Available online at www.sciencedirect.com
ScienceDirect
Energy Reports 8 (2022) 970–979
www.elsevier.com/locate/egyr

2022 The 5th International Conference on Renewable Energy and Environment Engineering (REEE 2022), 24–26 August, 2022, Brest, France

Study on the economics of wind energy through cryptocurrency

Raúl Vega-Marcos[a], Antonio Colmenar-Santos[a], Francisco Mur-Pérez[a,*], Clara Pérez-Molina[a], Enrique Rosales-Asensio[b]

[a] *Department of Electrical Engineering, Electronics, Control, Telematics and Chemistry Applied to Engineering, UNED, Juan del Rosal, 12, Ciudad Universitaria, 28040 Madrid, Spain*

[b] *Department of Electrical Engineering, University of Las Palmas de Gran Canaria, Campus de Tafira S/n, 35017 Las Palmas de Gran Canaria, Canary Islands, Spain*

Received 5 October 2022; accepted 6 October 2022
Available online xxxx

Abstract

The Green Pact signed by the European Union establishes a trend towards renewable energies to combat the greenhouse gas emissions. Among the technologies used to produce this type of energy, wind power generation technology stands out, which, in countries such as Spain, already has significant installed power. The main problems posed by this technology plans are the uncertainty intervals of wind power and its inclusion in the electricity market, due to the complex price system that does not always favor the producers. The main purpose of this research is to promote the installation of more wind power plants. For this, the installation of cryptocurrency mining equipment is proposed, which will be powered by the generation produced by these wind power plants. The article analyzes the production of cryptocurrencies is a growing business. In the research process, the latest cryptocurrency mining equipment is evaluated. It is analyzed which equipment is the most suitable for its installation in the wind power plant and an economic study is made for the construction project of a large wind power plant. Finally, it will be seen that in this way the amortization time of the facilities decreases and also the project is more attractive for the investor since they can decide between injecting energy into the electrical network or mining cryptocurrencies. If a wind power plant invests in cryptocurrency mining in parallel to the production of electrical energy for the grid, it can decide when to enter the electricity market pool or engage in mining. In this way, the idea of building many more wind power plants becomes more attractive. This would lead to a market where this renewable energy would be much more abundant and the price curve would shift to a lower price, as well as a significant reduction in greenhouse emissions.

Peer-review under responsibility of the scientific committee of the 5th International Conference on Renewable Energy and Environment Engineering, REEE, 2022.

Keywords: Cryptocurrencies; Mined; Wind power

1. Introduction

The main purpose of this research is to obtain greater profitability for a wind power plant. For this, a combination is made between a wind power plant and cryptocurrency mining equipment with the aim of increasing the

* Corresponding author.
E-mail address: fmur@ieec.uned.es (F. Mur-Pérez).

https://doi.org/10.1016/j.egyr.2022.10.103

Peer-review under responsibility of the scientific committee of the 5th International Conference on Renewable Energy and Environment Engineering, REEE, 2022.

profitability of the renewable energy plant. In the research presented here, an incentive is proposed for renewable energies with a higher degree of technological development, focusing on wind energy.

The research methodology is based on the study of a much faster amortization of the investment through the balance between the sale of energy to the distribution network and the generation of cryptocurrencies, obtaining the relevant economic benefit. This allows the creation of a greater number of generating plants based on renewable technologies. In addition, it will make it possible to compensate for the instability present in some energies such as wind power, which may not enter the energy market due to its variable nature and waste its production. The inclusion of renewable energies is essential to achieve a transition towards a low-emission energy system. However, the variation in the production of these technologies suggests diversifying the applications to make investment in renewable energy parks more attractive.

The results obtained show that the necessary investment for the cryptomining equipment is high, but that the amortization time is much shorter for the set of the wind power plant and the mining equipment. The study shows that the most modern cryptomining equipment is much more powerful and compensates for the fact that the price is also considerably higher, reducing the total amortization time significantly.

Currently, investment in renewable energy sources is booming to combat the effects of climate change by reducing greenhouse gas emissions that are very harmful to the environment and to humans [1]. According to the Intergovernmental Panel on Climate Change (IPCC) of 2018, at least 35% of greenhouse gases are caused by the energy sector [2] and an increase is expected in the coming years. Thanks to the commitment to renewable energies in Spain, it has been possible to reduce the trend, with Green House Gas emissions falling by 15.6% in 2020 compared to the previous year (Fig. 1.a) and a reduction of 34.6% since 2008 [3].

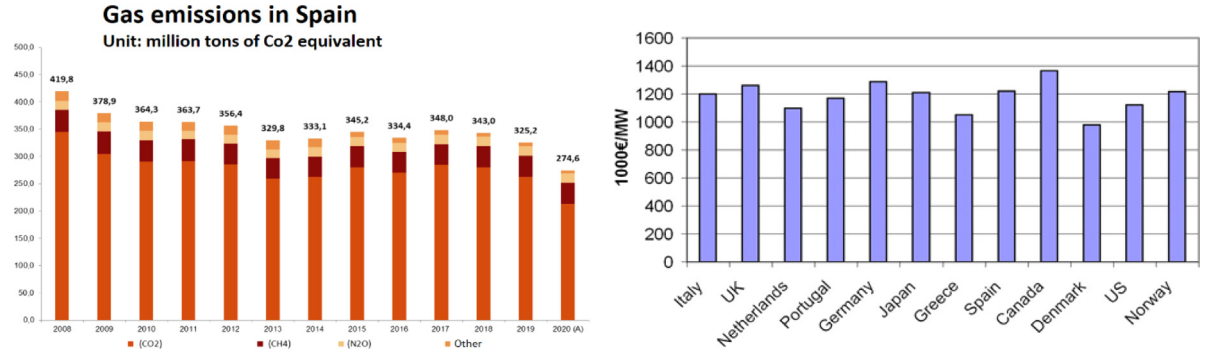

Fig. 1. (a) INE. Gas emissions in Spain [3]; (b) Cost per kW per country.

By 2050 the European Union expects the continent to be climate neutral in terms of emissions. For this reason, the Green Pact [4] has been signed, which seeks to implement renewable energies [5], abandoning others such as coal and natural gas. Also betting on a greater accumulation of energy to thus adjust the supply and demand curve. Countries such as Spain, Germany, Portugal, or Italy are currently renewing their regulations to promote renewable energies, both in large productions and at the user level. These regulations must be consistent with European regulations and with economic compensation mechanisms.

To assess the variation of these technologies it is necessary to obtain high quality data, considering potential locations using historical data that is not always available. Using data from satellites, data can be obtained to perform the necessary calculations. Two sources available to obtain information from European countries regarding wind and solar energy are:

- EMHIRES (European Meteorological-derived High resolution RES dataset) published by the European Commission [6–8].
- Renewables.ninja, published by ETH Zürich and the Imperial College. London [9,10].

In Ref. [11] you can see the comparison between the data obtained by the two previous sources with respect to the data obtained by local producers in several European countries. These data obtained must be evaluated, since they can cause a significant error in investment decisions and in the analysis carried out by the system operator. For

example, in Ref. [12] you can see the calculation error made in Germany. One of the main drawbacks of the creation of new renewable plants is the high cost of the initial investment and the long amortization periods to recover the invested capital. In addition, currently the variable price of energy makes it unprofitable for the owner of the plant to inject energy into the network at certain times, so production is stopped. For this reason, the combination of injection into the electricity network in the hours with the highest electricity prices and the production of cryptocurrencies when the energy is at a lower price is proposed. As will be seen later, the time for the recovery of the invested capital will be much shorter. In this study, wind energy is mainly analyzed as it is a clear example of the scarcity of energy production as it depends on the wind as an energy source.

The research methodology is presented in Sections 3 and 4. In the research process, an analysis of the most efficient mining equipment and the analysis of the difficulties in evaluating the production of a wind power plant by wind instability. Section 2 is divided into two clear sections, where the state of the art of wind technology and blockchain is studied. Therefore, in the first section, the state of wind technology in Spain will be evaluated as it is one of the main countries that have invested in wind energy production. The current state of wind forecasts for this type of technology will also be evaluated. The electricity market in this country will be analyzed, demonstrating the complexity of the system and how producers must deal with a price system that is not always favorable. In the second section, within this Section 2, the current state of the blockchain will be analyzed. It will be analyzed how the production of cryptocurrencies is a reality that is very profitable if there is a viable and economical source of energy.

Subsequently, the Section 3 is included with a simplified example of the feasibility of the study, obtaining a recovery of the investment of a wind power plant, as well as the necessary equipment for mining cryptocurrencies.

The results obtained are presented in Section 4. In this Section 4 it can be concluded that investing in a combination of blockchain technology with wind technology is a good way to promote renewable technologies and make wind energy production more attractive by diversifying its objectives. An analysis of the cryptomining equipment is carried out where the amortization time is obtained. It is shown that the amortization time decreases, in the best of cases up to 33%. A study of the most optimal investment in cryptomining equipment for a wind power plant of a certain power is also carried out. It is concluded that the optimal investment is one that provides a payback period between 3 and 10 years.

2. Theoretical background

A theoretical background of the topic addressed in this paper has been included as Supplementary Material. References included in the Supplementary Material have been used to provide a framework and support to the research here presented.

3. Results and discussion

Currently the price of electricity is the one that really marks whether Bitcoin mining is competitive. In the case of a renewable energy plant, it is especially useful since as long as the power plant is not supplying energy to the network (because it does not enter the electricity pool) it can be mining Bitcoin. In addition, whenever the price for obtaining the cryptocurrency is higher than the price of electricity, the central has the option of mining Bitcoin (always respecting market terms).

This section presents a simplified example of amortization of a wind farm through Bitcoin mining. The price of an investment in a wind power plant is mainly determined by the cost of the wind turbine itself [13]. The approximate cost per MW ranges between 1.2 and 1.5 million euros. Of this budget, the turbine will have a weight of approximately 76% while the connection to the network will have a weight around 9% and civil works around 7%. Depending on the country in which the wind farm is installed, the cost per kW per installed capacity will be different, as shown in Fig. 1.(b).

The lowest prices are found in Denmark while the highest are in Canada and Germany (Fig. 1.b). For this study, the installation project of the wind farm by the company Iberdrola in Salamanca (Spain) will be taken as an example. This project will have an installed power of 300 MW and for this it will have 50 model SG-170 wind turbines with a nominal power of 6.0 MW. The estimated budget is 400 million euros including the infrastructure for the evacuation of electrical energy [14]. This represents a price of 1.3 euros per watt.

Having the reference of a real project, it is interesting to evaluate the mining equipment that can be used. An investment in hardware called an ASIC (Application Specific Integrated Circuit) machine will be required.

They are state-of-the-art equipment specialized in cryptocurrency mining, being very efficient as they have the best relationship between energy consumption with respect to their computational capacity. ASIC (Application Specific Integrated Circuit) miners are computer equipment based on integrated circuits designed for very specific functions, in this case cryptocurrency mining.

Depending on the manufacturer and model, each ASIC machine will be designed for a particular currency, thus offering the best possible performance for this process. Bitmain stands out as a manufacturer, which has more than 90% of the market, although others such as Canaan, KNC, BitFury and Cointerra also stand out [15]. According to Ref. [16] you can see the latest ASIC models, as well as an estimate of the profit obtained. A table (Table 1) is made with the ASIC machines available for Bitcoin mining that have the highest estimated profitability according to their price and power to choose a model that fits the needs of the power plant.

Table 1. Miners profitability. April, 2022 [17].

Model	Release	Hashrate (Th/s)	Power (W)	Noise (db)	Algor.	Efficiency (J/T)	Profitability ($/day)	Price ($)
Bitmain Antminer S19 Pro+H	May 2022	198	5445	50	SHA-256	27,5	22,83	15 048
Bitmain Antminer S19 XP	Jul 2022	140	3010	75	SHA-256	21,5	18,56	11 620
Bitmain Antminer S19 Pro	May 2020	110	3250	75	SHA-256	29,5	12,04	9460
MicroBT Whatsminer M30S++	Oct 2020	112	3472	75	SHA-256	31,0	11,78	8399
Bitmain Antminer S19j Pro 104	Jul 2021	104	3068	75	SHA-256	29,5	11,39	8340
Bitmain Antminer S19j Pro 100	Jun 2021	100	3050	75	SHA-256	30,5	10,67	8322
Bitmain Antminer S19j Pro 96	Aug 2021	96	2832	75	SHA-256	29,5	10,52	8100
MicroBT Whatsminer M30S+	Oct 2020	100	3400	75	SHA-256	34,0	9,66	7925

Later it would be necessary to configure the IP addresses of each machine. It is a simple process where the machines are assigned to the internet connection that must be available in the plant. This IP address is later associated with a mining pool. The most important pools are found in [18] where the account and address where the machines are associated appear. This creates the central's own mining account. The pool AntPool [19] is taken as an example, where the evolution of the plant's mining can be seen.

It is also necessary to consider the cooling of this equipment since its electrical cost increases considerably. The specifications of each machine include the optimum operating temperature. At another temperature its efficiency decreases significantly. For this reason, a special container designed directly for the ASIC machines owned by the manufacturer BITMAN [20] with a capacity of 210 computers is added to the equipment investment.

The application of Bitcoin mining in this article consists of the amortization of a wind farm in a shorter period than usual by injecting energy into the electrical network. With this, it is possible to promote the creation of renewable plants. For this, the benefit obtained will be evaluated considering the budget of the wind farm, the investment made in the mining machinery, the benefit obtained by mining and the benefit obtained by pouring energy into the network.

To calculate the benefit obtained, it is necessary to rely on the most prestigious existing calculators that correspond to the Ref. [21]. The price is variable (Fig. 2.) and is constantly being updated, so the month of April 2022 [22] is taken as a reference, which gives a reward of 0.00000451 Bitcoins for each Hashrate (Th/s) of each team.

With the reference wind farm discussed above [14] we have a power of 300 MW. Some tables are made where the machines previously evaluated for their efficiency appear [16]. For each case several 210 ASICs will be selected per ANTSPACE cooling container [20] and a total of 100 containers (1).

$$Hashrate_{TOTAL} = Hashrate_{ASIC} \cdot 210 \cdot ASICs_{ANTSPACE} \tag{1}$$

The table (Table 2) calculates the total price (2) of the ASIC equipment by adding the price of the containers, as well as the total power consumed (3) (always less than the total power of the 300 MW wind farm).

$$PRICE_{TOTAL} = (PRICE_{ASIC} \cdot 210 \cdot ASICs_{ANTSPACE}) + (PRICE_{ANTSPACE} \cdot ASICs_{ANTSPACE}) \tag{2}$$

$$POWER_{TOTAL} = (POWER_{ASIC} \cdot 210 \cdot ASICs_{ANTSPACE}) + (POWER_{ANTSPACE} \cdot ASICs_{ANTSPACE}) \tag{3}$$

Fig. 2. MINERSTAT. Bitcoin calculator, April 2022.

Table 2. Comparison of price and power of mining equipment.

Model	(100 ∗ 210) ASIC			100 ∗ ANTSPACE		TOTAL	TOTAL
	Hashrate (Th/s)	Power (kW)	ASIC price ($)	ANTSPACE power (kW)	ANTSPACE price ($)	POWER (MW)	PRICE ($)
B.A. S19 Pro+ Hyd	4 158 000	114 345	316 008 000	103 000	11 000 000	217,35	327 008 000
B.A. S19 XP (140Th)	2 940 000	63 210	244 020 000	103 000	11 000 000	166,21	255 020 000
B.A. S19 Pro (110Th)	2 310 000	68 250	198 660 000	103 000	11 000 000	171,25	209 660 000
MicroBT W. M30S++	2 352 000	72 912	176 379 000	103 000	11 000 000	175,91	187 379 000
B.A. S19j Pro (104Th)	2 184 000	64 428	175 140 000	103 000	11 000 000	167,43	186 140 000
B.A. S19j Pro (100Th)	2 100 000	64 050	174 762 000	103 000	11 000 000	167,05	185 762 000
B.A. S19j Pro (96Th)	2 016 000	59 472	170 100 000	103 000	11 000 000	162,47	181 100 000
MicroBT W. M30S+	2 100 000	71 400	166 425 000	103 000	11 000 000	174,40	177 425 000

The calculations are made solely for the purpose of comparing between the different mining technologies and between the sale price to the network. The operating time of the wind turbines is not evaluated, but rather a mining use of close to 70% is calculated in the case of higher consumption.

Subsequently (Table 3), the daily production is calculated (4), as well as the amortization periods of the mining equipment (5) and the wind farm (6). As mentioned, the price of the Bitcoin used is from the month of April 2022, which corresponds to $40,000 and the benefit for the mining that we obtain corresponds to 0.00000451 Bitcoins for each Hashrate (Th/s) of each machine. The estimated price for the wind farm is 400 million as mentioned above. This price corresponds to the plant designed by Iberdrola in Salamanca (Spain).

$$PRODUCTION = Hashrate_{TOTAL} \cdot Bitcoin_{PRICE} \cdot 0.00000451 \tag{4}$$

Table 3. Production of mining equipment and amortization of the wind farm.

Model	Production ($/day)	BLOCKCHAIN amortization (days)	Wind Farm amortization (Days)	TOTAL (Years)
B.A. S19 Pro+ Hyd	750 103,2	435,951	533,260	2,65
B.A. S19 XP (140Th)	530 376	480,829	754,182	3,38
B.A. S19 Pro (110Th)	416 724	503,115	959,868	4,01
MicroBT W. M30S++	424 300,8	441,618	942,727	3,79
B.A. S19j Pro (104Th)	393 993,6	472,444	1015,245	4,07
B.A. S19j Pro (100Th)	378 840	490,344	1055,855	4,23
B.A. S19j Pro (96Th)	363 686,4	497,956	1099,849	4,37
MicroBT W. M30S+	378 840	468,338	1055,855	4,17

$$BLOCKCHAIN\ AMORTIZATION = PRICE_{TOTAL}/PRODUCTION \quad (5)$$

$$WIND\ FARM\ AMORTIZATION = PRICE_{WIND\ FARM}/PRODUCTION \quad (6)$$

With these data (Table 3) it is possible to obtain the total number of years necessary to amortize both the wind power plant and the mining equipment. To obtain the number of years required for amortization, the sum of both concepts must be valued (for the 365 days of the year).

Subsequently, it is compared with the amortization period of the wind farm without mining equipment (Table 4) for the same power produced by the wind turbines (a comparison is made with all the machines since the production necessary to feed them is not the same). In other words, using the energy consumed by the mining equipment, the benefit to the wind power plant of using this energy to inject electricity into the grid is calculated.

Table 4. Amortization of the wind farm without mining equipment.

Model	Total power (MW)	Total price ($)	Production ($/day)	Wind Farm amortization (Days)	TOTAL (Years)
B.A. S19 Pro+ Hyd	217,35	50,28	262 274,56	1525,12	4,18
B.A. S19 XP (140Th)	166,21	50,28	200 568,93	1994,33	5,46
B.A. S19 Pro (110Th)	171,25	50,28	206 650,80	1935,63	5,30
MicroBT W. M30S++	175,91	50,28	212 276,53	1884,33	5,16
B.A. S19j Pro (104Th)	167,43	50,28	202 038,72	1979,82	5,42
B.A. S19j Pro (100Th)	167,05	50,28	201 582,58	1984,30	5,44
B.A. S19j Pro (96Th)	162,47	50,28	196 058,21	2040,21	5,59
MicroBT W. M30S+	174,40	50,28	210 451,97	1900,67	5,21

For this last calculation, the value of the total average sale price in the daily market for the years 2019 and 2020 [23] is taken, which corresponds to €46.57/MWh ($50.28/MWh). Subsequent periods have not been considered due to the instability with the current price marked by the price of gas in Europe.

In Fig. 3 you can see the amortization time of the different technologies. It is done by comparing the time needed to amortize the wind power plant with the time needed to amortize the wind power plant that has cryptocurrency production.

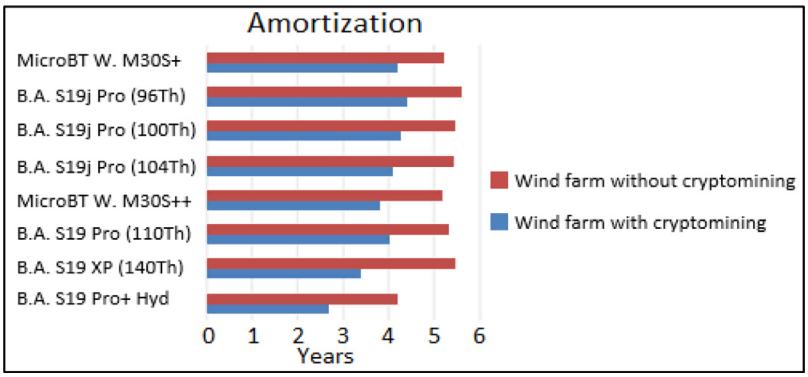

Fig. 3. Amortization.

For this, the data obtained in Tables 3 and 4 are compared, taking into account that it has been considered that the consumption of the mining equipment is injected into the network in the case of the wind power plant without mining.

From the data obtained, it can be seen that the equipment that produces the shortest payback time is the ASIC Bitmain Antminer S19 Pro+ Hyd (198Th). This equipment, despite being the most expensive, is the one that produces the most cryptocurrencies, so the amortization time is shorter. It must be considered that the investment is greater with this equipment, but in a short period it is amortized (2.6 years), generating great profits from this

Table 5. Annual production by B.A. S19 Pro+Hyd.

Date	Bitcoin price ($)	Fluctuation	Production ($/month)
Apr-22	42 515,50	−17,30%	23.918.259
Mar-22	42 690,55	5,41%	24.016.739
Feb-22	40 056,30	12,18%	22.534.769
Jan-22	40 465,25	−16,70%	22.764.835
Dec-21	50 826,05	−18,75%	28.593.587
Nov-21	61 219,45	−7,22%	34.440.679
Oct-21	55 130,00	39,90%	31.014.892
Sep-21	46 266,05	−7,02%	26.028.234
Aug-21	43 932,10	13,42%	24.715.207
Jul-21	35 797,75	18,63%	20.139.005
Jun-21	35 109,90	−6,09%	19.752.036
May-21	44 892,80	−35,38%	25.255.675
Apr-21	55 938,25	−1,78%	31.469.595

moment on. The following table (Table 5) represents the profits that would have been obtained last year by mining Bitcoin. For this, the average monthly price of Bitcoin during the last year is taken into account, which fluctuates greatly [24]. This fluctuation is therefore the biggest drawback of cryptocurrency mining, due to the uncertainty generated. However, the great growth of recent years, the forecasts made by experts and the tendency of countries and companies to bet on this technology give a high degree of certainty.

Finally, the number of mining equipment that the installation must be calculated so that it is attractive to carry out the project at an economic level. To perform these calculations, it is necessary to know the Hashrate and the cost of the equipment for each ASIC model. As previously mentioned, a key factor in mining equipment is the high temperature they reach, which is why it is necessary to include the ANTSPACE container that is responsible for cooling. As the BITMAN ANTSPACE container [20] includes a total of 210 ASIC computers, this number of computers is considered for the basis of the calculation. Depending on the number of years that the installation is intended to be amortized, the number of necessary mining equipment is calculated.

Using the same procedure as that applied in Table 4, we see that the number of years is obtained from the amortization of the mining equipment and the wind farm (7).

$$Years = \frac{Blockchain\ Amortization\,(days)}{365} + \frac{Wind\ Farm\ Amortization\,(days)}{365} \tag{7}$$

It is seen that the amortization of the mining equipment (8) is independent of the number of equipment, which is logical since the Hashrate relationship will be the same:

$$Blockchain\ Amortization\,(days) = \frac{Total\ Price}{Production} \tag{8}$$

$$Total\ Price = n_{containers} \cdot (PRICE_{container} + PRICE_{ASIC} \cdot 210) \tag{9}$$

$$Production = n_{containers} \cdot Hashrate\,(ASIC) \cdot 210 \cdot 0,00000451 \cdot PRICE_{BC} \tag{10}$$

The amortization of the wind plant (11) will be inversely proportional to the number of mining equipment. In this way, the more mining equipment, the greater the production, but the investment can become excessive and inefficient. Particularizing for each of the equipment we obtain a table (Table 6) where you can see the number of containers and equipment needed. Appendix 1 (supplementary material) shows the tables of each of the cryptocurrency mining equipment.

$$Wind\ Farm\ Amortization\,(days) = \frac{PRICE_{WIND\ FARM}}{Production} \tag{11}$$

Therefore, the number of necessary teams is obtained by means of the following Eq. (12):

$$n_{containers} = \frac{PRICE_{WIND\ FARM}}{(365 \cdot Years \cdot Hashrate\,(ASIC) \cdot 210 \cdot 0,00000451 \cdot PRICE_{BC}) - (PRICE_{container} + PRICE_{ASIC} \cdot 210)} \tag{12}$$

Table 6. Percentage of investment with respect to wind farm. B.A. S19 Pro+Hyd.

Date	N (containers)	N (ASIC)	TOTAL PRICE (CRYPT)	% PRICE (CRYPT)
2	181	38 084	593 030 692	148,3
3	81	16 992	264 593 660	66,1
4	52	10 935	170 285 033	42,6
5	38	8 062	125 539 295	31,4
6	30	6 384	99 415 832	24,9
7	25	5 285	82 291 748	20,6
8	21	4 508	70 200 004	17,6
9	19	3 931	61 206 477	15,3
10	17	3 484	54 255 630	13,6
11	15	3 129	48 722 512	12,2
12	14	2 839	44 213 512	11,1
13	12	2 599	40 468 386	10,1
14	11	2 396	37 308 180	9,3
15	11	2 222	34 605 788	8,7
16	10	2 072	32 268 446	8,1
17	9	1 941	30 226 864	7,6
18	9	1 826	28 428 247	7,1
19	8	1 723	26 831 659	6,7
20	8	1 631	25 404 869	6,4

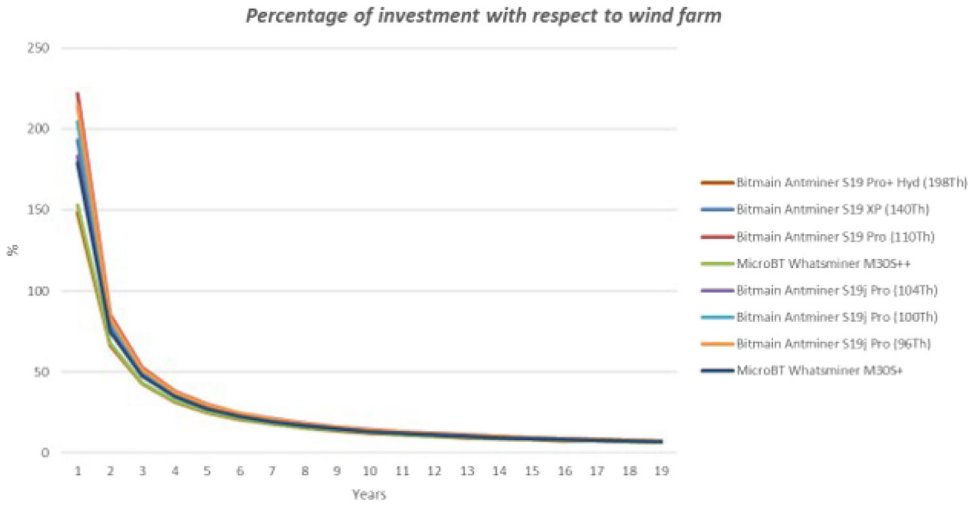

Fig. 4. Percentage of investment with respect to wind farm.

You can also see the percentage of the investment in the wind power plant that involves cryptocurrency technology. This information can be seen in the following figure (Fig. 4), where we conclude that from the second year the investment is much lower (close to 50%) for any model. This investment is still very high, so a payback period of ten years would be more interesting, where the investment in mining equipment is less than 15% of the price of the wind farm for any technology.

Due to the variability of the wind, the power used by a wind power plant is very unstable. In addition, due to the factors of buying and selling energy in the market, sometimes wind power plants cannot sell all their production to the market. For these reasons, mining cryptocurrencies using this technology is very useful, since it allows you to take advantage of all the production. In addition, through a daily analysis of the energy sale price, the producer can decide to use all the electrical energy generation in the mining of cryptocurrencies whenever the price per mining is more profitable. Thanks to this, the variability of the wind is less harmful, since it assures the producer that all the power generated will be used.

4. Conclusions

Due to the variable nature of the wind the forecast of wind power generation is not perfect. For this reason, it is required to maintain a reserve of energy from other energy sources. In addition, the current situation of the electricity market in Spain means that energy prices are not always profitable for wind energy producers, especially if they do not belong to large companies in the sector. For these reasons, the application of wind energy production in other fields is interesting, especially in the production of cryptocurrencies, which is a growing sector. The production of Bitcoin by feeding the machinery necessary for mining is an attractive business. It allows selecting the destination of the energy by making a balance between the price offered by the electricity market and the value of the cryptocurrency. According to the study carried out in a simplified way to assess the potential of this business model, the amortization time of the wind farm could be up to almost half. A much higher initial investment (even double) will be required. Currently the price of electricity is triggered by the socioeconomic situation that has caused an abusive price for natural gas in Europe. But this situation is not very sustainable, and the historical data tells us that the average prices are very far from these values. According to the tables in the previous section, the latest Bitmain Antminer model provides us with very good production data. We conclude that a very high investment with the aim of making the wind farm profitable in less than three years is not the right decision. The best investment in mining equipment will be the one that meets the objective of an amortization close to ten years, since the number of mining equipment will be much smaller, making the project much more attractive to investors. Although it must be considered that the market price is very variable, as well as the price of the cryptocurrency, so this investment is interesting by carrying out a continuous analysis of these parameters. In this way, you can decide between the sale in the electricity market or the option of producing cryptocurrencies through mining. In addition, if wind energy production is left out of the market by decision of the System Operator, that time lost in mining can be used. This greatly reduces the amortization time of the wind farm. These measures can promote the financing of new wind farms, thus contributing to compliance with the Green Deal scheduled for 2050 and helping the planet to reduce the gases that contribute to the greenhouse effect.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

Acknowledgments

The authors acknowledge the support of the Escuela Técnica Superior de Ingenieros Industriales (UNED) of Spain, project 2022-ETSII-UNED-05 and to Diana Lagunilla for her help with style corrections in the translation of the article.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.egyr.2022.10.103.

References

[1] Intergovernmental panel on climate change. In: Energy systems. Climate change 2014: Mitigation of climate change: Working group III contribution to the IPCC Fifth assessment report. Cambridge: Cambridge University Press; 2015, p. 511–98.
[2] Environmental Protection Agency. Global greenhouse gas emissions data. 2020, Available from: https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data.
[3] Instituto nacional de estadística, INE. Available from: https://www.ine.es/prensa/cma_2020_ea.pdf.
[4] EUR-Lex. Regulation (EU) 2021/1056 of the european parliament and of the council of 24 2021 establishing the just transition fund.
[5] EUR-Lex. Regulation (EU) 2021/783. Avaiable from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32021R0783&qid=1650298588667.
[6] Gonzalez-Aparicio I, Zucker A, Careri F, Monforti-Ferrario F, Huld T, Badger J. Emhires Dataset: Part I: Wind Power Generation. Tech. Rep., Joint Research Centre; 2016, http://dx.doi.org/10.2790/831549, Available from:.

[7] Gonzalez-Aparicio I, Monforti F, Volker P, Zucker A, Careri F, Huld T, Badger J. Simulating european wind power generation applying statistical downscaling to reanalysis data. Appl Energy 2017;199:155e68. http://dx.doi.org/10.1016/j.apenergy.2017.04.066, Available from:.
[8] Gonzalez-Aparicio I, Huld T, Careri F, Monforti F, Zucker A. EMHIRES dataset part II: Solar power generation. Tech. Rep., Joint Research Centre; 2017, http://dx.doi.org/10.2760/044693, Available from:.
[9] Pfenninger S, Staffell I. Long-term patterns of european pv output using 30 years of validated hourly reanalysis and satellite data. Energy 2016;114:1251e65. http://dx.doi.org/10.1016/j.energy.2016.08.060, Available from:.
[10] Staffell I, Pfenninger S. Using bias-corrected reanalysis to simulate current and future wind power output. Energy 2016;114:1224e39. http://dx.doi.org/10.1016/j.energy.2016.08.068, Available from:.
[11] Moraes L, Bussar C, Stoecker P, Jacque K, Chang M, Sauer DU. Comparison of long-term wind and photovoltaic power capacity factor datasets with open-license. Appl Energy 2018;225:209e20. http://dx.doi.org/10.1016/j.apenergy.2018.04.109, Available from:.
[12] Henckes P, Frank C, Küchler N, Peter J, Wagner J. Uncertainty estimation of investment planning models under high shares of renewables using reanalysis data. Energy 2020;208:118207. http://dx.doi.org/10.1016/j.energy.2020.118207, Available from:.
[13] Wind energy the facts. Investment costs in wind energy. Available from: https://www.wind-energy-the-facts.org/index-43.html.
[14] Iberdrola wind farm in Salamanca. Available from: https://www.iberdrola.com/about-us/lines-business/flagship-projects/villarino-wind-farm-and-photovoltaic-plant.
[15] Bit2me. What are ASIC miners. 2022, Accessed: April, 2022, available from: https://academy.bit2me.com/en/who-are-asic-miners/.
[16] Miners profitability. 2022, Accessed: April, 2022, available from: https://www.asicminervalue.com/.
[17] Cambridge. Bitcoin electricity consumption index. 2022, Accessed: 2022, available from: https://ccaf.io/cbeci/mining_map.
[18] BTC. 2022, Accessed: April, 2022, available from: https://btc.com/.
[19] Antpool. 2022, Accessed: April, 2022, available from: https://v3.antpool.com/minerIncomeRank.
[20] BITMAN antminer hydro container. 2022, available from: https://shop.bitmain.com/product/detail?pid=00020211231118285350583K2a0P505EF.
[21] Minerstat, available from: www.minerstat.com/coin/BTC?lang=es; Whattomine, available from: www.whattomine.com/asic; Asicminervalue, available from: www.asicminervalue.com; Coincalculators, available from: www.coincalculators.io; Coinwarz, available from: www.coinwarz.com/mining/bitcoin/calculator.
[22] MINERSAT. Bitcoin calculator. 2022, Available from: https://minerstat.com/coin/BTC.
[23] REE. Components of the final price and energy at closing (€/MWh | MWh). Available from: https://www.ree.es/en/datos/markets/componets-price-energy-at-closing.
[24] Investing. Bitcoin-historical data. Available from: https://uk.investing.com/crypto/bitcoin/historical-datahttps://www.ree.es/en/datos/markets/componets-price-energy-at-closing.