

A Work Project, presented as part of the requirements for the Award of a Master's degree in  
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**ECONOMIC ANALYSIS OF ROOFTOP SOLAR PHOTOVOLTAIC  
INVESTMENTS IN THE CITY OF PORTO**

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## Executive Summary of Rooftop Solar Analysis

**Location:** Porto, Portugal

**Date of analysis:** Dec/2022

**Recommendation:** install 8 solar panels (15.2 m<sup>2</sup>), for a net present value of 6201 euros, with a payback of 2.1 years.

### Main economic results

Financing	NPV (EUR)	Payback (years)	IRR (%/year)	LCOE (EUR/kWh)
Gov. subsidies and 75% debt	6201	2.1	61.8%	0.0235
Gov. subsidies and 100% equity	6229	3.2	31.6%	0.0232
No gov. subsidies and 100% equity	3729	9.7	10.0%	0.0483

(All rows are for 8 panels with 375W)

### Additional results

For smaller rooftop spaces, a similar NPV of 6039 euros can be achieved by installing a set-up of only 4 panels with 485W/panel. Batteries are not worth installing at their current price, yet the critical break-even price may be reached in the near future.

### Main inputs and assumptions

#### *Household and Economics*

Electricity consumption	4000	kWh/year	Inflation	2.2%	per year
Electricity price – buy	0.19	EUR/kWh	Bank loan interest rate	4.1%	per year
Electricity price – sell	0.03	EUR/kWh	Bank loan maturity	5	years
			Equity cost of capital	3.0%	per year

#### *PV panels*

Peak power	375	W/panel	System losses	13.5%	of output
Panel area	1.9	m <sup>2</sup> /panel	Degradation with age	0.5%	per year
Useful life	25	years	Maintenance costs	8	EUR/year per panel
			Total cost of optimal installation size (without subsidies)	3695	EUR
			Total cost of optimal installation size (after subsidies)	1195	EUR

### Government subsidies

There are currently no open government subsidies. However, the program is expected to re-open with a refund of 85% of the initial investment, up to a maximum of 2500 euros. This refund is applied retroactively, meaning we can invest now and apply for the subsidy later.

## **1. Introduction**

The accessibility to reliable and cheap sources of energy is of utmost importance for every part of the modern world. Even though the last century brought nearly universal electrification of the world (World Bank 2020), there are still major issues that keep on rising. After decades of stability, the energy supply chain is now on dire straits once again, as increasing disruptions, such as diplomatic and economic conflicts, occur. The recent energy crisis has resulted in market turmoil, showcased by the natural gas spike (NGI 2022), making access to energy significantly more expensive, negatively impacting both individual and economic endeavours. Furthermore, dominating energy sources are currently unsustainable from an environmental point of view and are putting us on track for climate disaster, with greenhouse gas concentrations at their highest level in the past 2 million years and with the last decade being the warmest ever on record (UN 2022).

The problem is now incredibly complex as it is not a matter of expanding infrastructure, but redesigning the incredibly vast and intertwined energy chains, creating new technologies, revamping worldwide behaviours, and much more. Renewable energies show potential as a solution, nonetheless, as a Finance student, I am especially interested in understanding if action toward this change must come at an economic loss, or if it can actually be the best of both worlds. Therefore, at the individual scale, this project aims to study a simple action that most people can take to strive for a solution: installing solar panels. Photovoltaic modules, or solar panels as they are widely known, capture sunlight which is converted into electric energy. Since sunlight reaches us every day, with no barriers to its usage, this process generates clean and environmentally safe electricity, through a reliable and inexpensive method.

The scope of this paper has a purely financial perspective and demonstrates that this solution, even if we do not have environmental concerns, is extremely viable and beneficial, giving ever-compelling arguments for more people to act towards this so-needed change.

## 2. Context, Approach & Valuation Methodology

The ambition of this paper is to assess the economic viability of installing a solar panel system, for residential purposes, in the city of Porto, Portugal. This study is part of the ‘Rooftop Photovoltaic (PV) payback’ project, coordinated by João Pedro Pereira (Associate Professor of Finance at Nova SBE), aiming to provide academic advice on rooftop solar systems. Several Master’s students analyse cities throughout the world, to showcase the possibility of households saving some money while contributing towards environmental sustainability.

For comparison purposes between different cities, the base case of the analysis takes the point of view of a ‘standard household’ consisting of a family of 4, with both parents and kids going out during the day. The main objective is to determine the optimal decision when choosing a rooftop solar system, i.e., what type and quantity of panels maximize economic returns.

In the valuation of this project, there are three main aspects: the acquisition and installation of the panels, the financing structure of the investment, and the cash flow generated during the useful life of the panels. Unlike a corporate project, the capital structure cannot be constant, and a loan needs to be paid back, therefore, for each year of the project, cash flow is estimated considering a Cash Flow to Equity (CFTE) basis.

### **Formula 1: Cash Flow to Equity at year t**

$$CFTE_t = \text{Savings from replacing grid energy}_t + \text{Income from selling to the grid}_t \\ - \text{Maintenance Costs}_t - \text{Debt Service}_t - \text{Investments}_t$$

The positive cash flows are the inflation-adjusted incomes from the opportunity cost of no longer having to buy so much energy and the selling of any production surplus.

Apart from the equity cost of financing the initial investment, there are some recurring costs every year, mainly the repayment of debt and the inflation-adjusted maintenance costs.

### **3. Data Gathering & Assumptions**

In order to estimate each component of the CFTE (*Formula 1*) for the lifetime of the project, extensive research was performed to realistically and thoroughly benchmark the reality of a standard household installing and having a solar panel system in the city of Porto.

#### **3.1 Setting up a Solar PV System**

At the absolute centre of this discussion is the current offering of solar PV systems that a Porto household has access to. The dynamics of this market have been rapidly changing as new players offer new technologies and solutions. Understanding and choosing the correct solar panel solution is key. Nevertheless, comparing the vast array of technicalities and offerings can be a daunting task even for the most research-savvy consumers.

A considerable number of entities, selling monocrystalline solutions (the most common type of solar panels), were consulted (*Appendix 1*) in order to realistically understand what type of offers one can currently purchase and what are likely to be the upfront costs, the energy generation capabilities, the maintenance costs, the useful lifetime, and other core inputs.

#### **Comparing Panel Offers and Technologies**

Analysing dozens of suppliers and benchmarking them against each other, one can quickly highlight that some are more cost-effective than others. However, for this exercise, it's very important to "compare apples with apples" as we can easily get attracted into a deal that, even though has a cheaper price tag, may actually provide us with an incomplete solution.

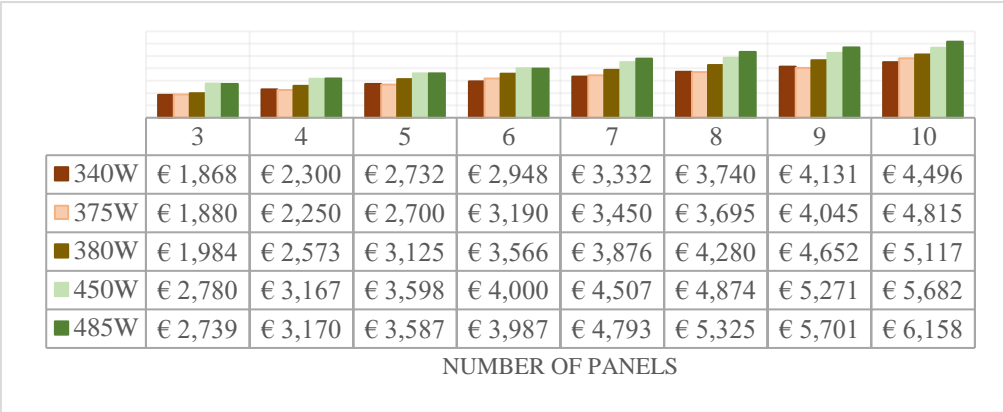
Therefore, all offers compared include the entire cost of setting up a system, i.e., solar panels, installation service, an optimal support structure, an inverter of adequate capacity, monitoring capabilities, and mechanical and performance warranties. The best offers, for the most common output power rates, ranging from 340 watts (W) to 485W, were chosen.

This analysis is showcased, alongside the details of the supplier, in *Appendix 2*. Some suppliers

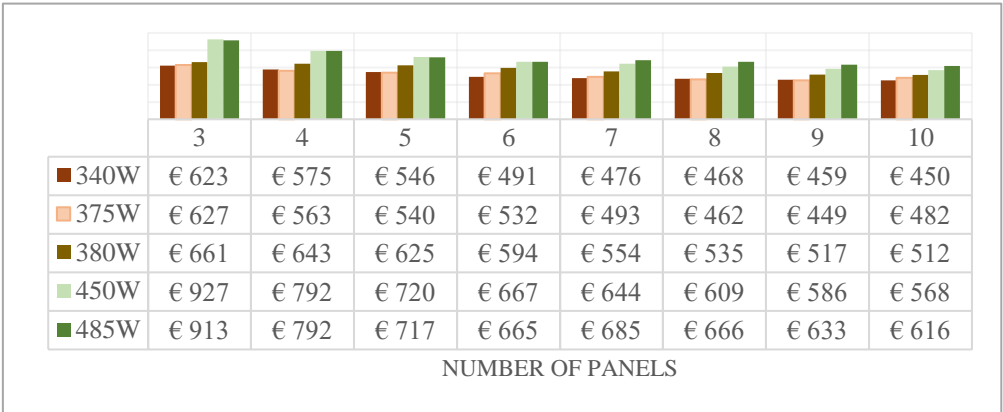
did not provide prices for offers for all numbers of panels between 1 and 20, hence, a simple linear interpolation was performed to fill some non-frequent gaps (*Appendix 3*).

This complete canvas of solar panel offerings allowed us to study how the prices changed according to the peak power per panel and number of panels bought.

**Table 1: Total cost of a solar PV system, per power and number of panels**



**Table 2: Cost per unit of a solar PV system, per power and number of panels**



From a quick analysis of *Table 1* and *Table 2* one can conclude that, as expected, prices are positively correlated with higher power rates, and price per unit decreases as the number of panels increases. Evidently, different solutions will yield different returns, as both their costs and energy generation capabilities will greatly affect the cash-flow profile of the project.

Consequently, deriving the best solution is not something that can be done arbitrarily, as choosing the lowest cost per unit. Instead, the approach was to take each combination, perform a scenario analysis and choose the one that maximizes economic terms (*section 4.1*).

## **Warranty, System Losses, and Degradation**

Since the panels will generate energy from the day they are installed until the day they stop functioning, one cannot accurately predict the duration of a solar PV project (NREL 2016).

The industry standard for a solar panel's productive lifetime is 25-30 years (Energy Sage 2022).

The suppliers considered include a standard performance warranty of 25 years. That is, while this guarantee is in place, the suppliers assure certain normal productivity of the panels and therefore the consumer is safeguarded from any major degradation or performance issues.

Therefore, we consider this value to be the lifetime of the project, as an extension from that would be severely exposed to risks and would change the low-risk profile of this valuation.

However, since it is not easy to accurately pinpoint when the panels will become non-operational, a sensitivity analysis is done regarding the useful lifetime (*section 4.3*).

Manufacturers of solar panels also predict a ~0.5% degradation rate (D. C. Jordan 2011) per year in the power output, which gradually results in the panel getting less productive as time goes by. More so, the power delivered by the panels is usually lower than the power produced by the PV modules. There are several causes for this loss, ranging from weather characteristics to infrastructure bottlenecks. The industry default of 13.5% has been widely used in the main databases (EC PVGIS 2022) and is therefore assumed for simplicity purposes.

## **Maintenance Costs**

Keeping the system up and running implies low and infrequent costs. Any performance issues are covered by warranty, so maintenance is mostly cleaning the panels once or twice per year, which the owner can do quite easily and cheaply on his own.

Regarding more thorough check-ups and minor parts replacements, the system should be serviced from time to time (Baklouti 2020). Costs should be around 15€ per panel, per service (*Appendix 4*). On average, yearly costs may be around 8€ per panel, rising along with inflation.

## **3.2 Solar Irradiance**

In order to estimate the future energy capabilities of the solar panel system, we must know what is the typical amount of solar irradiance that the city of Porto gets during every hour of the year. Information was collected from the European Commission's Photovoltaic Geographical Information System (EC PVGIS 2022) for a location in the centre of Porto (41.141N, 8.639W). The data comes from the PVGIS Sarah 2 Database, assuming a crystalline silicon PV, with the system loss default mentioned in *section 3.1*, mounted in a fixed position, at the optimized slope and azimuth, and in a roof with full sun exposure.

Our goal is to estimate what is the solar irradiance for the next decades in this location. For this particular metric, we can use historical results to accurately indicate future performance, since, even though some years are more or less cloudy than others, on average deviations from the mean are residual. The 2017-2020 average of the irradiance at that location was used. Note that since 2020 is a leap year, the 29<sup>th</sup> of February was discarded for normalization purposes.

## **3.3 Electricity Consumption**

The viability of installing solar panels in a household is highly dependent on how much electricity that household utilises. After all, the main purpose of installing solar panels is to replace a pricey energy supply with free sun-generated energy. However, solar panels themselves are not able to store energy, therefore, there must be a match between energy production hours (sunlight hours) and energy consumption. Hence the necessity to estimate the consumption amount and its distribution throughout time.

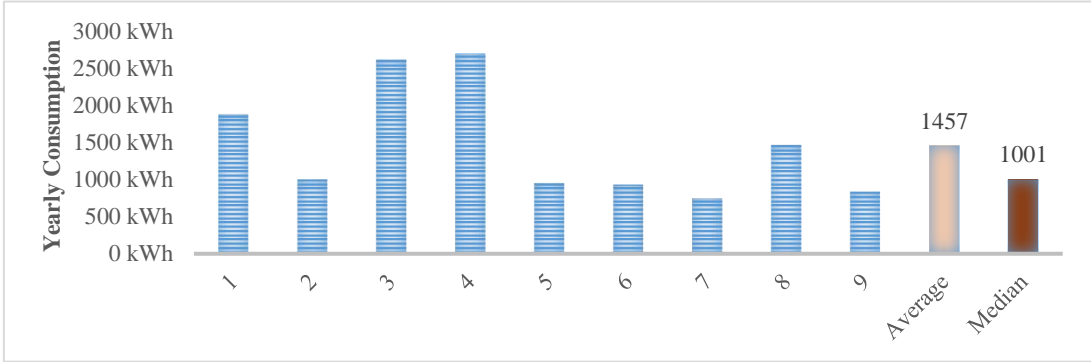
As mentioned in *section 2*, this study takes the point of view of a standard residential household of a family of 4 in Porto, in which, during the typical workday, both parents go off to work and the kids go to school.

**Consumption Quantity**

The total yearly kilowatt per hour (kWh) consumed is a core input for this analysis and its estimation was backed by two different approaches, empirical surveys and macro research.

The first was achieved by interviewing a sample of households that reside within the location of study, the city of Porto. Results were collected from a diverse range of participants, inhabiting houses of a varying number of residents, sizes, construction types, and ages, as well as with different electric equipment. *Figure 1* highlights the main results and estimates what the average yearly consumption per person may possibly be. Households with different characteristics and equipment (e.g., having gas and electricity or just electricity), yield different consumption levels. Hence, in order to estimate the consumption of the typical standard household of 4 people, the median consumption per person was used, pointing towards 4000 kWh of total yearly consumption. *Appendix 5* provides, in further detail, a description of each household surveyed.

**Figure 1: Survey of 9 Porto families regarding per-person electricity consumption**



The second approach was done with the objective of performing an “acid test” on the values estimated by the empirical surveys, i.e., to see if they make sense and match the range of academic and statistical research regarding domestic consumption. Macro data from national entities adhere to the range of the sample collected, with the energy consumption for domestic purposes per capita being 1300 kWh in 2020 (PORDATA 2020), a stable value for the past decade. Furthermore, one should also consider that two members of the specified standard

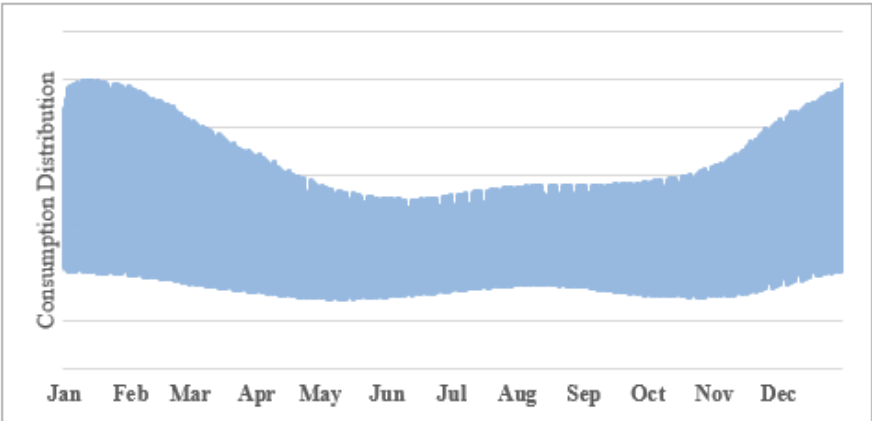
household are children. Academic researchers, with a large U.S. sample, have shown that age has complex relationships with energy consumption, concluding that residential energy consumption increases over the life course (Hossein Estiri 2019). One can therefore make an ‘educated guess’ in estimating that a family of 4 with 2 children has a slimmer electricity consumption than simply multiplying the per capita data by 4.

After carefully considering both the empirical survey results and macro research, the annual consumption is estimated to be around 4000 kWh for the standard household in the city of Porto. This is a core input for analysis purposes, that can dynamically change throughout the lifecycle of the investment, and therefore a sensitivity analysis is performed in *section 4.3*.

**Consumption Profiles**

In order to allocate the total yearly electricity consumption to every 8760 hours of the year, a load distribution must be defined. E-redes, the main Portuguese electricity grid operator, provides great data on nationwide users, and actively releases a lot of data characterizing consumers. One of their publications tackles this distribution load issue, providing data on several consumption profiles for each hour of the calendar year (E-redes 2022). The profile that best suits the standard residential household described, is the ‘BTN C’ profile briefly showcased in *Figure 2*. A thorough definition of this profile and how its consumption changes throughout the seasons, hours of the day, and days of the week, is included in *Appendix 6*.

**Figure 2: BTN C profile hourly electricity consumption throughout the year**



### 3.4 Electricity Production and End-Use

With the solar radiation for a location in the city of Porto obtained from section 3.2 and after choosing one of the solar panels' solutions in *section 4.1*, it is possible to estimate the electricity that is going to be produced in each hour of the year. The solar radiance data provides the PV system generation capabilities in kWh for a 1 kW panel,  $P(W)_t$ , hence the first step is adapting those generation capabilities to our system accordingly.

#### **Formula 2: Energy production at each hour (t) of the year**

$$\text{Energy Produced}_t = P(W)_t \times \text{Panel Efficiency (kWh)} \times \text{Number of Panels}$$

Naturally, yearly production will be the sum of the energy produced in all the hours of the year. In order to determine how much of that production is used for self-consumption and how much is sold to the grid, we must distribute the yearly energy consumption for each hour of the year according to the consumption profiles in *section 3.3*.

#### **Formula 3: Energy demand at each hour (t) of the year**

$$\text{Energy Demand}_t = \text{Total Yearly Demand (kWh)} \times \text{Profile Fraction Hour}_t$$

Since solar panels by themselves cannot store energy for significant periods of time, solar energy produced has to be consumed around the same time it is being generated. For calculation purposes, for each hour of the year, if demand surpasses production, all energy produced is used for self-consumption. However, if demand is inferior to production, there is a surplus and the not-utilised energy is discharged back to the grid.

### 3.5 Electricity Prices

As mentioned in *section 2*, there are two sources of positive cash flow of this project: the avoided cost of no longer having to buy so much energy and the selling of production surplus. At the centre of both income sources are the price that it costs to buy the electricity and for how much can we sell it. These values are very different and have very specific underlying

technicalities that anyone who is investing in a solar panel system should have knowledge of. Naturally, both buying and selling prices are expected to increase alongside inflation.

### **Buying from the Grid**

Understanding how much one pays for electricity is an exercise as simple as looking at how much one pays every single month. However, using our production capabilities to replace a portion of the used energy, will not proportionately reduce our monthly bill. In fact, a considerable part of our electricity bill is linked to fixed costs - e.g., the power kilo-volt-amperes (kVa) flat cost, the access to the grid cost, and other tariffs (ERSE 2022). These do not depend on the kWh consumed and must be paid anyhow. What we want to use, as an opportunity cost, is the price per unit we will avoid paying, as we replace kWh from the grid with electricity generated from the solar panels.

If we assume the family currently contracts the most competitive energy supplier on the market (Luzegas 2022), the price per kWh is at around 0.155€ (pre-tax), considering a normal 6.9 kVa power contract and a simple time cycle. Electricity, per month, in Portugal, is taxed at 13% for the first 100 kWh and 23% afterward. For a consumption of, for example, 333 kWh per month - 4000 kWh from section 3.3 divided by 12 months - this results in an after-tax variable cost of 0.19€ per kWh consumed. This is the real opportunity cost since, by each kWh of solar energy produced and used for self-consumption, we are saving 0.19€.

### **Selling to the Grid**

Most solar panel systems are frequently under a scenario in which the amount of energy being generated is superior to the amount being consumed by the household. Solar panel modules are not able to store the energy for more than a few minutes hence, any surplus of energy is discharged back to the public grid. Most frequently, until now, this was done for free. However, some solutions have arisen that enable selling the energy.

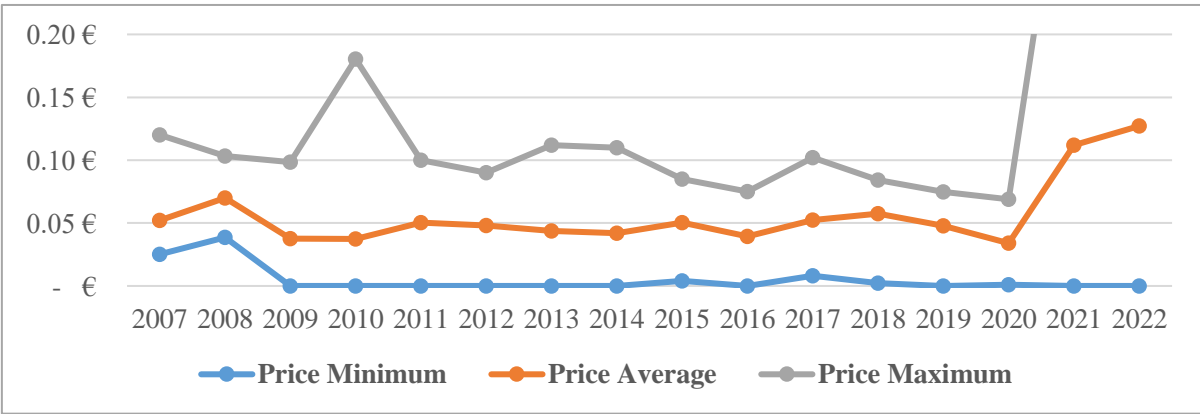
In Portugal, there is an administrative and legal process in order to be able to sell electricity.

Mainly, you need to register your panels with the appropriate government entity – DGEG - and register yourself with the tax authority as an energy seller. This process, although very bureaucratic, is usually straightforward and doable. After that, you have to sign a contract with a company that will buy your energy. Although increasing, there are only a few companies in Portugal that buy solar energy surplus. A list of consulted entities is in [Appendix 7](#). At this point, there is the choice between either accepting a fixed price or a variable price contract.

Through the fixed option, you enter into a simple contract with a willing counterparty, for a determined duration, allowing you to sell them your surplus energy at a pre-determined price. Visiting some companies’ offerings, we can see campaigns as high as 0.07€/kWh (EZO Energia 2022). Yet, these are short-term contracts and a more holistic look at other offers longer contracts should be around 0.03€/kWh net (NovaEnergia s.d.)

The other option is to accept a variable contract that is indexed to the Wholesale Iberian Market minus a commission of 20% and other periodic system management costs (~10%). These market dynamics are benchmarked by OMIE, the designated electricity market operator. *Figure 3* showcase the evolution of the spot market since 2007.

**Figure 3: Iberian wholesale market electricity prices, € / kWh (OMIE 2022)**



Due to the global turmoil in the energy market for the past year, Iberian wholesale electricity prices have spiked to unprecedented levels. The price average has risen from a decade-long stable level of around 0.05€/kWh, up to a current disruption at around 0.13€/kWh.

In order to fit with the risk-free profile of this investment, the fixed rate was chosen. Nonetheless, as the unpredictability of the future rises, this input needs to be studied carefully. A sensitivity analysis is performed in *section 4.3*, varying both the buying and selling prices.

### **3.6 Government Subsidies**

The Portuguese government has been running programs that aim to promote renewable energies such as solar (Fundo Ambiental 2022). They have been structured in such a way that successful applications receive back 85% of the investment (without VAT) up to a maximum of 2500€. There have been two phases of this support, which were very popular.

The last phase finished in April 2022, and, at the moment, there is no public information regarding the existence or non-existence of the next phase. European and National funds appear to still be allocated toward the environmental fund which is still making subsidies efforts toward sustainability. Nonetheless, no information regarding solar panels has come out.

Usually, these funds are structured in a retroactive manner, so we do not need to postpone our investment until a new phase is open. We can install it now and hand over the receipt later when a new phase finally comes back. The last phase accepted investments all the way back from 2020 onwards. However, if it does not open in the short to medium term, there is a risk that the subsidy is not applicable.

This current interregnum makes this assumption absolutely critical to this analysis, as receiving up to 85% of the investment back, or not, completely changes all financial metrics. Consequently, the only reasonable approach is, not to set an absolute position, but to present the analysis for both cases, with *section 4.4* assuming a no-subsidy scenario.

### **3.7 Financing Structure & Costs**

The way the financing is structured has an impact on economic terms but also on the distribution of the cash flows, as equity and debt have different costs and implications. We assume a 75%

debt base case and perform a scenario analysis around the financing structure.

**Debt Costs**

The debt cost was estimated by benchmarking regional and national banks for consumer and renewable energy loans. Naturally, as the demand for solar panels has boomed, demand for financing of these investments also grew, and banks developed new solutions.

Usually, this type of loan has a maturity ranging from 2 to 10 years with effective costs that depend on this maturity and on the nominal amount requested. In order to ask for realistic bank proposals, we stipulated a standard 5-year loan maturity and compared several offers, as showcased in Appendix 8. The best offerings converge at a 4.1% yearly all-in cost.

For valuation purposes, debt is projected to be repaid according to the annuity formula.

**Formula 4: Debt annuity**

$$\text{Annuity Payment} = \text{Loan Amount} \div \frac{1 - (\frac{1}{(1+r)^n})}{r} \quad \begin{matrix} n = \text{Number of Periods} \\ r = \text{Discount Rate} \end{matrix}$$

Suppliers of solar panels, following this trend of financialization of renewables, also started offering credit solutions. Most of them are advertised as having zero interest rate promotions, however, a closer inspection of several of these offers in Portugal yielded higher overall costs when compared to suppliers not offering credit (Appendix 9). Since none of these offers appear competitive, we will not consider 0% offers from suppliers, at least not yet.

**Equity Costs**

As mentioned in *section 2* of this document, the main value-creation of this project is based on avoided costs and the risk profile is assumed to be minimal. Equity costs are therefore capable of being proxied by risk-free benchmarks. Naturally, this value is constantly changing in response to market and macro dynamics. *Table 3*, extracted in November 2022, supports the 3% risk-free rate used for valuation purposes.

**Table 3: Risk-free rates benchmark**

<b>Instruments</b>	<b>Rate</b>
10y EUR Interest Rate Swap	3.01%
10y Portuguese Government Bond	2.99%

### **3.8 Inflation**

In 2022 inflation spiked, coming from a decade-long ‘dormant’ period where the European Central Bank (ECB) managed to keep it below their public long-term target of 2% (Trading Economics 2022). In fact, the euro area annual inflation for energy prices was 40% in September 2022 and overall inflation is projected to be around 10% for this year (Eurostat 2022). Inflation will remain high in the short term due to soaring energy and food prices, supply shortages, conflicts, and other social-economic problems. c

The Euro System predicts that, in 2023, inflation will be 6.0% and in 2024 will be 2.8% (ECB 2022). For the remaining useful lifetime of this project, inflation is expected to be tamed and converge toward the target.

Utilising a Compounded Annual Growth Rate (CAGR) approach to compute short-term volatility-adjusted inflation, yields a 2.2% yearly rate for the 25 years of the project.

#### **Formula 5: Compounded Annual Growth Rate**

$$CAGR = \left( \left( \frac{EV}{BV} \right)^{\frac{1}{n}} - 1 \right) \times 1$$

*EV = Ending Value; BV = Beginning Value*

*n = Number of Periods*

## 4. Analysis and Recommendation

After estimating each crucial input, we are now able to carefully analyse a possible investment.

Table 4 sums up all the base case assumptions from section 3.

**Table 4: Summary of base case inputs for the standard household**

<b>Energy Consumption</b>	4000 kWh / year	<b>Efficiency Degradation</b>	0.5% / year
<b>Electricity Buying price</b>	0.19 € / kWh	<b>Debt Portion</b>	75%
<b>Electricity Selling price</b>	0.03 € / kWh	<b>Debt Cost</b>	4.1%
<b>Power / Number of Panels</b>	Section 4.1	<b>Debt Maturity</b>	5 years
<b>Price per Panel</b>	Table 2	<b>Government Subsidies</b>	85%, max 2500€
<b>Duration of the Project</b>	25 years	<b>Cost of Equity</b>	3.0%
<b>Maintenance Cost Yearly</b>	8€ / panel	<b>Inflation</b>	2.2%

### 4.1 Optimizing for the Best Solar PV System

#### Optimal Solution Analysis

To estimate what the optimal solution in economic terms was, a scenario analysis for the main combinations of the number of panels and panel peak power was performed. The output of the Net Present Value (NPV) optimization analysis is expressed in Table 5.

**Table 5: NPV optimization analysis**

<b>NPV</b>	<b>340W</b>	<b>375W</b>	<b>380W</b>	<b>450W</b>	<b>485W</b>
3 Panels	4629 €	4923 €	4941 €	5277 €	5505 €
4 Panels	5218 €	5516 €	5490 €	5823 €	6039 €
5 Panels	5608 €	5900 €	5847 €	5872 €	6118 €
6 Panels	5923 €	6112 €	5768 €	5871 €	6145 €
7 Panels	5966 €	6163 €	5770 €	5729 €	5728 €
8 Panels	5809 €	★ 6201 €	5651 €	5708 €	5570 €
9 Panels	5650 €	6116 €	5547 €	5642 €	5559 €
10 Panels	5506 €	5588 €	5336 €	5553 €	5453 €
11 Panels	5392 €	5375 €	5214 €	5323 €	5208 €
12 Panels	5264 €	5159 €	5075 €	5091 €	4961 €

The recommended solar PV system is the one that maximizes the NPV, that is 8 panels of 375W peak power. The NPV graph curve is concave in a value within the studied range for all output power rates, hence, there seems to be no better solution outside of this scope.

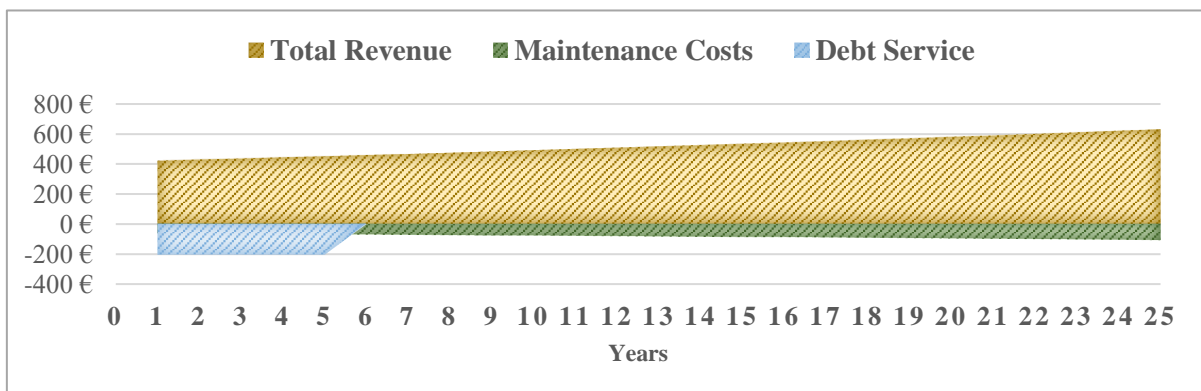
## Details and Outputs of the System

The optimal system costs 3695€ to purchase and install and has a capacity installed of 3 kilowatts peak (kWp), 1232€ per kWp. This results in 4762 kWh being generated in the first year, with 1751 kWh (37%) of that production being utilized by self-consumption, allowing the family to have 44% energy autonomy. This setup also results in a considerable amount of energy being sold back to the grid (63%), since 77% of all the generating hours have a production surplus, i.e., production surpasses demand for self-consumption.

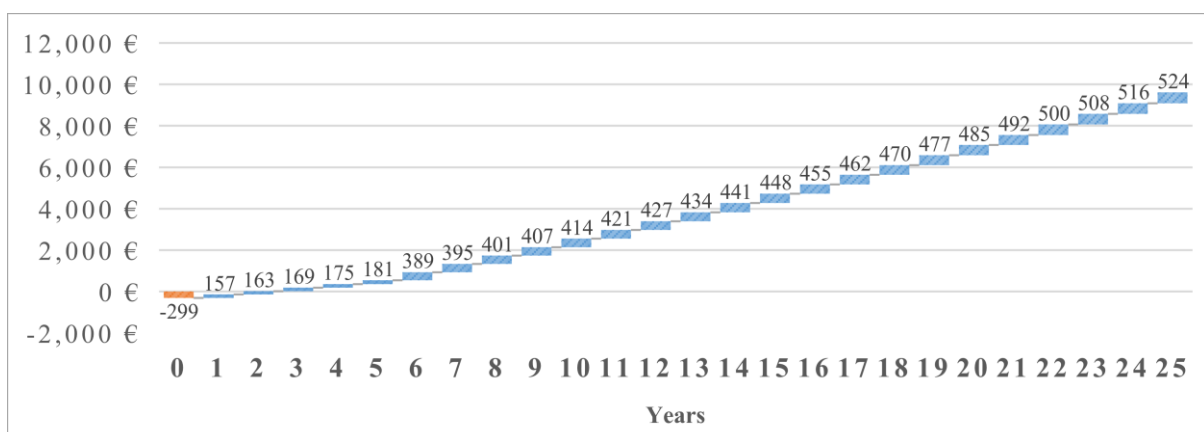
### 4.2 Financial Metrics

Considering the base case financing structure, the 3695€ investment would be supported by the maximum subsidies of 2500€, 896€ in debt, and 299€ in equity. This financing structure yields the cash-flow profile demonstrated in *Figure 4* and *Figure 5*.

**Figure 4: Yearly cash flows by source**



**Figure 5: Yearly and accumulated cash flow to equity**



As visually showcased, this investment rapidly becomes profitable. After the initial equity investment, the first 5 years have a debt annuity of 202€, but even with that, overall cash flow to equity is positive. From the 6<sup>th</sup> year forward, revenue from savings and selling to the grid greatly surpasses the maintenance costs. This results in a 6201€ NPV with an associated Internal Return Rate (IRR) of 61.8% per year. More so, since the initial investment is quickly paid back, the Payback Period (PB) is just 2.1 years.

A useful measure utilized, when measuring and comparing electricity generation sources, is the Levelized Cost of Energy (LCOE). This is the price of energy in € per kWh, which sets the NPV to zero assuming all energy generated by the panels is sold to the grid. The same discount rate as for the NPV calculation is used and, since this is a nominal value, the electricity selling price also grows with inflation. The LCOE of this setup is 0.0215€ per kWh.

**Formula 6: Levelized Cost of Energy**

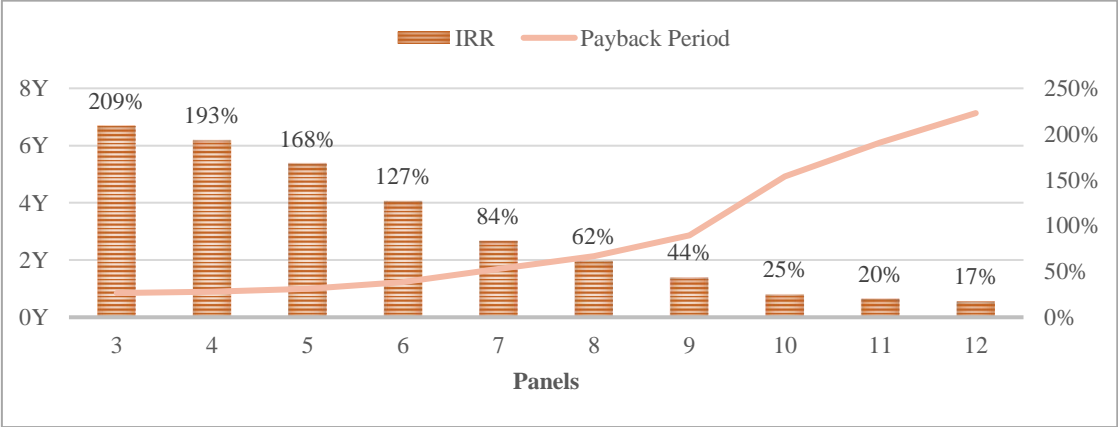
$$NPV = 0 \Rightarrow \sum_{t=1}^T \frac{(E_t \times p) - C_t}{(1+r)^t} = 0 \Rightarrow p = \frac{\sum_{t=1}^T C_t \div (1+r)^t}{\sum_{t=1}^T E_t \div (1+r)^t}$$

$E_t$  = kWh Produced in Year t       $C_t$  = Costs in Year t       $r$  = Discount Rate

**4.3 Sensitivity and Scenario Analysis**

This valuation considers several factors that are volatile in nature, thus, a sensitivity analysis was performed to understand how sensitive the economic terms are to these dynamics.

**Figure 6: Number of panels sensitivity analysis**



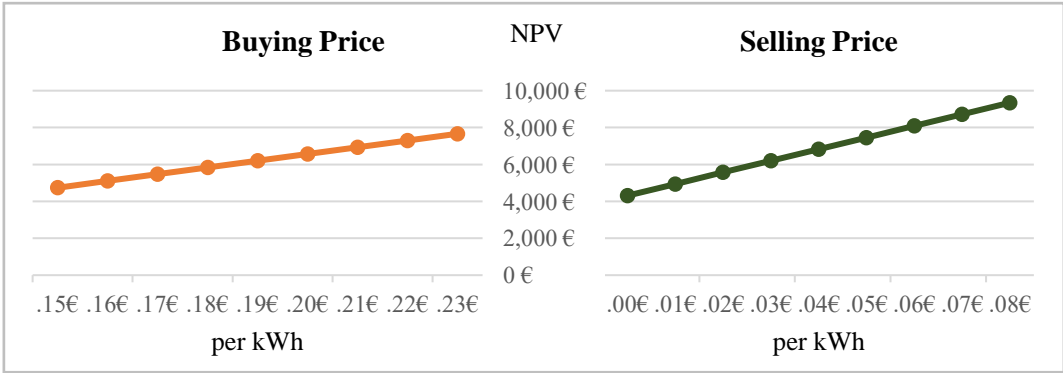
The NPV is concave around the 8<sup>th</sup> Panel but with not-so-significant changes around that value. Yet, other financial metrics behave very differently. IRR naturally lowers and the Payback Period increases as the number of panels rise since the upfront equity investment rises. Both these metrics are very sensitive to the number of panels.

**Table 6: Financing structure scenario analysis**

NPV (€)		Debt (%)	IRR (%)	
Subsidies	No Subsidies		Subsidies	No Subsidies
6229 €	3729 €	0%	32%	10%
6219 €	3700 €	25%	36%	10%
6210 €	3671 €	50%	44%	11%
6201 €	3641 €	75%	62%	12%
6191 €	3612 €	100%	-	13%

The NPV of the investments naturally changes significantly having government subsidies, or not, since up to 85% of the investment may be facilitated. The leveraging effect has a significant impact on the IRR of the subsidized scenario. In contrast, NPV changes are residual, since the debt interest rate is very similar to the equity discount rate.

**Figure 7: Electricity prices sensitivity analysis**



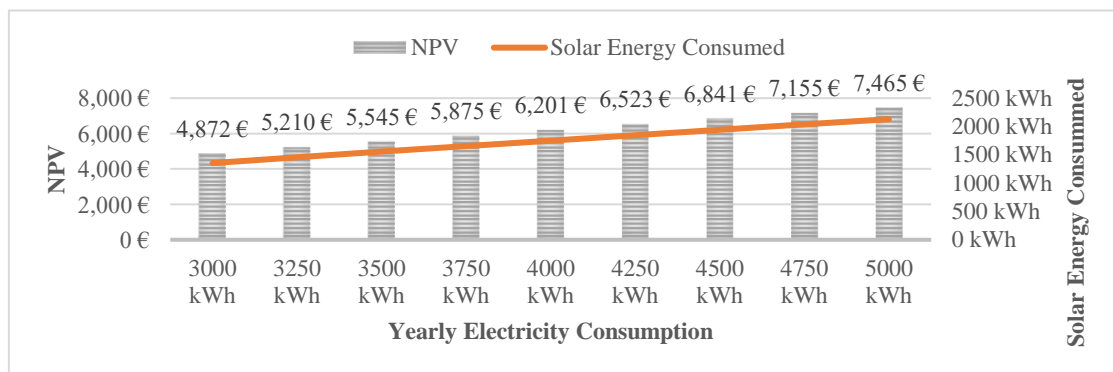
There is a positive correlation between both buying and selling electricity prices and the project’s NPV. The first is inherent to the savings logic, the more expensive energy becomes, the more value there is in replacing it. If this price slightly deviates from the base case scenario (0.19€/kWh) to just 3 cents higher, the NPV becomes 1097€ higher. With the rising energy prices in the current times, both these sensitivities are good arguments in favour of solar panels.

**Figure 8: Solar panels' useful lifetime sensitivity analysis**



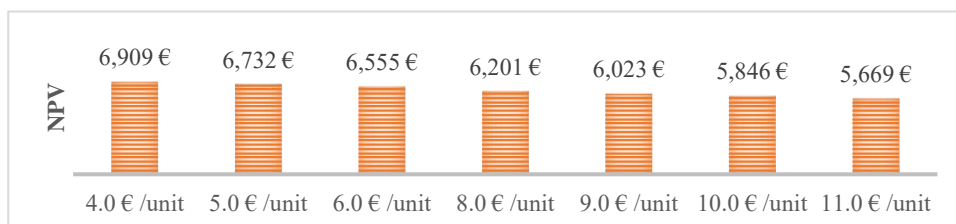
Since for every year revenues exceed maintenance costs, the longer the panels last, the higher the NPV. Major physical damage to the panels is unlikely since they are installed in a typically secluded and elevated zone. Plus, any performance issues, above what already is expected, are covered by warranty. Hence no foreseeable issue should render the lifetime below 25 years and thus any volatility of this input will likely occur on the upside.

**Figure 9: Yearly electricity consumption sensitivity analysis**



As the family's yearly electricity consumption rises, the amount of solar energy that is consumed increases and, therefore, there is less surplus to sell to the grid. Since the electricity buying price (0.19€ / kWh) is greatly above the selling price (0.03€ / kWh), for every kWh that is used, instead of being sold to the grid, the NPV rises.

**Figure 10: Maintenance costs sensitivity analysis**



Maintenance costs have a negative impact on NPV, with a -10% impact for a 3€ / unit increase.

## 4.4 No Government Subsidies Scenario

As of the writing of this paper, government subsidies are an unsure variable. Therefore, a proper analysis feels compelled towards considering a scenario where government subsidies do not exist, *ceteris paribus*. In fact, the recommendation becomes different, as per *Table 7*.

**Table 7: No government subsidies NPV optimization analysis**

NPV	340W	375W	380W	450W	485W
3 Panels	3095 €	3379 €	3312 €	2995 €	3256 €
4 Panels	3330 €	3669 €	3377 €	3264 €	3480 €
5 Panels	3365 €	★3684 €	3287 €	3313 €	3559 €
6 Panels	3502 €	3553 €	3209 €	3312 €	3586 €
7 Panels	3407 €	3603 €	3211 €	3169 €	3169 €
8 Panels	3249 €	3641 €	3091 €	3149 €	3011 €
9 Panels	3091 €	3556 €	2988 €	3083 €	3000 €
10 Panels	2947 €	3028 €	2777 €	2993 €	2894 €
11 Panels	2832 €	2816 €	2654 €	2764 €	2649 €
12 Panels	2704 €	2600 €	2516 €	2531 €	2401 €

In this scenario, the recommended set-up now becomes installing just 5 panels of 375W with an NPV of 3684€, an IRR of 15%, and a payback period of 7.8 years. Thus, becoming a significantly less appealing project, when in comparison to the base case.

If the government does not confirm or deny further subsidies at this stage, the investment will need to be made in a very uncertain scenario. However, from an economic and risk management perspective, there seems to exist a remarkably viable solution.

*Table 7* indicates that a very similar NPV of 3641€ can be achieved by installing the same set-up as the base case scenario (8x 375W), resulting in a similar IRR and payback period of 12% and 7.9 years, respectively.

On one hand, if the subsidies materialize, the set-up will be optimal and will create the most economic value from all available solutions. On the other hand, if the government decides to stop subsidizing households' renewable energy investments, the outcome would still be virtually the same as if we had the certainty that subsidies would not exist beforehand.

## 5. Economic Viability of a Lithium Battery Solution

The looming expansion of the residential solar panel market has also brought attention to complementary products such as batteries. Adding an energy storage system, in theory, can be a problem-solver for set-ups that have a significant production surplus, allowing energy that was going to be sold to the grid at a low price, to be used to replace energy consumed at a significantly higher price. Therefore, adding a battery will certainly result in increased savings in most cases. However, the key question is if these are enough to offset the cost of buying said batteries. As a matter of fact, batteries are very expensive and, even though their price has been decreasing over time, in most cases they are still not worth it.

The most common and cost-effective type is lithium batteries. *Appendix 10* showcases the search for compatible battery providers in the city of Porto. The best offer, in € per kWh of capacity, is the Tesla Powerwall 2, with 13.5 kWh of capacity for the price of 6750€.

Simulating the implementation of this battery system on the base case and testing the impact on the key measured metrics, resulted in the analysis portrayed in *Table 8*.

**Table 8: Battery case x Base case analysis**

	Base	Battery	Δ
<b>NPV</b>	6201 €	1917€	-4283€
<b>IRR</b>	61.8%	5.9%	-56.0%
<b>PB</b>	2.1 Y	13.4 Y	+11.2 Y
<b>LCOE</b>	0.0235 €	0.0960 €	+0.0725€

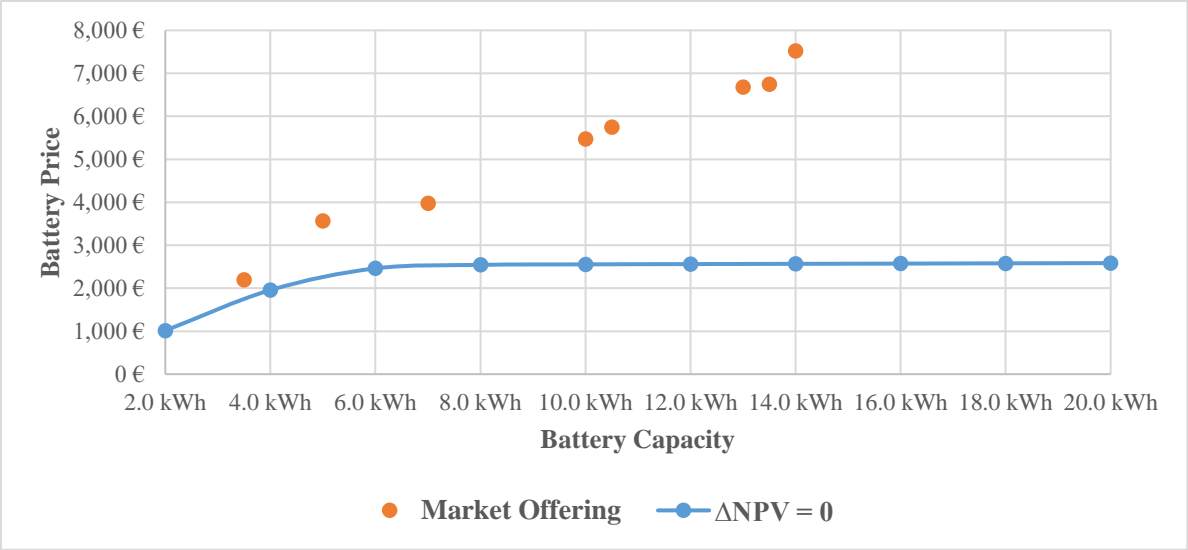
This analysis utterly concludes that adding a battery is far from ideal in this situation, as it results in expressively lower performance, all throughout the studied economic metrics.

A further sensitivity analysis demonstrated that, ceteris paribus, in order for the Battery case NPV to equal the base case NPV, the 13.5 kWh battery would have to cost 2556€, or -62% of its current price. Different capacity batteries, at different price points, also do not seem to generate enough savings to compensate for their cost.

*Figure 11* showcases a scenario analysis concluding what the price of a battery with a certain

capacity must be, in order to generate the same NPV as the Base case. In other words, for varying kWh capacity, what is the price point at which the installation of a battery breaks even? This value is then compared to the best offer in the market for that same capacity. The conclusion was that it is not worth it to add a battery since there is no solution within the breakeven region.

**Figure 11: Battery case scenario analysis x Base case**



For this particular set-up, installed capacity above 8 kWh capacity line becomes practically useless, since that storage capacity allows for almost every bit of energy generated to be used for consumption. Hence, any installation above that range is unnecessarily expensive. However, if we consider the low spectrum of capacity, from 4 to 8 kWh, we conclude that some market offerings are getting really close to the break-even line, meaning that in the near future they might become economically viable investments.

## 6. Group Part: Portugal – Comparing Results in Different Cities

The economic analysis of the rooftop solar set-up that allows optimizing the NPV was performed in parallel in different cities worldwide. In Portugal, the cities analysed were Porto, Lisbon, and Portimão, by Tomás Carvalho, Jéssica Gonçalves, and Bruno Lázaro, respectively. When conducting the study in cities located in the same country, there are similarities in certain assumptions. However, the dispersed location of these cities leads to divergences in others, causing heterogeneous outcomes and conclusions. This section aims to pinpoint which assumptions the different cities have in common, which ones diverge, and in what proportion and value these differences affect the result of the analysis.

**Table 9: Equal assumptions**

<b>Electricity Buying Price</b>	0.19 € / kWh	<b>Debt Maturity</b>	5 years
<b>Electricity Selling Price</b>	0.03 € / kWh	<b>Debt Portion</b>	75%
<b>Load Profile Distribution</b>	<i>E-rede 'BTN C'</i>	<b>Debt Cost</b>	4.1%
<b>Inflation</b>	2.2%	<b>Equity Cost</b>	3.0%
<b>Government Subsidies</b>	85% of the cost, up to a maximum of 2500€		

**Table 10: Distinct assumptions**

	<b>Porto</b>	<b>Lisboa</b>	<b>Portimão</b>
<b>Solar Irradiance (1kW)</b>	1587 kWh (Av. 2017-2020)	1580kWh (Av. 2018-2020)	1820 kWh (Av. 2017-2019)
<b>Electricity Consumption</b>	4000 kWh	3560kWh	3600 kWh
<b>Panel Costs &amp; Installation</b>	3695€ for 8x 375W	3945€ for 8x 390W	4402€ for 9x 380W
<b>Yearly Maintenance</b>	8€ per panel	7.5€ per panel	4.9€ per panel

- **Solar Irradiance:** Solar irradiance strongly depends on location, which is different for the three cities. Even though Porto and Lisbon have similar amounts of total solar irradiance, the hourly irradiance is significantly different. Consequently, the match with the distribution load differs, leading to different results.
- **Electricity Consumption:** Electricity consumption varies according to the different needs

of users, depending on the city's location. According to the collected electricity bills, households in Porto have a higher electricity consumption, while those in Lisbon and Portimão have a lower consumption. This difference may be driven by the fact that Porto, positioned in the north of Portugal, is subject to lower temperatures during the winter. Thus, increasing the likelihood of households utilizing electric heaters to warm their houses. Lisbon and Portimão, located in the south of Portugal, face higher average temperatures.

- **Panel Costs & Installation:** The best offers vary by city, affecting the outcome and recommendation. The main difference results from purchasing the equipment from local dealers, as in the case of Porto, versus from dealers distributed across the country, as in the case of Lisbon and Portimão. Different vendors provide various equipment with distinct materials and technologies, resulting in disparate output power rates and number of panels.
- **Maintenance Costs:** Similar to the cost of panels, maintenance costs vary by location and depend on valuation differences and assumptions.

To assess these assumptions' impact, each city's primary financial analysis was benchmarked against each other. For comparison purposes, all cities considered a scenario in which 8x panels were installed with 100% equity and government subsidies.

**Table 11: Valuation differences**

Scenario 8x Panels 100% equity	<b>Porto</b>	<b>Lisboa</b>	<b>Portimão</b>
<b>Consumption (kWh)</b>	4000	3600	3600
<b>Peak Power of 1 Panel (W)</b>	375	390	380
<b>Price for 8 Panels</b>	3695€	3945€	4030€
<b>Price per Wp</b>	1.24€	1.26€	1.33€
<b>Generation for 8 panels (kWh)</b>	4762	4928	5532
<b>Net Present Value</b>	6229€	6127€	7223€
<b>Internal Rate of Return</b>	31.6%	25.7%	28.1%
<b>Payback period (years)</b>	3.2	4.1	3.7
<b>LCOE (€/kWh)</b>	0.0232	0.0254	0.0195

**Table 12: Quantification of divergence factors**

Cities	Present Value of the Factors			NPV (100% Equity)
	Cost of Panels (After subsidies)	Maintenance	Revenue (Savings + Selling)	
<b>Lisbon</b>	-1445€	-1328€	8900€	6127€
<b>Portimão</b>	-1530€	-911€	9664€	7223€
<b>Porto</b>	-1195€	-1417€	8841€	6229€
<b>(Lisbon – Porto)</b>	-250€ (-245%)	+89€ (87%)	+59€ (58%)	-102€
<b>(Lisbon – Portimão)</b>	+85€ (8%)	-417€ (-38%)	-764€ (-70%)	-1096€
<b>(Porto – Portimão)</b>	+335€ (34%)	-506€ (-51%)	-823€ (-83%)	-994€

**Formula 7: Factors weight in NPV differences between cities (% in Table 12)**

$$Factor\ Weight = \frac{Factor_{City\ 1} - Factor_{City\ 2}}{NPV_{City\ 1} - NPV_{City\ 2}}$$

According to this analysis, one can conclude that there are several value levers behind valuation and recommendation disparities. The main difference between Lisbon and Porto is in the cost of panels. These two cities have similar irradiance levels, but the lower cost of solar panels in Porto gives it a significant advantage in the NPV. The main difference between Porto - Portimão, and Lisbon - Portimão is in the revenue. The cost of solar panels is higher in Portimão, but its superior solar irradiance allows Portimão to increase the savings and income cash flows, and therefore its NPV.

Investments in all three cities result in similar encouraging performance metrics. Therefore, Portugal seems to be an attractive location for solar PV investments, all throughout its territory.

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## Appendix

### Appendix 1: List of Consulted Suppliers

Supplier	Contact
Iberdrola	<a href="https://www.iberdrola.pt/02sicb/gc/prod/pt_PT/estaticos/docs/Iberdrola-Smart-Solar-10-2022.pdf">https://www.iberdrola.pt/02sicb/gc/prod/pt_PT/estaticos/docs/Iberdrola-Smart-Solar-10-2022.pdf</a>
Ikea / Contigo Energia	<a href="https://www.ikea.com/pt/pt/clean-energy/solar-systems/">https://www.ikea.com/pt/pt/clean-energy/solar-systems/</a>
Sun Energy	<a href="https://www.sunenergy.pt/particulares/autoconsumo/paineis-solares-fotovoltaicos-kits-de-autoconsumo/">https://www.sunenergy.pt/particulares/autoconsumo/paineis-solares-fotovoltaicos-kits-de-autoconsumo/</a>
Golden Energy	<a href="https://goldenergy.pt/paineis-solares/">https://goldenergy.pt/paineis-solares/</a>
Solar Shop	<a href="https://www.solarshop.pt/kit-autoconsumo-simples">https://www.solarshop.pt/kit-autoconsumo-simples</a>
Galp	<a href="https://www.galpsolar.com/">https://www.galpsolar.com/</a>
EDP	<a href="https://www.edp.pt/particulares/servicos/energia-solar/">https://www.edp.pt/particulares/servicos/energia-solar/</a>
Nortiago	Contacted through <a href="https://www.zaask.pt/">https://www.zaask.pt/</a>
Termohidro	Contacted through <a href="https://www.zaask.pt/">https://www.zaask.pt/</a>
Heliologics Tecnologias Ambientais	Contacted through <a href="https://www.zaask.pt/">https://www.zaask.pt/</a>
Gascan / Energyco	<a href="https://www.energyco.pt/kits-paineis-solares">https://www.energyco.pt/kits-paineis-solares</a>

### Appendix 2: Summary of Best Panel Offers

Supplier	Iberdrola	IKEA / Contigo Energia	Golden Energy	Solar Shop	Solar Shop
Peak Power	340W	375W	380W	450W	485W
# panels	€	€	€	€	€
3	1868	1880	1984	2780	2739
4	2300	2250	2573	3167	3170
5	2732	2700	3125	3598	3587
6	2948	3190	3566	4000	3987
7	3332	3450	3876	4507	4793
8	3740	3695	4280	4874	5325
9	4131	4045	4652	5271	5701
10	4496	4815	5117	5682	6158

**Note:** Calculated using the best offer for each technology, including installation, invertor, monitoring and same warranty.

### Appendix 3: Price per Unit Extended to 20 Panels Offerings

# panels	Price Per Unit				
	340W	375W	380W	450W	485W
1	754 €	758 €	800 €	1121 €	1105 €
2	685 €	689 €	727 €	1019 €	1004 €
3	623 €	627 €	661 €	927 €	913 €
4	575 €	563 €	643 €	792 €	792 €
5	546 €	540 €	625 €	720 €	717 €
6	491 €	532 €	594 €	667 €	665 €

7	476 €	493 €	554 €	644 €	685 €
8	468 €	462 €	535 €	609 €	666 €
9	459 €	449 €	517 €	586 €	633 €
10	450 €	482 €	512 €	568 €	616 €
11	438 €	479 €	499 €	565 €	613 €
12	430 €	477 €	489 €	563 €	610 €
13	408 €	474 €	465 €	560 €	607 €
14	388 €	472 €	441 €	557 €	604 €
15	368 €	458 €	432 €	554 €	601 €
16	361 €	444 €	424 €	551 €	598 €
17	354 €	431 €	415 €	549 €	595 €
18	347 €	418 €	407 €	546 €	592 €
19	340 €	405 €	399 €	543 €	589 €
20	333 €	393 €	391 €	540 €	586 €

Note: Some of the information gathered did not include details for offers of up to 20 panels. A linear interpolation was done to estimate some prices.

#### Appendix 4: Maintenance Services Offer

Supplier	Cost	Link
Worten	120€ up to 8x panels	<a href="https://www.worten.pt/campanha/manutencao-paineis-solares/produtos">https://www.worten.pt/campanha/manutencao-paineis-solares/produtos</a>

#### Appendix 5: Survey of Electricity Consumption in the City of Porto

House Number	1	2	3	4	5	6	7	8	9
Number of People	7	2	5	4	5	2	3	3	5
Type of Building	House	Apartment	House	Apartment	House	Apartment	Apartment	House	Apartment
Gas for Heating?	Yes	No	No	No	Yes	Yes	Yes	No	Yes
Gas for Cooking?	No	No	No	No	No	No	Yes	Yes	No
Gas for Water Heating?	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes
Yearly Consumption	13 139	2 002	13 071	10 789	4 755	1 859	2 242	4 390	4 183
Per Person	1 877	1 001	2 614	2 697	951	930	747	1 463	837

#### Appendix 6: BTN C Profile Description from E-redes Methodology

“Customers belonging to profile class C have the following characteristics: power less than or

equal to 13,8 kVA; annual consumption less than or equal to 7 140 kWh.

**Global analysis of the profile:** In this segment, the consumption profile is different from the previous profiles, having a characteristic aspect of domestic customers. Although the profile by type of day is similar throughout the months, in the winter months (December, January, and February) consumption stands out from the other months because it is higher. This means that these months will have a greater weight in the distribution of consumption throughout the year. It can also be seen that weekend consumption is as high as on weekdays.

**Analysis by type of day:**

- **Weekday:** minimum consumption is reached between 4 a.m. and 6 a.m., increasing considerably until 8 a.m. Between 8 a.m. and 1 p.m. consumption stabilises, with a tendency to increase, reaching a local maximum at 1 p.m. and then decreasing until 4 p.m. / 5 p.m. Finally, consumption increases again until 9 p.m., when it reaches its daily maximum, then decreases again until the end of the day. The highest consumptions occur between 8 p.m. and 10 p.m. (dinner time) in all months of the year.

- **Saturday:** the profile is very similar to that of weekdays, consumption being highest throughout the day, with the exception of the peak around 8 a.m./ 9 p.m. and the maximum value observed at 8 p.m. / 9 p.m., for which consumption is slightly lower. Minimum consumption is reached between 4 a.m. and 6 a.m. between April and November, as on weekdays, but it occurs later, between 5 a.m. and 7 a.m. in January, February, March and December. There is also a peak in consumption at lunchtime which is more pronounced on Saturdays than on weekdays. As on weekdays, the highest consumption occurs between 8 and 10 p.m. (dinner time), being anticipated to the period between 7 and 9 p.m. on cold months (January, October, November, and December).

- **Sunday/Holidays:** the profile is similar to that observed on Saturdays, although consumption during the lunch period has an even greater weight than that observed on Saturdays. The

minimum value is reached between 5 a.m. and 7 a.m.”

## Appendix 7: Companies that Purchase Solar-Generated Energy

Company	Contact
Alfa Energia	<a href="https://www.alfaenergia.pt/upp_venda_rede">https://www.alfaenergia.pt/upp_venda_rede</a>
EZU Energia	<a href="https://ezu.pt/venda_de_excedente">https://ezu.pt/venda_de_excedente</a>
SU Eletricidade (EDP)	<a href="https://sueletricidade.pt/">https://sueletricidade.pt/</a>
EcoChoice	<a href="https://www.ecochoice.pt/pt/home">https://www.ecochoice.pt/pt/home</a>
Energias Simples	<a href="https://www.energiasimples.pt/produtores/excedente">https://www.energiasimples.pt/produtores/excedente</a>

## Appendix 8: Credit Line Proposals

Bank	All-in Rate	Contact
Crédito Agrícola	4.10%	<a href="https://www.creditoagricola.pt/para-mim/financiar/simulador-credito-pessoal">https://www.creditoagricola.pt/para-mim/financiar/simulador-credito-pessoal</a>
BPI	4.10%	<a href="https://www.bancobpi.pt/particulares/credito/credito-energias-renovaveis">https://www.bancobpi.pt/particulares/credito/credito-energias-renovaveis</a>
Santander	4.60%	<a href="https://www.santander.pt/credito-pessoal/credito-energias-renovaveis">https://www.santander.pt/credito-pessoal/credito-energias-renovaveis</a>
Montepio	5.30%	<a href="https://www.bancomontepio.pt/particulares/credito/pessoal/credito-energias-renovaveis">https://www.bancomontepio.pt/particulares/credito/pessoal/credito-energias-renovaveis</a>
Banco CTT	5.30%	<a href="https://www.bancoctt.pt/campanhas/credito-pessoal-simulador">https://www.bancoctt.pt/campanhas/credito-pessoal-simulador</a>
Activo Bank	4.80%	<a href="https://www.activobank.pt/energias-renovaveis">https://www.activobank.pt/energias-renovaveis</a>
Millenium BCP	6.00%	<a href="https://ind.millenniumbcp.pt/pt/Particulares/Credito/Pages/Credito-Pessoal-Energias-Renovaveis.aspx">https://ind.millenniumbcp.pt/pt/Particulares/Credito/Pages/Credito-Pessoal-Energias-Renovaveis.aspx</a>
Cetelem	5.30%	<a href="https://www.cetelem.pt/">https://www.cetelem.pt/</a>

## Appendix 9: Supplier’s Zero Interest Attractivity Comparison

375W / panel set-up	Price	
	Regular Offering	"0% interest rate" Offering
4x panels	2250€	2632€
6x panels	3190€	3424€
8x panels	3960€	4188€
10x panels	4815€	5200€
<b>Supplier</b>	Contigo Energia	Gascan / EnergyCo

## Appendix 10: Solar Batteries Offerings

Supplier	Capacity (kWh)	Price (€)	Price per kWh	Warranty (years)	Link
Pylontech US3000C	3.5	2197	627.7	10	<a href="https://www.solarshop.pt/kit-baterias-litio-pylontech-us3000c-35kwh-com-armario">https://www.solarshop.pt/kit-baterias-litio-pylontech-us3000c-35kwh-com-armario</a>
Pylontech US3000C	7	3973	567.6	10	<a href="https://www.solarshop.pt/kit-baterias-litio-pylontech-us3000c-70kwh-com-armario">https://www.solarshop.pt/kit-baterias-litio-pylontech-us3000c-70kwh-com-armario</a>
Pylontech US3000C	10.5	5749	547.5	10	<a href="https://www.solarshop.pt/kit-baterias-litio-pylontech-us3000c-105kwh-com-armario">https://www.solarshop.pt/kit-baterias-litio-pylontech-us3000c-105kwh-com-armario</a>
Pylontech US3000C	14	7525	537.5	10	<a href="https://www.solarshop.pt/kit-baterias-litio-pylontech-us3000c-140kwh-com-armario">https://www.solarshop.pt/kit-baterias-litio-pylontech-us3000c-140kwh-com-armario</a>
Tesla Powerwall 2	13.5	6750	500.0	10	<a href="https://www.europe-solarstore.com/2-x-tesla-powerwall.html">https://www.europe-solarstore.com/2-x-tesla-powerwall.html</a>
LG CHEM Resu	10	5472	547.2	10	<a href="https://www.europe-solarstore.com/batteries/manufacturer/lg-chem/lg-chem-resu-10-48v-lithium-ion-storage-battery.html">https://www.europe-solarstore.com/batteries/manufacturer/lg-chem/lg-chem-resu-10-48v-lithium-ion-storage-battery.html</a>
LG CHEM Resu	13	6678	513.7	10	<a href="https://www.europe-solarstore.com/batteries/manufacturer/lg-chem/lg-chem-resu-12-48v-lithium-ion-storage-battery.html">https://www.europe-solarstore.com/batteries/manufacturer/lg-chem/lg-chem-resu-12-48v-lithium-ion-storage-battery.html</a>
Huawei LUNA2000	5	3567	713.4	10	<a href="https://www.solarshop.pt/baterias-solares-litio-huawei-luna2000-5-e0-modulo-5kwh">https://www.solarshop.pt/baterias-solares-litio-huawei-luna2000-5-e0-modulo-5kwh</a>