



Evaluating Mitigation Options for Crypto-related GHG Emissions

CCRI & Ecologic Institute

2026

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Ecologic Institute

Ecologic Institute is an independent, academic think tank for environmental research and policy analysis. Established in 2008 as a 501(c)(3) not-for-profit organization, Ecologic Institute in Washington, DC has been dedicated to improving environmental policy, sustainable development and policy practice. We strengthen the transatlantic and international dimensions in research, education and environmental policy discourse.

CCRI

CCRI is a research-driven company established in 2021 in Germany to provide data on sustainability aspects of cryptocurrencies, blockchain and other technologies. The interdisciplinary team has built a multi-year research track record with a specific focus on crypto-assets and their sustainability impacts. CCRI uses the most up-to-date data sources as well as methods based on formerly peer-reviewed studies published in renowned scientific journals. CCRI provides insights that help their clients, including asset managers, exchanges, and blockchain networks to understand, manage and disclose crypto-related environmental and climate impacts.

This report has been made possible by support from PayPal.

1. Introduction and Background

A crypto-asset is a digital representation of value or rights that can be transferred or stored electronically using distributed ledger technology or similar systems. These assets exist in various forms, including unbacked crypto-assets such as Bitcoin and asset-backed stablecoins (e.g., USD-backed tokens). Among these, Bitcoin is by far the most prominent example and has attracted significant attention due to the environmental implications of its underlying technology. Bitcoin operates on a proof-of-work (PoW) consensus mechanism, where so-called miners compete to solve complex computational puzzles (i.e., finding a valid cryptographic hash for a block) in order to validate transactions and add new blocks to the blockchain. This process ensures the integrity of the network but requires substantial computational power. To participate, miners rely on specialized hardware devices that consume large amounts of electricity. Depending on the energy mix used, this electricity consumption can result in significant greenhouse gas (GHG) emissions, thereby contributing to climate change. As a result, Bitcoin mining has become a focal point in discussions about the environmental sustainability of digital technologies.

1.1. Importance of Crypto-related GHG Emissions

Bitcoin mining, primarily conducted in data centers equipped with crypto-specific hardware, accounts for over 90% of total crypto-related GHG emissions. While more than 10,000 crypto-assets exist, their combined environmental footprint remains relatively small in comparison. As of March 2026, Bitcoin mining is estimated to generate approximately 64 million metric tonnes of carbon dioxide (MtCO₂) annually. Following Ethereum's transition from proof-of-work (PoW) to proof-of-stake (PoS) in 2022, Bitcoin has further solidified its position as the dominant emitter among blockchain networks. It currently produces roughly 22 times more emissions than the second-largest emitter, Dogecoin. Figure 1 illustrates the growth of Bitcoin's carbon footprint since its inception less than two decades ago, as well as its dominant share in total crypto-related emissions. Figure 1 also highlights Ethereum's emissions trajectory, which declined by more than 99.9% after its consensus mechanism change in 2022 (for details, please see [here](#)). This comparison underscores the significant effect technological design choices may have on environmental impacts.



Figure 1: Annualized CO₂ emissions of proof-of-work cryptocurrencies. Source: <https://indices.carbon-ratings.com/>

1.2. Research Gap: Limited Analysis of Mitigation Options

In response to growing concerns about crypto-related GHG emissions, efforts have been made to improve transparency and standardization in carbon accounting. In 2022, CCRI and South Pole, in consultation with PayPal's Blockchain, Crypto, and Digital Currencies (BCDC) team and other experts, introduced the Crypto Climate Impact Accounting Framework. This initiative marked the first coordinated effort to provide guidance for measuring and reporting emissions associated with crypto-assets and has since become the industry standard.

Today, various stakeholders, including crypto-asset issuers, investors, users, and service providers such as banks, exchanges, and asset managers, are increasingly exposed to crypto-related emissions. However, crypto networks differ fundamentally from other emission sources. They are decentralized, often anonymous, and continuously require energy input to maintain transaction validation and ownership records. This distinguishes them from activities that rely almost exclusively on centralized data center infrastructure, such as AI applications, and also from commodity mining, such as gold mining, where emissions primarily occur during the production phase.

Despite advances in measurement and reporting, there remains a significant gap in guidance on how to effectively mitigate crypto-related scope 3 emissions, particularly those arising from PoW mining. Given the limited direct control most stakeholders have over those emissions across the value chain, traditional mitigation approaches may not be directly applicable. In this context, market-based mechanisms, similar to those used for scope 2 emissions from purchased electricity, such as power purchase agreements (PPAs) or renewable energy certificates (RECs), may offer viable pathways for mitigation. However, these approaches have not yet been systematically assessed in the context of crypto-assets.

Addressing the foregoing knowledge gap, this report aims to identify and evaluate potential mitigation options for crypto-related GHG emissions and to develop practical guidance for stakeholders. By doing so, it seeks to support organizations in reducing their emissions footprint and progressing toward their corporate climate targets.

The remainder of this report is structured as follows: Section 2 provides background information on crypto-related carbon accounting. Section 3 introduces the analytical framework used to evaluate mitigation options. Section 4 presents and assesses these options, and Section 5 discusses the findings and outlines directions for future research.

2. Carbon Accounting as a Foundation

While the carbon footprint of blockchain networks, particularly Bitcoin, has been explored in numerous academic studies since around 2018¹, the question of how to allocate these network emissions to individual entities exposed to crypto-assets has long remained insufficiently addressed. This represented a critical gap, as investors, service providers, and

¹ Mora, C., Rollins, R. L., Taladay, K., Kantar, M. B., Chock, M. K., Shimada, M., & Franklin, E. C. (2018). Bitcoin emissions alone could push global warming above 2 C. *Nature Climate Change*, 8(11), 931-933.

Krause, M. J., & Tolaymat, T. (2018). Quantification of energy and carbon costs for mining cryptocurrencies. *Nature Sustainability*, 1(11), 711-718.

Stoll, C., Klačáň, L., & Gallersdörfer, U. (2019). The carbon footprint of bitcoin. *Joule*, 3(7), 1647-1661.

other stakeholders require robust methodologies to account for their share of emissions in line with corporate reporting standards.

In 2022, CCRI and South Pole, in consultation with PayPal's Blockchain, Crypto, and Digital Currencies (BCDC) team and other experts, introduced the Crypto Climate Impact Accounting Framework. This framework aims to allocate the emission burden in line with the actual drivers of emissions to align with the principles of the GHG Protocol, which is the most widely used standard to measure, manage, and report corporate GHG emissions. A key contribution of the framework is the introduction of a hybrid accounting approach that combines holding-based and transaction-based methodologies (see Figure 2). For proof-of-work (PoW) networks, emissions are allocated based on the dual incentive structure of mining: block rewards and transaction fees. The share of emissions associated with block rewards is allocated using a holding-based approach, reflecting the role of crypto-asset ownership. In parallel, emissions linked to transaction fees are allocated using a transaction-based approach, attributing emissions to transaction fees paid. As of today, block rewards remain the main source of miners' income. However, with each Bitcoin halving, the share of income from transaction fees increases (*ceteris paribus*; unless the Bitcoin price increases in the approximately four years between two halvings and/or a respective decrease in transaction fees overcompensate the effect). Therefore, transaction fees may play a more dominant role for miners' income in the long run – and will ultimately become miners' only income when the block reward reaches zero around 2140.

Emissions of crypto-asset networks are **attributed** to asset **holdings** and **transactions**, depending on the **respective incentivization factor** (i.e., share of the respective reward received by crypto miners through transaction fees vs. block rewards)

$$\text{User-specific footprint} = \text{Total network emissions} \times \left(f \frac{\text{Value held in crypto}}{\text{Total supply of cryptocurrency}} + (1-f) \frac{\text{Paid transaction fee}}{\text{Total network transaction fee}} \right)$$

Legend:
 Entity-specific data (blue) Network data (purple)
 f The factor f is the **share of the block reward** of the overall reward the miner receives. 1-f The factor (1-f) is the **share of the transaction fee** of the overall reward the miner receives

Notes:
 1) Overall reward = block reward + transaction fee = miners revenues ~ upper limit miners can spend on hardware and electricity
 2) The distinction of emissions associated with the validation of transaction vs. ensuring the integrity of the network is also reflected in the sustainability disclosure requirements provided in the Regulatory Technical Standard of the EU Markets in Crypto Assets (MiCA) Regulation

Figure 2: Overview of the hybrid allocation approach. For further details, please see: <https://www.southpole.com/publications/report-accounting-for-cryptocurrency-climate-impacts-publication>

For proof-of-stake (PoS) networks, where energy consumption is significantly lower and not directly tied to computational competition, the marginal electricity consumption of transactions can be used to determine the proportion of emissions attributable to transactions versus holdings. Importantly, the allocation between holding-based and transaction-based components is network-specific and evolves over time, reflecting changes in underlying drivers such as fee structures, protocol updates, and network activity.

Given their magnitude, crypto-related emissions are increasingly considered in carbon accounting standards. The Greenhouse Gas (GHG) Protocol, as one of the most important standards, is currently in the process of updating its Scope 3 standard, which provides guidance on accounting for indirect value chain emissions. Within this process, the Technical Working Group (TWG) is explicitly discussing the treatment of crypto-related emissions. Draft

guidance indicates that, for both fungible and non-fungible tokens, reporting companies should account not only for emissions associated with the creation (e.g., mining or validation) of tokens, but also for emissions related to the operation and cooling of the data infrastructure used to store, manage, or hold such assets. Furthermore, where companies own the underlying data infrastructure, these emissions are to be reported under Scope 1 and/or Scope 2, as applicable.²

As the TWG has not made a final decision on how to categorize crypto-related emissions going forward within the updated framework, we participated in the public consultation process and provided input to the GHG Protocol. As Section 1 shows, crypto-related GHG emissions have become significantly larger over the past decade – and various companies are exposed to those emissions along their value chains. Furthermore, there is plenty of academic research and first industry/regulatory guidance on how to account for crypto-related GHG emissions as described in this section. Therefore, we believe crypto-related GHG emissions should be categorized by stakeholders depending on their individual activities and exposure (i.e., asset owners may consider them as part of Category 15 – Investments; Service providers may classify them, e.g., in Category 1 – Purchased goods and services or Category 11 – Use of sold products, depending on their specific service offering) instead of putting all crypto-related emissions into Category 16 – Facilitated emissions, currently maintained as optional in many proposals.

These ongoing developments highlight both the increasing recognition of crypto-assets within established carbon accounting frameworks and the need for clear, practical guidance on how to consistently account for and ultimately mitigate these emissions.

3. Analytical Framework for Evaluating Mitigation Options

To systematically assess potential mitigation options for crypto-related GHG emissions, this report presents a multi-dimensional analytical framework. Given the complexity of crypto ecosystems – and the limited direct control that most stakeholders have over the emission sources – it is essential to evaluate mitigation measures not only based on their theoretical effectiveness, but also in terms of practical feasibility, accounting standards alignment, and broader strategic implications.

The framework presented in this report builds on six key dimensions, which together provide a comprehensive basis to compare available mitigation approaches:

Dimension 1: Mitigation Effect (Real-World Impact)

This dimension assesses the extent to which a given measure leads to actual, measurable emission reductions in the real economy. Particular attention is given to additionality, permanence, and the risk of double counting.

Dimension 2: GHG Protocol Conformity

This dimension evaluates whether a mitigation option is aligned with existing and emerging standards under the GHG Protocol, particularly with respect to Scope 2 and Scope 3 accounting. As corporate climate reporting increasingly relies on standardized methodologies, alignment with these frameworks is critical to ensure consistency, auditability, and regulatory acceptance. The GHG Protocol is the most widely used standard

² <https://ghgprotocol.org/scope-3-twg-subgroup-c-meeting-11>

to measure manage and report corporate GHG emissions. In 2023, over 95% of disclosing S&P 500 companies used the GHG Protocol.³

Dimension 3: Cost Effectiveness

This dimension examines the economic efficiency of mitigation options by comparing the tonne of CO₂ equivalent reduced or avoided per USD. It enables a relative assessment of how effectively financial resources are translated into climate impact, while acknowledging that cost-effectiveness may vary significantly depending on market conditions and project types.

Dimension 4: Ease of Implementation

This dimension captures the practical feasibility of adopting a given mitigation measure. It considers factors such as technical complexity, availability of required data, integration into existing processes, and organizational effort. Measures that are easier to implement may offer faster scalability potentially compensating for lower mitigation effect.

Dimension 5: Bitcoin/Crypto-specificity

This dimension evaluates the degree to which a mitigation option is tailored to the specific characteristics of crypto-assets and blockchain networks in order to link the mitigation effort and reduce the emissions at the source, rather than shifting mitigation to other sectors or activities while crypto-related emissions continue to rise unabated.

Dimension 6: Reputational Benefit and Credibility

Mitigation actions may also carry reputational implications. This dimension assesses how credible and transparent a given measure is perceived to be by stakeholders, including investors, regulators, and the public. High-quality, verifiable interventions may strengthen an organization's climate credentials, while less robust approaches pose a risk of greenwashing allegations.

Taken together, these six dimensions provide a structured and transparent basis for evaluating mitigation options in the context of crypto-related emissions. The framework is applied in Section 4 to assess potential measures, enabling a comparative analysis that supports informed decision-making for stakeholders across the crypto ecosystem.

4. Mitigation Options for Crypto-related GHG Emissions

4.1. Overview and Classification of Mitigation Options

Building on the analytical framework introduced in Section 3, this section provides an overview and classification of mitigation options for crypto-related GHG emissions. The identified options are based on a combination of desk research and insights gathered from nine stakeholder interviews, including crypto-asset service providers (CASPs), mining companies, academic experts, and non-profit organizations. Key insights from these stakeholder interviews can be found in Annex I. This mixed-method approach ensures both conceptual completeness and practical relevance.

³ <https://ghgprotocol.org/companies-and-organizations#:~:text=GHG%20Protocol%20standards%20and%20guidance,to%20CDP%20using%20GHG%20Protocol>

The identified mitigation options can be grouped into three overarching categories, reflecting different approaches to addressing crypto-related emissions. Each category comprises two distinct options, resulting in a total of six mitigation options considered in this analysis:

Type I: Rely on Crypto-specific Initiatives

The first category captures emerging, sector-specific solutions designed to address emissions within the crypto ecosystem itself.

- *A: Existing “green hashrate” / certificate option:* These initiatives aim to certify or label a mining activity based on the use of renewable energy sources (for an overview of crypto/Bitcoin specific initiatives, please see Annex II)
- *B: New “green hashrate” / certificate option:* This option reflects the development of new or enhanced certification schemes that seek to improve robustness, transparency, and credibility.

Type II: Apply Energy Attribute Certificates (EACs) to Scope 3 Emissions

The second category focuses on the use of market-based instruments that address the electricity mix associated with crypto-related activities, particularly mining.

- *A: Bitcoin time/location matching (attributional approach):* This approach seeks to match electricity consumption associated with Bitcoin mining to renewable energy generation based on temporal and geographic criteria.
- *B: Consequential approach:* Rather than focusing on attribution, this approach emphasizes the broader system-level impact of interventions, such as driving additional renewable energy capacity or influencing marginal generation.

Type III: Purchase Carbon Offsets

The third category includes traditional market-based mechanisms that aim to compensate for emissions by financing emission reduction or removal projects outside the crypto value chain.

- *A: Voluntary carbon market:* Organizations purchase carbon credits from voluntary markets to offset their crypto-related emissions.
- *B: Compliance carbon markets:* Organizations rely on regulated carbon markets to compensate for emissions in line with jurisdictional requirements.

This classification highlights the diversity of available mitigation approaches, ranging from established market-based instruments to novel, crypto-native solutions. While some options build on existing carbon accounting practices, others attempt to address the unique characteristics of decentralized blockchain networks more directly.

4.2. Evaluation of Mitigation Options

Based on the analytical framework introduced in Section 3, the identified mitigation options described above were evaluated across the six dimensions of mitigation effect, GHG Protocol conformity, cost effectiveness, implementation ease, crypto-specificity, and reputational benefit and credibility. The evaluation combines desk research with insights obtained from nine stakeholder interviews conducted with crypto-asset service providers (CASPs), mining companies, academic experts, and non-profit organizations during December 2025 and February 2026.

Type I: Rely on Crypto-specific Initiatives

The first category consists of crypto-specific initiatives that aim to address emissions directly within the blockchain ecosystem. These initiatives are typically based on “green hashrate” or certificate mechanisms that link mining activity powered by renewable energy with market-based claims.

Existing green hashrate initiatives generally certify miners that already operate with renewable electricity. As a result, their real-world mitigation effect is often limited, since the certificates typically represent existing low-carbon mining activity rather than triggering new emission reductions. While such mechanisms may improve transparency and allow market participants to signal support for renewable-powered mining, their environmental additionality remains uncertain, as it does not incentivize additional renewable energy deployment or changes in miner behavior.

New or enhanced green hashrate certificate mechanisms may address these shortcomings by creating stronger economic incentives for miners to switch to renewable energy sources. In theory, if the premium associated with such certificates is sufficiently high, it could trigger fuel switching or investment in additional renewable-powered mining operations. In this case, the mitigation effect could range from moderate to high. However, the cost effectiveness of such mechanisms remains uncertain and depends largely on the level of premium required to influence miners’ operational decisions.

Stakeholder interviews also highlighted several structural challenges associated with crypto-specific mechanisms. As blockchain networks are decentralized and lack a single accountable entity, engaging directly with miners or verifying energy sources can be difficult. Moreover, existing mechanisms currently lack standardized methodologies, independent oversight, or broad acceptance under established carbon accounting frameworks. As a result, their conformity with the GHG Protocol and their reputational credibility remain uncertain.

Type II: Apply Energy Attribute Certificates (EACs) to Scope 3 Emissions

A second category of mitigation options involves the application of Energy Attribute Certificates (EACs) to crypto-related Scope 3 emissions. Two conceptual approaches can be distinguished: an attributional approach based on time and location matching, and a consequential approach focusing on system-wide impacts.

The attributional approach seeks to match electricity consumption with renewable electricity generation in the same geographic region and time period. This approach has become a common best practice used by data center operators and users as it proves to be more effective than annually matched clean power procurements.⁴ Major technology companies, for instance AWS, Alphabet and Microsoft, already use this approach to mitigate their Scope 2 emissions. Others such as Meta have started to use the approach also to reduce Scope 3 emissions associated with fuel- and energy-related activities in data centers owned and operated by third parties. For further information regarding current industry practices, please see Annex III.

In the case of Bitcoin, such an attributional approach would involve the purchase of EACs from regions where mining activity is concentrated. It is noteworthy that Bitcoin miners seek locations with low electricity prices, which often correlates with a high share of renewable energy sources. Stakeholder feedback indicates that EACs in such regions (e.g. ERCOT / Texas) often originate from electricity markets with an already high supply of renewable generation, and the effect from purchasing respective certificates to drive additional

⁴ Xu, Q., Ricks, W., Manocha, A., Patankar, N., & Jenkins, J. D. (2024). System-level impacts of voluntary carbon-free electricity procurement strategies. *Joule*, 8(2), 374-400.

renewable energy deployment might be limited. The real-world mitigation impact of this approach, therefore, may be rather low or moderate. From a cost perspective, EAC prices in these regions are typically relatively low, often in the range of USD 1–10 per MWh, corresponding roughly to USD 2–20 per tonne of CO₂.⁵

The consequential approach instead focuses on influencing broader energy system outcomes. For example, companies may procure premium EACs linked to newly built renewable capacity or support renewable energy investments that would otherwise not have occurred. While this approach does not necessarily lead to immediate emission reductions, it may contribute to additional renewable energy capacity deployment, and therefore, yield a moderate real-world mitigation effect over time. Importantly, this approach is currently being discussed as part of the ongoing update of the GHG Protocol and may align with a “multi-statement” reporting approach where consequential impacts are reported separately from the GHG inventory.

Overall, EAC-based approaches were considered by stakeholder interview participants to be among the most practical mitigation options, as they built on established accounting practices for electricity-related emissions. Their effectiveness, however, strongly depends on the design of the procurement strategy, and the degree to which additional renewable generation is actually supported.

Type III: Purchase Carbon Offsets

Purchasing carbon offsets represents the most established mitigation approach across industries to address supply chain emissions beyond companies’ direct control, and can therefore also be considered as a potential option for addressing crypto-related emissions. Two variants are distinguished: the use of credits from voluntary carbon markets and participation in compliance carbon markets where applicable.

Voluntary carbon markets provide access to a wide range of carbon credits, including both carbon avoidance credits and carbon removal credits. Avoidance credits represent emissions that are assumed not to occur relative to a baseline scenario, typically resulting in lower real-world mitigation impact due to concerns around additionality and baseline assumptions. In contrast, carbon removal credits, such as those generated by direct air capture or nature-based sequestration, physically remove CO₂ from the atmosphere, and therefore generally provide a higher real-world mitigation effect. Prices in voluntary markets vary widely, ranging from below USD 5 per tonne of CO₂ for generic avoidance credits to more than USD 100 per tonne of CO₂ for technology-based removal credits.⁶

Compliance carbon markets, such as the EU Emissions Trading System (EU ETS) or the Regional Greenhouse Gas Initiative (RGGI), operate under legally enforced emission caps, and therefore ensure emission reductions within a regulated jurisdiction. Many compliance systems allow entities other than the directly regulated emitters to open registry accounts and purchase, hold, and cancel allowances or credits. Typical price levels currently range from approximately EUR 60–100 per tonne of CO₂ in the EU ETS and around USD 20–30 per tonne of CO₂ in the RGGI system.⁷ While these markets generally provide higher credibility due to regulatory oversight and the finite, capped unit supply, their applicability for

⁵ National Renewable Energy Laboratory (NREL) (2023/2024): U.S. Voluntary Renewable Energy Certificate (REC) Market Report

⁶ <https://www.ecosystemmarketplace.com/publications/2025-state-of-the-voluntary-carbon-market-sovcm/>

⁷ <https://tradingeconomics.com/commodity/carbon> and <https://www.rggi.org/auctions/auction-results/prices-volumes>

mitigating crypto-related emissions may be limited by geographic scope and regulatory constraints.

Stakeholder interviews highlighted that carbon offsets are currently less commonly used to address electricity-related emissions compared with instruments such as Energy Attribute Certificates (EACs). Moreover, the credibility of offset projects varies significantly, which has led to increasing scrutiny in recent years, especially in the voluntary carbon market⁸. Another limitation is that offset-based mitigation is typically reported separately from the corporate GHG inventory rather than directly reducing reported Scope 1, 2, or 3 emissions. As a result, while carbon offsets may represent a feasible mitigation option, their use in the context of crypto-related emissions raises questions regarding environmental integrity and reputational credibility.

4.3. Stakeholder Workshop Validation

To validate and refine the analytical framework, an expert stakeholder roundtable was conducted in June 2026. The roundtable comprised seven external experts: three from academia, and one each representing the crypto industry, data provision, a non-profit organization, and payment infrastructure. Of these, two experts are part of one of the Greenhouse Gas Protocol Technical Working Groups that are involved in updating the current standards. Given that certain assessment categories are inherently more complex to evaluate via desk research alone, the consultation focused explicitly on four key dimensions: mitigation impact, GHG Protocol conformity, implementation ease, and reputational benefit/credibility.

Evaluation Across the Four Dimensions

The expert panel evaluated and sorted the six mitigation options within the selected dimensions, with participants explicitly tasked with sorting the options from best to worst based on their performance against each specific criterion. This exercise yielded several key insights:

- **Mitigation Impact:** The compliance carbon market was ranked as having the highest real-world mitigation impact, closely followed by the consequential approach. Conversely, existing "green hashrate" / certificate options were perceived as having the lowest capacity to alter real-world emissions. During the discussion, participants noted that the mitigation effect of relying on the voluntary carbon market may vary significantly, depending on whether the underlying credits are based on permanent removals or traditional avoidance mechanisms.
- **GHG Protocol Conformity:** Market-based tracking mechanisms scored highest in terms of standard alignment, with the consequential approach and the attributional approach (Bitcoin time/location matching) taking the top two spots. Existing crypto-specific certificate initiatives were ranked lowest, underscoring their current lack of integration into standardized corporate accounting frameworks.
- **Ease of Implementation:** A clear, inverse relationship was observed between strict accounting standards and operational simplicity. The voluntary and compliance carbon market options were ranked as the easiest to implement due to their

⁸ Probst, B. S., Toetzke, M., Kontoleon, A., Díaz Anadón, L., Minx, J. C., Haya, B. K., ... & Hoffmann, V. H. (2024). Systematic assessment of the achieved emission reductions of carbon crediting projects. *Nature communications*, 15(1), 9562.

established infrastructure. On the other hand, a new "green hashrate" system and time/location matching were deemed the most resource-intensive and difficult to execute.

- **Reputational Benefit and Credibility:** Regulated instruments commanded the highest institutional trust. The compliance carbon market was ranked highest for credibility, followed by the consequential approach. Existing green hashrate certificates were viewed as offering the lowest reputational benefit, indicating caution among experts regarding non-standardized green claims in the crypto sector.

Consensus and Strategic Alignment

The roundtable also assessed the level of expert consensus on guiding principles for crypto-related carbon mitigation. To gauge this alignment, participants were presented with key statements and asked to indicate their level of agreement or disagreement on a structured scale. Three major strategic takeaways emerged from these statements:

1. **Prioritizing Real-World Impact:** There was unanimous agreement among the participants that the real-world mitigation effect should always remain the top priority of any selected measure. This strongly supports the report's emphasis on balancing practical operational feasibility with the capacity to drive long-term, system-wide improvements.
2. **Adherence to Global Standards:** The panel expressed a unified consensus that common guidelines and global best practices should be followed. This highlights the industry's need for verified, auditable frameworks rather than fragmented, siloed mitigation attempts.
3. **Nuance Regarding Crypto-Specificity:** When presented with the statement that Bitcoin-related emissions should be addressed with Bitcoin-specific measures, opinions were noticeably split. While a portion of the panel agreed, the majority disagreed, signaling that stakeholders value real-world mitigation effects and established, cross-industry environmental instruments (such as compliance markets and robust EAC frameworks) over forcing native, crypto-only solutions that may lack broader institutional credibility.

4.4. Takeaways

The evaluation highlights important trade-offs between the different mitigation approaches. Crypto-specific initiatives may provide the most targeted solutions for the sector but currently face the greatest uncertainty regarding standards, governance, and credibility. It is noteworthy that future crypto-specific initiatives may overcome some of these shortcomings. EAC-based approaches are comparatively easy to implement and align more closely with established GHG accounting standards, although their real-world mitigation effect strongly depends on market design and additionality. Carbon offsets offer a relatively straightforward mitigation pathway with potentially high climate impact, particularly in the case of carbon removal, but face credibility challenges and limited integration with GHG accounting standards.

These findings illustrate that no single mitigation option fully satisfies all evaluation criteria. Instead, stakeholders may need to consider a portfolio of approaches depending on their strategic objectives, reporting requirements, and risk tolerance, an observation that is also in

line with recent research on clean electricity claims.⁹ This structural trade-off was explicitly validated during our expert stakeholder roundtable. The consultation highlighted an inverse relationship between institutional credibility and ease of implementation: while well-established market mechanisms like compliance and voluntary carbon markets are seen as highly actionable and operationally straightforward, their direct integration into standard GHG accounting for crypto remains complex. Conversely, advanced tracking mechanisms like the consequential approach are highly valued for their protocol conformity and real-world impact potential but present technical hurdles to deploy. Furthermore, experts stressed that the voluntary carbon market cannot be viewed monolithically, noting that its ultimate mitigation impact varies dramatically depending on whether an organization selects traditional avoidance credits or permanent carbon removal options. The comparative framework developed in this report provides a structured basis for navigating these trade-offs and identifying mitigation strategies that balance environmental impact, practical feasibility, and credibility. Figure 3 summarizes the comparative assessment across the six dimensions, while the following discussion highlights the main findings and trade-offs.

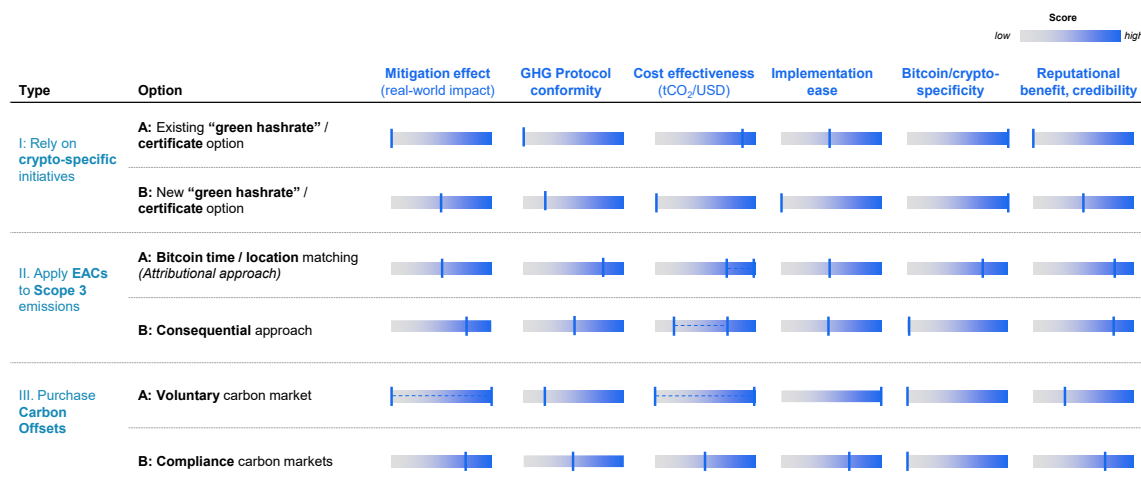


Figure 3: Overview of the evaluation of mitigation options across the six identified dimensions.

5. Discussion and Conclusion

This report sets out to address a key gap in the current discourse on crypto-related greenhouse gas (GHG) emissions: while measurement and accounting methodologies have significantly advanced in recent years, guidance on how to effectively mitigate these emissions remains limited. By introducing a structured analytical framework and applying it to a set of identified mitigation options, this report provides a first comparative assessment to support decision-making for stakeholders exposed to crypto-assets.

The analysis highlights that mitigation of crypto-related emissions is inherently challenging due to the decentralized, global, and continuously operating nature of blockchain networks, particularly those based on proof-of-work (PoW). Unlike traditional emission sources, where companies often have direct operational control or clear supplier relationships, crypto-related emissions are largely outside the direct influence of most stakeholders. This structural

⁹ Gagnon., P & Brown, M. (2026). Impacts from procuring clean electricity claims under different inventory accounting methods. *Joule*, 10(5)

characteristic fundamentally constrains the applicability of conventional mitigation strategies and necessitates alternative, often market-based approaches.

The imperative for alternative, market-based mechanisms is further reinforced by the strategic consensus reached during our expert workshop. The roundtable participants established a clear hierarchy of priorities for organizations navigating this space, unanimously agreeing that actual, real-world mitigation effect must always serve as the guiding north star for any corporate measure, and that actions should follow common guidelines and global best practices rather than isolated methodologies. Crucially, the panel challenged the notion that decentralized blockchain networks require isolated, native solutions; the prevailing sentiment indicated that Bitcoin-related emissions do not inherently require Bitcoin-specific mitigation instruments. Instead, leveraging mature, cross-industry environmental frameworks—provided they demonstrate environmental additionality and alignment with emerging standards—is viewed as a more credible path forward for institutional stakeholders than attempting to build siloed, crypto-native solutions from scratch.

Across the evaluated options, clear trade-offs emerge. Carbon offsets, particularly high-quality removal credits, can deliver meaningful real-world emission reductions but face scrutiny regarding credibility and limited integration into GHG inventories. Energy Attribute Certificate (EAC)-based approaches are better aligned with established carbon accounting practices and already used by corporate stakeholders. Their effectiveness, however, depends on whether they drive deployment of additional renewable energy capacity rather than merely reallocating existing supply, making the distinction between attributional and consequential accounting approaches increasingly important. Lastly, crypto-specific initiatives offer a more targeted but still emerging solution. While they have the potential to directly address emissions within the crypto ecosystem, current approaches often lack standardization, transparency, and broad acceptance, limiting their credibility and impact.

A key overarching finding is that no single mitigation option simultaneously maximizes real-world impact, cost effectiveness, ease of implementation, and credibility. As a result, stakeholders may consider adopting a portfolio approach, combining different mitigation instruments depending on their objectives, such as achieving near-term reporting compliance, driving long-term decarbonization, or managing reputational risks.

While this multi-stage assessment, which synthesizes desk research, stakeholder interviews, and expert validation, provides a robust foundation, several caveats apply. First, the findings represent a qualitative snapshot of an exceptionally fast-moving landscape; the maturity, costs, and availability of the identified mitigation options will inevitably evolve. Second, the evaluation is bounded by the ongoing revision of global carbon accounting standards, such as the GHG Protocol, which will ultimately dictate the formal compliance of these instruments. Consequently, future research should move from qualitative frameworks to empirical testing. Priority areas include quantifying the actual administrative costs of advanced tracking mechanisms, verifying the real-world grid additionality of emerging "green hashrate" models, and developing standardized accounting templates that bridge the gap between blockchain specifics and corporate climate reporting.

The evolving regulatory and standard-setting landscape will play a decisive role in shaping the future of crypto-related GHG emissions mitigation. In particular, the ongoing revision of the GHG Protocol, including discussions on the treatment of crypto-assets and the potential expansion of Scope 2 principles to Scope 3 emissions, may significantly influence which mitigation approaches are considered acceptable for reporting and claims. Greater clarity in this area will be essential to reduce uncertainty and enable consistent application across market participants.

Contact and Disclaimer

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Annex

Annex I: Key learnings from eleven stakeholder interviews across CASPs, miner and non-profit organizations (conducted between December 2025 and February 2026 in sessions of each 30-60 minutes)

Cluster	Key Insights
State of Crypto Carbon Accounting & Treatment in GHG Protocol	- No clear, crypto-specific guidance currently exists; reliance on general GHG Protocol principles - Ongoing debate on categorization with Scope 3 (e.g., investments vs. purchased goods vs. other categories) - Expectation that future GHG Protocol guidance will remain relatively high-level and flexible - Increasing discussion of extending Scope 2 concepts (e.g., EACs, matching) to Scope 3 - Emerging interest in multi-statement reporting (inventory vs. market-based vs. consequential impacts) - Strong view that crypto should be treated consistently with other sectors rather than as a special case
<u>Mitigation Option Type I: Crypto-Specific Initiatives</u> (e.g., Green Hashrate / Certificates)	- Emerging category with strong interest but limited maturity - Current solutions often rely on self-reported data and limited verification - Risk of low credibility without robust standards, registries, and governance - Potential to directly influence miner behavior if economic incentives are sufficient - Key challenge: ensuring additionality and avoiding double counting - Concepts from other sectors (e.g., SAF registries, buyer alliances) seen as transferable - Success depends on scaling participation (miners and buyers) and establishing trust - Viewed as promising but currently characterized by high uncertainty and early-stage development
<u>Evaluation Option Type II: Application of EACs to Scope 3 Emissions</u>	- Most widely accepted and practical approach among stakeholders - Builds on established Scope 2 accounting practices - Key challenge: additionality — unbundled EACs often do not drive new renewable capacity - Higher-integrity solutions (e.g., long-term contracts, premium EACs) seen as more credible - Strong interest in time- and location-based matching (e.g., hourly matching) - Ongoing debate between attributional and consequential approaches: (Attributional: easier to implement and widely used; Consequential: higher potential real-world impact but harder to measure and standardize) - Data availability and traceability remain major constraints
<u>Evaluation Option Type III: Purchase of Carbon Offsets</u>	- Less commonly used for electricity-related emissions compared to EACs - Wide variation in quality and credibility of offsets - Carbon removal credits viewed more favorably than avoidance credits - Compliance markets seen as more credible but limited in applicability - Offsets typically treated outside of the core GHG inventory (separate reporting) - Concerns about reputational risks and scrutiny (e.g., additionality, transparency) - Considered a feasible but generally less preferred mitigation option

Annex II: Overview of crypto/Bitcoin-specific initiatives

Type	Initiative	Entity	Approach	Critics	Publicly known users
Green Pool + Custody/ Wallet	Terra Pool / Systemic Trust	DMG	- Carbon neutral pool to receive carbon neutral bitcoin - BTC can be held and moved in a carbon neutral manner via Systemic Trust	- No details / no independent third-party review to underpin carbon-neutrality claims - Integration Terra Pool ↔ Systemic Trust unclear	• N/A
Green Pool	GreenHash Initiative	GlobePool	Committed to 100% renewable energy by 2030	Pledge only / no progress report	• N/A
	PEGA Pool	PEGA Mining	Claim to be “green” mining pool	No transparency about how “green” the pool is	• N/A
Certificate/ Token	Sustainable Bitcoin Certificates	Sustainable Bitcoin Protocol	- Miners receive Sustainable Bitcoin Certificates (SBC) - SBCs represent bitcoin mined with verifiable clean energy	- Definition of “clean” depends on accounting for RECs / EACs - Market liquidity for SBCs may be limited	- Miners (e.g. CleanSpark) - Investors / buyers (e.g. Melanion Capital)
	Clean Incentive	Clean Incentive	“Collect, validate and tokenize ESG attributes from a network of miners” (2023)	Status of initiative unclear	• N/A
	GMT-Token	Green Mining DAO	Primary offering is co-ownership of hydro-powered mining facilities	No independent third-party certification	• N/A
Rating	Green Proofs for Bitcoin	Energy Web Foundation	- GP4BTC certification platform using two scores: Clean Energy Score and Grid Impact Score - Based on miners’ energy use, location, and demand-response participation	- Auditability of data and unclear if scores capture true additionality - Certification of miners only	- Mining companies / hosting providers (e.g. Argo, Gryphon, Hive, DMG) - Institutions / financial services “may use” the registry
	Green Hashrate Initiative	DaoMine	- Aims to certify / label hashrate from miners who achieve a target (e.g., 75%) of renewable energy usage - Plan for a “green hashrate certification framework”	Self-reported / self-governed initiative	• N/A
Proposal	Green Miner Initiative	PayPal & Energy Web	Proposed incentive system for encouraging sustainable Bitcoin mining	• -	• -
	Change the Code	Greenpeace	Suggested changing the Bitcoin protocol	Not much support from Bitcoin stakeholders	• -
Others	-	BlockFills ↔ Isla Verde	BlockFills sells carbon offsets and RECs to crypto miners	• -	• N/A

Annex III: Best practice examples of tech companies applying EACs

Data center operators/users	Climate targets	Approach towards electricity consumption
Amazon / AWS 	- Net-zero carbon emissions across operations by 2040 100% of electricity consumed matched with renewable energy since 2023	- Aim to procure renewable electricity primarily in the same grids where the electricity is consumed - Market-based approach to account for carbon-free energy procurement through Renewable Energy Certificates (RECs) and Power Purchase Agreements (PPAs)
Alphabet / Google Cloud 	- Net-zero carbon emissions across operations by 2030 100% of electricity consumed matched with renewable energy since 2017 - Vision of 24/7 carbon-free energy by 2030, with power produced on same grid	- Usage of clean energy generation, energy storage, smarter computing loads, and advanced market instruments like time-based energy attribute certificates (T-EACs)¹ - In 2024, first company to receive bundled T-EACs issued directly by an EAC-issuing body in Europe, tested the purchase of unbundled T-EACs
Microsoft / Azure² 	- Carbon negative by 2030; Remove historical emissions by 2050 - Commitment to source 100% renewable energy for its data centers by 2025 - Vision of 24/7 carbon-free energy by 2030	- Procures renewable energy from on-site generation, unbundled EACs, PPAs, and green power products. - Purchased EACs include renewable energy certificates (RECs) (Green-e certified), guarantees of origin (GOs), renewable energy GOs (REGOs), International RECs (I-RECs), Tradable Instruments for Global Renewables (TIGRs), New Zealand Energy Certificate System (NZECS) certificates, J-Credits, Non-Fossil Fuel Certificates (NFCs), large-scale generation certificates (LGC), Green Electricity Certificates (GECs), Taiwan Renewable Energy Certificates (T-RECs), and PowerPlus.
Meta³ 	- Net-zero carbon emissions across value chain by 2030 100% of electricity consumed matched with renewable energy since 2020 - Vision of 24/7 carbon-free energy by 2030	- Apply Energy Attribute Certificates (EACs) to Scope 3 emissions to reduce emissions such as those associated with fuel- and energy-related activities - Examined different carbon accounting methodologies: 1) Annual Matching (current GHGP methodology), 2) Hourly Matching (24/7 CFE methodology), and 3) Carbon Matching (emissions matching methodology) → Suggests need for GHGP (and other carbon accounting frameworks) to adopt more accurate carbon accounting methodologies such as Carbon Matching that more accurately reflect real-world emissions impact

1) T-EACs come bundled with Google's PPAs. Many of these instruments are certified by Flexidao and can be traded to allow for hourly matching by others. 2) Second source. 3) Case study: carbon accounting approaches; 2025 Sustainability Report