Case Study of the Distributed Generation Photovoltaic System Installation Connected to Electrical Grid in a Rest Home: Technical Economic Analysis of Coast and Benefit

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ABSTRACT

The photovoltaic solar power generation is increasing worldwide. This is also the case in Brazil, due to the favourable climatic conditions, electric energy high cost for consumers, among other factors. This study aimed to analyse the technical-economic viability and benefits of the installation of a photovoltaic distributed generation (PVDG) system of 20,1 kWp on grid by net metering regime, as an alternative to reduce costs and energy diversification. The methodology used was a case study in a rest home. As results obtained were: elaboration and comparison of 5 projects from different companies to choose the one winner project; economic-financial feasibility confirmation of the PVDG system. However, depending on the possible regulatory changes proposed by the Brazilian electricity sector regulator agent, the electricity bill benefit can be reduced by 28%, 34%, 42%, 50% or 62%, significantly undermining the planned payback.

KEYWORDS

Technical-Economic Feasibility, Distributed Generation, PV Solar Energy, Rest Home.

INTRODUCTION

In the world energy matrix, there is still a predominance of non-renewable energy sources of fossil origin (oil and coal). This has had negative environmental consequences such as air pollution, global warming and climate change. Population growth and industrial development imply an increase in energy demand. However, this increase in demand will tend to be met by alternative and renewable energy sources in favour of greater sustainability for the environment and in defence of the survival of humanity.

Electricity production throughout the world is still based on centralized generation (CG), made in large plants that are located far from consumer centers and need a large infrastructure of transmission and distribution lines. However, a new distributed generation (DG) model has been developed in recent years in several countries, where the consumer produces his own energy at or near the point of consumption, thus becoming a “prosumer”. DG gives autonomy, flexibility and freedom to users in the electricity sector.

Among the alternative and renewable energy sources, solar energy stands out, for being widely distributed around the globe and for enabling clean electricity generation (Figure 01).

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Solar energy is also one of the main sources used in DG, mainly through photovoltaic (PV) technologies. According to international agencies, in the current global context of energy transition, distributed generation with solar photovoltaic technology is able to make a significant contribution to reducing the negative environmental effects of greenhouse gas (GHG) emissions. In Brazil, DG gained notoriety and has been expanding significantly since 2012. Brazil is located in the intertropical zone, recording high levels of solar irradiation throughout the year, which makes it a favourable place for the use of solar PV energy, which is the predominant GD. However, this has also caused divergences of interests between energy consumers and distributors. In this context, this research performs a complete case study on the implementation of a photovoltaic distributed generation (PVDG) system connected to the electricity grid in the city of Salvador, State of Bahia (BA) (Figure 02).

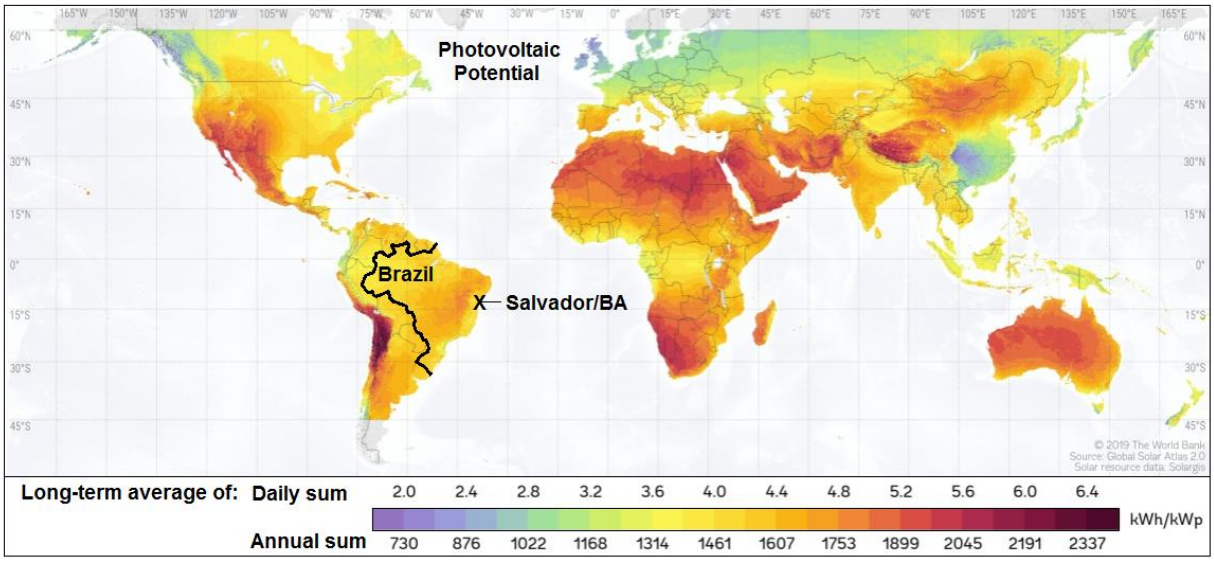


Figure 01: Global Solar Photovoltaic Potential. Source: [1].

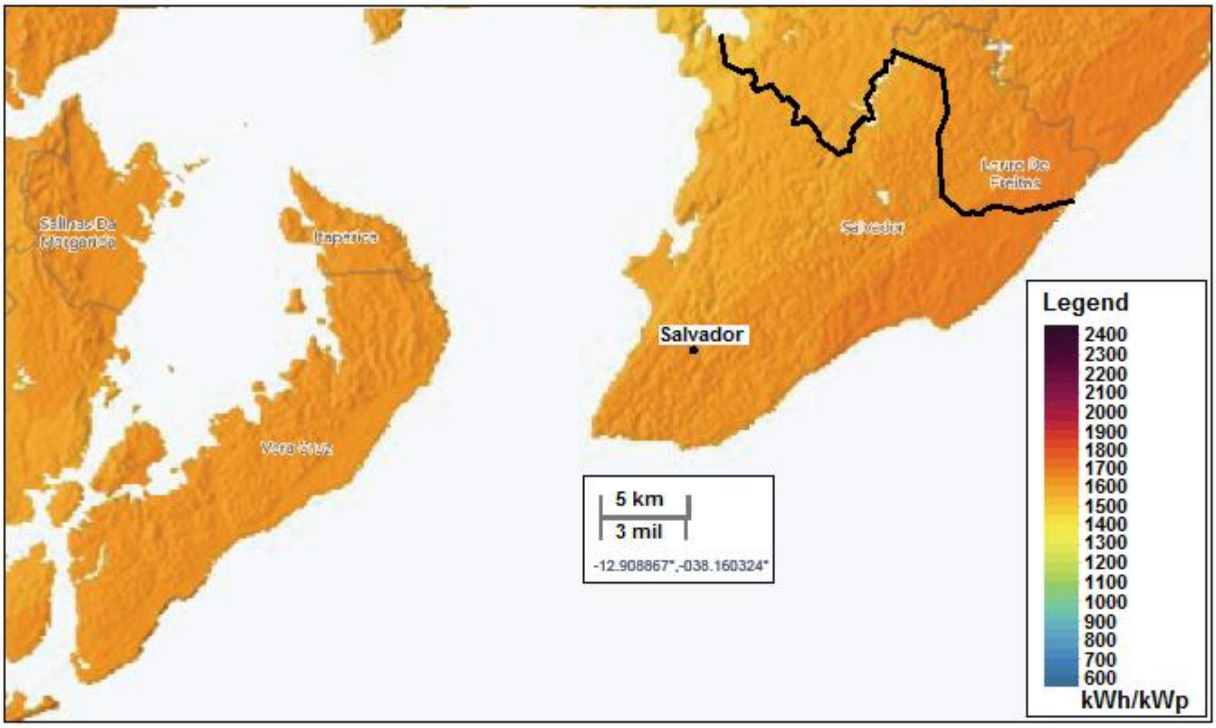


Figure 02: PV Solar Potential of Salvador City/Bahia, Brazil. Source: [2].

METHODOLOGY

This research is characterized as exploratory, descriptive, analytical, quantitative and case study, The methods adopted were: a bibliographic study and analyses of information from the Brazilian DG and the regulatory framework; preparation of a preliminary reference project, specifications and actions for the implementation of a PVDG project for analysis of energy consumption and technical and economic feasibility until its commissioning and monitoring of its first year of operation.

CASE STUDY ABOUT A REST HOME

According to [3] and [4], the FLH's rest home is a non-governmental organization whose main objective is to provide the elderly with a space for living and living with social integration so that they can exercise their citizenship in a participatory and autonomous way. The FLH is located at Rua Dep. Paulo Jackson, Nº. 100, Piatã, Salvador-BA, at coordinates 12º 94 '52 ''S and 38º 26' 47'' W and is formed by two buildings block (Figure 03) with a total 1,500 m^2 of built area. The building 1 (or block 1) is a rehabilitation and living center. The building 2 (or block 2) is a residential area known as the Rest home, consisting of 6 apartments to accommodate 54 seniors.

Figure 03: View of the side facade of the FLH´s rest home.

The introduction of a PV solar distributed generation (PVDG) system connected to the electric grid (framed as micro-generation) in the FLH´s rest home emerges as a solution to reduce electricity costs and energy diversification in the rest home. Thus, calculations of energy generation are made based on the information collected in the rest home itself, and among them is the income. This refers to the economic gains (R$) that are obtained with the introduction into the system. In this case, it is known that the energy consumed by the rest home is provided by the State Electricity Company of Bahia (*Compania de Eletricidade da Bahia* – COELBA).

After analyzing the electricity bill of the site, as well as the electricity tariff charged by the concessionaire in B3 COMERCIAL GRUP, including the tax on goods and services (*Imposto de Circulação de Mercadorias e Serviços* – ICMS), the social integration program (*Programa de Integração Social* – PIS) and contribution to the financing of social security (COFINS), it was possible to perceive that the kWh value to be paid by the household to the supplier is 0.78 R$/kWh, with the quote in 2018: U$ 1.00 = R$ 3.65, according to [5]. This charge refers to the use of the company's network and transportation of energy between the generation and the final consumer.

Therefore, the gain/revenue refers to the savings obtained considering a cost of 0.78 R$/kWh and the possibility of monthly average generation of the proposed system of 2,660.00 kWh, being possible to save monthly R$ 2,074.80 (annually R$24,897.60). The household no longer disburses R$24,897.60 (referring to year 1) in the payment of the energy bill to the concessionaire. Thus, in the cash flow, the name revenue means energy savings of R$ 24,897.60. As for this recipe, 2 factors must be taken into account:
(i) The power loss estimated by the manufacturers will be 1% per year (degradation), from the 2^{nd} year onwards. Consequently, it will impact the final value of net revenue;
(ii) Energy tariffs are adjusted annually.

In 2020, the average readjustment authorized by National Agency of Electric Energy (*Agência Nacional de Energia Elétrica* – ANEEL) for COELBA's energy tariff was 4.85%.This percentage and consecutive value will be increased in the tariff and considered in this analysis.

TECHNICAL EVALUATION

Evaluation of Solar Resource available at the Study Site

This phase quantified the global solar irradiation incident on the photovoltaic (PV) modules. A PV generator has its electrical characteristics basically dependent on the irradiance and temperature of the modules.

Full Sun Hours (FSH) is the number of hours in which the solar irradiance should remain constant and equal to 1 kW/m^2, so that the resulting energy is equivalent to the energy available by solar energy accumulated over a day [6]. The average solar irradiance data, shown in Table 1, were obtained from the SunData database of the Solar and Wind Energy Reference Center Sérgio Brito – CRESESB [7].

Table 1. Solar Irradiation in Inclined Plane.

Location: Lar FLH-Salvador/BR Latitude: 12º 94’ 52” S Longitude: 38º 26’ 47” O														
Angle	**Incline**	**Average daily solar irradiation monthly (kWh/m²*day)**												
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Auo**	**Sep**	**Oct**	**Nov**	**Dec**	**Average**
Horizontal plane	**0° N**	6.5	6.3	5.5	4.3	4.0	3.5	4.0	5.1	5.1	5.7	6.5	6.8	**5.27**
Angle equals latitude	**13° N**	6.0	6.1	5.5	4.5	4.4	3.9	4.5	5.6	5.2	5.5	6.1	6.2	**5.29**
Highest annual average	**8° N**	6.2	6.2	5.5	4.4	4.2	3.8	4.3	5.4	5.2	5.6	6.3	6.4	**5.31**
Highest monthly minimum	**33° N**	5.0	5.3	5.2	4.5	4.6	4.3	4.9	5.8	5.0	4.9	5.1	5.0	**4.95**

Source: [3], [4], [7].

Available Area for Study

The site made available for study was composed of three areas located on the roof of blocks 1 and 2 of the FLH. In building 1, an area was made available and in building 2, two areas totalling 172 m² (Figure 04). The areas are 100% flat, waterproofed, facing the geographic north and with the incidence of solar radiation for most of the day.

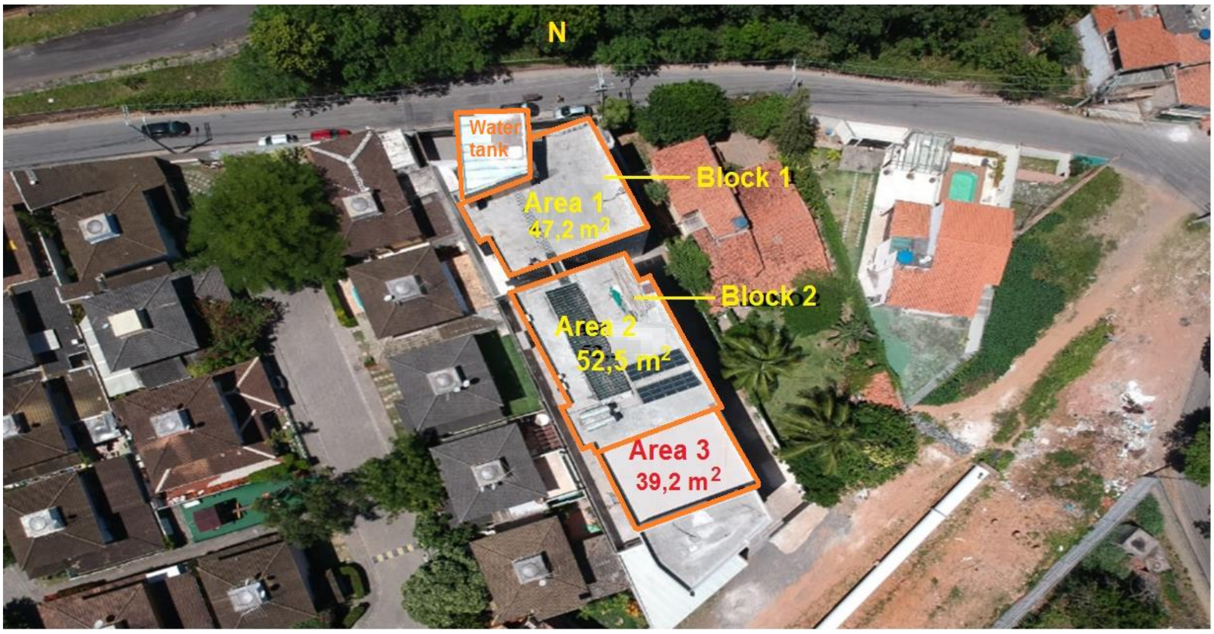


Figure 04: Aerial view of FLH Senior Home, Salvador/BR.

Area 1 had shaded regions due to the height of a tank, which would reduce the generation capacity of the PV modules, impairing the performance of the PVDG system. Due to the height of the tank, it was necessary to analyse the shading projected in area 1, to avoid installing the modules in the shaded regions for periods during the day. In the shading analysis, 11 manual measurements were made, from 7:00 am to 5:00 pm, between the 21st and the 30th, in the months of March, June, September and December 2018.

After comparing the data obtained and considering as a shaded area, the region that is affected by the shadow of the tank in the period from 9 am to 3 pm, the shaded area totalled 32.85m², In addition to the shading area, a distance of 1 m between the protection wall and the strings and 0.80 m between the rows of strings was assigned to be used in the maintenance of the PVDG system, Areas 2 and 3 showed no shading.

After shading analysis and considering the distances intended for the maintenance of areas 1, 2 and 3 (Figure 04), the three areas made available for the PVDG system study were 111 m² for the installation of PVDG system and 27.9 m² for maintenance, distributed as follows:

- *Area 1*: 39.5 m² for the installation of PVDG system and 7.7 m² for maintenance;
- *Area 2*: 40.0 m² for the installation of the PVDG system and 12.5 m² for maintenance;
- *Area 3*: 31.5 m² for the installation of the PVDG system and 7.7 m² for maintenance.

Survey of Electrical Loads

Electrical charges were surveyed, totalling 142.431 W, according to Tables 02, 03 and 04. The proposed solution for the supply of electricity to be met will be a total demand of 140,402 W, entering the building in GRUPO B3 COMERCIAL by Electricity Company of State of Bahia (*Companhia de Eletricidade do Estado da Bahia* – COELBA). The electric tariff for this group to active consumption (kWh) was considered R$ 0.78 and to reactive consumption surplus (kVAr) was considered R$ 0.31, already included the bills of PIS, COFINS and ICMS (COELBA, 2017).

Table 02. Lifting loads from FLH – Building 1.

INSTALLED LOAD CALCULATION LOAD INSTALLED BLOCK 01 – Rest Home			
LOAD	UND.	POWER (W)	TOTAL POWER (W)
LIGHTING AND OUTLETS (QDLF-A)	5	5,066 W	25,330 W
LIGHTING AND OUTLETS (QDLF-B)	1	6,829 W	6,829 W
LIGHTING AND OUTLETS (QDLF-H)	1	6,352 W	6,352 W
LIGHTING AND OUTLETS (QDLF-I)	1	6,266 W	6,266 W
HEATER	4	1,500 W	6,000 W
SHOWER	1	6,000 W	6,000 W
ITEMS, COND, SPLIT 30,000BTU's	3	2,900 W	8,700 W
ITEMS, COND, SPLIT 12,000BTU's	2	1,190 W	2,380 W
BOOSTING PUMP - 2HP	1	1,970 W	1,970 W
ELEVATOR - 4CV	1	3,660 W	3,660 W
TOTAL			73,487 W

Table 03. Lifting loads from FLH – Building 2.

INSTALLED LOAD CALCULATION LOAD INSTALLED BLOCK 02 - Physiotherapy Sector			
LOAD	UND.	POWER (W)	TOTAL POWER (W)
LIGHTING AND OUTLETS (QDLF-C)	1	10,901 W	10,901 W
LIGHTING AND OUTLETS (QDLF-D)	3	4,788 W	14,364 W
COOKTOP	1	3,200 W	3,200 W
ITEMS, COND, SPLIT 30,000BTU's	12	2,900 W	34,800 W
ELEVATOR - 4CV	1	3,660 W	3,660 W
TOTAL			66,925 W

Table 04. Total loads from the FLH.

INSTALLED LOAD CALCULATION TOTAL LOAD INSTALLED FROM FLH			
LOAD	UND.	POWER (W)	TOTAL POWER (W)
LIGHTING AND OUTLETS (QDLF-A)	5	5,066 W	25,330 W
LIGHTING AND OUTLETS (QDLF-B)	1	6,829 W	6,829 W
LIGHTING AND OUTLETS (QDLF-C)	1	10,901 W	10,901 W
LIGHTING AND OUTLETS (QDLF-D)	3	4,788 W	14,364 W
LIGHTING AND OUTLETS (QDLF-H)	1	6,352 W	6,352 W
LIGHTING AND OUTLETS (QDLF-I)	1	6,266 W	6,266 W
COOKTOP	1	3,200 W	3,200 W
HEATER	4	1,500 W	6,000 W
SHOWER	1	6,000 W	6,000 W
ITEMS, COND, SPLIT 30,000BTU's	15	2,900 W	43,500 W
ITEMS, COND, SPLIT 12,000BTU's	2	1,190 W	2,380 W
BOOSTING PUMP - 2HP	1	1,970 W	1,970 W
ELEVATOR - 4CV	2	3,660 W	7,320 W
TOTAL			140,412 W

Calculation of Photovoltaic Modules

The calculation of the PV modules was done according to two factors: area available for installation of the system; and PV module area, Table 05 presents the model configuration of the PV module.

Table 05. Configuration of PV Module (LUNA and TORRES, 2018a, 2018b).

Technology	Efficiency	Area	Nominal power (P_{mpp})	Nominal voltage (U_{mpp})	Nominal electricity current (I_{mpp})	Short-circuit current (Isc)	Open Circuit Voltage (Uoc)
Monocrystalline	18.40%	1.64m	300 Wp	32.16 V	9.34 A	9.82 A	40.08 V

The number of modules was calculated using Eq. (1) from the available area for installation and the module area:

$$\mathbf{N = A_{Disp} / A_{Mód.}} \quad (1)$$

At where:

N: Number of PV modules;

$\mathbf{A_{Disp}}$: Area available for installation (m^2);

$\mathbf{A_{Mód}}$: Area of the PV module, considering equal at 1.64 m^2.

Thus:

$N_{A1} = A_{1Disp} / A_{Mód} = 39.5/1.64 =$ *24 modules*

$N_{A2} = A_{2Disp} / A_{Mód} = 40/1.64 =$ *24 modules*

$N_{A3} = A_{3Disp} / A_{Mód} = 31.5/1.64 =$ *19 modules*

N = 24 + 24 + 19 = 67 modules

Calculation of Energy Estimate to be produced by the Photovoltaic Generator

Equation (2) calculates the nominal power of the PV generator:

$$\mathbf{P_{NomG} = N * P_N} \quad (2)$$

At where:

The number of modules was calculated using Eq, (1), from the available area for installation and the module area:

N: Number of PV modules;

$\mathbf{P_N}$**:** Module nominal power, considering power equal at 300 Wp.

Thus:

P_{NomG} = 67 * 300 Wp = 20.1 kWp

Equation (3) calculates the estimated energy, which will be produced in kWh and will be used to assemble table 06:

$$\mathbf{E_{Ger} = P_{NomG} * FSH * \eta_{cc/ca}} \quad (3)$$

At where:

$\mathbf{E_{Ger}}$**:** Estimated energy produced by the PV generator (kWh);

$\mathbf{P_{NomG}}$**:** Rated power of the generator, in kWp;

FSH: Number of Sunshine Full Hours in average daily (6 hours) at an intensity of 1.000 W/m^2 in hours;

$\mathbf{\eta_{cc/ca}}$**:** DC inverter efficiency for CA.

With data on the number of modules, nominal power of the PV generator, average solar irradiance of Salvador/BA for a slope of 13º and, based on the efficiency of the inverter being 70%, it was calculated how much the PV system will produce for one year (VILLAVA, 2012). According to Table 06, the PV generator with nominal power of 20.1 kWp will produce 28,944.15 kWh/year.

Table 06. Monthly calculation of the energy estimate that will be produced by the PVDG system of 20.1 kWp.

Month	Days	Installed Power	Solar Irradiation	Performance Rate	Monthly Estimate of Produced Energy
		kWp	kWh/m²	%	kWh
Jan	31	20,1	6,03	0,75	2,803.95
Feb	28	20,1	6,09	0,75	2,557.80
Mar	31	20,1	5,53	0,75	2,571.45
Abp	30	20,1	4,46	0,75	2,007.00
May	31	20,1	4,36	0,75	2,027.40
Jun.	30	20,1	3,94	0,75	1,773.00
Jul	31	20,1	4,49	0,75	2,087.85
Aug	31	20,1	5,56	0,75	2,585.40
Sep	30	20,1	5,18	0,75	2,331.00
Ouc	31	20,1	5,53	0,75	2,571.45
Nov	30	20,1	6,11	0,75	2,749.50
Dec	31	20,1	6,19	0,75	2,878.35
Total					28,944.15

ECONOMIC-FINANCIAL EVALUATION

For this evaluation, financial mathematics concepts will be used and the following indices will be used: cash flow, profitability, balance point, net present value (NPV), return on investment (ROI), Internal Rate of Return (IRR) and return on investment time (Simple and discounted payback).

For the proposed evaluation, it is necessary to identify the general parameters of power generation (Table 07):

Table 07. General Parameters to define the reference PVDG Project.

Nº	Parameters	Specifications
1º	**Area available for system installation**	Total area of 172.0 m^2, with effective area of 111 m^2
2º	**Number of photovoltaic panels arranged in 111 m^2**	67 modules of 300 Wp each
3º	**Installed power of solar generator**	20.1 kWp
4º	**System life**	25 years
5º	**Electricity tariff charged by COELBA GROUP B3 (including ICMS, PIS and COFINS)**	R$ 0.78/kWh
6º	**Value saved in the Period (month)**	R$ 2,650.31 kWh x 0.78 R$/kWh = R$ 2,067.24
7º	**Value saved in the Revenue Period (Year 1)**	R$ 2,067.24 x 12 months = R$ 24,806.90
8º	**Annual equipment efficiency loss**	1% of the revenue generated
9º	**Technical support**	1% of the amount of revenue per month, counted from the 11th year of installation; Annual maintenance cost (fixed): R$ 520.00
10º	**Attractive minimal rate**	4.67%
11º	**Depreciation**	Linear depreciation was considered, By counting the useful life of the system in 25 years, the depreciation will be 1% per year, with no residual value.

Considerations of Economic Feasibility Analysis about the projects

In beginning, it was realized a market research to finding expert companies in State of Bahia to implantation of PVDG systems. There are 5 companies with technical-commercial potential to make and implant a PVDG system project to FLH. Thus, it was required to companies the elaboration and presentation of business proposals about the specific PVDG system project.

Table 08. Five business proposals.

Business Proposals	Budget Amount for the implementation of the PVDG Project (*Quote of 2018: U$ 1.00 = R$ 3.65*)
Company A	R$ 86,363.21 (or *U$ 23,661.15*)
Company B	R$ 86,500.00 (or *U$ 23,698.63*)
Company C	R$ 89,117.86 (or *U$ 24,415.85*)
Company D	R$ 95,400.00 (or *U$26,136.99*)
Company E	R$ 95,000.00 (or *U$ 26,027.40*)

The sensibility analysis shows that the project was economically feasible in presented scenarios. The scenario 1 (investments of R$ 86,363.21) was the more probability, but with a competition continuous between companies of PVDG projects implantation in the DG Brazilian market and the continuous reduction of PV modules costs, the scenarios 3 and 4 presented economic feasibility too. Throughout the scenarios analyses was possible understand that with investment value reduction, the economics index was better (Ex.: NPV and IRR) and the payback times was reduced, according to Table 09.

Table 09. Comparative of 3 scenarios.

Index	Scenario 1 (Company A)	Scenario 2 (Company B)	Scenario 3 (Company C)
Investment	R$ 86,363.21	R$ 86,500.00	R$ 89,117.86
Costs in 25 years	R$ 143.525,14	R$ 143.525,14	R$ 143,525.14
Value in 25 years	R$ 1,148,422.75	R$ 1,148,422.75	R$ 1,148,422.75
Discount Tax	4.76%	4.76%	4.76%
NPV	R$ 443,519.06	R$ 443,382.27	R$ 440,764.41
IRR	32%	32%	31%
Payback discounted	4 years	4 years	4 years

In situations this type (with excluding projects), the ideal is that project chose will make by greater NPV, because this represent how much value above of investment will be congregated to investor in current values. Thus, it was make a strategic analyze of items of Table 09 to decision making and selection of a winner commercial proposal. However, after analyse, was made an additional step with technical visits, negotiation of attractive payment ways and specifications of sensors makers. Thus, it was decided that a *company B* showed better conditions in the evaluated items and better PVDG project.

IMPLEMENTATION, OPERATION AND MAINTENANCE OF THE PHOTOVOLTAIC DISTRIBUTED GENERATION IN THE ELDERLY HOME

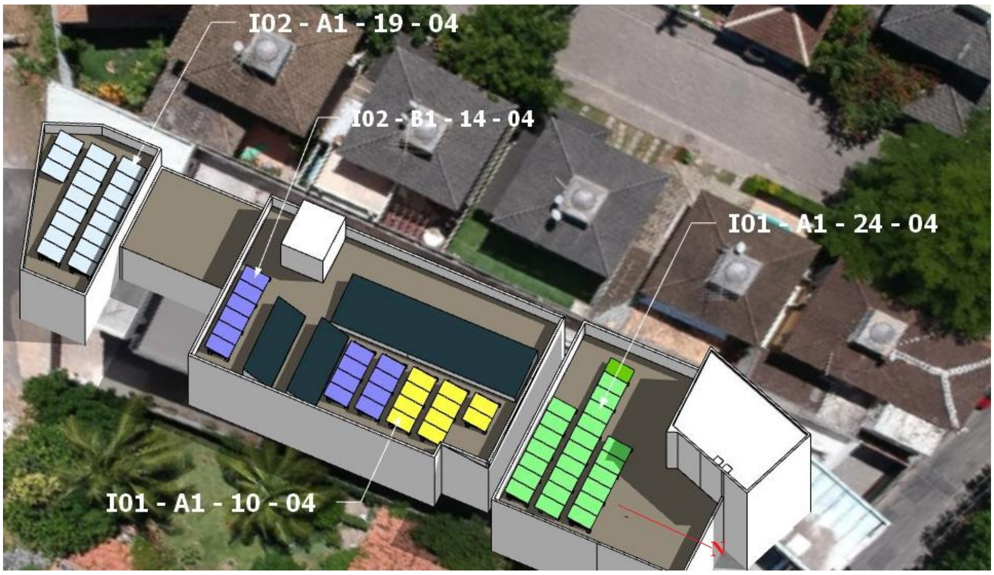
The implementation of FLH's PVDG project was carried out within the deadline established in the schedule by mutual agreement between FLH and company B. The implementation starting was in 05/22/2019 and ending was in 06/04/2019. It was the budget of R$86,500.00, which had been defined previously, fulfilled.

After the implementation of the PVDG system was completed, the system went through a period of commissioning and testing for 2 days and effectively met all the pre-defined requirements. The COELBA connected the PVDG system in the electrical grid in 07/27/2019.

The Photovoltaic Distributed Generation System

The dimensioning of the inverters was based on the nominal power of 20.1 kWp and formed by 2 systems, if there is some damage in one system, the other will continue to generate energy. Therefore, system 1 was formed with 34 PV modules with a nominal power of 10.2 kWp and system 2 with 33 PV modules with a nominal power of 9.9 kWp (Figure 11). The outputs of the inverters were connected to the AC bus of the general frame of Building 2, allowing the surplus to be injected into the electrical distribution network.

Figure 11: Distribution of PV Modules on the Geographic North face at 13º of Inclination.



Performance Evaluation of the Distributed Generation System

A performance evaluation of the PVDG system was carried out in its first year of operation. The period corresponded to September/2019 until August/2020. The system performance was satisfactory as shown in the table:

Table l0. PVDG System Annual Performance of the FLH.

Year			Real Energy (kWh)	Expected Energy (kWh)	Solar Irradiation Media (W/m²)	Installed Capacity (kWp)	Productivity (kWh/kWp)	Performance Rate	Capacity Factor (%)
	Months	Nº of Days							
1	SET-2019	30	2728	2751	231.80	20.1	135.72	81.32%	18.85%
2	OUT-2019	31	3143	2997	244.40		156.37	86.00%	21.02%
3	NOV-2019	30	2952	2749	231.68		146.87	88.04%	20.40%
4	DEZ-2019	31	3143	2921	238.23		156.37	88.22%	21.02%
5	JAN-2020	31	2660	2504	204.19		132.34	87.11%	17.79%
6	FEV-2020	29	2779	2685	234.03		138.26	84.88%	19.86%
7	MAR-2020	31	2493	2459	200.50		124.03	83.15%	16.67%
8	ABR-2020	30	2061	2241	188.82		102.54	75.42%	14.24%
9	MAI-2020	31	1731	2097	171.02		86.12	67.68%	11.58%
10	JUN-2020	30	1872	2550	214.84		93.13	60.21%	12.94%
11	JUL-2020	31	2026	2554	208.31		100.80	65.04%	13.55%
12	AGO-2020	30	2544	2873	234.32		126.57	75.02%	17.58%
Average			2511	2615	216,85		124.93	78.51%	17.12%

After successful commissioning, the operation of the PVDG system has been running regularly and with good quality. In October/2020, it was a predictive maintenance and a cleaning of PV modules.

The PVDG system has satisfactorily generated energy and has provided significant savings, even when considering the changes in FLH's consumption profile due to the coronavirus pandemic, the temporary closure of part of its activities and the new loads added to the buildings, Consequently, FLH was satisfied with the final result.

PROPOSED CHENGES IN THE DISTRIBUTED GENERATION REGULATORY FRAMEWORK IN BRAZIL AND POSSIBLE IMPACTS

The interest of society in PV solar energy has been increasing mainly after the Normative Resolution (REN) N^{o}. 482/2012 of ANEEL [8, 9, 10] and by the existing solar potential for generation in the country. REN N^{o}. 482/2012 published by ANEEL can be considered the initial regulatory framework of distributed generation (DG) in Brazil, since it established the net metering system and the general conditions for the access of micro and mini-generation distributed to electricity distribution systems.

In 2015, ANEEL approves REN N^{o}. 687/2015 [10], which amended REN N^{o}. 482/2012 [8], modules 1 and 3 of PRODIST (Distribution Procedures), defined remote self-consumption when the amount of energy generated in a given month is higher to the energy consumed in that month, the consumer gets credits and the term of validity of the credits went from 36 to 60 months. They can also be used to cut consumption of consumption units of the same holder of the Individual Taxpayers Register (CPF or CNPJ) located in another location, provided that it was in the service area of the same distributor and created the concept of shared generation, which consists of meeting consumers, within the same concession area or permission, through consortium or cooperative, composed of individuals or legal entities, which have consumer units with micro or mini-distribution distributed in a different place from the consumer units in which the in surplus will be compensated [11].

In July 2017, a wide-ranging reform of the current legal framework for the electricity sector was initiated, through the opening of public consultations 32 and 33 of 2017 by the Ministry of Mines and Energy (MME). Despite the period of contributions to consultations having ended in August, the text remains in the gestation of the Executive Branch, and has not been forwarded to the National Congress to date [12].

In 2018, the ANEEL [13, 14] developed six possible alternative scenarios (Figure 12) for updating the legislation regarding Distribution System Use Tariff (*Tarifa de Uso do Sistema de Distribuição* – TUSD) tariffs and sector charges for DG from 2020. According to [15], the ANEEL proposed a change in the Regulatory Framework in order to reduce the benefits of energy compensation in the net metering of distributed generation systems. ANEEL proposes to levy taxes on electricity generated by prosumers. This discussion and ANEEL's actions began due to pressure from energy distribution companies that wish to reduce the DG's incentives, alleging future losses in its economic-financial balance due to the full discount of sectorial rates in net metering. However, such proposals were questioned by Brazilian society, there were 2 public consultations on the topic in 2018 and 2019. The proposals are still under debate and are likely to be implemented in the coming years. The possible regulatory framework changes proposed can will be reduce the discount of electricity bill can be reduced by 28% (Alternative 1), 34% (Alternative 2), 42% (Alternative 3), 50% (Alternative 4) or

62% (Alternative 5), significantly undermining the planned payback. The Brazilian National Congress is making discussions about changes in DG regulation framework.

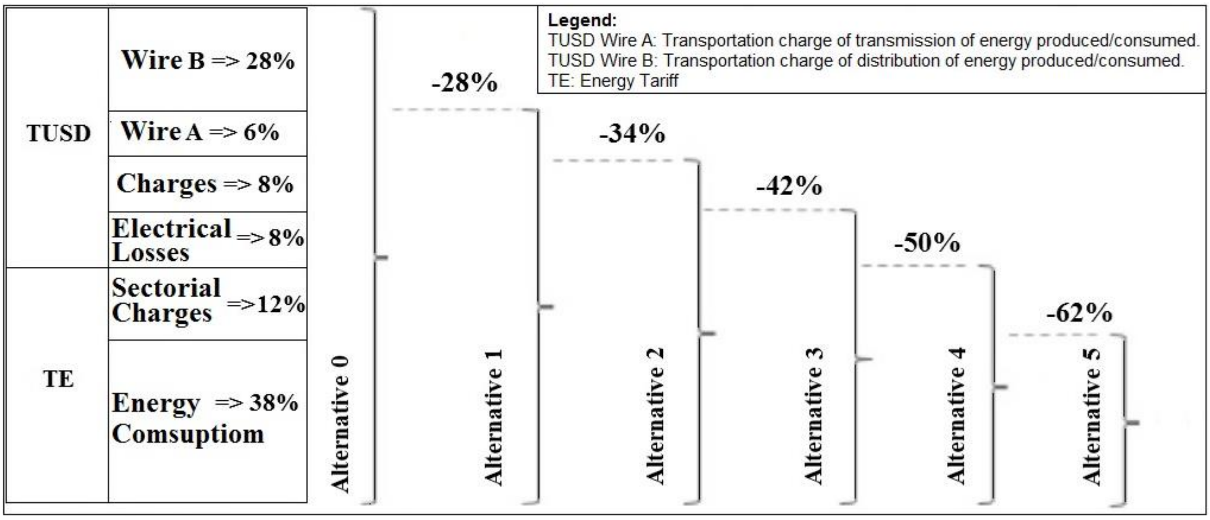


Figure 12. Six alternatives for DG Regulatory Framework Revision in Brazil.

ANALYSES AND DISCUSSIONS

Steps identified and simplified for implementing a Distributed Generation System

The FLH's PVDG system is working satisfactorily as planned and its process. From the experience of PVDG system implementing in the rest home, it was possible to identify 7 basics phases step-by-step (Table 11) to carry out an effective implementation of a PVDG system.

Table 11. Steps for a PVDG project successful implementation.

Step-by-Step for Implementing a Distributed Generation System	
1º	Consumption Analysis for Defining the Ideal Offer of a PVDG System.
2º	Specification of a PVDG System Preliminary Project.
3º	Market research to select a company to implement the effective project of the PVDG System.
4º	Implementation of the PVDG System.
5º	Commissioning of the PVDG System.
6º	Operation and Maintenance (O&M) of the PVDG System.
7º	Decommissioning of the PVDG System.

Possible Reduction of Payback PVDG System

According to Figure 12, the ANEEL proposed changes to DG regulation framework can reduce the discount of electricity bill, thus this situation can undermining the planned payback discounted (4 years):

a) Alternative 1 (Tax transference of 28%) => New payback discounted = 5.56 years

b) Alternative 2 (Tax transference of 34%) => New Payback discounted = 6.06 years

c) Alternative 3 (Tax transference of 42%) => New payback discounted = 6.90 years

d) Alternative 4 (Tax transference of 50%) => New payback discounted = 8 years

e) Alternative 5 (Tax transference of 62%) => New payback discounted = 10.53 years

Thus, it was demonstrated that new payback values are proportionally prejudiced in relation of original planned payback. However, in these cases, if the regulatory changes will be approved for Brazilian public power, the FLH could have a judicialization and legal insecurity about the question.

CONCLUSION

There was the effective implementation and operation of a 20.1 kWp PVDG system for micro-generation in a rest home in 2019, where the system was classified under the net metering system and its economic and financial viability features a 4 year payback; an average monthly savings generated in the electricity bill over a chosen period corresponding to one year of observation (September/2019 to August/2020) of R$ 2,074.80/month.

The cost-benefit ratio is favorable, as the monthly savings are 68.5% on the electricity bill. However, depending on possible regulatory changes proposed by ANEEL, energy compensation via net metering in the electricity bill can be reduced by 28%, 34%, 42%, 50% or 62%, significantly harming the planned return. Also depending on the new regulatory framework that will be approved in the national congress, there may or may not be a reduction in the planned financial return for the PVDG system. In addition, it was possible to establish the recommended steps for the adequate and qualified realization of a complete project for the implementation of a PVDG system.

The current Brazilian environment is very favorable to the expansion of the PVDG. This is evidenced by the growth of the DG market in recent years, but there are divergent interests between energy distributors and consumers/prosumers and DG companies and associations. Thus, there are six ANEEL scenarios for DG where in five of them the current benefits of prosumers will be reduced. Potential changes in the regulatory framework may also represent new risks and opportunities for DG. In the future, there is a need to ensure the economic and financial balance of distributors and benefits for prosumers. Therefore, the challenge is to create a future balanced regulatory solution to be adopted. In this context, new DG studies are strategic actions, as they will contribute to the evolution of the Brazilian electricity sector and the electricity consumer market.

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NOMENCLATURE

ANEEL – National Electric Energy Agency
CG – Centralized Generation
CNPJ – National Registry of Legal Entities
CPF – Register of Individuals
DG – Distributed Generation
FSH – Full Sun Hours
IRR – Internal Rate of Return
ICMS – Tax of Products and Services Circulation
MME – Ministry of Mines and Energy
NPV – Net Present Value
PRODIST – Procedures for Distribution of Electric Energy in the National Electric System
PVDG – Photovoltaic Solar Distributed Generation

PV – Photovoltaic
REN – Normative Resolution
ROI – Return on investment
TFSEE – Inspection Fee for Electric Energy Services
TUSD – Distribution System Use Tariff

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