Bitcoin Policy Institute

RFI Response: Climate Implications of Digital Assets

The Bitcoin Policy Institute is a non-partisan, non-profit research center working to study the policy and societal implications of bitcoin. We are pleased to submit the following document in response to the Request for Information on the Energy and Climate Implications of Digital Assets posted by the Office of Science and Technology Policy. (Document Number: 2022-06284.) The RFI expresses concern about the explosive growth of digital assets and their associated energy use and related emissions, given President Biden's commitment to cut greenhouse gas pollution by 50-52% by 2030 and achieve net-zero emissions by 2050. The RFI "seeks public input to better understand the climate impacts of digital assets" and lists a number of topics for commentators to address.

We welcome the opportunity to share our research and our perspective. Our comments address the following listed topics, and with respect to bitcoin only: *protocols*, *hardware*, *resources*, *economics*, *past or ongoing mitigation attempts*, and *potential energy or climate benefits*. We believe bitcoin, particularly on issues of energy and the environment, is poorly understood. Far from an obstacle to decarbonization, bitcoin could be instrumental in helping us accelerate renewable energy production and stabilize our new, greener grid.

In particular, we argue the following:

- Bitcoin's value—its economic value and promotion of American values and American national interests—must frame any discussion of its environmental impact.
- Bitcoin's value is inherently tied to its consensus mechanism: proof of work.
- While bitcoin mining is energy-intensive, its energy use is often overestimated and improperly characterized as a function of transaction volume.
- Due to bitcoin's exponentially decreasing schedule of issuance, mining's actual emissions are likely to peak at under 1% of global emissions, even if prices rise more than tenfold within the decade.
- Mining's profile as a consumer of energy is unique: extremely cost-sensitive, and invariant across times and locations.
- Bitcoin mining, as a buyer of first and last resort, incentivizes the buildout of renewable power production. As a controllable load resource (CLR) bitcoin mining also strengthens the grid, allowing it to reliably function at a high level of renewable penetration.
- Mining's energy use is increasingly non-rival, trending towards a diet of renewables and stranded, wasted energy resources such as flared methane.

Bitcoin and the Energy Transition

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Introduction

A complex technology like bitcoin raises a series of questions for policy makers, all of which must be considered before reaching an overall judgment, and certainly before taking action. In this report, we focus on a subset of these questions: the nature and importance of bitcoin's value, the role of proof of work in creating that value, and on bitcoin's unique profile as a consumer of energy, which dictate its likely future trajectory. Our conclusion is cautiously optimistic: *bitcoin could prove instrumental in accelerating renewable energy production, stabilizing our new, greener grid, and curbing methane emissions*.

What is Bitcoin's Value?

Price on the open market provides the most straightforward measure of bitcoin's worth. Bitcoin's market capitalization—price multiplied by total supply—is currently over $600 billion, lying between that of Berkshire Hathaway and Facebook (Meta). Market value cannot be ignored when weighing environmental impacts, in part because every industrial activity carries environmental costs, and in part because this same capital would find its way into other areas of the economy with their own impacts. The relevant question is not whether bitcoin has *any* negative environmental impacts, but rather, how bitcoin's environmental profile stacks up against its value, and how it compares to other investments.

In fact, researchers have found that "Bitcoin's carbon emissions are low compared to its market value, implying that Bitcoin is characterized by a lower carbon intensity than the average asset in the [typical equities] portfolio." Bitcoin mostly stores value, with a relatively small, but energy-intensive security budget. By contrast, airlines, energy companies, fast fashion companies, and cement producers put much of their value into carbon-producing activities.

But there are more ways of thinking about value than the point where supply meets demand. As a society, we champion inclusion, equality, transparency, property rights, and freedom. Bitcoin, in its own way, embodies and extends each of these:

- The bitcoin protocol is free, open-source software. Every line is inspectable by anyone.
- The bitcoin ledger is public and fully audited by tens of thousands of nodes worldwide.
- The bitcoin network is permissionless and censorship-resistant: it refuses no one and obliges any parties' wishes to transact.
- The bitcoin asset is issued not to insiders, but via regular mathematical contests open to all.
- The bitcoin network's rules are predictable and non-discretionary.
- The bitcoin public key infrastructure provides digital property rights via the ability to self-custody and transfer value.

In practice, bitcoin allows anyone in the world with a cell phone and an internet connection—including some 1.7 billion who are unbanked—to easily save in a digital asset with a fixed supply and to exchange value without a centralized counterparty or censor. Bitcoin is currently held by over 100 million users, disproportionately residing in countries with high inflation, weak respect for property rights, and poor governance on a per-capita basis.

Domestically, bitcoin and cryptocurrencies are more prevalent among communities that have been historically marginalized by the existing financial system: some 23% of Black Americans along with 16% of Hispanic Americans own cryptocurrencies, as compared to only 11% of white Americans. Bitcoin's inherent inclusivity, robust property rights, and transactional freedom are reflected in its pattern of adoption.

Beyond these societal ideals, bitcoin is also in the national interest. U.S. national security rests in part on domestic technology innovation and appreciation in our equity markets, where bitcoin gives us a clear advantage. China's June 2021 ban on bitcoin mining shifted the global distribution of "hashrate," a measurement of the computational effort put towards collecting and securing transactions. Though specific estimates are tricky, the United States now has a plurality of global hashpower. China views bitcoin as a threat to its authoritarian system and strict capital controls, accelerating rollout of its Digital Currency Electronic Payment (DCEP) instead. At the same time, China has slowed purchases of U.S. Treasury securities, redeploying their dollar reserves into western real estate and equity markets, giving them financial power to exert political influence over US corporations.

Bitcoin severely complicates China's CBDC ambitions, presenting an attractive store of wealth and effective cross-border payment system to those BRI nations that China seeks to entangle with the e-RMB. Meanwhile, global demand for bitcoin and dollar-pegged stablecoins has exploded, especially by citizens of emerging markets facing currency distress. As the industry becomes increasingly regulated and transparent, the combination of bitcoin and stablecoins can serve as an effective tool to support the dominance of the dollar at the digital front line competing against China's eRMB. The growth of these stablecoins promises to bolster demand for U.S. Treasuries, helping the Federal Reserve keep interest rates low in the face of inflation. In this way, bitcoin can serve a neutral reserve asset that helps reinforce, not undermine, the dollar system.

Why Proof of Work?

We have argued that any examination of bitcoin's environmental impact must begin with an understanding of its value. But critics argue that it would retain the same value even if it were somehow to abandon its energy-intensive consensus mechanism known as "proof of work." We disagree. Bitcoin's value is inextricably tied to proof of work. While some consensus mechanisms for distributed ledgers are less energy-intensive, they come with critical tradeoffs in fairness and security.

In Proof of Work, the right to publish a new block is awarded by lottery and you can increase your chances of having a winning "ticket" by using more energy to find one. Proof of Stake systems award this right to individuals in proportion to how much of the native asset they have already "staked". The more you stake, the more of the native asset you earn for staking. Wealth compounds, as does the power to control which transactions appear in the ledger. So whereas the amount of bitcoin one owns provides no direct influence over the network, Proof of Stake systems afford wealthier holders greater control. That compromises bitcoin's values of equality and inclusion.

Proof of work is also, arguably, more secure. To disrupt bitcoin, a malicious actor would have to control a substantial proportion of the network's total computational power. And even if most miners went offline, the network would continue to run. By comparison, a typical Proof of Stake network stops if more than 33% of validators go offline. This makes PoS systems more vulnerable to both attacks and internet disruptions. For example, when China banned bitcoin mining, the network kept running despite losing more than half of its computational power. But some of the biggest Proof of Stake networks have already suffered extended outages, like Polygon (March 2022) and Solana (six outages in January 2022 alone).

What are the negative environmental effects of bitcoin mining?

Bitcoin mining uses energy, some of which comes from fossil-fuel-burning power plants. Emissions from those plants, including greenhouse gasses and other air pollutants, are a negative externality associated with bitcoin, just as they are associated with every user of electricity. Additionally, the specialized machines used for mining create their own environmental impact as e-waste if they are not properly recycled.

Some of these environmental effects due to bitcoin mining are undeniable. In the wake of China banning bitcoin mining, many miners moved to Kazakhstan where they used cheap electricity generated from burning coal. (Kazahkstan has since intervened to prevent disruption of their power markets.) A nearly-shuttered coal plant in Hardin, Montana ramped up production to meet the demands of a bitcoin miner. (Recently, that miner announced they would exit the plant by year's end.) Similar stories are to be found in Kentucky where state-subsidized coal plants are now mining bitcoin.

Such anecdotes pair with viral media stories to create vivid images of world-ending destruction. One such story alleges that bitcoin uses two months' worth of household electrical power per transaction. Another claims that a single bitcoin transaction creates two iPhones worth of e-waste. An often-cited 2018 study suggests that bitcoin alone, apart from all other human activities, threatens to raise global temperatures by over two degrees within three decades. Though it has been thoroughly debunked within the academic community, the study continues to make the rounds in activist anti-bitcoin campaigns. No longer touted, but never corrected or clarified, is an infamous prediction by the World Economic Forum and by *Newsweek* in December 2017 that by 2020, bitcoin would consume all of the world's energy.

In our view, the terrifying visions arising from such stories bear no resemblance to reality. E-waste due to bitcoin mining, even given the most pessimistic estimate (30.7 metric kilotons) is only 0.07% of all e-waste (41.8 million metric tons), but actually, is far less (see point 7). While confidence intervals are large and sources disagree significantly, bitcoin's current estimated energy use is 0.23% of global energy according to the Cambridge Centre for Alternative Finance. Bitcoin mining is increasingly renewable. The Bitcoin Mining Council collects direct data from miners responsible for more than 50% of all hashrate, and reports a 64.6% sustainable power mix, estimating a 58.4% industry-wide sustainable power mix. Because of this greener mix of power, according to a recent report, bitcoin mining is responsible for a mere 0.08% of global carbon emissions. And according to another recent projection, bitcoin's global emissions are likely to peak at under 1%, by the end of the decade, declining thereafter, even if bitcoin's market capitalization manages to grow more than ten-fold in the period.

Further, the attempts to characterize energy use, emissions, or e-waste "per transaction" betrays a basic misunderstanding of how mining works (see 5). Bitcoin's base layer processes very few transactions, but each of these transactions can settle thousands of batched payments made on highly-efficient second-layer payment networks like the Lightning Network. In this way, bitcoin can scale in transaction volume without a meaningful difference in energy use, emissions, or e-waste.

All of the projections of bitcoin's future energy use and emissions must be qualified, of course. Because of bitcoin's ever-falling issuance schedule, the *rate* of bitcoin's price appreciation matters. Were bitcoin to reach $490,000 not in 2030, but in 2022, miners would find themselves sitting on a much more valuable block subsidy right now. In 2030, given that issuance will have halved twice, that block reward would not be as large an increase in dollar terms, and it is this latter scenario envisioned by the model on which mining achieves less than 1% of global carbon emissions. The impact of such unlikely near-term price spikes would be blunted by ASIC availability and electrical infrastructure availability, but still those effects need to be modeled and studied just the same.

Rather than review this literature in further detail, we would like to turn to some fundamental features of the protocol and the dynamics of the energy market that make us cautiously optimistic about bitcoin's role in incentivizing a transition to sustainable energy.

Environmental Benefits of Bitcoin Mining

Bitcoin has a unique energy demand profile. Its miners are:

- Portable and can operate in a wide range of geographies and climates even without a grid connection (helping bootstrap renewables and supporting infrastructure build-out),
- Exceptionally price sensitive as part of a global, zero-sum market (every miner anywhere is in direct competition with every other for the fixed block issuance);
- Deployable at scale (from solo home mining to gigawatt industrial operations);
- Interruptible and flexible, able to attenuate power demand with sub-second responsiveness (helping keep grids stable).

Because older and newer machines have different profitability profiles, bitcoin mining is especially well-suited to filling key niches in the energy system and developing symbiotically with renewable producers. Mining, in very non-obvious ways, may prove to be a powerful tool aiding the shift towards an energy system based on renewable sources. Additionally, it provides a profit-driven mechanism for waste methane recovery, and, as prices stabilize, at least some portion of bitcoin miners may replace large heating elements, increasing hashrate with little to no effect on emissions or electricity usage.

Renewable Energy and the Grid

We identify three major problems in the transition from a carbon-based power grid to a renewable-based power grid: *investment risk* for renewable energy producers; unique *challenges of an inverter-based grid*; and *curtailment and negative pricing*, which subdivides into problems of *transmission constraints* and *reducing excess supply* on the grid.

Investment Risk

The International Renewable Energy Agency (IRENA) reports that private finance is expected to provide much of the needed investment for the renewable energy transition to succeed. However, they identify a number of risks that are preventing large scale investment. They note that "[s]uch risks include political, regulatory, counterparty, currency and liquidity risk, as well as grid interconnection and transmission-line delay risk". While bitcoin mining may not solve all of these issues, we believe that it can address some of them.

Berkeley Lab's report on interconnection queues showed that wait times to be connected to the grid are getting longer and the percentage of proposed projects converting to grid connection is also decreasing. Additional risk is highlighted in Bastian-Pinto et al. (2020), which examined wind-power developments in Brazil where investment risks are tied to variability in spot prices in the energy market. As a hedge against electricity price volatility and in order to incentivize early investment in a renewable power plant, they suggest an investment model that includes a Bitcoin mining data center.

Additionally, the Berkeley Lab study found that US commercial power projects spent approximately 3.5 years waiting for connection approval between 2010-2020 compared to approximately 1.9 years between 2000-2009. The study noted that there's roughly 680 GW of "zero-carbon capacity" waiting to be connected. With only 16-19% of this total possible renewable power expected to come online, possibly due to the previously outlined investment risks, there is opportunity here to incentivize power plants to come online sooner, while they wait for approval, with the help of a mining facility. Applying the mining hedge here could allow both to be built in parallel.

Several studies have also noted that the falling prices of solar power, known as solar value deflation, will make it difficult to convince investors and developers to build solar plants if they expect to make less money or lose money running a solar plant. California is already experiencing this problem. "If the cost declines for building and installing solar panels tapers off, California's solar deflation could pull ahead in the race against falling costs as soon as 2022 and climb upward from there." As in the Bastian-Pinto et al. study, bitcoin mining can act as a hedge against solar value deflation risks that would otherwise deter investors from funding solar power plant construction.

The Modern Grid's Unique Challenges

Traditionally, the power grid ran with rotator-based generators which produced steam to spin turbines. These generators provide inertia, meaning that the spinning turbines are resistant to change and want to keep spinning, even in the absence of energy provided to spin the turbine. As a result, grid operators used this inertia to plan response to changes in power on the grid.

Historically, inertia gave grid operators time to rebalance supply and demand when a large power plant or transmission fails. However, inertia is not the only way to rebalance the grid. Energy intensive loads can participate in demand response programs to stabilize an electrical grid with high levels of renewable energy penetration.

Bitcoin Mining and Grid Resiliency – West Texas Case Study

Another option is to use highly flexible response loads like bitcoin mining. This is already happening in Texas' ERCOT grid. Lancium and IdeaSmiths, LLC released an industry white paper in 2021 that models the results of integrating bitcoin mining facilities which are located primarily in West Texas, where there is an overabundance of wind power. Among its results, the grid simulation found a reduction in CO_2 emissions when integrating a highly flexible data center like a bitcoin mining facility as compared to a 2030 projected energy use baseline. This was possible because without miners, natural gas would have been used to balance out renewable intermittency. The IEA Net Zero report emphasizes the importance of increasing demand response in order to manage increased renewable-based power production. Therefore, these results validate the IEA's findings. Overall, the model estimates a 3.91 MT drop in carbon emissions over the baseline. While this shows reduction in emissions and an increase in wind power, the real gains appear to be in the responsiveness to grid price signals and improved grid stability in the face of variable power generation.

Profitable bitcoin mining must more than cover capital and operational expenses with block rewards earned over the long term. Mining companies also know their break-even point at which electricity prices are too high for them to be profitable even in the short term. If electricity prices exceed this threshold, miners are incentivized to power down until prices fall back into their profit range. In ERCOT, ancillary services can be provided via Responsive Reserve Service (RRS), also known as Non-Controllable Load Resources (NCLR). These loads are shut off via a grid operated circuit breaker (or after instructions sent from the grid operator) when frequency drops below a threshold. Another type of demand response is known as Controllable Load Resources (CLR).

Bitcoin mining is leading the way in this area. In the 2021 Annual Report of Demand Response in the ERCOT Region, the authors noted, "This represents the first substantial amount of convention load to participate in the Ancillary Services market as a Controllable Load Resource." Currently, there is approximately 750 MW of CLR being provided by eight bitcoin mining loads. CLR provides more than NCLRs in the sense that they can both reduce and increase demand, and provide frequency response similar to the governor of a conventional thermal generator. Prior to 2020, there were no demand side loads capable of operating in this manner. Bitcoin mining acts like a virtual generator, providing or withdrawing energy as needed. Moreover, incorporating bitcoin mining in renewable-rich grids has a secondary effect of cleaning up bitcoin's carbon footprint.

Bitcoin Mining's Relevance to the Western and Eastern Interconnections

NREL provides some insight on ERCOT's approach and how it might apply to the larger grids in the US. First, ERCOT is a smaller and more "islanded" grid than the Western and Eastern Connections. As a result, there is inherently less inertia in a smaller grid and thus less response time. A smaller grid coupled with high wind power penetration (ERCOT reported in 2020 a maximum instantaneous penetration of 57.9% in 2020) forced ERCOT to develop a new approach to low-inertia.

Second, since ERCOT is unlike the Western and Eastern interconnections because of its smaller grid-size and high wind penetration, the effects of incorporating bitcoin mining as a flexible load are a little different. NREL reports that other "US regions have yet to deploy significant load response because of limited need given their size and limited [renewable] penetration." They suggest that concerns over low-inertia are likely to be minimal during this decade. However, they expect that ERCOTs methods could "allow these regions to add significant wind and solar while maintaining reliable operation." This suggests that bitcoin mining will be able to scale nationally to assist with grid operation in the coming years to decades.

Curtailment and Negative Pricing

As renewable power penetration increases in grid systems, curtailment becomes a greater concern. According to Shan and Sun (2019), this is a result of a "mismatch of intermittent generation and demand, transmission congestion, and many other reasons." They continue, "curtailment will reduce both the environmental and economic benefit from renewable power plants, lowering the return of public and private investors."

In 2018, over 346 GWh of solar and wind power were curtailed in California alone and this number is expected to increase as more renewables come online in order to meet the Paris climate targets. Similarly, additional wind can lead to negative pricing, especially in the Great Plains region. Negative pricing generally represents locations where "the economic value of additional generation resources has significantly declined". According to one study, large flexible loads "may have the opportunity to increase welfare by availing themselves of plentiful and cheap energy". Such loads would need to be able to easily co-locate in regions where negative prices are common (which is what bitcoin miners have done in West Texas).

One solution for solar generators is to build out their power plant as a hybrid of solar and battery storage. With excess power stored in a battery, this power could be sold back to the grid during peak times or at night, when the sun has set. Battery prices are expected to continue to decline and 4-hour batteries are already being included in new solar plant projects. Eid et al (2021) notes that ROI is lowered with the addition of batteries due to the additional investment, so this may not be an ideal solution depending on investment constraints. Another possibility is to add additional transmission lines that can send power to more distant locations that may need the excess power.

A secondary solution is to incorporate a bitcoin mining facility either with batteries or alone. Shan and Sun modeled California's power grid using curtailment data from the California Independent System Operator (CAISO) and determined that bitcoin mining could reduce 50.8-79.9% of curtailment and add an addition of 5.6-48.1 million dollars in revenue to the system, based on 2018 data. This study did not look at the addition of batteries. However, a recent report from Square and ArkInvest suggested that the coupling of battery and bitcoin mining could be beneficial to solar power operation. Eid et al (2021) ran simulations comparing using battery or bitcoin miners to increase profitability of solar power plants, and found that in all scenarios the bitcoin miners outperformed the use of batteries. As battery prices continue to drop, this calculus may change over time. Still, in terms of ROI, it is likely beneficial to run miners to consume at least some of the curtailed power. Finally, the Shan and Sun study showed that shifting mining to addressing curtailment could "reduce CO_2 emissions, stimulate the capacity expansion, and enhance the reliability of the grid."

Additional Environmental Benefits

In addition to assisting with the renewable energy transition, bitcoin mining can provide environmental benefits through energy efficiency and waste clean-up, potentially operating as a mechanism for reducing greenhouse gas emissions.

Utilizing Bitcoin Mining's Heat Generation to Improve Energy Efficiency

From a basic physics perspective, bitcoin mining converts electricity into heat. The heat can be allowed to mix with the surrounding environment or it can be used for productive purposes.

Research here is nascent. An undergraduate thesis examined the possibility of using mining to heat a multi-family house. A master's thesis studied tying a 45 MW bitcoin mining facility to an 8.34 acre cannabis greenhouse that would be co-located in Alberta, Canada. This thesis found a potential savings of 70,000 tonnes of carbon dioxide emission for such a closed loop energy system.

A recent news article reported a partnership between MintGreen and the city of North Vancouver to pipe the excess bitcoin mining heat into the city's buildings or, as needed, be sold to a local producer of sea salt. The partnership anticipates that, "compared to natural gas, the heat from MintGreen's digital boilers would save the atmosphere from 20,000 tonnes of greenhouse gasses" over the duration of the contract with North Vancouver. The city believes that bitcoin mining heat will help reduce their reliance on natural gas and meet their target of reducing emissions by 80% below 2007 levels by 2040.

Elsewhere, mining heat is being used to heat hot water, warm greenhouses during winter months and distill whiskey. Additionally, there is anecdotal evidence among the bitcoin community that some residential miners are retrofitting their homes, using their miners for a dual purpose of central heating and bitcoin accumulation. We believe that for the residential miners heating can offset their demand on the grid and also reduce their carbon footprint.

Bitcoin Mining as a Financial Incentive for Waste Clean Up

While our major focus has been on reducing a majority of emissions from the direct combustion of fossil fuels, byproducts from fossil fuel production, landfills, agricultural waste, and tires contribute harmful gasses to the atmosphere and land, as well. Landfills account for approximately 30% of total global methane emissions. Oil, gas and coal production produce methane emissions through the inefficiencies of methane gas flaring and leaks. Tires are also an environmental hazard and are a storage of wasted energy. We believe that reduction of greenhouse gasses from waste can be incentivized with bitcoin mining rewards and provide evidence from recent use-cases.

Bitcoin Monetizes Capture of Methane Emissions from Flared Gas and Leaks

The IPCC's recent 2021 report noted that about 0.3 degrees C of the currently 1.1-degree C global warming was attributable to methane gas. Methane gas, while having a shorter lifetime than carbon dioxide, is a much more potent greenhouse gas. The UN reports that when measured over a 20-year period, methane has an 84-86 times more global warming potential than carbon dioxide.

We know that recently and without government intervention, flared gas is being used to mine bitcoin. Crusoe Energy is now providing cloud computing services that run off previously flared gas and Exxon is testing a pilot with Crusoe where it is redirecting this wasted gas toward bitcoin mining to meet environmental standards. According to a CNBC report, Exxon is looking at bitcoin mining as a way to meet the World Bank's "Zero Routine Flaring by 2030". ConocoPhillips is reported to be running a similar test pilot project. Crusoe's website claims a 63% reduction in carbon dioxide equivalent emissions. Nezhadfard et al. studied power generation for methane recovery and found that certain combustion engines could indeed provide a net reduction in carbon dioxide equivalent emissions. The Cambridge Bitcoin Electricity Consumption Index estimates that global gas flaring recovery could run 4.6 bitcoin mining networks (based on May 8, 2022 energy usage).

Bitcoin as a Buyer of First Resort for Unconventional Energy Sources: Landfills, Agricultural Waste, Waste Coal and Tires

As previously mentioned, landfills account for 30% of global methane emissions. Agricultural waste, especially from livestock, contributes to both soil, water and air pollution. The EPA estimates that in the US, agriculture accounts for 26% of methane emissions while waste accounts for 19%.

Bioming is a Mexican company that uses pig waste to mine bitcoin. The pig waste produces biogas, a renewable source of energy. This approach can be extended to landfills of a certain size. It may be worthwhile for landfills to operate older miners, to generate additional revenue. Biogas can also be produced from sewage and industrial wastewater treatment.

In Pennsylvania, Stronghold Digital Mining is powering their bitcoin miners using a waste coal remediation power plant. The state incentivizes these plants to install pollutant reducing technology and Stronghold's website claims 90-99% reductions in NOx, particulate, mercury, and SO_2 emissions. However, these claims have not been independently verified. More research is needed on the environmental impacts of this kind of waste-to-energy bitcoin mining.

Lastly, tires contribute to landfill waste and release toxins into the environment. Because of their high energy content, they can easily catch on fire, releasing pollutants into the atmosphere. In 2019, 76% of tires were recycled in the US. The remaining 24% can be broken down using high temperatures, which avoids pollution from directly burning them for energy. From here, the decomposed tire waste can be converted into fuel. However, tire fuel does produce emissions that are comparable to conventional fuels, so the cost and benefits must be weighed for using tire-derived fuels for bitcoin mining as a form of waste clean-up and environmental hazard reduction.

Conclusion

When thinking about bitcoin and the environment we must weigh bitcoin's own *value*, its *negative environmental effects*, and its *positive environmental effects*. Bitcoin is a $600 billion digital asset, an embodiment and extension of deeply-held American values, and a means of advancing American interests. Proof of work, we have argued, is essential to bitcoin's value along all three of these dimensions, but like any industry, has environmental impacts. These, we have argued, are often exaggerated due to basic misunderstandings of bitcoin's protocol. Finally, we have explored the many ways in which bitcoin mining promises to help us confront the challenge of climate change. Mining reduces investment risk in renewables—particularly in advance of grid connection—and acts as a uniquely flexible controlled load resource. Mining has other environmental benefits, including innovative uses of waste heat, safe disposal of used tires, remediation of waste coal, and most of all, methane cleanup on wellsites, farms, and landfills, at scale. Especially in this nascent phase of its development, regulators must be mindful both of bitcoin's value and of bitcoin mining's unique and positive contributions to sustainability.