

# The Resource Cost of Bitcoin [1]

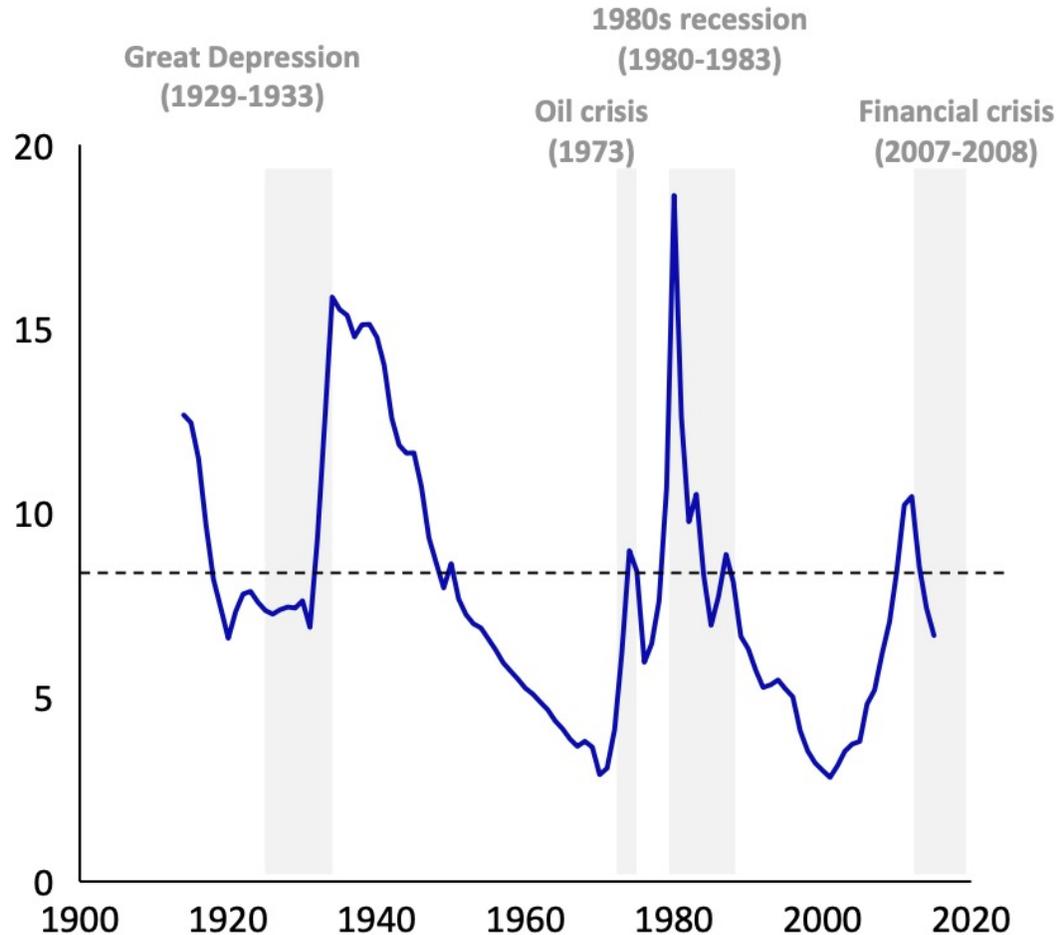
[1] Paper forthcoming

# History of the gold resource cost debate

- Friedman (1951): 1.5% of GDP would be devoted to gold production under a full-reserve gold standard
- Friedman (1960): revises estimate to for 2.5% of GDP (100% reserve)
- Meltzer (1983): estimates a resource cost of 0.5% of GDP (100% reserve)
- Garrison (1985): gold production is not wasteful, because fiat is not a substitute (as gold is still demanded during fiat periods). Cost of fiat (instability) should be considered too
- Friedman (1986): end of Bretton Woods may have increased propensity to buy gold among households
- White (1999): fiat only saves on resource costs under low inflation
- Watts & Snyder (2015): fiat inflation draws gold demand to levels seen during classical gold standard
- White (2019): resource costs of gold rose under fiat, and would outweigh resource costs of a reasonable gold standard

# White's rejoinder to Friedman

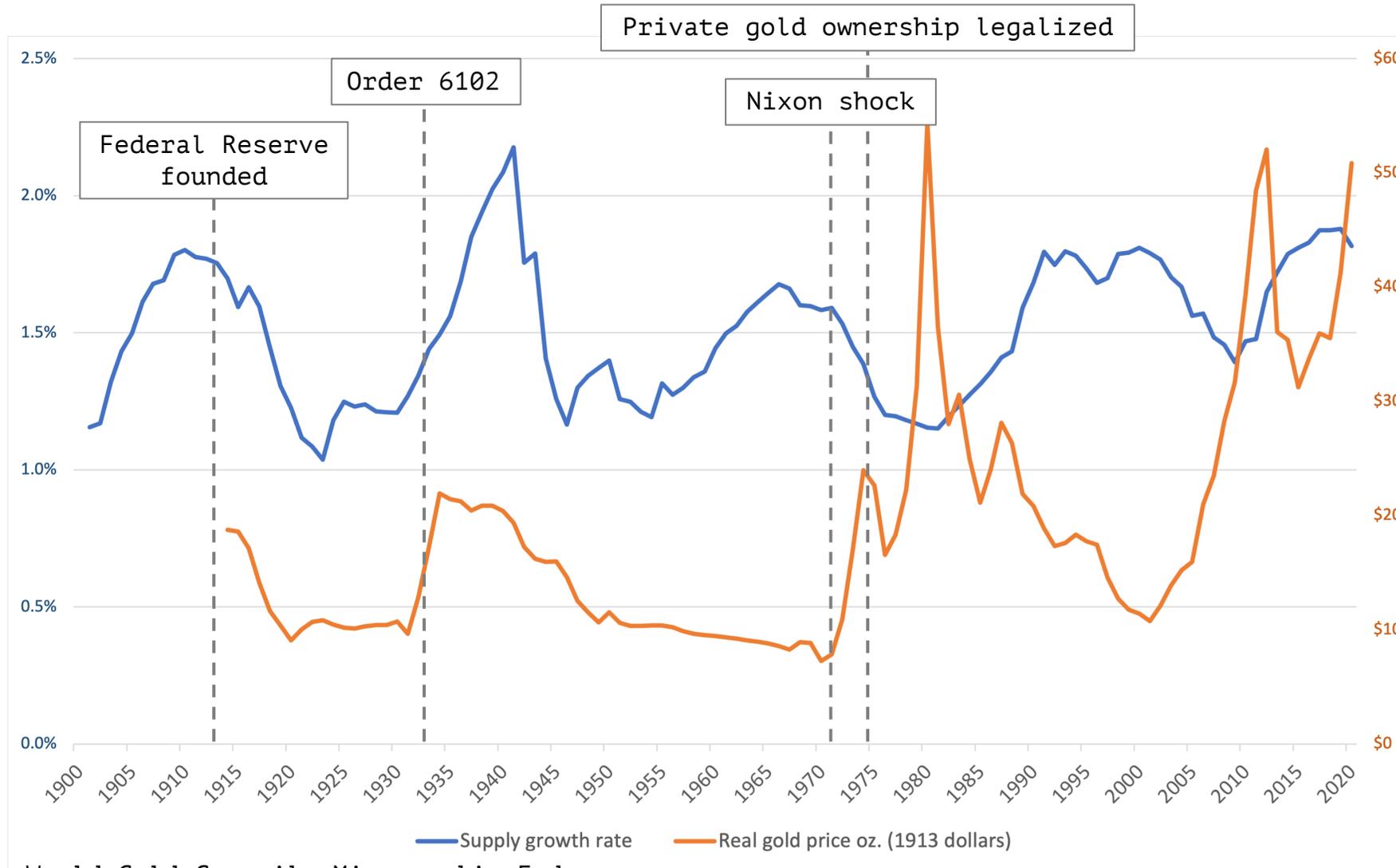
Ratio of gold to global GDP, World Gold Council



- Gold's peak share of global GDP came after the gold standard finally ended in 1971
- According to Larry White, 6.6 bps of GDP was spent acquiring gold from 2006-18, compared to 5 bps in a theoretical gold standard [1]
- Friedman's mistake was to assume full reserve, rather than more likely 2% reserve - so overstates resource costs by 50x
- Post-1971 pure fiat resulted in inflation and induced demand for gold, causing its resource costs to **increase**

[1] White, The Resource Costs of Fiat Money Are Now Higher Than Those of a Gold Standard (2019)

# Bans or fiat standards do not quash demand for gold



World Gold Council, Minneapolis Fed

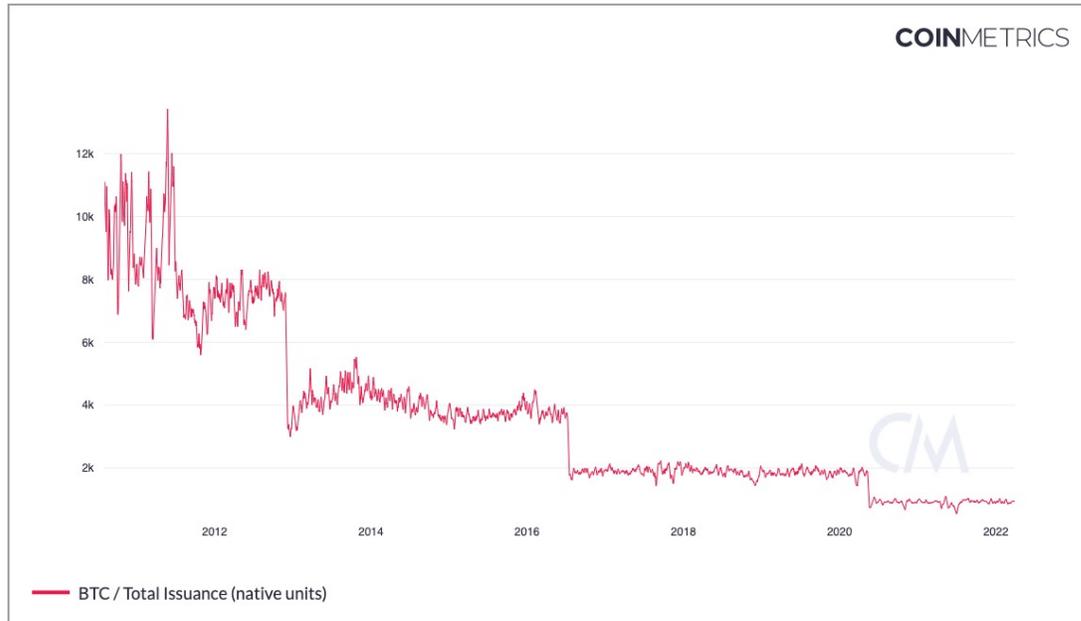
- Gold production soared after private ownership was banned in 1933
- Moving to a fully fiat standard increased gold price by 7x in real terms and kicked off a mining boom
- Bans and the promotion of alternatives cannot eliminate resource costs of monetary commodities; they tend to increase them!

# The purpose of Bitcoin mining

- Bitcoin mining is a **permissionless auction** which **initially distributes** units to a global audience with no administrator
  - Miners rationally incur costs equal to the revenue pool made available to the protocol, minus a margin
  - Historically, electricity cost has amounted to 50% of miner revenue [1]
  - Because mining is costly, miners earn relatively little seigniorage revenue (relative to a government issuing a fiat currency) - analogous to gold
- Bitcoin mining ensures that the ledger **converges to a single history**, without a central administrator
  - Miners are primarily incentivized through the revenue derived from issuance, but also

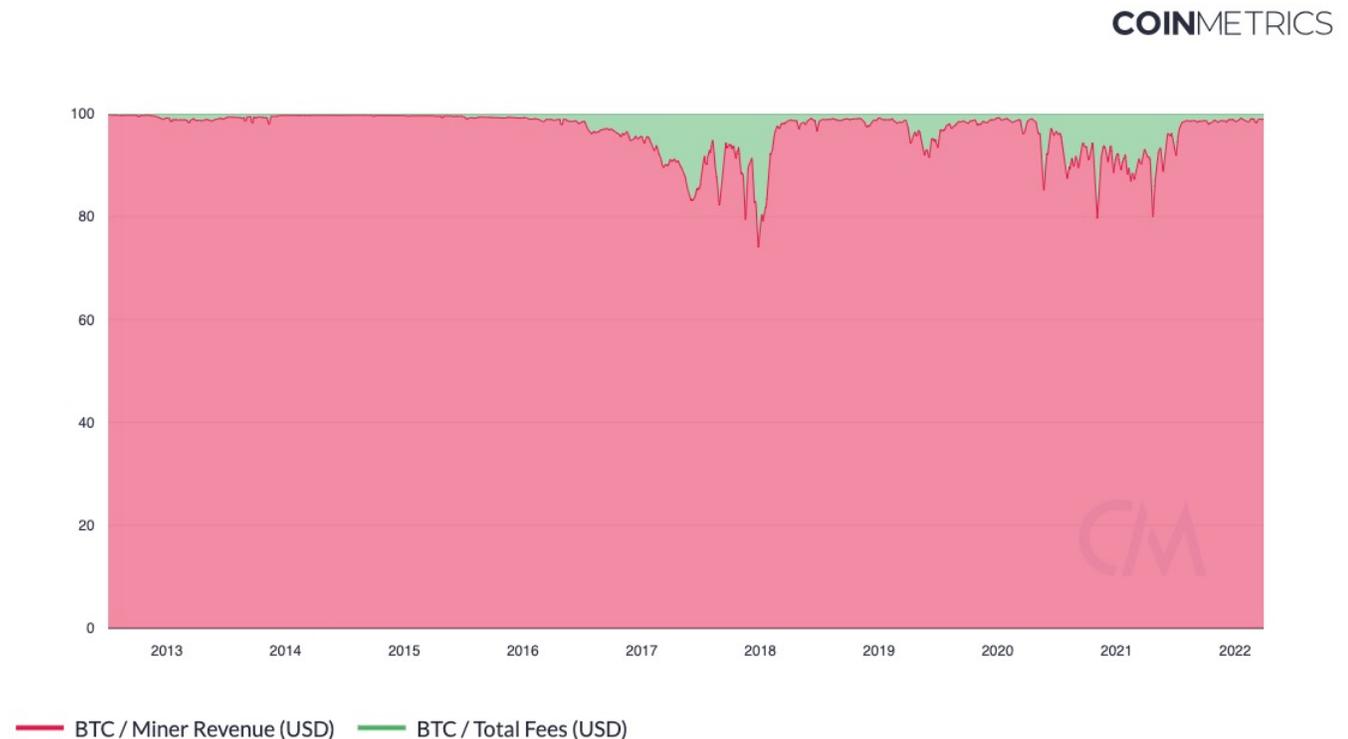
[1] Estimate courtesy of Bitcoin Net Zero (NYDIG & Nic Carter). Cambridge estimates long term electricity cost share of revenue at 43% and Digiconomist estimates 70%

# Issuance primarily powers miner revenue and resource consumption

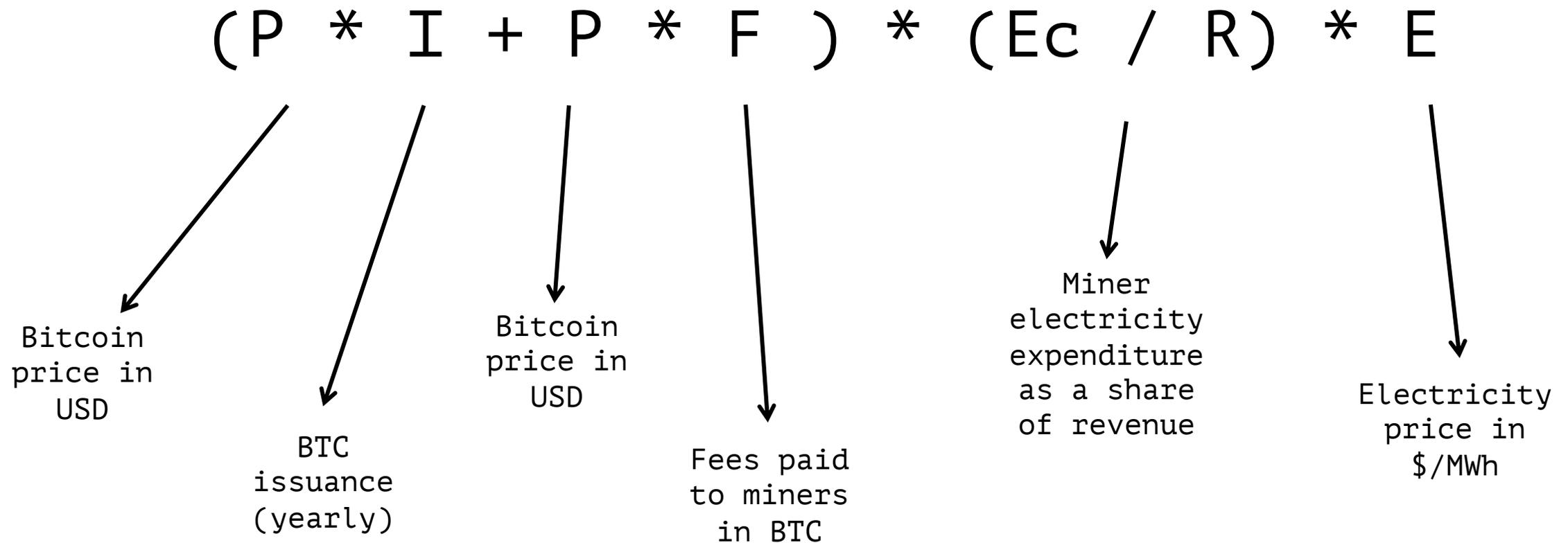


Bitcoin issuance structurally decays by 50% every 4 years

Issuance currently accounts for 99% of miner revenue



# How to ascertain and project Bitcoin's energy use (top-down method)



# Estimating energy consumption (2021)

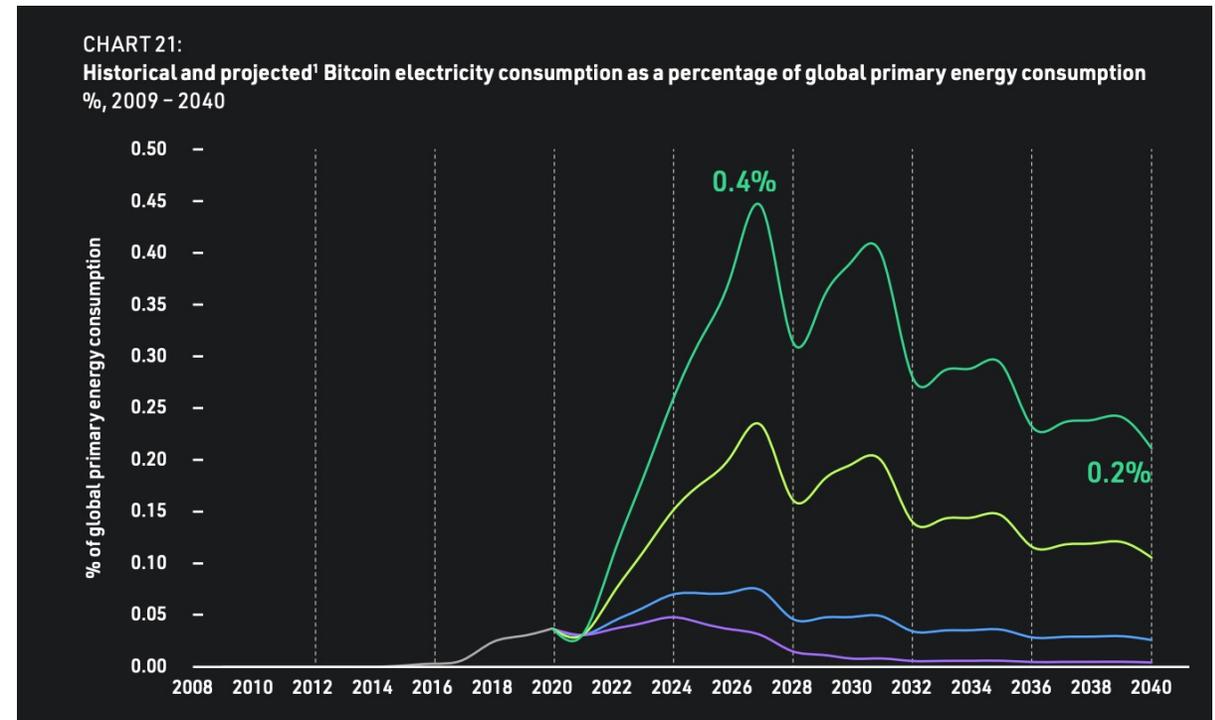
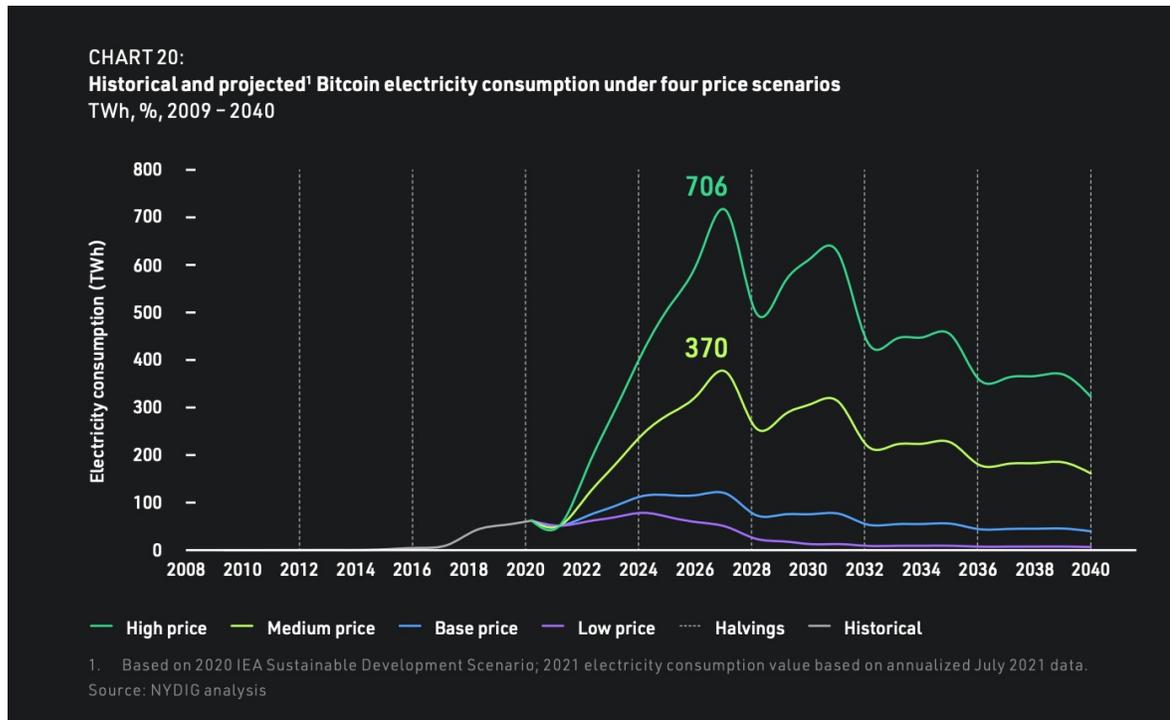
Revenue from issuance		Revenue from fees		Revenue devoted to electricity	
$(\$47,440 * 328,500$		$+ \$47,440 * 21,460$		$) * 30% * \$50/MWh$	
2021 avg. price (Coin Metrics)	6.25 BTC / block * 144 blocks / day * 365 [1]	2021 avg. price (Coin Metrics)	Coin Metrics data	NYDIG estimate [2]	Cambridge estimate
Bitcoin price in USD	BTC issuance (yearly)	Bitcoin price in USD	Fees paid to miners in BTC	Miner electricity expenditure as a share of revenue	Miner avg. electricity price in \$/MWh
<b>= 99.6 TWh [3]</b>					

[1] Issuance declines every four years by 50%; currently 1.8% annualized

[2] Miner margins were wide in 2021; NYDIG estimates the long run average at 50%; Cambridge, 43%

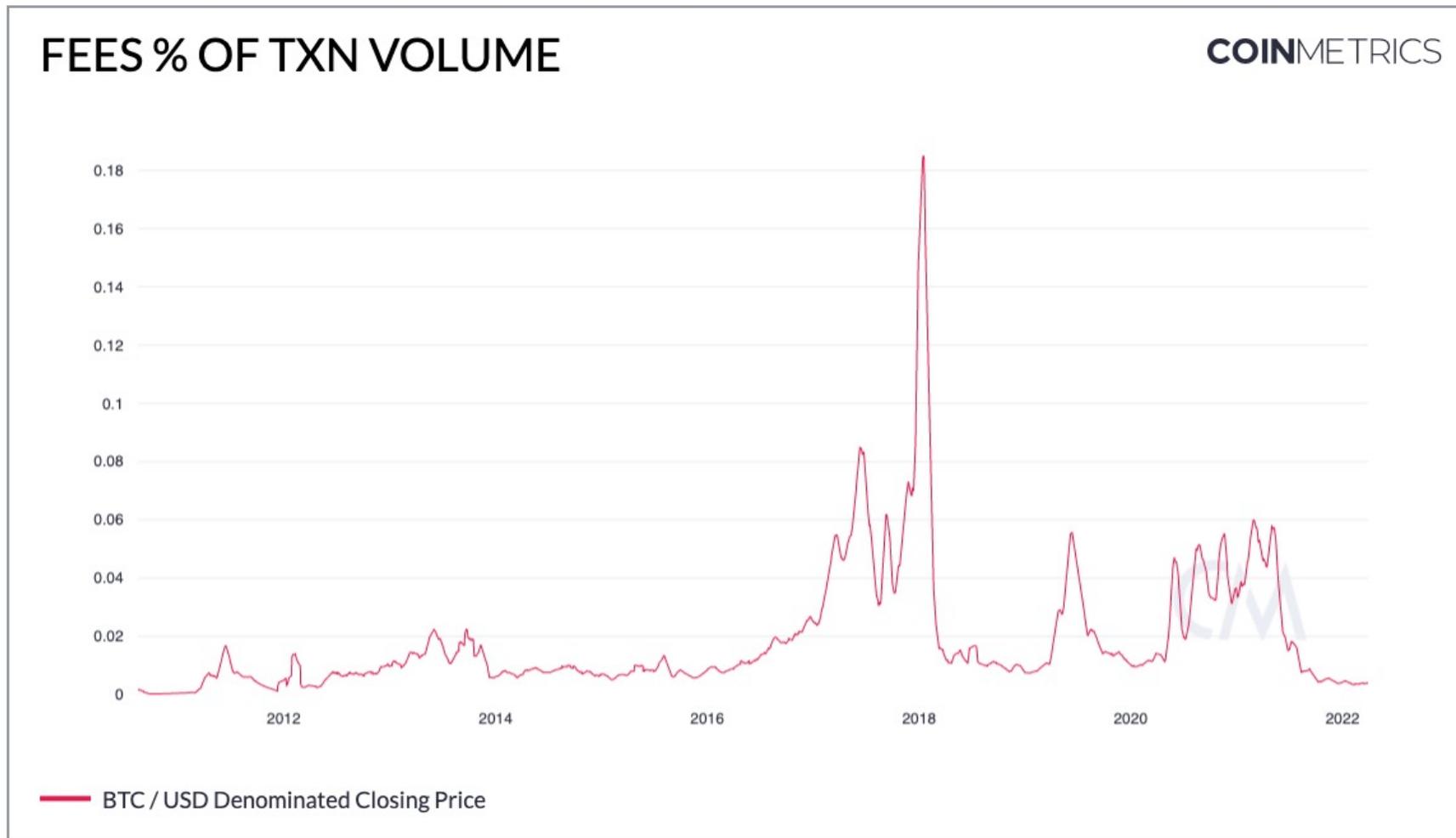
[3] Cambridge's bottom-up estimate for 2021 yielded 103 TWh cumulative consumption

# Bitcoin energy consumption is a function of price now, fees later



NYDIG's 'high price' scenario has Bitcoin matching the value of monetary gold by 2030; even then it only reaches 0.4% of global energy consumption

# Long term fee growth is capped by user willingness to pay



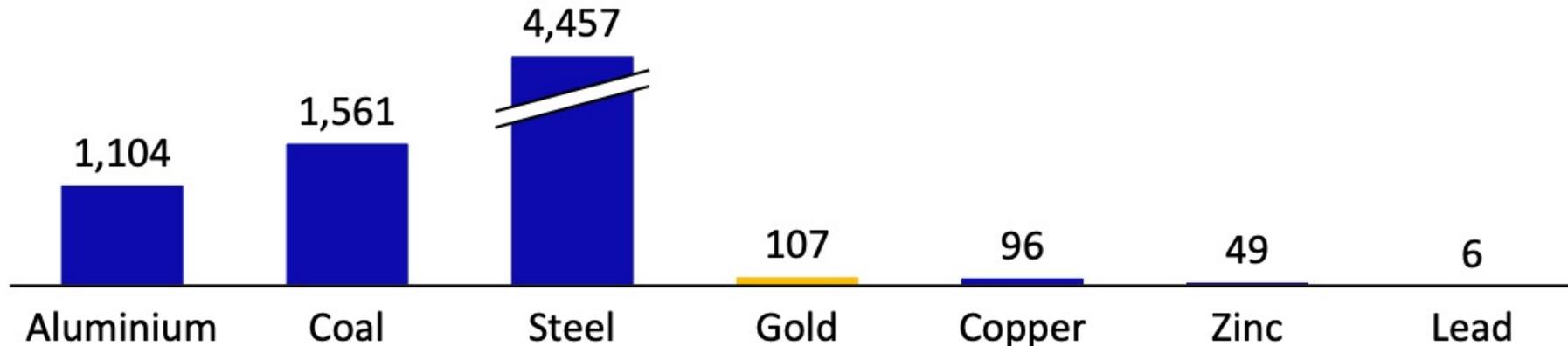
- With some exceptions, fees normally amount to ~1 bps of transaction volume
- This implies an upper limit on system fees – because users will only tolerate so much extraction before seeking alternatives
- If Bitcoin matches Fedwire (\$991T volume settled/year) fees at 1bps would amount to \$100B – only 5x higher than Bitcoin’s peak rate

# Bitcoin has lower emissions than gold but higher emissions intensity per unit produced

[1] World Gold Council  
[2] Bitcoin Net Zero, NYDIG

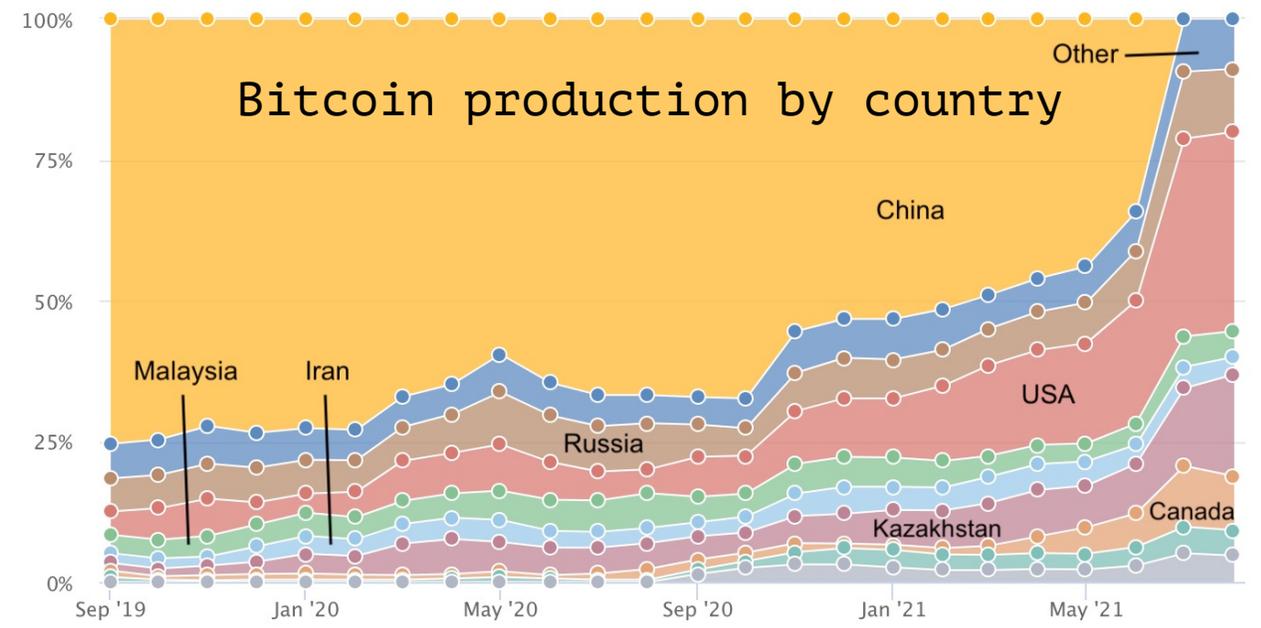
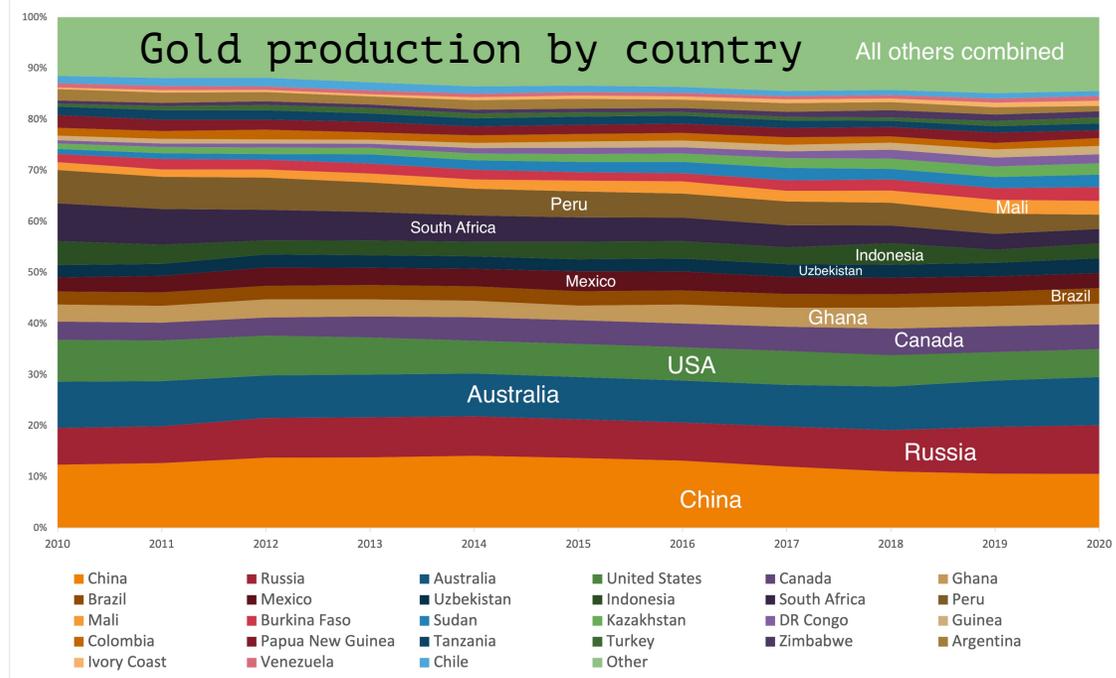
## Total scope 1 and 2 CO2 emissions from major mined products [1]

2021E, Millions tonnes CO2e



- Bitcoin's carbon production footprint in 2021 stood at 50-70 Mt CO2e [2]
- Gold production emissions are roughly twice those of Bitcoin, but gold mining created 9x more value in 2021

# Both gold and Bitcoin production are resistant in the aggregate to individual state action



Gold production is more distributed than Bitcoin, but Bitcoin is less geography-dependent and more malleable

Individual state bans cannot stop Bitcoin/gold production in the aggregate - bans merely improve the economics of miners in nations without bans

[1] World Gold Council

[2] Cambridge Center for Alternative Finance. Data is based on an estimate of 1/3 hashrate in participating pools

# Takeaways

- Like gold, Bitcoin's **resource cost stems primarily from issuance**, which induces rational producers to deploy resources to obtain it
- Long term, Bitcoin's issuance will trail off, and miner expenditure will equate to fees paid to use the network, which are naturally limited
- Discouraging gold or Bitcoin production locally just **supports it elsewhere**, leaving aggregate resource costs largely unchanged
- Banning Bitcoin **likely won't reduce its resource cost** - just like banning private gold ownership or entering a fiat standard failed to do
- Bitcoin or gold mining **do not constitute a waste** as they represent market-based mechanisms for users to obtain monetary commodities