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The CleanCoin project

Background and Carbon Footprint Methodology

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1. Overview

The CleanCoin project examined the climate impacts of cryptocurrencies, developing tools to calculate the Greenhouse Gas (GHG) emissions generated by the two main, digital currencies - Bitcoin & Ethereum – and suggesting ways in which to mitigate them.

It has developed a live emission counter tied to real time network activity and the power sources of network participants at http://www.cleancoins.io/. Furthermore, CleanCoin is defining the key attributes of a 'clean' and sustainable digital currency, and developing (i) labelling solutions for cryptocurrencies that encourage miners to source green power and (ii) carbon offsetting solutions for cryptocurrencies already mined and held in digital wallets to provide opportunities for wallet holders to take action.

2. Background

The CleanCoin Project is part of the Climate Ledger Initiative (CLI, previously '#CarbonBC'), and is among the first set of five CLI use cases. CLI has developed an international, 7-year, multi-stakeholder initiative at the intersection of climate and distributed ledger technology (aka 'Blockchain'). CLI was launched at the COP22 climate conference in Marrakesh, featured in the 'Hack4Climate' hackathon at COP23 in Bonn, and today is supported by UNFCCC, several UNFCCC Parties/countries and other stakeholders. By drawing attention and bringing clarity to the much publicised challenge of the high and resulting environmental impact of distributed ledger related technologies and applications, CleanCoin makes a valuable contribution to the overall effort at the climate/blockchain intersection.

There is currently no standard, label or benchmark with respect to the environmental impacts of cryptocurrencies and distributed ledger technology in general. The lack of accurate calculations of processing power, energy consumption, and resulting GHG emissions caused by the use of blockchain-type technology are alarming. Uncertainty, knowledge gaps and lack of mitigation options could lead to negative perceptions, which in turn may lead to a lack of engagement with this promising technology by those for whom climate and related environmental considerations are important.

Many experts believe Bitcoin is here to stay and will, for many years, act as a type of 'reserve digital currency'. Blockchain platforms such as Ethereum, Hyperledger, and IOTA are currently gaining the attention of governments and corporates. Processing demand for blockchain platforms may therefore be rise rapidly and substantially. This requires a clear understanding of the related environmental impacts.

As a CLI use case, CleanCoin directly addresses a ‘sore issue’ at the intersection of the climate and blockchain communities. It will also be compared with fiat currencies (please note that several governments currently plan to issue digital versions of their fiat currencies). By doing so, it could help to increase the attractiveness of distributed ledger technology for addressing Paris-Agreement type implementation challenges.

3. Carbon Footprint

The carbon footprints of different blockchain cryptocurrency networks were calculated by estimating the locations where the miners are based, then using the specific emission factor for electricity in these areas, and multiplying this with the estimated electricity used per terra- or mega-hash. To cover the whole lifecycle emissions, it was also estimated how much hardware and packaging material that are used per year. Since the hardware for cryptocurrency mining is only used for this specific purpose, all emissions from production and waste management of these materials should be part of the carbon footprint.

3.1 Bitcoin Carbon Footprint method

- The hashrate distribution among the mining pools were found at the website blockchain.info, a site which publicly publishes data concerning bitcoins (Blockchain.info (a), 2017).
- All major mining pools were researched to find out where the miners are based. This data was found from the mining pools own websites, bitcoin blogs, and similar sources (Tuwiner, J., 2017; Slushpool, 2017; Glikberg, G., 2017; Price, R., 2016; BitcoinWiki, 2017).
- The results were compared to the results from a global cryptocurrency benchmarking study published by the University of Cambridge Judge Business School. In this study, they had been able to map several mining facilities, consuming a total of 232 MW. They estimated that this is roughly half of the energy consumed by the Bitcoin blockchain (Hileman, Dr. H. & Rauchs, M., 2017).
- One of the bitcoin news sites had also made an attempt to map the mining facilities, these results were used as a comparison as well (Tuwiner, J., 2017)

3.2 Bitcoin Carbon Footprint Discussion

The comparisons with other studies showed that their CleanCoin estimates are of a similar magnitude, implying the methodology is sound and the results accurate.

We based assumptions on the distribution of miners in Europe and in global mining pools when they are public and spread over different locations on findings in the Cambridge study and the Bitcoin news site. These data were used to calculate the emission factors for the electricity used by all mining pools where the origin is unknown or described as global. This emissions factor is then changes as changes occur in the geographical distribution of the mining pools. Another assumption made based on the Cambridge study, is that the mining pools in the regions around Tibet and Sichuan source their electricity from hydro power plants (Hileman, Dr. H. & Rauchs, M., 2017). In other remote areas in China, it is common for the mining pools to source electricity directly from coal power plants (Simon, J. & Wong, J.I. 2017).

For the calculations of geographical distribution, we assumed that the hashrate share between countries has been roughly the same since the start.

Hashrates, however, have changed a lot over time. We used data from a scenario study of Bitcoin to track historical hashrates (Cocco, L. & Marchesi, M., 2016). For the live calculation, the hashrate distribution is continuously updated from blockchain.info and the emission factor for the total Bitcoin network changes depending on this distribution.

For the material impacts it is assumed that all miners use the five most efficient ASICS miners; Antminer S7, Antminer S9, Antminer R4, Antminer T9 and Avalon 6 (Bitcoinmining.com, 2017; cryptocompare.com, 2017). In addition to this, a power supply is needed for each unit (Antminer Distribution Europe, 2017). The average hashrate for these models (8.59 TH/s) as well as the average weight (6.5 kg including power supply) are used to calculate the power consumption of these units. The average efficiency of these miners is 0.17 W/Gh, the efficiency used for the calculation is therefore 170 W/Th.

The amount of hardware used can be linked to the hashrate, one unit can produce a certain hashrate and thus if the total hashrate of the network is divided by this number we get the total units needed to keep the network running. It is assumed that the average miner replaces the hardware every two months (Cocco, L. & Marchesi, M., 2016), therefore the units used during a year is six times the number we get when dividing the total hashrate by the hashrate for an average mining unit. The hardware is assumed to come in cardboard boxes, with Styrofoam protection, and plastic film. It is assumed that every package consists of 500 g of cardboard, 500 g of Styrofoam, and 100 g of plastic film. This data is used to calculate the material carbon footprint per tera-hash.

3.3 Bitcoin Carbon Footprint Assumptions

3.3.1 Power consumption

- Where it cannot be established if the miners in a Chinese area use hydro or coal, it is assumed they use grid electricity
- Where it is unknown how big mining factories in China are, their power usage is assumed based on the map of mining facilities provided in the cryptocurrency benchmarking study
- When a mining pool states it is global, it is assumed that the locations are equally distributed between USA, Canada, China, EU and Latin America
- When a mining pool states its origin is in several countries, it is assumed that miners are equally distributed between these countries unless there is information stating otherwise
- For the power consumption, it is assumed that all miners use the five most efficient ASICs currently on the market (Antminer S7, Antminer S9, Antminer R4, Antminer T9 and Avalon6). The average efficiency from these three miners are used for the calculation of energy consumption.

3.3.2 Material consumption

- For the material consumption, the average weight of the three mentioned miners is used to get the life cycle emissions from production and waste management
- For the material consumption, it is assumed that a power supply weighs 2.5 kg and is needed for every miner
- The miner hardware is assumed to be equal to a mini server, which has an emission factor of 56.1 kg CO_2e/year when not counting the electricity use during the use phase
- The power supply is assumed to be equal to a UPS unit, which has an emission factor of 14.65 kg CO_2e/year
- It is assumed that the miners change their hardware every 2 months to keep up with the efficiency rate of the network, this means almost 6 million miner units are used during the year
- It is assumed that all miners and power supplies are bought in packages consisting of 500 g of Styrofoam, 100 g of plastic packaging film, and 500 g of cardboard box

3.4 Ethereum Carbon Footprint method

The carbon footprint of Ethereum was calculated using a similar method. The geographic distribution of mining pools is live updated on the webpage ehermine.org (2017). Approximately 56% of Ethereum miners are located in Europe, 26% in China, and 18% in the US.

We used the eight most efficient GPUs as hardware for the calculation of an average hashrate (28.38 Mh/s) and efficiency (7.7 W/Mh) (Sanders, S., 2017; Radeon, 2017; Buntix, JP, 2017). We assume that the hardware uses the same kind of power supply as for bitcoin. The total weight of the hardware is 3.65 kg, and the packaging materials are assumed to be the same materials and amounts as for the bitcoin hardware.

3.5 Ethereum Carbon Footprint Assumptions

3.5.1 Power consumption

- It is assumed that all Ethereum miners in China use grid electricity
- For the power consumption, it is assumed that all miners use the eight most efficient GPUs currently on the market (Radeon RX Vega 56, Radeon RX 480 and 580, GeForce GTX 1060 and 1070, NVIDIA GTX 1070, and Sapphire Radeon RX 470 and 480). The average efficiency, 5.4 W/Mh, from these eight miners are used to calculate energy consumption

3.5.2 Material consumption

- For the material consumption, the average weight of the eight mentioned miners is used to get the life cycle emissions from production and waste management;
- For the material consumption, it is assumed that a power supply weighs 2.5 kg and is needed for every miner;
- The miner hardware is assumed to be equal to a small electrical item, which has an emission factor of 11.2 kg CO_2e/year when not counting the electricity use during the use phase;
- The power supply is assumed to be equal to a UPS unit, which has an emission factor of 14.65 kg CO_2e/year when not counting the electricity use during the use phase;
- It is assumed that the miners change their hardware every 6 months to keep up with the efficiency rate of the network;
- It is assumed that all miners and power supplies are bought in packages consisting of 500 g of Styrofoam, 100 g of plastic packaging film, and 500 g of cardboard box each.

4. Comparisons

To give a better picture of what these emissions mean, some comparison figures were found. The total carbon emissions from the Bitcoin and Ethereum networks are compared to country emissions from the World Bank (The World Bank, 2014).

The emissions per transaction was also compared to the emission from data centers per transaction in the Visa network. Since we do not know anything about the travel habits of major mining pool workers, or the business travel involved, or how many of them have office buildings, we decided it was best to only consider data centre emissions from Visa. All numbers were found in Visas annual corporate responsibility report (Visa, 2016).

It was also interesting to compare the carbon footprint of Bitcoin and Ethereum, to that of cash. The data for the banknote carbon footprint comes from a life cycle emissions report done by the Bank of England (Shonfield, Dr.P. et al. (2017). The life cycle footprint includes the material production, the transports involved, the production and electricity use of ATMs, the fact that the banknotes have to be replaced due to use after 2-5 years. The original footprint functional unit is £1000 in £10 banknotes used over 10 years, then we have recalculated this per banknote and times the value of the cryptocurrencies for comparison.

Additional comparisons to alternative cryptocurrency systems and future projections are presented in the White Paper and the Factsheet. To estimate the carbon footprint of the Ripple network we found information on the amount of validators that are currently active and how much energy it is believed they need for their work. According to the Ripple facts presented on the website there are 66 active validator, and it takes about as much electrical power to run a validator as to run an email serve (Ripple (a), (b), 2017). We assume that this presumed email server is equal to a rack server, and the carbon footprint of such a server is 1590 kg CO_2 per year (Dell, 2011). The actual transactions made on the Ripple network in the beginning of November 2017 was 12 transactions per second (Ripple (c), 2017). The carbon footprint per Ripple transaction is then 0.29 g CO_2.

For the future projections we investigated the hashrate growth per month during the last two years for Bitcoin and Ethereum. The Bitcoin hashrate has grown with 8% per month, and the Ethereum hashrate has grown with 18% per month. We then did a projection for the coming years to see what the carbon footprint for the networks could be in the beginning of 2020. In this projection a steady growth is assumed, as well as the currently most efficient hardware which is 0.098 Th/s for Bitcoin and 4.4 Mh/s for Ethereum (Bitcoinmining.com, 2017; Buntix, JP, 2017). The hashrate distribution and thus the electricity emissions factor is assumed to be the same as in the carbon footprint calculations for both networks.

5. Electricity sources

Since one solution for greener blockchains would be to use renewable energy, we examined the energy sources currently in use. By combining data on the geographical distribution of miners with statistics on electricity production by source for each country and region (IEA, 2015), we are able to display the global breakdown of the sources of Bitcoin and Ethereum's electricity supply in a live updating chart on the website.

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