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Overview of Solar Trackers: Historical Evolution and Integration into the Photovoltaic Market

Overview of Solar Trackers: Historical Evolution and Integration into the Photovoltaic Market

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Summary

The shift in the global energy paradigm has driven the search for renewable sources, highlighting photovoltaic solar energy. This article presents a study on solar tracker technology , devices that allow photovoltaic modules to follow the sun's trajectory, increasing the received irradiance and the capacity factor of power plants. The work provides a historical overview from the technology's emergence in 1975 to its current consolidation, as well as analyzing data on its insertion in the international and Brazilian markets. The results demonstrate that, although they have a higher initial cost, trackers provide productivity gains between 30% and 40%.

In Brazil, single-axis technology dominates energy auctions, establishing itself as a viable solution for maximizing electricity generation.
Keywords: Solar Energy. Solar Trackers. Photovoltaic Market. Energy Efficiency.

Abstract

The shift in the global energy paradigm has driven the search for renewable sources, highlighting photovoltaic solar energy. This paper presents a study on solar tracker technology, devices that allow photovoltaic modules to follow the Sun's trajectory, increasing received irradiation and the plant's capacity factor. The work conducts a historical review from the technology's emergence in 1975 to its current consolidation, in addition to analyzing data on its insertion in the international and Brazilian markets. Results show that, despite having a higher initial cost, trackers provide productivity gains between 30% and 40%. In Brazil, a dominance of single-axis technology is observed in energy auctions, consolidating itself as a viable solution to maximize electrical generation.

Keywords: Solar Energy. Solar Trackers. Photovoltaic Market. Energy Efficiency.

1. INTRODUCTION

The shift in the energy paradigm has been one of the greatest challenges facing modern society. because the use of fossil fuels, mainly oil, has generated environmental consequences. considerable, in addition to various geopolitical problems. Therefore, the search for clean and Renewable energy has been a current constant. According to data from the *Renewable Global Status Report* According to a 2018 *report ,* approximately 10% of the world's final energy consumption comes from solar sources. Renewables, a percentage that is expected to grow considerably over the next few years. (REN21, 2018).

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In this scenario, solar photovoltaic energy is a strong alternative to the problem. Because it is a clean, abundant, and renewable source, its inclusion in energy matrices is increasingly expected. energy sources in countries. At the end of 2019, photovoltaics represented 2.8% of total energy production. global electricity, and since 2016 the renewable energy source with the largest annual additions of power. (REN21, 2020). According to IEA data (2019), renewable energies will expand by 50%. of its capacity between 2019 and 2024, with 60% of that value related to photovoltaic solar energy. In 2019, the sector received 47% of investments in renewable energy (REN21, 2020).

With robust and growing development in the energy market, the sector has been seeking increasingly incorporating auxiliary technologies aimed at increasing the production capacity factor. Electrical energy from their power plants. Among these technologies, one of the most important is the solar tracker.

Photovoltaic modules were traditionally installed in a fixed location, generating less energy. Energy in the early morning and late afternoon due to the angle of the sun's rays relative to the plane of opening. In this context, the use of solar trackers allows the modules to follow The sun's path constantly increases the amount of radiation received throughout the day (RECA-CARDEÑA and LÓPEZ-LUQUE, 2018). In this way, it is possible to reduce the area of solar panels required. for the production of a certain amount of daily electrical energy, increasing the capacity factor of the power plants. (MORADI et al., 2016). With trackers, productivity gains can be, on average, between 30 to 40% per year (MOUSAZADEH et al., 2009).

Globally, solar tracking is the fastest growing sector in the photovoltaic market. The forecast is that its presence in plants will increase from 20% in 2016 to 40% in 2020 (JÄGER-WALDAU, 2018). Although it has existed since 1975 (MCFEE, 1975), its market entry began This has happened over the last 10 to 15 years (REW, 2009; BOLINGER, 2019; EPE, 2018). This is due to, among other factors, due to the recent increase in the reliability of the technology (BOLINGER et al., 2019).

2. THEORETICAL FRAMEWORK

The first active and automatic solar tracker was developed in 1975 by McFee (1975). The study model was a tower with a spherical receiver, surrounded by heliostats, which could moving along two axes that directed the sun's rays toward the receiver. In 1980, Semma and Immamura (1981) developed a two-axis solar tracker using active sensors, being These sensors were the great innovation of the system at the time.

The first photovoltaic power plant with a capacity in the order of megawatts was built in 1982. in Hisperia, California, United States, with 108 axle trackers. double (EERE, 2018). A few years later, in 1986, Rumala (1986) developed a method of following The Sun based on shading. In 1996, Kalogirou (1996) presented an axis tracker.

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The only one using light-dependent resistors for the first time. And in 1998, Khalifa and Al-Mutawalli (1998) develop a solar tracking system in a parabolic concentrator to increase its thermal power.

Although solar tracking systems have existed since 1975, their market integration... Photovoltaics is a relatively recent technology. In Spain, one of the main consumer markets in Europe... (UNEF, 2020), in 2006, the presence of solar trackers in power plants was insignificant; however, already In 2008, they accounted for 25% to 30% of new projects installed (RENEWABLE ENERGY). (WORLD, 2019). In the United States solar power generation sector, between 2007 and 2010, trackers They were an incipient part of the market; however, since 2014, they have grown steadily, reaching 74% presence in new projects in 2018, a cumulative total of 68% of installed capacity. (BOLINGER, 2019).

In Brazil, within the Regulated Procurement Environment, of the 31 projects in the first auction for Of the photovoltaic projects in 2014, 10 presented tracking (EPE, 2014); shortly after, In 2017 and 2018, the technology was considered in all projects (EPE, 2018).

3. MATERIALS AND METHODS

This work is characterized as descriptive and bibliographical research, based on... Secondary data analysis. For the construction of the historical review and market analysis, the following were used. databases from recognized bodies in the energy sector, such as the *International,* were consulted. *Energy Agency* (IEA), *Renewable Energy Policy Network for the 21st Century* (REN21) and the Company Energy Research Department (EPE).

The methodology included the collection of technical reports, scientific articles, and data from... Market *share* was used to map the evolutionary landscape of solar trackers. Compiled data on manufacturers, global installed capacity, and results of energy auctions. in Brazil (Regulated Procurement Environment) between 2014 and 2018, allowing for an analysis A comparison between fixed systems and systems with tracking.

4. RESULTS AND DISCUSSION

4.1 INTERNATIONAL MARKET

Globally, solar tracking is the fastest-growing sector in the photovoltaic market. In 2019, there was an increase of around 20% in the installation of tracking devices (UNEF, 2020).

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The forecast is that its presence in plants will increase from 20% in 2016 to 40% in 2020 (JÄGER-WALDAU, 2018).

The companies that dominated the production of solar trackers worldwide in 2019 are: presented in Figure 1. Their respective nationalities are shown in Table 1.

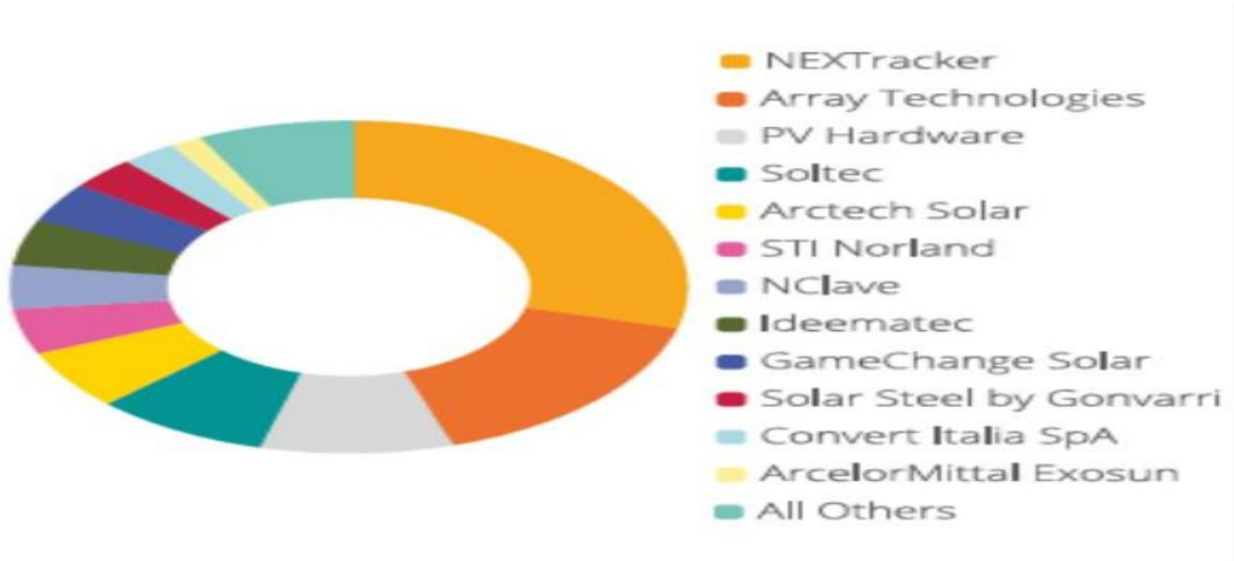

Figure 1 – Largest Manufacturers of Solar Trackers in 2019

Source: UNEF (2020).

Table 1 – Largest Solar Tracker Manufacturers in 2019 and their headquarters countries.

Manufacturer	**Thirst**
NEXTracker	United States
Array Technologies	United States
PV Hardware	Spain
Soltec	Spain
Arctech Solar	China
STI Norland	Spain
NClave	Spain
Ideatec	Germany
GameChange Solar	United States
Solar Steel by Gonvarri	Spain
Convert Italia SpA	Italy
ArcelorMittal Exosun	United States

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Source: Prepared by the author using data from *ARCELOR MITTAL (2020), ARCHTECH SOLAR (2020), ARRAY TECHNOLOGIES (2020), CONVERT (2020), GAMECHANGE SOLAR (2020), NCLAVE (2020), NEXTRACKER (2020), SOLAR STEEL (2020), SOLTEC (2020), STI NORLAND (2020).*

In 2013, the photovoltaic market had 2.9 GW of installed tracker capacity. solar (GVR, 2014). In 2015, the value increased to 4.91 GW (CISTON, 2018). Then in 2016, in In financial terms, the sector was valued at $7 billion, with expectations of exceeding that figure. annual installation of 70 GW in 2024 (GMI, 2017). According to REPORTS AND DATAS (2019), in In 2018, the market was worth $13.95 billion, with expectations of being valued at $49.21 billion. dollars in 2026. The graphs in Figures 2 and 3 summarize this data.

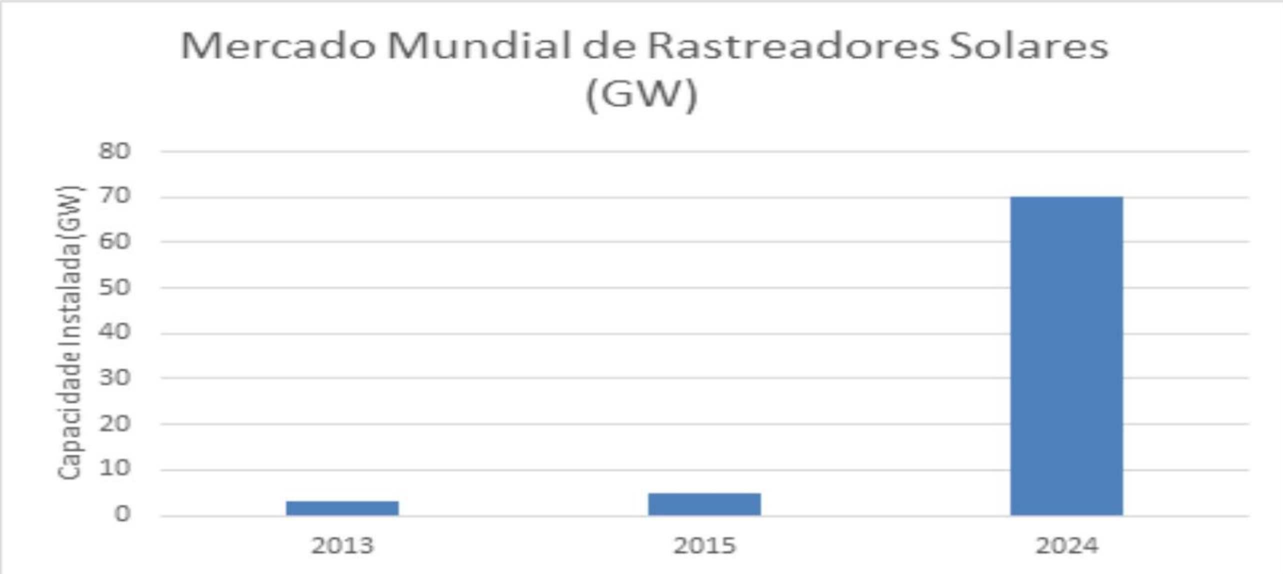

Figure 2–Worldwide Solar Tracker (GW) Market

Source: Prepared by the author using data from GVR (2014); CISTON (2018) and GMI (2017).

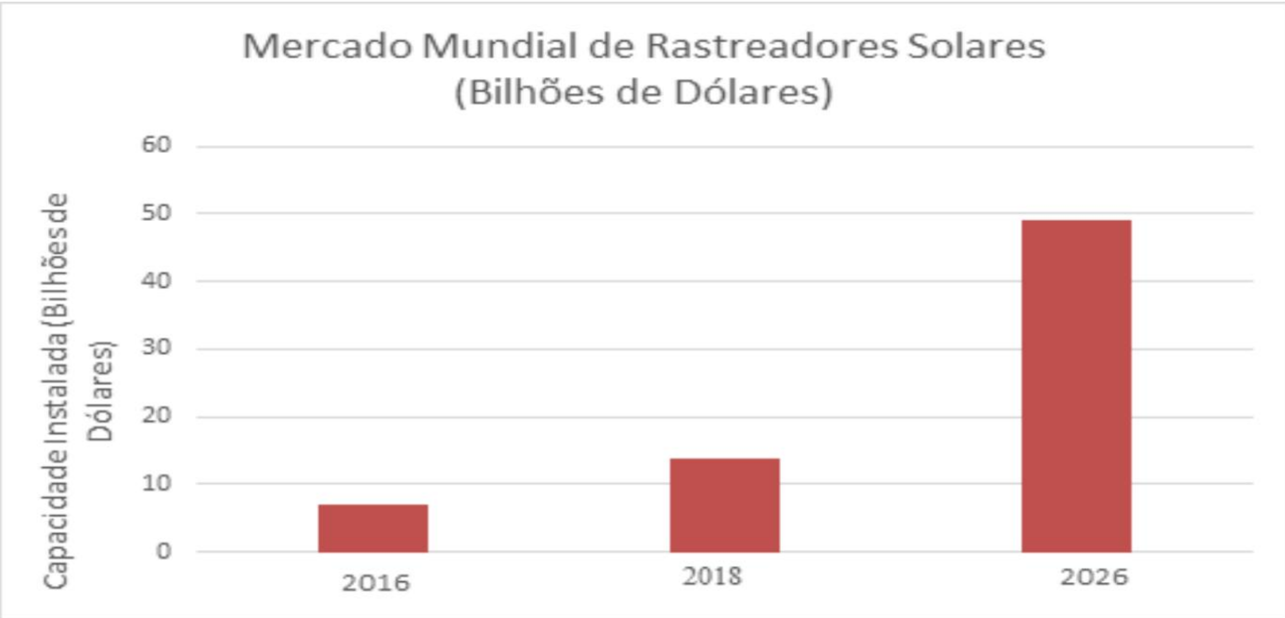

Figure 3 – Global Solar Tracker Market (Billions of Dollars)

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Source: Prepared by the author using data from GMI (2017) and REPORTS AND DATAS (2019).

Taking into account all the countries in the Americas, the continent is responsible for more half of the global demand for trackers in 2018 (PV MAGAZINE, 2019). However, dividing it into North America and South America and comparing it to other regions, Europe... makes it the dominant player in the market, with 38.32% (REPORTS AND DATAS, 2019). In 2015, the region was responsible for 36% of the world's installed capacity of solar trackers, with Spain and Germany as a key player, countries where there is a large presence of tracking manufacturers (GVR, 2016).

Single-axis trackers dominated the global market in 2018 with 54.81%. (REPORTS AND DATAS, 2019). However, this dominance has been decreasing over time, in This is due to the reduced cost and increased reliability of dual-axle technology. In 2015, the Single axles occupied 60% of the market, reducing to the aforementioned value in 2018. Following this According to the trend, a total installed capacity of dual-axis trackers of 9.6 is projected for 2023. GW (GMI, 2016).

Solar trackers are primarily used in the following sectors: utilities (power generation, transportation, distribution and marketing of energy and water); commercial; and residential. Figure 4 presents the proportion of resources invested by sector in North America in 2016, with also A forecast for 2024. Although it has decreased in recent years, more than half of The market for tracking devices has always been linked to the utilities sector. In 2015, it represented 85%. (GVR, 2016); 80% in 2016 (GMI, 2017); and in 2018, it reduced to 68.88% (REPORTS AND DATES, 2019).

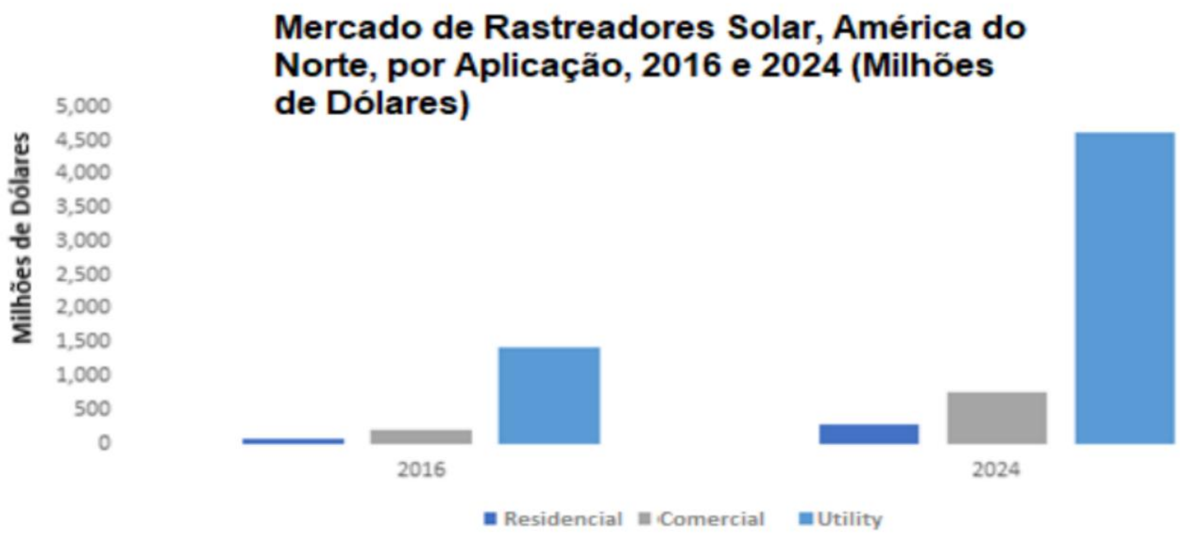

Figure 4 – Solar Tracker Market in North America, by Application, in 2016 and forecast for 2024, in Millions of Dollars.

Source: GMI (2017).

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Solar trackers are used in three main types of solar technologies: Photovoltaics (PV), concentrated power plant (CSP), and concentrated photovoltaics (PCV). According to According to 2018 data, approximately 40% of the tracker market belonged to the photovoltaic sector. (REPORTS AND DATAS, 2019). From the graph in Figure 5, it is possible to analyze the distribution in Types of technology across the study regions.

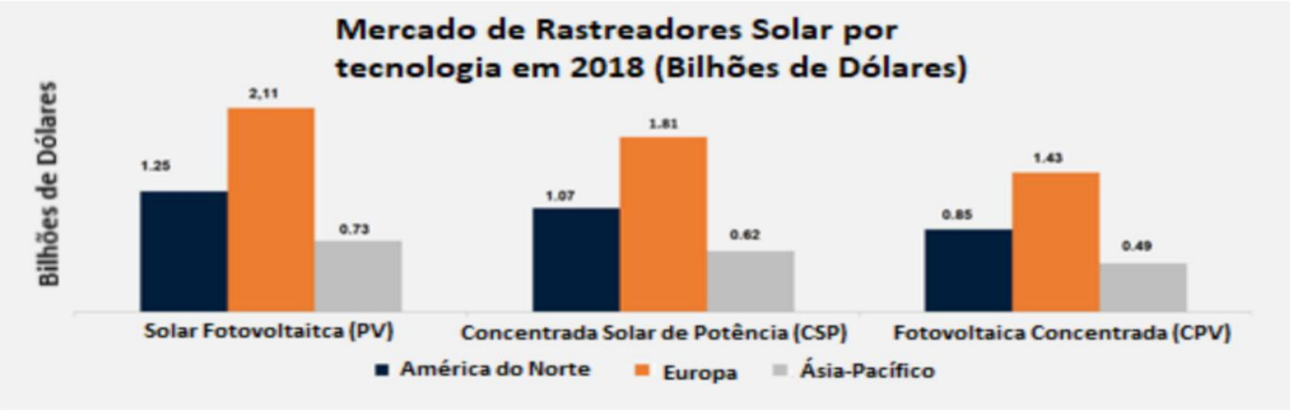

Figure 5 – Solar Tracker Market by Technology in 2018, in Billions of Dollars.

Source: REPORTS AND DATAS (2019).

4.2 DOMESTIC MARKET

The main data used to understand the Brazilian market are those from auctions of Solar photovoltaic energy in the Regulated Contracting Environment (ACR). The first auction took place in 2014. This section will analyze data from the winning projects of the following auctions: 1st Reserve Energy Auction of 2014 (LER/2014); 1st Reserve Energy Auction of 2015 (1st LER/2015); 2nd Reserve Energy Auction of 2015 (2nd LER/2015); A4 Auction of 2017 (A4-2017); and Auction A4 of 2018 (A4-2018). The references for this section were: EPE (2014), EPE (2015), EPE (2016), EPE (2017) and EPE (2018).

Between 2014 and 2018, Brazil installed just over 4 GW of solar photovoltaic energy. ACR, of which slightly more than 3 GW are systems with solar trackers. In all of them In auctions, the tracking system adopted is the single east-west axis system. According to the graph of Figure 6 shows that the only auction in which trackers did not predominate was LER/2014, in which, of the Of the 31 projects, only 10 used the technology.

In general, solar-tracked power plants have a higher cost than those with solar tracking. installed with fixed panels. For example, the average price of developments with trackers. In the first LER/2015, the cost was R$ 4,160/kWp; in contrast, for a fixed system, the value was R$ 3,572/kWp. However, the increase in the Capacity Factor (CF) of the plants provided by

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Tracking the Sun drives the use of technology. A comparison between the FCs for the

The number of projects with fixed panels and those with trackers is shown in the graph in Figure 7.

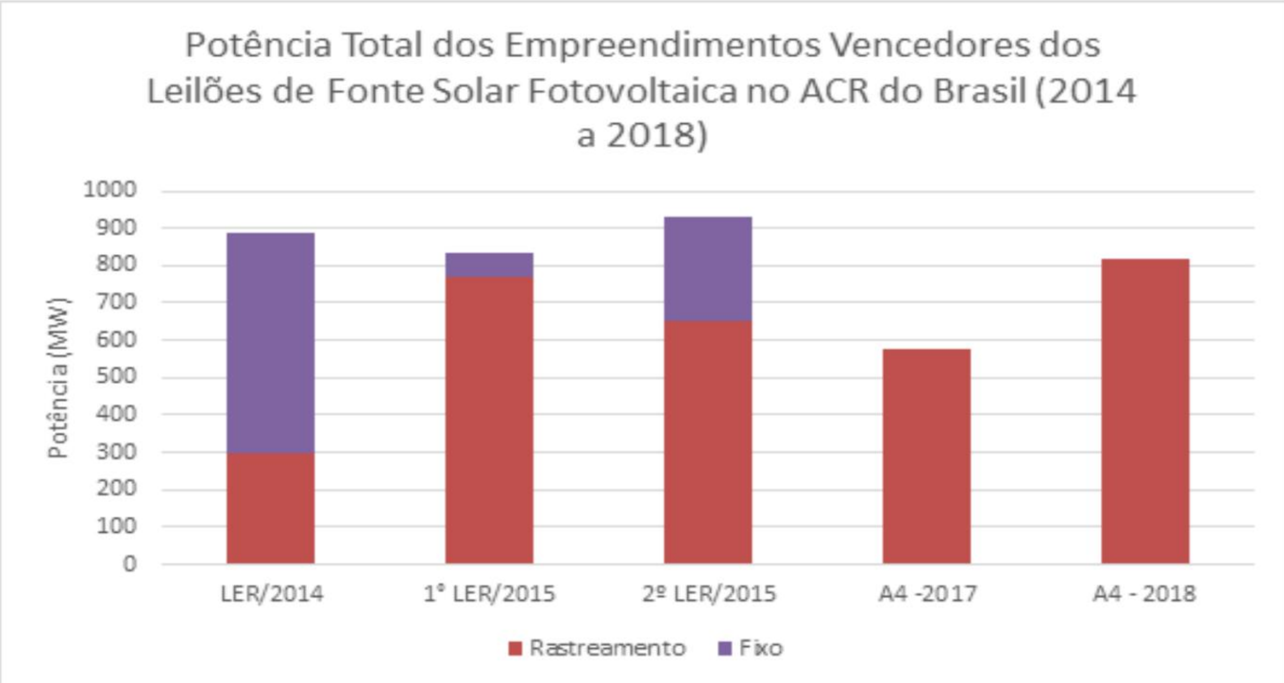

Figure 6 – Total Power of the Winning Projects in the Photovoltaic Solar Energy Auctions in the ACR of Brazil (2014 to 2018).

Source: Prepared by the author using data from EPE (2014), EPE (2015), EPE (2016), EPE (2017) and EPE (2018).

[Equation]

Figure 7 – Average Capacity Factors for the Winning Projects in the Auctions of Solar Photovoltaic Energy in the Brazilian ACR (2014 to 2018)

Source: Prepared by the author using data from EPE (2014), EPE (2015), EPE (2016), EPE (2017) and EPE (2018).

FINAL CONSIDERATIONS

Analysis of the presented data shows that solar trackers are no longer a experimental technology to become a dominant standard in the modern photovoltaic industry. From the development of the first active tracking device in 1975 to its current massive adoption, the The technology has proven its technical and economic viability.

In the Brazilian context, the predominance of single-axle trackers in ACR auctions, especially after 2014, it demonstrates that the gain in the capacity factor — and consequently in Power generation — offsets the higher capital expenditure (CAPEX) compared to fixed systems. The global expansion trend, coupled with the maturity of the supply chain and

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Global manufacturers point to a scenario where optimizing solar irradiance capture will be...

mandatory for the competitiveness of new centralized generation projects.

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