# Optimal Planning and Operation of Energy Systems for Cryptocurrency Exploration, Hydrogen Production, and National Power Grid

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**This study investigates the planning and optimal operation of demand and supply systems in a renewable energy framework. The demand system is categorized into cryptocurrency exploration, hydrogen production, and national power grid, while the supply consists of a national grid and a private solar power plant. The energy flow diagram considers feeding the cryptocurrency exploration and hydrogen production systems using both the national grid and solar power plant, and the solar power plant can also supply to the national grid. A linear optimization model is used to determine the optimal capacity of the solar power plant and demand planning to maximize investor profit while considering supply and demand limitations. The study includes 43803 decision-making variables and 26281 inequality constraints. The analysis focuses on the lifetime of system components, which aligns with the lifespan of renewable technologies. The system design considers variations in electrical energy consumption per bitcoin extraction, ranging from 70 $\frac{MWh}{BTC}$ to 300 $\frac{MWh}{BTC}$, as well as changes in the price of Bitcoin, ranging from 5000 to 55 $\frac{k\$}{BTC}$. Additionally, the price of hydrogen ranges from 2 $\frac{\$}{kg_{H_2}}$ to 12 $\frac{\$}{kg_{H_2}}$, and the price of electrolyzers ranges from 1250 $\frac{\$}{kW_{Elect}}$ to 3000 $\frac{\$}{kW_{Elect}}$, over the study's 4356 scenarios. These scenarios encompass 31 unique states of supply and demand system design, along with optimal utilization of the supply system. The variability in energy exchange tariffs between the national grid and demand sectors accounts for the differences among the 26 distinct supply and demand system designs.**

***Keywords:*** *Linear optimization, Energy systems, Cryptocurrency exploration, Hydrogen production, Investor profit*

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## Nomenclature

| | |
|---|---|
| $P_i$ | production capacity of water turbine i |
| $\rho$ | Water density |
| $\eta(h, \dot{V})$ | water turbine efficiency i |
| h | head |
| $\dot{V}$ | Water flow rate |
| g | Gravitational acceleration |
| v | Wind speed |
| Z | Height |
| NH | Network Hashrate |
| EoH | Efficiency of hardware |
| P | Output power |
| BP | Bitcoin price |
| InvC | Investment const |
| Miners | Miners |
| Elec | Electrolyzers |
| REC | Renewable energy conversion technology |

## 1. Introduction

As new security challenges emerge, the decreasing costs of renewable energy and advancements in digital technologies create significant opportunities for expanding power transmission. Wind energy and solar panels (PV) are projected to contribute more than half of the increased electricity generation by 2040 in the announced policy scenario, and nearly all in the sustainable development scenario. In the sustainable development scenario, electricity consumption is one of the few energy resources that will see an increase by 2040, driven mainly by the adoption of electric vehicles, along with the direct use of renewable energy and hydrogen. By 2040, wind projects are expected to compete for trillions of dollars in investment [1, 2]. While low-carbon hydrogen is currently expensive to produce, it has gained significant attention as a promising alternative fuel. Mixing it in gas networks can improve the scalability of supply technologies and help lower costs. Moreover, recognizing the benefits of avoiding CO2 and methane emissions can substantially improve the cost competitiveness of low-carbon hydrogen [1, 2]. The demand for hydrogen has increased more than threefold since 1975 and continues to rise. However, currently, the production of hydrogen is heavily reliant on fossil fuels, with 6% of global natural gas and 2% of global coal being used for its production [3-6]. By 2030, it is estimated that more than 230-250 TWh of surplus electricity can be harnessed to produce low-carbon energy. Additionally, renewable energy sources and hydrogen are expected to generate over 200 TWh of energy by 2030 [7-9]. Hydrogen fuel can be a valuable complement to electrons in addressing the challenge of remote decarbonization. In particular, low-cost wind and solar projects can be leveraged to produce hydrogen, which stands in contrast to the expensive production of hydrogen from fossil fuels [10].

Considerable research has been conducted in this area. For instance, in a study by Nordin and Rahman, the cost-effectiveness of two standalone photovoltaic and battery systems with and without hydrogen production was analyzed using levelized cost of energy (LCOE) analysis. The findings revealed that the LCOE for the standalone photovoltaic system with battery and hydrogen production was higher than the system without hydrogen production. However, comparing the minimum selling price of hydrogen with the standard price of hydrogen from previous sources demonstrated that the hydrogen production system offered a sound investment [11]. Abdin and Mérida analyzed an off-grid renewable hybrid energy system that produced power and hydrogen. The findings indicated that using a combination of hydrogen technologies could potentially replace the battery bank, and for long-term energy storage and a dependable power supply, hydrogen was a favorable option due to its higher energy efficiency compared to batteries [12]. Also, Huang and Liu visualized a sustainable hydrogen production scheme with a combination of coal-based and renewable hydrogen production that could provide low-carbon hydrogen at a low cost [13]. In Abadlia et al., the renewable energy source was a photovoltaic system and the storage system is hydrogen electrolysis from alkaline water using photovoltaic power. Three algorithms were applied in their proposed system. Two are used within production and a third is within the network [14]. Wang et al. have proposed a robust optimization approach to designing off-grid solar charging stations to supply the electricity of electric vehicles and the hydrogen of hydrogen vehicles. Their novelty is integrating the robust optimization approach as a strong frame in mixed-integer linear programming of a certain model to avoid uncertainties [15]. Zhang, G., et al also proposed a new hybrid design for the optimal location and size of an off-grid solar/hydrogen system using an improved exploration method, Harmony Improvement Search, and Geographic Information System (GIS). They considered social, economic, technical, and environmental criteria. The life cycle cost, the main objective function, is minimized and applied. The results show that optimization of solar energy based on the hydrogen storage scheme, due to limitations, can help reduce the cost of the hybrid energy system. [16]. Nikzad and Mehregan explored a legal approach for simultaneously generating electricity and mining Ethereum using a 5.2 kWp photovoltaic rooftop system. Results showed that the system can supply 83% of the mining system's electricity, reduce emissions, and be economically beneficial [17]. Niaz et al. conducted a techno-economic analysis of 50 US states and Washington D.C. to evaluate the feasibility of bitcoin mining using carbon capture and renewable energy. The profitability of bitcoin mining was analyzed based on grid and renewable power resources, direct air capture technologies, and methanol production. The net CO2 emission was evaluated for each state to determine its competitive advantages. The study offers a comprehensive overview of where bitcoin mining can be economically viable in the US and provides insights into achieving environmentally friendly regulations for cryptocurrency mining based on renewable energy and carbon capture [18]. Gundaboina et al. reported the effect of overclocking and undervolting on power usage and hash rate for mining dogecoin with solar energy. Results indicated that using solar energy, mining consumes 2000 Watts of power with overclocking and 1700 Watts of power with undervolting. Their work suggests the potential future of crypto-mining with renewable energy, reducing e-waste, and improving sustainable development through GPU optimization and renewable energy use [19, 20]. Lotfi et al. established a CryptoCurrency Farm Location (CCFL) as a facility for supplying energy through renewable energy. A new robust optimization was presented with the stochastic approach to address uncertainty in CCFL. The model's objective function included maximizing the profits coefficient under different scenarios by adding an energy-aware constraint. The profit of robust stochastic CCFL was 4.94% less than stochastic CCFL [21]. Sohrabi Tabar et al. mentioned that the optimization of day-ahead planning for a renewable multi-carrier system with various resources, loads, and storage units considers high energy-consuming loads such as multi-level electric vehicle charging stations and cryptocurrency mining farms. So that they generated different scenarios for uncertainties, and the conditional value-at-risk metric was used to evaluate risks. The role of flexible loads in energy management was analyzed, and a sensitivity analysis was proposed by them to indicate the effect of various parameters. The impact of the initial states of components on the objective function was shown in the sensitivity analysis [22]. Akbari et al. presented the energy management of electrical and thermal networks with renewable energy hubs, including renewable sources, bio-waste units, energy storage, and responsive loads. The proposed scheme minimizes costs and maximizes income, subject to optimal power flow equations and flexibility limitations. Numerical results demonstrate significant improvements in the economic situation and operation indicators of the energy networks [23]. Ibañez and Freier found that a net-decarbonizing effect led by renewable-based mining is indeed plausible [24]. Hajipor et al. studied the impact of cryptocurrency mining on distribution network performance. They proposed an energy management formulation and used Monte-Carlo simulation to determine annual profit under uncertainty. Financial indices were suggested to help microgrid owners choose optimal mining devices and numbers. Their study also highlighted the increasing trend of grid-interactive microgrids initiating mining business in various countries [25].

In addition to the vision for future hydrogen chain development, the tendency to invest in digital currency has flourished over the past decade. The need for electricity is referred to as the "Achilles' heel" of Bitcoin [26]. Bitcoin energy consumption is estimated as a carbon footprint, as it accounts for a significant share of the largest coal-fired mining facilities in China's provinces [26]. Bondarev, M in her article points out that as the complexity increases, the power required for the equipment used also increases, resulting in an exponential increase in power consumption. [27] Since in the year 2019, bitcoin miners consume more than 31 TWh per year to generate digital currency, which is 0.14% of the total energy costs in the world. If this trend continues, after February 2020, there will be bitcoin mining with all electricity in the world [28]. Radhakrishnan et al, found that the mining protocol requires significant resource requirements in terms of computing hardware and power consumption requirements that the future growth of the Bitcoin network and the use of Bitcoin as a currency can be associated with the crisis by examining the mining process and the resources required to process large volumes of transactions from 2014 to 2018 [29]. The mining process can help improve energy transfer and the development of renewable energies [30]. If a significant portion of Bitcoin miners become renewable energy sources, the Bitcoin network could be cleaner in the future - potentially turning Bitcoin into a clean asset and thus a carbon converter [31]. Jain and Dogra's research focuses on the decentralized distribution of solar energy between networks using active IoT (Internet of Things) devices and Blockchain technology. In this way, the users in the network are connected and participate in transactions without the need to know each other or the commitment of any intermediary [32]. Mattila et al. envisioned an independent local market of a residential society with rooftop PVs, smart and flexible appliances, electronics, a battery energy system, and smart meters that could measure bi-directional electricity flows [33].

Ghaebi Panah et al. emphasized the importance of implementing integrated regulatory policies across various markets to achieve a tangible global impact on reducing greenhouse gas (GHG) emissions. The levelized cost of hydrogen production using grid-connected electrolysis was calculated to be around 4 €/kgH2 in Europe. Furthermore, based on scenario-based analyses, it was indicated that investments in the water-splitting industry can be made as attractive as Bitcoin mining, provided that the products are purchased at prices above 20 €/kgH2 [34]. Alonso et al. considered several determinants of sustainable cryptocurrency mining, including energy price, generation, legal constraints, temperature, human capital, and R&D&I, by recalculating the Environmental Performance Index (EPI) via linear regression. Their study concluded that Denmark and Germany are the most sustainable countries for cryptocurrency mining, with eight of the top ten countries being European. The remaining two are Asian [35]. Karatas et al. presented an overview of the environmental and economic impact of Bitcoin through a systematic analysis of literature, examining its effects on global warming and the social environment. Nonlinear causal relationships are found between Bitcoin mining statistics and CO2 emissions. It is implied that authorities should consider reducing CO2 emissions by accounting for Bitcoin mining impacts [36].

Zhao et al. examined how emerging technologies like AI, blockchain, and quantum computing can help transition energy systems to renewable sources and mitigate climate change. They mentioned that Integrating these technologies can aid in designing and operating future smart energy systems with high renewable energy penetration [37]. Menati et al. studied the impact of integrating new cryptocurrency mining loads into the Texas power grid and the potential profit of utilizing demand flexibility from cryptocurrency mining facilities in the electricity market. Different demand response programs available for data centers were investigated, and the annual profit of cryptocurrency mining units participating in these programs was quantified. Simulations using a synthetic 2000 bus ERCOT grid model, along with added cryptocurrency mining loads on top of the real-world demand profiles in Texas, have been performed. results show that depending on the size and location of these new loads, different impacts on the ERCOT electricity market were observed, where they could increase the electricity prices and incur more fluctuations in a highly non-uniform manner [38]. Danehkar and Yousefi [39] evaluated global electricity production based on sources and countries and compared the costs of power generation from fossil fuels and renewable sources. They also reviewed hybrid energy systems consisting of hydro, solar, and wind sources.

Aghaie et al. [40] analyzed A novel geothermal energy-based power generation system for hydrogen production using exergoeconomic and thermodynamic procedures. The system incorporated a recuperator and was optimized using five decision variables. The simulation results showed that the system's performance improved, with the incorporation of a recuperator increasing power production, energy and exergy efficiency, and hydrogen production, while implementing the particle swarm optimization algorithm further improved the system's performance. The total cost rate of the system was also reduced.

In this study, an energy system consisting of two energy suppliers, the national grid and private power plants, and three demands, cryptocurrency discovery system, hydrogen production system, and the national grid has been considered and the developed structure of hydrogen production system capacity, cryptocurrency exploration system and solar power plant along with optimal utilization (energy exchange between units) determine the maximum profit in the studied horizon for the investor. Three regions with different potentials of renewable wind, solar, and hydropower potentials for hydrogen production and cryptocurrency have been investigated to identify a suitable trend for regional development planning by identifying the most profitable scenario.

## 2. Methodology

The proposed model has been developed for the feasibility, planning, and operation of an enterprise with a focus on digital currency mining and hydrogen selling. In this model, the tariff for selling hourly electricity for digital currency mining and hydrogen production through electrolyzer can be different from each other. It is also considered that if the business area is favorable to use renewable energy carriers to generate electricity, the sector/total electricity demand of the enterprise should be supplied through the renewable energy conversion technologies and, if possible, the production surplus should be supplied to the national network with a specific hourly tariff. Therefore, decision variables can be expressed in the form of 8 categories:

I. Electricity supplied by renewable energy conversion technology for supply to miners
II. Electricity supplied by renewable energy conversion technology for supply to electrolysis
III. Electricity supplied by renewable energy conversion technology for supply to the grid
IV. Electricity supplied from the grid for miners
V. Electricity supplied from the grid for the electrolyzer
VI. Number of each type of miner available in the market for use in the enterprise
VII. Number of each type of electrolyzer available in the market for use in the enterprise
VIII. Use or non-use of renewable energy conversion technology

The first 5 sets of decision variables are in the category of operation decision variables and the last 3 categories are in the category of planning decision variables. The number and numerical type of each set of decision variables are summarized in Table 1.

**Table 1.** Number and Numeric type of each category of decision variables.

| Decision variables category | Number | Numerical type |
|---|---|---|
| First to fifth | Dependent on the change in the price of electricity and the production capacity of the renewable energy conversion technology | Negative real number |
| Sixth and seventh | Depending on the number of available miners and electrolyzers | Arithmetic number |
| Eighth | Select / not to select the use of renewable energy conversion technology | Boolean number |

For an enterprise with similar conditions described, not all of the stated decision variables are necessarily present. For example, for an enterprise with a miner and reluctance to add a new minor, the sixth category of variables is no longer defined. If you want to use the software provided with the article, the business can set the upper and lower bounds of this variable to zero. Figure 1 shows the energy flow model of the enterprise.

The optimal values of the decision variables are expressed based on the energy flow diagram illustrated in Figure 1, bound by the constraints of the first law of thermodynamics for each technology, electricity exchange with the grid (sales), investment in the base year and the limit of each decision variable. NPV maximization has been selected as the optimal planning and operation evaluation index taking into account the different lifespans of technologies.

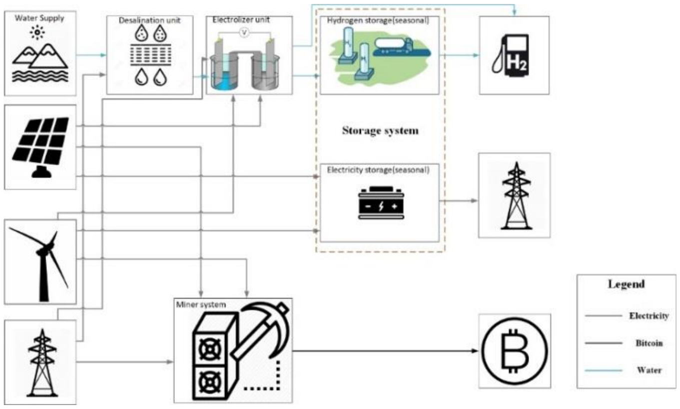


**Fig. 1.** Energy flow diagram of the enterprise studied in the article

### Module of renewable energy conversion technology

This module estimates the amount of electrical energy produced in each period based on energy conversion technology information and environmental conditions data.

### Water turbine model

It is considered that the head is fixed at all water inlets to the water turbine, to estimate the electrical generating power of the water turbine. Then, the production capacity of water turbine i is calculated by using Eq. (1).

$$P_i = \rho * \eta_i \left(h, \dot{V}\right) * h * \dot{V} * g \tag{1}$$

In Eq. (1), $\rho$ is water density $[\frac{kg}{m^3}]$, $\eta(h, \dot{V})$ is water turbine efficiency i in terms of head and water flow rate, $h$ is head [m], $\dot{V}$ is water flow rate $[\frac{m^3}{s}]$ and $g$ is the gravitational acceleration.

### Wind turbine model

To estimate the electric power generation of wind turbines, the wind turbine power generation graph in terms of wind speed has been used. This diagram is provided by the wind turbine manufacturer. Also, Eq. (2) has been used to estimate the wind speed at the appropriate altitude.

$$v_2 = v_1 * \left(\frac{Z_2}{Z_1}\right)^{\alpha} \tag{2}$$

In Eq. (2), $v_2$ is the wind speed at height $Z_2$ and $v_1$ is the wind speed at height $Z_1$.

### Solar energy model

The following two solutions can be used to obtain the output power of the photovoltaic panel:

Solution 1: The first solution is to use commercial software such as Pvsyst. In this case, it is possible to select the components of the solar system from the products in the software database or add to the database, the impact of location adjustment, geographical location, and panel installation on the amount of solar power plant production estimated.

Solution 2: Using some models such as the isotropic diffuse model by using geographic information and the location of the panel, estimated the amount of radiation that reached the surface of the panel. Then, using the solar power plant model, estimated the amount of electrical energy produced in each period.

Although the use of the second solution is more complex, it makes it possible to find the optimal capacity of the panel by placing it in an optimal structure.

### Hydrogen production model

This module estimates the amount of hydrogen produced based on the amount of electricity consumed. An electrolyzer with 100% efficiency requires 39 kWh of electricity to produce 1 kg of hydrogen. However, today's devices require 48 kWh/kg [41]. Increasing the electrolysis capacity is often associated with increasing the range of hydrogen production rate. Here, the electrical energy consumed to produce each kilogram of hydrogen is considered to be 54 kWh.

### Hydrogen compression module

The sale of hydrogen through the hydrogen refueling station and tanks is estimated at 700 bar. In this case, it is assumed that electrical energy is required to compress the hydrogen produced by the energy electrolyzer module equivalent to 30% of the low thermal value.

### Bitcoin mining

Here, some types of miners are examined and according to the amount of product awareness, the amount of electricity consumed for different types of bitcoins is calculated.

To calculate the energy consumption of this process, the power demand for Bitcoin mining is as Eq. (3).

$$P = \frac{NH.EoH}{10^3} \tag{3}$$

Where P is the power in MW, NH is the Network Hashrate (total hash problems solved in the Bitcoin network per second) in TH/s, and EoH is the Efficiency of Hardware (energy consumed by the hardware over the Tera hash Calculations) in kJ/TH.

Because hardware efficiency is publicly available, this data is easy to obtain. The minimum power demand is calculated as Eq. (4).

$$P_{min} = \frac{NH_{min}.EoH}{10^3} \tag{4}$$

Calculating the maximum power demand is a challenge. First, the cost of electricity per bitcoin is considered, and the price of bitcoin (BP) is gotten to define the profit margins for the miners. At this point, the investment is abandoned and the focus is only on the operating costs of the mining and hence the price of electricity. Therefore, it is concluded that:

Profitability of a mining device =

$$\begin{cases} Profitable\ when\ ECPB < BP \\ Nonprofitable\ when\ ECPB \geq BP \end{cases}$$

Now, the lowest hardware efficiency that is still profitable can be defined. During each recalculation of the hardness, the least efficient device under ECPB<BP is selected. It is called the maximum power consumption ($P_{max}$) meaning that the miner is consuming its maximum energy while it is still profitable in terms of the electrical process. Therefore, $P_{max}(TW)$ is given as Eq. (5).

### Module of optimal Planning and operation

Due to the high computational load, the energy supply model developed is a linear mathematical programming model. Constraints on this planning issue can be summarized in the following three categories.

Unequal constraints:

The first inequality constraint: The constraint is the maximum amount of investment at the beginning for the enterprise. Similarly, the maximum investment can be defined for other years.

The second unequal constraint: It is the amount of hydrogen production by the electrolyzer (s) in the firm. The constraint is based on the assumption that it is possible to produce hydrogen in the range of one to 100% of the nominal capacity.

Equal constraints:

The first equal constraint: The expression of the first law of thermodynamics is for renewable energy conversion technology. In this case, the amount of electricity supply to the miner, electrolyzer, and network is considered equal to the amount of renewable energy technology production to the electricity.

The second equal constraint: It is the constraint of the continuous function of the miner. In this case, the electrical energy required by the miner must always be supplied through renewable energy conversion technology and the national grid.

The upper and lower limit of decision variables: The minimum and maximum value acceptable by that decision variable without considering technical and economic constraints. These constraints are stated in Table 2.

In Table 2, n represents the number of periods for reviewing the energy supply system in a recurring period, an unequal constraint related to the investment constraint in the base year. $InvC_{Miners}$, $InvC_{Elec}$, and $InvC_{RECS}$ are the investment costs of each unit, existing miners, electrolyzers, and renewable energy conversion technology, respectively, and MaxInvC is the maximum investment by base year. $PD_{Elec}$ is the vector of the amount of electrical energy consumed by the electrolyzers to be added to the enterprise to produce one kilogram of hydrogen, and AvaElecDem is the demand vector of the electrolyzers available in each period. $EG_{RECS}$ is the vector of electrical energy generated per unit of time by the technology of converting renewable energy into electricity. The information on this vector can be obtained from the module on renewable energy conversion technology. MinerPowCon is the power consumption matrix of the considered miners for being added to the enterprise in each period. n is the number of rows of this matrix and the number of its columns, equal to the number of available miners to select. (8760/n) is a factor for converting power consumption to electrical energy consumption in each period. AvaMinerDem is a vector of the energy consumption of miners in each period. ND is the vector of the maximum amount of electrical energy that can be purchased by the global grid at any period.

$$\text{Pmax}(\text{TW}) = \frac{NH\ *Efficiency\ of\ least\ efficient\ hardware\ still\ profitable\ while\ mining\ bitcoin}{10^9} \tag{5}$$

**Table 2.** Constraints on the mathematical programming model for supplying energy to the enterprise.

| Constraint | Constraint types | Number | Description |
|---|---|---|---|
| $InvC_{Miners} * X_6 + InvC_{Elec} * X_7 + InvC_{RECS} * X_8 \leq MaxInvC$ | The first unequal constraint | 1 | The maximum investment in the base year |
| $X_2 + X_5 \leq PD_{Elec} * X_7 + AvaElecDem$ | The second unequal constraint | n | The amount of hydrogen production in each period |
| $X_1 + X_2 + X_3 = EG_{RECS}$ | The first equal constraint | n | Expression of the first law of thermodynamics for renewable energy technology |
| $X_1 + X_4 = MinerPowCon * \left(\frac{8760}{n}\right) * X_6 + AvaMinerDem$ | The second equal constraint | n | Miner continuous function constraint |
| $X_i \geq 0, i: 1\ to\ 5$ | Upper and lower bond | | |
| $X_5 \leq ND$ | Upper and lower bond | | |
| $X_i \geq 0, i: 6\ to\ 7, Integer$ | Upper and lower bond | | |
| $X_8: boolean$ | Upper and lower bond | | |

If the problem of mathematical programming in the standard form of Eq. (6) is considered, the size of matrix A will be the coefficients of unequal constraints and the size of matrix $A_{eq}$ will be the coefficients of constraints equal to each (2n) * (5n + MinerNum + ElecNum + 1).

$$\begin{aligned}
&Min\,Z = CX \\
&S.t. \\
&AX \le b \\
&A_{eq}X = b_{eq} \\
&lb \le X \le ub
\end{aligned} \tag{6}$$

As can be observed, the computational load of solving the optimization problem depends on the quadratic number of periods. The reduction in the number of periods examined is more pronounced in large numbers. To select the number of periods, it is sufficient to first detect a recurring trend (typically, the repetition of the annual radiation intensity during the study period). Next, periods should be determined based on the sensitivity of energy conversion technology to changes in input energy, changes in the price of energy carriers, and change in demand. Although increasing the number of periods seems to indicate an increase in study accuracy, the availability of information such as input energy to energy conversion technology and demand in that period may be associated with many approximations and ultimately the results of the study Be different from reality.

Considering the possibility of hourly changes in the electricity tariff for hydrogen production and cryptocurrency mining units, as well as the change in the intensity of the sun's radiation (consequently, the change in the produced electric energy), it causes the considering of 8760 variables for the amount of electric energy allocated from each energy supply unit. It becomes electric. In practice, since the change of electricity tariff is not hourly and also the proximity of solar radiation intensity in some hours of the day and night with other days in the same hour, the number of decision-making variables can be reduced. As a result, this issue has affected the constraints, but this point has not been seen in this study.

## 3. Results

The sample investigated in this study is the area of Nir City - Yazd province with an annual average radiation intensity of 2413 $\frac{kWh}{m^2 yr}$ for the installation of photovoltaic panels on a fixed optimal angle [42]. Considering the points close to the cities and settlements, These areas, located close to cities and settlements, are among the top 10% of areas with high solar radiation intensity on the surface of photovoltaic panels installed at a fixed angle [43]. Solar energy conversion technology is a preferred choice compared to other renewable energy sources due to its availability of high radiation intensity. The specific coordinates of this area are latitude 31.4848594665527 and longitude 54.1288185119628, with an altitude of 2508 meters. Using the model presented in the article [44], and climate information extracted with Meteonorm software, the optimal installation angle and solar radiation intensity have been calculated. Based on this, the annual solar radiation intensity at the optimal angle is estimated to be 2419.7 $\frac{kWh}{m^2 yr}$, which is in acceptable agreement with other reported results such as [42].

Figure 2 shows the hourly radiation intensity on a sloping surface with optimal placement in Nair City - Yazd province.

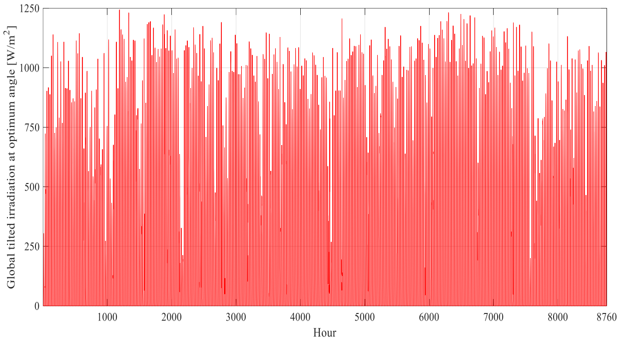


**Fig. 2.** Radiation intensity on a sloping surface with optimal placement in Nair City - Yazd province

The supply network includes a cryptocurrency discovery system (miner), a hydrogen production system (electrolyzer), and the entire network itself as part of its demand. Information regarding the investment cost of the miner and the hydrogen production system can be found in the table. It is worth noting that there are no limits on the sale of energy to the national network. Here, the capital investment cost limit is one million dollars.

The design of the system was driven by four main challenges, which are the long-term horizon of cryptocurrency price fluctuations, the consumption of electrical energy for cryptocurrency mining, the price of each unit of hydrogen, and the investment cost of each unit of the hydrogen production sector. While in practice these parameters may not always be independent of one another, to support or compare cryptocurrencies and hydrogen, each parameter can be considered independently. Table 4 provides a summary of the fluctuation range for each of the four challenges addressed in this study.

It should be noted that although changes to the electricity sales price of the grid to miners and electrolyzers may be constant, these prices may change during the studied horizon. However, this was not investigated in this study, and assuming a long-term contract with the national grid, this issue was not explored. Additionally, while changing the installation location of the power plant can impact solar power production, the selected location is expected to be in the highest decile in terms of solar radiation.

To study the effects of the four influential factors described in Table 4 on the design and operation of the system, a total of 4356 optimization problems were solved, resulting in the consideration of 31 different design and operation states. Changes in Bitcoin price in the last 5 years, were between 5 k$ to 67 k$, with this regard bitcoin price has been considered between 5k$ to 55 k$ in this study.

**Table 3.** General information on the energy system

| Solar Power Plant | | Cryptocurrency discovery system | | Cryptocurrency discovery system | |
|---|---|---|---|---|---|
| Item | Value | Item | Value | Item | Value |
| Panel Efficiency [%] | 15.38 | Nominal Efficiency [%] | 30 | Nominal Efficiency [%] | 3.25 |
| Inverter Efficiency [%] | 95 | Lifetime [yr] | 10 | Lifetime [yr] | 1 |
| Axilary Efficiency [%] | 88 | Energy Consumption | 60 | Energy Consumption | 900 |

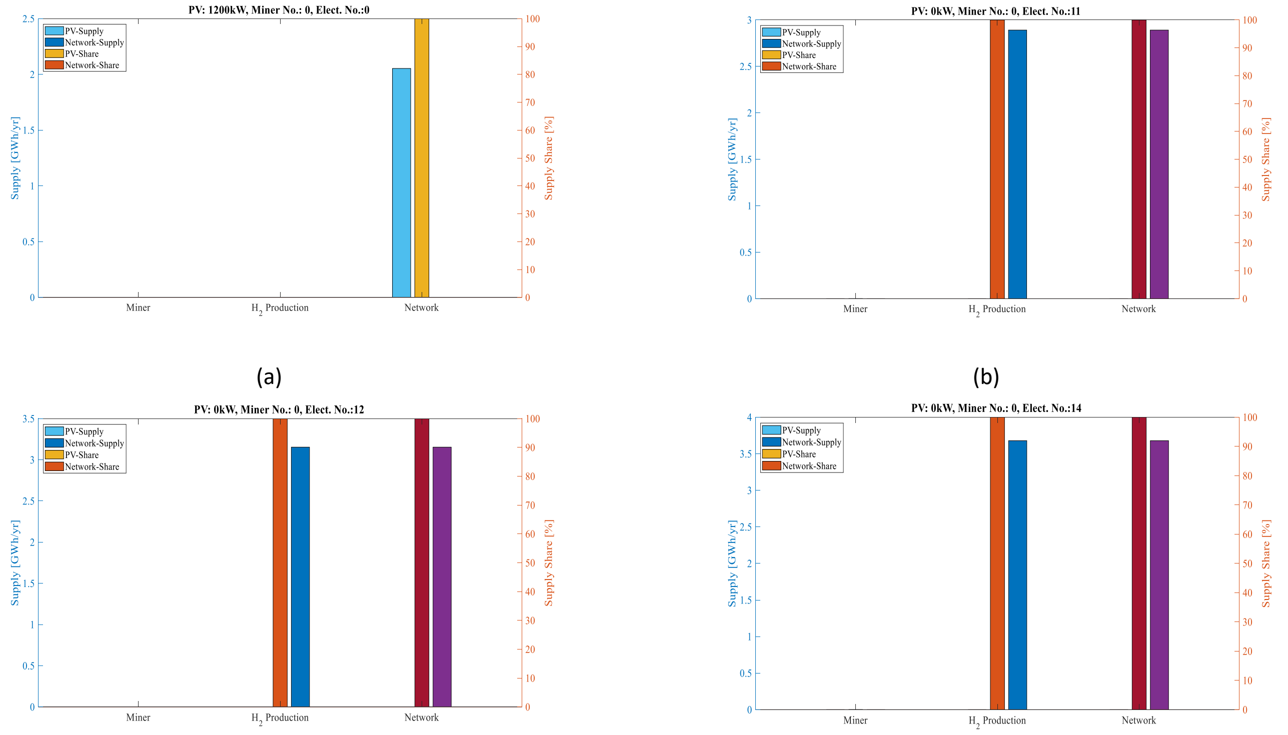
| | | | | | |
|---|---|---|---|---|---|
| | | Intensity [$\frac{kWh_e}{kg_{H_2}}$] | | Intensity [$\frac{kWh_e}{kg_{H_2}}$] | |
| Lifetime [yr] | 20 | Scrap Value [$\frac{\$}{unit}$] | 4 | Scrap Value [$\frac{\$}{unit}$] | 450 |
| Investment Cost [$\frac{\$}{kW}$] | 800 | | | | |
| Scrap Value [$\frac{\$}{unit}$] | 80 | | | | |

**Table 4.** The period of study of fluctuations of the main factors affecting the design and operation of the supply and demand system

| | Range of Changes | Linear Step |
|---|---|---|
| Bitcoin Price | $50{,}000\frac{\$}{BTC}$ $to$ $55{,}000\frac{\$}{BTC}$ | $5000\frac{\$}{BTC}$ |
| Electricity Consumption | $70\frac{MWh}{BTC}$ $to$ $300\frac{MWh}{BTC}$ | $23\frac{MWh}{BTC}$ |
| Hydrogen Price | $2\frac{\$}{kg_{H_2}}$ $to 12\frac{\$}{kg_{H_2}}$ | $2\frac{\$}{kg_{H_2}}$ |
| Investment Cost of Supplying Hydrogen | $1250\frac{\$}{kW_{Elect}}$ $to$ $3000\frac{\$}{kW_{Elect}}$ | $350\frac{\$}{kg_{H_2}}$ |

The effect of demand on the optimal supply system is illustrated in Figure 3. The figure shows the amount of energy required to satisfy the demand, as well as the contribution of each supplier to meet that demand. Additionally, the optimal number of miners, hydrogen production units, and the optimal capacity of the solar power plant have been determined and displayed in the figure.

Figure 3 uses a color spectrum close to blue to indicate the amount of energy supplied by the solar power plant and the national network (including other power plants in the network), while a color spectrum close to red is used to show the contribution of each supplier to meeting the energy demands. It is worth noting that the national network can function in two roles: consumer and producer. In this context, the amount of energy supplied by other power plants in the network and their respective shares in supplying the demands of the cryptocurrency discovery system and Bayan hydrogen production system have been calculated. A higher-intensity color, close to purple, has been used to display the amount of energy supplied by power plants in the national network to meet the two demands, while a dark red color has been used to represent their respective shares.

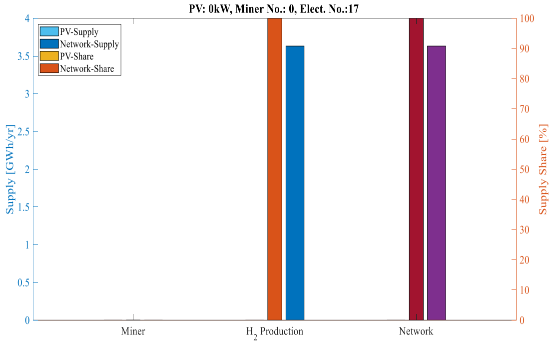


(a)

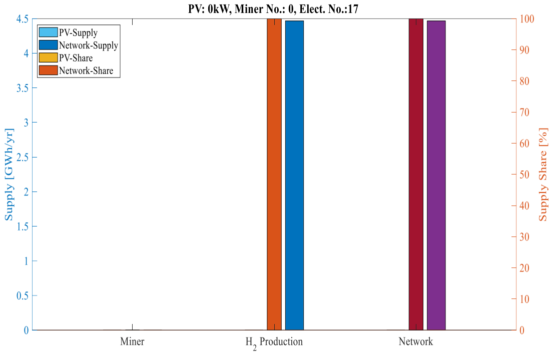
(b)

(c)

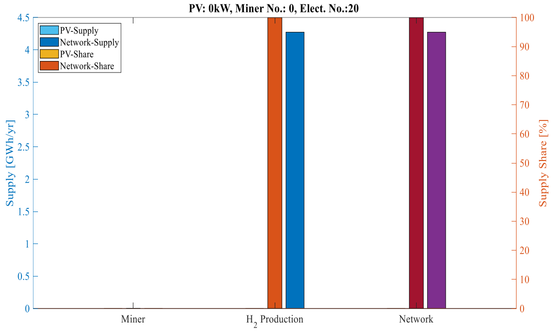
(d)


PV: 0kW, Miner No.: 0, Elect. No.:17
PV-Supply
Network-Supply
PV-Share
Network-Share
Supply [GWh/yr]
Supply Share [%]
Miner
$H_2$ Production
Network

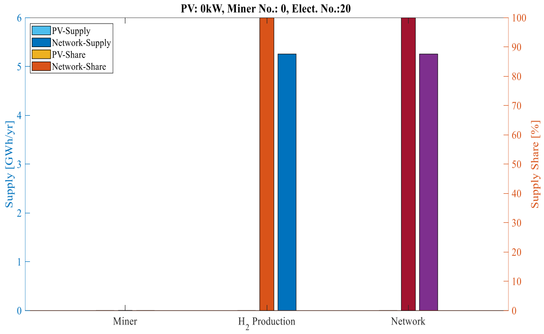
(e)


PV: 0kW, Miner No.: 0, Elect. No.:17
PV-Supply
Network-Supply
PV-Share
Network-Share
Supply [GWh/yr]
Supply Share [%]
Miner
$H_2$ Production
Network

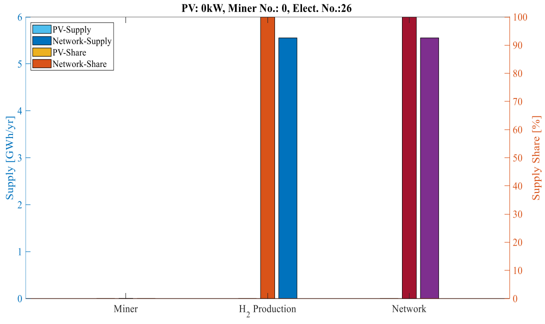
(f)


PV: 0kW, Miner No.: 0, Elect. No.:20
PV-Supply
Network-Supply
PV-Share
Network-Share
Supply [GWh/yr]
Supply Share [%]
Miner
$H_2$ Production
Network

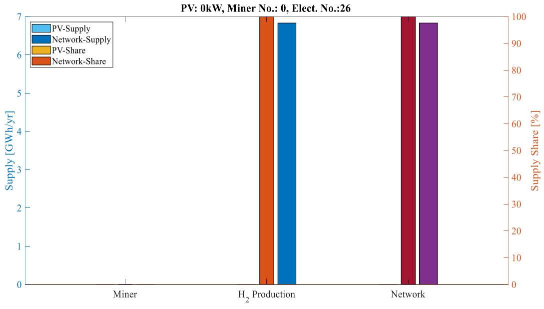
(g)


PV: 0kW, Miner No.: 0, Elect. No.:20
PV-Supply
Network-Supply
PV-Share
Network-Share
Supply [GWh/yr]
Supply Share [%]
Miner
$H_2$ Production
Network

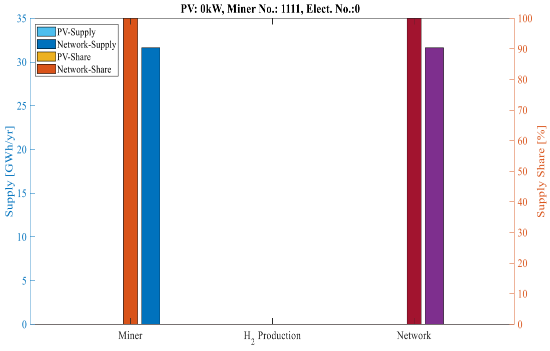
(h)


PV: 0kW, Miner No.: 0, Elect. No.:26
PV-Supply
Network-Supply
PV-Share
Network-Share
Supply [GWh/yr]
Supply Share [%]
Miner
$H_2$ Production
Network

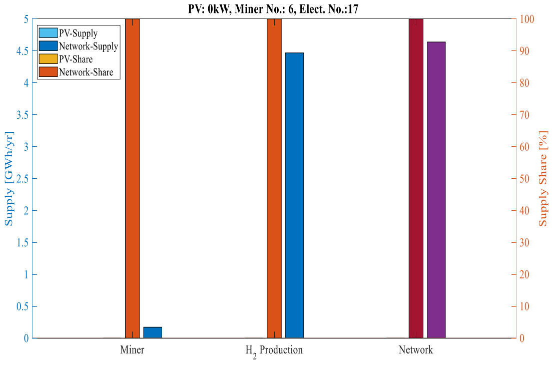
(i)


PV: 0kW, Miner No.: 0, Elect. No.:26
PV-Supply
Network-Supply
PV-Share
Network-Share
Supply [GWh/yr]
Supply Share [%]
Miner
$H_2$ Production
Network

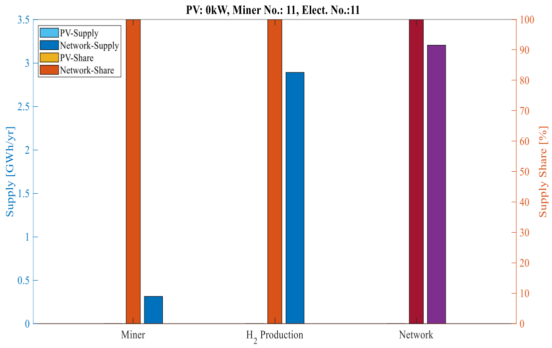
(j)


PV: 0kW, Miner No.: 1111, Elect. No.:0
PV-Supply
Network-Supply
PV-Share
Network-Share
Supply [GWh/yr]
Supply Share [%]
Miner
$H_2$ Production
Network

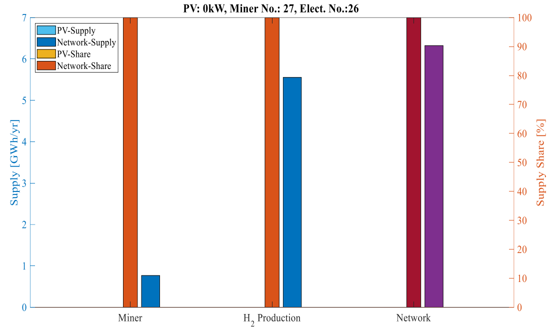
(k)


PV: 0kW, Miner No.: 6, Elect. No.:17
PV-Supply
Network-Supply
PV-Share
Network-Share
Supply [GWh/yr]
Supply Share [%]
Miner
$H_2$ Production
Network

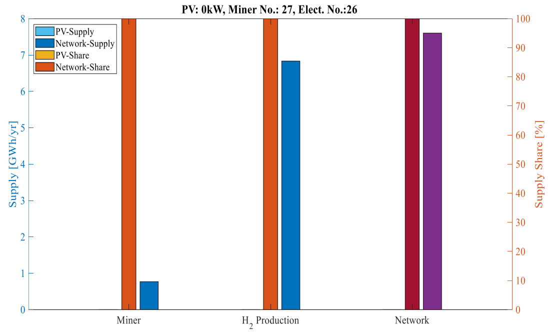
(l)


PV: 0kW, Miner No.: 11, Elect. No.:11
PV-Supply
Network-Supply
PV-Share
Network-Share
Supply [GWh/yr]
Supply Share [%]
Miner
$H_2$ Production
Network

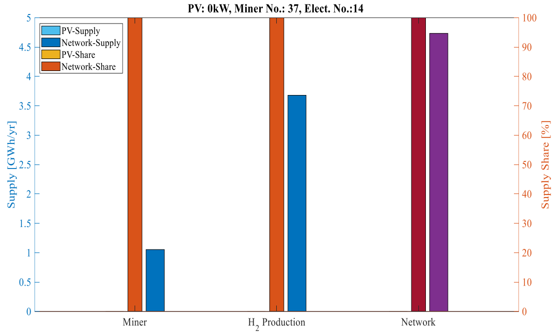
(m)


PV: 0kW, Miner No.: 27, Elect. No.:26
PV-Supply
Network-Supply
PV-Share
Network-Share
Supply [GWh/yr]
Supply Share [%]
Miner
$H_2$ Production
Network

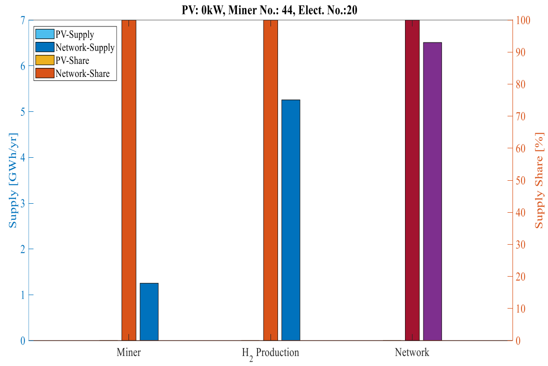
(n)


PV: 0kW, Miner No.: 27, Elect. No.:26
PV-Supply
Network-Supply
PV-Share
Network-Share
Supply [GWh/yr]
Supply Share [%]
Miner
$H_2$ Production
Network

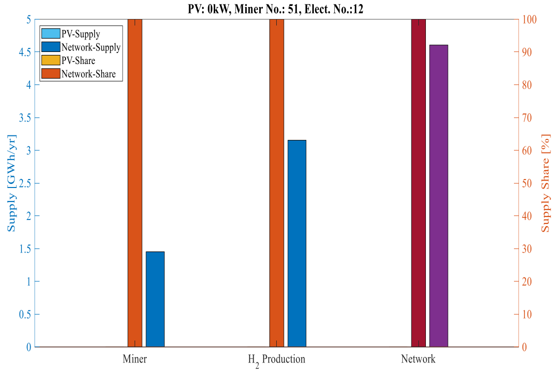
(o)


PV: 0kW, Miner No.: 37, Elect. No.:14
PV-Supply
Network-Supply
PV-Share
Network-Share
Supply [GWh/yr]
Supply Share [%]
Miner
$H_2$ Production
Network

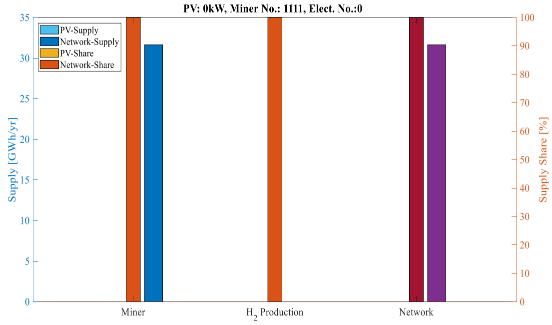
(p)


PV: 0kW, Miner No.: 44, Elect. No.:20
PV-Supply
Network-Supply
PV-Share
Network-Share
Supply [GWh/yr]
Supply Share [%]
Miner
$H_2$ Production
Network

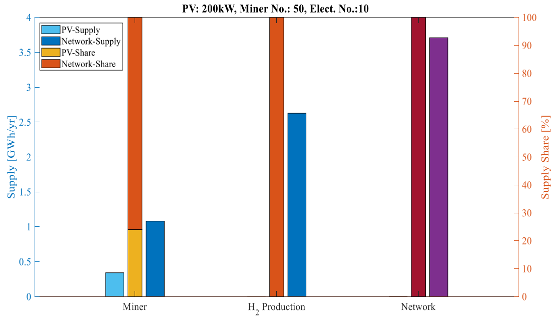
(q)


PV: 0kW, Miner No.: 51, Elect. No.:12
PV-Supply
Network-Supply
PV-Share
Network-Share
Supply [GWh/yr]
Supply Share [%]
Miner
$H_2$ Production
Network

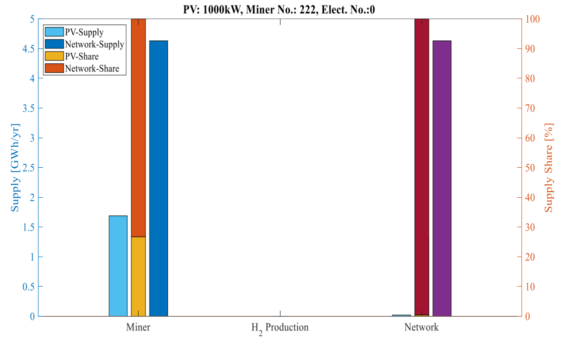
(r)

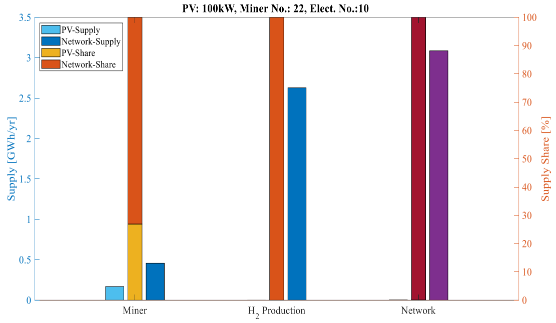

PV: 0kW, Miner No.: 1111, Elect. No.:0
PV-Supply
Network-Supply
PV-Share
Network-Share
Supply [GWh/yr]
Supply Share [%]
Miner
$H_2$ Production
Network

(s)


PV: 200kW, Miner No.: 50, Elect. No.:10
PV-Supply
Network-Supply
PV-Share
Network-Share
Supply [GWh/yr]
Supply Share [%]
Miner
$H_2$ Production
Network

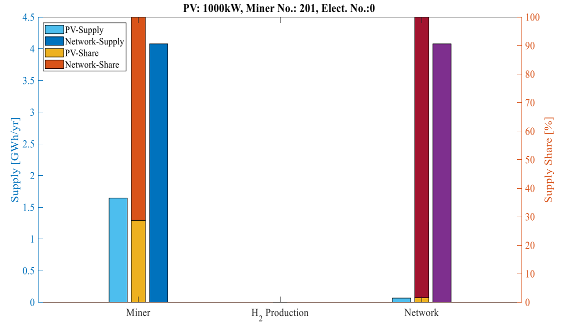
(t)

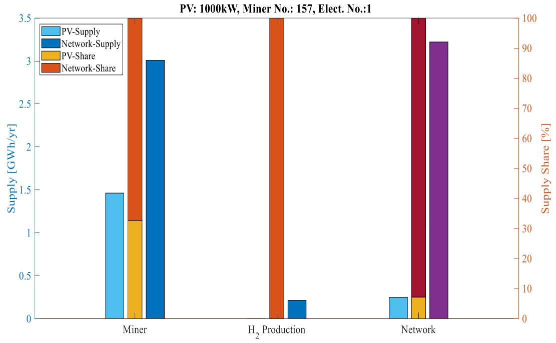

PV: 1000kW, Miner No.: 222, Elect. No.:0
PV-Supply
Network-Supply
PV-Share
Network-Share
Supply [GWh/yr]
Supply Share [%]
Miner
H2 Production
Network


PV: 100kW, Miner No.: 22, Elect. No.:10
PV-Supply
Network-Supply
PV-Share
Network-Share
Supply [GWh/yr]
Supply Share [%]
Miner
H2 Production
Network

(u)

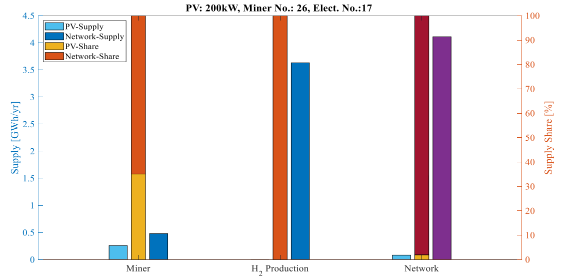
(v)

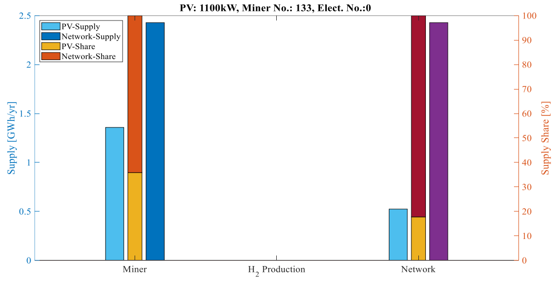

PV: 1000kW, Miner No.: 201, Elect. No.:0
PV-Supply
Network-Supply
PV-Share
Network-Share
Supply [GWh/yr]
Supply Share [%]
Miner
H2 Production
Network


PV: 1000kW, Miner No.: 157, Elect. No.:1
PV-Supply
Network-Supply
PV-Share
Network-Share
Supply [GWh/yr]
Supply Share [%]
Miner
H2 Production
Network

(w)

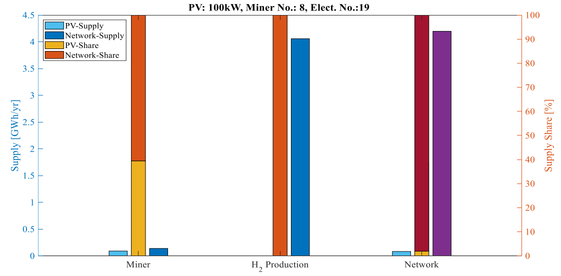
(x)

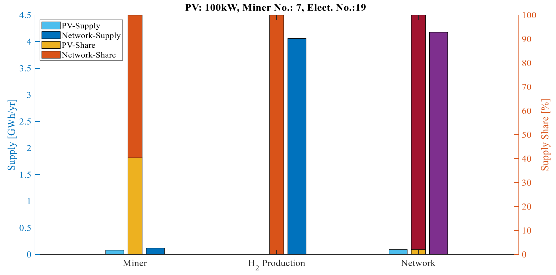

PV: 200kW, Miner No.: 26, Elect. No.:17
PV-Supply
Network-Supply
PV-Share
Network-Share
Supply [GWh/yr]
Supply Share [%]
Miner
H2 Production
Network


PV: 1100kW, Miner No.: 133, Elect. No.:0
PV-Supply
Network-Supply
PV-Share
Network-Share
Supply [GWh/yr]
Supply Share [%]
Miner
H2 Production
Network

(y)

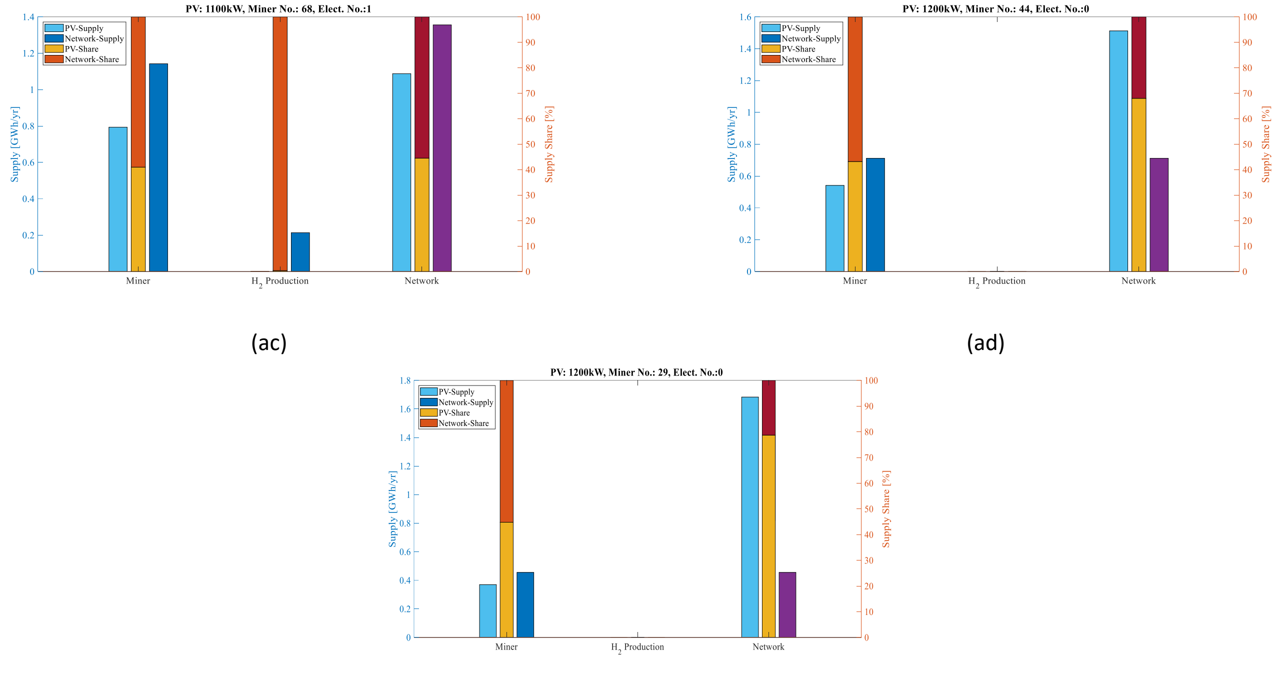
(z)


PV: 100kW, Miner No.: 8, Elect. No.:19
PV-Supply
Network-Supply
PV-Share
Network-Share
Supply [GWh/yr]
Supply Share [%]
Miner
H2 Production
Network


PV: 100kW, Miner No.: 7, Elect. No.:19
PV-Supply
Network-Supply
PV-Share
Network-Share
Supply [GWh/yr]
Supply Share [%]
Miner
H2 Production
Network

(aa)

(ab)



(ac)

(ad)

(ae)

**Fig. 3.** The effect of fluctuations of four parameters affecting demand and optimal supply

Throughout all the examined scenarios, solar panels were not selected as the primary supplier of electricity to the hydrogen production unit due to the low tariff offered by the national grid to industrial units and the high investment cost of solar panels. However, in certain scenarios, solar panels are used during specific hours to supply the electricity required by the cryptocurrency exploration unit, as it proves to be a more cost-effective solution.

Table 5 displays the optimal range of each of the 31 states studied, along with the frequency of each state. Among the 31 states, 26 have different configurations of miners, electrolyzer capacities, and private solar power plants. This highlights the impact of changes in the price of energy carriers on the various supply and demand sectors, resulting in different exploitation and energy exchange. The varying price of the electrolyzer is the main reason behind the existence of these 26 different supply and demand planning states.

**Table 5.** The optimal range of each of the 31 states

| Scenario | Energy Consumption per Bitcoin | Bitcoin Price | Hydrogen Price per kg | electrolyzer Price | number of cryptocurrency exploration units | number of hydrogen production units | Number of Power Plant Units | Number of States |
|---|---|---|---|---|---|---|---|---|
| **1** | 70-300 | 5 | 2 | 1250-3000 | 0 | 0 | 12 | 66 |
| | 139-300 | 10 | 2 | | | | | 48 |
| | 208-300 | 15 | 2 | | | | | 30 |
| | 277-300 | 20 | 2 | | | | | 12 |
| | 70-300 | 5 | 4 | 2300-3000 | | | | 33 |
| | 139-300 | 10 | 4 | | | | | 24 |
| | 208-300 | 15 | 4 | | | | | 15 |
| | 277-300 | 20 | 4 | | | | | 6 |
| **2** | 70-300 | 5 | 6-12 | 3000 | 0 | 11 | 0 | 44 |
| | 116-300 | 10 | 6-12 | | | | | 36 |
| | 162 | 15 | 8-12 | | | | | 3 |
| | 185-300 | | 6-12 | | | | | 24 |
| | 231-300 | 20 | 6-12 | | | | | 16 |
| | 277-300 | 25 | 6-12 | | | | | 8 |
| **3** | 70-300 | 5 | 6-12 | 2650 | 0 | 12 | 0 | 44 |
| | 116-300 | 10 | | | | | | 36 |
| | 162-300 | 15 | | | | | | 28 |
| | 231-300 | 20 | | | | | | 16 |
| | 277-300 | 25 | | | | | | 8 |
| **4** | 70-300 | 5 | 6-12 | 2300 | 0 | 14 | 0 | 44 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 116-300 | 10 | | | | | | 36 |
| | 162-300 | 15 | | | | | | 28 |
| | 231-300 | 20 | | | | | | 16 |
| | 277-300 | 25 | | | | | | 8 |
| **5** | 70-300 | 5 | 4 | 1950 | 0 | 17 | 0 | 11 |
| | 139-300 | 10 | | | | | | 8 |
| | 208-300 | 15 | | | | | | 6 |
| | 254-300 | 20 | | | | | | 3 |
| **6** | 70-300 | 5 | 6-12 | 1950 | 0 | 17 | 0 | 44 |
| | 116-300 | 10 | | | | | | 36 |
| | 162-300 | 15 | | | | | | 28 |
| | 231-300 | 20 | | | | | | 16 |
| | 277-300 | 25 | | | | | | 8 |
| **7** | 70-300 | 5 | 4 | 1600 | 0 | 20 | 0 | 11 |
| | 139-300 | 10 | | | | | | 8 |
| | 208-300 | 15 | | | | | | 5 |
| | 254-300 | 20 | | | | | | 3 |
| **8** | 70-300 | 5 | 6-12 | 1600 | 0 | 20 | 0 | 44 |
| | 116-300 | 10 | | | | | | 36 |
| | 162-300 | 15 | | | | | | 28 |
| | 231-300 | 20 | | | | | | 16 |
| | 277-300 | 25 | | | | | | 8 |
| **9** | 70-300 | 5 | 4 | 1250 | 0 | 26 | 0 | 11 |
| | 116-300 | 10 | | | | | | 9 |
| | 162-300 | 15 | | | | | | 7 |
| | 231-300 | 20 | | | | | | 4 |
| | 277-300 | 25 | | | | | | 2 |
| **10** | 70-300 | 5 | 6-12 | 1250 | 0 | 26 | 0 | 44 |
| | 116-300 | 10 | | | | | | 36 |
| | 162-300 | 15 | | | | | | 28 |
| | 231-300 | 20 | | | | | | 16 |
| | 277-300 | 25 | | | | | | 8 |
| **11** | 70 | 10-55 | 2-12 | 1250-3000 | 1111 | 0 | 0 | 360 |
| | 93 | 10 | 2-6 | 1250-3000 | | | | 18 |
| | 93 | 10 | 8 | 1950-3000 | | | | 4 |
| | | 10 | 10 | 2300-3000 | | | | 3 |
| | | | 12 | 3000 | | | | 1 |
| | | 15-55 | 2-12 | 1250-30000 | | | | 324 |
| | 116 | 15 | 2-8, 12 | 1250-3000 | | | | 30 |
| | | | 10 | 1600-3000 | | | | 5 |
| | | 20-55 | 2-12 | 1250-3000 | | | | 288 |
| | 139 | 15 | 2-6 | 1250-3000 | | | | 18 |
| | | | 8 | 1600-3000 | | | | 5 |
| | | | 10 | 2300-3000 | | | | 3 |
| | | | 12 | 3000 | | | | 1 |
| | | 20-55 | 2-12 | 1250-3000 | | | | 288 |
| | 162 | 20 | 2-10 | 1250-3000 | | | | 30 |
| | | | 12 | 1600-3000 | | | | 5 |
| | | 25 | 2-8,12 | 1250-3000 | | | | 30 |
| | | | 10 | 1600-3000 | | | | 5 |
| | | 30-55 | 2-12 | 1250-3000 | | | | 216 |
| | 185 | 20 | 2-6 | 1250-3000 | | | | 18 |
| | | | 8 | 1600-3000 | | | | 5 |
| | | | 10 | 2300-3000 | | | | 3 |
| | | | 12 | 2650-3000 | | | | 2 |
| | 185 | 25 | 2-8,12 | 1250-3000 | | | | 30 |
| | | | 10 | 1600-3000 | | | | 5 |
| | 185 | 30-55 | 2-12 | 1250-3000 | | | | 216 |
| | 208 | 25 | 2-10 | 1250-3000 | | | | 30 |
| | | | 12 | 1600-3000 | | | | 5 |
| | | 30 | 2-8,12 | 1250-3000 | | | | 30 |
| | | | 10 | 1600-3000 | | | | 5 |
| | | 35-55 | 2-12 | 1250-3000 | | | | 180 |
| | 231 | 25 | 2-6 | 1250-3000 | | | | 18 |
| | | | 8 | 1600-3000 | | | | 5 |
| | | | 10 | 2300-3000 | | | | 3 |
| | | | 12 | 3000 | | | | 1 |
| | 231 | 30-55 | 2-12 | 1250-3000 | | | | 216 |
| | 254 | 25 | 2-4 | 1250-3000 | | | | 12 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 6 | 2650-3000 | | | | 2 |
| | | 30 | 2-8 | 1250-3000 | | | | 24 |
| | | | 10 | 1600-3000 | | | | 5 |
| | | | 12 | 1950-3000 | | | | 4 |
| | | 35 | 2-8 | 1250-3000 | | | | 180 |
| | 277 | 30 | 2-6 | 1250-3000 | | | | 18 |
| | | | 8 | 1600-3000 | | | | 5 |
| | | | 10 | 2300-3000 | | | | 3 |
| | | | 12 | 2650-3000 | | | | 2 |
| | | 35 | 2-10 | 1250-3000 | | | | 30 |
| | | | 12 | 1600-3000 | | | | 5 |
| | | 40 | 2-10 | 1250-3000 | | | | 30 |
| | | | 12 | 1600-3000 | | | | 5 |
| | | 45-55 | 2-12 | 1250-3000 | | | | 108 |
| | 300 | 30 | 2-4 | 1250-3000 | | | | 12 |
| | | | 6 | 2300-3000 | | | | 3 |
| | | | 8 | 3000 | | | | 1 |
| | | 35 | 2-8 | 1250-3000 | | | | 24 |
| | | | 10 | 1600-3000 | | | | 5 |
| | | | 12 | 1950-3000 | | | | 4 |
| | 300 | 40-55 | 2-12 | 1250-3000 | | | | 144 |
| **12** | 93 | 10 | 10-12 | 1950 | 6 | 17 | 0 | 2 |
| | 139 | 15 | | | | | | 2 |
| | 185 | 20 | | | | | | 2 |
| | 208 | 20 | 6-8 | | | | | 4 |
| | 231 | 25 | 10-12 | | | | | 2 |
| | 254 | 25 | 6-12 | | | | | 4 |
| | 277 | 30 | 10-12 | | | | | 2 |
| | 300 | 30 | 6-12 | | | | | 4 |
| **13** | 208 | 20 | 8-12 | 3000 | 11 | 11 | 0 | 3 |
| | 254 | 25 | 8-12 | | | | | 3 |
| | 300 | 30 | 10-12 | | | | | 2 |
| **14** | 208 | 20 | 4 | 1250 | 27 | 26 | 0 | 1 |
| **15** | 93 | 10 | 8-12 | 1250 | 27 | 26 | 0 | 3 |
| | 139 | 15 | 8-12 | 1250 | | | | 3 |
| | 162 | 20 | 12 | | | | | 1 |
| | 185 | 20 | 8-12 | | | | | 3 |
| | 208 | 20 | 6-12 | | | | | 4 |
| | 208 | 25 | 12 | | | | | 1 |
| | 231 | 25 | 8-12 | | | | | 3 |
| | 254 | 25 | 6-12 | | | | | 4 |
| | 254 | 30 | 10-12 | | | | | 2 |
| | 277 | 30 | 8-12 | | | | | 3 |
| | 277 | 35 | 12 | | | | | 1 |
| | 300 | 30 | 6-12 | | | | | 4 |
| | 300 | 35 | 10-12 | | | | | 2 |
| **16** | 93 | 10 | 12 | 2300 | 37 | 14 | 0 | 1 |
| | 139 | 15 | 12 | 2300 | | | | 1 |
| | 185 | 20 | 12 | 2300 | | | | 1 |
| | 208 | 20 | 6-12 | 2300 | | | | 4 |
| | 231 | 25 | 12 | 2300 | | | | 1 |
| | 254 | 25 | 6-12 | 2300 | | | | 4 |
| | 277 | 30 | 12 | 2300 | | | | 1 |
| | 300 | 30 | 8-12 | 2300 | | | | 3 |
| **17** | 93 | 10 | 8-12 | 1600 | 44 | 20 | 0 | 3 |
| | 139 | 15 | 10-12 | | | | | 2 |
| | 185 | 20 | 10-12 | | | | | 2 |
| | 208 | 20 | 6-12 | | | | | 4 |
| | 231 | 25 | 10-12 | | | | | 2 |
| | 254 | 25 | 6-12 | | | | | 4 |
| | 254 | 30 | 12 | | | | | 1 |
| | 277 | 30 | 10-12 | | | | | 2 |
| | 300 | 30 | 6-12 | | | | | 4 |
| | 300 | 35 | 12 | | | | | 1 |
| **18** | 93 | 10 | 12 | 2650 | 51 | 12 | 0 | 1 |
| | 139 | 15 | 12 | 2650 | | | | 1 |
| | 208 | 20 | 8-12 | 2650 | | | | 3 |
| | 254 | 25 | 8-12 | 2650 | | | | 3 |
| | 300 | 30 | 8-12 | 2650 | | | | 3 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **19** | 116 | 15 | 10 | 1250 | 1111 | 0 | 0 | 1 |
| | 162-185 | 25 | 10 | 1250 | | | | 2 |
| | 208 | 30 | 10 | 1250 | | | | 1 |
| | 254 | 30 | 6 | 1600 | | | | 1 |
| | 277 | 40 | 12 | 1250 | | | | 1 |
| **20** | 208 | 20 | 6 | 2650 | 50 | 10 | 2 | 1 |
| **21** | 162 | 15 | 2 | 1250-3000 | 222 | 0 | 10 | 6 |
| | | | 4 | 1600-3000 | | | | 5 |
| | 208 | 20 | 2 | 1250-3000 | | | | 6 |
| | | | 4 | 1600-3000 | | | | 5 |
| | | | 6 | 3000 | | | | 1 |
| **22** | 162 | 15 | 6 | 3000 | 22 | 10 | 1 | 1 |
| **23** | 277 | 25 | 2 | 1250-3000 | 201 | 0 | 10 | 6 |
| | | | 4 | 2300-3000 | | | | 3 |
| **24** | 277 | 25 | 4 | 1950 | 157 | 1 | 10 | 1 |
| **25** | 277 | 25 | 4 | 1600 | 26 | 17 | 2 | 1 |
| **26** | 116 | 10 | 2 | 1250-3000 | 133 | 0 | 11 | 6 |
| | 116 | 10 | 2 | 1950-3000 | | | | 4 |
| | 231 | 20 | 4 | 1250-3000 | | | | 6 |
| | 231 | 20 | 4 | 1950-3000 | | | | 4 |
| **27** | 116 | 10 | 4 | 1600 | 8 | 19 | 1 | 1 |
| | 231 | 20 | | | | | | 1 |
| | 300 | 25 | | | | | | 1 |
| **28** | 185 | 15 | 4 | 1600 | 7 | 19 | 1 | 1 |
| **29** | 300 | 25 | 4 | 1950 | 68 | 1 | 11 | 1 |
| **30** | 185 | 15 | 2 | 1250-3000 | 44 | 0 | 12 | 6 |
| | | | 4 | 2300-3000 | | | | 3 |
| | 300 | 25 | 2 | 1250-3000 | | | | 6 |
| | | | 4 | 2300-3000 | | | | 3 |
| **31** | 254 | 20 | 2 | 1250-3000 | 29 | 0 | 12 | 6 |
| | | | 4 | 2300-3000 | | | | 3 |

Among the scenarios examined, the optimal energy system in 3038 scenarios was comprised of a cryptocurrency exploration system connected to the national grid, while the optimal energy system in 879 scenarios consisted of hydrogen production connected to the national grid. In 234 scenarios, the best option was a photovoltaic panel system connected to the national grid for selling electricity, and only 205 scenarios involved at least two energy suppliers and one consumer. Analysis of the results reveals that the current best option for the energy system is to connect the cryptocurrency discovery system to the national grid.

## 4. Conclusions

This study has proposed a demand and supply system planning for an energy system that consists of a hydrogen production unit, a cryptocurrency exploration unit, and a private solar power plant that sells electricity to the national grid. The study aimed to optimize the use of renewable energy technologies, minimize greenhouse gas emissions, and maximize profits for investors.

Based on the analysis of 4356 scenarios, the optimal energy system for 3038 scenarios was found to consist of a cryptocurrency exploration system on the demand side and the national grid on the supply side. For 879 scenarios, the connection of the hydrogen production system to the national grid was the best energy supply system. The connection of the solar panel to the grid was chosen for the sale of electricity in 234 scenarios. In total, in 322 scenarios, the solar panel was part of the supply system.

The study highlights the challenges associated with the use of renewable energy technologies, such as the high investment cost of solar panels and the low tariffs for the purchase of electricity by industrial units. The use of photovoltaic panels to meet part of the energy needs of cryptocurrency exploration units during specific hours was found to be more cost-effective.

The developed mathematical planning model consisted of 43803 decision variables and 26281 unequal adverbs. The optimization of both the demand and supply side planning was done using a linear integer optimization problem. The analysis of the different scenarios showed that the fluctuations and changes in the tariffs of energy carriers created 31 different states.

This study has important implications for policymakers, investors, and energy companies. The proposed energy system planning can help to reduce greenhouse gas emissions, promote the use of renewable energy technologies, and maximize profits for investors. The use of renewable energy technologies can also help to reduce the dependence on fossil fuels and promote energy independence.

However, the study also highlights the need for further research to address the challenges associated with the use of renewable energy technologies, such as the high investment cost and low tariffs for the purchase of electricity. Future studies could also consider the impact of energy storage technologies and the integration of renewable energy sources into the existing energy infrastructure.

In conclusion, the proposed energy system planning can serve as a useful guide for policymakers, investors, and energy companies to promote the use of renewable energy technologies, reduce greenhouse gas emissions, and maximize profits. However, further research is needed to address the challenges associated with the use of renewable energy technologies and to explore new opportunities for integrating these technologies into the existing energy infrastructure. This study considered linear optimization due to the reduction of computational load. This simplification affects the accuracy of the study and was not investigated in this study.

## References

[1] A. John Armstrong, E. D. J. H, Renewable Energy Overview. The Renewable Energy Policy Manual: United States Export Council for Renewable Energy.

[2] M. J. Aberuee, E. Baniasadi, M. Ziaei-Rad, Performance analysis of an integrated solar based thermo-electric and desalination system, Applied Thermal Engineering, 2017, 110, 399-411

[3] IEA, The Future of Hydrogen, in IEA. 2019: Paris.

[4] K. H. Chu, J. Lim, J. S. Mang, M.-H. Hwang, Evaluation of strategic directions for supply and demand of green hydrogen in South Korea, International Journal of Hydrogen Energy, 2022, 47, 3, 1409-24

[5] M. Neuwirth, T. Fleiter, P. Manz, R. Hofmann, The future potential hydrogen demand in energy-intensive industries-a site-specific approach applied to Germany, Energy Conversion and Management, 2022, 252, 115052

[6] C. Park, S. Lim, J. Shin, C.-Y. Lee, How much hydrogen should be supplied in the transportation market? Focusing on hydrogen fuel cell vehicle demand in South Korea: Hydrogen demand and fuel cell vehicles in South Korea, Technological Forecasting and Social Change, 2022, 181, 121750

[7] Council, H., Hydrogen scaling up, A sustainable pathway for the global energy transition. Hydrogen Council: Brussels, Belgium, 2017.

[8] Q. Bresa, A. Kovač, D. Marciuš, Introduction of hydrogen in the Kosovo transportation sector, Energies, 2022, 15, 19, 7275

[9] R. Bhandari, Green hydrogen production potential in West Africa–Case of Niger, Renewable Energy, 2022, 196, 800-11

[10] IRENA. Hydrogen: A renewable energy perspective. Abu Dhabi; 2019.

[11] N. D. Nordin, H. A. Rahman, Comparison of optimum design, sizing, and economic analysis of standalone photovoltaic/battery without and with hydrogen production systems, Renewable energy, 2019, 141, 107-23

[12] Z. Abdin, W. Mérida, Hybrid energy systems for off-grid power supply and hydrogen production based on renewable energy: A techno-economic analysis, Energy Conversion and Management, 2019, 196, 1068-79

[13] Y. Huang, S. Liu, Efficiency evaluation of a sustainable hydrogen production scheme based on super efficiency SBM model, Journal of cleaner production, 2020, 256, 120447

[14] I. Abadlia, L. Hassaine, A. Beddar, F. Abdoune, M. R. Bengourina, Adaptive fuzzy control with an optimization by using genetic algorithms for grid connected a hybrid photovoltaic–hydrogen generation system, International Journal of Hydrogen Energy, 2020,

[15] Y. Wang, M. Kazemi, S. Nojavan, K. Jermsittiparsert, Robust design of off-grid solar-powered charging station for hydrogen and electric vehicles via robust optimization approach, International Journal of Hydrogen Energy, 2020,

[16] G. Zhang, Y. Shi, A. Maleki, M. A. Rosen, Optimal location and size of a grid-independent solar/hydrogen system for rural areas using an efficient heuristic approach, Renewable energy, 2020,

[17] A. Nikzad, M. Mehregan, Techno-economic, and environmental evaluations of a novel cogeneration system based on solar energy and cryptocurrency mining, Solar Energy, 2022, 232, 409-20

[18] H. Niaz, M. H. Shams, J. J. Liu, F. You, Mining bitcoins with carbon capture and renewable energy for carbon neutrality across states in the USA, Energy and Environmental Science, 2022, 15, 9, 3551-70

[19] L. Gundaboina, S. Badotra, S. Tanwar, editors. Reducing resource and energy consumption in cryptocurrency mining by using both proof-of-stake algorithm and renewable energy. 2022 International Mobile and Embedded Technology Conference (MECON); 2022: IEEE.

[20] L. Gundaboina, S. Badotra, T. K. Bhatia, K. Sharma, G. Mehmood, M. Fayaz, I. U. J. S. Khan, C. Networks, Mining cryptocurrency-based security using renewable energy as source, 2022, 2022,

[21] R. Lotfi, S. G. Zare, A. Gharehbaghi, S. Nazari, G.-W. Weber, Robust optimization for energy-aware cryptocurrency farm location with renewable energy, Computers and Industrial Engineering, 2023, 109009

[22] V. S. Tabar, S. Ghassemzadeh, S. Tohidi, Risk-based day-ahead planning of a renewable multi-carrier system integrated with multi-level electric vehicle charging station, cryptocurrency mining farm and flexible loads, Journal of Cleaner Production, 2022, 380, 134898

[23] E. Akbari, S. F. M. Shabestari, S. Pirouzi, M. Jadidoleslam, Network flexibility regulation by renewable energy hubs using flexibility pricing-based energy management, Renewable Energy, 2023, 206, 295-308

[24] J. I. Ibañez, A. Freier, SoK: Bitcoin, Energy Consumption and Environmental Impact, %J Energy Consumption and Environmental Impact, 2023,

[25] E. Hajipour, F. Khavari, M. Hajiaghapour-Moghimi, K. A. Hosseini, M. Vakilian, An economic evaluation framework for cryptocurrency mining operation in microgrids, %J International Journal of Electrical Power and Energy Systems, 2022, 142, 108329

[26] Digiconomist, Bitcoin Energy Consumption Index 2020 [Available from: https://digiconomist.net/.

[27] M. Bondarev, Energy Consumption of Bitcoin Mining, International Journal of Energy Economics and Policy, 2020, 10, 4, 525-9

[28] A. Mikhaylov, N. Sokolinskaya, E. Lopatin, Asset allocation in equity, fixed-income and cryptocurrency on the base of individual risk sentiment, Investment Management & Financial Innovations, 2019, 16, 2, 171

[29] S. P. Mishra, V. Jacob, S. Radhakrishnan, Energy consumption–Bitcoin's Achilles heel, Available at SSRN 3076734, 2017,

[30] S. Imran, The positive externalities of bitcoin mining, 2018,

[31] D. G. Baur, J. Oll, The (Un-) Sustainability of Bitcoin Investments, Available at SSRN 3365820, 2019,

[32] R. Jain, A. Dogra, editors. Solar Energy Distribution Using Blockchain and IoT Integration. Proceedings of the 2019 International Electronics Communication Conference; 2019.

[33] J. Mattila, T. Seppälä, C. Naucler, R. Stahl, M. Tikkanen, A. Bådenlid, J. Seppälä. Industrial blockchain platforms: An exercise in use case development in the energy industry. ETLA Working Papers; 2016.

[34] P. G. Panah, M. Bornapour, X. Cui, J. M. Guerrero, Investment opportunities: Hydrogen production or BTC mining?, International Journal of Hydrogen Energy, 2022, 47, 9, 5733-44

[35] S. L. N. Alonso, J. Jorge-Vázquez, M. Á. E. Fernández, R. F. R. Forradellas, Cryptocurrency mining from an economic and environmental perspective. Analysis of the most and least sustainable countries, Energies, 2021, 14, 14, 1-22

[36] A. M. Karatas, E. Karatas, A. Kapusuzoglu, N. B. Ceylan. The Nonlinear Relationship Between Bitcoin Mining and Carbon Emissions in the Context of Renewable Energy. Renewable Energy Investments for Sustainable Business Projects: Emerald Publishing Limited; 2023. p. 127-39.

[37] N. Zhao, H. Zhang, X. Yang, J. Yan, F. You, Emerging information and communication technologies for smart energy systems and renewable transition, Advances in Applied Energy, 2023, 100125

[38] A. Menati, K. Lee, L. Xie, Modeling and analysis of utilizing cryptocurrency mining for demand flexibility in electric energy systems: A synthetic texas grid case study, IEEE Transactions on Energy Markets, Policy and Regulation, 2023,

[39] S. Danehkar, H. Yousefi, A Review on Hybrid Renewable Energy Systems (Hydro, Wind and Solar) and Related Novel Studies, Focusing on Power Generation Worldwide Journal of Water, Soil and Air Protection, 2021, 2, 1, 57-69

[40] E. Aghaie, E. Assareh, H. Yousefi, R. Moltames, A. Fathi, K. Choubineh, Exergoeconomic Optimization of a Novel Hydrogen Generation System Based on Geothermal Energy, Journal of Environmental Energy and Economic Research, 2021, 5, 4, 1-15

[41] D. Gardner, Hydrogen production from renewables, Renewable Energy Focus, 2009, 9, 7, 34-7

[42] Global Solar Atlas, [Available from: https://globalsolaratlas.info/.

[43] A. Fathi, A. Ghayedhosseini, M. Salehi, Optimizing Wind-Solar Power Plants: Novel Structures for Identifying Potential Sites and Capacity Ratios in Iran. Journal of Energy Management and Technology, 2023.

[44] A. Fathi, M. B. Ledari, Y. Saboohi, Evaluation of Optimal Occasional Tilt on Photovoltaic Power Plant Energy Efficiency and Land Use Requirements, Iran, Sustainability, 2021, 13, 18, 10213.