PHOTOVOLTAIC ENERGY PRODUCTION: A CASE STUDY AT GONÇALO MONIZ INSTITUTE (IGM) – FIOCRUZ-BA.

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Abstract: This article evaluated the use of photovoltaic energy in a public institute of health research, based on the potential savings, the environmental agenda of the Brazilian public service, the UN Agenda 2030 and the concept of “One Health”. Opportunity issues were also observed: physical structure of the institute, geographic location and favorable solar irradiation. The observed results met the expectations of the public institute and demonstrated the potential of this renewable energy source. However, replicating the experience in other public institutions depends on a series of factors that impact the cost/benefit of the necessary investment.

Keywords: Photovoltaic energy; Sustainability; Public service, Renewable energy.

PRODUÇÃO DE ENERGIA FOTOVOLTAICA: UM ESTUDO DE CASO NO INSTITUTO GONÇALO MONIZ (IGM) – FIOCRUZ-BA

Resumo: Este artigo avaliou o uso da energia fotovoltaica em um instituto público de pesquisa em saúde, com base no potencial de economia, na agenda ambiental do serviço público brasileiro, na Agenda 2030 da ONU e no conceito de “Saúde Única”. Também foram observadas questões de oportunidade: estrutura física do instituto, localização geográfica e irradiação solar favorável. Os resultados observados atenderam às expectativas do instituto público e demonstraram o potencial desta fonte de energia renovável. Contudo, replicar a experiência em outras instituições públicas depende de uma série de fatores que impactam o custo/benefício do investimento necessário.

Palavras-chave: Energia fotovoltaica; Sustentabilidade; Serviço público, Energia renovável.

1. INTRODUCTION

Excessive exploitation of the environment for energy production could lead to the depletion of natural resources in the next 50 years [1]. Most current forms of energy production cause environmental problems, resulting in health risks and reduced quality of life [2]. Energy production, therefore, can produce deleterious effects on human health. The concept of “One Health” proposes an integrated analysis of aspects of human health, environmental health and the environment [3], which includes sustainable energy production.

The effort to increase the share of renewable energy sources is also one of the Sustainable Development Goals (SDGs) of the 2030 agenda of the United Nations (UN), as described in SDG7. This SDG proposes as a goal to ensure reliable, sustainable, modern and affordable access to energy for all. And specifically in item 7.2, it reports that a substantial increase in the share of renewable energies in the global energy matrix is sought by the year 2030 [5].

The Environmental Agenda in Public Administration (A3P) is a program of the Ministry of the Environment that encourages public entities to reconcile the efficiency of their activities with the preservation of the environment [4]. Among these actors, the Gonçalo Moniz Institute - IGM/FIOCRUZ stands out - a unit of the Osvaldo Cruz Foundation, located in the city of Salvador/BA. In recent years, the IGM/FIOCRUZ has been developing actions aimed at environmental sustainability, such as the use of rainwater. On the other hand, it encountered a complex challenge with regard to the consumption of electricity, since the large number of equipment intended for scientific production in this institution demands high energy consumption, impacting the costs of the IGM/FIOCRUZ.

To reconcile the issues of “One Health” and environmental sustainability, in line with the guidelines of the A3P and the UN 2030 Agenda and aiming at a better allocation of its financial resources in its final actions, the IGM/FIOCRUZ sought alternative sources of sustainable energy and identified solar energy as a promising option, which unlike fresh water and fossil fuels is a virtually inexhaustible source [6].

A study contracted by the IGM/FIOCRUZ, through a bidding process, identified good potential for the production of photovoltaic energy in this public institution, considering the characteristics of its physical facilities, its location and the high solar irradiation in the city of Salvador/BA. As a result, IGM/FIOCRUZ implemented a photovoltaic mini-plant. Thus, the objective of this article was to verify if the results obtained with the implementation of this photovoltaic mini-plant point to a significant reduction in costs, guaranteeing the financial return on investment, and if they are aligned with the adopted sustainability assumptions.

2. METHODOLOGY

This is a case study, where 3 criteria were adopted to evaluate the investment made by the IGM/FIOCRUZ in a mini photovoltaic power plant:

- Time to return on investment (payback).
- Costs with electricity after the implementation of the mini photovoltaic power plant.
- Consumption of electricity supplied by the concessionaire after the implementation of the mini photovoltaic power plant.

As the photovoltaic mini-plant began operating on 03/30/2023, comparisons were made for the criteria of costs and consumption of electricity with the same months (April to July) of the year 2022. Regarding the payback criterion, the same was evaluated prospectively, extrapolating the results of the implanted system to its useful life.

Although the period of effective operation of the mini plant is short, the expectation is for an increase in the monthly production of photovoltaic energy, gradually as the months approach the summer. According to the Brazilian Atlas of Solar Energy [7], in the region where the IGM/FIOCRUZ facilities are located, there are no abrupt variations in solar irradiation, and the months in which the region seasonally presents the lowest levels of normal direct irradiation (May and June) are precisely among the data collected.

The evaluation of the 1st criterion, payback, was intended to verify whether it would be in line with a reasonable perspective, considered by the literature, in relation to the useful life of the equipment. The useful life of the equipment was estimated at 25 years, which is a reference used for equipment of this nature [8]. Within this horizon, a payback of up to 10 years is acceptable [9], so a perspective within this time interval was adopted.

The 2nd criterion was intended to assess whether the reduction of electricity costs with the concessionaire will have a practical effect to allow a better allocation of resources for the final activities of the IGM/FIOCRUZ. A target was not set for this criterion, but the objective was to assess whether the reduction in electricity costs will be reflected in a saved amount that has a noticeable effect on the resources to be invested directly in final research and teaching actions.

Finally, the 3rd criterion, reduction in the consumption of electricity supplied by the concessionaire, a reduction measured in kWh and not in monetary value, was intended to assess whether the adoption of photovoltaic energy is effective in relation to the sustainability assumptions adopted, considering the logic that the lower the demand on the supply of electricity by the concessionaire, the less impact on natural resources (less generation of non-renewable energy) and consequently less harm to human health.

3. RESULTS AND DISCUSSIONS

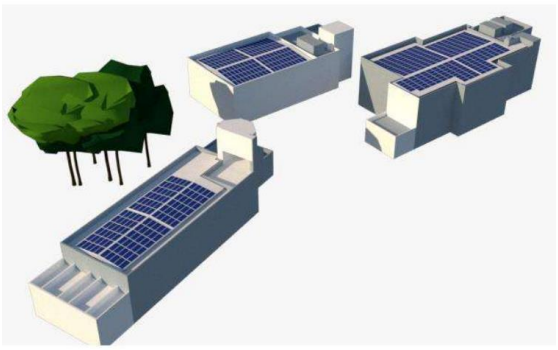
The installation of the photovoltaic mini-plant was an initiative carried out by the unit's Infrastructure and Logistics area. To this end, the first step taken was the hiring, in 2020, of an engineering company to prepare the project with the objective of presenting the technical solutions and the necessary information for defining the electrical and electronic equipment to be adopted, in addition to all the details for your installation. The contractor presented a solution with a generation capacity of 227.74 kWp to be installed on the roof of three of the IGM/FIOCRUZ buildings, considered those with the greatest generation potential due to the more favorable conditions for photovoltaic energy generation. Table 1 details the information designed for the system.

Table 1. Configuration of photovoltaic arrays

Equipment information	pavilions		
	Ítalo Sherlock	Aluízio Prata	Zilton Andrade
Modules	160	120	280
Inverters	2	2	4
DC Power	64.8 kWp	48.6 kWp	113.4 kWp
AC Power	50 kW	50 kW	100 kW

Figure 1 shows the configuration, initially designed, of the photovoltaic arrays on the roofs of the institution's pavilions, where the greatest potential for energy generation was identified.

Figure 1. Situation of photovoltaic arrays on pavilion roofs



The second step was to hire a company to carry out the installation, which took place in December 2021. On that occasion, the service was contracted through a bidding process for the amount of BRL 970,738.37, plus the amount paid for the project (BRL 29,700.00) totaled a total investment of BRL 1,000,438.37. The last step was the installation of the system, which suffered a significant delay to be put into operation, since it was necessary to intervene in the institution's electrical energy substation due to notes made by the Electricity Company of the State of Bahia (COELBA). After making all the necessary adjustments, the system was put into operation on 03/30/2023. It is important to point out that, due to this delay, the modules originally contracted were no longer manufactured. The new configuration had a smaller number of modules (386) of greater power (590 Wp) to meet the contracted generation capacity of 227.74 kWp. This reduction in the number of modules left spaces in the roofs, which may enable future complementation of the system, as can be seen in Figure 2.

Figure 2. Photovoltaic system implemented in the institution

3.1. Return on investment time (payback)

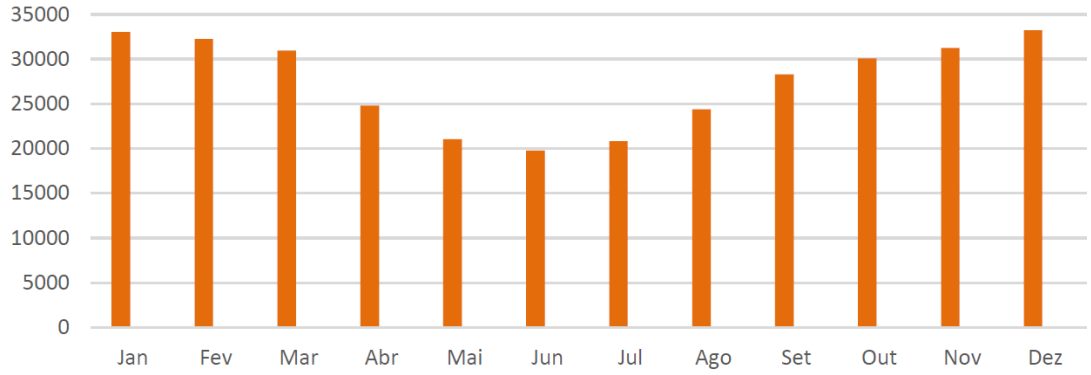
To calculate the return on investment, the SolarMarket software was used to obtain the average photovoltaic energy generation of the system. SolarMarket is a program that generates commercial proposals for solar energy using artificial intelligence and that complies with Law No. Social Renewable Fund (PERS). For the result found, the parameters shown in Table 2 were inserted.

Table 2. Parameters used for payback time

Parameters	Information
Investment	BRL 1,000,438.37
Number of modules	386
Module power	590 Wp
Total generation power	227.74 kWp
Tariff	A4 Horo-seasonal Green - Federal Government
Annual inflation rate	9.5% per year
Minimum system lifetime	25 years
Loss of system efficiency	20% in 25 years
Legal base	Law No. 14,300/2022
Solar radiation index	According to geographic location
Type of supply	three-phase

Figure 3 details the variation in photovoltaic energy generation over the months in the first year of system operation. This information generated by the SolarMarket software considered the characteristics of the installed equipment and the variation of solar radiation over the months in Salvador/BA.

Figure 3. Power generation over the first year of system operation



Based on information from the installed system (Table 2) and considering the behavior of energy generation over the months (Figure 3), the SolarMarket software calculated the average monthly generation of 27,490 kWh. To calculate the savings provided by the system, the tariff (A4 Horo-sazonal Verde - Federal Public Power) applied to the institution's last invoice (July/23) at off-peak hours, a period in which the institution's facilities consume the generated energy. To find the return on investment time, the simple payback formula was used, which compares the initial investment made with earnings over the period, whose calculations are detailed below.

Monthly savings:

Energy generated x tariff = 27,490 kWh x BRL 0.50 = BRL 13,745.00

Payback:

Initial investment / monthly savings = BRL 1,000,438.37 / BRL 13,745.00 = 73

Based on the calculations, a payback of 73 months was found, that is, approximately 6 years, therefore, much lower than acceptable in the reference used (up to 10 years [9]).

3.2. Electricity costs after the implantation of the mini-plant

In order to assess the institution's electricity supply costs, data were collected on the amounts spent indicated on the invoices, whose consumption readings occurred after the beginning of generation (04/01/23 to 07/31/23) and the same period in previous year (01/04/22 to 31/07/22). The same months of the year were used as a comparison criterion due to what was observed in the history of electricity consumption in the institution, which demonstrate similar behavior at the same times of the year. It is worth noting that as of 04/22/2023 there was a 6.91% increase in electricity tariffs for high voltage consumers. In addition, Decree No. 21,796/22 changed the ICMS (Tax on Circulation of Goods and Services) in the state of Bahia from 18% to 27%, which also affected the value of electricity tariffs in the year 2023.

Based on the data in Table 3, it can be seen that there was a reduction in the average amount paid in the period after the operation of the mini photovoltaic power plant compared to the same period in the previous year, even with increases in tariffs of approximately 16% due to the tariff readjustment and increase in the percentage charged by ICMS.

Table 3. Expenses with electricity in the institution

Year	2022			
Month	April	May	June	July
Value	BRL 167,243.81	BRL 190,366.76	BRL 168,176.15	BRL 163,010.91
Average	BRL 172,199.41			
Year	2023			
Month	April	May	June	July
Value	BRL 158,828.16	BRL 180,322.75	BRL 166,576.37	BRL 166,711.78
Average	BRL 168,109.77			

3.3. Consumption of electricity supplied by the concessionaire after the implementation of the mini-plant

In order to evaluate the institution's electricity consumption, data were collected for the off-peak period, since, at peak hours (6:00 pm to 9:00 pm on weekdays) the system does not capture sunlight to produce electricity. For the evaluation, similarly to item 3.2, the periods from April to July of the years 2022 and 2023 were compared, as detailed in Table 4.

Table 4. Electricity consumption at off-peak hours

Year	2022			
Month	April	May	June	July
kWh consumption	190,008.00	199,542.00	175,371.00	176,547.00
Average	185,367.00			
Year	2023			
Month	April	May	June	July
kWh consumption	143,934.00	157,458.00	141,141.00	143,241.00
Average	146,443.50			

Based on the data in Table 4, it can be seen that there was a significant reduction in the average consumption in the period after the operation of the mini photovoltaic power plant, compared to the same period in the previous year. This reduction may have other reasons not identified by the study, but the reduction in consumption is clear, especially when compared to the average of the last twelve months of consumption in off-peak hours before the start of operation of the mini-plant (April 2022 to March of 2023) which was 193,196 kWh.

Although the reduction in expenses and consumption, when compared to periods prior to the implementation of the system, may have other reasons, the influence impacted by generation from solar energy is well known. It is worth mentioning that the payback criterion, which uses data directly related to the investment, indicates a very attractive financial return. Therefore, the criteria adopted in the study for evaluating the investment made, show good results with the implementation of the photovoltaic mini-plant.

Therefore, the results obtained with the implementation of this photovoltaic mini-plant point to a significant reduction in costs and consumption of electricity with the concessionaire, guaranteeing the financial return on the investment in a very interesting period, in addition to being in line with the sustainability assumptions adopted by the institution. .

Finally, evaluating the possibility of replicating the experience in other public institutions, provided that previous studies are carried out with professionals in the area, seems to be an important measure for a better allocation of public resources and compliance with the principles of “One Health” and environmental sustainability, in line with the guidelines of the A3P and the UN 2030 Agenda.

4. CONCLUSION

It can be seen that the implementation of the photovoltaic mini-plant at the institution will provide an average reduction in monthly expenses of R$ 13,745.00. This good savings in financial terms can generate reductions of approximately one hundred and sixty-five thousand reais per year in the bills to be paid by the institution. Faced with the perspective of cost reduction, the amount to be saved can be directed towards investment in the implementation of other sustainable initiatives or allow a better allocation of resources for the final activities of the institution. In addition, the photovoltaic mini-plant is one of the clean forms of energy production that contributes to the preservation of the environment.

Another possibility to be evaluated is the purchase of electricity by public institutions in the Free Energy Market, as an alternative to replacing the supply by the local concessionaire. This initiative could generate other savings, such as prices being negotiated directly with generating agents and traders. As can be seen in the development of this article, the institution of the present case study has an average monthly generation by the photovoltaic mini-plant of 27,490 kWh, which implies the continuity of consumption with the concessionaire of approximately 150 thousand kWh, in addition to what is consumed at peak hours, which indicates a potential for acquisition in the Free Energy Market.

5. REFERENCES

[1] DA SILVA, Heitor Marques Francelino; ARAÚJO, Francisco José Costa. Energia solar fotovoltaica no Brasil: uma revisão bibliográfica. **Revista Ibero-Americana de Humanidades, Ciências e Educação**, v. 8, n. 3, p. 859-869, 2022.

[2] SHAHSAVARI, Amir; AKBARI, Morteza. Potential of solar energy in developing countries for reducing energy-related emissions. **Renewable and Sustainable Energy Reviews**, v. 90, p. 275-291, 2018.

[3] SOARES, Thiago Ferreira. Meio Ambiente e Saúde Única: o que podemos esperar? **Revista Brasileira de Meio Ambiente**, v. 8, n. 4, 2020.

[4] Ministério do Meio Ambiente. Portal A3P. O que é? Disponível em: http://a3p.mma.gov.br/o-que-e/. Acesso em: 24 jul. 2023.

[5] Nações Unidas Brasil. Os Objetivos de Desenvolvimento Sustentável no Brasil: Energia limpa e acessível. Disponível em: https://brasil.un.org/pt-br/sdgs/7. Acesso em: 24 jul. 2023.

[6] BURSZTYN, Marcel. Energia solar e desenvolvimento sustentável no Semiárido: o desafio da integração de políticas públicas. **Estudos Avançados**, v. 34, p. 167-186, 2020.

[7] PEREIRA, Enio Bueno et al. Atlas brasileiro de energia solar. São José dos Campos: Inpe, v. 1, 2017.

[8] DANTAS, Stefano Giacomazzi; POMPERMAYER, Fabiano Mezadre. Viabilidade econômica de sistemas fotovoltaicos no Brasil e possíveis efeitos no setor elétrico. Texto para Discussão, 2018.

[9] CALDAS, Thiago; SANTOS, Alex Álisson Bandeira. Modelo de simulação e análise de implantação de sistemas fotovoltaicos nas instalações de um centro de pesquisa. In: 13º Congresso Ibero-americano de Engenharia Mecânica. 2017.