

CLEANER PRODUCTION PRINCIPLES APPLIED TO THE PORT LOGISTICS SECTOR

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Abstract. *Much of the energy currently consumed in the industrial sector comes from non-renewable sources, such as oil, natural gas and coal. These, when used, contribute to the formation of greenhouse gases (GHG), which turns out to pollute the atmosphere and contribute to global warming. The use of solar energy as an alternative source for power generation has been increasingly used, and it is even being applied as a way to reduce operating costs within companies. The geographical location, relief, and climate of the State of Bahia are favorable for the generation of solar energy. In the first months of 2022, Bahia was responsible for approximately 1/3 of the country's solar energy generation. Company "K", which is located in the port of Aratu/BA, operates in the segment of mining, processing, and beneficiation of materials derived from magnesium oxide. The company performs logistics operations of cargo reception, storage and transport of the raw material for export. In this context, this work is based on the concepts of Cleaner Production (CP), using descriptive and exploratory research, applied to the sector of handling, transport, reception, storage and shipping of the product at the port in Aratu. Data collection was carried out, followed by subsequent analysis of the indicators that created the basis for the goals intended for the CP implementation proposal, aiming at environmental management, an opportunity for reduction in electric power consumption, related to the change of technology, as the objective of this work. From the application of the concepts of CP in the area of loading and storage at the Port of Aratu, it is expected that there will be an improvement in processes, and it is foreseen not only the reduction of consumption in electricity but also provide operational and economic gains, in addition to improving the image in front of the market in relation to environmental management and quality.*

Keywords: *Cleaner Production; Solar Energy; Environmental Management; Energy and Sustainability*

1. INTRODUCTION

The process of economic development is usually accompanied by an increase in the use of fuels. The search for clean and renewable energy has been a reality among countries and companies since the current energy matrixes in use do not support the demand. It is notorious for the growing concern with the environment, and solar energy gains notability, considering that it is part of the clean and renewable energy. Energy sources are one of the main influential vectors in environmental interference, their facilities compromise directly with the dynamics of biotics such as hydro power, petrochemical platforms, geothermal energy and natural gas (Silva, 2022).

The Brazilian electrical system, according to data from the National Agency for Electrical Energy (ANEEL), is driven by generation from various matrixes. The current total installed power in operation in Brazil is 182,974.2 MW, and of this total in operation, more than 83% of the plants are driven by sources considered sustainable, with low greenhouse gas emissions (ANEEL, 2022).

The use of energy by businesses in various sectors, its cost, and consumption has been increasing in recent years. Solar energy is among these sources as an option for businesses to generate their own energy. The future of solar energy tends to be favored by increasing global pressures for the use of renewable and clean energy sources and the continuous search for diversification of energy supply sources. This scenario should prevail in the upcoming years and solar energy should be considered as a relevant energy alternative for Brazil. (Marques, 2014).

The Earth receives from the sun the energy of about 10 billion Itaipus (Stensmann, 2023). Brazil has a favorable location for solar energy generation. It lies geographically in the tropics, which are considered to have a high energy potential. High rates of direct surface solar irradiation occur over much of Northeast Brazil and are the main requirement for the viability of this generation technology.

The change to a vision of sustainability based on the three pillars of ECO-EFFICIENCY: environmental, economic, and social, for a company or a process to be valid being environmentally compatible, economically profitable, and socially fair, implies the adoption of management models that identify the causes of environmental problems to avoid the need for corrective measures, reducing the impacts caused by these on the environment, enabling the definition of alternatives that are economically viable and that effectively contribute to improving the quality of life on Earth (Sadler, 1994).

The objective of this work was to evaluate, through the analysis of energy generation information indicators in Brazil, the electric energy consumption of Company "K" in its magnesium oxide loading area, at the port terminal in Aratu/BA, to elaborate a proposal for a CP program, demonstrating the viability of the project for the company and others in the industrial sector in the region.

2. LITERATURE REVIEW

2.1. Brazil's Solar Potential

Knowledge about the potential of the solar resource incident on the surface is essential, but not sufficient to drive the use of this energy source. The variability of the solar resource has impacts on technical aspects of the quality and safety of the electricity system. Thus, in addition to the available potential, reliable information about the variability of the solar resource is essential to support the development of projects for the use of this energy source (Pereira *et al.* 2017).

According to data from the National Electric Energy Agency (ANEEL, 2022), 83% of the energy currently consumed in Brazil is generated by sustainable sources, as shown in Figure 1.

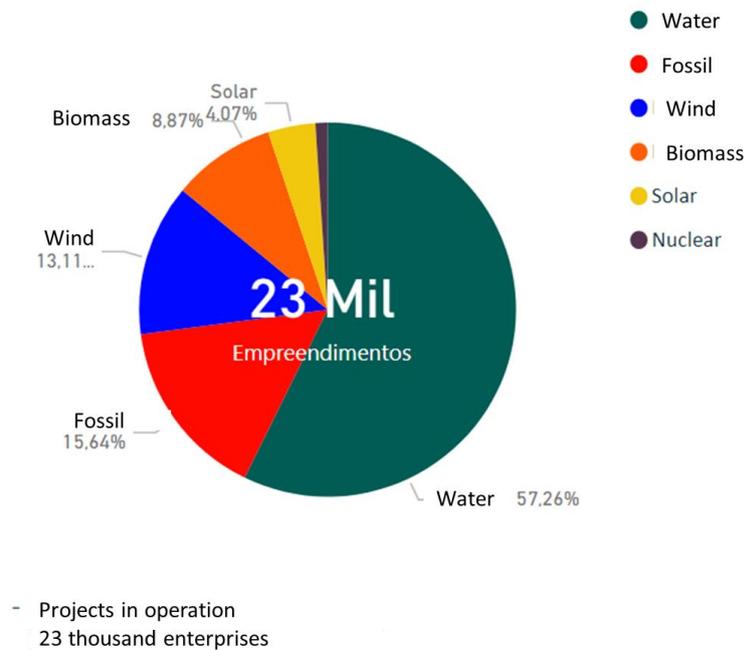


Figure 1 - Electricity matrix by fuel origin
(ANEEL, 2023)

The Northeast of Brazil has the highest rates of solar radiation in the country, which makes it a place of great potential for energy production through the sun's rays. It also presents greater stability in the production of solar energy throughout the year in all seasons (Pereira *et al.*, 2017).

For Rosa (2016) solar energy stands out in indications of energy sources for diversification of the energy matrix in the country, mainly because of the existing potential little used, but public policies for dissemination of the source could help in the diversification of the energy matrix.

After the ANEEL Normative Resolution No. 482/2012, there was a search for information about the generation of energy by the consumer, since the normative indicates that the user can generate their electricity from renewable sources or qualified cogeneration and even supply the surplus to the distribution network of their locality.

Photovoltaic solar energy is obtained by converting solar radiation into electricity through semiconductor materials. The photovoltaic solar modules are manufactured from silicon (Si) and can consist of monocrystalline, polycrystalline, or amorphous silicon crystals. When sunlight strikes a photovoltaic cell, it produces a small electric current. This current is collected by wires connected to the cell, and transferred to the other components of the system, so the more photovoltaic cells are connected in series or in parallel, the higher the current and voltage produced (Pereira *et al.*, 2017).

2.2. Cleaner Production

The Cleaner Production methodology is the result of a joint effort of UNIDO (United Nations Industrial Development Organization) and UNEP (United Nations Environment Programme), on waste management and energy and material waste (Kiperstok *et al.*, 2002). In general, the process of implementing CP follows the flow, as shown in Figure 2:

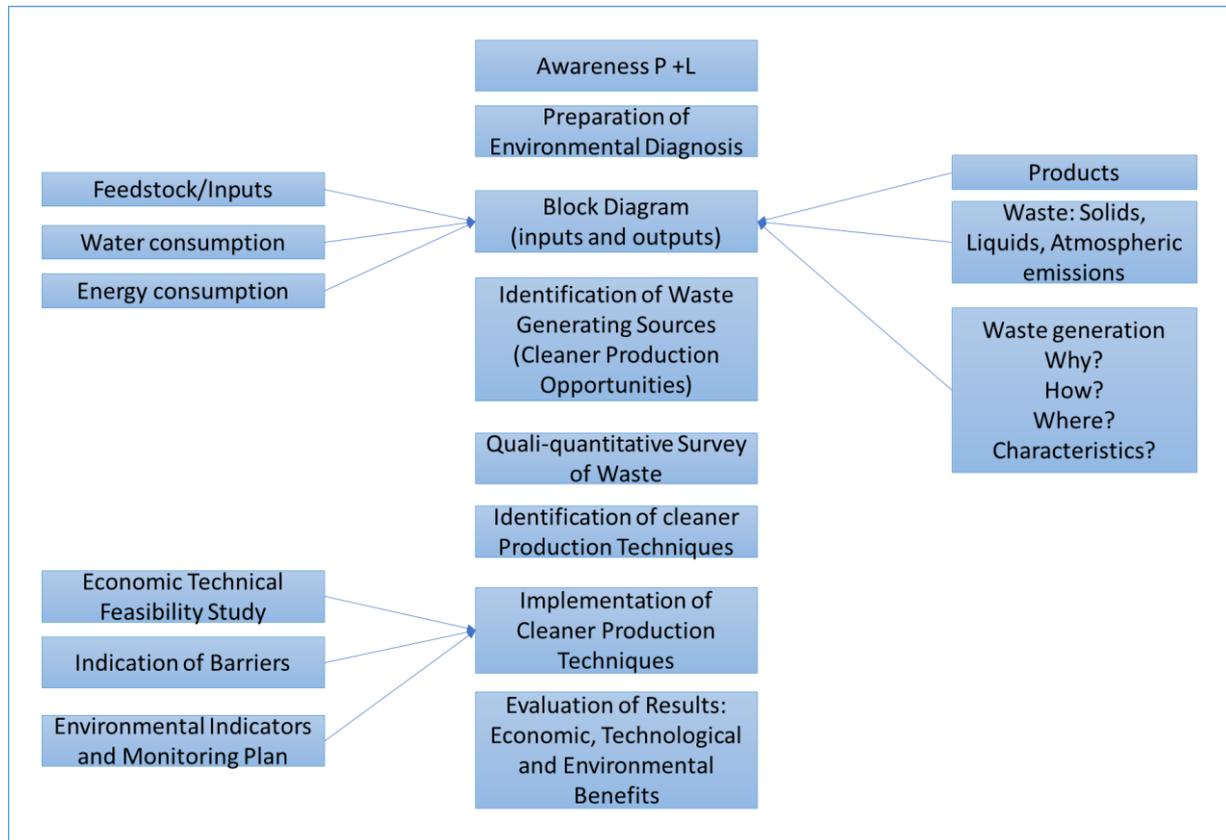


Figure 2 - Flowchart of Cleaner Production implementation - UNIDO/UNEP Methodology
 (CNTL, 2000)

Figure 3 presents the levels of efficiency of application and is a flowchart of the CP, to be implemented by integrating the production processes and the product in companies, to increase productivity, decrease the use of resources, raw materials, water and energy, non-generation, minimization or recycling of waste generated in their activities.

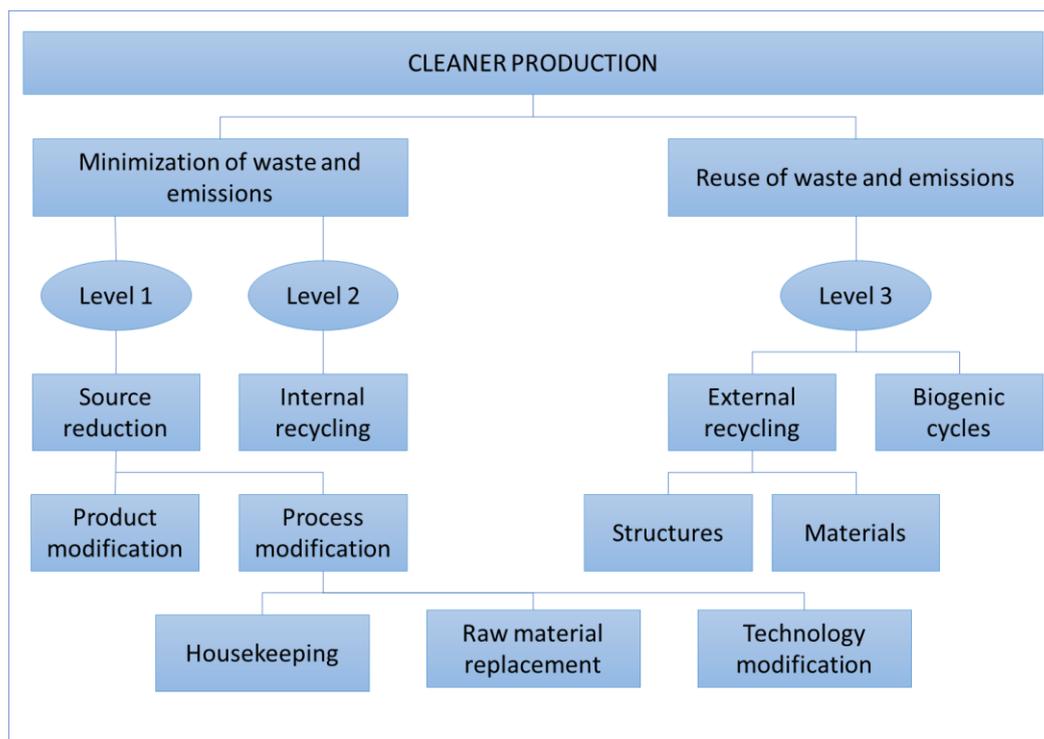


Figure 3 - Cleaner Production Organizational Chart (CNTL, 2000)

Business strategies, which until then were limited to the economic issue, such as competitiveness, efficiency, profitability, etc., began to introduce their concerns the environmental variable, becoming then vital to incorporate it into production processes (Silva, 2015). This led to the need for changes in the management and organizational structure, reorienting objectives and goals, and aiming the internalization of environmental issues in management models (Piotto, 2003; Radonjic & Tominc, 2007; Severo & Olea, 2010).

2.3. Statistic Process Control

Statistical process control (SPC) is accomplished through control charts, used to monitor the performance of a process from the definition of a control range. Studies developed by Walter Andrew Shewhart, between the 1920s and 1930s, in the United States, at the Bell Telephone Laboratories company resulted from the industrial application, analysis, measurements, and control charts. The control chart is used to analyze trends and patterns that happen over time (Montgomery, 2016). It is composed of a center line (LC) that represents the mean value of the quality characteristic corresponding to the process situation under control and a pair of control limits: one located below the center line - lower control limit (LIC) and, the other above the center line - upper control limit (OSL).

Control charts can be classified into two types: for variables and attributes. Control charts for attributes refer to quality characteristics that classify conforming and nonconforming items. Control charts for variables, on the other hand, express quality characteristics on a continuous scale.

Ribeiro (2012) argues that SPC enables the increase of process capacity, reduces scrap and rework, and, consequently, the cost of poor quality, providing companies with the basis for improving the quality of products and services.

3. METHODOLOGY

The storage facilities of the Port of Aratu, located in the municipality of Candeias/BA, are composed of warehouses, patios, tanks and silos. These installations are leased to private companies, except for the solid bulk yard, which is public and is explored by the Companhia das Docas do Estado da Bahia (CODEBA). Company "K" has a leased warehouse in a public port area, where it operates solid bulk cargoes, resulting from the sintering of magnesium oxide. The solar irradiation index data from the Sérgio Brito Center for Solar and Wind Energy Reference (CRESESB) were used to evaluate the energy potential of the region. Data from the new electric energy generation matrices of the National Electric Energy Agency (ANEEL) were also used.

Cleaner Production is the methodology that proposes strategies to companies to avoid waste of raw materials and energy, waste of any nature, responsible for additional costs to production processes and generate environmental problems.

Statistical process control was used to determine the process variability and statistical analysis of the data, using the R software. The controllable variables were the system current/energy. The energy consumption data was collected through information from the energy provider (COELBA) for the period 2017 and 2021.

4. RESULTS AND DISCUSSIONS

4.1. Analysis of energy consumption in Company "K"

Company "K" currently uses the energy distribution system provided by the third largest electric energy distributor in the country in a number of clients and the sixth in the volume of energy distributed, the Companhia de Eletricidade do Estado da Bahia (Coelba).

Using the R software, the electric energy consumption (kWh) between the years 2017 and 2021 was evaluated through the Exponentially Weighted Moving Average (EWMA) control chart, as presented in Figure 4. This model was employed to estimate and predict the time series of the company's electric energy consumption, the object of this case study.

The Y axis represents the energy consumption (kWh) and the X axis represents the analyzed years, being "1", "13", "25", "37" and "49" representing respectively January 2017, 2018, 2019, 2020, and 2021.

The quartiles are the separatrixes that divide the set into 4 equal parts, to provide a better analysis of the set dispersion, symmetry or asymmetry of the distribution. The system values were: Q1 (first quartile – a value of the set that delimits the 25% smaller values) = 10,214, Q3 (third quartile – a value of the set that delimits the 75% larger values) = 17,735, median = 14,720, maximum = 28,144 and minimum = 4,911 and the average: 14,714, referring to the consumption of electricity (kWh) in Company "K" between 2017 and 2021.

It is also observed that four intervals were identified in which the electric consumption deviated from the control limits (highlighted in red, totaling 19 points), and these occurred between the years 2018 and 2020. These were identified as periods of lower (2018) or higher (2020) cargo handling intensity at the port logistics company (see Figure 4).

From each observed item, the EWMA Graph enabled the visualization of an exponential forecast (symbolized in the EWMA graph as "+") related to each observation, allowing the study of the situations that fit into a growth or decrease curve of electric energy consumption.

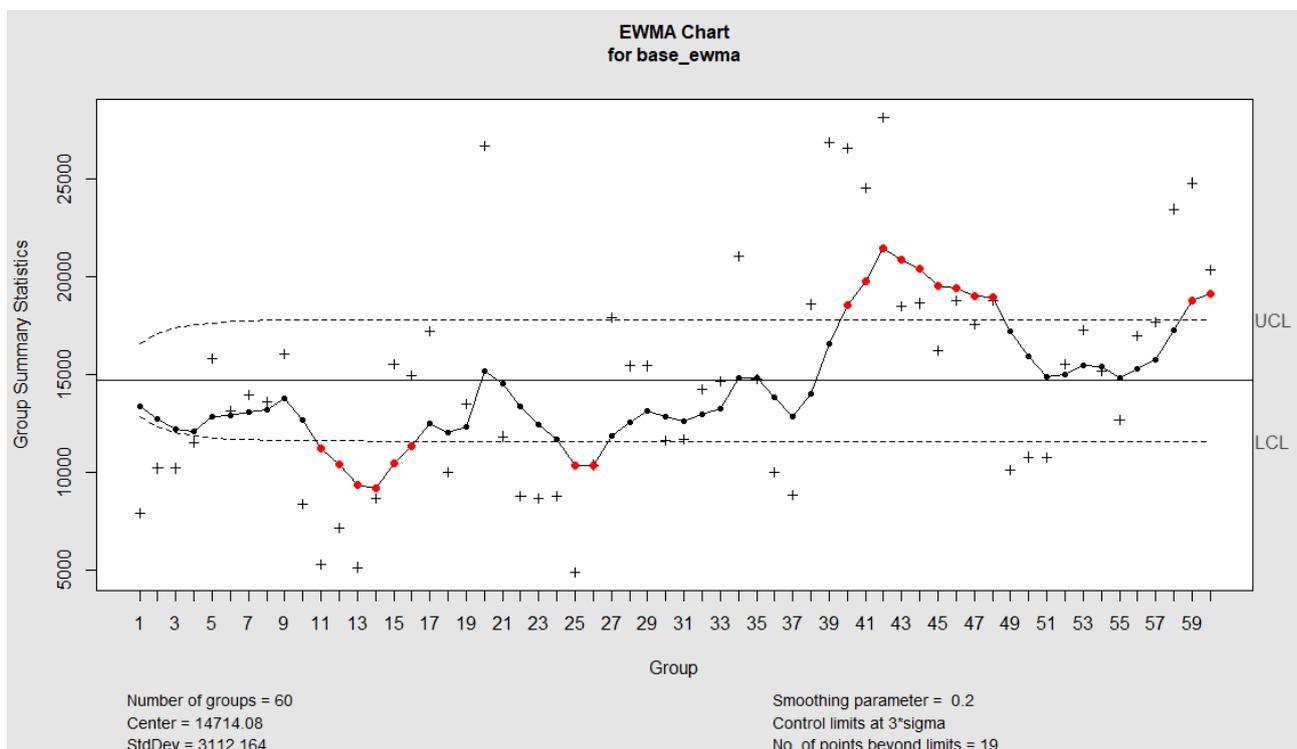


Figure 4 - EWMA chart of electric energy consumption (kWh) at Company "K" between 2017 and 2021 (Authors, 2022)

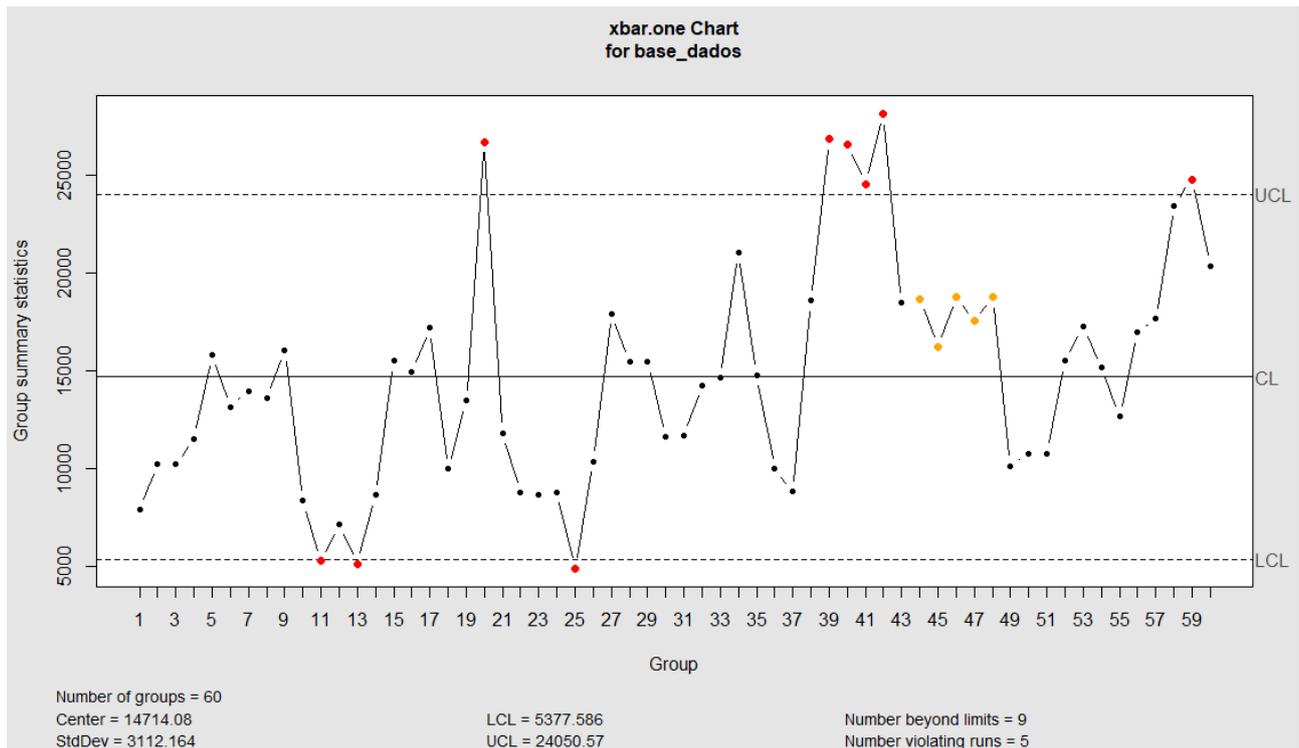


Figure 5 - Moving average chart (X-bar chart) of electric energy consumption (kWh) at Company "K" between 2017 and 2021 (Authors, 2022)

The Graph of individual values (X-bar one chart), Figure 5, was also prepared, being used for continuous or discrete quantitative variables, as identified in the case study situation, the evaluation of electric power consumption over time.

One can observe a correlation between electric power consumption (kWh) and the months of Aug/20 (x-44) to Dec/20 (x-48), identified in the chart by the yellow sign. During this period in Company "K" there was the closing of the four-months of the year in logistical operations, right after the resumption of activities after the COVID-19 pandemic.

Analyzing the EWMA control charts (Figure 4) and the of moving averages (Figure 5) one can observe a tendency for increase in energy consumption between the months of February and August of the years evaluated. Thus, it is possible to infer that during this interval there was a greater movement of cargo in the referred terminal, either via reception or export, since the reading is performed in a totalized way of the electrical equipment crowded in the structure.

4.2. Opportunity to implement CP applied to the port logistics sector

Figure 6 shows that among the new power plants installed in Brazil, there is a growing emphasis on the number of plants that use renewable sources, such as wind and solar energy, whose shares in 2021 would represent 49% and 17%, respectively, of the total installed power.

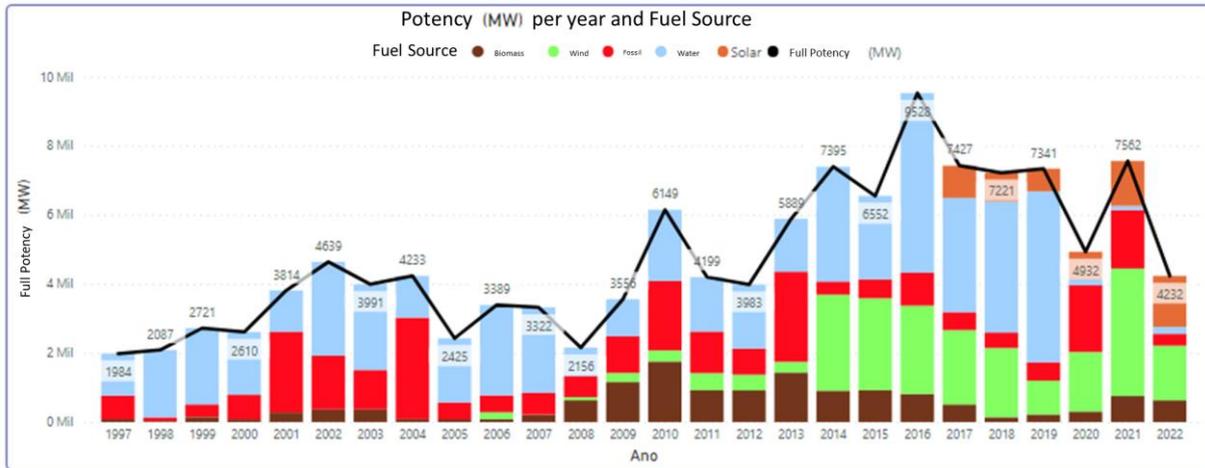


Figure 6 - Installed capacity of new power plants (MW) by year and fuel origin (ANEEL, 2022)

The use of energy from cleaner energy matrix sources contributes with less impact on nature, reduces electricity losses, optimizes the distribution network and makes consumers aware of more rational energy consumption (Cardoso, 2021). The Brazilian territory has reached the mark of 500,000 photovoltaic distributed generation (PVDG) consumer units. According to the Brazilian Association of Photovoltaic Solar Energy (ABSOLAR), adding the wind, thermal, hydraulic and solar sources, the country has more than 511 thousand UCs (Portalsolar, 2022).

Figure 7, shows the solar irradiation index and the monthly average, of the facilities of Company "K" located at the Aratu port terminal, in the municipality of Candeias/BA. Presenting an average monthly solar irradiation of 5.01 kWh/m².day.

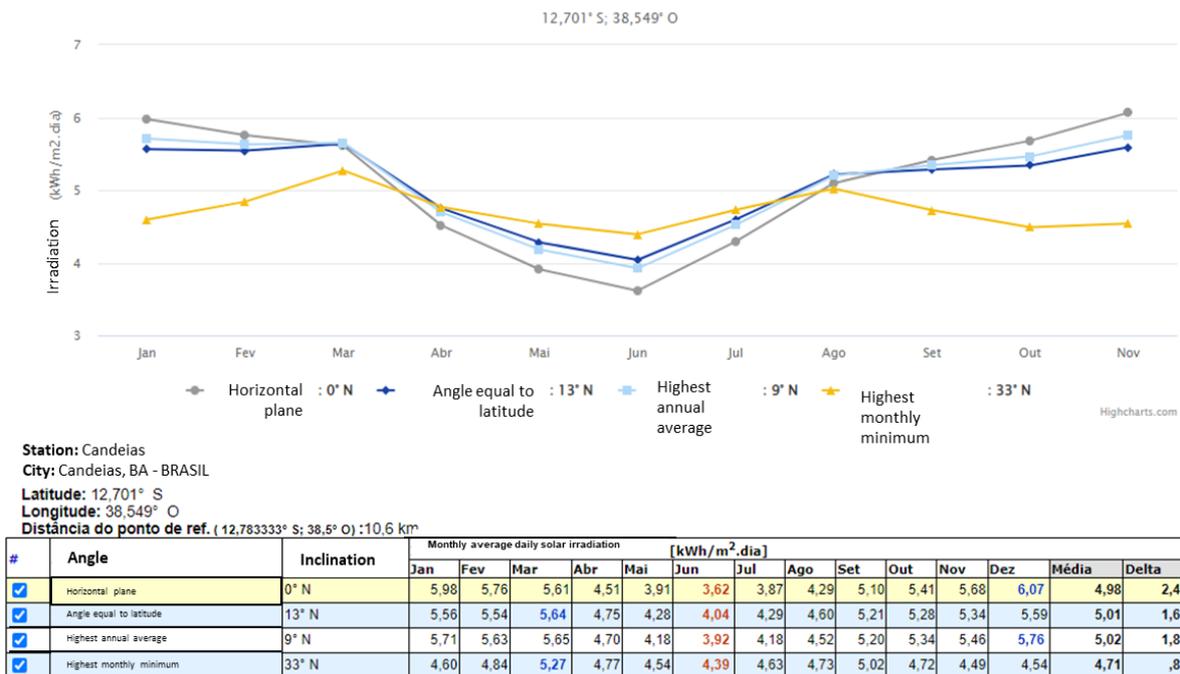


Figure 7 - Inclined plane solar irradiation (above) and monthly average daily solar irradiation (below) in Candeias/BA [kWh/m².day]. (CRESESB,2022)

Thus, through the analyses of this work, it is then suggested the application of the CP strategies related to Process Modification - Technology Change with the implementation of solar tube lighting. This type of technology enables the transfer of natural lighting to the interior of the unit, thus allowing energy savings.

In addition, it is also suggested the installation of a photovoltaic system for the use and conversion of solar energy into electricity, given the possibility of savings with the expense of electricity for Company "K" in the short term. It is also noteworthy that installations of the GDFV type have an estimated average useful life of 20 years, thus allowing the company to take advantage of this investment for a long period. Additionally, it was observed that the unit has a significant roof area available in the cargo storage area (about 5,000 m²).

The use of clean energy generation systems is recommended by the consumption trend that Company "K" has and also due to the opportunity to take advantage of the solar irradiation that the region has. Currently these have been some of the concerns of companies in different segments with respect to the scarcity of resources, alternative and sustainable sources for the generation of their energy, principles of Cleaner Production that advocate the sustainable use of sources of raw materials, helping to reduce water and electricity consumption.

5. CONCLUSION

This work sought to describe how the principles of CP can be applied in the sector of transport, storage and loading at the port terminal in Aratu. The geographical location of the enterprise allows the installation of clean energy systems for on-site power generation, being a cost-effective, profitable, and sustainable project.

The analysis of the data, through control charts, referring to the company's electricity consumption, as well as the identified potential for solar power generation and the rise of new energy matrices were necessary to present a proposal for a DFGV system. Studies and proposals aimed at sustainability, quality, and environmental management are increasing of interest to companies seeking to reduce the consumption of resources since they are following the new energy matrices on the rise in the country, such as public policies, government projects, Normative (e.g. No. 482/2012) that encourage the generation of energy itself.

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7. RESPONSIBILITY FOR INFORMATION

The authors are the only responsible for the printed material included in this paper.