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Evaluation of polyurethane coating performance under various atmospheric conditions

Evaluación del desempeño del revestimiento de poliuretano bajo variadas Condiciones Atmosféricas

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Abstract

A thorough wear analysis was carried out on four variants of polyurethane-based paint, each with different compositions. The central objective was to determine the magnitude of wear of each type, considering the influence of various environmental factors, which were evaluated under atmospheric conditions at altitudes of 0 m.a.s.l. and 2800 m.a.s.l. To achieve this purpose, accelerated laboratory tests were implemented to replicate adverse conditions for the coating. In addition, outdoor tests were carried out, considering different atmospheric conditions. Both types of tests were conducted in accordance with ASTM guidelines, thus ensuring an optimal quality standard for the results obtained. The results revealed the marked influence of UV rays on coating wear, as well as variations in color and gloss loss over the course of different tests and atmospheric conditions. Significantly, it was observed that outdoor tests generated more pronounced wear due to factors such as light, temperature, humidity and contamination, compared to simulated laboratory tests. In particular, it was noted that silica-protected paints exhibited less

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loss in both gloss and color under both normal and simulated conditions. This finding supports the conclusion that this compound can indeed extend the life of the paint.
Keywords: Wear, Coating, testing, atmospheric conditions.

Resumen

Se llevó a cabo un minucioso análisis del desgaste en cuatro variantes de pintura a base de poliuretano, cada una con composiciones distintas. El objetivo central fue determinar la magnitud del desgaste de cada tipo, considerando la influencia de diversos factores ambientales, los cuales fueron evaluados en condiciones atmosféricas a altitudes de 0 m.s.n.m. y 2800 m.s.n.m. Para alcanzar este propósito, se implementaron ensayos acelerados en laboratorio que replicaron condiciones adversas para el revestimiento. Además, se realizaron pruebas a la intemperie, considerando diversas condiciones atmosféricas. Ambos tipos de ensayos se rigieron por las pautas de la normativa ASTM, asegurando así un estándar óptimo de calidad en los resultados obtenidos. Los resultados revelaron la marcada influencia de los rayos UV en el desgaste del revestimiento, así como las variaciones en la pérdida de color y brillo a lo largo de distintas pruebas y condiciones atmosféricas. De manera significativa, se observó que las pruebas a la intemperie generaron un desgaste más pronunciado debido a factores como la luz, temperatura, humedad y contaminación, en comparación con las pruebas simuladas en laboratorio. En particular, se destacó que las pinturas con protección de sílice exhibieron una menor pérdida tanto en el brillo como en el color, tanto en condiciones normales como en las simuladas. Este hallazgo sustenta la conclusión de que este compuesto puede efectivamente prolongar la vida útil de la pintura.
Palabras clave: Desgaste, Revestimiento, ensayos, condiciones atmosféricas.

Introduction

In view of the importance of corrosion protection on metal surfaces, the need arises to understand how polyurethane-based automotive paint coatings under different atmospheric conditions affect the physical-chemical properties. The proposed comparative analysis between atmospheric conditions at 2800 meters above sea level and sea level conditions is intended to provide a comprehensive view of the physical and chemical variations experienced by automotive paint coatings at different altitudes, since understanding these differences will optimize the design and selection of coatings to suit specific environments and ensure effective protection against corrosion, UV, altitude, humidity. In addition, this comparative analysis will also contribute to existing scientific knowledge by providing relevant information for the optimization of painting processes and the development of new, more resistant and durable automotive paint formulations.

The main objective of this research is to carry out a physicochemical analysis of polyurethane-based automotive paint applied on steel surfaces in two contrasting atmospheric conditions: at 2800 meters altitude and at sea level. Through this study, I analyze how altitude influences the properties of polyurethane coatings, including their abrasion resistance, adhesion, impact resistance, corrosion resistance, color stability and paint film degradation.

In the introductory chapter of the book Polymer-Based Nanoscale Materials for Surface Coatings, the topic of polymer coatings and their importance in modifying surface properties to meet the requirements of various technological applications is discussed. These coatings have been shown to improve adhesion, scratch resistance, solvent resistance, among other characteristics. However, there is still a lack of research and optimization of polymer selection, coating processes and manufacturing conditions to obtain high-performance coatings. This means that it is essential to deepen these aspects in order to achieve significant advances in the manufacture of polymer coatings used in various industries. (Sayan Ganguly, 2023)

Two similar articles on corrosion protection and development of durable coatings have aroused great interest, mentioning that graphene-based coatings offer advantages in terms of corrosion resistance and improved properties, but there are still challenges to be solved. Research to better understand the durability of these coatings and explore their application in various industries is of vital importance. The combination of graphene's unique properties opens up opportunities for the development of high-performance multifunctional devices. What this means is that more research is needed to solve the challenges and harness the full potential of these coatings in various applications. (Sachin Sharma Ashok Kumar, 2022) (Geetisubhra Jena, 2022)

Progress in Polymer Science provides an overview of the paints and coatings industry, its infrastructure and the drivers of change in the industry. Different technological solutions are discussed and areas of development in high solids, waterborne, UV curable and powder coatings are described. In addition, resins commonly used in paint and coating formulations are examined. However, there is still much to be studied regarding the structure and reactivity of these resins. Which means that, in order to solve the foundation of the problem, a deeper understanding of the preparation, performance and curing reactions of resins used in paints and coatings is required. (Weiss, 1997). While the research conducted in Progress in Organic Coatings book focuses on the effect of silicate nanolayers in a polyurethane-based automotive clear topcoat. A partially intercalated structure was observed in the polymer matrix due to the dispersion of the nanolayers. Tests were conducted to evaluate the turbidity, reflectance spectra, and scratch and damage resistance of the nano-filled clear coat. A significant improvement in the strength and gloss of the nanofilled layer was found. Further tests were carried out to determine the optimum nanofiller/polymer ratio. This means that, despite the positive results obtained, other aspects such as adhesion, impact and flexure still need to be studied to gain a more complete understanding of the properties of the nanofilled coating. (Behdad Ahmadi, 2007)

A study conducted by the Universidad Internacional del Ecuador shows that, in the Ecuadorian market, automotive paint has undergone numerous upgrades to reduce its environmental impact. However, there are challenges related to regulatory compliance, lack of knowledge among untrained personnel, and the choice between water-based and solvent-based paint. This study focuses on evaluating the performance and durability of different brands of automotive paint, considering technical regulations and the needs of users and companies. Meanwhile, the Universidad Estatal del Sur de Manabí shows that automotive paint shops in Jipijapa represent an environmental problem when paint waste is improperly disposed of. The number of workshops was determined and the impacts on human health and the environment were evaluated. It is concluded that automotive paint shops do not cause serious pollution, but more research is needed to adequately address the environmental impact and health nuisance to people. This means that more research is needed on aspects such as the development of more sustainable technologies and the establishment of effective regulations for the use and disposal of automotive paints. In addition, adequate training of personnel involved in the application of paints and the promotion of environmental awareness among users and shop owners should be encouraged. These actions will contribute to mitigate negative impacts and ensure a more sustainable future for the automotive paint industry. (Auter Cuenca, 2020) (Chasing Guagua, 2011)

Paints, varnishes and dyes have been used throughout time to beautify buildings, components, vehicles and others. Likewise colors can generate a chemical process in us, in this way it can be considered that colors affect our perception of space, depth and height, that is why they have been used from the cultural point of view for a visual communication, but also throughout history paint has also been used to protect the material under it. (Berge, Butters, & Henley, 2009)

"A coating or liquid paint is a heterogeneous mixture of products that once applied and dried becomes a continuous film without stickiness and with the characteristics for which it was conceived." (Calvo, 2011, p. 3)

Generally the paint is composed of four ingredients, but they can also be found with fewer materials and with different proportions of these depending on their manufacture and purpose. Among the ingredients you can find:

Table 1. *Characteristics of the ingredients and their presence in the different paints.*

Ingredients	Feature	Mate	Brilliant
Resin or binder	Forms the film and allows the particles to hold together once the paint is dry.	15-20%	35-45%
Solvents	They are able to dissolve the binder and allow the formulation of an optimum viscosity for the paint to be manufactured (not essential).	50-60%	20%
Pigments	Substances in the form of fine particles that have the function of giving color to the paint.	15-20%	25-35%
Additives	They are used to modify the properties of the paint both for storage and when applied to a surface.	1-5%	1-5%

Source. (Ponce Moreno, 2007)

The following table shows the different resistance based on the isocyanate content, a compound found in the resin. Where it will be evaluated on a scale of 1-5, being 1 a poor resistance and 5 an excellent resistance.

Polyurethane

This polymer is a two-component paint obtained by condensation of hydroxyl bases combined with isocyanates.

"The base can be a polyester and the catalyst a poly - isocyanate. Once mixed, these components react to form a polymer that results in a film that conjugates aesthetic, physical and chemical characteristics different from other air-drying coatings." (Guerra Carvallo, 2014, p. 196).

Silicates

For the paint industry it is important to have a coating that is durable and above all that resists weathering, which is why silicates have been implemented in paints to increase their hardness and resistance to weathering.

These silicas are used when the life of the paint is to be prolonged by approximately 20 years, since this is the estimated time of protection it provides. (Calvo, 2011)

Atmospheric degradation of polyurethane-based paints

Within the polyurethane-based automotive paint, different failures can occur, such as poor application, poor coating selection, a defective product or simple exposure to the environment.

In general, among the conditioning factors of the life of the paint we have humidity, temperature, radiation and pollution, which when presented continuously in the paint come to degrade it progressively. These factors vary depending on the region and country where it is located, especially in a country like Ecuador where there are four regions (coast, highlands, east and island) and in a matter of minutes it is possible to change region. (Simancas & Morcillo, 1998)

Color represents a visual perception that occurs in the brain to obtain information from the photoreceptors found in the eye. In this way each individual interprets the different wavelengths in the spectrum of visible light. It should be emphasized that these processes are influenced by the individual, the light and the brightness to perceive color. To differentiate the color can be done through the spaces between these changing the perception of this. This requires a chromatic coordinate.

First it will be given by L which is called "neutral gray axis" since it has extremes of white (L=100) and black (L=0), this will show us the brightness of the color where a lower value will be darker and intermediate values will give us gray tones. Then there is a which is the chromatic coordinate in red-green, where its negative value will affect the green standard and a positive value will affect the red standard. Finally, there is the yellow-blue chromatic axis given by b which, like a, a negative value will indicate a deviation in the blue standard while a positive value will indicate a deviation towards yellow. (Datacolor)

Several instruments can be used for measurement, the most important of which are the glossmeter and the spectrophotometer.

Glossmeter: These are instruments that measure the gloss of a coating, i.e. the ability of the coating to reflect light. This device works with the angles, in this way it can detect the change of brightness in the paint.

Spectrophotometer: These instruments are currently used to determine color differences and this is due to their high accuracy. It works by emitting a radiant energy through a certain length, this passes through a reference target and by receiving the radiant energy from both the coating and the sample target can compare them and issue an appropriate result.

Methodology

In order to achieve the objectives established in this research, several analytical methods and techniques were implemented. As a first step, an analytical approach was employed, performing controlled tests on paint samples exposed to both atmospheric conditions, and their physical and chemical properties were measured and compared. For this purpose, a comprehensive analysis and comparison of the physical and chemical properties of polyurethane-based automotive paint was carried out in two different atmospheric conditions: at an altitude of 2800 meters above sea level and at sea level.

Secondly, the analysis was carried out using a laboratory method, making direct measurements and observations of atmospheric conditions at both altitudes using appropriate instruments and equipment. Atmospheric conditions at 2800 meters altitude and at sea level were characterized in detail. Key factors such as atmospheric pressure, temperature, relative humidity and solar radiation were considered.

Subsequently, the tests were carried out using an experimental approach, performing specific tests on the paint samples exposed to different atmospheric conditions, with the objective of evaluating their performance and durability. Physical analyses were performed on the polyurethane-based automotive paint samples exposed to different laboratory tests. This included adhesion tests, corrosion resistance, scratch resistance and changes in optical properties.

Finally, this analysis was carried out using quantitative and qualitative methods, making use of analytical techniques such as spectroscopy, chromatography and microscopy. A chemical comparison of the polyurethane-based automotive paint samples exposed to the different laboratory tests was carried out. In this way, the chemical components present in the paint samples were identified and quantified, possible contaminants were detected and any molecular degradation that might have occurred was evaluated.

For the following work two types of paint will be used, standard yellow, which will be called (PAE) and lemon yellow, which will be called (PAL) from the manufacturer Nubiola, each of these paints will be used without surface modification and with surface modification which will be the silica coating, so we will call the standard yellow paint with silica (PAES), while the lemon yellow paint with silicon (PALS). In this way we will obtain results of the paint in normal condition and with the use of additional protections, to know how useful these improvements are.

The material to which the coating will be applied will be a steel plate, since these alloys are the most commonly used in car bodies. Therefore, four of these plates with dimensions based on the ASTM G92-86 standard will be needed to apply the two shades of yellow together with the two shades with surface modification.

In the accelerated tests of the xenon chamber, specimens of 100x50 mm will be used due to the size of the specimen holder of this equipment.

Table 4. *Materials present in automobiles*

Material	*Presence in the vehicle (%)*
Steel	*34%*
Plastic	
Magnesium	
Aluminum	

Own elaboration

For this research, ASTM (American Society for testing and materials) standards will be used, which are a set of principles developed by consensus with the aim of providing a standard of quality and competitiveness of different products in different fields, such as metallurgy, petroleum, textiles, paints and plastics.

This research will be based on the regulations applied to the different methods to evaluate wear in different areas of paint, as well as the standards for the application of the different degradation equipment to be used for paint testing. In this way, the results obtained will be of quality and will be sustained on pre-established bases.

Table 5. *ASTM standards used in the investigation*

Regulations	**Name**	**Description**
ASTM G92-86	Standard Practice for Characterization of Atmospheric Test Sites	This practice provides suggested procedures for the characterization of atmospheric test sites, including the dimensions of the material to be used.
ASTM D523-08	Standard Test Method for Specular Gloss	It is a measurement of brightness obtained by comparing the specular reflectance of the

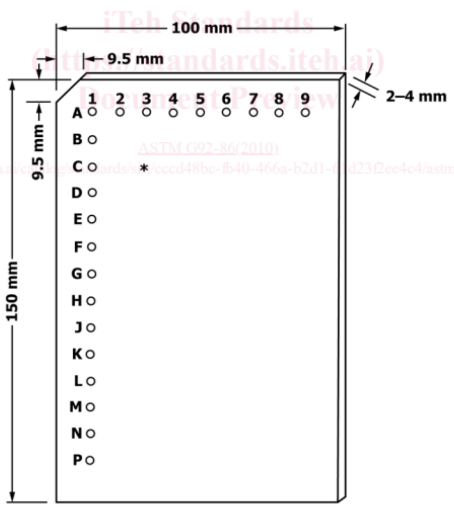
		sample with that of a black glass standard.
ASTM E1164-09	Standard Practice for Obtaining Spectrometric Data for Object-Color Evaluation	This practice provides procedures for selecting the operating parameters of the spectrometers used to provide data of the desired accuracy. It also provides for the calibration of instruments by means of material standards.
ASTM G7-05	Standard Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials	This practice gives procedures to follow for direct exposure of non-metallic materials to the environment.
ASTM G85-19	Standard Practice for Modified Salt Spray (Fog) Testing	It is applicable to ferrous and non-ferrous materials, as well as organic and inorganic coatings. Establishing and covering conditions for salt spray testing.
ASTM D6695-08	Standard Practice for Xenon-Arc Exposures of Paint and Related Coatings	This practice is intended to induce changes in properties associated with end-use conditions, including the effects of sunlight, moisture and heat. The exposure used

	in this practice is not intended to simulate deterioration caused by localized weathering events, such as atmospheric contamination, biological attack and exposure to salt water.

Source (ASTM, 2023) Own elaboration

In compliance with the ASTM G92-86 standard, the plate must be 100 mm wide and 150 mm long. Therefore, four plates with the respective dimensions will be used, which will be labeled with their respective identifications according to the standard.

Figure 3. Example of atmospheric sample



Source (ASTM, 2010)

Measuring equipment

The measurement will be performed with different measuring equipment such as those explained in the theoretical framework section, which are the glossmeter and the colorimeter, these together with the help of ASTM standards, will provide us with the appropriate values to obtain the desired results in the research and to be able to compare them later.

Wear test equipment

For the coating wear tests we will use the Q-FOG salt fog chamber, model CCT-600 with a prohesion cycle where the specimen with the coating will be exposed for 348 hours and the Q-Sun xenon arc chamber model Xe-1-S with ASTM cycle with daylight filter and a 340nm UV sensor with an exposure time of 190 hours. It should be noted that in both tests a specific ASTM standard will be used for each piece of equipment.

Table 6.*Saline chamber specifications*

Saline chamber	
Brand	Q-FOG
Model	CCT-600
Cycle	Prohesion
Humidity	100%
Chamber volume	640 liters
Test panels	75 mm × 15 mm

Source (Q-LAB, 2023)*Own elaboration*

Table 7. *Xenon arc chamber specifications*

Xenon arc chamber	
Brand	Q-Sun
Model	Xe-1
Cycle	ASTM
Irradiation control	340 nm
Test panels	51 mm x 102 mm
Temperature	35 - 103 C°

Source (Q-LAB, 2023)*Own elaboration*

Results

As a first stage, the analysis will be carried out through specific regulations to evaluate the wear of automotive paint, highlighting crucial aspects such as gloss, color and luminosity that face factors such as solar radiation, humidity, changes in altitude and other environmental elements. These tests represent a study of the physicochemical properties of polyurethane-based coatings applied in contrasting atmospheric environments at 2800 meters above sea level and at sea level, allowing a systematic comparison of the results obtained at different altitudes.

To carry out the gloss tests, as well as the color and accelerated tests, four paints were used, two of which are standard and the other two are of the same shade as the previous ones, but with a silicate coating. The paints used were: Standard yellow paint (PAE), Standard yellow paint with silicate (PAES), Lemon yellow paint (PAL), Lemon yellow paint with silicate (PALS).

Table 8 indicates the loss of gloss as a percentage. Both measurements are made after three months of exposure of the specimens to the different climatic factors, in the different regions at 0 and 2800 m.a.s.l. respectively.

Table 8. *Amount of gloss lost as a percentage (%)*

Brightness (%)	0 m.a.s.l.	2800 meters above sea level.
PAE	9	3.1
PAES	5.5	2.5
PAL	7.5	3.5
PALS	9.4	4.5

Source. Own elaboration

Based on the analysis of results at 2800 m.a.s.l. there is no loss of more than 5% while at sea level the value exceeds 5% but does not exceed 10%. This means that the closer you are to the sea, the greater the loss of brightness, due to the presence of different factors such as humidity, heat, salt, as well as greater exposure to UV rays.

Color wear under normal conditions

Table 9 shows the values obtained in the color measurement on the L axis, which represents the darkening of the coating at the fourth month of testing. On the other hand, it is also possible to observe the loss of color in the b coordinate, which represents the yellow-blue hue in the different atmospheric conditions. Both coordinates are measured both at sea level and at 2800 meters.

Table 9. *DL coordinate (brightness) and Db coordinate (yellow-blue) after 4 months of exposure in the different paint samples.*

COORDINATE	DL		Db	
	0 m.a.s.l.	2800 meters above sea level.	0 m.a.s.l.	2800 meters above sea level.
PAE	5	5.17	9.7	9.29
PAES	2.7	3.38	5.4	6.30
PAL	4.2	4.31	7.5	7.81
PALS	2.7	2.68	5.1	4.62

Source. Own elaboration

In the analysis of the results, the loss of luminosity in conditions of higher altitude exceeds those of lower altitude, except for the lemon yellow paint with silicate (PALS), where it presents a similar loss with a difference of 0.02 units within the coordinate.

In the case of coordinate b, paints without silicate protection have a greater loss of color at 0 m.a.s.l. than at 2800 m.a.s.l. However, paints with silicate protection show a greater loss of color at high altitudes, while at low altitude conditions, they lose less color.

It can be determined that in the cities of the coastal region, the paint becomes more opaque, but a silicate coating in lighter colors can help to maintain the luminosity in these paintings, keeping them at a similar level to that of the cities of the high altitude. On the other hand, the silicate can help to maintain the color at low altitudes where it presents values similar or lower than those of 2800 m.a.s.l. while the paintings without coating do not present much difference in the color variation having a variation between 0.3 - 0.5 units, indicating that the greater degradation is given in the luminosity and not in the tone of the color.

Color wear in accelerated tests

Saline chamber

As shown in Table 10, both the results at sea level and at 2800 m.a.s.l. are negligible, since the wear produced with this equipment is very low and no significant difference can be appreciated, this is because the camera does not simulate solar radiation (UV), which is one of the main factors that generate wear to the paint.

Table 10. *DL coordinate (luminosity) and Db coordinate (yellow-blue) after 348 hours of exposure in the saline chamber.*

COORDINATE	DL		Db	
	0 m.a.s.l.	**2800 meters above sea level.**	**0 m.a.s.l.**	**2800 meters above sea level.**
PAE	0.64	0.6	1.98	1.45
PAES	0.15	0.04	1.08	0
PAL	0.35	0.95	1.21	1.03
PALS	0.45	0.11	0.2	0.08

Source. Own elaboration

Xenon arc chamber

Table 11 shows the loss of luminance (DL) and color in the yellow-blue coordinate (Db) respectively, when exposing the paint to the Xenon

Arc Chamber under ASTM D6695-03b, for about 200 hours at the different heights.

Table 11.*DL coordinate (brightness) and Db coordinate (yellow-blue) after exposure to Xenon arc to the different paint samples.*

COORDINATE	DL		Db	
	0 m.a.s.l.	2800 meters above sea level.	0 m.a.s.l.	2800 meters above sea level.
PAE	3.0	1.78	5.9	3.96
PAES	2.7	2.09	5.4	4.14
PAL	2.4	2.26	4.6	4.33
PALS	1.2	1.58	2.3	3.05

Source. Own elaboration

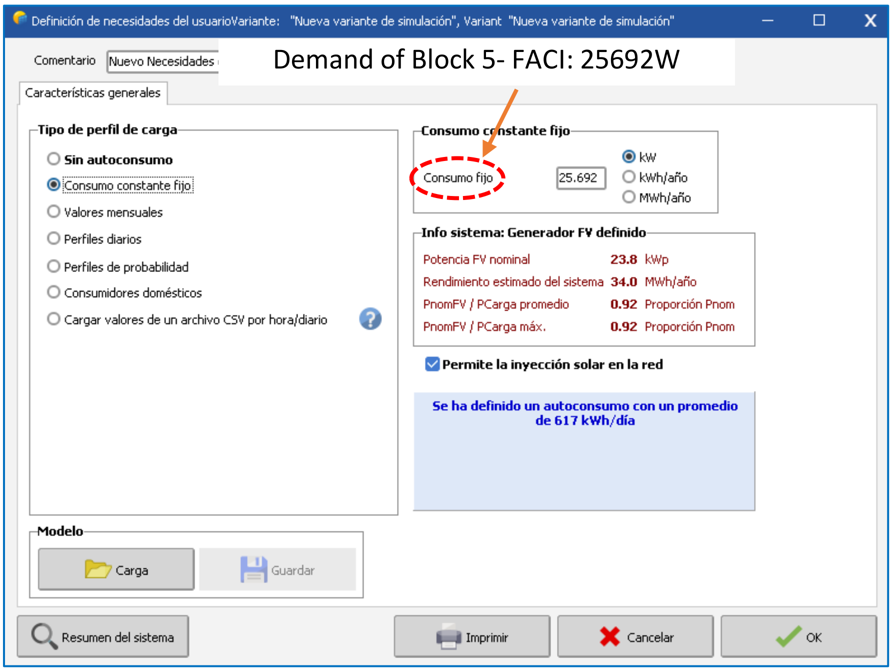
In the analysis of the results it can be seen that there is a greater loss of luminosity and yellow color at sea level with respect to accelerated tests, with the exception of the lemon yellow paint with silicate (PALS) which shows less loss at sea level both in the b-coordinate and in the L-coordinate. This shows that the environmental factors of cities near the sea wear the paint more, except for the PALS sample, where it can be seen that the silicate coating is not affected by these external factors and rather gains durability in these climatic conditions, becoming more effective at 0 m.a.s.l. than at 2800 m.a.s.l.

Once the key components of the system have been dimensioned in PVsyst (Figure 8) and the self-consumption needs for the building load have been established (Figure 9), the PV system performance simulation is run in PVsyst. The result of the simulation is the "PVsyst - Simulation Report" (Figures 10 and 11) which indicates various details related to the performance of the assisted PV system.

Among the information presented on page 5 of the PVsyst simulation report (Figure 11), it is possible to identify that the annual consumption of the load is 225044 kWh. Additionally, it can be observed that the PVsyst system contributes 36973 kWh to the load, while the grid provides the remaining energy, i.e. 188071 kWh. This means that, once the assisted PV system is implemented, about 20 % of the total energy to power the load will come from the solar panels throughout the year. Logically, this would represent a 20% reduction in energy consumption from the grid. This fact means that an economic saving of the same percentage (20%) would be expected in the monthly energy consumption bills of this building once the assisted photovoltaic system is implemented.

Finally, Table 9 shows an approximate budget for the materials, main equipment and services required to build the assisted photovoltaic system that we have studied in this article.

Figure 1. Entry of self-consumption parameters in PVsyst.



Note. Taken from (Cagua, 2023).

Figure 2. PVsyst simulation report (page 1).

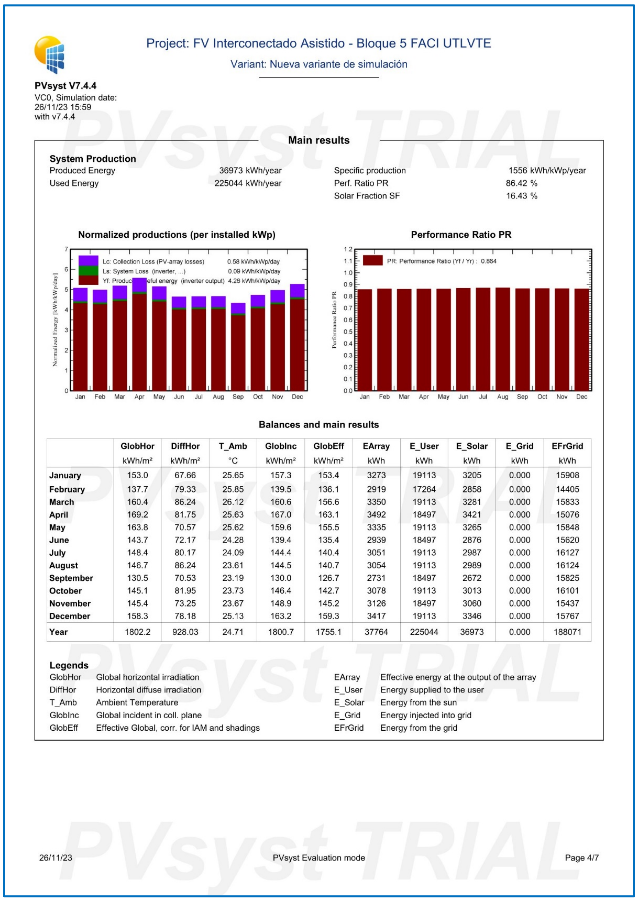

PVsyst - Simulation report

Grid-Connected System

Project: FV Interconectado Asistido - Bloque 5 FACI UTLVTE

Note. Taken from (Cagua, 2023).

Figure 3. Production of the assisted photovoltaic system.


Project: FV Interconectado Asistido - Bloque 5 FACI UTLVTE

Variant: Nueva variante de simulación

PVsyst V7.4.4
VC0, Simulation date:
26/11/23 15:59
with v7.4.4

Main results

System Production

Produced Energy	36973 kWh/year	Specific production	1556 kWh/kWp/year
Used Energy	225044 kWh/year	Perf. Ratio PR	86.42 %
		Solar Fraction SF	16.43 %

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E_User kWh	E_Solar kWh	E_Grid kWh	EFrGrid kWh
January	153.0	67.66	25.65	157.3	153.4	3273	19113	3205	0.000	15908
February	137.7	79.33	25.85	139.5	136.1	2919	17264	2858	0.000	14405
March	160.4	86.24	26.12	160.6	156.6	3350	19113	3281	0.000	15833
April	169.2	81.75	25.63	167.0	163.1	3492	18497	3421	0.000	15076
May	163.8	70.57	25.62	159.6	155.5	3335	19113	3265	0.000	15848
June	143.7	72.17	24.28	139.4	135.4	2939	18497	2876	0.000	15620
July	148.4	80.17	24.09	144.4	140.4	3051	19113	2987	0.000	16127
August	146.7	86.24	23.61	144.5	140.7	3054	19113	2989	0.000	16124
September	130.5	70.53	23.19	130.0	126.7	2731	18497	2672	0.000	15825
October	145.1	81.95	23.73	146.4	142.7	3078	19113	3013	0.000	16101
November	145.4	73.25	23.67	148.9	145.2	3126	18497	3060	0.000	15437
December	158.3	78.18	25.13	163.2	159.3	3417	19113	3346	0.000	15767
Year	1802.2	928.03	24.71	1800.7	1755.1	37764	225044	36973	0.000	188071

Legends

GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_User	Energy supplied to the user
T_Amb	Ambient Temperature	E_Solar	Energy from the sun
GlobInc	Global incident in coll. plane	E_Grid	Energy injected into grid
GlobEff	Effective Global, corr. for IAM and shadings	EFrGrid	Energy from the grid

26/11/23 PVsyst Evaluation mode Page 4/7

Note. Taken from (Cagua, 2023).

Table 1. *Approximate budget of the assisted photovoltaic system for Block 5 - FACI.*

Assisted Photovoltaic System Budget					
No.	Description	Quantity	Unit	Unit Cost	Total Value
1	330 Wp photovoltaic module. Manufacturer: Panasonic. Model: VBHN-330-SJ47	72	EA	$320,00	$23.040,00
2	Inverter 25 kW. Manufacturer: Fronius International. Model: ECO 25.0-3-S	1	EA	$3.500,00	$3.500,00
3	Structure	1	GB	$1.800,00	$1.800,00
4	Grounding rod.	1	EA	$16,00	$16,00
5	General switch.	1	EA	$35,00	$35,00
6	Differential switch of 30 mA sensitivity.	1	EA	$12,00	$12,00
7	gPV fuses.	8	EA	$8,00	$64,00
8	Photovoltaic Cable. 300 meters.	1	EA	$1.062,00	$1.062,00
9	MC4 connectors.	150	EA	$7,14	$1.071,00
10	SPD (varistors).	5	EA	$35,12	$175,60
11	Labor.	1	GB	$2.000,00	$2.000,00
				Total Power (W)	$32.775,60

Note. Taken from (Cagua, 2023)

Conclusions

The use of specialized tools such as PVsyst has made it possible to predict the performance of an assisted photovoltaic system designed for FACI's Block 5 building. Through the use of this software it has been possible to select the essential components of this type of photovoltaic system, such as the photovoltaic modules and the inverter. The results obtained in the PVsyst simulation report support the design decisions and ensure the efficiency of the proposed system.

On the other hand, meteorological and geolocation information has been used in this study, and at the same time information has been gathered through visual inspections of the installation site, in order to evaluate whether the conditions are favorable to support the implementation of the project in a technical manner.

In addition, the detailed study of the installed load in the "Block 5" building has revealed crucial information to determine the energy demand. This step has been essential to properly size the PV-assisted system, ensuring that it can meet the needs efficiently. Effective planning has been made possible by understanding consumption patterns and projecting solar power generation. A detailed budget has also been prepared considering the costs associated with equipment acquisition and installation.

To conclude, the results of this work have supported the feasibility of implementing an assisted photovoltaic system in Block 5. The detailed identification of the technical specifications of the main components, the accurate identification of the load and the presentation of a detailed budget form a comprehensive framework for the successful implementation of the project.

This work lays the groundwork for the transition to a more sustainable energy source in Block 5, and also suggests that the adoption of solar energy will not only be beneficial from an environmental standpoint, but may also have a positive impact on long-term cost reduction.

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