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Technical and Economic Study Report

"Integration of solar blinds in AC installations"

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Introduction

In order to complement the study of our project, *Integration of solar blinds in AC installations*, a technical and economic study was carried out. This type of study is essential to evaluate the viability of the project, guaranteeing the security and assertiveness of the investment.

In this study, ROI (return on investment) was calculated. Calculating ROI is important because it allows us to not only know when the initial investment will be recuperated, but also how much the profit margin will be. This parameter is given by:

$$ROI\ (\%) = \frac{Revenue - Cost}{Investiment} \times 100 \quad (Eq. 1)$$

Throughout this study, we will provide two examples of partners that decided to collaborate with us by providing data to enable this study to be conducted. In this case, it was *Instituto Nacional de Estatística* (INE) and *Comunidade Hindu de Portugal* (CHP), to which we appreciate, in advance, for their cooperation. These 2 cases are situated in Lisbon and have south-facing facades. In addition, 3 examples of ROI for each contributor will be presented, for 15, 20 and 25 years, to simulate the lifespan of the photovoltaic cells as best as possible.

Production

Firstly, with the assistance of *google maps*, the azimuth was determined for each building (on the south-facing facade):

$$\varphi_{INE} = 19°, \qquad \varphi_{CHP} = 0°$$

Then the data was extracted from PVGIS for the respective location and azimuth. In this way, the data obtained was put into the analytical model already made and the annual energy produced in 2020 was determined (it was assumed that the same energy is produced every year, as explained in detail in the analytical model report). It should be noted that a nominal power (STC: Standard Test Conditions) of 1 W was used for this part:

$$E_{INE} = 2925\,Wh, \qquad E_{CHP} = 2949\,Wh$$

Finally, in order to find out how much energy is produced each year for each energy tariff, we used the following timetables:

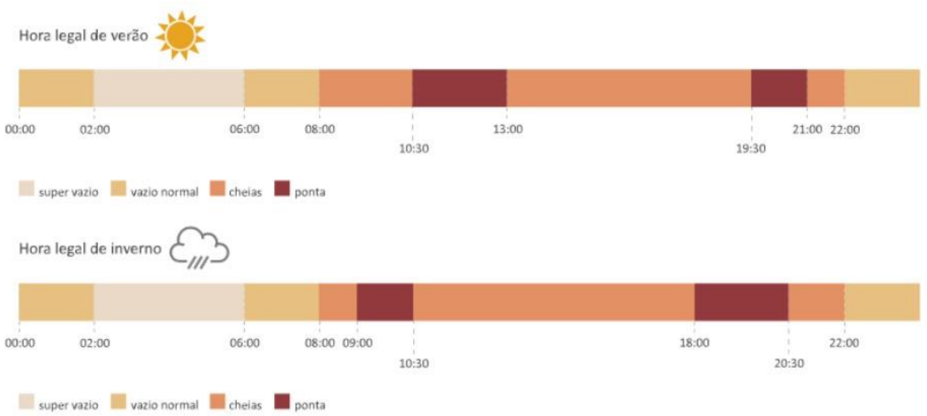

Figure 1 - Energy tariff schedules.

The following results were obtained:

Table 1 - Energy Produced at each Energy Tariff

Energy tariff	E_{INE} $[Wh]$	E_{CHP} $[Wh]$
Super Vazio	0	0
Vazio Normal	191	192
Cheias	2140	2160
Ponta	594	598

Price

Following this, the price of producing and installing our project was estimated. It was decided an estimate per m^2 to be as inclusive as possible.

So, we started by asking for prices for the mobile shading system, to estimate how much it would cost to produce. We received a response from Represtor and obtained an average price per m^2 of 171.71 €, which includes the mobile shading system, the motor and the installation.

Then, based on the European Commission's 2022 and 2023 reports called *Photovoltaics in the European Union*, the prices of DC-AC inverters in $\$/W_p$ (which had to be converted to € by multiplying by 0.94) and photovoltaic cells in $€/W_p$ were taken. In this way, an efficiency of 22% was considered, to make up the high efficiency price given in the report. This resulted in a peak power of $\mathbf{220\ W_p}$ (per m^2), giving an average production price for the inverters and cells of $9.72\ €/m^2$ and $68.20\ €/m^2$, respectively.

Finally, a price approximation has been made for cabling, boxes, gutters, etc, of 15% of the total value. The value of the inverter will be calculated together with the estimate of the installation's peak watt, since the values that the inverters support are standardised (i.e. they only build inverters with fixed values, for example $30\ kW$ or $2\ kW$), so it can't be added to the price per m^2. Therefore, the value of the cabling will be included in the installation, however, an approximation of the price per m^2 has been shown in the table below.

None of this price includes VAT (*IVA*), so 23% is added to the total value, giving a total of $353.10€/m^2$. Without considering the price of the inverter and cabling, the amount is $\mathbf{295.09€/m^2}$.

Table 2 - Prices per m^2

	Price [$€/m^2$]	Notes
Mobile Shading System + Installation + motor	171.71	Represtor
DC-AC inverter	9.72	Report CE 2022
Photovoltaic cells	68.20	Report CE 2023
Extras (cabling, ...) (15%)	37.44	Approaching
Total (excluding VAT)	287.07	
Total (with VAT)	353.10	VAT 23%

Note: These inverter and cabling prices (which depend on 15% of the final price) will not be the ones used because there are fixed power values for the inverters.

Table 3 - Additional Data Used

Data Used		Notes
Inverter price	$0.047\ \$/W_p$	Report CE 2022
Photovoltaic Cells Price	$0.31\ €/W_p$	Report CE 2023
Peak Power	$220\ W_p/m^2$	Calculated from the efficiency considered in STC

Instituto Nacional de Estatística

The *Instituto Nacional de Estatística* has 56 rectangular windows of $1.2m \times 1.5m$, 7 windows of $1.2m \times 1m$ and 18 windows of $1m \times 1.5m$ on its south-facing facade, which guarantees the highest performance, giving a total area of $\mathbf{136.2\ m^2}$. The peak power of the installation was then calculated: approximately $30\ kW_p$, so the price of the inverter will be approximately 1 325€. Now, multiplying the area value by the average price per m^2, adding the price of the inverter and multiplying everything by $1{,}15$ (in order to simulate a price for the cabling) it gives us an investment of around $\mathbf{48\ 100}$€, including VAT (*IVA*).

In this way, the total amount of energy produced each year by installing solar blinds can be calculated, and therefore the total amount of money saved each year:

Table 4 - Total Energy Produced and Money Saved Annually

	Total	Super Vazio	Vazio	Cheias	Ponta
Energy Produced Annually $[kWh]$	87650	0	5720	64130	17800
Price Used for each tariff $[€/kWh]$	-	0.0583	0.0663	0.101	0.145
Money Saved Annually [€]	9 991	-	379	7 035	2 577

On top of this price, the addition of the Special Consumption Tax is needed (*Imposto Especial de Consumo*) ($Total\ Energy\ Consumed \times 0.001$) and the Peak Hour Power (*Potência Horas de Ponta*) $\left(\frac{\text{Energy Consumed at Peak}}{Number\ of\ Hours\ at\ Peak} \times 0.4328\right)$. Thus, multiplying by VAT (*IVA*), annual savings are achieved:

Table 5 - Total Money Saved

Peak Hour Power	Special Consumption Tax	Total Savings excluding VAT	Total Savings with VAT (*IVA*) (23%)
1 926 €	88 €	12 005€	**14 766 €**

Based on these values, and based on an analysed study, it was considered that the cells age in a linear fashion, so that at the end of 30 years there will be losses of around 13% of the initial value. These losses were therefore considered in the annual value saved and the following formula was used to calculate the final price saved after a years:

$$\sum_{n=0}^{a} Total\ Saved\ \times \left(1 - n\left(\frac{0.13}{30}\right)\right) \quad (Eq. 2)$$

Next, to simulate the efficiency of the DC-AC inverter (an efficiency of 97% was considered), the value obtained from the sum was multiplied by 0.97, giving the value of the revenue obtained from the project for a years.

In addition, it was necessary to estimate Operation & Maintenance cost, so a value of 0.01 €$/W_p$ was considered (value taken from the European Commission report for Portugal), giving an annual associated cost of approximately 300 €.

Finally, ROI (return on investment) can be estimated for 15, 20 and 25 years, based on the formulas presented and the values obtained above, using equation 1:

Table 6 - Return on investment

Years	15	20	25
ROI (%)	322,0	453,1	587,2

Based on this table, it's expected that, in at least 15 years, there will be a return of $\mathbf{322,0}$ % on the amount initially invested, not forgetting that the real value of the return will depend on how long the photovoltaic cells last. A saving of around $\mathbf{13}$ % is also expected in the energy consumed from the grid.

Finally, based on the values calculated, a cash flow table was drawn up to see when the money invested would be recovered. The money invested is expected to be **recovered after 4 years**.

Note: Inflation has not been considered due to constants energy prices during the last years.

Comunidade Hindu de Portugal

In this case, the Comunidade Hindu de Portugal has 2 rectangular windows of $1.2m \times 1.5m$, 2 windows of $1.2m \times 1m$ and 2 windows of $1m \times 1.5m$ on its south-facing façade, giving a total area of $\mathbf{9\ m^2}$. The peak power of the installation was then calculated: approximately $2\ kW_p$, so the price of the inverter will be approximately 88€. Now, multiplying the area value by the average price per m^2, adding the price of the inverter and multiplying everything by 1,15 (to simulate a price for the cabling) it gives us an investment of around **3 180**€, including VAT.

In this way, the total amount of energy produced each year by the solar blinds can be calculated, and therefore the total amount of money saved each year:

Table 7 - Total Energy Produced and Money Saved Annually

	Total	Super Vazio	Vazio	Cheias	Ponta
Energy Produced Annually [kWh]	5800	0	380	4240	1180
Price Used for each tariff [€/kWh]	-	-	0.0639	0.0768	0.0797
Money Saved Annually [€]	444	-	24	326	94

On top of this price, we still must add the Special Consumption Tax (*Imposto Especial de Consumo*) and the Peak Hour Power (*Potência Horas de Ponta*). Thus, multiplying by VAT (*IVA*), annual savings are achieved:

Table 8 - Total Money Saved

Peak Hour Power	Special Consumption Tax	Total Savings excluding VAT	Total Savings with VAT (*IVA*) (23%)
66 €	6 €	516 €	**634** €

This way, the annual amount saved was considered, and based on the formula used above (in the case of INE), the final price saved at the end of a years was calculated.

In addition, it was necessary to estimate Operation & Maintenance cost, so a value of $0.01\,€/W_p$ was considered, giving an associated annual cost of approximately $20\ €$. To simulate the efficiency of the DC-AC inverter, an efficiency of 97% was considered.

So, in the end, ROI can be estimated for 15, 20 and 25 years, based on the values and formulas presented above, using equation 1:

Tabela 9 - Return on investment

Years	15	20	25
ROI (%)	171.0	260.2	341.1

Based on this table, it's expected that in at least 15 years there will be a return of $\mathbf{171.0}\ \%$ on the amount initially invested, not forgetting that the real value of the return will depend on how long the photovoltaic cells last. However, it's important to emphasise that the energy prices paid per kWh are much lower than INE's, so it's normal ROI to be much lower (around half of INE's). It is predicted a saving of around $\mathbf{31.5}\ \%$ in the energy consumed from the grid.

Finally, based on the values calculated, a cash flow table can be drawn up to see when the money invested will be recovered. The money invested is expected to be **recovered after 6 years**. When comparing this value with INE's, it's normal to be higher, as the price of electricity used is lower.

Note: Inflation has not been considered due to constants energy prices during the last years.

Conclusion

After conducting this market study, based on the study case of two potential collaborators, we concluded that in both cases there is always a positive return of more than 100 %, with one case recovering the initial investment after 4 years and the other after 6 years.

It can therefore be concluded that for our project to be reliable, a prior study case must be carried out for each candidate building, since the success of our project dependents on various factors, such as the total area facing south, the location, the price paid for electricity, etc.