GUIDANCE FOR ACCOUNTING AND REPORTING ELECTRICITY USE AND CARBON EMISSIONS FROM CRYPTOCURRENCY

PRODUCED TO ADVANCE THE CRYPTO CLIMATE ACCORD

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CRYPTO CLIMATE ACCORD

AUTHORS

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ABOUT CRYPTO CLIMATE ACCORD (CCA)

Surging demand for cryptocurrencies and accelerating adoption of blockchain-based solutions have highlighted an important issue: the technology's growing energy consumption and its impact on our climate. That's why we're working collaboratively with the crypto and blockchain industry to accelerate the development of digital #ProofOfGreen solutions and set a new standard for other industries to follow. Inspired by the Paris Climate Agreement, the CCA is a private sector-led initiative for the entire crypto community focused on decarbonizing the cryptocurrency and blockchain industry in record time. Together, we will #MakeCryptoGreen.

CONTRIBUTORS

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INTRODUCTION

The popularity of cryptocurrencies and blockchain-based solutions is accelerating. Global crypto adoption among retail investors grew 881% in 2021 vs. 2020, **according to new data from Chainalysis.** Over the course of the first half of 2021, the market diversified, **with Bitcoin's market share sliding** from near 70% to just under 50%. Amidst surfing crypto adoption, in August 2021, the crypto market again **surpassed a $2 trillion market cap worldwide.**

But this rapid growth has brought a major issue into the spotlight. The most widely used implementations of the technology consume large and growing amounts of energy, which is associated with growing greenhouse gas (GHG) emissions that negatively impact climate and worry investors concerned about crypto's environmental footprint. For example, **Bitcoin's annual electricity consumption** in late September hovered near 100 terawatt-hours (TWh) per year—after peaking at just over 130 TWh in May—equivalent to the total annual electricity consumption of a major country such as Argentina or Sweden.

To address this issue, in April 2021 nonprofits Energy Web, RMI, and the Alliance for Innovative Regulation co-founded the Crypto Climate Accord with a cohort of initial companies from the crypto and energy sectors. Since then, more than 200 organizations have joined the Accord, pledging to achieve net-zero emissions from all of their crypto-related operations by 2030.

The crypto industry has a unique opportunity to reduce emissions, showcase industry-wide decarbonization, create new demand for clean technologies, and increase access to customers and capital with interests in sustainability. However, to achieve these goals, any actor in the crypto industry will need a comprehensive way to measure, track, and report their electricity use and the associated GHG emissions. The crypto industry also will need guidance around the pathways and mechanisms available to achieve 100% decarbonization.

ABOUT THIS DOCUMENT

This document provides initial guidance on how various key stakeholders in the crypto sector can measure, track, and report their electricity use and GHG emissions.

Since the inception of the Crypto Climate Accord, the CCA supporter community has been researching and compiling various ways to account for and analyze the electricity usage and associated emissions of crypto-related activities. This work has been led by RMI and conducted in a collaborative and open manner with industry stakeholders to ensure that various perspectives, methodologies, and approaches were considered. Through this ongoing exercise, CCA supporters have identified and defined industry best-practices for accounting and reporting electricity use and carbon emissions from crypto-related activities. Further, based on our findings, we are designing and developing open-source solutions and mechanisms to verify electricity usage and mitigate the associated emissions for all industry actors.

In subsequent sections, we lay out a methodology that comprehensively analyses emissions from three separate perspectives:

- **Section 01 details how individual crypto mining operators can account and report the emissions that come from their own electricity consumption.**
- **Section 02 shows how actors such as cryptocurrency holders, exchanges, or application providers can account for emissions from the crypto that they use.**
- **Section 3 outlines how to model emissions from an entire cryptocurrency network.**

This guidance document primarily focuses on carbon accounting and offsetting for miners and users of public blockchain networks that employ a Proof-of-Work consensus mechanism, such as Bitcoin, since they represent the overwhelming majority of crypto- and blockchain-related energy consumption and associated carbon emissions. However, the emissions accounting and emissions-reduction strategies we describe could be applied to most crypto and blockchain networks, including those that use Proof-of-Stake and Proof-of-Authority consensus.

Since the target audience of this paper is market participants from the cryptocurrency and blockchain industries, we assume some knowledge of cryptocurrency and how blockchain networks function. For a brief explanation of these topics, please see **this article** by CoinDesk. This document does not assume prior knowledge of GHG protocols or carbon accounting practices.

UNDERSTANDING THE GHG PROTOCOL AND CARBON ACCOUNTING

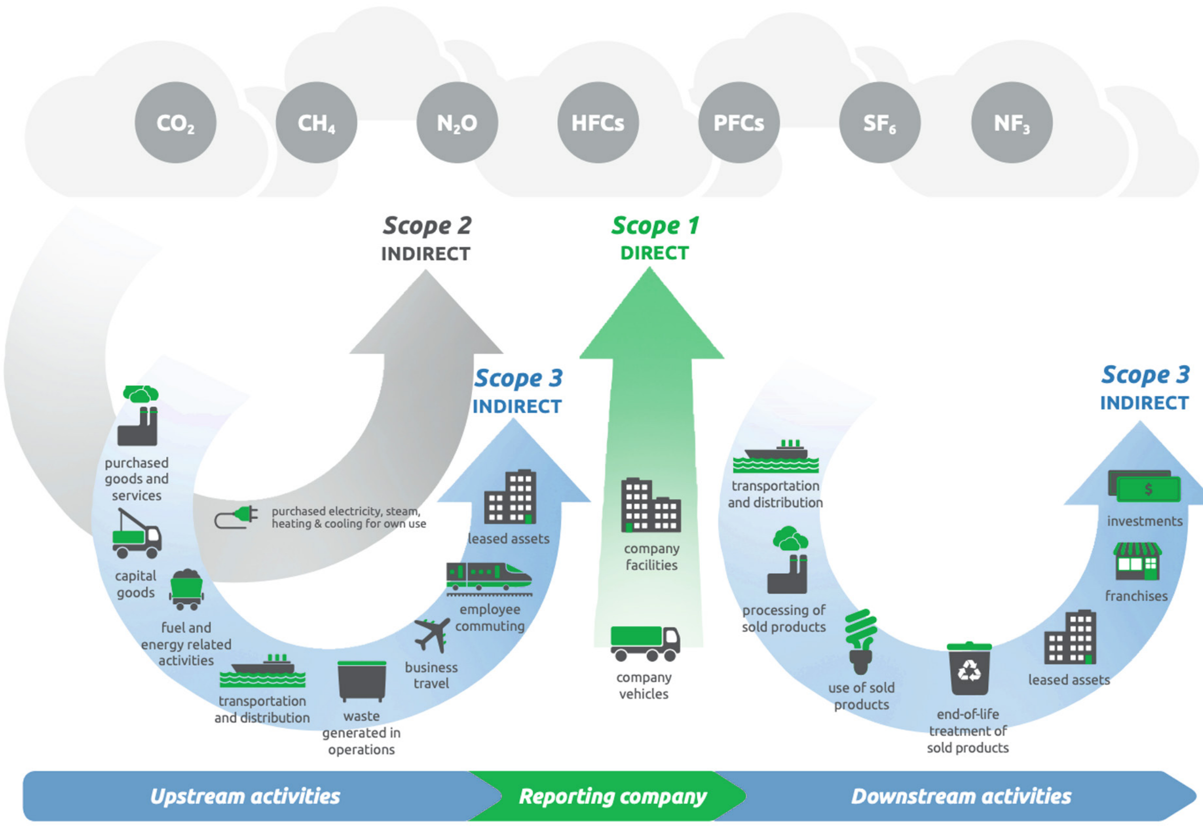
Carbon accounting is the process by which organizations (e.g., countries, companies) inventory and audit the amount of greenhouse gases (GHGs) they emit, including both direct and indirect emissions. The information provides a basis for understanding and managing climate impacts and may be used to inform business strategy and decision-making, as well as investment criteria and decisions.

The leading approach for carbon accounting is the **Greenhouse Gas Protocol**, a joint initiative of the nonprofits WRI (World Resources Institute) and WBCSD (World Business Council for Sustainable Development). The GHG Protocol defines three "Scopes" of emissions for GHG accounting and reporting purposes (also see Figure 1):

- **SCOPE 1:** Direct emissions that result from an organization's activities, such as fuel combustion from facilities (e.g., burning natural gas for space heating) and vehicles that your company owns or controls (e.g., burning gasoline or diesel for company automobiles or trucks).
- **SCOPE 2:** Indirect emissions associated with an organization's activities, often from the generation of purchased electricity consumed by your company (e.g., emissions from natural gas power plants that supply electricity to your local power grid).
- **SCOPE 3:** Other indirect emissions from an organization's supply chain, rather that its primary operations (e.g., embodied emissions in purchased raw goods, distribution and transportation, employee commuting, use of sold products, and end-of-life treatment).

FIGURE 1

OVERVIEW OF GHG PROTOCOL SCOPES AND EMISSIONS ACROSS THE VALUE CHAIN



Source: Greenhouse Gas Protocol Technical Guidance for Calculating Scope 3 Emission https://ghgprotocol.org/scope-3-technical-calculation-guidance

In the context of the cryptocurrency industry, cryptocurrency miners, meaning those actors who commit computational resources to verify transactions, are responsible for the emissions that result from the direct activities of their company (Scope 1), those which result from the generation of purchased electricity consumed by their organization (Scope 2), as well as a portion of the emissions from all other indirect sources of emissions from an organization's supply chain (Scope 3). The overwhelming vast majority of these emissions are the result of purchased electricity consumed by mining rigs. Industry actors who are downstream of mining operations, such as exchanges, application providers, corporates, and individual holders of cryptocurrencies are responsible for the majority of indirect emissions (Scope 3) of their holdings and transactions.

SECTION 01

SECTION 1: EMISSIONS ACCOUNTING FOR INDIVIDUAL MINING OPERATORS

For crypto miners, the overwhelming majority of the emissions associated with their activities is attributed to their Scope 2 electricity consumption (i.e., electricity consumption from running their server farms, plus supplemental electricity use such as for air conditioning the facilities in which the computers are located). Miners are also responsible for a portion of their indirect Scope 3 emissions from downstream activities. This section provides guidance on how to account for the Scope 2 emissions, while subsequent sections provide guidance on how to account for the Scope 3 emissions.[1]

There are five steps involved in determining the amount of emissions originating from mining activities:

1. Determine the boundaries for reporting
2. Obtain activity data
3. Determine electricity grid emissions factors
4. Match emissions factors and electricity consumption
5. Calculate the total emissions footprint

ACCOUNTING METHODS

Before going into a detailed explanation of the steps to calculate total emissions, it is worthwhile to first introduce accounting methods. Individual mining operators can employ one or more accounting methodologies to calculate their emissions footprint. These approaches are not mutually exclusive 'either/or' options. In fact, they are complementary and best used in tandem, when possible, to develop a more-holistic understanding of a mining operator's emissions impact (see Figure 2).

Two approaches use the attributional framework, which focuses on what portion of grid emissions should be assigned to a facility's electricity consumption. This is primarily about assigning responsibility for emissions; who or what do emissions 'belong' to. A third approach uses the consequential framework, which focuses on how actions—such as renewable energy investment—influence system-wide grid emissions, causing them to go up or down. This is primarily about cause-and-effect impact that results from various decisions.

- **Location-based Attributional Accounting:** This approach uses average emissions factors based on the generation mix for a facility's local electricity grid. Those average emissions factors are combined with electricity consumption data to calculate emissions that should be assigned to the facility's Scope 2 footprint.

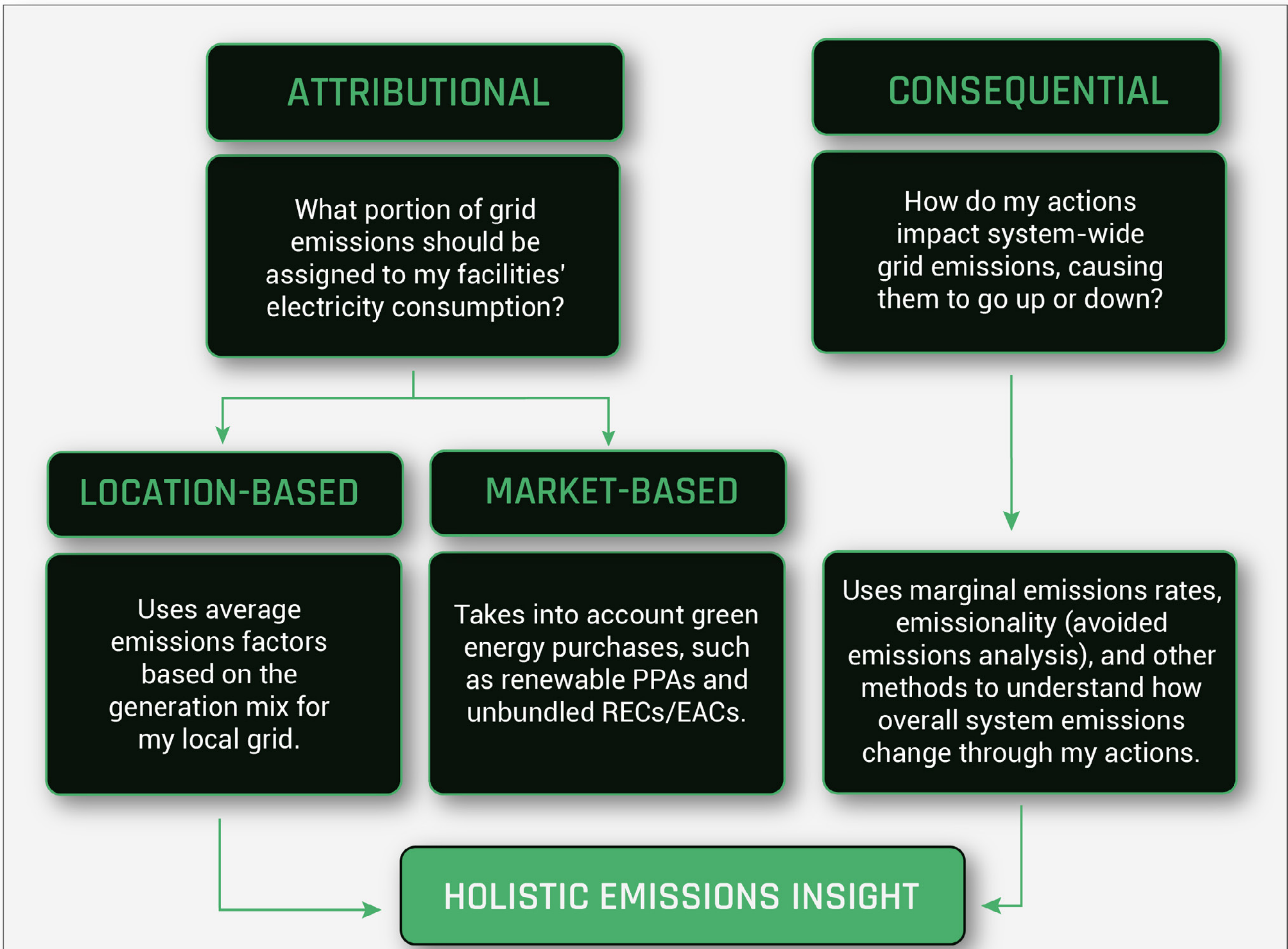
- **Market-based Attributional Accounting:** This approach builds upon the location-based approach, but also takes into account factors beyond the local grid's generation mix that can adjust (usually by lowering) a Scope 2 footprint, such as retail green electricity purchases, renewable energy power purchase agreements (PPAs), and unbundled energy attribute certificates (EACs) such as renewable energy certificates (RECs) and guarantees of origin (GOs).

- **Consequential Accounting:** This approach uses marginal emissions rates (rather than average emissions factors), emissionality (i.e., avoided emissions analysis), and other methods to understand how a mining operator's facility operations, strategies, and investments make overall grid emissions go up or down. Whereas attributional approaches can assess how green or not a given mining operator is or isn't, the consequential approach helps understand progress toward a decarbonized net-zero future for the cryptocurrency and blockchain sector.

[1]The Greenhouse Gas (GHG) Protocol Scope 2 Guidance provides general direction on how to measure emissions from corporate activities, and the Greenhouse Gas Protocol Project Accounting Guidance provides detailed direction on how to account for the effects of activity-related emissions. In this document, we draw inspiration from both approaches and apply it specifically to the cryptocurrency industry.

FIGURE 2

SCOPE 2 EMISSIONS ACCOUNTING APPROACHES FOR CRYPTOCURRENCY MINERS



Source: RMI

All three methods of emissions accounting are useful for different purposes, and therefore miners should calculate and report all three wherever possible. Similar to companies in other industries, there are no specific reporting requirements in the crypto industry, but market participants that would like to differentiate themselves on environmental grounds should seek to report their emissions calculation exercises on a regular basis. We recommend reporting at least once a year.

HOW TO CALCULATE EMISSIONS FOR CRYPTOCURRENCY MINERS

1. **Determine the 'boundaries' for reporting.** A miner should calculate the emissions from the generation of purchased electricity for all facilities of which they have financial and/or operational control. They should use a consistent approach to defining this boundary over time. Refer to Chapter 5 of the GHG Protocol Scope Guidance [2] for information on the three consolidation approaches for defining organizational boundaries.

2. **Obtain activity data (i.e., electricity consumption) for the reporting period.** The first step is obtaining activity data—the details of all electricity acquired and consumed. The best source of activity data is metered electricity consumption, utility bills, or reports that document electricity consumption in megawatt-hours (MWh) or kilowatt-hours (kWh). If those are not available, miners may use the best possible estimation and, ideally, should publish their estimation methodology (e.g., include transparent documentation of the assumptions and rationale behind any estimations). An example of an estimation is the Area Method, where shared electricity consumption by various building tenants is split between them based on each tenant's square footage.

3. **Determine electricity grid emissions factors.** The next step is obtaining the electricity grid emissions intensity figure (i.e., emissions factor) to use with this activity data. The type of data available for all three methods will vary widely between situations. Miners should choose emission factors according to the following hierarchies and must use the highest-ranked option possible under each of the three approaches. Use lower-ranked options only if higher ones are unavailable. The following pages 11-14 detail the necessary sub-steps for determining electricity grid emissions factors based on the three ranked methods.

[2] Adapted from the GHG Protocol Scope 2 Guidance Chapter 6.

LOCATION-BASED ATTRIBUTIONAL METHOD

a. Regional emission factors. These are average emission factors "representing all electricity production occurring in a defined grid distribution region that approximates a geographically precise energy distribution and use area. Emission factors should reflect net physical energy imports/exports across the grid boundary" (GHG Protocol). Examples of sources for these emission factors include eGRID total output emission rates (in the United States) and Defra annual grid average emission factor (in the United Kingdom).

b. National production emission factors. These are average emission factors "representing all electricity production information from geographic boundaries that are not necessarily related to the dispatch region, such as state or national borders. No adjustment for physical energy imports or exports, not representative of energy consumption area" (GHG Protocol). An example source of these emission factors is the International Energy Agency (IEA) national electricity emission factors.

The location-based method uses the most widely available emission factors and is therefore useful for comparisons of emissions figures between different organizations or over time. In the long run, cleaner energy decisions at an aggregate level will be reflected in location-based statistics. Other sources of emission factors include the IPCC Emission Factor Database, the GHG Protocol calculation tools and guidance, and CDM databases.

MARKET-BASED ATTRIBUTIONAL METHOD

Emission factors	Indicative examples	Precision
Energy attribute certificates or equivalent instruments (unbundled, bundled with electricity, conveyed in a contract for electricity, or delivered by a utility)	• Renewable Energy Certificates (U.S., Canada, Australia and others) • Generator Declarations (U.K.) for fuel mix disclosure • Guarantees of Origin (EU) • Electricity contracts (e.g. PPAs) that also convey RECs or GOs • Any other certificate instruments meeting the Scope 2 Quality Criteria	Higher
Contracts for electricity, such as power purchase agreements (PPAs) and contracts from specified sources, where electricity attribute certificates do not exist or are not required for a usage claim	• In the U.S., contracts for electricity from specified nonrenewable sources like coal in regions other than NEPOOL and PJM • Contracts that convey attributes to the entity consuming the power where certificates do not exist • Contracts for power that are silent on attributes, but where attributes are not otherwise tracked or claimed	
Supplier/Utility emission rates, such as standard product offer or a different product (e.g. a renewable energy product or tariff), and that are disclosed (preferably publicly) according to best available information	• Emission rate allocated and disclosed to retail electricity users, representing the entire delivered energy product (not only the supplier's owned assets) • Green energy tariffs • Voluntary renewable electricity program or product	
Residual mix (subnational or national) that uses energy production data and factors out voluntary purchases	• Calculated by EU country under RE-DISS project	
Other grid-average emission factors (subnational or national) – see location-based data	• eGRID total output emission rates (U.S.). In many regions this approximates a consumption-boundary, as eGRID regions are drawn to minimize imports/exports • Defra annual grid average emission factor (UK) • IEA national electricity emission factors	Lower

Source: Greenhouse Gas Protocol Technical Guidance for Calculating Scope 3 Emission
https://ghgprotocol.org/scope-3-technical-calculation-guidance

If a miner is using any of the certificate or contract options above, they must make sure that their source meets the Scope 2 Quality Criteria. These criteria can be found in Appendix 1 of this document and in Chapter 7 of the GHG Protocol Scope 2 Guidance.

A miner can skip calculating and reporting according to the market-based method only if none of their certificates or contracts meet Scope 2 Quality Criteria, or if their operations are in an area where they cannot obtain product- or supplier-specific data in the form of certificates, contracts with generators or suppliers, supplier emission rates, green tariffs, contracts, residual mixes, or other contractual instruments.

If only some operations are in locations that do not support the market-based approach, the miner can use the location-based method for those operations. The published market-based result should include a note on what percentage of the electricity consumption they reported in the market-based result used actual market-based emission factors.
The market-based method reflects the individual actions of electricity consumers in a more immediate way than the location-based method, as it takes specific certificates and contracts into account rather than a broad regional average.

CONSEQUENTIAL APPROACH

The consequential method looks at the actual additional or marginal impact that miners create by choosing to draw energy from a specific grid. It avoids arbitrarily sharing responsibility for all emissions among all grid users. It shows the macro impact that the electricity consumption has on the local grid.

For example, what if a miner decides to open a new mining pool on a grid with a lot of clean hydro power—to take advantage of that green electricity—but their added load causes a fossil-fueled peaking plant to ramp up in response? The attributional method would show them using lots of hydro power and a low emissions factor, but the consequential method will expose that their actions actually increased grid emissions overall.

For the consequential method, miners **should use marginal emission factors**, which are generally more accurate than average emission factors, and "reflect the emissions profile of a select subset of electricity generation facilities based on their role in the dispatch order of the system" (GHG Protocol). Miners should choose marginal emission factors from the following hierarchy:

1. Local or regional marginal emission factors. **The WattTime API provides a comprehensive set of real-time marginal emission rates for most of North America, Europe, and Australia. The CDM database also provides some marginal emission factors for specific regions.**
2. National marginal emission factors. **For the U.S., the EPA uses AVERT to produce a national weighted average of marginal emission factors. Here again, the CDM database provides marginal emission factors for specific regions and countries.**

If WattTime marginal emission rates are available for only some of the regions, miners should first seek to fill data gaps with marginal emission rates from the CDM database. If data gaps in geographic coverage still occur, miners should then use national marginal emission factors for the electricity consumption that occurs in those uncovered regions.

The published consequential result should include a note on each of the marginal emission factors used, and what percentage of the electricity consumption was covered with each of those factors. If marginal emissions rates are completely unavailable for any of the regions where power consumption occurs, the miner can skip calculating and reporting according to the consequential method and proceed with an alternative approach, such as the market-based and location-based attributional methods.

END OF DEEPDIVE

4. Match emissions factors and electricity consumption.

The fourth step in accounting for emissions from cryptocurrency mining is matching the emissions factors to each unit of electricity consumed.

For the location-based attributional method, this means matching units of electricity consumption to the appropriate emission factors based on the location(s) in which they are consumed. Also mapping data to emission factors based on a specific time period, especially if using real-time emission factors and real-time electricity data.

For the market-based attributional method, this means choosing a specific information source (and corresponding emission factor) for each unit of electricity. For example, if a miner has purchased enough RECs to cover half of their electricity use, they will need to use other instruments or information on the emission factor hierarchy to calculate the emissions for the remaining half.

For the consequential approach, this means matching each unit of electricity to the appropriate emission factor based on both location and time. If marginal emissions factors are not available for specific locations, miners should use the default grid emissions factors for their specific country, region, or jurisdiction.

In all cases, clearly document which method and emission factors were used in every calculation. It should be clear what amount and percentage of electricity consumption was matched with each emission factor.

5. Calculate the total emissions footprint and impact.

The final step is to calculate total emissions by multiplying each section of activity data by the appropriate emission factor, for each applicable GHG. Electricity emission factor sets may include factors for carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O). Then, multiply these GHG emission totals by global warming potential values to get total emission in metric tons CO2 equivalent (CO_2e).

It is important to make every effort to ensure that emissions accounting is accurate and complete. Any reported figures should maintain consistent accounting methodologies over time (unless it is possible to increase accuracy through improved methods).

Transparency can be an important differentiator. It is recommended that you clearly disclose all data sources, calculation methods, assumptions, and other factors that influence the outcome of the accounting process (especially in cases where there have been changes over time). Publish the outcomes of all three accounting methods—location-based attributional, market-based attributional, and consequential—with clear labels and on a regular basis. We recommend disclosing this information at least once a year.

NOTE: Currently, this document does not provide guidance for reporting "avoided emissions." If calculated, avoided emissions should be reported separately from the Scope 1, 2, and 3 emissions accounts detailed above. As explained later in this document, the CCA community is currently developing a suite of solutions that facilitate the creation of demand signals to decarbonize activities within the crypto industry. These mechanisms aim to incentivize industry participants to decarbonize their emissions directly, rather than indirectly, which is how traditional offsets claim to incentivize mitigation efforts.

NON-GRID CONSUMPTION: SCOPE 1 AND DIRECT TRANSFERS

So far, this section has detailed emissions reporting for mining operators who purchase energy from a local energy grid (Scope 2). However, there may be cases where miners have on-site energy production or direct line connections to specific energy production facilities. If the miners have on-site energy production from their equipment that they own and/or operate themselves (as in the case of power plant/mining operation hybrids), and the electricity is both produced and consumed by the same entity, they should not report emissions from that power generation as Scope 2. Instead, these emissions fall under Scope 1 (direct GHG emissions from sources that are controlled or owned), and should be measured and reported separately. For mining operations in the United States, this reporting should be conducted according to the EPA Scope 1 Guidance.

If electricity is coming from a direct line transfer (energy production from a third party is fed directly and exclusively to the miner), the miner's Scope 2 emissions will equal the Scope 1 emissions from the third party's energy production (including any transmission and distribution losses).

If the electricity comes from a mix of onsite owned/operated equipment and electricity purchased from the grid, the miner should report both Scope 1 from their energy generation and Scope 2 from grid purchases. In cases where some generation is sold back to the grid, they must use the "gross" electricity purchases from the grid, rather than "net" grid purchases, in Scope 2 calculations.

Individual mining operators may also report Scope 3 emissions—upstream and downstream lifecycle emissions associated with the mining rigs and other technology and materials used in running the mining operation. In a later section, we provide guidance for actors to calculate and report their Scope 3 emissions. The GHG Protocol Corporate Value Chain (Scope 3) Standard also provides guidance on accounting and reporting these emissions.

SECTION 02

SECTION 2: EMISSIONS OF DOWNSTREAM USERS (EXCHANGES, APPLICATION PROVIDERS, INDIVIDUAL HOLDERS)

To encourage the decarbonization of cryptocurrency networks, it is vitally important that action come not only from miners but also from downstream users such as exchanges, application providers, corporate and other individual large holders. For such users, the emissions that arise from the activities within cryptocurrency networks fall under their Scope 3 emissions: emissions that are "the result of activities from assets not owned or controlled by the reporting organization, but that the organization indirectly impacts in its value chain."

Examples of downstream use cases include:

- **Addressing corporate Scope 3 emissions**, such as companies that accept Bitcoin, Ether, or other cryptocurrencies and/or which hold cryptocurrencies on their balance sheets.
- **'Green' crypto exchanges and blockchain** that want to decarbonize the crypto that flows through their platform and/or the transactions that take place on their network on behalf of their users. Some crypto exchanges and investors are looking at covering the Scope 2 of their holdings with energy attribute credits, covered later in this document.
- **Investors with ESG screening criteria**, such as those that now take climate risk and sustainability into consideration with their investment decisions.

In the case of cryptocurrency networks, the majority of the emissions associated with the currency come from mining (which is also the process of verifying transactions). As a downstream user, conducting transactions contributes to the reason why miners operate their rigs and are the actions that result in the generation of emissions. Due to these dynamics, we encourage cryptocurrency users to calculate their emissions on a per transaction basis **as well as** on a value basis.

The primary reason we recommend cryptocurrency users employ both approaches is because in Proof-of-Work consensus there is a high correlation between a cryptocurrency's energy consumption and its market value. By calculating emissions according to both approaches, users will have a higher level of confidence that they are comprehensively accounting for the emissions associated with their activities. If or when the two approaches return different results, we strongly recommend that actors use the higher emissions number as their primary metric for assessing the appropriate amount of mitigation actions.

It is also highly recommended that users report the emissions from the use of cryptocurrency under their Scope 3 emissions, in a regular and timely manner (e.g., every quarter), with clear documentation of data sources and calculation methods.

Estimating per-transaction emissions for a crypto / blockchain network

On a per-transaction basis, actors should calculate the emissions of an individual transaction and then multiply by the number of transactions in their transaction history. This involves the following steps:

1. Model total network emissions for the crypto network of this document (see Section 3); or use the results from a third-party model that follows the guidance.
2. Divide the total network emissions by the total number of transactions that occurred in the reporting time period to find the emissions-per-transaction.
3. From transaction history, find the number of transactions the user engaged in.
4. Multiply the number of transactions by the emission-per-transaction to find total emissions from the use of the cryptocurrency or blockchain network.

Estimating per-transaction emissions for a crypto / blockchain network

When calculating emissions on a value basis, actors should employ a methodology that is based on a value share of the network. This is applicable to exchanges, application providers, and corporations, but not for individual holders.

This approach involves calculating the emissions of cryptocurrency holdings as a percentage of current total market capitalization of the cryptocurrency's network, and apportioning the electricity use of the entire network to that of the individual holdings.

There are also several existing crypto carbon emissions or electricity consumption calculators that employ robust accounting practices, mainly based on the attributional approach, such as:

- **Patch:** the Patch methodology estimates the daily electricity consumption of crypto networks using a bottom-up technique based on commercially available mining equipment.
- **Offsetra:** the Carbon.fyi methodology conducts a calculation of CO_2e emissions per transaction on the Ethereum network.
- **Zumo:** recommends two methodologies, depending on which type of activity a stakeholder conducts. These two methodologies are:
  - **BTC share:** the Zumo methodology looks at the average electricity required to mine one BTC since the genesis block. This is a cumulative total and useful for holders of BTC. It conducts a calculation of CO_2e emissions based on the value of miner revenues (block rewards and mining fees).
  - **Network share:** alternative methodology apportions the electricity use of the BTC network based on share of BTC holdings to give the share of electricity use over a defined time period (useful for wallets and platforms).

SECTION 03

SECTION 3: OVERALL EMISSIONS FROM AN ENTIRE CRYPTOCURRENCY NETWORK

For both mining operators and downstream crypto users, there may be times when they need to calculate the emissions of an entire cryptocurrency network—such as to understand their portion of the network's climate footprint or to track overall crypto sector progress toward net-zero targets, such as those of the CCA.

In this section, we look at how to model emissions from an overall cryptocurrency network. Calculations should take into account both the energy consumption and emissions of the miner who validates a block as well as all those that didn't. In an ideal world, every miner on the network would report their individual emissions as described in Section 1; the total of all these reported emissions over a year would be the overall annual network emissions. Our aim here is to get the best possible estimate of this total. This estimate can be used as an "emissions factor" to calculate the total exposure of a downstream player (e.g., a holder) of a specific cryptocurrency within a network. The estimate can also be valuable for a miner, as a portion of it is a representative figure of their Scope 3 emissions profile.

Modelling from a network-wide perspective is challenging because, similar to energy data availability across supply chains in other industries, data about miners—their locations, equipment, electricity consumption, etc.—is sparse. This is true for the most popular Proof-of-Work cryptocurrency networks, Bitcoin and Ethereum, and even more true for lesser-known networks. Due to the low and varying amounts of available data, here we present two modelling approaches, each with a different underlying method and level of detail. It is suggested that all cryptocurrency network participants, downstream of mining operators, select one of the two modelling approaches based on the amount and types of data available.

The first step in modelling emissions is estimating the total amount of electricity consumed by the cryptocurrency network. There are two approaches for doing so.

CRYPTOCURRENCY NETWORK APPROACH 1:

Cambridge Bitcoin Electricity Consumption Index (CBECI)

This approach involves emulating the most detailed models currently available for estimating the electricity consumption of the Bitcoin network. NOTE: this approach only applies to the Bitcoin network, and is not applicable to other networks, such as Ethereum. This approach is suitable if there is good data available on network hashrate, daily cryptocurrency issuance value, daily miner fees, currency market price, and mining equipment efficiency. Ideally, there should also be data on the market shares of the available mining equipment, the power usage effectiveness (PUE) of miners, and miners' electricity costs.

If all or most of this data is available, we recommend using or adapting the **methodology from the Cambridge Bitcoin Electricity Consumption Index.** This approach, which is used widely by application providers in the sector, is an economic model based on the profitability thresholds of different types of mining equipment. For each day, this model identifies all the mining equipment that is profitable (based on mining fees, mining equipment efficiency, and electricity prices). Then, it calculates a best-guess estimate using the efficiencies and shares of profitable hardware, hashrate, and PUE. The power consumptions for each day over the year are totaled to get a 7-day rolling figure, annualized based on an individual day's figure. In order to calculate the actual average over the year practitioners will need to also apply retrospective calculations, as **Zumo** did in their methodology.

Having reasonably reliable data on the efficiency and market shares of all the major mining equipment options is important for this approach. If sufficient data is not available, some of the parameters can be replaced with estimates, but these estimates and the assumptions behind them should be well-documented.

This model can be refined further in various ways. If data on the locations of miners is available, the model can be modified to use local average electricity prices instead of a global average. Better data on the capital, maintenance, and cooling costs could be factored in. Currently, however, this data is difficult to access even for the most popular cryptocurrency networks. As more data becomes available, we recommend adding layers of complexity and refining the model as much as possible.

CRYPTOCURRENCY NETWORK APPROACH 2:
Digiconomist Bitcoin Energy Consumption Index

This approach is suitable if the data required for the above approach is not available. This approach, based on the **Digiconomist Bitcoin energy consumption index,** requires data or estimates of the total mining revenues, the percentage of mining revenue spent on energy, and the price of electricity.

This model uses the following equation:

$$\text{TOTAL ELECTRICITY CONSUMED} = \frac{\text{TOTAL MINING REVENUES} \times \text{PERCENT SPENT ON ELECTRICITY}}{\text{PRICE OF ELECTRICITY}}$$

This is a very simple model but can still be useful for a ballpark estimate of network electricity consumption in situations where data is scarce. This model can be made more meaningful by conducting better data collection or modelling to get better estimates of the three parameters. Total mining revenues can be found by combining data on mining fees, cryptocurrency value, and number of blocks mined. The price of electricity can be more accurately estimated by gathering data on the locations of miners, and then using national or regional average electricity prices. The percent of mining revenues spent on electricity can be estimated by surveying miners, or modelling the split of various costs (cooling, maintenance, equipment, electricity) for the average miner.

Generally, Approach 1 is stronger than Approach 2, as it considers some of the nuances of the way mining behavior changes based on dynamic economic situations. However, both approaches rely on a set of assumptions and estimates that will vary based on the available information. Choose a model in such a way that key parameters rely on data and estimates with low uncertainty.

One way to broadly assess the overall uncertainty of each estimate is to calculate best-guess, upper bound, and lower bound estimates for both approaches, using the best data available. The range between the upper bound and lower bound can be used as a proxy for the uncertainty range of that estimate.

To determine the upper and lower bound estimates, we suggest users utilize **Bollinger Bands**, which are volatility bands placed above and below a moving average that usually consists of a middle band with two outer bands. The middle band is a simple moving average that is usually set at 20 periods. The outer bands are usually set two standard deviations above and below the middle band. A simple moving average is used because the standard deviation formula also uses a simple moving average. The look-back period for the standard deviation is the same as for the simple moving average.

Once users have calculated emissions according to both approaches, and have assessed the overall uncertainty of each estimate, we then recommend choosing the approach with the lower uncertainty range and using the best-guess result from that approach. After reaching an estimate of the total amount of electricity consumed by the cryptocurrency network, the next step is estimating the emissions from that electricity consumption.

CALCULATING OVERALL CRYPTOCURRENCY NETWORK EMISSIONS

To calculate the emissions associated with the total network energy consumption, it is important to collect data on hashrate location. The Cambridge Bitcoin Electricity Consumption Index provides a **methodology** for finding geolocational mining facility data based on the IP addresses of mining facility operators. This methodology—used to identify the location of mining activities—extrapolates from a representative sample of geolocation mining facility data, and is based on the aggregation of individual pool distributions that are periodically collected through the CBECI API.

While mining facility data can then be used as representative of hashrate location, it is worthwhile to note that virtual private networks (VPNs) and proxy servers can be used to obfuscate the actual location of mining facilities. In the future, if enough facility operators or mining pools volunteer data, it may be possible to take a bottom-up approach of compiling a list of mining facilities to arrive at more accurate network energy consumption figures.

The next step is to allocate the total electricity consumption estimate between all the locations of miners. Allocating electricity proportional to the hashrate share of that location is a reasonable assumption.

Then, multiply electricity consumption at each location by an appropriate emission factor. The emission factor to use will depend on the granularity of location data. For each location at which electricity consumption occurs, choose an emission factor based on the highest available option in the following hierarchy.

The hierarchy is a condensed version of the hierarchies in Section 1, with most of the market-based options excluded. In the future, it may be possible to collect data on the amount of mining electricity consumption that is associated with the purchase of energy attribute certificates or with special low-carbon supplier contracts. At present, however, collecting such detailed data is impractical, so this network-wide emissions estimation approach currently assumes that the number of miners taking special actions (through certificates or contracts) that reduce carbon emissions significantly is negligible, and reserved to specific use-cases.

1. **Marginal Emission Factors:** These emissions measurements "reflect the emissions profile of a select subset of electricity generation facilities based on their role in the dispatch order of the system" (GHG Protocol).
   - o WattTime's API provides real-time marginal emission rates for most of North America and Europe. The CDM database also provides a list of marginal emission factors for specific locations.

2. **Residual Mix:** Subnational or national, this emission factor is calculated using energy production data, but factors out voluntary purchases. An example is the factors calculated by the EU under the RE-DISS project, or the residual mix emission factor published by the Norwegian authority.

3. **Regional Emission Factors:** These are average emission factors "representing all electricity production occurring in a defined grid distribution region that approximates a geographically precise energy distribution and use area. Emission factors should reflect net physical energy imports/exports across the grid boundary" (GHG Protocol). Examples of sources for these emission factors include eGRID total output emission rates (U.S.) and Defra annual grid average emission factor (UK).

4. **National Production Emissions Factors:** These are average emission factors "representing all electricity production information from geographic boundaries that are not necessarily related to the dispatch region, such as state or national borders. No adjustment for physical energy imports or exports, not representative of the energy consumption area" (GHG Protocol). An example source of these emission factors is the IEA national electricity emission factors.

After multiplying every unit of estimated electricity consumption by an appropriate emission factor, sum the results to get a final estimate of overall network emissions in metric tons of CO_2 equivalent ($MTCO_2e$).

When publishing an estimate of cryptocurrency emissions, using such an estimate to allocate crypto emissions to downstream users, or using such an estimate to drive carbon offsetting decisions, it is important to be consistent and transparent. Clearly disclose all data sources, modeling methodology, calculation methods, assumptions, and other factors that went into creating the estimate. Also disclose any further actions, calculations, or publications that this estimate is being used for.

REDUCING EMISSIONS FROM MINING

REDUCING EMISSIONS FROM MINING

Up until now, we have focused primarily on how to calculate the energy consumption and corresponding emissions footprint of cryptocurrencies and blockchain networks. But of course, mining operators and downstream users alike have a variety of strategies and tools at their disposal to reduce crypto's carbon footprint en route to the net-zero future envisioned by CCA and our signatories and supporters.

1. **Energy Efficiency:** Miners can reduce their total amount of electricity use, which in turn will reduce their Scope 2 emissions. Energy efficiency can take various forms, such as optimizing existing infrastructure or sourcing more-efficient hardware. Energy-efficiency investments also usually have a short payback period, whereafter they save money via reduced energy costs.

2. **Load Shifting:** Altering the timing of electricity use. At certain times (generally off-peak times), electricity generation on the grid may be lower in emissions. By shifting electricity demand to such times, miners can reduce GHG impact as well as their electricity costs. This impact may be measured through contractual instruments. Over time and with scale, such shifts in demand timing can also contribute to reductions in grid average and marginal emission factors.

3. **Re-location:** Changing the location of mining operations. A significant change in location may result in drawing energy from a different grid, with different grid average and marginal emission factors. A new location will likely also mean new electricity suppliers, renewable attribute purchasing opportunities, market actors, and so on.

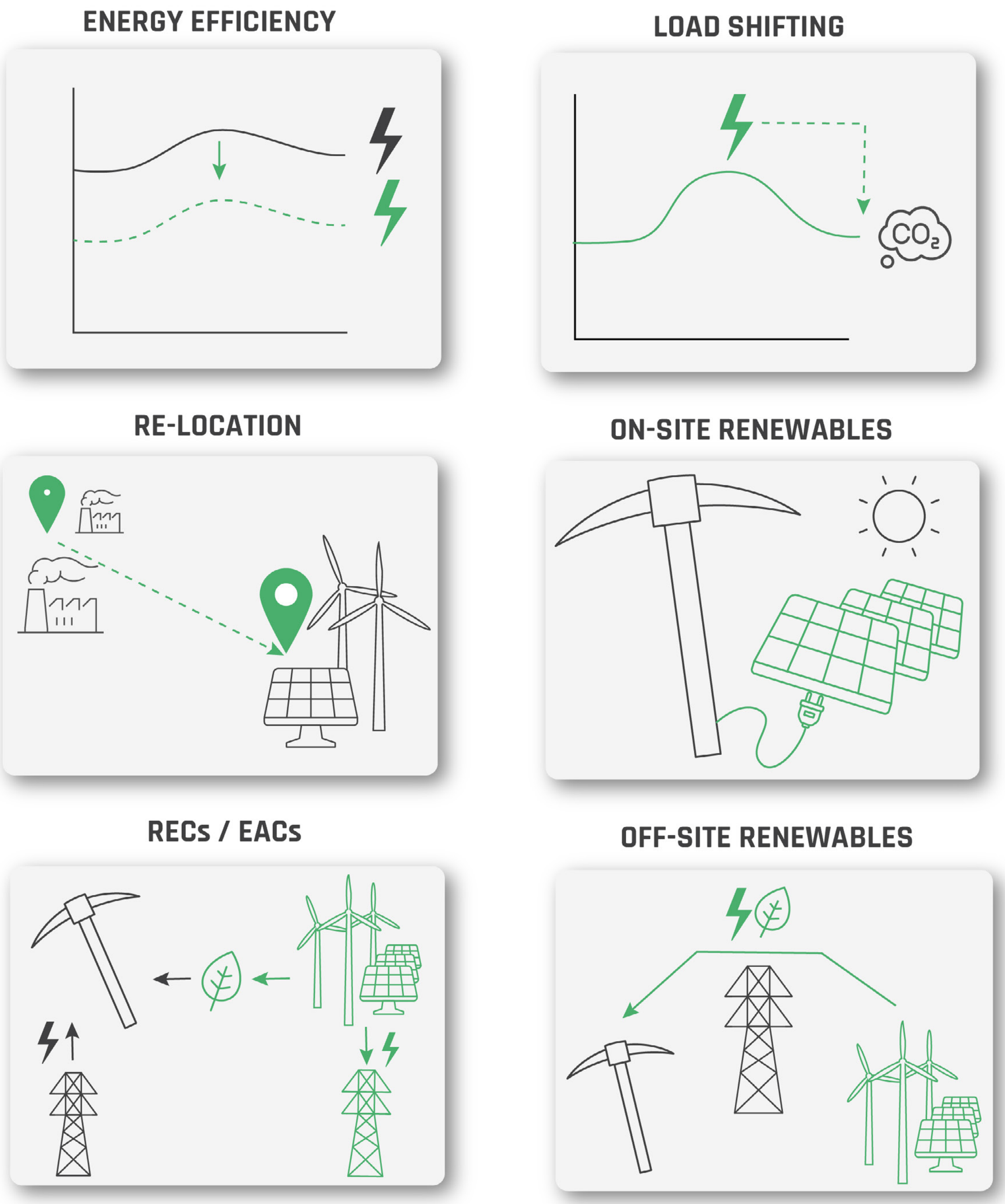
4. **On-site Renewables:** Investing in on-site renewables. This will result in low or zero Scope 1 emissions and/or reduced Scope 2 emissions. For example, on-site solar PV would contribute zero to a mining operator's Scope 1 emissions. That same on-site clean electricity generation would reduce the amount of electricity they'd need to source from the power grid, which would otherwise be a likely source of Scope 2 emissions.

5. **Unbundled EACs:** Unbundled energy attribute certificates (EACs) such as RECs, GOs, and I-RECs allow an actor to combine the green attributes of renewably-generated electricity with actual fossil-fueled 'brown' power consumed, lowering Scope 2 emissions via attributional accounting. Miners that procure EACs equal to the number of megawatt-hour (MWh) of electricity use of their mining can achieve and claim 100% renewable energy sourcing in line with overall industry standards. Similarly, stakeholders can claim 100% renewable energy sourcing for entire cryptocurrency networks and crypto holdings by procuring EACs equal to the estimated MWh electricity use. However, these procurements do not necessarily result in meaningful actual system-wide emissions reductions via consequential accounting.

6. **Off-site Renewables:** Entering contracts for renewable energy that meets additionality tests. These often take the form of either direct or virtual power purchase agreements (PPAs). Many such PPAs meet the criteria of 'additionality,' affirming that new renewable energy capacity is added to the world's electricity grids, displacing legacy fossil-fueled generation and helping to lower overall emissions. Miners still require EACs alongside a PPA in order to prove green sourcing.

FIGURE 3

EMISSION-REDUCTION STRATEGIES FOR MINERS



Even after implementing one or more strategies to decarbonize emissions—including the Scope 2 emissions that are the focus of this guidance document—some emissions footprint may remain. In such cases, actors targeting net-zero emissions can further look to carbon offsets as a way to mitigate the remaining carbon footprint. This is consistent with the approach leading tech companies and other corporations are taking today with their sustainability strategies: invest in energy efficiency and renewable energy first, to reduce their emissions footprint, then invest in carbon offsets to zero-out any remaining balance.

OFFSETTING EMISSIONS

Since downstream users' emissions from the use of cryptocurrency are indirect emissions, reaching net zero emissions as a user of cryptocurrency will require the purchase of mitigation credits. One incentive mechanism that offers a holder the possibility to offset their emissions is the solution the CCA community is currently developing with industry stakeholders to 'tokenize' EACs, such as RECs, GOs, and I-RECs. This open-source technical architecture will create tokenized pools for crypto miners, exchanges, and investors to procure high-quality EACs, carbon offsets, and carbon removal from verified providers.

In this architecture, EAC, carbon offset, and carbon removal providers mint and list their respective tokenized supplies, then deliver verification of certificate cancellations on the applicable EAC and carbon registries—all on a public blockchain—so that crypto (or any other) buyers can more easily procure these products and prove their environmental claims. This solution will offer a new digitized option for any crypto market participant to cover its respective energy use or carbon emissions associated with the energy use of their crypto holdings/activity. This solution is currently being **piloted with Protocol Labs** to enable and incentivize Filecoin storage providers (i.e., the equivalent to miners on Filecoin) to source their electricity from renewables in a verifiable way.

In addition to the mechanisms listed above, **Offsetguide.org** provides detailed explanations of the types of carbon offsets and recommendations for high-quality offsets.

HOW THE CCA COMMUNITY IS ADVANCING TECH SOLUTIONS TO SUPPORT CRYPTO'S DECARBONIZATION

To complement the solution to tokenize EACs as well as carbon offset and removal offerings, the CCA community is accelerating the development of open-source Green Hashrate software to verify the green credentials of miners and mining pools. This will support new incentive schemes for green mining that, taken together, will help establish the verified proportion of crypto mining powered with renewables.

- **Enabling green mining pools to acquire proof of renewables for any miners as part of the know-your-customer (KYC) process to join a green mining pool;**
- **Helping miners deliver proofs of renewable energy sourcing to local regulators and/or investors to meet ESG criteria;**
- **Over time, proving to crypto investors and regulators the actual amount of renewable electricity powering an entire cryptocurrency network at any time.**

APPENDIX 1 -

SCOPE 2 QUALITY CRITERIA

APPENDIX 1 – SCOPE 2 QUALITY CRITERIA

All contractual instruments used in the market-based method for scope 2 accounting shall:

1. Convey the direct GHG emission rate attribute associated with the unit of electricity produced.
2. Be the only instruments that carry the GHG emission rate attribute claim associated with that quantity of electricity generation.
3. Be tracked and redeemed, retired, or canceled by or on behalf of the reporting entity.
4. Be issued and redeemed as close as possible to the period of energy consumption to which the instrument is applied.
5. Be sourced from the same market in which the reporting entity's electricity-consuming operations are located and to which the instrument is applied.

In addition, utility-specific emission factors shall:

6. Be calculated based on delivered electricity, incorporating certificates sourced and retired on behalf of its customers. Electricity from renewable facilities for which the attributes have been sold off (via contracts or certificates) shall be characterized as having the GHG attributes of the residual mix in the utility or supplier-specific emission factor.

In addition, companies purchasing electricity directly from generators or consuming on-site generation shall:

7. Ensure all contractual instruments conveying emissions claims be transferred to the reporting entity only. No other instruments that convey this claim to another end user shall be issued for the contracted electricity. The electricity from the facility **shall not** carry the GHG emission rate claim for use by a utility, for example, for the purpose of delivery and use claims.

Finally, to use any contractual instrument in the market-based method requires that:

8. An adjusted, residual mix characterizing the GHG intensity of unclaimed or publicly shared electricity shall be made available for consumer scope 2 calculations, or its absence shall be disclosed by the reporting entity.

For further information refer to the **GHG Protocol Scope 2 Guidance Chapter 7**, from which this table is taken.

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