CARBONARA

THE BLOCKCHAIN COINPENSATOR

Carbon Dioxide (CO_2) Compensation for Blockchain Transactions

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Content

How green is blockchain technology?

The Carbonara Coinpensator (carbonara.info) is a blockchain-related open-source project, established by Unibright and Zühlke Engineering. The main goal of the project is to raise awareness about the energy consumption of public blockchains.

Carbonara enables the calculation of the energy consumed by personal blockchain transactions. Depending on various factors like the hashrate at the time of the transaction, mining time and contributing energy sources, #Carbonara proposes an approximated carbon dioxide amount to be compensated in green energy projects.

Photo by Roman Bozhko on Unsplash

Motivation

Preliminary Notes

Blockchain, as a technology, is still finding its way to mass adoption. Starting with the blockchain based cryptocurrency *Bitcoin* in 2009, the ecosystem around blockchain has evolved ever since, generating a wide range of protocols, applications, implementations, consulting providers and many other roles and players.

Still, in 2019, the best-known application for blockchain is cryptocurrencies – and among the most famous ones, Bitcoin and Ether are under the reputation to be implemented on protocols that are very energy consuming.

Moreover, cryptocurrencies – offering anonymity, or at least pseudonymity, by design – are under the reputation to be intransparent concerning their participants. This holds true for both users of the networks (those who send and receive cryptocurrencies via transactions) and the enablers of the network (those who "mine" new transactions to be put into the blockchain).

It is not an easy task to give an exact answer to the question "How much energy did my blockchain transaction consume?", as the calculation is dependant on a large number of parameters, of which the majority can only be estimated.

Carbonara wants to answer some of these open questions surrounding the energy consumption of blockchains. Furthermore, Carbonara wants to show which questions are still open to be answered in the future.

There are three key motivations for working on this project:

1. Creating knowledge around blockchain energy consumption
2. Incentivizing the future of blockchain to be more energy-conscious and sustainable
3. Inspiring individuals to contribute to CO_2 compensation projects

These key motivations are presented in detail in the following sections.

Creating knowledge around blockchain energy consumption

While dealing with the overall topic of blockchain energy consumption, we noticed that much of the information needed was difficult to research. Factors such as mining hardware, differences in energy sourcing in different geographical locations and the unification of available data with estimated data presented a significant challenge for the #Carbonara team. During the research phase and the MVP implementation phase, we gathered a lot of resources, estimations, personal findings and assumptions. Some of them helped us to disprove existing prejudices, while others confirmed them.

We explicitly want to tell the world what we do not know! We want to motivate everybody to participate in finding better data, better sources and calculation parameters leading to better results.

Carbonara wants to raise awareness for blockchain energy consumption. Communities of both the blockchain and compensation domains are encouraged to participate, create further knowledge and spread the word.

Incentivizing the future of blockchain to be more energy-conscious and sustainable

The evaluation of existing blockchain protocols in 2019 still appears to be tightly coupled with the monetary value of the associated cryptocurrency, coin or token. As blockchain technology matures, other metrics will be further taken into account: throughput ("How many transactions are possible per unit time?"), latency ("How long does it take for transactions to appear in the network?"), transaction types ("Token transfers vs. smart contract transactions"), target audience (IOT focused protocols, industry specific protocols, etc) and many more.

In that understanding, the emerging competition among existing and future blockchain protocols will also be coupled to the underlying consensus algorithm and energy consumption related to it. Picking the 'right' protocol for a specific use case will thus also be a question of how much information about the consensus algorithm, the distribution of the network and other eco-related attributes is available.

To reward thoughtful and eco-friendly protocols, certifications will very likely be established in the future, as well as benchmarks and revision processes.

Carbonara shows what parts of information on energy consumption of blockchain we already know, which parts we have to estimate, and how future blockchain projects can build their protocol in consideration of the eco-related effects.

Inspiring individuals to contribute to CO2 compensation projects

Independent to how exact or elaborate the calculations presented in this project may be, we believe that every individual motivated to think about CO_2-compensation of his or her blockchain transactions is already a benefit. We understand #Carbonara as an open project, aiming to integrate many potential partners in the future.

Carbonara is built open to potential compensation partners or online publications including our widgets from the very beginning, and every EUR raised for environmental projects through this project is considered a success in our understanding.

The Setup of #Carbonara

First idea and tasks

Carbonara was set up as a "side-project" between partners Unibright and Zühlke in January 2019. The team consists of members that are also working together on Unibright's Blockchain integration framework.

Being a non-profit project, the target of Carbonara is to be utilized by the community as fast as possible. It has been planned as an open-source project from the very beginning, explicitly motivating interested individuals, research groups or compensation partners to participate.

The idea of Carbonara is specified by a list of tasks to be accomplished.

For a user of #Carbonara we want to…

1. … offer an interface to enter a blockchain wallet address and a time range.
2. … determine transactions on that wallet in the given time range and calculate the related energy consumption.
3. … calculate the carbon footprint of these transactions, based on statistic.
4. … display an amount of CO_2 to be compensated and forward it to existing compensation portals or #Carbonara partners offering specific compensation projects.

Furthermore, we want to…

5. …determine all calculation parameters we would seek to know and include in the formula. Currently, parameters we do not know are estimated. The solution should allow better values to be added, as soon as knowledge rises.
6. … give the user the option to "play" with some parameters, because we do not know all parameters. This "gamification" approach will raise future awareness on how blockchain technology can be developed in an environmentally-friendly manner.
7. … model all formula parts and data sources separately, to allow them to be improved separately.
8. … use Bitcoin as an example. Due to the limited resources on the #Carbonara project, we are fine to use just Bitcoin as an example as long as the concept is open enough to allow the examination of other protocols as well.

Internal Hackathon

After an initial research phase in focus groups on behalf of both Unibright and Zühlke in February and March 2019, the basic implementation of Carbonara was developed in an internal 3-day hackathon of 8 participants from March 13th to March 15th in Bingen, Germany.

The scope of that 3-day-hackathon was:

- Educating the other team members on the learnings from the research phase
- Building a calculation model for estimating energy consumption of Bitcoin transactions
- Structuring the calculation model and dividing it into components to enable future research

- Building a software architecture and an API to implement the model and providing access to other research groups
- Building a web frontend to use the API
- Documenting learnings in this Green Paper
- Contacting potential partners for handling the actual CO2-compensation

The team was joined by a member of eth.events, sharing his knowledge on finding and querying blockchain metadata.

Evaluation, Launch and Afterwork

The hackathon is followed by an evaluation phase, reviewing concepts, testing the software, contacting potential partners and preparing marketing materials in April and May 2019.

The official launch date of Carbonara is set to June 26th, 2019. Future efforts on afterwork, maintenance and enhancements are equally spread between Unibright and Zühlke and given to the open-source community.

Implementation Details

The Carbonara backend is written in .NET core. Without referencing any third party tools under further licencing, the backend is platform-independent. The API is set up as REST Services. The application is hosted under the German Microsoft Azure cloud and can be found under carbonarabackend.azurewebsites.net

The HTML5 frontend is written in React and can be found under carbonarafrontend.azurewebsites.net

All developments are published open-source under GPL V3 licence, and can be found on the Carbonara GitHub-Repository: github.com/carbonara-coinpensator

The Formula

To calculate the amount of CO2 used for a single transaction in a blockchain, we need to combine a number of individual data points. Starting from the available hash rate in the world down to the geographical distribution of mining pools together with the typical energy mix used by these pools - and all of this relative to the time when the transaction was mined.

Basic definitions

Let tr denote a single transaction. The block, in which the transaction is mined, is then $B_{tr,0}$, and the following and previous block is denoted as $B_{tr,+1}$ and $B_{tr,-1}$, respectively. The timepoint of publishing block $B_{tr,0}$ is defined as $\mathrm{time}(B_{tr,0})$ and is a part of the block data structure. The period of time, in which $B_{tr,0}$ is mined and in which energy is required, is named Δt_{tr} and defined as:

$$\Delta t_{tr} = \mathrm{time}(B_{tr,0}) - \mathrm{time}(B_{tr,-1}).$$

Similar to the block time, we require also the amount of transactions per block. This varies naturally per block, since it depends on how many users want to submit a transaction. The function $\mathrm{trans}(B)$ returns the number of transaction of block B.

In the following, we consider all used elements as parameterized by the time in which the block of the transaction of interest was mined. This is for the sake of simplicity.

Average energy consumption

To determine the average energy consumption, we need to estimate how many machines with an average size of compute power and energy consumption are active. Let M be such a machine, then M_H is the hashrate per second of this machine while requiring M_P kilowatts of electrical power. To get an estimate of how many of such machines are used in parallel, we need to take the full hash rate of all active mining pools – and thus all machines – into account. This hash rate is denoted as F_H.

The energy consumption $E(tr)$ for a single transaction tr is computed as:

$$E(tr) = \frac{\frac{F_H}{M_H} \Delta t_{tr} M_P}{\mathrm{trans}(B_{tr,0})}$$

Estimating the CO_2 footprint

With the function $E(tr)$ we know about the required energy to mine a single transaction. This is independent of who is mining except that the estimation for the average machine M must be valid. But for the CO_2 footprint, it is quite important to understand which kind of energy mix the various active mining pools use.

Each mining pool p has assigned a hash power $H(p)$, a geographic location $\mathrm{geo}(p)$ and a carbon footprint $C(p)$ relating tons of CO_2 to energy in kWh. With that information we can estimate the carbon footprint $C(tr, p)$ of a transaction tr and Pool p as:

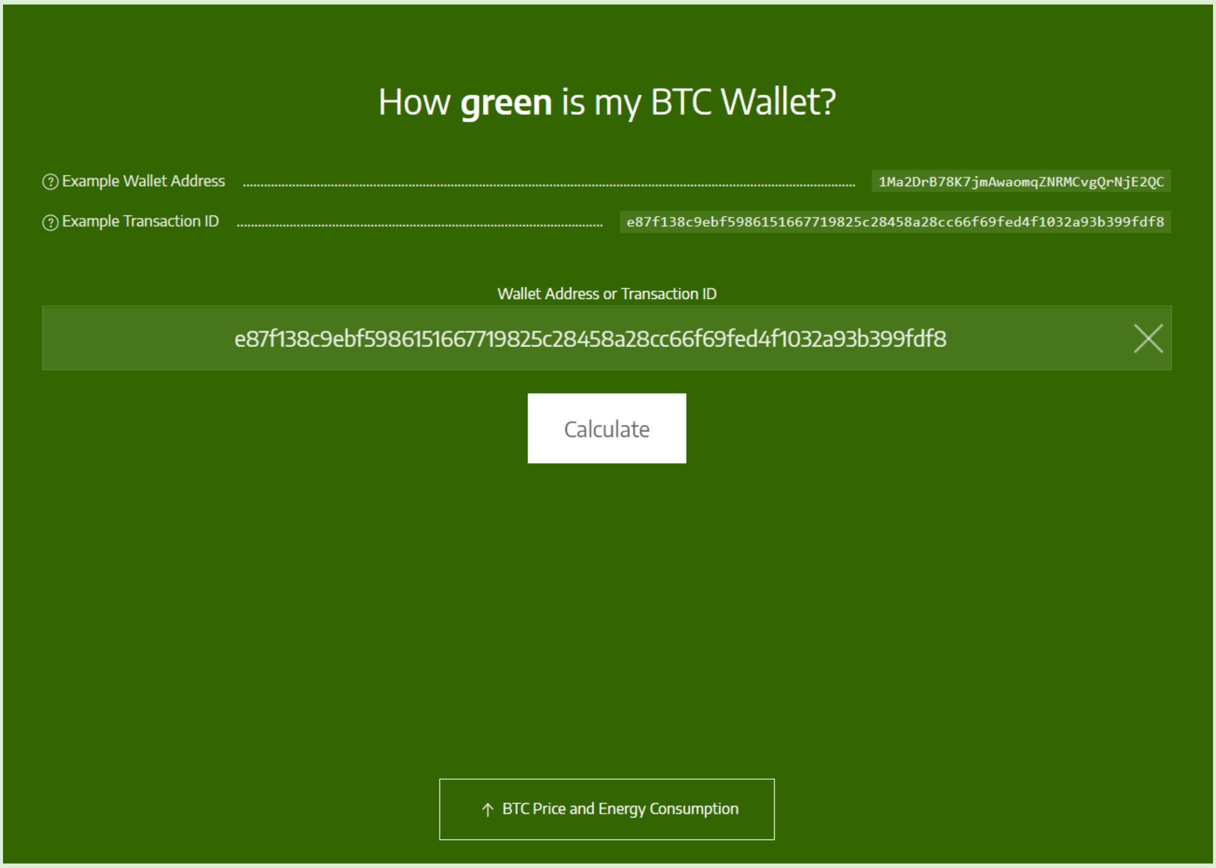
$$C(tr,p) = E(tr)\frac{H(p)}{\sum_{p\in P} H(p)}C(p)$$

The entire carbon consumption across all pools p from the set of all pools P:

$$C(tr) = E(tr)\sum_{p\in P}\frac{H(p)}{\sum_{p\in P} H(p)}C(p)$$

Fundamental Data Sources and an Example Walkthrough

To explain the underlying concepts, the application of the formula and the quality and source of the fundamental data used, an example walkthrough is provided.



How **green** is my BTC Wallet?

Example Wallet Address: 1Ma2DrB78K7jmAwaomqZNRMCvgQrNjE2QC

Example Transaction ID: e87f138c9ebf5986151667719825c28458a28cc66f69fed4f1032a93b399fdf8

Wallet Address or Transaction ID: e87f138c9ebf5986151667719825c28458a28cc66f69fed4f1032a93b399fdf8

At the frontend, **we start by either entering a Bitcoin wallet address or a Bitcoin transaction ID**. If a wallet address is entered, the user can select a transaction from that wallet. The state of the application at the time of the initial release only allows one transaction to be calculated at a time. Nevertheless, both the frontend and backend are already prepared to calculate multiple transactions at a time:

We start by **calculating the total energy consumption of the network for one transaction.** In order to get to that, we first need the transaction ID. That ID is used to fetch the current and previous block information which is used later in the calculation.

The service we currently use for fetching this information is https://chain.so. It is restricted due to the number of requests per second, so any future update of an API that can be triggered more frequently will be helpful. After that, calculating multiple transactions will be easily possible.

Returned block parameters look like this:

- *NumberOfTransactionsInBlock* – Read from the transaction block information
- *BlockTimeInSeconds* – Calculated by reading the previous block time and subtracting
- *TimeOfBlockMining* – Time when the block was mined, read from the transaction block information

What we need next is the actual global hash-rate at the time when the transaction was mined as well as an approximation of the mining hardware power used for that year.

Global hash rate is fetched from the following source: https://api.blockchain.info/charts/hash-rate

For the approximation of the mining hardware, we fallback to a static file *MiningHardware.json,* which contains a list of the most popular mining rig with its hash-rate and energy consumption for a given year. This list is assembled by going through the available specifications and selecting the technical specs of a well-known and established mining rig which came to market in that specific year. Based on https://en.bitcoin.it/wiki/Mining_hardware_comparison, we chose well known ASIC miners, then researched the production date and created a matrix binding production Date (year) to Name-of-ASIC and Hashing-Power and Power-Consumption. This is another subject for further improvement by the community.

From there, we get the following two values:

- *AverageMachineHashRate* – Hash rate of the rig as defined in the specification
- *AverageMachineEnergyConsumptionInKWH* – Energy consumption of the rig as defined in the specification

Finally, with the given data, we can calculate the total energy consumption for a given transaction. We do that in the method named *CalculateFullEnergyConsumptionPerTransactionInKwhByDevice* with the following steps:

- *NumberOfMachinesDoingTheMining = NetworkHashRate / AverageMachineHashRate*;
- *EnergyConsumptionPerMachinePerBlock*
  *= AverageMachineEnergyConsumptionInKWH * BlockTimeInSeconds / 3600;*
- *FullEnergyConsumptionPerTransaction*
  *= NumberOfMachinesDoingTheMining * EnergyConsumptionPerMachinePerBlock / NumberOfTransactionsInBlock*

Now that we have the energy consumption for a transaction, we can move on to **extract the distribution of the global hash-rate among pools for that date**. This is done by taking the timestamp of the mined block and use it to fetch the relevant data from the *HashRateDistribution.json* static file.

Data in this file is fetched from https://btc.com/stats/pool – Historical Distribution chart, where we currently split each year into two periods, and use the half of the year and end of the year distributions for each period respectively. Currently, the starting year is 2013.

The returned value is a list of pool objects containing:

- *Name* - Name of the pool
- *Percent* – Percentage of the pool participation in the global hash-rate for the given year period
- *PoolType* – Categorization of the pool (will be explained later in the document)

We now use the global pool hash-rate distribution to **distribute the energy consumption of a transaction per pool**. The result is:

- *EnergyConsumptionPerPool* – Key-value collection of pools with their energy consumption, based on the *FullEnergyConsumptionPerTransaction* and their participation in the global hash-rate at the moment of mining.

Next**, we need the geographical distributions of the hash-rate for each pool**. This data is stored in another static file - *HashRateDistributionPerPool.json.* Sources for this distribution are the coinbase data from BTC pool and https://slushpool.com/stats/?c=btc – Hashrate per Location graph for Slush pool. For the rest, we just assume that they are mostly working in a single region or are evenly spread (OTH). Again, this data is quite unprecise, especially for earlier years, and is a good starting point for improving the calculation by the community.

This is where the *PoolType* value comes in. It represents our **custom categorization of the pools, based on which we spread the distribution of their hash-rate across different countries/regions**. There are five categories:

BTC, SLUSH, US, CN, OTH

Distribution in those categories is spread geographically like this:

- BTC: China – 60.8%, EU – 25.2%, US – 14% -
- SLUSH: Canada – 14.65%, China, 5.8%, EU – 45.65%, Japan – 1.36%, Singapore – 0.94%, US – 31.99%
- US: US – 100%
- CN: China – 100%
- EU: EU – 100%
- OTH: US – 33.33%, China – 33.33%, EU – 33.33%

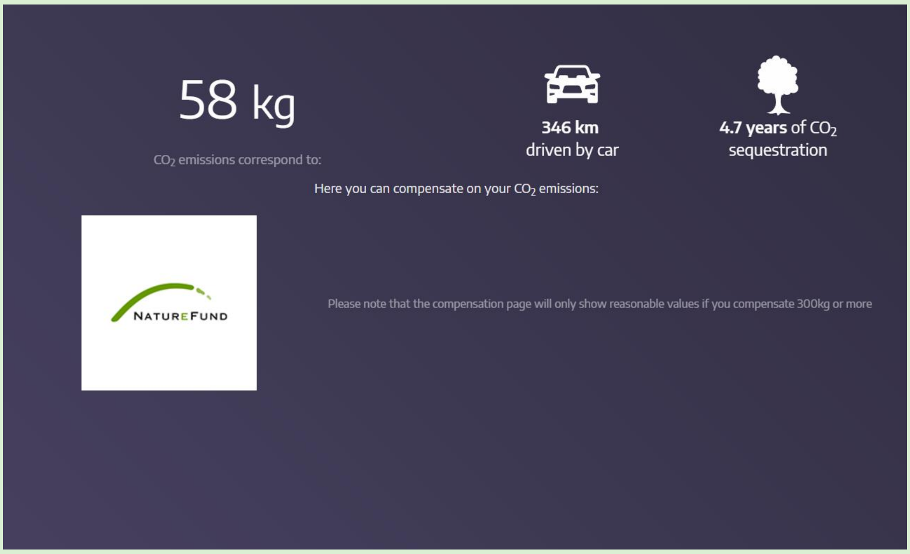
With this data we can further **distribute the transaction energy consumption per country**. We go through the *EnergyConsumptionPerPool* key-value collection and for each pool, based on its *PoolType,* distribute the energy consumption per region. Then we sum the consumption of each pool for a given region and arrive at:

> *EnergyConsumptionPerRegion* – *K*ey-value collection of regions with their energy consumption, based on the *EnergyConsumptionPerPool* and the pool geographical hash rate distribution.

Finally, we come to the last part of the formula. **The energy consumption is spread per country and we now need information about the average CO2 emission per each KWH of energy produced for those countries.** We fetch this data from another static file *CountryCo2EmissionPerKwh.json* which is populated from http://www.compareyourcountry.org/climate-policies?cr=oecd&lg=en&page=2.

In order to get to the final calculation**, we apply the average CO2 emissions on the energy consumed by a specific region, sum all the regions emission up and come to a number representing the emission of CO2 per transaction.** To better understand what the emission means, we also calculated the corresponding distance driven by car and the corresponding timespan on how long one tree would need to sequestrate that amount of CO2.

- We assume 1km driven by an average car leads to 6 kg of CO2
- We assume that one tree can sequestrate 12,175 kg of CO2 in one year



58 kg

CO_2 emissions correspond to:

346 km driven by car

4.7 years of CO_2 sequestration

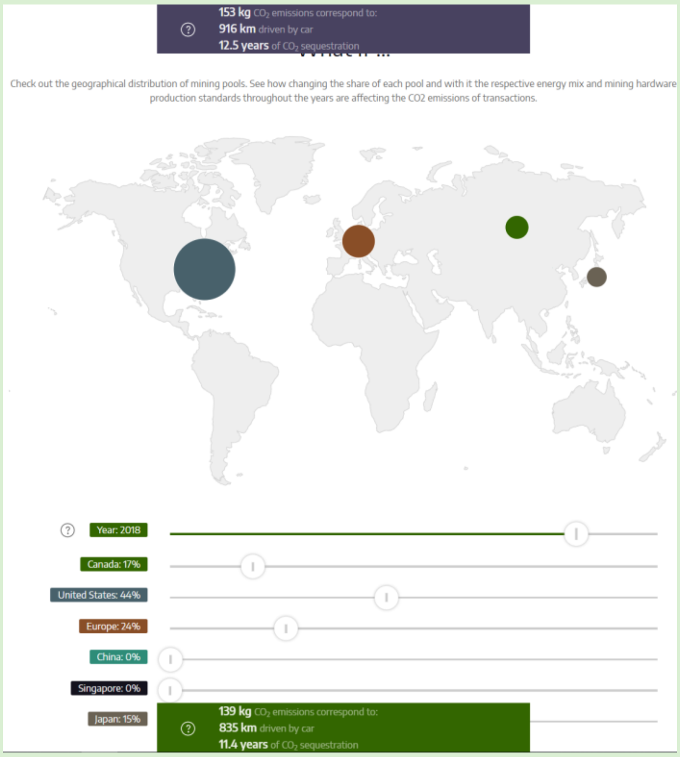
Here you can compensate on your CO_2 emissions:

Please note that the compensation page will only show reasonable values if you compensate 300kg or more

After the presentation of the final result, we give the option to compensate the calculated amount of CO2 with our partner naturefund.de

As compensation (in planting trees) will only show reasonable values if the user compensates on 300kg or more, we motivate each user to not only compensate single transactions. As soon as the feature of calculating multiple transactions at once is available, compensating on higher values will be more comfortable.

The application closes with a “gamification graph”.



153 kg CO_2 emissions correspond to:
916 km driven by car
12.5 years of CO_2 sequestration

Check out the geographical distribution of mining pools. See how changing the share of each pool and with it the respective energy mix and mining hardware production standards throughout the years are affecting the CO2 emissions of transactions.

Year: 2018
Canada: 17%
United States: 44%
Europe: 24%
China: 0%
Singapore: 0%
Japan: 15%

139 kg CO_2 emissions correspond to:
835 km driven by car
11.4 years of CO_2 sequestration

In that gamification graph we allow the user to play around with some of the input parameters of the formula. We show the years where the user can manipulate the mining equipment used by the formula and see what would be the CO2 impact in case that the whole network used the equipment from the selected year. The user can also manipulate the geographical distribution of the hash-rate and see what would be the impact in case, for example, all Bitcoin pools were based in the EU.

Future Work and Call for Participation

Unibright and Zühlke will continue supervising the Carbonara project and its enhancement. However, the long-term benefit of Carbonara will be dependent on the participation of willing individuals, research groups, partner portals and companies.

Please contact us and/or contribute to Carbonara if you want to…

- … provide better data on parts of our calculation
- … provide data on other Protocols
- … include the Carbonara backend on your blockchain explorer
- … integrate Carbonara on your compensation project
- … write an article, tweet, interview or blog entry on Carbonara

Further Inquiries:

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Github:

https://github.com/carbonara-coinpensator

Disclaimer

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