Decarbonising Crypto

Towards practical solutions

ZUMO®

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Decarbonising Crypto: Towards practical solutions

A survey report | June 2022

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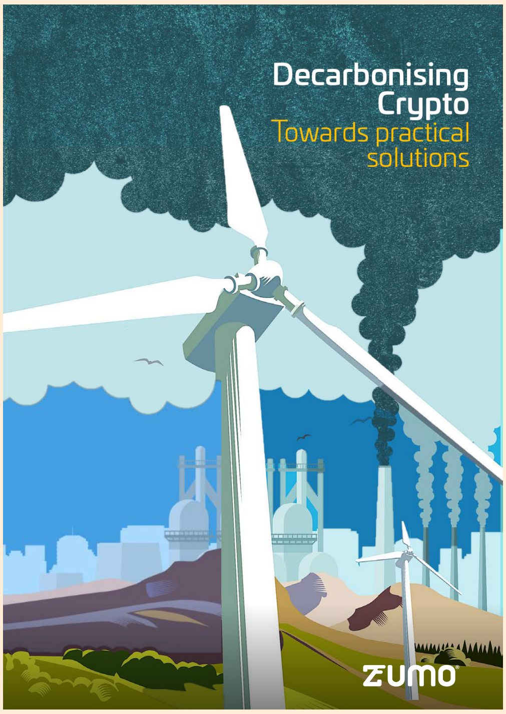
Zumo Decarbonising Crypto
Report Series

Report 01 **The State of Play**



Report 02 **Towards Practical Solutions**

Introduction

It has been an eventful six months since we released our inaugural 'Decarbonising crypto' report, detailing the current state of play in the industry, the terms of engagement and the scope of the challenge ahead.

The conversation, as we all know, is a fast-paced one. Set against the backdrop of a rapidly evolving and maturing industry, increasing regulatory interest and fierce public scrutiny, the topic of energy consumption in crypto is as prominent as it has ever been. And, we believe, a debate that has firmly reached its tipping point from talk into action.

In this follow-up 'Decarbonising crypto' report, we offer a practical and solutions-focused counterpart to our initial state-of-play review, focusing on the outcomes of our own 'Zero Hero' pilot implementation project, as the first practical step in Zumo's net zero strategy, and offering a practitioner's discussion both of the solutions frameworks we adopt today and the opportunities we look to embrace tomorrow.

1

Section 1 presents a simple visual overview of the Zero Hero pilot project and prevailing customer sentiment.

2

Section 2 offers a wallet/exchange provider's perspective of methodology considerations, key takeaways, renewable energy procurement strategy and evolution of practice.

3

Section 3 outlines a consideration of the next chapter in the delivery of crypto decarbonisation solutions.

Finally, our **BTC mining companion guide** considers how the decarbonisation discussion fits into the wider industry picture and a landscape of shifting geographies, commercialisation, solutions innovation, regulatory pressure and public scrutiny.

This is an area in which so much is happening, and yet so much remains still to be done: may this survey report provide a practically-oriented discussion to serve on the common journey ahead.

Executive Summary

1

Zumo has successfully completed its Zero Hero pilot project - a live trial to buy renewable energy certificates compensating for the electricity usage of bitcoin bought via the Zumo consumer app. End of pilot polling suggests that some **84% of customers agree** that the issue of environmental sustainability in crypto is an important topic the sector should be working urgently to address, with **the desire to compensate for the environmental impact of crypto holdings** and a **lack of currently available solutions** cited as the top reasons for engagement.

84% of customers agree that the issue of environmental sustainability in crypto is an important topic the sector should be working urgently to address

2

For practitioners in the industry, particularly those approaching the issue from a crypto wallet/exchange platform perspective, the Zero Hero 'live-test' offers a range of practical takeaways encompassing best attribution methodology & best-practice approaches to renewable energy procurement.

Looking ahead, renewable energy certificate (REC)[1] marketplaces must increase in sophistication and in efficiency if they are to meet the current requirements of net zero strategies.

Crypto - as an emerging electricity-focused sector - has a unique opportunity to shake up this marketplace and signal a new wave of demand.

For crypto, this is the **next frontier: to move beyond simple accounting mechanisms** towards the additional benefits - in procurement processes, in innovative technology solutions, in added renewable capacity - that **benefit the grid system as a whole.**

However, the story can only be written with the **collaboration of all participants** - miners, platforms and end users - within and outside of the crypto sector.

At the industry level, we see some of these developments beginning to play out amidst the geographical reshuffle of mining towards North America,

the commercialisation and industrialisation of mining on the corporate model,

early innovative energy-mining solutions, increased regulatory engagement, and intense public scrutiny.

[1] Although the term REC is not universal, it is a more readily understood term than the universal 'Energy Attribute Certificate' and we use it throughout this document.

Presenting Zero Hero

A Zumo pilot decarbonisation project

1

Section 1 Presenting Zero Hero
A Zumo pilot decarbonisation project.

"Hope is not a strategy"

Mark Carney former Bank of England Governor and climate finance reformer

The Zero Hero mission: identify, quantify and live test a way to offer Zumo customers a means to compensate for their bitcoin purchases based on the procurement of renewable energy certificates (RECs).

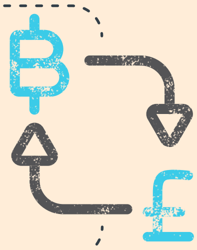
By the numbers

435 transactions

Total number of Zero Hero qualifying transactions over pilot period.

£1,500,000 BTC

Total Bitcoin value covered by Zero Hero REC purchase.



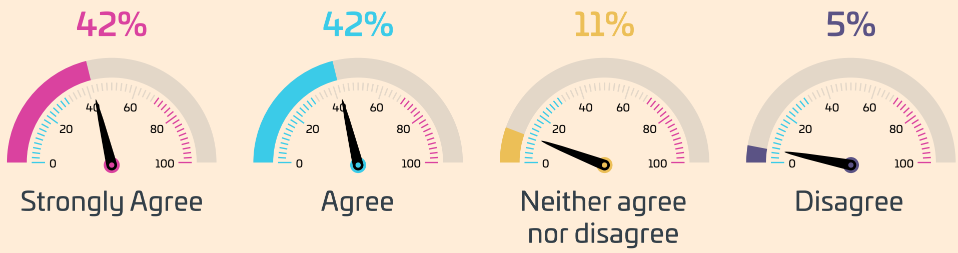
850 MWh[2]

Total electricity consumption compensated via purchase of renewable energy certificates.

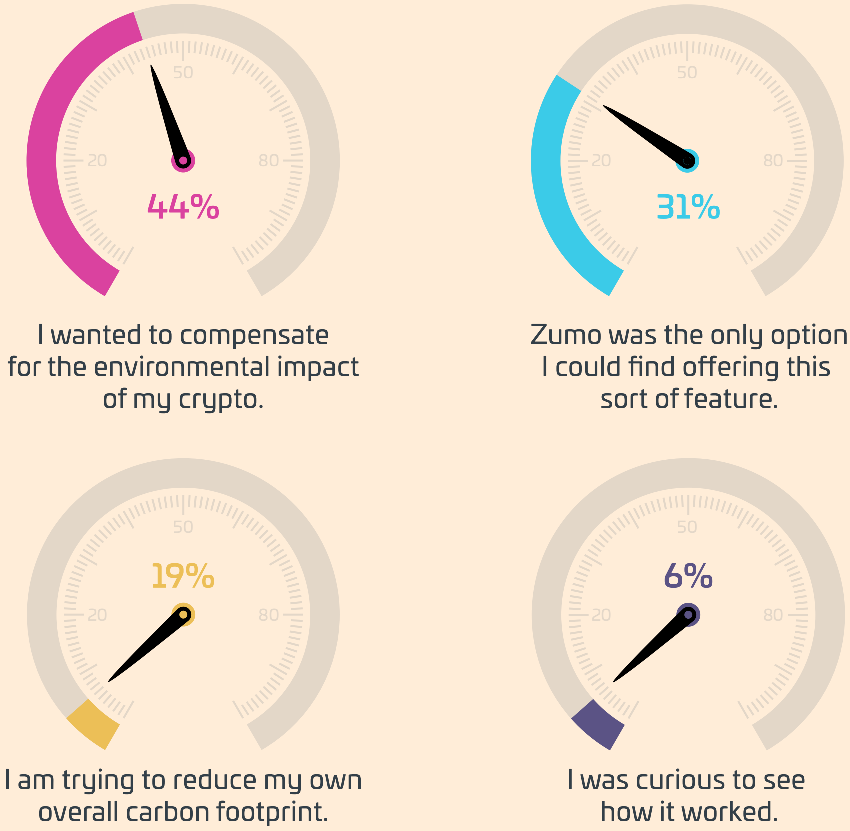
[2] 850 MWh = 50 BTC assuming 17 MWh per Bitcoin (please see Appendix 1 for calculation details).

From our customers

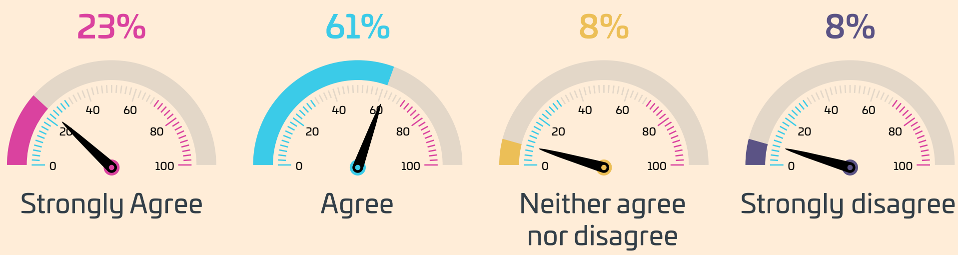
The issue of environmental sustainability in crypto is an important topic we should be working urgently to address.



What motivated you to get involved in the Zero Hero pilot?



I'm more likely to use a crypto wallet that offers built-in features that play a role in reducing the environmental impact of crypto.



Methodology

2

Section 2 Methodology

> "I have been impressed with the urgency of doing. Knowing is not enough; we must apply."
> **Leonardo da Vinci** attributed

How we quantify and practically address the environmental impact of crypto is far from a solved problem. But equally, the need to act to mitigate the climate crisis is far too urgent to wait for the perfect solution.

What do we mean by the environmental impact of crypto?

Cryptocurrencies rely on computing power - and therefore electricity consumption - to operate.

Electricity is by far crypto's most material environmental impact, and correspondingly the carbon emissions arising out of that power consumption are where the debate around crypto's environmental impact is centred.

Making headway will rely on a common willingness to innovate and iterate at speed, and in a way that is practical and applicable both for individual market participants and the wider sector.

In this chapter, we offer a longer-form consideration of some key points and takeaways concerning the specific methodology employed in the Zumo Zero Hero project; an elaboration of the rationale behind the evolution of our own methodology towards a 'network share' model; and some of the practical considerations of renewable energy strategy for those in the crypto space looking to adopt their own compensatory solutions.

While accepting that our own methodology is rapidly evolving as the industry and our applied knowledge develops, and recognising that others may choose to develop their own methodologies as well as build on those outlined here, we hope that this discussion is instructive for those approaching the question - perhaps for the first time - and wanting to explore the solutions they may be able to adopt.

The Zero Hero Methodology

Background

Zero Hero was a pilot project run by Zumo with the goal of modelling the electricity consumption attributable to Bitcoin (BTC) purchased via the Zumo consumer app, and compensating for this through the purchase of an equivalent amount of Renewable Energy Certificates (RECs).

A short definition of RECs

A Renewable Energy Certificate (REC) is a market instrument that represents a verified claim to one MWh of clean energy generation. RECs allow energy consumers and market participants to procure renewables where renewables may not have been available at point of use, or on a shared grid, and therefore have a central role to play in scaling the renewable energy market.

The pilot provided a first opportunity to gather data and 'live-test' an early solution for those wanting both to hold bitcoin and to compensate for the environmental impact of their holdings.

Model

Zero Hero applied the 'mined since genesis' model. The 'mined since genesis' approach attributes electricity usage on a lifetime per bitcoin mined basis, i.e. determining the energy cost of mining one BTC averaged 2009 - present[3].

This model was chosen for the Zero Hero pilot following consideration of a variety of available methodologies in our foundational state of play paper.

As well as the 'mined since genesis' model, this included a 'mined now' methodology, as well as 'network share' and 'transaction' models. Full details of the pros and cons of these respective methodologies, and the underlying assumptions /modelling trade-offs can be found in our prior report here.

Since the publication of our first report, a further hybrid model has been proposed by South Pole and the Crypto Carbon Ratings Institute (CCRI). We welcome this additional model and its applicability to different types of cryptocurrency.

[3] See Appendix 1 for further information on these methodologies.

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. 1: An overview summary of selected methodologies for attributing the environmental impact of Bitcoin.
Source: Decarbonising Crypto: a state of play report (Zumo, October 2021)

For those interested in examining these methodologies in more detail, or using them for their own purposes, these are laid out in detail in Appendix 1.

Get in touch

Decarbonising crypto is a shared journey. If you have any thoughts, ideas or questions relating to the methodologies and solutions outlined in this report - or would simply like to discuss ways to collaborate - drop us a line at hello@zumo.money

Zero Hero Pilot Key Takeaways

Focusing here, however, on the specific methodology as applied in our Zero Hero pilot, we would like to draw readers' attention to some selected points and clarifications particular to the combined 'mined since genesis'/REC purchase model as applied in the Zero Hero project and based on our practical experience and learning through this pilot.

A. Scope and limitations of approach

Zero Hero brought into practical focus the critical importance of attribution methodology and the challenges that can arise in mapping a purchase of RECs to what has happened on the Bitcoin network and when.

In this regard, the 'mined since genesis' lifetime average calculation method as applied in the Zero Hero project has both its benefits and drawbacks.

On one hand, standard REC purchase best practice indicates a REC purchase should relate to the period in which the energy was used[4]. As there is no easy way to finally determine BTC provenance once it is in circulation (i.e. the specific point in time at which each circulating Bitcoin was mined and at what electricity cost), there is an argument that a model that averages that electricity cost makes a 'best guess' at cumulative historical electricity consumption across the network over its lifetime. Seen this way, a REC purchase based on this method is a best attempt to account for historical use.

On the other hand, we know the electricity consumption of the Bitcoin network has generally trended upwards over its lifetime - a lifetime, we should say, of significant changes in the geography and energy mix of mining that makes it problematic to compare distant periods or average out over longer timeframes. And evidently, this is an argument for a bias towards actual recent energy usage over lifetime averaging.

As a final consideration, while Bitcoin miner revenue, incentive and therefore electricity consumption is still driven predominantly by the 'block reward' (more about which in our Bitcoin mining companion guide at the end of this report), a methodology that focuses on BTC purchased and a 'per bitcoin mined' calculation cannot as well capture the current incidentals - by which we mean transactions processed and the security provided to the network via the mining process - and their role in the Bitcoin network viewed as a whole.

[4] See, for example, RE100 guidance on 'Making Credible Claims'. However, bear in mind this is targeted to very large buyers of renewable electricity, so this is not a one-size-fits-all guidance document.

Importantly for Zero Hero, the purchase-driven model allows for attribution to individuals, an important consideration in user-empowered action.

B. Quantification triggers

The Zero Hero pilot made a conscious design decision to use the point of purchase of BTC via the Zumo app as the event triggering consideration in the final purchase of RECs.

It should be noted, in this early-stage pilot, this was still a manual and aggregated process i.e. RECs were not automatically acquired on a per-transaction basis, but rather qualifying purchases were batched and a single purchase of equivalent RECs made at the end of the campaign.

As with the 'mined since genesis' design decision before it, this yielded some practical insights with regard to ensuring the most proper and accurate coverage.

Positively, the purchase-driven model meant that larger purchases received larger weighting, which is correct given that the larger the bitcoin amount, the more electricity was used to first create it. It also makes sense that new exposure to BTC, i.e. purchase, is where the bulk of newly acquired environmental cost (to the user/platform) is accrued. Importantly for Zero Hero, the purchase-driven model allows for attribution to individuals, an important consideration in user-empowered action.

On the other side of the coin, it should be remembered that holding and selling are also actions with an environmental cost - holding on the basis of the environmental cost of the bitcoin when originally acquired, and the energy use for securing the network, and selling at least on the basis of the transaction cost of disposal. While these are of arguably lesser impact than new purchases (at least through the lens of determining new/additional liability), it did mean that those who simply held BTC for the duration of the project, or sold without purchasing, were not factored into our REC calculation.

This means an overweighting towards the purchase action (and particularly so where individuals may have purchased and sold a given amount of BTC multiple times without greatly increasing the overall size of their BTC holdings) and an underweighting to holders or sellers.

C. Ownership & transferability

Finally, just as Zero Hero presented valuable learnings about methodology within a REC procurement framework, so too we were able to obtain further clarity on what approach may work best for various stakeholders - and the distinctions to be made among them.

It is important to restate that a REC purchase model can make no claim as to the inherent properties of the BTC against which it is attributed. The BTC itself is not marked 'green' and it remains entirely fungible - under Zero Hero the owner of that BTC does not 'own' the RECs purchased and Zumo cannot transfer any 'rights' to claims regarding decarbonisation when it is moved from the Zumo wallet.

This is an important distinction that points to a key learning of the Zero Hero pilot - **the need to clearly distinguish between the actions taken by an infrastructure provider such as Zumo on behalf of its users, and the claims that can subsequently be made by those individual users.**

Here, there is a clear need for a holistic approach to crypto decarbonisation that can encompass all ecosystem groups: miners, wallet providers and end users included. From experience to date, it is increasingly apparent that such solutions must be tailored to the needs of each grouping – and may well differ for each according to their needs.

Combined and complementary solutions that can address the issue at source (miners), allow solutions providers to most accurately meet their obligations (wallets/exchanges) and give individual consumers a mechanism for ownership of their own footprint (end users) is, we believe, the direction of travel.

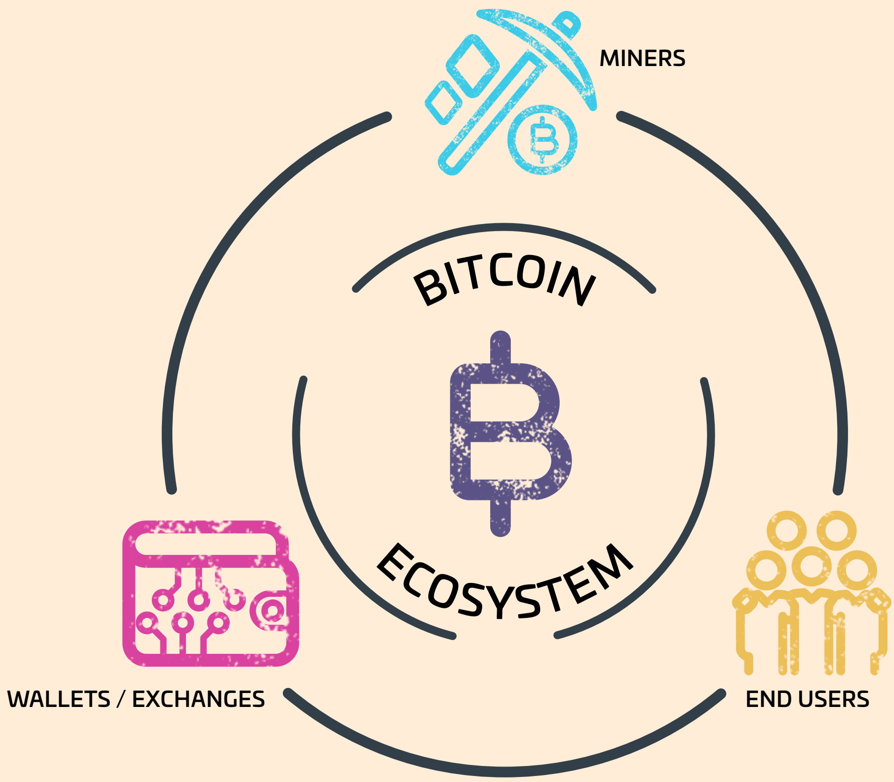


Fig. 2: Miners, platforms and end users are all integral parts of the Bitcoin ecosystem - and will each need to play their respective parts in the decarbonisation solution. Source: Zumo

The decision to move to a network share model explained

Having successfully completed the Zero Hero pilot, our observations can then be summarised as follows:

- There is a benefit in moving towards a methodology that is more reflective of recent energy usage, given current guidance and best practice with regard to RECs;
- There is a need for Zumo to adopt an approach capable of factoring in previously unfactored elements, notably transactions and network security as well as hold and sell behaviours;
- There is a need to be clear about Zumo the platform vs individual Zumo customers, and the solutions best suited to both.

While the fundamental design decisions are sound (a BTC-first approach over other cryptocurrencies; electricity attribution over carbon estimation[5]), we have formed a view, through learning, that we should tweak the specific attribution methodology.

This means that Zumo will be transferring to a 'network share' model. This is outlined in greater detail in the appendices to this report[6], but relies on the following process applied at platform (wallet/exchange provider) level:

Define time period (e.g calendar year 2021).

→ Calculate platform's average total BTC balance over the time period.

→ Determine platform's percentage network share by dividing the platform's average BTC balance by total circulating BTC supply at snapshot point at end of time period.

→ Apply the calculated percentage to the Bitcoin network's total assessed electricity consumption[7] over the time period to estimate the electricity consumption related to the specific platform for that time period.

It should be noted that this methodology does not currently include any attribution to transactions, as has been proposed by the recent South Pole and CCRI guidance. In the case of Bitcoin, with more than 90% of miner revenue currently coming from the block reward[8], transaction fees are not a key driver for electricity consumption, although in the case of other cryptocurrencies this may be far more significant.

[5] Please refer back to our earlier report, section 1, for the full information and rationale behind these design decisions: https:/zumo.money/wp-content/uploads/2021/11/Zumo-State-of-Play_07.pdf
[6] See Appendix 1 for full information.
[7] Based on University of Cambridge data https:/ccaf.io/cbeci/index
[8] NB: this is a conservative and ballpark figure based on the last period of observed network activity.

We have made this decision because, leading out of the considerations discussed above, we believe that the network share model is the methodology currently best suited to fairly and accurately capturing electricity consumption for Zumo as an exchange and wallet provider.

In regard to the need to have data related to most recent usage, the network share methodology allows for calculations related to both the most recent period (say the last 12 months), as well as for each historical period stretching back to the beginning of a platform's operations. In this sense, it addresses both the need to release calculations that are reflective of the most recent reality as well as retaining the ability to calculate for and factor in the usage of previous periods, which was the inherent advantage of the 'since genesis' lifetime averaging model.

Speaking to the questions of coverage and attribution, the network share model's approach of average total daily BTC holdings calculated at the platform level means that hold and sell behaviour can be captured as well as purchases, as well as offer a netting of buy/sell transactions based on the flows in and out of a platform over a time period. Further, attributing electricity cost to the BTC network as a whole, based on a platform's average bitcoin holdings, means that the methodology is no longer explicitly mining or block reward-driven: it is simply a calculated total network cost that encompasses the combined activity of the network, regardless of its mining, transaction and network security component parts.

Cambridge Bitcoin Electricity Consumption Index (CBECI)

The CBECI is the Bitcoin network power demand tracker of the Cambridge Centre for Alternative Finance (CCAF), an independent research centre at the University of Cambridge's Judge Business School. The index is updated daily, with methodology and assumptions freely available on the CCAF website alongside downloadable data.

For these reasons, the 'network share' / 'hybrid' model is best suited from a platform (i.e. Zumo) perspective.

This gives the network share model a flexibility to alter the underlying assumptions of its calculations - say, in the future, to add an extra weighting for transaction activity in addition to bitcoin holdings if the block reward/transaction fee revenue structure changes (as it inevitably must as mining rewards continually diminish with time[9]), without being tied to a 100% mining-driven calculation. This assertion is validated by the recently-published South Pole and CCRI guidance, which suggests exactly such a hybrid approach, and we include this in Appendix 1 for completeness.

For these reasons, the 'network share' / 'hybrid' model is best suited from a platform (i.e. Zumo) perspective. Returning to the question of which methodology suits which grouping, and how those solutions should be structured, this has several implications. First, it should be clearly stated we can no longer assign a direct 'benefit' to our users - that is, they are no longer termed 'Zero Heroes'. Moving forwards, calculations will be made by Zumo on platform level and are designed to best address the Zumo platform's environmental liability.

[9] Lyn Alden offers a good overview of a potential transition from block-reward to fee-based miner revenue over time in her fee-based security modelling guide here: https:/www.lynalden.com/bitcoin-security-modeling/

However, this is most certainly not to say that we are abandoning our users! As mentioned earlier, we believe in a solutions ecosystem. In this regard, the network share / hybrid models will, we believe, work best when the platform calculations performed by wallet and exchange providers to meet their obligations are matched with user-empowered action.

We still believe there is a place for the purchase-based methodologies we have trialled to date[10]. While this works less well for a platform, it is still an appropriate avenue (and one we will continue to use) for individual users, who cannot easily use network share methodology due to scale and requirements for structured data gathering, and who want a way to play their part in addressing this issue with action they can take on their own behalf. Here, 'mined now' and 'mined since genesis' models offer a readily available solution for attribution at the individual end user level.

Therefore, our longer-term ambition (and something we are actively working towards in the next phase of our initiative) is to tackle the problem from both ends - so that Zumo covers its own liability and our customers have the choice of addressing theirs, too, through their own tailored solution. It's through this sort of approach that we think we can begin to match models to stakeholders, and start to develop the solutions ecosystem that can truly work in tandem.

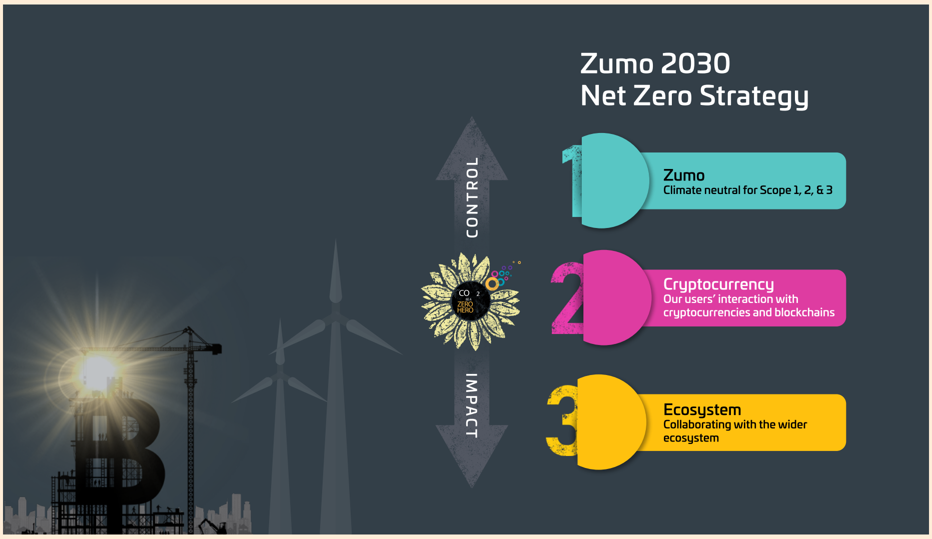


Fig. 3: Zumo net zero strategy graphic illustrating engagement at various levels of the ecosystem and our path to net zero by 2030. Source: Zumo

We end this segment by saying that we do not consider a purely transaction-based model suited to BTC specifically at this time - though it may work well for other cryptocurrencies where environmental impact is less driven by the block reward / miner revenue structure[11].

Aside from the non-transaction-driven nature of BTC energy consumption as it stands, this relates also to the difficulty of attribution in transactions, much of which we discuss in our prior report but which relates fundamentally to the difficulty of pinning down a common denominator of what a transaction is and how it should be assessed. This is based on considerations such as the growing number of transactions handled off-chain; differentiations to be made in distinguishing, from an energy attribution perspective, between purchase and disposal transactions; and similarly the difficulties of attribution when transactions are made cross-chain (say from ETH to BTC).

[10] See Appendix 1 and the 'mined now' and 'mined since genesis' methodologies.
[11] Those interested in further elaboration of transaction-based methodologies are referred to the Crypto Climate Accord guidance found on its webpage here: https://cryptoclimate.org/solutions/

SECTION 2
SECTION 3
CLOSING THOUGHTS
COMPANION GUIDE
APPENDIX 1
APPENDIX 2

Practical components of renewable energy strategy

Having considered, then, the underlying methodology of attributed electricity cost in the case of BTC, let us move on to offer some assembled pointers on the other factor of the equation, specifically the purchase of compensating Energy Attributes Certificates (EACs) such as Renewable Energy Certificates (RECs).

As crypto has the potential to be one of the largest users of renewable electricity globally (more about which later), we need to develop a robust strategy and framework for such purposes.

While in this segment we will focus on selected specifics of Zumo's strategy development, it should be said that the topic is an extremely wide-ranging one. Ensuring maximum positive impact in the adoption of renewables within the crypto sector will call for coordination and teamwork throughout the industry as well as a structured approach to technology and market solutions. Let us begin, however, with the fundamentals of an EAC compensation model.

Solutions Available

For those who have decided on their crypto electricity consumption attribution model, and wish to compensate for the environmental impact of this through the wholesale purchase of an equivalent amount of verified renewable energy[12], there are a variety of solutions available in the market.

These solutions can vary by geography in regard to their procurement processes, registration and underpinning terminology, as illustrated in the figure below.

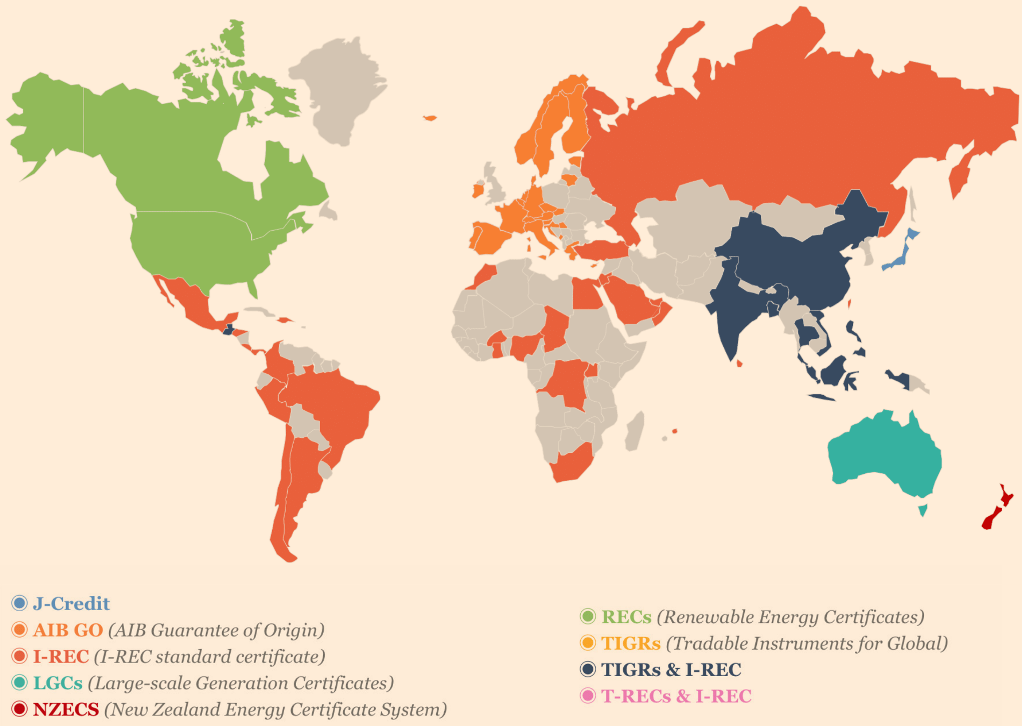


Fig. 4: A visualisation of EAC markets worldwide. Source: 3Degrees

[12] We still believe electricity attribution and compensatory action based on electricity usage is the better option over carbon footprint estimation, given what we still see as an unjustifiable amount of guesswork involved in getting from electricity usage to carbon footprint (see also the 'Methodology' section of our previous report: https://zumo.money/wp-content/uploads/2021/11/Zumo-State-of-Play_07.pdf)

Common to all, however, an Energy Attribute Certificate EAC (or Renewable Energy Certificate REC, to follow the North American terminology) is a market instrument that represents a verified claim to 1 MWh of clean energy generation.

Whenever a MWh of renewable energy is generated by an energy producer and supplied to the market, the producer receives an equivalent REC to document that fact. The REC owner is then free to sell its RECs - the claim to their clean energy - in the REC marketplace.

The buy side of the market comes from a combination of the voluntary market (those like Zumo looking voluntarily for a way to address environmental liabilities and support the decarbonisation of electric grids) and the compliance market (those like electric utilities procuring clean energy to cover compliance gaps with specific laws or mandates).

When a REC transfers ownership, and the purchaser subsequently uses that REC to make a claim about the renewable energy backing of their operations, that REC must be retired from the market to avoid the use of that REC for more than one buyer's claim. The claim has been used up, and the buyer - and only the buyer - has the right to the claimed clean energy attribute.

The main available avenue to procure clean energy for many companies is the 'unbundled[11]' REC, which gives purchasers unique ownership of verified clean energy as previously generated from a clean energy project. To make a claim about procuring 100% clean energy, the number of RECs a company procures and retires in their name must equal its MWh of electricity use. RECs can be differentiated by location/renewable energy type and other factors, and may vary in the attributes and claims they encompass.

> For crypto wallets like Zumo, similar to other digitally native companies, Scope 3 (i.e. company value chain) carbon emissions represent the largest emissions source.

For crypto wallets like Zumo, similar to other digitally native companies, Scope 3 (i.e. company value chain) carbon emissions represent the largest emissions source. While companies have historically only procured RECs to cover their Scope 2 (i.e. direct electricity use) emissions, industry developments such as the U.S. Security and Exchange Commission's proposed carbon disclosure rule and U.S. Environmental Protection Agency's new guidance[14] suggest that a growing number of digitally native companies will soon procure clean energy to cover the energy use and associated emissions of their value chains.

[13] i.e the REC is sold separately from the actual electricity.
[14] This new guidance from the EPA relates to procuring renewables on behalf of others and can be found here: https:/www.epa.gov/system/files/documents/2022-05/renewable_electricity_procurement.pdf

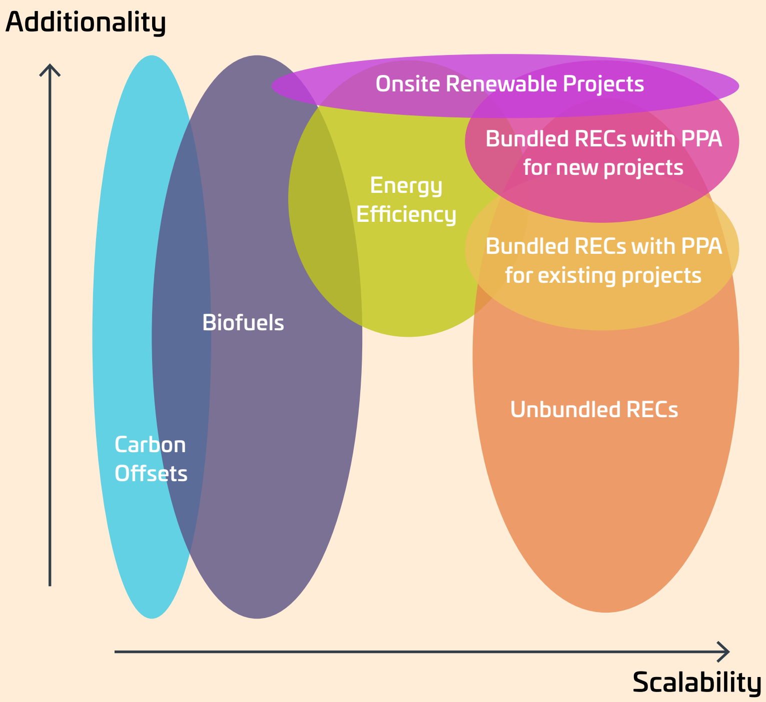


Fig. 5: A comparative visualisation of different decarbonisation options (note that 'carbon offsets' are not strictly a decarbonisation option). Source: Princeton Environmental Institute

All renewable energy procurement methods, bundled or unbundled, have the advantage of signalling market demand, which helps to stimulate renewable supply and thereby reduce the cost of clean energy overall due to an increase of capacity driven by steadily increasing uptake. REC prices are starting to increase as demand catches up with supply[15]. **The crypto sector therefore has an opportunity to scale the use of renewables by driving up both the demand for, and the price of, RECs.**

While it is not within the scope of this report to go into much further detail at this point, the RMI, an independent, non-partisan, nonprofit organisation of experts across disciplines working to accelerate the clean energy transition (as well as co-founder of the Crypto Climate Accord), and with whom we have worked closely in the past, will be issuing further renewable energy procurement guidance during the course of the year, which we encourage the interested reader to consult further.

In the case of miners, being those within the ecosystem who are the direct electricity consumers, there will be other further avenues of renewable energy procurement. This may include methods where RECs are bundled with electricity sales, such as Power Purchase Agreements (PPAs) - a contractual agreement between an energy buyer and an energy seller to buy the (renewable) energy generated at an agreed price - as well as green tariff or on-site clean energy generation solutions.

Some of these options may bring with them the advantage of added environmental benefit - supporting the installation of new renewable capacity through a PPA, for instance - beyond the REC method of accounting for liabilities by drawing on the existing pool of available renewable energy.

The crypto sector has an opportunity to scale the use of renewables by driving up both the demand for, and the price of, RECs.

[15] Cf. for instance https:/www.ecohz.com/news/impressive-growth-in-the-i-rec-market-global-renewable-energy-certificates, which illustrates the growth on the demand side.

Using RECs to make renewable energy usage claims

Using RECs to make an environmental claim - in the case of a crypto wallet/exchange such as Zumo, the claim that electricity consumption linked to BTC holdings is compensated by 100% verified clean energy - is something that brings with it specific requirements and considerations.

First, to make a public claim about being a 100% clean energy buyer, an entity must show a 1:1 relationship between MWh consumption and claimed RECs. It doesn't matter here what the grid mix is - the point is that it is the ownership of the RECs that gives the right to make a public claim about taking voluntary action to support decarbonisation beyond policy business-as-usual, and so those RECs must cover the electricity consumption in its entirety.

Furthermore, as mentioned earlier, the RECs used to make this claim must be retired (i.e. the REC is cancelled in the registry so that the owner will not ever be able to use the RECs again so as to avoid the issue of double counting).

RECs are the standard market instrument and therefore recognised as the main evidence used for accounting clean energy claims under the Greenhouse Gas (GHG) Protocol (the foremost and most widely-used corporate accounting and reporting standard), founded on the 'market-based' methodology.

Here, however, there are some peculiarities specific to the crypto sector. For wallets/exchanges, electricity usage is a Scope 3 emission (strictly speaking market vs location-based distinctions apply only to Scope 2, as explained further in Appendix 2). And it is only for miners themselves that electricity usage counts as a Scope 2 emission. However, due to the unique set-up of the crypto industry with regard to the significance of electricity consumption as the driving emissions variable further down the supply chain - and the ability of wallets/exchanges to be quantifying that electricity usage - we still believe that wallet providers should, in line with recent EPA guidance referenced earlier, procure RECs on behalf of suppliers (e.g. Bitcoin miners) to provide crypto holders full assurance about the green credentials of their crypto holdings. Those interested in further information about the GHG Protocol and how it relates to the crypto industry are encouraged to consult Appendix 2 at the end of this report.

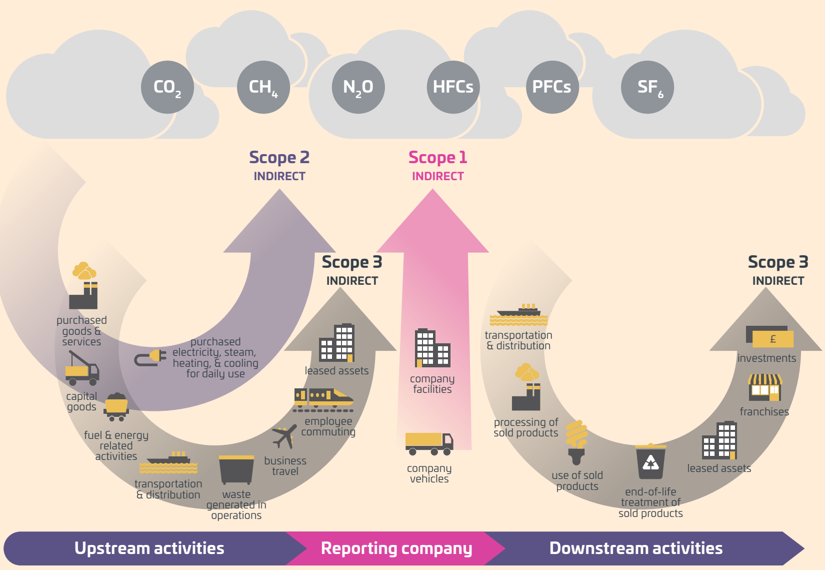


Fig. 6: Scope 1, Scope 2 and Scope 3 emissions as defined by the Greenhouse Gas Protocol. Source: GHG Protocol

Zero Hero purchase strategy & considerations

Currently, Zumo's net zero strategy in regard to blockchain activity has a heavy bias towards progressive renewable energy procurement. Traditionally, RECs have been bought by companies on spot markets through brokers and consultants at a large scale, but it is increasingly clear that a more sophisticated approach is required to scale the use of renewables and have maximum impact.

To the specifics of the Zero Hero pilot project, Zumo has made a REC purchase based on the activity of the pilot to compensate for BTC with value of £1.5 million set against a REC purchase of 850 MWh[16]. These RECs were procured from a Canadian hydro project in a single end-of-pilot transaction, bearing in mind the consideration to match the geographical REC purchase with an area of known BTC mining[17].

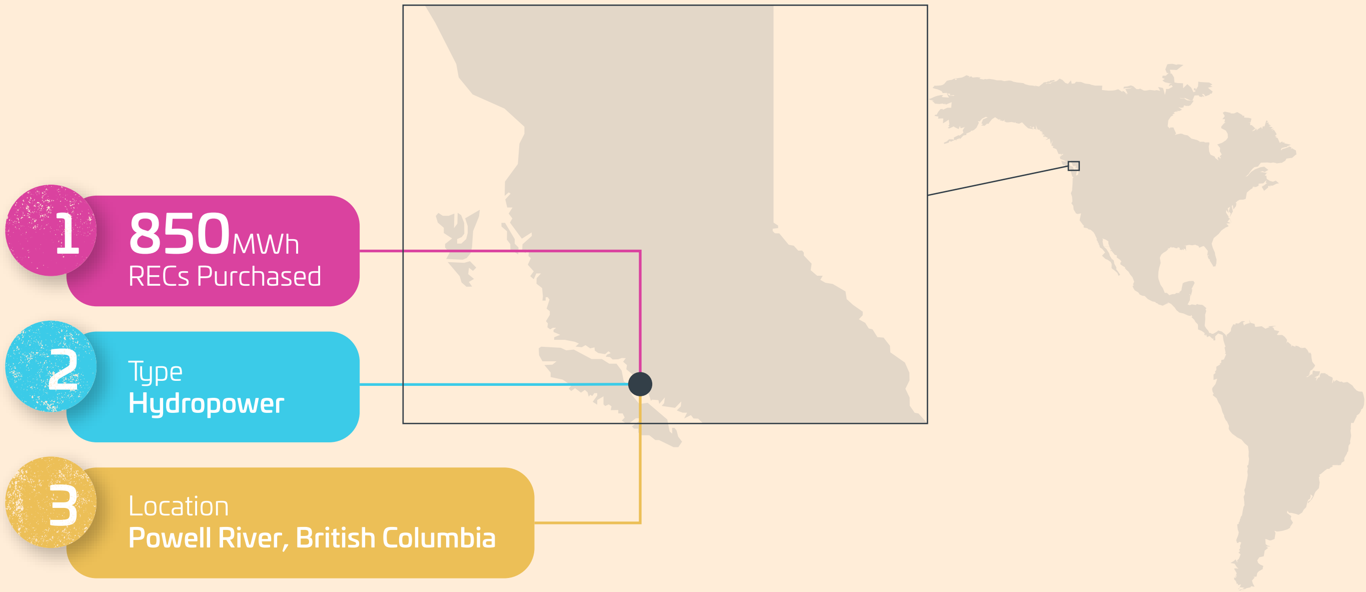


Fig. 7: Details of the REC purchase made by Zumo at the close of the Zero Hero pilot project. Source: Zumo

At the top level, the purchase strategy was driven by the following considerations:

- per Pareto principle, the need to address BTC as the 'first most significant action' before moving on consideration to other blockchains and tokens;
- the requirement that both methodology and record of action should be as transparent as possible, and publicly available; and
- that the REC purchase should correspond as closely as possible to the 'when' and the 'where' of the liability incurred.

Accordingly, the REC purchase made for the Zero Hero pilot was designed around BTC and is solely reflective of BTC purchased in the Zumo app.

[16] 850 MWh = 50 BTC assuming 17 MWh per Bitcoin (please see Appendix 1 for calculation details).
[17] Canada currently accounts for an estimated 6.48% of Bitcoin network hashrate, according to data from the Cambridge Centre for Alternative Finance.

This report aims to set out for the reference of all the underpinning methodology and design choices we have considered. And we also provide, as an auditable record, the proof of purchase for the amount stated in this report, which can be found by visiting the Zumo website. We consider it very important that records of actions are as easily identifiable and verifiable as possible and, to further this cause, we have additionally partnered with Zero Labs in their ongoing development of a blockchain-based solution that aggregates demand from small energy users and tokenises RECs.

Finally, to the thorniest question of 'when' and 'where', it remains the point of departure that a REC purchase should be as close to the 'when' and 'where' of its attribute as possible. In crypto, this is not always the easiest task. As already mentioned in the previous discussion, we believe that the proximity of 'when' will be best covered by a 'network share' model going forwards.

To speak briefly to the question of 'where', this variable can be just as tricky as the Bitcoin 'when', as we do not know in complete (or even majority) detail the locations of Bitcoin miners[18]. So while generally a REC purchase would be in the same geography as the electricity used, for Bitcoin REC purchases we cannot, at present, draw the same links.

Currently, our strategy is therefore to purchase RECs from countries where BTC mining is known to take place. However, this is not the only approach. Others[19] have proposed strategies that focus on largest marginal gain (i.e. targeting the dirtiest grids first).

We expect strategies and guidance to evolve quickly. The recently-published South Pole and CCRI guidance, and current consultation on RMI guidance, are testament to the speed at which this is developing. The forthcoming RMI guidance in particular looks set to offer comprehensive consideration of these variables.

And perhaps individual miners, known in location and with detailed forecasts of energy demand, can play the most important role here in advancing the cause of renewable procurement in ways inaccessible to solution providers downstream.

We continue to evolve our renewable energy procurement strategy, and to strive to tackle the problem collaboratively and dynamically as an overlapping crypto ecosystem.

[18] As an example, the Cambridge Centre for Alternative Finance's Bitcoin Mining Map has used mining pool samples ranging between 32% and 38% of total Bitcoin hashrate: https://ccaf.io/cbeci/mining_map/methodology (see Table 1).
[19] For instance, WattTime and others promote the concept of 'emissionality' (further explained in the following section).

The wider discussion

& where next

3

Section 3 The wider discussion & where next

> "Unlike most races,
> the race to zero emissions
> won't have one winner.
> In this race we all win, or we all lose"
>
> **Nigel Topping** High Level Champion for COP 26

Of course, the conversation doesn't stop there. This is such a fast evolving space: what holds today will not necessarily hold true tomorrow; solutions today are not necessarily the answers of tomorrow; and, undoubtedly, a body of work remains to be done to reach the ultimate destination of a decarbonised crypto sector.

In this paper, we have discussed the REC model and how it relates to BTC electricity consumption. This is not to imply it is some sort of silver bullet. While it is imperative we start down the road to action now, these are areas in which there is still progress to be made, and any balanced discussion must be alive to such considerations.

In this final chapter, then, we close by considering in a practical sense the action required to move on from the solutions of today, and outline what effective collaboration could look like, inside and outside of the crypto sector, in building on the progress made to date.

Building on the REC procurement model

Simply put, REC procurement processes in their current format are clunky and use outdated systems, pointing to the limitations of current renewable energy markets.

Partly, this is a question of procurement. RECs tend to be sold in minimum quantities to large bulk buyers, with no 'off the shelf' or pick'n'mix solution of the type available for carbon offsetting[20]. The process is manual, disjointed, managed with gatekeepers, different by jurisdiction and in general difficult to navigate for all but the largest players. This is problematic for crypto, since it makes REC-based solutions extremely tricky to implement for individual holders of crypto, and even for smaller organisations not accustomed to navigating the REC marketplace[21].

[20] The Gold Standard, for example, has multiple convenient options available for carbon offsets.
[21] Much of the existing guidance and operational initiatives, e.g. RE 100, are focused towards large users of electricity. However, this is changing with emergence of crypto-specific guidance such as RMI's recently released draft approach to evaluating the material impact of market-based renewable energy purchases.

Partly, it is a question of sophistication. RECs themselves tend to be issued on a monthly basis, and are issued and procured retrospectively[22] so as to account for historical load, most often on an annual basis. Even if a purchase is made in advance, it is based on estimated usage and not in real time as electricity is consumed. It also cannot factor in varying carbon intensity of country-specific grids over time.

And partly, it is a question of capturing extra attributes and nuances that cannot currently be captured. For instance, there is no way currently through RECs to send a market signal that a buyer wants to purchase clean energy at times of day when the grid is at its dirtiest.

With an eye to the future, the required actions are clear: the need to improve the efficiency and accessibility of REC markets; the need to work on the sophistication of available solutions with a view to benefitting the grid system as a whole, including specific considerations for different types of impacts such as procuring RECs matching load curves or based on maximum avoided emissions[23]; and the need as an industry to work together to shape guidelines and signal collective market demand in such a way as to facilitate this infrastructure progress.

Set against the backdrop of long-standing debate concerning REC take-up, efficacy and how to ensure RECs can live up to their full potential[25], crypto - as an emerging electricity-focused sector - has a unique opportunity to shake up the marketplace and signal a new wave of demand, stimulating the generation of renewable energy and accelerating the adoption of fit-for-purpose renewables-based solutions.

Providing Maximum Benefit

The key here is finding the solutions that provide the maximum possible additional benefit.

This is an area where miners - those able to make an impact directly at the source of electricity consumption - have a variety of options available to them that potentially provide valuable added benefits.

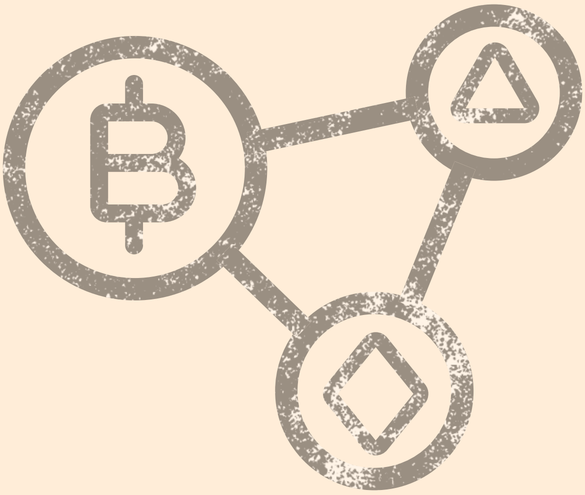
Emissionality and direct load matching

Emissionality is getting the biggest carbon saving for your buck (or the biggest marginal carbon reduction): a quantitative measurement that compares the impact of renewable energy projects on driving down emissions. Load matching refers to purchasing renewable energy at the actual time that it is being used, i.e. real-time matching. Such terms, along with others such as additionality and locationality, point to the growing imperative not only to procure clean energy, but to demonstrate proof of impact[24] in the process.

[22] Best practice, however, is to procure in advance based on forecasting.
[23] This is an area where companies with large data centres are already pursuing increasingly sophisticated strategies such as to match load with clean energy 24/7 and purchase renewables from the dirtiest grids (emissionality).
[24] As outlined in a piece by Energy Web on corporate renewables procurement: https://medium.com/energy-web-insights/the-next-era-of-corporate-renewables-procurement-is-here-1d98dd123b8b
[25] Cf. for instance https://recs.org/download/?file=The-supply-demand-of-European-renewable-energy_FINAL.pdf&file_type=documents

These include solutions such as renewable Power Purchase Agreements (PPAs), where a miner agrees to buy the clean energy from a renewable facility to be newly constructed; on-site generation, whereby a miner installs new on-site renewable capacity to meet its electricity demands; and usage of stranded energy (both renewable and non-renewable), whereby a mining operation draws on its locational flexibility to scavenge energy that no other consumer is able to productively use, therefore using energy that would otherwise go to waste. Some of these emerging solutions are further discussed in our review of the overall Bitcoin mining landscape in Appendix 1.

Looking ahead, this is arguably the next frontier: not simply to decarbonise the crypto sector, but in the process also to deliver additional benefits (in procurement processes, in signalled market demand, in innovative technology solutions) that also move us forward in society's overall drive toward decarbonisation. Implemented at speed (as the crypto sector is well positioned to do), it delivers a powerful signal to others of the progress that can be made where there is a common will to do so.



Working together

This brings us neatly to the topic of collaboration. It should be abundantly clear by now that this sort of progress isn't something achieved by any one market participant. Crypto is an ecosystem, and all key players in that ecosystem - miners, solution providers, end users - must agree and cooperate if meaningful progress is to be made. Otherwise, the story of crypto decarbonisation cannot be fully written. Increasingly, this means collaboration not just within the crypto ecosystem, but also outside of it: with regulators, with policymakers, with the society stakeholders with whom the crypto community must communicate, align and find common ground[26].

Specifically, we believe this means developing the standards, the auditability and the transparency that allows for industry-wide alignment and a commonly understood documentation of how the sector moves forward. There must be a shared understanding of roles and responsibilities within the ecosystem, the solutions available to be brought to bear and how these are to be applied by individual stakeholders to make common progress.

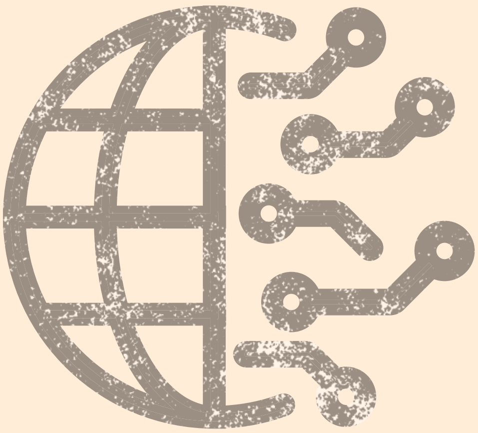
[26] For further discussion, please see the regulation & policy section of the Companion Guide at the end of this document.

There is reason for optimism that we are progressing well towards this target. In addition to the work undertaken on its own initiative, over the past six months Zumo has been privileged to contribute to, and align with, a number of active wider collaboration projects.

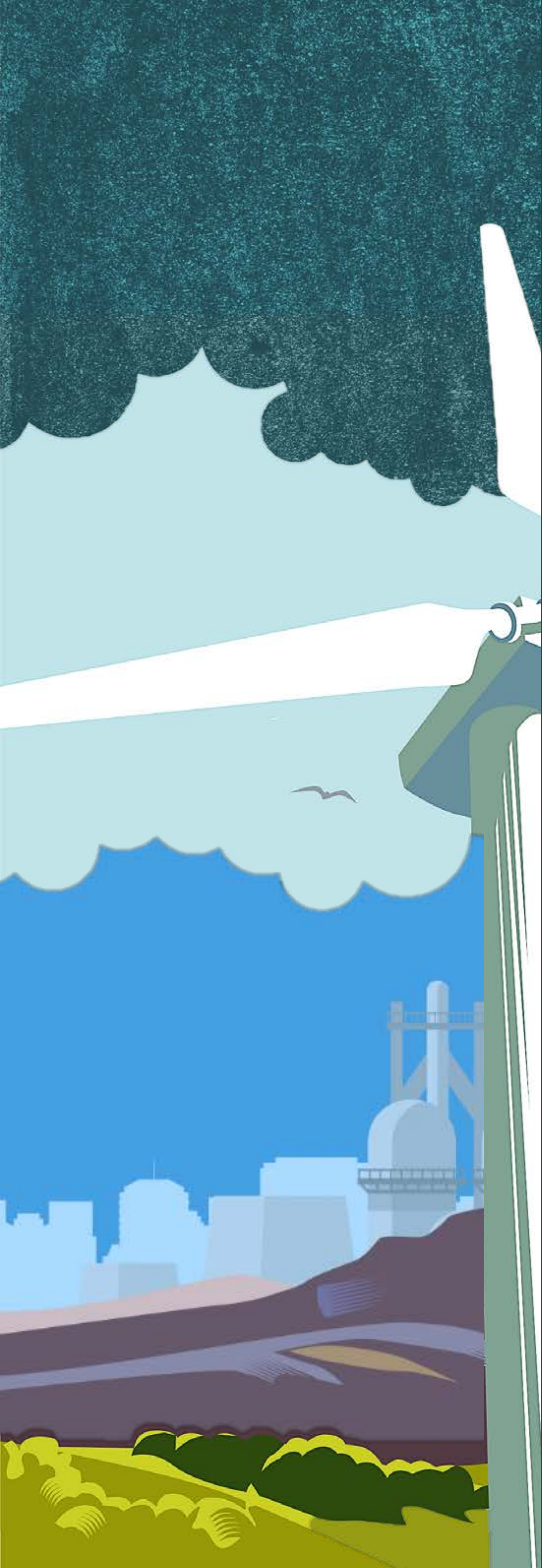
This includes both those within the sector, such as the RMI/Crypto Climate Accord's sectoral Guidance for Accounting and Reporting Electricity Use and Carbon Emissions from Cryptocurrency[27] and the Global Digital Finance ESG Working Group[28], and those outside the narrow scope of the crypto niche, such as feeding into OECD roundtable discussions and procuring initial funding from Innovate UK[29] to continue our practical solutions-based work in this area.

There is a lot of work currently ongoing to define standards and best practice for the space and, as we write this report, Energy Web and the RMI have further released a draft approach[30] to evaluating the material impact of market-based renewable energy purchases, currently being trialled with Bitcoin miners. We welcome this body of work being directed towards defining best practice and implementing practical solutions, and particularly the willingness to expose methodologies to public input and scrutiny. This is in line with our own opinion that action taken by the crypto sector must, in the spirit on which crypto was founded, be auditable and subject to public/independent scrutiny in the interest of the integrity of claims made.

It is when these current positive developments observed in pockets of the ecosystem can develop into standard practice across large parts of the ecosystem - with the fostered understanding and support of those outside of it - that we believe we will see full traction in addressing the decarbonisation imperative and see crypto meet its full potential as a driver and net positive for renewable energy worldwide.



[27] Cf. https://cryptoclimate.org/wp-content/uploads/2021/12/RMI-CIP-CCA-Guidance-Documentation-Dec15.pdf
[28] Cf. https://www.gdf.io/working-group/esg/ and also earlier report https://www.gdf.io/wp-content/uploads/2021/10/1-Nov._GDF-ESG-report-2021.pdf
[29] InnovateUK is the UK's national innovation agency, and forms part of UK Research and Innovation (UKRI), a non-departmental public body sponsored by the UK Government's Department for Business, Energy and Industrial Strategy (BEIS).
[30] Cf. https://www.energyweb.org/case-studies/GreenProofsforBTC/

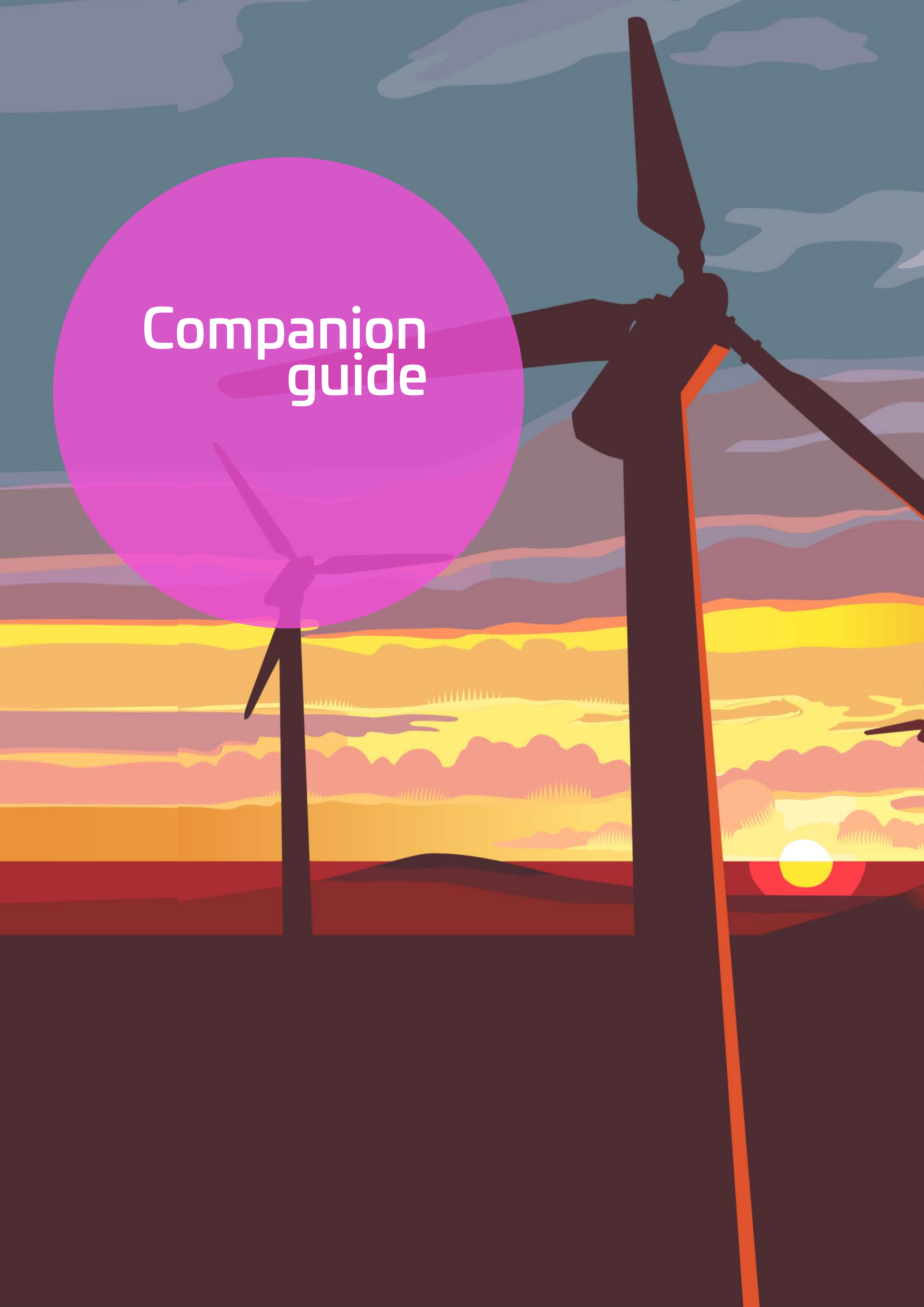


Closing thoughts

It seems fitting, therefore, to end this report on a positive note. Despite all the challenges, crypto is a space of optimism for the future, and the fundamental belief that things can be done a better way. A lot is being done, a lot must still be done - and a lot will continue to be done. However, we believe we have now moved decisively from the earliest phase of information gathering and evaluation into the phase of practical consideration and implementation.

We, and others, are now busy battle-testing the methodologies and solutions we will apply to decarbonise the sector, and learning together what works and what doesn't. The sector is ambitious like few others. In documenting this early part of our own journey, and thoughts for the road ahead, we welcome your feedback, thoughts and outreach, and we look forward to continued shared progress in the months and years ahead.

Companion guide



Companion Guide What's new in Bitcoin mining?

An overview of industry developments with a practical bearing on the decarbonisation debate

> "Thinking about how to reduce CO_2 emissions from a widespread Bitcoin implementation."
>
> **Hal Finney** Twitter, Jan 27, 2009

The question of Bitcoin energy consumption is by no means a new one. But the complexion of this question has transformed almost unimaginably in the short lifetime of the Bitcoin network's existence.

This companion guide considers how the decarbonisation discussion fits into the current wider industry picture, examining the Bitcoin mining landscape[31] through the lens of geography, commercialisation, energy solutions, regulation and public engagement.

Geographies are Changing

Since we last wrote on this topic, the geographical redistribution of Bitcoin mining has continued to evolve.

Though a Bitcoin mining ban by the Chinese government had dramatically reduced Bitcoin mining operations within China from a peak high of over three-quarters of the known miner capacity of the network[32], the latest data released by the CCAF[33] has revealed an uptick in covert mining operations in the country. China has subsequently re-emerged as a major mining hub, accounting for 21.11% of the total hashrate - the network's aggregate computing power.

The new mining map data, spanning September 2021 to January 2022, also highlights Kazakhstan (13.22%), Canada (6.48%) and Russia (4.66%) as notable mining destinations - a reminder of Bitcoin's ongoing geopolitical dimension. That said, it is the US that has cemented the top spot, with 37.84% of the total observed hashrate[34].

This begs the question: will the geographical reshuffle, which now points to a concentration in the North American region, be a boost for decarbonising Bitcoin?

[31] For ease, we restrict the discussion here to Bitcoin mining developments, in recognition of the role of the Bitcoin network as prime energy user within the crypto space (see also Zumo's state of play report).
[32] Cf. https://www.bbc.co.uk/news/technology-58896545
[33] Cf. https://www.jbs.cam.ac.uk/insight/2022/bitcoin-mining-new-data-reveal-a-surprising-resurgence/
[34] As commented earlier in this report, we still need to caveat this with the observation that the underpinning data comes from mining pools that only represent a limited proportion (in the case of the CCAF mining map, between 32-38%) of the total Bitcoin network hashrate.

Aggregate share of renewables in Bitcoin mining energy sources

Region	Regional average share of renewables	Regional share of Bitcoin hashpower	Regional weighted share of renewables in Bitcoin mining
Asia-Pacific	26%	77%	20%
Europe	30%	10%	3%
Latin America & the Caribbean	20%	1%	0%
Middle East & Africa	NA	4%	NA
North America	63%	8%	5%
Global		100%	29%

Fig. 8: Historically, the North American region has been a region of significantly higher renewable share in Bitcoin mining operations. Note also the scale of global redistribution, from 8% attributed to North America by the CBECI mining map in April 2020 to 37.84% for the US alone in January 2022. Source: Cambridge Centre for Alternative Finance (3rd global cryptoasset benchmarking study, mining map).

Mining is Commercialising

In answering that question, we can make a few observations. First, Bitcoin mining is, more and more, to be viewed as a maturing *industry*. Long gone are the days of mining some bitcoin on a spare laptop - these days, BTC mining is both a commercially lucrative business[35] and an industrial-scale operation displaying ongoing growth.

Given current mining reward structure and price levels, this has seen hashrate - the combined computing resource (and from this, energy consumption) devoted to the Bitcoin network - rally to all-time highs, even in the face of weak recent price action and a sharp drop-off in fee revenues resulting from transactions on the network.

[35] Per The Block Research, Bitcoin miners made more than $15 billion in revenue over the course of 2021 - a year-over-year increase of 206%.

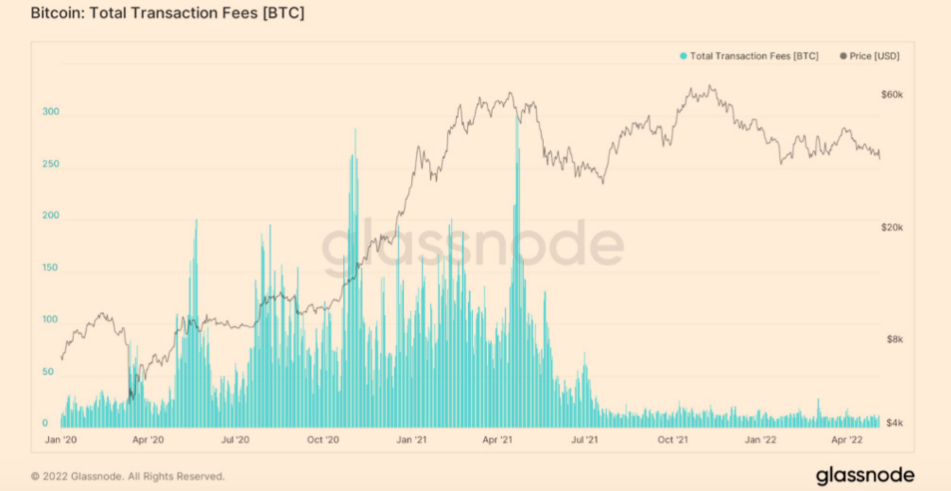


Fig. 9: Bitcoin hashrate dipped significantly around the time of the China ban in mid-2021 (see top), but has since rebounded to the advantage of North American mining share. Further, that hashrate has steadily increased in spite of a sharp drop-off in BTC transaction fees[36] (see bottom) and weak recent price action. Source: Glassnode

The industry that has emerged around this - more and more driven by the North American market - is increasingly public, commercialised and industrialised.

Public, in the sense of the at least 50 publicly-listed crypto mining companies, mostly domiciled in North America[37]. Commercialised, in the sense of the mega fundraises undertaken by Bitcoin mining entities to fund their operations, and a range of new miner-based exchange-traded fund (ETF) financial products[38]. And industrialised in the sheer scale of the power draw of today's mining operations[39].

As a result, the Bitcoin Mining Council's latest assessment for Q1 2022[40] estimates that 44 mining companies now represent 50% of the global Bitcoin network.

BTC mining as 'big business[41]' brings with it certain advantages from the environmental perspective: increased public visibility & accountability; efficiencies of scale; and identifiable counterparties for regulation, taxation, incentivisation and collaboration.

One consequence of commercialisation we can state with a degree of certainty: the money argument always wins. We mentioned in our previous report the potential alignment of greening and miner financial incentive. If renewable energy can win that argument - as the input of lowest cost - we can be optimistic that progress will be made because it makes economic and operational sense to do so. This argument is as strong as ever as we enter Bitcoin's, and indeed crypto's, commercialised/institutionalised era.

[36] As noted earlier in this report, BTC energy consumption is currently driven far more by miners' block reward than it is by miners' transaction fee revenue, as evidenced by the fact that hash rate remains near all-time highs even despite the lowest total transaction fees observed over many years.
[37] Cf. for instance https://hashrateindex.com/stocks
[38] For example, see Marathon Digital, which raised $620 million in 2021, as well as new Bitcoin miner ETF products such as the one released by Valkyrie here.
[39] For instance, Argo Blockchain's new flagship operation in Dickens County, Texas - in phase 1 - encompasses a 126,000 square foot data centre supporting 200 MW of electricity (approximately 50,000 mining machines).
[40] Cf. https://bitcoinminingcouncil.com/wp-content/uploads/2022/04/2022.04.25-Q1_2022_BMC_Presentation.pdf
[41] There is a potential irony here however of negating an existential reason for the purposely inefficient 'proof of work' mechanism in the first place - being a decentralised system immune to pressure at any identifiable point by any group of actors. Let us remember, there are far more energy efficient options than proof-of-work available to us today if such a guarantee is lost.

Innovative Solutions are Emerging

The question remains, have there then been any practical energy-relevant steps forward as a result of these observed market developments?

Clearly, some of the aforementioned publicly-listed miners have an explicit 'sustainable mining' focus[42], in addition to which there have been well publicised claims about the crypto sector's comparatively advanced (and advancing) renewables share compared to other industries[43].

From an evolving solutions perspective, we could assign the common thread of arguments (and headline solutions to date) to three core areas of interest: demand and creation of new, additional renewable capacity; stranded/curtailed energy; and grid utility[44].

Stimulating renewables and renewable capacity

As we wrote in the body of this report, one of the crypto sector's great potentials may be to signal a coordinated market demand for renewable energy, thereby driving overall adoption of renewables worldwide.

Here we see the first individual signals of direct solutions, adopted at source by the Bitcoin mining community to incorporate renewables through mechanisms such as renewable PPAs and on-site clean energy generation.

Bitcoin miner Bitfarms, for instance, has signed a five-year lease in Paraguay based on an annually-renewable PPA to secure 10 MW of green hydro electrical capacity[45]. Cleanspark, another Bitcoin miner, has looked to employ rooftop and ground-mount solar arrays on site along with other microgrid energy solutions in Bitcoin mining operations in Georgia[46]. And Block (formerly Square) and Blockstream have broken ground on a 100% solar and battery-powered Bitcoin mine in Texas[47].

While such instances are still comparatively few and far between, we expect to see more such solutions emerge as the cost of renewables continues to decrease - and pressure and incentive to adopt them rises.

[42] For instance Cleanspark, which describes itself as 'a sustainable bitcoin mining and energy technology company'.
[43] As suggested, for instance, in the Q1 2022 report of the Bitcoin Mining Council (though it does not provide much detail on its methodology). The issue of renewable share is also treated in the Cambridge Centre for Alternative Finance's Cryptoasset Benchmarking Study.
[44] There is in fact a fourth area we do not propose to cover here, which is the evolution of mining hardware energy efficiency. The reason we do not cover this here is because the conversation is more relevant to individual miner profitability than it is to Bitcoin network energy consumption, as any increased overall energy efficiency is automatically offset by an upwards adjustment in the Bitcoin mining difficulty algorithm.
[45] Cf. https://www.globenewswire.com/news-release/2021/09/08/2293209/0/en/Bitfarms-Provides-Bitcoin-Production-and-Mining-Operations-Updates-Over-2-000-Bitcoin-in-custody.html
[46] Cf. https://renewablesnow.com/news/bitcoin-miner-cleanspark-adds-20-mw-of-power-to-portfolio-750591/
[47] Cf. https://www.cnbc.com/2022/04/08/tesla-block-blockstream-to-mine-bitcoin-off-solar-power-in-texas.html

Stranded/curtailed energy

Another emerging solutions narrative has been the potential symbiotic relationship of Bitcoin miners and non- or under-utilised energy generation pockets - facilitating a win-win situation where Bitcoin miners can go behind the meter to procure extremely cheap energy while minimising the waste or curtailment of useful energy and / or the transmission of that energy. Seen this way, Bitcoin miners are useful, location-flexible scavengers - making profitable use of energy nobody else can.

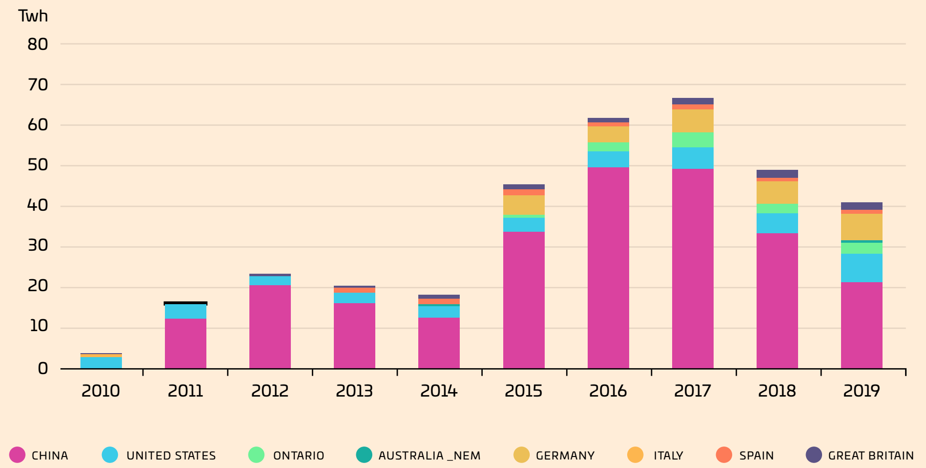


Fig. 10: Wastage of renewable energy is a non-trivial issue, with over 250 TWh of variable renewable electricity curtailed across key markets in the period 2010-2017. Source: IEA

For variable renewable energy generation facilities, this could involve a Bitcoin miner relocating to the site of renewable energy generation, and being online as an energy buyer when otherwise output would have to be curtailed (in the absence of a lack of grid demand and any way to store the energy in the meantime). Such behind-the-meter arrangements have already been observed with nuclear plants[48] (which often produce an excess of energy at night), and it would make sense that similar accommodations could be found with renewables facilities that may currently produce an unusable surplus of energy at specific periods.

More controversially, other emerging Bitcoin mining solutions have looked to capitalise on stranded/waste energy resulting from existing fossil fuel operations - most notably flared gas from oilfields, as well as landfill gas - on the basis that it is better to put energy to some sort of use if it is going to be wasted anyway[49].

Grid utility

Finally, linked to the renewables curtailment discussion, the solutions landscape is also one of proposed grid utility arising from Bitcoin miners' attributes as energy users that are not only flexible in location but also flexible in energy usage, inasmuch as operations can be powered up/down very flexibly as an 'easily interruptible load[50]'.

[48] For instance, the Nautilus Cryptomine facility is located "behind the meter" directly connected to Susquehanna nuclear power station, which will provide Nautilus Cryptomine with one of the lowest electricity costs among publicly traded bitcoin mining peers in the United States.
[49] See, for instance, EZ Blockchain, which has launched a new business line, EZ Energy, devoted to stranded, trapped and renewable energy through Bitcoin mining.
[50] For further discussion/explanation, see this short paper from Square/Ark Invest.

The simple theory of this is that, in an era in which we have greatly increased our generation of energy from variable renewable sources[51], we face grid integration issues due to the time fluctuations of supply/demand exacerbated by the increase of naturally-fluctuating energy sources in the grid mix.

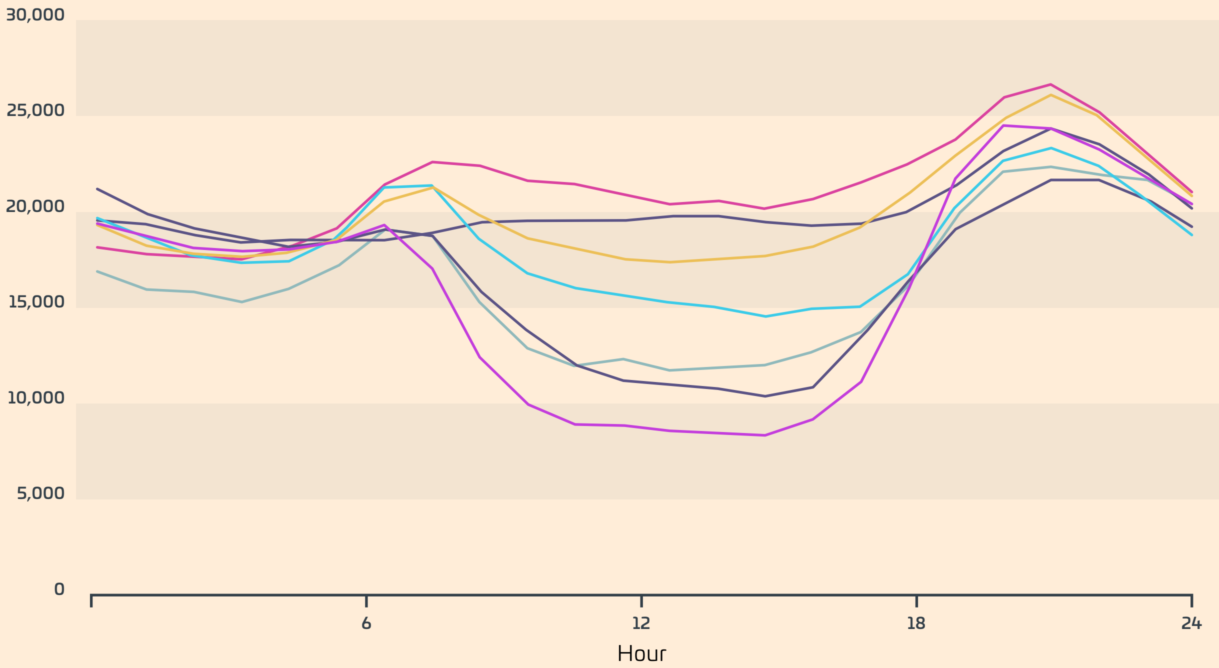


Fig. 11: The famous 'California duck curve' demonstrating supply/demand imbalance, with solar PV capacity peaking towards midday as demand is low (the belly of the duck) before decreasing as demand peaks in the evening (the neck). Source: IEA

Bitcoin mining, it is suggested, is a way of balancing the curve and acting as a flexible load matching tool that allows maximum effective usage of energy in the most economic way.

Practically, a good example of this is the state of Texas and its grid managed by the Electric Reliability Council of Texas (ERCOT). Texas is far and away the US state with the most clean energy capacity in development; indeed it is home to 17% of the clean energy capacity currently in development in the country. The state has more wind power than any other, and it is about to add more than 12 GW of solar[52].

At present, Texas incentivises high capacity power users to quickly shut down when demand is high. Financially, this incentivises Bitcoin miners' flexible load capacities. They can opt in daily to be a flexible load provider (to be on call to shut down) and the Texas grid gives a discount on power to essentially act as a 'reverse power plant'. It should be noted, this model is biased towards maximally high energy usage, and therefore is not necessarily optimal from a pure energy consumption perspective. Interested readers are directed to the 'Bitcoin Mining and the Grid' blog series[53], which gives a very comprehensive view to the considerations at play with reference to the ERCOT model.

[51] According to the IEA, for instance, in WEO 2018's New Policies Scenario, 21% of global electricity production is projected to come from variable renewables by 2040, up from 7% in 2018, supported by about $5.3 trillion of investment.
[52] Canary Media, 25 February 2022.
[53] See here and here

COMPANION GUIDE
APPENDIX 1
APPENDIX 2

On a summarising note, the Bitcoin mining solutions landscape is a fast-evolving one with significant nuance and breadth. At the current time, it is easier to cherry pick individual solutions than it is to point to truly wide-scale adoption, and of course such solutions hit the headlines more often than the silent polluters. Traction will come when these sorts of solutions are implemented at scale, with the collaboration of the majority, for the mutual good.

Regulators are Circling

It should be said, many of these developments are driven, at least in part, by the regulatory and public scrutiny that now accompanies the Bitcoin debate.

As well as the ESG mandates that come with being a publicly-traded entity, regulators have shown themselves keen to give extra additional scrutiny to evolving cryptocurrency markets and the headline-grabbing, energy-intensive proof-of-work consensus mechanism embodied in the public image by Bitcoin.

The US has had its presidential Executive Order on the Responsible Development of Digital Assets[54], complete with hearings[55] on the energy impacts of blockchains and, in New York State, a two-year moratorium on certain proof-of-work based mining operations passing State Assembly[56].

In the EU, another form of proof-of-work mining ban was narrowly defeated by EU parliamentarians[57] as part of the wider Markets in Crypto-assets (MiCA) Regulation, and UK regulators and policymakers have been equally busy[58].

Zumo has been active in this discussion wherever possible, feeding into OECD policy discussion, contributing as a Global Digital Finance (GDF) member to the GDF response to the White House Office of Science and Technology Policy's request for input on the climate implications of digital assets, and in the UK, participating in the wider regulatory consultation ongoing as part of Financial Conduct Authority (FCA) sprints.

Tellingly, the advanced regulatory conversation is an illustration of the need for collaboration not just inside of the crypto ecosystem but also outside of it. It is when those outside of the ecosystem can perceive and debate the considerations and developments occurring inside of it that informed decisions are made and we find the ways forward that allow for industry and policy to work together.

[54] Cf. https://www.whitehouse.gov/briefing-room/presidential-actions/2022/03/09/executive-order-on-ensuring-responsible-development-of-digital-assets/
[55] Cf. https://energycommerce.house.gov/committee-activity/hearings/hearing-on-cleaning-up-cryptocurrency-the-energy-impacts-of-blockchains
[56] Cf. https://cointelegraph.com/news/new-york-state-assembly-passes-ban-on-new-btc-mines-that-don-t-use-green-power. The bill subsequently passed state senate on 3 June.
[57] Cf. https://cryptoslate.com/eu-votes-against-a-de-facto-ban-on-bitcoins-pow-consensus-method-in-mica-draft/
[58] In April 2022, the UK Government set out its plans to transform the UK into a 'global crypoasset technology hub', in addition to which upcoming planned legislation will broach issues of safe crypto adoption and recovery of cryptoassets.

Public Scrutiny is Intensifying

Finally, there is something of a similar hue in the intensified public scrutiny observed of late around the crypto climate debate, again directed primarily at Bitcoin and its by now very publicly known energy usage.

Clean Up Bitcoin[59], a Greenpeace-coordinated campaign, has been just one public example of this. And while it is only right we look to drive down energy usage wherever we can, and use renewable electricity where we can't, such initiatives also run the risk of oversimplifying and polarising an issue the nuance of which is generally very poorly understood to begin with.

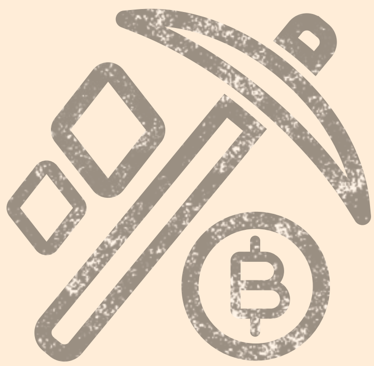
While 'change the code, not the climate' may be a catchy slogan, to say Bitcoin could collectively snap its fingers to transition to proof-of-stake is, we consider, naive, ignores the mechanisms of consensus in an anonymised decentralised network, and glosses over the scale of the technological challenge involved[60].

Proof-of-work and proof-of-stake blockchains currently fulfil very different practical purposes, and both consensus mechanisms have their own design tradeoffs and implications when looking at questions of decentralisation, resilience, immutability and network governance.

What are the relative merits of a proof-of-work system secured by energy versus a proof-of-stake system secured by capital? How do they differ and why? Why would we want a secure, decentralised network in the first place?

As with policymakers, the public has to see more than the energy consumption on its own - and understand something of the underlying drivers - before we can have a more nuanced debate.

One thing is for sure - the Bitcoin network will continue to be tested, it will continue to come under scrutiny and it is imperative as a community that we not only communicate openly on this topic but also continue to make the decarbonisation progress that the industry can - and should - achieve.



[59] Cf. https://cleanupbitcoin.com/

[60] After all, Ethereum is yet to make its own transition from proof-of-work to proof-of-stake, and it has a much more centralised structure in regard to its original public ICO, identifiable figureheads such as Vitalik Buterin, and large core development team.

Appendix 1
Reference Material - Calculation Models

For the sake of transparency and in the interests of making our methodology available to those who may be interested in using or adapting these methods, we have shared our data sources and methodologies in full here.

Data sources

All three methods outlined here utilise publicly available data from the University of Cambridge. This data is constantly updated and therefore calculations can be updated periodically to reflect energy use over time.

The data is available on the downloadable 'csv.data' spreadsheet on the Cambridge University Centre for Alternative Finance website: https:/ccaf.io/cbeci/index

The calculations look at electricity consumption only and therefore the University of Cambridge data is the only data source used. No assumptions are made about the grid mix or proportion of renewable electricity, and no further calculations to determine carbon footprint are made due to the inherent uncertainties in these factors.

Method for calculating average BTC electricity consumption since genesis ('mined since genesis' model)

- This method calculates the average amount of electricity consumed to produce one BTC since the first (Genesis) block was mined in 2009.
- It allocates 100% electricity consumption to the BTC (there are no separate calculations for transactions, securing the network etc).
- The table below shows the number of BTC mined per year (fixed) and the annualised electricity consumption (from the University of Cambridge data)

*No data for 2009, 2010 data replicated

Year	Block Reward (BTC)	No of BTC mined in year	Electricity consumption (TWh)
2009	50	2,625,000	0.003*
2010	50	2,625,000	0.003
2011	50	2,625,000	0.103
2012	50	2,625,000	0.082
2013	25	1,312,500	0.947
2014	25	1,312,500	5.370
2015	25	1,312,500	2.468
2016	25	1,312,500	8.273
2017	12.5	656,250	16.918
2018	12.5	656,250	42.229
2019	12.5	656,250	52.215
2020	12.5	656,250	66.781
2021	6.25	328,125	102.007
TOTAL		**18,703,125**	**297.398**

Fig. 12: Table illustrating BTC network electricity consumption (using CBECI data) and BTC mined annually / block reward since the genesis block. Source: CBECI/Zumo

- Apportion electricity consumption to each BTC by totalling the number of BTC and electricity consumption as follows:
  297.398 TWh / 18,703,125 BTC = **15.9 MWh per BTC**
- In Zumo's own calculations we have included a margin of error and assumed this to be **17 MWh per BTC**

Method for calculating electricity consumption as proportion of network usage ('network share' model)

- The method apportions the electricity consumption of the BTC network to BTC holdings, and therefore covers all network activity.
- This method looks at a snapshot in time (e.g. the latest calendar year) and calculates the electricity consumption of the BTC network over that time period. The total number of BTC in circulation for the period in question is also required (see Fig. 12)
- Determine the average (or maximum) BTC holdings over the equivalent time period for the calculation.
- Divide the average (or maximum) holdings by the total number BTC in circulation to give the share of BTC in circulation, and multiply this by BTC network electricity usage over the required period of time.
- Worked example for 2021:
  102 TWh / 18,703,125 BTC = **5.5 MWh per BTC**

Note that whereas the 'mined since genesis' model was used for BTC purchased, the 'network share' model is more likely to be used for BTC held, which in the case of platforms or wallets will be a higher number than BTC purchased.

Hybrid model proposed by South Pole & CCRI

Shortly before this white paper was published, additional crypto sector guidance was published by South Pole/CCRI that builds on the model above. Whilst the 'network share' model is appropriate for BTC because over 90% of miner revenue comes from the block reward (and therefore it is the BTC, not transaction fees, that incentivise miners and drive value), this guidance proposes a hybrid model which accounts for the proportion of miner income attributable to the block reward, and that attributable to transaction fees. This model can be applied to a variety of cryptocurrencies, and is represented in the diagram below.

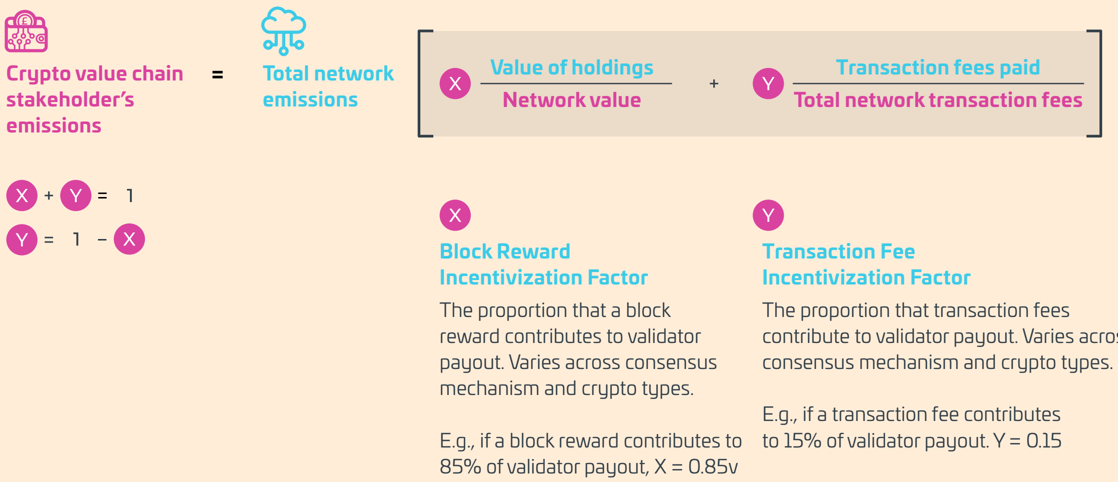


Fig. 13: Hybrid GHG emissions allocation equation from *Accounting for cryptocurrency climate impacts* (April 2022).
Source: Crypto Carbon Ratings Institute/South Pole

Method for calculating electricity consumption of BTC mined 'now' ('mined now' model)

This method is already used by others including the Green Bitcoin Project. It looks at a recent snapshot in time (e.g. the latest calendar year) and calculates the average electricity consumed to produce one BTC in this period.

- It allocates 100% electricity consumption to the BTC (there are no separate calculations for transactions, securing network the etc). As no averaging is carried out (as per the 'mined since Genesis' model) all electricity consumption is attributed to the BTC mined in a particular snapshot of time. It should be noted, therefore, that this model does not attribute any electricity consumption to the (approximately 90%) of BTC that has already been produced and is in circulation.
- Using data from the table above, electricity consumption of the BTC network in 2021 was 102 TWh and 328,125 BTC were mined.
- Apportion electricity consumption to each BTC as follows:
  102 TWh / 328,125 BTC = **310 MWh per BTC**

Appendix 2
Reference Material - The Greenhouse Gas (GHG) Protocol

What is the Greenhouse Gas Protocol?

The Greenhouse Gas (GHG) Protocol is a set of global standardised frameworks to measure and manage greenhouse gas emissions. Importantly, the GHG Protocol recognises both operational emissions (those that a company is directly responsible for) and value chain emissions (emissions resulting from the supply chain and use of sold products, among other things). The GHG Protocol defines these different types of emissions in three 'scopes'.

What are Scope 1, 2 and 3 emissions?

Scope 1 emissions are direct emissions that occur from sources that are controlled or owned by an organisation (e.g. emissions associated with fuel combustion in boilers or vehicles).

Scope 2 emissions are indirect emissions associated with the purchase of electricity, steam, heat, or cooling.

Scope 3 emissions are other indirect emissions, such as the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, outsourced activities, waste disposal, etc. Scope 3 emissions include all sources not within an organisation's scope 1 and 2 boundary.

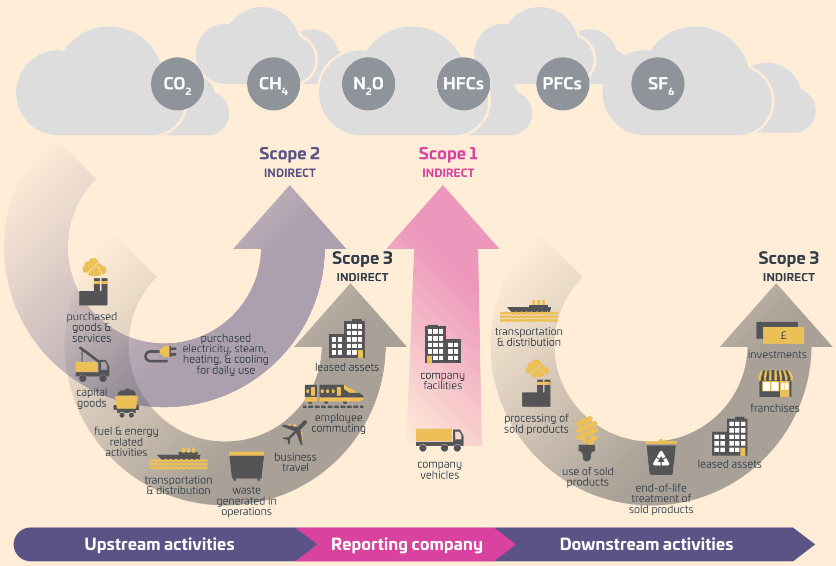


Fig. 14: Reference visualisation of Scope 1, 2 and 3 emissions. Source: GHG Protocol

It should be noted that Scope 3 emissions are often far more significant than Scope 1 and 2 emissions, and in some sectors can account for over 95% of an organisation's carbon footprint.

A company like Zumo has very little in the way of Scope 1 and 2 emissions. However, because of our interaction with blockchains, we have significant Scope 3 emissions.

However a Bitcoin mining company will have significant Scope 2 emissions, as they are directly using electricity[61].

Market-based and location-based options

The Greenhouse Gas Protocol Scope 2 guidance recognises two ways to report Scope 2 emissions in relation to electricity – location based and market based. Whereas with location-based, grid average carbon intensity figures are used, for market based the guidance states:

> "A market-based method reflects emissions from electricity that companies have purposefully chosen (or their lack of choice). It derives emission factors from contractual instruments, which include any type of contract between two parties for the sale and purchase of energy bundled with attributes about the energy generation, or for unbundled attribute claims."

It should however be noted that this guidance currently only applies to Scope 2 emissions – there is no reference currently within the guidance for Scope 3.

Further, the Science Based Targets Institute (SBTi) has confirmed

> "Renewable energy instruments such as renewable energy certificates (RECs) should only be used to meet reductions of scope 2 emissions using the market based approach. Please see the GHG Protocol Scope 2 Guidance for further guidance on scope 2 accounting".

Implications for crypto

The guidance is clear in that suitable market instruments, such as RECs, can be used to make valid net zero claims for Scope 2 emissions. However, as discussed previously, for wallets, exchanges, other intermediaries and holders of crypto, these are Scope 3 emissions. Guidance is in the process of being updated (see for instance the EPA guidance referenced in the body of this document), and Zumo and others are engaging with relevant industry bodies to ensure that guidance formally recognises that they can be used in a similar way for Scope 3 emissions that consist entirely of electricity consumption.

[61] At the risk of getting technical, some Bitcoin mining operations may also have Scope 1 emissions - for example those that utilise flared natural gas.

About Zumo

Zumo is a decentralised finance platform with the mission of bringing the benefits of blockchain technology and digital currencies to people and businesses everywhere.

Zumo Enterprise, its B2B Crypto-as-a-Service platform, is an intelligent, embedded crypto solution fully regulated in the UK.
Zumo App, its direct-to-consumer mobile application, allows individuals to exchange, store, send and spend cryptocurrency alongside their ordinary money.

Founded in Edinburgh in 2017 by entrepreneurs Nick Jones and Paul Roach, Zumo is a purpose-driven fintech business with transparency, accessibility and financial inclusion at its core. Its staff are based in locations across Scotland, London and Slovenia. It is partner to WasteAid; member of CryptoUK; signatory of the Crypto Climate Accord; and supporter of the UN Global Compact.

Zumo App is available for download on both iOS and Android app stores.

To find out more, please visit
https://www.zumo.money/