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Bitcoin: Energy Consumption as a Corollary to Environmental Impact and the Potential of the Evolution of Money

A meta-data study on the energy consumption of Proof-of-Work mining for Bitcoin and the corresponding environmental impacts that arise from such a system. Will be looking at claims for energy waste (and their incentives), as well as claims for energy conservation and preservation. The main conclusions will be drawn by running a comparison to the current energy expenditure of dominant financial systems (gold, federal reserve, et. al) and running a separate comparison to determine what the current benchmark is for acceptable energy usage for currencies. Financial frameworks will also be discussed in the scope of the effects of hyperinflation on a country, and its corollary effects on environmental goals.

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Predecessors to Bitcoin

To understand how Bitcoin came into existence, one must first look at what inspired its creation. Digital cash technologies were a topic of discussion among cryptographers from as early as 1982: prototypes such as eCash, B-Money, and bit gold all surfaced as raw products. What spurred the creation of these raw forms of what ultimately paved the way to the foundation of Bitcoin were the thoughts of forward thinkers such as David Chaum, Nick Szabo, Hal Finney, and Wei Dai. A collective understanding for a need of a digital economy stemmed from the recognition of the flaws in the current monetary system: inflation, spam, and the lack of the ability for the storage and transfer of information.

When *Bitcoin: A Peer-to-Peer Electronic Cash System* was published on October 31 2008 by Satoshi Nakamoto, it came with the vision that we needed “a system for electronic transactions without relying on trust”.[1] When the genesis block was mined on January 3 2009, embedded within was text to the headline of *The Times*, referring to the Chancellor being on the brinks of bailing out the banks (**Fig. 1**). While there is debate as to whether or not this was just a timestamp of the block or a dig at the instability caused by fractional reserve banking, it does have historical significance as to what the person, or group of people, behind the pen name of Satoshi Nakamoto were thinking. Finney, Szabo, and Dai were all supporters of Bitcoin, with Hal Finney receiving the first ever Bitcoin transaction from Satoshi Nakamoto on January 12 2009.

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Figure 1. Raw block data from Bitcoin’s Genesis Block

In the early days of Bitcoin’s existence, the value of Bitcoin was extremely hard to discern. Individuals on a prominent Bitcoin forum negotiated the price of each transaction, with no common ground between deals. A famous transaction occurred on May 22, 2010 in which two pizzas were indirectly purchased for 10,000 Bitcoin. But where, when, and how did Bitcoin first get to be traded on a unified exchange?

That takes us to programmer (and founder of Ripple, co-founder of Stellar) Jed McCaleb, who built a website (*Magic the Gathering: Online Exchange)* to allow for people to trade cards; this subsequently led to Mt.Gox. After a few months, McCaleb grew tired of this project, and it lay dormant until July 2010, when he read about Bitcoin on an online forum. Jed felt that the Bitcoin community deserved an exchange in which to trade, and re-opened Mt.Gox. McCaleb ended up selling Mt.Gox in 2011, citing a lack of time and resources to bring it to its full potential. At one point in 2013-2014, Mt.Gox was handling north of 70% Bitcoin volume. What happened next in those years can only be described as a catastrophe: 744,408 Bitcoin were stolen in a massive security breach that went undetected. The new CEO, Mark Karpelés, was arrested for embezzlement and fraud, and Mt.Gox went bankrupt.

The cryptocurrency market, which was still predominantly Bitcoin, went into a 150-week bear market from 2014 until 2016. Investor trust was lost as the price of Bitcoin plummeted. It would be fair to say that Bitcoin was ahead of its time in 2014, rocketing to relevancy much before the proper foundation was set in place.

Fractional Reserve Banking Collapse

In order to understand the economic atmosphere that preceded the creation of Bitcoin, we look to the Financial Crisis of 2007-2008. Economists have touted the series of events that took place during this time as the most serious financial crisis since The Great Depression in the 1930's.

Cracks in the financial system began in April 2007, with the subprime mortgage market in the United States. As the price of the average American household increased 125% over the last decade, investment banks answered increasing demand for an alternative to US Treasury Bonds by securitizing mortgages, creating Mortgage Backed Securities (MBS) (**Fig. 2**).

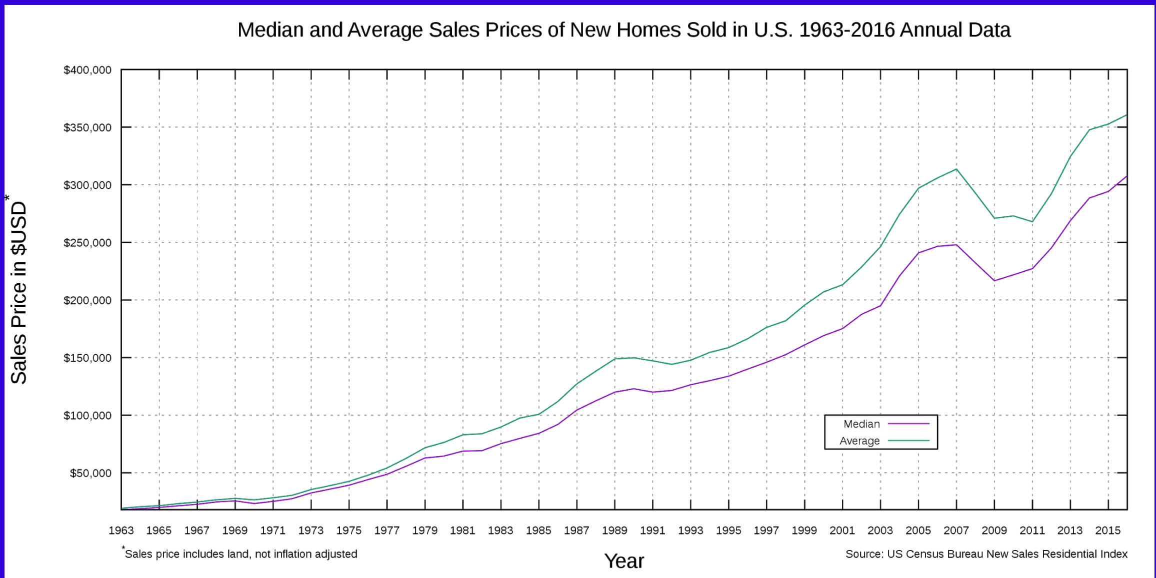


Figure 2. U.S. Homes Median and Average Price (Source:U.S. Census Bureau New Sales Residential Index)

Two hedge funds run inside of one of the largest investment banks, Bear Stearns, had unrealized losses in the billions of dollars after writing down the positions on their MBS's, which were declining in value as the housing crisis began in 2007. This in itself could have been an isolated event for Bear Stearns and its hedge fund investors, but due to the excessive use of leverage and inter-bank repurchase agreements across Wall Street, Bear Stearns quickly depleted all of their cash plugging this hole. As confidence in the bank waned, outside capital dried up. Without this capital, financial services firms could not operate, since the value of their actual assets was only a fraction of the reported assets - as investors and banks both stopped lending to and investing in Bear Stearns, the company's liabilities exceeded its assets almost instantaneously. By March 2008, Bear Stearns went insolvent.

The problems at Bear Stearns were not isolated. Every large bank across the globe used similar leverage on their balance sheet, owned toxic and declining financial assets, and relied on other banks to carry out repurchase agreements (the practice of lending securities for cash). As banks began to distrust each other, this flow of capital stopped, and banks were forced to deleverage. This was nearly impossible, as liabilities exceeded assets (30-50x). Many other banks began to fail, most notably Lehman Brothers in September 2008.

These problems spread beyond the United States, causing governments around the globe to step in to recapitalize these "too big to fail" institutions. Without banks, consumers would suffer; there were no safeguards in place to ensure that the banks wouldn't fail all at once. Ultimately, the excess leverage was never removed from the financial system (as would happen in a bankruptcy process when debts would be forgiven); instead, the debts were simply transferred and absorbed by governments via printing money (thus inflating their currency and deflating the debt load).

The banking system (called fractional reserve banking) is based on the idea that people are very unlikely to demand all their deposits back at once. As such, for each $1 deposited, up to $0.97 is lent back out. This creates leverage, as more money is outstanding than actually owned. And since the banks all lend to each other, counterparty risk is just as dangerous as credit risk. The interconnected nature of banks puts all consumer trust in the hands of a few powerful institutions, and the lack of hard assets backing capital formation ensures that no one actually owns what they think they own. This works until it doesn't – and when trust diminishes, the system breaks down.

Value Proposition of Bitcoin
A value proposition, credited to Michael Lanning and Edward Michaels, is defined as "a clear, simple statement of the benefits, both tangible and intangible, that the company will provide, along with the approximate price it will charge each customer segment for those benefits". [2] This proposition identifies how value will be delivered through the implementation of a product or service.

To identify Bitcoin's value proposition, one must first identify the key principles that define Bitcoin. The heavy underlying principles can be broken down into three main categories: Sound money, censorship resistance (decentralization), and immutability.

Sound money, by definition, is a currency that is backed by a tangible commodity and has intrinsic value. In the words of the late Stuart Chase, "the difficulty with our understanding of money appears to be that we want it to mean something substantial, tangible, solid...we persist in thinking about money as it behaved two hundred years ago."

The first point has been one of major contention amongst Bitcoin dissenters, as Bitcoin isn't backed by something you can see or touch, but rather mathematics. This may seem absurd at first, but it is worth noting that the most accepted currency in the world, the U.S. dollar, was taken off the Gold Standard in 1971 by President Nixon **(Fig. 3)**. The same can be said for the EU Euro, the British Pound, and countless other existing currencies. The fact of the matter is that the concept of currency being backed by tangible assets is quickly fading away in lieu of something greater: the building block of our world as we know it, math. As for intrinsic value, we look to the deflationary nature of Bitcoin.

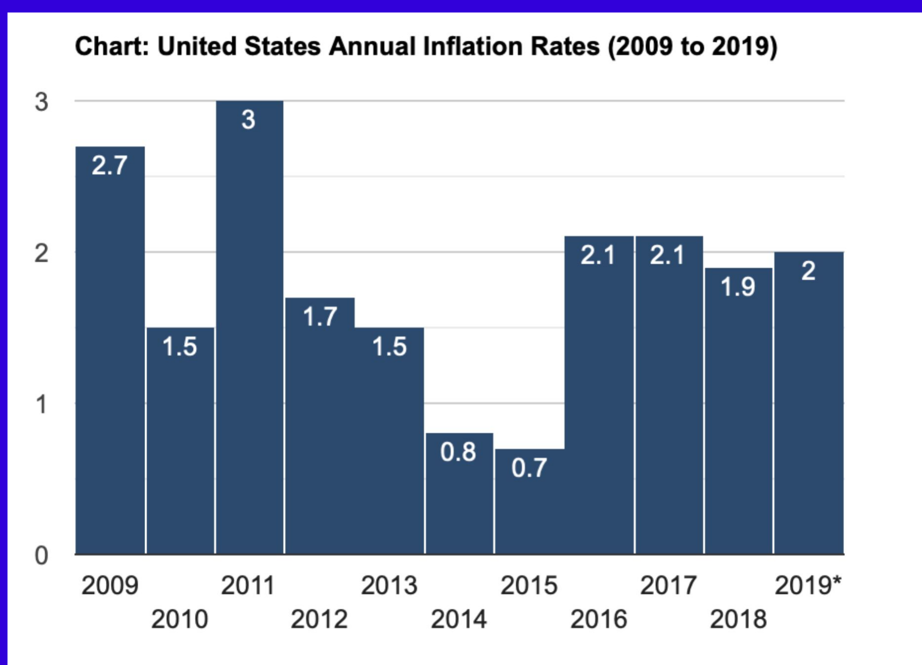


Figure 3. Annual U.S. Inflation Rates (SourceU.S. Inflation Calculator)

As the rest of the world practices an inflationary economy, Bitcoin has parameters that allow for its value capture to remain prominent. The total supply of Bitcoin is fixed at 21,000,000 – this number is capped and can not change without breaking the social contract of Bitcoin itself. Another touch point is the stock-to-flow ratio, a metric used to gauge the scarcity of an asset by comparing the amount held in reserves to the amount produced in a given timeframe. The stock-to-flow ratio of Bitcoin is not set in stone; rather, it is hard baked into the protocol to increase the stock to flow ratio every four years in an event known as the "Block Halving" - a half-life decay in the emission of new coins **(Fig. 4)**. This event takes place every 210,000 blocks (roughly every 4 years), in which the block reward that the miners receive for furthering the network is reduced in half. This presents a unique opportunity – the higher the stock-to-flow ratio, the more scarce (and therefore more valuable) an asset is. The dynamics of Bitcoin miners will be explored more in this report.

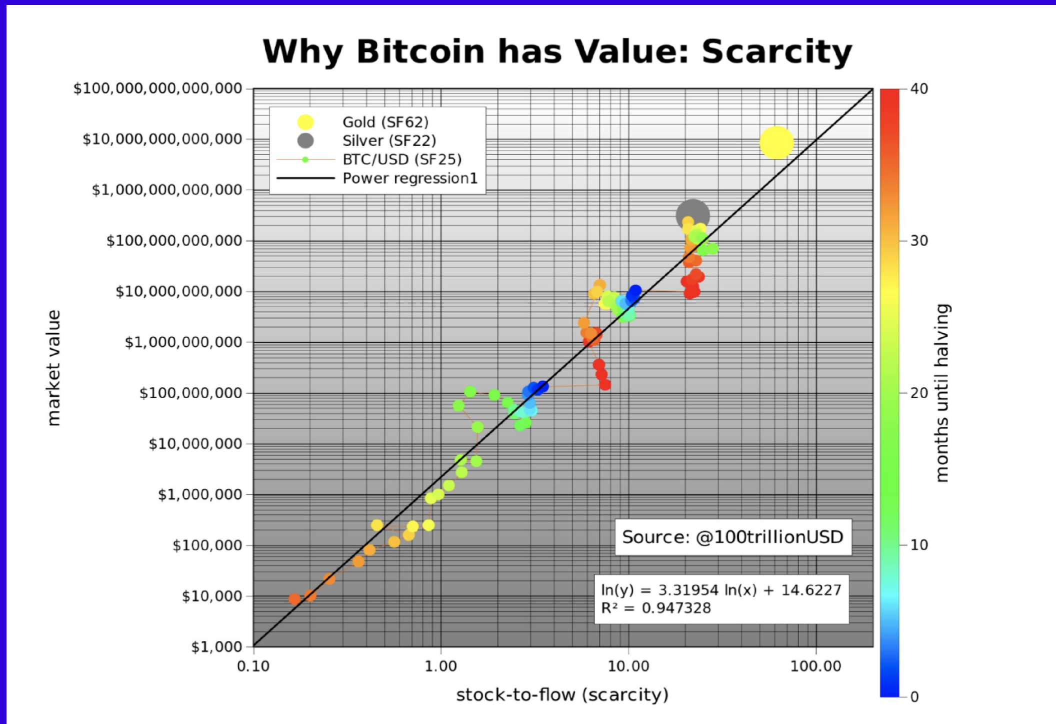


Figure 4. Stock-to-flow ratio of Bitcoin compared to Precious Metals

The second category, censorship resistance, is perhaps one of the most important breakthroughs of the blockchain industry. At present, if you have money sitting in a bank account you carry inherent risk of a third party controlling your financial 'freedom'. If you attempt to send money somewhere, it is at the discretion of that third party whether or not your transaction will be approved. This level of government interference seems justifiable – KYC/AML laws for the most part protect us against bad actors in the space. However, it is worth noting that there is no grey area between financial freedom and financial slavery – you either control your funds, or you do not.

What Bitcoin presents is an opportunity to separate money and state – what would be the next step from the separation of church and state. This would come with significant resistance, as money equates to power. Governments will be reluctant to relinquish such power, but it is my belief that this is both necessary and fundamental to the advancement of the world economy.

With Bitcoin being run on over 9500 nodes spread across the entire globe to date, there are now at minimum 9500 points of failure for the network **(Fig. 5)**. Since the entire ledger of the Bitcoin blockchain is broadcasted to each and every node, all it takes is for one node to remain active for the system to continue operating.

9557 NODES

24-hour charts »

Top 10 countries with their respective number of reachable nodes are as follow.

RANK	COUNTRY	NODES
1	United States	2390 (25.01%)
2	Germany	1897 (19.85%)
3	France	610 (6.38%)
4	Netherlands	525 (5.49%)
5	Canada	355 (3.71%)
6	China	316 (3.31%)
7	United Kingdom	313 (3.28%)
8	Singapore	307 (3.21%)
9	n/a	243 (2.54%)
10	Russian Federation	242 (2.53%)

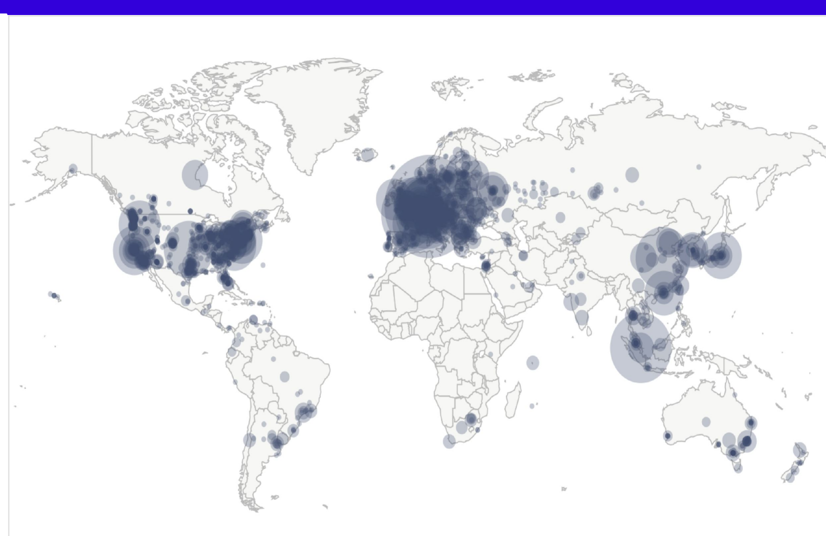


Figure 5. Current distribution of Bitcoin Nodes around the world (Credit: Bitnodes)

The third and last main value driver for Bitcoin is immutability. Immutability, in its simplest terms, means that the information is unalterable. Sound money is a huge benefactor of such an idea, as immutability breeds integrity. Picture the Bitcoin blockchain (ledger) as a fly trapped in amber. The fly represents the genesis block, and the amber represents each block that follows. As more and more amber surrounds the fly, it is now not only exponentially harder to get to the fly, but also harder to penetrate the inner layers of the amber. So too is the Bitcoin blockchain – as more and more blocks are mined, more and more information is both stored and further secured. The nature of the algorithm that Bitcoin uses (SHA-256) ensures that it is theoretically impossible to reverse engineer a block hash. Put another way, it is not possible to work from the output back towards the input.

This offers immense levels of trust in a protocol that is itself trustless. To know that once a transaction is set into the ledger (and is 'protected' by newer blocks), it will never change is a utility that provides enormous benefits to those who use it. However, there are downsides to this method. Immutability is a one-way street; therefore you can't roll back nefarious transactions either. If the majority of the network agrees to post non-truthful data to the blockchain (known as a 51% attack), there is no safeguard. Bitcoin itself has mitigated this issue by implementing the Proof-of-Work governance model, which predicates itself on distributed Byzantine Fault Tolerance (dBFT).

While there is not a perfect solution, there rarely ever is – with consistent iteration and upgrades to the network, there will be fewer holes to plug in a very large solution to overbearing problems.

Proof-of-Work and Bitcoin's Governance Model

Invented in 1993 by Cynthia Dwork and Moni Daor, Proof-of-work is by in large a protocol that is meant to deter cyber attacks such as distributed Denial-of-service (DDoS), which exhausts the resources of a computer by sending it numerous fake requests. What was initially designed to prevent junk mail via a method defined as "Pricing via Processing" has evolved into a fundamental governance model that revolutionizes the way transactions are sent in digital money. [3]

In essence, Proof-of-work creates an opportunity cost to participating in the network. It is a requirement to define a certain specific computer calculation (known commonly as mining) in order to create a new block of trustless transactions that will be placed on the ledger. This computation required is costly, which deters both spam and malicious actors in what is akin to a mathematical puzzle. 4 In doing so, a so-called distributed network arises – one where there are many independent actors in the space all working towards a common goal: advancing the ledger **(Fig. 6)**.

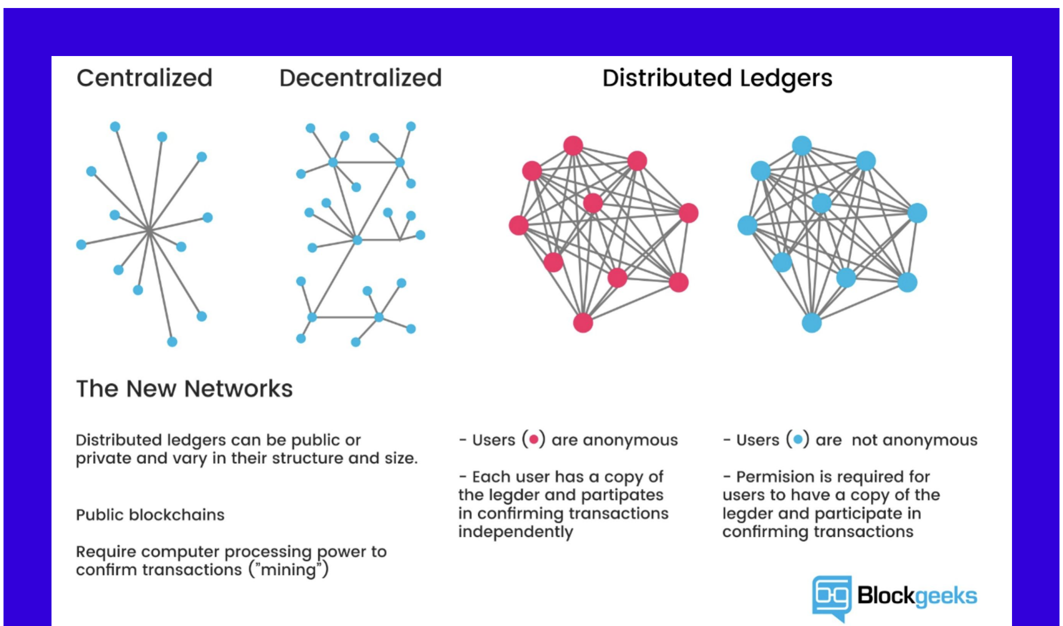


Figure 6. Differentiations between consensus networks

This action of mining serves two main purposes: to verify the validity of transactions and to introduce newly minted currency into the ecosystem as a reward for the energy expenditure required to solve the mathematical puzzle.[4]

The nature of mining Bitcoin is competitive, and therefore has asymmetric odds. Every computer that is mining is competing against every other miner to be the first to solve the puzzle; to the victor goes the spoils. This competition needs to have a balance, as the amount of miners increase, difficulty also increases **(Fig. 7, 8)**.

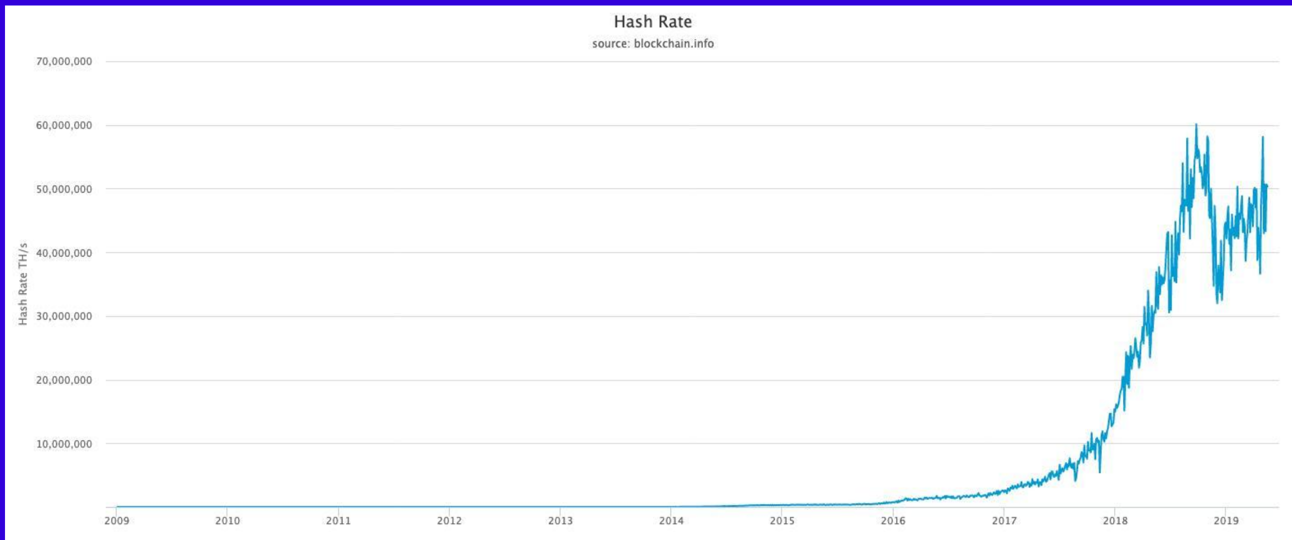


Figure 7. Hash rate of Bitcoin Network since inception (Credit: Blockchain.info)

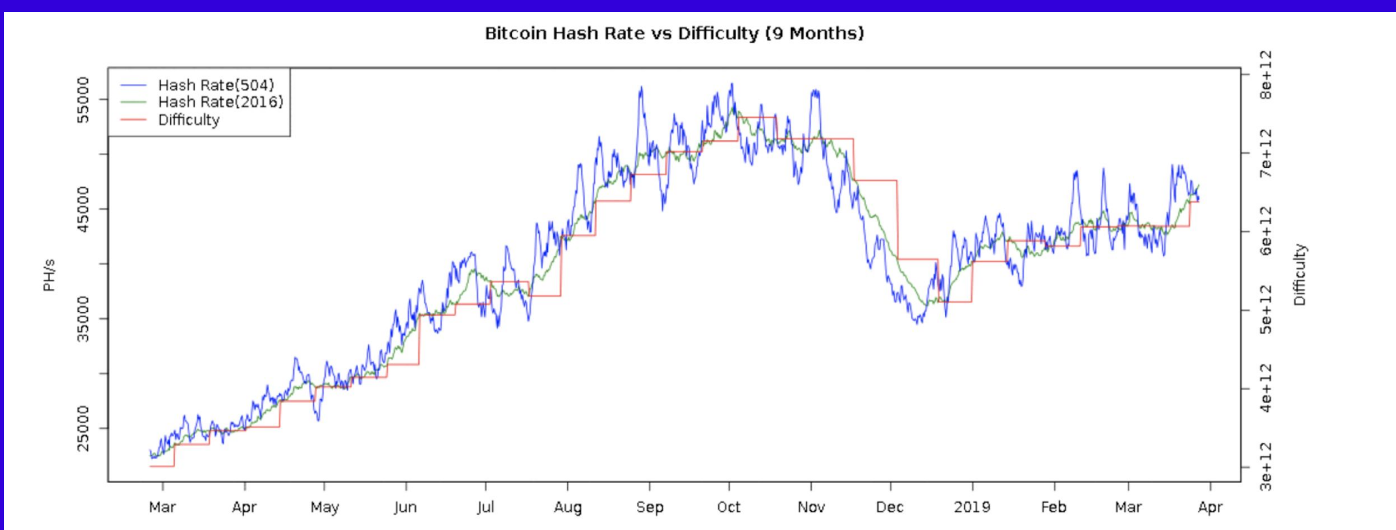


Figure 8. Difficulty adjustments in correlation to Network Hash rate (Credit: BitInfoCharts)

This difficulty adjustment keeps the economics of this consensus model in balance, with increased difficulty resulting in more costly block creation, and vice versa. The self-adjusting system is meant to be self-governing, and to date has yet to experience a black swan event.

Common Misconceptions Regarding Bitcoin

Due to Bitcoin's origins and early use case as a medium of exchange on the infamous Silk Road, there has been a developing sentiment among the public that using Bitcoin is akin to participating in illicit activities (drugs, crime, extortion, etc.). The main argument stems from the belief that Bitcoin isn't governed by a regulatory body, and is therefore anonymous and impossible to trace. In reality, it is quite the opposite. All Bitcoin transactions are posted on a public immutable ledger – while a name and address isn't available, the wallet address is, and analysis groups such as Chainalysis are able to analyze this blockchain data.

Chainalysis, among other companies, have worked directly with the IRS, FBI, SEC, DEA, ICE, and Europol to help identify the owner of a suspicious public address.[5] As for using Bitcoin for nefarious activities, a report conducted in 2018 revealed that 46% of all Bitcoin transactions ($76 B) were used for illegal activities, which fell in line with the percentages in the U.S. and European black markets. When you take into account the vast imbalance between the total Bitcoin market capitalization to that of the U.S. dollar, it becomes evident that Bitcoin is dwarfed by traditional currencies in funding illegal activities ($100 B, 2010).[6]

Another major misconception draws on a major point that will be discussed in detail later in this report: electricity. This misconception can be further divided into two categories: those who worry about Bitcoin's dependence on electricity, and those that worry Bitcoin uses too much electricity to be environmentally sustainable.

Is there a problem with Bitcoin because it needs electricity? The same argument could be made for refrigeration, which is completely reliant on electricity to keep products cool. Does that mean that refrigeration has a systemic problem?

Electricity was both misunderstood and mistrusted by the general public from its inception. In 1891, electrical appliances were installed into the White House for the first time. At the time, electricity was a nascent concept, merely a decade old. What we have now is an energy that is deemed as essential for an industrialized nation. In many ways, Bitcoin is the electricity of our age. Neither Bitcoin nor electricity are tangible objects, but both may very well change our lives in ways we could not have foreseen at the time. Right now, Bitcoin is still seen as raw, dangerous, difficult to use on the grand scale. While all of these concerns have merit, it is still too early to write off the technological innovation that has happened.

With time, there will be further iterations that mediate all of these points, making Bitcoin safer, easier, and more accessible. If these problems can be addressed, this could be the next technological revolution.

The total energy of the Bitcoin Network to date is estimated to be 6.1 GW (roughly 61.37 TW/h), which is more than the entire electricity expenditure of Columbia (59.4 TW/h), and roughly on par with Switzerland (62.1 TW/h) **(Fig. 9)**.

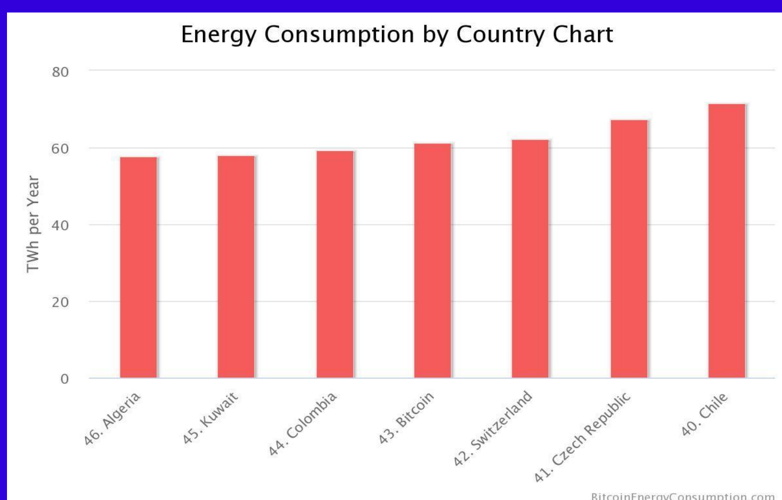


Figure 9. Energy Consumption by Country (Credit: BitcoinEnergyConsumption)

In 2017, Bitcoin accounted for 0.27% of the entire world's electricity expenditure (20,703 TW/h) **(Fig. 10)**. There is reasonable evidence for concern regarding the amount of electricity Bitcoin uses to maintain the network, but it should be noted that worldwide the electrical expenditure of all gaming systems (4.9 GW) is close to that of Bitcoin. 7 What value do you apply to the energy expenditure in Bitcoin versus the energy expenditure in other activities?

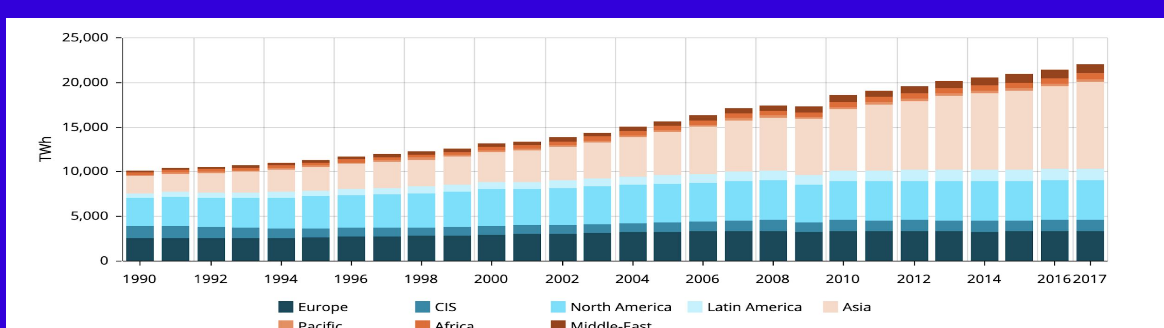
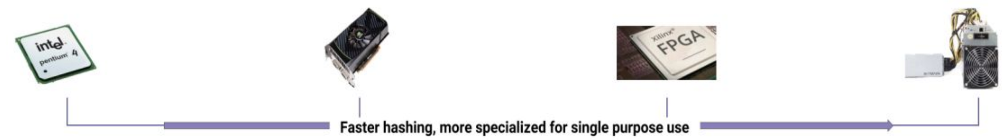


Figure 10. World Electricity Expenditure over the last two decades (Credit: Enerdata)

Overview

To mine Bitcoin, you need to ‘spend’ computational processing power. In the early days of Bitcoin, Central Processing Units (CPU’s) were sufficient because the network hashrate was small. As more and more miners entered the network, miners turned to Graphic Processing Units (GPU’s), which could handle more intensive queries. A decade later, the vast majority of the CPU/GPU units that were once dedicated towards mining the Bitcoin blockchain have gone away, and in its place is the current hardware: Application Specific Integrated Circuits (ASIC’s). These units are more efficient, as they are hard coded for a specific use (in this case mining the SHA-256 algorithm). These units harness much more computational power at a much cheaper cost, making them ideal for mining **(Fig. 11)**.



	2009 Standard multi-core Central Processing Unit **(CPUs)**	2010 Graphics Processing Unit **(GPUs)**	2011 Field Programmable Gate Arrays **(FPGAs)**	2012 Application-Specific Integrated Circuit **(ASICs)**
Function:	CPU is part of the computer that executes the software installed on the computer. It is highly agile, rapidly switching between tasks and able to follow conditional orders.	GPU is the video rendering system of a computer. It typically assists the CPU with less executive, more repetitive calculations.	FPGAs are customizable chips used to create personal digital circuits.	ASIC is a microchip dedicated to execute hashing algorithms as quickly as possible.
Strengths:	- Some cryptocurrencies specifically designed for CPUs (restrict participation of more productive hardware types) - No specialized hardware required; CPUs are included in all standard computer systems	- Containing more ALUs than CPUs, able to carry out higher quantity of bulky mathematical orders - No specialized hardware required; installment of special software easily allows mining - Produces less noise	- Faster than both CPU and GPU systems - More electricity efficient per hashing unit, than CPUs and GPUs - Can be re-modified for alternate use as it is not pre-programmed. - Combines the power of an ASIC with flexibility of the GPU	- Most efficient form of hardware as it produces significantly higher hashrate than that of GPUs while requiring a fraction of the power - Easy to use once configured by manufacturer; does not require progamming skills or additional hardware configuration by user
Limitations:	- Now unprofitable to use for most major cryptocurrencies - Fewer Arithmetic/Logic Units (ALUs) than GPUs, resulting in slower hashing attempts (ALUs are circuits that perform arithmetic operations) - Only supports select cryptocurrencies	- Engineered to run hot, reaching temperatures of 50-70'C under a heavy load - Inefficient as initially designed for gaming and computer graphics, wasted energy and potential when solely used for mining - Requires a computer (motherboards, CPU) to operate	- Scarce and difficult to purchase publicly - Not programmed during roduction; end user must configure each chip, which is challenging for the ordinary crypto miner	- Steep initial investment to purchase hardware - Separate ASIC required for each cryptocurrency coin as it is custom built for single hash algorithms - Generates significant heat and noise, requires ample electricity to run - Cannot be re-modified for alternate use (ie. becomes useless once profitable coins on an algorithm makes a fork) - Existence of ASIC-resistant coins (ie. ethereum)

Figure 11. Hardware Evolution for mining Cryptocurrency (Credit: Kraken Intelligence, thenextweb.com(TNW), 1stminingrig.com)

Breakdown of an ASIC Bitcoin Miner

The most owned Bitcoin ASIC miner is the Antminer S9, manufactured by Bitmain in 2017 during the Bull Run **(Fig. 12)**. It is estimated that over 1,000,000 Antminer S9’s were produced and sold in 2017 alone, showing tremendous exuberance in the space to mine new Bitcoin as a source of passive income.

Manufacturer	Bitmain
Model	Antminer S9 (13.5Th)
Release	September 2017
Size	135 x 158 x 350mm
Weight	4200g
Chip boards	3
Chip name	BM1387
Chip size	16nm
Chip count	189
Noise level	85db
Fan(s)	2
Power	1323W
Wires	10 * 6pins
Voltage	11.60 ~13.00V
Interface	Ethernet
Temperature	0 - 40 °C
Humidity	5 - 95 %

Figure 12. Antminer S9 Specifications (Credit: Bitmain)

Energy Consumption as a Corollary to Overall Network Hashrate
As mentioned earlier, the current total energy consumption of the Bitcoin network is estimated to be 61.37 TW/h this year, enough energy to power more than 5 million homes **(Fig. 13, 16)**.

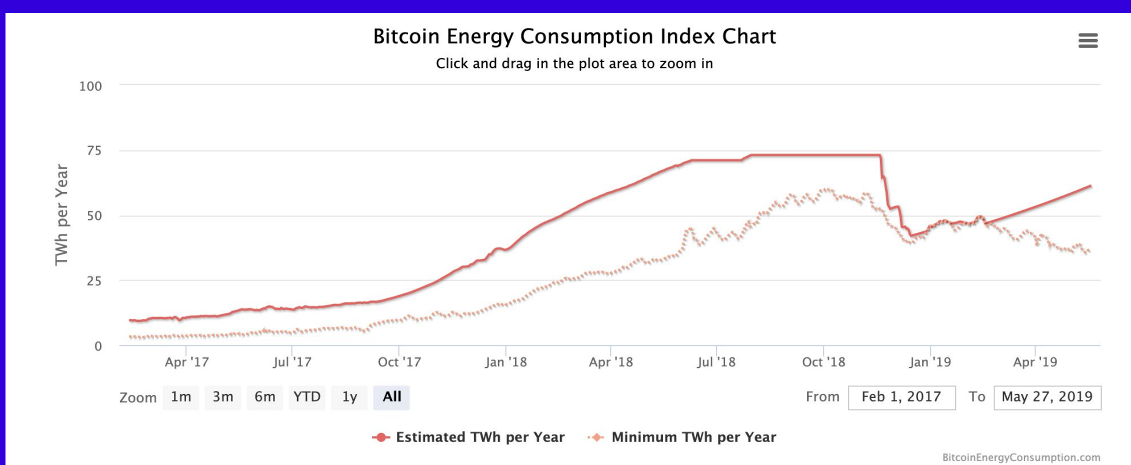


Figure 13. Bitcoin Energy Consumption (Credit: BitcoinEnergyConsumption)

From this energy consumption comes two fields of thought: Energy waste and energy conversion.

Those on the 'energy waste' side can argue that way too much electricity is being put to work to support a system that is barely used worldwide, and that energy could be put to use in other places (or just not generated at all).

Those on the 'energy conversion' side can argue that the energy is being put to secure the network – the more energy used by the network, the more expensive it is for a nefarious actor to attack the network (thus preventing double spends).

Based on the findings of this report, the 'energy conversion' side has a stronger argument. The notion that Bitcoin is wasting unnecessary energy is false – Bitcoin is more often than not using surplus energy that is expended whether or not it is put to use. Energy generators operate under peak capacity, meaning that there is often too much energy produced in case of a surge in energy demand.

China presents the most interesting case study, as it is both the largest contributor towards mining Bitcoin (up to 70% of the network hashrate), and it is also the largest producer of energy in the world (49% higher than the next highest producer, the United States, per Enerdata). It is a reasonable assumption that miners are drawn to the cheapest energy sources in order to reduce overhead costs, and China offers such a save haven. In a recent report by Reuters, it was determined that in 2015 80 GW (12% of total generated power) of wind generated energy was wasted.[8] This figure dwarfs Bitcoin's energy consumption (6.1 GW), leading to the reasonable conclusion that there is more than enough energy being wasted that could be put to work mining Bitcoin without generating new energy.

COMPARISON OF BITCOIN ENERGY TO LEGACY FINANCIAL SYSTEMS

Energy Used by Bitcoin Network
With Bitcoin using a significant amount of energy (61.37 TWh), and that energy is mostly seen as surplus, the argument then arrives to a singular contention point: Is the amount of energy that Bitcoin uses fundamental to its survival, or is there too much energy being directed toward such a network?

The simple answer is that Bitcoin itself uses minimal energy – if Bitcoin were to scale globally, and no new miners entered the space, the energy consumption would be almost identical. Network energy consumption moves in correlation to miners on the network, not the amount of transactions being validated: it is possible to verify a transaction from a library computer in milliseconds, as it takes negligible computing power. The network hashrate increasing is a question of economics – mining produces new Bitcoin (12.5 per block as of today). As mentioned earlier with the 'Block Halving', this reward will become 6.25 Bitcoin in mid-2020. Over the years, as miners rely more on transaction fees, it is projected that competition in the space will smooth out as mining becomes less economically beneficial.

Energy Consumption of Legacy Financial System
How does Bitcoin's energy consumption compare to the systems we have already become so accustomed to? We go back to the data from Figure 10, in which Bitcoin was found to use about 0.27% of worldwide electricity consumption.

First, we look at gold. In a report from LongHash in 2018, researcher Vladimir Jelisavcic draws data from the Barrick Gold Corporation 2017 annual report (the world's largest gold mining company). In 2017, Barrick Gold Corp. mined 5.3 million oz. of gold (6% of total mined gold), and cited diesel fuels as their main expenditure. Extrapolating the data for all gold mining, in total 92 million barrels of crude oil were consumed ($87.3 Billion dollars), whereas the entire world consumes 34 billion barrels of crude oil annually **(Fig. 14)**. Therefore, the direct cost of gold mining in terms of crude oil usage accounts for 0.27% of worldwide oil consumption (directly comparable to Bitcoin's electricity share).[9]

Figure 14. Comparison of Bitcoin and Gold Energy Expenditures (Credit: LongHash)

Next, we look at the Federal Reserve of the United States. In their 2019 Currency Budget Report, they approved a budget of 955.[9] million dollars for the facility, printing, quality assurance, and transportation of money, among others.[10] These costs are less than Bitcoin's projected 4.3 billion dollars found in Figure 14, but it is worth noting that this budget is pertaining only to the United States, whereas Bitcoin is a worldwide currency, and therefore costs can be attributed globally.

Lastly, we look at the heavy metal industry energy consumption. While it is not directly a financial system, aluminum smelting and production is prevalent in transportation, consumer goods, construction, and electrical processes due to its chemical properties. Therefore, we will treat it as a pseudo-financial system for the purpose of this report. In 2010, worldwide production of aluminum (621 TWh) consumed ten times as much electrical energy as Bitcoin (61.37 TWh), which accounts for 3% of the world's supply of electricity. [11]

Data Analysis

Based on the findings, it is evident that legacy financial systems consume an enormous amount of energy to function. While Bitcoin also consumes a seemingly enormous amount of energy, the purpose of that 'energy conversion' is not to function, but to strengthen the underlying security of the system.

Mining as a function of wealth generation (conversion of energy into Bitcoin, which holds monetary value) seems to have a two-pronged effect: mining tends to use renewable energy at a clip of 76%, and that mining tends to drive innovation to create cheaper energy. 7 These two effects are actually just parts of a whole – according to a recent report by the International Renewable Energy Agency (IRENA), renewable energy costs are down over 80% from 2009, and continue to decline.[12] The reasoning behind the rapidly decreasing costs of renewable energy has to do with the fact that the bulk of renewable energy expenditure derives from the initial set-up of the technology: building out the renewable energy plant, setting up power lines and other infrastructure, receiving government support, among others. These costs are a one time event; extrapolating over the lifespan of these renewable energy projects, financial advisory firm Lazard found that at scale, even unsubsidized renewable energy farms are more cost efficient than 'dirty' energy **(Fig. 15)**. When considering the geopolitical climate surrounding climate change and potential anthropogenic acceleration of this cycle, subsidies for renewable energy is very commonplace as of today.

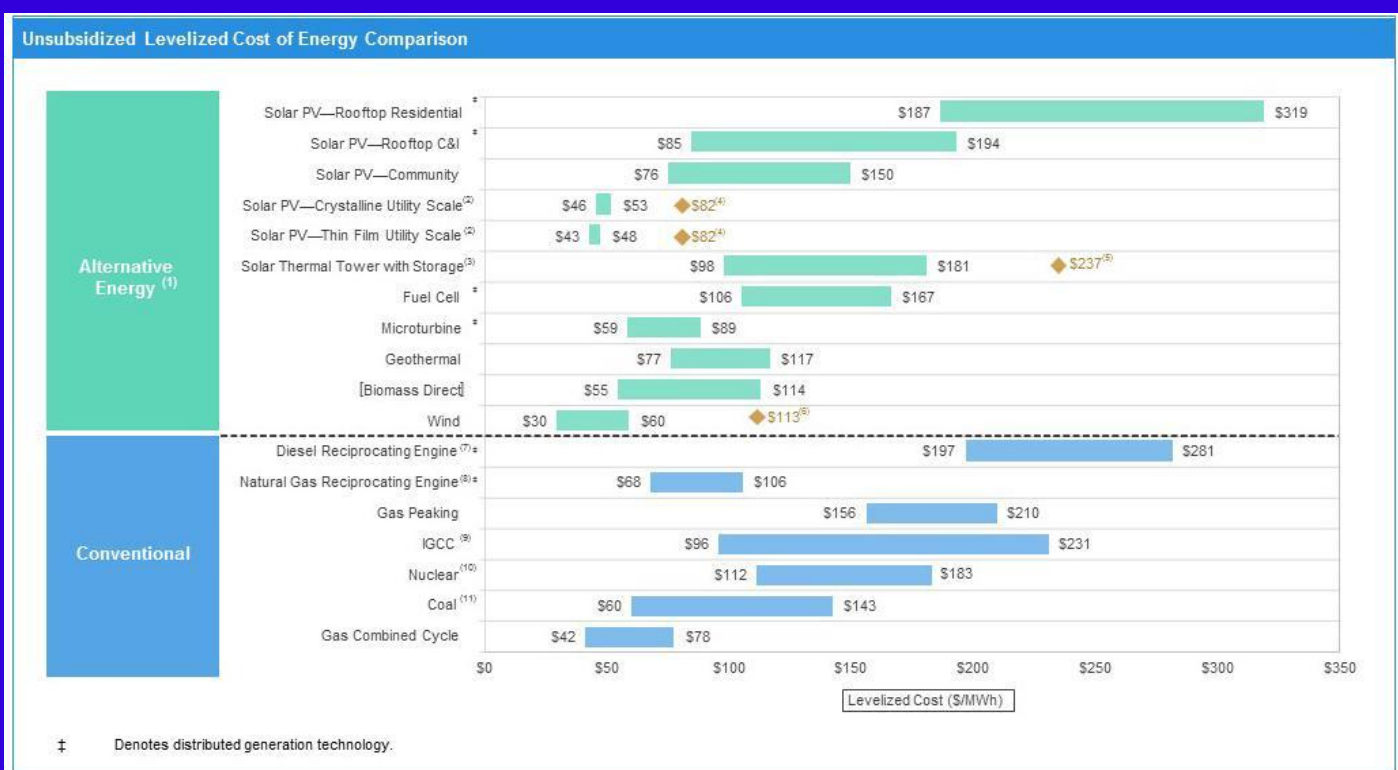


Figure 15. Unsubsidized Comparison of Energy Consumption (Credit: Lazard)

With the main operational costs of running a mining operation boiling down to electricity cost, it comes as no surprise that Bitcoin mining farms are turning towards large scale renewable energy sources, subsidized to a rate that minimizes the electricity expenditure in the overall cost equation.

that minimizes the electricity expenditure in the overall cost equation.

Another touch point regarding the energy consumption of the Bitcoin network is more of an ideological debate: would it be beneficial to both the financial/environmental landscape to leave behind conventional energy sources, and in its place turn to renewable energy sources? Does Bitcoin's electricity footprint of 0.27% cause a negative imbalance in the overall scheme of things (considering gold mining accounts for 0.27% of crude oil footprint)?

The findings of this report show that, environmentally, there should be no debate: Bitcoin does not negatively impact the environment any more than videogames, and is dwarfed by energy waste in China. The vast majority of the energy utilized by the network is from already accessible energy (i.e. no 'new' energy was created to meet the demands of the network).

Financially, the landscape is rocky in nature, both from a narrative standpoint and from the global economic standpoint. Bitcoin itself has yet to cement itself as a necessity to the general population, which brings the following narrative to the forefront: Bitcoin, to many, is seen inherently as a luxury – there was no qualms when Bitcoin was a nascent experiment, but do we really need to spend this much of our resources on something that less than 1% of the world utilizes? This argument, while understandable, holds little to no weight. It is frankly not up to the general population how people choose to spend their money/utilize energy; we operate in a relatively free market economy. To judge Bitcoin's success on the first 10 years of its history is both short sighted and a moot point – experiments on this grand of a scale will take decades to either fully come to fruition or be written off as a failure.

As for the global economic landscape, we have seen the effects of oil on our world: there have been wars fought over oil, there have been economic turmoil as a result of countries jockeying for oil control, and it could be argued that innovation has been snuffed out in the name of oil.

In essence, the findings of this section reveal that the world has placed unrealistic expectations on Bitcoin, at the very least, in terms of energy consumption: to move the goalposts for the largest thought experiment of this century is to entertain the multiple logical fallacies used to arrive at these expectations.

ENVIRONMENTAL IMPACTS OF BITCOIN ENERGY CONSUMPTION

Correlation of Energy Consumption to Environmental Impact

Having now gone over the energy consumption of the Bitcoin network, it is now prudent to further dissect this information to discover what environmental impact this energy consumption correlates to. It is notoriously difficult to gauge environmental impact of energy consumption, as there is no universally accepted indicator of environmental impact – for this reason, the use of 'carbon footprint' data will be the benchmark for this section, as there are no better commonplace alternatives.

Based on the findings of Digiconomist, the estimated annual carbon footprint of the network is 29,149 kt of CO2 **(Fig. 16)**.

Description	Value
Bitcoin's current estimated annual electricity consumption* (TWh)	61.37
Bitcoin's current minimum annual electricity consumption** (TWh)	37.01
Annualized global mining revenues	$6,245,010,168
Annualized estimated global mining costs	$3,068,344,951
Current cost percentage	49.13%
Country closest to Bitcoin in terms of electricity consumption	Switzerland
Estimated electricity used over the previous day (KWh)	168,128,490
Implied Watts per GH/s	0.130
Total Network Hashrate in PH/s (1,000,000 GH/s)	53,945
Electricity consumed per transaction (KWh)	468
Number of U.S. households that could be powered by Bitcoin	5,682,120
Number of U.S. households powered for 1 day by the electricity consumed for a single transaction	15.83
Bitcoin's electricity consumption as a percentage of the world's electricity consumption	0.27%
Annual carbon footprint (kt of CO2)	29,149
Carbon footprint per transaction (kg of CO2)	222.46

Figure 16. Statistics on Bitcoin Network Hashrate (Credit: Digiconomist)

Carbon footprint is colloquially defined as the total amount of greenhouse gases to both directly and indirectly support human activities. This metric is normally expressed in kilograms of CO2, but for the purpose of this report will be discussed in terms of kilotons of CO2. The Carbon Dioxide Information Analysis Center of the World Bank runs historical analytics for carbon dioxide emission, with data sets from 1960-2014. According to their analytics, the worldwide CO2 emissions in 2014 were 36,138,285 kt of CO2. 13 Therefore, Bitcoin accounts for roughly 0.08% of the worldwide carbon emission on an annual basis. This data point looks to shrink even further in the coming years if we extrapolate that renewable energy sources become more prevalent and if Bitcoin either maintains or grows its share of renewable energy use (76%).

Comparison to Primary Energy Users

These footprints, while not directly correlated to a hard metric of environmental impact, offer insight on the distribution of energy use, energy loss, and greenhouse gas emissions across industries. In essence, these footprints provide a benchmark on the macro scale for what is acceptable in these three categories, as well as developing models to show the benefit of utilizing better energy practices.

Keeping Bitcoin's carbon footprint in mind, we now turn to some of the major energy users: Aluminum, Iron and Steel, and Petroleum Refining. This data is presented in units of trillion-British Thermal Units (TBtu's), and therefore we have to convert the preliminary findings (61.37Twh), as shown in **Equation 1**:

$$61.37Twh\left(\frac{1\times10^{9}Kwh}{1Twh}\right)\left(\frac{3412.142Btu}{1Kwh}\right)\left(\frac{1TBtu}{1\times10^{12}Btu}\right) = 209.403TBtu(BTC) \quad (1)$$

Equation 1: Stoichiometry from TW/h to TBtu, Bitcoin

By comparing Bitcoin to these primary energy users, it is acknowledged that these comparisons are not equal value comparisons, and that the relative value of Bitcoin to that of any of these industries is weighed on a sliding scale, not head-to-head. The purpose of this comparison is to better understand the statistics of numerous industries in terms of environmental impact, giving the Bitcoin network some rudimentary benchmarks to compare against in the future.

In a 2016 proposal from the United States Department of Energy, it was estimated that the 2010 onsite energy consumption of aluminum manufacturing was 49.55 TBtu. 14 This value does not take into account offsite energy costs to transport, energy losses, et. al., and only accounts for the U.S. energy consumption. It is estimated that

North America accounts for 2.2% of worldwide aluminum manufacturing (with China and Australia accounting for the majority). Therefore, a more realistic accounting of onsite energy consumption is projected as 2,248 TBtu (10.73x greater than Bitcoin TBtu), which aligns with the earlier findings of this report that worldwide production of aluminum consumed more than ten times as much electricity as the Bitcoin network.

The findings for the iron and steel industry paint the same picture. According to the Worldwide Steel Association, in 2018 the United States accounted for 86.7 Million tons of steel production (4.7%), conservatively equating to 72 TBtu **(Fig. 17)**. By extrapolating worldwide the footprint caused by the iron and steel industry, a value of 1502 TBtu (7.2x greater than Bitcoin TBtu) was derived. Again, China heavily dominates the production of steel (928.3 Million tons), which provides no argumentative conclusion other than the reference earlier in the report to energy waste in China (both renewable and conventional).

25 January 2019

million tonnes (Mt)	2018	2017	%2018/2017
Europe	**311.8**	**311.7**	**0.0**
of which:			
EU (28)	168.1	168.5	-0.3
CIS	101.3	100.9	0.3
North America	**120.5**	**115.8**	**4.1**
of which:			
United States	86.7	81.6	6.2
South America	**44.3**	**43.7**	**1.3**
Africa	**16.1**	**15.1**	**7.2**
Middle East	**38.5**	**34.5**	**11.7**
Asia	**1 271.1**	**1 203.2**	**5.6**
of which:			
China	928.3	870.9	6.6
Japan	104.3	104.7	-0.3
Australia/New Zealand	**6.3**	**6.0**	**5.9**
World	**1 808.6**	**1 729.8**	**4.6**

Figure 17. World Crude Steel Production (Credit: World Steel Association)

The refined oil (petroleum) industry is where the numbers really begin to deviate. Using conversion tools (Equation 2), it is derived that the United States alone consumes 7.5 billion barrels of crude oil (43,290 TBtu) per year in energy from refining oil: [15]

$$7,500,000,000 oil barrels \left(\frac{5,772,000 Btu}{1 oil barrel}\right)\left(\frac{1\times10^{-12} TBtu}{1 Btu}\right) = 43,290 TBtu (U.S) \quad (2)$$

Equation 2: Stoichiometry from oil barrels to TBtu, Crude Oil

Even though the United States is the largest producer of crude oil in the world (19.9%), the worldwide energy consumption is staggering: 217,274 TBtu (1000x that of Bitcoin).

These results, while drastically in favor of the notion that Bitcoin has a negligible carbon footprint on the world, should be taken with a grain of salt: Bitcoin itself is still a developing project, whereas the three industries compared are already fully developed. Therefore, it is fair to assume that the Bitcoin network footprint will grow at a rate greater than that of the other industries in the short term, until Bitcoin reaches a fully developed state. At this time, it will be prudent to run these analyses again for further comparison. As argued earlier in the report, as mining becomes less economically feasible, the network hashrate should stabilize, providing for more accurate measurements.

SOUND MONEY, HYPERINFLATION, & THE CORRESPONDING IMPACTS OF CURRENCY DEVALUATION

Having now examined Bitcoin's actual energy consumption when it comes to the maintenance of the network, mining fees, and transactions, we now take a broader look at the societal benefits that are garnered by hard money.

Before we talk about how much energy is used in the pursuit of Bitcoin mining, it is important to understand what Bitcoin is trying to accomplish and then judge what level of energy would be appropriate for this type of activity. The goal of Bitcoin is to create the soundest money ever conceived.

Let us examine what money is and what we generally think of as money today: currency. The attributes of money can broadly be categorized as such **(Fig. 18)**:

What is the difference? "Money" is all of the below plus a "Store of Value". This means money is able to be saved for long periods and retrieved at a later time with its purchasing power unchanged.		CURRENCY	MONEY
Medium of Exchange	Is able to be used as an intermediary in trade.	✓	✓
Unit of Account	Is able to be numbered and counted.	✓	✓
Durable	Has a long usable life.	✓	✓
Divisible	It can be divided equally into smaller units *(You can make change).*	✓	✓
Portable	It is easy to carry or transport.	✓	✓
Fungible	Each unit is capable of mutual substitution, meaning units are of equal value *($1 in my wallet is worth the same as $1 in your wallet)*	✓	✓
Store of Value	Retains its purchasing power over long periods of time. Only gold and silver have been money throughout history.	✗	✓

Figure 18. Comparison of Currency and Money (Credit: Goldsilver)

The difference between currency and money boils down to one attribute – Store of Value. The store of value aspect of money is the area that relates to the soundness of the money. That is its ability to hold its value over time, fending off depreciation; it must have and retain purchasing power over time.

One of the main points of hard money is to allow for rational planning of the future. A significant pillar of our economic society is the ability to delay present consumption for the promise of future consumption. This requires the honest pricing of money. If you cannot count on a reliable and predictable interest rate, how do you financially plan for the future?

As noted by Saifedean Ammous, a Professor of Economics and well heralded academic of Bitcoin and sound money states in his book:

> From the preceding discussion, and from the understanding of monetary economics afforded to us by Austrian economics, the importance of sound money can be explained for three broad reasons: first, it protects value across time, which gives people a bigger incentive to think of their future, and lowers their time preference. The lowering of the time preference is what initiates the process of human civilizatios and

> allows for humans to cooperate, prosper, and live in peace.
>
> Ammous, Saifedean. The Bitcoin Standard (p. 73). Wiley. Kindle Edition.

For humans to address long-term environmental issues (climate change, the effects of pollution, etc.) they need to exhibit incredibly long-term thinking. Anything that interferes with this process, or encourages short-term thinking can have incredibly detrimental effects. Money that does not hold value or degrades people's ability to plan for the future can and will have a negative impact on the population's allocation of resources to projects where the benefit is in the distant future. This is prevalent in both financial planning (401k, mortgages, college funds, etc.) and environmental planning (renewable resource production, safe practices, investment in long term infrastructure). This negative impact happens at both the local and governmental levels, with varying degrees of impact

Hard Money and War

Another aspect of societal harm that can be associated with soft (not sound) money is the ability for humans wage total war. Prior to the industrialization of war making, it was of a fairly limited nature. Napoleon's invention of a people in arms, combined with the technological advancements made during the Civil War, led to the conditions that made World War 1 possible. There was still one ingredient that needed to be added; it must be paid for. This would have been nearly impossible under the Gold Standard (which all countries were based on), and was immediately abandoned by all participants with the commencement of hostilities.

> In retrospect, the major difference between World War I and the previous limited wars was neither geopolitical nor strategic, but rather, it was monetary. When governments were on a gold standard, they had direct control of large vaults of gold while their people were dealing with paper receipts of this gold. The ease with which a government could issue more paper currency was too tempting in the heat of the conflict, and far easier than demanding taxation from the citizens. Within a few weeks of the war starting, all major belligerents had suspended gold convertibility, effectively going off the gold standard and putting their population on a fiat
> standard, wherein the money they used was government-issued paper that was not redeemable for gold.
>
> With the simple suspension of gold redeemability, governments' war efforts were no longer limited to the money that they had in their own treasuries, but extended virtually to the entire wealth of the population. For as long as the government could print more money and have that money accepted by its citizens and foreigners, it could keep financing the war. Previously, under a monetary system where gold as money was in the hands of the people, government only had its own treasuries to sustain its war effort, along with any taxation or bond issues to finance the war. This made conflict limited, and lay at the heart of the relatively long periods of peace experienced around the world before the twentieth century.
>
> Ammous, Saifedean. The Bitcoin Standard (pp. 43-44). Wiley. Kindle Edition.

It is admittedly difficult to quantify the destruction wrought by war in terms of loss of life, loss of treasure, and environmental impact. Most estimates of 20th century wars conservatively put the loss of human life at over 200 million, both directly and indirectly (disease, PTSD, famine) caused by war.[16] The direct economic costs of the US involvement in the Middle East from 2001 to 2017 were found to have been $4.933 trillion, including spending and appropriations.[17] In hypothetical terms, what was the opportunity cost of this enormous spending on war on potential environmental projects, as well as healthcare, education, and infrastructure? Could it be argued that a sounder economic system would effectively mitigate the resources spent on war; if so, what amount of resources are we willing to dedicate towards this sounder economic system?

Hard Money and Hyperinflation

The most direct effect from unsound monetary practices to societal upheaval is hyperinflationary events. Venezuela is currently in a hyperinflationary spiral and is the 57th such occurrence since World War 1 **(Fig. 19)**. These events are accompanied by massive upheavals in society and political instability. The hyperinflationary environment of Weimar, Germany was the petri dish that both incubated National Socialism and the rise of Adolf Hitler. It is very hard to quantify the overall societal costs of this, but what level of resource allocation would be appropriate to mitigate or eliminate hyperinflationary events?

Location	Start Date	End Date	Month With Highest Inflation Rate	Highest Monthly Inflation Rate	Equivalent Daily Inflation Rate	Time Required For Prices To Double	Currency	Type Of Price Index
Hungary[1]	Aug. 1945	Jul. 1946	Jul. 1946	4.19×10^{16}%	207%	15.0 hours	Pengö	Consumer
Zimbabwe[2]	Mar. 2007	Mid-Nov. 2008	Mid-Nov. 2008	7.96×10^{10}%	98.0%	24.7 hours	Dollar	Implied Exchange Rate*
Yugoslavia[3]	Apr. 1992	Jan. 1994	Jan. 1994	313,000,000%	64.6%	1.41 days	Dinar	Consumer
Republika Srpska†[4]	Apr. 1992	Jan. 1994	Jan. 1994	297,000,000%	64.3%	1.41 days	Dinar	Consumer
Germany[5]	Aug. 1922	Dec. 1923	Oct. 1923	29,500%	20.9%	3.70 days	Papiermark	Wholesale
Greece[6]	May. 1941	Dec. 1945	Oct. 1944	13,800%	17.9%	4.27 days	Drachma	Exchange Rate‡
China§[7]	Oct. 1947	Mid-May 1949	Apr. 1949	5,070%	14.1%	5.34 days	Yuan	Wholesale for Shanghai
Free City of Danzig[8]	Aug. 1922	Mid-Oct. 1923	Sep 1923	2,440%	11.4%	6.52 days	German Papiermark	Exchange Rate**
Armenia[9]	Oct. 1993	Dec. 1994	Nov. 1993	438%	5.77%	12.5 days	Dram & Russian Ruble	Consumer
Turkmenistan ††[10]	Jan. 1992	Nov. 1993	Nov. 1993	429%	5.71%	12.7 days	Manat	Consumer
Taiwan[11]	Aug. 1945	Sep. 1945	Aug. 1945	399%	5.50%	13.1 days	Yen	Wholesale for Taipei
Peru[12]	Jul. 1990	Aug. 1990	Aug. 1990	397%	5.49%	13.1 days	Inti	Consumer
Bosnia and Herzegovina[13]	Apr. 1992	Jun. 1993	Jun. 1992	322%	4.92%	14.6 days	Dinar	Consumer
France[14]	May 1795	Nov. 1796	Mid-Aug 1796	304%	4.77%	15.1 days	Mandat	Exchange rate
China[15]	Jul. 1943	Aug. 1945	Jun. 1945	302%	4.75%	15.2 days	Yuan	Wholesale for Shanghai
Ukraine[16]	Jan. 1992	Nov. 1994	Jan. 1992	285%	4.60%	15.6 days	Russian Ruble	Consumer
Poland[17]	Jan. 1923	Jan. 1924	Oct. 1923	275%	4.50%	16.0 days	Marka	Wholesale
Nicaragua[18]	Jun. 1986	Mar. 1991	Mar. 1991	261%	4.37%	16.4 days	Córdoba	Consumer
Congo (Zaire)[19]	Nov. 1993	Sep. 1994	Nov. 1993	250%	4.26%	16.8 days	Zaïre	Consumer
Russia††[20]	Jan. 1992	Jan. 1992	Jan. 1992	245%	4.22%	17.0 days	Ruble	Consumer
Bulgaria[21]	Feb. 1997	Feb. 1997	Feb. 1997	242%	4.19%	17.1 days	Lev	Consumer
Moldova[22]	Jan. 1992	Dec. 1993	Jan. 1992	240%	4.16%	17.2 days	Russian Ruble	Consumer
Venezuela[23]	Nov. 2016	Ongoing	Nov. 2016	221%	3.96%	17.8 days	Bolivar	Exchange Rate***
Russia / USSR[24]	Jan. 1922	Feb. 1924	Feb. 1924	212%	3.86%	18.5 days	Ruble	Consumer
Georgia[25]	Sep. 1993	Sep. 1994	Sep. 1994	211%	3.86%	18.6 days	Coupon	Consumer
Tajikistan††[26]	Jan. 1992	Oct. 1993	Jan. 1992	201%	3.74%	19.1 days	Russian Ruble	Consumer
Georgia[27]	Mar. 1992	Apr. 1992	Mar. 1992	198%	3.70%	19.3 days	Russian Ruble	Consumer
Argentina[28]	May 1989	Mar. 1990	Jul. 1989	197%	3.69%	19.4 days	Austral	Consumer
Bolivia[29]	Apr. 1984	Sep. 1985	Feb. 1985	183%	3.53%	20.3 days	Boliviano	Consumer
Belarus††[30]	Jan. 1992	Feb. 1992	Jan. 1992	159%	3.22%	22.2 days	Russian Ruble	Consumer
Kyrgyzstan ††[31]	Jan. 1992	Jan. 1992	Jan. 1992	157%	3.20%	22.3 days	Russian Ruble	Consumer
Kazakhstan ††[32]	Jan. 1992	Jan. 1992	Jan. 1992	141%	2.97%	24.0 days	Russian Ruble	Consumer
Austria[33]	Oct. 1921	Sep. 1922	Aug. 1922	129%	2.80%	25.5 days	Crown	Consumer
Bulgaria[34]	Feb. 1991	Mar. 1991	Feb. 1991	123%	2.71%	26.3 days	Lev	Consumer
Uzbekistan ††[35]	Jan. 1992	Feb. 1992	Jan. 1992	118%	2.64%	27.0 days	Russian Ruble	Consumer
Azerbaijan[36]	Jan. 1992	Dec. 1994	Jan. 1992	118%	2.63%	27.0 days	Russian Ruble	Consumer
Congo (Zaire)[37]	Oct. 1991	Sep. 1992	Nov. 1991	114%	2.57%	27.7 days	Zaïre	Consumer
Peru[38]	Sep. 1988	Sep. 1988	Sep. 1988	114%	2.57%	27.7 days	Inti	Consumer
Taiwan[39]	Oct. 1948	May 1949	Oct. 1948	108%	2.46%	28.9 days	Taipi	Wholesale for Taipei
Hungary[40]	Mar. 1923	Feb. 1924	Jul. 1923	97.9%	2.30%	30.9 days	Crown	Consumer
Chile[41]	Oct. 1973	Oct. 1973	Oct. 1973	87.6%	2.12%	33.5 days	Escudo	Consumer
Estonia ††[42]	Jan. 1992	Feb. 1992	Jan. 1992	87.2%	2.11%	33.6 days	Russian Ruble	Consumer
Angola[43]	Dec. 1994	Jan. 1997	May 1996	84.1%	2.06%	34.5 days	Kwanza	Consumer
Brazil[44]	Dec. 1989	Mar. 1990	Mar. 1990	82.4%	2.02%	35.1 days	Cruzado & Cruzeiro	Consumer
Democratic Republic of Congo[45]	Aug. 1998	Aug. 1998	Aug. 1998	78.5%	1.95%	36.4 days	Franc	Consumer
Poland[46]	Oct. 1989	Jan. 1990	Jan. 1990	77.3%	1.93%	36.8 days	Zloty	Consumer
Armenia ††[47]	Jan. 1992	Feb. 1992	Jan. 1992	73.1%	1.85%	38.4 days	Russian Ruble	Wholesale
Tajikistan[48]	Oct. 1995	Nov. 1995	Nov. 1995	65.2%	1.69%	42.0 days	Tajikistani Ruble	Wholesale
Latvia[49]	Jan. 1992	Jan. 1992	Jan. 1992	64.4%	1.67%	42.4 days	Russian Ruble	Consumer
Turkmenistan ††[50]	Nov. 1995	Jan. 1996	Jan. 1996	62.5%	1.63%	43.4 days	Manat	Consumer
Phillipines[51]	Jan. 1944	Dec. 1944	Jan. 1944	60.0%	1.58%	44.9 days	Japanese War Notes	Consumer
Yugoslavia[52]	Sep. 1989	Dec. 1989	Dec. 1989	59.7%	1.57%	45.1 days	Dinar	Consumer
Germany[53]	Jan. 1920	Jan. 1920	Jan. 1920	56.9%	1.51%	46.8 days	Papiermark	Wholesale
Kazakhstan[54]	Nov. 1993	Nov. 1993	Nov. 1993	55.5%	1.48%	47.8 days	Tenge & Russian Ruble	Consumer
Lithuania[55]	Jan. 1992	Jan. 1992	Jan. 1992	54.0%	1.45%	48.8 days	Russian Ruble	Consumer
Belarus[55]	Aug. 1994	Aug. 1994	Aug. 1994	53.4%	1.44%	49.3 days	Belarusian Ruble	Consumer
Taiwan[57]	Feb. 1947	Feb. 1947	Feb. 1947	50.8%	1.38%	51.4 days	Taipi	Wholesale for Taipei

Figure 19. The Hanke-Krus World Hyperinflation Table (Credit: Cato Institute)

Lasting Remarks on Bitcoin as Sound Money
When talking about the energy use of Bitcoin, it is important to contextualize what Bitcoin is attempting to solve. The creation of sound money has far reaching societal impacts outside the scope of electricity usage. If the advent of a censorship resistance, immutable sound money like Bitcoin could make humans more long-term in their thinking, mitigate the ravages of war, and prevent hyperinflationary events, what would be the appropriate amount of resources that should be dedicated to maintain the network? Existing projects that claim to provide sound money currently take up massive amounts of resources **(Fig. 20)**:

	Yearly Cost	Energy Used (GJ)
Gold Mining	$105B	475M
Gold Recycling	$40B	25M
Paper Currency and Minting	$28B	39M
Banking System	$1,870B	2,340M
Governments	$27,600B	5,861M
Bitcoin Mining	$4.5B	183M

Figure 20. Expenditures of legacy financial systems compared to Bitcoin (Credit: Dan Held, Interchange)

The amount of energy, and by proxy dollars, that are used securing Bitcoin is incredibly miniscule by comparison. Bitcoin is not a company, it just is – this means that Bitcoin has no employees, has no overhead costs, requires no office space/service providers, and has no additional expenses other than the inherent cost of mining (which Bitcoin itself doesn't pay for directly regardless). This is why Bitcoin mining has a vastly lower yearly cost than the minting of paper currency, even though the energy consumed is much greater. If Bitcoin has the ability to solve or mitigate any of these issues, it should be seen as a worthwhile use of resources.

CONCLUSION

The rise of a universal currency that transcends borders and provides monetary freedom is at this point inevitable – Pandora's box has been opened, and that cannot be undone (**Fig. 21)**. Whether or not it is Bitcoin that becomes this form of sound money is still up for debate, but just as we had the separation of church and state in the late 18th century, so too will we have separation of money and state.

Fractional reserves, as well as other forms of financial malpractice that lead to the debasement of a nation's currency, has led to catastrophic effects: just look at the Thai Baht Crisis of 1997 or the Financial Crisis of 2007-2008. The rampant problems of the central banking system was one of the primary reasons that Satoshi Nakamoto created Bitcoin:

> The root problem with conventional currency is all the trust that's required to make it work. The central bank must be trusted not to debase the currency, but the history of fiat currencies is full of breaches of that trust. Banks must be trusted to hold our money and transfer it electronically, but they lend it out in waves of credit bubbles with barely a fraction in reserve.
>
> Satoshi Nakamoto

Arguments against Bitcoin based on the notion of energy waste were found to have no basis when compared to that of legacy financial systems – a benchmark was found to be inconclusive due to the nascent nature of the Bitcoin network. With a plethora of variables that would control the long-term energy consumption rate of Bitcoin, patience must be exercised to see how both the Bitcoin network evolves and how the geopolitical climate favors renewable energy sources in the future.

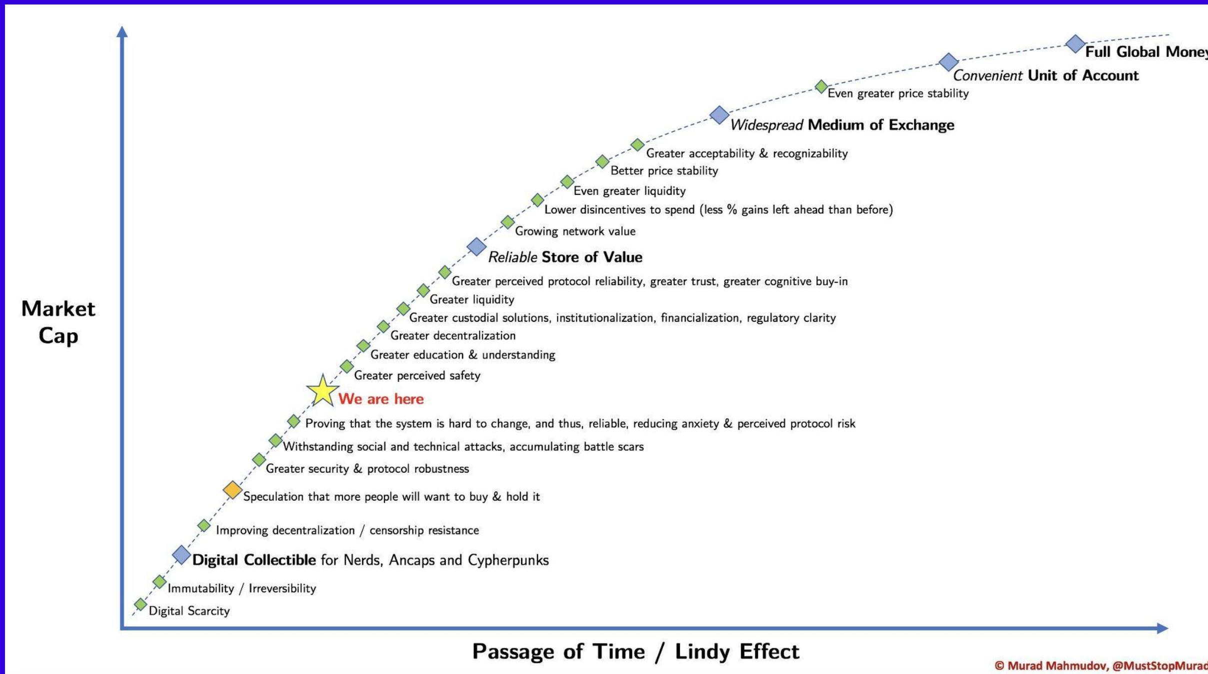


Figure 21. Lindy Effect of Bitcoin (Credit: Murad Mahmudov)

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