# The merit and nature of Bitcoin's energy consumption

Galaxy Mining Summer Series
June 22, 2021

CASTLE ISLAND
VENTURES

# Why spend energy anyway?

I. To generate settlement assurances

II. To fairly distribute new coins with limited seigniorage

# Distributed, leaderless convergence over a shared history

## Bitcoin: A Peer-to-Peer Electronic Cash System

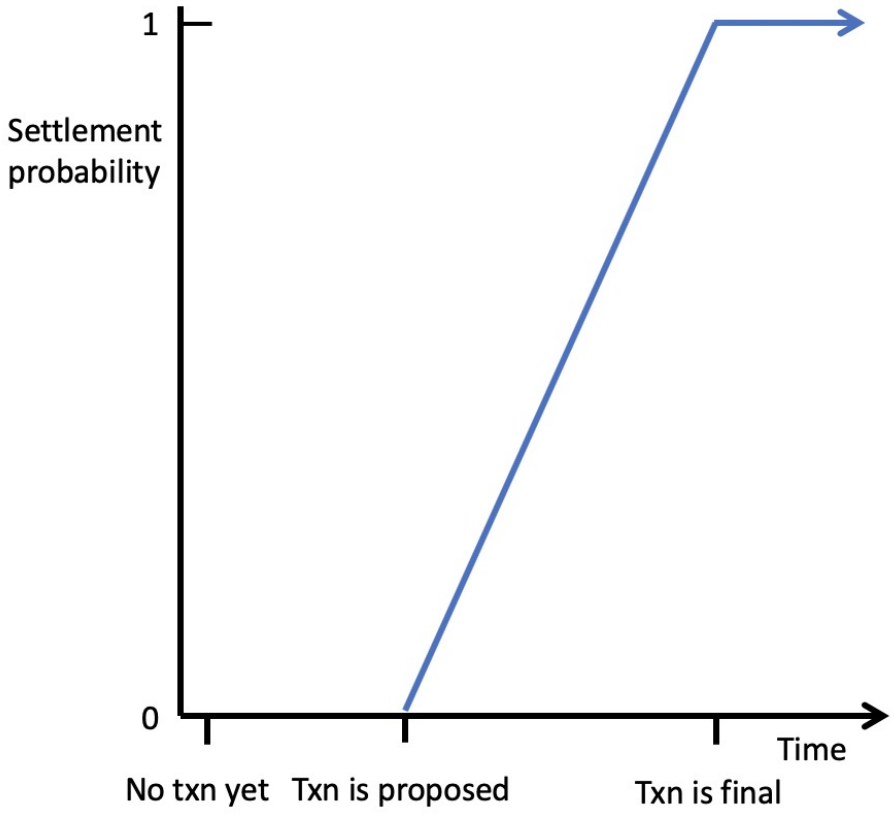
2008-10-31 - Link

The incentive may help encourage nodes to stay honest. If a greedy attacker is able to assemble more CPU proof-of-worker than all the honest nodes, he would have to choose between using it to defraud people by stealing back his payments, or using it to generate new coins. He ought to find it more profitable to play by the rules, such rules that favour him with more new coins than everyone else combined, than to undermine the system and the validity of his own wealth.

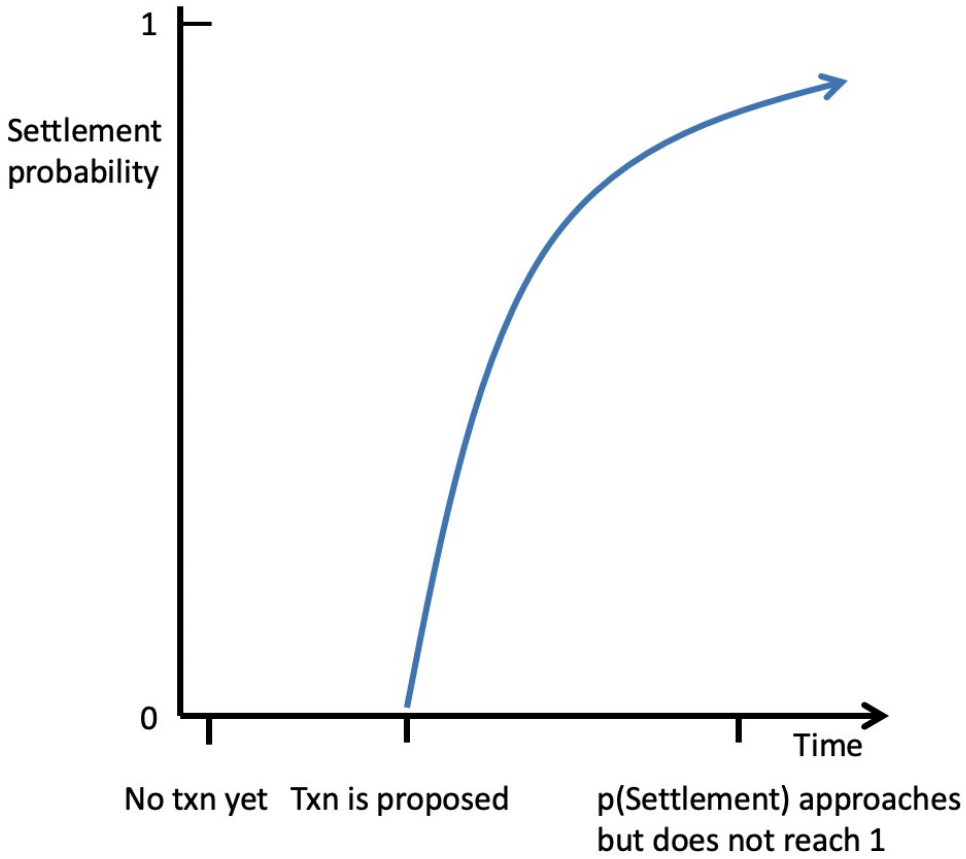
Mining is the hot sun baking the wet clay into a hard tablet, forever encoding the economic relationship therein described into an immutable ledger

It is a real-world incentive to induce miners to devise a shared history and stick to it

## How people think about finality



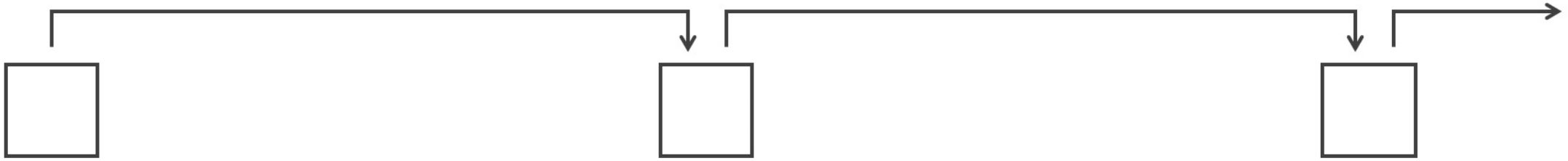

## What finality actually looks like



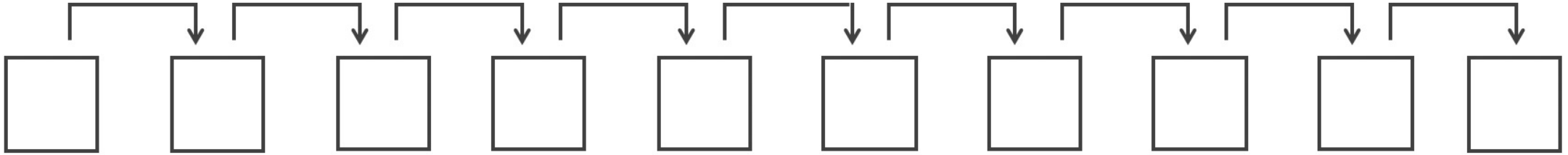
# Faster confs ≠ more security

## Settlement: the folk view

Bitcoin

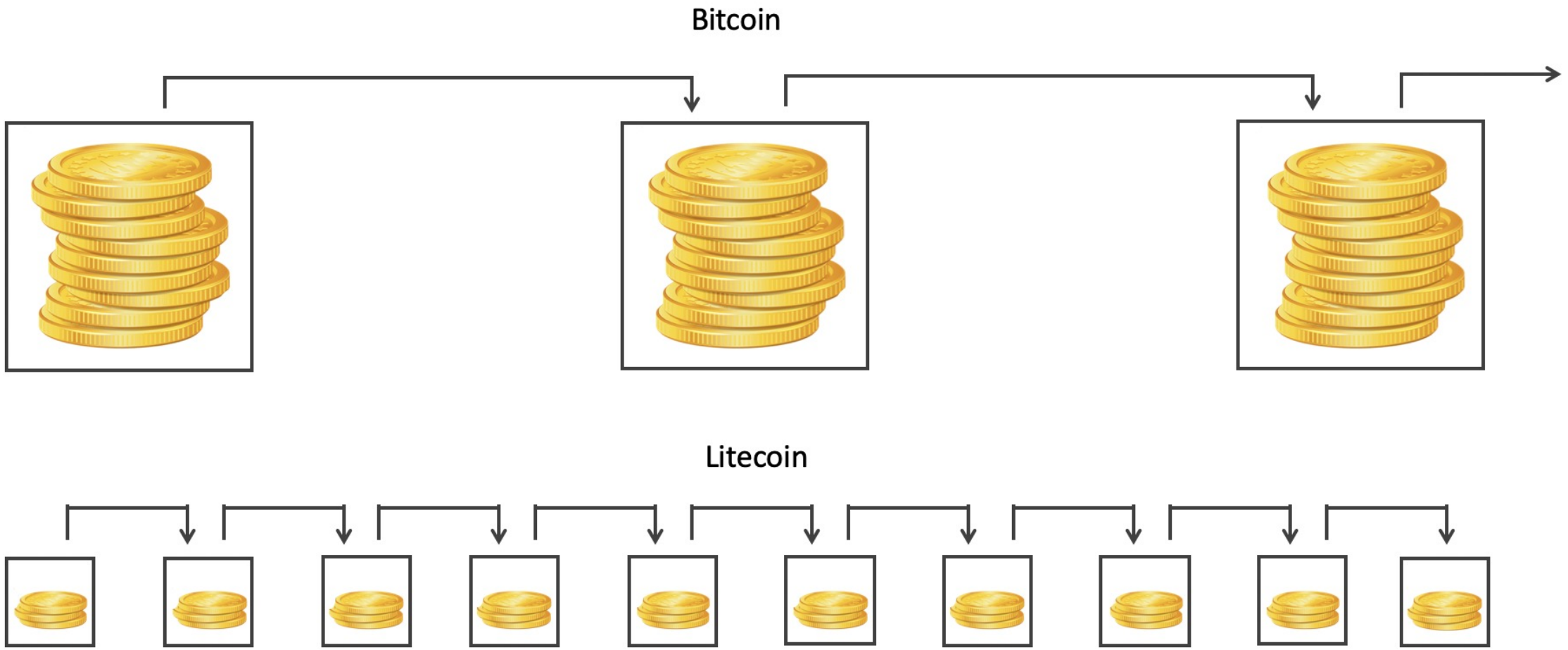


Litecoin

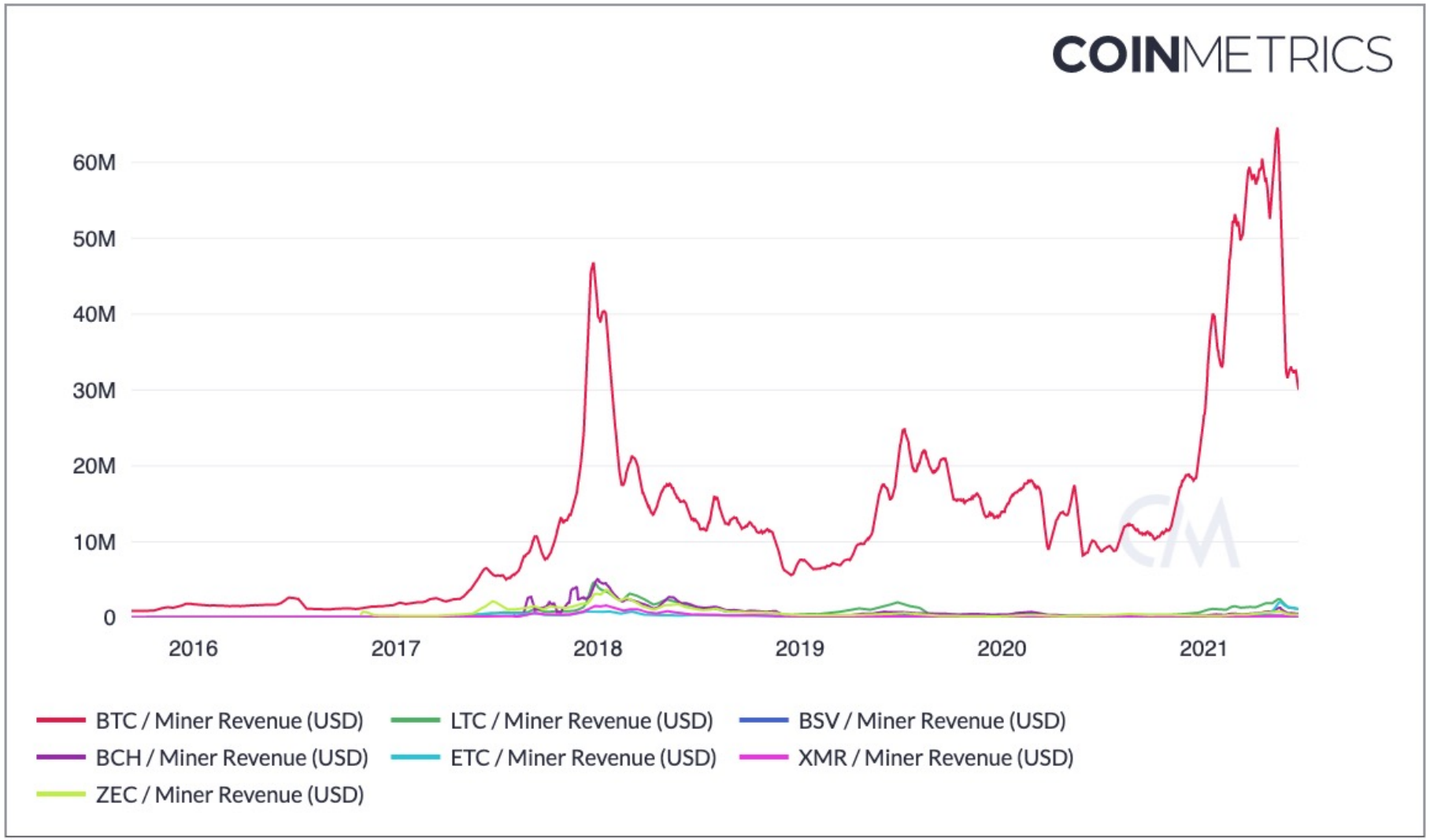


# It’s about the security spend!

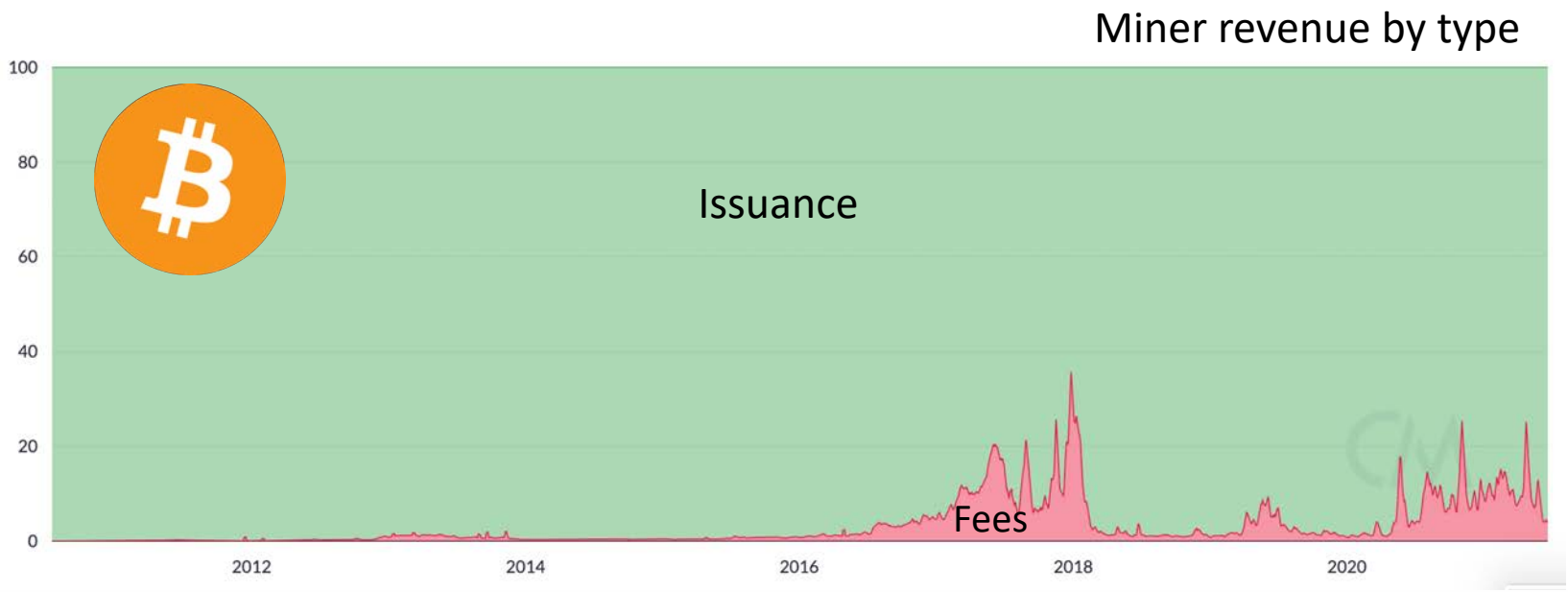
## Settlement: the ledger cost perspective



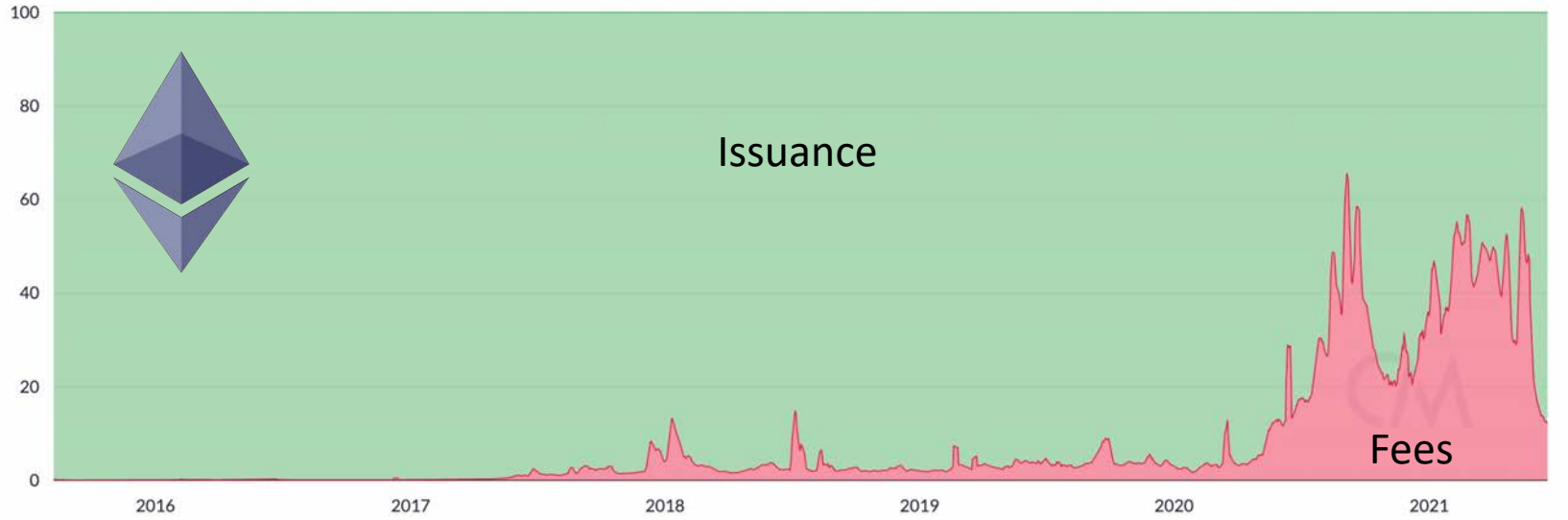
# Bitcoin versus other pure PoW coins



# From issuance to fee-driven security

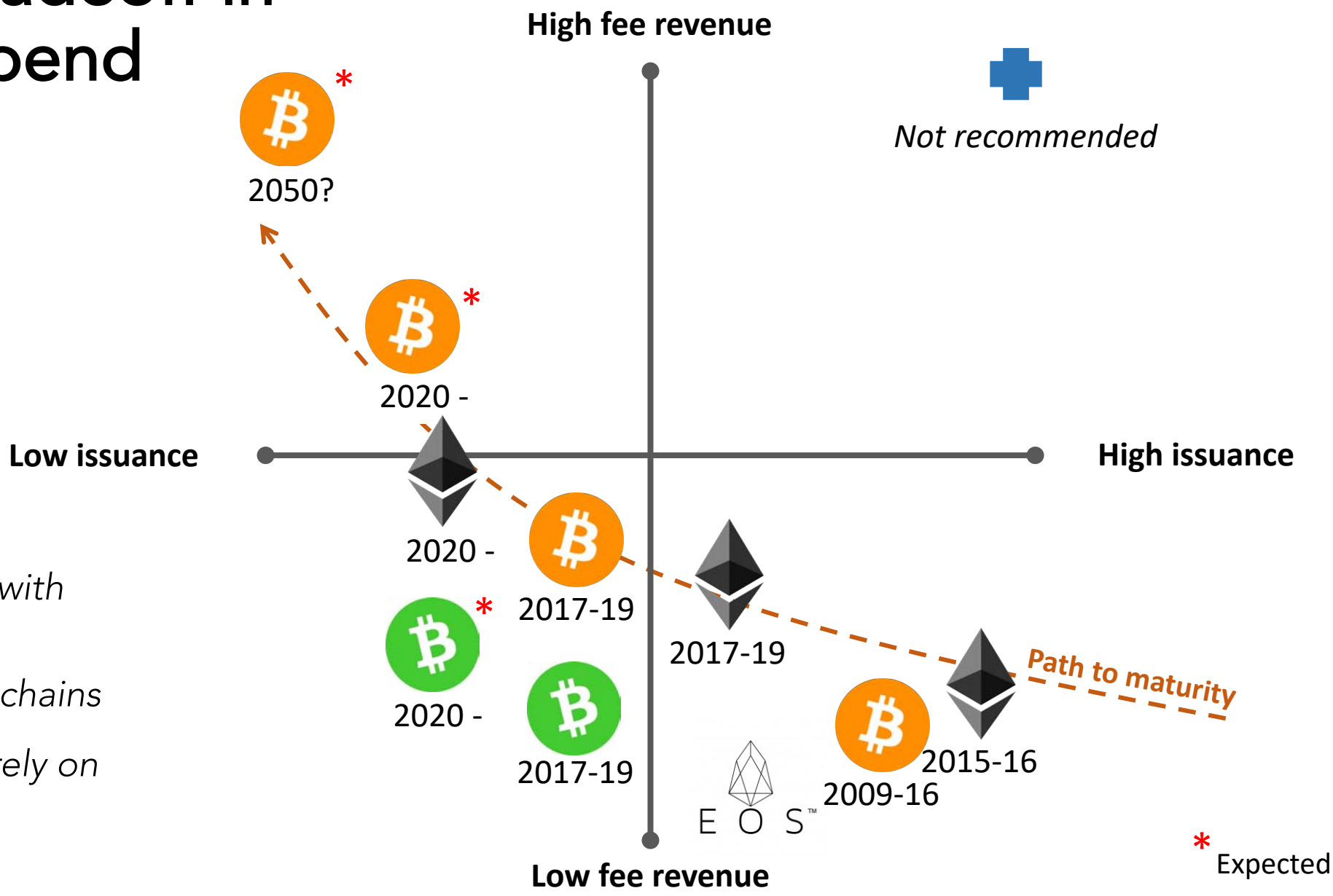



BTC: strong growth in fees but still issuance-led




ETH: further down the road to fee-based security

# The big tradeoff in security spend




- *You can subsidize miners/validators with fees or issuance*
- *Long term, major chains intend to reduce issuance and will rely on fees*

# Why spend energy anyway?

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# Satoshi considered Bitcoin issuance as analogous to gold mining

**satoshi**
Founder
Sr. Member

Activity: 364
Merit: 2804

**Re: Bitcoin minting is thermodynamically perverse**
August 07, 2010, 05:46:09 PM #29
*Merited by Foxpup (4), fillippone (2), BlackHatCoiner (1)*

It's the same situation as gold and gold mining. The marginal cost of gold mining tends to stay near the price of gold. Gold mining is a waste, but that waste is far less than the utility of having gold available as a medium of exchange.

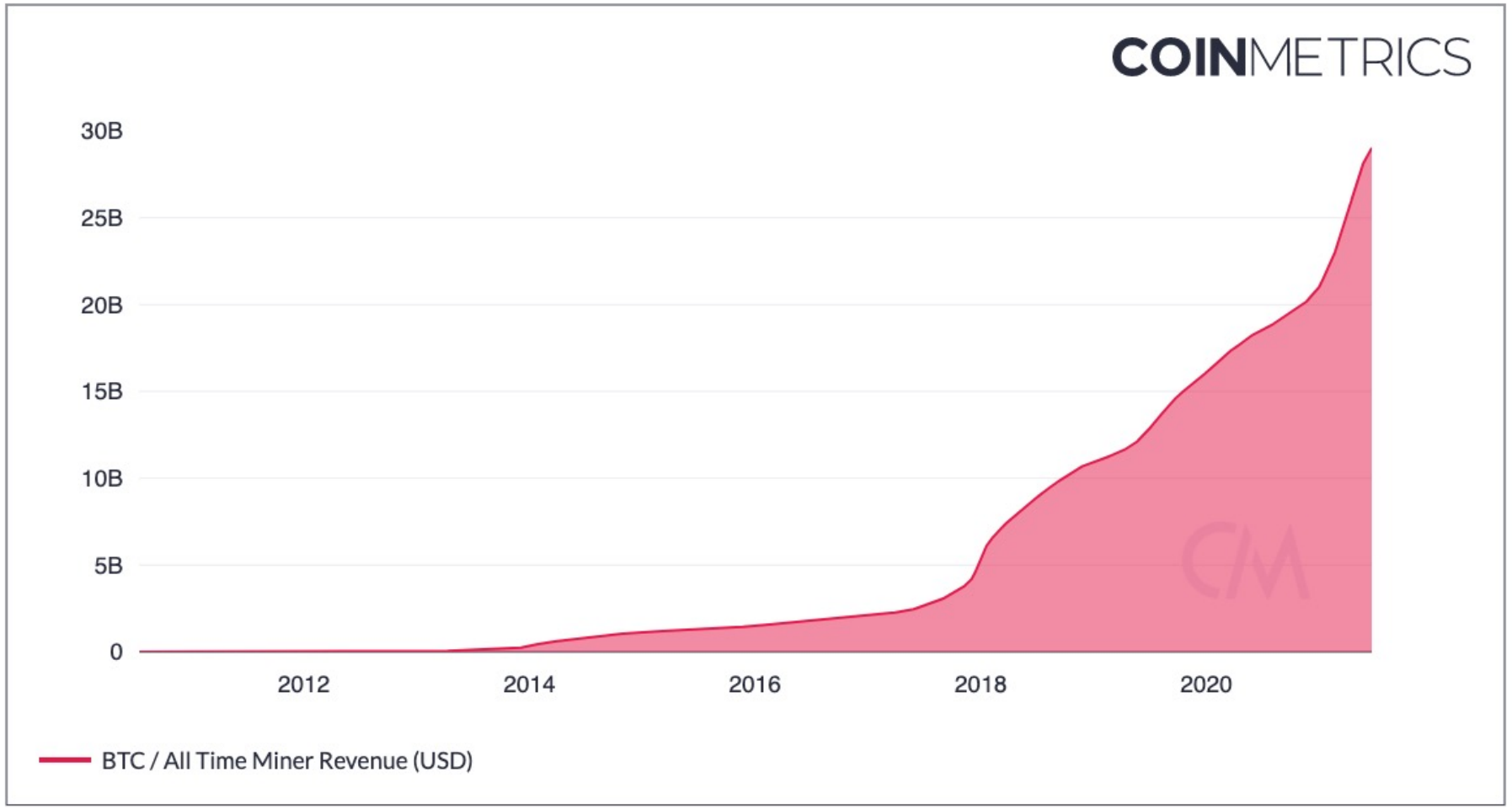
I think the case will be the same for Bitcoin. The utility of the exchanges made possible by Bitcoin will far exceed the cost of electricity used. Therefore, *not* having Bitcoin would be the net waste.

## 6. Incentive

By convention, the first transaction in a block is a special transaction that starts a new coin owned by the creator of the block. This adds an incentive for nodes to support the network, and provides a way to initially distribute coins into circulation, since there is no central authority to issue them. The steady addition of a constant of amount of new coins is analogous to gold miners expending resources to add gold to circulation. In our case, it is CPU time and electricity that is expended.

*Bitcoin White Paper*

# Bitcoin ‘cost’ $28b to issue an asset worth >$700b




Because of appreciation and the historical path of BTCUSD, miners incurred a max cost of $28b to create all the extant units of Bitcoin

The world got an effective *96% discount on Bitcoin issuance*

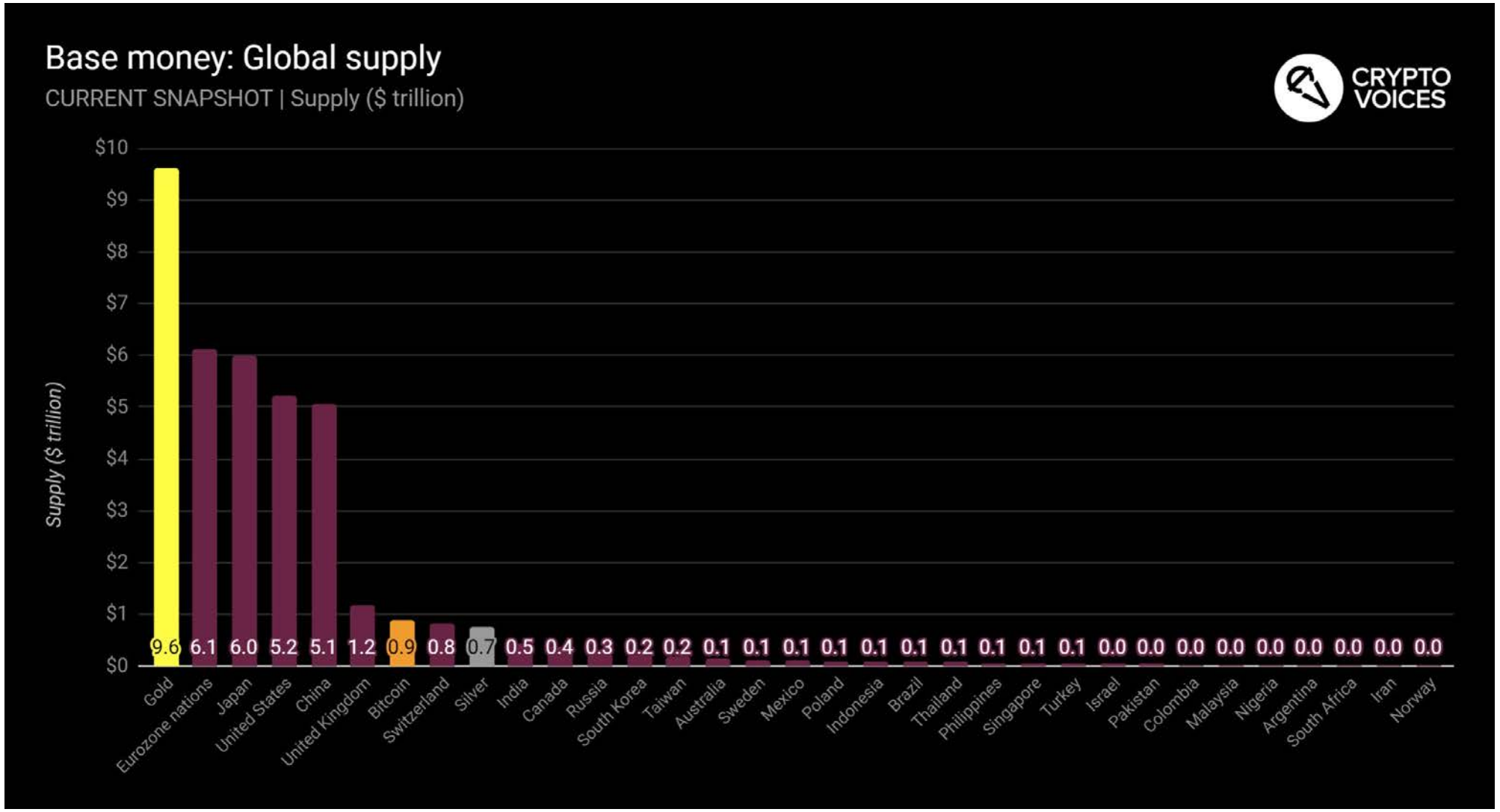
# Mining secures the Bitcoin economic system

# A sponataneous monetization from 0 to $1T


BTCUSD (log scale)

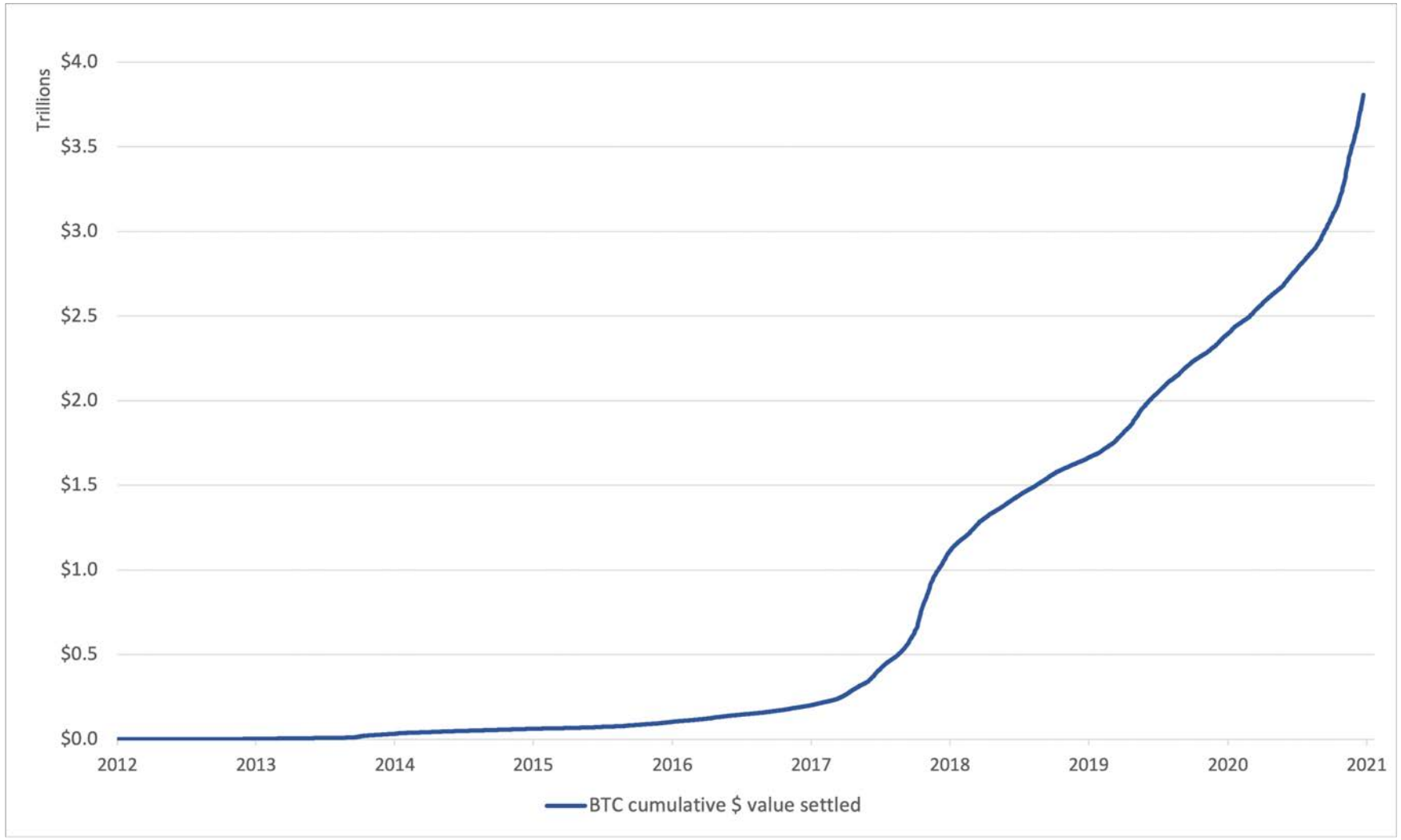
Bitcoin has undergone at least five distinct cycles – but each time has settled at higher lows

# Bitcoin is 5x away from being a tier-1 global reserve currency




Bitcoin trails only gold, the Euro, the Yen, the USD, and the Yuan in aggregate *base money* capitalization

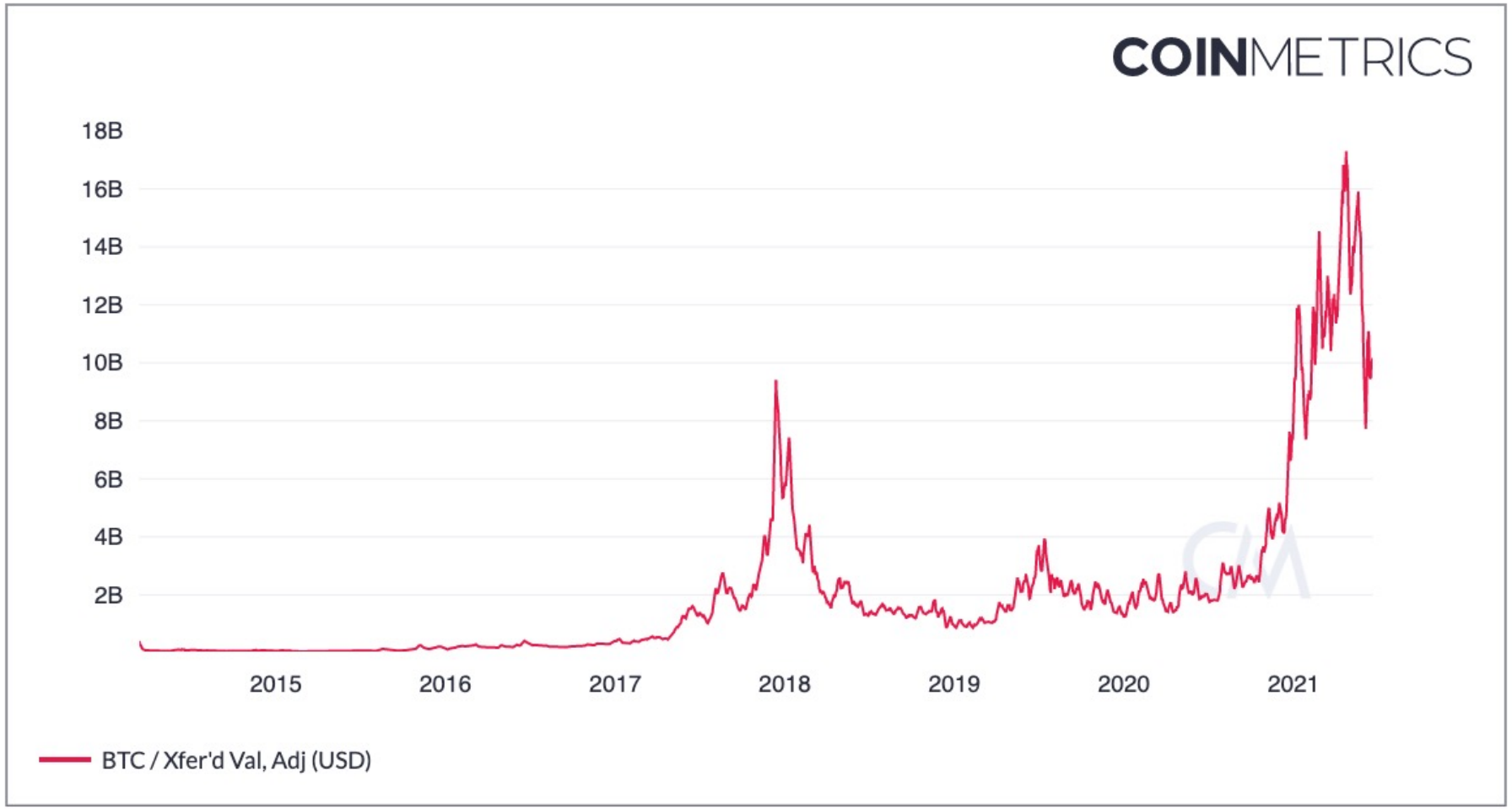
# A fast-settling payments network




Since inception, Bitcoin has settled an estimated $3.8T worth of transactions (CM adjustments)

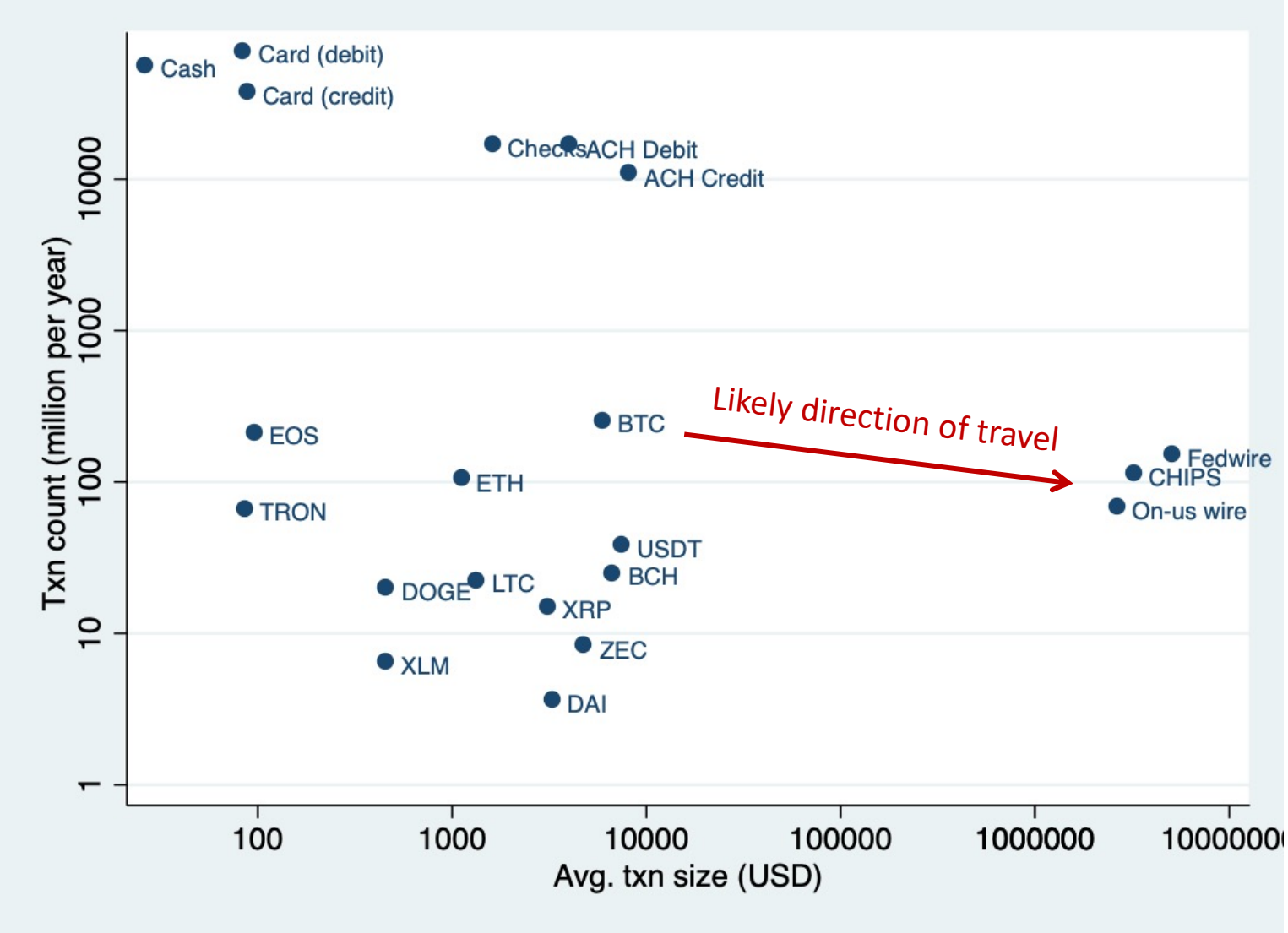
Coin Metrics

# Bitcoin settles >$10B/day on average



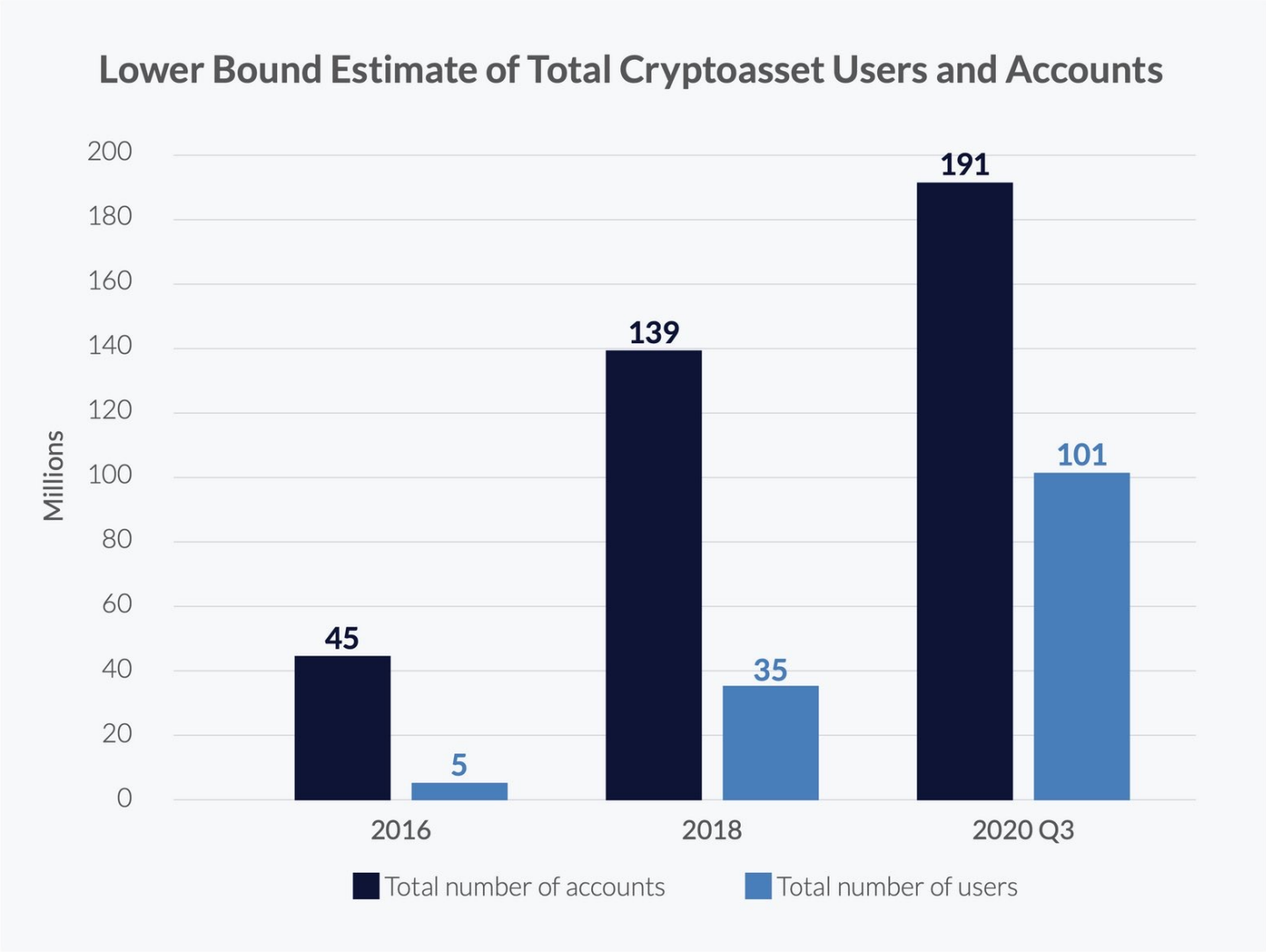

Bitcoin is superior where rapid final settlement between mutually-untrusting counterparties is desired, especially on a cross-border basis

# Utility-scale settlement network




Bitcoin grants you final, highly-auditable, reliable, 24/7 settlement, on a cross-border basis, with no political gating factors

# Bitcoin ownership is getting progressively distributed




According to the University of Cambridge, as of 2020, over **100 million individuals worldwide** hold cryptocurrency today

*Global cryptoasset benchmarking study, 1-3, Cambridge Center for Alternative Finance*

# A system of independent property rights

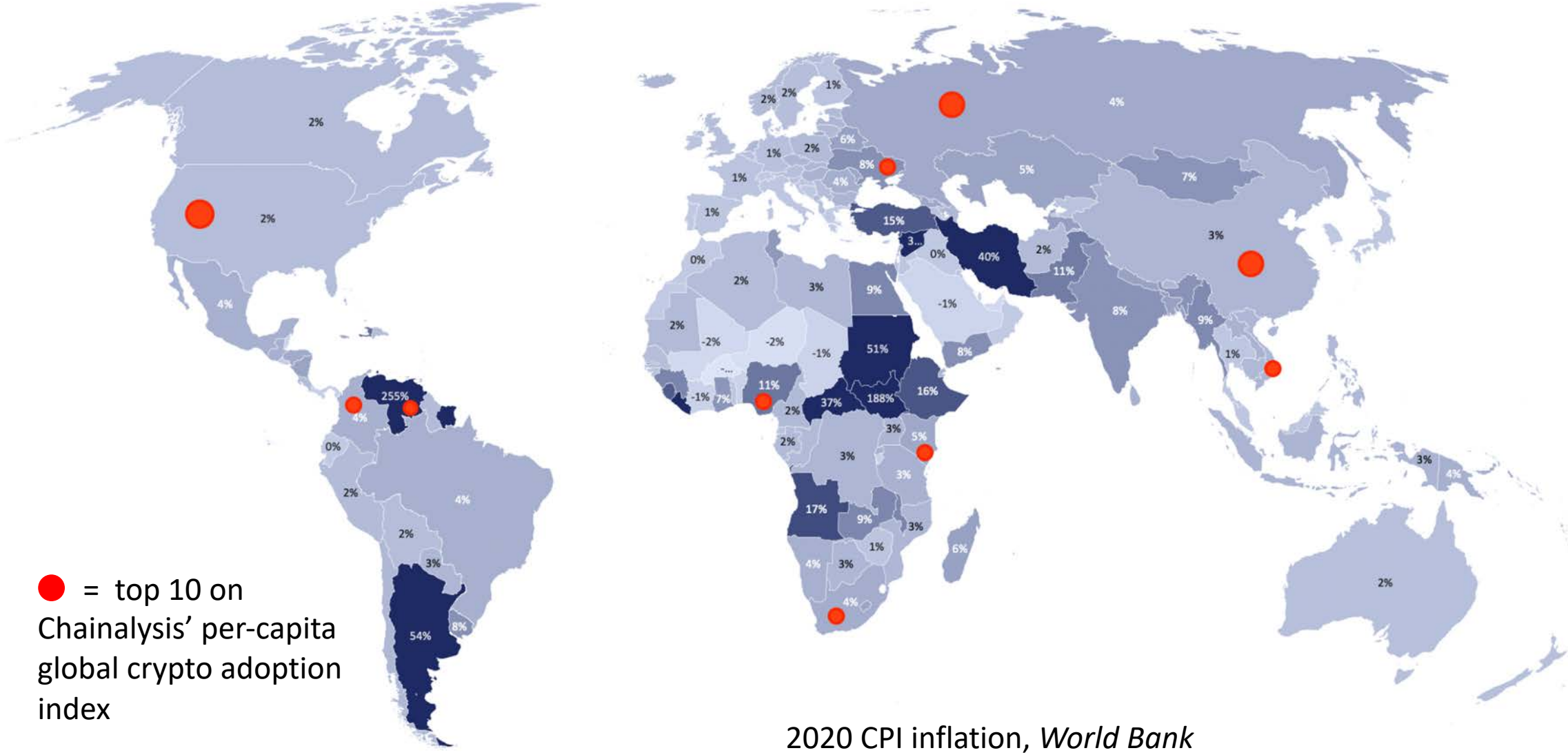
| Country | Score | Rank | Rank of individual weighted metrics feeding into index | | | |
|---|---|---|---|---|---|---|
| | | | On-chain value received | On-chain retail value received | Number of on-chain deposits | P2P exchange trade volume |
| Ukraine | 1 | 1 | 4 | 4 | 7 | 11 |
| Russia | 0.931 | 2 | 7 | 8 | 5 | 9 |
| Venezuela | 0.799 | 3 | 19 | 14 | 15 | 2 |
| China | 0.672 | 4 | 1 | 1 | 95 | 53 |
| Kenya | 0.645 | 5 | 37 | 11 | 57 | 1 |
| United States of America | 0.627 | 6 | 5 | 6 | 39 | 16 |
| South Africa | 0.526 | 7 | 12 | 9 | 41 | 10 |
| Nigeria | 0.459 | 8 | 14 | 7 | 112 | 3 |
| Colombia | 0.444 | 9 | 25 | 18 | 61 | 4 |
| Vietnam | 0.443 | 10 | 2 | 2 | 44 | 81 |

Source: Chainalysis, *The 2020 Global Crypto Adoption Index: Cryptocurrency is a Global Phenomenon*

Bitcoin penetration is high on a per-capita basis in countries with

- Inferior property rights
- A history of sovereign defaults and devaluations
- High rates of inflation
- Capital controls/monetary repression

# Drivers of Bitcoin adoption




● = top 10 on Chainalysis' per-capita global crypto adoption index

2020 CPI inflation, *World Bank*

# Estimating Bitcoin’s energy footprint

# How to estimate Bitcoin's CO2 footprint

PRECISION DECREASES AS YOU ADD STEPS AND ASSUMPTIONS

**Estimate hashrate**

Mostly knowable

*Adds uncertainty*

**Estimate energy consumption**

Must be inferred

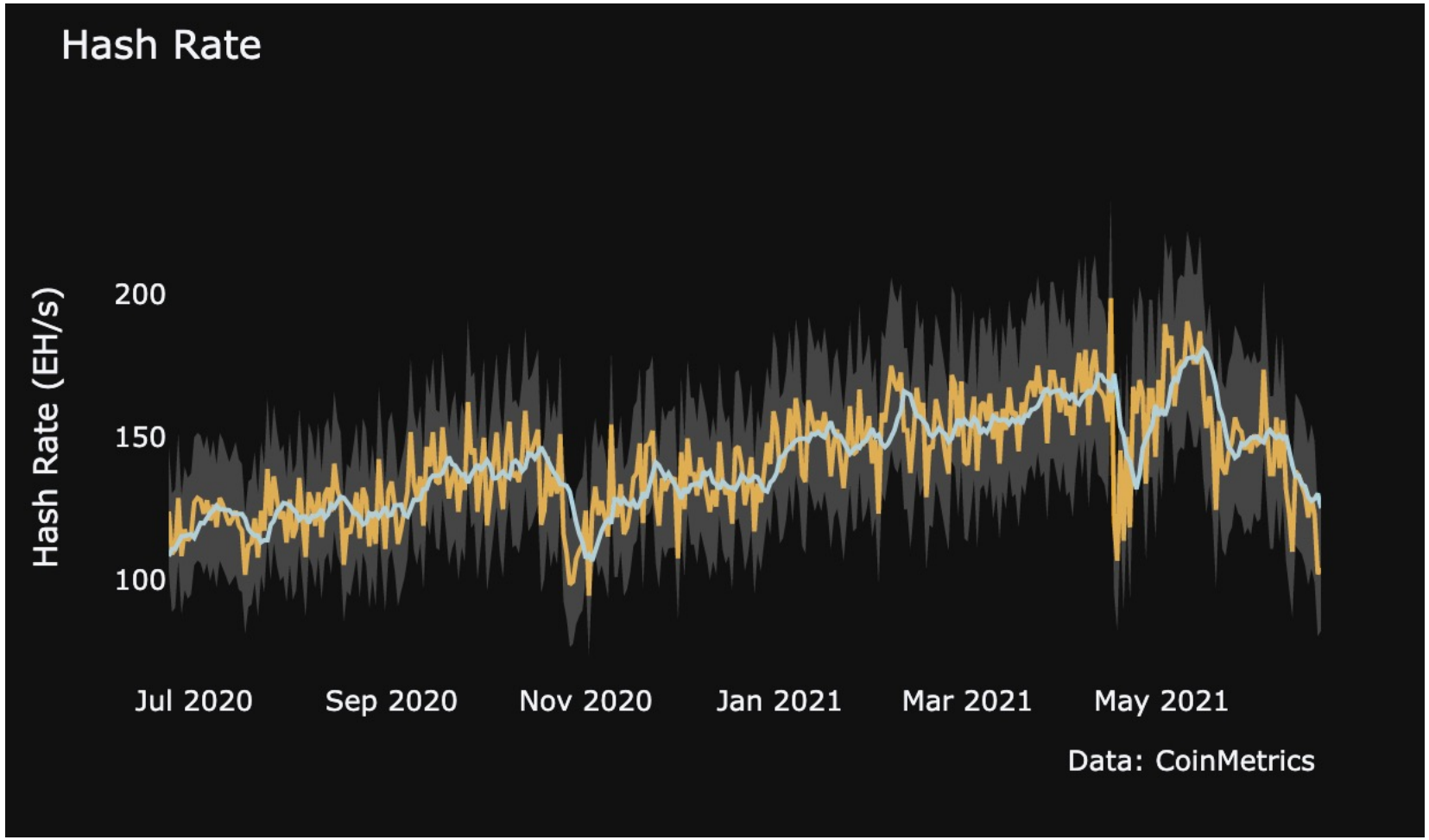
*Adds uncertainty*

**Estimate miner CO2e emissions**

Based on guesswork

| Sources of uncertainty | Hashrate is merely indicative of work done | Depends on crucial assumptions regarding the type of miner hardware active on the network | Depends on largely unknowable data regarding miner location and miner energy mix ! |
|---|---|---|---|

# Hashrate: largely (but not perfectly) knowable



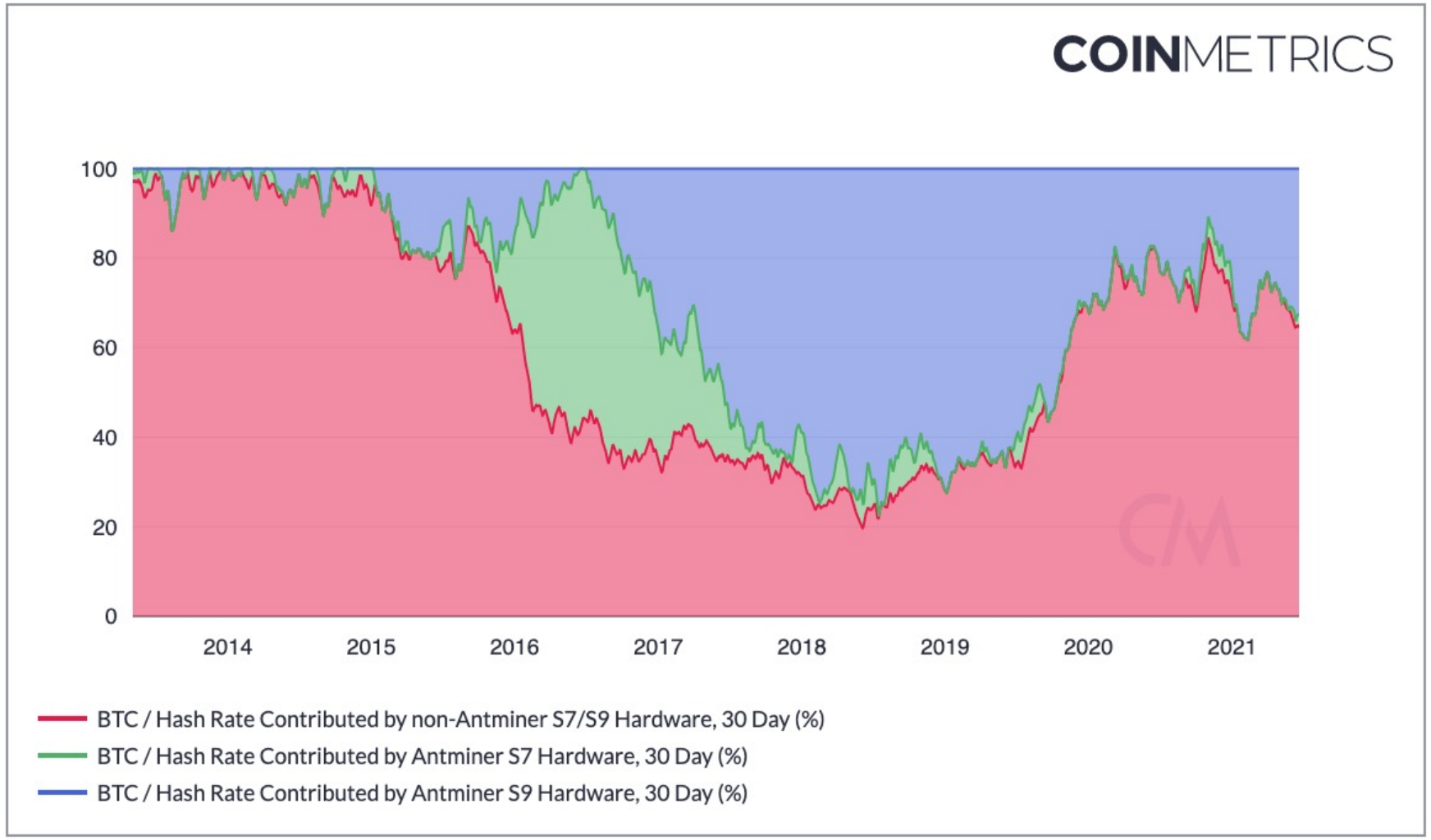

BitcoinKPIs.com has developed a confidence interval to illustrate the probabilistic nature of Bitcoin hashrate

# Energy consumption: must be grounded in estimates of varieties of miners active on the network


CBECI estimates are widely cited but merely give a range (and a best guess) based on varying assumptions about the efficiency of active hardware

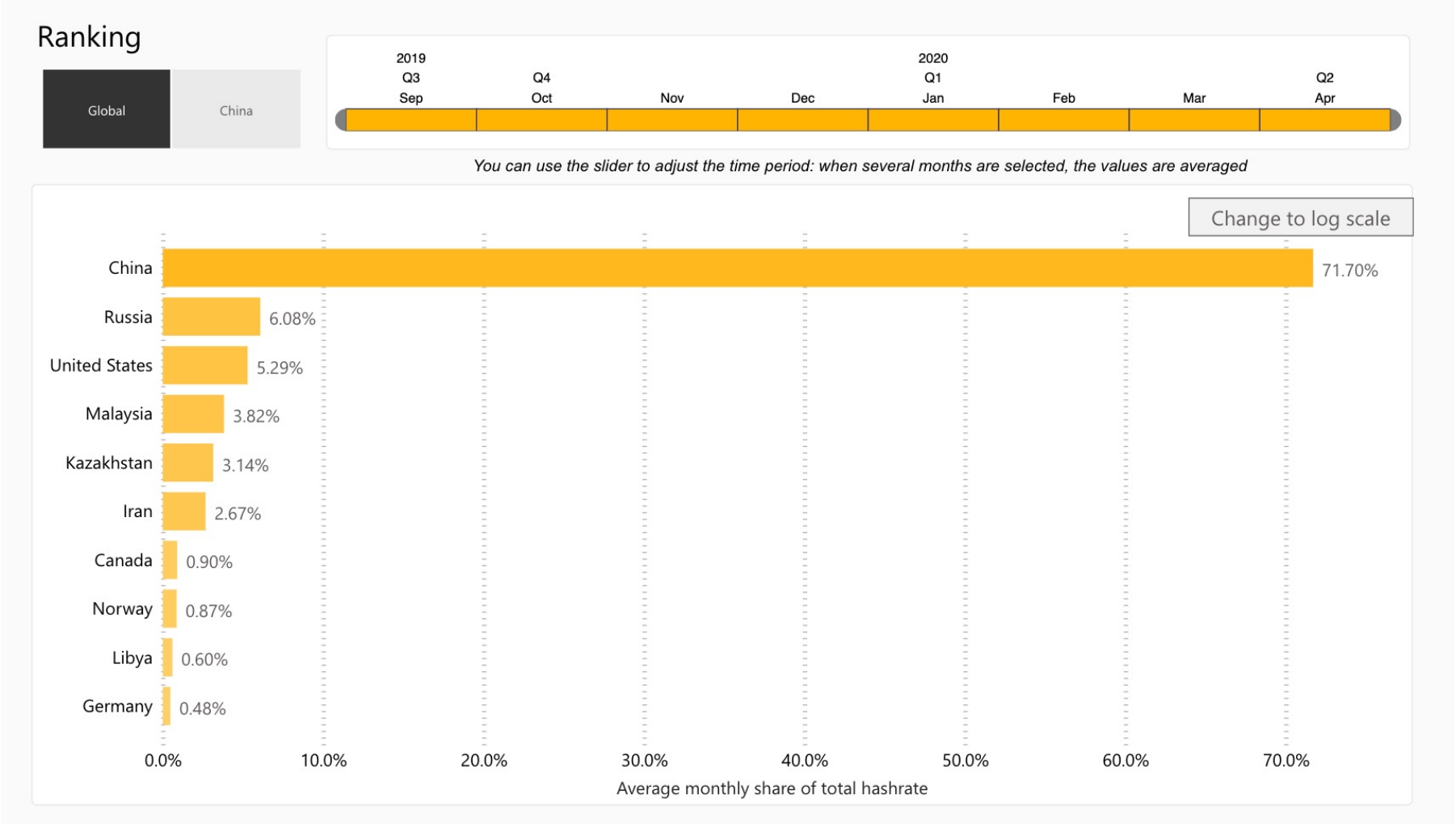
CBECI.org

# Thanks to nonce analysis, we can make reliable guesses about hashrate distribution by machine




Methodology originally developed by Karim Helmy

# CO2e: depends on best guesses about miner location and energy mix used

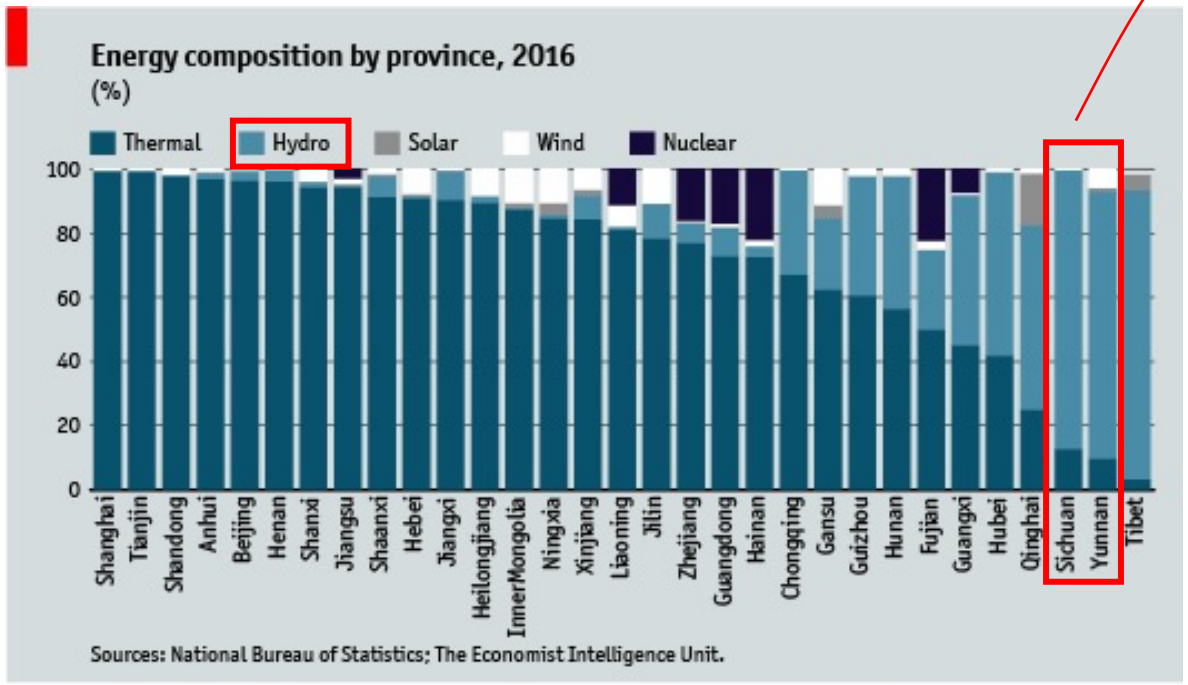



CBECI is the best data we have on miner location BUT:

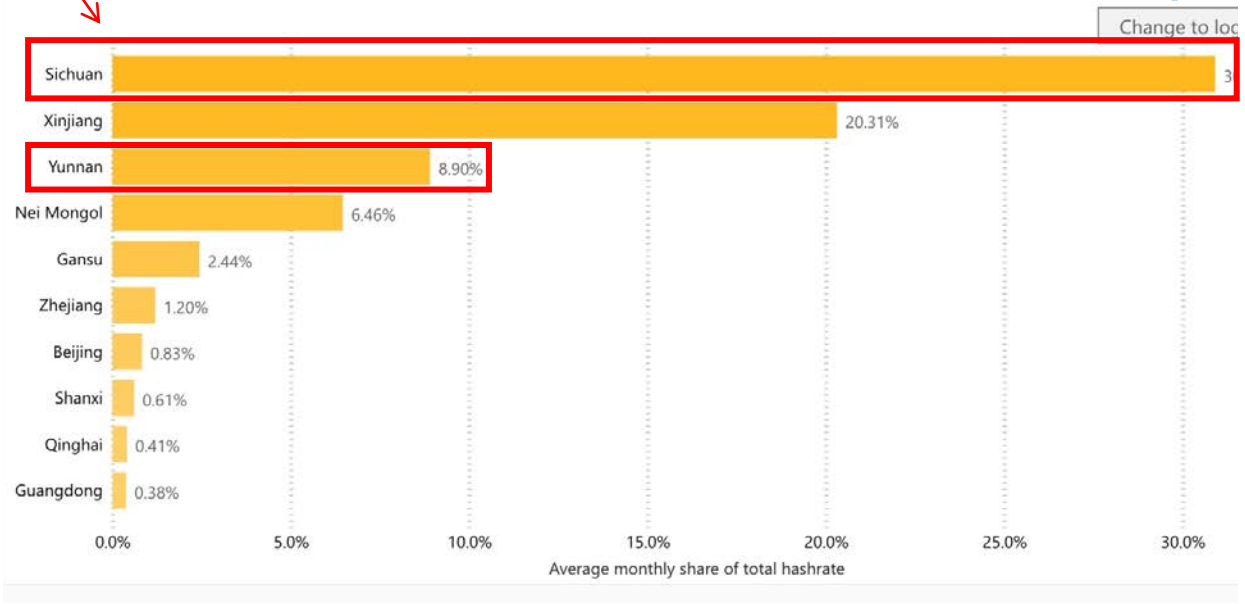
- It's out of date (extends only to Apr. 2020)
- Based on a small sample (3 mining pools)
- Gives us only country or province-level (in China) granularity, rather than miner location

# Bitcoin feeds on waste energy – much of it hydro

China's Bitcoin mining has historically been powered (in the wet season) by otherwise-curtailed hydro power in Sichuan and Yunnan provides: Bitcoin monetizes this waste energy

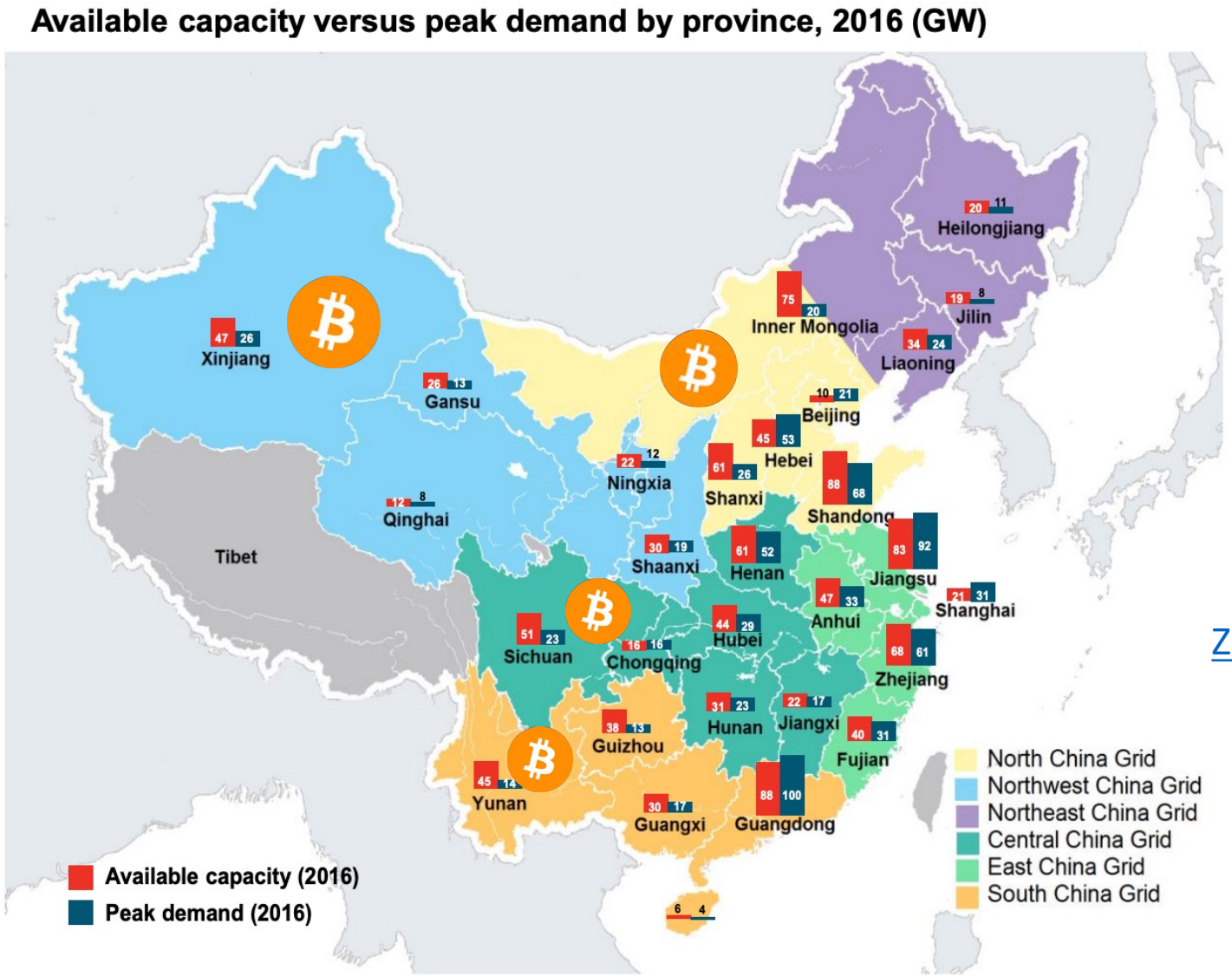



Energy mix by province in China, The Economist




Bitcoin hashrate by province in China during the wet season (Source: the University of Cambridge, CBECI.org)

# Bitcoin was heavily mined in China because China was the world's capital of excess energy




Zhou and Lu, 2017

# Bitcoin monetized waste/curtailed energy in Xinjiang, Inner Mongolia, Sichuan, and Yunnan

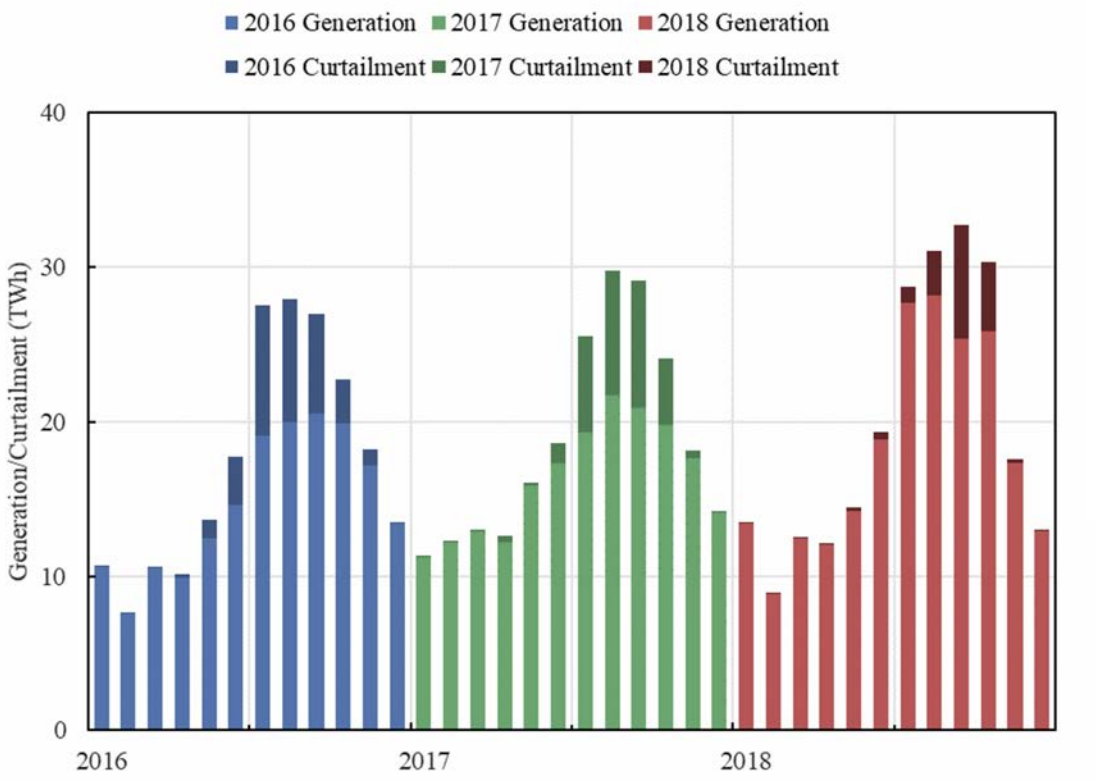

**The Northern Provinces**

- Xinjiang and Inner Mongolia
- 60-70% cheap and abundant coal
- The remainder: underutilized solar/wind assets

**The Southern Provinces**

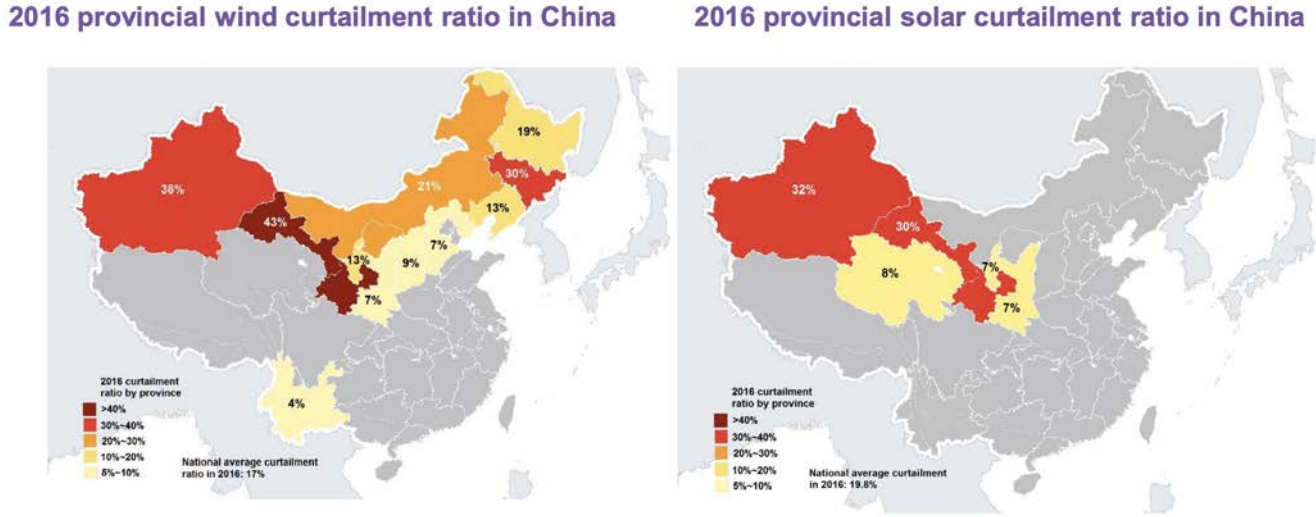
- Sichuan & Yunnan
- 90% hydro resources
- Cheap/free stranded energy, heavily curtailed
- Only relevant during wet season

# Curtailment of hydro/wind/solar was a significant problem in China in 2016-17




Liu and Davidson, 2021

Zhou and Lu, 2017




- In 2016, China curtailed 51 TWh worth of wind and solar
- In 2016, Yunnan alone curtailed 31 TWh of hydro
- Bitcoin energy consumption: 87 TWh (today)

# 2016 was peak energy curtailment, as grid imbalances were fixed

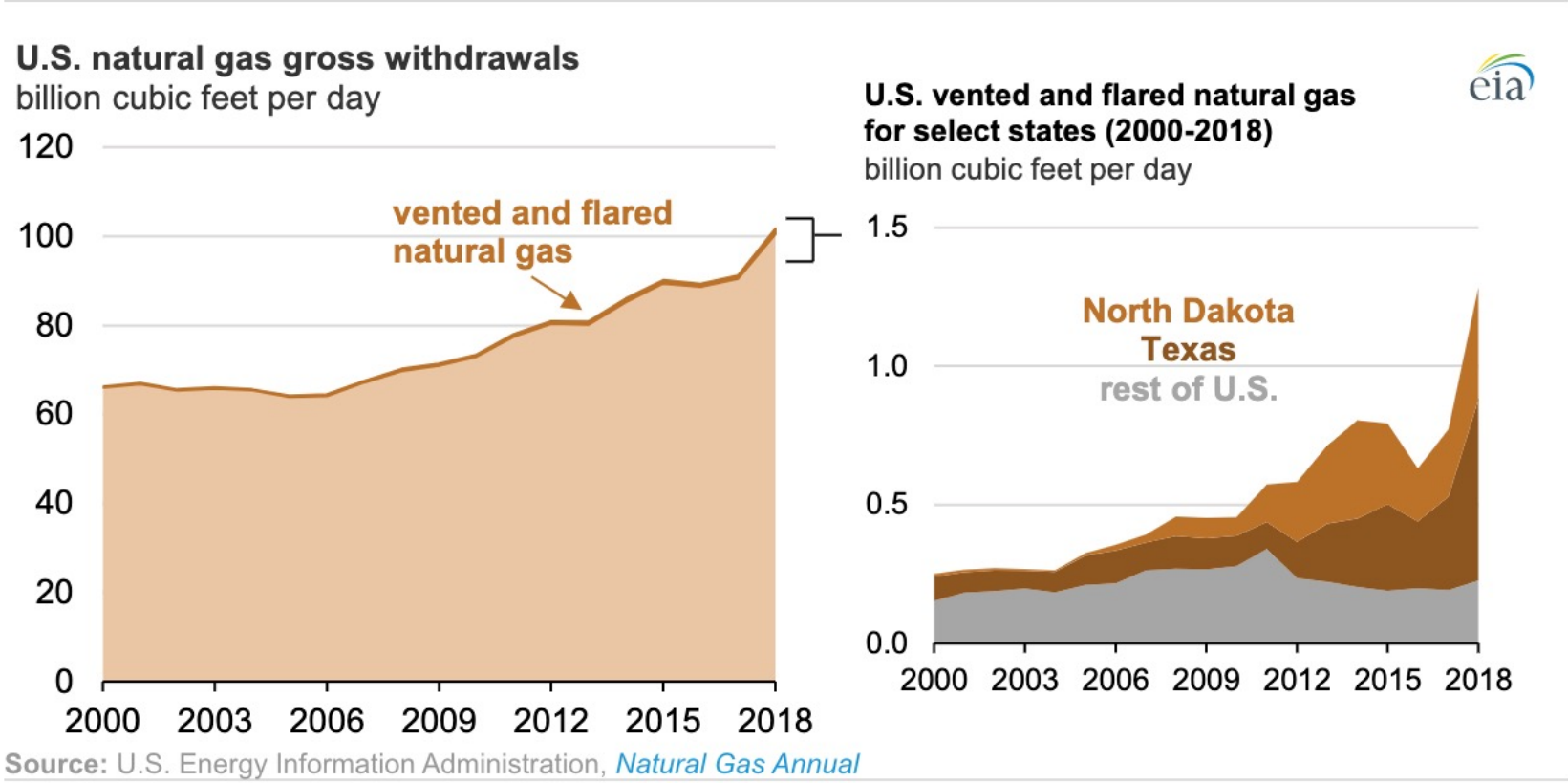
Figure 1: China's UHVDC Networks


Source: TLG Research

Fishman 2021

- In 2010, China decided to integrated their fragmented grid and began building an **Ultra High Voltage Transmission Network**
- Today they have built 40,000 km of UHV lines, massively reducing curtailment in far-flung regions where Bitcoin mining is popular
- This grid integration may well be a subtle reason behind the recent mining crackdown: miners are now competing with regular grid consumers rather than monetizing wasted energy

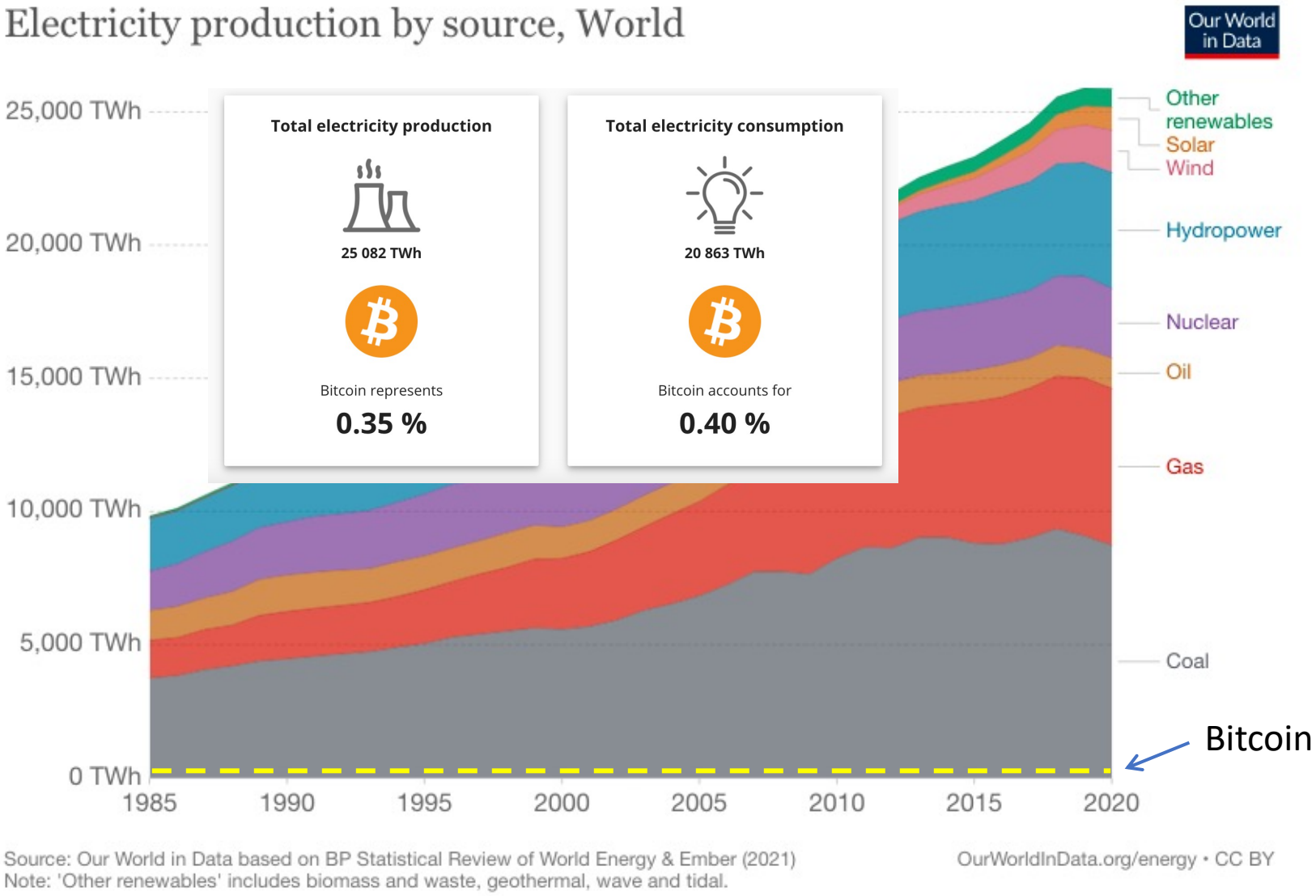
# Other sources of nonrival energy: flared gas




- The waste /uneconomical gas flared in the **U.S. alone** in 2019 would generate 77 TWh worth of energy if used in 7 Heat Rate plants (88% of BTC mining)
- Global flared gas could yield 550 TWh (6x BTC) worth of energy, or 230 TWh (2.5x BTC) if you exclude unstable countries

EIA 2019

# Bitcoin is an industry like any other




- Bitcoin still consumes a tiny share of the world's energy and accounts for an even smaller share of its CO2 emissions
- It is an industry like any other: the real question is how to render the grid sustainable
- Bitcoin miners just consume the energy available to them
- The policy question goes far beyond Bitcoin

# Summing up

- Bitcoin is a novel economic institution providing ~$1T in savings to 100m+ people worldwide and settling $10b/day – it clearly has value to society
- PoW is an inherent feature of the system and gives it its value
- Mining (and its cost) is partly distribution, partly system incentives
- The Bitcoin ‘cost’ debate is really the Bitcoin ‘value’ debate
- Bitcoin is a synthetic commodity and monetizes stranded energy
- It’s in the midst of a historic transition from a dependence on China to being more globalized
- Long term it will feed mainly or exclusively on nongrid, nonrival energy

# Further reading

The costs of a commodity standard

- The ‘Costs’ of a Gold Standard, Garrison (1985)
- The Resource Costs of Fiat Money Are Now Higher Than Those of a Gold Standard, White (2019)

The value of the Bitcoin institution

- Bitcoin and the Promise of Independent Property rights, Hasu and Zu (2018)
- Bitcoin: a Novel Economic Institution, Ark Invest (2020)
- Shelling Out: The Origins of Money, Szabo (2002) [not Bitcoin, but in support of commodity monies]

Bitcoin vs gold vs banking

- PoW is Efficient, Held (2018)
- Bitcoin vs the financial sector, McCook (2021)
- Bitcoins vs Gold and Banking, McCook (2021)

# Further reading, cont.

The merit of Proof of Work

- Gravity, LaurentMT, (2018)
- It's the settlement assurances, stupid, Carter (2019)
- Nothing is Cheaper than PoW, Sztorc (2015)
- The Anatomy of Proof of Work, Nguyen (2018)
- Blockchain PoW is a Decentralized Clock, Trubetskoy (2018)
- Bitcoin does not waste energy, Lewis (2019)
- Work is Timeless, Stake is Not, Nguyen (2018)
- Understanding Bitcoin's energy use, Van Valkenburgh (2021)
- The Last Word on Bitcoin's Energy Consumption, Carter (2020)

Future directions in PoW

- How Bitcoin could Drive the Clean Energy Revolution, Van Valkenburgh (2017)
- Bitcoin is Key to an Abundant, Clean Energy Future, Square Crypto (2021)
- Bitcoin: A way to make the oil and gas industry more resilient, Great American Mining (2021)
- Noahbjectivity on Bitcoin Mining, Carter (2021)