

Technological and marketing evaluation of solar panel cleaning robots



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ABSTRACT

This article aims to analyze the degree of innovation and viability of technologies that use autonomous robots to clean photovoltaic panels, also known as solar panels. How do they work and what would be the relevance of these features in tropical countries like Brazil? The current scenario is one of

protagonism for the so-called energy transitions, that is, new ways of using energy aiming at independence from the use of non-renewable sources, such as fossil fuels (oil, coal and natural gas). As a result, there is a gradual increase in investment in technological development sectors that enable renewable sources (solar, wind, hydroelectric, geothermal and biomass), even in countries like Brazil that are still late in the transition. The present study analyzes a specific technology to improve the functioning of photovoltaic panels with the use of autonomous cleaning robots that do not use too much force or pressure that harms the anti-reflective surface of the panels. This is a type of innovation that has been increasingly discussed in the Brazilian scenario, as it improves product lines that are still in the market absorption phase. Therefore, the study analyzes a patent on autonomous robots that perform cleaning functions without the use of water. The study investigates whether these products are viable technology in the Brazilian market. We also seek to analyze the technological transfer of protected or unprotected assets as an internationalization strategy.

Keywords: Energy transition, Autonomous robots and solar panels.

1 INTRODUCTION

Although the use of photovoltaic energy has been a technological branch known since the mid-1950s, there has been a radical advance in the last two decades, including as a result of government policy incentives motivated by the generation of positive scientific impact on the environment. The excessive increase in the emission of harmful substances has boosted investment in research, development and innovation (RD&I) in these strategic sectors, for what has been called the energy transition for some years. However, a scenario receptive to the use of renewable energy is not enough without there being a policy that provides subsidies for the entry of new actors capable of accelerating change. (MONTEIRO; SILVEIRA, 2018).



In 2022, according to the Energy Research Company's annual report, the use of renewable energy in Brazil grew by more than 7% in commerce and industry. With this, it is clear that Brazil, which is also late to the challenge of transition, shows clear signs of changes in cultural paradigms. (EPE, 2023).

In terms of the effectiveness of public policies, public management, which acts very often motivated by imposed contingencies, must become accustomed to the importance of diagnoses that attest to evolution or maturity in the face of these challenges. It is called a type of “fundamental uncertainty” that constitutes the basis of innovation in a public organizational environment. (MAZZUCATO, 2018).

The energy transition is, therefore, a process of readjusting the productive, technological and economic methods that involve a society's energy matrix for the use of sources based on fossil fuels and pollutants for forms of clean energy obtaining, that is, modes sustainable and renewable. The objective of the transition is to reduce productive dependence on so-called fossil fuels, mitigating climate anomalies and air and water pollution, thus promoting the responsible use of energy resources.

In the Brazilian context, considering that insolation rates are higher than those seen in countries with a more advanced history in terms of energy transition and commercialization of photovoltaic technologies, such as in the USA and China, it is inferred that the moment current market is one of intense scalability and market potential. (INPE, 2023).

Considering this latent potential of the Brazilian market for receiving knowledge and renewable energy technologies, with policies to reduce import costs for manufacturing commodities, it is known that, however, the estimated use of this type of source has already been for more than a decade it is still restricted to rates of 0.5%. It is inferred that a large part of this is due to the high cost of products which, although they promise savings in the short and medium term, still boast very high values in relation to so-called traditional product lines. (TIMILSINA et al, 2012).

One of the most common ways to use sustainable energy is through solar panels or photovoltaic modules, that is, electronic devices made up of cells that convert solar energy into electricity. In addition to the positive effects in terms of environmental impacts, the use of solar panels represents financial savings in the short or medium term, depending on the structure equipped.

This form of energy generation using solar panels is subject to climatic and humidity conditions in the environment in which they are installed. In parallel with the technological advancement of the matrix of this type of product, it is also observed that there is the promotion of innovations in areas considered accessory, such as cleaning solutions that can be applied to panels with the aim of reducing productivity losses caused by dirt. (GAIO and CAMPOS. 2017).

Emerging cleaning methods represent an innovative approach to maintaining the efficiency of photovoltaic panels while reducing costs associated with water and labor usage. The high cost of these



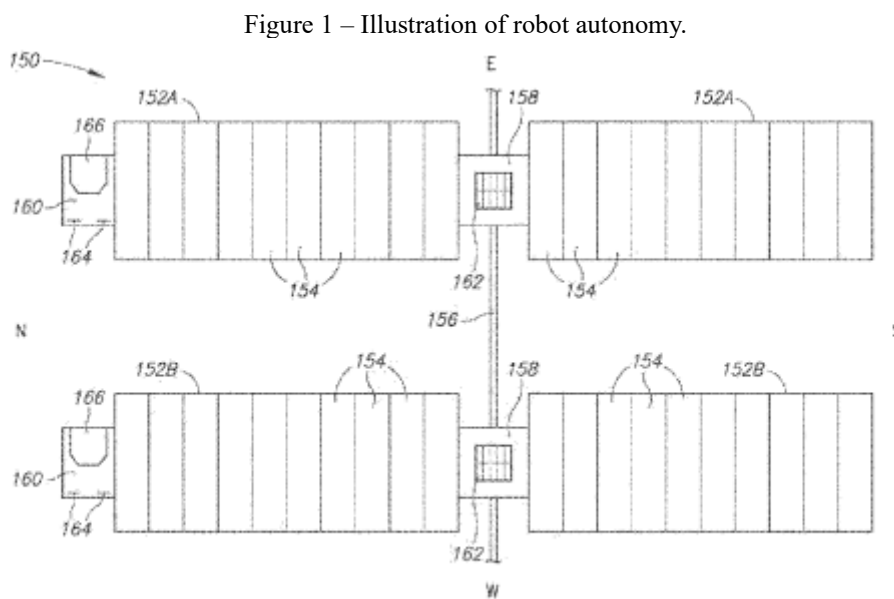
resources in automated cleaning can be a significant obstacle, making the search for cleaning alternatives imperative (Idem, 2017).

Therefore, this scientific article proposes to analyze a patent-protected technology called “waterless cleaning system and method for solar trackers using an autonomous robot”, registration US 10,985,691 B1. (MELLER; MELLER, 2021).

It is a waterless cleaning system that cleans solar panels and can be positioned at a pre-determined angle, including a docking station and an autonomous robotic cleaner (ARC). According to the patent description, the docking station is attached to a solar tracker and the ARC has a rechargeable power source, with at least one cleaning cylinder and a controller.

The cleaning cylinder has a set of fins that rotate to generate a directional airflow, pushing dirt from the surface of the solar tracker without using water. The controller includes a motion sensor to determine the angle of the solar tracker and the direction of the ARC. The docking station includes at least one electrical connector for recharging the rechargeable power source. (Idem, 2021).

The controller controls the ARC cleaning process and transmits and receives signals to and from the ARC, as shown in the following figure:



Authorship: MELLER; MELLER, 2021.

The aim of this study is to draw up a comparison between the data obtained by the patent and the Brazilian and international market reality, analyzing TT as a tool for the internationalization of accessory energy technologies.

A SWOT matrix was also prepared with a view to possible asset negotiations in this specific renewable energy sector.



It is also intended to approach notions of administrative efficiency and consistent public policies that allow the formation of institutional cooperation and collaboration partnerships with knowledge acquired in a market dominated by foreign entities in relation to Brazil, in allusion to the institutionalist theory that underpins the actions of government entities. (NORTH, 1990).

2 METHODOLOGY

This article is an exploratory and descriptive research that intends to analyze the patent entitled WATERLESS CLEANING SYSTEM AND METHOD FOR SOLAR TRACKERS USING AN AUTONOMOUS ROBOT, registration number US 10,985,691 B1. The article also carried out technological prospecting, adopting the WIPO Patent Scope, National Institute of Industrial Property (brazilian patente office) and Google Patents platforms as a research base. A bibliographical study and the elaboration of a SWOT matrix were also adopted to diagnose the current market scenario.

3 RESULTS AND DISCUSSIONS

3.1 PROSPECTING ON A WIPO BASIS

As a research strategy, the work starts from market prospecting that infers the relevance of solar panels in Brazilian patent protections. Therefore, initially taking the data obtained from INPI (brazilian patente office) as a reference, the following results were found using the “title” search strategy:

Table 1 – Search with Boolean operators on the Patentscope platform.

TERMS AND OPERATORS	RESULTS
AND solar panels	53
Panel AND solar	125
Energy AND solar	590
Energy AND solar AND robot	0
Energy AND solar AND cleaning	0
(Panel OR Panels) AND (solar OR solar)	501
Panel* AND solar*	534

Source: own authorship.

It can be seen, according to the aforementioned research, that there is a feasible hypothesis of absence or little demand for robots and solar panels in Brazilian patent protections. This fact alone does not allow the adoption of conclusions, but it serves as an initial guideline to consider whether there is a lack of interest or viability in the country, due to its climatic conditions or any other market contingencies, or whether there is no interest from a generally, that is, by market demand or scientific impulse.

To this end, it was decided to extrapolate the sampling spectrum to data on the WIPO platform, presenting the following results:



Table 2 – Search with Boolean operators on the Patentscope platform.

TERMS AND OPERATORS	RESULTS
<i>Solar energy</i>	207.249
<i>Solar energy AND robot</i>	826
<i>Solar energy AND cleaning</i>	7.541

Source: own authorship.

Given the WIPO results, it can be inferred that there may be demand yet to be explored in the Brazilian scenario, given that the use of robots may be something less common for photovoltaic panels as an accessory technology or with little relevance in cultural reception, when compared with other forms of technologies that address other panel structures or functions.

3.2 MARKETING ANALYSIS

With the gradual increase in resources used in RD&I in the area of energy transition in Brazil, greater maturity can be seen in negotiations involving technology transfer, that is, recipients are increasingly demanding. In this sense, considering the still incipient absorption of product lines of this nature by the Brazilian population, it can be said that the use of autonomous robots in our reality is a solution that may have difficulty in terms of MVP (minimum viable product).

The development of more efficient and longer-lasting semiconductor materials, such as monocrystalline and polycrystalline silicon solar cells, which convert a greater proportion of sunlight into electricity. Thin-film solar panels, such as cadmium telluride (CdTe) and CIGS (copper, indium, gallium and selenium), have been improved and become more efficient. These coatings are lighter and more flexible compared to traditional silicon cells, and their solar concentrating systems use lenses or mirrors to concentrate sunlight with high efficiency, especially in large-scale applications. (MELLER; MELLER, 2021)

Improved design and engineering techniques have led to reduced thermal losses, increased resistance to the elements and better absorption of sunlight. Some solar panels incorporate cooling technologies to maintain cell temperatures at optimal levels, which improves efficiency. RD&I also focused on disruptive technologies, such as organic solar cells, perovskite solar cells and other innovations that have the potential to overcome the efficiency limits of conventional technologies. (Idem, 2021).

These advances have resulted in solar panels that produce more electricity from the same amount of sunlight. Most modern solar panels generally have efficiencies ranging from 15% to 22% or even higher, depending on the type and quality of the panels. This means they can generate more energy with less space and therefore offer a better return on investment.

Additionally, these improvements make solar energy more affordable and attractive as a sustainable energy source. (ASSUNÇÃO, SCHUTZE, 2017). In Brazil, it appears that there is an



abundance of raw materials necessary for the production of silicon for the manufacture of photovoltaic cells.

Regarding panel maintenance, it is noted that the process described in the analyzed patent is relatively simple. Periodically, they should be cleaned to remove dirt and dust that could affect performance. Additionally, the electrical components of the solar system must be checked regularly to ensure they are functioning properly.

The formation of pills affects how pain works. Have no doubts about that. Note that on average 10% of pain performance is compromised by nutrition accumulation. The shape of the limpet should vary greatly according to the structure of the pain, as well as local climatic conditions and other factors. The autonomy of robots must be adjusted to these factors. (BLASQUES, PINHO, 2007).

For example, the impact of direct or diffuse radiation on the surface (Albedo) must be considered. (VILALVA, 2014). For this purpose, only for cleaning, however, given the autonomy of the product it is not necessary to consider so many variations in terms of efficiency of the device, it is still highly recommended, from a marketing point of view, that the product can take on new functions that facilitate simple removal damage, so it is possible to diagnose the plates and also suggest the appropriate solution for the irregularities found.

To this end, there is a vast plurality of types of cleaning robots on the market. It turns out that many of these robots, especially older ones, can operate in a way that impairs the functioning of the panel. Some exert pressure inappropriately, or compromise the functioning of anti-reflective surfaces. There are also robots that are not sufficiently autonomous, as they require constant operation from the user.

It must be considered that cleaning solar panels, in a residential or industrial environment, involves a certain complexity due to difficult access, therefore, the use of robots, especially in an industrial environment, depending on their degree of autonomy, can actually be attractive. That is, there is apparently a demand.

Some robots need a water supply to perform their cleaning function, so robots with autonomy have been developed, including in relation to the use of water. The question is whether in fact, as presented in the patent, in a large-scale environment such as an industry, the operation of robots will respond satisfactorily in relation to traditional cleaning methods.

Although such robots may not have immediate appeal in the Brazilian scenario, which is still considered to be of low maturity and absorption of photovoltaic technologies, the possibility of technological transfer to countries with more heated markets is suggested, through international patent deposits (patent cooperation treaty). In this sense, the following model SWOT is suggested for managers of these assets:



SWOT

	STRENGTH & OPPORTUNITIE	WEAKNESS AND TREATH
INTERNAL	Energy transition politics Natural resources Tax breaks Intellectual Property	Lack of maturity High prices Excess resources
EXTERNAL	Internationalization Technological Transfer RD&I advantages	Competition Autonomy of robots in products with integrated systems

4 CONCLUSION

According to this research, it is understood that the efficiency of technology as a minimally viable product depends on guaranteeing the autonomy of robots in relation to human maintenance considered to be recurring. That is, it appears that not just for cleaning, but there is an evident demand for autonomy in general.

There is an endless range of possibilities that involve the use of other types of robots and even artificial intelligence, thus creating a completely independent system for generating photovoltaic energy.

Cleaning would be, in this context, a basic test or step in terms of generating autonomy. And at this point, the article then analyzed whether there is viability in the Brazilian market, and, in the absence of demand, the internationalization of know-how or assets protected through patents is suggested. These possible inventions must take as a reference the maximum nullification of human action.

Not only as a possibility, but also as a profitable strategy in terms of MVP. It is estimated that the price for cleaning panels by human beings hired through outsourcing is quite high, reaching an average of R\$50.00 (fifty reais) per panel in many cases. In a country like Brazil, considering the rainfall rate and the fact that the energy transition is still in initial stages, accessory technologies, normally coming from foreign organizations that have exhausted their products in their respective countries of origin, it is possible that there will still be resistance cultural in the reception of this knowledge.



It is known, however, that it is merely a matter of time, especially in the industrial reality, for efficient supply and demand management to prioritize ways of saving resources in these renewable energy sectors, such as with the use of autonomous robots for cleaning them.

Even though the asset manager of this specific line does not hold a patent for the mechanisms, the mere internalization of knowledge or practices from countries whose transition is at a more advanced stage can be considered innovation with high value generation and also with a positive economic and socio-environmental impact.

5 FUTURES PERSPECTIVES

The work shows that there is, as expected, a growing demand in the renewable energy sector, and it is certain that the use of autonomous robots, like other techniques that improve the use of this type of technology, is equally useful.

It turns out that, given the incipient situation of the current Brazilian market, which is still resistant to the adoption of methods considered traditional, it is therefore suggested, for managers of this type of advisory asset, in terms of MPV, the possibility of technological transfer to countries strategic.

There is also discussion about this specific type of technology, about the degree of autonomy of the robots, how much this impacts the price of the final product and also the degree of reception in a tropical country which, except in atypical years like the current one, presents satisfactory rainfall levels. Climate change will certainly influence the relevance of this type of accessory product, in fact, to the extent that, through assertive public policies, companies are able to implement sustainable assets into their product lines with greater market appeal.

There is still a high degree of uncertainty, both internally and externally, but one point is certain: The energy transition is an inevitable reality. In terms of intellectual property asset management and technological transfer, both in the asset discussed in this study and in similar situations, everything will depend on the way in which the products will be presented, that is, on prospecting.

Increasingly, we will see the offering of accessory lines, for example, in the present case of autonomous panel cleaning robots, as other complementary assets, and the basis of the energy transition has not yet been properly implemented in Brazil, although it is easily perceived a growing trend imposed by foreign institutions that have reached high levels of RD&I and commercialization in countries that are already mass in this sense. The future scenario is conducive to investment in intellectual property and technology (TT and IP), as long as it is carefully planned.



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