The Tesla Powerwall: Does it bring something new?
A Market Analysis

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Abstract – The Tesla Powerwall solution was recently announced and it hit the media like a cheap solution for the residential sector to store energy with a combined use of PV systems and save money on the electricity bills with short payback times. The current work compares three scenarios in which the Powerwall can be used to see which one is the most attractive to invest in. We have chosen to compare different regions of the United States of America (California, Hawaii and Alabama States) and use Portugal as a comparison since the billing system is very different Powerwall can take advantage of this. Savings provided by using the Powerwall result mainly from different hourly tariffs and in California it would be 0.21€/kWh in the summer and 0.12€/kWh in the winter, in Hawaii it would be 0.26€/kWh plus approximately 800€/year on charge savings, in Alabama it would be 0.10€/kWh and finally in Portugal it would be up to 0.19€/kWh. All the cites/states practice different electricity prices as well as grid injection schemes. In this paper, all the scenarios involve 100% self-consumption regime in which grid injection is not evaluated even though it is allowed in some cities/states. The economic methods used to determine the attractiveness of the investment are namely the Profitability Index (PI), the Internal Return Rate (IRR), and the Discounted Payback Period (DPBP) of the Investment. The economical parameters such as interest rate, maintenance and operations rate, inverter replacement rate, Powerwall Battery replacement, VAT tax rate, electricity evolution rate, electricity price, prices for a PV system connected to a Powerwall system, and PV degradation rate are also considered. For this paper, a residential setting using a 2kW PV system connected to a 7kWh Powerwall Battery is considered for the three scenarios that follow. Scenario 1 considers an on-grid PV system connected to a Powerwall battery both in the USA and in Portugal. In this scenario, the State of Alabama is used since only the self-consumption scheme is practiced and there is no net-metering nor feed-in tariff schemes. The city of Aljustrel in Portugal is used in this scenario since a 100% self-consumption regime can be practiced therefore comparable with Alabama. Scenario 2 contemplates an off-grid PV system connected to a Powerwall battery both in USA and in Portugal. In this scenario the State of Hawaii, which practices the highest electricity tariffs, is compared with the city of Aljustrel. Lastly, scenario 3 suggests charging the Powerwall battery directly from the grid (without resorting to a PV system) in the super off-peak hours and using the Powerwall battery to feed the household grid in the on-peak hours both in USA and in Portugal. The State of California was chosen for USA since it practices the highest tri-hourly tariffs while Aljustrel city in Portugal practices the highest bi-hourly tariffs. Households in California can use tri-hourly tariffs while in Portugal households can only use the bi-hourly tariffs. The results for USA show that an off-grid PV system in Hawaii is the most attractive investment (scenario 2) since the profit on the investment can be tripled over the 25-year period. The results also show that the off-grid PV system solution in USA (scenario 2) is more attractive than the on-grid PV system in USA (scenario 1) due to the savings made on the charges related to grid distribution and due to the high electricity tariffs practiced in Hawaii (scenario 2). Charging the Powerwall battery from the grid (scenario 3) in the super off-peak hours to then use the battery power in the on-peak hours in California turns out to be a very good investment over a 25-year period since the profit on the investment can be doubled. The results for Portugal are not attractive in any scenario.

1. Introduction

Right now with all the cuts being made to the PV system incentives and feed-in tariffs around the world, batteries are an alternative option to use a PV system to charge the batteries during the day and using the solar production during the night when people get home from work. Unfortunately the batteries are still too expensive, some need monthly maintenance, needs a big dry place to be placed in, and can be dangerous to keep in the house without monitoring it weekly.

According to preliminary announcements, the Tesla Powerwall seems to be a big turning point on the PV market since it is composed of a cheaper battery, does not need much maintenance and monitoring since it is a lithium ion battery bank with built-in liquid thermal control, and does not take up much space (1300mmx860mmx180mm).

The Tesla Powerwall battery costs around 3000$ for the 7kWh daily cycle option with a 5 kW continuous power output and with 7 kW peak output. These values are fit for an off-grid like solution and it includes a DC to DC converter to place between the existing solar panels, and the home's existing DC to AC inverter [2]. It does not include an AC/DC inverter, therefore the Powerwall is an extra piece to add to the PV system, meaning additional costs and the overall price of the Powerwall is not very different from a regular set of batteries. Powerwall has a 10 year warranty, with 92% efficiency, 350-450 volts, 5.8A at nominal output, single and three phase compatibility, is wall mounted and weighs 100kg [1].

We were motivated to analyse the different ways that Powerwall can be used so we came up with three different scenarios namely a scenario with an on-grid 100% self-consumption PV system solution, a scenario with an off-grid PV system solution, and lastly a scenario where the Powerwall battery would be charged directly by the household grid in the off-peak hours and discharged into the household grid in the on-peak hours. The PV system sizes are of 2kW and there would be no grid injection. Since the Powerwall battery is made in the United States it was decided that we would study the scenarios using the States of America and to compare it to another country it was decided that Portugal would be a good choice since the electricity prices are lower than in the United States and new regulation for self-consumption was recently introduced (January 2015) and it greatly reduces the profitability of grid injection. The main objective of this work was to analyse the use and profitability of the Powerwall solution under different scenarios.

Until the issue of the most recent regulation, self-consumption was not allowed in Portugal and selling energy to the grid was under a feed-in tariff scheme. This feed-in tariff started in 2008 at 0.65€/kWh, has been declining over the years, due to the economic difficulties and the global cost reduction of the PV Systems [3], [4]. In January 2015, the feed-in tariffs that were already much lower than the energy market price for consumers, were cut again and a new tariff based on the Iberian market value is attributed to the producers who inject energy into the grid at approximately 0.04€/kWh. At the moment, the electricity price for consummers is approximately 0.16€/kWh (Excluding VAT) which is close to 4 times higher the grid injection tariff. Considering that the savings for self-consumption are much higher than the gains made on injecting to the grid, the new regulation favours the self-consumption [5]. According to [6] the city of Portugal that is the most attractive to invest in a PV system in the residential sector is Aljustrel located in the mainland of Portugal. Considering that the new regulation applies to the whole country and the electricity tariffs are almost the same, we only need to consider this city[6].

In the United States the regulation and electricity tariffs are different in almost all States. Net-metering is practiced in all States except for Alabama, Mississippi and Tennessee and the State with the highest electricity tariff is Hawaii. Therefore, Alabama is chosen for the scenario of on-grid 100% self-consumption since grid injection is not allowed in Alabama, its solar radiation and electricity prices were higher than the other two States. Hawaii is chosen for the off-grid scenario since practiced the highest electricity tariff. Lastly, for the scenario that only requires that the Powerwall battery be charged from the household grid in the off-peak hours and discharged back into the household grid in the on-peak hours all the States that practiced a big gap between the two were considered. Thus, the State of California presented the biggest gap between the super off-peak hourly tariff and the on-peak hourly tariff.

In Hawaii it works in a quite different way. There is a system called Energy Tax Credits that allows an income tax credit of 35% of the cost of equipment and installation of PV systems. Also for Alabama, a 30% federal solar tax credit for the PV system equipment that includes an additional incentive of $1000 per installation to reduce the initial costs.

Considering these different conditions, it is necessary to analyse the scenarios and conditions to evaluate profitability in each case.

The economic parameters used to determine the attractiveness of the investment are: Internal Rate of Return (IRR), Profitability Index (PI), and Discounted Payback Period (DPBP) of Investment.

The overall organization of the paper is as follows. After the introduction, we describe the experimental methodology used to calculate the economic measures in order to analyse the economic assessment of the PV Systems in Section II. The results of the main findings of the data analysis are reported and discussed in Section III. The main conclusions made in this paper are explained in Section IV.

2. Methods

In this section, all the methods that were used to calculate the profit of the investment are described. In order to analyse the cost-effectiveness of the different scenarios, proposed, the economic methods that determine the profitability and economic aspects of this type of project are namely the Internal Rate of Return (IRR), the Discounted Payback Period (DPBP) and the Profitability Index (PI). A brief description of all the economic methods is provided in section 2.1.

2.1 Economic Methods IRR, DPBP, and Profitability Index

The annual Simple Cash Flow (SCF) is calculated first to then be able to calculate the IRR, the DPBP, and the Profitability Index. The simple cash flow is the subtraction between the cash inflow and the cash outflow, as shown in equation 1 [7], [8].

$$SCF_y = Cash\,inflow_y - Cash\,outflow_y \qquad SCF_y = \sum_{y=1}^{Y}(Ts \times Es)_y - \sum_{y=1}^{Y}(M)_y \tag{1}$$

Where Y is the total number of years of the investment, Ts is the self-consumption tariff, Es is the annual electricity (kWh) generated by the PV System used in self-consumption and M is the maintenance cost.
The Discounted Cash Flow (DCF) contains the time value of money and represents the SCF value in the future. The DCF value is updated with the interest rate just as shown in equation 2.

$$DCF_y = \frac{SCF_y}{(1+r)^y} \tag{2}$$

$$0 = \frac{\sum_{y=1}^{Y} C_y}{(1+IRR)^y} - C_0 \tag{3}$$

r represents the interest rate in equation 3.
The DPBP considers the money value over time since it uses the DCF values to calculate the number of years needed to breakeven. The discount or interest rate is compared to the IRR indicator [9]. A favourable investment opportunity has a high IRR value and should be higher than the rates mentioned above. This economic method allows for a comparison across locations without considering the regional discount rates [10]. The IRR formula is presented in equation 3.
Where Y represents the total number of years of the investment, C_y is the yearly net cash flow, C_0 is the initial investment of the PV System.
The Profitability Index presents the relationship between the investment and its return, and indicates how much profit or loss the project makes in a certain amount of time. The PI is calculated by dividing the NPV of a project by its initial investment and adding 1, just as shown on equation 4.
The NPV compares the present value of all cash inflows with the present value of all cash outflows associated with an investment project and considers the present value of the money. However, its main drawback lies in the need for assuming an interest rate. NPV and IRR are commonly used to determine the investment profitability by calculating the difference between the discounted values of cash flows over the project lifetime.
Breakeven is achieved when PI=1, when PI=2 the profit is equal tothe investment and when PI=3 the profit doubles the investment. The time of the investment assumed for this work is 25 years [11].

$$PI = \frac{\text{NPV}}{\text{Initial Investment}} + 1 \tag{4}$$

2.2 Assumptions

All the assumptions are defined in this section in order to explain how the results are obtained. In this work, a 2kW PV system is used which is associated to the residential sector and the 7kWh daily cycle Tesla Powerwall Battery is used.
Three scenarios are considered in this paper and they all involve the use of a 7kWh Tesla Powerwall and all practice a 100% self-consumption regime in which solar production is not injected into the grid.
The scenarios are as follows:

- **Scenario 1** – On-grid – Resorting to a 2kW PV system with Powerwall without grid injection
- **Scenario 2** – Off-grid - Resorting to a 2kW PV System with Powerwall
- **Scenario 3** – Charging the Powerwall directly from the grid without resorting to a 2kW PV system

Scenario 1 considers an on-grid PV system connected to a Powerwall battery both in the USA and in Portugal. In this scenario, the State of Alabama is used since only the self-consumption scheme is practiced and there are neither net-metering nor feed-in tariff schemes. The city of Aljustrel in Portugal is used in this scenario since a 100% self-consumption regime can be practiced therefore comparable with Alabama. Scenario 2 contemplates an off-grid PV system connected to a Powerwall battery both in USA and in Portugal. In this scenario the State of Hawaii, which practices the highest electricity tariffs, is compared with the city of Aljustrel. Lastly, scenario 3 suggests charging the Powerwall battery directly from the grid (without resorting to a PV system) in the super off-peak hours and using the Powerwall battery to feed the household grid in the on-peak hours both in USA and in Portugal. The State of California was chosen for USA since it practices the highest tri-hourly tariffs while Aljustrel city in Portugal practices the highest bi-hourly tariffs. Households in California can use tri-hourly tariffs while in Portugal households can only use the bi-hourly tariffs.

In Portugal the hourly tariffs associated to the residential sector are chosen between the mono and the bi-hourly tariff. The hourly tariff that most benefits the PV System associated to a battery bank is the mono-hourly tariff since it generates the most profit because of the high value that is practiced in the off-peak hours compared to the same hours in the bi-hourly tariff. In the United States the hourly tariffs practiced in the residential sector are chosen between the mono, bi and tri-hourly tariff.

For scenarios 1 and 2 for both countries, the mono hourly tariff is used. After seeing the results using the mono-hourly tariffs, it was decided that the bi-hourly tariff scenario would not be needed since the results for the mono-hourly are too low and using the tariff prices associated to the bi-hourly tariffs would not be improved very much. For scenario 3, the bi-hourly tariff is used in Portugal and the tri-hourly tariff is used in the United States since it practiced higher electricity tariffs making it more attractive for the investment. For scenario 3 the Powerwall battery would be fully charged from the grid in the off-peak hours in both Portugal and the United States and discharged back into the grid in the on-peak hours for both Portugal and the United States. The off-peak hours in Portugal are from 12AM to 7AM and in the United States the super off-peak hours are from 10PM to 8AM. The on-peak hours in Portugal are from 7AM to 12AM and in the United States it is from 2PM to 8PM by [35], [13].

Savings provided by using the Powerwall result mainly from different hourly tariffs and in California it would be 0.21€/kWh in the summer and 0.12€/kWh in the winter [12]. Hawaii the savings would be 0.26€/kWh [14] plus approximately 700€/year on distribution charge savings. In Alabama the savings would be 0.10€/kWh [14] and finally in Portugal would be up to 0.19€/kWh [15], [12]. The electricity prices of each hourly tariff are shown in Table II in the results section.

The currency used in this paper is the euro and the dollar currency is based on the dollar value of the 9th of January of 2015 which is 1.1813$/€. The 7kWh Tesla Powerwall Battery price was advertised as 3000$00 so this is the value that is assumed in this paper on top of a typical 2kW PV system cost.

The city of Aljustrel in Portugal was chosen because it was proven to be the city with the best results in the residential sector according to [6] since the investment of the PV system is the lowest and the electricity tariff is the highest.

For the United States the State of California was chosen for scenario 3 because it presented the highest difference between the on-peak and super off-peak tariff prices out of all the States in America according to [16]. The State of Hawaii was chosen for scenario 2 since it presented the highest electricity tariff out of the entire United States according to [17]. To choose the right State for scenario 1, three States that have neither a net-metering scheme nor a feed-in tariff scheme for PV systems are studied. The three States are namely Alabama, Mississippi and Tennessee and all have different solar radiation values as well as different electricity tariffs [14]. Alabama had the highest solar radiation values as well as the highest electricity values therefore making Alabama the best State to choose to be used in scenario 1.

The solar radiation values are indicated by the *Retscreen* PV Project Analysis Software version 4 [18]. *Retscreen* uses a NASA meteorological database which is calculated based on the monthly average over 23 years [19]. It is possible to obtain the climate data of a specific location if the latitude and longitude coordinates are provided, and this was used for the Aljustrel city of Portugal since *Retscreen* does not have this city in the default database. The solar radiation values of the city of Aljustrel is 5.05 kWh/m2/d, the State of Hawaii is 6.00 kWh/m2/d, and the State of Alabama is 4.62 kWh/m2/d.

Retscreen is also used to calculate the solar production of the PV systems in all of the scenarios. First, the selection of the type of solar module and inverter that is used on the 2kW PV system of all the scenarios is necessary. Secondly, the slope and azimuth values is needed to be inserted. The Azimuth is 0 for all scenarios, and the optimum slope for Aljustrel is 31º, for Hawaii and Alabama is 18º. Finally, *Retscreen* calculates the annual solar production and the result outcomes are shown in Table III, in the results section. Since scenario 3 with the California State does not resort to a PV system, the solar radiation value and the solar production value is not needed.

Scenario 3 is very peculiar because the Powerwall is charged by the grid in the off-peak and super off-peak hours and discharged into the grid in the on-peak hours. The difference between the on and off-peak tariff for Portugal is 0.0864€/kWh and the difference between the on and super off-peak for the summer in California is 0.2963€/kWh and in the winter is 0.2116€/kWh. in the summer only 33% of the annual charge/discharge energy is considered since there are less months (June to September) associated to summer than the winter which is 67% of the annual charge/discharge energy. The annual charge/discharge for this scenario is 2555kWh for both Portugal and the United States. Measures to ensure a safe charge and discharge of the Powerwall battery have to be taken which includes equipment such as a hybrid inverter (since the Powerwall does not have) and a AC to DC battery charger (Portugal 1100€ and California 750$).

Hawaii (scenario 2) has savings on the distribution charges of approximately 836$/year or 708€/year in the residential sector, since 9$/month is for single phase service, 0.217096$/kWh is an extra fee over the annual consumption/production which is 3284kWh and finally a Green infrastructure fee of 1.29$/month [20]. In scenario 2 for Portugal there are also savings made from the distribution grid in the case of an off-grid scenario of approximately 130€/year in the residential sector, since the single phase 6.9kVA contracted power daily fee of 0.2962€ can be saved as a total of 108€/year (0.2962*365) [15], and also the savings made on the VAT of 23% which is approximately 25€/year .

All the steps taken to obtain the annual solar production are explained in the following subsections.

2.2.1. PV Module and Inverter Selection

For this work, the Solar World 245W Polycrystalline PV modules were selected since they are very efficient and obtained a perfect score (evaluated as “very good”) in the PV+Test2.0 in 2013 according to [21]. The chosen PV module type is crystalline silicon, and the lifecycle is usually assumed to be within 25-30 years [22]. Thus, in this work the lifetime of the system investment is assumed to be equal to 25 years.

Among all the components of a Residential PV system considered in this work, both the inverter and the Powerwall battery is expected to be replaced, at least once, within the lifetime of the system. Commonly, 10 years is considered as the inverter´s and the Powerwall´s lifecycle [23]. We assume in this work that the inverter replacement takes place in year 10 and in year 20. The inverter selected to work together with the Powerwall Battery is the *Multiplus Ecosolar* (Hybrid Inverter) 3Kva 2400W 24v which is an inverter, a charger and a regulator all in one and has an efficiency of 93% [24]. The inverter works as follows, first the solar energy is injected into the household grid for self-consumption, secondly the surplus energy is then directed into the batteries and when these are full and there is no consumption in the household the solar energy is injected into the distribution grid. In this paper grid injection is not considered and all the production is either used in self-consumption or injected into the Powerwall battery. Table I presents the inverter replacement cost rate assumed for each of the scenarios.

2.2.2. Performance Ratio (PV system losses)

Losses generated in the inverter, batteries, wiring (length, diameter and material), and module soiling (i.e. dust, snow, etc.) [25], [26] affects the performance ratio (PR) of PV systems in around 75-90%. The default PR value is 0.75 according to the methodology guidelines on life cycle assessment of PV systems for roof-top installations [27], therefore in this work the PR is assumed as 0.80.

2.2.3. Economical parameters

The economical methods (NPV, IRR, DPBP and PI) are calculated by considering the following parameters:

- Annual solar production value;
- Annual charge/discharge value;
- Maintenance and Operations cost;
- Inverter substitution cost rate;

- Average electricity evolution rate;
- Interest rate;
- Electricity tariff;
- PV system and Powerwall battery investment;
- Powerwall battery substitution cost;
- Degradation rate of the PV modules;
- Losses from the Powerwall Battery;
- Hybrid inverter and Powerwall Investment.

All cities and states present different solar production values, PV System initial investments, hybrid inverter linked to Powerwall investment, electricity tariffs, interest rates, electricity evolution rate. All cities and states practice the same maintenance and operations cost rate, inverter replacement rate, Powerwall battery rate, PV module degradation rate, Powerwall batter loss and hybrid inverter loss.

The steps taken to obtain all the parameters mentioned above are explained in the following subsections and the outcome is presented in the results section.

The Powerwall substitution assumed in this paper is considered in year 10 and in year 20. Since it is expected that the battery prices will drop it is assumed that the price of the Powerwall in year 10 would be 25% less then the current one (1904.68€) from the original price (2539.58€) and in year 20 there would be a 50% drop (1269.79€) on the Powerwall original price.

In order to roughly predict the electricity price during the next 25 years we calculated an average evolution rate of the electricity price for Portugal based on the past 25 years [28] and for the United States from the past 20 years [29], according to the data available.

The electricity tariffs that are considered in this work are the ones that are practiced at the present moment (year 2015) in all the cities and states [12], [14], [15]. For scenarios 1 and 2 the mono-hourly tariff is used while in scenario the bi-hourly tariff is used in Portugal and the tri-hourly tariff is used for the State of California.

To predict the interest rate for the next 25 years, we have used an average calculated based on the past 16 years of the real interest rate for Portugal and an average over the past 25 years for the United States [30].

In order to use realistic investment costs in this paper we had to obtain at least three quotes from different companies for Portugal and for the United States to then make an average investment value for each country. All the quotes are turnkey solutions, including all the components of the PV System, the Powerwall, mounting structure, delivery, and installation.

2.2.4. Operating and Maintenance Cost

The operations and maintenance (O&M) made during the PV system's lifespan include inverter and Powerwall battery replacement, which translates in extra costs. According to [31]–[33], the maintenance cost is estimated between 1-3% of the initial investment per year. Table I presents the operations and maintenance cost rate.

2.2.5. Degradation Rate and Efficiency loss rate

PV modules are significantly influenced by degradation phenomena since the lifecycle is a 25-year period and reduces the efficiency of the system over time [27]. Consequently, the payback period is affected since the predicted generation of the PV system is reduced. The methodology guidelines on the lifecycle assessment of PV systems recommends considering a linear degradation, reaching 80% of the initial efficiency at the end of a 30 years lifetime (i.e., 0.7% per year) [27], [34]. We assumed the PV module degradation as 0.7%/year. The Powerwall battery has an efficiency loss of 8% and this is reflected in the calculations of the economic methods.

3. Results and Discussion

The results obtained from the experimental section are presented in this section. All the parameters presented in Table I are common to both Portugal and the United States.

TABLE I: Information common to Portugal and the United States

Parameter Description	Value		Parameter Description	Value
Maintenance and operations rate [21]–[23]	2%		Powerwall Replacement Cost year 20	1.269,79 €
Inverter Replacement cost rate	8%		Hybrid Inverter efficiency loss rate	7%
Powerwall Cost	2.539,58 €		Powerwall efficiency loss rate	8%
Powerwall Battery Annual Charge/Discharge Energy	2555kWh		PV Degradation rate [24], [25].	0,70%
Powerwall Replacement Cost year 10	1.904,68 €		Project life time	25 years

Table II shows all the values of the parameters according to all the cities and states. Hawaii presents the highest solar production value and Alabama the lowest. Table II shows two types of Investments namely the investment that includes the 2kw PV system linked to a Powerwall battery (scenarios 1 and 2) and the investment that includes only the hybrid inverter linked to a Powerwall battery and a AC to DC battery charger (scenario 3). The PV system investment that is presented in the table below is after subtracting all the incentives therefore without incentives the PV system investment cost in Alabama and Hawaii is 10496.91€. Since the investment made in California does not consider a PV system, there are no incentives associated to it. The investments are lower in the United States compared to Portugal and Alabama manages to have better incentives than Hawaii. The highest mono-hourly tariff is practiced in the State of Hawaii and California State has the highest on-peak tariff and is higher than the mono-hourly tariff of Hawaii. The yearly savings made in an off-grid scenario is over 700€ in Hawaii and over 130€ in Portugal. All investment costs, electricity tariff prices and grid distribution savings presented in Table II include the local VAT tax rate.

TABLE II: Economic Parameters Different to Both Portugal and the United States

			Portugal		USA					
			Aljustrel		Alabama		Hawaii		California	
PV System Annual Solar Production (kWh)			3059		2711		3284		---------------------	
PV System with Powerwall Investment			8.226,92€	4.11€/W	6.755,27€	3.38€/W	6.822,99€	3.41€/W	---------------------	
Inverter and Powerwall Investment			4.476,68€		---------------------		---------------------		3.174,47 €	
Electricity Hourly Tariff	Mono-hourly		0,1952 €		0,0997 €		0,2641 €		---------------------	
	Bi	On	0,2267 €		---------------------		---------------------		---------------------	
		Off	0,1204 €		---------------------		---------------------		---------------------	
		Difference	0,1063 €		---------------------		---------------------		---------------------	
	Tri								Summer	Winter
		On	---------------------		---------------------		---------------------		0,3894€	0,3047€
		Off	---------------------		---------------------		---------------------		0,2540€	0,2201€
		Super Off	---------------------		---------------------		---------------------		0,0931€	0,0931€
		Difference							0,2963€	0,2116€
Savings from Grid Distribution Costs			132.98 €		---------------------		708.05 €		---------------------	
Interest Rate			2,40%		3,45%		3,45%		3,45%	
Electricity Evolution rate			2,43%		2,29%					

The values presented in Table II were used together with the values from Table I to calculate the IRR, Profitability Index and Discounted Payback Period for each of the three different scenarios.

As previously stated, the Profitability Index gives us an idea of the amount of profit a certain investment can make during the 25-year period of our project. An investment is considered to be good when there is double the profit on the investment (PI=2.00) before the end of 25 years. Table III presents the IRR, PI and DPBP values of scenario 1 (on-grid 100% self-consumption regime), scenario 2 (off-grid regime) and scenario 3 (Powerwall charged by the grid). Scenario 1 presents the worst results for both countries. Scenario 2 presents the most profitable results for the United States in the State of Hawaii, since the profit on the investment is tripled before the 26-year period, breakeven takes place on year 6 and the IRR is more than 5 times the interest rate of the United States (3.45%) making this investment a very attractive one. These results for Hawaii are influenced by the high electricity tariffs and high distribution grid savings, but unfortunately an off-grid solution for Portugal is not attractive at all since the electricity tariff is too low and the investment is too high. Scenario 3 has very good results for the United States more precisely in the State of California where charging and discharging the Powerwall battery from and to the grid is very attractive solution to invest in, since there is a possibility to double the profit on the investment and breakeven happens before the end of the warranty of the Powerwall battery. The IRR value in California is 4 times higher than the interest rate in the United States (3.45%) indicating that the investment is very attractive. Portugal presents really bad results on all three scenarios, since breakeven is only made after the 25-year period. This maybe due to high investment prices and low electricity tariffs because the solar production values are very similar to the ones in the United States.

TABLE III: The Economic Feasibility of the Tesla Powerwall Battery under three scenarios

	Scenario 1 - Alabama on-grid w/o Net-metering nor Feed-in Tariff			**Scenario 2 - Hawaii off-grid**			**Scenario 3 - California Charge Powerwall from Grid**		
	IRR	**PI**	**DPBP**	**IRR**	**PI**	**DPBP**	**IRR**	**PI**	**DPBP**
Portugal	-2%	0.526	> 25	1%	0.843	> 25	-7%	0.220	> 25
USA	a	-0.242	> 25	18%	3.029	6	14%	2.412	7

a - The IRR calculation for accumulated negative cash flows resulted in a very large absolute number that is not represented by excel. Nevertheless, the conclusion should be that the investment is not viable.

4. Conclusions

Analysing the proposed scenarios we have reached the conclusion that several scenarios are economically viable: in Hawaii, an off-grid solution is viable and in California, using the Powerwall to store energy from the grid without resorting to a PV system is viable because the gap between the on and off-peak hourly tariff is very high. These results were achieved even though the hybrid inverter and Powerwall battery replacement costs are consideredin year 10 and 20.

In Portugal, due to the investment cost and low electricity tariff, the Powerwall is not viable in any scenario.

Since the Tesla Powerwall battery does not have an incorporated AC/DC inverter, the Powerwall turns out to be an extra piece to add to the PV system adding extra costs. If the incentives are not attractive enough the investment turns out not to be viable.

In the future, the attractiveness of this kind of investment can be improved if the PV system costs decrease and the electricity prices increase, which is likely to occur. Both parameters, apart from the solar radiation values, play a big role on the possibility to double the investment in a period of 25 years as seen in the scenario that involves the State of Hawaii.

The Tesla Powerwall should be used in countries and regions where the electricity tariff is over 0.25€/kwh just like in Hawaii.

Acknowledgments

The authors would like to acknowledge the Portuguese Foundation for Science and Technology for their support through project PEst-OE/EEI/LA0009/2011.

Also acknowledged is the Funding Program + Conhecimento II: Incentive System to Research and Technological Development and Innovation of Madeira Region II, through the project "Smart Solar" – MADFDR-01-0190-FEDER-000015.

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