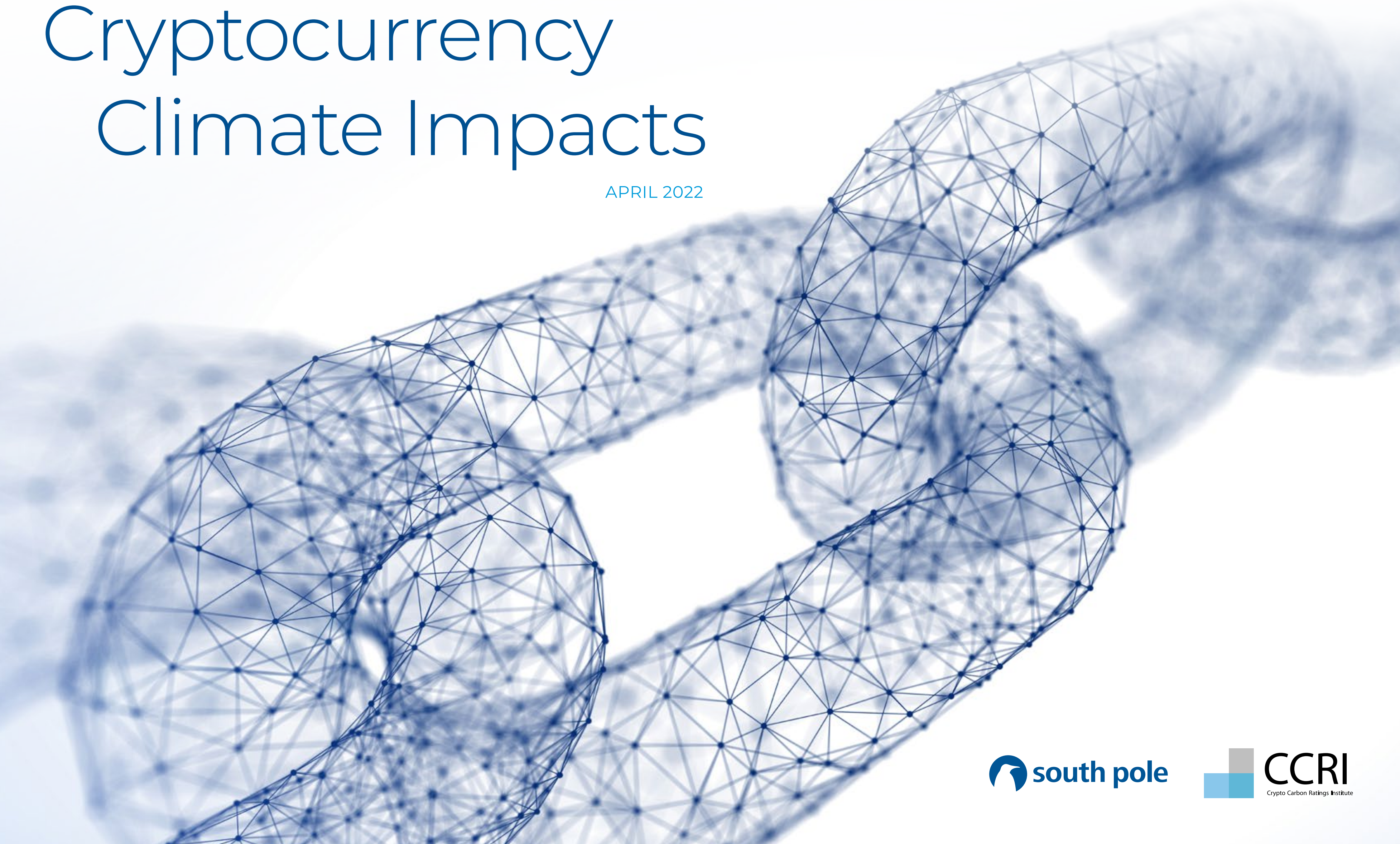
ACCOUNTING FOR

Cryptocurrency Climate Impacts

APRIL 2022



south pole

CCRI
Crypto Carbon Ratings Institute

Executive summary

As cryptocurrencies continue their journey into mainstream adoption, interest in understanding and addressing the associated environmental impacts has grown.

In recent years, researchers have developed methodologies to estimate the total electricity consumption and related greenhouse gas (GHG) emissions caused by the underlying blockchain infrastructure. At the same time, stakeholders along the value chain are considering their individual GHG exposure, particularly in light of current and emerging voluntary and mandatory climate-related disclosure requirements.

Some cryptocurrency networks use significant amounts of electricity to maintain the blockchain, which in turn generates substantial GHG emissions. Responsibility for these emissions needs to be allocated in ways that are consistent with existing GHG accounting standards and practices.

The GHG accounting framework presented in this report aims to inform best practices for allocating GHG emissions across the cryptocurrency value chain. The framework builds on established GHG accounting practices and standards, and provides guidance for stakeholders to calculate their value chain emissions related to their cryptocurrency holdings and transactions.

Accurately allocating and accounting for cryptocurrency-related greenhouse gas emissions is the necessary first step to understand risks, define mitigation measures, and design emissions reduction strategies.

Cryptocurrency can be held to store value or used to transact value. Understanding the use cases of cryptocurrencies and the economic incentives that users provide to block creators (miners or validators) can guide the allocation of indirect emissions responsibility to other value chain stakeholders.

This report evaluates existing emissions allocation methods, including the holding-based and transaction-based methods, and proposes a new hybrid approach.

The logic behind the holding-based, transaction-based and hybrid allocation methods and their application to different cryptocurrencies is assessed using three key considerations:

1. The dynamic and decentralized nature of cryptocurrency value chains
2. Financial incentives of miners and validators, which can drive electricity consumption and GHG emissions
3. Differences in incentive structure and electricity intensity between cryptocurrencies

The proposed hybrid allocation method can be used to guide best practices in accounting for GHG emissions across the cryptocurrency value chain. As cryptocurrency technology evolves and stakeholders implement cryptocurrency-related emissions accounting, there are opportunities to build upon this work and further develop accounting guidance for stakeholders.

FIGURE 1: Hybrid GHG emissions allocation equation

$$\text{Crypto value chain stakeholder's emissions} = \text{Total network emissions} \left[X \frac{\text{Value of holdings}}{\text{Network value}} + Y \frac{\text{Transaction fees paid}}{\text{Total network transaction fees}} \right]$$

$$X + Y = 1$$

$$Y = 1 - X$$

X — BLOCK REWARD INCENTIVIZATION FACTOR

The proportion that a block reward contributes to validator payout. Varies across consensus mechanisms and crypto types.

E.g., if a block reward contributes to 85% of validator payout, X = 0.85

Y — TRANSACTION FEE INCENTIVIZATION FACTOR

The proportion that transaction fees contribute to validator payout. Varies across consensus mechanisms and crypto types.

E.g., if a transaction fee contributes to 15% of validator payout, Y = 0.15

Read this report to understand

- **How cryptocurrencies generate GHG emissions**
- **How the consensus mechanism underlying a cryptocurrency network influences GHG emissions**
- **How stakeholders along the value chain can account for their cryptocurrency-related GHG emissions**

How to use this report

This report offers a practical and open-source framework to guide the responsible allocation of GHG emissions across the cryptocurrency value chain. The proposed framework intends to guide stakeholders in the cryptocurrency space who are interested in accounting for their GHG emissions. It may also serve as a reference point for impact investors and environmental advocates when designing parameters related to this issue.

This report is also intended to be a knowledge resource for researchers, policymakers, and others who are active in the cryptocurrency space. It can be used to inform decision-making, but avoids excessive detail in order to remain accessible.

The proposed framework lays an initial foundation. As technical data becomes more available, new use cases arise, and GHG emissions accounting guidance for cryptocurrency evolves, more formalized and specific guidance could be outlined.

About this report

This report was jointly developed by Crypto Carbon Ratings Institute (CCRI) and South Pole, in consultation with PayPal. The process included researching industry methodologies, identifying gaps in existing guidance, and engaging cryptocurrency and GHG accounting stakeholders for feedback through roundtable discussions. Findings informed potential allocation solutions, which were reviewed and evaluated by the stakeholders, and synthesized into the proposed framework.

This framework intends to align with the Greenhouse Gas Protocol (GHG Protocol)—the most widely used standard for corporate GHG accounting—and is designed with the existing GHG Protocol guidance in mind.[1] This report does not intend to provide any guidance that contradicts established value chain emissions accounting standards. Rather, it offers further guidance to cryptocurrency value chain stakeholders on how to appropriately account for GHG emissions in line with the GHG Protocol.

1 The Greenhouse Gas Protocol. (2004). Retrieved from https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf

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SECTION 1: Introduction

1.1 Climate impacts of cryptocurrency

The climate impacts of cryptocurrencies have attracted a vibrant debate and research in recent years. To date, research has mainly focused on calculating the overall electricity consumption and greenhouse gas (GHG) emissions at a cryptocurrency network level, particularly for the Bitcoin network.[2]

Cryptocurrency is one of the most widely adopted applications of blockchain technology. Depending on the type of blockchain protocol, the process to validate transactions and ownership of different cryptocurrencies may consume large amounts of electricity. Depending upon the method of electricity generation, this can result in significant GHG emissions and contribute to climate change.

As cryptocurrencies continue their journey into mainstream finance, stakeholders along the value chain are increasingly expected to assess the climate exposure associated with their activities. Although these GHG emissions are outside the direct control of most stakeholders in the cryptocurrency value chain, there is high interest in gauging GHG emissions exposure, particularly in light of current and future mandatory disclosures regarding corporate climate-related risks.[3]

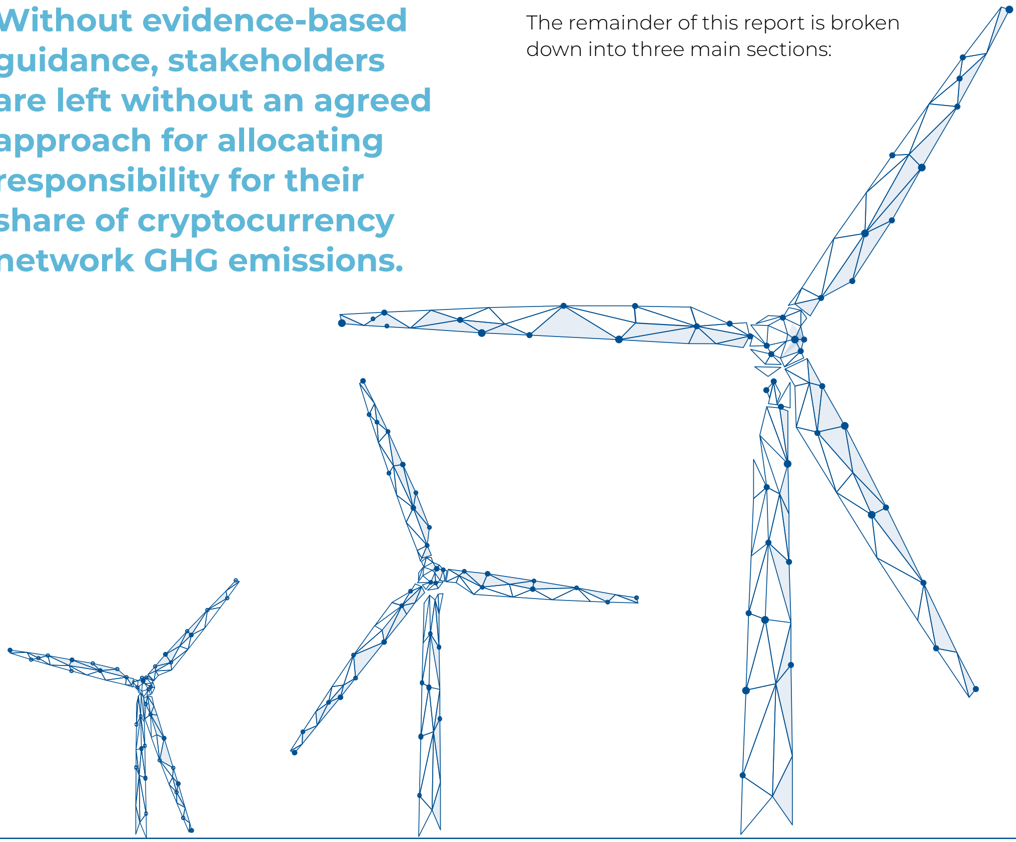
Without evidence-based guidance, stakeholders are left without an agreed approach for allocating responsibility for their share of cryptocurrency network GHG emissions.

1.2 Accounting for cryptocurrency-related GHG emissions

This report aims to bridge the current gap in GHG accounting guidance for the cryptocurrency industry, and assist companies active in the cryptocurrency value chain to assess their climate exposure. This report starts by exploring where these GHG emissions come from, which parties are responsible, and how emissions can be allocated.

The remainder of this report is broken down into three main sections:

1. Exploring the source of cryptocurrency-related GHG emissions and how stakeholders across the value chain influence these emissions.
2. Different methods for allocating cryptocurrency-related GHG emissions to both holdings and transactions, and a hybrid allocation method that applies to a wide range of cryptocurrencies and stakeholders.
3. Considerations for reporting allocated GHG emissions, and opportunities for further exploration.



2 Cambridge Bitcoin Electricity Consumption Index (CBECI). (2022). Retrieved from https://ccaf.io/cbeci/index

3 E.g. EU Taxonomy, Sustainable Finance Disclosure Regulations of the EU; Fossil Free Finance Act in the US; President Biden's Executive Order on Climate-Related Financial Risk

2

SECTION 2:

Understanding cryptocurrency-related GHG emissions

2.1 The size of the challenge

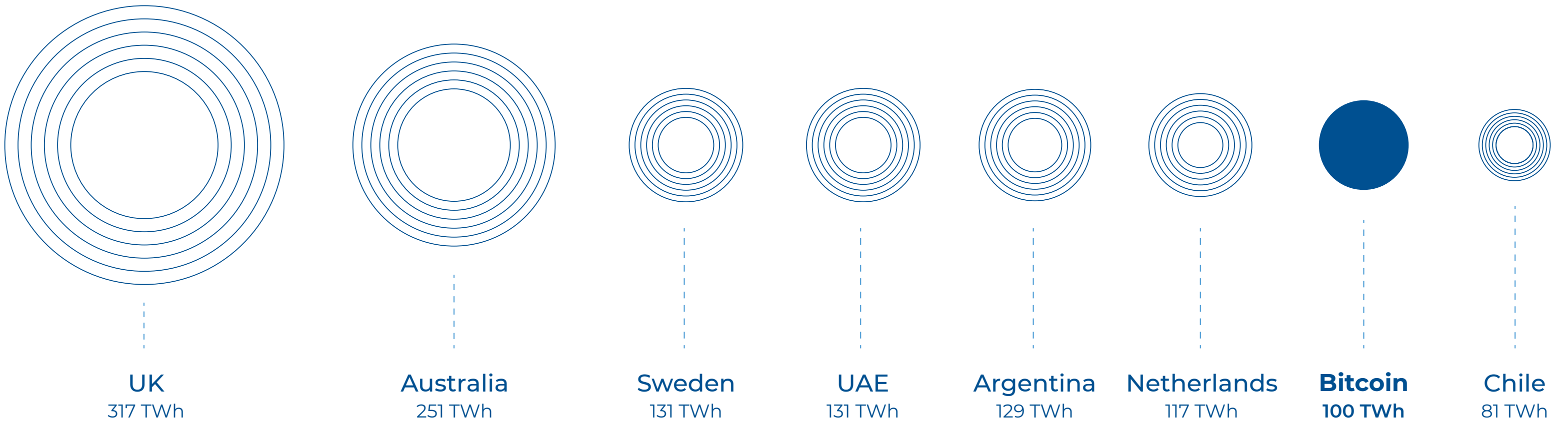
The first and largest cryptocurrency by market capitalization is Bitcoin, which is estimated to have consumed approximately 100 terawatt hours of electricity in 2021.[4] This is more than double the collective electricity consumption of Amazon, Google, Microsoft, Facebook, and Apple.[5] And this is just Bitcoin. Combined, other cryptocurrencies are estimated to consume an additional 50%.[6]

The industry is shifting from using Proof of Work (an electricity-intensive consensus mechanism) to Proof of Stake (a less electricity-intensive mechanism).[7] With this shift, overall electricity intensity and associated GHG emissions are expected to decrease. These kinds of changes highlight the importance of finding ways to continually measure cryptocurrency-related climate impacts.

The sources of electricity generation used in cryptocurrency networks are difficult to discern, constantly evolving, and are continually being studied. It is clear that a significant part of the electricity historically used for cryptocurrency networks has been generated from fossil fuel sources, generating substantial GHG emissions.[8] A standardized and fair approach to allocating these GHG emissions is required to account for climate impacts and lay the foundation for responsibility and future mitigation.

If Bitcoin was a country, it would use more electricity each year than Chile.[9]

FIGURE 2: Bitcoin's annual electricity consumption[10]



4 Cambridge Bitcoin Electricity Consumption Index (CBECI). (2022). Retrieved from https://ccaf.io/cbeci/index

5 Financial Times. (2021). How tech went big on Green Energy. Retrieved from https://www.ft.com/content/0c69d4a42626-418d-813c-7337b8d5110d

6 Gallersdörfer, U., Klaaßen, L., & Stoll, C. (2020). Energy Consumption of Cryptocurrencies Beyond Bitcoin. Joule, 4(9), 1843–1846.

7 CCRI. (2022). Energy efficiency and carbon emissions of PoS Networks. Retrieved from https://carbon-ratings.com/pos-report-2022

8 de Vries, A., Gallersdörfer, U., Klaaßen, L., & Stoll, C. (2022). Revisiting Bitcoin's carbon footprint. Joule. https://doi.org/10.1016/j.joule.2022.02.005

9 U.S. Energy Information Administration (EIA). (2020). Electricity Net Consumption. Retrieved from https://www.eia.gov/international/data/world/electricity/electricity-consumption

10 IEA. (2021). Key World Energy Statistics 2021. Retreived from https://iea.blob.core.windows.net/assets/52f66a88-0b63-4ad2-94a5-29d36e864b82/KeyWorldEnergyStatistics2021.pdf

2.2 Sources of GHG emissions along the cryptocurrency value chain

It is important to understand how cryptocurrencies cause GHG emissions, so that those emissions can be allocated, managed, and ultimately reduced. Emissions occur across the whole value chain, from hardware manufacturing to holding or transacting by cryptocurrency users.

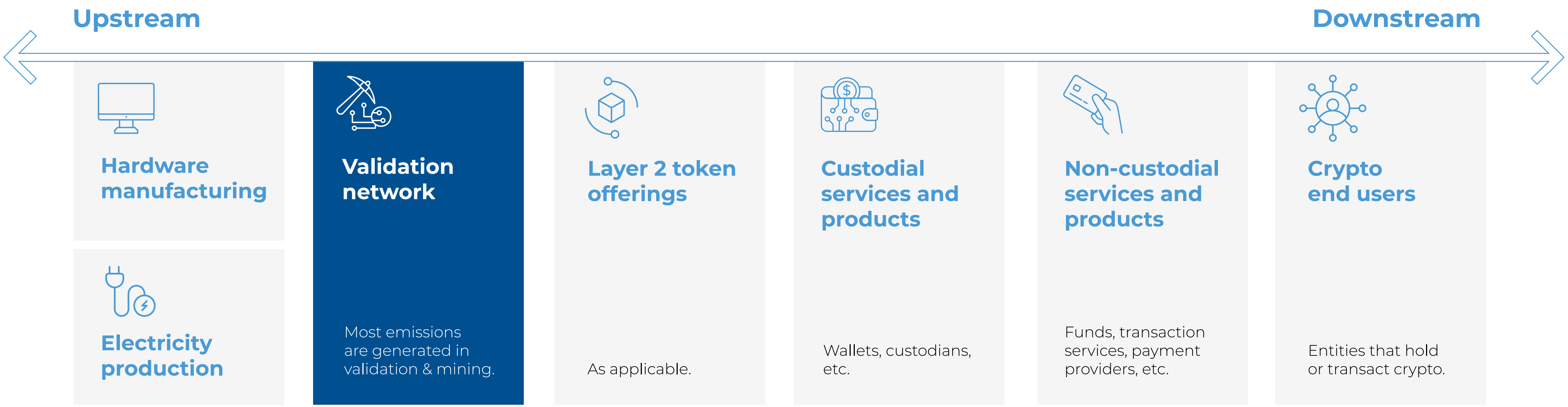
The generation of electricity needed to power cryptocurrency stakeholder activity is the primary source of GHG emissions for today's most popular cryptocurrency networks. Often, the vast majority of the electricity is used during the networks' block creation process which is called 'mining' or 'validation'.[11,12,13] During these processes, new block entries are suggested, which are confirmed by the network as valid, adding new blocks to the blockchain.[14] The 'mining' or 'validation' process could be energy-intensive depending on the type of consensus mechanism. However, the process is needed to prevent double-spending and is a key security feature of blockchain technology.

To understand 'mining' or 'validation' and the associated drivers of electricity use, it is important to first understand the two most common types of consensus mechanisms: Proof of Work (PoW) and Proof of Stake (PoS).

Consensus mechanism

The process by which the network agrees on the next valid block and its transactions.[15]

FIGURE 3: Typical cryptocurrency value chain



11 "Block producer" is a more accurate term that can be applied to all consensus mechanisms and cryptocurrencies. However, for the sake of simplicity, this paper uses the terms "miners" and "validators," as appropriate.
12 de Vries, A. (2020). Bitcoin's energy consumption is underestimated: A market dynamics approach.Energy Research & Social Science, 70, 101721. https://doi.org/10.1016/j.erss.2020.101721
13 Digiconomist. (2022). Bitcoin Energy Consumption Index. Retrieved from https://digiconomist.net/bitcoin-energy-consumption
14 IEA. (2019). Bitcoin energy use - mined the gap. Retrieved from https://www.iea.org/commentaries/bitcoin-energy-use-mined-the-gap
15 In blockchain systems, each block (with its predecessors) represents an individual state, e.g. the monetary distribution after all transactions that are included in the respective chain of block up until that point, have been executed.

2.3 Proof of Work protocols use a lot of electricity

In Proof of Work (PoW) systems, multiple miners compete to create a valid block by solving computationally-intensive (and thus electricity-intensive) cryptographic puzzles. The miner that is first to solve the puzzle, and thus create the valid block, receives a block reward (a compensation in cryptocurrency). They also receive the transaction fees from the transactions within the new block.

In large PoW networks like Bitcoin, thousands of miners across the world compete at once. Combined, these hardware devices require large amounts of electricity.

A main driver of PoW network validation activity is the price of the underlying cryptocurrency. When the price of the underlying cryptocurrency rises, the revenue potential of a mining operation also rises, therefore incentivizing existing miners to increase their computational power by buying and running additional hardware. New miners are also incentivized to start mining. This leads to more computing power being added to the network, increasing the overall electricity consumption and associated GHG emissions.

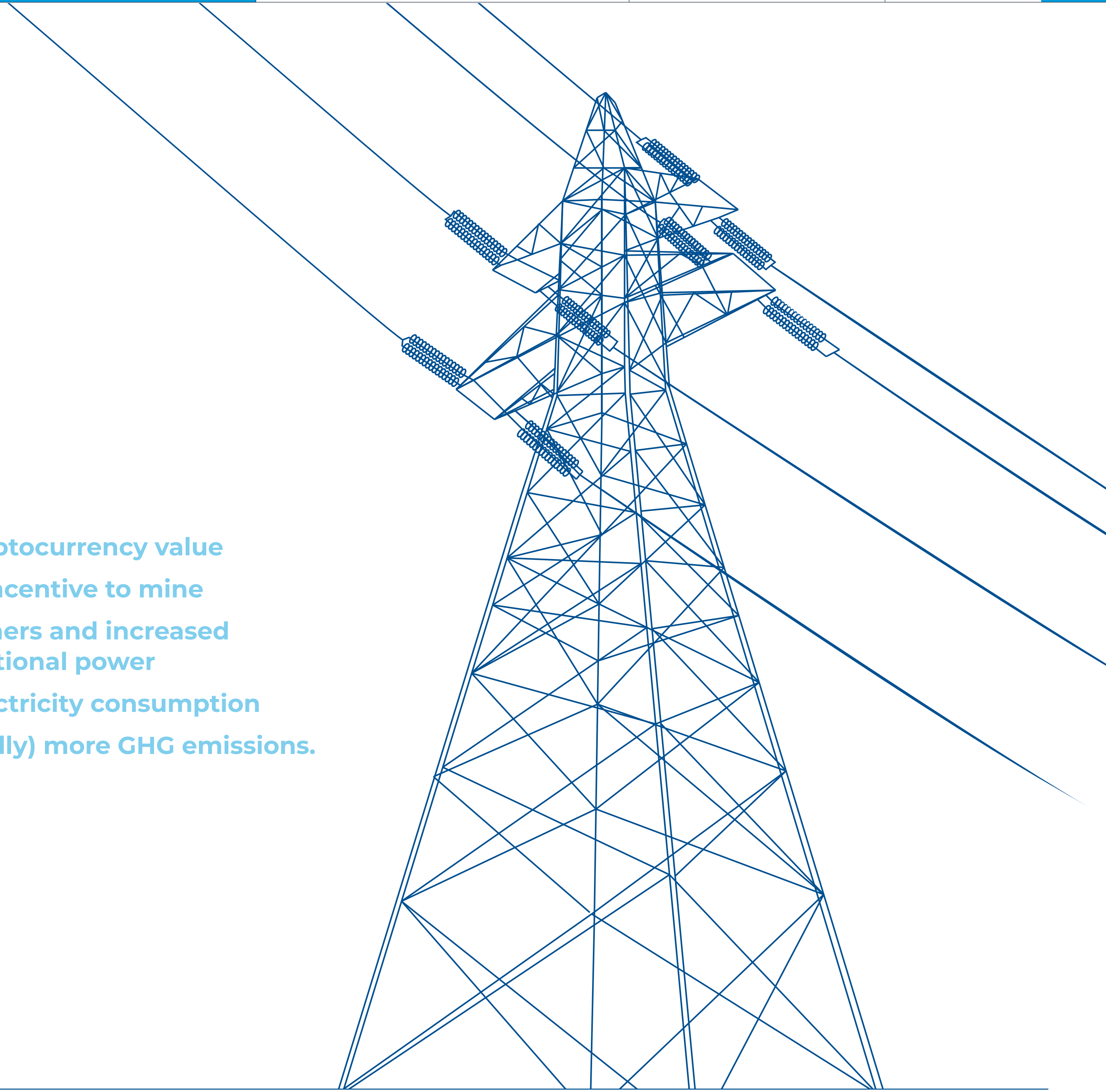
Higher cryptocurrency value

= greater incentive to mine

= more miners and increased computational power

= more electricity consumption

= (potentially) more GHG emissions.



2.4 Proof of Stake uses considerably less electricity

Another common consensus mechanism is Proof of Stake (PoS). Ethereum, currently the second largest cryptocurrency by market capitalization, plans to transition to PoS. Instead of relying on computational power as a scarce resource, validators are selected to produce and add a new block based on the amount of their own cryptocurrency they have 'staked' in the network.[16] A higher stake increases the likelihood of being selected to create a new valid block.

Stake

Locking up cryptocurrency tokens in order to support the security of the network and make a validator eligible to receive rewards.

In contrast to Proof of Work, an increase in the cryptocurrency's value does not incentivize increased computational power and associated electricity consumption. Rather, entities are incentivized to commit more stake and therefore increase their revenue, skipping the acquisition of additional electricity-consuming computing hardware. Proof of Stake networks are therefore estimated to consume orders of magnitude less electricity than Proof of Work networks.[17,18]

FIGURE 4: Electricity consumption of validation activity in PoS and PoW networks

PoW network

1. A new block is created

Miners collect and bundle new network transactions into a **new block**

2. Miners compete to find a cryptographic solution for the new block

All the miners race to **solve a cryptographic puzzle** for the block. The miner who finds the solution broadcasts the block to the other miners in the network.

3. The block is verified by network consensus

The other validators in the network check the correctness of the block and its transactions. If valid and accepted by the majority, the **block producer receives its rewards.**

POW electricity consumption:

All nodes consume electricity when verifying the new block. However, most of the total network electricity consumption originates from the **large number of attempts by miners** who use specialized machines to solve the cryptographic puzzle.

PoS network

1. Protocol chooses a block producer

A block producer is chosen from the set of validators in the network. This validator, chosen as a block producer, can **produce the next block.**

2. Block producer proposes a new block

The block producer proposes a new block by bundling **new transactions into the block.** They then broadcast it to the other validators in the network.

3. The block is verified by network consensus

The other miners in the network check the correctness of the block and its transactions. If valid and accepted by majority, **the miner who originally broadcast the block receives its reward.**

POS electricity consumption:

Since there is no requirement to use specialized machines to find the cryptographic solution, and because multiple validators are not competing at once to be the block producer, **PoS cryptocurrencies use considerably less electricity** than PoW cryptocurrencies.

16 "In decentralized networks, a scarce resource is required to prevent single actors from increasing their chance to be selected as the next block producer disproportionately. Both hardware and the cryptocurrency itself require upfront investments by the respective entity and can therefore be used as a means to select block producers. An alternative consensus mechanism relying on a different scarce resource is Proof of Space, requiring hardware storage.

17 CCRI. (2022). Energy efficiency and carbon emissions of PoS Networks. Retrieved from https://carbon-ratings.com/pos-report-2022

18 Platt, M., Sedlmeir, J., Platt, D., Tesca, P., Xu, J., Vadgama, N., & Ibañez, J. (2021). Energy Footprint of blockchain Consensus Mechanisms Beyond Proof-of-Work. Retrieved from https://arxiv.org/abs/2109.03667

2.5 Holding and transacting – the two main use cases of cryptocurrencies

There are two main ways cryptocurrency is used:

1. For holding, as a means of storing value
2. For transacting, to exchange goods and services

To comprehensively account for emissions across different currencies, it is critical to assess the emissions encouraged by both transaction fees and block rewards.

2.6 Financial incentives impact GHG emissions

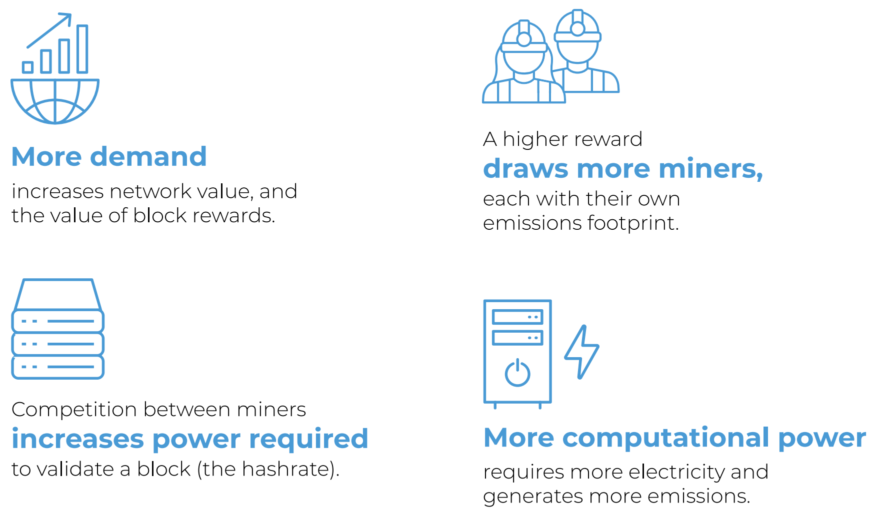
In both PoW and PoS networks, miners are incentivized by block rewards and transaction fees. Higher demand for a cryptocurrency leads to higher prices and consequently to higher value block rewards. A greater number of transactions generates more transaction fees.

For many cryptocurrencies, block rewards constitute the majority of the financial incentive for miners and validators, and consequently are the main driver of GHG emissions. For Bitcoin (a PoW network), miners receive the vast majority of their payout from block rewards and only a small portion from transaction fees. Holding and increasing the value of Bitcoin and its associated block rewards therefore has a much greater influence on miner incentives (and resulting GHG emissions) than transacting.[19]

Other cryptocurrencies may be more affected by the volume of transactions, the number of validators with a stake in the network, and the overall network value. Both transaction fees and block rewards drive GHG emissions, and the dynamics of the reward structure may change over time.

Ultimately, those that transact and hold cryptocurrency have a responsibility for the associated GHG emissions. When entities transact they pay a fee for validators to confirm the transaction, a process which incentivizes electricity consumption. Those that hold cryptocurrency (even with very few or no transactions) still contribute to network electricity consumption. They are benefiting from the ongoing consensus processes that secure the held assets and the incurred value that is gained during the holding period. Additionally, during the mining process, new coins are minted and paid to the miner as a block reward. These new coins increase the total supply of coins and thus deflate the value of the existing coins of holders. Consequently, block rewards represent an implicit value transfer from holders to miners and the contribution of holders to the continuation of the network.

FIGURE 5: Cryptocurrency holdings as a driver of network GHG emissions



19 Carlsten, M., Kalodner, H., Weinberg, S., & Narayanan, A. (2016). On the Instability of Bitcoin Without the Block Reward. Proceedings Of The 2016 ACM SIGSAC Conference On Computer And Communications Security. https://doi.org/10.1145/2976749.2978408

2.7 Emissions types from an accounting perspective

Regardless of the consensus mechanism, the validation of cryptocurrency networks requires electricity.

Until all cryptocurrency-related electricity generation sources verifiably reach net-zero emissions, accounting for associated GHG emissions is necessary.

The Greenhouse Gas Protocol is the most commonly used global standard for corporate GHG accounting.[20] Under this standard, GHG emissions for entities are categorized into three scopes.

Scope 1: Direct GHG emissions occurring from sources that are owned or controlled by an organization,

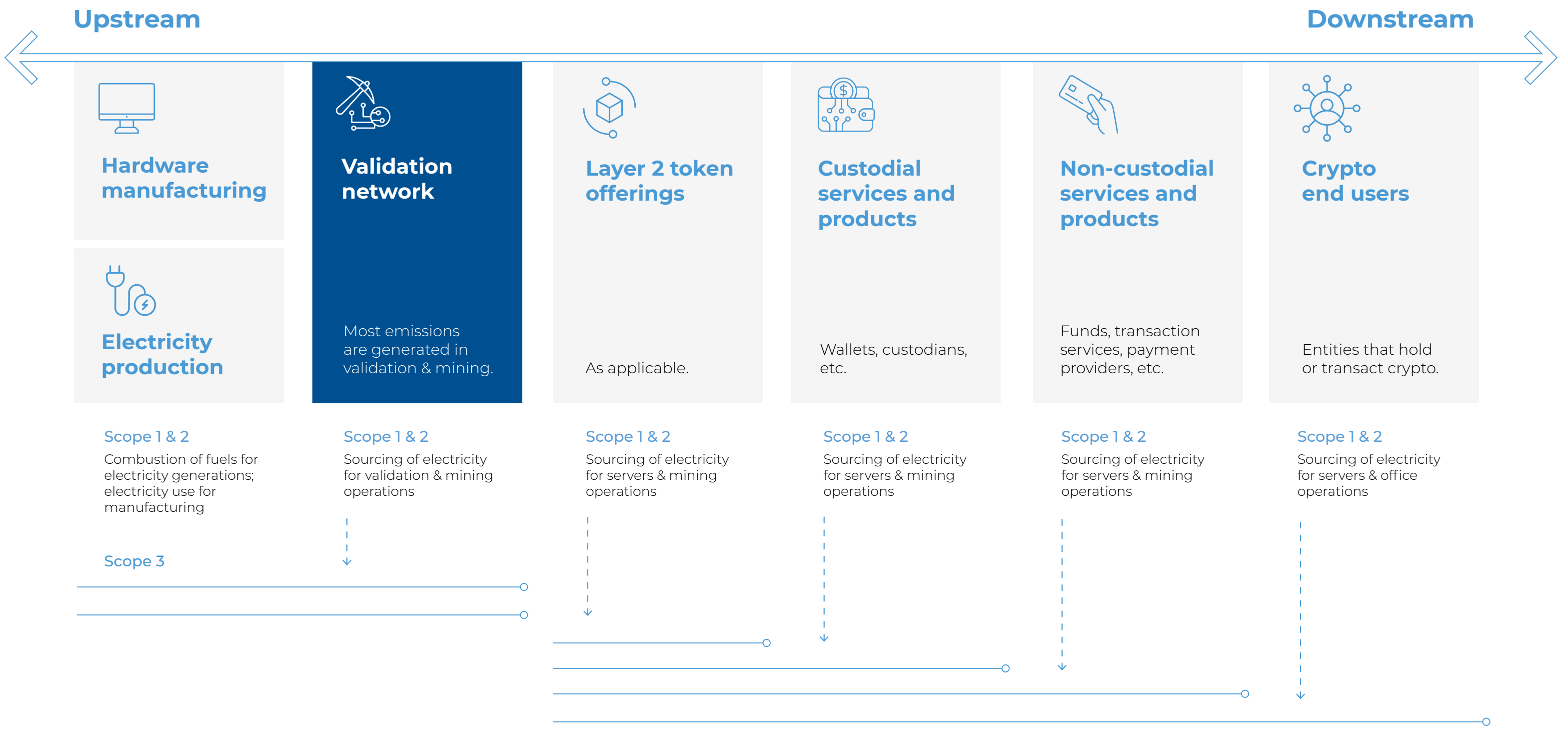
Scope 2: GHG emissions from the generation of purchased electricity consumed by the organization,

Scope 3: GHG emissions that are a consequence of the activities of the organization, but occur from sources not owned or controlled by the organization.[21]

The proposed framework provides Scope 3 accounting guidance to cryptocurrency value chain stakeholders for allocating GHG emissions to their cryptocurrency-related activities (i.e. transacting and holding cryptocurrency).

For network validators, the emissions generated from their validation activities would fall into Scope 1 and Scope 2. Accounting for these emissions from the validator's perspective is beyond the scope of this report, but it is being addressed by other research efforts.[22]

FIGURE 6: GHG emissions across the value chain



Refer to appendix (GHG Protocol Guidance) for more information on GHG Protocol inclusion and contextualization of Scope 1, 2, and 3 GHG emissions across the cryptocurrency value chain.

20 The Greenhouse Gas Protocol. (2004). Retrieved from https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf

21 The Greenhouse Gas Protocol. (2004). Retrieved from https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf

22 The Crypto Climate Accord. (2021). Guidance for Accounting and Reporting Electricity Use and Carbon Emissions from Cryptocurrency. Retrieved from https://cryptoclimate.org/wp-content/uploads/2021/12/RMI-CIP-CCAGuidance-Documentation-Dec15.pdf

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SECTION 3:

Allocating cryptocurrency GHG emissions

3.1 Identifying the right allocation method

It is important to define responsibility for allocating, managing, and reducing the emissions generated by cryptocurrency mining and validation.

In line with the GHG Protocol, stakeholders have a shared responsibility for GHG emissions along their value chain. Without cryptocurrency users and the services they employ (e.g., crypto wallets and exchanges), miners and validators would have no economic incentive to consume electricity. With more media coverage on GHG emissions from mining, users and service providers are becoming increasingly aware of how their activities incentivize mining.[23]

On-chain transaction

A cryptocurrency transaction that occurs on the blockchain and is dependent on the state of the blockchain for its validity.

There are four primary considerations that determine the volume of cryptocurrency network emissions that an entity is responsible for:

1. The value of their cryptocurrency holdings, which drives block reward value.
2. The number of transactions they submit on-chain, and the resulting transaction fees they pay.
3. The underlying consensus mechanism of the cryptocurrency being held or transacted.
4. The reward structure of the cryptocurrency (i.e., the percentage of the total validation incentive that the block reward and transaction fees each make up).

Current research proposes two methods for allocating cryptocurrency network emissions:

the holding-based method and the transaction-based method.[24,25]

THE HOLDING-BASED METHOD

Allocating GHG emissions to cryptocurrency holders based on their share of ownership in the total network

Existing accounting guidance for financed GHG emissions typically allocates emissions based on the ratio of value owned by an entity, relative to the total value of the asset.[26]

In the holding-based method, the same logic is applied, as all owners in the cryptocurrency network are responsible for the ongoing GHG emissions that mining and validating generates. A cryptocurrency holder or service provider's share of total network GHG emissions is equal to the percentage of total network value they hold.

This method works well for networks where the block reward makes up the vast majority of the miner payout. Those that hold more of the cryptocurrency have greater impact on its value, influencing the value of the block reward, and incentivizing GHG emissions-intensive mining and validation.

However, under the holding-based method, transactions are not assigned any GHG emissions. This is problematic for networks where transaction fees account for a significant share of the overall reward, creating a strong incentive for mining and validation.

The holding-based method does not properly account for the climate impacts of user transactions.

THE TRANSACTION-BASED METHOD

Allocating GHG emissions to stakeholders based on their share of transaction fees in the total network

In the transaction-based method, GHG emissions are allocated to stakeholders based on their proportional share of total network transaction fees. Network GHG emissions are divided among entities by comparing the value of the transaction fees paid by the reporting entity to the total transaction fees across the network for a given period of time.

Depending on the overall compensation, transaction fees can provide a meaningful incentive for miners or validators to invest in hardware and electricity, which ultimately causes GHG emissions. Therefore, the more fees paid by a user to the network, the higher the accountability of the user for network emissions.

However, this method does not incorporate the impact that holdings have on driving the underlying cryptocurrency value and thus, validator block reward incentives. Users that solely hold cryptocurrency would therefore be held less accountable for emissions, while users that mainly conduct transactions are assigned the major share of GHG emissions, despite limited miner incentivization.

The transaction-based method does not properly account for the climate impacts of holding cryptocurrency.

Refer to appendix (Emission allocation methods) for more information.

23 de Vries, A., Gallersdörfer, U., Klaaßen, L., & Stoll, C. (2021). The true costs of digital currencies: Exploring impact beyond energy use. One Earth, 4(6), 786–789. https://doi.org/10.1016/j.oneear.2021.05.009

24 Gallersdörfer, U., Klaaßen, L., & Stoll, C. (2021). Accounting for carbon emissions caused by cryptocurrency and token systems. https://doi.org/10.48550/arXiv.2111.06477

25 The Crypto Climate Accord. (2021). Guidance for Accounting and Reporting Electricity Use and Carbon Emissions from Cryptocurrency. Retrieved from https://cryptoclimate.org/wp-content/uploads/2021/12/RMI-CIP-CCAGuidance-Documentation-Dec15.pdf

26 PCAF. (2020). The Global GHG Accounting & Reporting Standard for the Financial Industry. Retrieved from https://carbonaccountingfinancials.com/files/downloads/PCAF-Global-GHG-Standard.pdf

3.2 The proposed hybrid allocation method

Under the hybrid allocation method, GHG emissions are allocated to stakeholders based on both the value of a user's holdings (which drives block reward incentives) and the transaction fees paid by the user (which drives transaction fee incentives).

Validators are incentivized differently, depending on the proportion of the total payout made up by block rewards or transaction fees. This proportion varies across cryptocurrencies and over time. The hybrid allocation method, as initially outlined by CCRI, aims to be a complete and consistent method for fairly allocating GHG emissions by actors across the value chain of different currency networks and consensus mechanisms.[27]

The hybrid method factors in the reward structure of the cryptocurrency, in terms of the percentage of the validation incentive that block rewards (see Figure 1 "X") and transaction fees (see Figure 1 "Y") make up. This reflects the extent to which a cryptocurrency user encouraged miners or validators to perform work, which determines electricity consumption and ultimately GHG emissions.

Refer to appendix (Accessing cryptocurrency network-specific variables) for more information.

FIGURE 1: Hybrid GHG emissions allocation equation

$$\text{Crypto value chain stakeholder's emissions} = \text{Total network emissions} \times \left[X \frac{\text{Value of holdings}}{\text{Network value}} + Y \frac{\text{Transaction fees paid}}{\text{Total network transaction fees}} \right]$$

$$X + Y = 1$$

$$Y = 1 - X$$

X — BLOCK REWARD INCENTIVIZATION FACTOR

The proportion that a block reward contributes to validator payout. Varies across consensus mechanisms and crypto types.

E.g., if a block reward contributes to 85% of validator payout, X = 0.85

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The proportion that transaction fees contribute to validator payout. Varies across consensus mechanisms and crypto types.

E.g., if a transaction fee contributes to 15% of validator payout, Y = 0.15

27 Gallersdörfer, U., Klaaßen, L., & Stoll, C. (2021). Accounting for carbon emissions caused by cryptocurrency and token systems. https://doi.org/10.48550/arXiv.2111.06477

3.3 Applying the hybrid method across stakeholders

It is important to understand the hybrid method's applicability across all cryptocurrency value chain stakeholders. First, there are industry precedents for allocating responsibility for GHG emissions based on the proportion contributed to an overall network.[28] Industry GHG accounting guidance for the technology sector indicates that within multi-stakeholder systems, GHG emissions may be assigned to stakeholders based on their relative cost and value.[29] The financial sector makes clear that entities with operational control over an asset (i.e., cryptocurrency asset owners and service providers) may be responsible for their relative share of total GHG emissions.[30] As cryptocurrency is at the intersection of these industries, it reasons that cryptocurrency stakeholders should account for their emissions based on how much they use and benefit from the cryptocurrency network.

The way that stakeholders use cryptocurrency influences how they encourage GHG emissions within the value chain. It is important to note these differences, but also that they are not mutually exclusive.

- For stakeholders holding cryptocurrencies, their emissions impacts are largely driven by their ownership share of the network (which influences block reward incentives).
- For stakeholders transacting in order to exchange goods and services, their activities have a greater impact on network transaction fees (which influences transaction fee incentives).
- To some extent, all users influence both block rewards and transaction fee incentives, based on their ownership share of the network and their portion of total network fees.

Only a hybrid GHG emissions allocation approach consistently and comprehensively accounts for the impacts of all users.

Refer to appendix (Determining Accounting Boundary) for more information on existing GHG accounting guidance.

Refer to appendix (Example hybrid allocation method calculations) for example calculations that apply the hybrid allocation method.

28 Malmodin, J., & Lundén, D. (2018). The energy and carbon footprint of the global ICT and E&M Sectors 2010–2015. Sustainability, 10(9), 3027. https://doi.org/10.3390/su10093027

29 Bergmark, P., Coroamă, V. C., Höjer, M., & Donovan, C. (2020). A methodology for assessing the environmental effects induced by ICT services. Proceedings of the 7th International Conference on ICT for Sustainability, 46–55. https://doi.org/10.1145/3401335.3401711

30 PCAF. (2020). The Global GHG Accounting & Reporting Standard for the Financial Industry. Retrieved from https://carbonaccountingfinancials.com/files/downloads/PCAF-Global-GHG-Standard.pdf

SECTION 4:

4 Additional considerations

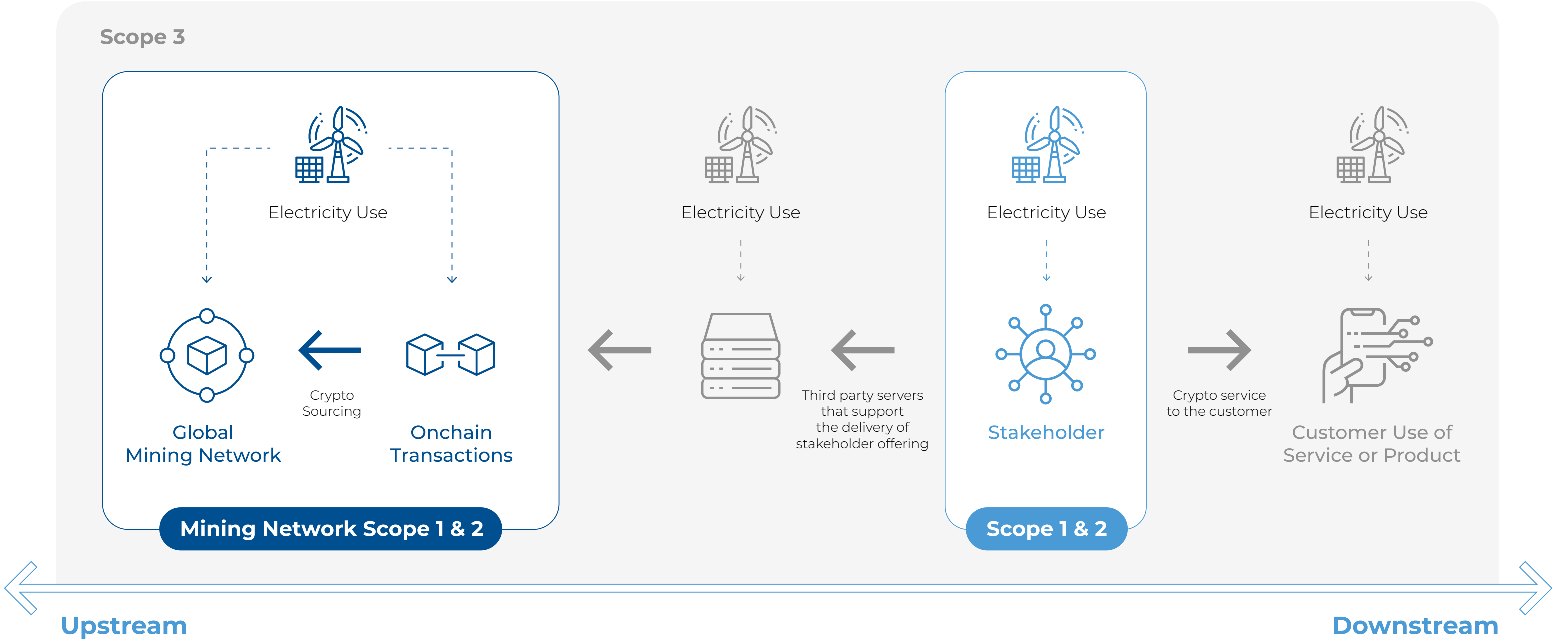
4.1 Cryptocurrency network emissions as part of an organization's GHG footprint

Once emissions are allocated, they must be reported appropriately, as per the GHG Protocol. Upstream cryptocurrency network GHG emissions would be reported as part of an entity's Scope 3 footprint. Doing so will encourage shared responsibility for GHG emissions across value chain stakeholders and incentivize collaboration. While the GHG Protocol has yet to weigh in on the appropriate designation, these emissions could be accounted for under Category 1 or Category 15 of the GHG Protocol Scope 3 Standard.[31]

In addition to accounting for the portion of total cryptocurrency network GHG emissions that their actions contribute to, stakeholders are also responsible for the GHG emissions generated by electricity that powers their own products and services. Different sources of GHG emissions associated with a stakeholder's service or product offering will be categorized in different GHG Protocol categories. Emissions associated with the delivery of a cryptocurrency-related product or service that occur onsite for a stakeholder through electricity use or electricity generation would be part of an entity's Scope 1 and 2 footprint. For example, GHG emissions generated from electricity used to power a cryptocurrency wallet or cryptocurrency service's offices, or onsite servers hosting the offering, would be categorized in Scope 1 and 2.

Stakeholders may also have indirect GHG emissions related to their cryptocurrency product or service that are not generated by a cryptocurrency network. Offsite servers that host the offering, third parties that help maintain the service, and end uses of a product would be included in an entity's Scope 3 footprint. An organization would have to account for all of these sources of GHG emissions, in addition to their portion of the total network emissions, to gain a holistic perspective of their cryptocurrency-related GHG exposure.

FIGURE 7: Cryptocurrency value chain stakeholder emissions by scope



31 The Greenhouse Gas Protocol. (2004). Retrieved from https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf

4.2 Opportunities to build on this framework

The method proposed in this document is an essential first step in allocating cryptocurrency network GHG emissions to users and service providers. As GHG accounting standards are developed, stakeholders can act to manage, and ultimately reduce emissions across the cryptocurrency value chain. While this framework aims to provide useful GHG accounting guidance to cryptocurrency stakeholders, many research and development opportunities remain:

- **Data:** Ideal data for allocating GHG emissions may not yet be available or publicly accessible. Proxy, secondary, or average data can be used to make assumptions where primary data is missing. For example, for the transaction portion of the equation, transaction fee data would be most accurate. However, if that data is unavailable, transaction count data could be used. Additionally, cryptocurrency activity managed by a third party (e.g. crypto custodians) may make necessary data less available for end users. In such cases, averages or estimates may be needed.
- **Layer 2 networks:** This framework accounts for Layer 1 mining and validation, as this makes up most of the cryptocurrency market. Layer 2 networks and their underlying hardware need to be measured or estimated separately, and their activities on the underlying Layer 1 need to be accounted for. As the hybrid allocation methodology already accounts for transactions, this framework can be extended to account for transactions caused by Layer 2, as well as novel use cases, such as DeFi or NFTs.
- **External influence:** The value of cryptocurrency is easily influenced by vocal important figures and large entities entering the market.[32] Further investigation of the impact of important actors on cryptocurrency prices and transaction volumes and, as a result, GHG emissions, may be worthwhile.
- **Lost coins:** When assigning responsibility for cryptocurrency network GHG emissions, the overall value of the network may need to be adjusted for lost coins, and their impact on price and the computational power required in mining.
- **Multiple Addresses:** If transaction fee data is unavailable and GHG emissions are therefore allocated based on the number of transactions, there may be double allocation of network GHG emissions, as both a sender and a receiver is involved in any given transaction. For certain cryptocurrencies, one transaction can draw from multiple senders and be sent to multiple receivers, so it is possible to allocate GHG emissions from any one transaction multiple times.
- **Derivatives:** Based on other industries' guidance, there is a risk of double counting GHG emissions if GHG emissions were allocated to derivative holders.[33] Thus, they are not included in this framework, but could be explored further in future.
- **Block reward:** When the block reward reaches zero, this method would not allocate associated GHG emissions. For Bitcoin, this point in time will be reached in the year 2140 – hopefully long after all emitting power generation resources have been replaced by renewable generation resources. As needed, this consideration could be explored further.

Beyond these technical considerations, there are other market considerations that may affect this framework in the future. As data availability, knowledge, and practical experiences further develop, more extensive and detailed guidance might be required.

32 Vox. (2021). When Elon Musk tweets, crypto prices move. Retrieved from https://www.vox.com/recode/2021/5/18/22441831/elonmusk-bitcoin-dogecoin-crypto-prices-tesla

33 Hokanson, A., & Salo, J. (2015). How to Account for Greenhouse Gas (GHG) Emissions of Derivatives. Retrieved from https://www.researchgate.net/publication/303938941_How_to_Account_for_Greenhouse_Gas_GHG_Emissions_of_Derivatives

Appendix

I. GENERATION OF NETWORK-WIDE GHG EMISSIONS

Due to the decentralized and anonymous nature of cryptocurrency networks, it is difficult to determine where mining or validation activities are occurring. As such, data on what types of electricity generation used for mining or validation activities is not always available and is instead estimated by reviewing hotspots of validation activities within a network. Regardless, knowing the electricity demand of cryptocurrency networks as well as the efficiency of existing mining and validation hardware, it is undeniable that the mining and validation processes of these networks generate GHG emissions.

II. GHG PROTOCOL GUIDANCE

According to the GHG Protocol, an emission source should be included under Scope 3 if:

- The emission source is large relative to Scope 1 and 2 GHG emissions
- The source contributes to GHG risk exposure
- The source is critical according to key stakeholders
- The source has potential emission reductions that could be either undertaken or influenced by the entity.[34]

As it relates to cryptocurrency owners and service providers, network GHG emissions meet the first three criteria. Available data on network GHG emissions clearly indicate that upstream network GHG emissions are large relative to an asset owner or service provider's Scope 1 and 2 GHG emissions. Particularly because of the size of the network GHG emissions and the current public criticism surrounding it, these GHG emissions will continue to contribute to value chain stakeholders' GHG risk exposure and be of importance to other stakeholders.

The connection between cryptocurrency asset owners and cryptocurrency service providers and their ability to reduce GHG emissions is less obvious. However, these stakeholders do have options to reduce their contribution to total network GHG emissions—namely, they can reduce the value, size, or frequency of their cryptocurrency transactions, as well as choose less GHG emission-intensive consensus mechanisms for their cryptocurrency. As cryptocurrency technology advances, additional opportunities for these stakeholders to further reduce network GHG emissions may arise.

While identifying specific reduction opportunities for non-mining and non-validating stakeholders is outside of the scope of this framework, the potential for reduction does exist. This, coupled with the significant size, risk, and criticism associated with network GHG emissions, indicate they should be included in the boundary of these stakeholders' Scope 3 GHG footprints.

An entity's location along the value chain will determine how it should approach and contextualize its cryptocurrency-related GHG emissions. Upstream stakeholders generate GHG emissions either from the production of equipment for miners or validators or the production and distribution of electricity for the validation network (this would be included within the Scope 1 and 2 footprint for these entities). The electricity used and GHG emissions generated by the validator network would be included within these stakeholders' Scope 3 footprints (i.e., use of sold products). While these stakeholders are not the focal point of this framework, their GHG emissions are relevant to downstream stakeholders who use their products and services.

Downstream stakeholders are responsible for the operational Scope 1 and 2 GHG emissions related to their cryptocurrency offerings. That is, they are responsible for the GHG emissions generated by servers and other electricity that is used to facilitate their products and services, or to access their cryptocurrency. Additionally, these stakeholders are responsible for the portion of the total network GHG emissions that their actions contribute to; these GHG emissions are allocated in their Scope 3 GHG footprints.

The different downstream stakeholder groups within the value chain are relatively consistent across cryptocurrency types, however, there are critical differences among their usages of crypto, as well as the different currency consensus mechanisms, that change the amount of total network GHG emissions the entity is responsible for.

III. DETERMINING ACCOUNTING BOUNDARY

Considering the high volume of GHG emissions generated by cryptocurrency networks, it is crucial to note why value chain stakeholders outside of miners and validators should take (partial) responsibility for these GHG emissions. This first requires an examination of existing GHG accounting guidance; specifically, available methods around Scope 3 boundary setting in adjacent industries

In the technology sector, the most relevant accounting guidance focuses on traffic in data networks; more specifically, methodologies on how to attribute emission reductions among multi-stakeholder services.[35] While GHG emissions reductions are outside of the scope of this framework, these attribution principles offer parallels for assigning GHG emissions responsibility within the cryptocurrency ecosystem.

Emission Reduction Attribution Principles - Technology Sector:

- Attributing GHG emissions based on a stakeholder's financial cost and value
- Attributing GHG emissions fully to all stakeholders ("touch it and it's yours")
- Attributing GHG emissions fully to the primary stakeholder ("winner takes all").[36]

Cryptocurrency asset holders and service providers are likely to agree that the "touch it and it's yours" and the "winner takes all" approaches would not offer fair emission allocation. Under the former, all stakeholders would be responsible for all GHG emissions on the network (an outsized responsibility), while in the "winner takes all" approach, the entity with the largest transaction on a block may be responsible for all associated GHG emissions—also unfair.

Therefore, of these, the financial cost and value approach would be most appropriate for cryptocurrency stakeholders as it splits downstream responsibility based on the relative amount contributed to the network by the stakeholder.

34 The Greenhouse Gas Protocol. (2004). Retrieved from https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf

35 Malmodin, J., & Lundén, D. (2018). The energy and carbon footprint of the global ICT and E&M Sectors 2010–2015. Sustainability, 10(9), 3027. https://doi.org/10.3390/su10093027

36 Bergmark, P., Coroamă, V. C., Höjer, M., & Donovan, C. (2020). A methodology for assessing the environmental effects induced by ICT services. Proceedings of the 7th International Conference on ICT for Sustainability, 46–55. https://doi.org/10.1145/3401335.3401711

It is also important to take into account the financial components of cryptocurrency operations, as it offers additional industry precedents outside of the technology sector. Existing precedent in the financial sector dictates that entities that have "operational control" over an asset should take accountability for them.[37]

Cryptocurrency custodians face unique considerations under this logic. "Operational control" may be defined as having the ability to buy, sell, or trade without the consent of the depositor. However, their users still have ownership and "operational control" of assets as they initiate transactions. As such, both entities in such a relationship have some responsibility for initiating transactions on the network, and should therefore take accountability for any associated GHG emissions.

IV. EMISSION ALLOCATION METHODS

It is important that whatever allocation method is used meets the following identified criteria:

- Consistency - an allocation method should be able to applied across different systems, parameters, and situations
- Continuity - methodology continues to function despite any system changes over time
- Completeness - the approach should adequately address all system GHG emissions.[38]

Existing network GHG emissions calculations primarily utilize two types of calculation methods: the holding-based approach and the transaction-based approach. These methods were evaluated with the above criteria in mind to determine applicability for cryptocurrency asset owners and service providers.

Holding-based method

For holders of crypto, the holding-based method allows each owner to account for their respective share of GHG emissions. This method works particularly well for networks like Bitcoin where block reward constitutes the majority (currently, approximately 99% for Bitcoin) of the miner payout.[39] The value of the block reward increases based on the value of the cryptocurrency and the value of the cryptocurrency increases as more users pay into the system. Thus, those that hold more value are more responsible for increasing the block reward and incentivizing miners to perform and generate GHG emissions.

However, the holding-based allocation method is not without its drawbacks. Notably, within each block on the blockchain, each transaction will take up an amount of space independent from value (therefore a large value transaction could take up the same amount of space as a small value transaction). Owning 100 units of a cryptocurrency may incur more GHG emissions if it is transacted over two 50 unit transactions instead of one 100 unit transaction. Moreover, one 50 unit transaction may occupy the same space as one 100 unit transaction in a block. Since block size is limited, higher transaction volume can increase traffic on the blockchain, increasing computational requirements and electricity use in the process. As such, it is important to not only note how much an entity owns in the network, but also how many transactions it took to acquire it. Currently, the holding-based approach does not account for this. Table 1 contains a comprehensive analysis of the holding-based approach.

TABLE 1: Holding-Based Allocation Method Analysis

Strength	Weakness
Allocation is consistent across reporting entities - factors such as batching won't affect allocation	Does not address the nuances of transaction emissions - namely, one large value transaction will have less of a verification emissions footprint than many, smaller value transactions
Increases accountability for entities that have a larger holding values, and thus, control over the market	% network ownership is not a static metric, and can change with network fluctuation outside of a reporting entity's control
	Not always possible for L2 technologies - leave out landscape
Opportunity	**Threat**
Fairly accessible for stakeholders methodology for stakeholders	Risk of double counting GHG emissions if boundaries are not clearly and consistently defined- can occur when different investments are made in the same value chain
Simple data collection process as both entity and network value are relatively accessible figures	Transaction stakeholders may be excluded
	Entities may report "reductions" when they experience decreases in relative value, without actually encouraging change
	Ongoing GHG emissions generation attributed to entities with low or no trading activity
	Entities may not want to disclose holding value

37 Any future formal, regulatory classification of cryptocurrency as a financial asset will further influence this logic. Here, the term "operational control" is in reference to the term defined by the GHG Protocol and detailed in the Glossary.
38 Gallersdörfer, U., Klaaßen, L., & Stoll, C. (2021). Accounting for carbon emissions caused by cryptocurrency and token systems. https://doi.org/10.48550/arXiv.2111.06477
39 Buy Bitcoin Worldwide. (2022). Fees. Retrieved from https://stats.buybitcoinworldwide.com/fees-percent-of-reward/

Transaction-based method

For cryptocurrency transactors, the transaction method allows each stakeholder to account for their respective transaction share of total network GHG emissions. Specifically, for consensus mechanisms like PoS where transaction fees are a greater portion of validator incentive, assigning allocation based on transaction fee value makes sense - the more transactions that are initiated, the more transaction fees are incurred and the more validators are incentivized. Users that have higher amounts of activity take on a larger share of GHG emissions than those that are less active. Since block size is limited, initiating more transactions increases computational requirements and electricity demand. Those that transact more then contribute to this demand and are more accountable under this method. However, like the holding-based method, this approach also loses some nuances. This method does not take into account the impact larger holdings have on driving cryptocurrency value and thus, validator incentives and GHG emissions. Table 2 contains a comprehensive analysis of the transaction-based approach.

TABLE 2: Transaction-based Allocation Method Analysis

Strength	Weakness
Reflects a fair emission share of an entity if a cryptocurrency is used for payment services or other services on the blockchain (smart contracts, dApps, etc.)	Only accounts for impacts when transacting, no holding emissions or downstream network GHG emissions
Data on transactions is usually readily available.	Need to translate different hashrates from different cryptocurrency types into comparable metrics. Differences between PoS and PoW - hashrate is generally driven by price, PoS emissions follow number of transactions more; potential for inconsistencies among currencies
Opportunity	**Threat**
By continually updating calculations by the latest hashrate activity, there is potential for more accuracy and addressing network impacts on on ongoing basis for POW systems	Applications such as batching and layer 2 protocols may make data collection and calculation difficult for downstream users
	Double or undercounting - as consumers use transaction services, both may take responsibility for transactions initiated
	Number of transactions isn't tied to value - potential for undercounting the impacts of high value
	Number of transactions is not always proportional to transaction fees - multiple transactions can have a smaller size than one large transaction

V. ACCESSING CRYPTOCURRENCY NETWORK-SPECIFIC VARIABLES

Cryptocurrency network-specific variables known as incentivization factors indicate the extent that block rewards and transaction fees each contribute to overall miner or validator participation in the network. These factors can be determined by reviewing publicly available data of the cryptocurrency validation reward structure. For instance, a block reward at times could constitute 95% of the total reward, and thus, the block reward incentivization factor would be 0.95, and thus the transaction fee incentivization factor would be 0.05.[40] Given that these values may fluctuate over time, taking an average of this data to align with the time period being measured should be sufficient.

Reporting entities then should identify the value of the currency transacted over time and—using network value data—determine their share of the total network value. By combining value share with the block reward incentivization factor, they should be able to determine the extent their share of the block reward (and thus miner and validator motivation) contributes to GHG emissions. Similarly, reporting entities should identify the total amount of transaction fees paid over the same time period and use total network transaction fee data and the transaction fee incentivization factor to determine the extent to which their transaction activity contributes to total GHG emissions.[41]

VI. EXAMPLE HYBRID ALLOCATION METHOD CALCULATIONS

See below for examples of the hybrid allocation method in practice.[42]

First, assume the following amounts that correspond to the values for total network emissions in 2021:

- For Bitcoin: 59.1 Mt CO_2e in 2021
- For Ethereum: 9.0 Mt CO_2e in 2021

In this example, assume the following cases:

- Company A holds 6 BTC for 1 year (0 transactions; average holding of 6 BTC over the year)
- Company B buys 1 BTC every month of the year (12 transactions; average holding of 6 BTC over the year)
- Company C buys 1 ETH every month of the year (12 transactions; average holding of 6 ETH over the year)

For the emission allocation, take the average daily block reward and transaction fee values to derive the block reward incentivization factor (X) and the transaction fee incentivization factor (Y). Use publicly available block explorers to derive the share of block reward and transaction fees from the miner revenue. Note, by looking at average values for the block reward incentivization factor (X) and the transaction fee incentivization factor (Y) in 2021, it becomes evident that their relation differ significantly across different cryptocurrency networks:

- For Bitcoin: X = 94% ; Y = 6%
- For Ethereum: X = 73%; Y = 27%

This leads to the following emission allocations for each company in this example:

- Company A: 17,700 kg CO_2e on holdings / 0 kg CO_2e on transactions / total 17,700 kg CO_2e
- Company B: 20,040 kg CO_2e on holdings / 440 kg CO_2e on transactions / total 20,480 kg CO_2e
- Company C: 480 kg CO_2e on holdings / 50 kg CO_2e on transactions / total 530 kg CO_2e

VII. CONSIDERATIONS FOR REPORTING

Potential options for categorizing cryptocurrency GHG emissions under the GHG Protocol.

To date, the GHG Protocol has not formally recommended what Scope 3 emissions category cryptocurrency GHG emissions should be classified under.

There is a possibility that some may consider accounting for cryptocurrency GHG emissions under the GHG Protocol Scope 3 Standard, Category 15. However, further regulatory and industry guidance around cryptocurrency is needed to further clarify how appropriate this allocation is for value chain stakeholders.

Given the different use cases of crypto, Category 1 could also be an appropriate classification. It may be tempting to account for cryptocurrency as a purchased good. However, as an asset with an indefinite lifespan, there are nuances that complicate this classification. For example, following traditional accounting approaches for a good would require knowing the GHG emissions of a given coin at the time it was generated, and then allocating those GHG emissions to all owners of that coin over its lifespan. This would require tracking each individual coin back to the point it was generated (a difficult technological process). Additionally, it would mean accounting for these GHG emissions indefinitely as the coin passes between users, requiring the sizable GHG emissions generated from the coin generation process to be accounted for again and again. This approach would potentially contradict the fungibility of cryptocurrency.

Alternatively, obtaining cryptocurrencies can be considered a purchased service. The verification of the transaction on the blockchain by a miner or validator (the process that is driving GHG emissions) is paid for by the user through transaction fees. From this perspective, GHG emissions are not pegged on the intangible cryptocurrency asset (which would be difficult to trace over its indefinite lifespan), but rather the services necessary to acquire it.

As the GHG Protocol considers the dynamics of cryptocurrency, more insights on the appropriate Scope 3 classification may be developed.

40 Buy Bitcoin Worldwide. (2022). Fees. Retrieved from https://stats.buybitcoinworldwide.com/fees-percent-of-reward/

41 If such data is available, reporting entities may also use transaction count data and compare the number of transactions they initiated to the total number of network transactions.

42 All calculations are performed with the CCRI Sustainability API. Link to documentation: https://docs.api.carbon-ratings.com

Glossary

Batch transactions: The process of aggregating several outgoing transactions in one transaction in order to minimize transaction costs.

Block reward: The block reward describes the reward in the form of coins that validators obtain after validating new transactions in a block. The block reward is usually one part of the incentive for validators to invest electricity and equipment in a network, together with the transaction fees.

Blockchain technology: The underlying technology of most cryptocurrencies. A blockchain describes the digital ledger of transactions that are summarized in blocks and secured by the network. The structure of the blockchain makes it very resistant against attempts of changing or hacking past transactions.

Control approach: Refers to the financial or operational control approaches set by the Greenhouse Gas (GHG) Protocol, to define the organisational boundaries for reporting entities.

Consensus mechanism: An algorithm that facilitates the functioning of decentralized ledgers. Specifically, it decreases the possibility of double-spending a cryptocurrency by confirming that all nodes in the network are consistent and valid (allowing honest nodes to align and dishonest nodes to be rejected).

Clearinghouse: an entity which collects and distributes on behalf of users, in this case, organizations that manage cryptocurrency transactions on behalf of buyers and sellers.

Cryptocurrency: a digital asset class that oftentimes uses blockchain technology to keep track of transactions in a decentralized ledger. Due to its decentralized structure, cryptocurrency is considered very secure against fraud.

Crypto custodians and custody solutions: a third party service that provides secure storage for cryptocurrency.

Crypto wallet: A software, service, device,or physical medium that allows to store the public and private keys which are needed to access the cryptocurrency and create transactions.

Downstream: any processes or stakeholders that are involved in a value chain after the reporting entity, e.g. when an electricity provider generates electricity, which is then used by a validator, this electricity consumption happens downstream from the electricity provider's perspective.

Equity share approach: The second approach that can be applied to define the organisational boundaries. With the equity share approach, the relative share of equity that the reporting entity owns in another entity is the deciding factor for accounting GHG emissions from operations.

Financial control approach: A subcategory of the control approach, describes the approach of accounting for all emissions from operations where the reporting has financial control.

Greenhouse gas (GHG) emissions: a measure of the global warming potential of different gases, summarized in the unit CO_2 equivalents (CO_2e).

Greenhouse gas (GHG) inventory: Provides an overview of an entity's total emissions, categorized in the three different scopes as well as the scope's different subcategories.

Greenhouse Gas Protocol (GHG Protocol): the most widely used international accounting tool for government and business leaders to understand, quantify and manage GHG emissions. The GHG Protocol was developed in a partnership between the World Resources Institute and the World Business Council for Sustainable Development.

Hashrate: a measure of the total computational power of all validators in a network. Most POW-cryptocurrencies adjust their hashing algorithm difficulty (mining difficulty) to the network's hashrate in order to guarantee a steady generation of new blocks.

Holding-based method: GHG emissions are allocated to the reporting entity based on a ratio of the amount held by an entity compared to the total network value.

Hybrid allocation approach: A more advanced method of allocating crypto's GHG emissions that takes the cryptocurrency-specific incentive structure into account. By taking into account how many transactions an entity conducted during a reporting period as well as how much of the total value was owned by the reporting entity, a fairer allocation is possible.

Incentivization factor: describes a network-specific and often fluctuating incentive structure for the validators. Describes the ratio of block reward to transaction fees

Holding-based approach: A simple method to allocate GHG emissions from a cryptocurrency based on the share of a crypto's total value that an entity owned during the reporting period. To be able to do so, the network's total GHG emissions are divided by the network's total coins or value in the reporting period.

Layer 1: The main layer of a cryptocurrency network. The layer where valid blocks are stored as part of the distributed ledger.

Layer 2: A layer that is on top of a crypto's main layer. Layer 2 transactions are usually not directly linked to the layer 1 structure but rather use the structure and rules of the main layer to settle transactions.

Nodes: A computer connected within a cryptocurrency network that aids in maintaining network data.

Operational control approach: A subcategory of the control approach, which describes the approach of accounting for all emissions from operations where the reporting has operational control.

Proof of Work (PoW): A type of consensus mechanism that is used to verify transactions on the decentralized ledger. With this consensus mechanism, validators that are able to computate more calculations in a shorter time are more likely to get the block reward and validate the transactions in that block. In order to obtain the block reward, validators must solve cryptographic problems.

Proof of Stake (PoS): A type of consensus mechanism, where the right to verify new transactions is given out to entities that stake a certain amount of their coins. The more coins an entity has staked, the higher the probability that that specific entity will verify new transactions.

Upstream: any processes or stakeholders that are involved in a value chain before the reporting entity, e.g. when an electricity provider generates electricity, which is then used by a validator, the electricity generation happens upstream from the validator's perspective.

Scopes 1, 2, and 3: A concept introduced by the GHG Protocol to delineate the different sources of a company's emissions and their influence over these emission sources.

- Scope 1: direct GHG emissions from sources owned or controlled by the company.
- Scope 2: indirect GHG emissions from purchased energy sources (electricity, heating and cooling, steam)
- Scope 3: other indirect GHG emission sources from sources not owned or controlled by the company.

Transaction fees: A fee that is paid by users of the cryptocurrency network to incentivize validators to include their transactions in a future block. Transactions fees constitute in many networks the other incentive for validators, besides the block reward.

Transaction method: A simple method to allocate GHG emissions from a cryptocurrency based on the number of transactions that an entity conducted during the reporting period. To do so, the network's total GHG emissions are divided by the network's total transactions during the reporting period.

Validators, miners, and block producers: Entities that validate and add new transactions to the distributed ledger by adding new blocks to the blockchain. In Proof of Work networks, validators are often also called miners.

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south pole

CCRI

Crypto Carbon Ratings Institute