Report

Roland Berger

NAVIGATING SUSTAINABLE PROFITABILITY

A COMPREHENSIVE RISK MANAGEMENT FRAMEWORK FOR BITCOIN MINING

CRYPTOOXYGEN Bitkern

Roland Berger

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1/ Introduction

Bitcoin mining is a highly attractive business when done right. Given the short-term volatility and business horizons, the long-term success of Bitcoin mining companies is determined by its ability to do appropriate risk management. Based on our in-depth market understanding and project experience, we have developed a comprehensive risk management framework that allows the top management and shareholders of Bitcoin mining firms to navigate through volatility and downtrends. It includes five key dimensions:

1. Market
2. Hardware
3. Operations
4. Financial & Treasury
5. Energy

The following article details these elements and provides an overview of appropriate mitigation and risk management options that the management and shareholders of Bitcoin mining companies can utilize.

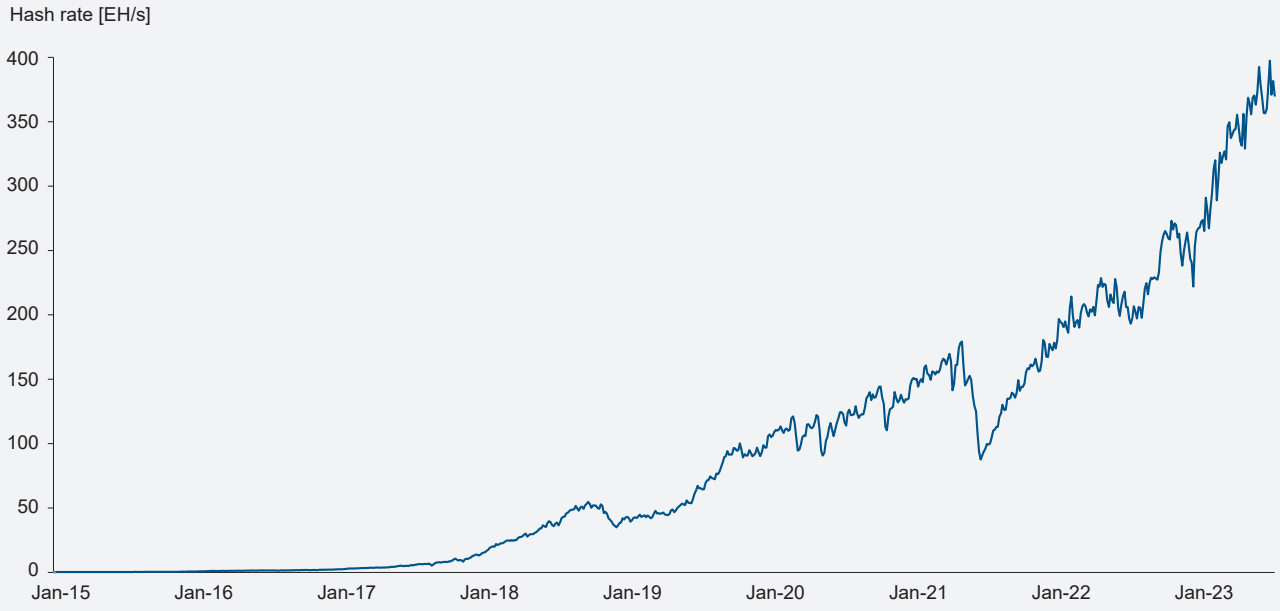
2/ Bitcoin: The Asset Class and the Mining Process

Bitcoin, the leading digital asset with a market cap of US$ 500 billion, provides a revolutionary new approach to value transfer by eliminating the middleman and making it a true peer-to-peer financial instrument that is censorship-resistant and inclusive. Since its inception in 2009, the asset has appreciated in value by more than an astounding 3,000,000%. Although many doubted its potential in the early days, Bitcoin has gradually gained recognition, both in pop culture and within institutional projects. Next, nearly all major international banks are working on their custody offering, and investment giant BlackRock has filed for a Bitcoin ETF. In addition, the number of active Bitcoin wallets recently crossed the 1 million mark. More and more governments are starting to consider this digital currency as a legitimate financial instrument, creating policies for its regulation and use.

At the core of Bitcoin's blockchain technology is a process called 'proof-of-work' (PoW). To truly understand the innovation Bitcoin brings to digital finance, it's crucial to grasp what proof-of-work entails. In essence, the proof-of-work mechanism is a method of achieving consensus among the vast network of computers—or nodes—that maintain the Bitcoin blockchain. It is designed to prevent fraud and ensure that all transactions on the network are legitimate. Think of proof-of-work as a complex mathematical puzzle embedded within each new 'block' to be added to the blockchain. These blocks contain a list of all recent Bitcoin transactions. The puzzle is extremely difficult to solve, requiring substantial computational power. It's akin to a lottery, where the first participant to find the correct solution wins. Once a miner solves it, the solution—which is the 'proof of work'—is shared with all other nodes on the network. If a majority of nodes agree that the solution is correct, the block is added to the blockchain, and the winning miner is rewarded with new Bitcoins— a process known as 'block reward'.

This system has two main benefits. Firstly, it secures the network. The difficulty of the puzzle means it's nearly impossible for any single entity to take control of the network, ensuring decentralization, one of Bitcoin's foundational principles. Secondly, it incentivizes miners to participate in the network as they can earn Bitcoins for their efforts. In summary, Bitcoin's proof-of-work is a robust and innovative mechanism that maintains the trust, integrity, and secure functioning of decentralized digital asset systems. Building on this understanding of Bitcoin mining, we see that the industry has evolved tremendously over the past decade. One of the measures is the total global hash rate (i.e. the total amount of computing power dedicated to the network), which currently sits at an all-time high of 400 EH/s.

F.1 / Bitcoin network total Hashrate



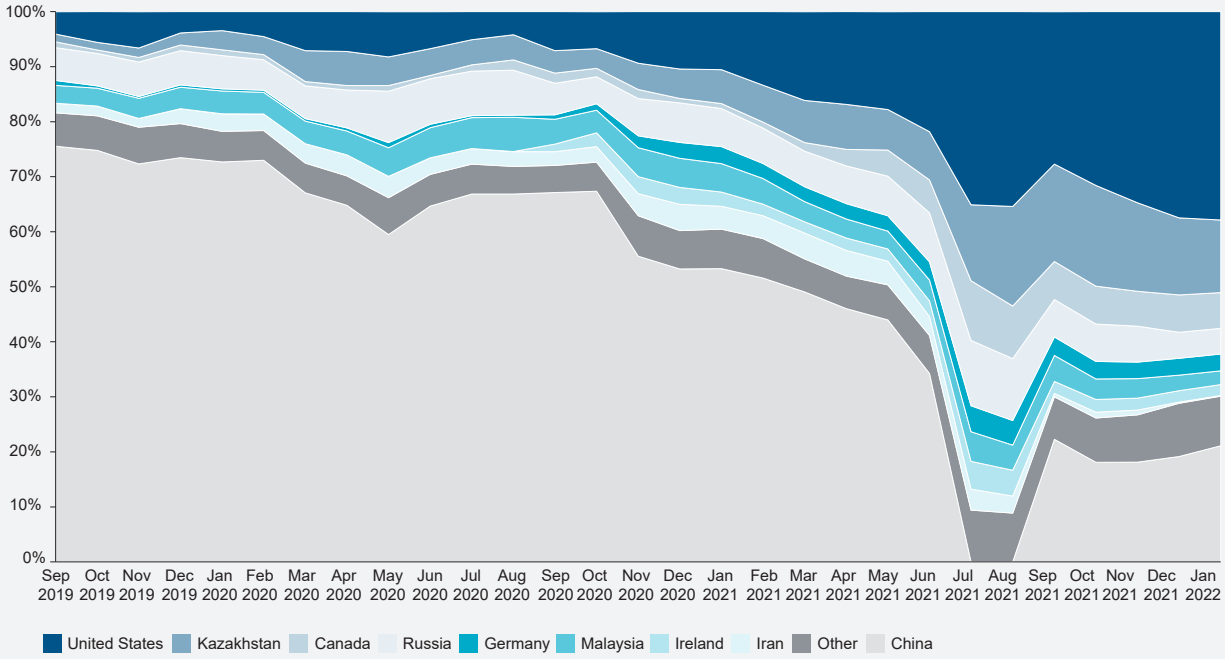
Source: Blockchain.com

This incredible growth showcases the increasing attention and resources dedicated to Bitcoin mining, cementing its place in the global financial landscape.

Furthermore, the industry's inherent characteristics contribute to its dynamism and flexibility. Given the mobile nature and short amortization period of mining equipment (e.g., a mining rig is usually replaced every 3-4 years), the industry is highly adaptable. A testament to this is how rapidly the hashpower shifts across geographies in the hunt for the most optimal setup, combining affordable power prices and stable regulation.

F.2 / Evolution of global hashrate by country

Share of global hashrate (monthly average)



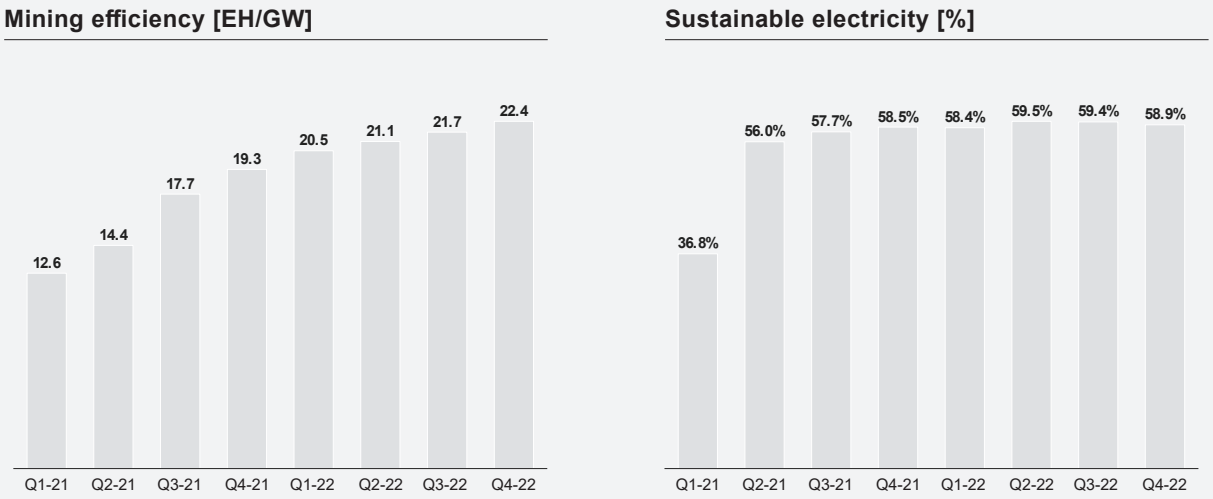
* To the researchers' knowledge, there is little evidence of large mining operations in Germany or Ireland that would justify these figures. Their share is likely significantly inflated due to redirected IP addresses via the use of VPN or proxy services.

Source: Cambridge Centre for Alternative Finance

The industry's rapid advancements are impressive: it is a constant race towards efficiency in computational power increase and lowering energy consumption. In addition, the hardware used for Bitcoin mining has increased in its efficiency by more than 50x since 2009. Usually, the cheapest form of electricity is CO2-neutral power. Hence, we have seen massive advancement in the amount of sustainable energy used for mining and a significant increase in mining efficiency

> *"Bitcoin mining is a very attractive but also ultra-competitive and complex business. It is easy to understand but hard to master. The key to sustainable success is applying a comprehensive risk management framework that covers all the dimensions laid out in this report."*
>
> **Pierre Samaties**

F.3 / Evolution of Bitcoin Mining Efficiency and Renewable Share of Electricity Mix



Source: Bitcoin Mining Council

In an industry that is constantly innovating, increasing performance, and dealing with an underlying asset that can exhibit significant volatility, appropriate risk management and flexibility are key.

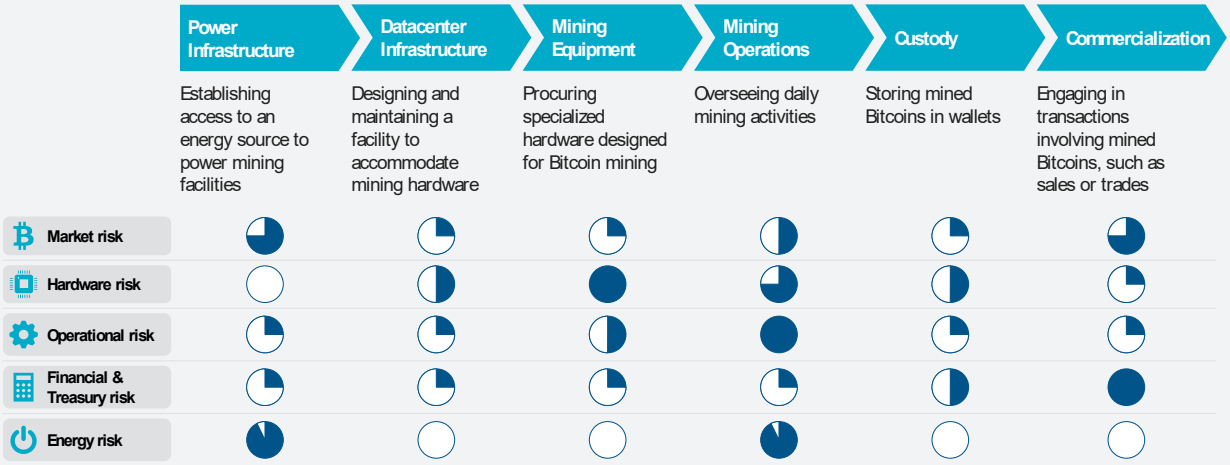
Each step in the Bitcoin mining value chain presents unique challenges and potential vulnerabilities. From the acquisition and setup of the mining rigs to maintaining optimal operating conditions, each stage requires careful consideration and effective risk management.

The following graphic provides a detailed depiction of the Bitcoin mining value chain, summarizing the associated risks at each step. This understanding is crucial for anyone involved in or considering entering the space. By appreciating the potential risks and rewards inherent in this dynamic sector, stakeholders can make informed decisions and contribute positively to the ongoing evolution of this transformative technology.

F.4 / Bitcoin Mining Value Chain

The Bitcoin Mining Value Chain – Processes in chronological order and the associated types of risk

Overview

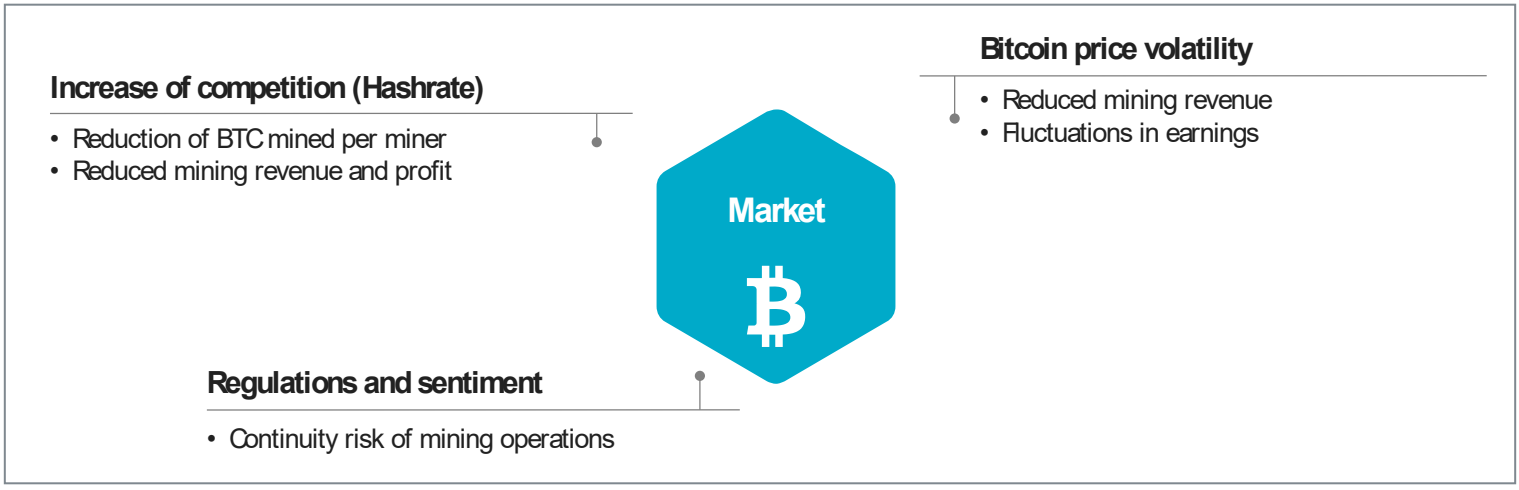


Source: Roland Berger

We will now deep dive into each of the risk dimensions and provide insights on the risk and mitigations.

3/ Key Risks and Mitigation Strategies

A. MARKET



1. Increase in Competition (Hashrate)

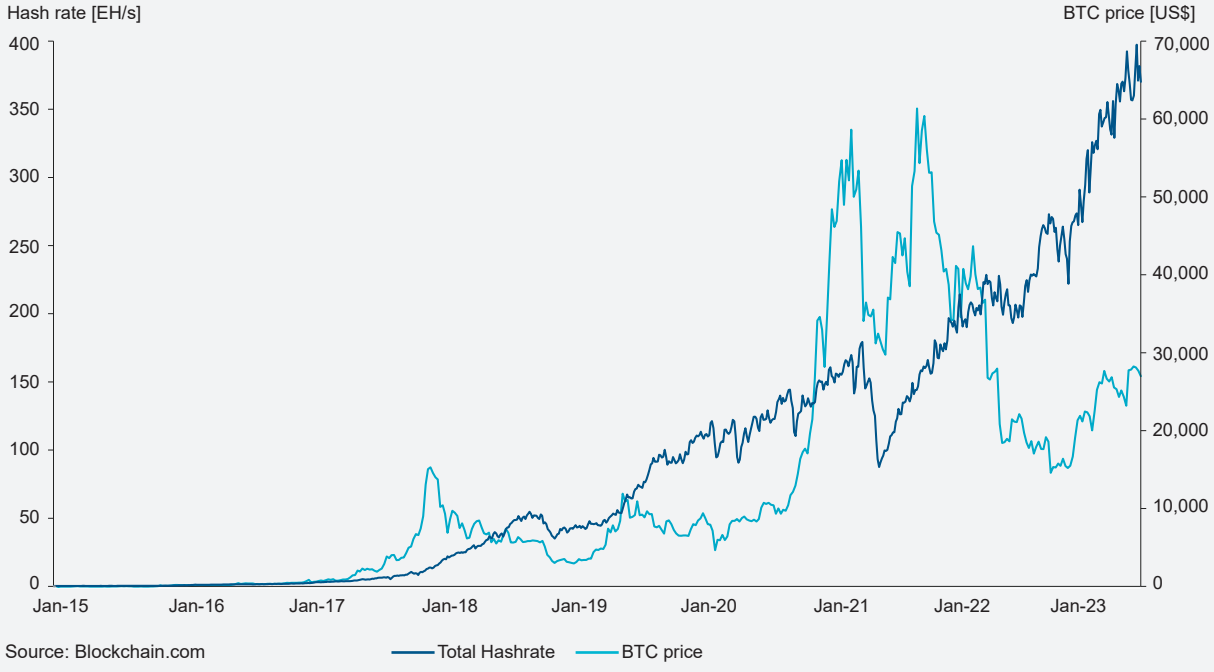
Key Risks: Reduction in the number of Bitcoins mined per miner and, therefore, reduced mining revenue and profit.

Description: The global network hashrate represents the total computational power dedicated to Bitcoin mining. An individual miner's share of the global hashrate can be seen as their market share in the mining industry. If the global hashrate rises, a miner's market share decreases unless they proportionately increase their own hashrate. Consequently, a reduced market share leads to a decrease in the number of Bitcoins mined by that miner.

An important factor in Bitcoin mining profitability is the "halving" event, which happens approximately every four years. The next one is scheduled for April 16, 2024. During each halving, the number of Bitcoins awarded to miners for each new block they mine is cut in half. This effectively reduces the revenue for miners unless the price of Bitcoin rises to counterbalance the reduction in new coins mined.

Predicting the global network hashrate and its reaction to halving events can be difficult and sometimes yields unexpected results. For instance, in late 2022, the Bitcoin network hashrate experienced a significant increase, even though the price declined. This outcome contradicted historical trends, further highlighting the challenge of forecasting hashrate changes and the complexity of the Bitcoin mining ecosystem.

F.5 / Bitcoin Network Total Hashrate and Bitcoin Price



Source: Blockchain.com

Mitigation Strategies:

- **Reduce operating costs:** Minimize the impact on profitability by cutting operating costs, focusing specifically on electricity, which is the largest expense for Bitcoin mining operations.

- **Hedge with Hashprice Futures:** Trade Hashprice Non-Deliverable Forward (NDF) contracts to hedge against an increase in global network hashrate. Hashprice is the revenue Bitcoin miners earn per unit of hashrate, which is the total computational power deployed by miners.

- **Increase hashrate:** Invest in additional mining rigs to increase the installed capacity of hashrate and, consequently, the share of the global hashrate network.

- **Upgrade miners to more efficient models:** Regularly exchange older generations of miners to keep up with the increased hashrate of the Bitcoin network.

- **Join Mining Pools:** Join Mining Pools, in which multiple miners collaborate and pool their resources to consolidate the computational power of various operations, thereby slightly increasing the likelihood of successfully mining Bitcoins

- **Monitor market trends:** Install pre-warning systems measuring different metrics and adjust their strategies accordingly to minimize the impact of changes in the hashrate and mining difficulty on their operations. Possible metrics indicating changes in hashrate and mining difficulty in the Bitcoin network include mining pool distribution, block difficulty adjustments, and miner revenue per terahash.

2. Bitcoin Price Volatility

Key Risks: Reduced mining revenue, fluctuations in earnings.

Description: Rapid price fluctuations can substantially impact the profitability and sustainability of mining operations, presenting a considerable risk to their survival. For example, when Bitcoin's price soared to an all-time high of around US$69,000 in late 2021 and subsequently dropped to about US$15,000 in late 2022, this volatility directly influenced miners' earnings. Such fluctuations can jeopardize the profitability and longevity of mining operations.

Mitigation Strategies:

- **A Risk adjusted commercialization strategy:** Adopt hedging strategies, such as futures contracts, to lock in earnings and guard against price decreases. Short selling through derivatives or margin facilities on exchanges may also provide stability, but these methods carry risks due to Bitcoin's volatility and limited market regulations.

- **Reduce operating costs:** Minimize impact on profitability by cutting operating costs, focusing specifically on electricity, which is the largest expense for Bitcoin mining operations.

- **Monitor market conditions:** Regularly monitor market conditions and adjust operations accordingly to be better positioned to respond to changes in the market and ensure adequate profitability even during periods of market volatility.

3. Regulations and Sentiment

Key Risks: Continuity risk of mining operations.

Description: The mining industry faces significant political and legal risks, which can have a substantial impact on miners. Taxes, tariffs, and regulatory changes are among the factors that can raise the cost of mining and create uncertainty for miners. Several regulatory actions across the globe have negatively affected Bitcoin miners. Notably, one of the main regulations that negatively affected crypto miners was China's aggressive policy toward mining, which led to a complete ban on such activities in June 2021. This forced Chinese Bitcoin miners to look for new places to set up operations. Many of them moved to the United States, while some left for Scandinavia and others to nearby Kazakhstan. However, other governments are also discussing restrictive regulations for Bitcoin mining. For instance, the U.S. Treasury Department proposed a 30% excise tax on cryptocurrency mining in March 2023, whereas the Swedish administration announced abolishing tax incentives for data centers starting in July 2023, resulting in a 6,000% increase in taxes per kilowatt hour.

Mitigation Strategies:

- **Proactive education:** Increase awareness and educational efforts for relevant stakeholders and increase Corporate Social Responsibility (CSR)

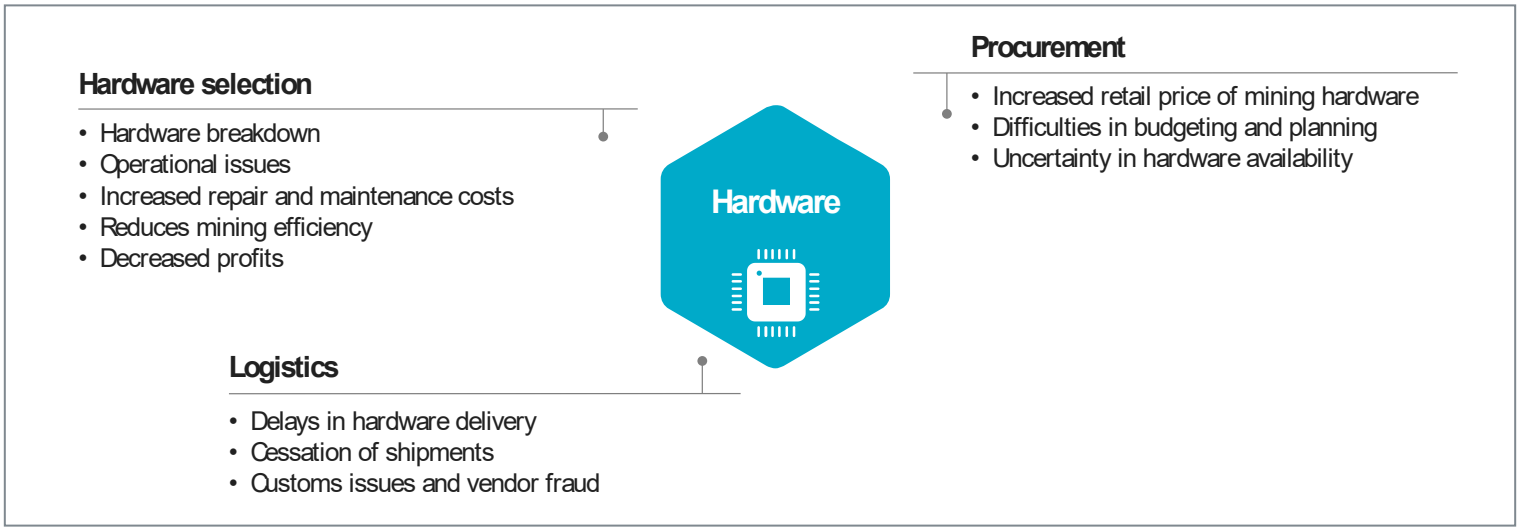
- **Diversify mining locations:** Diversify mining operations across multiple locations to reduce their exposure to political and legal risks in a specific region.

- **Comply with regulations:** Ensure that their operations comply with all relevant regulations and laws to reduce their exposure to political and legal risks.

- **Monitor regulatory changes:** Stay informed of changes in regulations and laws affecting their operations and adapt accordingly.

B. HARDWARE

1. Hardware selection



Key Risks: Hardware breakdown, operational issues, increased repair and maintenance costs, reduced mining efficiency, and decreased profits.

Description: Selecting the right mining hardware, including core mining hardware (ASIC miners) and supporting hardware (cooling technology), is critical for a successful mining business. The right ASIC miners enhance efficiency and profitability, while effective cooling ensures hardware longevity. During the 2022 bear market, advanced ASIC mining hardware helped some miners stay profitable despite challenging market conditions.

Mitigation Strategies:

- **Optimize hardware selection:** Conduct pilot projects to identify the best hardware and cooling solutions, consult experts in Bitcoin mining and data center design, and choose reliable hardware from reputable manufacturers.

- **Diversify suppliers and hardware:** Minimize dependence on a single hardware model by diversifying hardware resources and collaborating with multiple manufacturers.

- **Implement proactive maintenance and backup:** Anticipate potential failures through routine maintenance and monitoring, and establish an in-house repair center with backup hardware to minimize downtime.

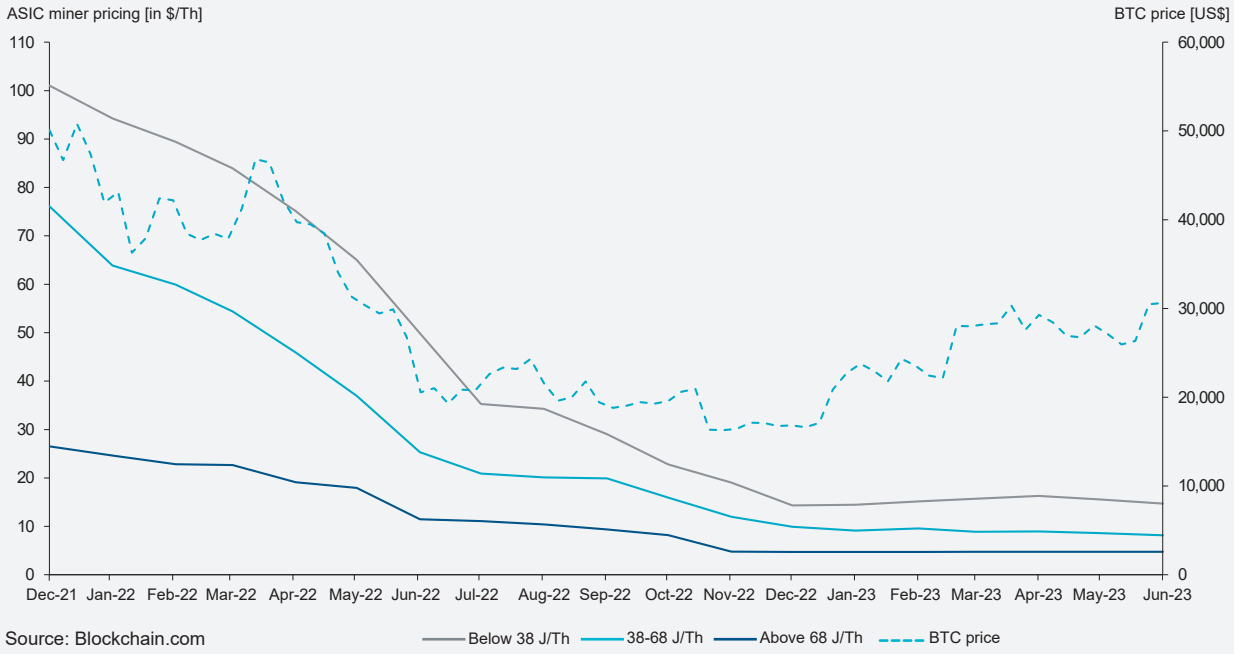
- **Manage obsolescence:** Regularly upgrade to the latest energy-efficient ASIC mining hardware and supporting infrastructure to maintain competitiveness and efficiency.

2. Procurement

Key Risks: Increased retail price of mining hardware, difficulties in budgeting and planning, uncertainty in hardware availability.

Description: ASIC miners' prices and availability can be affected by factors such as Bitcoin price volatility and supply-demand dynamics. Price fluctuations are often linked to Bitcoin's volatile market value, while hardware availability can be impacted by manufacturing delays, component shortages like semiconductors, and surges in demand.

F.6 / ASIC Price Index vs. Bitcoin Price



Source: Blockchain.com

Mitigation Strategies:

Well-balanced procurement strategy: A balanced procurement strategy for Bitcoin mining companies should involve regularly updating hardware with energy-efficient, high-performance ASICs to maintain competitiveness while mitigating excessive costs. Additionally, firms could lease mining equipment

or utilize cloud mining services, allowing for operational flexibility and reduced upfront costs, while closely monitoring market conditions to adjust resources and capacity as needed.

Leverage secondary market: Consider purchasing second-hand hardware to reduce costs and exposure to price volatility.

- **Financial planning:** Build a financial buffer to mitigate unexpected changes in capital expenditure.

- **Diversify hardware suppliers:** Source hardware from multiple suppliers to reduce the impact of disruptions.

- **Maintain order backlog:** Keep a sufficient supply of mining hardware during periods of high demand.

3. Logistics

Key Risks: Delays in hardware delivery, cessation of shipments, customs issues and vendor fraud (secondary market focused).

Description: Shipping mining equipment, such as ASICs, can be a complex and time-consuming process, often taking several weeks or even months. Geopolitical issues, including trade tensions, customs delays, and transportation disruptions, can further exacerbate these delays and increase lead times for shipping ASICs to mining operations. In some cases, geopolitical issues may result in a complete halt of shipments, making it challenging for miners to receive the hardware necessary to maintain their operations.

Mitigation Strategies:

- **Enhance relationships with logistics providers:** Work closely with logistics providers, miners can reduce the risks associated with shipping and ensure that the equipment is delivered in a timely and cost-effective manner.

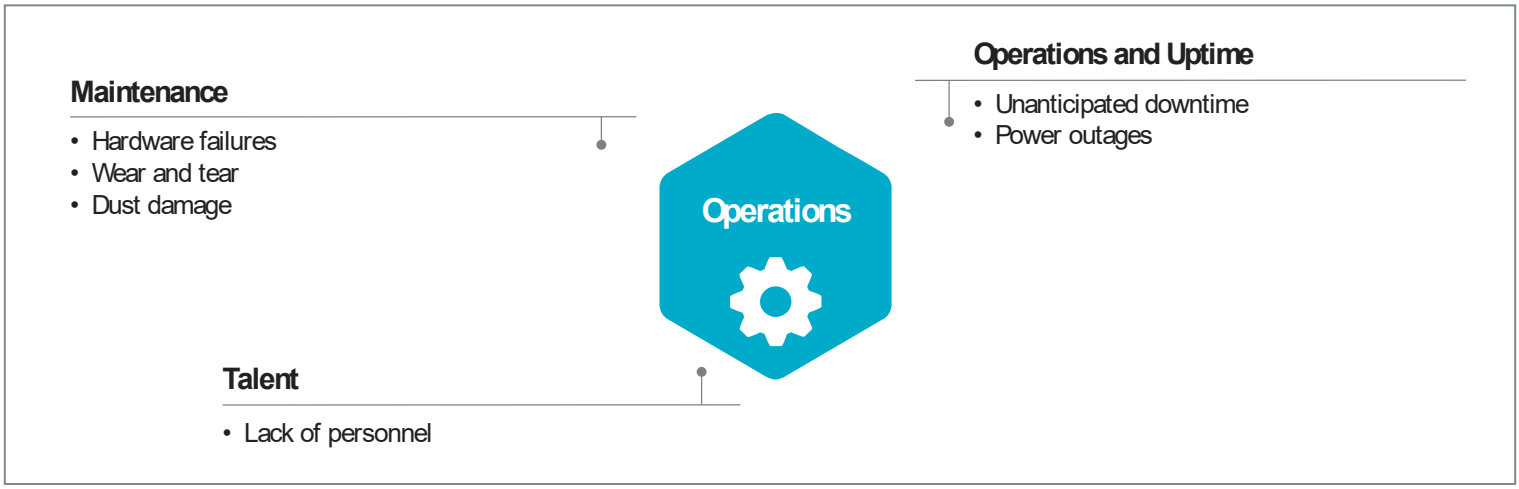
- **Maintain a flexible schedule:** Incorporate buffer in planning to accommodate potential shipping disruptions and maintain a flexible schedule to ensure enough time to receive the equipment and ramp up operations.

- **Conduct due diligence (secondary market focused):** Thoroughly research and evaluate secondary-market vendors before purchasing equipment.

- **Use escrow services (secondary market focused):** Employ escrow services to ensure secure payments and equipment verification.

Inspect and prioritize equipment with warranty (secondary market focused): Have equipment inspected before purchasing and prioritize equipment with a warranty to minimize risk of failure and ensure technical support access.

C. OPERATIONS



1. Maintenance

Key Risks: Hardware failures, wear and tear, dust damage.

Description: Operating and maintaining mining infrastructure presents a variety of challenges for miners. Hardware failures, maintenance issues, and the effects of harsh environmental conditions such as dust and humidity are common examples of maintenance risks. Miners must navigate these challenges to avoid unexpected costs, reduced profits, and potential downtime. Overclocking – a common practice to boost ASIC hardware computing power – can lead to multiple equipment failures if not properly managed.

Mitigation Strategies:

- **Develop a comprehensive O&M plan:** Develop a comprehensive O&M plan that outlines the procedures for operating, maintaining, and upgrading their mining infrastructure and hardware. This plan should include regular maintenance schedules, spare parts inventory management, and a clear process for addressing hardware failures.

- **Establish a relationship with equipment manufacturers:** Miners

should establish a relationship with equipment manufacturers to ensure that they have access to technical support and warranty coverage in case of hardware failures. This can help minimize the costs associated with O&M and ensure that the equipment remains in good working condition.

- **Avoid overclocking or moderately overclock:** Avoid overclocking their hardware, as this can result in hardware failures and decreased efficiency. If miners do decide to overclock, do so moderately.

- **Implement a preventive maintenance program:** Implement a preventive maintenance program to minimize the likelihood of hardware failures and extend the lifespan of the equipment. This program should include regular equipment inspections, cleaning, and replacement of critical components before they fail.

2. Operations and Uptime

Key Risks: Unanticipated downtime, Power outages.

Description: The ability to keep mining operations running continuously is crucial for profitability, especially during favorable market conditions. Unanticipated downtime due to hardware failures, power outages, or extreme weather conditions can be especially detrimental. Regions prone to frequent storms, for example parts of the US, face regular shutdowns that impact overall efficiency and productivity.

Mitigation Strategies:

- **Reliable power source:** Implement backup power solutions such as generators to prevent shutdowns during power outages.

- **Site selection:** Choose locations with reliable infrastructure to minimize the impact of external conditions on operations.

- **Network diversification:** Spread out mining operations across multiple locations to reduce the impact of any single incident on the overall hashrate.

- **Insurance coverage:** Consider obtaining insurance coverage for losses due to unexpected incidents.

3. Talent

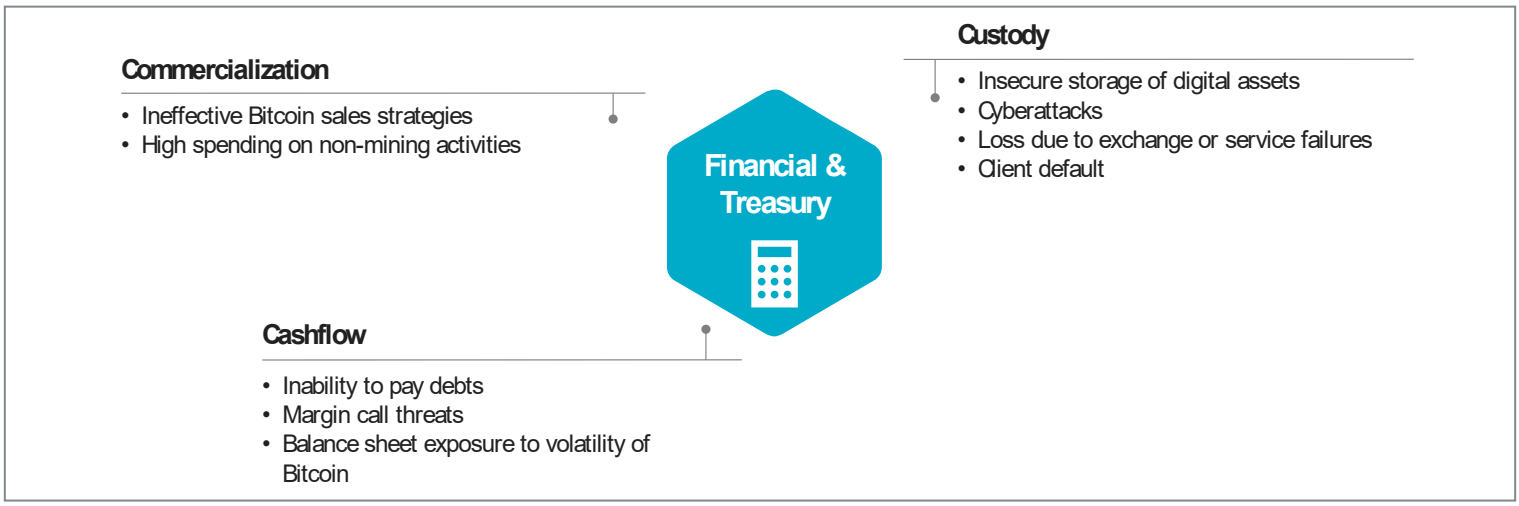
Key Risks: Lack of experienced personnel and operational staff.

Description: Effective operation and maintenance of mining infrastructure require a skilled workforce. Lack of expertise can lead to costly mistakes, such as improper overclocking or poor maintenance practices, resulting in hardware failures, decreased efficiency, and unexpected downtime.

Mitigation Strategies:

- **Talent acquisition and training:** Hire experienced personnel and invest in training to ensure your team has the necessary skills to operate and maintain the mining infrastructure.
- **Establish an effective communication system:** This ensures all team members are aware of their responsibilities and any changes in the operations or maintenance procedures.
- **Continuous learning and improvement:** Encourage a culture of continuous learning and improvement to keep up with the rapidly changing mining industry.

D. FINANCIAL & TREASURY



1. Commercialization

Key Risks: Ineffective Bitcoin sales strategies, high spending on non-mining activities.

Description: Ensuring financial stability for Bitcoin mining firms requires a

strong focus on cost control to maintain competitiveness in the global market for new Bitcoin blocks. Since miners have limited options to influence their mining revenue, management should prioritize minimizing expenses for their mining operations. In the face of decreasing Bitcoin mining profitability, firms with the lowest cost can sustain their business the longest.

Moreover, one of the critical decisions for CFOs in crypto mining companies is developing a Bitcoin commercialization strategy. The chosen strategy often reflects the company's outlook on Bitcoin price trends. If a firm expects the US$ value of Bitcoin to increase, they may hold onto their mined Bitcoin as long as possible. However, overly optimistic expectations can lead some firms into financial difficulties.

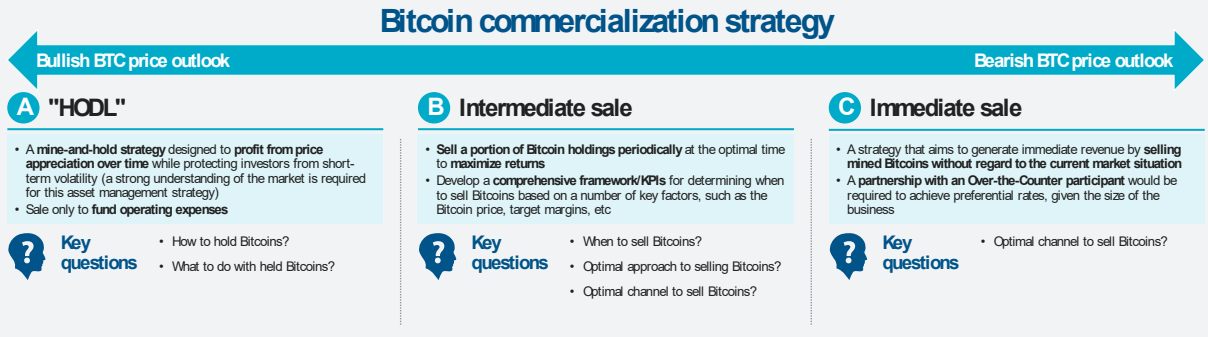
Mitigation Strategies:

For commercialization strategy:

- **Portfolio diversification:** Maintain a balance between liquidated, lend and held Bitcoins to benefit from potential price appreciation while ensuring cash flow for operational expenses.

- **Dynamic liquidation strategies:** Implement dollar-cost averaging, selling Bitcoins at regular intervals to reduce the impact of market volatility on realized gains, while utilizing algorithmic trading strategies to optimize the timing and execution of sales, minimizing slippage and maximizing returns.

F.7 / Overview of Bitcoin commercialization strategy



Source: Roland Berger

For expense management:

Reduce non-electricity costs: Minimize non-power-related costs, including maintenance, repair, and non-mining overhead expenses, to ensure competitiveness.

Automate and streamline operations: Maximize the use of automation and remote management through software tools to increase efficiency in maintenance and operational control. This will help reduce manual intervention and associated costs, further lowering OPEX.

Limit non-mining spending: Keeping overhead expenses for management, marketing, administration, etc. minimal to allow for the highest efficiency.

2. Custody

Key Risks: Insecure storage of digital assets, cyberattacks, loss due to exchange or service failures, client default.

Description: Bitcoin miners face various risks related to the storage and safekeeping of their digital assets, as well as risks associated with clients, exchanges, and third-party services. Inadequate key and wallet management governance can leave miners vulnerable to theft and cyberattacks. Additionally, miners may face technical risks if exchanges or services fail to fulfill their obligations or experience cybersecurity breaches.

Mitigation Strategies:

- **Secure storage and robust management:** Use cold wallets for secure storage and implement robust key and wallet management governance mechanisms to minimize the risk of theft from cyberattacks or bad actors.

- **Diversify and conduct due diligence:** Utilize multiple exchanges and banks, conduct thorough due diligence on their security measures and reputations, consider using decentralized exchanges to spread the risk of loss, and assess the financial stability and creditworthiness of potential clients.

- **Monitor and insure:** Regularly monitor accounts and transactions to detect suspicious activity or unauthorized access, and purchase insurance for digital assets to protect against losses resulting from theft or hacking.

- **Contractual protection:** Include clear payment terms, late payment penalties, and termination clauses in agreements to protect the miner's interests.

3. Cashflow

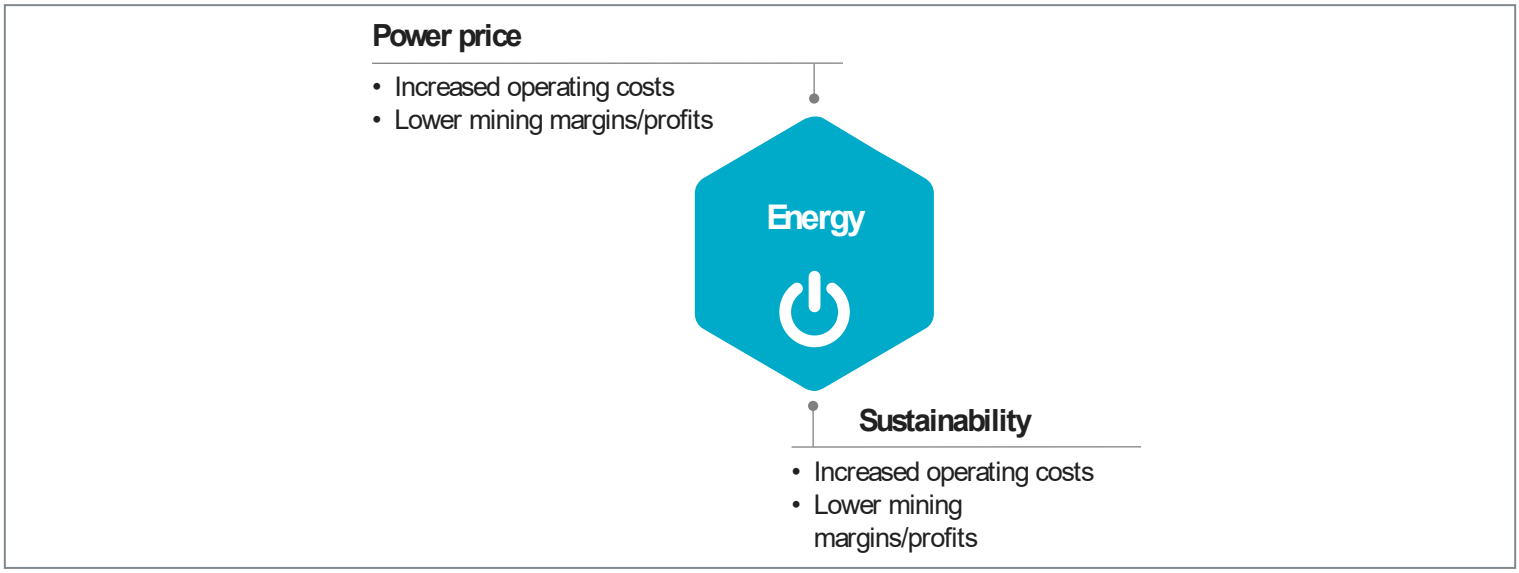
Key Risks: Inability to pay debts, margin call threats, and balance sheet exposure to Bitcoin price volatility.

Description: Bitcoin mining firms face credit default risk if they are unable to pay their debts, such as electricity bills and equipment purchases. Starting from Q3 2022, mining firms increasingly struggled to pay their debt as mining profitability decreased. Additionally, margin calls required them to contribute additional cash assets from their already distressed balance sheets.

Mitigation Strategies:

- **Manage leverage and prepare for margin calls:** Keep lending under control, maintain cash reserves in non-crypto currencies, and avoid over-optimistic planning based on Bitcoin price increases.
- **Implement hedging strategies:** Hedge leveraged bets and invest in market-neutral funds to protect against credit default scenarios and market volatility.
- **Pursue vertical integration:** Purchase or construct power production assets to reduce energy cost fluctuations and decrease reliance on a single production asset.
- **Maintain financial vigilance:** Monitor market conditions and key performance indicators and be prepared to adjust strategies based on market trends and company performance.

E. ENERGY

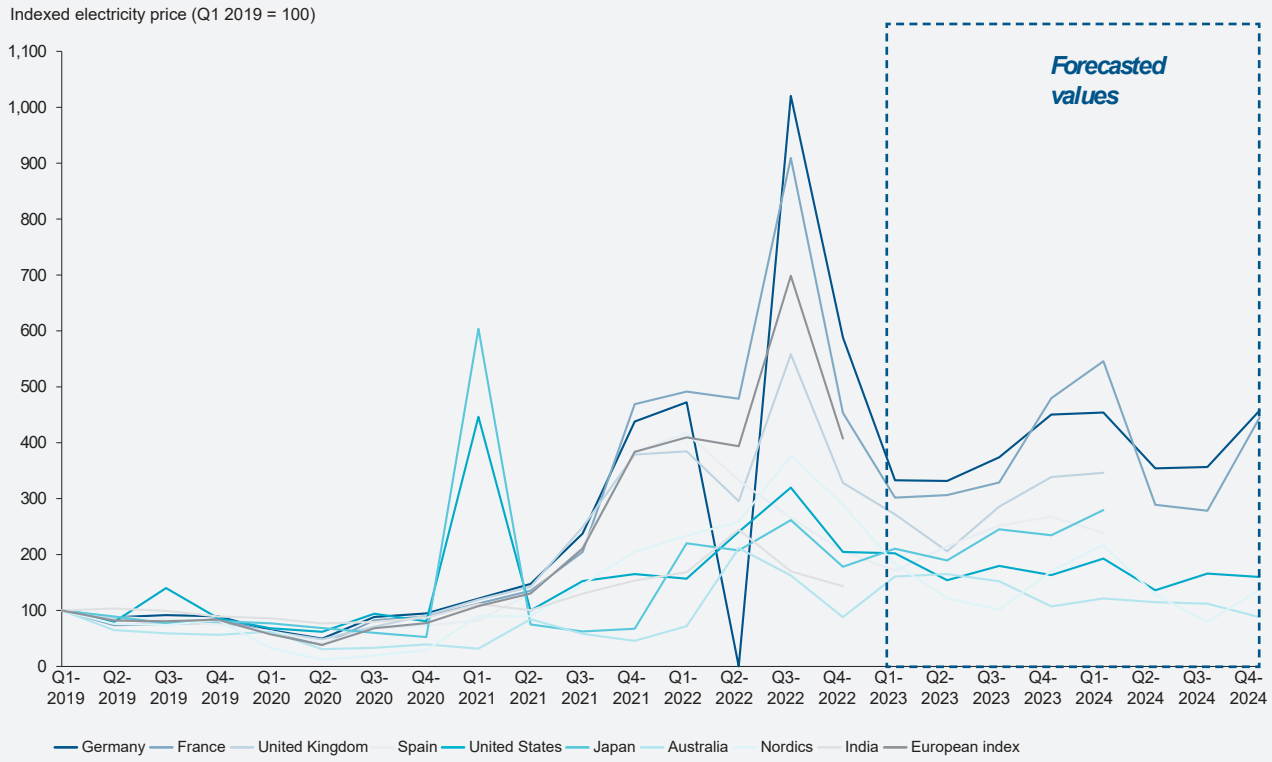


1. Power price

Key Risks: Increased operating costs, lower mining margins/profits.

Description: Power costs are a significant proportion of the operational expenses for miners, accounting for 70-80% of their overall costs. The fluctuations in electricity prices pose a significant risk for miners, as it can adversely affect their profitability. In recent years, the rise in energy prices has had a detrimental impact on the profitability of mining operations, and in the United States, which has the largest hashrate share of almost 40%, the surge in electricity costs has made it challenging for miners to sustain their operations. Texas, which is the largest Bitcoin mining hub in the US, has experienced a sharp increase of around 18% in electricity prices, further worsening the situation.

F.8 / Indexed quarterly average wholesale electricity prices for selected regions, 2019-2024



Source: International Energy Agency

Mitigation Strategies:

- **Secure long-term energy price stability:**

o Consider long-term contracts for utilities.

- Hedge the price of power if exposed to merchant power market risk.
- Switch to renewable energy sources such as solar or wind power to reduce their exposure to price increases in traditional electricity sources.
- Use energy hedging techniques such as buying futures contracts to lock in energy prices and reduce the impact of price increases.
- Collaborate with electricity providers to negotiate favorable PPA terms and reduce their exposure to electricity price increases.

- **Adopt energy-efficient equipment:** Invest in energy-efficient equipment to reduce their electricity consumption.
- **Diversify geographical footprint:** Diversify their operations across multiple locations to reduce the impact of electricity price increases in a specific region.
- **Curtail operations:** Consider pausing operations during periods of high electricity cost.

2. Sustainability

Key Risks: Environmental impact, regulatory scrutiny, and public perception.

Description: The mining industry's high energy consumption and the related environmental impact have been under increasing scrutiny, leading to reputational risk and potential regulatory restrictions. As societal and governmental focus on climate change intensifies, miners need to increase the consideration of sustainability in their operations. Failure to address these concerns could impact miners' ability to operate or lead to additional costs, such as carbon offset fees or taxes and operating license risks.

Mitigation Strategies:

- **Maintain strong relations with regulators and ecosystem players:** Engaging with key stakeholders in the energy sector and effectively communicating the benefits of Bitcoin mining, such as demand-side management of the grid and new revenue stream generation, can contribute to a better understanding and more favorable regulatory environment for mining operations.
- **Increase to renewable energy and other alternate power sources:** Increase the share of renewable energy sources will reduce the emission impact and potentially secure more favorable regulatory and public

standing. Additionally, miners could use alternate power sources, for example, harnessing methane from landfills and using it for Bitcoin mining reduces the potent GHG emissions from landfills while providing a sustainable energy source for mining.

- **Circular Economy practices:** Implementing circular economy practices can turn waste from mining operations into resources. For instance, excess heat from mining can be used for district heating, water purification, or greenhouse heating, providing a cost-effective and environmentally friendly solution.

- **Carbon Offsetting:** Investing in carbon offset initiatives can balance out the carbon footprint and demonstrate a commitment to sustainability.

- **Energy-efficient equipment:** Utilizing more energy-efficient equipment can help to reduce the environmental footprint of mining operations

4/ Conclusion

Bitcoin mining – and the broader, emerging decentralized datacenter industry – present intriguing and promising business opportunities. To capitalize on these, both investors and Bitcoin miners must strategically navigate this rapidly evolving landscape, seizing opportunities and outpacing adaptable competitors. Crucial to this endeavor is astute risk management, as outlined in this report.

At Roland Berger, we harness a unique blend of capabilities:

1. An in-depth understanding and genuine enthusiasm for the digital asset industry, particularly Bitcoin mining.

2. Expertise in financial management and commercialization.

3. Strong expertise in energy and commercial asset optimization.

As Bitcoin mining firms increasingly professionalize and contemplate going public, a robust strategy and diligent risk management become paramount.

We are eager to engage with you, helping you to leverage these exciting opportunities and master the Bitcoin mining landscape.

WE WELCOME YOUR QUESTIONS, COMMENTS, AND SUGGESTIONS

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