Implementation of a Solar Power System Using Frequency Converter for Water Collection Optimization in the Altamira Community of Japurá - Amazonas

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Abstract

Solar panels are renewable sources of energy, which over the last two decades have been widely used for electricity generation, and Brazil is beginning to move towards the implementation of alternative renewable energy sources as its energy matrix, especially solar photovoltaic. The residential photovoltaic system provides local generation and consumption, helps reduce grid load, increases system reliability, reduces transmission and distribution losses, lowers energy costs and reduces environmental impact. This paper discusses the use of solar energy applied for pumping water with two proposals, most economically viable and able to serve a community with 123 inhabitants, who live in that difficult-to-light region. With this we will apply two proposals of a photovoltaic kit for water abstraction that presents the economical *dimensioning of its implantation, proving to be a viable system for the riverside communities with difficult access to water.*

Keywords: Energy Efficiency, Water Capture, Photovoltaic.

1. Introduction

With the creation of solar panels in the nineteenth century (MACHADO; MIRANDA, 2014), there was an evolution in the electricity sector, based on concern for the preservation of the environment, as well as seeking other renewable sources for electricity generation in the world.

The main sources of energy in the world are coal, gas, water (hydroelectric), uranium and petroleum, which are causing environmental impacts, beginning in the Industrial Revolution, when humanity began to use fossil fuels more intensively to move their machines. Since then, greenhouse gas (GHG) emissions have optimized climate change, which in turn tends to increase the average temperature of the planet (MME, 2017).

Thus, in recent years there have been major discussions about global warming, where in 2018 there was a meeting of 30,000 delegates from 197 countries, with the mission of creating an action plan to implement the Paris agreement, the United Nations Conference on climate change COP-24 (UN, 2018).

According to BBC NEWS BRASIL (2018), for the past 22 years, 2018 has been the fourth warmest year since 1880, if this trend continues, temperatures could rise by 3 to 5 degrees by 2100.

Thus, there are different studies that present various sources of renewable energy to combat global warming, seeking to replace harmful or harmful matrices, such as hydroelectric and thermal, from current modules such as wind, solar and biofuel.

In Brazil, these sources have been increasing their availability as the country has been modernizing, and as the energy sector is developing. However, most of the energy production still comes from hydroelectric plants, which accounts for 63.7% (energy available for consumption in Brazil), thermal 27.2%, wind 8.1% and solar 1%. According to ANEEL (2018), solar energy use has grown to 1,602 MW, previously generating only 1,365 MW of energy nationwide (ANNEL, 2017).

However, Brazil, despite having favorable conditions for photovoltaic energy, still presents itself as a little explored resource. In recent years, the solar energy model has assumed and demonstrates the predominant and revolutionary role in the evolution of the energy sector in our country, mainly, following the regulation of the National Electric Energy Agency (ANNEL, 2017).

In the Amazon there is the Balbina Hydroelectric Power Plant, built on the Uatumã River, between 1985 and 1989, where energy production totaled 250 MW, with five 50 MW capacity generators. In 2017 a floating solar plant was built in the Balbina hydroelectric lake, with a capacity of generating 5 MW that should supply 9,500 families (MME, 2017).

According to Eletrobrás energy distribution of Amazonas (2015), in 2003 the light for all program was launched, benefiting more than 104 thousand households, with approximately 509 thousand people, where only a small part of the population was not served with this program. light for all, given the allocation of this population to protected areas, and it is necessary to propose and develop actions that bring income and economic diversity to these communities.

The lack of electricity in a society results in the existence of social asymmetries in the conditions and quality of life, such as: the permanence of poverty, the lack of opportunity for growth, the migratory flow to large cities and the disbelief of this society. future, where urban lifestyles are actually adopted as a possible way of life, with numerous environmental losses (ICMBio, 2017).

Some regions face difficulties to capture water, due to the isolation of some communities or because they have high slopes, making it difficult to access electricity and water, causing these populations to develop their domestic activities on the banks of the rivers.

The discussion of this study shows the electric power generation for the motor pump, which captures water, from these populations living in isolated communities with difficult access to electricity. Thus, it is glimpsed from the technological innovation to capture water from a certain region seeking to understand the terrain, climate, fauna, flora, proximity to rivers, ease of access, solar incidence, humidity and other environmental conditions aiming the development of the project.

Thus, this study aims to analyze the economic mode of electricity generation, with the implementation of a photovoltaic kit, which will capture water, aiming at the fulfillment of technological innovation, seeking to bring improvement in quality of life, with regard to electricity generation for the community of Altamira, Japurá-AM, having as a subsidy the demonstration of the costs to change the power generation model.

2. Material and Method

2.1 Study area

The project proposal was made for the Altamira community in the municipality of Japurá-AM, located on the right bank of the Japurá river (Figure 1). According to the IBGE (2017), this municipality was created by State Law No. 96 of December 19, 1955, with territory of 55.827,207 km². The present population of 7,326 inhabited by the latest IBGE census (2010), with a demographic density of 0.13 inhab / km², and its coordinates are in latitude 1 ° 52'45.39 "S, and longitude 66 ° 59'46.28" W.

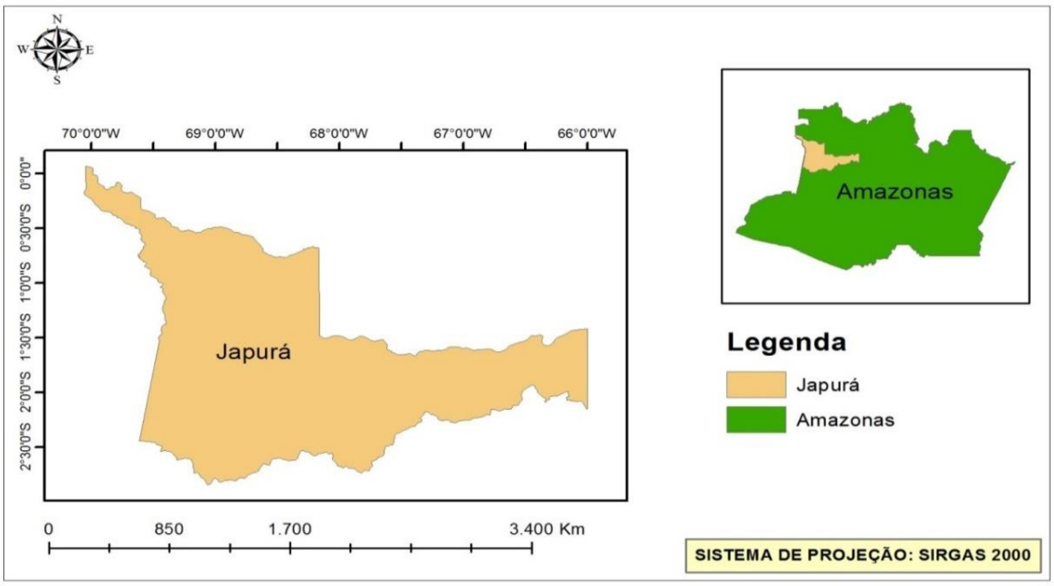

Figure 1: Map of the municipality of Japurá-AM.

Source: Own authorship (2019), marked by IBGE (2010).

The municipality of Japurá is bathed by the river of the same name, where are 43 riverside communities, where 41 communities are dependent on the energy produced from the diesel engine, which only work four hours a day (between 18:00 - 22:00h).

Therefore, the need for a pilot project to be implemented in the community, given the existence of 123 residents, without access to electricity, with income from the management of pirarucu, by RDS Altamira. To improve community water abstraction, a photovoltaic kit was proposed to eradicate the still existing electrical exclusion in this area, proposing an economic model, reducing the use of fossil fuel and advancing the use of renewable energy generation.

Two types of photovoltaic kit were proposed to the community, the first consisting of materials such as: solar plate, solar inverter, water pump, sensor float; and the second, by a solar plate and 12 V dc Shurflo 8000 motor pump. Thus, it was divided in two steps to demonstrate the most advantageous type from the economic question.

3. Case Study Application

3. 1. First Proposal of Inverter Photovoltaic Kit

According to Oliveira; Lira; Moraes (2018), photovoltaic solar energy can be applied to telecommunication equipment, irrigation, home supply etc. The materials to be used and the procedures required for research development are:

The. Solar plate; The solar plate is a device that converts solar radiation into electricity, which will be used for the generation of electricity; B. Solar inverter; Irrigasol solar inverter, used in variable speed drive with state-of-the-art technology for three-phase induction motors using photovoltaic or wind solar energy. It can be used in water pumping, ventilation and cooling systems with Maximum Power Point Tracking (MPPT) technology for maximum power point tracking, extracting maximum system performance and can convert panel power to 127 V, for pump motor operation; ç. Water pump; In this module I use 1 CV system, serving to supply the water tank of 5,000 liters, suitable for large flows and small manometric heights, and may be submersible or surface; d. Sensor float; used to drive the pump motor for when the water tank is full or dry; With this the system was designed to drive a 1 hp pump motor. This sizing of the system began with solar radiation, based on the need to use the site metric Solari index.

In addition, from the metric Solari we used the latitude and longitude of the Altamira community to know the solar radiation index. To obtain the time of solar radiation in this region, information was taken from the Ministry of Mines and Energy (MME, 2019) by adding the latitude and longitude coordinates that provided a table with Average Daily Capacity in h / day (Figure 2).

Figure 2: Solar radiation in the inclined plane, Japurá-AM.

Cálculo no Plano Inclinado

Estação: Japura
Município: Japura , AM - BRASIL
Latitude: 1,801° S
Longitude: 66,549° O
Distância do ponto de ref. (1,7825° S; 66,5475° O) :2,1 km

#	Ângulo	Inclinação	Irradiação solar diária média mensal [kWh/m².dia]													
			Jan	Fev	Mar	Abr	Mai	Jun	Jul	Ago	Set	Out	Nov	Dez	Média	Delta
☑	Plano Horizontal	0° N	4,58	4,77	4,61	4,33	3,97	4,17	4,22	4,82	5,07	5,01	4,87	4,58	4,58	1,10
☑	Ângulo igual a latitude	2° N	4,53	4,74	4,61	4,36	4,02	4,22	4,27	4,86	5,08	4,98	4,82	4,52	4,58	1,07
☑	Maior média anual	1° N	4,55	4,75	4,61	4,35	4,00	4,20	4,25	4,84	5,08	4,99	4,85	4,55	4,58	1,08
☑	Maior mínimo mensal	12° N	4,21	4,51	4,52	4,42	4,18	4,47	4,49	5,00	5,06	4,78	4,50	4,17	4,52	,89

Source: Cresesb, http://www.cresesb.cepel.br/index.php#data (2019).

According to the data obtained MME to Solari metric from the northern region of Altamira-AM, had presented daily average solar radiation capacity.

According to Daniel (2010), to do the sizing we have to follow the following steps.

3.1.1 Step 1 - dimensioning of the pump

For the dimensioning of the pump it was taken as reference the voltage and electric current of the pump motor, the following formula, seeking the necessary energy for the operation, from the equation 1:

$$Pb = T \times C \quad \text{(Eq. 1)}$$

Pb = electric power of the pump motor;

T = electric voltage;

C = electric current.

3.1.2 Step 2 - How much energy will be used

To know how much energy will be used during the operation of the pump motor to fill the water tank, one must know the operating time it takes to fully fill it. From then on, it was sized according to the time it took to fill this box using the diesel engine, which lasted about 3:30 h / day, multiplying by the electric power of the pump motor, described by equation 2:

$$GEb = Pb \times t \quad \text{(Eq. 2)}$$

GEb = water pump power generation;

Pb = electric power of the pump motor;

T = pump operating time.

3.1.3 Step 3 - calculate the energy generated from a solar panel

To calculate the energy generated from a solar panel, multiply the solar panel power by the solar irradiation time according to equation 3.

$$Ep = Pp \times Is \quad \text{(Eq. 3)}$$

Ep = energy generated by the solar panel throughout the day;

Pp = solar panel power;

Is = time of solar radiation in the inclined plane.

3.1.4 Step 4 - Number of solar plates

To know the number of solar plates, it was based on the power generated from the solar panel (Ep) and the result of the water pump equation 4.

$$N = Eb / Ep \qquad \text{(Eq. 4)}$$

N = number of solar plates.

GEb = water pump power generation;

Ep = energy generated by the solar panel throughout the day.

3.1.5 Step 5 - Number of solar plates

According to the number of solar plates, which can be connected in parallel, the supply of generated power need (Eg) to drive the pump during the water tank supply is obtained by equation 5.

$$Eg = Ep \times n \qquad \text{(Eq. 5)}$$

Eg = energy generated during the day for pump motor operation.

Ep = energy generated by the solar panel throughout the day;

N = number of solar plates.

3.1.6 Step 6 - The return on investment

From this, the return on investment made in the equipment was based on the Payback equation 6.

$$T\,(\text{years}) = \frac{Ct}{Cd \times (365\text{day} / \text{year} / 7 \text{ days of the week})} \qquad \text{(Eq. 6)}$$

T (years) = return on investment time;

Ct = total investment cost;

Cd = total cost of diesel spent per week;

This calculation will show the return on investment of this system, used to replace the fuel that was used to start the light motor and drive the pump motor.

3. 2 Second Proposal of the Non Inverter Photovoltaic Kit

According to the manufacturer, the inverterless system, created by Solenerg Engineering Company, is a system specially designed for pumping water from wells, lakes and rivers. The characteristic of this type of system is that it does not need storage of the electric energy produced by the solar panels, since the pumped water can be stored in reservoir.

This system consists of only the following materials: solar plate and Shurflo 8000 pump, which fill a 500l water tank. For this system, indicated, it was made sizing, using the same formulas of the first proposal, based on the characteristic of the pump motor and also on the amount of water needed to pump.

4. Results and Discussion

4.1 First Proposal of Inverter Photovoltaic Kit

In the first proposal of the photovoltaic solar kit was made the sizing using the driver and according to data from the metric Solari in the region of Altamira-AM, a daily average of 4.58 h / day was observed. For this, the step by step for application follows.

4.1.1 Step 1 - First Proposal - dimensioning of the pump

The driver promotes the conversion of direct current energy from photovoltaic modules to three-phase alternating current energy, where the rated current output is 14 A, depending on the motor pump electrical current. The design of the water pump was made with reference to the completely empty water tank, being necessary to pump 5000 l of water / day, based on these technical specifications of the motor pump in voltage of 127 V and current of 14 A, has up .

$$Pb = 127 \text{ V} \times 14 \text{ A} = 1{,}778 \text{ W}$$

4.1.2 Step 2 - First Proposal - How much energy will be used

The panels that were used are of JINKO POLI 330w brand, for the sizing of the solar plates, being necessary to calculate the power of the water pump (Eb) during the operation period of 3:30 h / day. .

$$GEb = 1{,}778 \text{ W} \times 3.30 \text{ h / day} = 5{,}867.4 \text{ Wh / day}$$

4.1.3 Step 3 - First Proposal - calculate the energy generated from a solar panel

The energy generated from a solar panel, multiplied by the power of the solar panel and the solar irradiation time according to the data obtained by the cresesb (2019) of 4.58 h / day of solar irradiation, using the solar panel power of 330W.

$$Ep = 330 \text{ W} \times 4.58 \text{ h / day} = 1{,}511.4 \text{ Wh / day.}$$

4.1.4 Step 4 - First Proposal - Number of solar plates

Regarding the number of solar plates, the generated power of the solar panel (Ep) and the operating time of the water pump (Eb) were calculated, obtaining the result of 4 solar plates.

$$N = \frac{5{,}867.4 \text{ Wh / day}}{1{,}511.4 \text{ Wh / day}} = 3.88 \cong 4 \text{ solar plates}$$

4.1.5 Step 5 - First Proposal - Number of solar plates

From these four solar panels connected in parallel, to reach the pump drive for 3h30min, and supply the 5000 l water tank, culminating in the energy generated has:

$$Es = 1{,}511.4 \text{wh / day} \times 4 = 6{,}045.6 \text{ Wh / day}$$

Having a ready-sized system, a battery is needed for energy storage, as there is no pre-analysis included to choose the replacement of the system, which uses battery, a driver was used to convert the energy and automatically start the pump. In this case it will not be used on the battery to store energy.

4.1.6 Step 6 - First Proposal - The return on investment

With the value of the investment made, the return on investment of this system is calculated by replacing the fuel.

The value of the photovoltaic kit of the first proposal costs around R $ 6,912.40, being spent four (4) liters of diesel during 3: 30h, where the value of diesel is R $ 4,50, since the pump Water was turned on every three days. Therefore, during the operation of the water pump was spent around 4l diesel / day, multiplying by the value of diesel $ 4.50 l. totaling $ 18 / day and $ 54 / week.

$$T \text{ (years)} = \frac{6{,}912.40 \text{ R\$}}{\$\ 54 \times 52.14 \text{week / year}} = 2.45 \cong 3 \text{ years}$$

4.2 Second Proposal of Non Inverter Photovoltaic Kit

With this basic system the inverter was not used, different from the previous one. According to Pereira (2010), this system is basically made up of only the solar panel and the Shurflo 8000 pump, which is designed to be connected directly to the solar panel without any other components between the panel and the pump.

4.2.1 Step 1 - Second Proposal - dimensioning of the pump

The pump sizing to 500 l water tank capacity, being used daily, has a voltage of 12 V and current of 10 A

$$Pb = 12 \text{ V} \times 10 \text{ A} = 120 \text{ W}$$

4.2.2 Step 2 - Second Proposal - How much energy will be used

By sizing the solar plate, the power output of the water pump (Eb) was calculated during the operating period of 4:58 h / day.

$$Eb = 120 \text{ W} \times 4.58 \text{ h / day} = 549.6 \text{ Wh / day}$$

4.2.3 Step 3 - Second Proposal - calculate the energy generated from a solar panel

Calculating the energy generated from a solar panel, the solar panel power was multiplied by the solar irradiation time of 4.58 h / day of solar radiation, from the solar panel power of 155 W.

$$Ep = 155 \text{ W} \times 4.58 \text{ h / day} = 709.90 \text{ Wh / day.}$$

4.2.4 Step 4 - Second Proposal - Number of solar plates

The number of solar panels were scaled based on the generated solar panel power (Ep) and the water pump operating time (Eb):

$$N = \frac{549{,}60 \text{ Wh / day}}{709{,}90 \text{ Wh / day}} = 0{,}77 \cong 1 \text{ solar panel}$$

4.2.5 Step 5 -Second Proposal - Number of solar plates

With an arrangement of a solar plate connected to direct current, supplying the energy requirement to drive the pump for 4h58min and supplying the 500 l water tank, with a solar plate we have:

$$Es = 709.90 \text{ Wh / day} \times 1 = 709.90 \text{ Wh / day}$$

4.2.6 Step 6 - Second Proposal - The return on investment

The value of the first proposal photovoltaic kit costs around R $ 826.99, and it was spent 1 liters of diesel for 40 min, since the value of diesel is R $ 4.50. Since the water pump is activated every three days, then during the operation of the water pump it costs around 1l diesel / day multiplies R $ 4,50, totaling R $ 4,50 and three days of the week the expense reaches R $ 13.50 / week.

$$T \text{ (years)} = \frac{867.55 \text{ R \$}}{\$ 13.50 \times 52.14 \text{week / year}} = 1.23 \cong 1 \text{ year and 3 months}$$

4.3 Project Return on Investment

The results obtained in this dimensioning show the total equipment used in a photovoltaic kit to drive the pump motor.

In a water pumping system, the average cost is $ 7,000, and can pump approximately 5,200 l of water / day to a community, reducing the time spent by residents who needed to get canned water for their consumption, transport water for a rural family that consumes about 6 hours of work between collection and transport in bucket, a work typically done by women and children (OLIVEIRA, 2010).

With the sizing made of the first proposal, the results were obtained, and it was used in a Payback table. In the first item, there is the diesel expense in one year, in the second item there is the initial investment value of the first one (Table 1).

Table 1: One-year diesel and investment spending of the first proposal.

Item	Description	Spent
1º	Diesel in a year	R$ 2.815,56
2º	Initial value of investment	R$ 6.912,40

Source: Own authorship (2019).

Table 1 shows that in one year 40.73% of diesel is spent, compared to the initial investment value of the first proposal. Thus, in the other proposition there is no use of fuel (Table 2).

Table 2: Return on investment time and possible spending on diesel.

TRI	0 year	1 year	2 year	3 year	4 year	5 year
Initial value of investment	-R$ 6.912,40	-R$ 4.096,84	-R$ 1.281,28	R$ 1.534,28	R$ 4.349,84	R$ 7.165,40
Diesel spend	-R$ 2.815,56	-R$ 5.631,12	-R$ 8.446,68	-R$ 11.262,24	-R$ 14.077,80	-R$ 16.893,36

Source: Own authorship (2019).

Table 2 shows the return on investment given in the third year, with 22.20% of its initial investment. In five years, he has 103.66% profit and 3.66% more than the initial value used in the project.

It can also be observed that after three years the percentage of profit with the use of the photovoltaic kit is achieved, compared to the use of the diesel engine there is a big difference in fuel expenditure, which in three years would be spent 734.04% a more compared to using the photovoltaic kit, which would already have a return on investment of 22.20%.

According to Valverde (2017), the Payback determines the time required for the invested capital to be recovered. Discounting the investment, the profits will be obtained over the investment period until the capital invested is completed and the time taken for this process is accounted for. The lower the payback, the more interesting the investment becomes.

In proposal two, a design was made without the use of the inverter, using the same Payback calculation as in the first proposal (Table 3).

Table 3: Diesel spend in one year and investment expenditure of the first proposal.

Item	Description	Spent
1º	Diesel in a year	R$ 703,89
2º	Initial value of investment	R$ 867,55

Source: Own authorship (2019).

Table 3 shows that in a year 81.13% of diesel is spent, almost the same as the initial investment value of the second proposal, adding the return on initial investment (Table 4).

Table 4: Two-year return on investment

TRI	0 year	1 year	2 year	3 year	4 year	5 year
Initial value of investment	-R$ 867,55	-R$ 163,66	R$ 540,23	R$ 1.244,12	R$ 1.948,01	R$ 2.651,90
Diesel spend	-R$ 703,89	-R$ 1.407,78	-R$ 2.111,67	-R$ 2.815,56	-R$ 3.519,45	-R$ 4.223,34

Source: Own authorship (2019).

Table 4 shows the two-year return on investment, with 62.27% of your initial return on investment. In five years, there is a 305.68% return on investment and 243.41% more than the initial value of the investment. If in two years you continue to use the diesel engine, the expense will reach up to 390.88% more, compared to the initial value of the investment.

Compared to the two systems it can be said that both have their advantages and disadvantages, in the first proposal there is a system that can fill a reservoir of 5000 l, whereas the second proposal can only supply a reservoir of 500 l where in this view The most advantageous is the first proposal, given the service to the whole community.

In the community there are 30 residences, and the second proposal can serve only one residence, having this condition as a disadvantage.

In terms of return on initial investment compared to both systems, the second proposal is the most unfeasible, due to the short term return on investment, with a positive balance of 62.27% of your initial investment and in the first proposal your return. It is long-term according to the Payback calculation, with this return in three years and may have 22.20% of the initial investment.

In this case the community requested the photovoltaic kit which is to serve all homes in the community. Therefore, even though a high initial value of equipment expenses to attend all the homes presents better results. This would have to multiply the initial value of the photovoltaic kit (VIKF) by the total community residences, so one has: VIKF = 867.55 x 30 = $ 26,026.50 apparently a high expense when compared to the first proposal. However, from figure 3, there is the comparison of the best proposal.

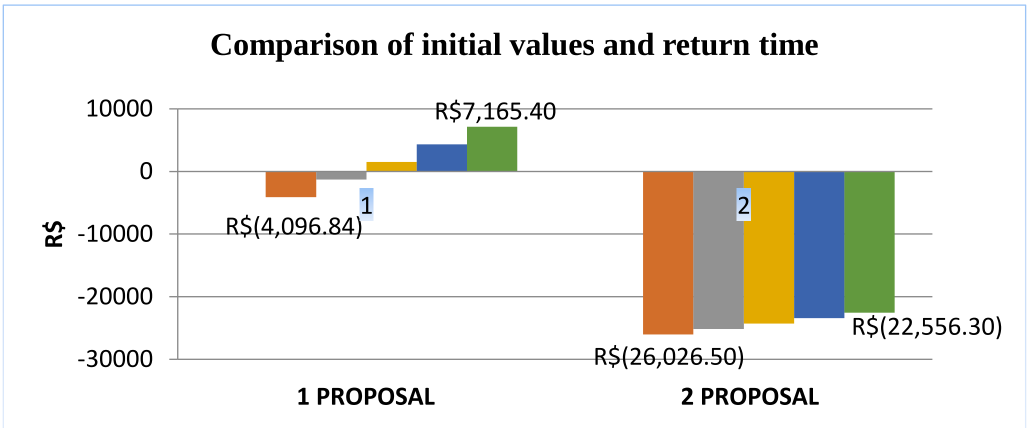

Figure 3: Comparison of initial values and return time
Source: Own authorship (2019).

We can see that the first proposal has a low initial value and a quick return on investment compared to the second proposal, which even with a high investment value, has a long term return.
That is why it is taken as an indication of the first proposal, to serve the whole community, with low investment cost and a quick return on investment made in the photovoltaic kit.

5. Conclusion

This work demonstrated the results of two proposals for a photovoltaic water supply kit in the region of difficult access to water, seeking to replace the use of diesel engine, bringing savings to the residents of the community, which has a large fuel expense. given the high value of this material.
Using Payback to calculate the two proposals of the photovoltaic kit both are viable, each with its advantages, in the first proposal it was found that it has a high value, but can meet the whole community and its return time is soon. However, due to the high volume of water that this equipment can pump to be stored, there is a great advantage related to another proposal that serves only one residence.
The second proposal is economically less infeasible due to its short-term payback time, showing an economical kit, but only serves a residence with the 500 l reservoir.
With this was made another comparison of the two proposals, which would be to serve the whole community, having the best efficiency the first proposal, which ensures the sustainability of the system.
This project is an excellent alternative to the community water supply problem, showing economic, ecological and social viability.

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