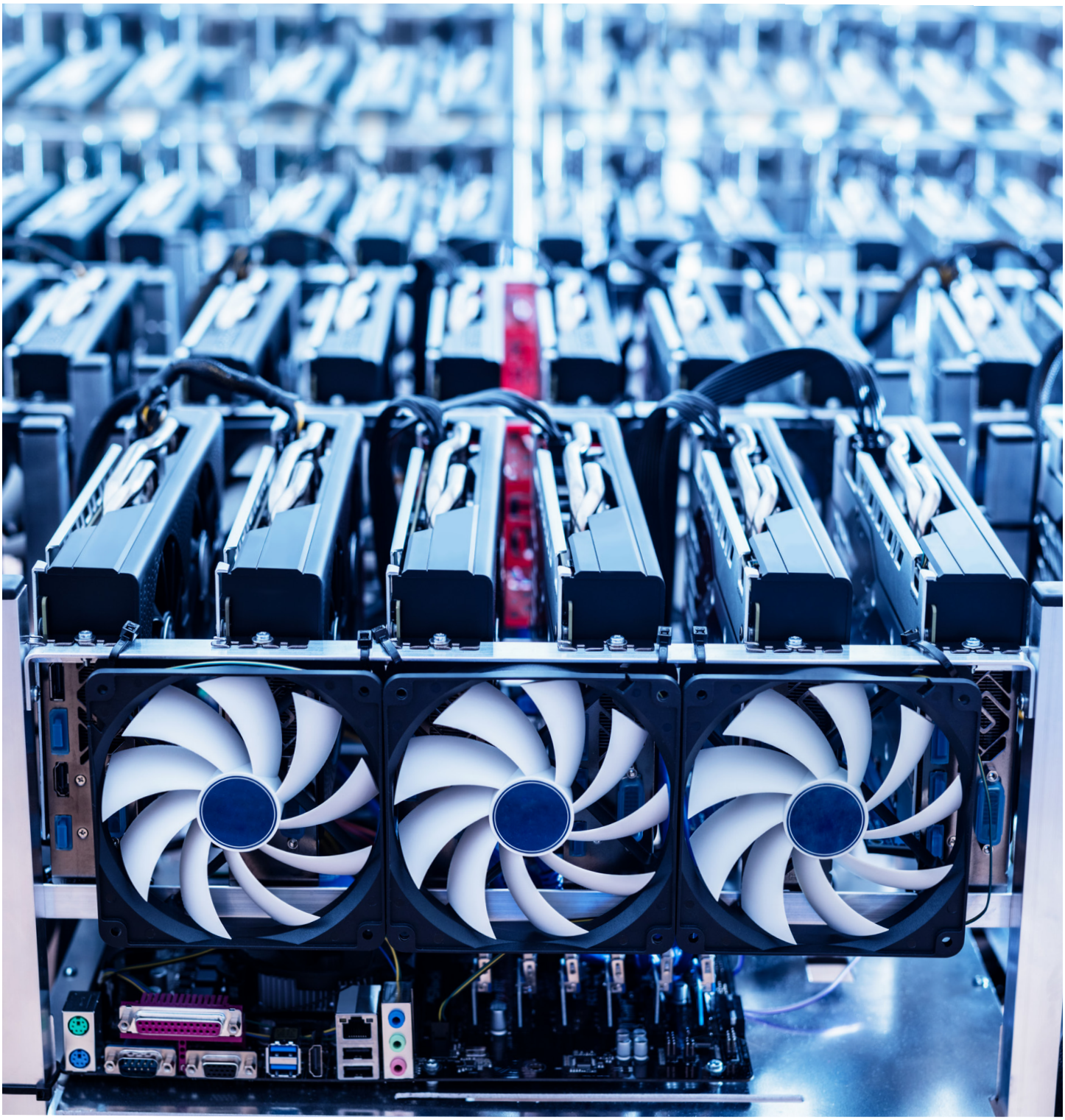

THE ENERGY BOMB

How Proof-of-Work Cryptocurrency Mining Worsens the Climate Crisis and Harms Communities Now

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BECAUSE THE EARTH NEEDS A GOOD LAWYER

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Mandy DeRoche, Deputy Managing Attorney,
Clean Energy Program, Earthjustice

Jeremy Fisher, Senior Advisor for Strategic Research and Development, Environmental Law Program, Sierra Club

Nick Thorpe, Climate & Energy Senior Program Associate, Earthjustice

Megan Wachspress, Staff Attorney,
Environmental Law Program, Sierra Club

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Executive Summary

Cryptocurrency mining is an extremely energy-intensive process that threatens the ability of governments across the globe to reduce our dependence on climate-warming fossil fuels. If we do not take action to limit this growing industry now, we will not meet the goals set forth by the Paris Agreement and the Intergovernmental Panel on Climate Change to limit warning to 2 degrees Celsius. And cryptocurrency mining operations harm local communities now, including by increasing local pollution and impacting electricity rates and delivery. In our paper, we discuss several such examples where fossil-fueled cryptocurrency mining has increased local air, water, and noise pollution, increased costs on others, and increased climate pollution at a time when we should be doing everything in our power to move in the opposite direction to mitigate the worst impacts of the climate crisis.

The cryptocurrency mining industry is opaque: there are few, if any, reporting standards, and there is little or no formal tracking of mining operations. This paper is the first attempt to comprehensively document the explosive growth of cryptocurrency mining in the United States and examine how this industry is impacting utilities, energy systems, emissions, communities, and ratepayers — based on public filings before utility and financial regulators, investor presentations and reports, and local media reports.

Cryptocurrency Mining's Explosive Growth in the United States

After cryptocurrency mining was banned in China in 2021, the amount of mining operations exploded in the United States. As of this writing, it is estimated that 38% of Bitcoin — the predominant proof-of-work cryptocurrency — is mined in the United States. We estimate that in the year prior to July 2022, Bitcoin consumed around 36 billion kilowatt-hours (kWh) of electricity, as much as all of the electricity consumed in Maine, New Hampshire, Vermont, and Rhode Island put together in that same time period. And while proof-of-work mining proponents claim that cryptocurrency always looks for the cheapest energy, the last two years have demonstrated that the industry preferentially seeks readily-available energy and minimal regulation, re-starting defunct coal and gas plants, flooding the restructured electricity market in Texas, and tapping into power grids where regulators have little oversight. This explosive growth strains energy grids, raises retail electricity rates, and increases total carbon emissions and local air pollution.

What is Cryptocurrency Mining, and How Does It Work?

Proof-of-work cryptocurrency mining is designed to consume enormous quantities of energy. The process effectively entails millions of computing machines racing to solve a complex, but meaningless, problem. In Bitcoin's algorithm, for example, the computer or mining machine that successfully solves the problem is rewarded with Bitcoin (and functionally verifies the blockchain). As long as the reward is high enough (i.e., the price of Bitcoin is high enough), miners will attempt to use more — and faster — mining machines to increase their chances of winning that reward. As more mining machines enter the race, the difficulty of the computational problem gets harder, and the electricity required to win increases. Over time, the electricity used by miners in these races increases exponentially.

The design of proof-of-work cryptocurrency mining incentivizes miners to ramp up operations as quickly as possible, often irrespective of the source of energy. Indeed, big mining operations have shown a willingness to invest in otherwise uneconomic power sources, like defunct coal plants or low-capacity gas plants, as long as that electricity can be made available quickly. Unlike other large electricity users, cryptocurrency mining operations have a short time horizon, and most have shown little interest in investing in new clean energy.

In addition, the mining industry is becoming highly concentrated. The energy and technology requirements of cryptocurrency mining means that mining operations require the backing of large capital. For example, the National Bureau of Economic Research estimates that 0.5% of mining companies control 70% of mining. This increasing concentration in turn lends itself to the arms race where large corporations are able to leverage enormous capital to build massive mining facilities, like the 750 megawatt Whinstone mining facility an hour east of Austin, Texas.

Proof-of-Work Cryptocurrency Mining Increases Emissions in the United States

Top-down estimates of the electricity consumption of cryptocurrency mining in the United States imply that the industry was responsible for an excess 27.4 million tons of carbon dioxide (CO_2) between mid-2021 and 2022 — or three times as much as emitted by the largest coal plant in the U.S. in 2021. But these estimates are simply based on the likely energy consumption to solve cryptocurrency's

puzzles. A ground-up approach, looking at how the industry has actually been deployed, suggests that proof-of-work cryptocurrency might be yet more impactful.

Tracking down the energy sources — or even just the consumption — of proof-of-work cryptocurrency mining in the United States is difficult. The industry is notoriously opaque, and little-to-no reporting requirements exist at either the state or federal level. The most reliable sources of information are a patchwork of filings before the Securities and Exchange Commission (SEC) by publicly-traded cryptocurrency companies, environmental permit applications, utility and other energy filings, and local reporting.

Cryptocurrency miners procure their electricity in four different ways: (1) outright purchase of power plants that supply mining rigs "behind-the-meter;" (2) power purchase agreements with power generators or utilities; (3) electricity purchases from a local utility; and (4) by burning fossil gas at oil and gas wells. Each type of mining produces excess emissions, and impacts electricity and energy consumers.

- **Behind-the-Meter at Power Plants.** Most egregiously, we identified four fossil-fueled power plants (the Scrubgrass and Panther Creek waste coal plants in Pennsylvania and the Greenidge and North Tonawanda gas plants in New York) that have been purchased and converted to mine proof-of-work cryptocurrency mining.
- **Power Purchase Agreements (PPAs).** Power plants or utilities may agree to sell a specific amount of electricity to a cryptocurrency miner. In some cases, a PPA is just a financial transaction, and in some cases, it can even change the amount that a power plant operates. In either case, when a cryptocurrency mining facility holds a contract with a fossil plant or a fossil-heavy utility, it provides a direct incentive to keep running polluting power plants. For example, an arrangement between Marathon Digital and the Hardin coal plant in Montana, which had been on the verge of retirement, led to ramped up operation and an 800% increase in CO_2 emissions (and 500% increase in sulfur dioxide emissions) from the plant in one year. Another example is the recent AboutBit agreement to purchase electricity from the Merom coal plant in Indiana. There, the plant's owner had previously announced a May 2023 retirement date, which has now been postponed, and a nearby coal mine has reopened to serve the plant.
- **Electricity Purchases.** Cryptocurrency miners that rely on retail electricity seek low cost—and rapidly available—electricity, wherever they can find it. An influx of new, large customers (sometimes doubling the utility's existing load) has forced utilities to seek additional generation resources or reduce off-system sales, strained their ability to manage the system, and raised prices for other customers. We found numerous examples of utilities making significant investments to serve cryptocurrency miners that were — or are likely to be — paid for by existing ratepayers. In some of these cases, the mining operation left abruptly months later, leaving behind stranded costs that are picked up by the utility and its customers:
  - The Nebraska Public Power District spent $17.6 million, or 18% of its 2020 budget, on transmission and a substation for a cryptocurrency mining operation.
  - Big Rivers Electric utility plans to spend $12.7 million in upgrades to service a new cryptocurrency mining operation in Paducah, Kentucky.
  - Entergy Arkansas reported that a cryptocurrency mining operation left "virtually overnight" in search of lower rates in 2019 after the utility expended significant funds on facility upgrades on the customer's behalf.
  - In 2018, a mining operation in Washington State left more than $700,000 in utility bills unpaid after it declared bankruptcy.
- **Combusting Fossil Gas at Oil and Gas Wells.** Some companies mine cryptocurrency at the site of previously closed or low-operating fossil gas wells and use on-site generators to power their mining equipment. There is also an increasing amount of companies that sell cryptocurrency mining rigs specifically designed to tap into gas at oil-producing wellheads. The cryptocurrency mining operations provide additional revenue to oil drilling companies, by finding entities that would have otherwise been unwilling to gather oil-drilling's "associated gas" as required.

The Industry Keeps Greenwashing Its Poor Practices

The proof-of-work cryptocurrency mining community is well aware that its extraordinary energy consumption — and fossil fuel habit — is unattractive when much of the rest of the economy strives to rapidly decarbonize. In the last year, the industry and its trade organizations have rolled out a series of sustainability claims that are anywhere from outright fiction and greenwashing to no more than hopeful theories, undermined by actual practices.

One of the most widespread mischaracterizations is that mining is "sustainable" when the facility is physically located near existing wind power or solar power. But most mining facilities draw power from the grid — meaning their electricity is generated by whatever existing energy is in place in the region, or is contracted by their utility. Worse, adding a new large-scale load, like a cryptocurrency mining facility, to the grid generally requires existing fossil generators to increase their output. Mining facilities located near wind or solar sites do not have a special claim to energy produced by that energy, but instead drive increased emissions from gas and coal plants.

Another myth put forward by proponents is that proof-of-work cryptocurrency mining only uses "wasted" (or curtailed) energy from solar or wind overproduction. The fact is that mining operations operate and draw on the grid at all hours, not just when there is excess solar or wind. Mining operations would likely fail to be profitable using only the sparse hours in which solar or wind curtails. Few cryptocurrency mining operations are even located where wind or solar might provide curtailed energy, and operate far in excess of the amount of curtailed energy even available.

Proponents of proof-of-work cryptocurrency like to claim that the intensive demand of mining will spur new renewable development, and stabilize the grid. The reality is that clean energy allocated to cryptocurrency mining is then unavailable for grid decarbonization. As such, there are few mining facilities that are actually building new renewable energy to power their operations. The only claim to grid stability is that cryptocurrency mining operations may be willing to curtail operations if they paid enough to do so. A miner's participation in demand response programs during emergency periods (which many other electricity users do as well) can amount to tens of millions of dollars a year and is often paid by other ratepayers. Unlike batteries, mining operations cannot store electricity produced at peak solar or wind hours for later use, and provide no other grid services.

Today, the cryptocurrency mining industry already uses half the electricity of the entire global banking sector (while holding a miniscule fraction of the value), and continues to increase. In the United States, the industry has shown little indication of slowing its growth when prices are high. Miners have demonstrated, consistently, from their initial rush to China where coal is a predominant source of electricity to the recent deal between AboutBit and a soon-to-be-retired coal plant in Indiana, that proof-of-work cryptocurrency mining prioritizes the short-term need for large amounts of electricity over longer-term investments in renewable energy. And unlike other industries where self-imposed, or regulation-based, community standards could result in more sustainable practices, proof-of-work mining is an inherent arms race towards increased energy consumption, until prices no longer support growth.

Regulators and Policymakers Can Take Steps to Reduce the Harm of Cryptocurrency Mining

State, local, and federal policymakers and regulators can help ensure cryptocurrency mining does not undermine climate or health goals, or adversely impact ratepayers.

The massive energy consumption of cryptocurrency mining threatens to undermine decades of progress towards achieving climate goals, and threatens grids, utilities, communities, and ratepayers. Some jurisdictions have, or are considering, simply banning the practice of mining proof-of-work cryptocurrencies. Shy of a complete moratorium, there are actions that can be taken by state, local, and federal officials to protect energy systems, communities, and ratepayers.

POLICY AND REGULATORY OPTIONS

- Local and state officials can enforce pollution and noise ordinances, ensure that they are not extending economic development dollars on false promises of long-term jobs or revenue, develop careful zoning codes, and — in the cases where municipalities run the electric utility — develop tariffs that protect existing ratepayers.
- Utility regulators can influence or bar problematic power purchase agreements, create protective electricity rates or system benefits charges that ensure speculative mining operations do not leave a trail of stranded assets, critically assess utility plans for energy procurement for cryptocurrency mining facilities, and ensure that mining facilities do not increase electricity or capacity costs for existing customers.
- Utilities can develop electricity rates that protect against stranded assets, ensure that they do not need to expand power capacity to meet cryptocurrency mining load, and charge rates sufficient to fully protect existing ratepayers from the increased marginal cost of production.
- Grid operators can develop comprehensive guidance and rules around the interconnection of high-density loads, study the impact of cryptocurrency mining on congestion, resource adequacy, and wholesale market prices, and create rules that minimize the impact of cryptocurrency mining on other customers.
- Environmental regulators at all levels should consider affirmative regulation to minimize the local health and environment impacts cryptocurrency mining places on local communities.

I. Cryptocurrency Mining's Explosive Growth in the United States

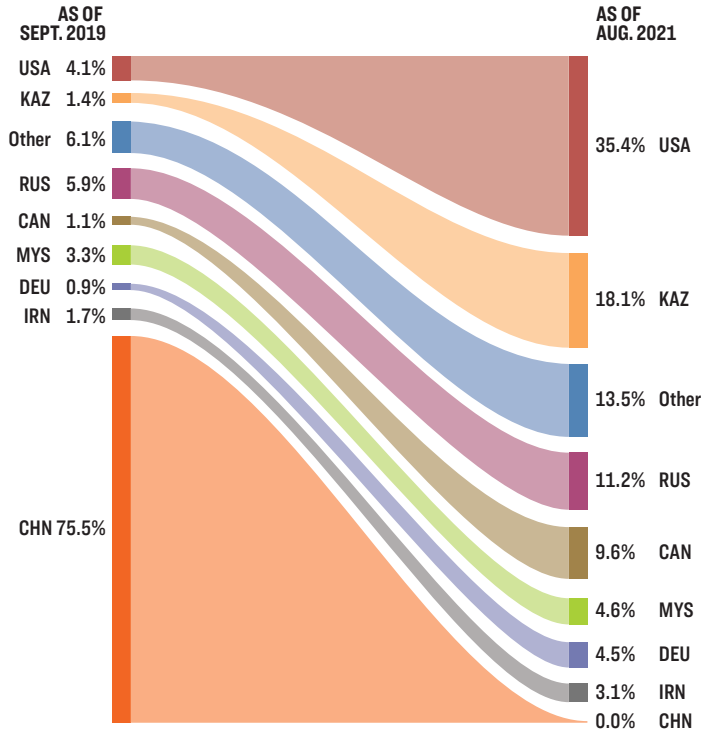
So-called "proof-of-work" cryptocurrencies are secured by the use of intensive computing—and electricity—resources. Cryptocurrencies, starting with Bitcoin, innovated an approach to tracking, and verifying, transactions that requires no central entity, like a bank. But the currently predominant cryptocurrency, Bitcoin, bases its security on an approach that requires machines to compete to solve complex puzzles. The growth in the value of Bitcoin led to an arms race—and explosive energy consumption globally, and over the last year, in the United States. The Cambridge Centre for Alternative Finance estimates that Bitcoin alone increased its electricity consumption from less than a gigawatt (GW) per day in early 2017 to more than 11 GW in July 2022.[1] By early 2022, prior to the collapse of Bitcoin prices,[2] Bitcoin was consuming over 10.5 billion kilowatt hours (kWh) every *three months*—or the equivalent output of ten large coal-fired power plants.[3]

In its April 2022 report, the Intergovernmental Panel on Climate Change (IPCC) warned that soaring electricity use by proof-of-work digital currencies is likely to "be a major global source of CO_2 if the electricity production is not decarbonized."[4] The White House's Office of Science and Technology Policy (OSTP) recently estimated that proof-of-work cryptocurrency mining likely comprises somewhere between 0.9% to 1.7% of total annual U.S. electricity usage, or 36 to 66 billion kWh per year in mid-2022.[5]

Bitcoin has been at the center of cryptocurrency energy debates, and rightfully so: Bitcoin mining uses far more electricity than any other cryptocurrency, for two reasons. First, Bitcoin makes up more than 40% of the cryptocurrency market share, by far the largest of any currency.[6] Second, Bitcoin is the most energy-intensive cryptocurrency in wide circulation, because it uses a "proof-of-work" mining method that is designed to require increased energy inputs for the same economic output over time. Because of its outsized energy footprint, this paper focuses on Bitcoin as a proxy for other proof-of-work cryptocurrencies. As of this writing, the second largest energy consuming cryptocurrency, Ethereum, was in the process of transitioning from a proof-of-work construct to a "proof-of-stake" verification, an alternative mechanism of securing cryptocurrency transactions that does not require machines to solve the same volume of puzzles—and hence uses only a small fraction of proof-of-work algorithms.[7]

Until last year, the majority of Bitcoin mining was physically located in China. In May 2021, Chinese officials initiated a crackdown on cryptocurrency mining operations; within a month, more than 90% of operations were shut down or planned to.[8] Bitcoin mining, however, continued its upward trajectory, with much of the computing shifting to the United States.[9] Although there had been some indications of growth in U.S.-based mining in 2020,[10] in a matter of months, the amount of U.S.-based mining exploded, with little regulatory oversight.[11] In 2019, the U.S. accounted for just 4% of global mining; as of August 2022, nearly 38% of Bitcoin mining activity is estimated to be based out of the U.S.[12] By January 2022, U.S. Bitcoin operations were consuming an estimated 3.7 billion kWh per month—more than the January electricity sales of the entire state of Kansas or Nevada.[13] Assuming that the efficiency of mining machines in the United States is roughly consistent with those used in other countries, we estimate that Bitcoin mining consumed 35.8 billion kWh from June 2021 to July 2022, or as much electricity as all of Maine, New Hampshire, Vermont, and Rhode Island put together—or every industrial electricity customer in Georgia.[14]

Migration of Cryptocurrency Miners, Sept. 2019 — Aug. 2021[15]



When primarily located in China before it was banned, cryptocurrency mining was often powered by hydroelectric facilities and coal plants. When miners fled China, they began to power operations with gas and fossil-heavy grids (especially in the United States) and hard coal (in Kazakhstan). The share of renewable energy used to power Bitcoin mining is estimated to have dropped from 41.6% in 2020 to about 25.1% in August 2021.[16] At least one estimate suggests that U.S.-based Bitcoin miners are already responsible for at least one-quarter of the global greenhouse gas emissions caused by Bitcoin mining.[17] OSTP estimates that Bitcoin mining in the United States alone is responsible for between 21 to 35 million tons (Mt) CO_2 per year; and global Ethereum operating on a proof-of-work algorithm accounts for 25 to 50 MtCO_2 per year.[18]

This paper identifies the impacts from proof-of-work cryptocurrency mining have on our electric system, utility bills, air and water quality, communities, and decarbonization goals. The rapid rise of massive, centralized, proof-of-work cryptocurrency mining operations affects utilities, ratepayers, and the environment. It also threatens to reverse ongoing trends toward the decarbonization of the U.S. power sector, further entrenching fossil fuel production and consumption. This paper seeks to educate advocates, policymakers, regulators, and the public about the immediate threat that proof-of-work cryptocurrency mining poses to communities, ratepayers, and climate action and to provide a much-needed corrective to myths that cryptocurrency mining companies have promoted about the relationship between their business model and clean energy.

II. Proof-of-Work Cryptocurrency: A Brief Introduction

What are "proof-of-work" cryptocurrencies, and why do they use so much energy? In short, proof-of-work cryptocurrencies' mechanism for protecting the integrity of ownership is to require computers or mining machines to compete to solve complex mathematical puzzles, and reward the winner (the miner) with currency. The mechanism is designed to promote an arms race: more machines competing to solve the puzzle theoretically means that no single entity can control, or monopolize, the system. The person or company with the most computational power will be rewarded with the most currency. Consequently, cryptocurrency mining operations are running immense computational operations, often *tens of thousands* of mining machines, around the clock to secure the best chances of winning.

Cryptocurrencies generally use a "distributed ledger," meaning that ownership and transaction records are not centrally located but can only be established through computations conducted across participants' mining machines. To minimize the chances of participants trying to cheat each other by writing false transactions into the ledger, cryptocurrencies need a mechanism to decide how a transaction can be considered valid. For proof-of-work cryptocurrencies, the first mining machine to solve a cryptological problem (i.e., a puzzle) gets to validate the next set of transactions, and in doing so, earns a reward. The form of the puzzle requires mining machines to perform millions of computations, in effect guessing at the answer. To induce individuals to commit computing power towards these validation puzzles, the Bitcoin network rewards participants with new Bitcoins if they successfully validate a set of transactions—that is, be the first to solve the puzzle, thereby adding another "block" (or solution) in the chain (that in turn becomes an input to the *next* puzzle). Operations that try to earn this new Bitcoin are called "miners" (because they are "mining" new Bitcoin), as are the mining machines that are specially designed to *only* solve these puzzles.[19]

The puzzle that Bitcoin miners try to solve is calibrated approximately every two weeks such that across the global network, rewards are earned, on average, about every ten minutes.[20] As more miners enter the system, the reward becomes harder to earn. To have a better chance of earning the reward, miners add new machines to the system, consequently consuming more energy, and in doing so, make the reward harder to earn. The entire system can be compared to an unbounded lottery, played every ten minutes. To have the best chance of winning the lottery, you need to buy more tickets, but as more people buy tickets, your chances of winning the lottery decrease. The winning strategy, to date, has been to buy as many chances at the lottery as possible, as quickly as possible—*i.e.*, build mining centers as quickly as possible.[21] Importantly, the vast majority of computational energy in the Bitcoin system at any one time is wasted: the system works if there are twenty thousand mining machines competing—or two million.[22]

Will the explosive growth in energy consumption ever come to an end for proof-of-work cryptocurrencies? There are two countervailing forces that drive the trajectory of energy use for Bitcoin: difficulty drives the value of

mining down, and the price of Bitcoin drives the value of mining (and energy consumption) up. Difficulty is driven by miners entering the system, increasing the complexity of the problems and thereby raising the energy cost of winning a block of Bitcoin. By design, the Bitcoin reward offered to miners is cut in half approximately every four years. These two factors together make it increasingly costly to obtain new Bitcoin.[23] But higher Bitcoin prices can overwhelm these barriers. Even at the relatively depressed price of Bitcoin as of this writing (~$20,000), Bitcoin miners can afford to pay well above what ordinary users of electricity pay—and can afford to keep adding new processing power.

III. No Longer a Hobbyist's Experiment: How Cryptocurrency Mining Transformed Into Massive, Centralized Operations to Maximize Profits

In October 2010, just one year after Bitcoin was publicly introduced, its network processed around ten billion calculations (gigahashes) per second (Gh/s),[24] meaning the entire network could be run by between 6,000 and 7,000 mining machines.[25] With Bitcoin trading at a modest 20 cents, Bitcoin miners were mostly restricted by the cost of acquiring hardware and allocating it to Bitcoin mining.[26] Cryptocurrency mining was largely a hobbyist's exercise, with miners found in garages, basements, or home offices.[27] But today, these small operations are in the minority; in 2020, 4.5% of Bitcoin holders held 85% of the currency.[28]

Beginning in early 2012, miners began switching to specialized equipment, first using modified graphics processing units and quickly advancing to application-specific integrated circuit (ASIC) machines. As mining got more popular (and thus more competitive), the estimated power dedicated to Bitcoin mining rose from less than 1 GW at the start of 2017 to nearly 4.4 GW by the end of 2018.[29]

Today, the scale of cryptocurrency mining is expanding rapidly in the United States. Cryptocurrency mining is now the largest source of electricity demand for some utilities. In Texas alone, we tracked 2,234 MW of cryptocurrency mining facilities, almost entirely built since mid-2021. Eight of the facilities are between 150 to 300 MW each.[30] A single 300 MW facility might host nearly 100,000 machines,[31] consuming enough electricity to power, on average, nearly 49,000 nearby homes.[32] Unlike many industrial operations or even data centers that reduce energy usage at off-peak times, these facilities typically run 24 hours a day, seven days a week, 365 days a year, at full capacity. Any downtime is a lost opportunity to "win" blocks of Bitcoin, and mining machines can run for hours with minimal human supervision.

Cryptocurrency is touted as a democratizing form of finance[33]—but it is increasingly a highly concentrated industry that relies on large financial institutions to fuel its growth. Because of the immense amount of capital needed to purchase enough ASIC miners, with high-performance machines many thousands of dollars each, cryptocurrency mining is beyond the reach of only a few mining companies.[34] Even small-scale miners' operations are part of high-density loads, as many pool their computing power to increase their chances of validating a coin. Almost 80% of all computing power on the Bitcoin network is owned by seven mining pools.[35] A 2021 paper from the National Bureau of Economic Research tracing rewards within a subset of those pools found that 90% of rewards (Bitcoin blocks) were received by just 10% of miners—nearly 70% were received by just *half a percent* of miners.[36]

A. Proof-of-Work Cryptocurrency Mining Incentivizes Mining As Quickly As Possible to Maximize Profits

The structure of proof-of-work cryptocurrency mining—where the first mining machine to solve the puzzle gains a reward, where the reward falls over time, where there is no limit on the number of entrants in the competition to earn the reward, and where there is a perception that the value of cryptocurrency is effectively limitless—creates an incentive to mine cryptocurrency as quickly as possible. Mining equipment, too, quickly becomes obsolete.[37]

The ability to get existing mining equipment running as soon (and often) as possible is incentivized over nearly all other considerations. Bitcoin is designed so that the reward that miners receive for validating a transaction

shrinks over time. These are known as "halving" events. At the inception of Bitcoin, miners that successfully validated transactions were provided 50 Bitcoin. That reward has fallen approximately every four years. Today, in 2022, it is just 6.25 Bitcoin. At the height of Bitcoin's value in March 2022, that 6.25 Bitcoin was worth $294,146. The next halving event is projected for 2024, at which point the value per computational effort of mining Bitcoin will immediately fall by 50%. Miners looking towards that halving event will seek to mine as much Bitcoin today as feasible, knowing that the value of mining will sharply decline at that event.[38]

B. Cryptocurrency Miners Often Value *Speed* of Access to Energy Over Price, Even to the Point of Reviving Dying Fossil-Fueled Power Plants

Proponents of proof-of-work claim that it seeks low-cost energy, or even excess energy. This is true—but only to an extent. Utilities with particularly inexpensive energy due to subsidized hydropower, for example, have seen a higher number of interconnection requests from miners. But because proof-of-work cryptocurrency mining rewards speed above all other considerations, miners are turning to any and all readily available energy options, such as defunct or otherwise uneconomic power plants, so they can set up mining operations as quickly as possible.

Accordingly, some of the fastest growth of cryptocurrency mining in the United States recently has occurred where miners have made direct deals with defunct generating stations, and in Texas's unique electricity market.

Miners have invested at power plants that have otherwise struggled to demonstrate economic value, a trend that would seem to be counter to prudent planning. But unlike other customers, miners have been willing to pay above-market prices for electricity from otherwise retiring coal plants (such as at the Hardin coal plant in Montana), or inefficient plants (such as the Panther Creek and Scrubgrass waste coal plants in Pennsylvania) because energy from these plants could be procured quickly, and with few regulatory hurdles.

Similarly, Texas's deregulated electricity market means end-users are not limited to a particular retail electricity provider based on location, and the absence of a wholesale capacity market (basically, a requirement that utilities pay for a guarantee of available electricity) can lead to price extremes (both low and high). Both of these characteristics have made Texas attractive to geographically flexible miners who can shop around for favorable terms, and can shut down operations when prices spike. Texas's restructured market makes it easy for miners to build facilities with few obligations to the grid.

Given the uncertainty as to future Bitcoin prices, the fact that Bitcoin cannot be widely used as a currency for ordinary transactions, and the exceptional volatility in prices, mining operations cannot—and generally do not—bet on the long-term stability of their enterprise. There is little reason for cryptocurrency miners to make investments lasting even a year or two to build solar or wind generation, as long as existing fossil fuel plants can provide the same electricity, faster.

IV. The Scale and Source of Bitcoin Energy Usage is Largely Invisible to Regulators

Although cryptocurrency mining operations have become increasingly specialized, concentrated, and capital-intensive—and thus identifiable as a distinct class of business and energy user—it is difficult or impossible to find information about the scale, location, or fuel source of cryptocurrency mining operations in the United States.

Proof-of-work cryptocurrency mining operations are not tethered to any particular geography: miners seek speed to market, cheap energy, flexibility, and distance from regulators. For example, multiple companies offer mining equipment in shipping containers to chase the best prices,[39] and when prices fluctuate, mining facilities can migrate quickly. For example, in April 2022, Marathon Digital announced that it would abandon its new position adjacent to the Hardin coal plant in Montana, noting that it could complete the transition by the third quarter of 2022, or in less than half a year.[40] Similarly, Compass Mining recently announced that it would close its Georgia facilities and move its mining machines to Texas, reportedly just two months after proposing to ship Texas mining machines to Georgia to chase a faster interconnection.[41]

Currently, the primary sources for publicly available information about cryptocurrency's energy usage and environmental impacts are local journalists, company press releases, and Securities and Exchange Commission (SEC) filings for publicly-traded cryptocurrency mining companies. Occasionally, information about mining operations may be found incidentally through regulatory oversight of utilities or generation facilities

(such as through utility tariff filings that identify new interconnection requests or Federal Power Act Section 203 filings before the Federal Energy Regulatory Commission (FERC) relating to the sale of generation facilities).

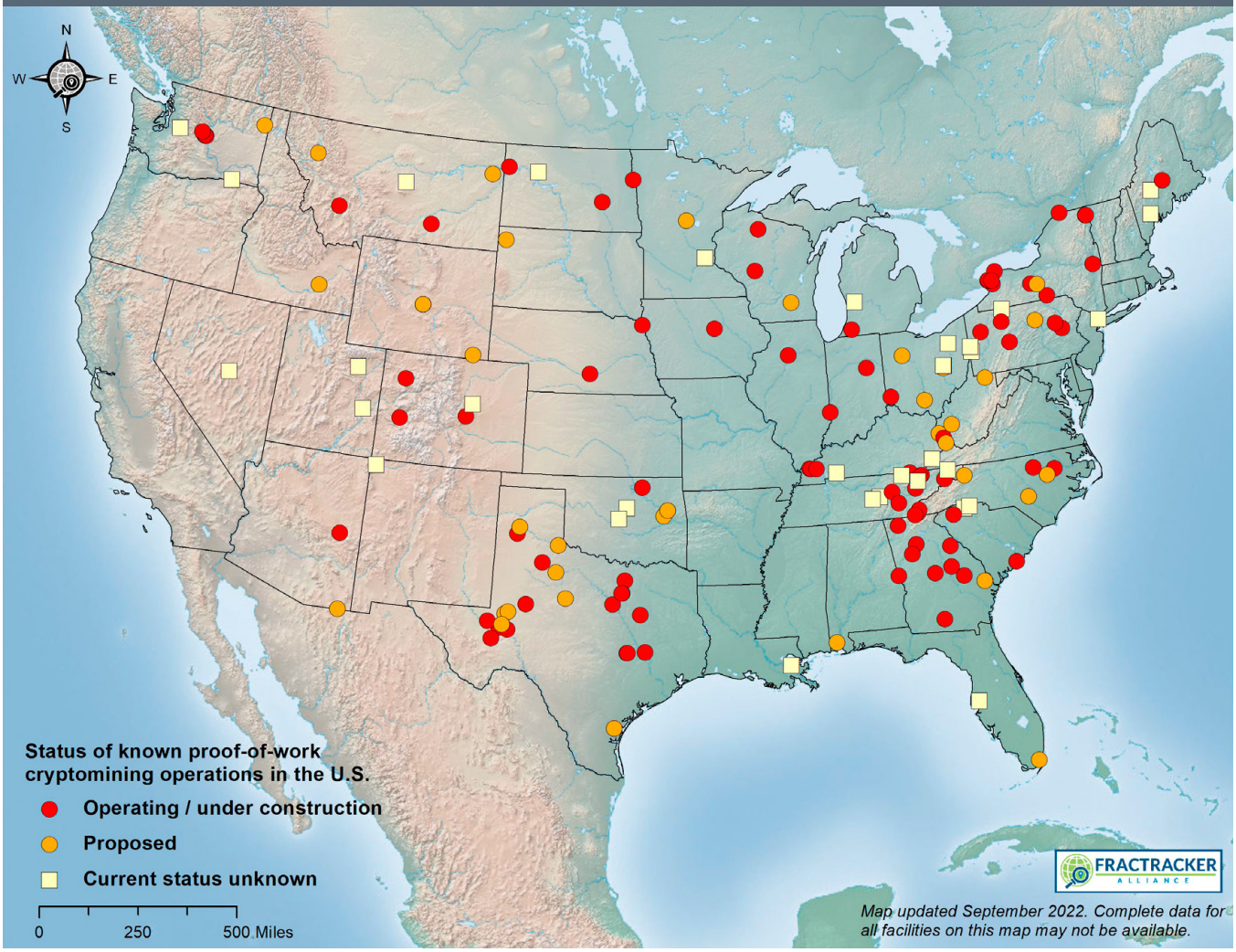
Many mining operations, however, are not owned by publicly-traded companies. Among those that *do* file reports with the SEC, many do not disclose the fuel sources associated with the miners listed in their 10-K or 8-K reports, or provide only partial or selective information, such as describing the energy supply as "reliable, renewable" or as having "high emissions free content."[42] If the mining company reports a Power Purchase Agreement (PPA) with a utility, and that utility is required to file an integrated resource plan or other public information about its generation under state law (or does so voluntarily),[43] that information can be used to help determine fuel mix when operations use energy from the grid.

In the cases where the mining company directly purchases generation resources, there may be additional information through the U.S. Environmental Protection Agency (EPA) or state air or water permitting processes,[44] or within filings under Section 203 of the Federal Power Act if FERC approval is required for the purchase.[45]

V. Where *Do* The Electrons Come From?

Despite the lack of centralized information about the location or energy source for large-scale cryptocurrency computing centers, we were able to identify more than 140 cryptocurrency mining operations through a patchwork of SEC filings, investor presentations, public utility commission dockets, grid operators' public processes, local newspaper coverage, and local activist efforts. Using this information, we then attempted to determine how these operations were obtaining electricity and the greenhouse gas emissions associated with that electricity usage.

FracTracker Alliance, Status of known proof-of-work cryptocurency mining operations in the U.S. (Sept. 2022).[46]



A. Types of Electricity Procurement by Cryptocurrency Miners

There are four primary means by which proof-of-work cryptocurrency mining companies power their operations: (1) operating behind-the-meter at a power plant;[47] (2) purchasing power directly from a power plant or utility; (3) purchasing electricity from the grid either through a power purchase agreement with a utility or by paying a retail rate (which may be a general industrial rate or an even lower "economic development" rate); or (4) hooking up a generator to oil and gas wells to burn gas that would not be combusted, or otherwise not be injected into the pipeline system, either through flaring or venting. In nearly all of these scenarios, these unregulated, energy-intensive proof-of-work cryptocurrency mining operations are financing the continuation of fossil fuel extraction and generation—in direct opposition to what is needed to prevent the worst of the impacts from the climate crisis.[48] And in some places, investments in fossil generation will be made in response to this boom in demand that will have ongoing effects for decades.

1. Behind-the-Meter Generation at Fossil-Fueled Power Plants

Cryptocurrency mining operations most directly drive increased greenhouse gas emissions when they outright purchase fossil fuel plants. We have identified several fossil fuel power plants where greenhouse gas emissions and local pollution increased dramatically after those plants were acquired by cryptocurrency mining companies and began operating around-the-clock.

i. Burning Waste Coal to Generate Electricity for Cryptocurrency Mining in Pennsylvania

In July 2021, Stronghold Digital Mining Inc. filed an S-1 report with the SEC disclosing plans to purchase three waste-coal-fired power plants in Pennsylvania with a combined capacity of 300 MW and install 57,000 ASICs dedicated to mining cryptocurrency.[49] To date, Stronghold has purchased the 94 MW Scrubgrass power plant in Venango County and the 94 MW Panther Creek facility in Carbon County.[50]

Burning waste coal to generate electricity for cryptocurrency mining is one of the worst possible choices for the climate and for local air pollution.[51] According to U.S. Energy Information Administration data, Pennsylvania's waste-coal-fired power plants had average CO_2 emissions of over 2,760 pounds per megawatt-hour (MWh), making them the second most carbon intensive fuel behind residual fuel oil.[52]

The Scrubgrass plant relies on a mixture of rejected waste coal and dirt that emits hundreds of tons of dangerous air pollution, including sulfur dioxide, nitrogen oxide, and hazardous air pollutants.[53] The waste coal is also carried on hour-long trips by large trucks over two-lane country roads, endangering communities along the route with additional air pollution. Adding insult to injury, the plant receives subsidies from Pennsylvania taxpayers and ratepayers because it burns "waste," including $4/MWh for the Pennsylvania Coal Refuse Reclamation tax credit and $16/MWh from the Pennsylvania Tier II Alternative Energy Portfolio Standard Program.[54] Stronghold, which owns and operates the two waste coal plants, has claimed that 60% of their generation costs will be covered by subsidies from taxpayers and ratepayers.[55]

ii. Burning Fossil Gas to Generate Electricity for Cryptocurrency Mining in New York State

In upstate New York, the Fortistar North Tonawanda gas-fired power plant plans to power proof-of-work cryptocurrency mining full-time behind-the-meter. Prior to the change in operations, the facility operated rarely, at only a 2 to 13% capacity factor, meaning its emissions of greenhouse gases and other harmful air pollutants were relatively small compared to what the plant was capable of.[56] Running the plant full-time to mine cryptocurrency could cause a nearly 3,000% increase in its annual CO_2 emissions along with dramatic increases in other harmful local air pollutants such as haze-producing nitrogen oxides, particulate matter, and carbon monoxide.[57] This significant increase in air pollution will spew into several nearby environmental justice areas.[58]

About a hundred miles away, on the western shores of Seneca Lake, among the productive vineyards and farms of the Finger Lakes, the former coal-fired and now fossil gas-fired Greenidge Generation Station began operating as a cryptocurrency mining facility full-time in 2020. In its first year of mining operations, CO_2 emissions at the plant increased 479%.[59] Other local air pollutants rose sharply as well when it began operating 24 hours a day.[60]

Fortunately, it is not clear how much longer Greenidge will continue to pollute; the New York State Department of Environmental Conservation denied an air permit renewal application for the Greenidge gas plant in June 2022, concluding the plant's expanded operations and significant increase in air emissions over the past two years were inconsistent with the state's climate law, because its behind-the-meter cryptocurrency mining "was creating a significant demand for energy for a wholly new purpose unrelated to its original permit."[61] There are

also serious question as to whether the plant's owners can safely and effectively address and remediate the existing coal ash contamination or water pollution issues on site.[62]

2. Power Purchase Agreements with Fossil-Fueled Power Plants or Utilities

As the Greenidge plant's air permit denial demonstrates, outright ownership of fossil fuel resources entails legal responsibilities and both invites scrutiny and requires transparency that many cryptocurrency mining operations have sought to avoid. Therefore, a large number of mining operators instead set up mining facilities in close proximity to, and directly connected with, fossil fuel power plants, and enter into power purchase agreements for electricity from those plants. Some of these arrangements are negotiated with the local utility to purchase electricity at rock bottom prices, often with no scrutiny from regulators. For example, Cipher Mining has negotiated PPAs with an average fixed price of 2.73 cents per kWh.[63] For many others, the electricity rate paid by miners in PPAs is unknown.

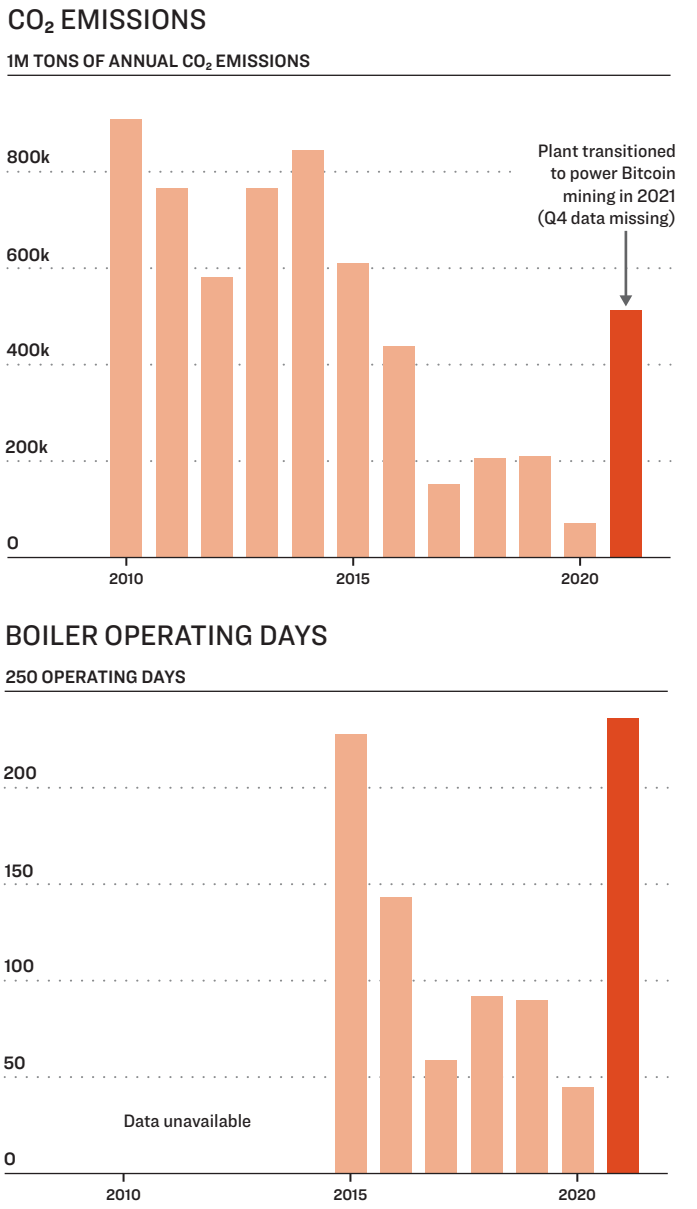
These arrangements, often not publicly available, can prolong the operation of coal- or gas-fired power plants that were otherwise likely to retire or even had an announced retirement date.

i. A Coal Plant in Hardin, Montana That Hardly Operated Powered Up to Mine Cryptocurrency

One prominent example of this practice is the Big Horn Data Hub operated by Marathon Digital Holdings at the 115 MW Hardin Generating Station, a coal plant just north of the Crow Indian Reservation in Big Horn County, Montana. Before cryptocurrency mining operations ramped up at Hardin, the plant had been slated to close permanently in 2018 and generated power for just 75 days per year on average from 2017 through 2020.[64] In late 2020, publicly-traded cryptocurrency mining company Marathon announced a partnership with the plant's operator, Beowulf Energy, to utilize roughly 37 MW of power from the plant to mine cryptocurrency around the clock. Hardin operated 323 days in 2021.[65]

The plant's operations were enormously profitable for Marathon, which won approximately 34 Bitcoin on December 1, 2021 alone[66]—equivalent to $1,945,786 at the time.[67] Hardin's neighbors were not so lucky. In 2021, nitrogen oxide emissions increased 842%, sulfur dioxide emissions increased 508%, and CO_2 emissions increased 850%.[68]

As Hardin plant powered Bitcoin mining, emissions spiked



Sources: Provided by the Montana Environmental Information Center from reports submitted to the Montana Department of Environmental Quality. Graphic is adapted from The Guardian.

As with all coal plants, delaying a retirement date and increasing operations to mine cryptocurrency increases all pollution from the plant. Additional years of operations mean millions of tons more of coal ash or coal combustion residuals (CCR)—a toxic solid waste byproduct of burning coal.[69]

In early April 2022, Marathon Digital announced that it would transition its operation at Hardin to other locations to use "more sustainable sources of power" and reduce its pollution by the end of 2022.[70] However, agreements between Marathon and Compute North suggest the

miners were simply moved to a behind-the-meter operation at fossil gas-powered Wolf Hollow Generating Station in Texas.[71] And even in leaving, Marathon left millions of dollars' worth of infrastructure intact, "so another miner can come in right behind us with a minimal delay and then com[e] up to speed," according to its CEO.[72] The Hardin plant's owner is currently in discussions with potential tenants that are interested in moving into the Big Horn Data Hub.[73]

ii. A Coal Plant's Polluting Operations in Merom, Indiana Are Extended to Mine Cryptocurrency

Cryptocurrency mining may also help prolong the life of the Merom Generating Station, a 1,080 MW coal-fired power plant in southwest Indiana. Hoosier Energy, a generation and transmission rural electric cooperative that has owned the plant for around 40 years,[74] previously announced the plant would retire in May 2023.[75] Then, in February 2022, Hoosier Energy announced plans to sell the plant to Hallador (a coal-mining company) and purchase a portion of the plant's energy and capacity from the new owner. [76] Shortly thereafter, in May 2022, the public learned that AboutBit, a cryptocurrency mining company, would be constructing a new mining site adjacent to the Merom plant and purchasing 115 MW of electricity from WIN Energy, a distribution cooperative that purchases all of its power from Hoosier Energy.[77] It is unclear whether the PPA between WIN and AboutBit was known to Hallador, Hoosier Energy, or both, before the two parties reached an agreement on the sale of the plant, but it makes the Merom plant considerably more economically viable as a merchant generator than it would otherwise be.[78] In fact, AboutBit's co-founder responded to criticism about keeping a coal plant open by stating, "It's 100 percent correct. For anyone to say their crypto operation is green, unless they are 100 percent hydro, they can't make that claim. As an operation, it's not humanly possible."[79] Hallador also plans to reopen a coal mine in Knox County, Indiana, to supply this plant's extended operations.[80]

3. Retail Purchases of Electricity from the Grid

Some miners simply purchase energy from their local utility as retail customers. Miners seek out utilities where industrial electricity rates (which are often lower than residential rates on a cent per kWh basis) are particularly low.

One of the largest cryptocurrency mining companies, Riot Blockchain, only pays 2.5 cents per kWh for its electricity. These rates are roughly 10 to 11 cents less than the going residential rate,[81] and about 5 cents less than the large consumer rate.[82]

At the same time, miners often also participate in demand response programs, which will pay miners to stop drawing electricity during periods of high demand. Although such programs mitigate some of the impacts of mining on the grid, other customers must effectively pay miners to shut down, which may be extremely profitable for such large consumers like mining operations during extreme weather events than actually mining.[83] As described further below in Section VIII.D, while demand response programs are essential tools to mitigate the pressure the power grid faces from extreme weather events like heat waves, the vast amount of new and increasing load placed on the grid by cryptocurrency miners who often pay lower electricity rates than others, but then are paid very high rates for demand response are not fair to other electricity users.

The impacts on other ratepayers from discounted electricity rates provided to miners and from the payments to miners for demand response can be severe, which is discussed further below in Section VII.B.

4. Combusting Fossil Gas at Oil and Gas Wells

Many cryptocurrency mining companies are utilizing electricity generated from combusting fossil gas at oil and gas well pads. This type of mining operation can reopen orphaned wells, often in remote areas such as in rural South Dakota or western Pennsylvania, that should otherwise be plugged or capped to prevent methane and other pollution.[84] Some of these operations are literally off-the-map. One journalist visited a "small installation [in Kentucky], miles from the nearest paved road, [that] draws methane gas from a long abandoned well that [the miner] has fixed up with a generator and satellite internet . . . ."[85] The mobility and remoteness of these operations make them and their pollution extremely difficult to quantify.

This type of cryptocurrency mining also incentivizes further oil and gas drilling, as it converts what would be a loss for drillers ("waste" flared gas that could go to beneficial end uses or minimized) into a new source of revenue.[86] Some miners claim these operations are a kind of environmental mitigation because they use the "waste" flared gas to generate electricity.[87] As one professor at University of California, Santa Barbara, has observed, "This is basically a way to monetize flaring. It's not a way to stop flaring."[88]

Just one of the companies engaging in flare-based generation for cryptocurrency mining, Colorado-based Crusoe Energy, claimed in April 2022 to operate 86 "Digital Flare Mitigation" data centers in Montana, North Dakota, Wyoming, and Colorado, with more planned in

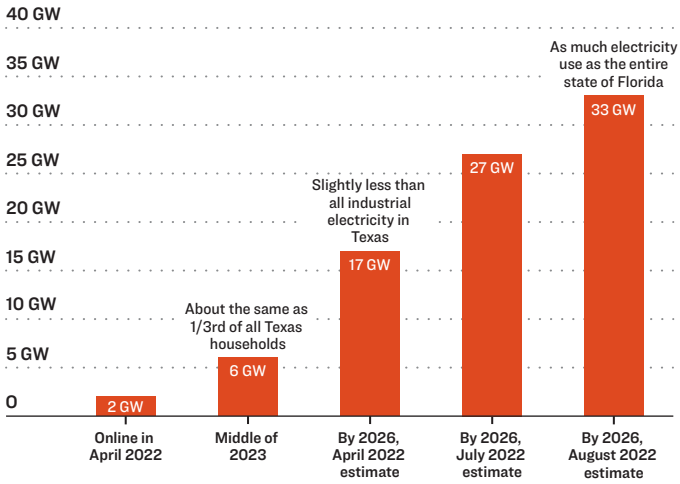
Texas and New Mexico.[89] Major oil companies have also expressed interest in these operations.[90] In March 2022, Exxon Mobil announced that it would consider expanding a North Dakota-based pilot program with aforementioned Crusoe Energy to Alaska, the Qua Iboe Terminal in Nigeria, Argentina's Vaca Muerta shale field, Guyana, and Germany, which would use up to 18 million cubic feet of gas per month.[91]

When regulators do locate and inspect wellhead miners, they can find violations of law. For example, in January 2022, inspectors from the Pennsylvania Department of Environmental Protection found 30 methane-gas-fired generators with an estimated capacity of more than 10 MW that were cryptocurrency mining without authorization.[92] In Adams County, Colorado, inspectors found four cryptocurrency mining operations at oil and gas wells operating without proper authorization.[93] Concerned about these operations and their pollution, in May 2022, the county "prohibit[ed] cryptocurrency / digital currency / electronic currency mining operations on oil and gas facilities."[94]

VI. The Climate and Energy Impacts of Cryptocurrency Mining in the United States are Substantial

The scale, and explosive growth, of cryptocurrency mining in the United States is hard to fully document, because most mining operations do not readily disclose their energy consumption, much less location and source of electricity. But both ground-up accounting and top-down estimates reveal the same trend: cryptocurrency mining operations have a substantial emissions impact. The most obvious way cryptocurrency mining increases global emissions is by driving huge increases in electricity demand. For example, Texas's grid operator, the Electric Reliability Council of Texas or ERCOT, recently disclosed that it expected nearly 6 GW of new cryptocurrency load to be interconnected by mid-2023.[95] ERCOT continues to adjust its forecasts of crypto-related load—announcing 17 GW by 2026 in April 2022,[96] to 27 GW by 2026 in July 2022,[97] to 33 GW by 2026 in August 2022.[98]

Texas Crypto Boom is Getting Even Bigger



Texas Blockchain Council. *ERCOT Large Flexible Load Task Force Meeting*, at 4 (April 22, 2022)

6 GW of cryptomining equipment operating at 85% load factor results in 44.7 TWh per year. Texas residential consumption in 2021 was 156.1 TWh. Source: Energy Information Administration, *Annual Electric Power Industry Report*, Form EIA-861. (Last accessed August 3, 2022).

33 GW of cryptomining equipment operating at 85% load factor results in 245.7 TWh per year. Total Florida consumption in 2021 was 244 TWh. Source: Energy Information Administration, *Annual Electric Power Industry Report*, Form EIA-861. (Last accessed August 3, 2022).

Based on the current grid generation mix and estimated Bitcoin energy consumption, we estimate Bitcoin mining in the United States is responsible for between 11 to 76 million annual excess tons of CO_2 in the last year, with a central estimate of 27.4 million tons CO_2.[99] For context, that is about three times as much CO_2 as was emitted by the largest coal plant in the United States in 2021.[100] The White House's OSTP arrives at a similar estimate, of about 21 to 35 million tons by mid-2022 from Bitcoin mining, and 25 to 50 million tons CO_2 from all cryptocurrency mining activity in the United States.[101] According to the U.S. House Committee on Energy and Commerce, the CO_2 emissions from global mining of Ethereum and Bitcoin in 2021 equaled the tailpipe emissions of more than 15.5 million gas-powered cars.[102]

In the absence of a comprehensive strategy to reduce all emissions from the power sector, adding this massive amount of new electricity demand will drive up emissions. Until the grid and all new generation build-out has been completely decarbonized, proof-of-work cryptocurrency miners will never exclusively rely on renewable energy to power their operations.

But cryptocurrency mining threatens to derail or reverse decarbonization in ways that go beyond simply adding electrical load. At a moment when the cost of fossil fuel generation exceeds wind or solar alternatives, the economic fundamentals of cryptocurrency mining distort the U.S. energy market and drive increased coal and gas generation.

The acceleration of cheap renewable energy in the U.S. pushed higher cost coal, gas, and nuclear plants out of service. As the cost and risk of retaining and operating coal plants increased, and the cost of new solar, wind, and storage — along with fossil gas — fell, coal plants retired in waves.[103] But to cryptocurrency miners, with their short-term focus on mining as much as possible, as quickly as possible, these same power plants look like an attractive, ready source of electricity, even if they do come with above-market rates. Ready access to transmission infrastructure, a low cost of acquisition, and utilities eager to offload liability make the purchase of otherwise uneconomic fossil fuel power plants a profitable choice for miners, at least in the short-term. In the long-term, acquisition of these power plants risks creating new long-lived environmental impacts and remediation obligations. And because cryptocurrency mining operations are focused on near-term margins, they are unlikely to foot the bill for these long-run social obligations.[104]

The largest partnerships between specific power plants and cryptocurrency mining operations we have been able to identify are at existing coal plants and gas plants that were on the verge of retirement, have struggled to find buyers, or were operating infrequently: Hardin (MT), Scrubgrass and Panther Creek (PA), Coal Creek (ND), and Merom (IN) (coal plants); and Greenidge and Fortistar North Tonawanda (NY), Odessa and Wolf Hollow (TX) (gas plants). In most cases, the resulting increased emissions of these power plants are directly attributable to the cryptocurrency mining operations that support their operations in part or in whole.[105]

These behind-the-meter operations are particularly pernicious but relatively rare. As discussed above, the majority of cryptocurrency mining operations appear to be served by electric utilities, taking service under a power purchase agreement or that utility's existing tariffs (i.e., retail rates). In both cases, energy is served by increasing the output of existing generators, or those on the operating margin, or adding new resources. In today's energy system, the operating margin is almost entirely composed of fossil generators that are able to serve incremental load.[106]

Marginal emissions, or the emissions that are associated with incremental additions or reductions in demand, vary across the country, primarily determined by the resource mix on the grid, and to a lesser extent market structures and local fuel costs. According to data aggregated by the EPA, these marginal emissions vary from half a short ton of CO_2 per MWh consumed in New England and California to just under one short ton of CO_2 per MWh in the Midwest / Central regions and Rocky Mountains, where coal dominates the margin.[107]

A 300 MW data center in Texas might be estimated to contribute 1.4 million tons of CO_2 to the atmosphere, while a similarly sized data center in North Dakota (not affiliated with a specific generator) might contribute more than 2 million tons of CO_2 to the atmosphere every year. In some cases, the net impact might be higher than the utility-wide average, such as when a utility procures from or constructs specific energy sources to serve its customers, and changes in the energy mix that serve the utility might be attributed to the new demand (at least financially).

It is at least theoretically possible for cryptocurrency miners to develop truly zero-emission sources of electricity. (See Section VIII.C below.) But simply purchasing energy from existing renewable sources is insufficient, because but for the cryptocurrency mining operation, energy from that renewable facility would be consumed by other customers. Additionality, or contracting for new clean energy sources, is key. Miners that fund *new* renewable development can fairly claim to be non-emitting. For example, Aspen Creek Digital announced in June 2022 that it is developing a 6 MW solar behind-the-meter cryptocurrency mining center in Colorado.[108] To the extent that Aspen actually builds new solar facilities and relies exclusively on the energy they produce, it is as close as feasible to a non-emitting mining facility, albeit a tiny fraction of overall cryptocurrency usage.[109] But as of this writing, we were unable to determine what, if any, steps have been taken to construct the facility.[110] The overwhelming majority of the 140 mining operations we were able to identify, in contrast, rely in whole or in part on fossil-fuel generation.[111]

VII. Cryptocurrency Mining Harms Communities and Electricity Ratepayers

A. Most Environmental Impacts from Cryptocurrency Mining Are Borne by Local Communities

The climate impacts of cryptocurrency mining will be felt globally, but the operations also have disproportionate and damaging impacts on local communities, as well as generating enormous quantities of electronic and packaging waste, which in turn cause toxic contamination where it is ultimately disposed.

1. Local Air Pollution

Cryptocurrency mining that relies on fossil fuel combustion for energy generation indirectly causes all of the air pollution impacts of the underlying combustion method. For coal combustion, this means fine particles, sulfur dioxide, nitrogen oxides, and air toxics; for gas, the biggest air pollution impact is typically nitrogen oxides. Where cryptocurrency mining occupies an existing generation plant, it is unlikely to add pollution controls unless compelled to do so. When cryptocurrency mining facilities use electricity from fossil-fueled grids, like most in the U.S. and especially so with a coal-heavy grid like Kentucky's, it increases the pollution in another community.

In fact, last year, the World Health Organization released new Global Air Quality Guidelines, finding that "[a]ir pollution is one of the biggest environmental threats to human health, alongside climate change." Air pollution exposure, especially to particulate matter, is estimated to cause 7 million premature deaths annually and result in the loss of millions more health years of life across the globe.[112]

2. Water Usage and Thermal Pollution

The environmental impacts of fossil-fueled cryptocurrency mining operations are not limited to climate and air pollution. Many cryptocurrency mining operations use water to cool their operations, whether at the site of the mining machines or the water use that comes with fossil-fueled electricity generation, or both.[113] The Fortistar North Tonawanda gas plant in New York, for example, will consume 500,000 gallons of water per day for cooling purposes once ramped up for full-time mining operations, approximately 12% of the City of North Tonawanda's current total water consumption.[114] This water will flow to the City's wastewater treatment facility, which is in need of $3 million in emergency repairs and $30 million for long term repairs, which will be borne by local residents.[115] The Greenidge gas plant, also in upstate New York, is permitted to discharge up to 134 million gallons of water, at temperatures up to 108 degree Fahrenheit, into the Keuka outlet at Seneca Lake.[116] This thermal pollution endangers health and wildlife habitability, including but not limited to potential harmful algal blooms, fish deaths, biodiversity loss and migration, oxygen depletion, direct thermal shock, and changes in dissolved oxygen.[117] And thermal pollution from the Merom coal plant in Indiana (which will supply 115 MW of power to a new AboutBit facility) has been associated with the "virtual collapse" of the largemouth bass population in the nearby Turtle Creek Reservoir.[118]

3. Fire and Safety Risk

Mining equipment operating 24 hours a day, 7 days a week in small, enclosed spaces generates tremendous amounts of heat, creating a fire risk.[119] The risks of fire at the facility can originate from "unsafe equipment, wiring failure, . . . overloading of electrical network[s], overheating of the equipment due to . . . incorrect cooling system[s]."[120] Cryptocurrency mining facilities often operate in low-tech environments, in previously unused warehouses, or old industrial sites.[121] Fires and fire risk are common enough as to drive a market in cryptocurrency mining insurance and industry "guidelines."[122]

There is also fire and explosion risk associated with electric grid equipment serving the mining operations, in addition to the mining facilities. For example, recently in Buffalo, New York, there was a fire and explosion from "faulty equipment" serving a mining operation.[123] Some localities have instituted new fire and safety regulations or instituted moratoria on the basis of fire risks for neighbors and damaged grid equipment not sized for the load.[124]

These fire risks are especially of concern in drier areas of the country where wildfires abound and especially in the dog days of summer, when drought warnings cover much of the country.[125]

4. Noise Pollution

While all fossil fuel plants entail air and water pollution, cryptocurrency mining introduces yet another local environmental harm: noise pollution.[126] Mining companies acknowledge this: Compass Mining's website explicitly

states that, "Bitcoin mining isn't a quiet activity. . . A typical ASIC's noise levels range between 50 DB and 75 DB, or a noise level similar to a food blender or a loud vacuum."[127]

Neighbors have reported much worse:

- At a mining facility in **Limestone, Tennessee**, residents have described the noise as "like a jet engine idling on a nearby tarmac."[128] A commissioner who voted to approve the operation told a reporter that he has "never regretted a vote like this one. I sure wish I could take it back."[129]
- In **Cherokee County, North Carolina**, residents offer that the noise is "like living on top of Niagara Falls" and "like sitting on the tarmac with a jet engine in front of you. But the jet never leaves. The jet never takes off. . . . It's just constant annoyance."[130]
- In **Elk County, Pennsylvania**, a local farmer said, "My family, farm, and businesses have been severely impacted by the constant noise from the site, and it has led to death for some of my animals as well as health issues with my horses."[131]
- In **North Tonawanda, New York**, one neighbor described it as "that whistling and that howling and it's nonstop." Another resident stated "she continues to hear the whine one mile away from the plant.[132]
- In **Adel, Georgia**: "An inescapable drone that is driving many of them crazy. 'It's comparable to torture,' said [a] city councilor who has heard the noise and received complaints from constituents." One local resident offered, "'I wear earplugs inside my own house' . . . The noise sounds like 1,000 hair dryers blowing in unison."[133]
- In **Plattsburgh, New York**, one local resident described the "constant, high-frequency whine . . . 'like a small-engine plane getting ready to take off.' It wasn't just the decibels, but the pitch: 'It registers at this weird level, like a toothache that won't go away.'"[134]

5. Enormous Amounts of Electronic and Other Solid Waste

ASICs, the specialized machines used exclusively in the proof-of-work cryptocurrency mining process, have a limited lifespan, and recent changes in the hardware (to mine faster) potentially increase machine turnover and thus the annual amount of electronic waste.[135] Today, the average lifespan of a well-kept, maintained machine is projected to be around 3 to 5 years. In harsh or poor conditions, they can deteriorate in as little as a few months.[136]

Cryptocurrency mining results in enormous amounts of electronic waste.[137] This externality of cryptocurrency mining also suffers from a lack of data, but a recent estimate found that in 2021 alone, proof-of-work mining generated more than 30,000 metric tons of waste,[138] which is comparable to the e-waste produced by the whole country of the Netherlands.[139] Much of this waste is sent to low-income communities around the world who bear the harms of this toxic pollution but do not see any of the profits from the mining.[140]

When cryptocurrency mining operations first begin, there is also a tremendous amount of solid waste from installation and construction. One community in North Carolina, for example, needed to revise their solid waste ordinances after large amounts of solid waste could not be handled by the local waste processing center.[141]

B. Impacts on Electricity Prices for Local Residents and Businesses

In a similar vein to the problematic climate impacts emerging from proof-of-work cryptocurrency mining, these operations harm existing electricity customers both by increasing the total *quantity* of electricity needed on the grid and by introducing specific risks that are attributable to the intensity, portability, and extreme time-sensitivity of cryptocurrency mining operations. In this section, we explore the risks faced by utilities and their ratepayers, grid operators, and localities when energy-intensive cryptocurrency mining operations move in.

1. Utilities, and Their Customers, Face Unique Risks from Cryptocurrency Mining Operations

High-density electricity users such as miners frequently demand the construction of transmission and distribution lines, substation upgrades, and other infrastructure to facilitate the delivery of huge quantities of electricity to a new energy intensive mining rig.[142] Ratepayers may be left on the hook for these investments if and when a cryptocurrency mining operation abruptly leaves (as they are generally capable of doing).[143] For example, one cryptocurrency mining operation in Washington that declared bankruptcy in 2018 left more than $700,000 in unpaid utility and electricity bills.[144] Mining operations may leave solely because they can get a better deal on electricity somewhere else. For example, after the New York Municipal Power Authority increased rates for supplemental electricity used by high-density load customers in Plattsburgh because the rates for local residents there skyrocketed, many cryptocurrency miners moved west to Massena, increasing electricity costs in Massena.[145]

There is ample evidence of utilities expending significant sums to serve cryptocurrency mining operations — financial outlays that will be passed on as higher rates to the utility's other customers. Americans are already struggling to keep up with their electricity bills, particularly those living in disadvantaged communities. 25% of U.S. households (30.6 million) face a high energy burden (i.e., paying more than 6% of income on energy bills) and 13% of U.S. households (15.9 million) have a severe energy burden (i.e., paying more than 10% of income on energy).[146]

As an example of customers being stuck holding the bag for costly infrastructure upgrades, one need only look to Kentucky. There, the Kentucky Public Service Commission recently approved $12.7 million in transmission upgrades for Big Rivers Electric to provide service to Blockware Mining in Paducah, the costs of which will be allocated across all of Big Rivers' ratepayers.[147] These investments are often made instead of long-overdue transmission upgrades that would benefit ordinary ratepayers.

In addition to discounted infrastructure, Kentucky also offers discounted electricity rates to cryptocurrency mining operations.[148] Recently, Kentucky Power, a utility serving 165,000 consumers in 20 counties, recently requested additional discounted electric rates to as many as eight new cryptocurrency mining operations, which would add more than 395 MW of new load for a utility with approximately 80% coal generation.[149]

Yet many Kentucky residents and local businesses struggle with ever increasing energy burden from their bills.[150] As the executive director for Appalachians for Appalachia, recently said, "[l]ocal energy infrastructure is being pushed to the limit. Meanwhile these miners are receiving benefits that local business owners, and everyday people, are not being extended as well."[151]

Nebraska customers are also being forced to pick up the tab for cryptocurrency miners. Compute North operates cryptocurrency mining facilities where power is supplied by the Nebraska Public Power District. In 2020, the Power District spent $17.6 million, or 18% of its 2020 capital budget, constructing a transmission line and substation to increase the delivery capacity to the Compute North facilities from 30 MW to 100 MW.[152] This new infrastructure was built specifically to serve Compute North, not for general benefit — but retail electricity customers will likely subsidize the cost. Customers will do so as the $17.6 million is rolled into the Power District's revenue requirement *and* through residential rates that are higher per-kWh than Compute North itself pays.

Empirical evidence strongly supports the conclusion that cryptocurrency mining operations push electricity rates higher for the surrounding community. Several other localities have seen local electricity prices rise when proof-of-work cryptocurrency miners show up. For example, in Plattsburgh, New York, residents' electricity bills increased 30% when a mining boom came to town a few years ago.[153] A recent study found that Plattsburgh residents and small businesses paid $189 million and $90 million, respectively, more in electricity bills due to crypto's arrival.[154]

Some states, recognizing the risks of cryptocurrency mining's unique position as a new, unregulated industrial user, have begun requiring miners to pay for upgrades as opposed to passing those onto the community at large. Likewise, some utilities, recognizing the risks cryptocurrency mining operations pose to their existing customers, have begun to develop tariff provisions to mitigate these risks. In November 2021, Idaho Power became the first investor-owned utility to submit an application with its state regulator, the Idaho Public Utilities Commission, to create a separate class of "Speculative High-Density Load Customers," since the utility received at least 17 separate inquiries totaling 1,950 MW — roughly 52% of its until-then-record peak demand.[155] According to the utility, these inquiries reflected customers with: (1) high energy use and load factor; (2) the ability to relocate and disaggregate equipment to obtain favorable rates; (3) volatile load growth and load reduction; (4) high responsiveness to short-term economic signals or volatility; and (5) lack of demonstrated long-run financial viability.[156] To meet demand from these mining operations, Idaho Power would need to procure additional generation resources or wholesale energy purchases, but doing so risked over-procurement (and stranded assets) if and when these highly mobile and high-risk customers left or went out of business.[157] On June 15, 2022, the Idaho PUC approved Schedule 20 for Speculative High-Density Load[158] — finding that the new rate is "fair, just, and reasonable."[159] However, cryptocurrency mining company GeoBitmine LLC has challenged the new Schedule, leaving its ultimate fate uncertain.[160]

Similarly, prompted by approximately 150 MW of "crypto-mining related interest" in its service territory, Entergy Arkansas recently submitted a proposed tariff for "Large Power High-Load Density" customers. Entergy's filing provides more examples about how explosive growth of crypto's energy consumption can harm customers. According to testimony submitted by Entergy, a 15′ x 15′

x 30′ pod of mining machines in the New Orleans area used more energy than the nearby airport.[161] Entergy also described an incident in 2019 where a new cryptocurrency mining customer requiring significant facility upgrades opted to pay a monthly minimum for those upgrades under Entergy's tariff—only to move its shipping containers "virtually overnight" "shortly after taking service . . . effectively disappearing" and leaving Entergy unable to even reach the customer to recoup their upfront costs, forcing existing customers to pick up the bill.[162]

To prevent such interconnect-and-run incidents from recurring, Entergy Arkansas's rate filing proposes safeguards: to protect customers from a disappearing miner, new cryptocurrency customers would be required to pay a security deposit; contribute to any construction upfront; and post a surety bond or letter of credit.[163] And to address the potential increase in capacity requirement due to the influx of shipping containers full of mining equipment with insatiable energy demand, the cryptocurrency mining tariff would require miners to select between two interruptible rates that would allow Entergy or the grid operator to require the miner to cease operation on 30 minutes to an hour's notice ten to twenty times per year, ensuring the additional cryptocurrency load is available as a demand response resource and will not—at least in theory—add to Entergy's capacity obligations and require it to construct new generation resources.[164]

Some utilities have gone further in an effort to protect their existing ratepayers: the Chelan County Public Utility District in Washington instituted two moratoriums on new mining operations as well as a new rate structure to discourage miners from setting up shop within its footprint after the utility was overwhelmed by demand for cheap hydropower from crypto miners.[165] The New York Municipal Power Agency, an association of 36 municipal power authorities, petitioned the New York State Public Service Commission to prevent high-density load customers, specifically cryptocurrency companies, from requesting disproportionately large amounts of power, which according to those utilities could be up to 33% of a municipal utility's total load.[166] While not a utility, Missoula County, Montana adopted emergency "green" regulations to require cryptocurrency miners to purchase or build new sources of renewable energy to offset 100% of their energy demands.[167]

It remains to be seen whether the Arkansas Public Service Commission will approve Entergy's proposal, or whether the tariff's safeguards will be sufficient to protect Entergy's current customers from stranded transmission or generation asset costs. But utilities should consider incorporating elements of Entergy's proposed tariff or the Chelan County Public Utility District's proposed rate structure—upfront deposits, guarantees, or cost coverage for infrastructure investments; interruptible rates designed to avoid the need for new capacity buildout; and even temporary moratoria[168] as appropriate—as requests from new cryptocurrency mining customers accelerate. Fitch Ratings, a ratings agency that advises on the creditworthiness of both investor-owned and public power utilities, has already advised utilities as much.[169]

2. Rural Electrical Cooperatives and Cryptocurrency: A Costly Partnership for Ratepayers

One pattern that emerged in our research is the predilection of cryptocurrency miners for rural electric cooperatives. Rural electric cooperatives—which supply 13% of U.S. electricity to 42 million people over 56% of the U.S. land mass[170]—often lack the regulatory oversight that investor-owned utilities are subject to. Thus, rural electric cooperatives generally do not need to obtain approval from state or federal regulators to propose new rate structures or enter into large-scale contracts. Although regulation varies by state, many rural electric cooperatives have only minimal reporting requirements (such as a ten-year or integrated resource plan) to the state utility commission and most (but not all) are exempt from oversight by the Federal Energy Regulatory Commission with respect to their wholesale rates.[171] Cooperatives also lag investor-owned and municipal utilities in decarbonization; as of 2020, "six out of the top ten most carbon-intensive emitters were cooperatives."[172]

In theory, ratepayers are protected from excessive rates by cooperatives' governance structure and non-profit status. Ratepayers are also "members," who vote for a cooperative's board of directors and thus select its leadership. However, cooperative elections tend to be low-information and low-turnout, and incumbent leadership is rarely unseated. Further, under the cooperative model, if rates are higher than necessary to cover costs, any excess income is returned to member-customers in the form of "patronage capital" or "capital credits." In practice, as Representative Jim Cooper (TN) has described, cooperatives rarely provide a full and accurate accounting as to whether they have distributed patronage capital to member-customers.[173]

Without active engagement by customers (and greater transparency than cooperatives generally provide),

cooperatives tend to increase sales rather than minimize rates.[174] Courting large-scale cryptocurrency mining operations is a surefire way to increase sales. The complex changing of ownership and related transactions surrounding the gigawatt-scale, coal-burning Merom Generating Station in Sullivan County, Indiana, previously discussed in Section V, is one example of a cooperative increasing electricity sales through partnership with cryptocurrency mining operations.[175] The upshot of the deal (which involves selling a coal plant to a coal mining company) is that a coal plant previously slated to retire in 2023 will now operate indefinitely.

Merom is not the only example of cooperatives entering into large-scale electricity sales to cryptocurrency mining operations with little or no transparency and at significant risk to their member-customers. Big Rivers Electric Cooperative reached a 100 MW power purchase agreement with Blockware Mining to supply its mining operation in Paducah, Kentucky.[176] According to local reporting, Big Rivers intends to spend $12.7 million on infrastructure upgrades at the proposed mining site.[177] And the Rayburn County Electric Cooperative in North Texas found that serving two cryptocurrency mines interested in connecting to the utility's service territory north and east of Dallas would require up to $40 million to fortify power lines to avoid blackouts while consuming enough electricity to power as many as 60,000 Texas homes.[178] As of this writing, it is unclear whether the Rayburn County Electric Cooperative followed through on these investments, especially considering that "upgrades to the grid threaten to drive up bills for consumers already shouldering price shocks for almost everything."[179]

3. Grid Impacts and Reliability

Proof-of-work cryptocurrency mining operations drawing energy from the grid are placing a mostly-unplanned-for load on already-strained grids across the country. In January 2022, Fitch Ratings issued research finding that "[d]igital asset or crypto currency mining in the US could pose power supply risks to public power utilities unless they are sufficiently mitigated."[180] This is largely due to cryptocurrency mining's energy intensity and ability to quickly scale operations up or down.

The sheer speed and magnitude of load growth associated with cryptocurrency mining is unprecedented and threatens the ability of both generation and transmission resources to get electrons where they are needed without overheating or unbalancing the physical infrastructure. For example, if mining operations for which we were able to find SEC reports and other data expand to the extent their literature suggests, by the fourth quarter of 2022, there could be up to 1,626 MW of demand directly for proof-of-work mining operations in New York State alone. Assuming these facilities operate 24/7/365, their annual energy use of over 14,000 GWh would be a whopping 9.5% of New York State's total 2020 electricity consumption.[181]

Perhaps the most worrying site of potential grid instability due to cryptocurrency mining load increases is Texas, and how that impacts Texans both from a safety perspective and financially. The instability of Texas's grid was exposed, with tragic consequences, by Winter Storm Uri in February 2021, in which at least 246 people lost their lives,[182] and 69% of Texans lost electricity for an average of 42 hours.[183] Evidence is also becoming public that cryptocurrency miners are taking advantage of such extreme weather. One cryptocurrency miner resold electricity valued at more than $125 million to the Texas grid during that storm and the state still owes the miner $86 million, with that amount likely to be paid by ordinary utility customers.[184]

A February 2022 report by five former Texas Public Utility Commissioners and a former regulatory advisor found that ERCOT still has not improved its ability to restart power plants during a blackout, improved its load forecasting and resource assessments (including accounting for extreme weather), or adequately winterized the state's gas system.[185] In 2021, an analysis by ERCOT found that four of the five extreme risk scenarios considered by ERCOT would leave the grid short of a significant amount of power.[186]

Yet, as of August 2022, 33 GW worth of cryptocurrency mining operations have applied to connect to the Texas grid over the next several years — a third more than ERCOT's announcement in April 2022.[187] This 33 GW figure represents 41% of ERCOT's record peak demand of 79.8 GW on July 20, 2022.[188] By some measures, this is equivalent to New York State's entire energy demand.[189] If the cryptomining facilities run at an 85% load factor, the would consume as much electricity as the entire state of Florida.[190] Wood Mackenzie predicts that Bitcoin mining could more than double the *rate* of demand growth in ERCOT's territory.[191]

Further impacting average Texans, it appears that cryptocurrency miners are buying electricity low and selling it high. As the Tech Transparency Project recently found: "Programs that appear to be unique in the country allow miners to leverage their contracts to resell electricity at massive mark-ups and collect millions of dollars in

incentive payments from the state grid operator. . . . Some miners already view themselves as energy traders. One bitcoin miner called his company '[a]n energy arbitrage operation disguised as a bitcoin mining company.'"[192]

In response to the overwhelming influx of cryptocurrency mining, ERCOT has instituted new processes aimed at ensuring the system can handle the enormous load.[193] As a temporary measure, ERCOT will now require new, large cryptocurrency miners to seek permission to connect to the state's power grid and will require utilities to submit studies on the impact of miners and other large users on the grid.[194] Any project that will add 20 MW of demand on the site of a generator within the next two years, and any project that will add 75 MW of demand without its own power generation on site within the next two years, will have to undergo a review process.[195] Local officials are also sounding the alarm on grid instability that would be caused by cryptocurrency mining operations. For example, the City of Brenham's Planning and Zoning Committee said that the city's current power grid cannot sustain the amount of electricity required for large scale and commercial-like cryptocurrency mining setups, thus necessitating the committee halting the approval of more mining setups.[196]

4. Tax Incentives for Cryptocurrency Miners are Breaking the Bank

Making matters worse, some states provide additional subsidies or tax breaks in an effort to encourage cryptocurrency mining operations. Kentucky passed a law last year that waives taxes on energy purchases by cryptocurrency mining companies, while Wyoming exempted from taxes any natural gas used to power mobile mining rigs. In 2021 alone, a total of 33 states had bills supporting cryptocurrency developments and 17 enacted new laws to create working groups, provide tax breaks, and/or establish subsidies for cryptocurrency mining operations, according to the National Conference of State Legislatures.[197]

Kentucky has proven particularly short-sighted in offering benefits to cryptocurrency miners in addition to discounted electricity, offering cryptocurrency-specific tax incentives estimated to cost Kentucky taxpayers at least $9 million a year in lost revenue.[198] These tax incentives include "tax exemptions totaling 9 percent on electricity consumed at larger cryptocurrency mining operations, . . . sales-tax refunds on mining equipment, as well as potential incentives on income taxes and wage assessments."[199]

Kentucky is not alone. In Texas, the City of Corpus Christi is forgoing $7 million annually in sales tax and franchise fees, equating to $70,501,509 over ten years, to accommodate Bootstrap Energy's $1.1 billion cryptocurrency mining operation.[200] Bootstrap has contracted with AEP Texas for 600 MW.[201]

5. Reports of Cryptocurrency Mining Jobs Have Been Greatly Overstated

Despite the purported economic development justification for cryptocurrency mining incentive programs, these operations actually create few jobs. Most of the work that is created at cryptocurrency mining sites is hiring temporary workers to set up the mining machines; less than a dozen people may be required to maintain the operation. As a Berkeley Haas professor similarly observed: "These are warehouses full of computers and they only require one or two IT people to run the whole operation, so it's unlikely that it brings jobs or stimulates the economy."[202] And Fitch Ratings found "[c]ryptocurrency mining operations typically bring in very little additional economic benefits in the form of jobs or ancillary business to a local economy."[203]

Here are just a few examples of the meager job benefits of cryptocurrency mining operations:

- The **Blockware Mining** operation in Paducah, Kentucky will provide just 10 full-time jobs in its initial phase.[204]
- **Core Scientific**, with seven facilities, reported 205 full-time employees in the United States, as of December 31, 2021.[205]
- **Marathon Digital Holdings**, which mines cryptocurrency in Montana and Texas, has nine full-time employees, as of December 31, 2021.[206]
- **Stronghold Digital Holdings**, which mines cryptocurrency in Pennsylvania, has 16 full-time employees, as of March 24, 2022.[207]
- **AboutBit**'s $50 million facility adjacent to the Merom coal plant in Indiana is expected to create 15 jobs.[208]
- The **Greenidge** cryptocurrency mining operation in New York employed 5 union workers on site as of October 2021.[209]
- "A $1.9 billion facility by **FX Solutions** and **Atlas Power** near Williston, North Dakota, would create around 100 temporary construction jobs and support only 30 employees over the long-term. Meanwhile, the first stage of the project would draw 240 MW of electricity—roughly, the amount of energy needed to power the city of Fargo—and eventually ramping up to a powerhouse 700-megawatt scale."[210]
- "In Rockdale, Texas, during the BTC boom of 2017, a cryptocurrency mining company promised to build

the largest crypto mining facility in the world—one that could eventually be used for other data-driven applications and create more than 300 jobs. In reality, the facility only generated 14 of 350 promised jobs and was quickly scaled back."[211]

The municipalities who handled an earlier boom in cryptocurrency mining in the mid-2010s can attest to the lack of economic development benefits from cryptocurrency mining. The former mayor of Plattsburgh, New York has said that due to the automated nature of these servers, the new mines provided few local jobs: "when you look into it, and I have—[the jobs,] they just don't materialize."[212] "I'm pro-economic development, but the biggest mine operation has fewer jobs than a new McDonald's."[213] The former head of the Bonneville Power Administration and Chelan County Public Utility District testified before the U.S. House Energy and Commerce oversight subcommittee panel, stating that: "we heard substantial reservations from our community about supporting cryptocurrency mining due to . . . [the r]elatively low number of local jobs per unit of electricity consumed."[214]

For local communities, the above-described tax incentives and promise of jobs that do not materialize end up being a bad deal; a recent Forbes study estimated that cryptocurrency mining tax incentives end up costing counties and municipalities across the U.S. roughly $1 million per job.[215] As one reporter who interviewed community members in Kentucky observed: "Some see echoes of what they say were the worst elements of the now largely defunct coal industry: out-of-state money, absentee owners, and huge fortunes made with little wealth trickling down to local communities."[216]

VIII. Breaking Through the Bitcoin Myths

Proponents of proof-of-work cryptocurrency often make grandiose statements about how energy-intensive mining advances environmental and climate goals, using a variety of half-truths and cherry-picked information. In this section, we explore the narratives and messaging used by proof-of-work miners, identify the elements of truth that make some of these statements so confounding, and explore how climate and environmental advocates can probe these often deeply misleading statements.

Myth 1: Cryptocurrency Mining is Already Sustainable Because it is Located *Near* Clean Energy, or Because it Purchases Renewable Energy Certificates or Carbon Offsets

1. Claims of Co-Location

It is not uncommon for cryptocurrency mining companies and advocates to tout that, while their operations are energy intensive, they are "sustainable" or run on renewable energy.[217] One industry-funded organization, the Bitcoin Mining Council, claims 58% of energy used to power Bitcoin in 2020 was from renewable sources, based on selected companies' self-reporting.[218] The Cambridge Centre for Alternative Finance puts this number much lower—at 39%.[219]

What explains the discrepancy? In many cases miners are claiming (or implying) "renewable" energy simply by being in proximity to wind or solar farms with which they have no contractual relationship. In our opinion, they're greenwashing.[220]

For example, in Argo Blockchain's 2021 Sustainability Report, released August 18, 2022, the company claims that it "is taking action against climate change" by "select[ing] sustainable energy sources."[221] Argo's primary mining facility is the Helios facility, a 200 MW facility east of Lubbock, Texas. Argo does not hold a power purchase agreement with a renewable energy provider, instead noting that "Argo currently uses grid electricity in a low carbon part of the ERCOT market,"[222] and has purchased renewable energy certificates (RECs).[223]

But simply locating new demand in a region rich in renewable resources does not mean that the new demand is served by the renewable resources of that region. When a load is added to the grid, it is served by the generation available on the grid at the time electricity is consumed (unless it specifically causes new generation to be built for its exclusive use). Large loads, like cryptocurrency mining operations, can themselves cause changes in the generation mix as the grid dispatch patterns shift in response to the new load's requirements. The generators that adjust output in response to load changes will set the "marginal" emissions rate.[224] In almost every circumstance, new demand drives an instantaneous increase in the output of fossil generators.[225]

For example, the aforementioned Argo Helios facility in West Texas pays for market-based grid generation, and therefore drives changes in marginal generation in Texas, which is typically gas and coal. According to recent research from the Proceedings of the National Academies

of Science, while the average emissions rate of all generation in West Texas has fallen to about 0.375 tCO_2/MWh, the marginal emissions rate holds steady at around 0.5 tCO_2/MWh, or equivalent to the output of a gas-fired generation station.[226] The current wind in West Texas will generate irrespective of whether Argo's Helios facility exists or not. Argo does not pay for incremental wind generation, and has not built wind to serve its facilities. Therefore, it drives existing fossil-based generation to increase its output—and results in an increase in emissions.

2. Claims of "Carbon Neutrality" by Purchasing Renewable Energy Certificates or Carbon Offsets

Co-location is not miners' only form of greenwashing. Miners often claim "carbon neutrality" when in fact they are simply purchasing offsets or renewable energy certificates—paying renewable generators elsewhere while increasing load on (and pollution from) fossil fuel plants locally.

Examples abound. In late 2021, at the opening of its massive Denton, Texas facility, Core Scientific claimed that it would "increase the Company's total power capacity to more than 800MW while remaining 100% net carbon-neutral."[227] This claim of carbon neutrality is entirely based on unbundled renewable energy certificates (RECs).[228] Prior to Denton, Core's largest facility was a 125 MW facility in Calvert City, Kentucky, opened in late 2019. Core Scientific's Calvert City facility holds a contract with the Tennessee Valley Authority, a provider whose resource mix is just 3% wind and solar.[229] And yet Core Scientific's claimed carbon neutrality is entirely based on RECs it purchases from wind farms in North Dakota.[230] Argo Blockchain, discussed above, too has purchased renewable energy certificates to offset its fossil generation.[231]

Separate from RECs, several mining companies rely on purchase of carbon "offsets" to advertise to the public and their investors that they are a sustainable operation. For example, Greenidge Generation LLC has claimed that it is "significantly reducing greenhouse gas emissions now," by purchasing voluntary carbon offsets, despite using a fossil gas plant 24 hours a day to mine cryptocurrency.[233] As a general matter, many carbon offsets programs are unverifiable and hard-to-measure, and in many instances, not actually reducing carbon pollution.[234] That being said, non-proof-of-work blockchain technology could be a key tool in properly verifying whether offsets are achieving

Claims of Carbon Neutrality via Voluntary REC Purchases

To drive clean energy buildout, some states have established renewable portfolio standards (RPS), that require a certain minimum amount of electricity to be generated by "renewable resources." Most states allow utilities to demonstrate compliance with RPS by retiring RECs. Utilities can either generate their own RECs through their own renewable resources, or can purchase RECs on the market. RECs can be purchased with or without the associated electricity. RECs that are purchased without the accompanying electricity are known as "unbundled RECs." Each REC represents the non-energy attributes of a megawatt-hour generated by renewable energy resources. In other words, when you purchase a REC, you're purchasing the legal right to claim all of the "renewableness" of that electricity. Often the REC will also include the avoided emissions value of that MWh of electricity. However, the avoided emissions value of any particular MWh of renewable energy is highly dependent on the grid mix and marginal resource at the time the MWh is generated. In other words, the avoided emissions value of a REC can vary from state to state, month to month, and hour to hour. Because clean energy deployment today far exceeds RPS standards in most states, there is a glut of RECs on the market. Some people and businesses purchase these excess RECs in order to claim their homes or businesses are powered by clean energy. In some cases, these REC purchases can effectively spur new clean energy development that offsets fossil energy: specifically, this can occur where the demand for the REC is incentivizing the construction of new, additional renewable electricity that would otherwise not be built. But in most cases, REC purchases provide little or no additionality: usually, REC sales revenues are not driving the decision about whether to build a new wind or solar facility. A clean energy project would have been built irrespective of the REC sale. Where the REC sale is not the result of additional, incremental clean energy development, it has little or no incremental climate benefit.[232]

reductions in pollution.[235] But, the key is to reduce pollution in the first place, not create a problem and then seek creative new ways to account for the harms.

Myth 2: Cryptocurrency Mining Uses Energy That's Being Wasted From Variable Wind and Solar Output

One of the most common storylines from cryptocurrency mining proponents is that cryptocurrency mining thrives on energy that would otherwise be wasted from "curtailed" solar and wind projects.[236] Curtailment for wind and solar projects occurs when an energy system produces more electricity than can be absorbed by demand at a particular moment, or more electricity than can safely fit on a transmission system. In these circumstances, grid operators will direct to generators to reduce, or cease operations. Wind and solar projects are particularly susceptible to curtailment because they have almost no cost to start and stop, unlike large thermal generators that may take hours to turn off, or even succumb to damage if turned off too quickly.

As renewable energy penetration has grown, so has curtailment. In California's electricity market (CAISO), curtailment has risen to 2.1 million MWh in 2022—or an 81% increase from 2021.[237]At a first glance, it might therefore appear that CAISO could handle a 200 MW cryptocurrency facility to harness the 1.5 million MWh of "wasted" energy in 2021.[238] In reality, curtailments are sporadic. Measured in five-minute increments in California, there were only 15% of hours in which curtailments rose above 200 MW in 2021.[239] In other words, a 200 MW mining facility in California could have only operated on "free" just energy 15% of the time, a daunting prospect for an industry that typically requires mining operations to operate around-the-clock to be profitable. A 2019 paper exploring cryptocurrency use of curtailed resources concluded that a cryptocurrency operation seeking to maximize profit by operating only on curtailed energy would only operate about half the time, and that a cryptocurrency mining operation scaled to consume all of the curtailed energy would lose an extraordinary amount of money.[240]

Even if absorbing curtailed wind and solar worked in theory, in practice it ignores that clean energy developers actively seek to avoid curtailment by integrating into regions not susceptible to oversupply. Further, utilities, states, and the federal government are working quickly to build transmission that would relieve congestion and constraints that can lead to curtailment. And, finally, energy storage (i.e., batteries) work to both absorb any excess clean energy *and* redeploy it during hours of need, presenting a far superior solution to the problem of curtailment.

Only in the edge cases where an extraordinary amount of clean energy is built without storage or sufficient transmission, or where cryptocurrency miners are willing to locate behind transmission constraints, run at thin capacity factors, and cease operations when transmission and/or storage come online does this thesis hold water. We are not aware of any cryptocurrency mining facilities currently operating in the U.S. that were built—or financed—with these constraints in mind.

Myth 3: Cryptocurrency Mining Incentivizes Clean Energy Development, or Helps to Decarbonize the Grid

Proof-of-work enthusiasts argue cryptocurrency mining will drive clean energy development and decarbonize the grid.[241] The most carefully constructed of these arguments essentially stipulates that the primary barrier to massive clean energy deployment is transmission congestion (causing curtailment and reduced economic margins for new renewable development) and integration (lengthy queues to interconnect to regional grids). Proponents argue that the incremental revenue from cryptocurrency mining could incentivize the development of wind and solar energy that would otherwise not be deployed, either because grid revenues are insufficient or because a location is transmission congested.

But this theory rests on the same faulty assumptions as the "waste electricity" thesis: that renewable developers will gamble on long-term transmission build-out and cryptocurrency miners will be willing to forgo mining (and profits) whenever wind or solar generation dips—and cease operations or limit itself to curtailed electricity once the renewable resource can serve a general load.

The leading thought paper on cryptocurrency mining as a driving force for more clean energy acknowledges that mining operations would likely "still mine with grid electricity during other periods when profitable to do so, so it wouldn't be entirely green from day one."[242] But more to the point, if a clean energy facility is built entirely to serve a cryptocurrency mine without respect to its ability to serve the remainder of the grid effectively—or at all—then it has little to no value in decarbonizing the remainder of the grid.

Moreover, there are other constraints to clean energy deployment beyond interconnection delays (or curtailment caused by inadequate transmission

infrastructure): supply chain (i.e., materials), state or local policies, land use, and labor availability. To the extent cryptocurrency miners induce developers to locate wind and solar farms at non-grid useful locations that remove clean energy from the critical supply chain, they remove opportunities to decarbonize other elements of the grid.

Even if a mining operation did incentivize new renewable development in a location where interconnection delays were the only barrier to development, to further grid decarbonization, the mining operation would have to go away in a timeframe that is relevant for decarbonization. For that renewable resource to have decarbonization value, it must *offset* existing fossil fuel use in some way, either by reducing utilization of fossil fuel power plants, or enabling electrification of other end uses traditionally powered by fossil fuels, such as transportation or home heating. To realize that outcome, the cryptocurrency mining facility must cease to exist, allowing that electricity to flow to those other purposes. As of yet, no proof-of-work proponents have come forward with a solid plan that would allow a developer to build clean energy for an offtaker that expects to go out of business.

Instead, miners have done the opposite. For example, Compute North has recently announced that it has energized a new 280 MW mining facility near Odessa, Texas, which sits "behind the meter" at a wind farm.[243] The wind farm in question is King Mountain Wind Ranch,[244] a 278 MW wind farm built in 2001 and owned by FPL (NextEra).[245] For the last two decades, King Mountain has contributed to the larger Texas grid, and will now be taken *out* of circulation for grid use. So, while the Compute North facility may be able to legitimately claim that it uses primarily wind energy, this type of project is not additional and is not contributing to broader decarbonization of the energy system. Instead, it represents price seeking behavior from the wind farm owner, resulting in *less* overall renewable energy on the broader grid.

Myth 4: Cryptocurrency Mining "Acts Like a Battery"

Cryptocurrency mining proponents make the perverse claim that "Bitcoin mining is strengthening the grid,"[246] and "provide[s] critical grid reliability products usually provided by fossil fuel plants."[247]

Mining operations simply do not provide ancillary services, such as load balancing, that maintain the operability of the grid. They also do not provide storage capacity. Energy consumed by a mining operation cannot be exported or redeployed.

When miners talk about "grid benefits," they are actually touting an ability that *all* large-scale customers have: The ability to shut off in emergencies or periods of peak demand. In the middle of a heat wave causing high electricity demand, Texas Bitcoin miners voluntarily shut down their operations, curtailing 1,000 MW of load in mid-July 2022 for 3.5 hours.[248]

But is cryptocurrency miners' willingness to pause operations during times of high demand and grid strain really a grid service? As external experts put it: it's complicated.[249]

For most grids, the demand for electricity varies hour by hour, day to day, and month to month. On particularly hot or cold days, demand may spike well above normal use. The cost of maintaining capacity to serve those peak hours, and the cost of operating the most expensive generators to serve these peak hours, can be extreme—but failing to serve load during the highest moments of strain can be even more costly for customers. Utilities and grid operators often hold capacity in reserve simply to serve those peak conditions.[250] Paying a customer with non-essential energy needs to reduce their demand can be a way of aligning demand with supply and retaining reliability, a practice known as "demand response."[251]

Most industrial customers do not adjust their energy use based on the real-time price of electricity, which constitutes a relatively small portion of their overall costs (and thus any savings would be heavily outweighed by disruptions that might have cascading impacts on meeting production deadlines, etc.). Demand response payments help make non-price-responsive customers responsive: a manufacturing plant might incur substantial operational cost and product risk when it stops operation, or other types of data centers may impair customer services by ceasing operations. But cryptocurrency miners are only responsive to electricity prices, and have no other service provided to customers aside from processing cryptographic puzzles: if the cost of energy rises above their breakeven, they can simply cease operations without experiencing additional costs or inconvenience.[252]

Unless a demand response program is carefully calibrated to cryptocurrency miners' extremely low costs of temporality paused operations, miners effectively become energy traders, able to convert cheap electricity into cryptocurrency most hours, while also receiving high prices for foregone electricity during peak periods or emergencies. During this summer's heat wave in Texas,[253] Riot Blockchain announced that it received $9.5 million (equaling the value of 439 Bitcoin at the time) in demand response payments in July alone.[254] In addition to this

hefty payout, Riot still was able to mine 318 Bitcoin that month.[255] In fact, demand response company Voltus estimates that a cryptocurrency mining company can generate up to 10% of its annual revenue by providing shutdown services to the grid.[256]

By increasing the demand on the grid, miners increase the need for demand response, the cost of such programs, and thus the cost of providing electricity to all other customers.[257] ERCOT's independent market monitor expects that Texans could be paying an extra $1.5 billion for electricity this year alone[258]—partially to pay cryptocurrency miners to shut down their operations during high demand.

As explained by Professor Severin Borenstein,

> *[T]he crypto mining business model is based on buying electricity at wholesale prices or on a real-time variable price tariff. They would already have a strong incentive to cut back during grid emergencies without the additional payments from the demand response program, especially in Texas with its $5000/MWh wholesale price cap. That means the mining companies get paid for taking demand off the grid that they never would have put on the grid at those high prices anyway.*[259]

Myth 5: Cryptocurrency Miners are No Worse than Any Other Electricity Users

Many miners will respond to critics of its insatiable need for energy by comparing it to other industries such as banking, telecommunications, or to data center operations.[260] But as described above, the huge premium placed on immediate access to large amounts of electricity without the long-term commitments necessary to finance renewable development attract cryptocurrency miners to fossil fuel sources, such as Hardin, Greenidge, Merom, Scrubgrass, or coal-heavy grids like Kentucky's.

Electricity demand in comparable sectors has not increased and, in some cases, even declined as energy efficiency increased.[261] For example, electricity demand by data centers has not increased, even though internet traffic and data center workloads have increased significantly.[262] In sharp contrast to cryptocurrency mining, data transmission networks and mobile communications networks are rapidly becoming more energy efficient.[263] However, even as ASICs have become more energy efficient than the hardware previously used for cryptocurrency mining, the efficiency gains have not resulted in decreased overall energy consumption because of the substantially increased scale of mining.[264]

Moreover, Bitcoin's ratio of energy consumption to human participation—people actually buying Bitcoin, holding it, or even working at mining facilities—is wildly larger than other electricity users. Bitcoin already uses half as much electricity as the entire global banking sector, according to one estimate, and will overtake the banking sector within two years if current trends continue.[265] One study estimates that the average electricity footprint of non-cash transactions by the global banking system is no more than 0.4 kWh, while the average electricity footprint per Bitcoin transaction ranges from 491.4 kWh to 765.4 kWh.[266] By some estimates, a single Bitcoin transaction uses more energy than 100,000 Visa transactions.[267]

IX. Recommendations to Mitigate the Risks of Proof-of-Work Cryptocurrency Mining

Proof-of-work cryptocurrency mining poses significant risks to grid stability, retail electricity rates, our climate, and local air and water quality. Therefore, policymakers and regulators at all levels of government, as well as utilities and impacted community members, should review proof-of-work cryptocurrency mining proposals carefully with these risks in mind.

Because the type of operations and impacts of cryptocurrency mining vary from community to community, solutions will necessarily be project-specific. As such, we offer the following high-level recommendations to policymakers, regulators, utilities, and impacted community members as they face the risks of proof-of-work cryptocurrency mining.[268]

LOCAL GOVERNMENTS, DECISION-MAKERS, AND COMMUNITY MEMBERS

Given the significant local impacts and outsized role of local decision-making in the approval process for cryptocurrency mining operations, local governments, including zoning and planning boards, as well as community members are on the front lines of the cryptocurrency mining boom. As such, local actors should approach proposals for new cryptocurrency mining facilities with an eye toward noise pollution, whether

they truly create stable, good-paying jobs, what grid and infrastructure upgrades are needed, fire and safety risks, as well as increases in local air, water, and solid waste pollution.

- **Mitigate local air, water, and solid waste pollution.** In addition to any local air pollution from the electricity generated to power mining operations, mining operations can use significant amounts of water for cooling. In water-constrained areas of the country, local regulators should assess the consumptive needs of cryptocurrency mining operations, particularly if the mining operation uses municipal (i.e., treated) water supplies that might impact residential water costs. In addition, mining equipment, after their useful lives are over, contribute to significant e-waste pollution. The initial construction of a mining facility also creates a large amount of solid waste. Preventative measures can be taken to ensure recycling and proper waste handling. States and municipalities with climate laws and regulations on the books are well-situated to make some of these arguments.
- **Calibrate or forego economic development incentives.** Cryptocurrency mining operations offer relatively few local jobs. Prior to offering economic development incentives, local governments should require cryptocurrency miners to provide a guarantee for a high number of local jobs over a sustained period. Any tax incentives or local municipal utility incentives should be carefully weighed against a realistic assessment of job growth potential, as well as other costs borne by the community as a result of the operation.
- **Ensure miners bear their fair share of grid and infrastructure upgrade costs.** Large energy consumers such as cryptocurrency mining operations may require grid and infrastructure upgrades, which may be paid by local governments or all electric utility customers. Utility regulators and local governments should ensure that ratepayers and community members do not foot the bill for these projects unless they benefit the community as well.
- **Protect against fire and safety risks.** Cryptocurrency mining rigs can present a unique risk of overheating and fire risk. Local governments should ensure that facilities have the technical capacity to mitigate fire, and carry appropriate levels of insurance. Additionally, local governments in cold weather climates can require the excess heat from cryptocurrency mining operations to be recycled for local benefit.
- **Consider noise pollution mitigation.** Cryptocurrency mining operations can be extremely loud operations. Local governments can review, update, and enforce noise ordinances to mitigate noise levels.
- **Update local land use codes.** Planners and local leaders are working on model codes for communities. For example, the American Planning Association recently published a Zoning for Data Centers and Cryptocurrency Mining Guide.[269] Many zoning codes from communities who have already implemented such codes are available online as well, including from municipalities across the country.[270]

ELECTRIC UTILITY REGULATORS

Cryptocurrency mining operations in the United States have, thus far, sought to build new mining facilities in jurisdictions where energy costs are low and easy to access, and where regulators either encourage electricity consumption as economic opportunity (or supportive of utilities), or where there is relatively thin regulatory oversight. State and local utility regulators, including officials that oversee municipal utilities and rural electric cooperative board members, public utilities commissions, energy regulators, and regional energy system market monitors can provide critical ratepayer protections.

- Utility regulators should refuse to approve power purchase agreements with cryptocurrency mining operations unless those utilities can demonstrate the agreement will not adversely impact other ratepayers, including by raising rates or otherwise increasing costs. State regulators and lawmakers should work with non-jurisdictional utilities, such as municipal and cooperative utilities, to do the same.
- Utility regulators should ensure that cryptocurrency miners are not provided discounted rates, and instead allocate costs and adopt rates in a manner that protects existing consumers from higher wholesale costs, cost shifting, and stranded assets. In fact, several utilities have argued that cryptocurrency mining operations should face substantially higher rates than other industrial consumers given the short-term view of the industry. In the short run, new utility infrastructure may be required to support mining center interconnection, and over the long-run, utilities may need to procure new generation to serve substantial new load. Utilizing traditional "cost causation" principles, utility regulators should ensure that mining operations pay their fair share over the short- and long-run.

- Utility regulators should critically assess utility plans to increase or maintain obsolete capacity (such as old fossil generators) in response to cryptocurrency mining operations, and ensure that existing ratepayers are held harmless. These reviews can occur in resource planning, procurement, or rate proceedings, and through other regulator inquiries.
- Utility regulators should consider Systems Benefit Charges (SBCs), or on-bill surcharges to cryptocurrency mining operations, to fund mitigation measures and protect ratepayers against stranded asset costs.
- Utility regulators, market monitors, and federal electricity regulators should review the impact of cryptocurrency mining operations on regional resource adequacy and the cost to serve customers. In non-restructured (i.e., non-market-based) regions, utility regulators should assess if cryptocurrency mining impacts utility load forecasts and system costs. In restructured states, market monitors should assess the impact of mining operations and load increases on the wholesale cost of energy and grid congestion. This necessarily requires a comprehensive reporting requirement for mining operations to ensure accurate data needed for planning.
- State environmental and energy regulators should establish and require best management practices for high-density load energy users, including but not limited to energy efficiency requirements, power density limits that set caps on the number of kW of energy consumption or load per thousand square feet, and take service as fully interruptible load.

ELECTRIC UTILITIES AND GRID OPERATORS

- Utilities should develop rate structures for high-density energy users such as cryptocurrency miners that ensure those operations pay their fair share of infrastructure upgrades at the time of interconnection (either through a deposit requirement or other mechanism); incorporate interruptibility provisions to avoid, where possible, increases to the utility's capacity obligations necessitating new generation build-out; and protect customers from rate shocks due to either the magnitude of new requests or the sudden departure and resulting stranded assets.
- Independent system operators should develop guidance around the interconnection of large-scale, high-density electricity users, including emergency response rules, that prioritize the integrity of grid operations and treat cryptocurrency mining as the highly interruptible, "flexible" load it claims to be.

FEDERAL AND STATE POLICYMAKERS AND REGULATORS

- States should consider imposing a moratorium on cryptocurrency mining operations until the impacts on climate goals and energy costs can be ascertained and mitigated. New York State is already considering such a moratorium, and several municipalities have already implemented them. In the absence of a moratorium, state environmental regulatory agencies should take a hard look at fossil power plants purchased or primarily serving cryptocurrency operations, including whether those plants are properly operating under previously obtained permits. In states with oil and gas drilling, stronger and more proactive enforcement may be required to stop unpermitted flare mining operations.
- Below are additional options that state policymakers and regulators should consider:
  - Reviewing a cryptocurrency mining facility's local and state environmental permits, including local stormwater and solid waste permits, as well as air and water permits.
  - Establishing revenue assurance or bonding requirements as a way to protect customers in the event that a high-density-load customer does not pay its utility bills.
  - Regulating electronic waste and other solid waste from proof-of-work cryptocurrency mining operations.
  - Creating a registry for proof-of-work mining over a certain megawatt threshold and requiring those operations to disclose their energy source.
  - Establishing minimum energy efficiency limits, for both the mining rigs themselves or one set around a kWh per transaction or block.
  - Requiring public power authorities to halt all discounted energy provided to proof-of work mining operations.

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