

ANALYSIS OF ECONOMIC VIABILITY IN THE IMPLANTATION OF RESIDENTIAL PHOTOVOLTAIC AND PHOTOTHERMIC SYSTEM

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ABSTRACT

This work presented an analysis of the economic feasibility of the use of photovoltaic and photothermic systems, reconciled with market technology in a 110m² residence, composed of 09 rooms, located in Porto Real, southern Rio de Janeiro state, with the purpose of comparing and clarify the best cost and benefit of both acquisitions.

In order to evaluate the applicability, it was considered the individual implantation of the photovoltaic cell and reconciled with solar water heater.

For the development of the study, an exploratory quantitative applied research was carried out, using as a procedure a case study with the residence energy analysis, object of study (characterization of the residential consumer load and design of the photovoltaic system and solar collector). Through the collected data it was possible to raise the cost and expenses involved for both presented scenarios and to carry out the economic viability analysis.

The definition of solar supply systems and methods of investment analysis was carried out through bibliographic research.

In order to assist in decision making, we used the methods of analysis of Internal Rate of Return (TIR), Net Present Value (VPL) and Payback

Keywords

Renewable Energies, Investment Analysis, Economic Viability.

1. INTRODUCTION

Brazil is experiencing a period of great instability in politics and economy, and as a consequence, the country faces critical factors such as the increasing risk of default, the devaluation of the real against the dollar and high inflation rates.

According to the Energy Research Company [13], residential energy consumption dropped by 5.4% in January 2016 compared to the same month in 2015. Factors such as the deterioration of the economic scenario linked to the increase in tariffs contributed significantly to this as the increase in the unemployment rate to 7.6% in January 2016 [13], credit became more restricted and expensive due to indebtedness, thus reducing the disposition to acquire goods.

The increase in electricity generation from non-renewable sources of 26.9% of the national total, against 23.3% in 2013 [11]

is an alarming indicator for a negative contribution to the global sustainable development plan. The graph of figure 1 shows the national supply of electricity by source, illustrating the predominance of renewable energy, especially in hydroelectric generation.

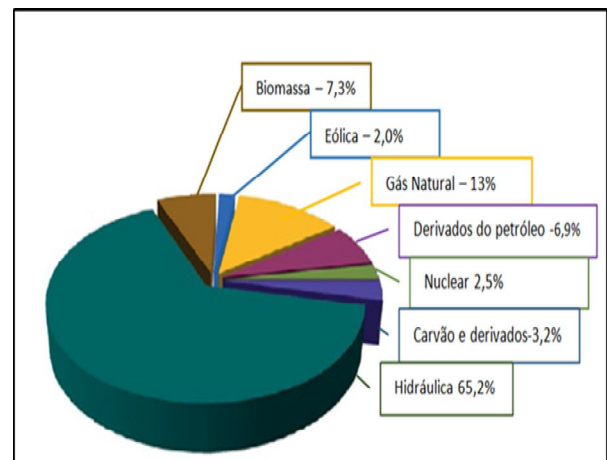


Figure 1. Internal Supply of Electric Power

Source: Modified from [11]

Given these scenarios, the search for alternative sources of energy emerges as an aggregator in the search for a sustainable development model, providing energy and consequently contributing to the reduction of social and economic impacts as well as a necessity due to the great reliance on exhaustible sources such as oil and of hydroelectric plants affected directly by the climatic instability generated by global warming.

The continental dimension of the Brazilian territory is privileged to occupy part of the northern and southern hemisphere and present a large coastal region which provides favorable conditions for the use of the various alternative forms of energy [6].

The Sun, for human parameters, presents itself as an inexhaustible and eternal source of energy and therefore is considered a strongly recommended option in the search for alternative sources. [6].

Among the technologies developed through solar supply, we highlight the solar collector (photothermic energy) for heating and

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systems with cell modules (photovoltaic energy) for power generation, which have favorable characteristics such as silent process, non-emission of carbon dioxide during operation, flexibility and simple operation and maintenance [10].

This work was based on the analysis and the economic feasibility for the individual and reconciled implementation of photovoltaic cells and solar collectors modules in a 110m² residence, located in the city of Porto Real-RJ, as resources to reduce the consumption of conventional electric energy.

Despite the current incentives for solar energy in Brazil, the stimuli are still much lower in relation to countries that lack diversity in clean energy alternatives and still depend significantly on fossil fuel [17]. The insufficiency of the incentives and the high cost of the equipment present themselves as strong impediments to the use of this energy source mainly in residences. Given this scenario, the work is justified by the need to verify the economic viability in the use of alternative sources of energy in common homes in the face of a growing need for sustainable development. For this, it is necessary to use financial primordial methods.

2. PROCEDURES

They are considered as preliminary stages of the investment analysis of the reconciled solar and photovoltaic system; survey of consumption, sizing, budgeting and subsequent application of economic methods.

2.1 CONSUMER SURVEY

The city of Porto Real is located in the southeast region of the State of Rio de Janeiro, at 385m altitude, with an area of 50.7km². Its geographical coordinates have the following data: Latitude: 22° 25 '11 "S, Longitude: 44° 17' 25" W [14] Figure 2 shows a photo of the residence, used as object of this study.



Figure 2. Residence object of study

For a decision aid and the proposal that best fits, the PV system and the reconciled solar are calculated individually by means of software.

In order to identify the residential demand and subsequent design of the solar systems, monthly consumption in kWh was considered in the twelve-month period in order to settle the energy cost. The current cost of the energy tariff is 0.74 / kWh. Graph 3 shows the values in kWh / month between June 2015 and May

2016, as well as the average and maximum consumption of the residence, object of the study.

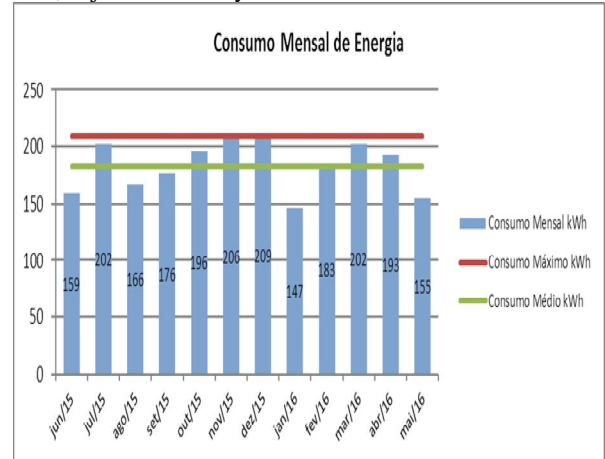


Figure 3. Monthly, average and maximum energy consumption

2.2 DIMENSIONAMENTO

During the design, the solar simulator was used in América do Sol, where data were entered of the location of the installation, the monthly values of consumption in kWh (kilowatt hours), the cost of the tariff and the type of connection. Figure 4 shows the power of the panels.

Características do Sistema Fotovoltaico	
Capacidade do seu sistema (Potência)	1,2 kWp
Área ocupada pelo seu sistema*	de 8 a 11 m ²
Inclinação aproximada dos módulos	23°
Rendimento anual	1.350 kWh/kWp
Emissões de CO ₂ evitadas	474 kg/a

Figure 4. Photovoltaic system power. Source: [2]

The residence network under study, is biphasic type with 3 conductors, 220Volts (phase / phase) and 127 Volts (phase / neutral).

The market offers four models of residential kit, 1.5kWp, 2.0kWp, 3.0kWp, 5kWp or specific designs. The microgeneration model that best suits is the connection of the type tie grid of 1,5kWp (kilo watt peak) and can generate up to 210kWp / month.

The connection grid tie, is a system where its production is directly delivered to the network and with functioning dependent of the same [8].

Its advantage over Off Grid is that it does not use accumulators (batteries) and load controllers, leaving the system approximately 30% more efficient [13].

The model that best meets the specification is the one of 1,5kWp containing 6 photovoltaic solar panels of 250Wp and inverter 1300W. Figure 3 shows the Grid Tie configuration.

With the Grid Tie system defined as the first scenario, the second scenario is considered considering two steps; a) solar heater, b) photovoltaic, grouping them making the so-called reconciled solar system.

According to [18], a water heating system by Solar Energy is composed of solar collectors known as boards and the Boiler (thermal reservoir).

Its working principle starts with the plates responsible for the absorption of solar radiation and transfers the energy to the water, which circulates inside its copper pipes.

The thermal reservoir is an enclosure for storage and conservation of already heated water suitable for use. The cold water tank supplies the Boiler, always keeping it at the maximum level [18].

For dimensioning the solar heater it is considered the number of people adopting three for this case. The only points of use of hot water are the showers, it is considered four daily baths of 8 minutes.

The calculations were carried out by the software "online dimensioners" of the company Soletrol [18].

According to the results, the estimate of daily hot water consumption is 360 liters, but with comfort reduced by 25%, since it was not considered hot water in washbasins, sinks, hygienic showers and dishwashers.

The selected model has a capacity of 400 liters with stainless steel structure, power of 3000 W, working pressure 5 mca and full weight of 429 kg.

With the solar heater dimensioned, it is subtracted the consumption of electric showers of power of 5500W, which will be replaced of the invoice of energy and calculates the photovoltaic system to take care of the other loads.

Considering four 8-minute daily baths by equation 1, the consumption of water heating of 89.1 kWh / month is obtained.

A rede da residência objeto de estudo, é do tipo bifásica a 3 condutores, 220Volts (fase/fase) e 127 Volts (fase/neutro).

$$P = E \cdot t \text{ (kWh)} \quad (1)$$

The photovoltaic system of the reconciled system is the difference of the monthly average of the total consumption and the monthly water heating consumption resulting in 93.7 kWh / month.

The solar simulator [2] specified a connected system of 300Wp.

In view of this, the economic viability analysis has as scenario 1: a photovoltaic system sized to reduce 100% of the electric power consumption with grid type configuration with an installed power of 1.5 kWp, working voltage of 220V, biphasic and 23 ° slope installation for the city of Porto Real and scenario 2: a system reconciled with the combination of a solar heating system of 400 liters, 3000W and pressure 5mca with a photovoltaic system of 300Wp, 220V and connection biphasic

The photovoltaic system of the reconciled system is the difference of the monthly average of the total consumption and the monthly water heating consumption resulting in 93.7 kWh / month.

2.3 BUDGET

The equipment costs required for both scenarios were raised as an initial investment to analyze the economic viability of the project. Only own resources will be considered as source of

financing of the investments in question. In Table 1, it is possible to see the total cost of R\$ 11,625.44.

Table 1. Budget Table Scenario 01

Sistema fotovoltaico (cenário 1)			
Equipamentos	Quantidade	Valor Unitário R\$	Valor Total R\$
Módulos Policristalino de 250W	6	R\$ 1.026,24	R\$ 6.157,44
Inversor: 1,5kW Monofásico	1	R\$ 4.988,00	R\$ 4.988,00
Conjunto de Grampos	1	R\$ 20,00	R\$ 20,00
Conjunto de Ganchos	1	R\$ 20,00	R\$ 20,00
Cabos Solares 4mm2	40	R\$ 2,00	R\$ 80,00
Conectores MC4	2	R\$ 5,00	R\$ 10,00
Painel de Proteção CC: DPScc	1	R\$ 150,00	R\$ 150,00
Chave Seccionadora CC	1	R\$ 50,00	R\$ 50,00
Painel de Proteção CA: DPS CA + Disjuntor 15.	1	R\$ 150,00	R\$ 150,00
TOTAL			R\$ 11.625,44

As well as, in table 02, a total of R \$ 6,199.00 is presented in the costs for the implementation of scenario 2.

Table 1. Budget Table Scenario 02

Sistema conciliado fotovoltaico e fototermico (cenário 2)			
Equipamentos	Quantidade	Valor Unitário R\$	Valor Total R\$
Módulos Policristalino de 300W	1	R\$ 1.150,00	R\$ 1.150,00
Conversor On Grid Tie- 220v - 500w Watts	1	R\$ 1.110,00	R\$ 1.110,00
Conjunto de Grampos	1	R\$ 20,00	R\$ 20,00
Conjunto de Ganchos	1	R\$ 20,00	R\$ 20,00
Cabos Solares 2,5 mm2	40	R\$ 1,00	R\$ 40,00
Conectores MC4	2	R\$ 5,00	R\$ 10,00
Painel de Proteção CC: DPScc	1	R\$ 150,00	R\$ 150,00
Chave Seccionadora CC	1	R\$ 50,00	R\$ 50,00
Painel de Proteção CA: DPS CA + Disjuntor 5A	1	R\$ 100,00	R\$ 100,00
Aquecedor Solar	1	R\$ 3.549,00	R\$ 3.549,00
TOTAL			R\$ 6.199,00

Because it is the implementation of alternative sources of energy for own consumption, the revenue used in the calculation of economic viability will be raised through the savings generated by the electricity bill. Based on data collected on the annual consumption of the residence will be considered the total of 2,194 kWh at a rate of 0.74 / kWh valuing R \$ 1,623.56 per year. In this case, because there is no commercialization, only an economy in the consumption of the local concessionaire, it does not fit the incidence of income tax thus making unnecessary the depreciation calculation, since it only has an impact on this calculation basis. The minimum utility rate (service availability rate) defined in [1] as 50 kWh per month was considered as a fixed cost, ie, one that does not change according to the energy consumption. In invoices with consumption up to 50 kWh, that is, with minimum rate, ICMS (excise tax on goods and services) is exempted [3], reducing the rate to 0.56 / kWh. In these cases, the public lighting contribution rate is also not charged, therefore, we will consider in this analysis as a fixed cost only the minimum consumption, with the total annual value of R \$ 336.00. Because it is a fixed minimum rate there will be no impact of variable cost.

For the economic analysis of both scenarios, an index of 6.5% pa was used to simulate an inflationary process (value based on the ceiling defined by the government of inflation IPCA -

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National Broad Consumer Price Index for the year 2016) [4]. It is worth mentioning that extra charges arising from emergency situations, such as crises in the hydrological situation of the country, were not considered in the calculations because they are occasional charges.

Although there are currently fixed-income investments with a yield close to the Selic rate (Special System of Settlement and Custody), currently set at 14.25% per annum [5], the study will use for calculation purposes as a minimum rate of attractiveness income of savings, defined as 8% per year, since Brazil tends to have a more conservative profile and the vast majority still use the savings account for investment [7].

3. ANALYSIS OF ECONOMIC VIABILITY

To achieve greater efficiency in the implementation of energy projects, it is necessary to make decisions that involve costs. The present work uses the methods of investment analysis: Internal Rate of Return (TIR), Net Present Value (VPL) and Discounted Payback.

Cash flow will be used as a recovery factor for initial capital and as a basis for subsequent calculations of economic viability analysis. In general, the companies in the industry estimate a term of 05 to 10 years in the return of the investment. In Tables 3 and 4 it is possible to verify the financial projections of the first ten years in the two presented scenarios.

Table 3 - Cash Flow Table - Scenario 1

SISTEMA FOTOVOLTAICO - CENÁRIO 01											
Dados Macroeconômicos	Ano 0	Ano 1	Ano 2	Ano 3	Ano 4	Ano 5	Ano 6	Ano 7	Ano 8	Ano 9	Ano 10
Inflação (IPCA)%		6,50%	6,50%	6,50%	6,50%	6,50%	6,50%	6,50%	6,50%	6,50%	6,50%
DRE											
Receita Operacional		1.623,56	1.729,09	1.841,48	1.961,18	2.088,66	2.224,42	2.369,01	2.522,99	2.686,98	2.861,64
Custo Operacional		336	357,84	381,1	405,87	432,25	460,35	490,27	522,14	556,08	592,22
(-) Custo Fixo		336	357,84	381,10	405,87	432,25	460,35	490,27	522,14	556,08	592,22
(-) Custo Variável		0	0	0	0	0	0	0	0	0	0
Lucro Líquido		1287,56	1371,25	1460,38	1555,31	1656,40	1764,07	1878,73	2000,85	2130,91	2269,42
(+) Recursos Próprios		-11.625,44	0	0	0	0	0	0	0	0	0
(-) Recursos Terceros		0	0	0	0	0	0	0	0	0	0
(-) Fluxo de Caixa		-11.625,44	1.287,56	1.371,25	1.460,38	1.555,31	1.656,40	1.764,07	1.878,73	2.000,85	2.130,91
(-) Recursos Acumulados		1.287,56	2.658,81	4.119,19	5.674,50	7.330,90	9.094,97	10.973,71	12.974,56	15.105,46	17.374,88

Table 3 - Cash Flow Table - Scenario 3

SISTEMA CONCILIADO FOTOVOLTAICO E FOTOTERMICO - CENÁRIO 02											
Dados Macroeconômicos	Ano 0	Ano 1	Ano 2	Ano 3	Ano 4	Ano 5	Ano 6	Ano 7	Ano 8	Ano 9	Ano 10
Inflação (IPCA)%		6,50%	6,50%	6,50%	6,50%	6,50%	6,50%	6,50%	6,50%	6,50%	6,50%
DRE											
Receita Operacional		1.623,56	1.729,09	1.841,48	1.961,18	2.088,66	2.224,42	2.369,01	2.522,99	2.686,98	2.861,64
Custo Operacional		336	357,84	381,0996	405,87	432,25	460,35	490,27	522,14	556,08	592,22
(-) Custo Fixo		336	357,84	381,10	405,87	432,25	460,35	490,27	522,14	556,08	592,22
(-) Custo Variável		0	0	0	0	0	0	0	0	0	0
Lucro Líquido		1287,56	1371,25	1460,38	1555,31	1656,40	1764,07	1878,73	2000,85	2130,91	2269,42
(+) Recursos Próprios		-6.199,00	0	0	0	0	0	0	0	0	0
(+) Recursos Terceros		0	0	0	0	0	0	0	0	0	0
(-) Fluxo de Caixa		-6.199,00	1.287,56	1.371,25	1.460,38	1.555,31	1.656,40	1.764,07	1.878,73	2.000,85	2.130,91
(-) Recursos Acumulados		1.287,56	2.658,81	4.119,19	5.674,50	7.330,90	9.094,97	10.973,71	12.974,56	15.105,46	17.374,88

3.1 NET PRESENT VALUE – VPL

To verify the feasibility of a project in the long term, it is necessary to take into account that the invested capital will not have the same value in the future in other words, we can say that it is necessary to consider the interest that this capital would yield in safe sources. The VPL calculation basically consists in bringing the value of the future to the present by deducting the cost of this capital, through equation 2 it is possible to obtain this result.

$$VPL = -Investimento\ Inicial + \frac{FC1}{(1+i)^1} + \frac{FC2}{(1+i)^2} + \dots + \frac{FCn}{(1+i)^n} \quad (2)$$

The results of the Net Present Value obtained in year 10 (maximum term stipulated for return on investment) are shown in Tables 5 and 6. In scenario 01 (table 5, photovoltaic system), where only the photovoltaic system was applied, the result is negative (VPL = - 421.77) which indicates the project's not feasibility, since its result is lower than the expected minimum yield, however, in scenario 02 (table 6, photovoltaic and photovoltaic reconciled system) the result within the stipulated

period is positive (VPL = 5,004.67) indicating that the project would yield beyond the expected minimum.

Table 5 - Table 5 - Discounted Cash Flow Table - VPL - Scenario 1

SISTEMA FOTOVOLTAICO - CENÁRIO 01			
Anos	Fluxo de Caixa	Fluxo de Caixa Descontado	Saldo
0	-11625,44		-11625,44
1	1287,56	1192,19	-10433,25
2	1371,25	1175,63	-9257,63
3	1460,38	1159,30	-8098,33
4	1555,31	1143,20	-6955,13
5	1656,40	1127,32	-5827,81
6	1764,07	1111,66	-4716,15
7	1878,73	1096,22	-3619,93
8	2000,85	1081,00	-2538,93
9	2130,91	1065,98	-1472,95
10	2269,42	1051,18	-421,77

Table 6 –Discounted Cash Flow Table - NPV - Scenario 2

SISTEMA CONCILIADO - CENÁRIO 02			
Anos	Fluxo de Caixa	Fluxo de Caixa Descontado	Saldo
0	-6199,00		-6199,00
1	1287,56	1192,19	-5006,81
2	1371,25	1175,63	-3831,19
3	1460,38	1159,30	-2671,89
4	1555,31	1143,20	-1528,69
5	1656,40	1127,32	-401,37
6	1764,07	1111,66	710,29
7	1878,73	1096,22	1806,51
8	2000,85	1081,00	2887,51
9	2130,91	1065,98	3953,49
10	2269,42	1051,18	5004,67

3.2 DISCOUNTED PAYBACK

The payback period can be understood as the expected time for the return on investment. In a simple way, the procedure consists of the sum of the future cash flows until it covers the invested initial value [16]. However, this procedure does not consider the amount of capital invested in time, so for the study in question was used the discounted payback method, deducting the cost of capital of the project, in this case, the minimum rate of attractiveness. Through equation 3, it is possible to obtain the term for return of invested capital. For scenario 01 (photovoltaic system), the result obtained was 10.41 years, that is, the term is higher than stipulated (10 years) on the other hand, scenario 2 (reconciled system) presented a result of 5.36 years, in this case a period shorter than stipulated

$$PRI = p + \frac{(CF_p)}{CF_p - CF_{p+1}} \quad (3)$$

3.3 INTERNAL RETURN RATE - TIR

The Internal Rate of Return (TIR) method is used to indicate the profitability of a project over a given period. In the case of investment projects, a comparison is made with the TMA (minimum rate of attractiveness) [15]. In this project the TIR obtained for scenario 1 (photovoltaic system) was -1% while the TIR of scenario 2 (reconciled system) was 13%. In comparison with the 8% TMA presented, scenario 2 presented the highest profitability in the stipulated period

4. CONCLUSION

Through the definition and design of solar systems as well as the definition and use of the primordial financial methods of investment analysis, it was possible to verify that only the second scenario (solar system reconciled with photothermic) presented economic feasibility within the stipulated period (maximum of 10 years), that is, the reconciled acquisition of both systems is more profitable than the exclusive use of the photovoltaic system. The use of financial methods was of great importance in helping decision-making since it is possible to perceive that the great majority of the proposals currently presented for the disclosure of these systems use basic calculations, without great financial perspectives in the projection of results.

Although the equipment has a service life of at least 25 years and there are already some government incentives in place, it is still possible to say that the initial investment and the time of its return is still very high for a large in the Northeastern states where the lowest per capita incomes are indicated by the IBGE in 2015. There are some proposals that would considerably make possible the acquisition of equipment, such as the possibility of using the FGTS in fixed-term financing [17], in addition to the availability of the resource, the inferiority of the FGTS yield of 3% per year [9] in relation to savings (8% per year) would decrease the minimum attractiveness rate and consequently the calculation of the time in the return on investment.

The environmental issue can not be forgotten, every year we are more subject to hydrological crises due to lack of rain as well as climatic oscillations and this will always reflect in the economy. Sustainability is a necessity that must be given due importance in the country's investments.

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