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Research on the Problem of the Efficiency of Bitcoins: The Energy Costs for the Generation of This Cryptocurrency on a Global Scale

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Abstract. The work is devoted to the problems of efficiency of bitcoins, especially power inputs due to generating of this cryptocurrency. Nowadays the problems of mining power input efficiency seem to have passed from a comparative problem to the problem of existence of this blockchain technology, requiring a different engineering policy or different managerial decisions. The comparative analysis of bitcoins generating power input and the world's power input has shown that there are almost no trustworthy methods of evaluating input power for blockchain technologies. This problem is solved by application of contemporary methods by setting up big mining companies, located in areas with cheap electric energy and free power balance, possessing their own technological resources and thinking of creating alternative power capacities for mining objectives. At that the state systems start to introduce various limitations for power capacities used for crypto-currencies including quotas and price privileges. Represented are the results of the analyses of the dynamics of alternation of the main parameters, influencing power consumption at generation of bitcoins on the basis of available literary data and own investigation. Given are the results of calculations regarding bitcoins generation, the costs of consumed electric power per mining of one bitcoin. A more objective index of bitcoin power consumption is suggested, it being correlated with its unit and the unit of heshrate e_h showing that $N_{btc} \cdot LgH$ duplex is constantly growing despite a decrease in general mass of generated bitcoins, while the relative bitcoin energy consumption decreases with time, still such decrease happens slower than the growth of its market value.

Keywords. bitcoin energy consumption, blockchain technologies, cryptocurrency mining, power input efficiency, power consuming, heshrate.

1. Introduction

Bitcoin, though its creators are convinced of its exceptional decentralized and inclusive systematic character, actually possesses one quite centralized controlled function. This is technological energy consumption, which is controlled and in case some effort is exerted can give information, regarding the state of the system , being the dominant factor for the system. Miner's activity is reduced to selecting all variants to solve the task of determining the necessary hash. Such work requires:

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- access to the source of electric power;
- corresponding capacity of computer hardware;
- operation velocity;
- hashing volume.

Access to electric energy appears to be the weakest spot for the blockchain technology. Mining can’t be done without application of electric power sources.

Energy consumption remains so far an insurmountable obstacle for development of the blockchain technologies, alongside with acquisition of costly mining equipment. According to the data provided by I. Kaminski the average amount of power, consumed on mining operations throughout nowadays world can be compared with energy consumption on the island of Cyprus [1]. Dino Mark Angaritis believes that in 2015 the average number of solutions with regard to hash search for each mining problem was equal to 3·1020 hashes, it being beyond the capabilities of many types of computer resources [2]. The data regarding power consumption on mining operations, provided by different sources differ very much, just showing quite a big value, that could be compared with the level of power consumption of such countries like Switzerland, Kuwait [3], Austria, Argentina [4, 5] et al. A. De Vries, the creator of Diginomist index believes that with application of the most up-to-date computer hardware at least $15 \cdot 10^6$ MWt·h. of the world electric power has to be consumed on mining, even the figure $30 \cdot 10^6$ MWt·h. is not the limit, as the system of nowadays mining, including its operational modes is a kind of a «black box» [6]. According to the data provided in [7] generating of 18 million of bitcoins, already completed, required about $20 \cdot 10^6$ MWt·h. or 0.13% of the total world’s energy consumption. According to the data, mentioned in [8] at the total world energy consumption of $158 \cdot 10^9$ MWt·h, generation of bitcoins cost only $9.6 \cdot 10^6$ MWt·h. or just 0.006% of the world’s consumption. According to the data, provided by A. Narayan [9] in 2018 $1{,}8 \cdot 10^6$ MWt·h. of energy was spent on bitcoins. In 2019 году according to the data, provided in [10] the general consumption on bitcoins was equal to – $53 \cdot 10^6$ MWt·h. The data, provided by M. Straube, the German mathematician [11] the annual world’s energy consumption is at least $14 \cdot 10^6$ MWt·h. According to the words of the scientists, working at Lawrence Laboratory in Berkley it was supposed that by the year of 2020 energy efficiency of the branch could grow by 45%. The specific growth was equal only to 3-5%.

In general such numerous comparative evaluations can provide information verifying the fact that there are practically no reliable methods of evaluating power consumption at mining and in general for the blockchain technologies.

Transition of mining procedures to big specialized companies, possessing tremendous technological resources leads to the fact that many countries start to imitate access to the sources of electric energy for them. The farms, as a rule, are set up in the regions with cheap electric energy and free energy balance. Still, China. Embracing more than 80% of the world mining market introduced limitations on energy resources used on crypto-currencies, not only in limits, but also in privileges in price policy. Some US states, Canadian, Italian, suppliers gradually introduce such limits for their mining farms and special «workshops» that include a great number of powerful video cards. The mining companies are seriously considering the problems of creating powerful energy capacities of their own, especially for mining objectives.

2. The main material

With the increase in the volume of operational stock of bitcoins, involved into work, the task of selecting variants of hash search becomes more complicated, its record length grows, making the task of searching a hash-reply much more difficult, thus requiring an essential increase in power consumption. Just within the period between 2016-2020, according to the data mentioned in [12], bitcoins hashing operations became 5 times more complicated, it inevitably caused a substantial growth in power consumption.

The average transactions time of a regularly scheduled unit, determining the velocity of these operations has varied since 2012 within rather wide limits [12, 13] depending on the system load. A steady dynamics (see Fig.1) can be observed only due to appearance of new mining devices and technologies, for instance, during the period of active mining by private participants in 2012-2016 (area I) on the basis of the first GPU-video cards in the first decade of this century, when mining farms amalgamated, or during the period between 2017-2020 (area III), when more powerful mining machinery emerged: the up-to-date ASIC (Application Specific Integrated Circuit mining), especially well-known ASIC Antiminer S9, Bitmain S9, system, Bitmain S9, «cloud» mining, more traditional Antiminer S7, Antimner D3, by Bitmain company [14], using Scrypt algorithm. In general the contemporary bitcoins mining is executed by the devices, the aggregate capacity of which exceeds $9\cdot10^3$ MWt·h.

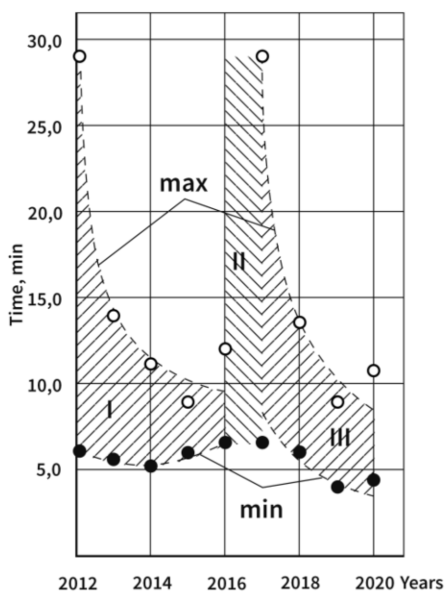


Figure 1. The dynamics of the average duration of a transaction and confirmation of a mining unit (the data provided by [13] source)

The dynamics of average daily transactions since 2012 is represented in Fig. 2. The aggregate bitcoins hashing only between April 2019 and March 2020 was within the values of 40 TH/s to 100 TH/s, the difficulty of the mining problem being increased by 2.5 times [16]. Undoubtedly, we should expect growth in power inputs per a unit of cryptocurrency, the design data are shown in Fig. 3.

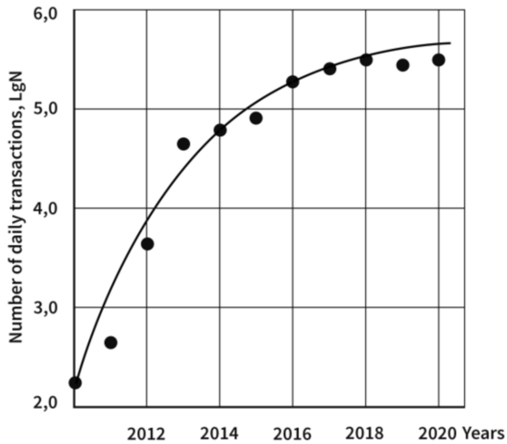


Figure 2. The dynamics of daily confirmed transactions in the bitcoin system (the data taken from [15] source)

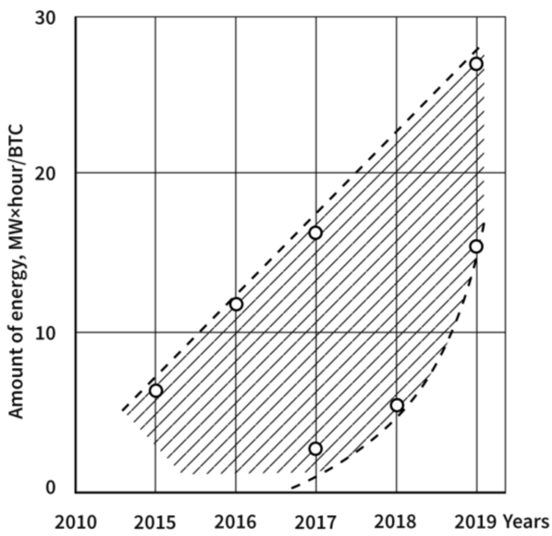
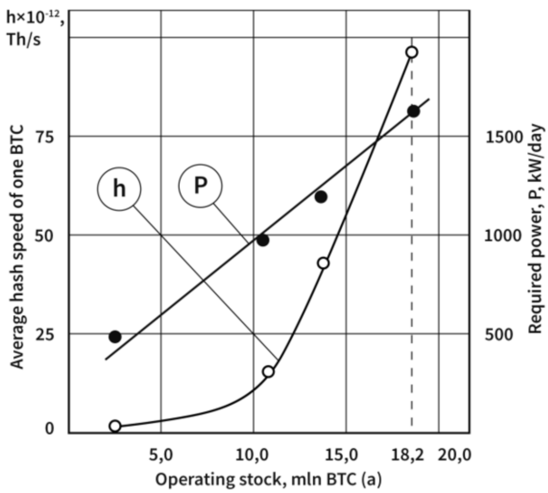


Figure 3. The design bitcoin annual power consumption

In 2010 hash rate of mining of one unit, consisting of 50 bitcoins was equal to $1{\cdot}10^{-11}$ TH/s, or per one bitcoin $0.2{\cdot}10^{-12}$ TH/s [17]. Later, after every of 250 thousand of generated units (12.5 million bitcoins) system required a new unit size, consisting of 25 bitcoins, hash rate each of them amounted to $1.4{\cdot}10^{-11}$ TH/s [18, 19], while after 2015 for each of 12.5 unit bitcoins that figure was equal to $4.5{\cdot}10^{-11}$ TH/s.

The growth in enumeration of possibilities for the search of a new hash also required an increase in engineering power consumption (see Fig. 4a). It's logical to maintain that reconsideration of the volume of one unit in favor of its preservation or increasing can promote energy saving, so this variant may be worth discussing. Hashrating of such volumes is beyond the opportunities of private miners and for larger companies it means variants enumerating, expressed by the figure with 21 zeroes (zeta) and at such capacity the last bitcoins have to require $n=1\cdot10^{24}$ hashrating units (see Fig. 4b).



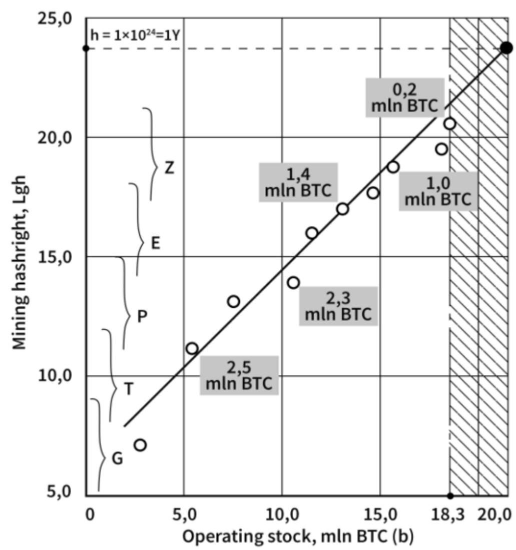


Figure 4. Dynamics of hashing of one bitcoin and requirements in powerful equipment (a) for ensuring the necessary hashrate capacity, depending on application of the entire operation resources of bitcoins (b) (acc. to the data, provided in [20] source)

With regard to the fact that all participants must their hashing apparatuses working 24 hours a day we are able to evaluate energy consumption both of transacting and mining. In practice miners' operating modes (except the companies dealing with professional mining) are far from being uniform, it making any balance calculations of integral inputs power merely evaluative. It can be shown that such calculations are far from being real. That is the reason why it is very difficult to select an objective system of evaluating power inputs for the blockchain technology. Due to the efforts by Michel Rauchs from Cambridge Centre of Alternative Finances there appeared an index of energy consumption by bitcoin CBECI (Cambridge Bitcoin Electricity Consumption Index), it helped aided to launch in real time the meter of total energy consumption in the network of bitcoins.

Today, it's the most efficient method and real data on power inputs in the blockchain technologies. In March 2020 (when the article was written) that index was fluctuating within $(33.5 \div 96.1) \cdot 10^6$ MWt·h [6], it being 0.21% of the world's energy supplies [21]. It was shown that in a year $12.5 \cdot 6 \cdot 24 \cdot 365 = 657$ thousand bitcoins are generated, thus in 2020 one bitcoin requires 96.4 MWt·h. (though the design data, see Fig.3 give the result two times less as compared to the data supplied in that source). At the average price of 1 KWt·h \$0.07 the costs of power inputs on mining of one bitcoin is \$48.20. According to the data provided by M. Rauchs power inputs per one bitcoin [6] in 2018 were equal to 33 MWt·h. and its price was \$2.310. This figure is quite comparable to our evaluations (see Fig.3). Growth both in power inputs per one bitcoin and the power input share in its production cost is evident. Despite growth in the volume of hashing and energy value of each subsequent bitcoin total consumption of electric energy on mining operations in the system of bitcoin are systematically reducing (Fig.5). The reason is restricted only by the opportunities, provided by the designers of up-to-date mining facilities.

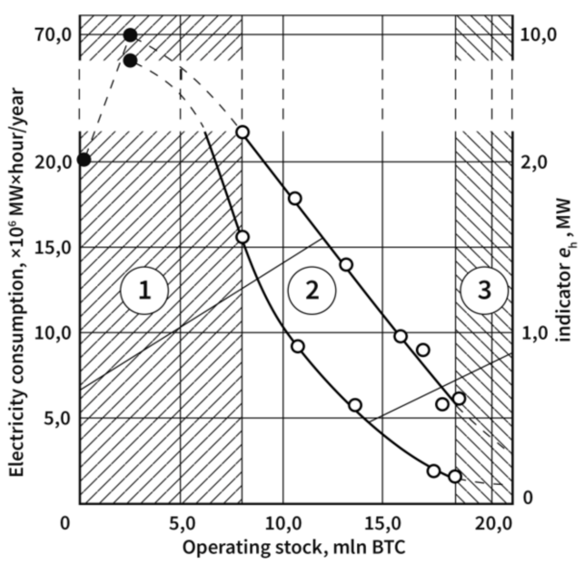


Figure 5. The dynamics of energy consumption of the bitcoins market in 2000- 2020 and energy value of one bitcoin: 1 – the area of evaluating data; 2 – area of the design data; 3 – the forecast area

Professional mining becomes more and more oriented on small methods of energy saving, for example, application of PoS (Proof-of-Stake) system, instead of the algorithm of conclusive consensus of PoW (Proof-of-Work) type, as a way of reduction in energy consumption by mining equipment and ensuring the system safety. It should be noted that the schedule (see Fig.5) does not take into account such events like, for example, bankruptcy of Mt. Gox company, and losses of more than 750,000 bitcoin units in 2014, or release of the final version of Bitlicense, development of the bitcoin project in 2015, or the scandal with «Silk Road» web-site in 2013, when the system of bitcoins was used for drugs trading, and these certainly influenced the dynamics and energy of hashing and supporting of transactions in the system.

The dimensional quantity of energy consumption reflects more precisely the value of generated power inputs of bitcoins, it should be brought in correlation not only to one bitcoin, but also to one hash rate in its logarithmic expression (1):

$$e_h = \frac{E}{N_{btc} \cdot LgH} . \quad (1)$$

The formula takes into account not only reduction of the number of generated bitcoins in time interval, but also growth in volumes of the required hashrate within this interval. These indices are interrelated and they accompany further development of the blockchain technology of bitcoin. e_h index, unlike power input shows in the schedule the opportunity for minimal satiation of bitcoin power input with approximation to the specified limit of 21 million bitcoins (see Fig.5). The terms of bitcoin technology presume that $N_{btc} \cdot LgH$ duplex constantly grows, reducing the mentioned figure of bitcoin power inputs, simply by its existence.

On the other hand, according to the data provided by Digiconomist, in 2019 there were around 100 million of financial transactions for one bitcoin. The share of traditional financial instruments is 500 billion transactions per year. i.e. 5,000 times bigger. But for one traditional financial transaction about $3 \cdot 10^{-7}$ MWt·h of energy is consumed, while for mining of one unit (9 bites) as we have calculated – $96{,}4 \cdot 10^3$ MWt·h. Thus, 100 million of transactions require nearly $1 \cdot 10^4$ MWt·h of energy (without mining), while 500 billion of traditional financial operations require $15 \cdot 10^4$ MWt·h.

It should be noted there that with approximation to the sacred figure 21 million of bitcoins, power input of each of them increases in geometric series and $150 \cdot 10^6$ MWt·h landmark will be achieved very quickly. Even now it is evident that the growing complexity of bitcoin mining must be correlated with its power inputs, which has gradually become a natural limitation for any blockchain systems. Generating of 2.758 thousand bitcoins (approximately 99.8% of the entire pool of bitcoins), remaining prior to 2032, by extrapolating to the present-day situation can require energy consumption exceeding $0.9 \cdot 10^9$ MWt·h, and it is likely to be 4.3% of the world's energy consumption and will be equal to losses on goods production 50 billion dollars' worth. This, actually, is payment for confidence. It is not paid attention to nowadays, as 80% of bitcoins are in work and energy collapse cannot be seen so far.

Mining of bitcoins in 2015 – 2020 grew from 13.1 to 18.2 million of units of the virtual currency, while energy consumption grew from $4.5 \cdot 10^6$ MWt·h to $20 \cdot 10^6$ MWt·h, i.e. by more than four times. Nevertheless bitcoin profitability remains exceedingly high. For an average price of 1 KWt·h. $0.05 – 0.07 energy expenses on one bitcoin are about $2.160, at the market price of this crypto-currency within $6.5÷8.7 thousand.

3. Conclusion

Despite the systematic growth in hashing volumes and energy value of each generated bitcoin in the system of this blockchain technology there happens to be reduction of total power inputs. With regard to popularity and prospects of development of bitcoin, opportunities for decentralization and confidentiality at obtaining this product, already praised by millions of people, we can rightfully expect appearance of more energy efficient technologies, simple and convenient, capable of providing a great number of users with opportunities of creating local systems of distributed register.

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