The transition towards an environmental sustainability for Cryptocurrency mining

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Abstract. As Cryptocurrency becomes more and more popular so does its demand for mining rigs. At the end of 2020 there were approximately 5,392 different cryptocurrencies available with a total market capitalization of more than $201bn [1]. Cryptocurrencies are using decentralized, distributed systems in order to operate. The mining process involves solving cryptographic equations, which are ultimately used for ensuring encryption of the blockchain transactions, through the use of IT equipment - the most efficient way of doing it being by building mining farms which use Graphics Processing Units (GPUs). The Crypto farmers are rewarded with a share of the transaction they facilitate. As the Cryptocurrency market grows exponentially every year, so does its hunger for energy. For example, the Bitcoin Energy Consumption Index is evaluated to reach 77.782 TWh/year in 2021 [2], which, for comparison, is approximately 1.5 times larger than the entire electricity consumption of Romania in 2020 [3]. In this paper, the transition of Cryptocurrency mining processes towards environmental sustainability will be analysed. A Crypto-farm's Energy Performance Indicators (EPI) and Power Quality Indices (PQI) will be evaluated and, with the use of dedicated software solutions, the authors will propose an action plan to minimize the environmental impact of the energy boundary and to maximize the EPI, thus maximizing the profitability of this new type of business.

1 Energy boundary description

The case study is a cryptocurrency farm located in Bucharest, in a warehouse that was retrofitted for this business. The warehouse has a useful surface of 4,000 m².

As cryptocurrency transactions are based on a public key encryption, also known as an asymmetric encryption. Cryptocurrencies use a decentralized ledger known as blockchain, which is essentially a series of chained data blocks that contain key pieces of data, including cryptographic hashes.

The creation of blockchain requires the existence of nodes (individual devices that exist within the blockchain), miners (specific nodes that verify (solve) unconfirmed blocks in the blockchain by verifying the hashes, transactions (separate transactions are bundled and form a list that gets added to an unconfirmed block), hashes (one-way cryptographic functions used by nodes to verify the legitimacy of transactions which are generated by combining the header data from the previous blockchain block with a nonce), a consensus algorithm (a protocol within blockchain which helps different nodes come to an agreement whilst verifying data – Proof of Work and blocks (individual sections that contains a list of completed transactions – a block that was verified cannot be later modified).

The cryptocurrency mining business is extremely dependent on the mining power of the rigs as the process implies that the farm has to constantly verify cryptocurrency transactions by decrypting crypto blocks (usually 1 MB of data / block – which can usually contain several thousand transactions). The verification / decryption process is rewarded with a small share of the cryptocurrency as long as the proof of work or hash is obtained.

The hash is a 64-digit hexadecimal number that is less than or equal to the target hash (transaction encryption). It can be thus concluded that the Hash-rate (MH/s, GH/s, TH/s) of the mining rig severely impacts the economic efficiency of the business.

The Capital Expenditures (CAPEX) for setting up the business are estimated at 450,000 EUR, out of which the actual implementation costs (IC) were approximately 100,000 EUR and included retrofitting the existing electricity distribution network of the warehouse, installing ventilation modules, ICT network design and installation and programming the GPU’s.

The rest of 300,000 EUR were used for building the mining rigs. The farm is made up of 100 rigs, as presented in Fig. 1, out of which:

- 30 rigs have 13 Nvidia P104-100 8 GB Ram and MB Asus B250 Mining Expert 4 GB Ram, 120 GB SSD Memory and an IBM 2,880W power supply. These rigs mine ETH (Ethereum) at 470 MH/s with an average electricity use of 2 kWh/h. Each rig mines 0.9 ETH/month;
70 rigs have 6 AMD RX 580 8 GB Ram, 120 GB SSD Memory and an HP 1,200 W Power Supply. These rigs mine ETH at 200 MH/s with an average electricity use of 1 kWh/h. Each rig mines 0.4 ETH/month.

The ventilation system is made up of 44 high capacity fans with a rated power of 0.75 kW. This leads to a low efficiency cooling of the mining rigs.

The warehouse lighting system is comprised of 10 LED lamps with an installed power or 150W/lamp. The warehouse also has a close circuit tv (CCTV) system.

**Fig. 1.** Cryptocurrency farm overview (Ventilation system not shown)

The total cryptocurrency mining capacity of the system is of approximatively 55 ETH/month. At a price of 2,007.74 USD/ETH, the monthly generated income is 110,425.70 USD/month, respectively 1,099,840 EUR/year. The viability of the business if also proven by the evolution of ETH in the last 12 months, as seen in Fig.1.

Considering an 8,600 hours/year operation time, the yearly electricity use for the mining rigs is 1,123.2 MWh/year. The existing ventilation system has an average yearly electricity use of 171 MWh/year. The total yearly electricity use is approximatively 1,294.27 MWh/year. As the warehouse has a medium voltage connection via a 400 kVA power transformer, the electricity price is approximatively 70 EUR/MWh. Considering ICT maintenance and periodical upgrades of the system, which amount to 5,000 EUR/month, the yearly operational costs (OPEX) rise to an average of 150,599 EUR/year.

**Fig. 2.** ETH price evolution 20.02.2020 – 20.02.2021 [4]

### 2 Energy Performance Analysis

The first step in proposing a practical guide for transitioning towards an environmental sustainability for the Cryptocurrency mining business is to properly establish the energy baseline and the energy performance baseline for the analysed energy boundary.

In order to do so, firstly, relevant EPI’s to be determined must be selected.

Considering that the energy boundary has no need for any other form of energy except electricity, the most relevant EPI is the specific electricity use ($W_{sp}$), determined with equation (1):

$$W_{sp} = \frac{W^e}{ETH \cdot ETH}$$  \hspace{1cm} (1)

where $W^e$ [MWh/year] is the annual electricity use and $ETH$ [ETH/year] is the yearly ETH generated by the mining rigs.

The environmental sustainability of the business can be evaluated by determining the specific equivalent CO$_2$ emissions generated over a year ($A_{CO2}^{eq}$), with equation (2):

$$A_{CO2}^{eq} = \frac{A_{CO2}^\text{tons CO}_2\text{,eq/year}}{ETH}$$  \hspace{1cm} (2)

where $A_{CO2}$ [tons CO$_2$/year] is the annual CO$_2$ equivalent greenhouse gases emission determined by using the average conversion factor for Romania of 355 gCO$_2$/kWh [5].

The global EPI used was Energy Intensity (EI) which was determined by using equation (3):

$$EI = \frac{EE \cdot t.o.e.}{PV \cdot EUR \cdot 10^3}$$  \hspace{1cm} (3)

where $EE$ [t.o.e./year] is the annual equivalent energy use of the energy boundary, expressed in tons of oil equivalent (t.o.e.) and $PV$ [thousand EURs/year] is the yearly production / income generated.

A fourth relevant EPI used in order to financially quantify the sustainability of the business is the specific CO$_2$ equivalent emission reported to the yearly production / income, determined with equation (4):

$$A_{g}^{CO2} = \frac{A_{CO2}^\text{tons CO}_2\text{,eq/year}}{PV \cdot EUR \cdot 10^3}$$  \hspace{1cm} (4)

The resulting baseline EPI’s are presented in Table 1.

| EPI          | Value | Measuring Unit (M.U.) |
|--------------|-------|-----------------------|
| $W_{sp}$     | 1.96  | MWh/ETH               |
| $A_{CO2}$    | 0.70  | tons CO$_2$/ETH       |
| $EI$         | 0.0840 | t.o.e./thousand EUR   |
| $A_{g}^{CO2}$| 0.418 | tons CO$_2$/thousand EUR |

As it can be observed, the EI of the cryptocurrency mining business is similar to various other production sector business, with an average variation range of 0.06 – 0.1 t.o.e. per thousand EUR, close to the global average of 0.134 t.o.e. per thousand EUR [6].

### 3 Power Quality Analysis

As the energy boundary is powered by a 400 kVA Power Transformer that also ensures the power supply of 2 other warehouses, in order to properly analyse the Power Quality influence of the mining rigs, without overlapping electromagnetic perturbances and multiple PQI values in the point of common coupling, the PQI analysis was done over a period of time in which only the cryptocurrency farm was operating.
By using a Chauvin Arnoux C.A. 8336 Power Quality
and Energy Analyzer in the Point of Common Coupling
(PCC) over a period of 7 days, the following PQI values,
presented in Table 2 and Table 3, were measured /
determined.

Table 2. PQI Values

| PQI          | Value  | MU. |
|--------------|--------|-----|
| Voltage      | 393.86 | V   |
|              | 396.16 |     |
|              | 392.10 |     |
| Current      | 90.05  | A   |
|              | 98.98  |     |
|              | 105.05 |     |
| Frequency    | 49.99  | Hz  |
| Power Factor | 0.23   |     |
| Voltage Total| 2.92   |     |
| Harmonic Distorsion Factor (THDv) | 2.75 | % |
| Current Total| 115.93 |     |
| Harmonic Distorsion Factor (THDd) | 146.26 | % |
|              | 182.43 |     |

Table 3. PQI Testing

| PQI Limits                      | PASS TEST |
|--------------------------------|-----------|
| Voltage: 400 ±10% V [7]         | Yes       |
| Frequency: 50±1% Hz [8]         | Yes       |
| Power Factor: 0.90a             | No        |
| THDv: 8% [9]                    | Yes       |
| THDd: 20% [10]                  | No        |

a. Set by the end-user in order to minimize the reactive energy bill

As it can be observed in Table 3, the analysed energy boundary failed to pass the THDI test [10] and the Power Factor Testa.

The other PQI limits were easily respected by all CNC machines.

As [11] has demonstrated, the abnormally large THDd values are generated by the power sources which ensure the DC power to the mining rigs.

However, as proven in [12], THDd values are highly impacting the energy losses in the Power Transformer.

The influence of the current harmonics on the overall energy losses can be determined by applying equation (5):

\[ \Delta P_{\text{single phase}} = R_{\text{net}} \cdot I^2 \]

\[ = R_{\text{net}} \cdot \left( I_1^2 + \sum_{n=2}^{\infty} I_n^2 \right) [W] \]

(5)

where \( R_{\text{net}} \) is the analysed networks resistance, determined with (6), \( I_1 \) [A] is the average fundamental root-mean-square value of the electrical current, \( I_n \) [A] is the average root-mean-square value of the nth rank current harmonic and THDd [%] is the average measured total current harmonic distortion factor.

\[ R_{\text{net}} = r_0 \cdot l_{\text{net}} + R_F [\Omega] \]

(6)

where \( r_0 \) [\( \Omega/km \)] is the specific resistance of the electric wires, \( l_{\text{net}} [km] \) is the length of the considered electric network and \( R_F [\Omega] \) is the power transformer internal resistance.

4 Energy Performance Improvement Actions

The main issues identified within the analysed energy boundary are presented in Table 4.

Table 4. EPI / PQI atual status

| Indicator | Value | Issue                        | Impact                                      |
|-----------|-------|------------------------------|---------------------------------------------|
| EI        | 0.0840| Large                        | High Electricity Use                        |
| PF        | 0.23  | Small                        | High Reactive Energy Input                  |
|           |       |                              | Lowers the transit capacity of the local distribution grid |
| THDd      | 148.2 | Large                        | Additional Losses in the power distribution grid |
|           |       |                              | High Environmental Impact                   |

To mitigate the various issues identified in the energy analysis stage, the EP\(\)As presented in Table 5 were evaluated from a technical and economical point of view.

Table 5. EPIA proposals

| EPIA                                                                 | Impact                                      |
|----------------------------------------------------------------------|---------------------------------------------|
| Modernizing the cooling system                                       | Reduce Electricity Use                      |
| Implementing a photovoltaic (PV) system                             | Diminish the environmental impact          |
| Installing Active Filters in the PCC                                | Improving PQI values                        |
|                                                                      | Diminish the environmental impact          |

The main criterions used in the technic and economic analysis of the EP\(\)As were the Net Present Value – NPV (7), the Internal Rate of Return – IRR (8), the Simple Payback Period (9), determined by considering a variable annual net income and the Benefit – Cost Analysis – BCA (10).

\[ NPV = \sum_{t=1}^{\text{test}} \frac{l_i - C_i}{(1 + \alpha)^t} - IC [EUR] \]

(7)

where \( t_{\text{test}} \) is the analysis time-frame, in years, selected as per [13]. \( l_i \) is the yearly income in the \( t \)th year, in EUR/\( y \), \( C_i \) are the yearly expenditures in the \( t \)th year, in EUR/\( y \), \( \alpha \) is the discount rate – 9.86%/year for this end-user and \( IC \) is the investment cost, in EUR.

\[ NPV = \sum_{t=1}^{\text{test}} \frac{l_i - C_i}{(1 + IRR)^t} = 0 [EUR] \]

(8)

where the CAPEX can be included in the yearly expenditures as a depreciation cost.

\[ SPP = \frac{IC}{\sum_{t=1}^{\text{years}} l_i - C_i} [\text{years}] \]

(9)

\[ BCA = \frac{IC}{NPV} [-] \]

(10)

An average escalation rate for electricity prices of 5%/\( \text{year} \) was also considered, as determined in [14].

The actual cooling system should be replaced with a centralized high efficiency cooling system, as displayed in Fig. 3. The Hot-Aisle Containment System (HACS) was proposed as it has been proven to lower the electricity use by up to 40% compared to the Cold-Aisle Containment System (CACS).

This system also allows for an optimization of the space in the warehouse, where all the 100 mining rigs will
be included in a single HACS by regrouping the GPUs in order to minimize the number of racks required.

The IC of this EPIA is approximately 30,000 EUR. The yearly C1 is estimated at 2,000 EUR/year. The annual electricity use of the system is estimated to be up to 90 MWh/year. The timeframe analysis was considered to be 10 years.

![Image](https://example.com/image1.png)

Fig. 3. Hot Aisle Containment Cooling System [15]

As the warehouse is the end-user’s propriety, the PV System can be installed on its roof. The proposed PV System will be presented in Table 6. By using RETScreen Expert software the estimated efficiency and expected electricity production were determined. The simulation results are also presented in Table 6.

Table 6. PV System and Simulation results

| Component                  | Value | M.U. |
|----------------------------|-------|------|
| PV Panel type              | CS3W-410P | -    |
| Panel rated Power         | 410   | Wp   |
| Rated efficiency          | 18.56 | %    |
| Installation angle        | 30    | °    |
| Technical warranty        | 25    | Years |
| Quantity                  | 1,000 | Pcs. |
| System Peak Power         | 400   | kW   |
| Inverter rated power      | 100   | kW   |
| Number of Inverters       | 4     | Pcs. |
| Expected electricity production | 595,307 | MWh/year |

Considering an investment cost of 656 EUR/kWp, as determined by the authors consultancy experience, the total IC for the EPIA is of approximately 262,400 EUR. The C1 for the PV system will be less than 2,500 EUR/year, as the system will not be exposed to excessive dusting and as Bucharest does not have particularly heavy winters or significant number of hailstorms.

Installing an Active Filter (see Fig. 4) in the PCC will generate an additional IC of approximately 23,000 EUR with an annual C1 of 3,000 EUR/year. By implementing this EPIA the end-user will obtain a THD reduction of up to 90% and a PF improvement of up to 0.92, thus minimizing the reactive energy bill. The actual reactive energy bill is approximatively 1,500 EUR/month. The timeframe analysis was considered to be 6 years.

![Image](https://example.com/image2.png)

Fig. 4. Active Power Filter (APF) [16]

The reduction of the THD will also lead (as per equation (5) and (6)) to a decrease in the total active energy losses of up to 18%, which amounts to approximatively 30 MWh/year.

The Technical and Economic Analysis results for all three EPIAs will be presented in Table 7.

Table 7. EPIA Economic Analysis results

| EPIA  | NPV [EUR] | IRR [%] | SPP [years] | BCA [-] |
|-------|-----------|---------|-------------|---------|
| HACS  | 1,717     | 12      | 7.33        | 1.06    |
| PV System | 325,138   | 20      | 6.62        | 2.24    |
| APF   | 53,396    | 73      | 2.33        | 3.32    |

As can be observed from Table 7, all three EPIA’s lead to positive financial results over the study period. The end-user should be highly motivated to implement all three EPIA’s as the total NPV reaches 380,251 EUR.

5 Sustainability Improvement Analysis

By implementing the Energy Performance Improvement Plan (EPIP) presented in Chapter 5, a major Environmental Impact Reduction (EIR) will also be achieved.

In order to quantify the yearly and life-cycle EIR, the methodology presented in [5] was used. The electricity conversion factor of 355 gCO₂ equivalent/kWh was considered. The conversion factor also considers the energy losses in the national power grid, which for Romania are situated at approximatively 7% for a Low Voltage (LV) internal distribution grid.

The EIR was determined and will be presented in Table 8.

As can be observed, by implementing the EPIP, the end-user can obtain a total EIR of 250.38 tons of CO₂ equivalent / year, respectively 5,631.25 tons of CO₂ equivalent for the EPIP Lifecycle.

The EIR amounts to approximatively 54.49 of the annual CO₂ equivalent emissions. This will lead to an overall improvement of the A₁²/ eq / year to a value of 0.19 tons of CO₂ equivalent per thousand of EUR of income.

Table 8. EPIA Economic Analysis results

| EPIA  | EIR [tons CO₂ eq / year] |
|-------|--------------------------|
| HACS  | 28.40                    |
| PV System | 211.33                  |
| APF   | 10.65                    |
| TOTAL | 250.38                   |

6 Conclusions

If a linear electricity use escalation with regard to mining capacity is considered when analysing the Cryptocurrency Mining businesses, it is strongly recommended that a novel regulatory framework should be developed.

Considering the ETH mining power use (24.26 TWh/year), presented in Fig. 5, by extending the implementation of the proposed EPIP to the whole sector, an overall EIR of up to 4,693,230 tons of CO₂ equivalent/year, which represents 5% of all of Romania’s latest reported CO₂ emissions.
power quality mitigation. The new cryptocurrency ion is
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The regulatory framework should guide both new
crypto-miners and existing ones in optimizing their
electricity use and minimizing their Environmental
Impact.
Rules and regulations regarding the necessity of
ensuring at least 50% of the electricity use by means of
using alternative, clean, energy sources and the necessity
to use Best Available Technologies (BAT) when
equipping the cryptocurrency farm should also be drafted
up as soon as possible the national, European and
International policy makers.
If every cryptocurrency mining business owner will
always choose the BAT regarding the GPUs and Power
Supply, the same cannot be stated about lighting, cooling
and power quality mitigation. The new cryptocurrency
policy should mandate the minimum efficiency level that
is acceptable for these three types of equipment, in order
to fully optimize the electricity use in the individual
energy boundaries.

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