Gold and Bitcoin – A Short Study of Two Carbon Impacts

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In a previous article (Björk Danielsen, 2020), I discussed how investors could think about ESG and commodity futures. I argued that exposure to commodity futures contracts cannot reasonably define a carbon footprint. This is because a long or short position in a commodity futures contract does not create nor destroy any supply of the commodity in question.

However, there are also popular commodity investments where investors prefer to buy the actual commodity "physically" and store it. This has long been the case for investment in gold, and more recently, direct investments in bitcoin and other cryptographic assets. For these investments the carbon impact becomes a tangible and meaningful quantity to understand, as investors directly contribute to demand.

It may be argued that withholding scarce commodities from other uses "lock in" the one-time emissions from producing them. Once the investment is ended, this internalized carbon content can be seen as passed on to the next investor, or consumed by a commercial buyer. In fact, it is unlikely an investor in either gold or bitcoin will be the first owner of that asset.

In this article, I share an approximate analysis of the emissions "internalized" into gold and bitcoin. The calculations are based on the relevant emissions from production without delving into later lifecycle emissions. The goal is to give investors useful "rules of thumb" for understanding the orders of magnitude at play. I also want the reader to understand the underlying assumptions and calculations, so that they are able to recreate the results using the cited public sources.

Throughout this article, I will be speaking in the unit that I believe makes the most sense for judging investment carbon impact: metric tons CO2 equivalent per million dollars of capital (tCO2e/M$). I not only want to compare gold and bitcoin emissions but I also want to put them into context using multiple comparisons, including: how do these emissions compare to the currently traded prices of carbon; how do these emission intensities compare to the equivalents of industrial and agricultural commodities; and how do they compare to the emissions from the activities of corporations underlying popular equity indices?

Results Relative to the Price of Carbon

The table on the next page presents the intensities I have arrived at for gold and bitcoin. Additionally, it also introduces a third commodity: the emission allowance. The European Union Allowance (EUA) is the largest market for the price of carbon, based on trading certain European emissions restricted to a common cap by regulation. Emission allowances are also becoming increasingly interesting commodity investments, but here I will only use them as carbon content measures.

From the table below, one can conclude that based on 12-month average prices as per June 2021, the emission intensity of bitcoin is about 12 times that of gold. But perhaps more interestingly, matching the emissions intensity of gold to allowances under the European scheme would only make up 1.5% of the price of the commodity, while emission compensation through the use of EUA's would cost 18% of the price of bitcoin.

Table 1

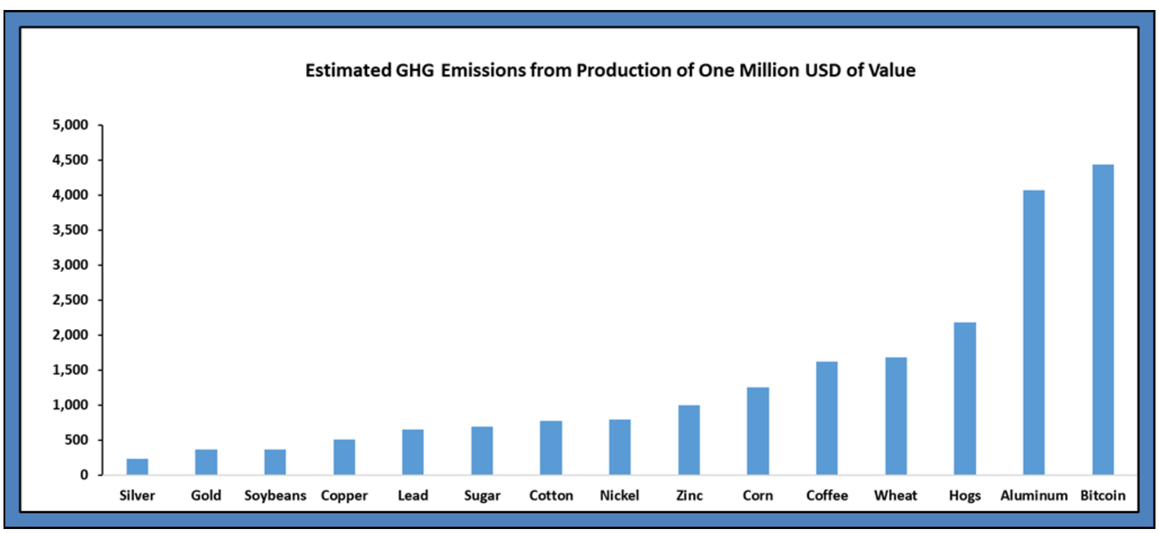
	CO2e internalized	1y avg price Jun 21	Resulting intensity
Gold [1]	21.76 tCO2e/kg	$59,639/kg	364 tCO2e/$M
EUA Carbon Price[2]	-1 tCO2e/allowance	35.5 €/allowance	-23,916 tCO2e/$M
Bitcoin [3]	131 tCO2e/coin	$29,595/coin	4,435 tCO2e/$M

[1] Based on Table 3 of World Gold Council (2019). Upstream and recycling Scope 1 & 2 (direct and indirect) emissions divided by all production.
[2] Assuming the emission rights' nominal allowance quota as its internalized emissions.
[3] See Appendix A for calculation.

Relative to Other Commodities

Physically storing base metals or grains for their value is not unheard of, yet is very uncommon as these commodities are perishable goods with industrial uses. Nevertheless, by expanding my methodology from the previous section to a broader set of commodities, it is possible to place gold and bitcoin in a broader commodity context. Figure 1 shows that on a per dollar basis, precious metals such as gold and silver generally hold lower intensities compared to industrial commodities or even grains and softs. Simultaneously, only the most emission heavy industrial commodities come close to the emission intensity estimated for producing bitcoin.

Figure 1

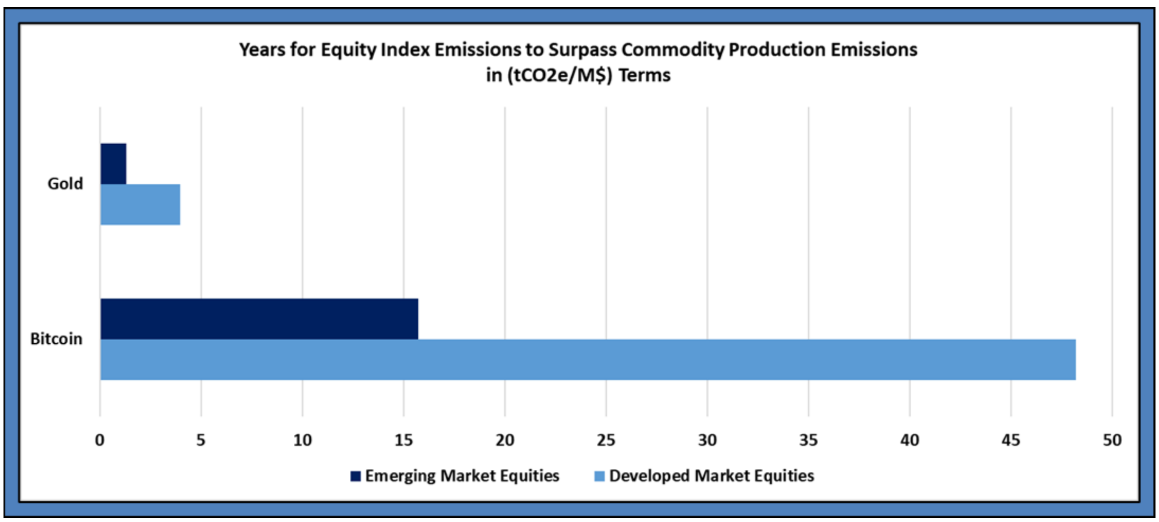


Compared to Equity Indices

The emissions from an equity investment are essentially different from a precious metal investment. Equity investments produce both ongoing annual emissions and annual cashflows. There is no unequivocal way of comparing the two, so I have settled for the simplest: the number of years it takes for the companies underlying a similar size equity investment to emit a similar GHG footprint as the one-time emission that is needed to produce the same value of the compared commodity.

According to a proprietary analysis of APG Asset Management, the capitalization weighted emissions of the MSCI World developed market and emerging market indices were as per June 2021 approximately 93 and 282 tons per million dollars invested. This means that the emissions from producing a million dollars' worth of gold today creates the same carbon footprint as 1-4 years' worth of ongoing emissions attributed to a million dollars invested in equities. By the same calculation, mining bitcoin produces emissions equivalent to a staggering 16 to 48 years' worth of current equity index emissions at the same dollar value. See Figure 2.

Figure 2



Conclusions

Precious metals, and gold in particular, are primarily used for store-of-value purposes. Mining these metals causes considerable initial one-time emissions, which the global gold producing industry would have to cut in the coming years to be in line with national Paris agreement aspirations. The industry has presented ambitious roadmaps towards decarbonization (World Gold Council, 2020). Investors who include gold in their portfolios should track the industry's progress towards these goals over the coming years.

However, studying the current situation, I was able to conclude that the high value of gold causes its total mining emissions per dollar of value to be low compared to that of most industrial commodities. Furthermore, I concluded that the production of investment gold today produces reasonable emissions when compared to the ongoing emissions produced by the constituent companies of popular equity indices.

Meanwhile, the same cannot be said for investments into bitcoin. Today, many cryptographic assets, and bitcoin in particular, are extremely carbon intensive in nature. To make matters worse, unlike precious metals, the emissions of bitcoin are not limited to its primary mining emissions – simply transacting these assets in the future will produce considerable further emissions. The number calculated in this study are indicative and likely to change, given that the bitcoin network's emissions fluctuate as the hash rate and the sources of energy used to create it will be variable due to changes in profitability and regulation. Nevertheless, bitcoin will remain energy intensive in the future, as the miners' cost base will remain tied to power.

Bitcoin's decentralized nature also makes it much harder to "green" compared to traditional mining: it cannot be efficiently regulated with carbon border taxes or local cap-and-trade schemes that are likely to affect the gold industry in the coming years. Individual investors can today choose to buy bitcoin generated with fossil-free energy sources. However, such purchases are likely to support the price of bitcoin, which in turn is likely to not only increase mining activity, but also increase the emission intensity of that activity more directly than in the case of traditional mining.

I therefore conclude that for a more sustainable future, cryptographic assets will have to undergo technological changes. Most centrally, modified coins or tokens that are not reliant on the proof-of-work based consensus mechanisms described in Appendix A will have to become commonplace. Currently, it is hard to make the case that bitcoin can reasonably be part of a sustainable investment portfolio.

Appendix A

Bitcoin Emission Intensity Calculation

Bitcoin's decentralized transaction validation protocol is based on a Proof of Work (PoW) consensus mechanism for validating blocks of transactions. Validators, or "miners," essentially compete in solving an arbitrary computational problem based on reverse-engineering cryptographic hashes (Keenan *et al*., 2018). The miners are awarded for validated blocks in bitcoin. This "mining" is done today primarily using specialized computer hardware, and the total computations done by miners is described by the bitcoin network hash rate.

Because bitcoin is not centralized, there is no exact central registry of the identity of miners or the hardware and power source they use to produce these hashes. What can be deduced about its public ledger is the current hash rate and the approximate geographical distribution of the hardware producing it. Power use and carbon intensity of that power must then be separately estimated.

Various studies have estimated power usage under different assumptions. Some studies have performed a bottom-up analysis, studying the efficacy of the likely mining hardware portfolio in use. Meanwhile, others have turned the problem around, calculating total mining revenue assuming the power share fixed. The Cambridge Bitcoin Electricity Consumption Index (CBECI) uses the former approach while the

Digiconomist's Bitcoin Energy Consumption Index (BECI) the latter. Both of these indices are available publicly on the internet on a daily basis. Both indices are quite volatile, as changes in the price of bitcoin will immediately trigger a response in the form of additional mining hardware being deployed or removed from the network. Current values of both indices are seen in Table A1 below. Because both of these methods have their particular advantages and drawbacks, I have used the average of the latest CBECI and BECI numbers as my best point estimate.

Table A1

	As of 1 Jun 2021	1 year average
CBECI	70 TWh	51 TWh
BECI	105 TWh	85 TWh
Average	88 TWh	68 TWh

For estimating the carbon intensity of this power, multiple estimates also exist. At the time of analysis, the current best estimate remains that of Stoll *et al*. (2019), setting intensity at 480-500 kilograms of CO2 equivalent per megawatt hour of power (kgCO2eq/MWh). I will use the midpoint of 490 kgCO2e/MWh for this analysis. This is a fairly high intensity, reflecting the currently large share of mining taking place in China's predominately coal-powered grid. We can contrast the intensity of the power used by bitcoin miners with the 2019 U.S. and E.U. grid averages of 408 kgCO2e/MWh and 255 kgCO2e/MWh respectively (EIA, 2020; EEA, 2021).

The final piece of the puzzle is the output of mined bitcoin. This comes by construction from the bitcoin algorithm releasing one block approximately every 10 minutes, implying (365*60*24)/10= 52,560 blocks per year. Miners of a particular block are rewarded by a block reward, which is also by construction halved roughly every 4 years. As of 2021, the block reward stands at 6.25 bitcoins (BTC). This translates to 6.25*52,560 = 328,500 bitcoins as being produced per year. Attributing the full emissions of the hash rate to the production of bitcoins thus gives us (490,000 tCO2e/TWh * 88 TWh)/328,500 BTC = 131 t/BTC or 4,435t/$M, when using the current 12-month trailing average price of bitcoin ($29,595). (TWh stands for terawatts of power.) Looking at the many approximate values plugged into this calculation, it is clear that this estimate is a very rough estimate. All of the inputs used are likely to change a lot in the coming years based on the economics of mining and attempts to regulate the market.

It is also essential to note that this estimate does not include the additional energy or broader ecological footprint attributable to the production of the specialized chips often used for the sole purpose of bitcoin mining.

Appendix B
Approximate Emissions from Producing Selected Commodities

Comparing emissions of different commodities on equal footing is challenging. The table on the next page summarizes various estimates of directly caused emissions. Different sourced studies use slightly differing assumptions and methodologies in their analysis. These estimates are also based on data samples from different geographical locations and time periods. Because of these differences, the numbers in the table below should only be seen as an effort to form indicative and somewhat comparable measures of CO2 equivalent emissions. I have attempted to include Scope 1 and 2 emissions measures that are available from publicly available sources, excluding LULUCF (Land Use, Land-Use Change, and Forestry) offsets, and based on a global warming potential (GWP) of 100 years. I have chosen not to deduct any figures for carbon sequestered into the commodity itself, nor any downstream emissions such as emissions or sequestrations caused when consuming the commodity. These numbers should reflect both energy-related and other direct emissions caused by the work of mining, growing or refining the commodity in question. For agricultural products, I base my analyses on regional U.S. supply in order to match the price benchmarks used in the intensity calculation. For the intensity's price denominator, I use 12-month average prices of the most liquid futures contract. The 12-month average was applied in order to smoothen results and to control for effects of commodity price seasonality.

Table B1

	GWP 100 CO2e emissions (ton per ton)	12-month average price per ton from futures	Emission intensity tCO2e/$M	Source of life-cycle analysis
Silver	196	$820,809	239	Nuss and Eckelman (2014)
Soybeans	0.17	$483	366	Field to Market (2016)
Copper	4.08	$7,940	514	International Copper Association (2017)
Lead	1.3	$1,987	654	Davidson *et al.* (2016)
Sugar	0.23	$331	696	Seabra *et al*. (2011)
Cotton	1.3	$1,676	776	Field to Market (2016)
Nickel	13	$16,267	799	Nickel Institute and Sphera (2020)
Zinc	2.66	$2,662	999	International Zinc Association (2016)
Corn	0.22	$176	1,250	Field to Market (2016)
Coffee	4.51	$2,778	1,624	Giraldi-Díaz *et al.* (2018)
Wheat	0.38	$226	1,682	O'Donnell (2008)
Hogs	3.9	$1,742	2,183	Thoma *et al.* (2011)
Aluminum	8.27	$2,033	4,068	Aluminum Association (2013)

Abbreviations: GWP stands for Global Warming Potential, and tCO2e/$M stands for metric tons CO2 equivalent per million dollars of capital.

Endnotes

The views and analyses in this article may not reflect those of the author's employer. In addition, the author would like to thank Alex de Vries, the founder of Digiconomist.net, for good discussions on the future outlook for bitcoin emissions.

For further coverage of cryptoassets, one can also read past *GCARD* articles, as well as a transcription of a JPMCC industry panel, on this topic.

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