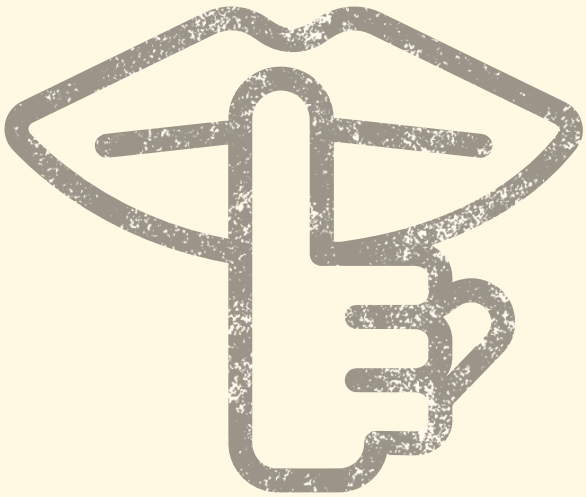
Much of this has to do with financed emissions - the carbon footprint derived from the money we hold in, or borrow from, financial institutions as part of bank, savings, pension and investment accounts.

It is emerging that these financed emissions are far higher than might be appreciated - but far less visible than the carbon footprint of cryptocurrencies because there is not such a clear and direct link, and because we are so used to putting our money in the bank.

> **"Within traditional finance, one of the things that's increasingly gaining prominence is financed emissions - that is, the emissions our money is responsible for when it sits in our bank account or pension pot etc...what is that money actually funding through the financial institutions that hold it and invest it? Recent reports show financed emissions to be hugely significant, but they are very complex to calculate, and show a tangled web of emissions."**
>
> Kirsteen Harrison, Environmental and Sustainability Adviser, Zumo

Two recent and highly credible reports that have investigated these financed emissions of banks and investment companies are from the highly respected global carbon disclosure platform CDP and Greenpeace/WWF.

In April 2021, a CDP report[8] showed that financed emissions globally are 700 times greater than the direct emissions of the finance sector itself.



8. Cf. https://www.cdp.net/en/articles/media/finance-sectors-funded-emissions-over-700-times-greater-than-its-own

Shortly after the CDP report was published, Greenpeace and WWF produced a report[9] focusing on the UK finance sector. This shows that financed emissions from UK banks and asset managers are responsible for nearly double the UK's annual carbon emissions. If the UK banks and investors in this study were a country, they would be ranked 9th biggest emitter of CO_2 in the world – ahead of Germany (for reference, this is a much bigger country than Bitcoin electricity usage has been compared to, and this study is limited to the UK financial sector).

Fig 8. UK financed emissions estimated at nearly double the UK's domestically produced emissions. Source: WWF/Greenpeace: the global emissions of the UK finance sector

Clearly, comparisons of cryptocurrency against other sectors requires careful contextualisation.

9. Cf. https://www.wwf.org.uk/updates/uk-banks-and-investors-responsible-more-co2-emissions

3 Collaboration: Working together for change

3 Collaboration:
Working together for change

Having discussed methodology, having discussed the way in which we respond to the need to decarbonise and the conversation around it, there is also a question of how the crypto industry might be able to collaborate to work together for change.

While we are wary of presenting crypto as a homogeneous mass - as we and round-table participants have noted, there is an incredibly broad range of technology, of mechanisms and even of philosophy contained under the crypto label - nevertheless we are able to define specific groups of actors within the ecosystem that we hope will be able to find common ground, and mutual interest, in tackling decarbonisation within the sector.

As with figures for electricity consumption, proof-of-work systems bring relative clarity when it comes to delineating the stakeholders involved: the miners who secure the network; the wallets, exchanges and platforms that enable transactions and storage; and the end users and investors on which the whole system depends. The challenge now is to find a way to identify where among these actors the responsibility for environmental mitigation lies, and the mechanisms by which progress can be made for the benefit of all. This will require open dialogue and a willingness to take individual and organisational responsibility for contributions to environmental impact within the cryptocurrency ecosystem.

> **"There's a question here as to where responsibility and accountability lies, and also what kind of metrics and calculations need to be applied along that chain so that each of us can take the correct amount of responsibility..."**
>
> Kirsteen Harrison, Environmental and Sustainability Adviser, Zumo

It is our opinion that the most effective collaboration will be the collaboration that can effectively engage, communicate with and meet the needs of all these stakeholder groups in the name of full decarbonisation of the sector - a collaboration that is based on full and transparent disclosure and leaves the space for best practice to emerge naturally from open and continuing discourse.

Zumo's own net zero strategy recognises the need for us to reduce our own carbon footprint as far as possible (pillar 1), but that our own footprint is minor in comparison to blockchain-related emissions (pillar 2). However, although wallets, platforms and exchanges have a responsibility for these emissions, it is the miners (pillar 3) that have the potential for the most positive impact, by utilising renewable energy supplies. Thus our net zero strategy recognises the increasing impact (coupled with decreasing control) as we move to this third pillar.

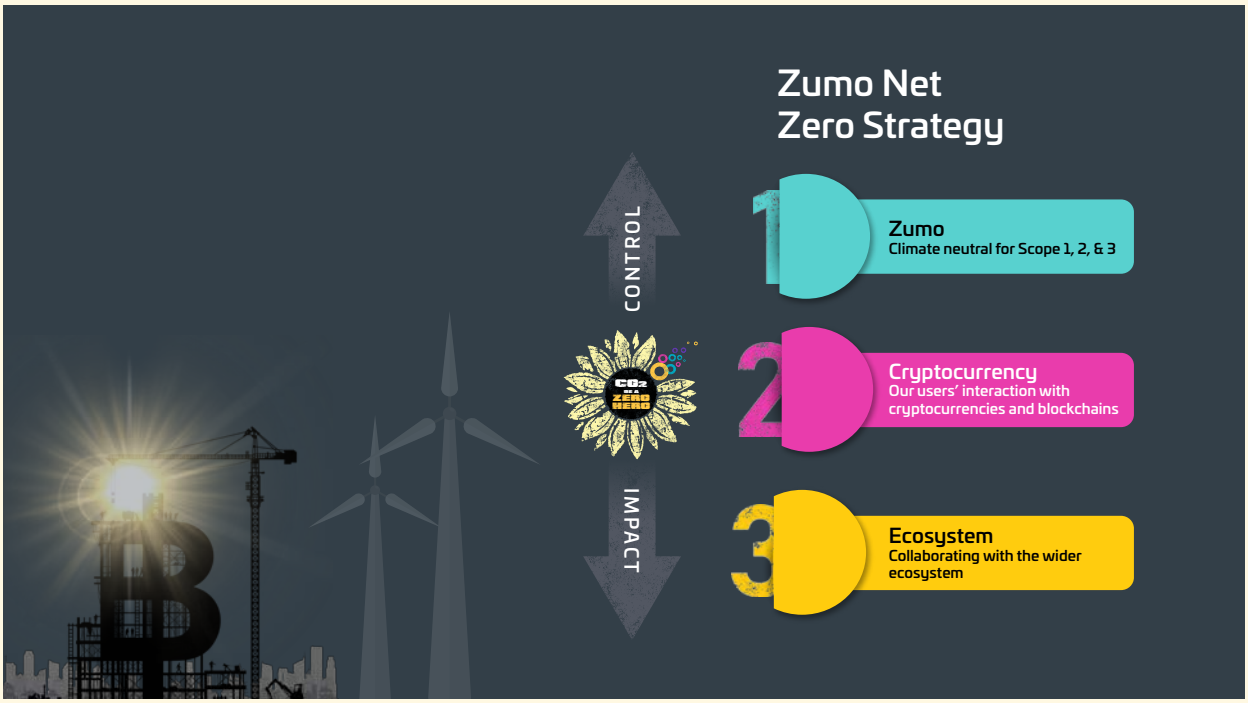


Fig. 9 Zumo net zero strategy graphic illustrating engagement at various levels of the ecosystem

Collaboration in action

Already, industry bodies and organisations have begun to emerge that strive to bring actors together to tackle the environmental impact of the crypto sector and how it approaches decarbonisation.

Two of the most well-known of these are the Crypto Climate Accord (CCA) and, though focused solely on Bitcoin mining, the Bitcoin Mining Council (BMC).

The Crypto Climate Accord is a decentralised public initiative led by the private sector to decarbonise the crypto sector in record time. The CCA is accelerating the development of open-source decentralised solutions to simplify the estimation, procurement, and verification process for crypto miners, exchanges, and investors to decarbonize. If successful, the CCA will have the crypto industry set an example of decarbonisation for other industries to follow. More than 170 companies, including Zumo, and spanning the crypto and finance, technology, NGO, and energy and climate sectors have joined the Crypto Climate Accord, and this list continues to grow.

On the mining side - which, as we have seen, is a critical part of the energy debate - the Bitcoin Mining Council is a voluntary global forum of Bitcoin mining companies and other companies in the Bitcoin industry that aims to increase public awareness and share best practices. Speaking to environmental impact specifically, it has recently published data[10] collected from a survey of its mining members analysing energy consumption and the renewable energy mix.

While it is encouraging to see such dedicated, voluntary efforts towards collaboration, round-table participants offered a note of caution regarding the need to remain as impartial and independent as possible - we need to be transparent and open with the data, whether good or bad. Biased or partisan reporting will only undermine credibility: we need to make sure we are using independent, verifiable sources.

> **"By working together with research institutions that are completely independent, that are not for profit, working together to get the data but in a way that's verifiable by the researchers and where the researchers will report that data no matter what it tells - whether it's a good thing or a bad thing, it will get reported - I just think that adds to the credibility of those estimates and those disclosures in the first place."**
>
> Michel Rauchs, Digital Assets Lead, Cambridge Centre for Alternative Finance

10. Cf. [https://bitcoinminingcouncil.com/wp-content/uploads/2021/07/2021.07.01-Mining-Council-Press-Release-Q2.pdf]

Finally, the point was made that progress on decarbonisation may naturally align with the best financial interest of all participants in the ecosystem, particularly miners.

Bitcoin miners are interested in as high a Bitcoin price as possible; the greater the price, the greater the value of their mining rewards. With a market capitalisation of some $800 billion[11] as of September 2021, Bitcoin is already the juggernaut of the cryptocurrency space. Continued price increases rely on increasingly large injections of capital - and more and more, this is likely to come from larger-scale institutional investors. This type of investor expects to see - and be able to prove - certain standards, not least from the environmental perspective. Those with an interest will want to do what is necessary to attract that money. Environmental, Social and Governance (ESG) is increasingly becoming a key consideration within the crypto sector, and investors are likely to be key drivers of decarbonisation.

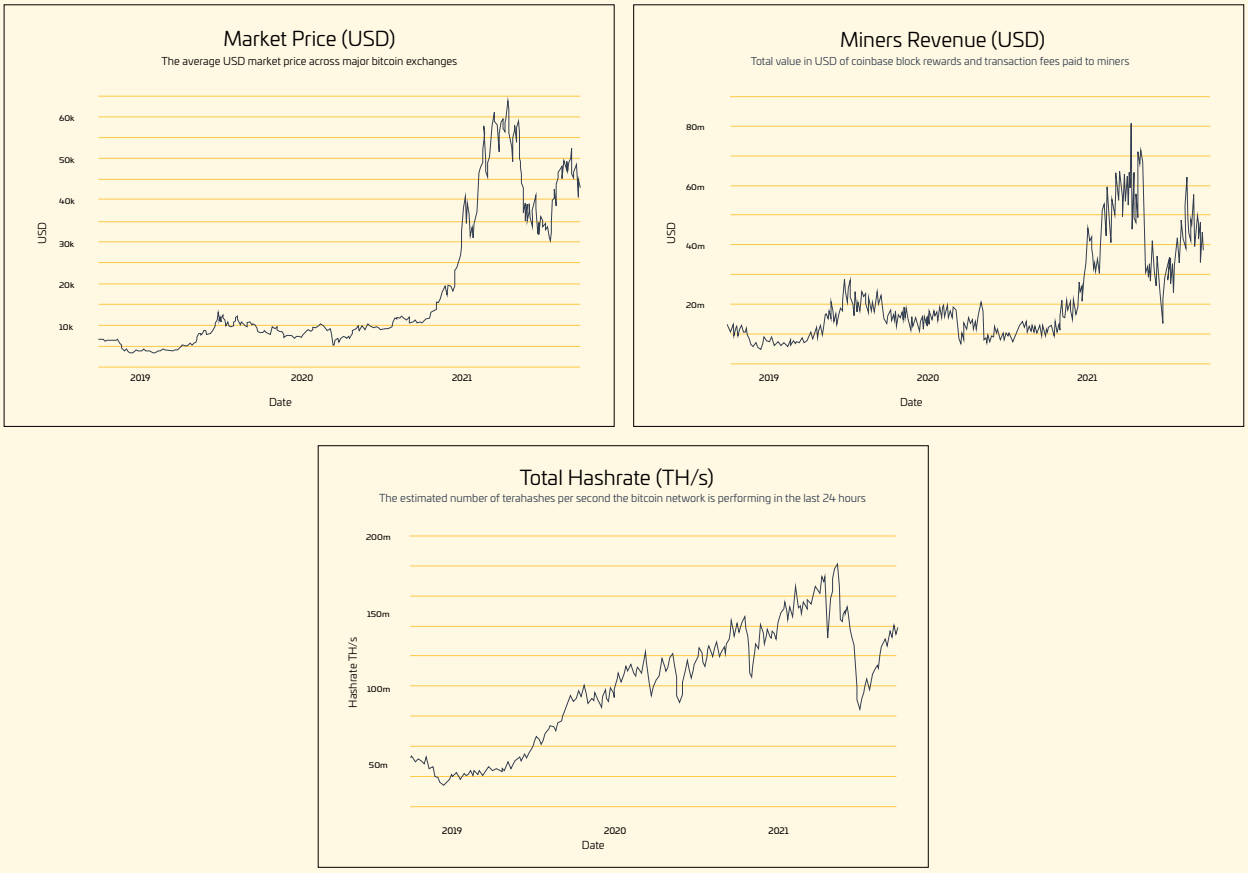


Fig 10. The correlation of Bitcoin price, Bitcoin miner revenue and Bitcoin hashrate
Source: Blockchain.com 27 September 2021

"Institutional investors are the ones who are going to decide whether there's inflows or outflows of the ecosystem. And what is that going to drive? It's going to drive miner revenues and the electricity level."

Michel Rauchs, Digital Assets Lead, Cambridge Centre for Alternative Finance

11. https://www.statista.com/statistics/377382/bitcoin-market-capitalization/

4 Technology: The path ahead

4 Technology: The path ahead

As with much of the discussion in this state of play report, there is a nearer picture and a further picture when it comes to considering crypto technology and how it intersects with the environmental impact of the crypto sector.

In the nearer view, the technology discussion cannot progress beyond Bitcoin. This, after all, stands as the bad, and until that is addressed then it does not matter what other technology is being developed: it is tainted by association.

In the further view, of course, blockchain technology is advancing at a pace that takes it further and further on from its Bitcoin origins. This produces its own questions - and opportunities - that will surely shape the cryptocurrency landscape in ways we have barely begun to imagine.

Bitcoin tech

To begin, however, with the Bitcoin conundrum. One option here is to attempt to reduce the number of on-chain transactions that need to take place in the first place (after all, it is these on-chain transactions, verified as part of the mining process, that are associated with big energy costs). 'Off-chain transactions' on the other hand can use various mechanisms to keep a running tally of accounts and balances outside of the main blockchain, whether through a trusted third party or as part of 'layer 2' solutions such as the Bitcoin Lightning Network, with only two main network transactions required - one to fund the agreed payment channel from the main blockchain and another to close it. The upside is that this potentially increases the number of transactions that can be handled while also reducing energy consumption for the off-chain component[12]. On the downside, concerns remain as to the security of such off-chain records[13] and, if we are to turn to third-party intermediaries to process transactions off-chain, the advantage of recreating a flow and system that we already have with conventional payments. Realistically, the outcomes of such scaling technology can at best mitigate energy consumption as demand increases, as opposed to effecting any reduction in overall electricity usage.

Here arose in the round-table discussion a main point: that proof-of-work systems such as Bitcoin were never designed to be efficient. Indeed, they were designed to be inefficient: that is where their security comes from. The question becomes whether this is valued sufficiently, by a sufficient number, to justify its existence. The trend towards custodial solutions, where users do not own the underlying cryptoasset, as well as the rise of alternative, more efficient yet potentially less decentralised and secure consensus mechanisms[14], suggests that this may no longer be the case as cryptocurrency evolves in its use cases and finds more and more mainstream adoption.

12. See https://medium.com/coincorner/comparing-bitcoin-lightning-energy-usage-to-the-real-world-2d64c62b1783 for further discussion

13. Some of the reservations with the Lightning Network are outlined here: https://www.investopedia.com/tech/bitcoin-lightning-network-problems/

14. https://techcrunch.com/2021/05/14/solana-a-blockchain-platform-followed-by-top-crypto-investors-says-its-a-lot-faster-than-ethereum/ By way of example, one of the latest-generation blockchains, Solana, is described as having 608 validators vs 33,700 for the testnet of ETH 2.0 or the 11,259 public nodes (as at 28 September 2021) of the Bitcoin network

> "It has to be useless to be secure, that's the problem... can you optimise that? It's an oxymoron. The only thing you can try doing is just getting completely rid of the whole proof of work and doing something else entirely like a proof of stake but that's an ongoing experiment..."
>
> Alex de Vries, Digiconomist

Putting the proof of work transition to the test

Perhaps the best barometer for whether a technology shift does take place away from energy-intensive, first-generation blockchains such as Bitcoin is what happens with the crypto world's number two blockchain, Ethereum.

The transition of Ethereum from its current proof-of-work consensus mechanism to a proof-of-stake model has been planned for some time - as far back as 2014[15] - and would reportedly reduce energy consumption by 99.95%.[16]

While we do not yet have an exact date for when 'ETH 2.0' will be fully live and operational (it will not be before 2022), there is a sense that this could be a watershed moment in determining whether a large, established proof-of-work chain can indeed be effectively migrated to a proof-of-stake system.

> "If they [Ethereum] do succeed and if everything is successful, that could potentially become a game changer because then you would have a massive currency switching from proof of work to proof of stake, which could shift some external dynamics."
>
> Alex de Vries, Digiconomist

In particular, there are questions of whether Ethereum, which has been rapidly catching up to Bitcoin on multiple metrics[17] , and is the base on which a great volume of crypto applications are built, could surpass Bitcoin as the number one cryptocurrency and whether, with the precedent set, there may be a further move over time away from proof-of-work systems. This is particularly interesting to monitor - as one round-table participant pointed out - as Bitcoin miner rewards rapidly taper off with each scheduled halvening of the rewards paid out for mining a Bitcoin block, and whether this can be offset by continuing increases in the Bitcoin price.

15. Cf. https://ethereum.org/en/eth2/vision/
16. Cf. https://blog.ethereum.org/2021/05/18/country-power-no-more/
17. Cf. https://www.theblockcrypto.com/data/on-chain-metrics/comparison-bitcoin-ethereum

The pace of technological change

Looking beyond Bitcoin and Ethereum for a moment, we can also observe that the cryptocurrency landscape is rapidly evolving and increasingly rich in technological innovation aside from the big two of Bitcoin and Ethereum.

Figure 11 below shows the growth in active crypto ecosystems since Bitcoin appeared on the scene in 2009. Of some 800 crypto ecosystems active today, it is interesting to note that, restricted to those with a market capitalisation of at least $1 billion, there are just 5 proof-of-work blockchains amidst the total number - Bitcoin, Ethereum, Bitcoin Cash, Bitcoin SV and Litecoin (see figure 2 in the 'Methodology' section for reference) - even though this handful of proof-of-work cryptocurrencies dominates the entire energy debate.

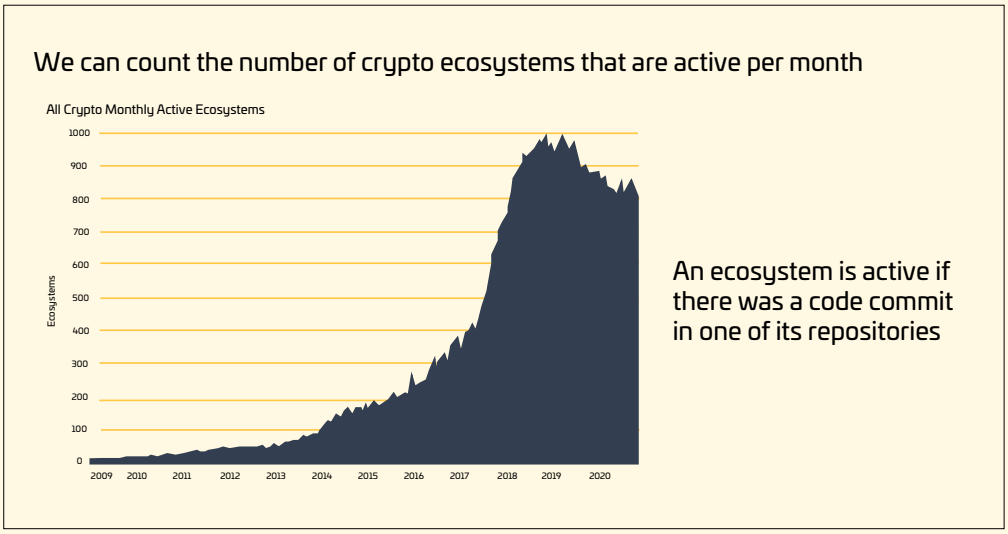


Fig 11. Active crypto ecosystems 2009-present

Source: https://medium.com/electric-capital/electric-capital-developer-report-2020-9417165c64444

It is instructive also to view the source of current growth in terms of where active development is taking place. While both Bitcoin and Ethereum retain strong and active developer communities, it is interesting to note that the fastest growth in development is often in alternative projects, many of which - Tezos, Cardano, Polkadot, Solana, Avalanche, Stellar to name just a few - are far less energy-intensive, as well as offering increased transaction throughput on-chain and progress in terms of blockchain interoperability.

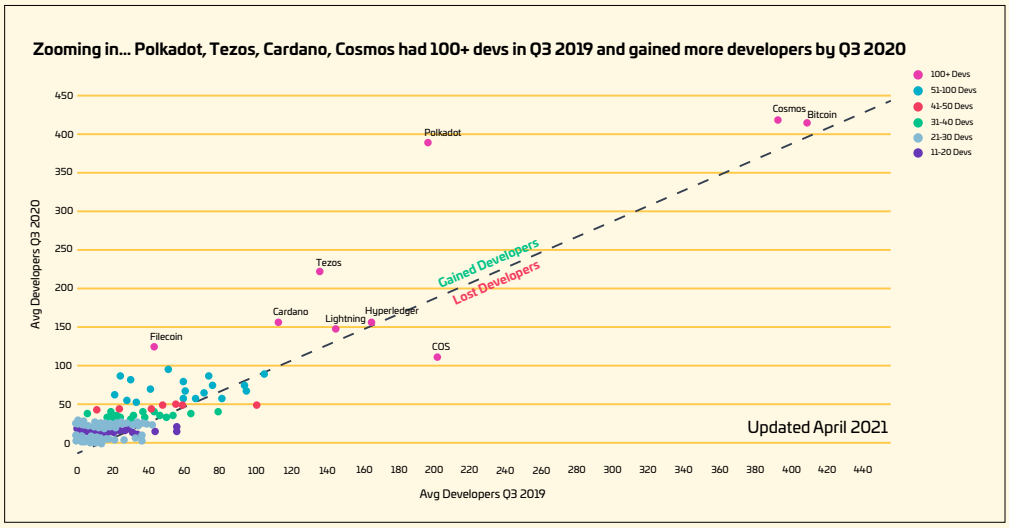


Fig 12. An illustration of developer growth in different crypto ecosystems

Source: https://medium.com/electric-capital/electric-capital-developer-report-2020-9417165c64444

We should therefore bear in mind that, of the new projects being launched today, many will have completely different implications in terms of energy consumption - this will surely have a bearing on the issue over time and is a trend that we should continue to monitor as it relates to the question of energy usage in the crypto sector as a whole.

The wider picture: utility, blockchain technology and the climate challenge

In the same way as crypto has diversified away from only Bitcoin, so too it has diversified away from any one single application. Decentralised finance, blockchain gaming, NFTs: these are comparatively recent trends - ones that did not exist when Bitcoin was created but ones that potentially change the factors of the energy-utility equation we discussed in the 'Benchmarking' section and, as technology continues to evolve to meet new use cases, will continue to impact the debate. As cryptocurrency has continued to develop and evolve, the breadth and scope of applications has increased exponentially; the entirety of the ecosystem as recently as 2017 does not even compare with that of a single protocol today in 2021.

Increasingly, this is not even restricted to cryptocurrency itself. Many onlookers - including in government and private enterprise - have come to appreciate the value of blockchain technology in a wide range of applications spanning the whole of society (see also figure 13 below). To give just one example pertinent to the energy debate, the United Nations has recently written that "blockchain... could be of great benefit to those fighting the climate crisis, and help bring about a more sustainable global economy[18] ", citing benefits in helping to accelerate climate action with regard to transparency, climate finance and clean energy markets. With the continuing emergence of green blockchain projects and initiatives, this is a space that merits continuing attention.

Fig 13. A sample of areas of blockchain technology application across private enterprise and public life. Original source: Matteo Gianpietro Zago, The Internet of Blockchain Foundation.

18. https://news.un.org/en/story/2021/06/1094362

> **"We think the sector is really well positioned to become an early adopter of a lot of useful technologies that we, the CCA community, and others are building to make progress toward meaningful climate action."**
>
> Doug Miller, Crypto Climate Accord, and Global Markets Lead, Energy Web

Finally, the round-table discussion raised some interesting points about how crypto technology can stimulate global renewable energy markets, both by providing an opportunity to invest into and subsidise new renewables projects and by making use of stranded or curtailed renewable sources that might otherwise go to waste.

As was pointed out in the discussion, not all electricity used to mine Bitcoin is simply drawn from the grid. A mining rig can be used in any location in which there is cheap electricity and a moderate bandwidth connection. This means that Bitcoin miners can make use of two important sources of electricity that would otherwise be wasted – stranded renewables, and supplies that would otherwise be curtailed due to low demand.

From a market perspective, there is also the opportunity to turn the challenge of energy consumption into the opportunity of making a positive impact: to look at mining and the energy requirements of systems such as Bitcoin as a demand for renewable power. The focus, as participants pointed out, is on turning what could be viewed as a problem into useful impacts from a climate perspective.

Conclusion

The aim of this report has not been to provide definitive answers - as we have seen, the variables are nuanced, rapidly evolving and much less black and white than popular reports may have led to suggest - but rather to contextualise the issue, provide a state-of-play snapshot based on the input of a wide range of expert voices close to the issue, and thereby provide the material and perspective to facilitate a more open and transparent discussion surrounding the decarbonisation of the crypto sector.

Members of the round-table included in this report continue to publish their own research, projects and methodologies touching and expanding on the issues raised in this report, and we invite you to follow and engage in this discussion.

Decarbonising the crypto sector is an issue we believe must be tackled; but equally, it is an issue that must also be demystified. At Zumo, we look forward to building on this work to facilitate and support collective efforts to understand, assess and contribute to the decarbonisation of the crypto sector.

About Zumo

Available for download on both iOS and Android app stores, Zumo is a secure, easy-to-use cryptocurrency wallet that allows anyone to buy, sell, store, send and spend cryptocurrencies alongside traditional British pounds, as well as providing crypto-as-a-service solutions for fintechs, banks and payment providers.

Founded in Edinburgh by entrepreneurs Nick Jones and Paul Roach, Zumo is a rapidly growing, purpose-driven fintech business with transparency, accessibility and financial inclusion at its core.

Through its new generation of smart money solutions, Zumo aims to deliver a fairer and financially fitter future for all, and bring the benefits of blockchain and digital currencies to people and businesses everywhere.

A values and sustainability-driven business, Zumo is proud to partner with WasteAid and support the decarbonisation of the crypto industry as a signatory of the Crypto Climate Accord.

zumo.money