BURN THE WORLD DOWN WITH BITCOIN...OR MAYBE NOT?

- BLOCKCHAIN SUSTAINABILITY FROM CRYPTOCURRENCIES AND BEYOND

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Today

- Our study about the environmental impact of Bitcoin
- Cases from own (qualitative) research on blockchain and sustainability
- Q&A

Authors

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Who is this guy?

- 🇮🇹🇩🇰
- MSc Environmental Science
- PhD in Planning and development
- Research domain: industrial ecology

The study of material and energy flows across industrial systems and the environment

- Research focus: life cycle assessment

I make models so say how good/bad a product is for the environment, “all-inclusive”

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Wine is good
...for research
Skt. Anna Gade
VINHANDLEN
SMAG FØRST
- smag før du køber
VINHANDLEN
SMAG FØRST
- smag før du køber
P
Zone
KOMMENDE SMAGNINGER
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KOMMENDE SMAGNINGER

Bitcoin – a life cycle perspective

- Bitcoin requires mining 👇
- Mining requires electricity 👇
- Producing el generates impact😢
- Mining grew >500% since January 2018 😱😱😱…
- And therefore…

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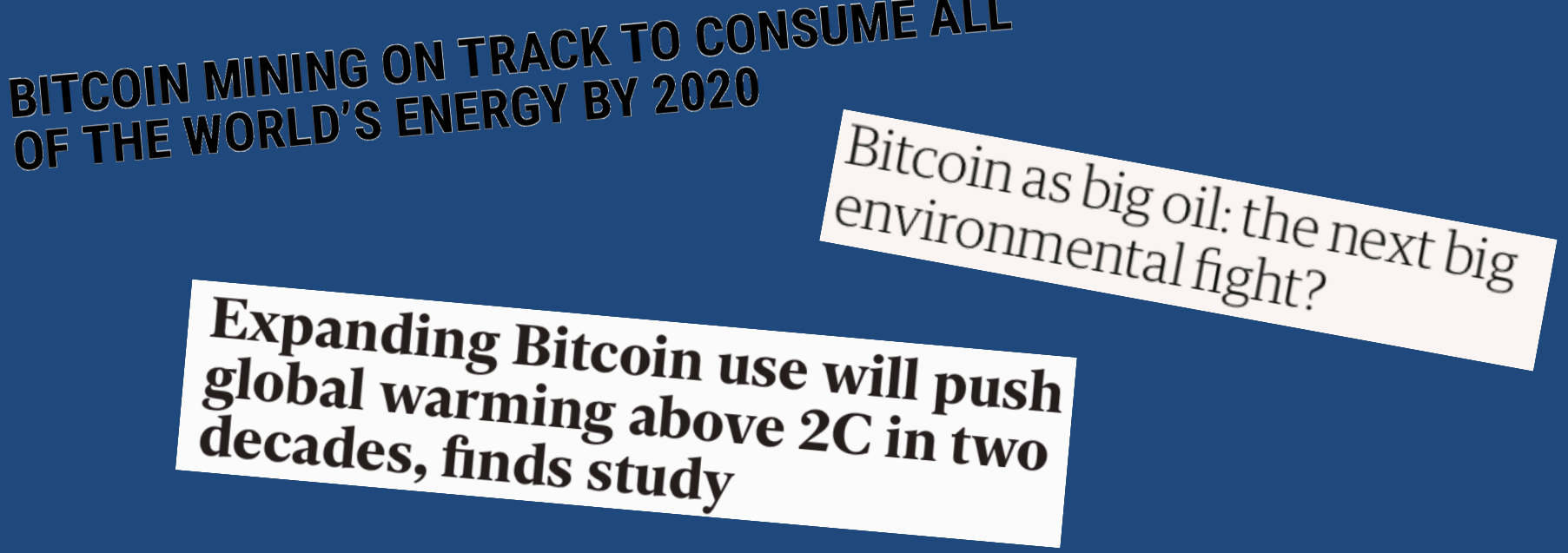
Bitcoin – an environmental disaster?



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Other claims* about Bitcoin mining…

- …uses more energy than mining gold 🏆
- …is equal to Switzerland's energy consumption 🇨🇭
- …will use all the world's energy by 2020 🌍
- …will be alone responsible for not reaching the Paris Agreement 🇫🇷

*refs in Köhler and Pizzol, 2019

Some perspective, CO_2-eq of

- Bitcoin 22-63 Mt (17 in our own study)
- Danish people 50-60 Mt (depends how you count…)
- Coca Cola 2.2 Mt (their own report)
- Amazon 51.17 Mt (their own report)

Why aren't media saying that Amazon will burn down the world?
Are these comparisons meaningful?
Is this impact a problem?

https://sustainability.aboutamazon.com/environment/sustainable-operations/carbon-footprint
https://www.coca-colacompany.com/news/reducing-carbon-in-our-value-chain

Previous Bitcoin carbon footprint estimates

- Assumptions and “back on the envelope” calculations (e.g. world average impact/kWh, 70% of miners in China and the rest impact free)
- No standard method and data, not (always) peer-reviewed
- Previous results: 22-63 $MtCO_2$-eq/yr (Stoll et al. 2019; Digiconomist 2019; McCook 2018) but hardly comparable

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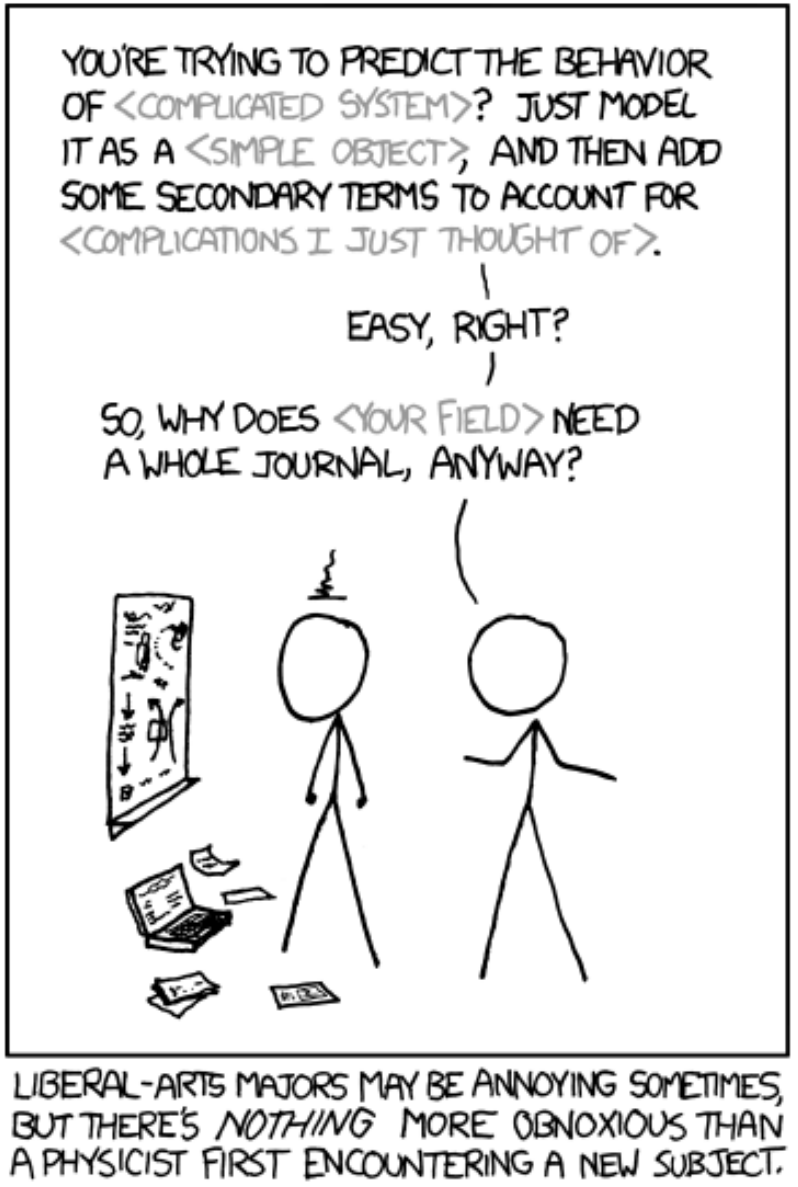
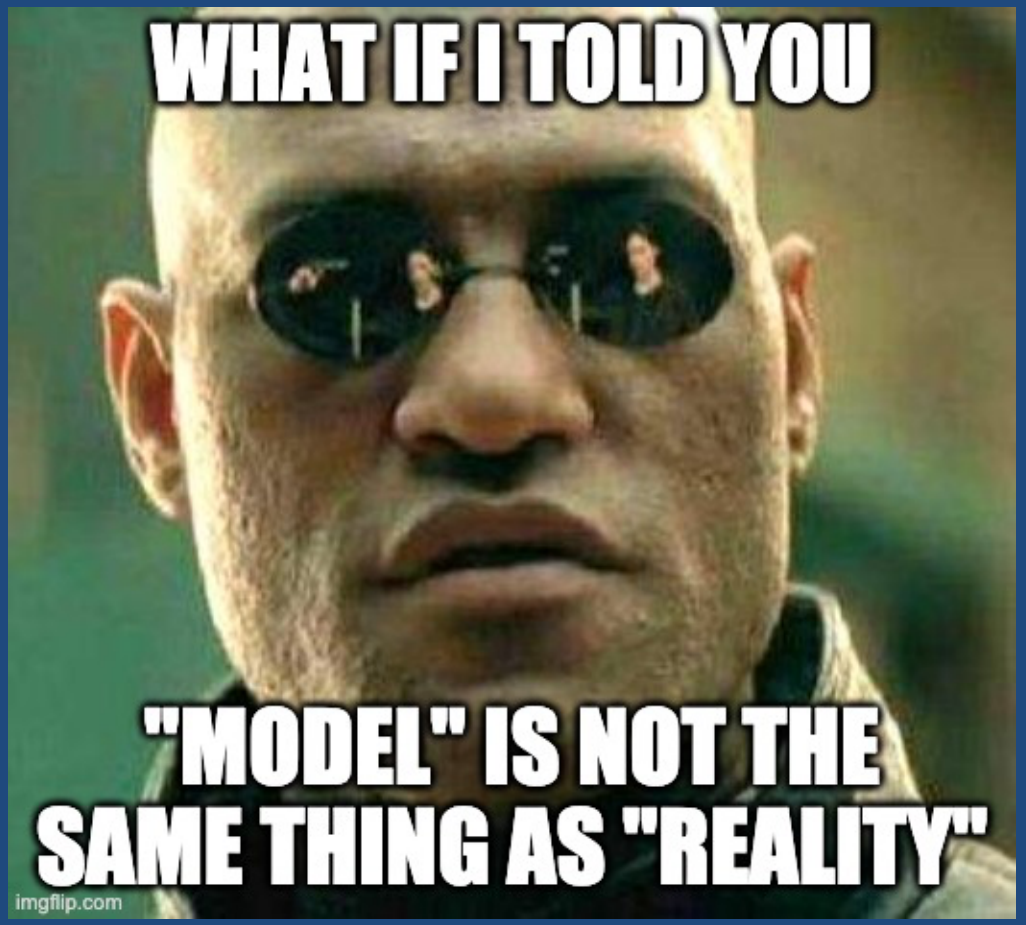


Carbon footprint, not as simple as you would like it to be!

- “function” of Bitcoin? comparability…
- Bitcoin vs financial services? blocks ≠ transactions
- High energy = high impact? renewables…
- Where are miners? yesterday, today, in 5 years…
- Electricity only? machine production…

Two overall problems

- Media: alarmist claims
- Academia: contrasting results


WHAT IF I TOLD YOU
"MODEL" IS NOT THE SAME THING AS "REALITY"
imgflip.com

Our work

- Can we improve the validity of this analysis? use established methodology: LCA & databases
- What are hotspots of Bitcoin mining?
- What will the future impact of Bitcoin be?

Environmental Science & Technology

Policy Analysis

pubs.acs.org/est

Life Cycle Assessment of Bitcoin Mining

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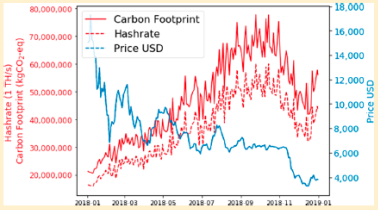
Supporting Information

ABSTRACT: This study estimates the environmental impact of mining Bitcoin, the most well-known blockchain-based cryptocurrency, and contributes to the discussion on the technology's supposedly large energy consumption and carbon footprint. The lack of a robust methodological framework and of accurate data on key factors determining Bitcoin's impact have so far been the main obstacles in such an assessment. This study applied the well-established Life Cycle Assessment methodology to an in-depth analysis of drivers of past and future environmental impacts of the Bitcoin mining network. It was found that, in 2018, the Bitcoin network consumed 31.29 TWh with a carbon footprint of 17.29 $MtCO_2$-eq, an estimate that is in the lower end of the range of results from previous studies. The main drivers of such impact were found to be the geographical distribution of miners and the efficiency of the mining equipment. In contrast to previous studies, it was found that the service life, production, and end-of-life of such equipment had only a minor contribution to the total impact, and that while the overall hashrate is expected to increase, the energy consumption and environmental footprint per TH mined is expected to decrease.



INTRODUCTION

Today, there are many expectations that blockchain technology will change the world for the better.[1−6] The technology is, in extreme synthesis, a distributed ledger that removes the middlemen and establishes trust between unknown parties.[2] Currently, the most mature implementations of blockchain are in the financial sector[7] with the cryptocurrency Bitcoin being a prominent example.[8,9]

While in traditional finance, banks act as a trusted authority and keep track of transactions and balances, in the Bitcoin network, the entire memory of transactions is stored digitally in "blocks" that are linked as a chain—hence blockchain—and kept by a network of peers. A consensus mechanism is how the peers in the Bitcoin network continuously agree on the order of newly added blocks and thus secure the data in a decentralized fashion. Bitcoin's consensus mechanism is based on a proof-of-work (PoW) approach where peers in a network compete in winning the right to add the next block to the chain, a process called "Bitcoin mining" that is performed by "miners". The miners compete in solving a puzzle, which requires substantial computational power. To do so the miners try to find a "nonce value", which is a random value. Every time the miners guess the nonce value an algorithm is applied that maps the data of their suggested block—including the guessed nonce value—to a value of a fixed length. This output value is called a hash. A miner wins the right to add a new block when this hash is lower than a target value.[10] The target value of the puzzle is adjusted automatically so that, on average, only one block is mined every 10 min.[11] Thus, the more miners join the network or the more efficient miners become, the more difficult it becomes to mine a block, while the block generation time remains approximately constant. The hashrate corresponds to the number of hashes guessed per second. In 2018, the hashrate of the entire Bitcoin network ranged from around 15 to 60 million Tera hashes (TH) per second.[12]

With the increasing popularity of cryptocurrencies concerns were raised regarding the sustainability of Bitcoin, under the rationale that since the Bitcoin network uses a high amount of electricity for mining, its environmental impact might be substantial. A wide range of estimates of Bitcoin's energy consumption have been published in the media, reflecting the uncertainty of such assessments. For example, claiming that Bitcoin mining uses more energy than mining gold,[13] is equal to Switzerland's energy consumption,[14] was to use all the world's energy by 2020,[15] and be alone responsible for not reaching the Paris Agreement.[16] Recent studies—both in gray and academic literature—estimate the energy consumption of Bitcoin to be 22−67 TWh/yr (mid-March 2018),[17] 43 TWh/yr (October 2018),[18] 45 TWh/yr (November 2018),[19] 62 TWh/yr (average of 2018),[20] 39−83 TWh/yr (mid-November 2018),[21] and 105.82 TWh/yr (29 July 2018).[22]

Stoll et al. estimate the annual carbon emissions of Bitcoin between 22.0 and 22.9 $MtCO_2$ (November 2018).[19] Digiconomist proposes the estimate of 30.35 $MtCO_2$/yr[20] (average 2018). McCook[22] estimated the carbon footprint to

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Bitcoin Mining changes all the time!

- Location of miners → literature meta-analysis and scenarios
- Energy efficiency of equipment → sensitivity analysis
- Background system (and uncertainty) → ecoinvent (10000 activities) and Monte Carlo

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The basis for comparing products

Function	Functional Unit (FU)	Reference flow (RF)
WHAT should the product do?	HOW MUCH of FUNCTION should be provided?	HOW MUCH of PRODUCT is needed to provide the function?
Computing	Computing 1 TH	Electricity + machines

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Functional unit

❌ Transactions, one block can include many

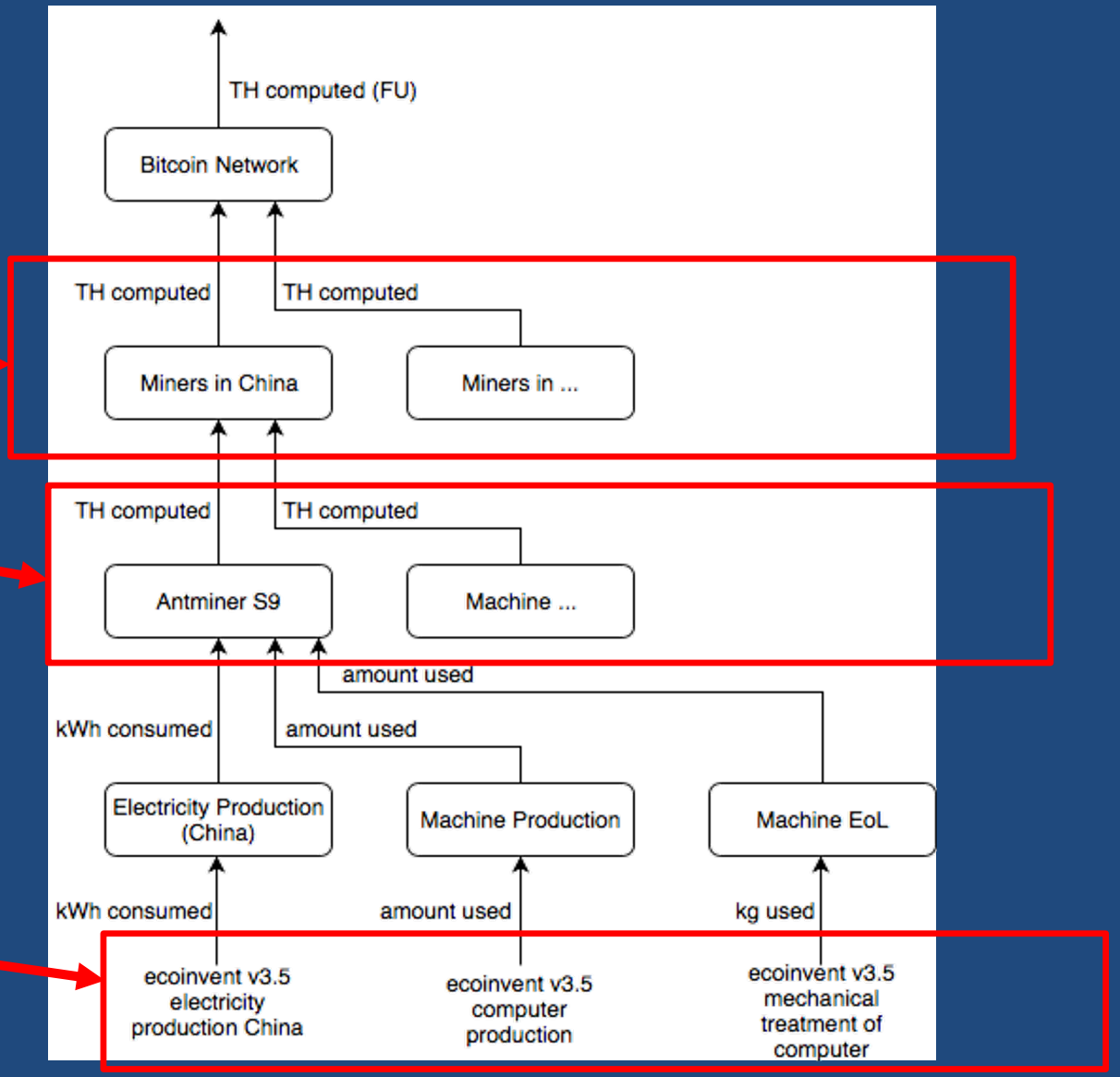
❌ Blocks, are variable

❌ Hashrate variable too, no comparisons between studies at different points in time

✅ Computing 1 TH can then be linearly upscaled to obtain the impact of Bitcoin for a given period according to the actual hashrate

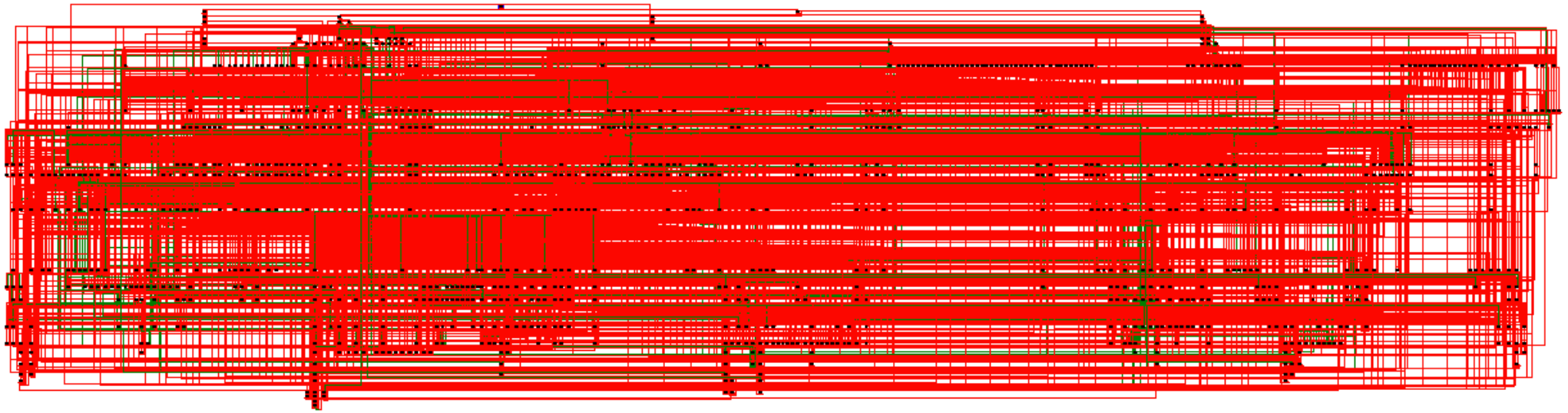
Retrospective model (attributional)

- Locations
- Machines
- Bg database with average techs (e.g. average energy mix per country)



What is a background database?

- (video of spaghetti monster)



Location of miners (retrospective model)

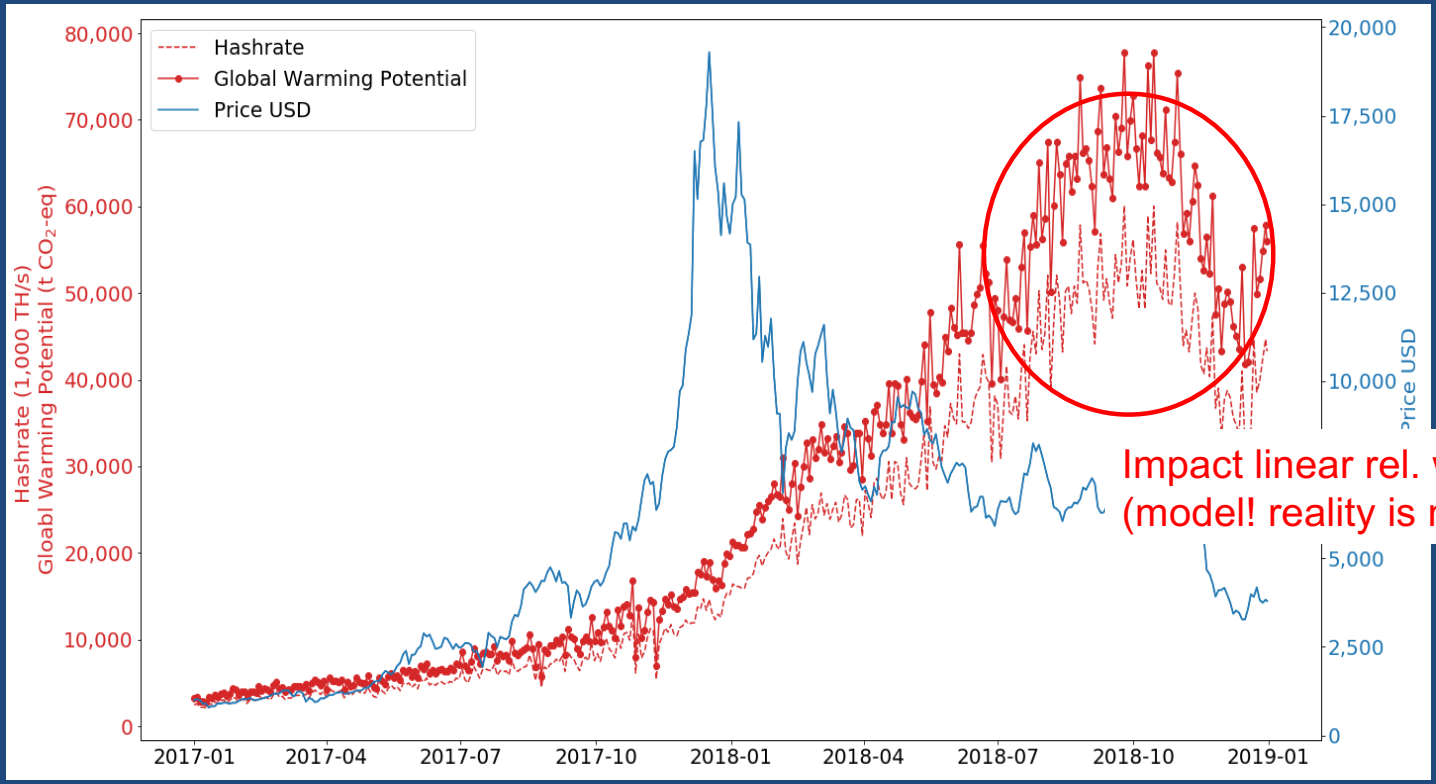
Miners locations as 2018 (own estimate based on triangulating different literature sources)

Table 1. Geographic Distribution of Bitcoin Miners Used in the Attributional Baseline Model

location	share
China	53.5%
Inner Mongolia	12.3%
Xinjiang	10.7%
Sichuan	30.5%
Canada	12.8%
Quebec	4.0%
British Columbia	4.1%
Alberta	4.7%
U.S.	13.7%
New York state	7.5%
Washington state	6.2%
Iceland	4%
Georgia	4%
Norway	4%
Sweden	4%
Russia	4%

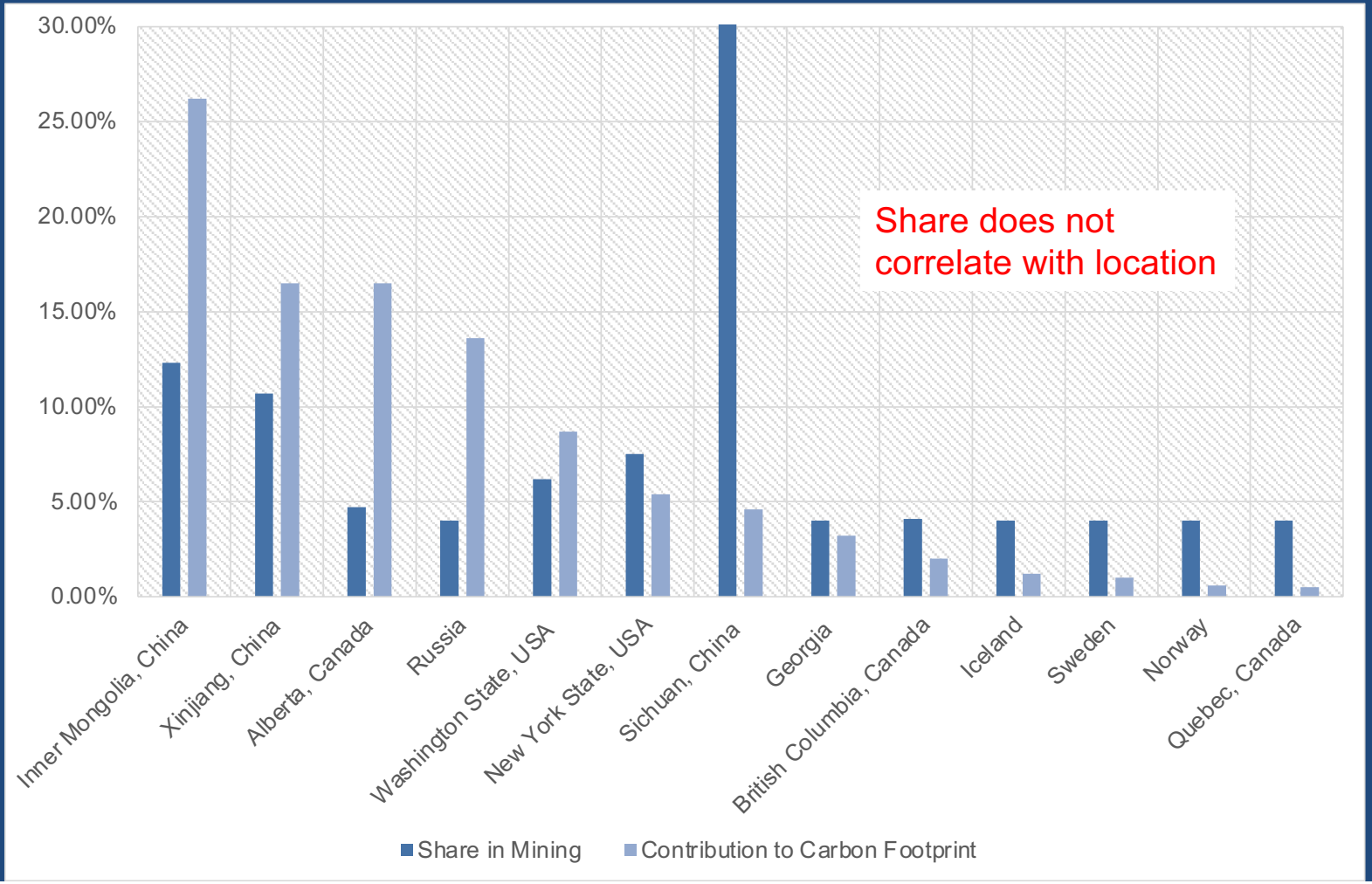
Carbon footprint (retrospective model)

31.29 TWh in 2018 15 $mgCO_2$-eq / TH 17.28 $MtCO_2$-eq in 2018

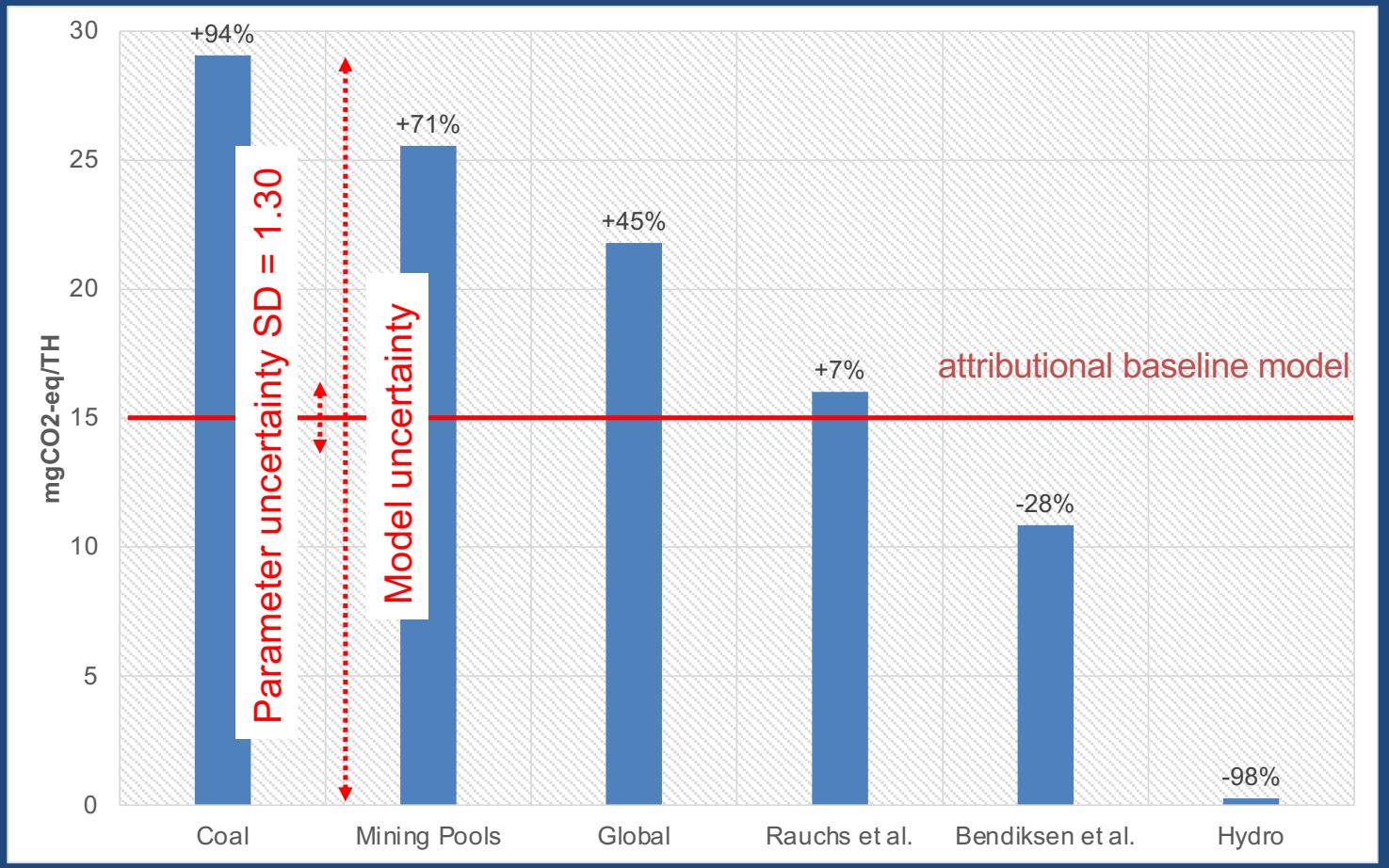


Impact linear rel. with hashrate
(model! reality is more complex)

Mining versus footprint share



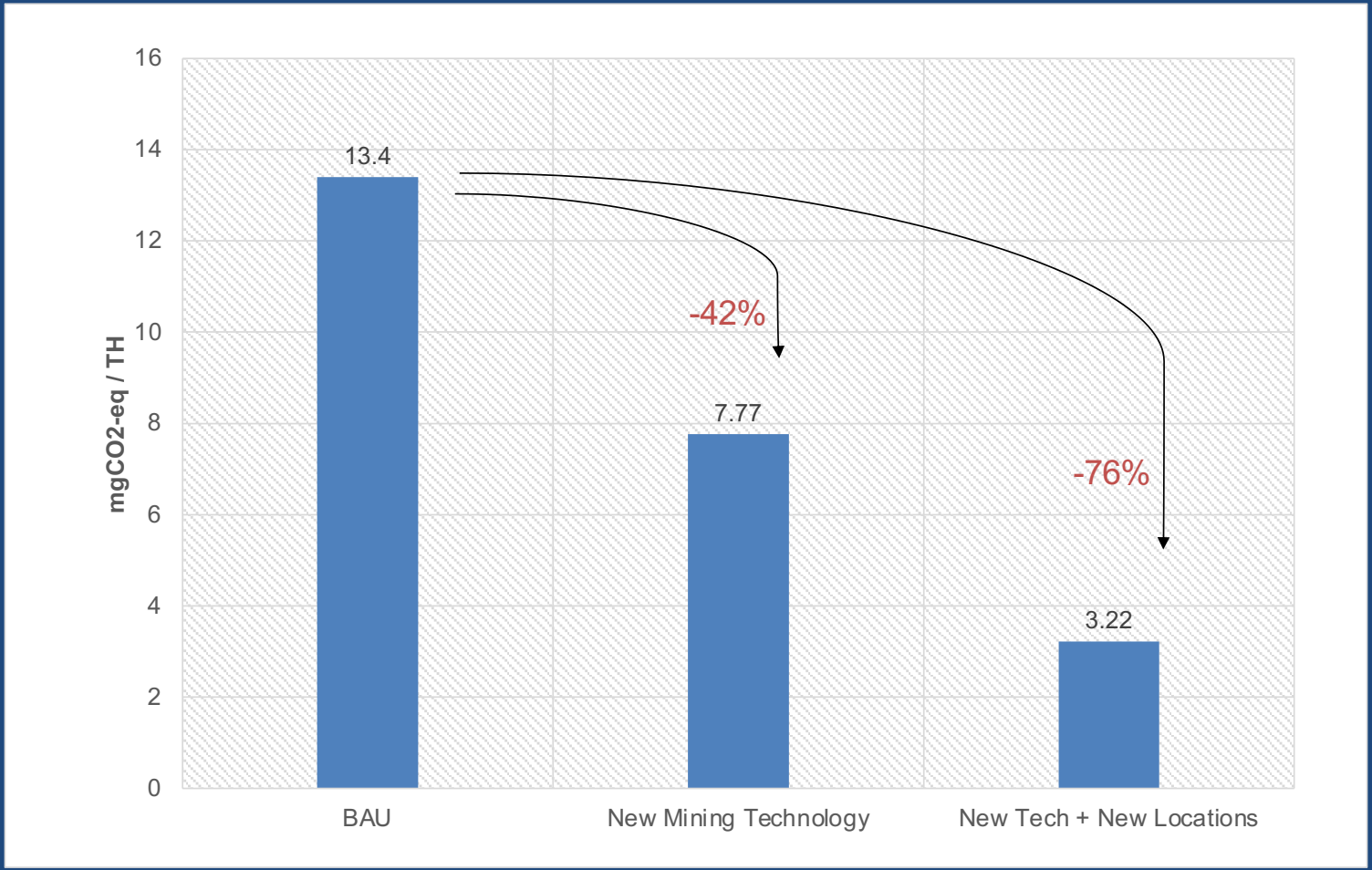
Sensitivity to electricity mix



Prospective model (consequential)

- Functional unit increase in demand for computing 1 additional TH
- BAU scenario bg database with marginal techs (modern only)
- New tech scenario only most efficient mining equipment
- New tech & locations scenario only locations with competitive conditions (e.g., lower energy prices and temperatures)

Prospective scenarios (consequential model)



Wrap-up on mining and outlook

- Major impact drivers: location and mining efficiency
- Hashrate expected to 👆, impact/TH 👇
- Further research:
  - Increase geographical accuracy via expert interviews and surveys
  - From mining to entire Bitcoin network (nodes, but not expected to be major)

Why is this useful?

- We see hotspots (relative contributions to impact)
- We see absolute energy consumption (**substantial!**)😱
- Miners will move to locations with cheap electricity. Can be unused electricity from hydro (Sichuan), but also cheap electricity from coal (Inner Mongolia)

Why is this useful?

- Plattsburg (New York): miners flocking to a city with cheap electricity 👉 increase its energy consumption 👉 to city is no longer able to provide cheap electricity 👉 has to import it from elsewhere

= miners shift the environmental impact to other users

- True improvement miners established new capacity of renewable energy production ✅ (= their own wind turbine)

= green marginal (= due to additional demand) electricity consumption

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The elephant in the room

Couldn’t we just “mine” Bitcoin in another way?

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