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Perspective

Electrical power consumption reduction in the bitcoin mining process using phase change material

Jacob Geels

Department of Mechanical Engineering, Arkansas Tech University, 1811 N Boulder Ave, Russellville, AR, 72801, USA

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Corresponding author
Email address: jacobgeels808@gmail.com

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ABSTRACT

In this paper, the idea of applying phase change materials (PCMs) as a method of energy use reduction in bitcoin mining will be investigated. The possible applications discussed include the implementation of PCMs in the mining equipment itself, the integration of PCMs into the mining warehouse envelope, and the use of PCMs in air conditioning systems. These applications aim to decrease energy requirements for warehouse climate control systems by decreasing their cooling load, and by increasing the efficiency of the miners by keeping them at a cooler operating temperature. This reduction in energy usage will help reduce bitcoin's carbon footprint produced by fossil fuels electricity production.

1. Introduction

Cryptocurrencies have been around for a little more than a decade and have gained enormous popularity over the last few years due to their decentralized nature and increasing value. With the prices of the most notable cryptocurrency, bitcoin, being over $57,000 per unit as of the writing of this paper, it is no wonder so many individuals and companies have taken up bitcoin mining [1]. Bitcoin "mining" is the process of validating a user-to-user transaction on the bitcoin network, also known as the blockchain. There is a need to check the validity of each coin being exchanged since bitcoin is a digital currency, making it easy to counterfeit. Known as double-spending, it is one of the digital currency's biggest issues and is a security threat to the coin's value [2]. The validation is done by using computational power provided by "miners" or network users to verify the history of the bitcoin being used in the transaction [3]. Each transaction or block is checked to ensure all bitcoins involved have a history within the blockchain and are valid. If a person tried to use a counterfeit coin in a transaction, it would not be verified, and the transaction would not go through. The blockchain is known as a Proof of Work Mechanism [4]. Whichever user verifies the transaction is then rewarded with a set amount of bitcoin for their efforts. That is where the "mining" comes in. The more computational power you have, the more likely you are to solve a block and get rewarded. These computations are usually done either by CPU or GPU, which draw power.

An estimate of bitcoin's network wide power usage can be seen in the bitcoin Energy Consumption Index and is estimated to be around 199.41 TWh annually. If bitcoin were a country, it would rank 23rd in the world in power usage. This much power usage makes an estimated carbon footprint of 94.72 Mt of CO_2 per year, comparable to the country of Thailand [5]. Due to the daunting nature of bitcoin's CO_2 emissions and the risk, it poses to the environment, much research is going into developing technologies that reduce bitcoin's energy usage and, thereby, carbon footprint. One such technology is the implementation of PCMs into the mining equipment itself, as well as the mining warehouse envelope. This new idea has the potential to reduce the temperature of the electronics and the buildings they are housed in, reducing energy usage needed to keep them cool so that they run at peak efficiency. Applications of PCM's in this field were examined for their feasibility.

2. Energy usage of bitcoin mining

The major issue with bitcoin mining, or the mining of any cryptocurrency for that matter, is the enormous amounts of energy required to run their networks. This is because bitcoin and most other cryptocurrencies are proof of work systems. This means that the network of users each simultaneously tries to solve "blocks", or puzzles given to the users by the network to verify transactions. The process of verifying transactions must start with a proof of ownership. Since bitcoin is a digital currency, it could be easily counterfeited, flooding the market with fake coins leading to inflation and the devaluation of the coin. This is avoided by the proof of work system. All users on the network agree on a set of rules that determine who owns what coins. If someone were to make a duplicate coin and try to use it in a transaction, the network would not be able to verify ownership, and the transaction would not go through. Whichever user solves the problem the fastest gets a reward of a few bitcoins for their efforts. This is how "mining" of bitcoin is done. The problem comes in with how this proof of work system operates. All users on a network must have the computational power to solve these puzzles. These devices are usually CPU or GPU, which both draw power. Since all users on the network are trying to solve a single block at once, there are many computers running at once, only doing a single task. Once the block is solved, all the computing devices move to the next block [4]. This is an incredibly inefficient system. Bitcoin is estimated to use approximately 1994.26 kWh of electrical energy per transaction. This is enough to power the average household in the United States for 68.35 days [5]. The enormous energy consumption is not the only issue. Per transaction, bitcoin also has an estimated carbon footprint of 947.27 kg CO_2. This is comparable to the carbon footprint of 2,099,484 VISA transactions [5]. All this energy is being used, and carbon is being released for a single transaction. Clearly, something must be done to mitigate this issue. One might think, why not just get rid of bitcoin? The issue is that it has value. With a price per coin of over $57,000 as per the writing of this paper, mining bitcoin is very lucrative [1]. Companies that have invested millions of dollars into their mining operations will not simply stop due to its ever-increasing environmental impact. Because of this, ways to lower bitcoin's energy consumption and thereby its carbon footprint are the alternative. That is what this paper aims to investigate, and it is discussed below.

3. Phase Change Materials

A Phase Change Material (PCM) is a material that absorbs and releases heat as it changes from one phase to another (solid-liquid, liquid-gas, etc.). Known as latent heat capacity, this property of a material is how much heat energy it can absorb or release per unit mass before it transitions to another phase. As the material absorbs heat energy, it thaws at a constant temperature until the entire body moves to a higher energy phase. The opposite is also true. Once the material is in a higher energy phase and heat energy is no longer being added, the PCM will steadily release heat energy until it freezes back into its solid state. This is also true for liquid-gas transformations, but most applications only use solid-liquid transformations due to the volumetric changes that occur in the latter case. Different materials have their own well-defined melting, freezing, and evaporating temperatures. This means that PCMs can be tailored to a specific application based on the operating temperature ranges for that application. The primary advantage of a PCM over a constant phase material is sensible heat capacity versus latent heat capacity. Sensible heat capacity is a material's ability to absorb heat energy per unit mass per degree Celsius when no phase changes occur. This is important because, for most substances, their latent heat capacity is much higher than their sensible heat capacity. Take water as an example. Its latent heat capacity is 334 kJ/kg, where its sensible heat capacity is only 2.1 kJ/kg/C [6]. This means that it takes approximately 159 times more energy to melt 1 kg of ice than it does to raise the temperature of 1 kg of ice by 1 degree C. Because of this PCM's make excellent insulation/thermal storage materials. Also, due to being able to absorb such huge amounts of energy, they can also be used as passive heat sinks. If a system cannot get rid of enough heat at peak operating temperatures, PCMs can be used to store that heat until it can later be removed once the system is no longer at peak conditions. These two premises are what will be investigated further later in this paper.

As with the application of any technology, PCMs are chosen based on a variety of selection criteria. The first criteria for a PCM are that it must be able to absorb vast amounts of heat energy when changing phase. This means it needs a high latent heat capacity (heat of fusion) and be very dense. Next, the PCM must have a fixed/well-defined boiling and freezing point so that it can be used as a design criterion. The PCMs must also be resistant to cycling fatigue. As they are frozen and thawed many times over their life, PCMs that wear out or lose heat transfer capabilities with this fatigue is undesirable. PCMs chosen have to be able to avoid supercooling. This is the ability of the substance to stay liquid well below its freezing point. Materials that have this ability are undesirable for thermal storage applications since they do not change phase at the design temperature, not utilizing the energy storage benefits that occur at the phase transition. PCMs must also be non-hazardous. They must not be poisonous or corrosive to typical construction materials. Lastly, PCMs must be practical economically. To be used commercially, PCMs must be price competitive with current insulations [7].

There are two main types of PCMs: organic and inorganic. There are also Eutectic PCMs, which are just various mixtures of organic or inorganic PCMs. Both organic and inorganic PCM's have their benefits and disadvantages. Organic PCM's advantages are that they are chemically stable, freeze without supercooling, are compatible with conventional construction materials, and melt congruently. Their initial cost is more than inorganics, but after installation costs, they are competitive. The drawbacks of organic PCMs are that they are highly flammable, can produce toxic fumes when burned, and have low latent heat storage capacity. Some examples of organic PCMs are paraffin waxes and fatty acids. Inorganic PCMs consist primarily of salt hydrates. Their main advantages are that they are non-flammable, low-cost, readily available, and have a high latent heat capacity. The disadvantages of using inorganic PCMs are chemical instability, issues with supercooling, and corrosiveness [8].

4. Applications of PCMs in Electronics

One way to implement PCMs into a mining setup is to have them in the electronics themselves. This can be done at different levels in electronics. The first level PCMs can be applied at is the chip level. At this level, PCMs are most useful whenever the electronics operate transiently, they cycle between on/off or to take care of peak heat levels. In both cases, the PCMs would act as a heat reservoir, either to store excess heat until the off-cycle as in the first case or to store excess heat until peak heat load subsides and release it then as in the second case [9]. For bitcoin mining operations, however, the former is not useful since most mining operations run 24/7, meaning there is no off-cycle for the PCM to release its stored heat. However, it can be used if there is an allowable operating temperature range that contains the PCM in use's freeze/melt point. This would allow the PCM to thaw and refreeze, keeping the electronics within the desired range while still utilizing the high heat capacity of the PCM when it changes phase. Another method of PCM implementation in electronics would be at the circuit board level. Like their application at the chip level, the implementation of PCMs at the board level requires either transient operation or an established operational temperature range that contains the PCM's freeze/melting point. The PCMs can be integrated into the board structure or help passively cool the electronics. They can also be added to more widely used heat sinks, such as cooling fins, to increase the sink's thermal mass [9].

5. Applications of PCMs in the bitcoin mining warehouse

One of the most promising applications of PCMs is their integration into buildings. There are multiple ways how this can be done, including active building systems, passive building systems, free cooling systems, and peak load shifting systems. The primary system of focus in this paper will be passive building systems, or the integration of PCMs into building materials, effectively increasing heat storage capacity. In these systems, the entire building envelope acts as thermal storage. The PCM melts during the day, absorbing energy, and freezes at night, releasing that energy back into the building environment. This reduces both the energy needs for cooling the building during the day and heating it during the night. This type of system also has the benefit of not needing pumps or fans to cool the PCMs like active systems do, further lowering energy needs.

PCMs can be integrated into many different construction materials. Wall panels, roof panels, wall insulation, and concrete floors are some examples. Walls panels for many buildings consist of plasterboard/drywall because of its cheap nature. These panels consist of a gypsum-water mixture put between two pieces of paper. PCMs could be added to these panels by either direct integration or by encapsulation, depending on the design considerations for the desired PCM. It has been shown that the temperature of a room can be reduced by up to 4^{o}C when using PCMs impregnated gypsum board [10]. Plasterboard/drywall is also commonly used as roof panels, so a similar process to that of the wall panels could be applied here as well. Wall insulation's thermal performance can also be increased when PCMs are added. PU-enhanced foam has the potential to reduce the peak cooling load of a wall by up to 40%. In addition, standard cellulose insulation impregnated by microencapsulated PCMs has also been shown to have a measurable impact on cooling load; however, the exact measured impact depends on the wall orientation [11]. Floor thermal performance can also benefit from PCM impregnation. PCMs can be added to concrete slabs by either direct immersion, some form of encapsulation, or by utilizing lightweight aggregates to absorb the PCM before adding to the concrete [12]. PCM panels can also be used as a floor substitute [13]. This addition gives the possibility of the most energy savings. This is because the floor is the only envelope surface that is in direct contact with another solid (the ground), its main mode of heat transfer is conduction, which is the most efficient form of heat transfer. This means that the heat flux of the floor of a building is typically much higher than the walls or roof, leading to a larger heat loss through this surface. The application of PCM in building materials is usually done in buildings where people work/live to help keep the building at a comfortable temperature without running an HVAC system continually. In addition to implementation into mining warehouse envelopes, PCMs can also be implemented into air conditioning systems to help shift the cooling load away from peak hours. These augmented systems are similar in configuration to traditional air conditioning systems as they still have a compressor, heat exchanger, evaporator, etc. However, they also include a cold storage device that uses PCMs as its energy storage medium [14]. These cold storage devices charge themselves during the night when cooling loads and power demand are low and release it during the day to supplement the main cooling system. This cold energy is stored in the form of solidified PCMs and is released as excess waste heat from the air conditioning system is inputted into the cold storage device, melting the PCM. This type of system helps to maintain the desired temperature band more easily within the building and lowers operational costs by not having to pay premium electric prices during peak hours [15]. The mentioned methods can similarly be applied to bitcoin mining setups as the electronics must be kept cool. While human comfort temperatures and optimal electronic temperatures are in different temperature ranges, the same premise of reducing cooling load can still be applied. The only difference would be the need to select a PCM whose phase change range is within the desired operating range for the mining equipment.

6. Conclusions

The enormous energy requirements of bitcoin mining and the ability of PCMs to be used as excellent thermal storage materials were discussed. In addition, design requirements and considerations of PCMs were reviewed. Lastly, the possible applications of PCMs in building envelopes in the form of impregnation of the wall, roof, and floor materials were evaluated. PCMs have been shown to be able to reduce the cooling requirements of electronics and rooms. With this knowledge, bitcoin's miners can reduce the energy use, and thereby carbon footprint, of their mining operations. More research needs to be done to make PCM-impregnated construction materials cheaper to manufacture, making them cheaper to implement. These materials must be competitive with traditional construction materials if they are to be used, as Bitcoin mining is done to make turn profit.

Ethical issue

The author is aware of and complies with best practices in publication ethics, specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests, and compliance with policies on research ethics. The author adheres to publication requirements that the submitted work is original and has not been published elsewhere in any language.

Data availability statement

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

Conflict of interest

The author declares no potential conflict of interest.

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