18th International Conference on Renewable Energies and Power Quality 2020 (ICREPQ'20)
Granada (Spain), from 2 to 4 of September, 2020

ECONOMIC VIABILITY OF BUSINESS MODELS FOR PHOTOVOLTAIC SOLAR GENERATION IN BRAZIL: STUDIES OF CASES

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Abstract

In the last years, worldwide, more capacity of solar energy has been added than any other type of electric power generation technology. The current expansion market is largely due to the increase in market competitiveness of photovoltaic solar energy and demand for electricity. However, the markets continue to be driven largely by government or regulatory incentives and not by innovative business. Therefore, this paper presents: (i) overview of photovoltaic systems regarding the most adopted business models in Brazil; ii) business model economic viability case study. The results presented shows that for the Acquisition and Rental models, all case studies were economically viable, but in the Shared Solar Generation model the Consumer Units C1 and C2 were considered unfeasible by Levelized Cost of Energy - LCOE criterion

Key-Words
Solar Energy, Distributed Photovoltaic Generation, Business Models, Economic Viability.

1. INTRODUCTION

The use of renewable energy sources is growing over the years due to environmental concern, sustainable socioeconomic development, rising oil prices, scarcity of materials for non-renewable energy sources and policies directed at sustainability.

In this aspect, Geissdoerfer [1] claims that the ability to move between new business models quickly and assertively is a key competitive advantage of a modern organization.

Osterwalder and Pigneur [2] believe that a business model is how a company creates, delivers and captures value. According to Richter [3] this definition has been extensively tested in practice and has been successful in the field of renewable energy.

The REN21 [4] showed that in 2018 the photovoltaic solar energy was the world most added type of power generation technology in the world. However, markets in most places continue to be driven largely by government or regulatory incentives rather than innovative business models.

The purpose of this poster is to present the most adopted business models in Brazil. Then the economic indicators will be presented, such as Net Present Value - NPV, Internal Rate of Return - IRR, Profitability Index – PI Payback - PB and Levelized Cost of Energy - LCOE for study of cases in order to determine their viabilities.

2. METHODOLOGY

Figure 01 presents the general flowchart of the methodology used for the economic viability analysis of the photovoltaic business models presented in this paper.

The first step of the methodology in conducting a systematic literature review, consulting articles, journals and books on the subject.

The second step is the choice of business models to analyze. Among the various business models, three were chosen for the economic viability study, namely, Acquisition, Rental or Third Part and Shared Generation.

The next step is to obtain cash flows for each business model, which consists of obtaining sources of income and expenses over the project's lifespan.

At last the Economic Indicators can all be calculated and analyzed

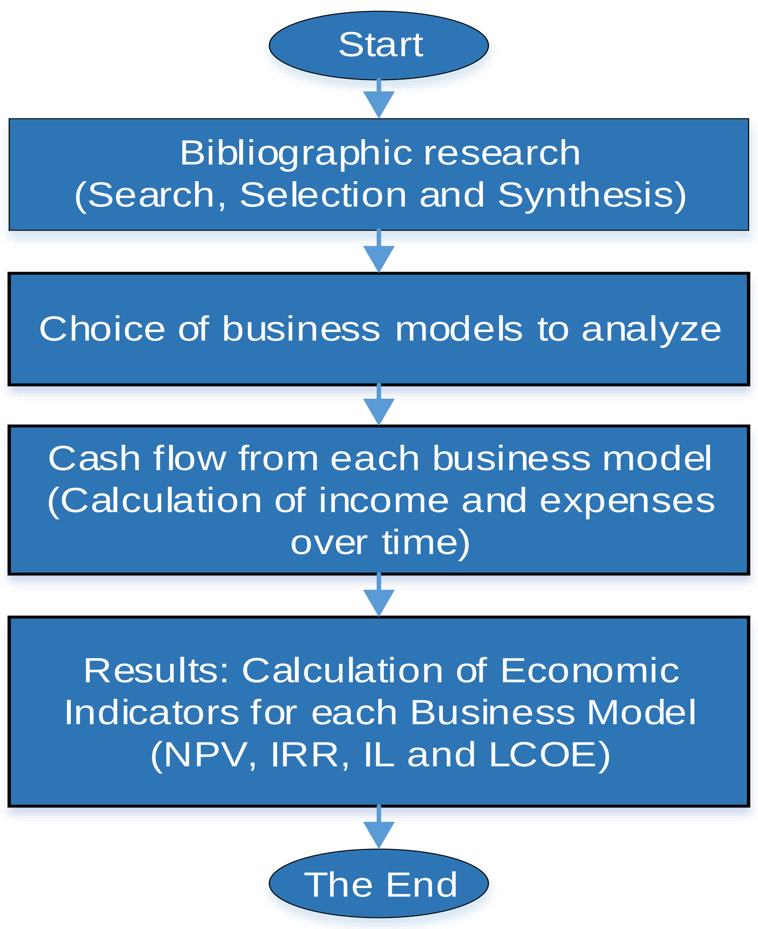

Fig. 01. General flowchart of the methodology.

3. BUSSINESS MODELS AND ECONOMIC INDICATORS

Revenues (R_{aqt}) and expenses (D_{aqt}) over time for each of the business models are listed bellow [5]:

Acquisition: $$R_{aqt} = P_{fv} * E(ima) * \left(1 + E(via)\right) * E(PR) * \left(1 - E(q_r)\right) * T_e * \left(1 + E(Rpe) - E(ifc)\right) \quad (1)$$

$$D_{aqt} = E(O\&M) * INV + E(NTI) * PI + CD * T_e * \left(1 + E(Rpe) - E(ifc)\right) \quad (2)$$

Third Part: $$R_{aqt} = P_{fv} * E(ima) * \left(1 + E(via)\right) * E(PR) * \left(1 - E(q_r)\right) * T_e * \left(1 + E(Rpe) - E(ifc)\right) \quad (1)$$

$$D_{agt} = AG * R_{agt} + CD * T_e * \left(1 + E(Rpe) - E(ifc)\right) \quad (3)$$

Shared: $$R_{aqt} = P_{fv} * E(ima) * \left(1 + E(via)\right) * E(PR) * \left(1 - E(q_r)\right) * T_e * \left(1 + E(Rpe) - E(ifc)\right) * F_{cu} \quad (4)$$

$$D_{aqt} = \left(E(O\&M) * INV + E(NTI) * PI\right) * F_{cu} + CD * T_e * \left(1 + E(Rpe) - E(ifc)\right) \quad (5)$$

The Net Present Value (NPV) indicates the potential for value generation, if NPV is positive, the investment will bring good result [6].

$$NVP = -INV + \sum_{t=1}^{T} \frac{(R_t - D_t)}{(1+i)^t} \quad (6)$$

The Internal Rate of Return (IRR), given by equation (7) is the interest rate that makes the NPV of cash flow equal to zero.

$$0 = -INV + \sum_{t=1}^{T} \frac{(R_t - D_t)}{(1+i_{rr})^t} \quad (7)$$

The Payback is the period of time when the return on investment occurs [7].

The Levelized Cost of Energy (LCOE), given by equation (4), represents the cost of kWh generated by the photovoltaic system.

$$\text{LCOE} = \frac{INV + \sum_{t=1}^{T} \frac{C_t}{(1+i)^t}}{\sum_{t=1}^{T} \frac{E_{fv}}{(1+i)^t}} \quad (8)$$

Indicator	Situation	Acceptability criteria
NPV	NVP > 0	Project will be accepted
	NVP = 0	Project can be accepted
	NPV < 0	Will not be accepted
IRR	IRR >MARR	Can not be accepted
	IRR ≤ MARR	Project will be rejected
Payback	Smaller than lifespan will be accepted.	
	Greater than lifespan will be rejected.	
LCOE	Should be less than the power rate	

Table 01 - Economic indicators and acceptability criteria

Table 01 presents a summary of all indicators, as well as their acceptability criteria that will be used in the economic viability analysis of photovoltaic systems in each of the cases studies.

4. RESULTS

The choice of the consumer units was made according to the convenience sample, where individuals to apply the methodology are readily accessible. In this sense, for the case studies of the acquisition and rental models, two consumer units located in the city of Goiânia-GO were chosen, both with supply below 2.3 kV, that is, belonging to Group B, one of the sub- group B1 (low voltage, residential) and another of B3 (low voltage, commercial). For Shared Generation a simulator was used, once we don't have any data of these PVS installed at the State of Goiás.

a) Acquisition

Table 02 presents the parameters used in the calculation of economic indicators for the acquisition business model.

Parameters	Values
PVS Power (B1)	1,83 kWp
PVS Power (B3)	5,37 kWp
Average annual irradiance	5,41 hsp
Yearly Variability	1,0%
Annual Drop in Yield Performance	0,70%
Inverter Exchanges (year 15)	1
Performance ratio	70%
Annual O&M Costs	0,93% of INV
Price of Energy Tariff	0,87 R$/kWh
Annual Adjustment Energy Taxes	5,31 % a.a.
PVS Cost (B1)*	R$ 11.312,51
PVS Cost (B3)*	R$ 29.613,22
Inverter percentage cost	20% of INV
Average inflation per year	5,85% a.a.
Minimum Attrac. R.Return (MARR)	10% a.a.

Table 02 - PVS data (Own Source)

The results for the acquisition model are shown at Table 03.

Indicators	B1	B3	Decision
NPV (R$)	8.91	44.233	Accepted
IRR (% a.a.)	17%	23%	Accepted
Payback (years)	6,4	4,8	Accepted
LCOE (R$/kWh)	0,51	0,21	Accepted

Table 03 - Results and Decisions - Acquisition

b) Rental or Third Part

As shown in [5], the revenue amounts for the SPV owner in this model may range from 90% to 70% of the revenue generated for the duration of the contract. The results presented are from the rent model. Table 4 shows the results.

In the rent model, we noticed that for consumer unit B1, the indicators present an acceptability of the business with little profit margin. LCOE also lower than the Price of Energy Tariff value.

Indicators	B1	B3	Decision
NVP (R$)	7.098	35.724	Accept
LCOE (R$/kWh)	0,79	0,49	Accept

Table 04 - Results and Decisions Rental

For B3 the indicators point to a positive return on investment with a good margin and also a LCOE (R$ 0,49) much lower than the Price of Energy Tariff value (R$ 0,87).

c) Shared Generation

For the Shared Generation model, the choice of consumer units was chosen based on the Cooperative Simulator software options [8]. Table 05 lists the member's profiles according to the available options. Table 06 summarizes the results found for the economic viability criteria for the Shared Generation business model case.

In the shared generation model, there is a large share of the value of the land for the construction of the plant, since it is larger. The results for consumer units C1 and C2 were not favorable considering the LCOE above the energy tariff value (R$ 0.87), another disadvantage for consumers C1 and C2 are the IRR values that are very close to the MARR (10%).

Qty	Av. Cons	Description	Code
5	150 kWh	Couple Average Consumption	C1
10	300 kWh	Low Cons. Family	C2
5	500 kWh	High Cons.Family	C3

Table 05 – Consumer Profiles – Cooperative Simulator

Indicators	C1	C2	C3	Decision
NVP (R$)	1.1592	4.784	52.714	Accept
IRR (%a.a.)	10,4%	10,5%	15,6%	Accept
Payback (Years)	10,3	7,4	8,2	Accept
LCOE (R$ /kWh)	1,11	0,93	0,76	Accept for C3

Table 06 - Results Decisions – Shared Generation

5. CONCLUSIONS

This work presented for three business models an economic viability analysis, and for most of the presented configurations, the projects were viable. A constant was noted, the bigger the system the smaller the Payback and the larger the NPV. At this point larger systems tend to be, in any model, more profitable over time.

The acquisition model is superior in return for those who has lower energy consumption, but for a medium consumer, others business models could be better like rental or shared generation, once the initial investment is zero or divided buy all the shareholders. It would be advisable for lower energy consumer to buy an SFV or rent a system until one can invest in the purchase.

Only for Shared Generation the projects of small and medium size UCs proved unfeasible, but this may be due to the data chosen for the simulation and the price of land that is one software's inputs.

It is noteworthy that the variables used in the calculations may be different for other regions of the country and therefore the results are specific to the systems studied here.

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