Bitcoin and other PoW coins are an ESG nightmare

By Tim Swanson
February 14, 2021

Abstract

This paper looks at the energy consumption of seven proof-of-work-based anarchic (public) blockchains such as Bitcoin and Ethereum. By using a hashrate division method - similar to the Cambridge Bitcoin Electricity Consumption Index - a lower bound and upper bound of mining hardware are provided. Based on this method we are able to show that proof-of-work chains continue to consume resources in direct proportion to the underlying coin value. Due to the rapid increase in coin value, proof-of-work-related activities - such as semiconductor manufacturing - are once again squeezing supply chains and retail channels, crowding out socially productive goods and services from entering the marketplace.

The model identified a bounded range for energy consumption. If we took the most efficient energy consumption assumptions (the lower bounds), these seven proof-of-work chains in aggregate consume 59.3 TWh per year, or roughly the footprint of Kuwait. In most cases - such as with Bitcoin itself - the lower bound is not realistic because the necessary amount of hashing equipment (miners) for that degree of efficiency has not been manufactured. In contrast, if we took a less conservative assumption and used the upper bound these same proof-of-work chains in aggregate consume 180.1 TWh per year, or roughly the footprint of Poland or Thailand. The upper bound scenario is likely unrealistic for coins that have seen their value (measured in USD) decline or stay the same (such as Litecoin). For those that have seen rapid appreciation (such as Bitcoin), it is possible that older equipment has temporarily been reconnected.

The paper is organized into several sections. Sections 1-4 provide a foundation for understanding how traditional financial market infrastructure, such as a real-time gross settlement (RTGS) system, operates, and uses Bitcoin and Ethereum as examples of how proof-of-work-based systems inherently result in socialized losses and e-waste. Section 5 contains calculations of smaller proof-of-work networks. Section 6 is a summary of the calculations found in the preceding sections. Sections 7 and 8 briefly look at misinformation spread as memes on social media. Sections 9 and 10 look at news reports covering several large ASIC and GPU mining operations. Section 11 provides several recommendations framed as a Call to Action.

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(1) Background

This paper is a sequel to our occasional series on the energy consumption of proof-of-work (PoW) cryptocurrencies such as Bitcoin.

We will get to resource consumption in the next section, but let us start in reverse order this time.

Many Bitcoin promoters conjure a future world in which the future of finance clears and/or settles on the Bitcoin blockchain, and in which that the demand for PoW generating equipment (miners) will simultaneously usher in a greener world.

Source: Twitter

Putting aside the continual greenwashing that many advocates are guilty of, some of the same promoters are unaware of how clearing and settlement occur in existing financial market infrastructure.[1] Take for example, a real time gross settlement (RTGS) system such as Fedwire.

Fedwire is categorized as systemically important financial market infrastructure due to the enormous amount of value it transfers and secures.

According to (Bilger 2020):

> In 2018, Fedwire executed 158 million transfers with an aggregate value of $716 trillion (Federal Reserve, 2019). While many of the fund transfers executed by Fedwire were of small value, the average value per transfer in 2018 was $4.5 million.

[1] As one reviewer noted: this leads to a Bastiat-esque "what is not seen" argument: if Bitcoin forces really smart people to work even harder on renewable energy, that would come at the cost of those really smart people working on other things that could easily be just as important. You can't just make people do more stuff in the abstract by throwing more problems into the world and expect the result to be better on-net. If that were true, then we should advocate destroying cities to help promote the development of next-generation construction and medical technology.

> Bureau of Economic Analysis (2019) estimated that 2018 total gross domestic product (GDP) was $20.5 trillion (para. 12). Fedwire may be viewed as a kind of force multiplier for the American economy by processing annual banking payments at 35 times the country's GDP. Further evidence of Fedwire's role promoting the efficiency of American financial markets can be seen by considering Fedwire payments against the aggregate value of all deposits at U.S. lending institutions - $12.6 trillion in March of 2019 (Federal Reserve Bank of St. Louis, 2019). Fedwire payments for the previous year were 57 times this figure.

We have discussed these types of large aggregates before in the past. For instance, a December 2015 paper from the Federal Reserve Board pointed out that, in the aggregate, U.S. payment, clearing and settlement systems process approximately 600 million transactions per day, valued at over $12.6 trillion.

Per day!

Fedwire® Funds Service - Annual Statistics

Annual Fedwire Funds Service Statistics

Year	Transfers originated (number)	Annual volume growth (percent)	Value of transfers originated[1] ($millions)	Annual value growth (percent)	Average value per transfer ($millions)	Average daily volume of transfers[2] (number)	Average daily value of transfers[2] ($millions)
2020	184,010,202	9.8	840,483,038	20.8	4.57	727,313	3,322,067
2019	167,650,062	5.8	695,835,129	(2.8)	4.15	667,929	2,772,252
2018	158,430,742	3.8	716,211,759	(3.2)	4.52	631,198	2,853,433

Source: Fedwire

When we mention these large, socially significant aggregates in conversations and debates at cryptocurrency-related conferences and events, many promoters are at a loss for words because they are unaware of these post-trade processes.

Another group - typically self-deputized coinfluencers - will proclaim that Bitcoin can move and secure the same value if not more, via metaphors.

Source: Twitter

The container ship fetish is a sleight-of-hand trick because Bitcoin versus a RTGS is *not* even a false dichotomy.

Why?

Simply: the Bitcoin blockchain only transfers and secures bitcoins. It does not move actual money like Fedwire does.[2] In point of fact, all ramps into and out of the Bitcoin network necessarily involves connections and hooks into traditional financial infrastructure. Bitcoin is co-dependent on traditional finance, not the other way around. In other words, Fedwire can (and does) live without Bitcoin but Bitcoin intermediaries cannot live without Fedwire or other RTGS systems.

A tangentially related argument is that Bitcoin transactions are structured to move blocks of data that can include additional information beyond bitcoin itself: even if a single coin is a 'container ship,' Bitcoin structurally has more *capacity* or *flexibility* than traditional networks.

The problem with this argument is that it is entirely possible to do that with a non-proof-of-work system as well. In fact, a blockchain may not be necessary at all. The fact the U.S., or international co-ops like SWIFT, set up its payments system to move around specific types of (messaging) data was a generational choice but not a permanent design constraint. In other words, a PoW-based network architecture does not have an exclusive monopoly on richer or broader forms of data. That is a red herring when comparing the two systems.

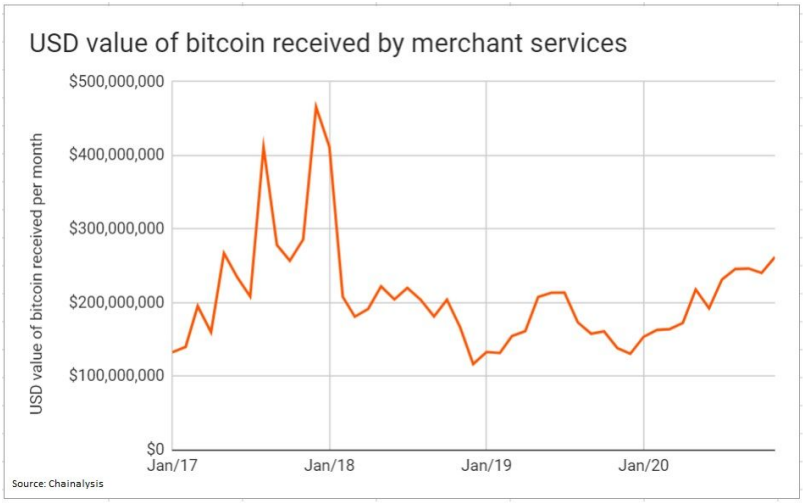
What about "stablecoins" piggybacking on top of Bitcoin?

The ongoing growth of parasitic stablecoins (such as Tether) rely on reliable banking access, specifically dollars cleared by the New York Federal Reserve. Not to mention all the new traditional-style institutions and intermediaries hooking into Bitcoin for custody and trading. Don't like old, monocle-wearing trusted third parties? Here are newer, hoodie-wearing trusted third parties to hold your coins!

[2] There is a clear distinction between Bitcoin and actual money that is beyond the scope of this article (it partially has to do with the unit-of-account). We could focus on the non-money-moving-related functions of the financial system that of course Bitcoin does not provide at all (although "DeFi" on Ethereum partially does). However, for the purposes of this article, *the act of* securing, transferring, and verifying payments is what we wanted to highlight.

More to the point, the majority of Bitcoin transactions today are simply bitcoins moving from one known intermediary to another, typically between coin exchanges for speculative purposes. If most of the endpoints and miners are self-doxxed then there is no longer a Sybil attack problem, removing the *raison d'etre* for proof-of-work.

How can we visualize this?



Source: Chainalysis

The monthly line chart (above) shows the USD value of bitcoins received by merchant services during the four year period (January 2017 - December 2020). Merchant services include processors such as BitPay, whom we have written about many times.[3]

Despite oodles of free marketing that bitcoin has received, payment-related activity is still lower than during the 2017 bubble. By some measures it is a *zombie chain* because Bitcoin users do not spend volatile chainletter earnings. Or more precisely, merchant processors handled *less* than $4 billion of bitcoin last year.

What is another key difference between an RTGS and proof-of-work chain such as Bitcoin?

Settlement finality.[4]

[3] In 2016 I visited Hong Kong a few times. On one visit I met with a couple of executives at a coin exchange. They said that their number one product was pre-loaded debit cards that were sold to mainlanders, typically to skirt capital controls and/or bribe folks with. Some of the large cryptocurrency payment processors (like BitPay) also provide payroll services, perhaps some of those coins are miscategorized as "payments." In another anecdote, one commenter explained that: I can say w/ high confidence that most of that volume in '17 was related to bitcoin wallets converting BTC to USD through Bitpay in order to load funds to prepaid cards - up until Visa killed that product in early Jan 2018. So not really representative of "BTC payment activity".

[4] This dovetails into conversations around legal recourse and recovery due to disputes. See also: Settlement Risks Involving Public Blockchains and Code is not law

We have discussed this multiple times but it bears repeating: proof-of-work chains - by design - allow mining participants to fork or reorganize the chain. Block making is permissionless. Now in practice, this does not frequently happen because the cost to acquire hash-generating equipment needed to successfully double-spend or reorg a chain is often quite prohibitive.

Either way, all a proof-of-work chain can guarantee is *probabilistic* finality that some type of confirmation has occurred but that there is a possibility that a well-funded attacker could reverse or reorganize the chain. For example, in August 2020, Ethereum Classic was hit by three separate 51% attacks, one that was more than 7000 blocks deep.

In practice, the way some financial institutions involved in the cryptocurrency world (such as trading desks) mitigate the risk of a double-spend or reorg is requiring a certain amount of blocks confirmed (often 3-6 confirmations) before allowing users to have access to recently transferred funds.

In contrast:

> Fedwire transfers are one-way, which means banks can wire funds out, but cannot debit other banks and wire funds in. Fedwire is a payment system and does not perform the traditional banking functions of managing deposits and withdrawals. It simply transfers funds between accounts within the Federal Reserve System. Once Fedwire transactions are complete, they are irrevocable.

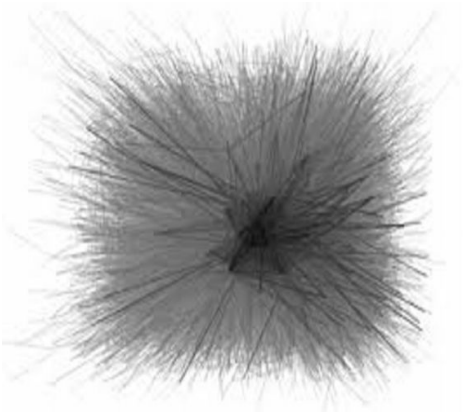
What about the actual network infrastructure? Surely Fedwire needs millions of hash-generating machines to secure all of those transactions each day!

According to (Bilger 2020) Fedwire has around 6600 nodes, 25 which are considered "core" which also have backups in case of disruption. Critically: ***none*** of the nodes in Fedwire is purposefully consuming oodles of extra energy to generate hashes.

Why not?

Because there is no Sybil attack problem in Fedwire, there are no nyms. Anarchic chains such as Bitcoin - by design - allow pseudonyms to participate in block making. To make it expensive to double-spend or conduct a block reorganization, proof-of-work was purposefully integrated in Bitcoin so that the attacker has to expend real economic resources to succeed.

This entire kludge is negated in Fedwire because all participants are known: it is permissioned.



Source: Soramäki et al. 2006

What does this image (above) represent?

A single day of Fedwire transactions in 2004. According to (Bilger 2020), a group of researchers isolated links and the nodes that connect them, that team was able to determine that just 66 nodes and 181 links comprised 75% of the value of daily payments. These core nodes and links are illustrated above. And as mentioned a moment ago, the inner ring of approximately 25 densely connected financial institutions is also evident.

What does this all mean?

The participating computing infrastructure for Fedwire involves between ten and twenty thousand computers, *none* of which need to generate SHA256 hashes. Its participants securely transfer trillions of dollars in real value each day. And most importantly: Fedwire does not take the energy footprint of Egypt or the Netherlands to do so.

As we will see below, the more than 2 million machines used in Bitcoin mining alone consume as much energy as Egypt or the Netherlands consumes each year. And they do so while simultaneously *only* securing a relatively small amount of payments less than $4 billion last year.

In other words, Bitcoin currently uses about three orders of magnitude more computing machinery than Fedwire yet processes and secures significantly less.[5] It is monumentally *less* efficient per watt on purpose.

Remember, the original purpose of Bitcoin was to enable P2P payments between unknown participants without intermediaries. Today, it has metastasized into a network that is primarily

[5] One counter-argument from promoters is: "what about stablecoins" such as Tether that piggyback on top of Bitcoin via Omni? Through an FMI lens, a lengthy rejoinder can be found in Parasitic Stablecoins. Through a technical lense, it bears mentioning that these piggyback coins arguably make the underlying PoW networks less secure; see Watermarked tokens and pseudonymity on public blockchains.

used for speculators to trade various coins and rarely used for actual payments.[6] And it involves a vestigial PoW infrastructure whose participants are identifiable because nearly all of the miners and major endpoints are self-doxxed.

This oxymoronic phenomenon -- a resource intensive permissioned-on-permissionless infrastructure -- has led to Ray Dillinger - one of the first Bitcoin users - to declare Bitcoin a disaster:

> Bitcoin mining has encouraged corruption (Because it's often done using electricity which is effectively stolen from taxpayers with the help of government officials), wasted enormous resources of energy, fostered botnets, centralized mining activity in a country where centralization means it's effectively owned by exactly the kind of government most people thought they *DIDN'T* want looking up their butts and where the people who that government allows to "own" this whole business work together as a cartel.
>
> There's a pretense of monitoring the network to guard against a 51% attack, but to me it seems pretty clear that what they're guarding against is merely the mistake of the cartel failing to give the latest warehouse full of miners a distinct network identity. The whole idea of proof-of-work mining is broken the instant hardware comes out which is specialized for mining and useless for general computation because at that point the need to have compute power for other purposes is absolutely irrelevant in having any effect on mining, and there ceases to be any force that causes mining to be distributed around the world. It becomes a "race to the bottom" to find where people can get the cheapest electricity, and then mining anywhere else - anywhere the government tries to make sure ordinary people actually get the benefit from electricity bought for tax money, for example - becomes first pointless, then a net loss.

We interviewed Dillinger a couple of years ago. Be sure to check it out.

Source: Bloomberg Video

[6] According to Chainalysis, more than three quarters of on-chain activity in a given day for Bitcoin are transfers between intermediaries, specifically exchanges. Due to volatility, users typically resort to utilizing 'parasitic stablecoins' (such as USDT). In this case, PoW chains are superfluous due to the usage of permissioned end points.

Nornickel is a Russian mining and smelting corporation. Last year a series of news articles described how BitCluster, a Russian cryptocurrency mining company, was building a mining farm above the Arctic Circle in Norilsk. It chose this location in part because of the natural ambient cooling and in part to re-use land from a closed nickel smelting plant. The farm will utilize a local coal power plant to generate 11.2 MWh to power bitcoin miners.

The next several sections will dive into the energy consumption of the largest proof-of-work chains, including Bitcoin. As we will show, PoW chains are the equivalent of adding an undead country - a zombie chain - to the power grid: one that consumes energy and produces little beyond emissions.

If you are an asset manager considering whether or not to include proof-of-work coins in your portfolio - and have an ESG mandate - or a policymaker considering whether or not to encourage the proliferation of these types of coins in your jurisdiction, it is pretty clear that PoW coins such as Bitcoin are an ESG nightmare and *not* a suitable fit. If and when some (or all) of these coins transition to proof-of-stake is beyond the scope of this article.

(2) Bitcoin

There are multiple ways to estimate how much energy and how many resources (mining equipment, physical plant) are used generating hashes for a PoW chain.

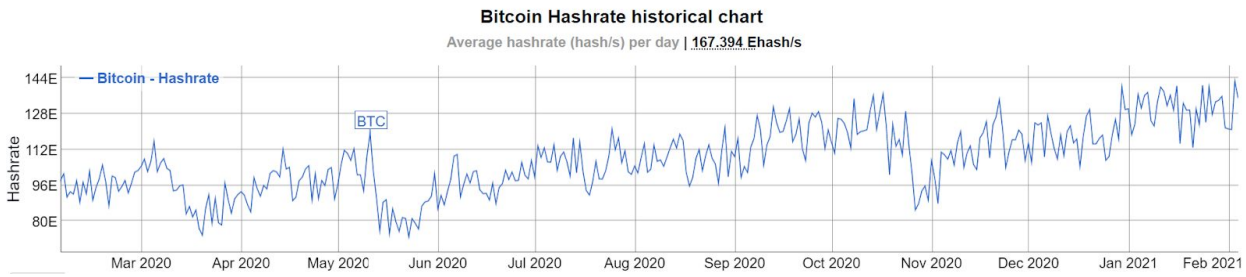
One involves surveying miners and mining pools, and hoping they provide accurate self-reported information. Another method involves a bit of detective work, physically visiting locations or obtaining purchase order documents from mining manufacturers. However, this makes it hard to ascertain how much second hand equipment is being re-used.

For example, Bitcoin has a carbon footprint comparable to that of **New Zealand**, producing 36.95 megatons of CO2 annually, according to Digiconomist's Bitcoin Energy Consumption Index (BECI). According to this tool, Bitcoin consumes as much power as **Chile** — around 77.82 TWh.

The Cambridge Bitcoin Electricity Consumption Index (BECI), a separate tool from researchers at Cambridge University, shows a much larger figure of 121.88 TWh — more than the entire annual energy consumption of the **Netherlands**.

There is one more simple method that everyone can do at home on their own computer. One that can create lower and upper bounds with a high degree of confidence. This is the **hashrate division** method which we have used multiple times in the past.

The way this works is by taking the publicly known hashrate of a network and dividing it by common hashing (mining) equipment metrics.



Source: BitInfoCharts

For example, on December 30, 2020, the Bitcoin network hashrate momentarily spiked to a record high 178.6 EH/s. That is exahashes per second (an exahash is one million terahashes).

How can we derive aggregate energy usage from this singular number?

Last May, Bitmain began shipping its Antminer S19 Pro. There is a bit of public information on how much each of these hashing units consumes and performs.

On paper a single S19 Pro generates a maximum hashrate of 110TH/s or terahashes per second with a power consumption of 3250 watts.

If the entire Bitcoin network were solely comprised of S19 Pro's (which it is not), it would consist of around 1.624 million hashing machines consuming 46.2 TWh in a year. According to estimates from the EIA, that is about as much as **Portugal** or **Singapore** consumes each year. This is a likely **lower bound** for how much energy is being used.

But wait, where does the Egypt number come from?

Recall that the S19 Pro is basically the *most* efficient, mass produced machine available today. Due to variance (the inhomogeneous Poisson process), the network hashrate varies day to day. In the process of writing this article it has gone from as low as 140 EH/s to the spike mentioned above.

Due to the rapid increase in Bitcoin's price over the last few months -- because hashrate follows coin value -- over the next several months it is likely that the hashrate will continue to grow as purchase orders are fulfilled and hit 200 EH/s by the end of this summer. This is why manufacturers like Bitmain are crushing it, with $327 million in cash holdings as of last month.

In practice, the network is *not* comprised of 1.6 million S19 Pro's because Bitmain has not even produced half a million of them.

To get a more accurate figure we must look at older, but more common systems that are still running.

For instance, the Antminer S17e system can churn out 64TH/s running at around 2880 watts. If the entire network was comprised of S17e systems there would be about 2.8 million machines involved.

That's about 70.4 TWh in a year. Which is about as much energy as **Colombia** or **Bangladesh** use.

But that is still not the upper bound.

Enter the older, but reliable Antminer S9i first released in May 2018 which can churn out 14 TH/s and consumes 1320 watts.

If the whole network was using S9i's, then there would be about 12.8 million of these machines churning out hashes.

In a year these would consume 147.5 TWh or roughly the same amount of energy that **Malaysia** or **Egypt** use each year (this is larger than either Chile or the Netherlands).

While there are probably botnets trying to use CPUs or GPUs to mine bitcoin, the amount of hashrate generated by them is likely marginal. Thus the S9i approximation is probably the **upper bound**.

Manufacturers such as Bitmain, MicroBT, or Canaan will eventually reveal how many systems they have sold which will give us some better refinement on the lower bound, the minimum amount of machines being used.

But it is clear that the spectrum is at a bare minimum Portugal and likely closer to Malaysia or Egypt, especially with so many people and companies trying to bring on older systems right now. This would put Bitcoin around the **27th** largest 'country' by energy consumption.

Is the hashrate division method a better estimate than the Cambridge or Digiconomist BECI models?

They both have their tradeoffs. The Digiconomist model is inherently more conservative because it is based on miners' income, whereas the Cambridge model uses a similar framework as the hashrate division method, starting with mining hardware that is available.

In any case, it is clear that while the energy consumption is somewhere between the Netherlands and Egypt, there is *not* an equivalent economic gain to the same degree.

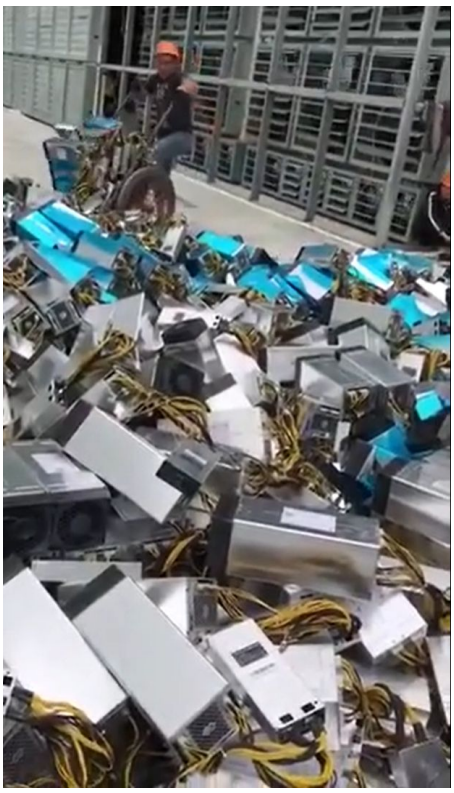
Another way to say this is that: historically as a country develops it produces more economic output per unit of energy input, getting more output with less input. For example, U.S. energy consumption has been relatively flat since 2000 yet its GDP has more than doubled over the

same period. Likewise following reunification, Germany's GDP growth rapidly outpaced energy consumption.

But the opposite occurs with Bitcoin and other PoW coins. The more valuable a PoW coin becomes, the more energy is used to extract (mine) it. We have written about this phenomenon before, in which the marginal cost to mine eventually equals the marginal value of the coin (MC=MV).[7]

As a result, PoW is clearly not something a fund with an ESG mandate should want to be involved in.

(3) Socialized losses and e-waste



Source: YouTube

Speaking of older systems, because these hash generating systems are single use ASICs (i.e., they can only do one specific thing: generate SHA256 hashes), they are often discarded in a time frame of 18-24 months. Some parts are salvaged and reused - such as the power supplies - and sometimes a new buyer is willing to acquire used machines second hand (as in the case of North Korean coin miners).

[7] One reviewer commented: From an outside view, even taking into account economies of scale and miniaturization, it is extremely rare that consuming more of something takes less energy than consuming less of something. A contrived example is: if you invade a country with more soldiers you could lose fewer soldiers because the war finishes more quickly." But that's not really the same situation at all.

One estimate is that around half of all data center energy usage is now tied to Bitcoin mining. In fact, the energy consumption of Bitcoin is *more* than the combined energy use of Amazon, Google, Microsoft, Facebook, and Apple. And the e-waste that is generated annually from *discarded* mining equipment is roughly equivalent to what **Luxembourg** throws in the trash each year.

This also does not include the socialized costs - and privatized gains - that miners place on specific geographies due to the type of energy used in generating the hashes.

Below are several recent examples:

- In December 2020, Gazprom (the state owned petroleum company in Russia) announced that a natural gas subsidiary in Siberia was setting up coin mining equipment on-site. Based on recent stories, similar setups have been built in natural gas fields in the U.S.

- Another example of socialized losses and privatized gains: the Republic of Georgia. Bitfury Group used its political connections to obtain property at below-market rates and now the Republic has the distinction of having 10% of the country's energy production siphoned off by Bitfury's mining operations.

- A coal-fired powered plant in Yates County, NY was converted to natural gas back in 2017. The owners of this 20 MW plant are trying to expand it to 106 MW, to mine more bitcoins. Putting aside the emissions this plant will create, it will also consume vast quantities of water - 150 million gallons per day - which will get discharged back into the lake solely to provide cooling to machines that can and do one thing: generate SHA256 hashes. Unsurprisingly the locals sued.

- Miners in southern China depend on coal-fired power plants, especially during the winter. Due to trade frictions between Australia and China involving coal transportation ships - PoW miners which depend on these taxpayer financed coal-fired plants - are struggling with the ensuing power shortage.

- Kazakhstan is allocating taxpayer funds to build more than a dozen mining farms. These are mostly powered by coal-fired plants. Miners at a 180 MW facility in Ekibastuz will consume as much electricity as needed to power 180,000 U.S. homes.

- Due to concerns that the record price for PoW coins like Bitcoin could cause an energy crisis in Abkhazia, the state-owned utility (Rosseti) has banned all coin mining.

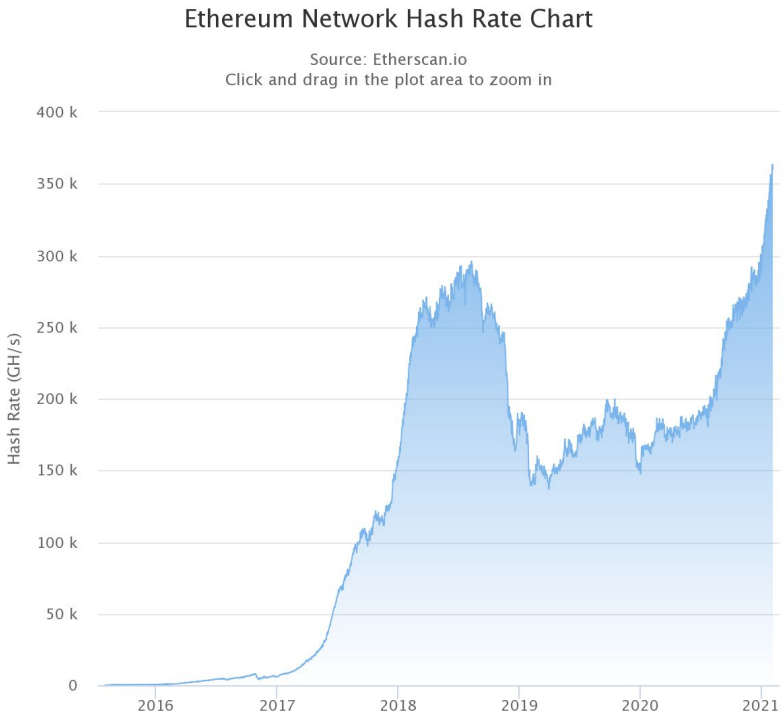
Why? Because state-run facilities are regularly targeted by electricity thieves:[8]

> Beginning with the 2017 "crypto boom," Rosseti started noticing abnormal jumps in electricity consumption in numerous Russian regions. The firm identified unauthorized cryptocurrency mining farms and estimated the damage to be over 718 million rubles—about $9.5 million—a significant part of which has already recovered through court procedures.
>
> The "black" miners are known to do more than just tap into power lines. Illegal Bitcoin operations actually build their own transformer stations.

This is by no means an exhaustive set of sources on the topic. The examples serve to reinforce how PoW mining can be a one-way wealth extraction (privatizing gains) whilst externalizing environmental costs.

(4) Ethereum

Like Bitcoin, the past month has seen Ethereum (ETH) hit several new record prices. Unsurprisingly this has also led to a new record in hashrate, at over 360,000 GH/s.



Source: Etherscan

[8] Several months prior to that report, Rossetti announced that it had been victim to at least $6.6 million in stolen electricity via coin mining. Following the run up in coin prices in 2017, one of the culprits believed to have stressed parts of the European power grid in early 2018 were coin miners.

In December 2020, a mining manufacturer in China, Linzhi, revealed an early demonstration of its new Phoenix mining machine via F2Pool. According to the demo, the Phoenix could generate 2,600 MH/s and consume 3,000 watts. It has *not* shipped any to the retail market and it is unclear when it might.

In contrast, the most efficient ASIC mining system on the market today (for Ethash) is the InnoSilicon A10+ Pro. A single A10+ Pro can generate 500 MH/s and consume 1,300 watts. This is just slightly faster than the A10 which the previous article used as a baseline.

The Ethereum network hovers at over 360,000,000 MH/s per day. That is equivalent to 720,000 A10+ Pro's.

Annually these machines would consume 8.2 TWh. That's about as much as the **Congo (DRC)** or **Trinidad and Tobago** consume. This would probably be the **lower bound**.

As mentioned in the previous article, there are many mining farms that still use GPUs to mine Ethereum. So much so that it has led to a massive, publicly reported on shortage of high end cards from Nvidia and AMD.

Without any modifications, the top-of-the-line GeForce RTX 3090 can churn out 122 MH/s and consumes 350 watts.[9] This makes it about 50% faster compared with the 3080.

A network entirely composed of 3090's would involve 2.95 million GPUs. Altogether they would consume about 9.1 TWh per year. This is about as much as **Bolivia** or **Panama** consume annually.

As you can see, as these GPUs have closed in on the previous generation of ASIC, this has led to some speculation that GPU manufacturers such as Nvidia may once again roll out GPUs just for cryptocurrency mining (again). The last time was a major dud as Nvidia had to write-off over $57 million in hardware due to a glut in 2018.

What is an upper bound for Ethereum mining?

This is a bit harder to guesstimate compared with the upper bound for Bitcoin or Bitcoin Cash, because of the unknown factor: how many GPUs are being used. Anecdotally it appears that a lot of less efficient GPUs and older ASICs are likely being used due to the run-up in ETH.

For example, an overclocked RTX 2080 can generate 35.3 MH/s and consume 235 watts.

An entire network of overclocked 2080's would consist of 10.2 million GPUs. These would consume about 21 TWh per year. This is about as much as **Azerbaijan** or **Ecuador** uses annually.

[9] With some tweaking this can reportedly be increased to 150 MH/s.

In the summer of 2018 it was estimated there were around 10 million GPUs churning hashes for the Ethereum network. For instance, JPR Research estimated that 3 million GPUs were sold to cryptocurrency miners in 2017. During those heady days, mining farms such as Genesis Mining, rented 747s to fly large batches of GPUs to its mining farms.

Because of the mix of older, less efficient GPUs (such as the RTX 10 series) or first generation ASICs that have been switched back on, it is likely that the network hashrate is closer to the **upper bound** of **Ecuador** than mid-range of Bolivia or Panama. This would put Ethereum around the **70th** largest country by energy consumption.

Unlike many Bitcoin promoters, most Ethereum developers - and even some miners - believe that this energy footprint is temporary, pointing to an ongoing transition to proof-of-stake which started with the Beacon chain (Phase 0) launched last December. Obviously the work-in-progress towards PoS has been known since before mainnet was even launched, yet it has been a slow slog.

Despite the desire of developers to quickly sunset proof-of-work, last month we contacted Vitalik Buterin who pointed out that there is currently no EIP to switch over from PoW to PoS. Based on the roadmap at least one EIP is expected to be crafted during the year.

It also bears mentioning that Buterin - unlike Bitcoin promoters - recognizes the large aggregates of energy consumption that PoW chains account for. In an interview three years ago he explained:

> "I would personally feel very unhappy if my main contribution to the world was adding Cyprus's worth of electricity consumption to global warming."

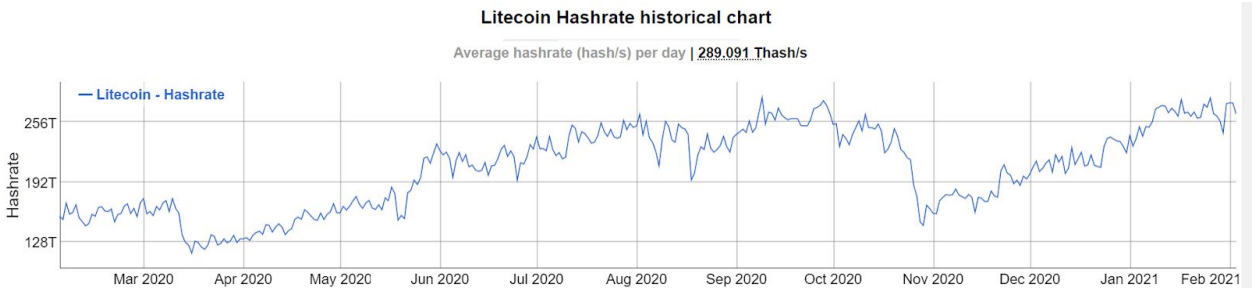
While "DeFi" usage and total-value-locked (TVL) has soared since the previous two articles on this topic were published, this would be an ends-justify-the-means argument. Not a fallacy *per se,* but also not a frequently used argument, because greenwashing is not part and parcel to the Ethereum ecosystem.

(5) Other large PoW chains

(5a) Litecoin

The fact that Litecoin is still a "Top 10" coin in 2021 should indicate how ridiculous proof-of-work coins are for society. No one really uses it for anything. Except one guy who invested more than he could afford to.

In fact, the hashrate is roughly the same today as it was two-and-a-half years ago because -- as pointed out many times -- hashrate follows coin price. Its most recent surges were due to PayPal adding it as an option users could buy or sell with, and an adult website (PornHub) that announced it would accept it as a form of payment.



Source: Bitinfo Charts

Despite having launched several years ago, Bitmain's Antminer L3+ is still basically the top ASIC mining unit that is used today. It generates ~500 MH/s with ~800 watts. A slightly more powerful L3++ is on the market as well.

At around 300 TH/s, there are the equivalent of about 600,000 L3+ machines generating hashes for Litecoin. In aggregate, these machines would consume 4.2 TWh per year. It would be placed around **130th**, between **Namibia** and **Cyprus**.

The Antminer L3++ specifications are similar:

- Hash Rate: 580 MH/s ±5%
- Power Consumption: 942W + 10% (at the wall, with APW3 ,93% efficiency, 25C ambient temp)

If only L3++'s were used, the outcome would be about the same.[10]

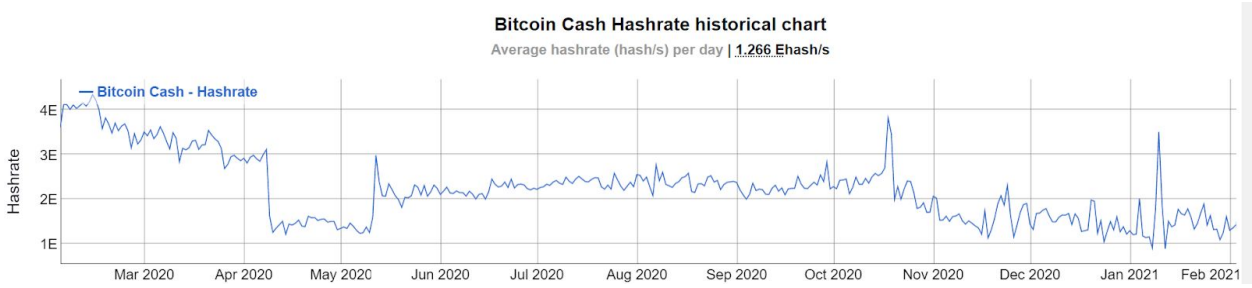
This consumption is pretty absurd once we factor in things like how there are only a couple of active developers who basically just merge changes from Bitcoin into Litecoin. In other words, one of the largest PoW networks has very few users or developers, yet consumes the same amount of energy as **Cyprus**.

How is that a socially useful innovation?

(5b) Bitcoin Cash

Unlike Bitcoin, Bitcoin Cash has seen a dramatic decline in hashrate since it briefly peaked at over 5 million TH/s in 2018. In fact, it is now oscillating around 1.3 million TH/s, or half of what it was 15 months ago.

[10] A network of only L3++ would comprise 517,241 machines and consume 4.3 TWh.



Source: BitInfoCharts

The calculations for Bitcoin Cash are very straightforward since it is just a modified version of Bitcoin.

Recall from above that a single S19 Pro generates a maximum hashrate of 110TH/s or terahashes per second with a power consumption of 3250W.

A network consisting of just Bitmain S19 Pro systems would comprise about 12,000 systems.

In a given year these would use about 336 GWh, this will serve as our **lower bound**.

Not counting e-waste, that would put the energy usage of Bitcoin Cash somewhere around **174th** or about the same as **Burundi**. Despite the fact that BCH has almost doubled in value since the last article, the hashrate decline is likely due to more efficient hardware now available.

This presents a problem for potential malicious forks as an attacker could rent hardware (via NiceHash) or purchase older discarded hardware previously used for Bitcoin mining. There are disagreements as to how to prevent this but most of them involve some kind of centralized group of developers manually inserting themselves into the validation process (via block signing).

For an upper bound, let us use an S9i for approximation. Recall it churns out 14 TH/s and consumes 1320 watts. That would involve about 93,000 systems consuming 1,073 GWh placing it somewhere between **Fiji** and **Benin** at 160th place.

Unlike last update, there is relatively little economic activity beyond speculators moving coins from one intermediary to another. In fact, an economist with Chainalysis noted that Bitcoin Cash saw less merchant processor volume, about $12 million in 2020.[11]

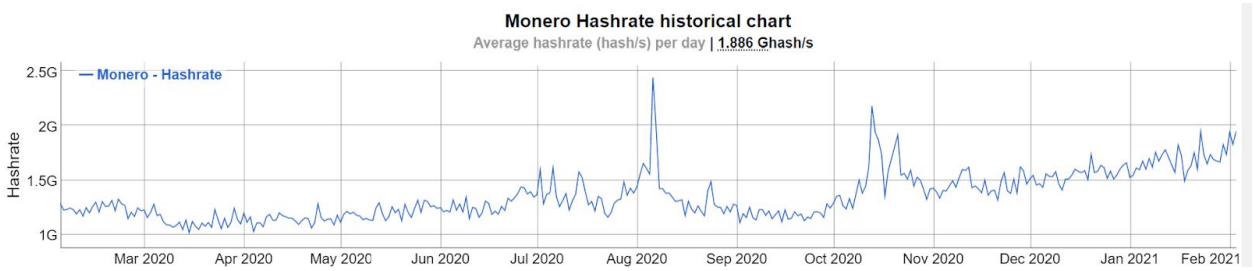
Clearly on-chain payments is not *the* use case, even though the infrastructure exists to do so.

(5c) Monero

[11] Private correspondence, February 10, 2021

Unlike the previous article, it appears that the decision makers behind Monero stopped trying to fork it every six months to prevent involvement from ASICs.

At the time of this writing Monero's hashrate is hovering near its all-time high, likely due to the fact that XMR's price has also risen, reaching a two-and-a-half year high.[12]



Source: BitInfoCharts

Compared with the previous article, the hashrate has increased nearly six fold to about 2 GH/s. And it is believed that most of this hashrate is still generated by GPUs and CPUs.

There are lots of how-to guides for building a CPU-focused Monero mining system, and NiceHash even has an easy-to-use profitability calculator.

In the previous article we looked at a Vega-based GPU build, which could still work, but again, CPU mining is still typically used for Monero. Currently the top performing CPU system on Monero Benchmarks is a modified 3990X Threadripper which generates 64,000 hashes/s and sips 600 watts. Note: these are self-reported, user-submitted numbers.

If the entire network were composed of just this type of machine, there would be 31,250 systems running. They would consume 164 GWh annually. This would place it around **195th**, between **American Samoa** and **Saint Kitts and Nevis**. This would be the **lower bound**.

For comparison, a slightly more common Ryzen 3600 generates 7,400 hashes/sec and consumes 100 watts. A network would consist of around 271,000 systems. They would consume about 237 GWh annually. This would place it around **190th** between **Chad** and **Sierra Leone**.

In terms of GPUs, a RTX 3090 generates 2053 hashes/sec and consumes 350 watts. A network of these would involve 974,184 systems. Altogether they would consume about 2,987 GWh per year. This would place it around **136th**, between **Montenegro** and **Jamaica**. This is not the upper bound.

[12] The XMR price is still well below the highs from late 2017 - early 2018.

As you can see, just like ASICs in sections above each older or slightly less energy efficient CPU or GPU system will incrementally increase the aggregate energy consumed.

For instance, in the previous article we looked at a 12-card Vega build, the user was able to generate 28,100 hashes/sec and consume 1920 watts. That's about 2341 hashes per card.

That's about 854,335 GPUs each sipping 160 watts. Altogether these consume 1,197 GWh annually. This is still not the upper bound.

What is the upper bound then?

Without knowing how many large scale (organized criminal botnet) farms there are, it would be hard to guess because of how easy and common CPU mining is, especially CPU-cycle theft. For instance, cryptojacking malware is so common today, that there is a distinct possibility that you know someone who is a victim, it might even be you. Monero is typically the top coin mined in this process. We could do an entire article on all of the variants that have come and gone.

A few months ago a manufacturer, ASICLine, claimed to be shipping a mining system that can generate hashes for Bitcoin, Litecoin, Ethereum, and Monero. Because of how inflexible ASICs are, it is unlikely that their claim is true. While we would like to be able to say for certain how much energy Monero is consuming, there is a possibility that someone has built a custom ASIC (or FPGA) which could throw off our estimate.

Based on the same electricity consumption chart as the others, we can guesstimate that Monero drinks around 1 GWh a year and would be placed somewhere definitely above **Chad** and probably below **Montenegro**.

(5d) BSV and ZEC and DOGE

There are hundreds, if not thousands, of dead PoW coins. Three proof-of-work coins that have remained in the "Top 50 as measured by USD" over the past few years are Bitcoin SV (BSV) and Zcash (ZEC) and Dogecoin (DOGE).

BSV was created (forked) by Craig Wright, an Australian who claims - *without* sufficient evidence - to be Satoshi Nakamoto.

Due to a lack of interest beyond a core group of his followers, BSV -- as measured in USD -- has declined relative to its cousins BTC and BCH. As a result, its hashrate has also

declined. At the time of this writing it is just over 600 PH/s, which is a two-and-half-year low. This makes it relatively inexpensive to successfully double-spend or reorg the chain.[13]

If the BSV network was composed only of S19 Pro's there would be around 5,454 systems consuming 155 GWh per year. That is about as much as **America Samoa** at around 200th place. This is the lower bound. An upper bound is unknown but if we re-use the S9i there would be about 43,400 of these systems consuming 502 GWh. That would put it around **Andora** or **South Sudan**, around 170th place.

There are a number of gambling-related apps that have been built around BSV, but no substantive economic analysis beyond the regular speculation that dominates in other chains.

Zcash received a lot of attention when it first launched for its privacy and confidentiality (opt-in) properties. For one reason or another, it has not seen as much market interest as Monero (despite arguably having stronger technical capabilities).

Either way, at the time of this writing Zcash's current hashrate (6.79 GH/s) is hovering near its all-time high. That may sound like a relatively small number compared to Bitcoin or Ethereum, but it uses a hashing algorithm called Equihash, which is more difficult to generate hashes. Unlike Monero, it is primarily mined via GPUs instead of CPUs. There are a variety of online calculators and guides comparing different setups.

There are also multiple ASIC miners for ZEC available including the Antminer Z15. The Z15 churns out 420 KH/s and consumes 1,510 watts. If the entire network were comprised of these ASIC machines there would be about 1,620 of them. Altogether they would consume 21.4 GWh each year. It would rank around **215th**, near the **Falkland Islands** and **Kiribati**. This would be the lower bound.

One of the slightly dated comparisons involved tweaking a Nvidia 1080 Ti. One user was able to achieve around 641 H/s at 300 watts. A network of these GPUs would comprise 1.06 million GPUs. These would consume about 2,783 GWh. That would place it around **140th**, between **New Caladonia** and **Mauritius**. While there may be older GPUs and even some CPUs mining, this is probably closer to the upper bound.

What about Dogecoin?

We wrote a bit about Dogecoin in 2014 but stopped because it merge mined with Litecoin in September of that year. While it is no longer independent -- as it piggybacks off of Litecoin

[13] Due to the size of its blocks, BSV also regularly sees orphans and accidental reorgs.

mining -- people still mine it with the same L3+ machines mentioned above (both Litecoin and Dogecoin use the same hash generating algorithm called 'scrypt'). Despite new record highs in prices, Dogecoin's hashrate is about 30% less than its all-time high. In fact, it is nearly identical to Litecoin's hashrate because it uses the same farms and pools. While some have suggested that this is an efficient usage of resources (two-chains-for-the-price-of-one) it creates a top-heavy situation that in theory, makes them both less secure.

(6) Status check

With all of these numbers and calculation spread around, let us briefly collate them in an easy to view section.

If the entire **Bitcoin** network were solely comprised of:

- S19 Pro: it would consist of around 1.624 million machines consuming 46.2 TWh in a year. That is about as much as **Portugal** or **Singapore** consumes each year. This is a likely **lower bound** for how much energy is being used.
- S17e: it would consist of around 2.8 million machines consuming 70.4 TWh in a year. Which is about as much energy as **Colombia** or **Bangladesh** use.
- S9i: then there would be about 12.8 million of these machines consuming 147.5 TWh or roughly the same amount of energy that **Malaysia** or **Egypt** use each year. While there are probably botnets trying to use CPUs or GPUs to mine bitcoin, the amount of hashrate generated by them is likely marginal. Thus the S9i approximation is probably the **upper bound**.

If the entire **Ethereum** network were solely comprised of:

- A10+ Pros: it would consist of about 720,000 machines consuming 8.2 TWh. That's about as much as the **Congo (DRC)** or **Trinidad and Tobago** consume. This would probably be the **lower bound**.
- GeForce RTX 3090: it would consist of 2.95 million GPUs consuming 9.1 TWh per year. This is about as much as **Bolivia** or **Panama** consume annually.
- GeForce RTX 2080 (overclocked): would consist of 10.2 million GPUs consuming about 21 TWh per year. This is about as much as **Azerbaijan** or **Ecuador** uses annually and is a possible **upper bound**. Because of the mix of older, less efficient GPUs (such as the RTX 10 series) or first generation ASICs that have been switched back on, it is likely that the network hashrate is closer to the **upper bound** of **Ecuador** than mid-range of Bolivia or Panama. This would put Ethereum around the **70th** largest country by energy consumption.

If the entire **Litecoin** network were solely comprised of:

- Antminer L3+ there would be about 600,000 machines consuming 4.2 TWh per year placing around **124th**, between **Moldova** and **Cambodia**.
- It is commonly believed that there are few, if any, dedicated GPU miners due to the inefficiencies relative to ASIC equipment. Hypothetically these GPUs would serve as an upper bound.

If the entire **Bitcoin Cash** network were solely comprised of:

- S19 Pro: would involve about 12,000 systems consuming 336 GWh, this will serve as our **lower bound**. Not counting e-waste, that would put the energy usage of Bitcoin Cash somewhere around **174th** or about the same as **Burundi**.
- S9i: it would involve about 93,000 systems consuming 1,073 GWh placing it somewhere between **Fiji** and **Benin** at **160th** place. This is a possible upper bound.

If the entire **Monero** network were solely comprised of:

- A single (modified) 3990X Threadripper: there would be 31,250 systems consuming 164 GWh annually. This would place it around **195th**, between **American Samoa** and **Saint Kitts and Nevis**. This would be the **lower bound**.
- A single Ryzen 3600: would consist of around 271,000 systems that consume about 237 GWh annually. This would place it around **190th** between **Chad** and **Sierra Leone**.
- An RTX 3090: a network of these would involve 974,184 systems consuming about 2,987 GWh per year. This would place it around **136th**, between **Montenegro** and **Jamaica**. Because of rampant CPU-cycle theft and cryptojacking, this is not the theoretical upper bound.

If the entire **BSV** network were solely comprised of:

- S19 Pro: there would be around 5,454 systems consuming 155 GWh per year. That is about as much as **America Samoa** at around **200th** place. This is the lower bound.
- S9i: there would be about 43,400 of these systems consuming 502 GWh. That would put it around **Andora** or **South Sudan**, around **170th** place. This is a likely upper bound.

If the entire **ZEC** network were solely comprised of:

- Antminer Z15: there would be about 1,620 of them consuming 21.4 GWh each year. It would rank around **215th**, near the **Falkland Islands** and **Kiribati**. This would be the lower bound.
- A tweaked Nvidia 1080 Ti: would comprise 1.06 million GPUs consuming about 2,783 GWh. That would place it around **140th**, between **New Caladonia** and

> **Mauritius**. While there may be older GPUs and even some CPUs mining, this is probably closer to the upper bound.

What does this all mean?

As mentioned above (and in numerous previous articles) there are hundreds if not thousands of dead or dying PoW chains.

If we took the most efficient energy consumption assumptions above (the lower bounds), these seven PoW chains consume 59.3 TWh per year. Roughly the footprint of Kuwait, around 46th place. But in most cases - such as with Bitcoin itself - the lower bound is not realistic because the necessary amount of efficient hashing equipment (miners) have not been manufactured.

In contrast, if we took a less conservative assumption and used the upper bound these same PoW chains consume 180.1 TWh per year. Roughly the footprint of Poland or Thailand, around 25th place. The upper bound scenario is likely unrealistic for coins that have seen their value (measured in USD) decline or stay the same. For those that have seen rapid appreciation (such as Bitcoin), it is possible that older equipment temporarily comes back online until newer replacements are installed.

And yet, in either scenario, these PoW networks are *not* also adding the equivalent GDP output of similar sized countries. Society is in effect, at a net loss.

How so?

As we have mentioned in this article and others, historically, as a country industrializes, its growth is often limited by access to energy which throttles its energy consumption. Simultaneously, as it grows and develops, it becomes more efficient per wattage of input.

For example, according to the Energy Information Agency:

> In the United States, energy intensity has been declining steadily since the early 1970s and continues to decline in EIA's long-term projection. A country's energy intensity is usually defined as energy consumption per unit of gross domestic product (GDP). Greater efficiency and structural changes in the economy have reduced energy intensity.

Despite dozens of RTGS systems being deployed across the world, in no instance do any of them consume the footprint of a small or medium sized country to operate.

The next section will look at some of the coin promoters and how they try to whitewash this issue away.

For instance:

Source: Twitter

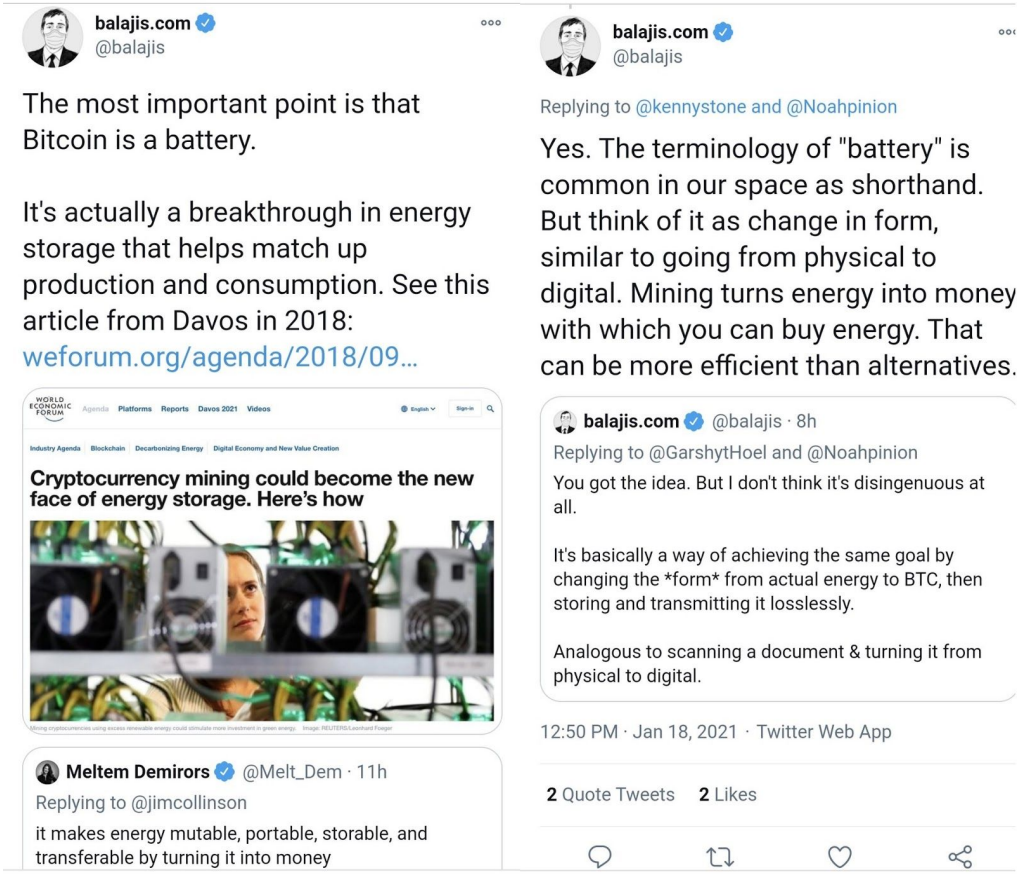
Only two nuclear reactors have been built in the U.S. in the past 25 years. One of the reasons why others may not be built in the future: the shale boom.

Interested in hearing the twenty-first century equivalent of "smoking is good for you"?

Source: Twitter

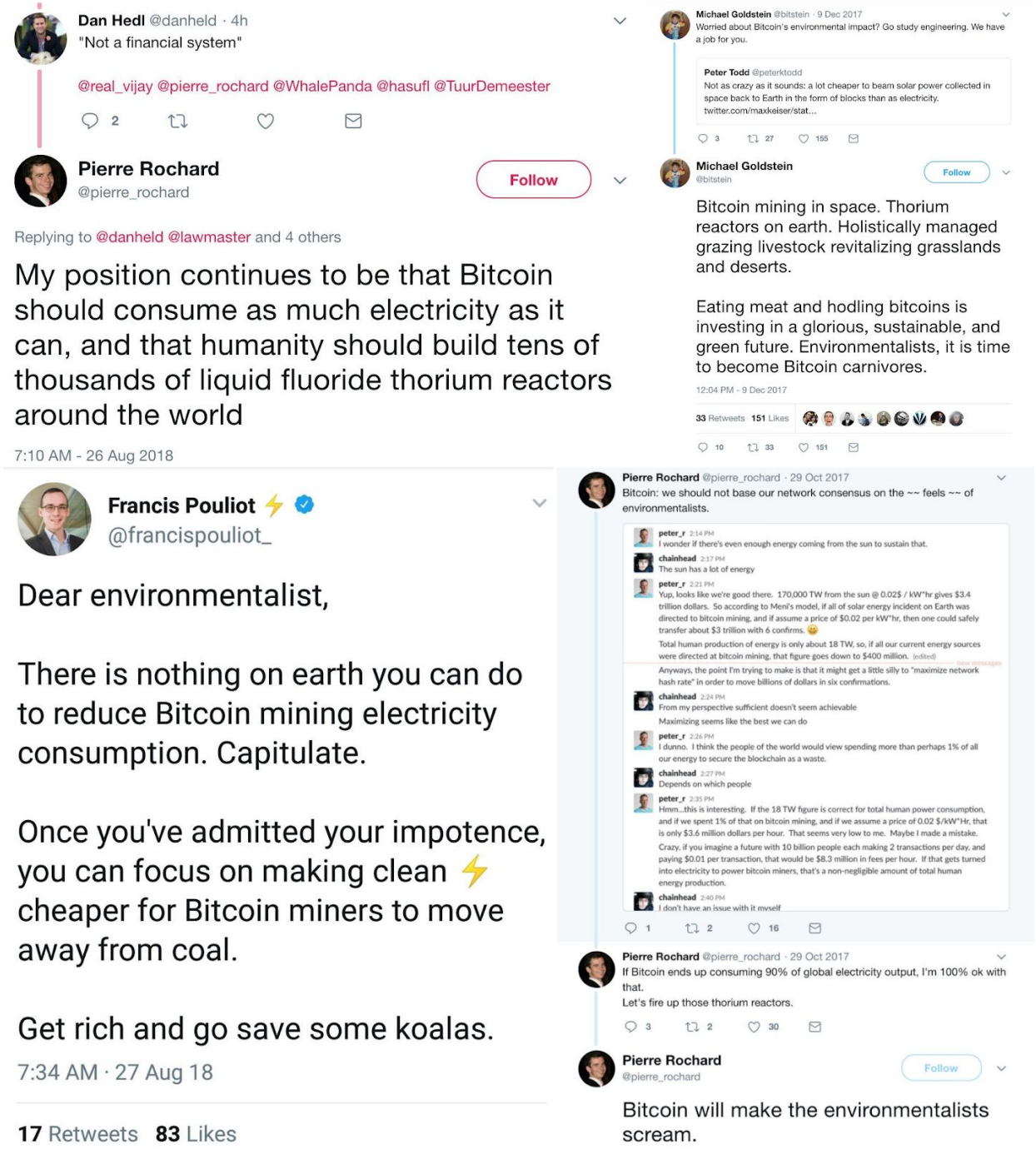
On with the show!

(7) Coin promoters



No, Bitcoin is not a battery.

Contrary to the musings of venture capitalists with a heavy stake in coins (and coin mining), mining PoW chains is not the same as a battery. It should be obvious that energy used in mining is not reusable, it is turned into heat as it enters the environment. When miners pay bills they convert some of their holdings into actual money, energy is *not* released in this process because no energy was stored to begin with.



Source: Twitter

It is hard to know where to start with this batch of Bitcoin promoters, nearly all of whom work for prominent cryptocurrency intermediaries.

Fun fact: despite continual claims that Bitcoin will spur development of Thorium-based nuclear power plants, to date, there have been zero Thorium plants built let alone funded by Bitcoin personalities.

What about stranded energy?

In practice “stranded energy” means there is some kind of inefficiency in storage and/or the transportation grid. In some cases capital could be used to increase efficiencies (e.g., new pipelines) which could reduce the price of energy extraction or transmission. Yet because it is stranded, it centralizes PoW mining in that specific area.[14]

But what about renewables?

Source: Twitter

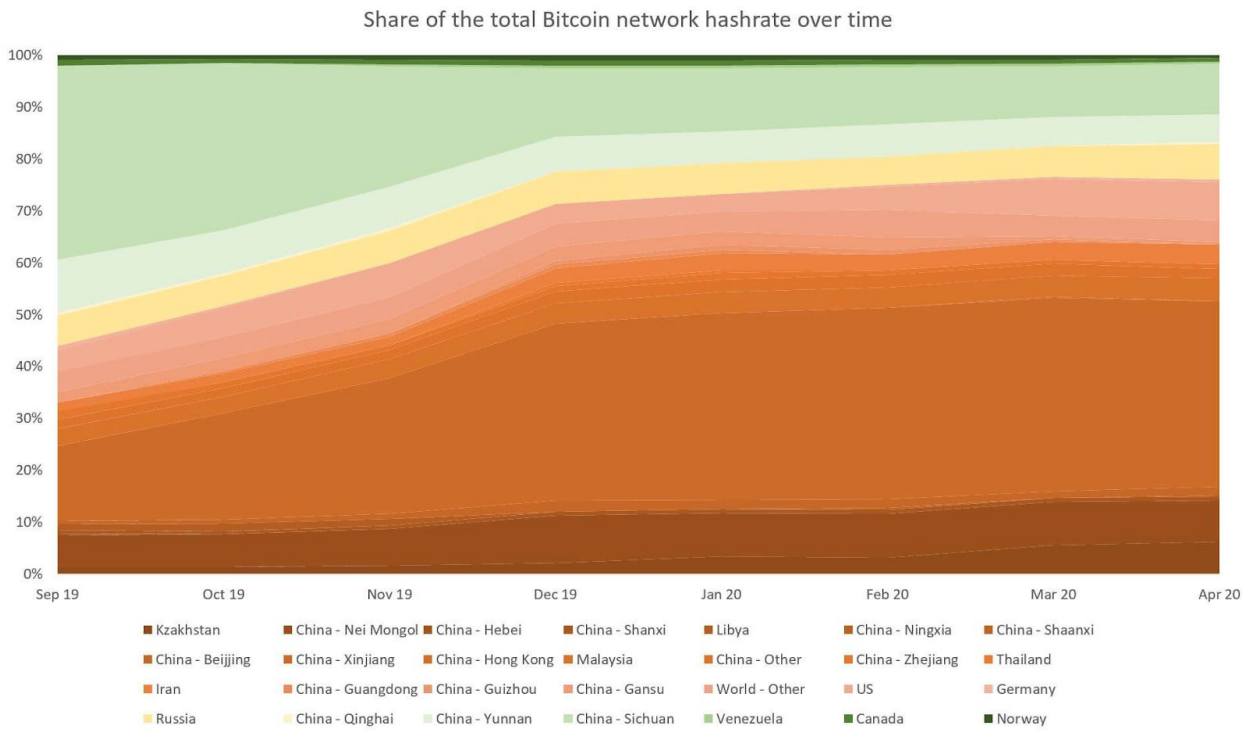
Hitchen’s Razor: That which can be asserted without evidence, can be dismissed without evidence.

Even when a region has hydroelectricity available, the hydro power is not consistent throughout the year. Consistent energy generation has led Bitcoin miners to areas which they perceive as stable, which often involves coal power. The “renewable argument” that many Bitcoin promoters use, neglects to account for the ‘seen and unseen’ opportunity costs involved. For example, solar panels and wind farms still require land that could otherwise be used for different, more productive purposes; likewise dams can be deconstructed allowing habitats to regrow and rivers restored.[15]

In terms of cyclical generation, even in the summer, when hydroelectric dams are at their peak output in the northern hemisphere, Cambridge BCIE estimates that more than half of energy generation still relies on non-renewables such as coal or gas.

Many miners themselves do not provide any reason to believe this. Cambridge surveys miners, and they indicated that while a majority has renewables in the energy mix, *only* 39% of mining is done with renewables (as it can be a small part of the energy mix).

[14] PoW mining might also be inadvertently subsidizing energy that would otherwise be anathema (e.g., “dirty” hydrocarbon extraction due to its lower costs).
[15] Another unseen cost: scarce resources such as rare earth minerals used to construct solar panels or PoW equipment (and the e-waste it generates) that could have been used in more productive endeavors or not consumed at all.



Source: Digiconomist

The location data above is from Cambridge, sourced from mining pools rather than a survey. If you look at where miners are situated most of the time, you also see that while they use some renewables during the summer (wet season) in China, they are using fossil fuels the rest of the year.

According to Stoll *et al.*, the carbon intensity of the energy used for mining Bitcoin was 480-500g CO2 per kWh in 2019 and went up to more than 550g CO2 per kWh recently due to increasing popularity of Iran and Kazakhstan. 8% of miners are now using sanctioned Iranian oil-based energy to mine.

There is also a steady stream of on-the-ground local stories providing anecdotes to the rush for relatively cheap energy. For instance, clandestine Bitcoin mining in Iran is believed to be one of the reasons for a rash of blackouts (and smog).

Lastly, even if Bitcoin miners were mostly run on renewables (which is not occurring) Bitcoin mining could not be considered environmentally friendly. Why? Because of the regular cycle of e-waste that is created as next generation ASICs are introduced.

(8) Whataboutisms

Whataboutery is commonplace and normalized in the cryptocurrency world.

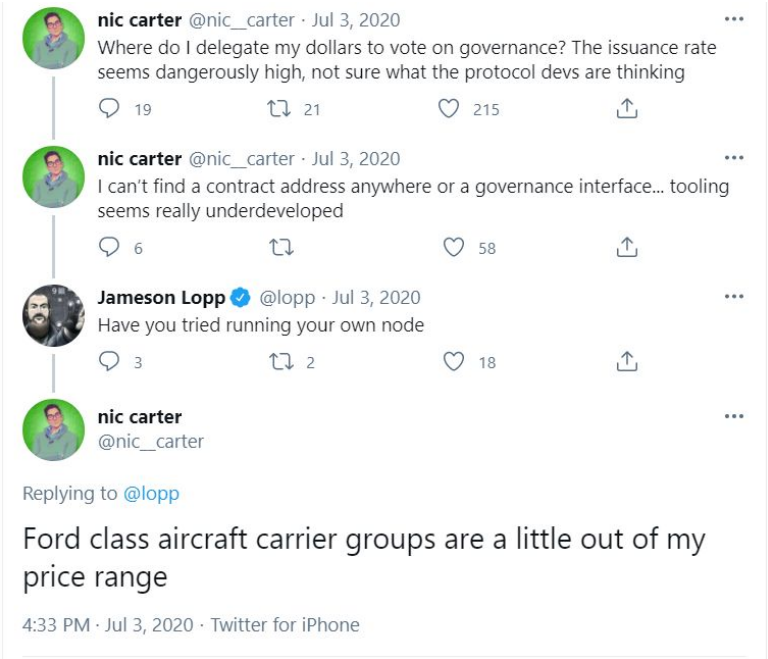
Tired of policy makers pointing out that illicit activity is attracted to KYC-less chains? Whatabout HSBC! Dislike the moans from hospitals impacted by Bitcoin-funded ransomware operations? Whatabout nuclear warfare!

This fallacy rears its head in the discussion of energy consumption: ignore this category of waste because there is also a category of waste there!

Source: Twitter

This is not a contest to waste as much energy as possible. Aircraft carriers, submarines, and airborne infantry divisions do not protect RTGS systems. All wasteful activities - such as nuclear warhead production - can clearly be categorized as bad and undesirable. It is also unclear from that thread how Bitcoin can end war or reduce military spending.

Speaking of poor analogies:



Source: Twitter

If we are going to play along with this game above: we actually know who participates in Federal Reserve decision making processes. Whereas we still do not have a regularly updated list of who funds those with merge control in the Bitcoin Core github repo.

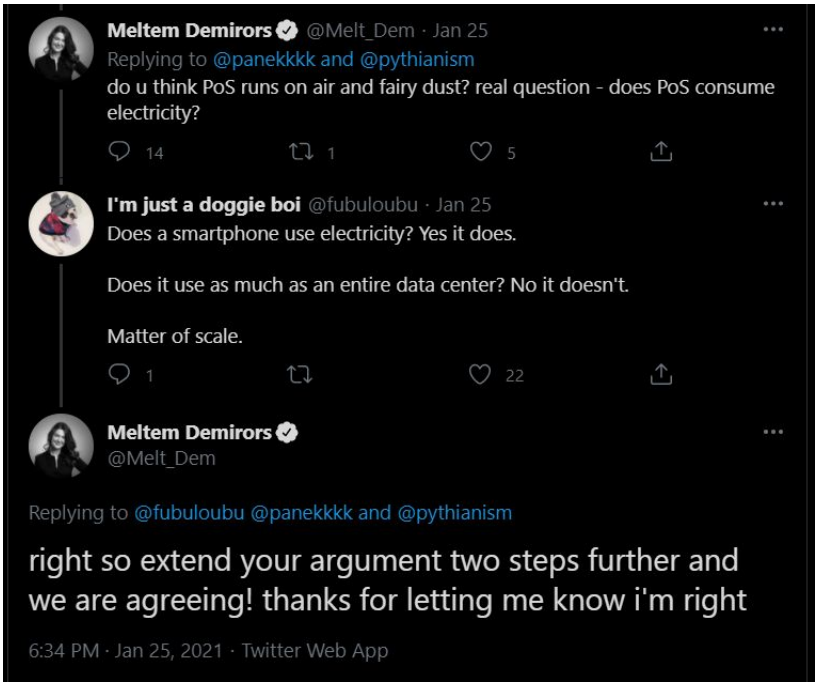
At the time of this writing about 70 RGTS systems are live across the world. But only a small handful of countries with an RTGS also have nuclear weapons and/or aircraft carriers. And only six have both.[16] This illustrates that you *can* have one - a secure large value transfer system - without the other.

Source: Twitter

Held's argument is a Whataboutism. Why? Because this is not a contest over who wastes more (or less).

As Galloway correctly points out in that thread: no one is trying to run a PoW-based payment system with Christmas lights. Christmas light operators are not incentivized to string up more lights as the aggregate market capitalization of light manufacturers increases.[17]

[16] The six countries that have both are: China, France, India, Russia, the U.K., and the U.S.
[17] There are some good jokes waiting to be made about "alternative" Christmas light implementations. With faster or slower blinking; or larger bulbs!



Source: Twitter

No one is trying to run a PoW-based payment system with smartphones. Furthermore, telecoms do not need to consume oodles of more energy per extra unit of phone added to their networks. PoW chains empirically and theoretically will consume energy in direct proportion to the value of the coin price. That is why we continue to see ever larger amounts of ASIC machinery sold by Bitmain and MicroBT to miners, not less. Yet PoW chains do *not* have a monopoly on securing permissionless payment systems.

Proof-of-stake (PoS) chains require some electricity too. If this was a comparison of say Polkadot or Avalanche (both of which are PoS-based), they would consume several orders less than Bitcoin does today.

And if these were compared to running full nodes (since there is no hash generation needed)?

For instance, according to Bitnodes there are approximately 9,415 nodes relaying transactions on the Bitcoin network (including the 25 or so mining pools).

At the time of this writing, there are about 110 validators alive on Polkadot and about 830 up on Avalanche. Yet both PoS networks are arguably just as secure as Bitcoin yet neither requires burning mountains of coal to stymie malicious actors. While we could debate ways to quantify "decentralization," more is not necessarily better.[18] In this case, the thousands of extra non-block making validators in Bitcoin are essentially superfluous.

[18] One model to measure could be "sliding windows" as described in Measuring Decentralization in Bitcoin and Ethereum using Multiple Metrics and Granularities from Lin *et al.*

Source: Twitter

Nevertheless, bitcoin believers argue that disputes about its environmental impact are missing the point.

"Energy use in itself is not bad," Meltem Demirors, chief strategy officer of digital asset management firm CoinShares, told CNBC. "Sending and storing emails uses energy. Yet, we don't infer email to be bad because it consumes energy."

"What we have here is people trying to decide what is or is not a good use of energy, and bitcoin is incredibly transparent in its energy use while other industries are much more opaque."

Demirors questioned why the banking industry, for instance, wasn't under more scrutiny for its energy usage. She said bitcoin miners were "incentivized to use renewables" because it's getting cheaper to produce it.

Source: CNBC

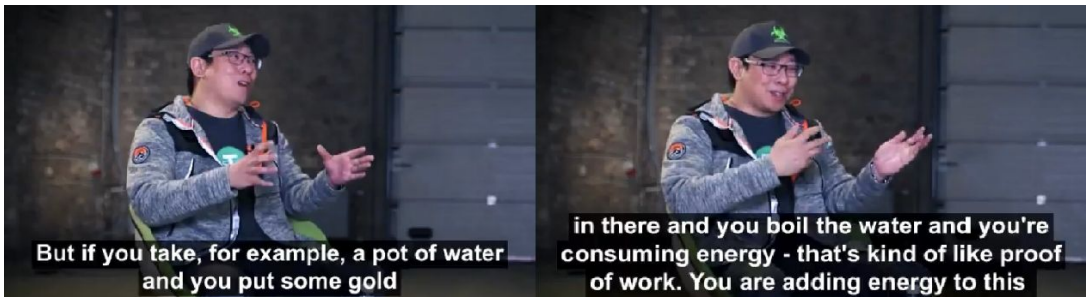
Virtually every sentence is incorrect. And this is all Whataboutery. Bitcoin mining usage could boil the ocean? But what about banks!

For what it is worth, nearly every large bank has announced some kind of carbon neutral initiative or has attempted to provide some semblance of where the energy is sourced.[19] That is not an excuse to justify their wastes or privatized gains (and socialized losses).

The bar should be: how can a value transfer system reduce its energy consumption and externalities, not to distractingly point fingers at other entities that also waste.

Speaking of which, in her examples above, it is also a different type and magnitude of waste. Banks do not generate more revenue if they leave their computers on 24/7 whereas PoW miners have to be left on around the clock to generate hashes in order to compete for block rewards.

Furthermore, banks as a whole provide many more services (and products) beyond just processing payments. In contrast, Bitcoin has very limited functionality, including the inability to do any on-chain lending.



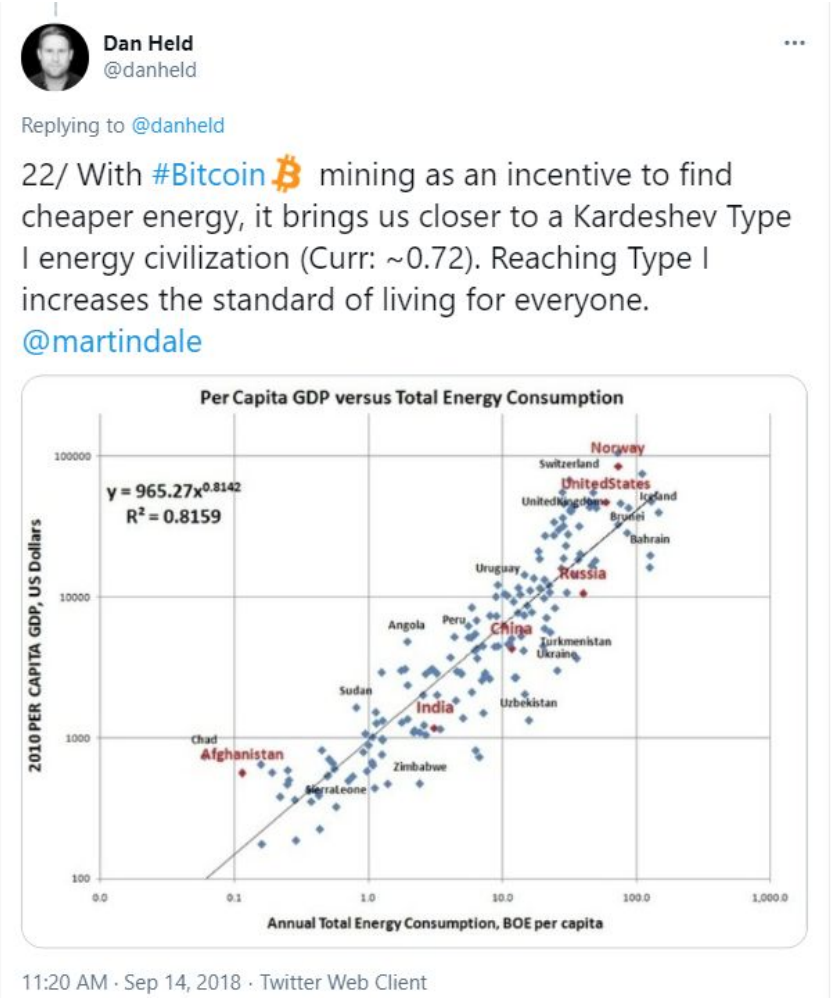
Source: Bloxlive

That is not an accurate description of boiling gold (alchemy?) or what proof-of-work is as described by the original creators (Dwork and Naor). Neither its supply schedule nor energy consumption is what creates value for PoW coins, external demand is.

Claiming that PoW imbues a cryptocurrency with value because it requires real effort to produce it is a variation of the Labor Theory of Value. And saying PoW can promote energy efficiency is like saying paying people to dig holes and fill them up again helps the economy.[20]

[19] In 2019 over 50 banks and other financial institutions launched the Partnership for Carbon Accounting Financials (PCAF) to assess and disclose the impact their loans and investments will have on climate change using common carbon accounting standards. Several other initiatives track the aspirations of banks including Mighty Deposits and Bank Track.

[20] Ironically they do not yet realize it but PoW proponents are embracing a type of impaired Keynesianism.



Source: Twitter

The chart (above) that Held uses, does not actually describe what he is saying about Kardeshev scale civilizations. If anything, assuming a "million dollar" bitcoin happens, PoW will actually drag Norway, China, and the U.S. back down towards Afghanistan. Why? Because if energy consumption goes up in those countries (via PoW mining), per capita GDP is decreasing because Bitcoin itself does not really produce anything.[21] As a result, productive capacity for goods and services is being squeezed (or crowded out) by PoW-related endeavors.

In his accompanying article for this image Held states that: "The pressure to find cheap electricity sources will accelerate the effort to build fusion reactors."

But that basically saying if you leave your car running it is good because it incentivizes finding alternate power sources.

[21] Bitcoin-focused intermediaries (such as coin exchanges) do enable trading of various financial products (such as derivatives) which likely contribute to some kind of economic output. But these trusted third parties are - from an accounting perspective - separate from the Bitcoin network which only produces intangible bitcoins.

Speaking of which:

Source: Twitter

Due to the demand shock from COVID-19, depending on geography, the cheapest sources of energy today might actually be oil and gas. Perhaps the near-future of mining are cars parked outside of refineries in Houston, churning up hashes for PoW networks.

And last but not least:

Source: Twitter

According to modeling from the Resources for the Future, a think tank, Miami will become the most vulnerable major coastal city in the world with “100-year floods” occuring every few years rather than once a century in many locations. A quarter of all homes at risk from flooding due to climate change reside in Miami-Dade county. If the mayor wanted to stave off this crisis the *last* thing he should be encouraging is direct investments in proof-of-work based cryptocurrencies.

(9) Competing for scarce resources

Due to the rapid rise in some cryptocurrency prices, foundries that churn out semiconductors have months of backlogs due to GPU and ASIC demand. Why? Because there are only a small handful of foundries capable of manufacturing state-of-the-art chips and as a result there is a limited capacity irrespective of what the ultimate destination may be.

This has led to a shortage of chips used in automobiles to the point where large manufacturers such as Ford or General Motors (GM) have announced plant shutdowns. In its most recent earnings announcement, GM estimated that:

> The semiconductor shortage will shave $1.5 billion to $2 billion off adjusted earnings before interest and taxes this year.

How much semiconductor output capacity is being squeezed because of PoW miners?

Digiconomist estimates that TSMC - the largest semiconductor manufacturer in the world which produces most, if not all, ASICs for cryptocurrency mining - would need 3-4 months at full-capacity of its 7nm output just to produce the ASICs for PoW mining equipment that have been ordered.[22]

This also impacts any industry or job that needs cutting edge GPUs, including squeezing smartphone manufacturers, console manufactures, graphic designers, and e-sport gamers. Why? Because the surge in mining demand has resulted in street prices for GPUs doubling what the original MSRP is.

History repeats itself: in November 2017, Chen Min (a chip designer at Avalon Mining) gave a presentation which noted that 5% of all transistors in the entire semiconductor industry were used for mining and that was driving up DRAM prices. Last cycle this negatively impacted a variety of ancillary set of actors, such as astronomers who rely on GPUs to chug through cosmic signals.

We are witnessing a similar phenomenon today. For instance, MSI announced that it may launch mining-specific GPUs this year.[23]

[22] According to Digiconomist: 28 TWh annually of Antminer S19 Pro's is about a month of capacity. If the Bitcoin network doubles from current levels, it will take about 3-4 months (not including replacement of older ones). And that is just production for Bitcoin-specific hardware.

[23] *Tom's Hardware* recently compared 30 different GPUs to find out which ones had the best return-on-investment for Ethereum. Surprisingly, it was the Nvidia 1060 first released in July 2016.

Source: Tom's Hardware

The current surge in demand for GPUs for mining has led some participants to acquire hundreds of gaming laptops *en masse*,crowding out, again, anyone who needs a high performance GPU. The image (above) comes from a Weibo account tracking various China-based miners who are showing off their GPU farms consisting of high-end laptops.

"Laptop mining" has pushed new buyers down the performance curve, to hardware that is two generations old.

Source: Tom's Hardware

Below are three publicly listed companies that have announced large purchases of mining equipment in the past several months:

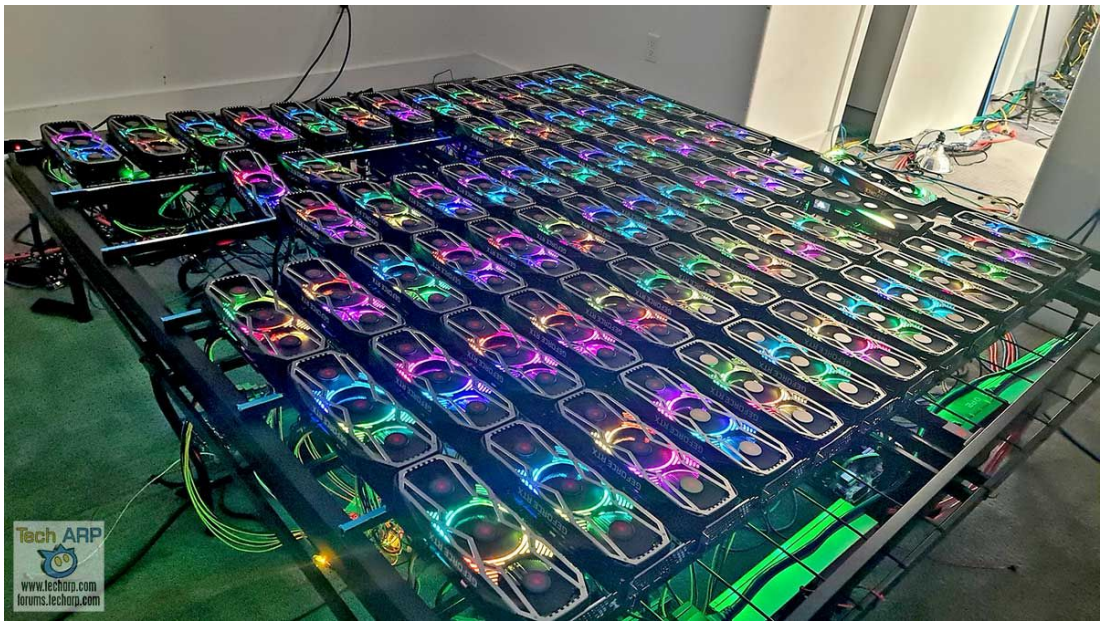
- Riot Blockchain - which pivoted during the last bull run from a biotech company (Bioptix) to a coin mining company - announced it was purchasing and installing about 10,000 S19 Pro's from Bitmain.
- Hut 8 purchased 5,400 mining machines from MicroBT for $11.8 million
- The9, a gaming company, purchased 26,007 mining machines from Canaan

A few days ago UK-listed Argo Blockchain announced it would build a 200 MW mining facility in West Texas.

Private companies have also announced large purchases of coin miners. For instance, last month Blockstream announced that it had purchased $25 million worth of equipment from MicroBT and that this would be part of its 300 MW of mining capacity.

And an anonymous buyer in Russia, recently acquired 20,000 mining systems that consume 70 MW for a new farm in Bratsk, Siberia.

And this is just the tip of the iceberg.



Source: Tech ARP

A GPU farm of 78 GeForce 3080s was photographed (above) churning up hashes for Ethereum last month.

An entire paper or two could be written on large bulk purchases of ASICs or GPUs which crowd out other industries that need the same resources for actual productive activities.

(10) Undead countries are an ESG nightmare

Is it a stretch to call Bitcoin a 'smoldering Chernobyl sitting at the heart of Silicon Valley'?

In May 2014 we briefly discussed a hypothetical "million dollar" bitcoin. At the time, Bitcoin's price had dropped below $500 and we were already able to empirically discern that hashrate grows (or declines) *directly proportional* to coin value.

In the previous articles we found that, despite the introduction of increasingly energy efficient hardware, a PoW network like Bitcoin consumes ever larger amounts of energy. That is because of the *Red Queen's Race*: miners do not downsize farms in aggregate, they simply replace aging hardware with newer ones; they must run faster in order to stay in the same place.

That is why anyone that has access to a hashrate chart can project with decent certainty what the likely outcome of a "million dollar" bitcoin will be in the future.

If a $40,000 bitcoin has already led miners to consume the energy equivalent of the Netherlands or Egypt, a million dollar bitcoin would be about 25 times as much.

What does that mean in actual numbers?

- If the Netherlands is the proxy: 2,757 TWh, roughly midway between India and the U.S.
- It Egypt is the proxy: 3,764 TWh, roughly the same as the U.S.

Critical to any analysis of energy usage is economic output. In a million dollar bitcoin world, society would be bearing the externalities of mining activity that does *not* produce a proportional amount of GDP. For instance, much of the coin mining industry is reliant and dependent on taxpayer funded utility companies and grids. As a result, we would see the equivalent of an additional U.S.-sized energy usage *without* seeing anywhere near the economic output, this would be a huge net loss.

This also does not take into account e-waste that is created via discarded single-use ASICs. And it does not take into account other PoW networks such as Litecoin which are basically ghost towns yet consume country-sized energy units too.

Miners will surely lead to greener sources of energy production, right?

This is a red herring.

Through the usage of either permissioned systems (like an RTGS) or a proof-of-stake chain, the energy consumed by PoW chains did not need to take place at all. In fact, PoS chains can provide the same types of utility that PoW chains do, but without the negative environmental

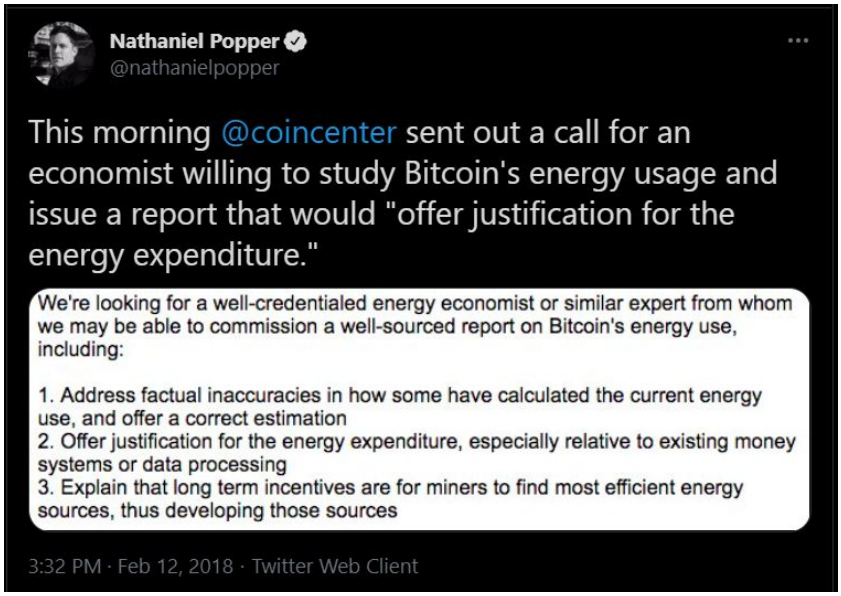
externalities. PoW chains are the equivalent of adding an undead country - a zombie chain - to the power grid: one that consumes energy and produces little more than emissions.

Because of disputes among its undead participants these zombie chains must utilize the judicial and legal resources of third party countries. The chains also have a parasitic relationship to other government-run services that they continue to rely on such as taxpayer-financed energy grids.

(11) Call to Action

What can be done?

For starters, do not patronize coin lobbying organizations that weaponize misinformation. They are *not* dedicated to protecting consumers or the environment. Their mission is to convince legislators around the world to take a hands-off approach to regulations, including potential taxes on miners.



Source: Twitter

Nearly three years ago, the executive director of Coin Center, Jerry Brito, solicited names to hire to whitewash easy-to-prove energy consumption numbers.

Why? Because it is bad for business. Some Bitcoin promoters like to present themselves as being part of the cutting-edge future, one disassociated with the *ancien régime*. But as we have seen repeatedly in this paper, PoW miners compete for the same scarce resources and capacity that society relies on to generate real goods and services.

Source: Twitter

This is not true. Agrawal, who works with Brito at Coin Center, attempts to limit the available options when there are a wide range of other possibilities.

For instance, according to The New Republic:

> In 2020, Tesla sold about $1.58 billion worth of these [carbon] credits—almost exactly the value of the Bitcoin purchased.

Tesla is going to account for its Bitcoin holdings as intangible assets (goodwill) which is not how this line item was intended for. This is clearly shrewd opportunism (and accounting), not some re-imagination of resource consumption.

According to Digiconomist:

> If 12 million people used Bitcoin to buy a Tesla, it would be enough to completely offset the combined total of CO2 saved by these EVs (by Tesla's own account).

Elon Musk says he is now a fan of Bitcoin but PoW miners are directly cannibalizing the chip production capacity required to produce Tesla vehicles, a point that Tesla's latest 10-K filing indirectly touches on.

Like parasitic stablecoins, miners in proof-of-work networks such as Bitcoin piggyback on top of the current energy extraction and generation infrastructure.[24] Furthermore, Bitcoin itself is not an alternative to an RTGS (traditional finance) so much as it is a shadow payment service that enables illicit activities to occur via a spectrum of intermediaries (e.g., underregulated coin exchanges). Continually comparing one versus the other is specious because one fully depends on the other to exist.

[24] Again, PoW chains such as Bitcoin often involve hundreds or thousands of superfluous nodes that maintain copies of the blockchain and verify balances; all of this subsists on top of the existing energy exploration and production infrastructure.

What can you do?

Most developed and developing countries levy taxes on polluters or “sin” activities.[25] Clearly proof-of-work mining falls into both categories.

Contact your local Public Utility Company and explain the socialized losses and privatized gains that are possibly accruing to miners. In addition to levying a tax on coin mining activity, perhaps introducing a tax on PoW-based holdings at intermediaries could be discussed since they directly benefit from miners providing the underlying blockchain infrastructure.

And if you are a user of a cryptocurrency, publicly advocate for switching to proof-of-stake (PoS) chains or accelerating such transitions if they are already underway. You can still enjoy decentralized finance in a way that does not dramatically contribute to climate change.[26]

Acknowledgements

Thanks to the following people for their helpful feedback: CK, JG, VB, RG, KR, JH, MW, and AV.

[25] Another consideration that funds with an ESG mandate should consider is not just the environmental impact of PoW mining but also the human rights that may be violated in the production of said coins.
[26] Decentralized Finance: On Blockchain- and Smart Contract-Based Financial Markets by Fabian Schär