



**BLOCKWARE  
SOLUTIONS**

# Bitcoin Energy Gravity

Modeling the relationship between the price of Bitcoin and its cost of production

## Abstract

*This Blockware Intelligence Research Report models the relationship between the price of Bitcoin and its mean operating cost of production for modern mining rigs. It demonstrates how this relationship plays an important role in Bitcoin price cycles and the long-term monetization of the asset.*

## Key Points

- 1. All Bitcoins are acquired at one of two market prices:  $\$/BTC^1$  or  $(Energy * Time) / BTC$ . Both prices are increasing over time, but not necessarily at the same rate. The prices of Bitcoin grow due to increasing scarcity (time, halvings, and mining difficulty) and more users joining the monetary network due to Bitcoin being the most superior monetary technology.*
- 2. Bitcoin Energy Gravity is the maximum USD price ( $\$/kWh$ ) modern mining rigs are willing to buy electricity at to make a profit. From this maximum bid price, it is possible to get a better understanding of when the price of Bitcoin is overextended and when the price may be approaching a bottom.*
- 3. Money itself is fascinating. For something to become money, it needs to be both scarce and well distributed. This is a paradox, and Bitcoin solved this with a predetermined Proof of Work distribution schedule that exponentially decreases over time.*
- 4. During times of historically high energy gravity (the cost of production and the price of Bitcoin are severely disconnected), market participants act in their own self-interest to close this arbitrage opportunity.*
- 5. When Energy Gravity decreases and the price of Bitcoin goes below some miners' cost of production, the weakest miners purge their Bitcoin treasuries and shut off their mining rigs. Capitulations historically mark price bottoms because this large increase in temporary sell pressure (the bottom) ends with a significant reduction in day-to-day sell pressure.*
- 6. Bitcoin is an ultra-unique commodity (due to it being actively monetized from 0) where miner operating margins regularly explode higher. This will continue occurring and Bitcoin mining will continue to be one of the fastest-growing industries in the entire world. The challenge, as always, will be able to outsurvive the weaker miners.*

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<sup>1</sup>  $\$/BTC$  refers to any fiat exchange rate. It could also be euro, yen, etc.

## Bitcoin's Two Market Prices

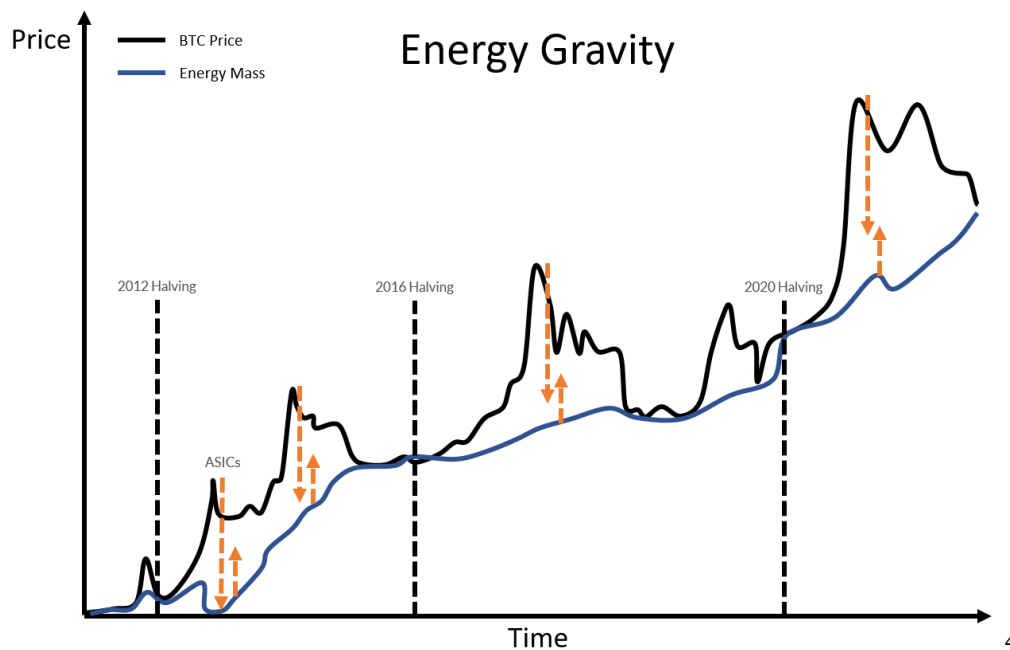
Bitcoin has two important market prices.

1. \$ / BTC<sup>2</sup>
2. (Energy \* Time) / BTC

USD / BTC (or any other fiat exchange rate) is how most individuals think about the “price” of Bitcoin. However, (Energy \* Time) / BTC is an important, but less intuitive exchange rate for Bitcoin. To exchange kWh for BTC, you need specialized hardware, known as Bitcoin mining rigs and electricity.

Due to the invisible hand<sup>3</sup>, these two market prices commingle to ensure Bitcoins are fairly distributed over 140+ years at a market rate with no insiders or premines, and so that the USD price of Bitcoin will not get too far ahead of global adoption. This interactive relationship enables Bitcoin's price to scale with Bitcoin's adoption in a reflexive positive feedback loop.

**The prices of Bitcoin grow due to increasing scarcity (time, halvings, and mining difficulty) and more users joining the monetary network.** The energy gravity model illustrates how price and mining infrastructure inevitably scale together, and this report provides quantitative and qualitative analysis as to why this is the case.



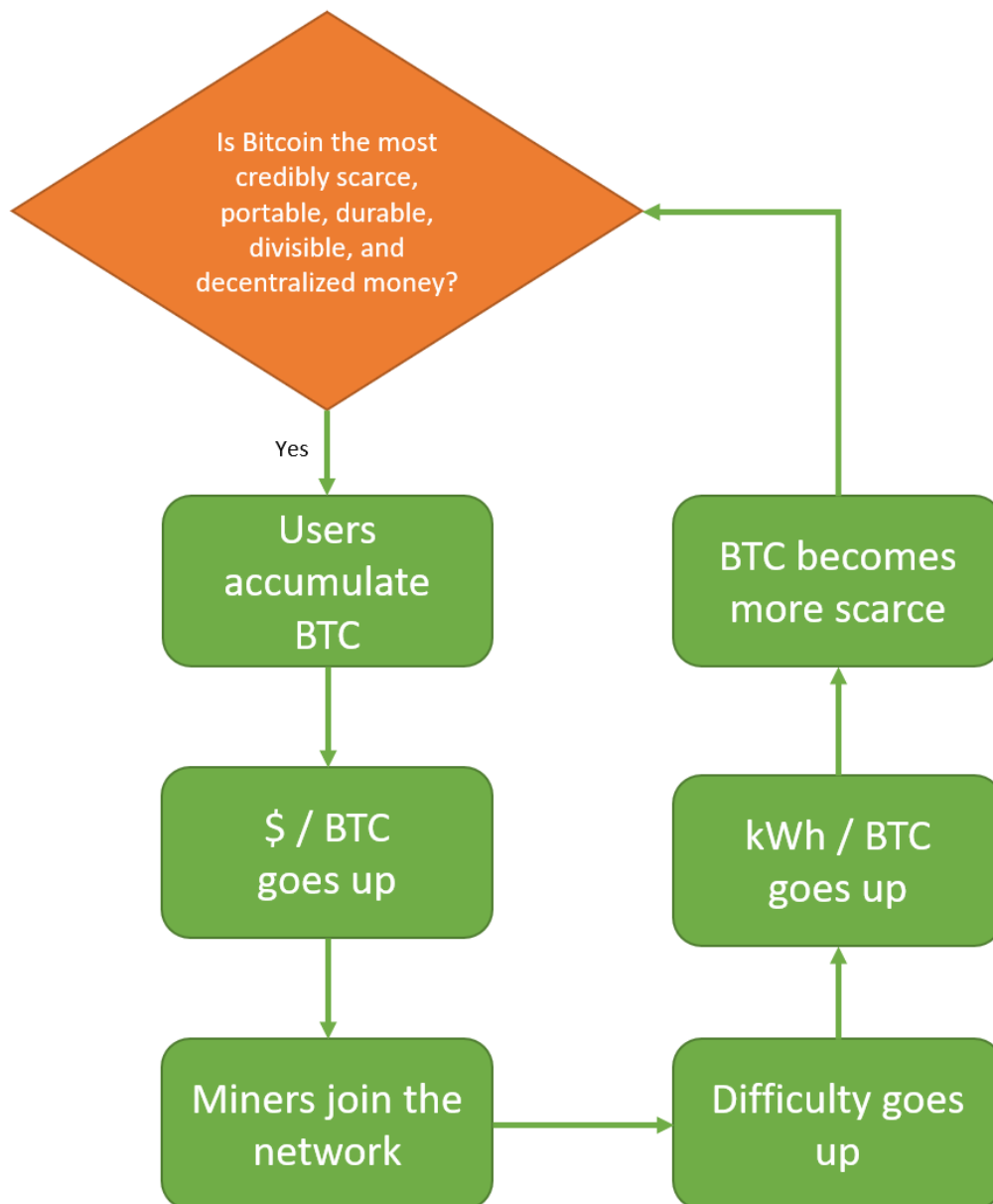
<sup>2</sup> \$ / BTC refers to any fiat exchange rate. It could also be euro, yen, etc.

<sup>3</sup> In reference to Adam Smith's economic concept published in 1759.

<sup>4</sup> This model (page 4) is based on original work from [Charles Edwards](#) at [Capriole Investments](#).

## Bitcoin Adoption Feedback Loop

In short, Bitcoin adoption boils down to individual humans slowly identifying the world's objectively best form of money (immutably scarce, portable, durable, divisible, and fungible) and then acting on that information. Price signals, information transmitted over the internet, books, and podcasts are all mediums by which people learn about Bitcoin.





## Bitcoin Energy Gravity Model

What is the breakeven electricity rate of modern mining rigs (\$ / kWh)?

**Energy Gravity:** The maximum USD price (\$ / kWh) modern mining rigs<sup>5</sup> are willing to pay for electricity to make a profit.

**Energy Mass:** The estimated mean operating cost of production for a modern mining rig using commercial electricity rates<sup>6</sup>.

Above high-end retail electricity rates (currently ~ \$0.30 per kWh)<sup>7</sup>, modern mining rigs would theoretically be willing to outbid nearly all other electricity buyers.

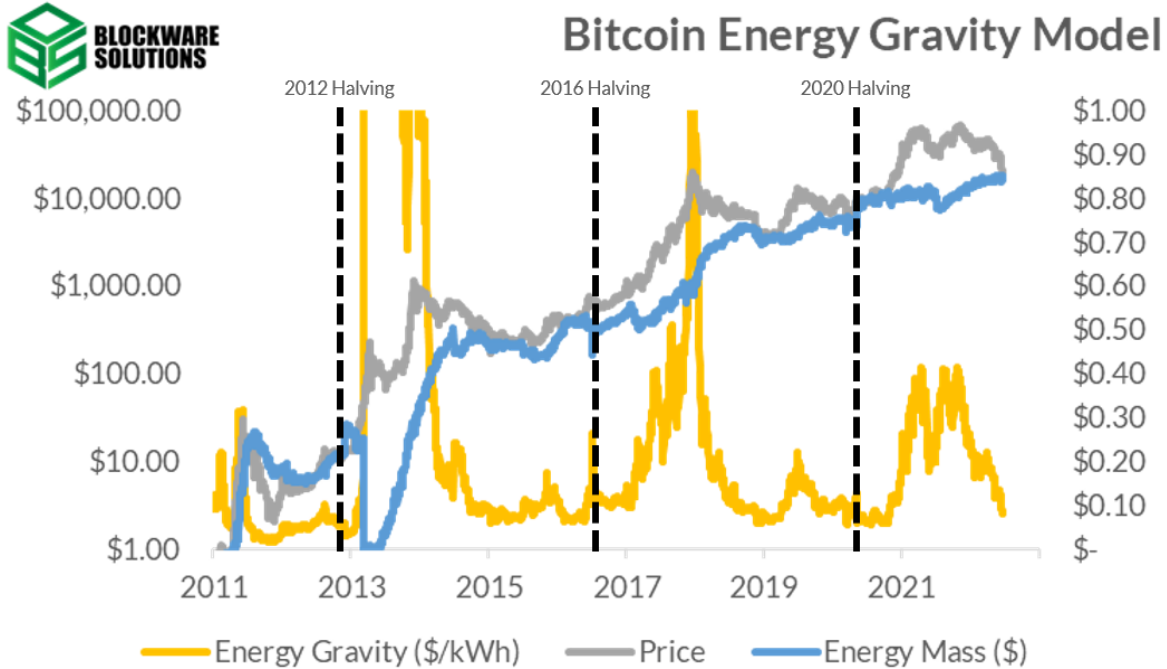
This indicates that the Bitcoin cost of production (kWh / BTC) and the Bitcoin price (\$ / BTC) are severely disconnected, and the “gravity” for the two prices to converge is HIGH due to markets naturally trending toward efficiency. Due to Bitcoin’s difficulty adjustment combined with PoW mining, the cost of production naturally rises toward the market price, unlike all other commodities. If there are large profits to capture in a market (kWh / BTC can be used to make profits on the \$ / BTC exchange rate), then market participants will inevitably try to capture those profits. This is clearly reflected in the model below. **Bull market price peaks always coincide with modern Bitcoin mining rigs economically willing to outbid virtually all other uses of electricity.** Of course this is unsustainable.

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<sup>5</sup> “Modern mining rigs” is defined as the mean efficiency (J/TH) of top mining rigs over the past 2 years.

<sup>6</sup> Historical [eia.gov](http://eia.gov) mean US commercial grade electricity rates \* 0.6

<sup>7</sup> Eurostat - [ec.europa.eu](http://ec.europa.eu)



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Virtually all other commodity producers never get to experience the same magnitude margins as Bitcoin miners historically have.

Bitcoin miners have demonstrated these high margins because economic systems converge on the most immutable, perfectly scarce, divisible, portable tool as money. Individuals in our global economic system are actively converging on Bitcoin from the price of 0. Because Bitcoin adoption is occurring so fast, the price occasionally goes on rapid parabolic bull runs. During these bull runs, miner margins explode due to it taking time and energy to manufacture, buy, and deploy Bitcoin mining rigs. Investors can buy Bitcoin in a matter of seconds, but building a mining farm from scratch can take weeks or even years. Because of this unique dynamic, hash rate and difficulty usually lag price.

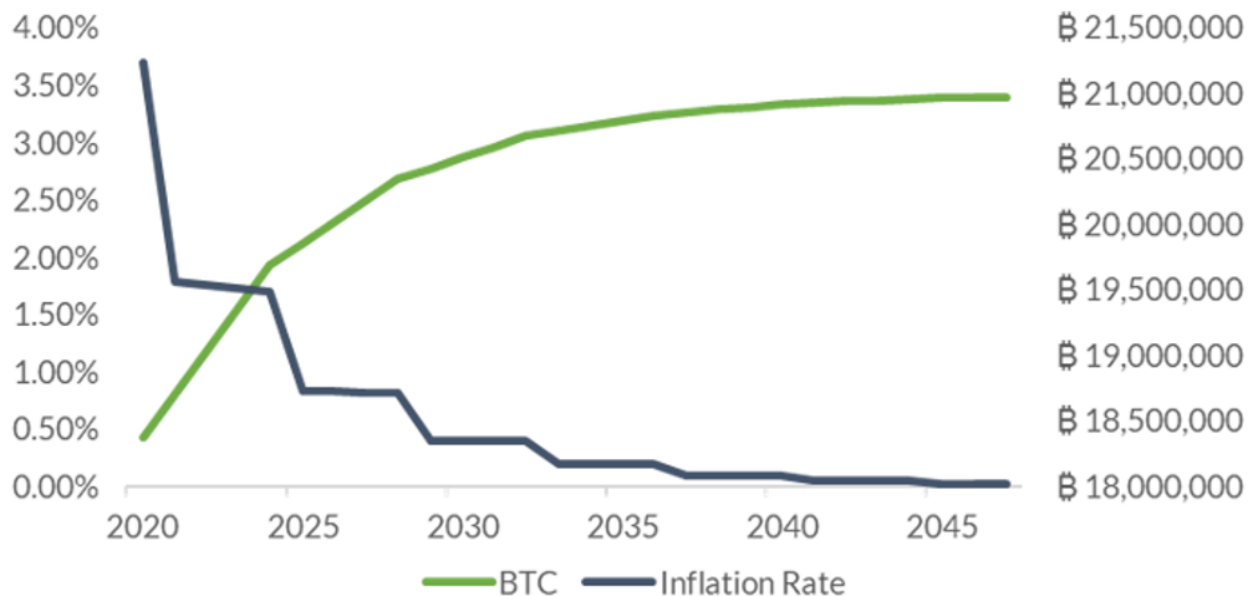
<sup>8</sup> This model is based on the [Bitcoin Energy-Value Equivalence](#) report and model by Charles Edwards.

## The Idea of Money and Monetization

Money itself is fascinating. For something to become money, it needs to be both scarce and well distributed. This is a paradox, and Bitcoin solved this with a predetermined Proof of Work distribution schedule that exponentially decreases over time.



### Bitcoin Supply Schedule



As mentioned above, a key ingredient of perfect scarcity is the fair distribution of coins over time at a market rate. There are two ways to acquire BTC:

1. \$ / BTC
2. kWh / BTC

All BTC was acquired at one of these market prices. There are no insiders in Bitcoin, which is an overlooked key to its immutable scarcity. For if Satoshi pre-mined 20.9M out of the 21M BTC, it would not be scarce (Satoshi would effectively have a money printer). It likely would have gained no sustainable traction.

Bitcoins are distributed through Proof of Work mining over a long period of time (100+ years). As more miners join the network, mining difficulty adjusts up, guaranteeing the supply schedule stays intact and miners effectively pay a market rate for new BTC (in kWh). This distribution method ensures the price of Bitcoin doesn't get too far ahead of the physical energy infrastructure used to initially distribute coins at a market rate.

**le:** This ensures that adoption cannot happen too fast with too few entities owning too many coins at a high market price.

**le:** Price grows over time with increasing scarcity and actual capital adoption. Capital adoption can be thought of as both wealth stored in the coin itself and the energy mining infrastructure producing it.

**le:** Bitcoin has one of the largest CAGR of all asset classes, which drives adoption itself in a massive positive feedback loop.

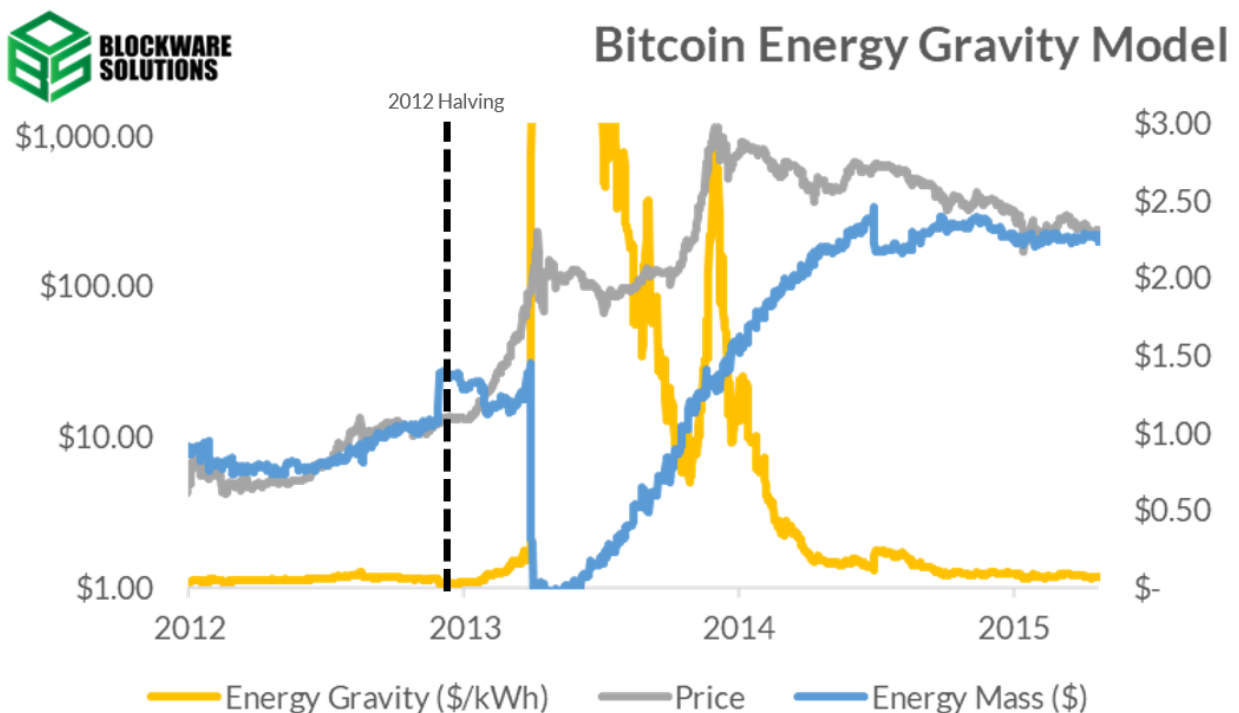
Although supply exponentially decreases over time due to block subsidy halvings, this source of new supply that is mined at the market price (kWh / BTC) acts like gravity on the BTC price. Why? Because free markets trend toward efficiency.



## 2013 - The First Bitcoin ASICs

When the price of 1 BTC was trading at \$229.43 at the beginning of 2013, you could mine 1 BTC for less than \$1 with new Bitcoin ASICs (just discovered). At this point, there was effectively a massive arbitrage opportunity.

In fact, the profits from this arbitrage opportunity were so huge, that it is possible the 2013 mid-year short bear market can be partially explained by this disconnect. The miners who created the first Bitcoin ASICs had a large incentive to build and deploy more ASICs instead of buying spot BTC.



When gravity is high, this doesn't mean the price can't explode higher in the short term as it did at the latter end of 2013. This is because gravity itself is a function of time. In physics, gravity on Earth is 9.8 meters / second <sup>2</sup>. It requires time to accelerate objects. Bitcoin Energy Gravity is the same. Price in the short term can continue to explode higher if buyers continue bidding BTC, but the gravity itself (mining energy arbitrage) takes time to converge the two prices.

Mining infrastructure/difficulty was well behind price at the time. This doesn't mean the price must immediately drop. It just means the arbitrage trade is unlikely to exist forever. The price will drop OR more mining infrastructure will be built out. Historically a bit of both occur.

## Energy Gravity (“the arbitrage”)

Markets are the most efficient pricing mechanism humans have discovered. During times of high Energy Gravity (the cost of production and the price of Bitcoin are severely disconnected), market participants act in their own self-interest to close this arbitrage opportunity.

- Investors purchase mining rigs instead of buying Bitcoin.
- Investors buy equity in mining stocks instead of buying Bitcoin.
- Bitcoin holders sell BTC to mine (more) BTC.
- Miners sell the BTC they mine to buy more ASICs.
- Miners sell BTC to build more hosting facilities.
- ASIC manufacturers sell BTC to build more ASICs.
  - Investors deploy capital into ASIC manufacturers instead of buying BTC.
- Energy companies start mining BTC and selling what they mine
  - ExxonMobil, Conoco Phillips, etc.
- Utilities and grid operators build more energy production assets (solar, wind, nuclear, etc.) instead of buying or holding BTC.
- Investors start mining just to make USD profits and have no intention of holding BTC.

An important thing to note is that miners don't necessarily have to start selling in size for the market to naturally compress this arbitrage opportunity. Capital simply has other even more attractive opportunities (mining, ASIC manufacturing, data center build-outs, power production, etc.) that compete with spot BTC bids. Price peaks are not necessarily caused by more sell pressure. Instead, it could simply be a lack of new spot bids.

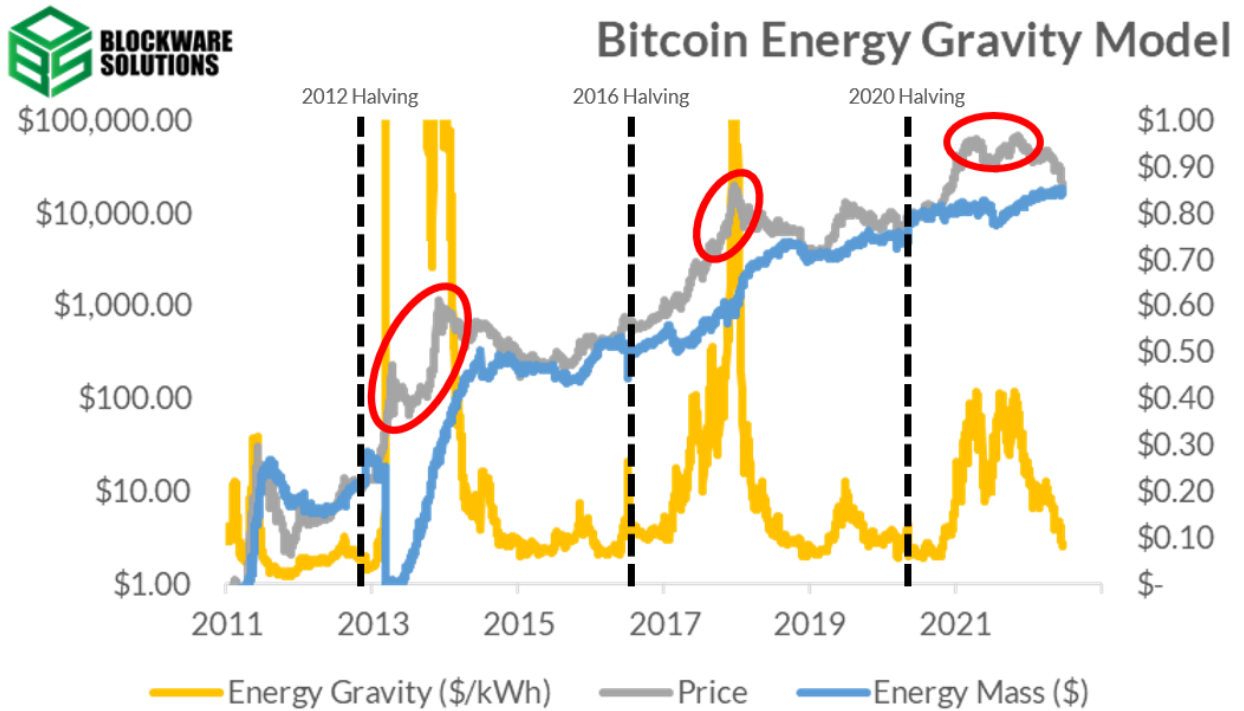
## Miner Market Game Theory

Exaggerated but here's an example: If the price of Bitcoin soared to \$10,000,000 tomorrow, but the cost to mine remained at \$10,000 - \$20,000 for the average miner, many miners and other investors would consider selling BTC to mine more BTC. New capital will move into surrounding industries to capture these profits instead of buying spot BTC.

Miners could (and sometimes do) attempt to finance their expansion, but that would be risky. What if *\*anyone\** else starts selling all of the BTC they mine for a huge USD profit? What if speculators start to recognize the price was bid too high relative to its cost to produce and it has a chance to crash? Then the bear market becomes somewhat self-fulfilling and momentum takes over.

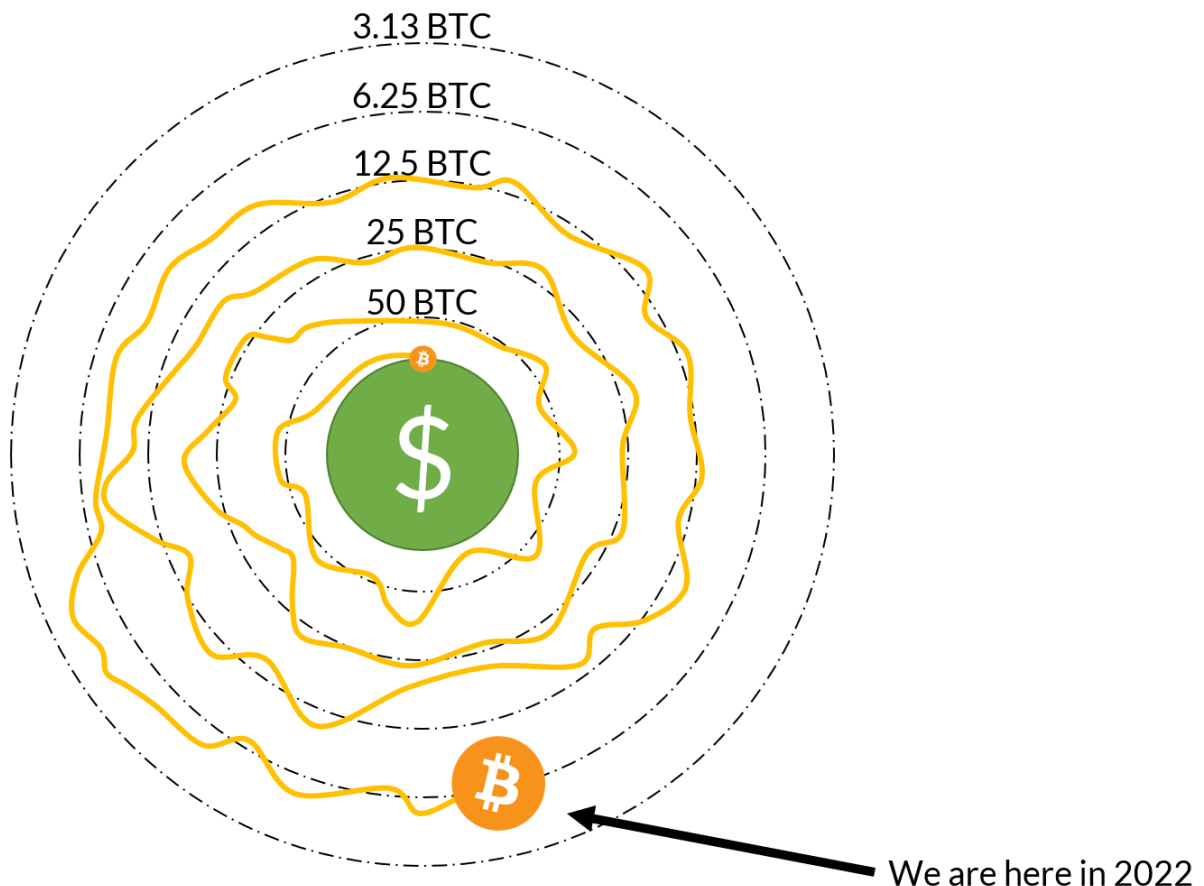
If an arbitrage opportunity exists, efficient markets say someone will capture the profits eventually.

As halvings occur and Bitcoin mining infrastructure is built out (increasing difficulty adjustment), gravity decreases (the arbitrage opportunity goes away).



## Gravity Visualized

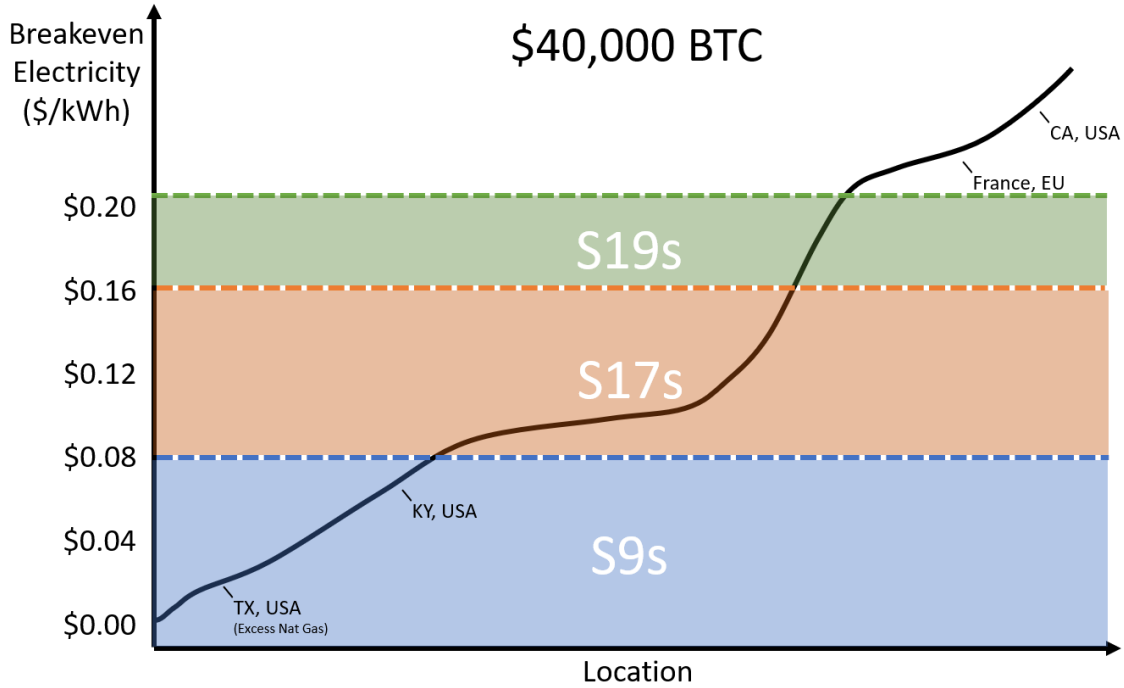
As the Bitcoin block subsidy halves algorithmically every four years (50 BTC, 25 BTC, 12.5 BTC, etc.), miners join the network, time goes on, and user adoption accelerates, Bitcoin becomes less anchored to the Dollar system.



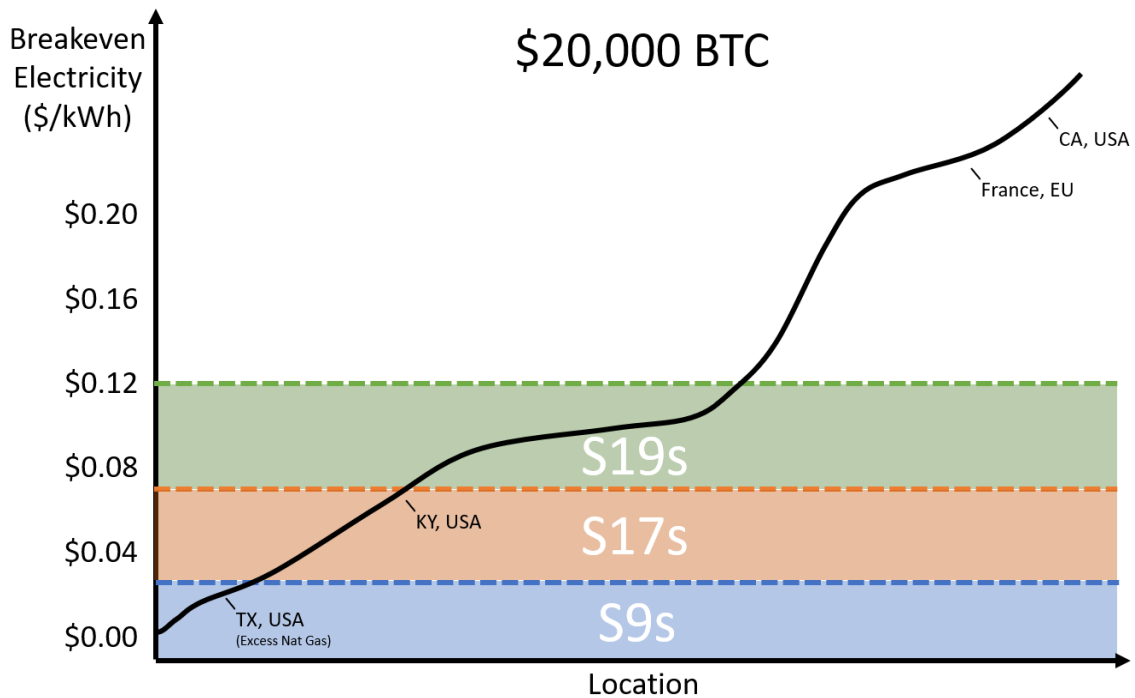
## Weak Miners Occasionally Capitulate

When Energy Gravity decreases and the price of Bitcoin goes below some miners' cost of production, the weakest miners purge their Bitcoin treasuries and shut off their mining rigs. Capitulations historically mark price bottoms because this large increase in temporary sell pressure (the bottom) [ends with a significant reduction in day-to-day sell pressure](#). This was also identified by [Charles Edwards in 2019](#).

Below, you can visualize what these miner capitulations look like broken down by machine type, breakeven electricity rate (Energy Gravity), and location / energy source.



Notice how a 50% drop in Bitcoin price knocks out most available energy sources for profitably running S9s. At the start of 2022, S9s were estimated to be ~ 20% of the entire network.<sup>9</sup>



<sup>9</sup> [CoinShares Research](#)





In the example above, not only are most old generation mining rigs shut off, but the inefficient miners in terms of energy expenses are forced to capitulate their ASICs and BTC treasury, adding sudden disruptive sell pressure (the price bottom).

During a miner capitulation, difficulty drops, and the well-capitalized miners now are able to mine more BTC. The surviving miners are those with the lowest operating expenses and therefore the lowest sell pressure. This was clearly articulated in [previous Blockware Research](#) that outlined the \$148M monthly decrease in sell pressure that was likely to occur after the 2020 halving.

#### Bitcoin at \$10,000 – Prior to Halving

Total BTC Sold to Cover Electricity Expenses	21,123
USD Value of BTC Sold	\$ 211,225,815
USD Profit per Month	\$ 328,774,185
Minimum Percent of Sell Pressure from Miners	39.12%

#### Bitcoin at \$10,000 – Post Halving

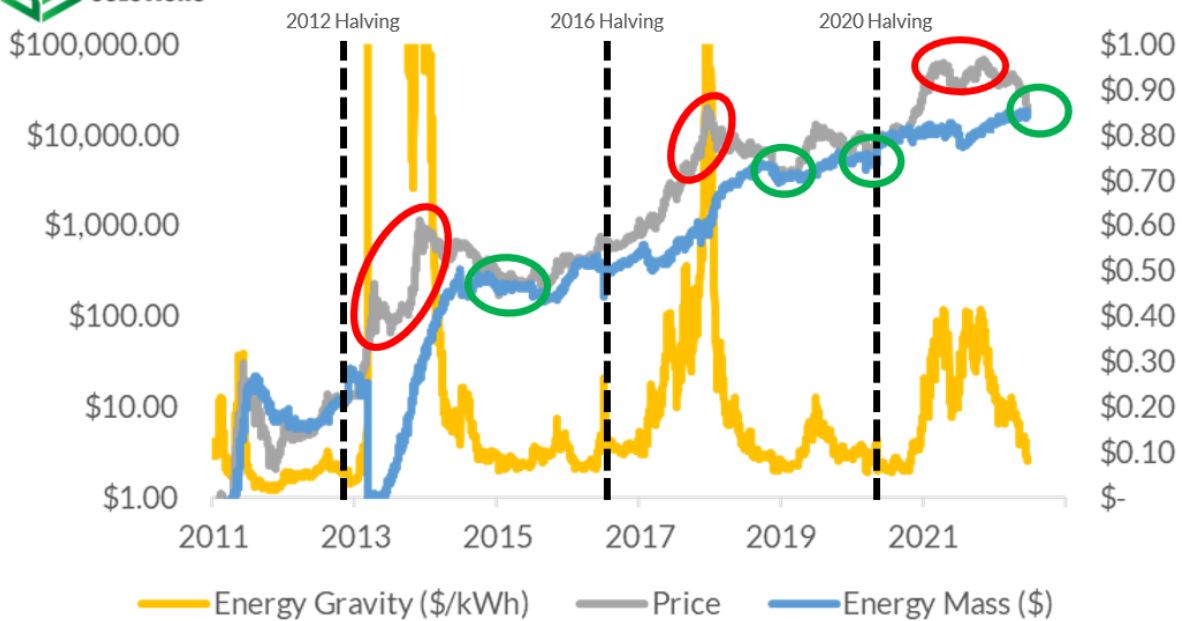
Total BTC Sold to Cover Electricity Expenses	6,300
USD Value of BTC Sold	\$ 63,003,202
USD Profit per Month	\$ 206,996,798
Minimum Percent of Sell Pressure from Miners	23.33%

For the Intermediate Term, after Halving, there will be far less sell pressure on the network even as Bitcoin is back at \$10,000.

After the cleansing, there will be **\$148,222,613 less selling from monthly operational expenses.**

Green circles below highlight price-induced miner capitulations. This occurs when energy gravity is low and Energy Mass (operating cost of production) is declining due to weaker miners capitulating, lowering the network difficulty.

## Bitcoin Energy Gravity Model



Miner capitulations can be accurately mapped on a more micro level using estimated hash rate data based on average block times. Charles Edwards from Capriole Investments created the hash ribbon metric to measure miner capitulations. Hash ribbons indicate a miner capitulation is occurring when the 30-day moving average of Bitcoin’s hash rate crosses below the 60-day moving average.

The Bitcoin network is currently experiencing a miner capitulation that started in early June of 2022.

### Bitcoin: Hash Ribbon



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## Bitcoin's Future

**Bitcoin is an ultra-unique commodity ([due to it being actively monetized from 0](#)) where miner operating margins regularly explode higher. This will continue occurring and Bitcoin mining will continue to be one of the fastest-growing industries in the entire world. The challenge, as always, will be able to outsurvive the weaker miners.**

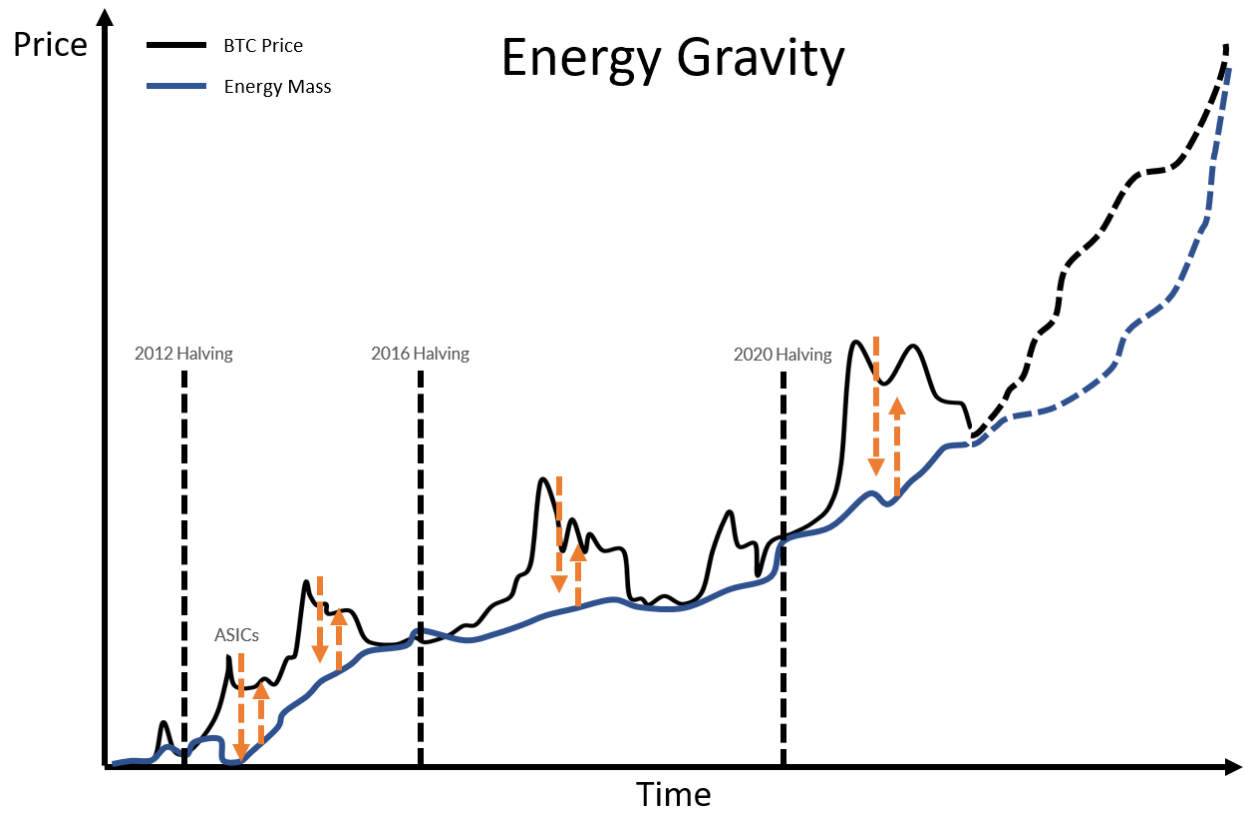
As usual, we can continue to expect the USD price to get bid faster and more aggressively than the kWh price during Bitcoin bull markets. This is because building out massive BTC mining infrastructure takes time, and doing the arbitrage at scale takes time. If you can't immediately and efficiently start converting kWh to BTC, then you may just buy instead, even if the potential profits appear ripe.

General macro uncertainty and high inflation could force capital to flood into both BTC and mining at unprecedented amounts (both Bitcoin price and energy infrastructure grow in tandem rapidly). Hyperbitcoinization will likely coincide with a rapid increase in nominal energy prices. If the cost of production starts rising due to increases in energy prices, then gravity (the arbitrage opportunity) won't return and both \$ / BTC and kWh / BTC could be increasing.

Political jurisdiction bans and uncertainty make Bitcoin mining more profitable elsewhere (China ban, Russia turning machines off, Kazakhstan confiscation, etc.). This removes participants performing the arbitrage from the market, making the market more inefficient. On top of that, supply chain issues including buying machines and building infrastructure take time. This arbitrage isn't easy to pull off by any means, which explains why miner margins rarely go to 0.

**Conclusion:** Bitcoin and Bitcoin mining are going to grow in tandem rapidly. However, when Bitcoin ASICs are theoretically willing to outbid virtually all other consumers of electricity (2013, 2017, and 2021), it is likely a sign that the price of Bitcoin has temporarily overheated. When miner capitulations occur, if you can outlive the weakest miners, you'll be around to enjoy the good times when they inevitably come.

Zooming out, Bitcoin and Bitcoin mining will outperform nearly all other asset classes over the next 10 years. Bitcoin mining becomes a particularly attractive industry when you consider the potential to lock in long-duration energy contracts at fixed electricity rates.







## About Blockware Solutions

While the Bitcoin mining case is compelling, it is difficult to procure ASICs, build large mining facilities, and source cheap scalable electricity all on your own. As an institution, hedge fund, or high net worth individual, it makes sense to purchase and host ASICs with a trusted partner like Blockware Solutions.

With Bitcoin mining experience dating back to 2013, Blockware Solutions has sold over 300,000 ASICs, hosted 400+ MW of clients, and mined thousands of BTC from the Blockware Mining Pool.

If you are looking for a trusted partner to assist you in deploying capital to the Bitcoin mining space, Request a Quote from [Blockware Solutions](#).

## Blockware Intelligence Research Team

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## Other Notes

Original Model Adjustments from [Charles Edwards Original Bitcoin Energy Model](#)

- **Energy Gravity Calculation**
  - **What are modern ASICs willing to buy electricity at?**
  - If modern mining rigs are willing to buy electricity at a price greater than \$0.30 per kWh, then modern mining rigs effectively would be willing to outbid almost all retail and industrial electricity consumption. This is a sign that the market is overheating, miners are too profitable, and the price of Bitcoin is out of whack with the cost of production.
- Adjusted historical energy rates for inflation for energy mass
- Total Miner Revenue, not supply growth rate
- Energy Mass Calculation (estimated op ex cost of production)
  - Bitcoin's price and its cost of production trend towards each other in the long run.
  - The further they separate, the higher the **"gravity"** is on the price of Bitcoin.
- 2013 double bubble potentially caused by ASIC arbitrage
  - The first peak occurred about right before the first ASICs came out and the price dropped while hash rate and difficulty soared.

Special thanks to @ChrisFriedl, @Croesus\_BTC, @kanemcgukin, @CalebFranzen, @JoeConsorti, @MitchellHODL, @PricedinBTC, @w\_s\_bitcoin, @granthbartel, @libertyhodl, @JesusHODLerBTC, @upsguyXBT, @kudzaiikutukwa for their feedback on the report.