

Carbon Dioxide (CO2) Compensation for Blockchain Transactions

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# “How green is blockchain technology?”

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

**To motivate the personal examination of the topic, #Carbonara enables the calculation of consumed energy of personal blockchain transactions.** Depending on different factors like given hashrate by the time of 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 exactly tell “How much energy did my blockchain transaction consume”, as the calculation is dependant on a large amount of parameters, of which the majority can only be assumed, estimated or sometimes even guessed.

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

The motivation for working on this project can be explained by three key incitements.

1. Creating knowledge around blockchain energy consumption
2. Incentivizing the future of blockchain to be more energy attentive and sustainable
3. Inspiring individuals to contribute to CO2 compensation projects

These key incitements 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 many parts of the information needed are hard to research. Many different domains like mining hardware, differences in energy sourcing in different geographical locations and the missing unification of available data with estimated data challenged the #Carbonara team big time. 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 others confirmed them.

We explicitly want to especially 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 blockchain and compensation domain are encouraged to participate, create further knowledge and spread the word, non-profit oriented.

## Incentivizing the future of blockchain to be more energy attentive and sustainable

The evaluation of existing blockchain protocols in 2019 still appears to be tightly coupled to the value of the connected cryptocurrency, coin or token. With the maturing of a new technology, other metrics will be considered important to decide for a specific protocol: Throughput (“How many transactions per time period are possible”), latency (“How long do transactions need to be present in the network?”), transaction types (“Token transfers vs. smart contract transactions”) or target audience (IOT focused protocols, industry specific protocols, …) 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 the other about eco-related attributes will be available.

To reward thoughtful and eco-friendly designed 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 on how exact or elaborated the presented calculation of this project may be, we believe that every individual motivated to think about CO2-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 assumptions whose parameters can optionally be varied by the user.
4. … display an amount of CO2 to be compensated and forward it to existing compensation portals or #Carbonara partners offering specific compensation projects.

Furthermore, we want to…

1. …determine all calculation parameters we would love to know and include them in the formula. Parameters we do not know now are approximately estimated. The solution should allow better values to be added, as soon as knowledge rises.
2. … want to give the user option to “play” with some parameters, because we do not may know all parameters. This “gamification” approach will raise future awareness on how blockchain technology can be expanded in an ecologically sensitive manner.
3. … model all formula parts and data sources separately, to allow them to be improved separately.
4. … using 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 both Unibright and Zühlke side in February and March 2019, the basic implementation of #Carbonara was aroused in an internal 3-day hackathon of 8 participants from March 13th to March 15th in Bingen, Germany.

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 fronted to use the API
* Documenting the 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 March and April 2019.

The official launch date of #Carbonara is set to April 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 put many information particles together. 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 denote a single transaction. The block, in which the transaction is mined, is then , and the following and previous block is denoted as and , respectively. The timepoint of publishing block is defined as and is a part of the block data structure. The period of time, in which is mined and in which energy is required, is named and defined as

.

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. Function return the number of transaction of block

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 come towards the energy consumption, we need to estimate how many machines with an average size of compute power and energy consumption are active. Let be such a machine, then is the hashrate per second of this machine while requiring kilo Watt of electrical power. To get estimate how many of such machines 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 .

The energy consumption for a single transaction is the computed as

## Estimating the CO2 footprint

With function we know about the required energy to mine a single transaction. This is independent of who is mining except that the estimation for average machine must be valid. But for the CO2 footprint, it is quite important to understand which kind of energy mix the various active mining pools use.

Each mining pool has assigned a hash power a geographic location and a carbon footprint relating tons of CO2 to energy in kWh. With that information we can estimate the carbon footprint of a transaction and Pool as

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

# 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.

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 block and previous block information which is used later in the calculation.

The service we use now for fetching the information is [https://chain.so](https://chain.so/).

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 and is a 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.

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 the <http://www.compareyourcountry.org/climate-policies?cr=oecd&lg=en&page=2>.

In order to get to the final calculation, we apply the avg 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 C02 per transaction.

In the ‘gamification’ graph we allow the user to play around with some of the input parameters of the formula. On the y axis 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. On the x axis, the user can manipulate the geographical distribution of the hash-rate and see what would be the impact in case that, for example, all bitcoin pools were based in the EU.

TODO: Insert Screenshots of the Frontend and explain the actions in the backend taking place to provide the result. Specifically pay attention to mentioning our information sources (and our “guessings”) on:

* Mining
* Pools
* Geographicals Distribution
* Consensuns Algorithms
* Hashrates
* Energy types
* CO2 consumption comparisons
* …

# Future Work and Call for Participation

Unibright and Zühlke will continue supervising the #Carbonara project and its enhancement. Yet, the long-term benefit of #Carbonara will be dependant on participation of interested 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 to your compensation project
* … write an article, tweet, interview or blog entry on #Carbonara

To join, contribute and participate, use one of the channels we established.

* Press contact:
* Contact the Team:
* Join the Zühlke and Unibright Twitter Communities:
* Join Unibright on Telegram:

# Disclaimers

DISCLAIMERS ON USED DATA AND APROXIMATIONS