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TECHNICAL AND FINANCIAL FEASIBILITY IN INNOVATION PROCESSES: A COMPARATIVE STUDY FOR THE INSTALLATION OF SOLAR ENERGY SYSTEMS IN RESIDENCES

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ABSTRACT

Brazil stands out for the incidence of solar radiation throughout its territory, a factor that has stimulated the spread of photovoltaic energy. This study **aims** to analyze the technical and financial feasibility of replacing electric energy by photovoltaic energy, given the current conditions of the legislation and the changes expected for urban residences. The theoretical approach is based on the innovation processes through the lens of the triple helix, besides discussing concepts on feasibility analysis for modernization projects. The **methodology** is classified as qualitative and descriptive, and used documentary and bibliographic research for data collection. The main **results** present analyses based on capital budgeting techniques, proving the feasibility of using photovoltaic energy in all scenarios. As a main contribution regarding originality, the paper provides a data set, analysis tools, and discussion with theory that allows readers to understand how such analyses can be replicated in other scenarios.

Keywords: Feasibility analysis; Photovoltaic energy; modernization projects.

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1. INTRODUCTION

Innovation is a process discussed since the beginning of the 20th century and has proven to be a determining factor for the economic development of companies, both in the public sector and in private institutions. Having the ability to innovate becomes a competitive differentiator for companies, opens new markets, and challenges the ability to learn and adapt (Silva, Floriani, and Hein, 2018). Innovation refers to new ways of doing processes, with available technologies to create innovative products, new production processes, and new learning models (Porter, 1999).

It can be said that innovation is a process of continuous change, which results from the search for the new, whether to meet needs and desires or to use the available natural, technological, and economic resources in a more correct and conscious manner (Moreira and Queiroz, 2007). According to Hashi and Stojcic (2010), all activities that are intended to drive and implement new technologies, as well as act to improve products or services, are innovations. According to the Organization for Economic Cooperation and Development (OECD, 2017), scientific, technological, organizational, financial, and commercial factors must be considered.

Schumpeter (1988) pioneered the concept of innovation as the central force in the dynamism of the capitalist system, emphasizing the importance of large companies in economic development through their innovative capacity. Following the idea of innovation highlighted up to this point, this article proposes the triple helix model perspective, which, according to Philippi and Martins (2014), concerns the relationship between universities, industry, and government, in the study and feasibility of new innovation projects. In this model, expanding the roles of each sector increases the possibility of innovative actions and favors regional growth (Etzkowitz and Leydesdorff, 2000; Dalmarko *et al.*, 2012; Philippi and Martins, 2014).

Regarding innovation processes and continuous systems improvement, it can be highlighted that the electricity sector is in an environment of constant innovations, which raises competition, hitherto held by state-owned companies, as is the case of the Companhia Paranaense de Energia Elétrica - COPEL. The search for clean energy sources has grown significantly and has changed this scenario (Farret, 2010). Given the need for new forms of energy production, solar energy, technically defined as photovoltaic, is one of the most promising alternatives to meet the demand necessary for human development (Santos, 2018; Souza Jr *et al*., 2019). Solar energy, more specifically, is obtained through the direct conversion of sunlight into electricity. Sun rays are absorbed by photovoltaic plates made of semiconductor materials. The intensity of the heat generates the electrical energy (Cepel, 2017).

With the advancement of technology and improvement of photovoltaic power semiconductors, its cost has been reduced, making it attractive and feasible in many cases of deployment. The cost of the watt of energy produced has gone from $79.67 to $0.36 in forty years (Dantas and Pompermayer, 2018). The number of installations of photovoltaic energy systems has grown in recent years, and according to data from the National Electric Energy Agency (ANEEL), there has been a 145% increase in installations of this nature in Brazil, from 10,000 in April 2017, to 24,514 in April 2018 (ANEEL, 2018). And since the generation of technologies, such as photovoltaic energy, depends on the development of new and in-depth studies, the roles of the university as a research agent, and of the government as a funding and driving agent, are essential.

Previous studies related to the feasibility of installing photovoltaic systems show, according to Shayani, Oliveira, and Camargo (2006), that the cost of solar generation is still higher than the implementation of a small hydroelectric plant. However, the cost of energy generated by the solar system during its lifetime is shown to be ten times more efficient for isolated systems. Currently, studies indicate that photovoltaic systems have a growth potential in the country (Dantas and Pompermayer, 2018). According to Santos (2016), the installation of photovoltaic energy generating systems proved to be feasible for the residential sector, specifically in a condominium with four energy consuming units. As a differentiator, this study analyzes the feasibility of installing photovoltaic generators in urban residences, in cases where there is only one energy consuming unit.

Given this context, this study seeks to answer the following question: **is the replacement of electric power by photovoltaic energy in an urban residence technically and financially feasible?** To answer the question, the general objective is to analyze the technical and financial feasibility of replacing electric energy with photovoltaic energy, in light of the current legislation and the changes foreseen for urban residences.

Besides this introduction, the second section presents the theoretical foundation. The third section describes the research method, detailing the procedures performed to reach the proposed objectives. The fourth section presents and discusses the results. The study ends with the final considerations containing the conclusions reached, the limitations, and the recommendations for future studies.

S&G Journal
Volume 16, Number 2, 2021, pp. 133-144
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2. THEORETICAL FOUNDATION

Innovation through the lens of the triple helix

The innovation process has proven to be a determining factor of competitiveness and progress of the business sector, playing a prominent role in its management as an indicator of regional socioeconomic development (Terra *et al*., 2018). Schumpeter (1988) recognizes the possibility of radical innovation that can be defined as one that produces a key change in the activities developed by an organization. This change involves inventions or incremental innovations and includes small modifications and improvements in routine practices. The defined concepts apply to both products and services (Schumpeter, 1988).

From the disruptive vision proposed by Schumpeter, other authors, such as Leydesdorff and Etzkowitz (2000), proposed a model such as the triple helix, which is based on the interaction between university, industry, and government. According to Etzkowitz (2005), the triple helix approach demonstrates the key role that the grouping of the three helices has so that innovation really happens.

Figure 1 presents the triple helix, so that the actors involved now have a greater role in technological development and regional innovation (Coutinho and Silva, 2017). The first version of the triple helix model is called the “Triple Helix I”. In it, the state overlaps with the other helixes, which are the university and the government. In the second version, “Triple Helix II,” the three spheres are distinct and separated by strong boundaries, where a laissez-faire policy is in place. The third version, the “Triple Helix III”, which features a greater interrelationship between university, industry, and government, where the university is the center of studies and development of innovations (Etzkowitz, 2005).

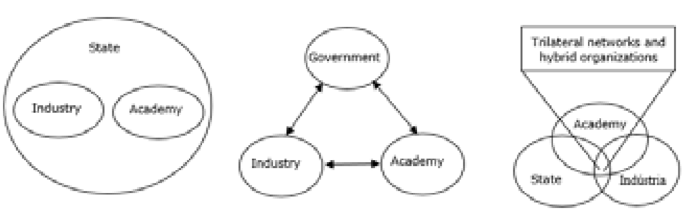

Figure 1. Representations of the stages of development of the triple helix
Source: Elaborated from Dossa and Segatto (2010).

According to Eberhart and Pascuci (2014), the relationship between the three actors (university, government, and industry) is analogous to a helix, since by moving in a synchronized manner, they can achieve greater efficiency in social and economic development. In this model, the university acts as a knowledge producer for generating innovation, the company is responsible for creating products or services, and the government contributes with resources and tax incentives to enable the development of new technologies (Eberhart and Pascuci, 2014). The triple helix model is used to investigate different innovation contexts, as in the case of the innovation of solar energy generation as an alternative and renewable source. In this study, the model will be used to analyze the feasibility of installing solar photovoltaic energy systems in homes.

Photovoltaic energy

The electric sector has been undergoing modifications over time, following the process of innovation and continuous improvement. This is evidenced by consulting the contents published by several authors, as in the case of Santos (2008), in which the most used electric power generation model in the country comes predominantly from hydroelectric plants. The search for clean energy sources has been instigating the search and development of alternative sources of energy generation, including photovoltaic energy (Villalva, 1983).

Photovoltaic solar energy is obtained by means of semiconductor materials, which absorb the solar heat and transform it into electric energy (Santos, 2016). According to Carvalho, Abreu, and Neto (2017), the implementation of photovoltaic power generation systems can become feasible if we consider three factors: 1) the high residential energy tariffs; 2) solar radiation availability; 3) significant reduction in solar panel values.

In Brazil, the incidence of solar radiation is high in all regions, which favors photovoltaic energy systems and shows that the sector has become favorable for growth (Amaral, 2018). Santos (2016) explains that photovoltaic solar energy has several advantages, mainly the following: a) it is obtained in a static and silent way, without environmental impact; b) it is a renewable energy source; c) it is an excellent energy option, if considering the distribution logistics, since energy is produced in the same place as its consumption, reducing transmission costs; d) installation deadlines are short, besides presenting a high degree of reliability of the systems and a low maintenance rate (Santos, 2016).

From a legal standpoint, in 2012 ANEEL approved Normative Resolution No. 482, dated April 17, 2012, in order to promote energy production by renewable sources. The normative establishes conditions for the access to micro and mini-generation distributed in urban and rural residences, besides commerce and industry, by means of distribution systems interconnected to the concessionaires that manage the networks (ANEEL, 2012).

S&G Journal
Volume 16, Number 2, 2021, pp. 133-144
DOI: 10.20985/1980-5160.2021.v16n2.1672

According to the Energy Research Company (2018), the residential sector accounts for 28.9% of all energy consumed in Brazil. Therefore, the use of photovoltaic systems is directly related to the ability to decentralize the production of electricity, i.e., electricity consumers start to produce their own energy through photovoltaic plates installed on the roof of their home or any available building (Dassi *et al.*, 2015).

For Miranda (2013), home production capacity can be related to the exemption or reduction of charges for energy consumed in the residence, and which has been produced by the system. The question, in terms of expanding the number of residential units with photovoltaic energy, comes up against the implementation cost, proof of viability, and service availability. The availability is variable in each location. The implementation cost and feasibility analysis are discussed below.

Feasibility analysis for modernization projects

As mentioned before, Brazil has high rates of solar radiation, which configures a wide possibility of using this factor to generate electricity through photovoltaic energy systems (SOUZA Jr. *et al*., 2019). However, for the same author, before installing photovoltaic energy systems, an economic and financial feasibility study is needed due to the high initial cost of implementing the capturing systems that transform solar heat into electric energy.

For such an investment analysis, some verification methods are proposed, such as: Discounted Payback, Net Present Value (NPV), and Internal Rate of Return (IRR). The basis of the analysis of these methods is grounded on the comparison with the Minimum Rate of Attractiveness (MRA) formulated from the expectation resulting from the opportunity cost, liquidity, and risk (Greca *et al.*, 2014; Dalfovo *et al.*, 2019).

Initially, the capital investment survey allows the owner to identify the minimum volume that should be spent to meet their requirements. According to Bordeaux-Rêgo *et al.* (2010), during the capital investment process, an analysis of the resources available to implement the new system is performed, as well as where these resources will be allocated to make the project feasible. The cost applied in the project must be lower than the economic and financial benefits it will provide; otherwise, the project may be considered unfeasible (Bordeaux-Rêgo *et al*., 2010). For Gitman (2010), capital investment is an outlay of funds that the company makes in order to produce long-term benefits. The most common reasons for its realization are to expand operations, replace or renovate fixed assets, and obtain some long-term benefit.

For assessing the economic and financial viability of an investment project, the realization of the cash flow is essential (Lemes Jr. *et al.*, 2002). Following the same authors' idea, the company creates a system that generates a database with the following information: a) the project's economic life; b) the cost of capital and the required rate of return; c) the project's incremental cash inflows; and d) the competitors' responses to the project.

According to Greca *et al.* (2014), to perform the calculations for the investment feasibility analysis, it is necessary to define the MRA with the minimum value that the investment must reach in order to be considered feasible. The MRA is used as a parameter for the NPV and IRR calculations, so that a comparison of results can be made and the subsequent acceptance or rejection of an investment project (Greca *et al.*, 2014).

After defining the MRA to know if a project is feasible or not, it is necessary to analyze the return time of the investment, measured by the Discounted Payback (Souza Jr. *et al*., 2019). According to Lemes Jr. *et al.* (2002), payback is one of the most used tools in long-term investment decisions. For calculating payback, a period in which a project's investment must be recovered is determined. If the payback occurs within this period, the project is accepted. If it is longer than this period, the project is rejected (Gitman, 2010). This model emerged as a correction of the simple payback, which does not consider the time value of money (LEMES Jr. *et al.,* 2002).

NPV is the value of net cash inflows minus the present value of cash outflows for investment, discounted at the company's cost of capital (Lemes Jr. *et al.,* 2002). According to Gitman (2010), NPV is equal to the value of cash inflows minus the initial investment (Equation 1). Another calculation method used in the viability of investment projects is IRR. For Lemes Jr. *et al.* (2002), IRR is the rate of return responsible for equating the company's outgoing cash flow to its incoming cash flow. It depends only on the cash flows of a certain investment, dismissing the use of other rates. According to Assaf Neto and Lima (2010), to evaluate the investment proposal of a project, the IRR calculation requires knowledge of the capital expenditure and the incremental net cash flows generated by the decision. Therefore, it can be stated that the higher the IRR, the better the project will be, that is, the project is recommended if the calculated rate is higher than the required return, thus defining that it adds economic value, according to equation 2 (Assaf Neto and Lima, 2010). Chart 1 summarizes both equations.

S&G Journal
Volume 16, Number 2, 2021, pp. 133-144
DOI: 10.20985/1980-5160.2021.v16n2.1672

Chart 1. IRR and NPV Equations

NPV – Equation 1	IRR – Equation 2
$VPL = \sum_{t=1}^{n} \frac{FC_t}{(1+r)^t} - FC_0$ NPV: Net Present Value; FC: Cash Flow; t: the time at which the cash flow occurred; i: discount rate (or minimum rate of attractiveness); n: period	$0 = \sum_{n=1}^{n=N} \frac{Fc_t}{(1+Tir)^n}$ IRR: Internal Rate of Return; CFt: Net Cash Flow at time n; n: project duration

Source: Elaborated based on Assaf Neto and Lima (2010).

In view of the aforementioned about the calculations and considerations necessary to make a project viable, one can observe that its implementation often requires high investments, which also involves some risks. The scenario analysis emerges as a method that considers several possible outcomes to get a sense of the return on an investment (Gitman, 2010). For Solomon and Pringle (1981), the analysis of scenarios involves conditional probabilities. Through it, the expected return, or the net present value of a project, can be examined, assisting in decision making (Morais *et al.,* 2018). This technique becomes useful to provide notions of variability of return in reaction to variations of some fundamental result, using several possible outcomes (scenarios), such as cash inflows to provide those who wish to make the decision regarding an investment project, a notion between what is expected from the return and what they can effectively get from it (Gitman, 2010). Next, the methodology presents the development of the empirical research and data analysis.

3. METHODOLOGY

As for the approach to the problem, this research can be classified as qualitative, because according to Richardson (1999), this methodology type describes the complexity of a certain problem, analyzes the interaction of variables, and understands and classifies dynamic processes experienced by social groups. In this study, qualitative analysis will be applied to the benefits obtained from a new energy generation technology. The research is descriptive whenever it allows describing, identifying, reporting, and comparing data (Raupp and Beuren, 2009). In this paper, this stage consists of describing information from data collection and also discuss the analysis done for replacing conventional electricity by photovoltaic solar energy, from financial tools for decision making.

In this research the viability of installing photovoltaic plates, solar energy generators, in a specific residence in the city of Marechal Cândido Rondon, PR, was analyzed. The choice was made based on the comparative criterion, considering one installation with a cash payment and another financed. For this, the data was analyzed aiming to ascertain the energy consumed by the residence, as well as the savings generated in the electricity bill after the installation of the photovoltaic systems, and the payback time of the value invested in the purchase.

The technical instruments used were bibliographic and documentary research with secondary sources that, according to Raupp and Beuren (2009), refer to documents not yet analyzed or that can reorganize information according to the needs of the study. For this survey stage, budgets were collected from the companies installing the systems as a source of investment. Moreover, a survey of the cost of electricity consumed in the residence was carried out in order to demonstrate the cost savings generated by the new system, complemented by the legislation in force. Chart 2 shows the methodological script.

Chart 2. Methodological Script

Documentary Research Script	Items that make up each stage
1st Initial investment survey	Photovoltaic module; Photovoltaic inverter; Solar Monitoring; Metallic structure for fixing the modules; Condumax Solarmax Flex SN DC cable; MC4 connector pair; DPS Surge Protector; MDWH Circuit Breaker - B32-2.
2nd Energy Saving Survey	Power consumption history.
3rd Costs Survey	Possible maintenance costs; Insurance costs against system damage.
4th Installation Expenses	Electrical and mechanical installation services; Connection of the generator system to the local utility; Commissioning of the system; Release, consultation, and project with local utility; Project approval with the regulatory agencies and agents (COPEL, ENERGISA, ANEEL, ONS).
5th Taxes levied on the purchase of the photovoltaic system	PIS/COFINS: 9.25%

Source: The authors themselves (2019).

S&G Journal
Volume 16, Number 2, 2021, pp. 133-144
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Data collection occurred between May and July 2019. A residence located in the municipality of Marechal Cândido Rondon was selected for the survey of technical information about the installation of the photovoltaic system. For data collection, the budget performed by the company MM2, located in the city of Marechal Cândido Rondon, was surveyed, according to the energy demand of the residence. Through the budget, it was possible to analyze the items that make up the initial investment of the project, which include photovoltaic module, photovoltaic inverter, solar monitoring, metallic structure for fixing the modules, conductor cables, connector pair, surge protector, and circuit breaker.

With the survey of the residence's consumption history, it is possible to ascertain the savings that the photovoltaic system generated for the consumer. The research aimed to verify occasional costs resulting from the maintenance of the systems, including preventive maintenance, such as cleaning the plates and checking the electrical connections yearly, to ensure operation efficiency. The expenses generated by the installation of the photovoltaic system (installation, grid connection, and system release) are included in the project supplied by the company. Possible reinforcements on the house roof where the panels will be installed are not included in the project. As for the taxes levied on the energy bill, the homeowner is exempt from paying ICMS and IPI, and is required to pay PIS/COFINS at a monthly rate of 9.25%. Next, the main results are presented.

4. DATA ANALYSIS AND RESULTS

Table 1 shows the project's input data, which represent the initial investment. The rates presented represent the value corresponding to the standard executed by COPEL in an agreement in effect with the companies. The technical data were obtained by the company responsible for the budget. The depreciation was considered based on WEG, the equipment manufacturer.

Table 1. Project input data

Solar Irradiation	5.00	KWh/m². Day
COPEL Minimum Rate	50	KWh
Regular Rate	R$ 0.79	/KWh
Compensated Ratio	R$ 0.70	/KWh
Average Tariff Readjustment	7%	Per year
Direct Consumption	60	%
Compensated Consumption	40	%
Generator Power	6.75	WKp
System Performance	80%	-
Energy Generated	9,720	KWh/year
Degradation (2nd to 25th)	0.60%	Per year
Degradation 1st year	2.50%	-
Maintenance	0.40%	Per year
OPEX Readjustment	1%	Per year

Source: The authors themselves (2019).

Table 2 demonstrates the reduction of the power generation capacity. This reduction occurs annually, gradually, and at the end of 25 years, the power generation capacity of the photovoltaic module is 80.7%. When making the investment, it is important to verify that at the end of 25 years there will be this 20% difference in the energy generation capacity of the system. The utility's energy consumption from this period tends to increase. Table 2 presents the energy generation of the modules, as well as the revenue that the system implementation will generate, which corresponds to the savings that the owner will have with electricity. In addition, the annual and accumulated cash flows are shown, representing the savings generated during the 25 years in which the apex modules will lose energy potential. Given the data presented by the company, it was possible to define an MRA due to current market rates in order to calculate IRR, NPV, and discounted payback, which meets the proposal of Greca *et al.* (2014) as essential methods to know if the project is viable.

The MRA which, according to Greca *et al.* (2014), is used to compare investment returns, was set at 1.53% p.m. (arising from 0.35% - savings on 06/18/2019; 0.70% – assumed risk; and 0.48% – liquidity loss). By converting it to an annual rate, a parameter of 19.98% p.a., which was used to calculate the return on budgets, was obtained. Since the investment applied to savings would have, on average, a yield of 4.28% p.a., it is considered that the MRA is adequate, given the amount invested and the risk assumed.

However, if we consider that the investment for installing the photovoltaic modules today is R$ 25,886.00, and if we have the promised annual cash flows return, as presented in Table 2, at a rate of 19.98% per year, the investment will take about four years and two months to pay itself off. In the budget, the company presents a payback time of only three years and seven months, but for this, it uses an MRA of only 9% p.a., or 0.72% p.m., which in practice does not match the market reality.

The NPV calculation shows that, besides recovering the investment made, the owner can still obtain a return due to his savings of R$ 2,728.08 above the 19.98% MRA. Consequently, an IRR of 32.33% p.a. was reached, which matches what is sold by the company. Thus, following the idea of Morais *et al.* (2018), it is possible to analyze that in this scenario, the investment is viable; however, it pays itself off in a lon-

Table 2. Generation and Return on Investment

Geração				Receitas		Fluxo de Caixa	
Ano	Ano/Kw	Tarifa		Mensal	Anual	FC anual	FC acumulado
0	-	R$ 0,70	R$ 0,79	-	-R$ 25.886,00	-R$ 25.886,00	-R$ 25.886,00
1	9.720,00	R$ 0,70	R$ 0,79	R$ 73,04	R$ 6.876,48	R$ 6.772,94	-R$ 19.113,06
2	9.477,00	R$ 0,75	R$ 0,85	R$ 596,82	R$ 7.161,79	R$ 7.057,21	-R$ 12.055,85
3	9.420,14	R$ 0,80	R$ 0,90	R$ 634,50	R$ 7.614,02	R$ 7.508,40	-R$ 4.547,45
4	9.363,62	R$ 0,86	R$ 0,97	R$ 674,57	R$ 8.094,80	R$ 7.988,12	R$ 3.440,67
5	9.307,44	R$ 0,92	R$ 1,04	R$ 717,16	R$ 8.605,91	R$ 8.498,16	R$ 11.938,83
6	9.251,59	R$ 0,98	R$ 1,11	R$ 762,44	R$ 9.149,27	R$ 9.040,44	R$ 20.979,27
7	9.196,08	R$ 1,05	R$ 1,19	R$ 810,58	R$ 9.726,90	R$ 9.616,99	R$ 30.596,26
8	9.140,90	R$ 1,12	R$ 1,27	R$ 861,75	R$ 10.340,98	R$ 10.229,97	R$ 40.826,23
9	9.086,06	R$ 1,20	R$ 1,36	R$ 916,15	R$ 10.993,79	R$ 10.881,67	R$ 51.707,90
10	9.031,54	R$ 1,29	R$ 1,45	R$ 973,98	R$ 11.687,79	R$ 11.574,55	R$ 63.282,45
11	8.977,35	R$ 1,38	R$ 1,55	R$ 1.035,46	R$ 12.425,56	R$ 12.311,18	R$ 75.593,63
12	8.923,49	R$ 1,47	R$ 1,66	R$ 1.100,82	R$ 13.209,86	R$ 13.094,34	R$ 88.687,97
13	8.869,95	R$ 1,58	R$ 1,78	R$ 1.170,30	R$ 14.043,63	R$ 13.926,96	R$ 102.614,93
14	8.816,73	R$ 1,69	R$ 1,90	R$ 1.244,17	R$ 14.929,99	R$ 14.812,14	R$ 117.427,07
15	8.763,83	R$ 1,80	R$ 2,04	R$ 1.322,69	R$ 15.872,24	R$ 15.753,21	R$ 133.180,28
16	8.711,25	R$ 1,93	R$ 2,18	R$ 1.406,16	R$ 16.873,90	R$ 16.753,69	R$ 149.933,97
17	8.658,98	R$ 2,07	R$ 2,33	R$ 1.494,89	R$ 17.938,73	R$ 17.817,32	R$ 167.751,29
18	8.607,02	R$ 2,21	R$ 2,50	R$ 1.589,23	R$ 19.070,70	R$ 18.948,08	R$ 186.699,37
19	8.555,38	R$ 2,37	R$ 2,67	R$ 1.689,50	R$ 20.274,04	R$ 20.150,19	R$ 206.849,56
20	8.504,05	R$ 2,53	R$ 2,86	R$ 1.796,10	R$ 21.553,25	R$ 21.428,16	R$ 228.277,72
21	8.453,03	R$ 2,71	R$ 3,06	R$ 1.909,43	R$ 22.913,10	R$ 22.786,76	R$ 251.064,48
22	8.402,31	R$ 2,90	R$ 3,27	R$ 2.029,89	R$ 24.358,68	R$ 24.231,07	R$ 275.295,55
23	8.351,89	R$ 3,10	R$ 3,50	R$ 2.157,95	R$ 25.895,38	R$ 25.766,50	R$ 301.062,05
24	8.301,78	R$ 3,32	R$ 3,75	R$ 2.294,08	R$ 27.528,94	R$ 27.398,77	R$ 328.460,82
25	8.251,97	R$ 3,55	R$ 4,01	R$ 2.438,79	R$ 29.265,46	R$ 29.133,99	R$ 357.594,81

Source: The authors themselves (2019).

ger time than the company advertises. Table 3 summarizes the MRA, NPV, IRR, and discounted payback results obtained through the financial calculations.

Table 3. Financial Calculation Results

MRA	19.98% p.a.
NPV	R$ 21,124.04
IRR	32.33% p.a.
Discounted Payback	3 years and 7 months (9% return on return) and 4 years and 2 months (19.98% return on return capital)

Source: The authors themselves (2019).

In another scenario, Table 4 shows the generation and return on investment, considering that the photovoltaic power generation system will be acquired by the owner by means of financing, where the amount invested, the interest paid, the return, and the benefits that the project will offer in the long term are considered (Gitman, 2010). Considering the financed amount of R$ 25,886.00 (value of the installed system), with a contracted interest rate of 1.09% p.m. and a payment term of 60 months, at the end of this term, the amount paid by the owner to the creditor bank will be R$ 42,145.20.

The analysis of this data used the same basis of 19.98% MRA as the previous analysis. Taking into consideration the MRA presented by the contractor (9% p.a.) and the promised cash flows, the investment pays itself off in five years and six months. However, using the real annual rate obtained of 19.98% p.a., this investment pays itself off in six years and four months. In this scenario, an NPV of R$ 4,864.84 was obtained, more than if the amount were invested at MRA. According to the calculations, an IRR of 21.81% p.a. is found, surpassing the comparative base of 19.98% p.a., corroborating the literature of Assaf Neto and Lima (2010), in which the higher the IRR, the better for the investor. In this case, it can be seen that, by needing to finance the use of this technology, the investor pays interest and loses return on his capital but does not lose out on savings in energy bill expenses, as shown in Table 4.

S&G Journal
Volume 16, Number 2, 2021, pp. 133-144
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Table 4. Generation and return on investment with financing

Geração				Receitas		Fluxo de Caixa	
Ano	**Ano/Kw**	**Tarifa**		**Mensal**	**Anual**	**Anual**	**Acumulado**
0	_	R$ 0,70	R$ 0,79		-R$ 42.145,20	-R$ 42.145,20	-R$ 42.145,20
1	9.720,00	R$ 0,70	R$ 0,79	R$ 573,04	R$ 6.876,48	R$ 6.772,94	-R$ 35.372,26
2	9.477,00	R$ 0,75	R$ 0,85	R$ 596,82	R$ 7.161,79	R$ 7.057,21	-R$ 28.315,05
3	9.420,14	R$ 0,80	R$ 0,90	R$ 634,50	R$ 7.614,02	R$ 7.508,40	-R$ 20.806,65
4	9.363,62	R$ 0,86	R$ 0,97	R$ 674,57	R$ 8.094,80	R$ 7.988,12	-R$ 12.818,53
5	9.307,44	R$ 0,92	R$ 1,04	R$ 717,16	R$ 8.605,91	R$ 8.498,16	-R$ 4.320,37
6	9.251,59	R$ 0,98	R$ 1,11	R$ 762,44	R$ 9.149,27	R$ 9.040,44	R$ 4.720,07
7	9.196,08	R$ 1,05	R$ 1,19	R$ 810,58	R$ 9.726,90	R$ 9.616,99	R$ 14.337,06
8	9.140,90	R$ 1,12	R$ 1,27	R$ 861,75	R$ 10.340,98	R$ 10.229,97	R$ 24.567,03
9	9.086,06	R$ 1,20	R$ 1,36	R$ 916,15	R$ 10.993,79	R$ 10.881,67	R$ 35.448,70
10	9.031,54	R$ 1,29	R$ 1,45	R$ 973,98	R$ 11.687,79	R$ 11.574,55	R$ 47.023,25
11	8.977,35	R$ 1,38	R$ 1,55	R$ 1.035,46	R$ 12.425,56	R$ 12.311,18	R$ 59.334,43
12	8.923,49	R$ 1,47	R$ 1,66	R$ 1.100,82	R$ 13.209,86	R$ 13.094,34	R$ 72.428,77
13	8.869,95	R$ 1,58	R$ 1,78	R$ 1.170,30	R$ 14.043,63	R$ 13.926,96	R$ 86.355,73
14	8.816,73	R$ 1,69	R$ 1,90	R$ 1.244,17	R$ 14.929,99	R$ 14.812,14	R$ 101.167,87
15	8.763,83	R$ 1,80	R$ 2,04	R$ 1.322,69	R$ 15.872,24	R$ 15.753,21	R$ 116.921,08
16	8.711,25	R$ 1,93	R$ 2,18	R$ 1.406,16	R$ 16.873,90	R$ 16.753,69	R$ 133.674,77
17	8.658,98	R$ 2,07	R$ 2,33	R$ 1.494,89	R$ 17.938,73	R$ 17.817,32	R$ 151.492,09
18	8.607,02	R$ 2,21	R$ 2,50	R$ 1.589,23	R$ 19.070,70	R$ 18.948,08	R$ 170.440,17
19	8.555,38	R$ 2,37	R$ 2,67	R$ 1.689,50	R$ 20.274,04	R$ 20.150,19	R$ 190.590,36
20	8.504,05	R$ 2,53	R$ 2,86	R$ 1.796,10	R$ 21.553,25	R$ 21.428,16	R$ 212.018,52
21	8.453,03	R$ 2,71	R$ 3,06	R$ 1.909,43	R$ 22.913,10	R$ 22.786,76	R$ 234.805,28
22	8.402,31	R$ 2,90	R$ 3,27	R$ 2.029,89	R$ 24.358,68	R$ 24.231,07	R$ 259.036,35
23	8.351,89	R$ 3,10	R$ 3,50	R$ 2.157,95	R$ 25.895,38	R$ 25.766,50	R$ 284.802,85
24	8.301,78	R$ 3,32	R$ 3,75	R$ 2.294,08	R$ 27.528,94	R$ 27.398,77	R$ 312.201,62
25	8.251,97	R$ 3,55	R$ 4,01	R$ 2.438,79	R$ 29.265,46	R$ 29.133,99	R$ 341.335,61

Source: The authors themselves (2019).

Table 5 presents the results of the MRA, NPV, IRR, and discounted payback, obtained through the financial calculations.

Table 5. Financial Calculation Results

MRA	19.98% p.a.
VPL	R$ 4,864.84
TIR	21.81% p.a.
Discounted Payback	5 years and 6 months (9% return remuneration) and 6 years and 4 months (19.98% return capital remuneration)

Source: The authors themselves (2019).

Besides the values informed by the company providing the service, in practice, the research revealed that there are costs in purchasing insurance for the residence, since there is the risk of climatic events and electrical damage completely damaging the equipment. Another present cost reflects the need to sanitize, at least twice a year, the roof of the residence, because dust accumulation can decrease the efficiency of the plates or limit the useful life of the equipment. Thus, to conclude, this study proposes a scenario that also considers these two variables. According to Solomon and Pringle (1981), new value probabilities can assist in decision making about the implementation of a new system.

Thus, considering that the annual sanitation cost would be R$600.00 (R$300.00 each), and that the cost of the residence's additional insurance is quoted, on average, in the amount of R$300.00 per year, we have the revenues and cash flows presented in Table 6. According to the MRA of 19.98% p.a., the investment presents a NPV of R$ 407.75 and IRR of 20.13% p.a., that is, the return is greater than the MRA, making investment feasible (Greca *et al.*, 2014). The discounted payback, in this scenario, presents a return on investment in 8 years and 5 months. The annual and accumulated cash flow had a reduction in value for considering the two new values; however, it still represents a saving in the consumer's energy bill.

Table 7 presents the MRA, NPV, IRR, and discounted payback results, obtained through the financial calculations, for the three proposed scenarios.

Table 6. Generation and return with financing, considering insurance and cleaning fee

Geração				Receitas		Fluxo de Caixa	
Ano	Ano/Kw	Tarifa		Mensal	Anual	Anual	Acumulado
0	-	R$ 0,70	R$ 0,79	-	-R$ 42.145,20	-R$ 42.145,20	-R$ 42.145,20
1	9.720,00	R$ 0,70	R$ 0,79	R$ 573,04	R$ 5.976,48	R$ 5.483,01	-R$ 36.662,19
2	9.477,00	R$ 0,75	R$ 0,85	R$ 596,82	R$ 6.261,79	R$ 5.270,42	-R$ 31.391,77
3	9.420,14	R$ 0,80	R$ 0,90	R$ 634,50	R$ 6.714,02	R$ 5.184,46	-R$ 26.207,31
4	9.363,62	R$ 0,86	R$ 0,97	R$ 674,57	R$ 7.194,80	R$ 5.096,98	-R$ 21.110,33
5	9.307,44	R$ 0,92	R$ 1,04	R$ 717,16	R$ 7.705,91	R$ 5.008,31	-R$ 16.102,02
6	9.251,59	R$ 0,98	R$ 1,11	R$ 762,44	R$ 8.249,27	R$ 4.918,77	-R$ 11.183,25
7	9.196,08	R$ 1,05	R$ 1,19	R$ 810,58	R$ 8.826,90	R$ 4.828,62	-R$ 6.354,63
8	9.140,90	R$ 1,12	R$ 1,27	R$ 861,75	R$ 9.440,98	R$ 4.738,11	-R$ 1.616,53
9	9.086,06	R$ 1,20	R$ 1,36	R$ 916,15	R$ 10.093,79	R$ 4.647,46	R$ 3.030,94
10	9.031,54	R$ 1,29	R$ 1,45	R$ 973,98	R$ 10.787,79	R$ 4.556,88	R$ 7.587,81
11	8.977,35	R$ 1,38	R$ 1,55	R$ 1.035,46	R$ 11.525,56	R$ 4.466,53	R$ 12.054,35
12	8.923,49	R$ 1,47	R$ 1,66	R$ 1.100,82	R$ 12.309,86	R$ 4.376,58	R$ 16.430,93
13	8.869,95	R$ 1,58	R$ 1,78	R$ 1.170,30	R$ 13.143,63	R$ 4.287,17	R$ 20.718,10
14	8.816,73	R$ 1,69	R$ 1,90	R$ 1.244,17	R$ 14.029,99	R$ 4.198,42	R$ 24.916,53
15	8.763,83	R$ 1,80	R$ 2,04	R$ 1.322,69	R$ 14.972,24	R$ 4.110,45	R$ 29.026,98
16	8.711,25	R$ 1,93	R$ 2,18	R$ 1.406,16	R$ 15.973,90	R$ 4.023,34	R$ 33.050,32
17	8.658,98	R$ 2,07	R$ 2,33	R$ 1.494,89	R$ 17.038,73	R$ 3.937,19	R$ 36.987,51
18	8.607,02	R$ 2,21	R$ 2,50	R$ 1.589,23	R$ 18.170,70	R$ 3.852,07	R$ 40.839,59
19	8.555,38	R$ 2,37	R$ 2,67	R$ 1.689,50	R$ 19.374,04	R$ 3.768,05	R$ 44.607,64
20	8.504,05	R$ 2,53	R$ 2,86	R$ 1.796,10	R$ 20.653,25	R$ 3.685,18	R$ 48.292,82
21	8.453,03	R$ 2,71	R$ 3,06	R$ 1.909,43	R$ 22.013,10	R$ 3.603,50	R$ 51.896,32
22	8.402,31	R$ 2,90	R$ 3,27	R$ 2.029,89	R$ 23.458,68	R$ 3.523,06	R$ 55.419,38
23	8.351,89	R$ 3,10	R$ 3,50	R$ 2.157,95	R$ 24.995,38	R$ 3.443,90	R$ 58.863,28
24	8.301,78	R$ 3,32	R$ 3,75	R$ 2.294,08	R$ 26.628,94	R$ 3.366,03	R$ 62.229,31
25	8.251,97	R$ 3,55	R$ 4,01	R$ 2.438,79	R$ 28.365,46	R$ 3.289,48	R$ 65.518,79

Source: The authors themselves (2019).

Table 7. Summary of the financial calculations presented above

Calculations	C1 – prompt payment	C2 – with financing	C3 - with insurance and financing
MRA	19.98% p.a.	19.98% p.a.	19.98% p.a.
NPV	R$ 21,124.04	R$ 4,864.84	R$ 407.75
IRR	32.33% p.a.	21.81% p.a.	20.13% p.a.
Discounted Payback	4 years and 2 months	6 years and 4 months	8 years 5 months

Source: The authors themselves (2019).

5. FINAL CONSIDERATIONS

This research had the general objective of analyzing the technical and financial viability of substituting electric energy by photovoltaic energy, given the current conditions of the legislation and the changes foreseen for urban residences. The objective was considered to have been met, since the analysis was performed by comparing the purchase of the photovoltaic energy equipment on demand and financed, obtaining the feasibility result in both cases. The financed scenario was also observed through the analysis of scenarios with added values such as insurance and annual cleaning of the plates. In all of them, the viability was proven.

In a first scenario, the purchase of the photovoltaic equipment was cash and an NPV of R$ 21,124.04 was obtained, IRR of 32.33% p.a., and the discounted payback presented a return on investment in 4 years and 2 months, characterizing it as viable. However, as for the return-on-investment time presented in the budget, the installing company promised 3 years and 7 months, which differs from the reality ascertained.

S&G Journal
Volume 16, Number 2, 2021, pp. 133-144
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In a second scenario using the same budget, it was considered that the acquisition would be made through a loan, in which the owner would pay fixed installments for 60 months and interest at 1.09% p.m. In this scenario, an NPV of R$4,864.84 was obtained, IRR of 21.81% p.a., and discounted payback presented a payback time of 6 years and 4 months. The investment, despite having a lower return, can be considered viable.

The third scenario analyzed considered the investment financed with the addition of insurance and cleaning of the installed plates. In this scenario, the NPV is R$1,150.60, the IRR is 20.41% p.a., and the discounted payback presents a payback time of 8 years and 2 months. In this context, the project is viable, but with a lower return than in the previous scenarios. However, due to the high acquisition cost of the equipment, it is important to take such variables into consideration, since electrical and weather-related problems can cause the total loss of the equipment. It is concluded, therefore, that the investment made by the owner of the residence in question is viable, according to the calculation parameters used.

Theoretically, the triple helix analysis is confirmed, given that the university is the source of technical basic research and, in this case, the proponent of this feasibility study; the companies present themselves as producers and installers of the photovoltaic plates; and the government assumes its role as regulator and fiscal incentive in the development of laws to ensure the production of photovoltaic energy in residences.

As limitations of this research, equipment maintenance costs were not considered since there is no standardization for such a need. The investment budgets were carried out in only one company, and, above all, the study was applied to a single residence. This study did not consider possible taxes on home-generated solar energy, which are being studied by the National Electric Energy Agency (ANEEL) and which, if approved, could lead to a reduction in viability.

The study method of this research can be applied to other technical and economic feasibility studies, in other contexts, or used as a way to add other financial analysis techniques. As a managerial contribution, the study shows that there is expansion potential for the activity, and that disseminating such information is worthwhile.

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