

## *Retraction*

# **Retracted: Mining Cryptocurrency-Based Security Using Renewable Energy as Source**

### **Security and Communication Networks**

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This article has been retracted by Hindawi, as publisher, following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of systematic manipulation of the publication and peer-review process. We cannot, therefore, vouch for the reliability or integrity of this article.

Please note that this notice is intended solely to alert readers that the peer-review process of this article has been compromised.

Wiley and Hindawi regret that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

### **References**

- [1] L. Gundaboina, S. Badotra, T. K. Bhatia et al., "Mining Cryptocurrency-Based Security Using Renewable Energy as Source," *Security and Communication Networks*, vol. 2022, Article ID 4808703, 13 pages, 2022.

## Research Article

# Mining Cryptocurrency-Based Security Using Renewable Energy as Source

Lokesh Gundaboina <sup>1</sup>, Sumit Badotra, <sup>1</sup> Tarandeep Kaur Bhatia <sup>2</sup>,  
Kulbhushan Sharma <sup>3</sup>, Gulzar Mehmood <sup>4</sup>, Muhammad Fayaz <sup>5</sup>,  
and Inam Ullah Khan <sup>6</sup>

<sup>1</sup>Department of Computer Science and Engineering, Lovely Professional University, Phagwara, Punjab, India

<sup>2</sup>School of Computer Science, University of Petroleum and Energy Studies (UPES), Dehradun, Uttarakhand, India

<sup>3</sup>VLSI Centre of Excellence, Chitkara University Institute of Engineering and Technology, Chitkara University, Punjab, India

<sup>4</sup>Department of Computer Science, IQRA National University, Swat Campus, Peshawar, Pakistan

<sup>5</sup>Department of Computer Science, University of Central Asia, Naryn, Kyrgyzstan

<sup>6</sup>Department of Engineering, Kings College London, London, UK

Correspondence should be addressed to Muhammad Fayaz; [muhammad.fayaz@ucentralasia.org](mailto:muhammad.fayaz@ucentralasia.org)

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Cryptocurrency mining and blockchain technology using renewable energy as the main electricity source has gained attention for sustainable development in financial areas. However, very few studies have been reported concerning the power usage of cryptocurrencies using renewable energy. In this article, we report the effect of overclocking and undervolting on power usage and the hash rate for mining dogecoin with solar energy as renewable energy. The mining rig used in this work consists of different graphics processing units (GPUs) and non-LHR (lite hash rate) cards. The UnMineable software has been used for mining dogecoin as well as for wallet integration. The results indicate that mining dogecoin with solar energy as renewable energy consumes 2000 Watts power with overclocking and 1700 Watts power with undervolting technique. This work implicates the potential future of crypto-mining with renewable energy and the hardware configuration associated with it, which is expected to reduce e-waste and improve sustainable development. To reduce the e-waste and high electricity consumption, we have introduced two important techniques named GPU optimization and use of renewable energy for mining, which helps the miners to reduce the e-waste and electricity consumption significantly at the same time getting most out of the GPU by not having any impact on the environment.

## 1. Introduction

Cryptocurrency may be a decentralized digital currency designed to be used as a medium of trade through the Internet, because of the growing usage of knowledge technology. In late 2008, Satoshi Nakamoto launched the primary cryptocurrency, bitcoin [1]. Despite the presence of over 900 cryptocurrencies [2], bitcoin has been the foremost eminent digital cash since its launch in 2009 [3] and you'll be able to get bitcoin by merchandising it, giving services, or

exchanging it for alternative currencies [2]. The method of getting virtual money is understood as mining. The users install free package referred to as a wallet-free consumer on their computers as the initial step in bitcoin mining so as to transmit and receive cash victimization bitcoin addresses. The bitcoin network' miners are accountable for publication of the blocks. A block may be a container of bitcoin group actions within the public blockchain that uses a secure hashing technique (SHA-256) when transactions are confirmed into blocks [4]. one among the bitcoin network'

miners creates a replacement block. Miners are salaried with twenty-five new bitcoins every ten minutes for every block [5]. As a result, this mining method generates transaction hashes, and the miner keeps their block in a loop for as long as possible for major quantity of electricity [5]. Initially, mining was carried out on ordinary PCs. Miners tried to boost their hash rates by using completely different hardware as mining got a lot of popular [6]. As a result, bitcoin protocols gradually increased the problem of mining [7]. Computing resources offered to overall public where old generation hardware is a major problem since their hardware could not maintain the challenges of manufacturing a good return. Furthermore, the cryptocurrency network' introduction of assorted pools has created selecting a mining pool more complex. Every pool needs distinctive hardware. As a result, additional in-depth analysis is going to be needed to see acceptable criteria for selecting the best bitcoin mining equipment, such as energy usage, hash rates, and hardware rating [7]. Due to its increased energy usage, cryptocurrency mining has recently attracted a lot of public attention. This was mostly owing to multiple newspaper headlines portraying cryptocurrency as a severe climate concern due to their insatiable thirst for electricity [8]. Mining cryptocurrency necessitates a significant amount of processing power and an uninterrupted energy supply. Energy consumption has grown significantly in tandem with the development in the number of different cryptocurrencies put into circulation throughout the world, leading some to assume that these trends will result in cryptocurrencies using a large proportion of global energy. Although this may appear implausible, there is some truth to it, since the quantity of energy required by mining activities continues to rise at an alarming rate. It is arguable how much global energy is consumed in the production of cryptocurrencies [8, 9]. According to the Cambridge Bitcoin Electricity Consumption Index, bitcoin, the most widely mined cryptocurrency network, consumes 122.87 Terawatt-hours of electricity per year, which is more than the combined consumption of the Netherlands, Argentina, and the United Arab Emirates. According to Digiconomist, a cryptocurrency analytics site, a single bitcoin transaction consumes 2,106.37 kilowatt-hours of electricity, which is similar to the amount of power used by the average American household over 72.2 days [9]. The Ethereum network consumes 99.6 terawatt-hours of power every year, which is above the requirement of the Philippines or Belgium and in line with Digiconomist. On the other hand, one Ethereum group action consumes 220.05 kilowatt-hours of power, which is the quantity spent by a mean American household in 7.44 days [9, 10]. In recent years, several firms have been developed that have decided to support their mining operations with renewable energy sources in areas where these sources are available. Their economic models are distinct from those of other mining towns that still rely on fossil fuels for power [9]. These businesses can demonstrate how renewable energy may benefit even the most energy-intensive activities. Figure 1 depicts the process of how the proof-of-work algorithm works in cryptocurrency mining. Proof-of-work (PoW) is a decentralized consensus method in which network

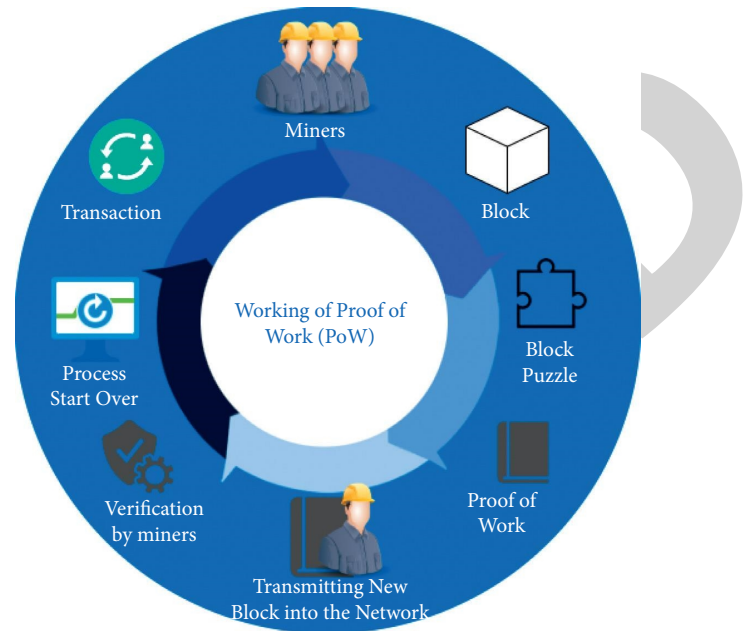


FIGURE 1: Working of the proof-of-work algorithm.

participants solve a random mathematical puzzle to secure the system.

The amount of energy required by cryptocurrency mining is expected to increase as bitcoin usage expands and mining efficiency drops. Mining bitcoin is a competitive activity, and as crypto blockchains become longer and the rivalry for crypto rewards intensifies, so does the required processing power. As the need for processing power grows, crypto networks require more electricity. To address this issue, we have used renewable energy mining, GPU undervolting, and GPU overclocking techniques in this study, which reduces both energy consumption and e-waste by mainly utilizing renewable energy. This will have a huge impact on cryptocurrency mining in the future, as well as an increase in the use of renewable energy sources for mining cryptocurrency, both of which are environmentally friendly.

When compared to prior studies [1, 9, 11–14] in this work, we have incorporated a few approaches that will help miners to mine cryptocurrencies with maximum profitability and get the most out of their mining rigs while lowering power and resource usage:

- (i) Using renewable energy as the main energy source for mining cryptocurrency, as mining rigs consume a lot of electricity today and the electricity consumption of cryptocurrency is high as it can be compared to the power consumption of few countries; with this technique, we can reduce the power consumption as well as its impacts on the environment.
- (ii) Overclocking the GPUs in the mining rig: Overclocking the GPUs will help the miners to get most out of their mining rigs even though it consumes a bit more power, but when mining cryptocurrency

like Ethereum, one need to solve the block as soon as possible where the extra performance really helps.

- (iii) Underclocking the GPUs in a mining rig: Underclocking technique is the best technique when it comes to mining because when mining cryptocurrencies for a long time GPU's temperatures will reach higher temperatures, to maintain these temperatures, and without compromising the performance, underclocking the GPUs is the best option, and the overall electricity consumption will also be reduced, which helps to increase the life span of the GPUs.

This article presents mining cryptocurrency with renewable energy as its main source of electricity and helps the miner to attain maximum mining profits with lower electricity footprint, which also reduces the e-waste significantly.

The rest of this article is divided into the sections listed as follows. Section 2 presents the literary background for mining cryptocurrency using renewable energy as a source, followed by Section 3's methodology, implementation, and evaluation aspects. Section 4 contains experimental results, whereas Section 5 provides a detailed explanation of the results obtained using the accepted methodology. Section 6 concludes the work and discusses its future scope.

## 2. Background

Before we look into the performance and evaluation of cryptocurrency mining and see how effectively we can mine cryptocurrency with renewable energy, we must first understand a few fundamentals about cryptocurrency mining. In this section, we will briefly discuss blockchain in cryptocurrency, cryptocurrency mining, the use of renewable energy for mining, the hardware required for mining, and mining efficiency for cryptocurrency with renewable energy as a source. The main reason for using renewable energy as our main source of electricity is because it not only reduces the cost of mining but also helps the environment significantly, and the traditional power we all are using now causes damage to our environment as carbon emission, which are being emitted while generating the power is really harmful; even though mining is not huge now, in the coming future, it is going to big, and it is important to mine and get profits, but at the same time, it is important to take care of the environment as well.

*2.1. Blockchain in Cryptocurrency.* A blockchain may be a distributed info that may be accessed by network nodes. A blockchain is a distributed digital information that holds data. In cryptocurrency systems like bitcoin, blockchains are well-known for firmly storing a decentralized record of transactions. Blockchain improves to integrate and secure data from third party [9, 10].

A blockchain associated an everyday information store knowledge in essentially completely different ways. A blockchain organizes data into blocks; every of that contains a group of data. Once a block' storage capability is exhausted, it is closed and joined to the block before it, forming the

blockchain, or data chain. Once the freshly inserted block is combined into a replacement block, all further information is added to the chain [10]. A database organizes data into tables, whereas a blockchain organizes data into linked blocks, because the name suggests. This info creates an irreversible data chronology when used localized [10]. A completed block is additional to the timeline indefinitely. A timestamp is assigned to each new block when it is added to the chain [10, 15]. In Figure 2, the flow of cryptocurrency transactions in the blockchain is mentioned, and this process is the same for all cryptocurrencies.

*2.2. Cryptocurrency Mining.* Mining is the process of producing a cryptocurrency. The practice of adding transaction records to the blockchain's public ledger of past transactions is known as pushing transactions into blocks. Mining is a highly competitive, energy-intensive activity that requires cutting-edge technologies. By contributing their computer capacity to the network, miners solve artificial mathematical problems, algorithms, which form the basis of cryptographic proofs (proof-of-work protocol) [15]. Proof-of-work mining guarantees that bitcoin remains a decentralized and dispersed network, with coins allocated equitably in a competitive manner. Proof-of-work is based on the notion of allowing nodes to compete with one another by utilizing their processing capacity to solve puzzles continually [15, 16]. When one of the nodes is fortunate, it is assigned to propose the next block on the blockchain. As a result, the system is entirely decentralized. Nobody gets to choose which node gets to propose the next block. The nodes continue to solve mathematical puzzles, validate transactions, and distribute cash [16]. The usage of a lot of computer power in proof-of-work is quite energy-intensive, and besides this, most cryptocurrencies utilize proof-of-work methods, and mining them is also very energy-intensive. The proof-of-work algorithm is time-consuming and energy-intensive, but it is necessary for preventing double-spending and safeguarding the blockchain and distributed network. It also ensures that currencies are allocated fairly in a competitive system [17]. In addition to this, the act of producing a new digital coin necessitates the use of big and powerful computers to solve complicated cryptographic riddles, and cryptocurrency mining uses a lot of energy [18]. Each transaction is confirmed through mining since bitcoin operates on a decentralized network with no central authority. Bitcoin, the most popular cryptocurrency, consumes around 80 terawatt-hours of power yearly, according to statistics from the University of Cambridge Bitcoin Electricity Consumption Index.

*2.3. Use of Renewable Energy for Mining.* The ability to deliver adequate energy at the lowest cost is the most important factor for a bitcoin mining center vs physical location. Miners will not pick the source of energy based on whether it has a detrimental influence on the environment but only based on profit. Due to a paucity of statistics, determining the fraction of mining that uses fossil fuels vs renewable energy is challenging today [19]. Nonetheless, miners will

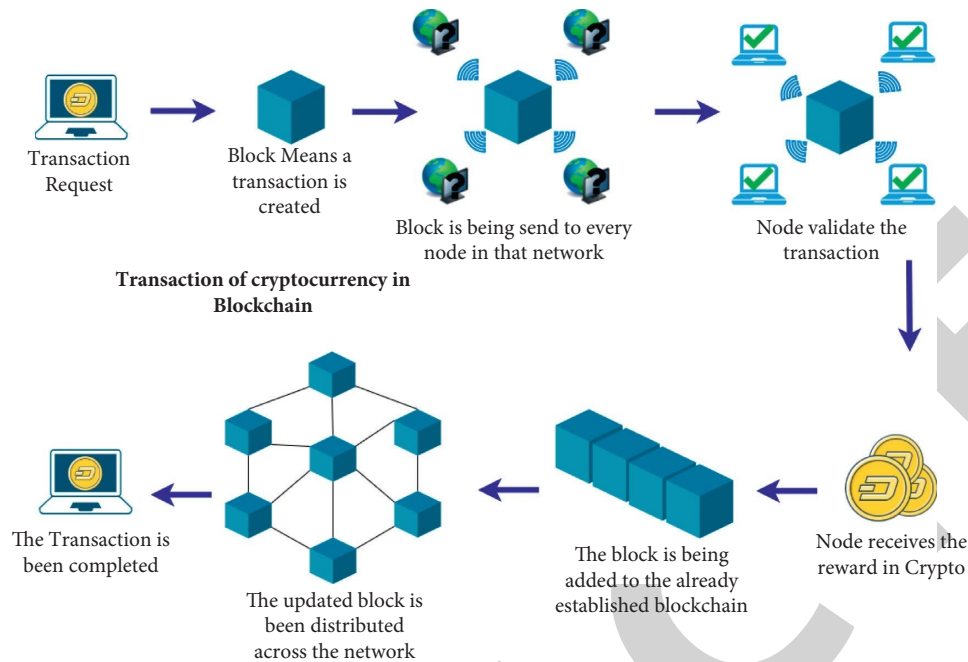


FIGURE 2: Transaction of cryptocurrency in blockchain.

increasingly pursue renewable energy sources rather than fossil fuels in the long term. The study also implies that, in the long term, it may be more advantageous for miners to pick places where renewable energy is produced despite the marginal cost of renewable energy being lower than that of fossil fuel-generated power [19]. The cryptocurrency mining sector provides one of the first methods in which players are rewarded for utilizing energy effectively. The concept is that as competition increases, more investments will be made in renewable energy sources to reduce mining's marginal costs, resulting in novel proof-of-work mining systems that improve the efficiency and allocation of our global energy use [19, 20]. The amount of energy used by bitcoin mining has been a hotly disputed subject. However, recent data reveal that renewable energy provided 56% of the energy needed in worldwide bitcoin mining in the June quarter [20].

**2.4. Hardware Required for Mining.** Mining, as we've seen, necessitates the solution of mathematical problems and is computationally challenging. We'll take a brief look at the hardware required for these calculations right now [20]. The initial generation of mining was carried out entirely on general-purpose central processing units (CPUs) that only executed the code. With the current levels of difficulty, CPU mining is no longer economical. As a result, when people began to use graphics, the second generation of mining formed [11, 20]. Instead, use a graphics processing unit (GPU). Mining with a GPU needs a basic setup with readily accessible graphics cards. It was also feasible to combine many GPUs to boost mining productivity and revenue. GPUs, on the other hand, used a lot of power and putting together a multi-GPU arrangement necessitated the purchase of expensive gear. Field Programmable Gate Arrays (FPGAs) were introduced in 2011, and they promised

superior performance and cooling than GPUs [11, 21]. Despite this, FPGA mining was short-lived. ASICs, or application-specific integrated circuits, now dominate the mining industry. These are chips that have been specifically developed, produced, and optimized for mining [21]. CPUs, GPUs, FPGAs, and now ASICs have all been used in cryptocurrency mining. It also progressed from being more accessible to individuals to being mined by huge corporations with greater money and, as a result, greater profits [21]. Another intriguing aspect regarding crypto-mining is that companies selling/renting equipment (ASICs) have made the majority of the profits, at the expense of people wanting to get rich. Mining technology has evolved from CPUs to ASICs, resulting in a 20-fold gain in speed and energy efficiency [21, 22].

**2.5. Mining Efficiency for Cryptocurrency with Renewable Energy as the Source.** Renewable energy, primarily electricity, fuels 39% of proof-of-work mining, in step with Cambridge. This is often considerably on top of the worldwide renewable energy in power generation average for 2019 [22]. In step with many sources, together with Coin Shares Research' Bitcoin Mining Network analysis [23], renewables account for up to seventy-four percent of bitcoin POW mining. Once coping with the renewable's quantitative relation in bitcoin mining and POW mining in general, the dynamical nature of renewables provides a major difficulty. In China' Szechwan Province, wherever mining is common, the typical power generating capability during the rainy season is three times that in the dry season [24, 25]. Additionally, as a result of electricity generation varies throughout the year, bitcoin miners could also be restricted to using low-cost hydropower throughout specific seasons. Finding the foremost efficient power sources



could be a vigorous competition because energy is a miner's costliest operational expenditure. It is a viable choice, given the dramatic visit the worth of affordable renewable electricity over the preceding decade [25, 26]. New renewable capability made in 2019 offers lower power rates than new coal capacity, creating it a viable option for a sector that depends heavily on low-cost electricity [26]. Proponents of Pow cryptocurrency argue that mining uses excess renewable energy generation, decreasing curtailment and helping to fund renewable energy development, which is the cheapest source of electricity in many regions of the globe [12]. Despite evidence to the contrary, miners have depended mostly on baseload electricity, which is primarily supplied by fossil fuels [13]. This, however, offers an intriguing question Will Pow miners follow a historical pattern, exporting energy from places with abundant, and shift to locations with abundant renewables as renewables prices fall [27, 28]. Several efforts try to hasten the transition to renewable energy. The Alliance for Innovative Regulation, Energy Web, and the Rocky Mountain Institute have teamed up to assist the bitcoin sector by 2030 [28]. The high-level aims of the agreement are being finalized prior the United Nations' COP twenty-six Climate Conference later this year [29]. Jack Dorsey, the business executive of Twitter and Square, proclaimed the Bitcoin Clean Energy Investment Initiative in December 2021, a \$10 million fund to help the bitcoin ecosystem boost its usage of renewables. Table 1 shows energy use, carbon footprint, and cryptocurrency algorithms [30], with nonrenewable energy sources.

*2.6. Comparison of Existing Work.* Compared to previous works, they mainly focused on mining the cryptocurrency and their effect on the environment and their overall energy consumption and carbon footprint [28]. Mining rigs and GPUs consume a lot of energy for mining cryptocurrency with nonrenewable energy. To reduce this kind of impact, using renewable energy sources is nearly impossible by optimizing the mining rig. In this article, we have implemented a few techniques named overclocking and undervolting. These techniques will help further to optimize the mining rigs and combine them with renewable energy source.

### 3. Methodology

Before diving into the methods, it is necessary to review recent work on the subject of cryptocurrencies. Table 2 shows a comparison of several cryptocurrencies obtained from early studies. For example, Sankaran et al. [9] Ethereum coin has various power consumption, needed hash rate, and reward per block values since each cryptocurrency has its unique set of variables. It is nearly impossible to consider every single possibility. As a result, we utilized Dogecoin. The previous study discussed the key characteristics of several cryptocurrencies. Taking into account the existing information and improving on it by including other techniques such as undervolting the GPU, utilizing sustainable

energy as a source of mining bitcoin would benefit both the environment and the miners.

Because it is practically difficult to cover every cryptocurrency on the market in 2021 [31, 32], we chose dogecoin as an example of how mining is done. For solving cryptographic equations with one's hardware, crypto-mining entails receiving digital currency rewards tokens of appreciation and monetary incentives. To demonstrate how this works, consider bitcoin [32]. Bitcoin is based on a blockchain, which is a decentralized and replicated digital database of transactions that spans a peer-to-peer computer network [33]. Each block on a blockchain is filled with bitcoin transaction data until it reaches one megabyte in size. Next, it is up to the bitcoin miners to verify each block to ensure that it is valid and accurate [14].

Now, here's where it gets interesting. Each block comes with a complex, mathematical problem that is extremely difficult to solve. The bitcoin miner that solves this complicated puzzle first wins all the transaction fees and scores BTC rewards [34]. As such, Bitcoin network needs high powered hardware which use to have rewards to miners with higher-powered hardware while yelling to miners with lower powered internals [35].

The POW algorithm is used by both Dogecoin and Bitcoin. Furthermore, it uses significantly less energy than BTC, which generates a lot of heat and energy [36]. The Script algorithm, which is less advanced than bitcoin's SHA-256 technique, is used by Dogecoin. Script uses fewer resources as a result, allowing miners to create DOGE with less powerful hardware [37]. Before diving into Dogecoin mining, you should know what you're getting yourself into. The first factor you should consider is that cryptocurrency is extremely volatile [38]. The miner can mine 300 dogecoins in one week, which is \$64.04 worth as of this writing. The following week, miners' precious DOGE could be worth nothing but a \$5 bill. Here are some other concerns you should consider: increased wear and tear on your hardware [38, 39]. Mining requires your laptop to be continuously running for hours and hours on end, which can affect the lifespan of your system's internals [39].

Electricity laptops packed with powerful GPUs typically do not have the best battery life, which means miners have to keep it plugged in all day. Consider how this affects their electricity bill [39]. It may affect overall profitability unless they altruistically want to contribute their resources to the Dogecoin blockchain, even if you're operating at a loss, to help verify transactions and maintain its integrity [40]. Energy consumption, Dogecoin, according to data from TRG Datacentres, is less taxing on the environment than bitcoin and Ethereum [40]. DOGE uses 0.12 kWh of energy per transaction, whereas BTC and ETH waste 707 kWh and 62.56 kWh per transaction, respectively. Still, mining is not exactly environmentally friendly, so you may want to keep that in mind [40].

Because GPU mining is the most popular and well-known technique of cryptocurrency mining that uses only solar renewable energy as a source of electricity, we mined Dogecoin with it. GPU mining is becoming increasingly popular because of its efficiency and inexpensive cost. Don't

TABLE 1: Annual energy consumption of top 3 cryptocurrencies [30].

Cryptocurrency	Algorithm	Energy consumption (TWh)	Carbon footprint (Mt CO <sub>2</sub> )
Bitcoin	SHA-256	204.50	97.14
Ethereum	Ethash	109.33	51.93
Dogecoin	Scrypt	6.42	3.05

TABLE 2: Comparison of previous studies of different cryptocurrencies.

Parameters	Sankaran [9]	Krause [11]	Xue [1]	Eshani [13]	de vries [14]	Peng [12]
Cryptocurrency	Ethereum	Vertcoin	Monero	Ravencoin	Haven protocol	Dogecoin
Mining algorithm	Keccak-256	Verthash	RandomX	KAWPOW	CryptoNight POW	Scrypt
Power consumption	104 TWh	203 kWh	193 kWh	185 kWh	156 kWh	105 kWh
Reward per block	2.19302 ETH	12.5 vertcoin	4.99 XMR	5000 RVNs	5.0907 XHV <sub>s</sub>	10000 DOGE
Hash rate with respect to RTX 3080	101 MH/s	1.50 MH/s verthash	4305.8 H/s	8.74 TH/s	46.62 MH	2.2 GH/s
Required hash rate	15,500 MH/s	1,000,000 MH/s	425.38 MH/s	4.25 TH/s	436 MH/s	500 MH/s
Required mining hardware	GPU	Average-level GPU or CPU	CPU	GPU	GPU or CPU	GPU or CPU

get me wrong: the rig is expensive to build, but it outperforms the competition in terms of hash rate and overall manpower. To mine bitcoins, GPU setups use graphics cards. A typical setup includes a processor, motherboard, cooling, a rig frame, and two to eight graphics cards, among other things. A well-built and well-performing GPU mining machine costs roughly \$230,500 RS (nearly \$3500). It is a substantial investment, but it will pay off far faster than, say, a CPU miner. To make the mining process even more efficient, we applied undervolting and overclocking techniques, which allowed GPUs to consume less power while still delivering the same hash rate.

GPU shortage and Nvidia's crackdown. If you decide that you want to build a mining rig and secure a couple of GPUs, you should know that there is a shortage of graphics cards due to the skyrocketing popularity of crypto mining. Nvidia's upset that all the crypto nerds are buying up all the GPUs, thwarting their main consumer base (gamers) from securing their products, so the gaming giant implemented crypto limiters on some graphics cards (e.g., RTX 3060 Ti, 3070 and 3080). This drastically reduces their mining performance. Figure 3 is completely about the cryptocurrency mining process, which is from creating a crypto wallet to mining cryptocurrencies. To get started on mining DOGE, you'll need a Dogecoin wallet and this will collect all your DOGE rewards once you've reached your pay-out threshold. When you sign up for an account, make sure you keep the provided seed phrase, which is a string of 12 words in a safe place. If you get a new device, you'll need it for security purposes. If you lose it, you can never retrieve your seed phrase. And you will not have access to your crypto wallet anymore.

One of the best mining software to mine dogecoin is unMineable. unMineable will link with the crypto wallet,

and when starting mining, when a certain number of coins get mined, the respective tokens will be transferred to the wallet, and this process of mining completely depends on the hardware, which is being used for mining the cryptocurrency, in this case its dogecoin. unMineable is very easy to use; once everything is being set up, the mining software will automatically start mining and the software will also display information like hash rate, and the tokens are rewarded, and also in detailed panel, a lot more information will be available like the number of equations being solved, time taken to solve a particular set of equations, and a graph with the information regarding the hash rate and the token that are being awarded.

Once the earned tokens reach a minimum of 30 DOGE, unMineable will send your Dogecoin directly to your Atomic Wallet. Now, you can track how much DOGE you can make per day and determine whether it is worth it for you; at the end, cost of electricity can be reduced using solar as energy source. Which will not only reduce the cost of the electricity which also help the miner to gain more profit out of mining and also helps the environment by reducing the usage of fossil fuel in the long run. In the experimentation results, you can see how effectively one can gain profit with this method. In Figure 4, the research workflow, which is being adopted in this article, is described through a detailed block diagram. The flow chart in Figure 5 represents the workflow that we followed for the work; first, we decided which cryptocurrency to mine; we chose Dogecoin because it is nearly impossible to mine every cryptocurrency out there, and Dogecoin is clearly mineable at the time we are writing this paper as it is still in proof-of-work. We optimized the mining rig, which consists of GPUs, after selecting the coin to mine.

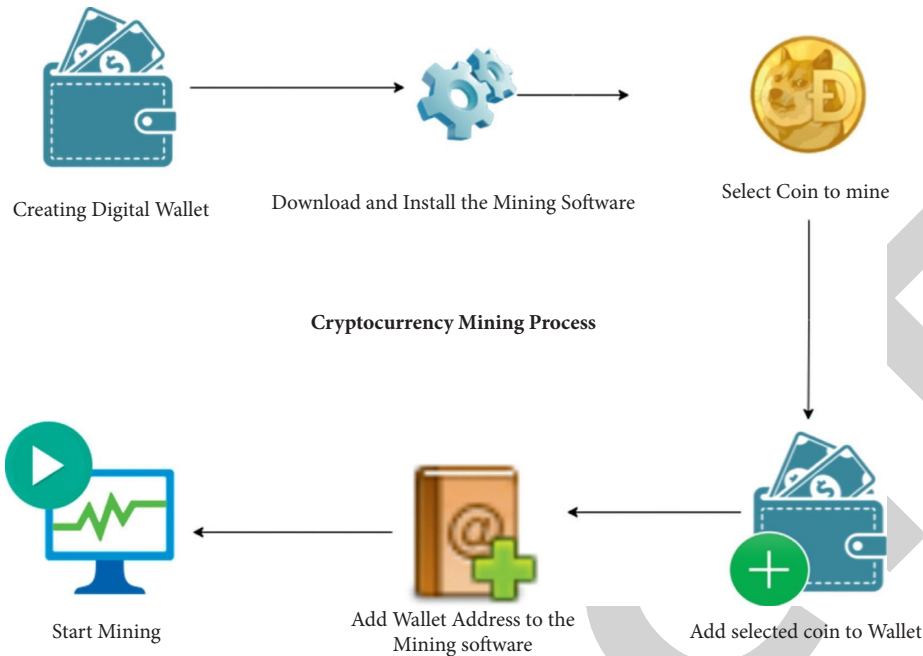


FIGURE 3: Mining process of cryptocurrency.

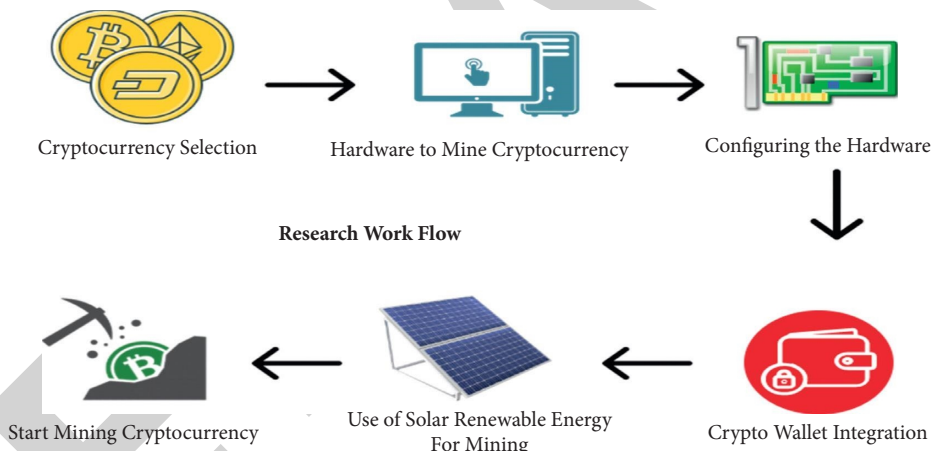


FIGURE 4: Research workflow adopted by this paper.

Optimizing the mining rig is a complex task because our workflow includes three separate techniques. Using renewable energy to power the GPUs in our mining rig helps to reduce the overall environmental impact, while overclocking and undervolting the GPUs helps us to keep the GPUs running at lower temperatures with zero performance degradation. After completing these optimization processes, we began mining, which yielded the following results, as shown in Section 4 that is the Experimentation Results section.

#### 4. Experimentation Results

In comparison with previous techniques used in many studies, our mining techniques, which include GPU overclocking, undervolting, and using renewable energy as the

primary source of mining, will help to reduce the environmental impact caused by cryptocurrency mining while also allowing miners to attain more profits because renewable energy is less expensive than traditional electric power.

All the experiments and simulations using a PC consist of Nvidia RTX 3080, RTX 3090, RTX 3060, RTX 2070, AMD RX 5700 XT, AMD RX 580, and GTX 1660 Super, which is a non-LHR (lite hash rate) card, and in the experiment, we have performed both with and without overclocking the GPU, and for the power source, we have used solar power renewable energy. In Table 3, the data that is being represented are regarding the GPU's power usage when it is overclocked with its hash rate, MHz, and its fan speeds were also included. Basically, GPU overclocking is the process of increasing the speed of your graphics card beyond its preset



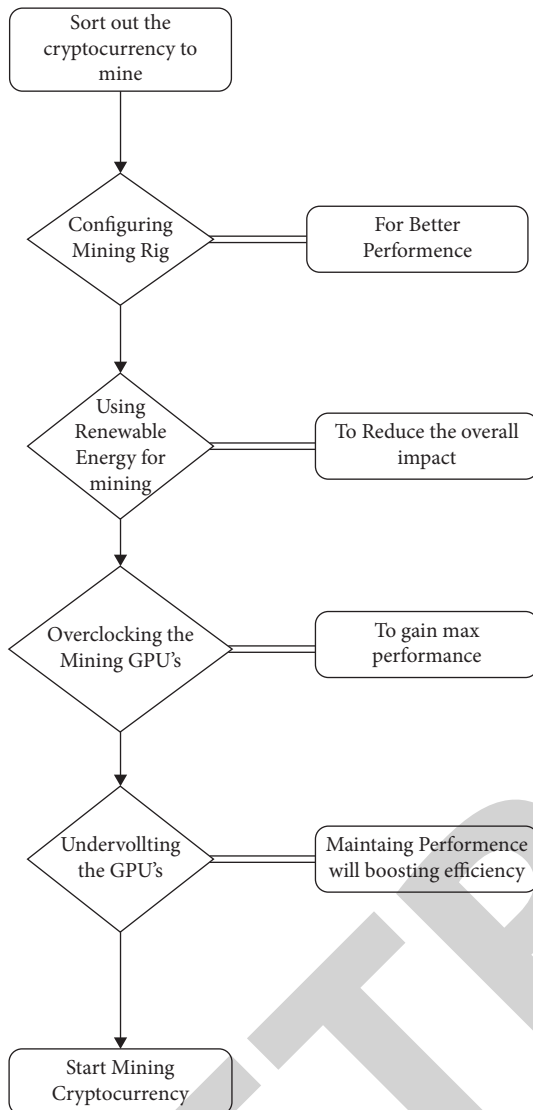


FIGURE 5: Complete methodology flowchart.

TABLE 3: Power consumption, frequency, hash rate, and fan speeds of GPU, when it is overclocked.

GPU power consumption (watts)	M (W) Hz	Hash rate (MH/S)	Fan speed (RPM)
200	1750	73.40	1250
215	1800	76.03	1350
231	1850	82.31	1400
262	1900	86.72	1460
291	1950	92.13	1570
315	2000	96.31	1650
320	2050	98.01	1670

settings. Before we go into the overclocking procedure, let us first discuss what overclocking a GPU does. Overclocking a GPU improves its performance by increasing the speed at which the graphics processor operates. All GPUs are programmed to run at a specific pace, known as the base clock; however, various cards typically have the ability to exceed the manufacturer's speed.

The GPU's temperature will rise as a result of overclocking, and it will use more power. Finding a suitable balance between increased performance and a steady temperature for your graphics card is critical as every GPU is unique. In addition to this, the manufacturers are different. Therefore, RTX 3080 may be able to safely overclock to a faster speed than your friend's RTX 1080. As a result, the miner has to experiment with overclocking speeds on your own to discover the sweet spot. If the miner uses the MSI Afterburner overclocking software to push your GPU too hard, your graphics card may either display graphical flaws or your PC will crash. You do not need to be concerned; if this occurs, simply reduce your GPU speeds to a safe level. It is recommended to begin slowly and gradually increase your workload until you notice any issues. The reading mentioned below is based on RTX 3060 GPU from Nvidia and manufactured by MSI. In Table 4, the information is completely regarding the profit, which is being made with the help of solar renewable energy; note that this profit is not per GPU; it is for the complete mining rig with 8 RTX 3060 GPUs and the data are taken after running the GPUs for mining dogecoin for straight 7 days and the electricity savings are also calculated per day. We have used a household solar power, which has a maximum output of 5kW hybrid solar system (hybrid solar system has both functions: on-grid and off-grid solar systems). Our mining rig consists of 8 RTX 3060 GPUs, which requires 2000 Watts max for mining.

In Table 5, we have mentioned few of the best graphic processing units, which are currently available in the market as of now, and we also mentioned their power consumption, clock speeds, hash rate, CUDA Cores for Nvidia GPU's and for AMD GPU's Streaming process, and VRAM for each individual card are. Note that these values are regarding mining dogecoin as of 2021 and also these readings are for individual cards not for a complete mining rig. Figure 6 depicts the hash rate and power consumption of the graphic cards, which are mentioned in Table 5.

Figure 7 depicts the changes that are taking place in the hash rate with respect to undervolting of the GPU. Undervolting basically lowers the voltage of your GPU while maintaining the stock clock speed. Reason for undervolting the GPU is you are basically eliminating the amount of heat generated from all the power inside your computer. You are basically aiming for less heat generation, which benefits your system by reducing wear via limiting circular movement. Higher temperatures result in a higher consumption of power, which generates a lot more heat. Undervolting single-handedly reduces power consumption in the long run, so your system automatically draws less power, reducing the temperature inside your machine. When you are performing undervolting as stated above, you not only reduce the amount of heat that is being generate but also help the GPU to run longer and also reduce the amount of energy its being consumed, which will to gain more profit. This technique is used by most of the miners, but combining with the use of renewable energy, it is much more profitable but also helps the environment a lot. The graph shown in Figure 8 compares to

TABLE 4: Crypto-mining profit when it is being mined with renewable energy.

GPU power consumption (W)	Profit per day (Rs)	Electricity savings (Rs)	Total savings (Rs)
200	319.17	39.219	358.389
215	326.51	39.219	365.729
231	331.29	39.219	370.509
262	343.61	39.219	382.829
291	357.96	39.219	397.179
315	369.72	39.219	408.939
320	374.51	39.219	413.729

TABLE 5: Best dogecoin mining GPUs with their individual hash rates and power consumption.

GPU	Power consumption (W)	Clock speeds (MHz)	Hash rates (MH/S)	CUDA cores	VRam
RTX 3090 OC	350	1395	121	10,496	24 GB GDDR6
RTX 3080 OC	320	1370	100	8704	10 GB GDDR6
RTX 3060 Ti	200	1410	60	4864	8 GB GDDR6
AMD RX 5700 XT	225	1465	54	2304 SP	8 GB GDDR6
RTX 2070	225	1620	36	2304	8 GB GDDR6
AMD RX 580	185	1257	28	2048 SP	8 GB GDDR5
GTX 1660 super	125	1530	26	1408	6 GB GDDR6

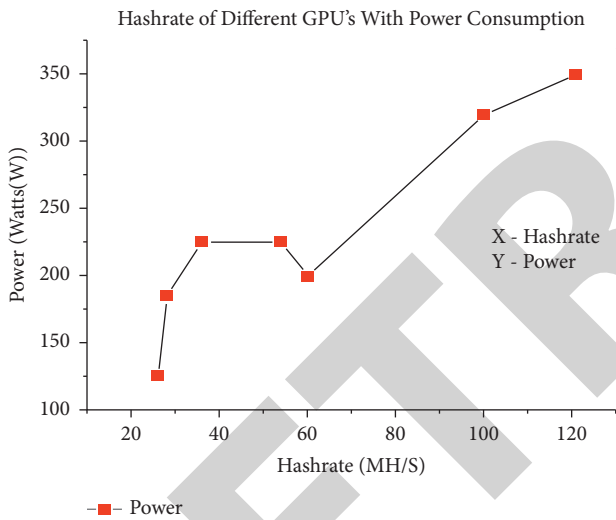


FIGURE 6: Hash rate of different GPUs with respect to their individual power consumption.

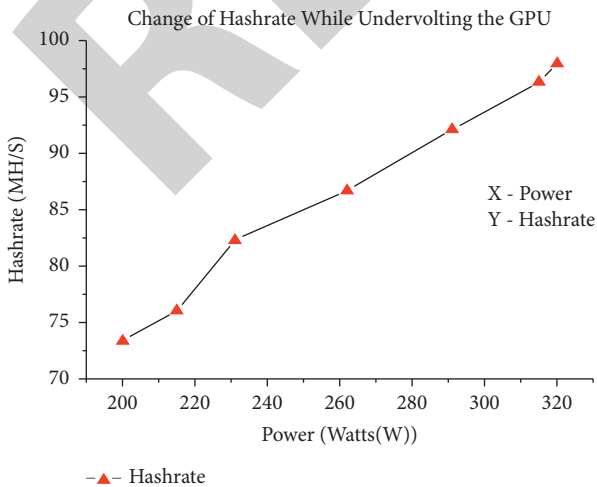


FIGURE 7: Hash rate changes while undervolting.

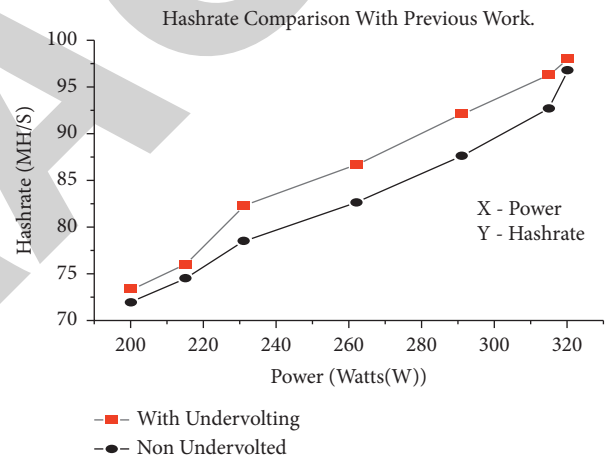


FIGURE 8: Hash rate comparison with previous work.

earlier studies [32], with the blue line representing undervolting and the red line representing the usual mining strategy, which is adopted by every single miner. In Figure 8, the undervolting technique clearly shows the advantage over the conventional method. The undervolting technique gives a higher hash rate, while consuming less power, and on top of that, we have used renewable energy as the primary source of mining, which further reduces energy consumption.

To conclude our work, the techniques we used in our article were clearly demonstrated above. Using renewable energy for mining is just a part of our work; optimizing the mining rigs or GPUs further helps our work to stand out when compared to previous works, such as using techniques including renewable energy for powering the mining rigs or GPUs combined with overclocking and undervolting the GPUs help to get better results. All of this is accomplished by keeping the GPUs at lower temperatures and with boost in performance.

TABLE 6: Comparing our mining technique to previous works.

Parameters	Jingming Li [23]	Naderzadeh [19]	Mohsin [6]	Leonhard [41]	Our work
Currency	Monero	Ravencoin	Bitcoin	Ethereum	Dogecoin
Power consumption	193 kWh	185 kWh	204.50 TWh	104 TWh	89 kWh
GPU used	Nvidia GPUs	Nvidia GPUs	ASIC	RTX GPUs	RTX GPU
Average mining hash rate	425.38 MH/s	4.25 TH/s	200 TH/s	15,500 MH/s	500 MH/s
Type of energy source	Renewable energy	Renewable energy	Renewable energy	Renewable energy	Renewable energy
Hardware optimization	×	×	×	×	✓
Overclocking	×	×	×	×	✓
Mining algorithm	RandomX	KAWPOW	SHA-256	Keccak-256	Scrypt
Undervolting	×	×	×	×	✓
Mining efficiency	×	×	×	×	✓

## 5. Discussion

Mining cryptocurrency has the ability to remove barriers to green energy adoption:

- (i) Developers can boost their profitability and pricing power by combining bitcoin mining activities into renewable energy projects
- (ii) When it comes to comparing our work to other research papers from 2016 to 2022, the main advantage of our work was the GPU optimization, and for mining, it is our core part of our paper; in the Experimentation Results section, one can clearly see the advantages of our techniques
- (iii) According to Digiconomist, the bitcoin network generates between eight and twelve thousand tons of electronic waste each year
- (iv) Our goal will be to achieve the most hash rate with the least amount of power consumption, so a good start is undervolting the GPU
- (v) Another technique we have used is overclocking. Overclocking is the process of increasing the default memory and core clock rates of the GPU to make it faster than the manufacturer intended

The findings of the study described earlier will provide a clear picture of how to mine cryptocurrency while using renewable energy as the primary source of electricity. In Table 2, it is mentioned that overclocking the GPUs will not only increase the amount of power that is being consumed but also perform way better when it is compared to stock. In Table 3, after experimentation, solar as renewable energy is quite useful and of low cost. In Table 2, there are values regarding overclocking of the GPU to get better result, but due to this process of overclocking, the GPU temperature will increase and it also reduces the lifetime of the card to overcome this problem in Figure 7; the values of undervolting mentioned in the process of undervolting the energy consumption of the cards will reduce by 20% and it does not have any impact on the overall performance of the GPUs. By taking all the above results into consideration, mining with the help of renewable energy not only is profitable but also helps the environment a lot. Figure 8 compares the hash rate to the

earlier studies [32], which show how effective the undervolting technique works.

Unlike typical laptop hardware, these circuits cannot be used and hence quickly become obsolete. Consistent with Digiconomist, the bitcoin network generates between eight and twelve thousand tonnes of electronic waste per year. Bitcoin is widely utilized all around the world. Despite the actual fact that proponents of bitcoin have emphasized the importance of renewable energy. Despite the fact that actual figures are unknown, even the foremost optimistic projections recommend that mining contributes considerably to CO2 emissions. Renewable energy surpluses are oftentimes wasted instead of used. On a sunny or windy day, significant amounts of renewable energy are lost when solar panels or wind turbines produce more electricity than users want, and the networks become overwhelmed. Extra renewable energy is sometimes cheaper to waste than to store in standard Li-ion batteries. This is a widely held concept that is neither cost-effective nor economical.

Our goal is to get the maximum hash rate while using the least amount of power; thereby, undervolting the GPU is a good place to start. Undervolting is available via the “Core Voltage” slider; before playing with the settings, do some research on the make and model of your card, identify your base voltage, and only go down in minor increments. Increase the memory clock if you’re mining a memory-intensive algorithm, and the same goes for the core clock. Efficiency is crucial in mining since it determines profitability. The most expensive things in mining are power and cooling equipment. To minimize power consumption and heat, we used Nvidia graphics cards for this undervolting technique. Undervolting works with both AMD and Nvidia GPUs. When using the default fan speed, power consumption is reduced by approximately 30%, and fan speed is reduced by approximately 33% after undervolting. It also runs much quieter while undervolting, and we’ve noticed that undervolting keeps the GPUs much cooler, 5–10 degrees Celsius colder with very little hash rate loss.

Another technique we have used is overclocking. Overclocking is the process of increasing the default memory and core clock rates of the GPU to make it faster than the manufacturer intended. When overclocking, you can increase the power limit and/or voltage, but keep in

mind that this will increase power consumption. Experimenting with high clocks and temperatures is generally safe, but bear in mind that they may cause your hardware to fail faster than usual. You can raise your mining earnings while lowering your power usage with proper overclocking! The opposite of overclocking is underclocking. When you underclock, the memory and core clocks are slowed down. You can also reduce the power limit and voltage when underclocking, resulting in decreased power usage, but underclocking reduces the performance significantly. GPUs will require more power to work at higher clocks when you increase the clocks. Finding a balance between power consumption (reducing the power limit) and hash rate (memory and core clocks) can improve the GPU's mining efficiency. You could increase the power limit by utilizing renewable energy because it is less expensive and has no environmental impact, and it also allows the GPU to function at greater clock speeds but remember that more power usage equals higher temperatures. Also, as a conclusion part, Table 6 is depicting the comparison of our mining technique to previous works.

## 6. Conclusion

- (i) Today, cryptocurrency mining is powered by electricity generated from nonrenewable resources to reduce the use of coal, and other fossil fuels in this paper, we have demonstrated the mining of cryptocurrency with renewable energy.
- (ii) Mining cryptocurrency with the help of renewable energy not only will help the miners regarding their profitability but also has a significant impact on the environment as well, and as previously stated in our paper, electricity is the main source of energy for mining and to reduce the electricity consumption there is no way but to use renewable source of energy and some hardware optimization miner can not only run their mining rigs at lower temperatures but also run their mining rigs for a long time, which reduces the e-waste issue we had now.
- (iii) Mining hardware is relatively expensive when the hardware configuration is not concerning the crypto that is being mined the mining hardware might get fried due to the load mining forces the hardware into. To reduce these issues, we have gone through configuring the hardware for mining.
- (iv) Most of the time when mining cryptocurrency with GPUs, energy consumed by those GPUs will be relatively high in general, and the cards consume more energy when mining; to reduce this energy consumption, we have demonstrated two different techniques, namely, undervolting and overclocking, which do not compromise the performance of the card.

In comparison with previous techniques used in many studies, our mining techniques, which include GPU overclocking, undervolting, and using renewable energy as the primary source of mining, will help to reduce the

environmental impact caused by cryptocurrency mining while also allowing miners to attain more profits because renewable energy is less expensive than traditional electric power. In this article, we have demonstrated mining of cryptocurrency with renewable energy is the source of electricity for mining, and the experimentation results contain a complete overview regarding the use of renewable energy for mining and the results have shown the profitability margin while mining; the experimentation results also had information regarding the mining rig configuration to get maximum profit out of the mining rig with least amount of power consumption. Cryptocurrency mining may be thought of as an attempt to shift energy consumption into profit.

## 7. Future Scope

Today, bitcoin mining is mostly powered by electricity generated from nonrenewable resources, which is less expensive than electricity generated from renewable sources. The novel technique suggested here involves mining cryptocurrencies with renewable energy and transforming it into coin with value to reduce emissions and expenses. And not only mining cryptocurrency with extra renewable energy offers huge potential to address financial and technological gaps, but it has the ability to turn waste into value while also lowering financial risks. In the coming future, the profits from this type of cryptocurrency mining might encourage a broader spectrum of further investments in renewable assets, which not only helps miner to attain more profits but also helps the environment as using renewable energy will not cause any damage to our environment.

## Data Availability

All the data are available in the paper.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

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