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RE: Request for Information on the Energy and Climate Implications of Digital Assets

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INTRODUCTION

Thank you for the opportunity to provide insight into the evolving energy and environmental impacts of digital assets that use distributed ledger technology. The Information Technology and Innovation Foundation (ITIF) is a non-profit, nonpartisan research and educational institute—a think tank. Its mission is to formulate, evaluate, and promote policy solutions that accelerate innovation and boost productivity to spur growth, opportunity, and progress.

Distributed ledger technology, including cryptocurrencies that use blockchain technology, allows multiple parties to engage in secure, trusted transactions without intermediaries such as banks and financial institutions. Blockchains are digital ledgers that record information that is distributed among a network of computers that ensure each computer has identical records. Blockchains use a consensus protocol—a set of rules that allow each computer in the network to determine when to add new information to the ledger—to make the blockchain resistant to tampering and ensure consistency in the data among all computers in the network. Digital assets that rely on blockchain technology, including certain cryptocurrencies and non-fungible tokens (NFTs), have seen a surge in popularity as speculative investments, but the technology has also been used for a number of commercial and non-commercial applications, including the decentralization of some financial transactions such as money transfers or for supply-chain tracking.

In response to the potential applications of this technology, a rich ecosystem of legitimate blockchain-based startups and companies has emerged. The coming years will likely see many new blockchain applications such as tracking goods in global supply chains, enabling peer-to-peer transactions between connected devices, and increasing carbon offset transparency. A 2018 report from the World Economic Forum and Bain & Company estimated that by deploying blockchain, global businesses could generate an extra $1 trillion in trade finance (lending for importers and exporters) than otherwise would be generated.[1] Additionally, blockchain-backed technologies are powerful tools to improve commodity transparency, accountability, and traceability. For example, there are ongoing efforts to use these technologies to track the embodied carbon of construction materials, allowing buyers and sellers to track products up and down the supply chains.[2] Digital assets can facilitate smart contracts such as peer-to-peer electricity sales across mini-grids or enable electric vehicle (EV) owners to seamlessly access and pay for private charging networks.

As the dissemination and adoption of blockchain-backed digital assets surges, so too has its environmental and energy impacts. While early assessments of environmental and energy impacts were likely overblown, many popular blockchain technologies consume vast amounts of electricity today, producing millions of tons of carbon dioxide emissions and electronic waste. Some nations have issued outright bans on digital asset mining and cryptocurrency transactions, either in response to these concerns or other concerns about the potential for cryptocurrencies to undermine the government's ability to control its financial systems and trace financial transactions.[3] These bans are likely counterproductive from an energy standpoint as the operations move to other jurisdictions that may be just as or more carbon-intensive. For example, China's ban on mining means that miners can no longer use the cheap and clean hydroelectric power available during Sichuan's rainy season.[4] While the environmental and energy concerns for digital assets should be addressed, heavy-handed regulatory policies that attempt to restrict how operators use data centers are likely to be unsuccessful. Moreover, these broad restrictions could stymie legitimate innovative developments and uses for digital assets and blockchain-based applications.

TOPIC 1: PROTOCOLS

The proof-of-work (PoW) consensus algorithm that supports many digital assets, including Bitcoin, Ethereum, and Dogecoin, is highly secure and decentralized. Before participants can confirm new transactions to the blockchain, they must first solve a mathematical proof of work. The difficulty of the proof can vary based on the quantity and efficiency of the miners. For example, Bitcoin is structured such that the average time to find a new block takes approximately 10 minutes.[5] In theory, miners would not spend more on these activities than the economic value they generate (otherwise, it would be a money-losing proposition). However, as the price of many popular digital cryptocurrencies is likely highly inflated due to speculation, there is a large financial incentive to engage in mining. As more miners participate, the PoW difficulty increases, and thus the overall energy use increases.[6] The hashrate is the total computational power used by proof-of-work cryptocurrencies to process all transactions. The hashrate is the best indicator of total energy usage as it indicates how many calculations per second are performed by computers on the blockchain network. More computations require more energy. Hashrates have significantly increased for Bitcoin over time, indicating that overall energy usage has also increased. As Figure *1* illustrates, miner revenue for Bitcoin has been volatile, changing in response to factors such as the number of miners and the price of Bitcoin. Increases in miner revenue incentivize more miners to enter the market, which results in more energy usage. Additionally, as Figure *2* shows, as the price per Bitcoin swings, so does the hashrate, indicating that energy demand increases as prices increase but can also crash due to sinking prices. While there are expected efficiency gains with better hardware, if the hashrate increases faster than efficiency savings, then net energy usage will continue to increase.

Figure 1: Bitcoin hashrate and miners revenue over time (2009-2022)

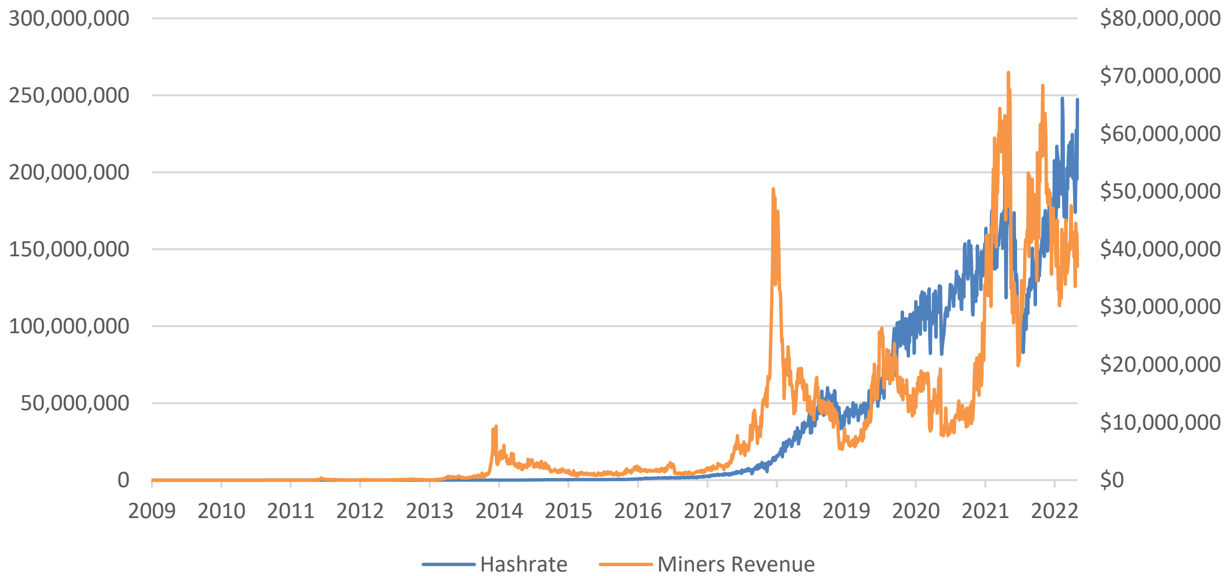
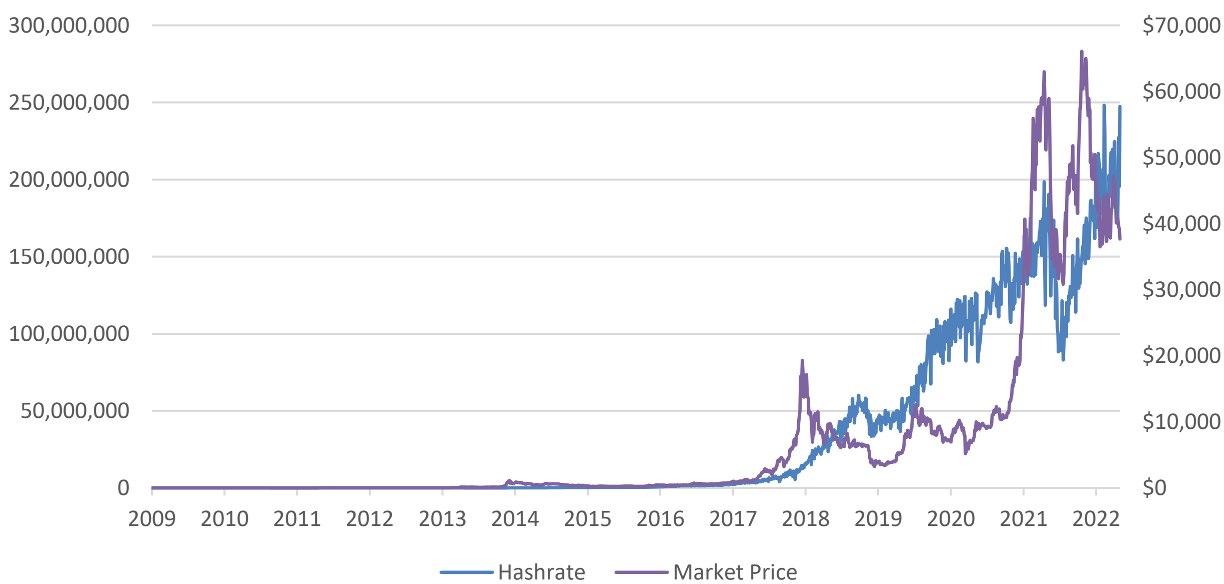


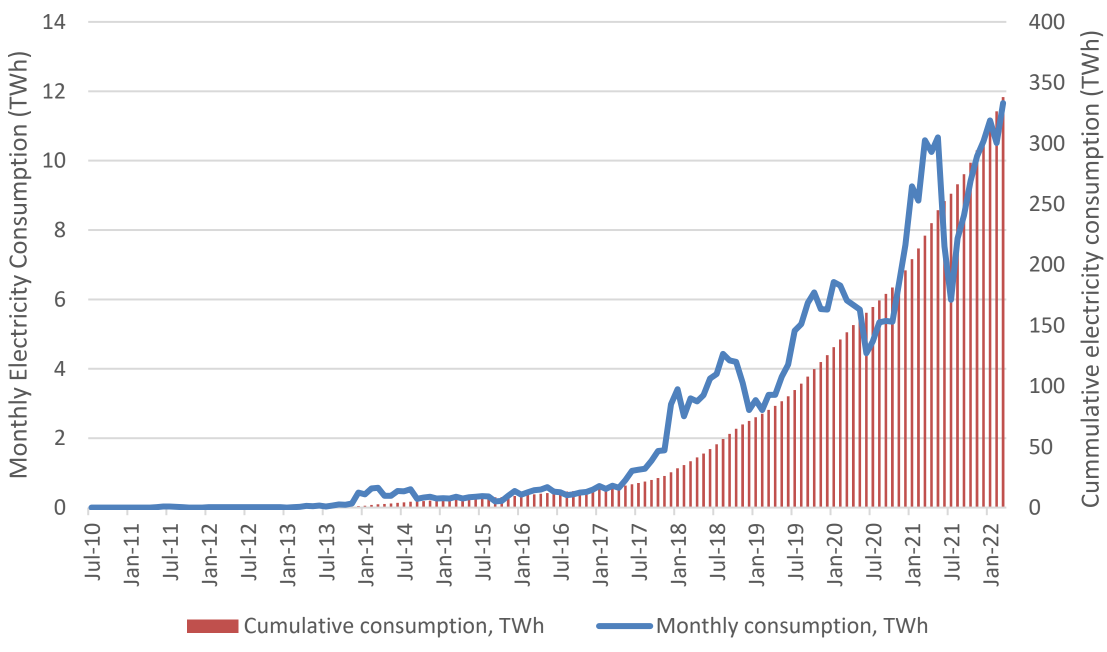
Figure 2: Bitcoin hashrate and market price over time (2009-2022)



It is estimated that Bitcoin mining and validation, the earliest and largest PoW digital asset by market capitalization, consumed close to 70 terawatt-hours (TWh) of electricity globally in 2020, and as much as 110 TWh in 2021 (one terawatt-hour is enough electricity to power 93,000 American households for a year.)[7] As of July 2021, following China's decision to ban crypto mining operations, the United States accounts for 35 percent of global mining operations, the highest rate of any country.[8] However, as seen in

Figure *3*, total electricity demand from PoW protocols, particularly Bitcoin, will likely rise if its value increases. Likewise, if the price of Bitcoin drops, the electricity demand will also decrease. Even if the price of Bitcoin does not fall, the protocol does have some safeguards in place that will limit some of the potential growth in energy consumption. Most importantly, the payout to miners halves approximately every four years, so unless the price of Bitcoin doubles in that period, miner revenue, and thus the incentive to mine, will decrease as well.

Figure 3: Global Bitcoin Cumulative and Monthly Electricity Demand (TWh)



Close to 70 percent of U.S. mining operations are located in just four states – New York, Kentucky, Georgia, and Texas.

Table 1 estimates U.S. emissions associated with Bitcoin mining operations in these four states, with the remaining emissions estimated using a national carbon emissions intensity standard. At 16 million tons in

2021, this is equivalent to the emission from roughly 3.5 million cars, however, it is less than 0.25 percent of annual U.S. emissions.

Table 1: Estimated Emissions from Bitcoin Mining in U.S. - 2021

State	Percent Share of U.S. Mining[9]	EIA Estimated Carbon Intensity (metric tons per MWh[10]	Estimated CO_2 emissions (metric tons)
New York	20%	0.21	1,584,714
Kentucky	19%	0.78	5,637,048
Georgia	17%	0.33	2,210,372
Texas	14%	0.43	2,304,428
Remaining U.S.	30%	0.38 (U.S. Average)	4,389,000
Total	100%	0.38 (U.S. Average)	16,125,565

A significant change is on the horizon, however. Developers have already created other consensus mechanisms such as proof-of-stake (PoS) that provide a number of benefits over PoW, including lower latency and higher throughput and requiring considerably less computing power (and thus less electricity) to achieve consensus on a blockchain.[11] PoS protocols achieve consensus by requiring that validators stake (or put up as collateral) crypto assets to validate transactions instead of requiring miners to solve computationally hard problems. Their ability to validate transactions is proportional to how much they have staked. This setup means that more participants can join the network without driving up the computational requirements for validators.[12]

Table 2: Consensus mechanisms of top 12 cryptocurrencies by market cap (as of April 2022)[13]

Name	Market capitalization	Consensus Mechanism
Bitcoin	$807B	Proof-of-work
Ethereum	$379B	Proof-of-work* (plans to transition to proof-of-stake)
Tether	$83B	n/a (fiat-backed stablecoin)
Binance Coin	$50B	Proof-of-staked authority
USD Coin	$50B	n/a (fiat-backed stablecoin)
XRP	$36B	Trusted validators
Solana	$36B	Proof-of-stake / proof-of-history
Terra	$35B	Delegated Proof-of-Stake
Cardano	$32B	Proof-of-stake
Avalanche	$21B	Avalanche
Polkadot	$19B	Nominated proof-of-stake

Dogecoin	$19B	Proof-of-work

As shown in Table 2, PoW cryptocurrencies still hold a significant market share because these were some of the earliest created cryptocurrencies. However, alternatives, such as Solana, built on proof-of-stake or alternative consensus mechanisms, have rapidly been adopted in the past few years. These protocols are significantly more energy-efficient, with the energy use of a single Solana transaction approximately two to three times that of a single Google search.[14] Moreover, Ethereum is set to convert this year from a PoW protocol to a PoS protocol with Ethereum 2.0 (although the roll-out has been delayed several times).[15] Proponents of PoS claim that it uses 2,000 times less electricity per validation than Bitcoin's PoW method.[16] Bitcoin, the largest and most popular digital asset, has not announced any plans to change from the PoW to PoS protocol and is unlikely to do so. There are remaining unanswered issues regarding the security of the protocols, the influence of validators with already large holdings of digital assets that rely on PoS, and concerns with locking up digital assets for some period of time necessary to carry out the PoS protocol.

TOPIC 2: HARDWARE AND THE ENVIRONMENT

Validating and recording new digital asset transactions requires significant computing power. Originally, much of the necessary computing could be done using traditional computer processing units (CPUs). However, with increasing digital asset valuation and increased competition among miners, greater computing power was required. Almost all large miners now rely on graphical computing units (GPUs) faster than CPUs to perform many parallel operations. However, most GPU mining equipment is considered obsolete every 1.5 years.[17] This heavy demand for GPUs and computer processing have created a potentially significant electronic waste concern alongside frequent turnover. It is estimated that the e-waste associated with Bitcoin mining operations alone has grown by more than 1,300 percent between 2017 and 2022, from 2.5 kilotons per year to more than 35,000 metric tons per year.[18] The U.N. estimates that global e-waste totaled 53.6 million tons in 2019.[19] Additionally, much of the e-waste associated with mining cannot be repurposed or downcycled for other computing purposes.

Better mining equipment, such as application-specific integrated circuit (ASIC) units, have higher efficiencies and are likely to last longer than GPU systems. ASICs, however, are designed with only one purpose, mining digital assets, and cannot be repurposed for other uses. ASIC units are larger than GPUs and put off significant heat. Modern ASIC Bitcoin mining facilities in North America, Europe, and China (before it was banned) are estimated to consume 474 trillion gallons of fresh water in 2021, equivalent to about two days of total U.S. freshwater consumption.[20] This water is used onsite to cool units down and in power plants to generate electricity. Much of this water is recycled or reused onsite, however. In water-stressed areas, such as the American southwest, digital asset mining operations may significantly impact the local surrounding areas and divert water away from other uses.

Innovations in processing and equipment efficiency will likely reduce the environmental and energy load. Additionally, whereas today's equipment generally runs 24/7/365 at the same rate regardless of the carbon intensity of the electricity on the grid, more advanced mining operations can load-follow low-carbon electricity. As more and more renewable energy comes online, advanced mining equipment can ramp up when the grid is relatively low-carbon and ramp down when the grid is more carbon-intensive. Some technology companies are now pursuing 24/7/365 clean energy to reduce their corporate emissions further. Similarly, some digital asset mining firms could choose to follow a similar policy, driving greater investment into low-carbon resources. Digital asset miners also choose to collocate in areas with cheap electricity and high amounts of renewable energy, such as the Pacific Northwest and Texas, or take advantage of existing low-carbon nuclear or geothermal power.

TOPIC 3: RESOURCES

As the U.S. grid becomes less carbon-intensive, emissions will drop. However, mining operations have the potential to provide a continued lifeline to uneconomic fossil-fuel power plants. There is anecdotal evidence to suggest that Bitcoin mining operations offered a financial lifeline to a coal power plant in the Ohio River Valley[21] and a coal and natural gas power plant in Texas.[22] Alternatively, digital asset mining may provide a much-needed financial lifeline to zero-carbon nuclear facilities. Additionally, it may provide a means of funding advanced new nuclear reactors, such as small modular reactors (SMR), which have struggled to take off in the face of cheaper renewable alternatives. One company, Talen Energy, announced plans to finance a small-scale (~300 MW) new nuclear facility to feed electricity and heat/cooling to a mining operation.[23]

As digital assets become more popular and their practical, rather than speculative, uses increase, mining operations will likely locate to or require increasing amounts of renewable energy. This is likely for both financial and social governance reasons. At zero-marginal cost, renewable energy such as wind and solar is already some of the cheapest electricity in the U.S. Additionally, just as large technology companies like Meta, Alphabet, and Amazon choose to locate their energy-intensive data centers in states with high renewable penetration and favorable renewable energy procurement policies, it can be expected that digital asset operations will follow the same trend, even choosing to co-located with low-cost renewables.

As the efficiency and protocols shift from high energy to less energy-intensive processes, the total energy load, related emissions, and water use are expected to decrease. However, too little research or data to corroborate such a claim. Additionally, there may be an efficiency bounce-back effect, whereby more efficient operations increase mining overall, negating the total energy and emission benefits.

It is uncertain if digital asset mining drives increased investment in renewable energy deployment. Still, it is possible that mining could play a role in helping balance excess renewable energy generation or even provide an incentive for the efficient use of flared natural gas. Because methane is 80 times more potent greenhouse gas than CO_2, capturing and burning flared natural gas and using the energy for digital asset mining is better.[24] There is some evidence to suggest that this option is being pursued in Texas.[25] More research should be conducted on the relationship between mining operations, load growth, marginal increases in grid-carbon intensity, and whether increased mining operations lead to increased marginal emissions.

TOPIC 4: ECONOMICS

The energy requirements of digital assets are directly correlated to their value for PoW protocols. As the speculative value of cryptocurrencies like Bitcoin increases, the financial incentive to do mining increases. However, as the value of the cryptocurrencies decreases and miners' payoff decreases the financial incentive to mining decreases. Currently, Bitcoin is the most highly valued asset, with more miners likely to enter the market, which can increase overall energy demand and other environmental impacts. The energy requirements for digital assets are not likely to be correlated to their value for other blockchain protocols, such as PoS protocols. Instead, the energy requirements will be related to energy efficiency of the blockchain protocols and the total number of transactions. As more businesses and communities increase their use of digital assets, the total number of transactions increases the overall required energy demand. These transactions are more likely to have similar energy usage profiles as other non-blockchain digital transactions, such as credit card payments or bank transfers. Improvements in data center technology and protocols are likely to make the process more energy-efficient, lowering total transaction costs.

TOPIC 5: PAST AND ONGOING MITIGATION

Efforts to mitigate digital assets' environmental and energy impacts have relied on heavy-handed government prohibitions, bans, or policies that push cryptocurrency miners to other jurisdictions. This was seen after China banned mining due to its large energy and environmental impact in July 2021. Most mining assets merely moved to other jurisdictions, including the United States. Most efforts to improve environmental and energy performance have been driven largely by competitive market needs. Current mitigation efforts include switching to less energy-intensive protocol standards, more efficient mining rigs, colocation with low-carbon intensive electricity such as the Pacific Northwest, and other measures to reduce energy costs and impacts.

TOPIC 6: POTENTIAL ENERGY OR CLIMATE BENEFITS

While digital assets' energy and environmental impacts are estimated to be large, there are potential benefits. First, on the hardware side, digital asset resources could serve as valuable grid balancing resources if they are part of demand response programs that allow utilities to call on those resources to ramp down demand when needed.[26] Second, mining operations may stabilize electric grids with a high amount of renewable power by using electricity when supply is plentiful and demand is low, such as in the middle of the day. This keeps renewables from being curtailed and keeps electricity power prices from dipping below $0 per MWh, which helps facilitate financing of greater amounts of renewable energy. Third, the market push for increased low-cost renewable electricity may drive more renewable resources onto the grid. Utility electricity demand has been flat. Electric vehicles and electrification will increase demand alongside mining operations, requiring utilities to increase electricity supply. This could push utilities to invest in greater amounts of renewable generation. For example, as data center demand for low-carbon electricity increased in the 2000s, so did the supply of low-cost wind and solar, particularly in Texas, North Carolina, and the Midwest.

Beyond physical infrastructure, digital assets, alongside blockchain technology, have the potential to facilitate innovations in the climate technology space. For example, secure blockchain and digital assets facilitate peer-to-peer electricity sales and trading between residential solar and battery systems and other distributed energy resource (DER) applications.[27] This can help facilitate increased financing for residential and commercial projects, increase grid reliability and resiliency, and bring new technologies to market. Blockchain and digital assets can enable so-called "smart contracts," which are highly automated and secure contracts between parties that execute once certain pre-defined conditions are met. Smart contracts are speedy, secure, and highly secure, leading to financial and energy savings. Blockchain will handle significantly more and increasingly complex transactions on a decentralized electric grid, such as vehicle-to-grid charging, neighborhood sharing of batteries, and solar resources, bypassing the utility entirely and providing households and businesses micro-digital payments for reducing demand. Several U.S.-based technology startups have emerged, with blockchain investment in the energy sector projected to reach $5.8 billion by 2025.[28]

When these systems are in place, suppliers and customers will be able to use smart contracts to automate sales by creating parameters that automatically trigger transactions based on the type of energy, price, time of day, location, and more. For example, the European transmission system operator TenneT has partnered with IBM for a pilot program testing whether blockchain can improve the efficiency of DERs.[29] In this pilot, TenneT sends a price signal to participating customers who own electric vehicles or small-scale batteries, can record their availability, and store and sell power back to the grid to reduce their demand, thereby helping make the grid more predictable TenneT.[30] Another company called Grid+ is rolling out a pilot in Texas that connects devices to a small-scale battery, smart home device, and the home's smart meter to intelligently manage power usage and programmatically buy and sell electricity on behalf of the user.[31]

Finally, blockchain-based technologies can potentially change how environmental product supply-chain transparency and accountability are conducted. Traditional carbon offsets, for example, are difficult to create, track, verify and monitor because they rely on a network of organizations with tracking protocols. Already, blockchain technology is providing governments and consumers of carbon offsets greater transparency and accountability by providing information on the quality of carbon offsets.[32] It can also prevent double-counting and a means of rescinding carbon credits that no longer provide a carbon benefit, for example, from a forest that has gone up in flames. Some companies have begun using blockchain to track chain-of-custody for commodities used in EV batteries, such as cobalt and lithium.

TOPIC 8: IMPLICATIONS FOR U.S. POLICY

U.S. federal policy regarding digital assets and blockchain should acknowledge both the realized and potential costs and benefits of these technologies to the economy and society. More research and data are necessary to determine their impacts on the grid, decarbonization efforts, and other sustainability goals from an energy and environment perspective. Outright bans on digital asset mining are counterproductive as it merely shifts miners to other jurisdictions that may be dirtier or lack environmental regulations. Moreover, restrictions on mining operations raise the prospect of policymakers deciding what type of computations are "worthy" uses of electricity. This unprecedented proposition would likely face political and legal hurdles. Instead, policymakers would be better off taking a technology-neutral approach by focusing on data centers, requiring them to meet certain energy efficiency targets or use renewable energy sources to minimize their environmental impact.

This does not mean that government has no role to play in promote energy efficiency among digital assets. On the contrary, the government has three important roles. First, it should set procurement standards for government use of digital assets that reward implementations using energy-efficiency blockchain technologies. As government agencies experiment with blockchain solutions, they should lead by example by ensuring that they are pursuing projects that use energy-efficient options available. Government adoption will help validate these emerging alternatives to the significantly less energy-efficient first-generation blockchain technologies. Second, the government should support energy-efficient digital assets' research and development (R & R&D) of energy-efficient digital assets. For example, increased R&D can help identify and address potential security risks of newer protocols or provide additional insights on the energy implications of different blockchain technologies. Moreover, R&D could help identify pathways for transitioning existing PoW blockchain technologies to more energy-efficient consensus mechanisms. Finally, the U.S. government should continue efforts to develop a digital dollar. As U.S.-backed digital currency would keep the U.S. competitive as the nature of money evolves and create a digital platform for payments. By leading in the development of a national digital currency, the United States can also prioritize the features it would like to see in such a technology, including energy efficiency.

Policymakers adopting technologies should ensure they take a tech-neutral approach to different applications. Digitizing processes, for example, offers benefits irrespective of the technology being used. Instead, policymakers should look to the unique benefits of technology and the particular challenges of a project when deciding what technology to adopt. Some projects will require traditional centralized approaches for efficiency, while others may be better suited for distributed, tamper-resistance blockchains. For example, a digitization project that requires many different entities to provide inputs without any particular entity controlling those inputs, may call for a blockchain.

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