Financial Valuation of Bitcoin Mining Operations: Mining Profitability of Renewable vs Non-Renewable Sources

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I. Introduction

With the recent influx of interest in the cryptocurrency Bitcoin among major banks and investors, the question of supplying said Bitcoins has arisen. Due to the increased demand, Bitcoin mining operations have scaled up to supply the requisite quantity of the asset in the market. The scaling up of mining and transaction operations has greatly increased the consumption of energy in order to power mining devices and maintain the activities on the Bitcoin network. The increase in energy consumption is an inevitable consequence that has resulted in the Bitcoin network consuming up to 87.1TWh of electrical energy annually, an estimate comparable to the annual amount of total energy consumed by a country such as Belgium [1]. In addition, while already relatively high, the consumption of energy by the Bitcoin network is predicted to continue to increase. Given these concerns, diverging investment strategies concerning the profitability of renewable vs non-renewable will be analyzed and an optimal strategy given certain constraints will be devised. After elucidating the basic functions of the Bitcoin network and concomitant mining operations necessary to understand the root cause of the high energy consumption, the revenue per unit energy generated from a common mining scheme will be explored, then finally a strategy based on a derivative of Net Present Value (NPV) will be considered.

II. Bitcoin Functionality and Mining Operations

The general operations of Bitcoins and its associated decentralized network, in addition to the quickly developing history and the concomitant increase in energy consumption of bitcoin mining are important to consider in order to gauge the future growth and to plan for said growth in a financially efficient way. In essence, Bitcoin is a peer-to-peer decentralized network capable of managing transactions using cryptographic protocols on a public ledger called a blockchain [5]. Due to the decentralized nature of the cryptocurrency, a process called mining is necessary, in which blocks of transactions are verified and appended to the blockchain ledger, a process which is resource and energy consuming as a whole [6]. In order to process the large amounts of transactions on the Bitcoin network, large networks of computers are tasked with the computationally difficult process of solving the cryptographic hash necessary to verifiy a block onto a blockchain.

Originally, Bitcoin mining was performed using the Central Processing Unit (CPU) of the networked computers, but miners realized that cryptographic hashes could be solved faster using Graphical Processing Units (GPU) and then eventually, in the modern day, miners have scaled up to large warehouses of networked Application-Specific Integrated Circuits (ASICs) [2, 3]. Given that solving the requisite cryptographic hashes increases in difficulty as more Bitcoins are mined, miners were required to scale up operations and use more powerful devices in order to stay financially competitive. This scaling up of mining to large networks of high energy consuming devices has not only necessitated greater energy usage for powering the devices but also has required an increase in power usage for the cooling systems that are now required to keep the warehouses and devices at a sufficient temperature. Considering the growing number of Bitcoin users and miners and increased energy consumption, inevitably, the question of financial sustainability and profitability arises.

III. Revenue Generated Per Unit Energy

The amount of energy consumed and the number of cryptographic hashes solved per second, known as hashrate, is highly dependent on the mining device used. Currently, it is estimated that the most commonly used mining device is the Antminer S9, which has a hashrate of 14 terahashes per second (TH/s) and uses 1,372W of power, and of which will also be used as the device to estimate the energy consumption [2]. To estimate the energy consumption *N* of the Bitcoin mining network in 2021, we will consider the equation from [4], which states

$$N = \frac{\rho \cdot \gamma}{1000}$$

where ρ is the hash rate, which is estimated to be 153,717,000TH/s as of the beginning of March 2021, and γ is the energy efficiency of the Antminer S9, which is 0.098W per GH/s. We can then conclude that *N*=15,064.244MW, and the daily energy consumption *E* is found to be *E=N*(24 hours)*=361,542.384MWh. It is important to note that it is not possible to know the exact rate of energy consumption of Bitcoin mining due to the decentralized nature of the network, however, the above calculation is sufficient for our needs although it may be an overestimate compared to [1], which states that 87.1TWh is an upper bound for yearly energy consumption. The overestimate may also be more appropriate when considering future profitability and financially sustainable energy production due to the fact that the hash rate is constantly increasing as seen in Figure 1.

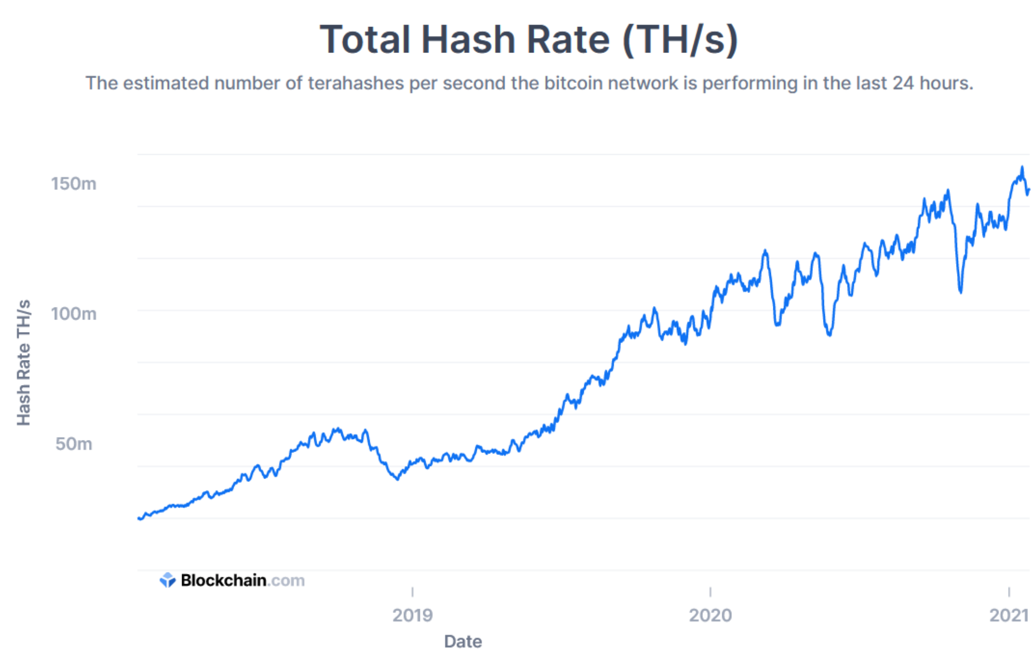

Figure 1: The 7-day moving average of hash rate of Bitcoin from 2018 to 2021 (https://www.blockchain.com/charts/hash-rate)

Currently, the 5-day moving average of the price of Bitcoin stands at 54,042.12 USD per Bitcoin and, as of May 11, 2020, the reward for solving the cryptographic hash is a block, which on average is solved every ten minutes, and of which is worth 6.25 Bitcoins [7]. Given these parameters, we can denote the monetary value in US Dollars per Bitcoins mined per hour as

$$D = current\ price\ of\ Bitcoin \cdot reward\ per\ block \cdot blocks\ per\ hour = 54{,}042.12 \cdot 6.25 \cdot 6 = \$2{,}026{,}579.50$$

Then we can find the revenue of Bitcoin per mega-watt hour considering only the Antminer S9, which will be denoted by τ_A, such that

$$\tau_A = \frac{D}{E} = \frac{2{,}026{,}579.50}{361{,}542.384} = 5.61\ \$/MWh$$

We can then use τ_A as a baseline revenue estimate when investigating the profitability of using renewable vs non-renewable energy sources as a way to power Bitcoin mining operations.

IV. Renewable vs Non-Renewable Energy Sources

Considering the amount of energy needed to power Bitcoin mining operations, renewable energy sources, specifically wind and solar energy, are prime areas of interest due to ecological tariffs and production cost reasons, however non-renewable energy sources will also be considered for the sake of comparison. According to the investment bank Lazar, the cheapest levelized cost of energy regarding renewable energy sources are wind energy, which ranges from $26 to $54 per MWh, and solar energy from photovoltaic solar cells, which ranged from $29 to $42 per MWh [8]. In comparison to our τ_A value, on average the profitability of Bitcoin mining would be at a deficient when only considering the cost of the cheapest renewable energy sources. Despite the current lack of profitability on this front, renewable energy sources may still provide the cheapest prices even when compared to non-renewable energy sources. The investment bank Lazar reports that the cheapest levelized cost of non-renewable energy sources after applying a carbon emission tax are gas combined cycle based energy, which ranges from $53 to $92 per MWh, coal based energy, which ranges from $86 to $165 per MWh, and nuclear energy if the midpoint of the marginal cost of operating a fully depreciated facility is considered, which ranges from $29 to $198 per MWh [8].

Furthermore, it is important to consider that our calculated daily energy consumption E is an overestimate compared to other sources and mining before May 11, 2020, when the reward for each mined block was 12 Bitcoins, along with using more powerful machines could have been more profitable in the past. In order to increase the threshold of profitability, either more powerful, higher end, and energy efficient mining devices currently on the market could be used, as the Antminer S9 is becoming obsolete and is considered more of a middle-of-the-line product, or finding a cheaper or new way to produce energy. Despite the lack of profitability from an energy cost vs revenue per unit energy basis, the price of electricity may actually be the least impactful variable on the return on investment.

V. Long-Term Investment Profitability

From a long-term investment perspective, Bitcoin differs from fiat currency in that the asset does not experience the same type of depreciation typically associated with fiat currency, and in fact the coin has appreciated %5,400,000 in the last 10 years, which may allow for Bitcoin mining to be profitable from a long-term perspective. Typically, from an investment planning or capital budgeting standpoint, Net Present Value (NPV) is used to valuate the profitability of an investment [9]. However, when applying NPV to cryptocurrency based investments, especially Bitcoin, the base assumptions of NPV do not hold. NPV works under the assumption that money devalues over time, the devaluation being based on a discount rate variable, however, since the inception of Bitcoin, the value has appreciated at an exponential rate and is forecast to continue to appreciate well into the future. Due to these differences in the mechanics of fiat money and cryptocurrency, an alternative is introduced that is derived from NPV to account for such differences.

Net Coin Value (NCV) is introduced, which models the difference between the net coin flow and the operating expenses and is valued at the price of a given coin on the day of the purchase of the mining equipment [10]. NCV states

$$NCV=\sum_{i=1}^{n} C_i$$

where n is the last day of mining operations and C_i is defined as the difference between the amount of coins mined daily and the electricity bill such that

$$C_i=(1-k)\frac{M_0}{(1+r)^i}-\frac{e}{P_0}$$

where k represents administrative fees, M_0 is the estimated amount of coin mined on the first day, r is the growth rate of the hashrate of the network, e is the daily electricity cost, and P_0 is the price of the coin on the day of purchase of the equipment [10]. Using NCV, a forecast of the profitability of Bitcoin mining using various energy sources over an extended period of time can be valuated.

VI. Case Study: The Effect of Energy Pricing on the Profitability of Bitcoin Mining

In short, an analysis of the impact of renewable vs non-renewable energy pricing on the long-term profitability of Bitcoin mining will be realized. All variables in the NCV equation are kept constant and only e, the daily energy cost, will be variable for this experiment. The most common mining machine on the market, the Antminer S9, at a population of 100 machines, a number of machines representative of a small-medium sized mining operation, over the course of five (5) years will be evaluated. The prices for the energy sources are given in the table below as

Type	*Price [$/GWh]*	*Renewability*
Wind	26	Renewable
Solar	29	Renewable
Gas Combined Cycle	53	Non-Renewable
Coal	86	Non-Renewable
Nuclear	29	Non-Renewable

The lower bound of the prices of the various energy sources is used as per the report [8] and may be an underestimate when compared to real world commercially available prices.

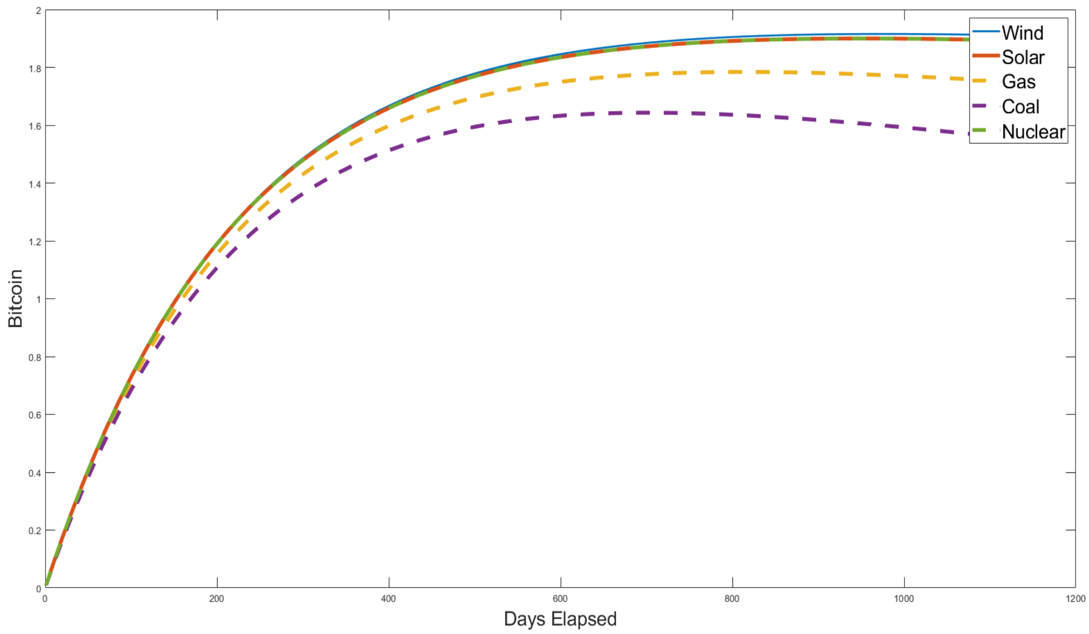

Figure 2: Net Coin Value (NCV) of Bitcoin mining operations at various energy prices

In Figure 2, the profitability of Bitcoin mining per day over the course of five (5) years given by NVC can be seen. Given the various energy prices, on average renewable energy outperforms non-renewable energy, with the exception of nuclear energy, when it comes to long-term profitability. The NVC for gas and coal reaches its max at around 1.78 and 1.64, respectively, while for wind, solar, and nuclear NVC reaches its max at around 1.90. That is to say, at the peak of revenue generation, wind, solar, and nuclear generated 0.12 to 0.26 more Bitcoin per day or, considering the current price of Bitcoin, about $6,480 to $14,040 more per day than gas and coal, respectively.

In [10], the break-even point given the cost of equipment is given by

$$NCV(i) > \frac{Equipment\ Cost}{P_0}$$

Given that the upper end cost of a new Antminer S9 is around $2,100 and given that the price of Bitcoin on the first day of mining is $54,042.12, the mining operation would reach the break-even point on about day four (4). Given all of the above, despite Bitcoin mining not being profitable from a revenue per unit energy standpoint at the current time, due to the exponentially appreciating price of Bitcoin, mining operations can be highly profitable over an extended period of time.

VII. Conclusion

Considering the growing popularity of mining Bitcoins, new investment strategies need to be developed in order to ensure the profitability of Bitcoin mining. Bitcoin mining is an essential aspect of the Bitcoin ecosystem and is the means of productions of the Bitcoins that will eventually be used in the marketplace. While mining is now less profitable due to the decrease in the reward from mined blocks, the widespread use of soon-to-be obsolete devices, increased hash rate, and relatively expensive energy sources, investment projection methods such as Net Coin Value (NCV) shows that mining operations can be profitable over an extended period of time due to appreciation. In order to ensure profitiability, factors such as the use of renewable vs non-renewable, specifically the price therewith, need to be taken into account. Further research in the field of Bitcoin mining financial planning is needed and the basis for such solutions could also lead to more more profitable methods outside of the realm of Bitcoin mining, and such solutions would ultimately be of benefit to the financial industry and businesses alike.

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