HOW CRYPTO MINING WILL TRANSFORM THE ENERGY INDUSTRY

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Implications of the crypto economy for the electric system

The crypto economy is here to stay and crypto mining and staking is one of the main areas of interest for investment funds, corporates and governments.

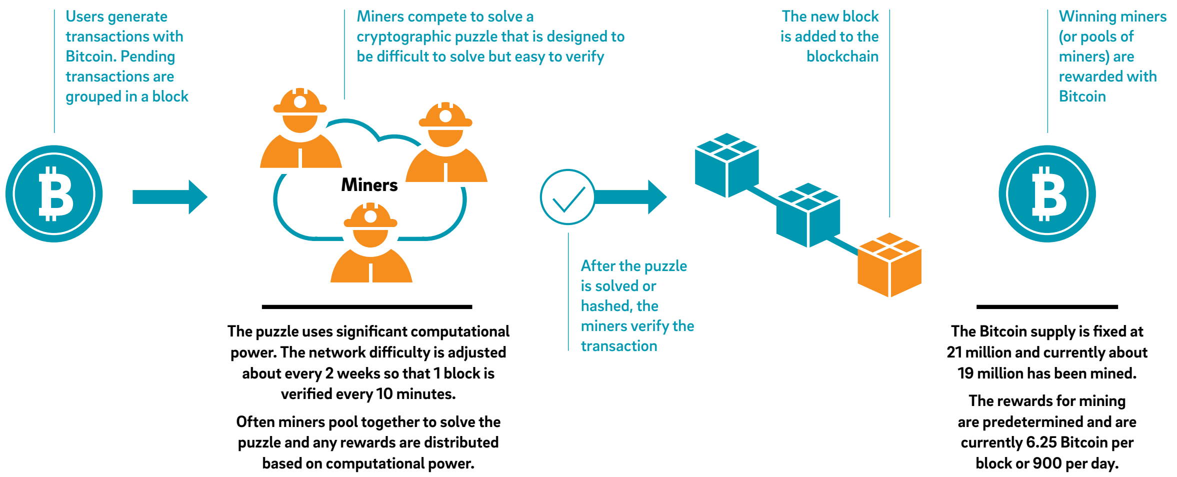
Crypto mining refers to the process of validating transactions and therefore securing and powering a blockchain protocol. The most famous protocol is Bitcoin – the current king of crypto since its genesis block in 2009. Bitcoin mining is energy intensive. At the time of writing, the total annual power consumption of Bitcoin is 145 TWh[1] (~0.32% of the total global energy consumption). The energy intensity is rooted in the choice of its consensus mechanism, commonly known as proof-of-work. However, the same laborious consensus mechanism is also the main reason for Bitcoin's security – it is too costly (or in other words requires too much "work") for malicious actors to rewrite transactions. In a nutshell, a Bitcoin mining rig consists of specialized machines dedicated to solving an algorithmic puzzle. The brute force approach and the

[1] Feb 17, 2022, range of 55 to 361 TWh, Cambridge Bitcoin Electricity Consumption, University of Cambridge

dynamically adjusted difficulty of mining so that a block is mined around every ten minutes (an intelligent design feature built into the protocol) are two factors for the high energy demand of Bitcoin mining.

How does Bitcoin mining work?

The Bitcoin mining process



Source Roland Berger

The answer to the much debated question of whether Bitcoin mining consumes too much energy is in the eye of the beholder, e.g. it depends on what legacy systems Bitcoin is replacing and what benefits it brings to society. While this is a highly interesting debate that touches on philosophical, economic and philanthropic elements, this article will focus on the impact and changes that Bitcoin mining (and proof-of-work based mining in general) brings to the electrical system and how miners can form a symbiosis with power and utility companies around the world.

Bitcoin mining growth

Bitcoin mining uses a tremendous amount of power. Some of the larger Bitcoin mines are served by dedicated power plants. While the global energy mix used for mining is now over 57% from clean energy sources,[2] the demand it can create on the power grids is immense.

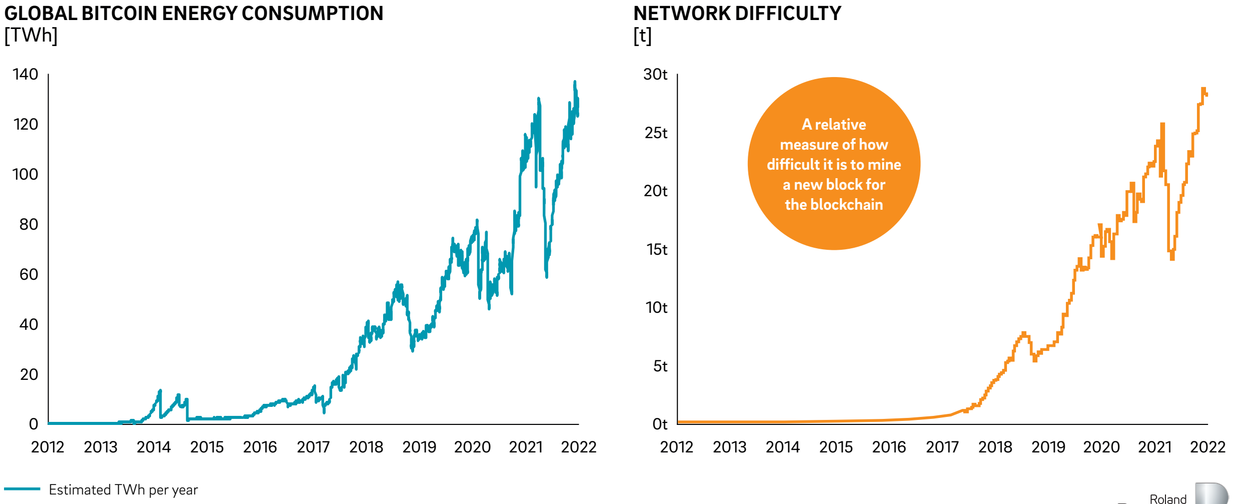
In the past five years, the energy consumption has grown from 11.8 to 120.5 TWh[3] per year, which is the equivalent of adding 2,400 wind turbines every year. For context, the US has installed on average about 3,000 wind turbines a year.[4] On February 12, 2022, the Bitcoin network hash rate (the aggregate volume of mining algorithm operations)

[2] Bitcoin Mining Council Q3 2021 Report, defining clean sources as hydro, wind, solar, nuclear, geothermal and carbon generation with carbon offsets
[3] University of Cambridge
[4] USGS

reached a new all-time high of 248.11 million terahashes per second (TH/s).[5] NYDIG, a Bitcoin company, estimates that electricity consumption could rise to a peak of 706 TWh in 2027 under its high Bitcoin price scenario.[6]

Bitcoin energy consumption and network difficulty reached new all-time highs

Development of global Bitcoin energy consumption and network difficulty



Source University of Cambridge, Blockchain.com, Roland Berger

After the Bitcoin mining ban in China in September 2021, and after some countries began restricting mining due to concerns around the strain it causes in their utility grid, global hash rates quickly found new homes and the United States has taken the leading position in global Bitcoin mining.

This large growth in energy use will affect decarbonization objectives if fossil fuel is used as the source of power. We expect a continued movement towards using clean energy given the increasing spotlight being placed on sustainability by regulators and investors and the influence of economic concerns. In view of the inherent incentive of miners to minimize energy costs, and the fact that clean energy in most locations is the cheapest source of energy,[7] we expect the Bitcoin mining industry to continue to move quickly to clean energy. This is especially true in countries with a strong policy push for decarbonization. We are also seeing a continued movement towards better energy efficiency, partially offsetting the growing energy use. For instance, Intel claims that its recent circuit innovations have 1,000 times better performance per watt than mainstream circuits.[8]

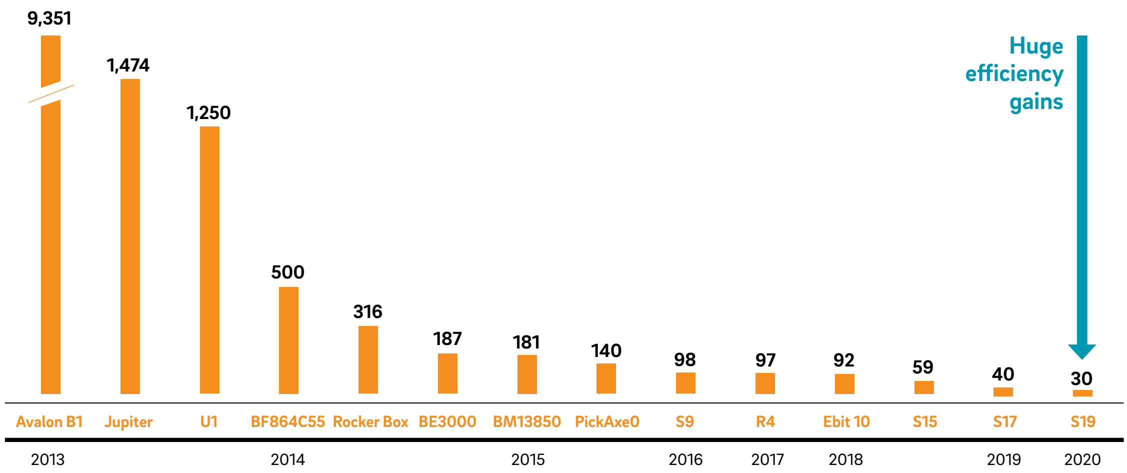
Without a doubt, even with the tremendous efficiency improvements, the exponential expansion of crypto mining operations will add to global power generation demand, especially in the US. This new surge in demand will amplify the needs of the electricity

[5] A hash is the computation run by specialized mining computers in support of the blockchain. A terahash is a trillion hashes
[6] NYDIG, Bitcoin Net Zero, September 2021
[7] "As available" energy
[8] https://www.intel.com/content/www/us/en/newsroom/opinion/thoughts-blockchain-custom-compute-group.html#gs.qb4u05

sector, which already faces the challenge of meeting long-term electrification demands from weaning the transportation and building sectors off fossil fuels to move towards net zero goals.

The efficiency of ASIC[1] mining machines improved tremendously over recent years

Improvement in ASIC mining machine efficiency [J/Th]



1 ASIC stands for Application-Specific Integrated Circuit, machines specialized just for mining cryptocurrency
Source Bitcoin Mining Council, Roland Berger

Special attributes of Bitcoin mining

While crypto mining operations share the same flat, very high load factor[9] usage characteristics as other types of data centers, their business model and the nature of their output create a distinctive set of customer attributes when compared to other types of electricity users.

- **Energy price sensitive:** With the cost of power representing over 80% of Bitcoin's operating costs, miners are extremely sensitive to the cost of power and are highly incentivized to find the best deal globally. In the search for the lowest power price, miners often seek to strike deals with utilities and power plants to be directly located onsite (and circumvent grid costs) or utilize excess energy (e.g. flared gas). At the time of writing this article, most of the Bitcoin mining facilities globally operate with power costs between 30 and 80 USD per MWh, with mining profits that can pay off the cost of the mining equipment in a little over a year.

- **Agnostic to location and flexible:** Mining rigs are often organized in modular containers, making them very flexible to deploy and move. They prefer locations with stable regulatory regimes that offer accommodating relationships with the utilities and that ideally have colder climates to reduce cooling requirements. Hotter locales such as Texas and the Middle East are viable with new technology such as hydro

[9] Load factor is the actual amount of energy used in a period of time divided by the total peak energy in that same period of time. It is used as a measure of efficiency.

cooling and immersion cooling – note the UAE's announcement that it will deploy 500+ MW of mining capacity. They can operate anywhere in the world, creating a global market. Besides the cooling infrastructure, miners only need a stable internet connection. In addition, Bitcoin miners try to maximize the use of their assets, including utilization of the heat for other purposes (e.g. greenhouses).

"The crypto economy will transform many industries, the energy industry being one of them. Miners and utilities can form a symbiosis in the energy system of the future."

PIERRE SAMATIES
Partner

- **Focused on the short term:** Miners use specialized computers designed to mine as fast as possible. Those with faster machines earn more. The lifetime value of the mining machines is less than three years, driven both by rapid technological developments and by the intense use of the machines given their high profit margins (on average north of 30%). Combined with the acknowledged volatility of crypto-currency markets, this means that miners are generally unwilling to make contractual commitments for power that extend more than three years or so. Mining equipment that is older than 3 years is often used only in regions where miners have very low (or nearly free) energy costs. From a utility's point of view, miners can therefore be seen as short-term users of the overall power system that can help bridge gaps of oversupply until further economic development. On the other hand, based on the potential short-term time horizon of the mining operations (if miners don't decide to continuously upgrade the technology and commit to long-term operations), utilities will not be keen to invest in additional infrastructure to accommodate them if they do not pay the full costs over time of the infrastructure upgrades.

- **Demand response ready:** Miners can form a perfect symbiosis with utilities with regard to balancing supply and demand on a short-term basis within the overall system. While a miner would prefer to run as much as possible, there are no adverse impacts, other than lost revenue, if they are shut down. Mining rewards are gained in sprints, not marathons, and they are not bound by a time of day. They verify a block of transactions in the blockchain, in the example of Bitcoin, every ten minutes on average. The miners can control the pace and degree of their shutdown and hence can be very scalable as demand response resources. Of course, utilities or market operators would have to make it worthwhile for miners to interrupt their revenue-producing operations. There are very few energy users that are this large and have this degree of flexibility to ramp up and down in a matter of minutes – with some miners claiming they can shut down in seconds.

Given these distinctive attributes, and a large amount of fast interruptible power, crypto mining can serve the electric system in three beneficial ways: (1) New revenue streams and asset optimization, (2) Demand response and load balancing and (3) System control and planning. The potential negative issues are explored below, after the following section.

Crypto mining's impact on the electric system

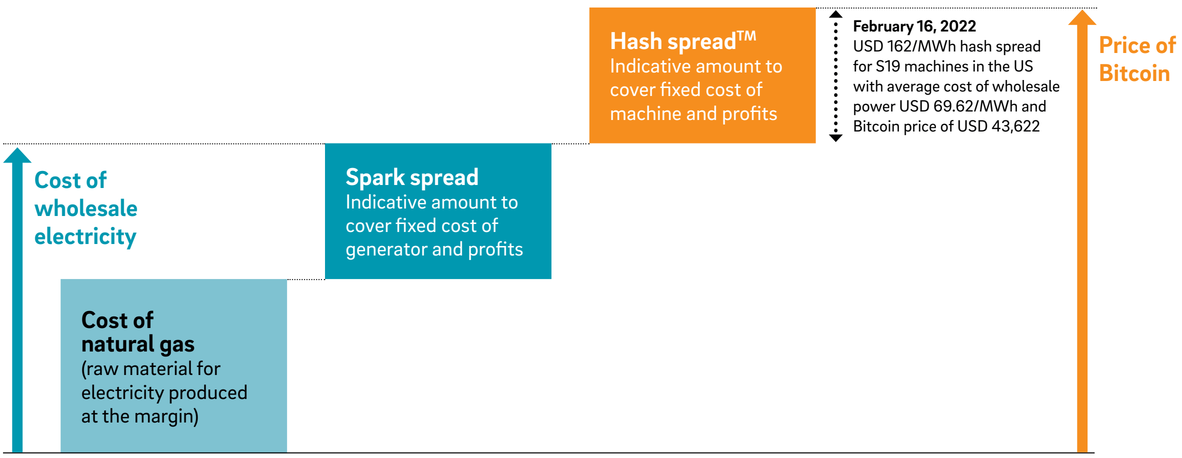
1 *New revenue streams and asset optimization*

Due to the geographic flexibility of crypto, this load can be easily situated near the point of generation. Typically, the system works the other way round, with generation situated as close as possible to load centers or large transmission systems carrying load from further away. This provides a unique opportunity to obtain value from under-utilized generation capacity.

Crypto mining offers an entirely new way to monetize power generation. It can basically convert power into a globally accepted cryptocurrency. Generators anywhere with excess power can earn from that power instead of curtailing energy or finding and connecting to other users. Bitcoin can unlock new uses for energy that otherwise wouldn't be used. For instance, hydro dams can generate more power in the rainy season than can be absorbed, oil & gas companies can utilize flare gas, etc. Generators constrained by transmission availability can find new outlets for their power, potentially enabling more solar and wind in rural areas. Locating mining containers near this generation can help improve the utilization of the assets and will extend their marketable lives. Nuclear facilities in the US are beginning to use cryptocurrency mining to increase their revenues and improve their economics as they compete with lower priced generation. This may even impact community solar or other virtual power plants with the new revenue streams, making them less dependent on regulatory subsidies.

What influence does electricity cost have on the Bitcoin price?

Bitcoin and electricity pricing connection
(US example with wholesale energy purchase)



Source BitOoda, Roland Berger

With the green energy transition in mind, there is understandable concern around any tool that may help improve the profitability and lifetime of fossil-fuel-based power plants. The industry is under tremendous pressure to use clean power generation. Assistance can also be provided for solar generation, enabling a value stream for projects that are in long interconnection queues or in areas that are already filled with too much solar power in a particular location. The additional value streams with crypto capital can accelerate a renewables buildout.

This could potentially change the economics of transmission, particularly for projects that are primarily designed to arbitrage the price of generation in two different regions. With low costs, remote generation now has an alternative option for use instead of depending on transmission lines to connect the power to cities and load centers. In additional, in hotter climates with significant seasonal demand curve differences (like the Middle East), Bitcoin miners can help increase the utilization of assets in winter months, when the load is significantly lower than in the summer (mainly based on AC consumption).

2 *Demand response and load balancing*

More dynamic participation of customers in balancing electricity supply and demand on a very short-term basis is a megatrend in the utility industry. To maintain power reliability and quality, electric system operators must match supply and demand in real time. With electricity supplies becoming more intermittent and highly variable (e.g. solar and wind), and new electricity demands also being more volatile (e.g. EV charging), flexible tools to manage both supply and demand are all the more important and valuable.

"Crypto mining offers an entirely new way to monetize power generation."

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Typical supply-side means for matching available generation with customer load include flexible peaking generation plants, or batteries and other forms of storage. The main instruments on the demand side for real-time system balancing are extreme peak pricing (to discourage peak usage) and demand response programs (to control peak usage voluntarily). Rather than adding new supply resources to meet peak electric system demands, it is often less costly to recruit customers who are willing to reduce their electricity usage in response to requests from the utility, in return for a discount or payment. Hence the term "demand response." This saves money for both the utility and its customers.

Crypto mining can take demand response to a new level, with large loads that can be quickly curtailed for a fee. Forbes describes it as a "shock absorber for green power." It can provide a seasonal balance in hot climates where air conditioner usage and water desalination create seasonal load patterns.

Innovative utilities such as Black Hills Energy are developing new flexible tariffs to accommodate this new use case. Other uses for these tariffs could be interruptible data center loads, which would include other applications that are non-mission-critical computations such as some machine learning and computational biology. These tariffs may also be used for other large flexible load applications such as the production of green hydrogen, another use case that will compete with crypto mining for low energy pricing and curtailed energy.

3 *System control and planning*

Just as demand response can be implemented at the wholesale level to manage the system, crypto mining also has the potential to help local utilities with distribution management. Given the locational flexibility of mining operations, the utility can strategically place the operations where it's most beneficial from a system control point of view. With the integration of distributed generation, the grid is becoming more complex, with power needing to flow in two directions instead of one. Given that the system must always be in balance and that it is more difficult to predict new demand and supply in this environment, the utilities are going to need more tools to manage and control power flow. Crypto mining can be an additional tool, a vacuum of sorts, absorbing "waste" power where it is not needed in the system so that the grid can operate smoother. This tool can be added to other strategies such as advanced control systems, demand response and improved system architecture to optimize the grid of the future.

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BILL KEMP
Director

System risks

The intense power usage of crypto mining can cause grid reliability and equipment problems if large mining operations are conducted in grids that do not have the demonstrated capacity to handle the expected increase in loads. Many governments have banned or significantly regulated the mining of cryptocurrency due to its impacts on the reliability of grids that were already stressed, including China, Iran and Turkey. Growth in crypto mining could raise similar locational concerns in other countries if the increase in mining loads occurs in areas where the grid is at or near capacity.

From the perspective of other utility customers, service to new large crypto mining loads could be detrimental if the energy volumes demanded would require significant new utility investments in long-lived generation or transmission assets. The full recovery of such additional fixed costs, or at least the costs of their acceleration from when they would be needed to serve other customers, is threatened by the volatility of the cryptocurrency market, the reluctance of crypto miners to commit to long-term energy purchase obligations, and the portability of the miners' major physical assets (their computers). In other words, the utility and its other customers face significant risks of stranded generation or transmission costs should the crypto miners leave before their cost responsibility is discharged.

Utilities can largely mitigate such risks through collecting prepayments or securing obligations from the crypto miners before undertaking system expansion investment on their behalf, and by managing a staged interconnection process that requires growing levels of financial commitments from the crypto miners as any system expansion projects progress. This helps improve the credibility of new service requests that may sometimes have speculative elements. Most utilities already have such processes in place for new large customer loads.

Again, to present the risk picture fairly, these system reliability and stranded investment threats are much smaller and more manageable if the existing generation and transmission system has adequate capacity to serve the new crypto miner loads, or if the crypto mining operations are not connected to the grid.

Conclusion

The rise of the crypto economy and the increased investments into proof-of-work mining activities come with major implications for the energy system. If handled well with the right regulatory and commercial framework, it will lead to very positive opportunities for governments and utilities that embrace the potential symbiosis, including an indirect acceleration of renewable energy growth. On the other hand, if it is not properly designed with a holistic view of the energy system and the energy transition objectives, it will lead to risks in the system. Hence, it is important to understand the in-depth mechanics of the industry and bridge it to national energy strategies.

Further reading

THE RISE OF THE CRYPTO ECONOMY
→ rb.digital/Crypto_Economy

EXPERTISE: ENERGY & UTILITIES
→ rb.digital/Energy_and_Utilities

NEXT LEVEL GRID OPERATIONS
→ rb.digital/ Next_level_grid_operations

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