How Eco friendly is our money and is there an alternative?

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***Token money* is money whose face value exceeds its cost of production [1]. Examples of token money include United States Dollar, Euro, Pound, Swiss Franc, Yen and, lately, there has been token money deployment of digital cryptocurrencies, such as *Bitcoin*, *Ether* and *Ripple's XRP*. However, what is the cost of producing a currency? How much does one transaction cost in terms of energy consumption? What carbon footprint does money leave and are there more Eco friendly options? This paper will shed light on the energy consumption of a few currencies and make comparisons to real life examples. The goal is to make you look at the money production from an energy consumption point of view, and understand that there can be large economic and environmental benefits of choosing one currency over the other, on a macroeconomic level.**

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INTRODUCTION

What carbon footprint does money leave behind and how energy efficient is it? Are some currencies more environmentally friendly than others? We wish to make a comparison in an easy and understandable way. We then need to quantify the underlying efficiency of moving and upholding current money systems.

The following currencies will be compared :

- American Dollar (USD) - on Visa network
- Bitcoin (BTC)
- Ethereum (ETH)
- Ripple (XRP)

The currencies will be measured in electricity consumption and carbon footprint. A comparison will be made between the currencies and households, dishwashers and the number of car miles driven. Furthermore we will look at some Fortune top 50 companies [2] such as Facebook, Alphabet (Google) and Amazon, and even the energy consumption of entire countries. Some (to the best of our knowledge) of the performed calculations, comparisons and conclusions have never been published before, and we hope this paper will act as a starting point for discussions concerning the existential purpose of money and what currency fits that purpose the best, further we hope more calculations will be made which will enable people to better understand and benchmark current and future currency systems on a holistic level.

MONEY IS ALL ABOUT EFFICIENCY - A HISTORIC PERSPECTIVE

One of the fundamental properties of money is that it should be a good *medium of exchange*. Its purpose is to enable more efficient trade. Before the introduction of token money, welfare improving trades would only occur if there existed a *double coincidence of wants*. A good medium of exchange creates a situation where agents on the market do not have to rely on the existence of said double coincidence of wants. They trade goods and services for that medium of exchange and later buy the goods and services they want. Before the introduction of token money there was no standardized value in the middle. To put it in layman's terms: money should make it cheaper to enable trade. Keeping this in mind one could ask the question on whether we can measure which kind of token money costs the least.

Let us dig deeper into the efficiency and cost of money. We can now start looking at the comparison between currencies in terms of electricity consumption and how they relate to other big energy consumers.

A. Macro perspective

In this section we look at the electricity consumption of a number of currencies, including XRP, the cryptocurrency issued by the United States based company Ripple. We will later compare the currencies to the the electricity consumption of companies as well as countries in order to gain some perspective on world wide power consumption.

We begin by looking at the table 1, which shows the annual electricity consumption of four currencies. The * indicates electricity consumption via Visa network and throughout the paper we will use USD on Visa networks as a guideline for USD. We

Table 1. Annual electricity consumption C, [3, 4]

Currency	TWh
Bitcoin (BTC)	26.05
Ether (ETH)	9.68
Visa* (USD)	0.5406
Ripple (XRP)	0.000536112

selected the Visa ledger to represent USD because it's the current largest USD network in terms of transactions in the world with a total of 82.3 billion transactions in 2016 [5]. This table demonstrates the amount of power that is required for each of the currencies yearly. Note that the table does not take into account the number of transactions made with each currency. More on this in subsection B.

Table 2. Annual electricity consumption [3, 6–9]

Country	TWh	Company	TWh
Syria	18.24	Apple	1.454
Ecuador	21.96	Facebook	1.83
Nigeria	25.5	Google	6.20
United States	3913	Amazon	7.2

Table 2 shows the annual electricity consumption of four countries and four large international companies.

It appears the amount of power required to have *Bitcoin* running is comparable to the energy consumption of entire nations. Bitcoin is consuming substantially more electricity than Syria and Ecuador annually, and almost equal to Nigeria's consumption. Apple, Facebook, Google and Amazon have the common denominator that they run some of the largest server farms in the world, giving a good indicator what, so-called, "large energy usage" sums up to in TWh numbers. Notice how all these companies combined only use 64% of Bitcoins annual energy use, compared to Ripple's XRP who only uses a super small fraction compared to any of these companies.

Keeping in mind *Bitcoin* is not even a widely used currency (in a comparative example to USD or other big currencies), one cannot hesitate to think there must be a less costly option in terms of electricity consumption.

B. Comparative section

Let's begin by looking at how the energy consumption of the four currencies in Table 1 compare to U.S households:

As indicated in table 3, *Bitcoin* seems to be very costly in terms of how many households (2,4 million) could be powered, compared to Visa (41,000) and Ripple's (XRP) with only 50 households worth of energy usage to uphold its entire system.

Until this point we have only looked at how the annual energy consumption of each currency compares with that of nations and some of the world's largest companies. This was done in order to shed light on how costly some of the currencies can be, even without taking into consideration the amount of transactions that are made for each currency. In order to create a fair comparison *among* the currencies one must, of course, compare

Table 3. Number of U.S. households that could be powered by each currency (C).

Currency	Households
Bitcoin (BTC)	2, 412, 037
Ether (ETH)	879, 629
Visa (USD)	41351
Ripple (XRP)	50

the consumption *per transaction*, rather than the total consumption. By doing so we can get a fair estimate of how the currencies compare if they were used to the same extent. Then we can create real life comparisons of how much power could be saved if one currency was used instead of another.

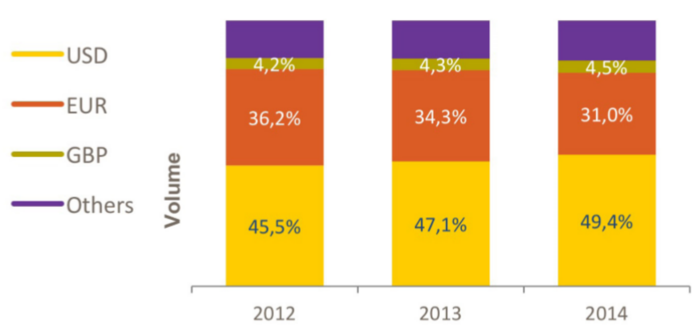
Let us begin by looking at how much electricity is used for one single transaction for each of the currencies. The table clearly shows the superiority of *Ripple's XRP* over for instance *Bitcoin (BTC)*. A more intuitive way of showing the benefits of having a lower energy consumption is to relate it to real life examples. This will be done in subsection B. Note that there are two possible ways to calculate electricity *per* transaction. See table 14 for the distinction between *current* annual transactions and *potential maximum* annual transactions.

Table 4. Electricity consumed per transaction

Currency	KWh
Bitcoin (BTC)	118
Ether (ETH)	20.294
Visa (USD)	0.006490
Ripple (XRP)	0.00001133

The distribution of transactions are shown in figure 1 below, where we can see that USD is the most commonly used currency of 2012-2014 and that none of the current cryptocurrencies yet has a noticeble amount of tranactions. Bitcoin only averages about 300, 000 transactions per day in 2017. [10]

Fig. 1. Worldwide international currency usage, 2012-2014



Notice how energy usage per transaction for Ripple is equivalent to 0.0021% of Bitcoin and 0.0056% of Ether. Even more remarkable is that it's significantly lower than Visa, which has been around for decades and is built to be as efficient as possible.

Fig. 2. Annual TWh consumption

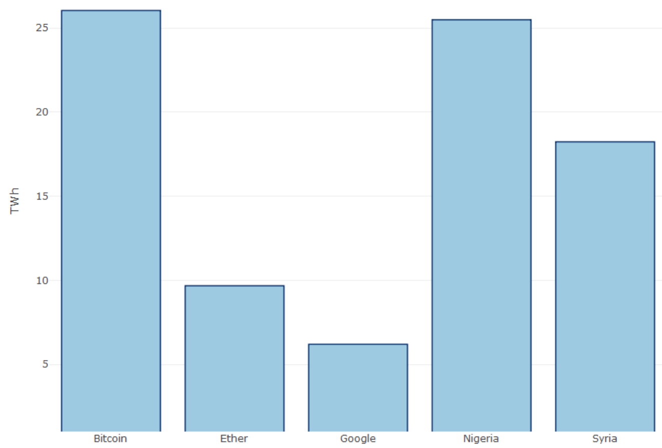


Figure 2 shows the annual energy consumption of Bitcoin and some of the countries and companies mentioned above in the tables. This gives a clearer picture on how costly Bitcoin actually is for the environment.

Hypothetical scenario

Suppose that Visa, Ether and Ripple's XRP would have the same amount of transactions as Bitcoins hypotetical maximum: Today Bitcoin can sustain *maximum* 7 transactions per second [11], that is

$$7 * 60 * 60 * 24 * 365 = 220.752M$$

annually.

How would the currencies compare in their total energy usage and in comparison to other electricity powered commodities?

Table 5. Hypothetical annual electricity consumption with 220.752M transactions

Currency	TWh
Bitcoin (BTC)	26.05
Ether (ETH)	12.141
Visa* (USD)	0.001, 432, 68
Ripple (XRP)	0.000, 002, 501

In table 5, get a better understanding of the currencies energy usage with the same number of transactions (220.752M). This improves our insight into how costly Bitcoin and Ether is compared to both Visa and Ripple's XRP. Further we see that Ripple is the most efficient currency in terms of energy use, only using 0.17% of the second most energy efficient money system (Visa).

Columns 2-4 in Table 6 show the number of light bulbs, dishwashers and car miles driven that could be powered by the energy use of 220.752M transactions for each of the currencies. We use a Tesla Model 3 as guideline, equipped with entry model

Table 6. Number of light bulbs, dishwashers and driven car miles that could be powered by the energy use of 220.752M transactions

Currency	Light bulbs	Dishwashers	Car-miles driven
Bitcoin (BTC)	148.68M	69.577M	114.75 Billion
Ether (ETH)	69.29M	32.42M	52.48 Billion
VISA (USD)	8177	3826	6.311 Million
Ripple (XRP)	14	6	11018

battery capacity (50KWh). See appendix C for further assumptions. A low number represents a more energy efficient currency, a direct example of this would be if you deducted the number of dishwashers with Ripple from Bitcoins number of dishwashers:

$$69.5777M - 6 \approx 69.577M$$

you get the number of dishwashers that could have been powered by the saved energy if using Ripple instead of Bitcoin. See calculations C. Using the same technique, we can easily calculate substantial numbers. Given this hypothetical scenario, if everybody switched from Bitcoin to Ripple's XRP with the saved energy we would be able to go to the moon and back 240.000 times! This assuming that the "Biohazard filter" in Tesla Model 3 would enable protection from the vacuum in space, and the power in the battery would allow the car to fly and not just spin it's wheels. This gives a completely new perspective of a currency actually "going to the moon".

Quantifying in terms of USD

Leaving the hypothetical scenario behind, we will now compare the currencies' actual energy consumption by quantifying the electricity use into the cost of USD. Highlighting electricity usage in cost of USD as well as doing comparisons to cost of commodities gives us a better understanding of the cost of transactions and upholding the money systems. Highlighting costs for basic tasks such as making a transaction makes one realize that less cost enables more transactions and vice versa.

Furthermore, this cost have to be paid by the participating parties using the currency. In the case of Bitcoin, Ether and Ripple (XRP) the cost is added directly as a transaction fee, or it can be added indirectly where the fee is included in the goods' or services' price, leaving customers paying a higher price or businesses with lower margins or fewer sales. It's obvious there are benefits for all parties using a currency which enables trade with lower costs, especially for transfers.

Table 7. Cost in USD for current annual energy usage

Currency	USD
Bitcoin (BTC)	3.124 *billion*
Ether (ETH)	1.161 *billion*
VISA (USD)	64.87 *million*
Ripple (XRP)	64333

From a cost perspective we have several billions reasons to switch from Bitcoin to Ripple's XRP.

Table 8. Cost in USD per transaction

Currency	USD
Bitcoin (BTC)	14.1 *USD*
Ether (ETH)	2.45 *USD*
VISA (USD)	0.07 *cents*
Ripple (XRP)	0.000136 *cents*

Table 7 and 8 represent the actual cost in terms of electricity used, translated into the average cost of 0.12 USD per KWh [12]. When we calculate cost in this way we get more of a whole system approach to cost rather than just the direct cost materialized in the fee's you pay for a transaction. How can the current transfer fees be lower than *true cost* and why do we measure the true cost? Firstly, miners often get a subsidized price on electricity [3]. Secondly, in the case of Bitcoin and Ether the miners are provided with dual payments from transaction fee's and in form of direct payment from the system in the form of "mined" Bitcoins or Ether. Both these circumstances can subsidize the transfer fee's.

Some people reading this will object to this type of calculation because it shows higher transfer fees than would actually be paid, but we argue that showing the total cost is more important in the perspective of showing cost, especially when cost relates to CO2 emissions.

We would have gotten an even higher total cost per transfer if we had chose to calculate the actual current amount of transactions instead of potential maximum for current system. More on this in tables 13 and 14.

Table 9. Cost of 104.2M transactions in USD, iPhone X and Tesla Model 3

Currency	USD	iPhone X	Tesla model 3
Bitcoin	1469.22M	1.46922M	4198
Ether	255.29M	255,290	729
VISA	72940	73	2
Ripple (XRP)	141.7	0	0

In Table 9 we highlight the total cost of Bitcoins current anual transaction amount with current energy costs (0.12 USD per TWh) in USD with Bitcoins current annual transactions (104.2M). We then calculate how many iPhone X and Tesla Model 3 this would buy. We want to show which currency costs the lowest amount of electricity and what one could buy if we swished from one currency to another. We later make comparative examples if Ether, Visa and Ripple's XRP would have the same amount of transactions as bitcoin has today (104.2M).

As we can see in table 9, we could finance

$$4198 - 0 = 4198$$

extra Tesla Model 3's if Ripple's XRP was used instead of Bitcoin. Even though this is a somewhat extreme example, it shows there can be large benefits of using XRP as opposed to Bitcoin on a macroeconomic scale.

DISCUSSION

A background check

Both Bitcoin and Ethereum have an inbound design with "proof of work". Proof of work is a vehicle by which someone can prove effectively to you that they have engaged in a significant amount of computational effort. This is done by servers solving highly complex mathematical equations to create new blocks on blockchains, giving birth to new coins in the system (the reward for mining). These power hungry systems require huge amounts of electricity which makes the cost per transaction extremely high. The average Bitcoin direct transaction fee today is around 10 US Dollars, even if you just transfer 1 US Dollar in value [5]. In this particular case, the transaction fee is 1000 percent of the actual transferred amount. To put this in perspective, the transaction fee is now more than twice the cost of one unit of Bitcoin itself when people first heard of it (5 US dollars in 2011).

To be fair, blockchains are not only about payments. A blockchain can have hundreds of different uses where energy efficiency is not the priority. One can still argue that payments is the underlying cause of any kind of asset movement and one of the fundamentals of a currency. Also, for the sake of this paper, not having too broad of a scope, we focus on currencies as assets to enable payments and value transfer.

Carbon footprint

Proof of work systems are closely linked with high amounts of electricity usage, CO2 emissions and transfer fees. One can judge the system's usability by, among other, its design; it's a system that has less need for trust. This proof of work design also makes it arguably easy to take the opposite standpoint - pointing out the infeasible possibility of these systems and inbound designs to actually replace today's large money systems with vastly larger number of transactions. It would simply not be cost effective. The cost would be too high in both a macro perspective "the earth eco system" and micro perspective "your own wallet".

So how does this electricity usage translate into CO2 emissions? All electricity is not created equally in the case of CO2 emissions. For example, a coal power plant emits 30 times more than a nuclear power plant per TWh! [13]. Also, we know that the creation of electricity varies between countries, ex. China depends 73% on coal [14] compared to USA that only use 52% [15] on average through the country. Also we know that the miners for Bitcoin and Ether are mainly based in China. Bitcoin hashpower (server capacity) is up to 80% China located [16].

This tells us that CO2 emission depends on many variables: where the servers are located, what energy source is used, the CO2 emission that the source emits, and so on.

With this knowledge we know that we would have access to large amounts of specific data sources which tell us these values. We do not have access to such data and believe that our assumptions would be too broad if we were to collect those data from different sources. Therefore we have chosen a straightforward simplistic approach of translating electricity into CO2 emissions. We have chosen to use the following method: On average, electricity sources emit 1.222lbs CO_2 per KWh [17]. This will create a somewhat unfair comparison for Ripple's XRP and Visa since they have almost all nodes in the US and Europe, compared to Ether and Bitcoin which are mainly based in China. Even though the assumption ; 1.222lbs CO2 emissions per KWh favors Bitcoin and Ether, the results are too strong to ignore.

In the following tables we show the current annual CO2 emissions for each of the currencies given their current annual consumption of electricity.

Table 10. Current annual C02 emissions

Currency	LBS of CO2
Bitcoin (BTC)	31833.1M
Ether (ETH)	11828.96M
VISA (USD)	660.61321
Ripple (XRP)	655128

Table 11. C02 emissions per transaction

Currency	LBS of CO2
Bitcoin (BTC)	144.2029
Ether (ETH)	20.003
VISA (USD)	0.00794
Ripple (XRP)	0.0000138

We will now compare a number of things with the emissions from the different currencies, given 220.752M transactions (the current maximum for Bitcoin). Firstly, we compare them with the number of car miles that could be driven for the same CO2. A typical passenger vehicle emits 0.9060 lbs per mile driven [18]. We also look at the number of times a Boeing 747 can travel around the world with the same emission as the different currencies, given 220.752M transactions. According to [19] a Boeing 747 emits $10.1kg/km = 35.83lbs/mile$. Also, the radius of Earth at the equator is 3,963 miles [20]. This tells us that the emission for flying around the globe once is

$$35.83 \times 3963 = 141994.29$$

lbs of CO2. Looking at table 12 we see the calculations of these comparisons given the current amount of maximum TPS (transactions per second) for Bitcoin.

Table 12. Annual CO2 emissions and comparative examples of car miles driven and trips around the world in a Boeing 747

Currency	CO2	Car miles	Boeing 747
Bitcoin (BTC)	31833.1M	35135M	224,185.7
Ether (ETH)	4415.70M	4873M	31,097.7
VISA (USD)	1.7527M	1.9345M	12.34
Ripple (XRP)	3057.26	3374.5	0.021

Table 12 shows the annual number car miles driven and trips around the globe in a Boeing 747 one can get for the same amount of CO2 as the different currencies emit, given 220,079M transactions. A Boeing 747 can take around 550 passengers on a flight. [21]. This means that if we switched from Bitcoin to Ripple's XRP the entire population of Japan (126M [22]) could travel around the globe once each year.

A greener alternative?

Running a validator (server) on Ripple's network does not require any fees and it is comparable in cost in terms of electricity to running an email server [23]. High trade fee gives people incentive to hold assets instead of trading. This compares to, for example, when governments implement contractionary monetary policy and increase the interest rate on loans and savings accounts. This, ceteris paribus, tends to make people hold on to money instead of spending or trading. One could ask if it's good for a currency to have a built-in design that disincentivizes people of trading?

If high fees disincentivize trade the opposite can be stated for low fees. It will enable more trade and higher economic movement, resulting in the exchange of more goods and services at a low cost.

Thinking back on the foundation of money as a *medium of exchange*, we can look at exchange feasibility as a utility where lower fees further utilize the asset potentially making us all wealthier when lower barrier to trade is enabled.

Here we argue that the asset utility is at the core of its valuation because this is what enables efficient trade.

The value of Ripple's XRP lies in its ability to handle transactions and payments at a lower electricity cost and therefore lower CO2 emissions combined with lower trade fees.

CONCLUSION

The aim with this paper is to open a discussion on the topic of sustainability of different currencies. We will briefly touch on the topic of utility because the utility of a currency is bound to its efficiency. A low efficient, energy hungry, carbon emitting, currency is by design more limited than an efficient currency when it comes to some of the most fundamental utilities that a currency enables: trade and payments. It becomes apparent that for a currency to be adopted in the widest way possible, efficiency is on top of the list for having a high yield of utility (payment and trade possibilities). But is it just utility that is behind the actual value? Recall the reasons why money came into existence. It provided agents on the market with an easy and widely accepted medium of exchange. The main point to be made here is that money should increase *efficiency* no matter what trust model the currency uses. It needs to be efficient in order to have a chance of being widely adopted and functional for us all and the planet Earth. Our aim is not to embrace or discredit any model for trust on the basis of its trust component alone. We would rather state that if there is trust (regardless of model enabling it), the main value driver behind this trusted asset is going to be its utility and scalability along with the costs associated with a further utilization and scaling of this asset. In this frame of reference Ripple's XRP is way ahead of it's current competition.

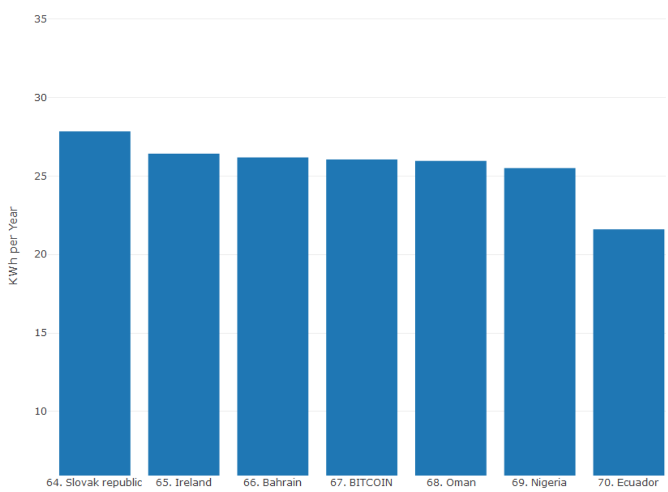
A lot of digital assets lack a clear purpose. They may be used to store value, purchase commodities or for consumer transactions, but were not created with a single explicit application in mind. In contrast, XRP is specifically about the transfer of value and built for banks, financial institutions, payment services, providers and enterprises, making it one of the few digital assets with a real, clear use case behind it. XRP is also in a unique space where it's not built to replace current currencies but to work as a bridge currency where the systems upholding the current currencies can utilize Ripple's XRP for moving their native assets more efficiently and consequently costing less in terms of electricity, C02 emissions and cost less in any currency of your choice that you utilize with XRP.

Bitcoin can process up to maximum seven transactions per second [11], any of which can take more than four hours to clear. Compare that with a traditional payments service, for example VISA, that averages 2,000 transactions per second. It's clear that Bitcoin in it's current state does not have the scalability to meet typical customer demands.

Sustainability

The continuous block mining cycle gives people all over the world incentive to mine Bitcoin. As mining can provide a solid stream of revenue, people (and more lately large companies) are very willing to run power-hungry machines to get a piece of it. Over the years this has caused the total energy consumption of the Bitcoin network to grow to epic proportions, as the price of the currency has reached new highs. The entire Bitcoin network now consumes more energy than a number of countries. If Bitcoin were a country, it would be ranked 67th in the world by energy consumption, see figure 3.

Fig. 3. Energy consumption by countries (and bitcoin) [3].



Bitcoin is a mined digital asset, meaning that new coins are created by huge data centers processing complex math problems. This inefficient system demands massive amounts of electricity: the cost of producing one coin could power 3.67 U.S. homes for a day, or 46.75 Hong Kong homes and 25.7 mainland China homes, respectively. [24]

Final thoughts

How big a carbon footprint per transaction do you find acceptable? What is the most sustainable and trustable way of creating a store of value? Do we really need a proof of work to place value into a currency or can utility in itself be the creator of value? High utility in this case is associated with a high number of possible transactions per second and no or little energy cost. Can a currency with high cost in electricity have a sustainable value and is that value worth the cost in the long run? Can we accept (by design) natural resource destruction made by money systems? Should we trust a value more because it costs more for us all or should we place trust in something that costs less, and how would that model look? These are some questions we hope you all ask yourself and continue to have as a guideline forward.

We would argue that new technology should be about making the world a better place for most, if not all people. With provided information in this paper, Which currency does best fit this purpose from a payment perspective according to you and why?

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Some of the references listed below have up to date inputs, which means that they will change at any given time period. Our data was obtained the 13th of November 2017.

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APPENDIX

C. Calculations

This subsection derives all the figures that we calculated throughout the paper. Links to references are provided in each step of the calculation.

Transactions

In terms of calculations for transactions, there is one fundamental difference in the comparison of Visa to the others (Bitcoin, Ether and Ripple (XRP)). For Visa’s transactions we used the current amount 83.2 billion [5] and for the others we used the maximum transactions per second (TPS) the current infrastructure could potentially uphold.

This has the following implications:

1. Visa potentially can handle more transactions under it’s current infrastructure. But it wouldn’t be sensible from a business perspective having much more power than needed, because this creates unnecessary overhead costs. Still we recognize that Visa’s current system probably can handle a bit more transactions for scalability reasons. The comparison is has therefore the potential to be a bit tilted to Bitcoin, Ether and Ripple (XRP) advantage.
2. Bitcoin, Ether and Ripple (XRP) is currently under utilizing it’s potential maximum TPS (transactions per second).

Table 13. Maximum potential transactions annually and Current annual transactions. See subsection *calculations for table 4* for sources.

Currency	Maximum Potential	Current
Bitcoin (BTC)	220.752M	104.2M
Ether (ETH)	473.04M	91.25M
VISA (USD)	Unknown	83.2 billion
Ripple (XRP)	47304M	401.5M

Therefore we are also in this case tilted in favoring Bitcoin, Ether and Ripple (XRP) with current design of the calculations. We encourage anyone that want to calculate current use with current energy usage to do so. But we firmly believe the best way is to calculate current maximum TPS with current energy use to be the best way where possible. Unfortunately (for Visa) in this case this data is not shared by them. When looking at daily graphs of how many transactions Ether [25, 26] and Ripple (XRP) has, we see that they have been averaging about 250k and 1.1M respectively. This gives

$$250k \times 365 = 91,250,000 \quad \text{and} \quad 1.1M \times 365 = 401.5M$$

Table 14. KWh per transaction (current) and maximum TPS

Currency	KWh per Maximum potential	KWh per current numb
Bitcoin (BTC)	118	250
Ether (ETH)	55	106
VISA (USD)	Unknown	0.006490
Ripple (XRP)	0.00001133	0.0013352

Calculations for Table 1 (Annual TWh)

Visa

According to USA Today [27], the Visa network electricity consumption equals to the electricity consumption of 25,000 US households in the year 2011, that same year the Visa network had about 50.9 billion number of transactions [28]. In 2016 there were 83.2 billions transactions on the Visa network [5]. Thus we assume that since the number of transactions nearly doubled, the number of US households energy equivalent also nearly doubled. The increase was $\frac{80.3}{50.9} \approx 1.65$, or 65%. This gives $25000 \times 1.65 = 41351$ Households the year 2106.

Households has an average of 10800 KWH [12]. This gives

$$\frac{X}{10800} = 41351 \;\Rightarrow\; X \approx 540MKWh = 0.54TWh, \qquad (1)$$

where X represents the annual energy consumption of the Visa network. Digiconomist [3] calculated a similar number estimating Visa network annual energy consumption equal to that of 50,000 U.S. households in 2016.

Ripple (XRP)

In order to calculate the annual TWh of Ripple we reasoned as follows: In the words of the creators of XRP (Ripple), *"How much does it cost to run a validator? - It is comparable in cost to running* ***an email server*** *in terms of electricity."* [23]

- Current amount of validators : 72 [29]
- Current amount of verified validators : 22 [29]

Average electricity consumption for a mail server is 7,446 kWh per year. [30]. This gives

$$7446kWh * 72nodes = 536112kWh = 0.000536112TWh. \qquad (2)$$

Currently, only the *verified* validators are needed to sustain 1500 TPS (transactions per second), which means only 22 validators are needed to sustain current throughput in TPS. We choose to include all validators including the non-verified because we see their current state as a necessary first step to become a verified validator, therefore should be calculated in the total TWh.

Calculations for Table 3 (Annual U.S. households)

Visa

The Visa network electricity consumption equates of 25,000 US households the year 2011 [27]. That same year, the Visa network had about 50.9 billion number of transactions [28]. In 2016 there were 83.2 billions transactions on the Visa network [5].

The increase was $\frac{80.3}{50.9} \approx 1.65$ This gives

$$25000 \times 1.65 = 41351$$

households in 2016.

Bitcoin

Bitcoin has an annual consumption of 26.05TWh [3], and households have an average of 10800 KWH [12]. This means

$$\frac{26050MKWh}{10800} = 2,412,037 \quad (3)$$

US households could be powered by Bitcoins electricity consumption.

Ripple (XRP)

Ripple has an annual consumption of 0.000536112 TWh, see calculations for table 1. US Households has an average of 10800 KWH [12]. This means

$$\frac{536112KWh}{10800} = 49.64 \approx 50 \quad (4)$$

US households could be powered by Ripples (XRP) electricity consumption.

Ether

Ether has an annual consumption of 9.68 TWh [4]. US Households has an average of 10800 KWH [12]. This means

$$\frac{9680MKWh}{10800} = 896296.2962 \approx 896,296 \quad (5)$$

US households could be powered by Ethers electricity consumption.

Calculations for table 4 (Electricity per transaction)

Ripple

In order to get Ripple's per electricity cost we used [31], which states that Ripple's XRP can sustain 1500 transactions per second, that is

$$1500 * 60 * 60 * 24 * 365 = 47304M$$

transactions annually. This gives

$$\frac{536112}{47304M} = 0.00001133KWH \text{ per transaction.} \quad (6)$$

Bitcoin

In order to get Bitcoin's electricity cost per transaction we used [11], which states that Bitcoin can sustain *maximum* 7 transactions per second.

$$7 * 60 * 60 * 24 * 365 = 220.752M$$

transactions annually.

$$\frac{26050MKWh}{220.752M} = 118.00, \quad (7)$$

where M denotes millions.

Ether

We use the same procedure as for Ripple. Ether can sustain 15 transactions per second [31]. that is

$$15 * 60 * 60 * 24 * 365 = 473.04M$$

transactions annually.

$$\frac{9600MKWh}{473.04M} = 20.294, \quad (8)$$

Visa

Visa has 0.54 TWh annual electricity and 83.2 billion transactions per year [5]. This gives

$$\frac{540MKWh}{83200M} = 0.00649. \quad (9)$$

Calculations for table 5 (Annual electricity consumption with 220.752M transactions)

Bitcoin

Bitcoin's annual energy consumption is stated in table 1, and its equal to 26.05 TWh per year with 104.2M transactions, but can potentially uphold 220.752M transactions with current infrastructure and coding.

Ether

Ether costs 55KWh per transaction, see calculations for table 4. Using the same amount of transactions as Bitcoin can currently sustain, i.e 220.752M, we get the following annual consumption:

$$220.752M \times 55 = 12141MKWh = 12.141TWh. \tag{10}$$

Visa

The Visa network costs 0.00649 KWh per transaction. Given 220.752M annual transactions (bitcoins potential sustainable maximum), we get

$$220.752M \times 0.00649 = 1.43268MKWh = 0.00143268TWh \tag{11}$$

of annual consumption.

Ripple (XRP)

Ripple (XPR) costs 0.00001133 KWh per transaction. Given 220.752M annual transactions (bitcoins potential sustainable maximum), we get

$$220.752M \times 0.00001133 = 2501.12KWh = 0.000002501TWh \tag{12}$$

of annual consumption.

Calculations for table 6 (Number of light bulbs, dishwashers and driven car miles that could be powered by the energy use of $220.752M$ transactions)

Here we calculate the number of light bulbs and dishwashers that could be powered for one year by the electricity usage of the different currencies in table 5. We also calculate the number of car miles that could be driven by that electricity.

According to [32], a dishwasher uses 1200 W. A standard light bulb uses 40 W. We use the following formula in order to calculate the TWh per year:

$$\frac{Watts \times \text{Hours used per day} \times \text{days per year}}{1000} = KWh \text{ Consumption}$$

Assuming that a light bulb is on 12 hours per day, every day of the year, we get $\frac{40\times12\times365}{1000} = 175.2$. We also assume that a dishwasher is used 3 times per week, assuming 2 hours of usage each time, we get: $\frac{1200\times2\times156}{1000} = 374.4$.

A tesla model 3 has a standard battery of 50 KWh [33] and it has a range of 220 miles. [34]. This tells us that is uses $\frac{50}{220} =$ 0.227 KWh per driven mile.

Bitcoin

Bitcoins annual usage is 26.05 TWh. This gives

$$X \times 175.2 = 26050MKWh \rightarrow X = 148.687M \tag{13}$$

light bulbs could be powered every year.

Moreover,

$$Y \times 374.4 = 26050MKWh \rightarrow Y = 69.5779M \tag{14}$$

dishwashers could be powered every year.

Lastly, let's look at the number of car-miles that could have been driven for the same electricity consumption:

$$Z \times 0.227 = 26050MKWh \rightarrow Z = 114.755Billion \tag{15}$$

car miles could be driven.

Ether

Ethers annual usage given the hypothetical scenario is 12.141 TWh. This gives

$$X \times 175.2 = 12141MKWh \rightarrow X = 69.297M \tag{16}$$

light bulbs could be powered every year.

Moreover,

$$Y \times 374.4 = 12141MKWh \rightarrow Y = 32.427M \tag{17}$$

dishwashers could be powered every year.

Lastly, let's look at the number of car miles that could have been driven for the same electricity consumption:

$$Z \times 0.227 = 12141MKWh \rightarrow Z = 52.484Billion \tag{18}$$

car miles could be driven.

Visa network

Visas annual usage given the hypothetical scenario is 0.00143268 TWh. This gives

$$X \times 175.2 = 1432680KWh \rightarrow X = 8177 \quad \textbf{(19)}$$

light bulbs could be powered every year.

Moreover,

$$Y \times 374.4 = 1432680KWh \rightarrow Y = 3826 \quad \textbf{(20)}$$

dishwashers could be powered every year.

Lastly, let's look at the number of car-miles that could have been driven for the same electricity consumption:

$$Z \times 0.227 = 1432680KWh \rightarrow Z = 6.3113Million \quad \textbf{(21)}$$

car miles could be driven.

Ripple (XRP)

Ripple (XRP)'s annual usage given the hypothetical scenario is 0.000002501 TWh. This gives

$$X \times 175.2 = 2501KWh \rightarrow X = 14 \quad \textbf{(22)}$$

light bulbs could be powered every year.

Moreover,

$$Y \times 374.4 = 2501KWh \rightarrow Y = 6.7 \quad \textbf{(23)}$$

dishwashers could be powered every year.

Lastly, let's look at the number of car miles that could have been driven for the same electricity consumption:

$$Z \times 0.227 = 2501KWh \rightarrow Z = 11018 \quad \textbf{(24)}$$

car miles could be driven.

Calculations for Round-trips to the moon

On average, the distance from Earth to the moon is about 238,855 miles [35]. The difference between using Bitcoin and using Ripple (XRP) in amount of car miles driven is

$$114.75 \ \ Billion - 11018 \approx 114749990000.$$

This means the amount of times we could go to the moon if Ripple (XRP) was used instead of Bitcoin (in this hypothetical scenario) is

$$\frac{114749990000}{X} = 238,855Miles \rightarrow X = 480,416.94. \quad \textbf{(25)}$$

We could actually go to the moon 240208 times back and forth if ripple (XRP) was used instead of Bitcoin, given that the milage was the same as a Tesla model 3.

Calculations for table 7

12 cents per KWh is a typical residential rate [12], we therefore use this number when calculating prices of KWh.

Bitcoin

$$26050MKWh \times 0.12 \ \ USD = 3.124 \ \ billion \ \ USD \quad \textbf{(26)}$$

Ether

$$9680MKWh \times 0.12 \ \ USD = 1.161 \ \ billion \ \ USD \quad \textbf{(27)}$$

Visa network

$$540.6MKWh \times 0.12 \ \ USD = 64.87 \ \ million \ \ USD \quad \textbf{(28)}$$

Ripple (XRP)

$$536112KWh \times 0.12 \ \ USD = 64333.44 \ \ USD \quad \textbf{(29)}$$

Calculations for table 8 (Cost in USD per transaction)

We use the hypothetical maximum number of transaction for each of the currencies.

Bitcoin

$$\frac{3.124 \ \ billion \ \ USD}{220.752M} = 14.1USD \quad \textbf{(30)}$$

Ether

$$\frac{1.161 \ \ billion \ \ USD}{473.03M} = 2.45USD \quad \textbf{(31)}$$

Visa network

$$\frac{64.87 \ \ million \ \ USD}{83.2 \ \ billion} = 0.07cents \quad \textbf{(32)}$$

Ripple (XRP)

$$\frac{64333.44 \ \ USD}{47304M} = 0.000136cents \quad \textbf{(33)}$$

Calculations for table 9 (Cost in USD for 104.2 M transactions)

Bitcoin

$$14.1\ \ USD \times 104.2M = 1469.22M\ \ USD \tag{34}$$

Ether

$$2.45\ \ USD \times 104.2M = 255.29M\ \ USD \tag{35}$$

VISA

$$0.0007\ \ USD \times 104.2M = 72940USD \tag{36}$$

Ripple(XRP)

$$0.00000136\ \ USD \times 104.2M = 141.7USD \tag{37}$$

Now we look at the number of Iphone X's we could by, we estimate the cost of the Iphone X to be 1000 USD [36].

Bitcoin

$$\frac{1469.22M\ \ USD}{1000} = 1.46922M\ \ Iphone\ \ X \tag{38}$$

Ether

$$\frac{255.29M\ \ USD}{1000} = 255290\ \ Iphone\ \ X \tag{39}$$

VISA

$$\frac{72940\ \ USD}{1000} = 72.94\ \ Iphone\ \ X \tag{40}$$

Ripple (XRP)

$$\frac{141.7USD\ \ USD}{1000} = 0.14\ \ Iphone\ \ X \tag{41}$$

Now we look at the number of Tesla model 3 we could by, we estimate the cost of the tesla model 3 to be 35,000 USD [37].

Bitcoin

$$\frac{1469.22M\ \ USD}{35,000} = 4197.77\ \ Model\ \ 3 \tag{42}$$

Ether

$$\frac{255.29M\ \ USD}{35,000} = 729.4\ \ Model\ \ 3 \tag{43}$$

VISA

$$\frac{72940\ \ USD}{35,000} \approx 2\ \ Model\ \ 3 \tag{44}$$

Ripple (XRP)

$$\frac{141.7USD\ \ USD}{35,000} \approx 0\ \ Model\ \ 3 \tag{45}$$

Calculations for table 10

On average, electricity sources emit 1.222lbs CO_2 per KWh [17].

Bitcoin

$$26050M \times 1.222lbs = 31833,1M \tag{46}$$

Ether

$$9680M \times 1.222lbs = 11828.96,31M \tag{47}$$

VISA

$$540.6M \times 1.222lbs = 660.61321M \tag{48}$$

Ripple (XRP)

$$536112 \times 1.222lbs = 655128.864 \tag{49}$$

Calculations for table 11

LBS CO2 emmisions per transaction for all of the currencies.

Bitcoin

$$\frac{31833,1M}{220.752M} = 144.2029 \tag{50}$$

Ether

$$\frac{11828.9631M}{473.04M} = 20.003 \tag{51}$$

VISA

$$\frac{660.61321M}{83.2\ \ Billion} = 0.00794 \tag{52}$$

Ripple (XRP)

$$\frac{655128.864}{47304M} = 0.00001384933 \tag{53}$$

Calculations for table 12

CO_2 emissions for Bitcoins potential maximum TPS (220.752M) transactions

Bitcoin

$$144.2029 \times 220.752M = 31833,1M \tag{54}$$

Ether

$$20.003 \times 220.752M = 4415.7022M \tag{55}$$

VISA

$$0.00794 \times 220.752M = 1.7527M \tag{56}$$

Ripple (XRP)

$$0.00001384933 \times 220.752M = 3057.26 \tag{57}$$

Now we compare this with the number of car miles which could be driven for the same CO2. A typical passenger vehicle emits 411 grams =0.9060 lbs per mile driven. [18]

Bitcoin

$$X \times 0.9060lbs = 31833,1M \Rightarrow X = 35135.87M \tag{58}$$

Ether

$$X \times 0.9060lbs = 4415.7022M \Rightarrow X = 4873.84M \tag{59}$$

VISA

$$X \times 0.9060lbs = 1.7527M \Rightarrow X = 1.9345M \tag{60}$$

Ripple (XRP)

$$X \times 0.9060lbs = 3057.26 \Rightarrow X = 3374.459 \tag{61}$$

Lastly we look at the number of times that a Boeing 747 can travel around the world with the same emission as the different currencies given 220.752M transactions. According to [19] a Boeing 747 emits 10.1kg/km = 35.83 lbs/mile. Also, the radius of Earth at the equator is 3,963 miles [20]. This gives the emission for flying around the globe once is

$$35.83 \times 3963 = 141994.29$$

lbs of CO2.

Bitcoin

$$X \times 141994.29lbs = 31833,1M \Rightarrow X = 224,185.7 \tag{62}$$

Ether

$$X \times 141994.29lbs = 4415.7022M \Rightarrow X = 31097.7 \tag{63}$$

VISA

$$X \times 141994.29lbs = 1.7527M \Rightarrow X = 12.34 \tag{64}$$

Ripple (XRP)

$$X \times 141994.29lbs = 3057.26 \Rightarrow X = 0.021 \tag{65}$$

Additional Tables and Graphs

Fig. 4. Total number of transactions per day made in complete payment networks

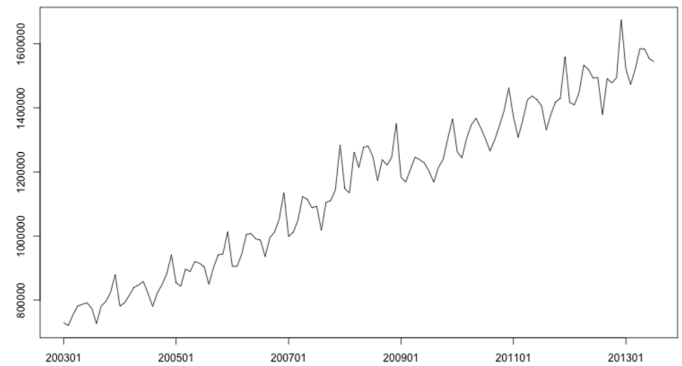

Fig. 5. Caption of how much one bitcoin transaction can cost. 2017-11-12.