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Cryptocurrency Mining: The Downside of Technological Innovation

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PART I

Over the last decade cryptocurrencies have emerged as one of the most appealing investments in the world.[1] The concept of a virtual currency is so appealing, it has the potential to displace traditional currencies like the U.S. dollar.[2] In the process of simply existing, however, cryptocurrencies use an overwhelming amount of electricity.[3] Cryptocurrency mining, the process in which new units of cryptocurrency coins enter the market, is responsible for the use of an astonishing amount of electricity.[4] The energy use is so high because the technology used during the mining process requires a significant amount of energy.[5] As new technologies and cryptocurrencies emerge, the electricity consumption will also continue to rise.[6] Today, there are over 8,000 different types of cryptocurrencies in circulation.[7] As the various types of cryptocurrency platforms continue to grow, so too will the environmental impacts of cryptocurrency mining.

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[1] Jon Huang et. al., *Bitcoin Uses More Electricity Than Many Countries. How Is That Possible?*, N.Y. TIMES (Sept. 3, 2021), https://www.nytimes.com/interactive/2021/09/03/climate/bitcoin-carbon-footprint-electricity.html.
[2] *Id*.
[3] *Id*.
[4] *Cryptocurrency Mining Regulations*, EZ BLOCKCHAIN (Sept. 24, 2021), https://ezblockchain.net/article/cryptocurrency-mining-regulations/
[5] HUANG, et al., *supra* note 1.
[6] CORRIE E. CLARK & HEATHER L. GREENLEY, CONG. RSCH. SERV., R45863, BITCOIN, BLOCKCHAIN, AND THE ENERGY SECTOR 5 (2019); Audrey Carroll, *The Other Side of the (Bit)Coin: Solutions for the United States to Mitigate the Energy Consumption of Cryptocurrency*, 12 GEO. WASH. J. ENERGY & ENVTL. L. 53, 54 (2021).
[7] Adam Hayes, *10 Important Cryptocurrencies Other Than Bitcoin*, INVESTOPEDIA (Dec. 18, 2021), https://www.investopedia.com/tech/most-important-cryptocurrencies-other-than-bitcoin/#citation-1.

Cryptocurrencies are a digital asset that use an electronic payment system.[8] The users of the electronic system validate individual payments by utilizing specific protocols.[9] To verify an individual payment, a consensus system is needed to validate a new transaction.[10] The consensus system is used to add new transactions to the blockchain and to confirm the creation of new tokens.[11] This validation process is conducted by specialized companies or groups of individuals who utilize massive amounts of computing power.[12]

Bitcoin was the first cryptocurrency created that utilized a consensus system,[13] and today has the largest market capitalization network.[14] The environmental cost, however, is just beginning to be realized. The annual energy consumption of the Bitcoin network consumes approximately 201.89 tera-watt hours ("TWh") of electrical energy.[15] This amount of electrical energy consumption is equivalent to the power consumption of Thailand.[16]

This Comment discusses the energy consumption used in cryptocurrency mining and the environmental impacts of that consumption. Part II of this Comment provides a brief overview of what cryptocurrency is, the process of cryptocurrency mining, the different technology

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[8] DAVID W. PERKINS, CONG. RSCH. SERV., R45427, CRYPTOCURRENCY: THE ECONOMICS OF MONEY AND SELECTED POLICY ISSUES 2 (2020); *see also What Is Cryptocurrency?*, COINBASE, https://www.coinbase.com/learn/crypto-basics/what-is-cryptocurrency (last visited Apr. 1, 2022) (defining cryptocurrency as a "decentralized digital money designed to be used over the internet").

[9] DAVID W. PERKINS, CONG. RSCH. SERV., R45427, CRYPTOCURRENCY: THE ECONOMICS OF MONEY AND SELECTED POLICY ISSUES 2 (2020).

[10] *See generally What Is Cryptocurrency?*, COINBASE, https://www.coinbase.com/learn/crypto-basics/what-is-cryptocurrency (last visited Apr. 1, 2022).

[11] *Id.*; *see also What Is Blockchain?*, COINBASE, https://www.coinbase.com/learn/crypto-basics/what-is-a-blockchain (last visited Apr. 1, 2022) (defining blockchain as a "a list of transactions that anyone can view and verify. The Bitcoin blockchain, for example, contains a record of every time someone sent or received bitcoin. Cryptocurrencies and the blockchain technology that powers them make it possible to transfer value online without the need for a middleman like a bank or a credit card company").

[12] *Id*.

[13] PERKINS, *supra* note 9, at 2.

[14] *Today's Cryptocurrency Prices by Market Cap*, COINMARKETCAP, https://coinmarketcap.com (last visited Apr. 1, 2022).

[15] *Bitcoin Energy Consumption Index*, DIGICONOMIST, https://digiconomist.net/bitcoin-energy-consumption/ (last visited Apr. 1, 2022).

[16] *Id*.

associated with cryptocurrency mining, and why cryptocurrency mining is so energy intensive. Part III of this Comment analyzes three opportunities for cryptocurrency mining operations to be run on renewable energy resources. This section will also analyze various renewable energy resources and their potential to provide the required energy output for cryptocurrency mining operations.

PART II

Part II of this Comment will provide an explanation of what cryptocurrency is, the process of cryptocurrency mining, the different technologies associated with cryptocurrency mining, and why cryptocurrency mining is so energy intensive. To effectively analyze potential solutions for cryptocurrency mining operations, it is necessary to discuss what cryptocurrency is and how it is traded.

WHAT IS CRYPTOCURRENCY?

Cryptocurrency is a digital asset made popular today due to its ability to exchange value without relying on a financial intermediary. [17] When Bitcoin launched as the first cryptocurrency, it was considered an enigma. Created in 2008 by an anonymous author, Satoshi Nakamoto, the concept was published in an article detailing a digital payment system called

[17] *Bitcoin Energy Consumption Index*, DIGICONOMIST, https://digiconomist.net/bitcoin-energy-consumption/ (last visited Apr. 1, 2022); James Chen, *Fiat Money* (Sept. 09, 2021), https://www.investopedia.com/terms/f/fiatmoney.asp (describing fiat currency as a "government-issued currency that is not backed by a physical commodity, such as gold or silver, but rather by the government that issued it").

Bitcoin.[18] Bitcoin was intended to be an alternative method of payment to fiat currency[19] that could be transmitted between users without the assistance of a trusted intermediary, such as a bank.[20]

As a digital asset, cryptocurrency is a type of virtual currency.[21] The Internal Revenue Service ("IRS") defines "virtual currency" as a "digital representation of value that functions as a medium of exchange, a unit of account, and/or a store of value."[22] The IRS further defines cryptocurrency as "a type of virtual currency that utilizes cryptography to validate and secure transactions that are digitally recorded on a distributed ledger, such as a blockchain."[23] Distributed ledger technology ("DLT") is "a way of recording and sharing data across multiple data stores (also known as ledgers), which each have the exact same data records and are collectively maintained and controlled by a distributed network of computer servers, which are called nodes."[24] A blockchain is a data structure of blocks that are linked together to form a collection of records on a DLT.[25] Rather than having a storage mechanism, a blockchain has a set of protocols that govern the way that information is forged.[26] Blockchain technology is

[18] Gregory V. Ficcaglia, *Heads or Tails: How Europe Will Become the Global Hub for Bitcoin Business if the United States Does Not Reexamine Its Current Regulation of Virtual Currency*, 40 SUFFOLK TRANSNAT'L L. REV. 103, 103 (2017).
[19] James Chen, *Fiat Money* (Sept. 09, 2021), https://www.investopedia.com/terms/f/fiatmoney.asp (Fiat currency is "government-issued currency that is not backed by a physical commodity, such as gold or silver, but rather by the government that issued it").
[20] *Id*.
[21] *Virtual Currencies*, INTERNAL REVENUE SERV., https://www.irs.gov/businesses/small-businesses-self-employed/virtual-currencies (Apr. 20, 2021).
[22] *Id*.
[23] *Id*.
[24] Robby Houben & Alexander Snyers, CRYPTOCURRENCIES AND BLOCKCHAIN 15 (2018).
[25] Koshik Raj, FOUNDATIONS OF BLOCKCHAIN: THE PATHWAY TO CRYPTOCURRENCIES AND DECENTRALIZED BLOCKCHAIN APPLICATIONS 6 (2019).
[26] *Id*. at 6.

known for its integrity that cannot easily be compromised.[27] This integrity is achieved by cryptography, which is the process of binding the blocks together.[28]

Cryptography protects information by converting it into an indecipherable format that can only be deciphered by a person who possesses a secret key (i.e., encrypting and decrypting the information).[29] Cryptocurrency is secured via this process and uses a system of public and private digital keys during a transaction.[30] A transaction "occurs when two parties agree to transfer cryptocurrency from one account to another."[31] The buyer will unlock their cryptocurrency to be used as payment with their private key which allows the seller to lock the cryptocurrency using their private key.[32]

Blockchain uses two technologies to work: encryption and peer-to-peer ("P2P") networks.[33] A transaction cannot be altered once it has been added to the blockchain because transactions are added in an addition-only manner.[34] These transactions are grouped together to form a "block."[35] Each block is added to a blockchain in a way so as to link it to the previous block, thus any change in data to a previous block is immediately known to users as they try to add a new block.[36] This data is encrypted in order to ensure that parties trading assets on blockchain have rights to that asset, and that data held in blockchain cannot be manipulated.[37] P2P networks

[27] *Id*. at 7.
[28] *Id*.
[29] *See* HOUBEN, *supra* note 24, at 20.
[30] HOUBEN, *supra* note 24, at 20.
[31] PERKINS, *supra* note 9, at 11.
[32] PERKINS, *supra* note 9, at 11.
[33] CORRIE E. CLARK & HEATHER L. GREENLEY, CONG. RSCH. SERV., R45863, BITCOIN, BLOCKCHAIN, AND THE ENERGY SECTOR 2 (2019).
[34] *Id*.
[35] *Id*.
[36] *Id*.
[37] *Id*.

act as an arbiter of information and distribute the information to participating users without the use of a central authority.[38]

Cryptocurrencies can be categorized based on specific algorithms used by developers to create blocks that are added to the blockchain.[39] There are two well-known cryptographic validation methods used to ensure correct sequencing of transactions on the blockchain: Proof of Work ("PoW") and Proof of Stake ("PoS").[40]

In a PoW system, cryptocurrency miners have to solve computations, or puzzles, to be allowed to add new "blocks" to the blockchain.[41] Over time the puzzle becomes more complicated and requires more computing resources, which consumes more energy, in order to solve it.[42] Essentially, in a PoW system, the creation of a new block is similar to a lottery or a game of dice.[43] For example, consider Bitcoin, a PoW based system.[44] In this example, each Bitcoin miner has a 1000 sided dice and is trying to roll a number less than ten.[45] Statistically, rolling a number less than ten could take a very long time, but the more miners that join the game the less time it takes to roll a ten.[46] In essence, the more Bitcoin miners who join the game, the quicker each round is played.[47] If a Bitcoin miner has successfully rolled a number less than ten, then all miners can look at the dice and verify the number.[48] The first Bitcoin miner who rolled the number less than ten takes the prize and a new round begins.[49]

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[38] CLARK & GREENLEY, *supra* note 33, at 2.
[39] Audrey Carroll, *The Other Side of the (Bit)Coin: Solutions for the United States to Mitigate the Energy Consumption of Cryptocurrency*, 12 GEO. WASH. J. ENERGY & ENVTL. L. 53, 55 (2021).
[40] *See* HOUBEN, *supra* note 24, at 18.
[41] *See* HOUBEN, *supra* note 24, at 18.
[42] *See* HOUBEN, *supra* note 24, at 18.
[43] HUANG, et al., *supra* note 1.
[44] *See* HOUBEN, *supra* note 24, at 19.
[45] *Bitcoin Mining is NOT Solving Complex Math Problems [Beginner's Guide]*, BRAIINS (Apr. 14, 2021), https://braiins.com/blog/bitcoin-mining-analogy-beginners-guide.
[46] *Id*.
[47] *Id*.
[48] *Id*.
[49] *Id*.

In a PoS system, a user who validates the transaction must stake their ownership of a certain amount of coins in order to partake in the validation of transactions.[50] Under a PoS system, the act of transaction validation is called "forging" rather than "mining."[51] A forger is determined to be the creator of a block based on their stake in a currency and the age of that stake within the blockchain's ledger.[52] A forger who stakes their cryptocurrency on the network makes themselves available to be randomly selected to create a new block.[53] Another forger will then "attest" that the block exists.[54] Once a sufficient number of forgers have attested that they have seen the block, then it is added to the blockchain.[55] A forger will receive an award for both creating new blocks and for attesting about blocks they have seen.[56]

For example, consider Ethereum 2.0 ("ETH"), a cryptocurrency that utilizes a PoS system.[57] Under the Ethereum 2.0 PoS system, a forger must stake at least thirty-two ETH to act as a validator on the network.[58] The Ethereum 2.0 network requires at least 524,288 ETH to be staked in order to launch the network.[59] Next, for every block proposed, a random committee of forgers is selected.[60] Members of this committee will then attest to the block.[61] Once the

[50] *See* HOUBEN, *supra* note 24, at 19.
[51] *See* HOUBEN, *supra* note 24, at 19.
[52] Colin Harper, *Making Sense of Proof of Work vs. Proof of Stake*, COINCENTRAL (Jan. 24, 2018), https://coincentral.com/making-sense-of-proof-of-work-vs-proof-of-stake/.
[53] Everett Muzzy, *What Is Proof of Stake?*, CONSENSYS (May 15, 2020), https://consensys.net/blog/blockchain-explained/what-is-proof-of-stake/.
[54] *Id*.
[55] *Id*.
[56] *Id*.
[57] *Proof-of-Stake (POS)*, ETHEREUM, https://ethereum.org/en/developers/docs/consensus-mechanisms/pos/ (last visited Apr. 1, 2022).
[58] Everett Muzzy, *What Is Proof of Stake?*, CONSENSYS (May 15, 2020), https://consensys.net/blog/blockchain-explained/what-is-proof-of-stake/.
[59] *Id*.
[60] *Id*.
[61] *Id*.

required ETH has been staked and a sufficient number of forgers attested, then rewards will be distributed to the members of the committee.[62]

The unique feature of cryptocurrency is its potential to act as an alternative form of money.[63] Historically, money has received its value from government decree.[64] In contrast, cryptocurrencies employ a user agreement, a network of users, and cryptographic protocols to implement a valid transfer of value.[65] Typically, cryptocurrency users will use a pseudonymous address to identify each other and a private key to make changes to a public ledger in order to initiate a transaction.[66] Other computers in the network will validate these transactions.[67] A valid transaction is made through the use of blockchain technology, meaning that cryptocurrency users can only send cryptocurrency to public ledgers to which they have access.[68] This protects the public ledgers against manipulation and allows users to make these transfers without a centralized intermediary.[69] Generally, outside of the cryptocurrency universe, a financial transaction requires the use of the intermediation of a third party such as a bank, broker-dealers, or a securities settlement system.[70] One of the key advantages of blockchain technology is that it enables decentralized authentication of transactions allowing a transaction to occur without the use of a trusted, centralized intermediary.[71]

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[62] *Id*.
[63] PERKINS, *supra* note 9, at 11.
[64] PERKINS, *supra* note 9, at 2; *see also* James Chen, *Fiat Money* (Sept. 09, 2021), https://www.investopedia.com/terms/f/fiatmoney.asp (explaining that fiat money is not backed by a physical commodity and derives its value from the government that issues it).
[65] PERKINS, *supra* note 9, at 2.
[66] PERKINS, *supra* note 9, at 2.
[67] PERKINS, *supra* note 9, at 2.
[68] PERKINS, *supra* note 9, at 2.
[69] PERKINS, *supra* note 9, at 2.
[70] *See* HOUBEN, *supra* note 24, at 17.
[71] HOUBEN, *supra* note 24, at 17; *See* CYBER-DIGITAL TASK FORCE, U.S. DEP'T OF JUST., CRYPTOCURRENCY ENFORCEMENT FRAMEWORK 5–6 (2020) (explaining the ways in which bad actors may exploit the anonymity of decentralized cryptocurrency. Illicit actors may seek to: "(1) engage in financial transactions associated with the commission of crimes, such as buying and selling drugs or weapons on the dark web, leasing servers to commit cybercrimes, or soliciting funds to support terrorist activity; (2) engage in money laundering or shield otherwise

CRYPTOCURRENCY MINING

There are three main approaches to obtaining ownership of cryptocurrency: purchasing cryptocurrency from a platform directly by exchanging fiat currency; earning cryptocurrency in return for a product or service; or creating cryptocurrency through mining.[72] There are a variety of ways to add a new block to a blockchain.[73] As discussed above, under PoW, miners are given a difficult computational problem during the process of creating a block on a blockchain.[74] A miner is an individual (or entity) that maintains the network using powerful computers (called nodes).[75] Miners use these computers to solve the computational puzzles which in turn expend electrical energy.[76]

Generally, when a miner solves the puzzle, the miner can post the next block and may receive an award for doing so.[77] Once the puzzle has been solved and has been identified, the miner will announce it to the community via P2P networking.[78] Other users then validate the solution and confirm the block.[79] Once the solution is validated, the block is added to the chain.[80] This validation process does not require users to go through the resource-intensive-computation process.[81] Typically, the award for solving the puzzle is an amount of the cryptocurrency that has just been mined.[82] In the case of Bitcoin, the miner who has solved the

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legitimate activity from tax, reporting, or other legal requirements; or (3) commit crimes directly implicating the cryptocurrency marketplace itself, such as stealing cryptocurrency from exchanges through hacking or using the promise of cryptocurrency to defraud unwitting investors").

[72] CLARK & GREENLEY, *supra* note 33, at 2.
[73] CLARK & GREENLEY, *supra* note 33, at 2.
[74] CLARK & GREENLEY, *supra* note 33, at 2.
[75] Everett Muzzy, *What Is Proof of Stake?*, CONSENSYS (May 15, 2020), https://consensys.net/blog/blockchain-explained/what-is-proof-of-stake/.
[76] *Id*.
[77] CLARK & GREENLEY, *supra* note 33, at 3.
[78] CLARK & GREENLEY, *supra* note 33, at 3.
[79] CLARK & GREENLEY, *supra* note 33, at 3.
[80] CLARK & GREENLEY, *supra* note 33, at 3.
[81] CLARK & GREENLEY, *supra* note 33, at 3.
[82] HUANG, et al., *supra* note 1.

puzzle is rewarded with 6.25 Bitcoins, each worth approximately $50,000.[83] Understandably, cryptocurrency mining has become extremely popular and is considered to be a very lucrative competition.

CRYPTOCURRENCY MINING TECHNOLOGY

As the difficulty level of computations has increased, the technology used by miners has continued to advance.[84] Initially, cryptocurrency miners could solve cryptocurrency computations relatively easily using a central processing unit ("CPU") such as a personal laptop or a desktop computer.[85] As interest in cryptocurrency mining increased, however, graphic cards replaced CPUs because they could more efficiently run hashing algorithms at a faster rate.[86] Graphic cards were later replaced with Field Programmable Gate Arrays ("FPGAs") because an FPGA could be configured and programmed by cryptocurrency miners after manufacturing.[87] This configuration increased hash rates even further and required less energy consumption.[88] FPGAs have now been replaced with Application-Specific Integrated Circuits ("ASICs") which can be designed for a specific use, such as cryptocurrency mining.[89] By design, ASICs can only fit one mining algorithm and cannot be used to mine any alternative cryptocurrency.[90] The hyper-specialization of technology used in cryptocurrency mining implies that cryptocurrency

[83] HUANG, et al., *supra* note 1.
[84] HUANG, et al., *supra* note 1.
[85] HUANG, et al., *supra* note 1.
[86] CLARK & GREENLEY, *supra* note 33, at 3.
[87] CLARK & GREENLEY, *supra* note 33, at 3.
[88] HARALD VRANKEN, SUSTAINABILITY OF BITCOIN AND BLOCKCHAINS 1, 3 (2017).
[89] CLARK & GREENLEY, *supra* note 33, at 3.
[90] *Bitcoin's Growing E-Waste Problem,* SCIENCE DIRECT (Sept. 13, 2021), https://www.sciencedirect.com/science/article/pii/S0921344921005103?dgcid=author.

miners rapidly cycle through vast amounts of powerful technology as new and updated versions are released.[91]

ENERGY CONSUMPTION OF CRYPTOCURRENCY MINING

In cryptocurrency mining, there are four main factors that contribute to energy consumption: hardware computing power; network hash rate; the difficulty; and the thermal regulation for the hardware.[92] Each of these factors has a significant impact on the amount of energy used during the process of mining.[93] The PoW competition becomes more difficult over time because cryptocurrencies are designed to take a certain amount of time for the creation of a new block.[94] In order to maintain the per block status, cryptocurrency platforms have had to increase the difficulty of the computational puzzles as more miners join in the competition.[95] As the mining network increased, minors have sought more powerful equipment to keep up with the competition, which has consumed more energy.[96]

For example, a single Bitcoin transaction consumes approximately 2127.35 kilo-watt hours ("kWh") of electrical energy.[97] This amount of electrical energy consumption is comparable to

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[91] *Id*.
[92] *Id*. at 4.
[93] *Id*.
[94] Elliot Hill, *Bitcoin's Hash Rate Reaches All-Time High – Is a Breakout Imminent?*, YAHOO! FINANCE, (Jan. 6, 2020), https://finance.yahoo.com/news/bitcoin-hash-rate-reaches-time-200042609.html?guccounter=1&guce_referrer=aHR0cHM6Ly9wbHVzLmxleGlzLmNvbS9kb2N1bWVudC8_cGRtZmlkPTE1MzA2NzEmY3JpZD03ZDFiNzQ4Yi1kOTkyLTRiMzYtOWIxYi0xYWE2YjIzMmQ2MDkmcGRkb2NmdWxscGF0aD0lMkZzaGFyZWQlMkZkb2N1bWVudCUyRmFuYWx5dGljYWwtbWF0ZXJpYWxzJTJGdXJuJTNBY29udGVudEl0ZW0lM0E2MkhXLUY1WDEtRjYwQy1YM1k3LTAwMDAwLTAwJnBkd29ya2ZvbGRlcmlkPWMyNzQ4MmFlLTdjNzktNDI4Yy1iNmMwLWU3ZGFhZThkYjc2OCZwZG9wZW5kb2Nmcm9tZm9sZGVyPXRydWUmcHJpZD1iYzc2ZmJiYy1mN2M3LTRhYjAtODlhOS05ZTYxMDk2OTQ4ZWUmZWNvbXA9M3luaGsmZWFyZz1jMjc0ODJhZS03Yzc5LTQyOGMtYjZjMC1lN2RhYWU4ZGI3Njg&guce_referrer_sig=AQAAAMuV38H10q0zKRBNaqFsz3y5FZplPiKqlwvtdeNGXvOxW884mjHCODKTopOAc6RefiWKD33UbkQ8y0HbMozFnM0FxheCKtjBhP6KNZloXlcXJmGglm2gBUKM56EMA0tYYciRcG2KA-HPpERLKDVjiG5hULryuGpmCJvW-MkSpr1r.
[95] CARROLL, *supra* note 39, at 56.
[96] CLARK & GREENLEY, *supra* note 33, at 5.
[97] *Bitcoin Energy Consumption Index*, DIGICONOMIST, https://digiconomist.net/bitcoin-energy-consumption/ (last visited Apr. 1, 2022).

the power consumption of an average U.S. household over 72.92 days.[98] Further, a single Bitcoin transaction has a carbon footprint of 1010.49 kgCO2, which is equivalent to 168,415 hours of watching YouTube, and 303.00 grams of electronic waste, which is equivalent to the weight of 1.85 iPhone 12s.[99] Each year, the Bitcoin network produces a carbon footprint of 95.90 Mt CO2 and 28.75 kt of electronic waste.[100]

Under a PoW system, miners are rewarded on a first-come, first-served basis.[101] This means that the miner who first solves and publishes the solution is rewarded with the specific cryptocurrency.[102] Ultimately, miners who did not win the competition have expended a large amount of energy and have received nothing in return.[103] One of the major criticisms of the PoW system is that there are more miners consuming energy for "useless" calculations than the single miner who wins the competition for the single block.[104] Another major criticism is that the technology that miners use is continuously evolving.[105] As the technology used in cryptocurrency mining becomes obsolete, a significant amount of electronic waste is generated by miners.[106] Specifically, the use of ASICs generates more waste than previous technology because these circuits cannot be reused for any other purpose.[107]

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[98] *Id*.
[99] *Id*.
[100] *Bitcoin Energy Consumption Index*, DIGICONOMIST, https://digiconomist.net/bitcoin-energy-consumption/ (last visited Apr. 1, 2022).
[101] CLARK & GREENLEY, *supra* note 33, at 3.
[102] CLARK & GREENLEY, *supra* note 33, at 3.
[103] CLARK & GREENLEY, *supra* note 33, at 3.
[104] CLARK & GREENLEY, *supra* note 33, at 3.
[105] Nathan Reiff, *What's the Environmental Impact of Cryptocurrency?*, INVESTOPEDIA (August 26, 2021), https://www.investopedia.com/tech/whats-environmental-impact-cryptocurrency/.
[106] *Id*.
[107] *Id*.

PART III

As a result of the energy consumption consumed due to cryptocurrency mining, Part III will provide three potential solutions for cryptocurrency mining operations to run the technology on renewable energy or carbon-free resources. First, Part III proposes the requirement of a federal mandate that cryptocurrency miners utilize purchase power agreements. Next, Part III will explore whether solar energy, wind energy, hydroelectric energy, and nuclear energy can produce the required output to sustain cryptocurrency mining operations under a purchase power agreement mandate. Second, Part III will consider minimum energy efficiency standards as an additional requirement. Finally, Part III will evaluate current cryptocurrency state regulation and propose state regulations that will reduce the energy consumption of cryptocurrency mining.

FEDERAL MANDATE OF PURCHASE POWER AGREEMENTS

One potential way for Congress to achieve energy-efficiency in cryptocurrency mining is to require cryptocurrency miners to enter into a purchase power agreement ("PPA") with a renewable energy or carbon-free plant of their choice. To accomplish this goal, Congress would need to pass legislation specifically requiring cryptocurrency mining operations to purchase their power from renewable energy or carbon-free plants through a PPA.

Under a PPA, a purchaser signs a contract with a third-party developer to purchase power generated by hydroelectric power, solar power, wind power, or other forms of energy generation at an agreed-upon price.[108] The third-party developer owns the equipment necessary for the energy generation for the duration of the PPA.[109] Typically, a purchaser will sign a contract to

[108] *Purchase Power Agreement*, BETTER BUILDINGS U.S. DEPARTMENT OF ENERGY (last visited Apr. 1, 2022), https://betterbuildingssolutioncenter.energy.gov/financing-navigator/option/power-purchase-agreement#case-studies.
[109] *Id*.

purchase the electric energy generated by the third-party developer at a rate that is lower than the utility's retail rate.[110] Further, a PPA is generally a long-term agreement of ten to twenty-five years in length with an option to extend the term at the end of the agreement.[111]

Today, it is well established that greenhouse gas ("GHG") emissions increase the temperature of the planet.[112] Human activity has resulted in the increase of GHG emissions due concentrations of carbon dioxide ("CO2") in the atmosphere from the burning of fossil fuels to produce energy.[113] In 2020, the annual CO2 emissions in the U.S. was 4.71 billion tonnes.[114] In contrast, the annual worldwide CO2 emissions in 2020 was 34.81 billion tonnes.[115] One way to reduce the GHG emissions is to transition from burning traditional fossil fuels to sustainable renewable energy resources for the generation of power.[116]

Currently, coal is the second largest producer of electricity in the U.S.[117] Additionally, coal requires some form of carbon capture and sequestration ("CCS") to be climate neutral.[118] CCS is "the capture and separation of CO2 and subsequent compression and transport to storage locations such as saline aquifers."[119] Carbon capture, utilization, and sequestration ("CCUS") technologies were anticipated to address the "global need for affordable, secure, resilient, and

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[110] *Id*.
[111] *Id*.
[112] *Energy and the Environment Explained*, U.S. ENERGY INFORMATION ADMINISTRATION (last visited Apr. 1, 2022), https://www.eia.gov/energyexplained/energy-and-the-environment/greenhouse-gases-and-the-climate.php.
[113] *Id*.
[114] Hannah Ritchie & Max Roser, *Fossil Fuels*, Our World in Data (last visited Apr. 1, 2022), https://ourworldindata.org/fossil-fuels.
[115] *Id*.
[116] *Energy and the Environment Explained*, U.S. ENERGY INFORMATION ADMINISTRATION (last visited Apr. 1, 2022), https://www.eia.gov/energyexplained/energy-and-the-environment/greenhouse-gases-and-the-climate.php.
[117] *What is U.S. Electricity Generation by Energy Source?*, U.S. ENERGY INFORMATION ADMINISTRATION (last visited Apr. 1, 2022), https://www.eia.gov/tools/faqs/faq.php?id=427&t=3.
[118] James Gunnar Groesbeck & Joshua M. Pearce, *Coal with Carbon Capture and Sequestration is Not as Land Use Efficient as Solar Photovoltaic Technology for Climate Neutral Electricity Production*, SCIENTIFIC REPORTS (Sept. 7, 2018), https://www.nature.com/articles/s41598-018-31505-3.pdf.
[119] *Id*.

reliable sources of clean energy."[120] Both the government and industrial sectors agreed that CCUS technology was an important solution to environmental risks.[121] Additionally, these sectors agreed that CCUS technology was necessary to achieve sustainable and cost-effective production of electricity.[122] A recent study of the Chevron Australia's Gorgon liquified natural gas ("LNG") facility, which incorporates the world's largest CCS system, however, was found to be significantly lacking in meeting the anticipated commitments.[123] Chevron's CCS system was expected to lock away eighty percent of field emissions over the first five years.[124] Chevron's CCS facility was anticipated to capture approximately 9.6 million metric tons of CO2 but only captured five million metric tons within the five year period.[125] This means that the CCS facility had a shortage of approximately forty-eight percent of anticipated performance.[126] Unfortunately, Chevron's CCS failure is only one of many CCS projects that have ended in disappointment.[127] These failures necessitate the consideration of alternative forms of renewable energy resources to supplement electrical energy consumption for cryptocurrency mining operations. Therefore, it is necessary that Congress enact legislation that will ensure that all electrical energy consumption that is used for cryptocurrency mining is sourced from renewable

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[120] *Carbon Capture Opportunities for Natural Gas Fired Power Systems*, U.S. DEPARTMENT OF ENERGY (last visited Apr. 1, 2022), https://www.energy.gov/sites/prod/files/2017/01/f34/Carbon%20Capture%20Opportunities%20for%20Natural%20Gas%20Fired%20Power%20Systems_0.pdf.
[121] *Id*.
[122] *Id*.
[123] Jason Deign, *The Carbon Capture Project that Couldn't: Chevron Misses Targets for its Huge Australia Facility*, Canary Media (Oct. 1, 2021), https://www.canarymedia.com/articles/carbon-capture/the-carbon-capture-project-that-couldnt-chevron-misses-targets-for-its-huge-australia-facility?utm_campaign=canary&utm_medium=email&_hsmi=166490183&_hsenc=p2ANqtz-86IiQ-hxcwtH9Hu5DJfMTNGSlcmufTgGiODkVfUmrQUIR259FvsSfmH-J9F7DyZuVuF0zzcbs3akiyTgTbx_ZdB7QzGg&utm_source=newsletter.
[124] *Id*.
[125] *Id*.
[126] *Id*.
[127] *Id*.

energy or carbon-free resources.

SOLAR ENERGY

Solar photovoltaic ("PV") has the greatest potential to provide for a sustainable future among the renewable energy sources.[128] The PV effect is the process of converting light to electricity.[129] Solar energy is an affordable source of electricity and is one of the fastest growing industries in the U.S.[130] The U.S. has installed over three million solar PV systems with approximately one million installations built within the last two years.[131] In 2020, the U.S. generated a total of 88 TWh of electricity via solar PV energy.[132]

One of the major concerns of solar energy development is the loss of agricultural land to solar energy facilities and the impact of these facilities on the natural habitat.[133] U.S. government agencies and energy developers have sought out agricultural land to develop into solar energy facilities because this land has already been disturbed from its natural state to bare, graded land.[134] Using agricultural land rather than clearing land for development prevents long-term effects on the habitats of native plants and animals on newly disturbed land.[135] Additionally, agricultural land is also close to transmission lines.[136] Proximity to transmission

[128] James Gunnar Groesbeck & Joshua M. Pearce, *Coal with Carbon Capture and Sequestration is Not as Land Use Efficient as Solar Photovoltaic Technology for Climate Neutral Electricity Production*, SCIENTIFIC REPORTS (Sept. 7, 2018), https://www.nature.com/articles/s41598-018-31505-3.pdf.
[129] *Solar Photovoltaic Technology Basics*, NATIONAL RENEWABLE ENERGY LABORATORY (last visited Apr. 1, 2022), https://www.nrel.gov/research/re-photovoltaics.html.
[130] *Solar*, U.S. DEPARTMENT OF ENERGY (last visited Apr. 1, 2022), https://www.energy.gov/solar.
[131] *Id*.
[132] *What is U.S. Electricity Generation by Energy Source?*, U.S. ENERGY INFORMATION ADMINISTRATION (last visited Apr. 1, 2022), https://www.eia.gov/tools/faqs/faq.php?id=427&t=3 (converting 88 billion KWh to 88 TWh).
[133] Jessica Owley & Amy Wilson, *The New Agriculture: From Food Farms to Solar* Farms, 44 COLUM. J. ENVTL. L. 409, 411 (2019).
[134] *Id*. at 414.
[135] *Solar Explained*, U.S. ENERGY INFORMATION ADMINISTRATION (last visited Apr. 1, 2022), https://www.eia.gov/energyexplained/solar/solar-energy-and-the-environment.php.
[136] Owley & Wilson, *supra* note 133, at 414.

lines is a major factor in siting solar energy facilities "because building new transmission infrastructure to connect to renewable energy plants is legally complex and prohibitively expensive."[137] Farmland advocates strongly object to the conversion of agricultural land to solar energy facilities.[138] Residents of these communities are resistant to solar energy facilities because they are worried the land will decrease in value.[139] Additionally, residents are also concerned about the aesthetics of the solar panels.[140]

As mentioned above, a single Bitcoin transaction consumes approximately 2127.35 kWh of electrical energy and annually the Bitcoin network consumes approximately 201.89 TWh of electrical energy.[141] The U.S. does not currently produce enough Solar PV electrical energy to support a largescale cryptocurrency mining operation, such as the Bitcoin network. The U.S., however, is expected to add 38 GW of total installed solar capacity within the next two years.[142]

Unfortunately, even with the additional solar capacity over the next few years, solar PV has not advanced to the point of producing enough electrical energy to support the current energy needs of cryptocurrency mining operations on its own. Solar PV, however, could be used to supplement a portion of the energy required for cryptocurrency mining operations with another renewable energy resource such as wind energy or hydroelectric energy. Additionally, cryptocurrency mining operations could supplement their remaining energy needs with a carbon-

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[137] Owley & Wilson, *supra* note 133, at 414.
[138] Owley & Wilson, *supra* note 133, at 460.
[139] Owley & Wilson, *supra* note 133, at 460; *see also* Ellen Rosen, *As Demand for Green Energy Grows, Solar Farms Face Local Resistance*, N.Y. TIMES (Nov. 2, 2021), https://www.nytimes.com/2021/11/02/business/solar-farms-resistance.html (detailing landowners willingness to lease land to solar developers over the objection of their neighbors because leasing the land "can be more lucrative and more reliable than traditional farming." Local neighbors object to solar farms because they consider these farms to be an "encroachment on their pastoral settings, the loss of agricultural land and [result in] a decline in property values").
[140] Owley & Wilson, *supra* note 133, at 460.
[141] *Bitcoin Energy Consumption Index*, DIGICONOMIST, https://digiconomist.net/bitcoin-energy-consumption/ (last visited Apr. 1, 2022).
[142] Suparna Ray, *Solar Power and Battery Storage Will Likely Account for Most of the 78 GW of Capacity Additions in 2022 and 2023*, U.S. ENERGY INFORMATION ADMINISTRATION (Dec. 23, 2021), https://www.eia.gov/electricity/monthly/update/archive/december2021/.

free resource such as nuclear energy.

WIND ENERGY

Wind energy has the next greatest potential to provide for a sustainable future among the renewable energy sources. Wind energy refers "to the process by which wind turbines convert the kinetic energy in wind into mechanical power."[143] China, as the world's largest producer of wind energy, produced over 466 TWh of electricity in 2021 via both onshore and offshore wind turbines.[144] In 2020, the U.S. generated approximately 338 TWh of electricity from wind energy. [145] Additionally, wind energy provided 8.4% of total U.S. electricity generation.[146] Requiring cryptocurrency platforms to enter into purchase power agreements with renewable energy resources such as wind energy would undoubtedly provide the required energy output for current cryptocurrency mining operations.

On the other hand, wind energy has several aesthetic concerns such as "visual pollution" and noise created by wind farms.[147] Visual pollution refers to concerns of visual perception of wind

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[143] Avi Brisman, *The Aesthetics of Wind Energy Systems*, 13 N.Y.U. ENVTL. L.J. 1, 43–44 (2005).
[144] *Wind Power Generation, 2021*, OUR WORLD IN DATA, https://ourworldindata.org/grapher/wind-generation (last visited Apr. 1, 2022); *see also* Max Tingyao Lin, *China Continues Strong Renewables Policy Support After Record PV, Offshore Wind Power Expansion in 2021*, S&P GLOBAL (Jan. 31, 2022), https://cleanenergynews.ihsmarkit.com/research-analysis/china-continues-strong-renewables-policy-support-after-record-.html (detailing China's offshore wind power projects which installed offshore wind facilities capable of generating 16.9 GW of energy. At the end of 2021, the renewable expansion in China has allowed renewable capacity to reach 1.063 TW and has reached a total installed generation capacity of 44.8%).
[145] *Wind Explained Electricity Generation from Wind*, U.S. ENERGY INFORMATION ADMINISTRATION (last visited Apr. 1, 2022), https://www.eia.gov/energyexplained/wind/electricity-generation-from-wind.php (converting 338 billion KWh to 338 TWh).
[146] *Id*.
[147] Avi Brisman, *The Aesthetics of Wind Energy Systems*, 13 N.Y.U. ENVTL. L.J. 1, 74 (2005); *Cf. Wind Energy & the Threat to Bats*, Bat Conservation International, https://www.batcon.org/article/wind-energy-the-threat-to-bats/?gclid=CjwKCAiA6seQBhAfEiwAvPqu1zKrQE1Ndi4a3isqZIqjBPBt2bvgUef--AN1QpxSCYD83YmQTtCCnRoCvPUQAvD_BwE (last visited Apr. 1, 2022) (migrating bats are being killed by the blades of wind turbines in the thousands. The West Virginia's Mountaineer Project determined that an estimated 2,092 bats were killed beneath 44 giant turbines last summer. The West Virginia ridge has approved ninety-two additional turbines which could kill an estimated 30,000 bats in a single season).

turbines and their impact on the landscape.[148] Moreover, current wind turbines generate a small amount of noise as a result of mechanical components of the wind turbine.[149] A wind turbine located over 800 feet away from a residence generates around the same amount of noise as a kitchen refrigerator.[150] Technological advancements in current wind turbine technology, however, have helped to reduce the amount of turbine noise generated.[151] With these advancements, more electricity output is generated and the noise concern of the wind turbines is reduced. Thus, wind energy is a viable option to produce the required energy output for current cryptocurrency mining operations.

HYDROELECTRIC POWER ENERGY

Hydroelectric power ("hydro") is another viable option to produce the required energy for current cryptocurrency mining operations. Hydro power is "a renewable source of energy that generates power by using a dam or diversion structure to alter the natural flow of a river or other body of water."[152] Hydro power relies on the endless, constant flow of the water cycle to produce electricity.[153] In 2020, the U.S. generated 291 TWh of electricity from hydro plants.[154] As mentioned above, the Bitcoin network consumes approximately 201.89 TWh of electrical energy annually.[155] The current capacity of electricity generated from U.S. hydro plants would

[148] *Id.*
[149] *Id.* at 75.
[150] *Id.*
[151] *Id.*
[152] *How Hydropower Works*, ENERGY EFFICIENCY & RENEWABLE ENERGY, https://www.energy.gov/eere/water/how-hydropower-works (last visited Apr. 1, 2022).
[153] *Id.*
[154] *Hydropower Explained Where Hydropower is Generated*, U.S. ENERGY INFORMATION ADMINISTRATION (Apr. 8, 2021), https://www.eia.gov/energyexplained/hydropower/where-hydropower-is-generated.php (explaining that the U.S produced 291 billion KWh of conventional hydroelectricity generation in 2020. The 291 billion KWh's converted to TWh's, is 291 TWh's of electricity generation).
[155] *Bitcoin Energy Consumption Index*, DIGICONOMIST, https://digiconomist.net/bitcoin-energy-consumption/ (last visited Apr. 1, 2022).

meet the bare minimum consumption requirements of the Bitcoin network. As the cryptocurrency mining technology continues to evolve, however, the electricity consumption of the technology will also increase. This indicates the current electricity generation of U.S. hydro plants would not support a long-term goal of producing the electricity output required to sustain a cryptocurrency mining operation. Like solar PV, however, cryptocurrency mining operations could supplement their remaining energy needs with another renewable energy resource such as solar PV or hydroelectric energy. Additionally, cryptocurrency mining operations could consider a carbo-free energy source such as nuclear energy.

It is important to note that hydro energy has adverse impacts on a waterways ecosystem.[156] Dams create reservoirs that may obstruct fish migration, change natural water temperatures, water chemistry, and change river flow characteristics.[157] Native plants and animals in and around the river may be adversely affected due to these changes.[158] Congress enacted the Electric Consumers Protection Act of 1986 ("ECPA"), however, which mandates the Federal Energy Regulatory Commission ("FERC") "give equal weight to . . . 'the protection, mitigation of damage to, and enhancement of, fish and wildlife (including related spawning grounds and habitat).'"[159] In pursuit of this regulation, the U.S. Department of Energy has supported research and development of hydro power turbines that prevent the death and injury of fish that pass through the turbine.[160] As a result of this research, fish deaths due to hydro power turbines have been reduced to less than two percent in comparison with fish deaths of five to ten percent.[161]

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[156] *Hydropower Explained Hydropower and the Environment*, U.S. ENERGY INFORMATION ADMINISTRATION (Dec. 9, 2021), https://www.eia.gov/energyexplained/hydropower/hydropower-and-the-environment.php.
[157] *Id*.
[158] *Id*.
[159] Dan Tarlock, *Hydro Law and The Future of Hydroelectric Power Generation in the United States*, 65 VAND. L. REV. 1723, 1751 (2012).
[160] *Hydropower Explained Hydropower and the Environment*, U.S. ENERGY INFORMATION ADMINISTRATION (Dec. 9, 2021), https://www.eia.gov/energyexplained/hydropower/hydropower-and-the-environment.php.
[161] *Id*.

Even with the advancement of hydro power technology and the significant electrical energy output of hydro power turbines, however, hydro energy only produces enough electrical energy to sustain the current energy needs of cryptocurrency mining operations. As the electrical output of cryptocurrency mining operations continue to increase through the evolution of technology, the current hydro energy output will not be capable of sustaining the long-term energy output required for cryptocurrency mining operations.

NUCLEAR ENERGY

Finally, nuclear energy is another potential resource that could provide a sustainable future for cryptocurrency platforms. It is important to note, however, that nuclear energy is not a renewable energy resource, but rather a carbon-free resource.[162] The terms carbon-free and renewable are often used interchangeably, but these two resources create different economic and environmental impacts.[163] Carbon-free energy is produced by a resource that generates no carbon emissions.[164] Whereas renewable energy is a naturally replenishing resource that produces zero emissions.[165]

Nuclear energy is energy derived from the core of an atom.[166] An atom is a tiny particle that makes up solids, liquids, and gases.[167] A vast amount of energy is present in the bonds that hold

[162] Sarah Dillemuth, *What's the Difference Between Carbon-Free & Renewable Energy?*, MCE CLEAN ENERGY (Feb. 15, 2002), https://www.mcecleanenergy.org/mce-news/whats-the-difference-between-carbon-free-renewable-energy/.
[163] Sarah Dillemuth, *What's the Difference Between Carbon-Free & Renewable Energy?*, MCE CLEAN ENERGY (Feb. 15, 2002), https://www.mcecleanenergy.org/mce-news/whats-the-difference-between-carbon-free-renewable-energy/ (describing the difference between carbon-free energy resources and renewable energy).
[164] *Id*.; *see also* Mariah Zebrowski, *Nuclear Power as Carbon-Free Energy? The Global Nuclear Energy Partnership*, 20 Colo. J. Int'l Envtl. L. & Pol'y 391, 396 (2009) (explaining the negative consequences associated with increasing carbon emissions on the environment).
[165] *Id*.
[166] *Nuclear Explained*, U.S. ENERGY INFORMATION ADMINISTRATION (July 14, 2021), https://www.eia.gov/energyexplained/nuclear/.
[167] *Id*.

the nucleus together and can be released when those bonds are broken.[168] This nuclear energy can be released through nuclear fission and can be used to generate electricity.[169] Nuclear energy is the largest source of carbon-free energy is the U.S.[170] In 2020, the U.S. had a nuclear power plant generating capacity of 96.5 million KW and generated a total of 790 TWh of electricity from nuclear power plants.[171]

While nuclear energy can produce vast amounts of energy, nuclear power plants do have significant disadvantages.[172] These disadvantages include the requirement of substantial security measures to protect against potential acts of terrorism, the unresolved issue of how to dispose of toxic waste generated at nuclear power plants, and the potential misuse of radioactive materials.[173] Further, an uncontrolled nuclear reaction has the potential to result in widespread air and water contamination.[174] In an effort to mitigate these safety concerns, the U.S. Nuclear Regulatory Commission ("NRC") requires certain safety measures be put in place at nuclear power plants.[175] These safety measures include the training and skills of the reactor operators, maintenance and testing activities.[176] Additionally, nuclear power plants are restricted areas that are guarded by armed security teams to prevent potential terrorist attacks.[177]

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[168] *Id*.
[169] *Id*.
[170] *Nuclear Provides Carbon-Free Energy 24/7*, Nuclear Energy Institute, https://www.nei.org/fundamentals/nuclear-provides-carbon-free-energy (last visited Apr. 1, 2022).
[171] *Nuclear Energy*, U.S. ENERGY INFORMATION ADMINISTRATION (Sept. 2021), https://www.eia.gov/totalenergy/data/monthly/pdf/sec8.pdf (converting 789,879 million KWh to 790 TWh).
[172] Roland M. Frye, *The Current "Nuclear Renaissance" in the United States, Its Underlying Reasons, and Its Potential Pitfalls*, 29 ENERGY L. J. 279, 291 (2008).
[173] *Id*.; *Cf*. and M. Frye, *The Current "Nuclear Renaissance" in the United States, Its Underlying Reasons, and Its Potential Pitfalls*, 29 ENERGY L. J. 279, 302 (2008) (explaining a major issue with nuclear energy is the significant cost of the plant construction and financing which accounts for half and two-thirds of total costs).
[174] *Nuclear Explained Nuclear Power and the Environment*, U.S. ENERGY INFORMATION ADMINISTRATION (Dec. 17, 2021), https://www.eia.gov/energyexplained/nuclear/nuclear-power-and-the-environment.php.
[175] *Id*.
[176] *Id*.
[177] *Id*.

One of the major concerns associated with nuclear power plants is the creation of radioactive waste.[178] Radioactive waste can remain radioactive and hazardous to human health for thousands of years.[179] To protect human health, the NRC regulates the handling of radioactive waste with special provisions that govern their handling, transportation, and storage.[180]

Radioactive waste is classified in two ways: low-level waste and high-level waste.[181] Low-level waste is waste that has "become contaminated with radioactive material or [has] become radioactive through exposure to neutron radiation."[182] Low-level waste typically includes "contaminated protective shoe covers and clothing, wiping rags, mops, filters, reactor water treatment residues, [and] equipments [sic] and tools . . . ."[183] Low-level waste is stored either until it can be disposed of as ordinary waste, because it has decayed to low enough levels, or until the amount is large enough for shipment and has been approved by the Department of Transportation.[184] High-level radioactive waste is "the highly radioactive materials produced as a byproduct of the reactions that occur inside nuclear reactors."[185] There are two forms of high-level waste.[186] The first is used reactor fuel (called spent fuel) that is accepted for disposal.[187] Spent fuel is no longer effective in creating electricity because its fission process has been reduced.[188] The second form of high-level waste is waste material that remains after spent fuel is

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[178] *Id*.
[179] *Nuclear Explained Nuclear Power and the Environment*, U.S. ENERGY INFORMATION ADMINISTRATION (Dec. 17, 2021), https://www.eia.gov/energyexplained/nuclear/nuclear-power-and-the-environment.php.
[180] *Id*.
[181] *Id*.
[182] *Low-Level Waste*, U.S. NUCLEAR REGULATORY COMMISSION (Mar. 12, 2020), https://www.nrc.gov/waste/low-level-waste.html.
[183] *Id*.
[184] *Id*.
[185] *High-Level Waste*, U.S. NUCLEAR REGULATORY COMMISSION (Mar. 12, 2020), https://www.nrc.gov/waste/high-level-waste.html.
[186] *Id*.
[187] *Id*.
[188] *Id*.

reprocessed.[189] This waste material is still highly radioactive and potentially harmful.[190] The only way for radioactive waste to become nontoxic is through decay.[191] For high-level waste, this process can take hundreds of thousands of years.[192] Until the waste becomes nontoxic, the waste must be stored in a way that provides adequate protection to the environment and the public for an extended period of time.[193]

Currently, the U.S. has over 90,000 metric tons of high-level nuclear waste with no permanent disposal solution.[194] In 1987, U.S. government officials proposed Yucca Mountain, Nevada, as a final repository for nuclear waste.[195] Due to concerns over nuclear waste leakage at the site, however, the absence of a waste transportation plan, lack of protective health and oversight standards, and lack of consent from the state of Nevada, the project was abandoned.[196]

Today, a more permanent solution to high-level nuclear waste is the process of vitrification.[197] Vitrification is the process of converting liquid radioactive waste into a managed immobile solid—glass.[198] The radioactive material's conversion into glass prevents toxic species from leaking into the environment.[199] The U.S., the United Kingdom, France, India, and other countries continue to use vitrification of nuclear waste as an alternative to the traditional storage of radioactive waste as a way to prevent environmental risks.[200]

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[189] *Id*.
[190] *High-Level Waste*, U.S. NUCLEAR REGULATORY COMMISSION (Mar. 12, 2020), https://www.nrc.gov/waste/high-level-waste.html.
[191] *Id*.
[192] *Id*.
[193] *Id*.
[194] Padmaparna Ghosh, *Nuclear Power 101*, NATURAL RESOURCES DEFENSE COUNCIL (May 14, 2021), https://www.nrdc.org/stories/nuclear-power-101.
[195] *Id*.
[196] *Id*.
[197] Mitch Jacoby, *As Nuclear Waste Piles Up, Scientists Seek the Best Long-Term Storage Solutions*, Chemicals & Engineering News (Mar. 30, 2020), https://cen.acs.org/environment/pollution/nuclear-waste-pilesscientists-seek-best/98/i12.
[198] *Id*.
[199] *Id*.
[200] *Id*.

As previously mentioned, the U.S. generated a total of 790 TWh of electricity from nuclear power plants in 2020.[201] Nuclear energy can provide the required energy for cryptocurrency miners to enter into purchase power agreements with nuclear power plants and provide the required energy for cryptocurrency mining operations. The major concerns of nuclear power plant safety and environmental risks have been addressed with significant power plant safety regulations and alternatives to traditional nuclear waste management. With the advancements in nuclear energy and the significant electrical energy output of nuclear power, nuclear energy is a sustainable option to produce the required energy for current cryptocurrency mining operations.

MINIMUM ENERGY EFFICIENCY STANDARDS

Minimum energy efficiency standards are another approach to the reduction of energy consumption of cryptocurrency mining. Establishing minimum efficiency standards for the equipment used in the cryptocurrency mining process or the cooling equipment that maintains the cryptocurrency mining operations would help reduce the overall energy consumption produced through cryptocurrency mining.

Under the Energy Policy and Conservation Act, the Department of Energy ("DOE") maintains federal energy efficiency standards for appliances and other equipment.[202] Approximately sixty commercial product categories are regulated under the DOE's Appliance and Equipment Standards program and have set minimum energy efficiency standards.[203] Currently, the DOE maintains the Federal Energy Management Program ("FEMP") to enable

[201] *Nuclear Energy*, U.S. ENERGY INFORMATION ADMINISTRATION (Sept. 2021), https://www.eia.gov/totalenergy/data/monthly/pdf/sec8.pdf.
[202] CLARK & GREENLEY, *supra* note 33, at 19; Energy Policy and Conservation Act, 42 U.S.C. §§ 6201–6422 (1975).
[203] CLARK & GREENLEY, *supra* note 33, at 19.

federal agencies to meet energy and water reduction requirements and goals.[204] FEMP provides procurement guidance for computers by requiring federal agencies to purchase ENERGY STAR-qualified products or FEMP-designated products.[205] FEMP's procurement guidance and the ENERGY STAR efficiency requirements for computers are technology neutral.[206] This means that one brand of technology is not favored over another brand.[207] Additionally, ENERGY STAR's efficiency requirements are limited to desktop computers, workstations, notebook computers, tablets, laptop computers, thin-client, and small-scale servers.[208] All other computer categories are excluded, such as game consoles, e-readers, handheld gaming devices, and smartphones.[209]

While the devices used for cryptocurrency mining are currently excluded, as with FEMP, Congress could consider minimum national energy efficiency standards that address cryptocurrency mining operations. These standards would specifically focus on the technology used during the process of cryptocurrency mining. Additionally, these standards would be required to be updated annually. As previously discussed above, ASICs are the current technology used in the mining process, and where the current focus should lie for a minimum energy efficiency standard.

The creation of standards through Congress has, historically, been a slow process. A significant disadvantage of this approach is that once the minimum efficiency standards are set for a specific technology, such as ASICs, technological innovation will likely have already

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[204] *About the Federal Energy Management Program*, OFFICE OF ENERGY EFFICIENCY & RENEWABLE ENERGY (last visited Apr. 1, 2022), https://www.energy.gov/eere/femp/about-federal-energy-management-program.
[205] *Purchasing Energy-Efficient Computers*, OFFICE OF ENERGY EFFICIENCY & RENEWABLE ENERGY (last visited Apr. 1, 2022), https://www.energy.gov/eere/femp/purchasing-energy-efficient-computers.
[206] *Id*.
[207] *Id*.
[208] *Id*.
[209] *Id*.

progressed to a new and improved type of technology.[210] As noted above, cryptocurrency miners have progressed through several different technologies as cryptocurrency mining has become more popular. Since the creation of Bitcoin in 2008, the mining technology has progressed from CPUs to graphic cards, to FRPGs, and finally, to the current technology of ASICs.[211] Technological innovation progresses so quickly that a minimum energy efficiency standard may become merely a quick fix to an issue that requires a more long-term solution. To prevent the standards from continuously becoming obsolete, these standards should be updated annually to account for the new technology that cryptocurrency miners are using as the technology evolves.

STATE REGULATION

Finally, state regulation is another approach to the reduction of energy consumption of cryptocurrency mining operations. Current state regulations are inadequate to solve the energy consumption issue because no state in the U.S. has passed a law regulating the energy consumption of cryptocurrency mining.[212] Although, in 2021, the only state that has pending legislation authorizing the research and development authority to conduct a study about cryptocurrency mining operations being powered with renewable energy resources is the state of New York.[213] It is important to note, however, that this legislation is only regarding a *research study* on the powering of cryptocurrency mining operations with renewable energy and is not legislation *requiring* these operations to run on renewable energy.

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[210] CLARK & GREENLEY, *supra* note 33, at 3.
[211] CLARK & GREENLEY, *supra* note 33, at 3.
[212] Heather Morton, *Cryptocurrency 2021 Legislation*, NATIONAL CONFERENCE OF STATE LEGISLATURES (Dec. 16, 2021), https://www.ncsl.org/research/financial-services-and-commerce/cryptocurrency-2021-legislation.aspx.
[213] *Id*.

State regulation of virtual currency is not a new concept and some have already passed strict regulations regarding virtual currency business activity within their various territories. For example, the New York Department of Financial Services, a New York regulatory agency, has published strict requirements on virtual currency businesses within the state.[214] The Department of Financial Services requires businesses, who conduct virtual currency business activity within New York, to obtain a license (called a BitLicense) in order to lawfully conduct business in the state of New York.[215] The New York state regulation, however, has been criticized for providing vague definitions, imposing excessive compliance costs, and bypassing federal anti-money laundering regulations.[216]

Another example is the California minimum energy efficiency standards for computer products.[217] In 2016, the California Energy Commission ("CEC") established energy efficiency standards for computer products due to the lack of national standards.[218] These standards set a baseline energy use goal based on the type of computer and includes desktops, mobile gaming systems, notebook computers, workstations, small-scale servers, and more.[219] The California minimum energy standards go further than FEMP by including mobile gaming systems, however, they do not go so far as to include smartphones. The focus of the California energy efficiency standard is on the amount of energy the computer consumes during idle, sleep, and off modes.[220] These same standards apply to both computers and computer monitors.[221]

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[214] Anisha Reddy, *Coinsensus: The Need for Uniform National Virtual Currency Regulations*, 123 DICK. L. REV. 251, 267 (2018).
[215] *Id*.
[216] *Id*.
[217] CLARK & GREENLEY, *supra* note 33, at 21.
[218] CLARK & GREENLEY, *supra* note 33, at 21.
[219] CLARK & GREENLEY, *supra* note 33, at 21.
[220] CLARK & GREENLEY, *supra* note 33, at 21.
[221] CLARK & GREENLEY, *supra* note 33, at 21.

Rather than regulate the technology used during cryptocurrency mining, states should impose a minimum efficiency standard for technology that is used for the *purpose* of cryptocurrency mining. Until the federal government adopts such a standard, each state would impose a minimum efficiency standard because adopting the standard at the state level would be a faster process than waiting for the federal government to adopt the standard. As discussed previously, the environmental impacts of cryptocurrency mining operations are currently happening in the here and now. Adopting minimum efficiency standards at the state level will help to minimize further environmental impacts.

One of the major drawbacks of regulating the technology itself is that, because of technological innovation, the technology used during cryptocurrency mining changes very quickly. Once the standard for a specific type of technology has been passed, a new and more powerful technology will already be available on the market. If a state were to regulate the technology that is used for the purpose of cryptocurrency mining (rather than a specific type of technology), however, then the state regulation would be a step ahead of the inevitable changes in the types of technology used during the process of cryptocurrency mining. Additionally, a standard on the technology used for the purpose of cryptocurrency mining would encompass both individual cryptocurrency miners as well as largescale virtual currency companies (such as Bitcoin and Ethereum). Thus achieving the goal of reducing the energy consumption of cryptocurrency mining with the requirement that technology used for the purpose of mining run on renewable energy or carbon-free resources.

PART IV

CONCLUSION

Cryptocurrency mining poses an environmental risk that will only continue to get worse in the foreseeable future. To mitigate these risks, legislators must act now to encourage innovation and transition to more energy-efficient cryptocurrency mining operations.

This Comment proposes three approaches to influence the behavior of cryptocurrency miners. One proposal is to impose a federal regulation to mandate that cryptocurrency miners purchase their energy through a purchase power agreement from either renewable energy resources, such as solar PV, wind energy, or hydroelectric energy, or through a carbon-free resource such as nuclear energy. Further, this Comment proposes an additional requirement of imposing a minimum energy efficiency standard to reduce the energy consumption of cryptocurrency miners. Finally, this Comment proposes individual state regulations on technology that is used for the purpose of cryptocurrency mining. This solution would prevent the regulations from becoming obsolete as the technology used during cryptocurrency mining evolves.

Currently, the debate revolving around cryptocurrency has mainly centered on the growing financial impact of cryptocurrency. Now, while cryptocurrency is at the forefront of legislative debate, is the time to broaden the cryptocurrency discussion and take action to reduce the environmental impact of cryptocurrency mining.