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Financial Revolution of Payment Methods toward Energy Efficiency Growth: Which One is the Most Sustainable?

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Abstract. Environmental issues have been a crucial concern in every global sector. One sector that might cause environmental problems is the financial sector. Surrounding issues come from various factors such as the usage of fossil fuels that lead to global warming and climate change which slowly assassinate human beings. This article will focus on efficiency comparison between using paper money, plastic cards and cryptocurrency. The main goal is to prove which of the three financial payments is the most energy-efficient in the past, present, and future. The parameters used in this study are electricity usage and CO_2 emissions. The whole analysis is based on a quantitative-descriptive method which provides in depth analysis of electricity usage and CO_2 emissions level among financial equates from every generation. Even though plastic cards have the highest efficiency level initially, over time, cryptocurrency is going revolutionary, making them more efficient than paper money and plastic cards. This proves that cryptocurrency could be the most energy-efficient payment method in the future.

INTRODUCTION

Sustainability has become a topic of concern on the agendas of global and local leaders. Reducing carbon footprint and energy usage is one of the crucial topics that need to be addressed to help ensure a sustainable future for the planet and the global economy [1]. Recently, several federal and state agencies make statements that show how much of a priority it will be to address the Green Economy, especially the global climate crisis. The Biden administration rejoining the Paris climate accord was the first indication of this, committing to reduce carbon emissions by at least 55% by 2030 from 1990 levels [2]. The financial sector contributes a significant amount to all energy consumption in the world. In the financial sector, many transactions are still growing every day, which uses lots of energy, emits CO_2, and air pollution. There are three kinds of transaction payments commonly used: conventional currency or paper money, plastic cards, and digital currency, especially cryptocurrency. Whether in cash, plastic cards, or with crypto, every transaction consumes energy and emits pollutants into the environment depending on the energy source. The impact is startling when looking at the total transactions across an entire year for any form of currency. In the early years, paper money and plastic cards have been used as legal tender for trade goods and services worldwide. Over the years, cryptocurrency was created to answer the weaknesses of paper money and plastic cards. The conception of cryptocurrency enabled instantaneous, borderless transactions without the high fees or foreign exchange barriers.

Theoretically, cryptocurrency is meant to avoid concerns regarding sustainability because these are digital assets by design [1]. Empirically, prior studies found in most researches regarding cryptocurrency, particularly Bitcoin, only told how massive the energy used in the mining process and this sparked a debate over the years, with many oppositions from

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environmentalists to politicians confronting extreme energy usage to mine cryptocurrency. A study from Digiconomist's Bitcoin Energy Consumption Index shows that if Bitcoin were a country, it would rank in the top 30 worldwide for energy use [3]. That is roughly enough electricity to power countries with populations in the tens of millions, with an environmental burden of an estimated 34 megatons of carbon emissions or more. To put the energy consumed by the Bitcoin network into perspective, we can compare it to another payment system like VISA, for example. The same study also highlighted that the carbon footprint of a single transaction from Bitcoin produced 808.34 kg CO_2 compared to only 0.45 grams CO_2 per VISA transaction [3]. Discourse on the long-term sustainability of cryptocurrency has been a topic of concern whether digital coins could be accepted as the future of payment. Often this debate leads to comparing cryptocurrency against Visa and other payment methods in terms of transaction processed and energy usage. Studies conclude that Bitcoin is significantly more energy-intensive per transaction than VISA [3,4,5]. Then, is all the opposition coming toward cryptocurrency warranted. The gap between the theoretical relationship and the empirical conditions need to be assessed by comparing energy efficiency using electricity usage and CO_2 emissions between three types of payment methods.

LITERATURE REVIEW

Sustainability Agenda

Sustainability issues are crucial to guarantee the future of the earth and global economy and have to be dealt with [1]. In this context, two agreements have been consented globally which are Sustainable Development Agenda of United Nation and Paris Agreement of United Nation Framework. Expediting the adoption of energy interventions is critical to meet two objectives. First, to boost the enhancement of global rate energy efficiency by twice as much by 2030 which is put forward in the Sustainable Development Agenda of the United Nation [6]. Second, to accomplish the objective to limit global average temperature by 2°C inscribed in the Paris Agreement of the United Nation Framework [7]. Hence, reducing CO_2 emissions and increasing energy efficiency is a crucial matter that we need to be concerned about.

There are several ways to achieve energy efficiency and less CO_2 emissions. Firstly, lowering energy consumption by creating technology innovations. The lower rate of energy usage means the less CO_2 emissions [8]. Recent suggestion by cryptocurrency that has been making technological breakthroughs by swapping the original consensus mechanism, i.e. the proof-of-work algorithm, to other protocols (such as proof of-stake, proof-of-authority or proof-of-elapsed-time algorithms) in order to reduce the energy consumption [9]. Mechanism transformation from proof of work to proof of stake is the key to fight climate change through lower consumption of energy [10]. The second way is by using renewable energy which emits far less CO_2 compared to fossil fuels [11]. The greater proportion of renewable energy carrying out the most significant reduction of global greenhouse gas emission [12,13]. The third way is redeeming CO_2 emissions that can be done by trees-planting [14]. The more trees are planted then the more CO_2 emissions absorbed by the trees.

In the context of energy efficiency and clean energy [15] believe that development of cryptocurrency through blockchain might potentially reduce climate change through less carbon consumption, less energy usage, and clean energy usage of trading. Conversely, [16] shows that early generation of cryptocurrency, (i.e. Bitcoin) has impacted the environment negatively due to the extremely energy-hungry process. It is supported by [1] which shows that plastic cards such as credit cards, become the lowest energy and least CO_2 emissions among financial payments. Nevertheless, cryptocurrency's developers always invent new technology to solve these environmental problems in order to transform cryptocurrency into a greener economy.

Efficiency's Indicators

The indicator of efficiency is derived from the ratio of the output and input. Energy efficiency is merely interpreted as performing the same task or producing the same amount of output using less energy [17,18,19]. In this case, while input can be measured in a variety of terms such as kilowatt hours for electricity, output is measured by the quantity of transactions [19]. Another measurement of efficiency using CO_2 Emissions per transaction [19].

METHODOLOGY

This study aims to analyze the most efficient financial payments measured by using a quantitative-descriptive method and utilize two parameters, that is, energy usage and CO_2 emissions. The data are collected from secondary sources such as previous studies, real-time data, and supporting websites. In addition, there will be a thorough discussion about invigorating energy efficiency from the past, present, and future prospects from each financial payment. To discover energy efficiency development of cryptocurrency, this study exploits the prior data converted into indexes using Bitcoin that verifies lots of huge transactions per day from people worldwide. In the era of globalization, where technology advances at an increasing pace, there have been many attempts to create environmentally friendly transaction means. In this new era, the world has become faster, and everything in our life needs to be done more efficiently as the basis. The basis index is used as the standard measure or benchmark for the energy efficiency comparison. This study also uses the trend analysis method to find the pattern of electricity consumption and CO_2 emissions per transaction, and make reliable predictions in the future. According to [20], trend analysis is used to investigate the uncertainties in the future based on the pattern summary. Acknowledging that some data sources are using their own assumption and different methods, we consider there might be some lack of data to determine the exact amount of energy consumption that will be compared apple to apple.

RESULTS AND DISCUSSIONS

Any means of payment, whether paper money, plastic cards, or cryptocurrency, cannot avoid energy consumption and its impacts, such as CO_2 emissions, which harms the environment. The main goal of this article is to focus on the environmentally-friendly transaction means, and other factors like convenience or low fees have not been considered. Paper money, which is the first generation of the transaction, consumes a lot of energy, especially in the printing process. Study proves that paperless is a prodigious movement that encourages utilizing less paper and making intentional choices to support a greener environment [21]. Moreover, the use of ATMs in paper money transactions also contributes a significant amount to paper money energy consumption. On to the next generation, which consists of all kinds of plastic cards, the energy consumption becomes more efficient. Plastic cards have become a global transaction economy. One of the major advancements in transactional means is the advent of digital money or cryptocurrency, which is designed to be more efficient in energy use and eco-friendly [13,15,22].

However, many studies have argued that the advent of cryptocurrency does not make the transaction more energy-efficient [23,24,25] Studies proved that cryptocurrency consumes even more energy than paper money, let alone plastic cards. In a nutshell, plastic cards are in the first position as the most energy-efficient transaction means. However, keep in mind that this study only uses bitcoin as a crypto parameter, even though crypto consists of various kinds of coins, therefore the comparison is not compatible and is too generalized. So, this paper wants to attest which type of financial payment is more efficient using function calculation in the parameter of electricity consumption and CO_2 emissions.

TABLE 1. Energy Consumption and CO_2 Emissions per Transaction

Type of Financial Payment	Financial Payment	Estimate of Electricity consumption per transaction (kWh)	*Estimate of CO_2 Emissions per transaction (gram)
Cash	*Paper money	0.0440	0.00002320
Plastic Card	*Visa	0.0008	0.00000046
	*MasterCard	0.0006	0.00000051
Crypto	Gen 1 : Bitcoin	**707.0000	0.46600000
	Gen 2 : Ethereum	**62.5600	0.02730000
	Gen 3 : XRP	**0.0079	0.00000450

Source: *[1], **[26]

Until 2021, it is undeniable that credit cards dominated by Visa and MasterCard rank first with the most efficient energy consumption compared to Bitcoin. However, cryptocurrency does not consist of Bitcoin itself, but there are various kinds of cryptocurrency. The electricity consumption score differences between credit cards and Bitcoin are so high that they give us the false impression that cryptocurrency will take years, if not never, to catch up. However, based on the data in **TABLE 1**, there are indications that cryptocurrency grows revolutionary in each generation to reduce energy wastage. The first generation of cryptocurrency, Bitcoin, introduced back in 2009, consumes 707 kWh per transaction and emits 4.66E-01 gram CO_2 per transaction due to the proof of work (PoW) mechanism. This considerable energy consumption has provoked many controversies among society due to environmental concerns. However, after Bitcoin was first introduced, the second generation of cryptocurrency, Ethereum, was launched in 2015. The energy consumption of Ethereum is 62.56 kWh per transaction. The total electricity consumption of Ethereum only needed 4% energy from Bitcoin, which shows the remarkable evolution of crypto technology.

Even though the second generation still uses proof of work (PoW) protocol, this technology invented a new smart contract mechanism. In other words, within six years, cryptocurrency society has made a breakthrough that changes almost the whole system of operation by inventing a new transaction mechanism that can save a lot of energy consumption. This trend seems to be continuing to the third generation, XRP, which was firmly established in 2018. XRP's energy consumption is merely 0.0079 kWh per transaction, with energy uses about 0.00113% from Bitcoin. Besides, CO_2 emission on XRP is 0.00069% from Bitcoin, which proves that recent coins have been more efficient than the second generation. Considering the huge energy consumption differences among generations of cryptocurrency, many would believe that pattern will continue to the following generations of cryptocurrency. Again, it is not hard to see that the energy consumption of plastic cards is the smallest, but this amount stays unchanged from time to time and has not been making any improvement at all in order to become more energy-efficient. Although there have been several new plastic cards that use renewable energy and emit less CO_2, the pace of development is much slower than cryptocurrency. Considering that the blockchain energy consumption intensity strongly relates to carbon emission behavior [8], the following explanation and analysis will focus solely on energy consumption. Even though some articles and websites currently seem to be glorifying plastic cards as the most environmentally-friendly means of payments [27,28], **TABLE** 2 gives us another perspective.

TABLE 2. Energy Consumption Index

Coins/ Generation	*Kilowatt Hour (kWh/ transaction)	First Generation as Basic Efficiency		Second Generation as Basic Efficiency	
		Index (Bitcoin as basic)	The efficiency to Bitcoin (kWh/ transaction)	Index (Ethereum as basic)	The efficiency to Ethereum (kWh/transaction)
Bitcoin/1	707.000000	100.000000000	1.0	1,130.1151000	0.09
Ethereum/2	62.560000	8.848656300	11.3	100.0000000	1.00
Bitcoin Cash/2	18.975000	2.683875500	37.3	30.3309000	3.30
Litecoin/1	18.522000	2.619802000	38.2	29.6068000	3.38
Cardano/3	0.548000	0.077496500	1,290.4	0.8758000	114.18
Dogecoin/1	0.120000	0.016973100	5,891.7	0.1918000	521.33
Chia/3	0.023000	0.003253200	30,739.1	0.0368000	2,720.00
XRP/3	0.007900	0.001117397	89,493.7	0.0126000	7,918.99
IOTA/x	0.000110	0.000015558	6,427,272.7	0.0002000	568,727.27
**Algorand/3	0.000008	0.000001131	88,375,000.0	0.0000127	7,820,000.00

x = crypto whose not using blockchain
Source: *[26] **[29]

TABLE 2 includes only several eco-friendly cryptocurrency, but there are many other cryptocurrency out there and many other groups and organizations working on launching their new versions of cryptocurrency. Each one has innovative features that make them better and more sustainable than the current ones, not to mention cryptocurrency integrating solar and renewable energy in their systems. At present, cryptocurrency is considered the most dangerous transaction means of all compared to paper money and plastic cards. However, they have been working on their system, and their great works clear the path toward being revolutionary while the other means are stuck with their current system. **TABLE 2** shows how these revolutionary works turn the most wasteful energy consumption cryptocurrency into the most energy-efficient transaction means. The index number in **TABLE 2** indicates that as cryptocurrency moves from the first generation to the second generation, energy efficiency has increased around eleven times. Next

to the following generations (Algorand), this efficiency keeps improving at an extraordinary pace, more than eighty-eight million times more efficient. Many new and inventive cryptocurrency keep coming out with new innovative technology, making them more and more energy-efficient than ever. As a result, from hundredths kWh per transaction, a cryptocurrency that is Algorand has come side by side with the current champion with about 0.000001131 kWh per transaction. Moreover, unlike the energy consumption calculation of cryptocurrency, the energy consumption calculation of plastic cards only involves the transaction process. This surely would result in plastic cards consuming less energy than cryptocurrency because the calculation of cryptocurrency' energy consumption involves the whole system. Nevertheless, as **TABLE 2** indicates, cryptocurrency are making even further improvements on energy consumption, giving them incredible potential to catch up with plastic cards.

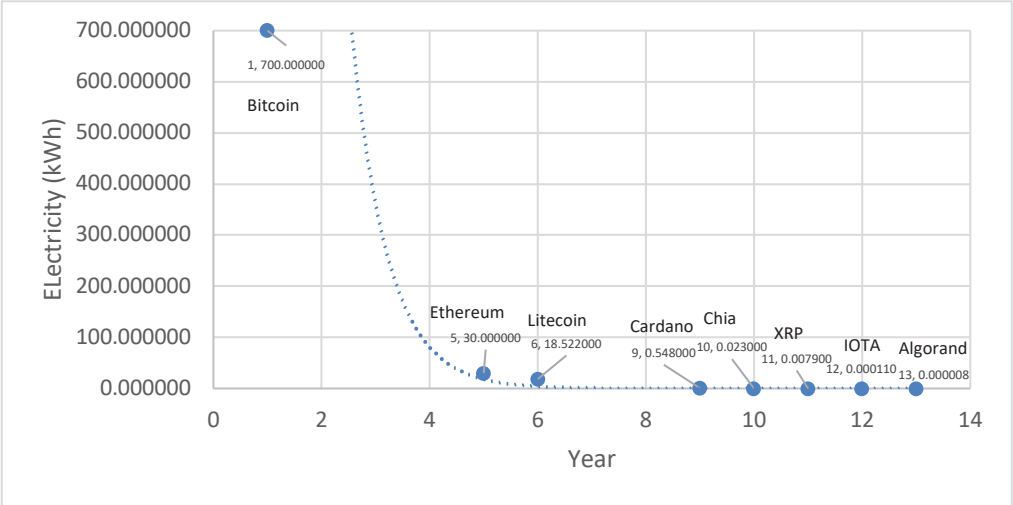

FIGURE 1. Cryptocurrency's Electricity Consumption per Transaction (kWh)

Where 0 represents the year of 2008, 1 represents the year of 2009, … , and 14 represents the year of 2022. According to **FIGURE 1**, three kinds of functions are used to predict cryptocurrency's energy consumption trend. These three functions are exponential, linear, and logarithmic. Among the three functions, the exponential function possesses the highest R-square which is 99.81%. It means that exponential functions are the most accurate in predicting the crypto's energy consumption in the future. The equation of exponential function is:

$$y = 31993e^{-1.495x} \tag{1}$$

From the exponential function, the prediction of electricity usage calculation for paper money will be reached by 2018 and in 2022, cryptocurrency will have efficiency tie with MasterCards. Which means, before 2022, MasterCards are the most efficient transaction means compared to cryptocurrency and paper money. In reality, the data shows that by 2018 Chia's energy consumption is even more efficient than that of paper money and also by 2020 IOTA, which is represented as cryptocurrency, has proved to be more efficient than MasterCards.

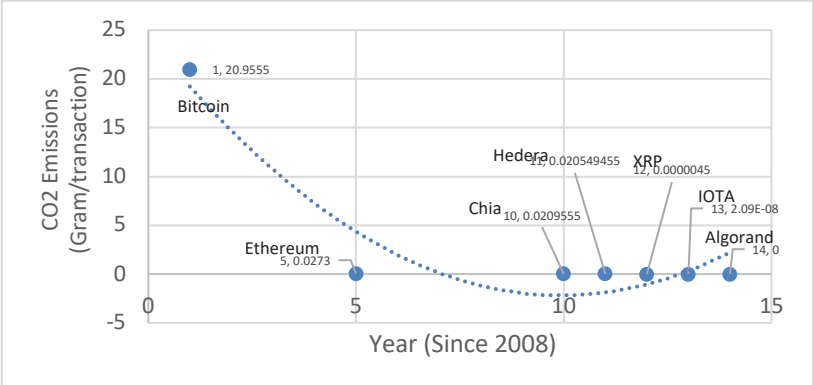

FIGURE 2. Cryptocurrency's CO_2 Emissions per Transaction (Gram/Transaction)

FIGURE 2 shows the same pattern for carbon emission where 0 represents the year of 2008, 1 represents the year of 2009, … , and 14 represents the year of 2022. Three functions are used to project cryptocurrency's carbon emissions, which is quadratic polynomial, linear, and logarithmic. Using the R-square score, it is found that the Polynomial function is the best representation of the function (90,33%). The equation of quadratic polynomial shows:

$$y = 0.268x^2 - 5.3262x + 24.277 \quad (2)$$

As the quadratic polynomial above, if y is substituted by 0,0000232 (paper money's carbon emission), x is found to be 12.79 ~ 13 which represents year 2021. It means that by 2021, cryptocurrency's most efficient carbon emission is tied with that of paper money. In fact, the data shows that even before 2021, cryptocurrency's carbon emission which is represented by XRP is even more efficient. On the other hand, it is predicted that cryptocurrency's carbon emission is tied with Visa' by 2021. In fact, the actual data shows that by 2021, cryptocurrency (IOTA) even emits less carbon compared to Visa (**TABLE 1**). Visa is used instead of MasterCards because its carbon emission is less than MasterCards'.

CONCLUSION

This article has not considered specifically the features of the new systems, whether they are using proof of stake, proof of storage, or others. Regardless, with the growing improvements, cryptocurrency has excellent potential to become the most energy-efficient means of transaction. Considering the fast advancements, many can be sure that this will happen in the near future. In the past, plastic cards are the most efficient financial instrument [3,4,5]. Nevertheless, according to the estimation results and analysis on the discussion part, it is found that by 2022, cryptocurrency's energy efficiency will surpass plastic cards' and in 2018, cryptocurrency's energy efficiency managed to surpass that of paper money. This happened because cryptocurrency's energy efficiency experienced exponential growth. The same patterns are found in carbon dioxide emission, where cryptocurrency is predicted to surpass plastic cards' and that of paper money by 2021. In reality, even before 2021, crypto is more efficient than plastic cards and paper money, both in energy consumption and carbon emission.

This implies that our focus should not lay on how dangerous cryptocurrency is but instead, we should focus on the extraordinary revolution that cryptocurrency has been achieving. This will help us see the great potentials that lie within cryptocurrency. Most current articles about cryptocurrency devote their attention to how energy-wasting Bitcoin, instead of the potential of other new cryptocurrency that are becoming more prominent. For future research, this topic is still new and needs further exploration. There are still many opportunities for further explorations on cryptocurrency. The cryptocurrency society has been making incredible progress at an incredible pace on this issue as more and more cryptocurrency are starting to switch or combine their energy with renewables. There have been many new digital currencies, and many will show up in the near future with their more advanced technology and breakthroughs that significantly reduce their system's energy consumption.

This study only uses two indicators which are energy consumption and carbon emission per transaction. For plastic cards and paper money, this paper only uses energy consumption per transaction without considering the energy consumption of the whole system or the transaction process. Moreover, this study only uses a few kinds of cryptocurrency to compare with paper money and plastic cards. For future research, it is suggested that using more kinds of cryptocurrency and more indicators. Hence, the results can be more reliable and comprehensive.

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Fazida Karim; Mohd Nasir Ismail; Norhilmi Muhammad; Noor Suhana Sulaiman; Abdullah Mazlan

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A seasonal field investigation to perceive outdoor thermal comfort and thermal adaption at Malacca tourist area-a pilot test

Golnoosh Manteghi; Tasneem Mostofa

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Amalia Baharuddin; Harnani Mat Zin

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Hasamon Pengman; Mustakim Melan; Suhaila Abdul Hanan

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Village factors influencing the effectiveness of village fund program by Indonesian government in empowering local community economy in Merauke Regency

Inez Cara Alexander Phoek; Alexander Phuk Tjilen; Edi Cahyono

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Jurina Jaafar; Zulhafizal Othman; Noraini Ahmad Basri; Sharifah Abdullah; Wan Abdul Rahim; Wan Aida Wan Yahaya

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Khai Lin Chong; Faizatul Akmar Abdul Nifa; Sharima Ruwaida Abbas; Noreliaezani Mohamad Zahir

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Terms and condition of services (T & C) for drop trailer method (DTM) of haulage industry in Malaysia

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Flora Goyak; Mazura Mastura Muhammad; Muhamad Fadzllah Zaini

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Flora Goyak; Mazura Mastura Muhammad; Muhamad Fadzllah Zaini

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The challenges in implementing building information modelling (BIM) for Malaysian affordable housing

Mohd Kamaruzaman Musa; Mohd Eizzuddin Bin Mahyeddin; Nurifahizati Abd. Jalil; Mohammad Ashraf Abdul Rahman; Mariah Awang; Peniel Ang Soon Ern; Suraya Rani Adnan; Kamarul Aini Mohd Sari; Faridahanim Ahmad

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Issues and problems for the implementation of the IBS for affordable housing projects

Mohd Kamaruzaman Musa; Mohammad Ashraf Abdul Rahman; Ishak Baba; Zarith Anisa Idris; Mariah Awang; Mohd Syafiq Syazwan Mustafa; Nuramidah Hamidon; Fatimah Mohamed Yusop; Faridahanim Ahmad

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The effects of lean tools and techniques implementation in Malaysian small and medium enterprise (SME), large and multinational industries: A survey

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Prediction of future temperature and rainfall characteristics using statistical downscaling model (SDSM) for Pondok Tanjung station in Kurau river basin

Muhammad Shafiq Amir Bin Kamarazaman; Nuramidah Binti Hamidon; Nur Aini Binti Mohd Arish; Mariah Awang; Hasnida Harun; Noor Yasmin Zainun; Mohammad Ashraf Abdul Rahman; Faridahanim Ahmad; Kamaruzaman Musa; Fatimah Mohamed Yusof; Suraya Hani Adnan; Mohd Syafiq Syazwan Mustafa

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The semi-skilled manufacturing worker readiness on automation implementation in industry 4.0

4.0

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Lee Sing Pei; Rumaizah Ruslan; Md. Fauzi Ahmad; Norhadilah Abdul Hamid; Ahmad Nur Aizat Ahmad

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In-silico interaction of antimalarial activity of secondary metabolic compounds *Ginkgo biloba* L. against wild type protein *Plasmodium falciparum* dihydrofolate reductase-thymidylate synthase (PfDHFR-TS)

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Study in-silico interaction of artemisinin ligands against the wild-type *Plasmodium falciparum* Kelch13 protein model and the *Plasmodium falciparum* Kelch 13 protein model in mutations of C580Y, R539T, and F446I)

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Shiau Wei Chan; Fadillah Ismail;

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Siti Farhanah Hasnan; Razamin Ramli; Mohd. Noor Abdul Hamid

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Passively mode-locked erbium doped fiber laser based carbon nanotube saturable absorber with MHz fundamental repetition rate: An experimental study

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Uttam Sahay; Gagandeep Kaur

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Adam Haikal Ibrahim; Zaihisma

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Raden Gemalla Rachma Dewi Wiratmadja; Erwinna Chendra; Liem Chin; Agus Sukmana

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Solar analysis using building information modeling (BIM) Block A UTHM Campus Pagoh - Case study

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Monica Kashkari; Tejwant Singh Brar

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