ISSN: 2230-9926

Available online at http://www.journalijdr.com

IJDR

International Journal of Development Research
Vol. 11, Issue, 04, pp. 46100-46105, April, 2021
https://doi.org/10.37118/ijdr.21559.04.2021

RESEARCH ARTICLE OPEN ACCESS

# ECONOMIC FEASIBILITY OF HYBRIDIZING PHOTOVOLTAIC SOLAR ENERGY WITH AN AQUAPONICS SYSTEM: AN ALTERNATIVE FOR COEXISTENCE IN THE BRAZILIAN NORTHEASTERN SEMIARID REGION

**Túlio Pinheiro Moura*, Juan Carlos Alvarado Alcócer and Olienaide Ribeiro de Oliveira Pinto**

Academic Master's Degree in Sociobiodiversity and Sustainable Technologies, University of International Integration and Afro-Brazilian Lusophony, 62790-970, Redenção, Ceará, Brazil

**ARTICLE INFO**

***Article History:***
Received 11th January, 2021
Received in revised form
16th February, 2021
Accepted 28th March, 2021
Published online 22th April, 2021

***Key Words:***

Aquaponics system, Integrated cultivation, sustainability, Photovoltaic solar energy.

****Corresponding author:***
***Túlio Pinheiro Moura***

**ABSTRACT**

The work had as objective to study the economic viability of the hybridization of photovoltaic solar energy with the aquaponics system as an alternative of coexistence in the semiarid Brazilian Northeast. The work was developed in the municipality of Aracoiaba, Ceará, Brazil, in which an aquaponics system of the NFT (Nutrient Film Technique) type implanted with alternative items was built, and a photovoltaic solar energy system to meet the energy demand of the system. In the economic feasibility analysis, a literature-based survey was conducted to size the photovoltaic system and estimate the energy generation over 25 years of operation. Afterwards, it was possible to evaluate the profit generated year by year and to conclude whether the investment is viable or not. The system was dimensioned to attend an estimated monthly consumption of 75 kWh, and presented an installed power of 1.005 kW. With this power, it was observed that in the first years the system will always generate credits for future use. In addition, the unit will be charged only the availability cost equivalent to 30 kWh. Given the above, the development of a low-cost aquaponics system integrated with photovoltaic solar energy to verify the financial viability of the system in a rural application can enable decision making for rural producers living in semi-arid regions such as the Brazilian Northeast.



**Citation:** ***Túlio Pinheiro Moura, Juan Carlos Alvarado Alcócer and Olienaide Ribeiro de Oliveira Pinto,* 2021.** "Economic feasibility of hybridizing photovoltaic solar energy with an aquaponics system: an alternative for coexistence in the Brazilian northeastern semiarid region", *International Journal of Development Research*, 11, (04), 46100-46105.

# INTRODUCTION

The emergence of renewable energy projects in rural areas, especially in areas that lack economic development such as the Semiarid region of Northeast Brazil, can bring several benefits to the community. Socioeconomic characteristics of many regions, such as high unemployment, lack of economic development alternatives, and high rates of migration of the economically active population, make it advantageous to invest in these technologies (SIMAS; PACCA, 2013). Some research with renewable sources using Solar energy and biomass have already been developed in some municipalities of Marciço de Baturité, Ceará, which is a Semiarid region, such as: photovoltaic solar energy (MACIEL FILHO *et al*., 2018),biodigesters (OLIVEIRA, 2018; SILVA *et al*. 2018; SANTOS, 2018; PINTO *et al*., 2018; ALCOCER *et al*., 2019; ALCOCER *et al*., 2019a; ALCOCER *et al*., 2020b). The proposal of living with the semi-arid region is a positive action to address the economic and socio-environmental issues of the region (SOUSA *et al*., 2017). Thus, the use of renewable sources available in the semi-arid region such as solar energy, biomass and windenergy can be used to produce energy benefiting the inhabitants of this region. In addition to the costs with the implementation of the aquaponics system, there are also variable costs such as feed and electricity, which represent most of the production costs, and these can be reduced by alternative sources. Brazil, due to its territorial extension, solar incidence and large coastal area, is a promising country in the generation of renewable energy, especially wind and solar (PINTO; MARTINS; PEREIRA, 2017). According to the Solar Portal (2018), solar PV has grown ninefold as a sustainable source. In rural areas, the installed capacity has reached approximately 15.8 MW. This growthwas due to the ease of access and purchase of photovoltaic systems, in addition to prices that are more affordable for consumers. Thus, solar energy becomes an important ally for rural producers in saving electricity in rural production. Photovoltaic solar energy presents countless advantages if compared to other sources of electric energy. As it is renewable and inexhaustible, do not present damage to nature in the installation and generation, unlike hydroelectric plants, which for installation need to deforest the fauna and flora of the site of deployment, or thermoelectric plants, which release gases or other polluting agent in its generation, in addition to direct and indirect jobs formed due to solar energy (VERAS, 2017). The semi-arid northeastern region of Brazil has a great potential to generate electricity through solar energy, more specifically, photovoltaic solar energy, but it is still not widely used. Deploying the use of sustainable energy in rural areas has become a form of saving and financial return, besides being an environmentally friendly system. This technology is growing more and more and becoming an intelligent solution for several farmers, emerging asa complementary generation alternative for the expansion of the generating capacity and its applications should be stimulated in the most different segments, including the production of food in aquaponics systems. In this context, the objective of this work was to study the economic viability of hybridizing photovoltaic solar energy with the aquaponics system as an alternative for coexistence in the Brazilian Northeastern Semiarid region.

# MATERIALS AND METHODS

The research was developed in the municipality of Aracoiaba, Ceará, Brazil. The municipality has a latitude of 4°21'57.38 "S and longitude of 38°48'54.52", the predominant climate is tropical hot semiarid, tropical hot mild semiarid and tropical hot sub-humid, having an average temperature of 24°C to 26°C and average annual rainfall of 1.010.3 mm (IPECE, 2017). The methodology adopted for the implementation of the aquaponics system was adapted from Silva (2016) and Oliveira (2018). The equipment used in the photovoltaic solar energy system has the INMETRO "A" classification with energy efficiency at 17%. In addition, they have international certifications such as: TUV, UL, IEC, and VDE. The inverter has the following features: Recommended PV Power (STC) 1900 W (Maximum Input Power); Nominal Output Power 1500 W and 1 MPPT (algorithm that searches for the Maximum Power Point) (CANADIAN, 2020). The DC string box is the protective component for the DC part of the PV system. Cables exit the PV modules and pass through the string box, then are connected to the inverter, while providing over-voltage and over-current protection and allowing circuit sectioning. The string box has 2 inputs and 1 output, i.e. it can connect one or two arrangements in parallel, one output, voltage 1000Vdc and 25A. The voltage and AC current. These specifications are the ones we use in our power grid standards. Direct current (DC) cables are 6 mm long and their main characteristics are: protection against environmental actions (UV rays, ozone); excellent mechanical resistance; doubleinsulation; halogen free; acid and alkali resistant; flame retardant; 25-year life span; continuous voltage up to 1.8KVdc; and double insulation (SOLAR CABLE, 2020). The alternating current cables (AC), the 2.5 mm cable was used, which has the following characteristics: flexible conductor; made of bare electrolytic copper wires; soft temper and Insulation (70°C) and alternating voltage up to 750Vca.

**Economic Feasibility Analysis of a Solar Photovoltaic System:** In the economic feasibility analysis four methods were used to evaluate if the installation of the solar powered aquaponics system is feasible, i.e. to prove that the project will not bring financial risks to the investor. The methods that were used for this analysis are: NPV (Net Present Value), IRR (Internal Rate of Return), discounted Paybac k and simple Payback. The Net Present Value (NPV) technique is a method for investment analysis, so that it calculates in terms of present value the impact of future events associated with an investment alternative, according to equation 1 (SANTOS, 2016).

$$VPL = -I + \sum_{T=1}^{T} \frac{FC_t}{(1+K)^t} \tag{1}$$

Where: $I$ = initial investment; $FCt$ = cash flow in the t-th period; and $K$ = cost of capitalor opportunity cost.

The Internal Rate of Return (IRR) aims to determine the yield that a particular business may come to give in a period. The IRR is the most widely used technique for evaluating investment alternatives and is determined by equation 2 (SANTOS; LEANDRO, 2016).

$$VPL = -I + \sum_{T=1}^{T} \frac{FC_t}{(1+i)^t} = 0 \tag{2}$$

The discounted payback is the indicator that shows the time required for the financial recovery of a given investment. In it the values of capital inflow and outflow are based on present values, since it discounts the capital costs in cash flows. This method aims to determine the ($T$), according to equation 3 (SAMANEZ, 2010; SANTOS, 2016).

$$I = \sum_{T=1}^{T} \frac{FC_t}{(1+K)^t} \tag{3}$$

Simple *payback*, like discounted payback, is an indicator that shows the time required for the financial payback of an investment. However, it is less effective, since it does not consider the time value of money. In this method, the cash flows of each period are added together until the sum equals the initial investment. Therefore, it becomes more reliable to usethe discounted payback (SAMANEZ, 2010).

# RESULTS AND DISCUSSIONS

**System Economic Feasibility Analysis:** For the study of the economic viability of the solar energy aquaponics system, the production of fish and vegetables was analyzed, as well as the energy production of the system throughout the useful life of the modules and inverters, in order to have an estimate of the savings generated, in Reais, each year of operation of the system. Next, some considerations will be presented to carry out the analysis. Table 1 presents the data from 1 cycle of fish and lettuce production obtained in 7 months of analysis. This information was replicated in a year by year production, until reaching 25 years of data, and thus, the financial return of production was obtained, to verify if the initial aquaponics system integrated with solar energy is an economic alternative for small rural communities. It was observed in Table 1, the total revenue for one cycle of fish and lettuce production is R$1.407.10. For the financial viability analysis, an annual income in fishproduction is considered, so an annual income of R$1.095.50 in fish production and R$1.316.00 in lettuce production can be estimated, i.e. the total income in one year ofproduction of the system is approximately R$2.411.50. The cost with feed in twelve months is equivalent to R$531.36. The period of 25 years for the analysis of energy generation and estimated savings generated, since the modules used have a reference of 80% yield in 25 years of operation. Thus, taking this reference is used to estimate the generation of the modules. It is important to consider that the modules are exposed to the natural degradation process, causing an average annual decay

**Table 1. Production parameters of the aquaponics system**

| Product | Cycles (days) | Production | Feed costs (R$) | Total Revenue (R$) |
|---|---|---|---|---|
| Fish | 213 | 91.30 Kg | 309.96 | 639.10 |
| Lettuce | 56 | 252 units | - | 768.00 |
| | | | Total Revenue | 1.407.10 |

**Table 2. Energy tariff discounts for low-income units**

| Monthly electric energyconsumption parcel (kWh) | Discount (%) | Tariff for applying the reduction |
|---|---|---|
| From 0 to 30 | 65 | |
| From 31 to 100 | 40 | B1 subclasslow income |
| From 101 to 220 | 10 | |
| From 221 | 0 | |

around 0.8% in efficiency. Thus, based on the energy generation estimate for the first year, this depreciation was considered year by year for the next 25 years. In Table 1 you can see the production in one cycle of fish equivalent to 91.30 kg, which occurred in a period of 7 months and 3 days. In lettuce production one cycle takes only 56 days, 252 units are obtained, so in one cycle of fish production lasting approximately 7 months 960 units of lettuce can be obtained. As can also be seen the feed cost for one cycle of fish production is equivalent to R$309.96. Thus this is the fixed cost for producing the fish. Therefore at the end of each cycle the total revenue for both products is R$1.407.10 in 7 months of production. Next is the investment analysis study to find out if this idea is really feasible in financial terms.

**Estimated Savings:** Based on data on generation, consumption, current tariff and initial investment cost, fixed costs and revenue in the production of fish and lettuce, the economic viability analysis of the aquaponics system with photovoltaic solar energy was carried out. It is important to note that the tariff charged in the unit under study was 0.18767 R$/kWh. Thus, the unit is benefited with the social tariff for electricity, as provided by law and published on 12/01/2016 at Aneel. This law states that the Tarifa Social de Energia Elétrica, or TSEE, was created by Law n. 10.438, of April 26.2002. Through it, discounts are granted to consumers classified in the Low Income Residential Sub-class. Consumers in the Low-Income Residential Subclass benefit from exemption from the cost of the Energy Development Account (Conta de Desenvolvimento Energético - CDE) and from the cost of the Program of Incentive to Alternative Sources of Electric Energy (Programa de Incentivo às Fontes Alternativas de Energia Elétrica - PROINFA) (ANEEL, 2016). In addition to these exemptions, cumulative discounts are applied to the rest of the residential tariff, as shown in Table 2 below:

For the purpose of analyzing economic viability, two periods were considered for the first year: Jan/20 to Jun/20 and Jul/20 to Dec/20. For the first period, a tariff of 0.18 R$/kWh wasused; in the second period, upon analyzing the property's energy bill, an increase of approximately 2.99% in the tariff was seen. Thus, in the next periods a conservative annual increase of 7.5% applied from every April (the period in which an Enel tariff readjustment usually occurs) was considered, based on the previous tariff, this was done until the 25th year (VERAS, 2017). For verification purposes, the estimated savings with and without energy generation from the photovoltaic system were calculated year by year. The column "Energy Credits (kWh)" indicates the months in which the system generated more energy than it needed to consume. In the months in which credits were generated, these are marked in green with the symbol (↑). If the credits are needed to reduce the next months, this is signaled by the symbol (→), which represents the use of credits from the previous month. Note that in each period, credits are being accumulated and are represented by (↑), if the generation in the current period requires credits, they are signaled by (→). Table 3 shows the total savings of the photovoltaic system, including the fixed costs of fish production, production revenue and savings in the value of electricity. It is observed in Table 3 that in the period "Sep / 29 to Apr / 30" the estimate of generation of the solar energy system was equivalent to 516.02 kWh, and the accumulated consumption remained 630kWh. It is observed that there was a need to use credits to compensate for the difference in consumption. Thus, the symbology → was used to indicate that there was compensation in that period. Therefore, the unit generated less energy and maintained the same estimated consumption. In other words, the photovoltaic system generated less energy in those periods. It can also be noted that from the first to the fourteenth year the unit was taxed with the availability cost equivalent to 30 kWh, due to the fact that the system has generated accumulated credits since the first month of operation of the system.

By analyzing Table 3, it was observed that the total estimated economy in 25 years with the photovoltaic system connected to the grid, taking into account the efficiency losses of the module, tariff increase and use of generated credits, an economy of R$ 8.483.80 was obtained, representing approximately 45.00% of the total cost paid without the use of the photovoltaic system. However, the system continues to generate after its 25 year life, but with a drop in efficiency greater than 0.8% per year.

**Discounted payback analysis:** The payback analysis was carried out to find out if it is really feasible to invest in the entire aquaponics system with photovoltaic solar energy. Thus, savings values were used, year by year, in order to determine the discounted cash flow using the NPV method, and apply it using the discounted payback technique, and thus determine the minimum period of return on investment. The initial investment for the installation of the whole aquaponics and solar energy system was R$10.336.22. The annual revenue obtained from the production of fish and lettuce is R$2.411.50, and the operational cost of R$531.36 for fish feed. To analyze the viability of this investment, one must consider the minimum rate of attractiveness (TMA), defined based on the annual average of the index referring to the savings rate yield in the last two years. This data can be obtained from the Portal Brasil *website*. Table 4 presents the yield index for the last two years, 2018 and 2019. The index presented has an average yield per year of 4.51%. It was then defined a minimum rate of attractiveness of 10% p.a., thus ensuring a higher return than investing in savings accounts. The value of the AMR will be compared with the internal rate of return (IRR) in order to assess the economic feasibility of the entire project. Table 5 illustrates the investment feasibility methods. Figure 1 presents the trend ofthe cumulative cash flow over the entire 25-year lifetime of the PV system with the fish and lettuce production. The calculations for the determination of NPV, IRR, and Payback's were facilitated by the use of the Microsoft Excel tool that has several economic analysis functions. Table 5 shows that the investment will be viable, with estimated time to recover the investment in *payback* discounting 7 years and 3 months of operation of the photovoltaic system, with a net present value (NPV) of positive return in the eighth year of $ 326.81. The internal rate of return (IRR) for the investment presented 19% p.a., being higher than the minimum rate of attractiveness (TMA), and even higher than the savings rate of 4.51%. Therefore, as a decision criterion through the NPV, IRR and discounted *Payback* techniques, the investment in the project for the implementation of the solar powered aquaponics system is feasible, presenting a total gain in 25 years estimated at R$ 9.357.19.

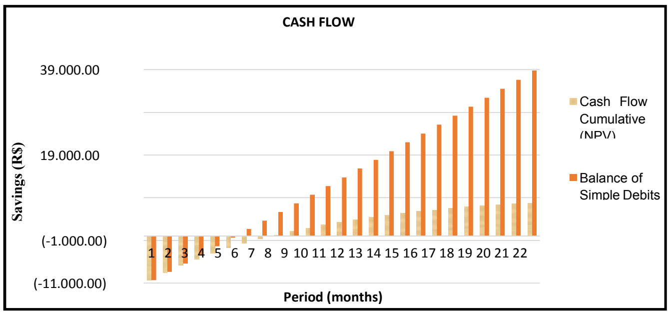


**Figure 1. Cumulative cash flow over the entire 25-year life span of the PV system with the fish and lettuce production by the aquaponics system**

One can analyze that the accumulated value is low, but one justification for this value being lower than expected is precisely because the unit is classified as low income, and therefore has a 65% discount benefit on the current tariff. When analyzing the simple payback in Table 5, the return on investment shows a reduction in comparison to the payback discounting, resulting in 5 years and 2 months. However, this method does not match reality, since it does not take into account the interest rate for correcting money over time. From a technical point of view, the current system proved to be efficient to be replicated in rural communities, or even on terraces where water and sunlight are available.

**Table 3. Estimated total annual savings from the use of credits generated**

| Year | Periods | Annual module efficiency (%) | Generation with depreciation (kWh) | Consumpion (kWh) | Energy Credits (kW) | Tariff Readjustment (%) | Pricing (R$/kWh) | Cost Without GD (R$) | Cost with GD (R$) | Total annual savings (R$) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1° | jan/20 at jun/20 | 100.00 | 757.06 | 630 | 127.06 | 0,00 | 0.18 | 113.40 | 5.40 | 108.00 |
| | jul/20 at dec/20 | | 862.88 | 630 | 359.95 | 3.00 | 0.18540 | 116.80 | 5.56 | 111.24 |
| 2° | jan/21 at jun/21 | 99.20 | 751.01 | 630 | 480.95 | 0.00 | 0.18540 | 116.80 | 5.56 | 111.24 |
| | jul/21 at dec/21 | | 855.98 | 630 | 706.93 | 7.50 | 0.19931 | 125.56 | 5.98 | 119.58 |
| 3° | jan/22 at jun/22 | 98.40 | 738.99 | 630 | 815.92 | 0.00 | 0.19931 | 125.56 | 5.98 | 119.58 |
| | jul/22 at dec/22 | | 842.28 | 630 | 1028.21 | 7.50 | 0.21425 | 134.98 | 6.43 | 128.55 |
| 4° | jan/23 at jun/23 | 97.60 | 721.26 | 630 | 1119.46 | 0.00 | 0.21425 | 134.98 | 6.43 | 128,55 |
| | jul/23 at dec/23 | | 822.07 | 630 | 1311.53 | 7.50 | 0.23032 | 145.10 | 6.91 | 138.19 |
| 5° | jan/24 at jun/24 | 96.80 | 698.18 | 630 | 1379.70 | 0,00 | 0.23032 | 145.10 | 6.91 | 138.19 |
| | jul/24 at dec/24 | | 795.76 | 630 | 1545.47 | 7.50 | 0.24760 | 155.99 | 7.43 | 148.56 |
| 6° | jan/24 at jun/24 | 96.00 | 670.25 | 630 | 1585.71 | 0.00 | 0.24760 | 155.99 | 7.43 | 148.56 |
| | jul/24 at dec/24 | | 763.93 | 630 | 1719.65 | 7.50 | 0.26617 | 167.68 | 7.98 | 159.70 |
| 7° | jan/24 at jun/24 | 95.20 | 638.08 | 630 | 1727.72 | 0.00 | 0.26617 | 167.68 | 7.98 | 159.70 |
| | jul/24 at dec/24 | | 727.26 | 630 | 824.98 | 7.50 | 0.28613 | 180.26 | 8.58 | 171.68 |
| 8° | jan/24 at jun/24 | 94.40 | 602.34 | 630 | 1797.33 | 0,00 | 0.28613 | 180.26 | 8.58 | 171.68 |
| | jul/24 at dec/24 | | 686.54 | 630 | 1853.86 | 7.50 | 0.30759 | 193.78 | 9.23 | 184.55 |
| 9° | jan/24 at jun/24 | 93.60 | 563.79 | 630 | 1787.66 | 0.00 | 0.30759 | 193.78 | 9.23 | 184.55 |
| | jul/24 at dec/24 | | 642.60 | 630 | 1800.26 | 7.50 | 0.33066 | 208.31 | 9.92 | 198.39 |
| 10° | jan/24 at jun/24 | 92.80 | 523.20 | 630 | 1693.46 | 0.00 | 0.33066 | 208.31 | 9.92 | 198.39 |
| | jul/24 at dec/24 | | 596.33 | 630 | 1659.79 | 7,50 | 0.35546 | 223.94 | 10.66 | 213.27 |
| 11° | jan/24 at jun/24 | 92.00 | 481.34 | 630 | 1511.13 | 0.00 | 0.35546 | 223.94 | 10.66 | 213.27 |
| | jul/24 at dec/24 | | 548.62 | 630 | 1429.76 | 7.50 | 0.38212 | 240.73 | 11.46 | 229.27 |
| 12° | jan/24 at jun/24 | 91.20 | 438.99 | 630 | 1238.74 | 0.00 | 0.38212 | 240.73 | 11.46 | 229.27 |
| | jul/24 at dec/24 | | 500.35 | 630 | 1109.09 | 7.50 | 0.41077 | 258.79 | 12.32 | 246.46 |
| 13° | jan/24 at jun/24 | 90.40 | 396.84 | 630 | 875.93 | 0.00 | 0.41077 | 258.79 | 12.32 | 246.46 |
| | jul/24 at dec/24 | | 452.31 | 630 | 698.24 | 7.50 | 0.44158 | 278.20 | 13.25 | 264.95 |
| 14° | jan/24 at jun/24 | 89.60 | 355.57 | 630 | 423.82 | 0.00 | 0.44158 | 278.20 | 134.43 | 143.77 |
| | jul/24 at dec/24 | | 405.27 | 630 | 199.09 | 7.50 | 0.47470 | 299.06 | 120.92 | 178.14 |
| 15° | jan/24 at jun/24 | 88.80 | 315.75 | 630 | - | 0.00 | 0.47470 | 299.06 | 163.42 | 135.64 |
| | jul/24 at dec/24 | | 359.88 | 630 | - | 7.50 | 0.51030 | 321.49 | 153.15 | 168.34 |
| 16° | jan/24 at jun/24 | 88.00 | 277.86 | 630 | - | 0.00 | 0.51030 | 321.49 | 195.01 | 126.48 |
| | jul/24 at dec/24 | | 316.70 | 630 | - | 7.50 | 0.54858 | 345.60 | 188.33 | 157.27 |
| 17° | jan/24 at jun/24 | 87.20 | 242.29 | 630 | - | 0.00 | 0.54858 | 345.60 | 229.14 | 116.46 |
| | jul/24 at dec/24 | | 276.16 | 630 | - | 7.50 | 0.58972 | 371.52 | 226.36 | 145.16 |
| 18° | jan/24 at jun/24 | 86.40 | 209.34 | 630 | - | 0.00 | 0.58972 | 371.52 | 265.76 | 105.76 |
| | jul/24 at dec/24 | | 238.60 | 630 | - | 7.50 | 0.63395 | 399.39 | 267.15 | 132.24 |
| 19° | jan/24 at jun/24 | 85.60 | 179.20 | 630 | - | 0.00 | 0.63395 | 399.39 | 304.81 | 94.58 |
| | jul/24 at dec/24 | | 204.24 | 630 | - | 7.50 | 0.68149 | 429.34 | 310.60 | 118.75 |
| 20° | jan/24 at jun/24 | 84.80 | 151.96 | 630 | - | 0.00 | 0.68149 | 429.34 | 346.23 | 83.11 |
| | jul/24 at dec/24 | | 173.20 | 630 | - | 7.50 | 0.73261 | 461.54 | 356.63 | 104.91 |
| 21° | jan/24 at jun/24 | 84.00 | 127.64 | 630 | - | 0,00 | 0.73261 | 461.54 | 390.01 | 71.53 |
| | jul/24 at dec/24 | | 145.49 | 630 | - | 7.50 | 0.78755 | 496.16 | 405.21 | 90.95 |
| 22° | jan/24 at jun/24 | 83.20 | 106.20 | 630 | - | 0.00 | 0.78755 | 496.16 | 436.15 | 60.01 |
| | jul/24 at dec/24 | | 121.04 | 630 | - | 7.50 | 0.84662 | 533.37 | 456.29 | 77.08 |
| 23° | jan/24 at jun/24 | 82.40 | 87.51 | 630 | - | 0.00 | 0.84662 | 533.37 | 484.68 | 48.69 |
| | jul/24 at dec/24 | | 99.74 | 630 | - | 7.50 | 0.91011 | 573.37 | 509.90 | 63.47 |
| 24° | jan/24 at jun/24 | 81.60 | 71.41 | 630 | - | 0.00 | 0.91011 | 573.37 | 535.69 | 37.69 |
| | jul/24 at dec/24 | | 81.39 | 630 | - | 7.50 | 0.97837 | 616.37 | 566.10 | 50.28 |
| 25° | jan/24 at jun/24 | 80.80 | 57.70 | 630 | - | 0.00 | 0.97837 | 616.37 | 589.28 | 27.10 |
| | jul/24 at dec/24 | | 65.76 | 630 | - | 7.50 | 1.05175 | 662.60 | 624.99 | 37.61 |
| Total | | | | | | | | 15.330.70 | 8.483.80 | 6.846.89 |

**Table 4. Savings annual yield index**

| Year | Cumulative Index(%) |
|---|---|
| 2018 | 4.68 |
| 2019 | 4.34 |
| Average | 4.51 |

Source: Portal Brasil (2020).

**Table 5. Discounted Payback Estimate**

| Year | Cash flow (R$) | Simple Debt Balance (R$) | Discounted Cash Flow (Present value) (R$) | Accumulated Cash Flow (NPV) (R$) |
|---|---|---|---|---|
| 0 | -10.336.22 | -10.336.22 | - 10.336.22 | 10.336.22 |
| 1 | 2.099.38 | - 8.236.84 | 1.908.53 | - 8.427.69 |
| 2 | 2.102.62 | - 6.134.22 | 1.737.70 | - 6.689.99 |
| 3 | 2.110.96 | - 4.023.26 | 1.586.00 | - 5.103.99 |
| 4 | 2.119.31 | -1.903.95 | 1.447.51 | - 3.656.48 |
| 5 | 2.128.27 | 224.32 | 1.321.49 | - 2.334.99 |
| 6 | 2.137.24 | 2.361.57 | 1.206.42 | - 1.128.57 |
| 7 | 2.146.88 | 4.508.45 | 1.101.69 | - 26.88 |
| 8 | 2.156.53 | 6.664.98 | 1.006.04 | 979.16 |
| 9 | 2.166.89 | 8.831.87 | 918.97 | 1.898.13 |
| 10 | 2.177.26 | 11.009.12 | 839.43 | 2.737.56 |
| 11 | 2.188.40 | 13.197.52 | 767.02 | 3.504.58 |
| 12 | 2.199.54 | 15.397.06 | 700.84 | 4.205.42 |
| 13 | 2.211.52 | 17.608.58 | 640.60 | 4.846.02 |
| 14 | 2.223.49 | 19.832.07 | 585.52 | 5.431.53 |
| 15 | 2.236.37 | 22.068.44 | 535.37 | 5.966.90 |
| 16 | 2.249.25 | 24.317.68 | 489.50 | 6.456.40 |
| 17 | 2.263.09 | 26.580.77 | 447.74 | 6.904.14 |
| 18 | 2.263.09 | 26.580.77 | 447.74 | 6.904.14 |
| 19 | 2.276.93 | 28.857.70 | 409.53 | 7.313.67 |
| 20 | 2.291.81 | 31.149.51 | 374.73 | 7.688.40 |
| 21 | 2.306.69 | 33.456.19 | 342.87 | 8.031.27 |
| 22 | 2.322.68 | 35.778.88 | 313.87 | 8.345.14 |
| 23 | 2.338.68 | 38.117.56 | 287.30 | 8.632.43 |
| 24 | 2.373.07 | 42.846.50 | 240.93 | 9.136.46 |
| 25 | 2.391.55 | 45.238.05 | 220.73 | 9.357.19 |

The solar energy system supplied the energy demand of the entire aquaponics system, and thus reduced the cost of electricity, since the system requires constant operation and its consumption is proportional to the size of the system. The system was sized to meet an estimated monthly consumption of 75 kWh, and presented an installed power of 1.005kW. With this power, it was observed that in the first years the system will always generate credits for future use. In addition, the unit will be charged only with the availability cost equivalent to 30 kWh. The consumer unit benefits from the social tariff, which consists of the right to a 45% discount on the tariff. Thus, the tariff is around 0.18 cents per kilowatt consumed. This is an important factor in the viability analysis, since even with this benefit, the system is viable. In the analysis, an increase of 7.5% on the tariff was considered once a year, and so for the next 25 years. The use of solar energy to generate electricity is a highly secure and renewable source,bringing savings to the unit in question. In addition, the aquaponics system can help in the development of income for rural communities that try to produce their own food, or even sell the production that is made in the unit itself.

# REFERENCES


Agência Nacional de Energia Elétrica - ANEEL. Tarifa Social de Energia Elétrica - Tsee. 2016. Available at: <https://www.aneel.gov.br/tarifas-consumidores/-/asset_publisher/e2INtBH4EC4e/content/tarifa-social- introducao/656827?inheritRedirect=false>. Accessed on: 10 feb. 2021

ALCÓCER, J. C. A.; PINTO, O. R. O.; OLIVEIRA, J. de; SILVA, M. E. D,; LIMA, A. C. A. de. Use of biodigester in piggery: an alternative to environmental sustainability in the region of Maciço de Baturité, Ceará. Journal Environmental Management and Sustainability, v.9, p. 783-818, 2020. (a)

ALCOCER, J. C. A.; PINTO, O. R. O.; SILVA, M. L.; QUEIROZ, D. M. B. Rural biodigesters: an alternative to environmental sustainability? 1. ed. Fortaleza: Imprece, 2019. v.1, 110 p. (b)

CANADIAN. Datasheets inverters Canadian. 2020. Available at: <https://download.aldo.com.br/pdfprodutos/Produto39513IdArquivo17204.pdf>. Accessed: 10 Feb. 2021.

IPECE - Instituto de Pesquisa e Estratégia Econômica do Ceará. Basic municipal profile of Aracoiaba. Fortaleza, 2017. Available

LEANDRO, Wankes. How to calculate the feasibility of a project using investmentanalysis techniques: Simple Payback, NPV and IRR. 2016. Available at: <http://www.wankesleandro.com/single-post/2016/12/01/Como-calcular-a-viabilidade-deum- projeto-utilizando-tC3A9cnicas-de-anC3A1lise-de-investimento-Payback-Simples-VPLe- TIR>. Accessed on 03 Dec. 2016.

MACIEL FILHO, P. N.; ALCÓCER, J. C. A.; PINTO, O.R.O, DOLIBAINA, L. I L. Sustainable energy public policies planning: encouraging the production and use of renewable energies. Revista Eletrônica em Gestão, Educação e Tecnologia Ambiental, v.22, p.10, 2018.

OLIVEIRA, F. I. C. de. Small-scale aquaponics: implementation, production and economic feasibility. Monograph - Agronomy course, Redenção, 2018. 72f.

OLIVEIRA, J. Biogas production from organic substrates in biodigesters: study in the macroregion of Maciço de Baturité-CE. 2018. 92 f. Dissertation (Master in Sociobiodiversity and Sustainable Technologies) - University of International Integration ofAfro-Brazilian Lusophony - UNILAB, Redenção, 2018.

PINTO, L. I. C.; MARTINS, F. R.; PEREIRA, E. B. P. The Brazilian wind energy market, social and environmental impacts. Environment and Water Journal, v.12, n.6, p.1082- 1100, 2017.

PINTO, O. R. O; ALCOCER, J. C. A.; OLIVEIRA, J.; SILVA, M. E. D.; BARBOSA, C. E. Use of the biodigester: A sustainable proposal in the rural area of Maciço de Baturité, Ceará.Revista Educação Ambiental em Ação, v.65, p.1-10, 2018.

SAMANEZ, C. P. Financial Mathematics. 5ª ed. São Paulo: Pearson Prentice Hall, 2010.

SANTOS, J. Construction of a homemade biodigester for biogas production for energy generation in rural areas in Brazil and to be applied in Timor- Leste. 2018. 49 f. Monograph (Bachelor's degree in Energy Engineering) - University of International Integration of Afro-Brazilian Lusophony - UNILAB, Redenção, 2018.

SANTOS, J. O. dos. Grid-connected photovoltaic systems: a case study. 2016. 174f. TCC (Graduation) - Electrical Engineering Course, Universidade Federal do Ceará Campus de Sobral, Sobral, 2016.

SILVA, C. E. V. da. Assembly and operation of an aquaponics system. 2016. 60 f. Course completion paper (Bachelor in Aquaculture Engineering) - Universidade Federal de Santa Catarina, Florianópolis, 2016.

SILVA, M. L.; ALCOCER, J. C. A.; PINTO, O. R. O.; QUEIROZ, D. M. B. Biodigestor como uma tecnologia de aproveitamento dos dejetos de suínos: Alternativa sustentável no município de Barreira, Ceará. Linkscienceplace Magazine, v.5, p.1-15, 2018.

SIMAS, M.; PACCA, S. Wind energy, job creation and sustainable development. Estudos avançados, v.27, n.77, 2013.

SOLAR CABLE. Nexans Solar Cable. 2020. Available at: < https://www.nexans.com.br/eservice/Brazil-pt_BR/navigate_227613/Cabos_para_painel_solar.html#>. Accessed on: 10 Apr. 2020.

SOLAR PORTAL (Comp.). Rural areas achieve good results in solar energy use. 2018. Available at: < https://www.portalsolar.com.br/blog-solar/energia-solar/2904.html>. Accessed on: 03 Mar. 2021.

SOUSA, A. B.; COSTA, C. T. F.; FIRMINO, P. R. A.; BATISTA, V. S. Social technologies for living with the semiarid in the Cariri region of Ceará. Cadernos de Ciência & Tecnologia, Brasília, v.34, n.2, p.197-220, May/Aug. 2017.

VERAS, C. K. O. Economic feasibility analysis of a grid-connected photovoltaic system at Mirassol farm. 2017. 144 f. TCC (Graduation) - Energy Engineering Course, Universidade da Integração da Lusofonia Afro-Brasileira, 2017.


*******