TESLA POWERWALL: ANALYSIS OF ITS USE IN PORTUGAL AND UNITED STATES

Sandy Rodrigues*, Fábio Faria*, Ashkan Ivaki*, Nuno Cafôfo*, Xiaoju Chen**,

Herlander Mata-Lima*** and F. Morgado-Dias*

Abstract

The Tesla Powerwall battery solution provides the user with the option to control how and when the energy is used by storing energy from the photovoltaic (PV) system and/or from the grid to then be used when the electricity is more expensive. This option helps save money on the electricity bills and cut down on the PV system payback times. Since the Powerwall battery is perceived as being a cheap energy storage solution and energy usage can be controlled, three scenarios were considered to determine which is the most attractive to invest in. One is an on-grid PV system and Powerwall solution without grid injection incentives, then an off-grid PV system and Powerwall solution, and lastly a Powerwall solution without a PV system. The United States of America and Portugal were considered in this work in which the States of California, Hawaii, Alabama and the city of Aljustrel were chosen for comparison because of their different billing and grid injection schemes. The results show that over a 25-year period an off-grid solution in Hawaii can triple the investment and a Powerwall without a PV system solution in California can double the investment while all other scenarios are not viable investments.

Key Words

Powerwall Battery, on-grid, off-grid, PV system, Profitability Index, IRR

1. Introduction

All over the world, feed-in tariffs as well as PV system incentives are lowering and self-consumption schemes are being favoured. As a result, batteries connected to PV systems are becoming a popular option to lower the electricity bill where the batteries are charged during the day, and discharged during later hours when there is a higher demand for electricity in the household as reflected in [1]. Unfortunately, the battery solution is still too expensive, and some batteries need monthly maintenance as well as a safe place for installation, as they can be dangerous to keep in the house without frequent monitoring.

Recently, a new technology in the battery industry, the Tesla Powerwall battery, was announced and is meant to revolutionise the PV market since it is composed of a smaller, safer, and cheaper battery. It does not take up much space due to its small (1300mmx860mmx180mm), light weight (100kg) wall-mounting solution, and does not need much maintenance and monitoring because of the lithium ion battery bank with built-in liquid thermal control [2]. The cost of the Tesla Powerwall battery is around 2539.58€ (3000$) for the 7kWh daily cycle option which has a 5 kW continuous power output and a 7 kW peak output. This battery is placed between the PV panels and the DC to AC inverter [3] and does not include an DC-AC inverter, therefore consequently adding additional costs to the overall price of the PV system investment. The Powerwall battery has a 10 year warranty, with a 92% efficiency rate, at 350-450 volts and 5.8A at nominal output, with single and three phase compatibility [2].

The purchase of a Tesla Powerwall battery can be perceived as an investment because there is a return on the investment through savings made on the electricity bill. This allows to determine the attractiveness of the investment by its profitability and payback time. Due to this fact, the research in this paper is motivated to determine what kind of Powerwall battery investment application is the most profitable out of three different scenarios. The scenarios are namely an on-grid solution, an off-grid solution, and a Powerwall battery standalone solution where the battery is charged by the household grid in the off-peak hours, and discharged back into the household grid in the on-peak hours without the need to resort to a PV system. The two countries chosen for comparison are the United States of America and Portugal. The USA was chosen because of its variety of grid injection schemes and to pay tribute to the Powerwall battery development location. Portugal was chosen to analyse the advantages of use under the new regulation implemented in January of 2015, which greatly reduces the profitability of grid injection. The purpose of this work was to determine which factors influence the Powerwall battery investment by analysing three different scenarios.

Self-consumption was not allowed in Portugal until the beginning of 2015, and selling energy to the grid was only permitted under a feed-in tariff scheme which initiated in 2008 at 0.65€/kWh. The feed-in tariffs have been declining over the years, due to the economic difficulties of the country and to global PV system cost reduction [4], [5]. Even though the feed-in tariffs were very low at the end of 2014, these were lowered again in January 2015 by introducing the new regulation in which a new grid injection tariff based on the Iberian market value has an average of approximately 0.04€/kWh. In 2015, the electricity price for consumers is at approximately 0.19€/kWh which is almost 4 times higher than the grid injection tariff price [6],[7]. The new regulation favours the self-consumption scheme, as the savings made on self-consumption are much higher than the ones made on grid injection [8]. According to [9] the city of Aljustrel in Portugal is the most attractive to invest in a residential sector PV system and since the new regulation applies to the whole country and the electricity tariffs are almost the same in all regions, only this city is considered for analysis in this work [9].

On the other hand, the regulation and electricity tariff in the United States is different in almost all States. For the on-grid scenario, the State should not have a grid injection scheme, because should it be provided it would be wise to take advantage of it to reduce the payback on the investment. Net-metering, is practiced in all States except for Alabama, Mississippi and Tennessee in which Alabama presents the highest solar radiation values and electricity prices thus making this State chosen for the on-grid scenario [10]. The State of Alabama practices a 30% federal solar tax credit for the PV system equipment and an additional incentive of 846,53€ ($1000) per installation to reduce the initial costs [11]. The State of Hawaii is chosen for the off-grid scenario as it practices the highest electricity tariff in the USA and consequently generates higher savings [10], [12]. There is an energy tax credit incentive of 35% towards the PV system installation and equipment costs practiced in the State of Hawaii. Finally, in order to make the most savings on the electricity bill for the standalone

Powerwall battery scenario, there has to be a big gap between the prices of the on-peak and off-peak tariffs [6], in order to make the highest savings and this takes place in the State of California.

The economic measures used in this work to determine the attractiveness of the investment are: Internal Rate of Return (IRR), Discounted Payback Period (DPBP) and Profitability Index (PI). These economic measures were calculated based on the economic parameters such as maintenance and operations (O&M) costs, inverter and Powerwall Battery replacement costs, and others.

The overall organization of the paper starts with the introduction, then in Section 2 the methodology used to calculate the economic measures to analyse the economic assessment of the PV systems is described. The results of the key findings of the data analysis are discussed in Section 3 and finally the main conclusions are explained in Section 4.

2. Body

The investment attractiveness of the different scenarios is analysed by the economic measures such as the IRR, the DPBP and the PI. A brief description of the economic measures, are provided in section 2.1 while section 2.2 defines the assumptions used in this research.

2.1. Economic Measures

The simple cash flow (SCF) is the subtraction between the cash inflow and the cash outflow, as shown in equation 1 [13]. The IRR, DPBP and PI depend on the SCF value to be calculated.

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

Where Y is the total number of years of the investment, Ts is the self-consumption tariff, Es is the annual self-consumption PV system production, and M is the maintenance cost. The Discounted Cash Flow (DCF) covers the time value of money, represents the SCF value in the future, and is updated with the interest rate r, as shown in equation 2. The DPBP considers the money value over time since it uses the DCF values to calculate the number of years needed to breakeven. The Net Present Value (NPV) as shown in equation 3, compares the present value of all cash inflows with the present value of all cash outflows associated with an investment.

$$DCF_y = \frac{SCF_y}{(1+r)^y} \qquad (2) \qquad\qquad NPV = \sum_{y=1}^{Y} \frac{C_y}{(1+r)^y} - C_0 \qquad (3)$$

Where C_y is the yearly net cash flow, and C_0 is the initial investment of the PV system. The interest rate should be lower than the IRR indicator [14] for the investment to be profitable. This economic method allows for a comparison across locations, as there is no need to consider the regional discount/interest rates [15]. The IRR formula is presented in equation 3 when NPV = 0 and r = IRR. The PI indicates how much profit the project makes during the investment lifetime and is calculated as shown on equation 4. Breakeven is achieved when PI=1, when PI=2 the investment is doubled and when PI=3 the investment is tripled in a timeframe of 25 years for this case [16].

$$PI = \frac{\text{NPV}}{\text{Initial Investment}} + 1 \qquad (4)$$

2.2. Assumptions

For this work, the 7kWh daily cycle Tesla Powerwall battery (2,539.58€) was chosen for the investment attractiveness calculations, and the PV system has an installed power of 2kW and practices a 100% self-consumption scheme (without grid injection). The currency used in this paper is the euro, and the dollar value is based on the currency rate of the 9th of January of 2015 which is 1.1813$/€. The annual charge/discharge of the battery is assumed at 2555kWh for both Portugal and the United States. The three scenarios studied in this work are as follows:

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

The new renewable energy regulation allows the city of Aljustrel in Portugal to adapt to any of the scenarios mentioned above therefore this city is used in all three scenarios. Since the USA has different renewable energy regulations throughout the States, there was a need to analyse all the States in order to associate the State to the scenario, as explained in the introduction section. Therefore, the State of Alabama was chosen for scenario 1, the State of Hawaii for scenario 2, and the State of California for scenario 3.

In Portugal, the hourly tariffs associated to the residential sector are chosen between the mono and the bi-hourly tariff while in the USA, the hourly tariffs practiced in the residential sector are chosen between the mono, bi and tri-hourly tariff. The mono hourly tariff is used for scenarios 1 and 2 in both countries, since the bi-hourly tariffs would not significantly improve the investment attractiveness. For scenario 3, the bi-hourly tariff is used in Portugal and the tri-hourly tariff is used in the United States since these electricity tariffs are higher and therefore contribute to higher savings and consequently making the investment more attractive [6], [9], [17].

The savings made on an on-grid solution in Alabama (scenario 1) is 0.10€/kWh [10] and in Portugal it is 0.19€/kWh [7], [6]. An off-grid solution in Hawaii (scenario 2) provides savings on the electricity tariff of 0.26€/kWh [10] and savings on the distribution charges of approximately 836$/year or 708€/year in the residential sector. The later savings can be broken down into 9$/month for single phase service, 0.217096$/kWh as an extra fee over the annual consumption/production which is 3284kWh and finally a Green infrastructure fee of 1.29$/month [18]. An off-grid solution in Portugal (scenario 2) provides electricity tariff savings of 0.19€/kWh and savings made from not using the distribution grid of approximately 130€/year in the residential sector. This is done by cutting down on the single phase 6.9kVA contracted power daily fee of 0.2962€ which is a savings of 108€/year (0.2962*365) [7], and also the savings made on the VAT of 23% which is approximately 25€/year.

The savings provided by using the Powerwall in scenario 3 result from the difference between the hourly tariffs (on-peak and off-peak), which in the State of California it is 0.2963€/kWh in the summer and 0.2116€/kWh in the winter [6] while in Portugal the savings are of 0.0864€/kWh all year round. The summer months (June to September) in the State of California only account for 33% of the annual charge/discharge energy and the rest is associated to the winter months. Measures to ensure a safe charge and discharge of the Powerwall battery in scenario 3 are taken which includes equipment such as a hybrid inverter and an AC to DC battery charger (Portugal 1100€ and USA 635€). All the savings and electricity prices are presented in Table 3 in the Results section.

The solar radiation values are calculated by the *Retscreen* PV Project Analysis Software version 4 [19] which uses a NASA meteorological database calculated based on the monthly average over 23 years [20]. The latitude and longitude coordinates of the city of Aljustrel in Portugal were provided to the NASA meteorological database to collect the climate data for this city since *Retscreen* does not have this city in the default database. As a result, the solar radiation value for the city of Aljustrel is 5.05kWh/m2/d, the State of Hawaii is 6.00kWh/m2/d, and the State of Alabama is 4.62 kWh/m2/d. The solar production values of the PV systems in all the scenarios were calculated on *Retscreen* by the three steps that follow. First, the solar module and inverter models used on the 2kW PV system of all the scenarios are selected. Secondly, the slope and azimuth values are inserted as follows: 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 2, in the results section. Since scenario 3 (California) does not resort to a PV system, the solar radiation and the solar production values are not indicated.

1.2.1. PV Module and Inverter Selection

The SolarWorld 245W Polycrystalline PV modules were selected for this work due to their high efficiency values and because they were highly evaluated in the 2013 PV+Test2.0 [21]. The PV module type is crystalline silicon and has a lifecycle between 25-30 years [22]. The inverter and the Powerwall battery is expected to be replaced commonly every 10 years [23] and therefore the replacement of these two components takes place in year 10 and in year 20. The 3KVA 2400W 24v

Multiplus Ecosolar 3-in-1 Hybrid Inverter was chosen to work together with the Powerwall Battery since it includes an inverter, a charger and a regulator with an efficiency rate of 93% [24]. The energy flow between the two components starts with the injection of the solar energy into the household grid for self-consumption, and then the surplus energy is injected into the Powerwall battery without grid injection.

1.2.2. Performance Ratio (PV system losses)

Losses generated in the inverter, batteries, wiring, and module soiling [25], [26] affects the PV system performance ratio (PR) between 75-90% and therefore the default PR value is 0.75 according to [27] and for this work the PR is assumed as 0.80 due to the type of PV modules that are used.

1.2.3. Economical parameters

The economical methods (IRR, DPBP and PI) are calculated by considering the economic parameters that are mentioned below and respective values presented in Tables 1, 2 and 3.

All cities and states differ in solar production values, PV System initial investments, hybrid inverter linked to Powerwall investment, electricity tariffs, interest rates, and the electricity evolution rate. The common economic parameters in all cities and states include the same O&M cost rate, inverter replacement rate, Powerwall battery replacement rate, PV module degradation rate, Powerwall battery loss and hybrid inverter loss.

The Powerwall battery replacement assumed in this paper takes place in year 10 and in year 20 where battery prices are expected to drop, therefore the Powerwall battery cost in year 10 would be 25% less (1904.68€) than the current price and in year 20 there would be a 50% drop (1269.79€).

The electricity price for the next 25 years is predicted by calculating an average evolution rate of the electricity price for Portugal based on the past 25 years [28] and the same was done for the United States from the past 20 years [29]. The same approach was used to predict the interest rate for the next 25 years in which an average is 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 for the investment costs to be realistic in this research, at least three quotes from different companies for Portugal and for the United States had to be received to then make an average investment value for each country. All quotes include turnkey solutions in which they include all the components of the PV system, the Powerwall battery, mounting structure, delivery, and installation.

1.2.4. Operating and Maintenance Cost

The O&M made during the PV system's lifespan include inverter and Powerwall battery replacement, which adds extra costs estimated between 0.5-2.4% of the initial investment per year according to [31]. The O&M cost rate as well as the inverter and Powerwall battery replacement costs are presented in Table 1.

1.2.5. Degradation and Efficiency loss rate

The degradation phenomenon negatively influences the efficiency of the PV modules over a 25-year period and consequently extends the predicted payback period on the investment and according to [27], [32] a 0.7% per year is recommended and assumed in this research work. The Powerwall battery also experiences degradation and translates into an efficiency loss of 8% which is reflected in the calculations of the economic methods.

2.3. Results and Discussion

This section presents the results obtained from the methodology presented in section 2. Table 1 presents the common parameters of both Portugal and the United States.

TABLE 1:
Common parameters of Portugal and the USA

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

Table 2 shows that the highest annual solar production takes place in Hawaii and the lowest in Alabama. The PV system cost value in the USA is after subtracting from the incentives being the real price at 10,496.91€. Portugal presents the highest investment cost and Alabama manages to have better incentives than Hawaii.

TABLE 2:
Solar radiation and investment costs of Portugal and the United States

		Portugal		USA				
		Aljustrel		**Alabama**		**Hawaii**		**California**
PV System Annual Solar Production		3059 kWh		2711 kWh		3284 kWh		---------
Investment	**PV System with Powerwall**	8,226.92€	4.11€/W	6,755.27€	3.38€/W	6,822.99€	3.41€/W	---------
	Inverter and Powerwall	4,476.68€		---------------------		---------------------		3,174.47€

Table 3 presents the electricity prices and interest rates associated to the respective countries. Hawaii practices the highest mono-hourly tariff but it is lower than the California on-peak tariff. The difference between the Californian on-peak price and super off-peak price in the summer is higher than the Hawaiian electricity price. The off-grid solution in Hawaii contributes to power distribution charge savings of over 700€ per year and for Portugal over 130€ in savings. All values presented in Table 2 and Table 3 include the local VAT tax rate.

TABLE 3:
Electricity prices, savings and evolution rate of Portugal and the USA as well as their interest rates.

			Portugal	USA			
			Aljustrel	**Alabama**	**Hawaii**	**California**	
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 €	----------------	
Electricity Evolution rate			2.43%	2.29%			
Interest Rate			2.40%	3.45%	3.45%	3.45%	

Table 4 presents the results of the IRR, PI and DPBP for each of the three different scenarios based on the values presented in Tables 1, 2 and 3. Scenario 1 (on-grid solution) presents the worst results for both countries with payback times of over 25 years. In scenario 2 (off-grid solution), Hawaii presents the most profitable results since the investment is tripled before the 25-year period, breakeven takes place on year 6 and the IRR value is more than five times the interest rate of the USA (3.45%). The high electricity tariffs and high distribution charge savings favour the results for Hawaii.

TABLE 4:
The Economic Feasibility of the Tesla Powerwall Battery under three scenarios

	Scenario 1 - Alabama on-grid w/o Net-metering and w/o Feed-in Tariff			**Scenario 2 - Hawaii off-grid**			**Scenario 3 - California Charge Powerwall from Grid**		
	IRR	**PI**	**DPBP**	**IRR**	**PI**	**DPBP**	**IRR**	**PI**	**DPBP**
PT	-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. Nonetheless, the conclusion is that the investment is not viable.

Scenario 3 (Powerwall charged by the grid and discharged back into the grid) has very good results in California since there is a possibility to double the investment in which breakeven (year 7) takes place before the end of the warranty (year 10) of the Powerwall battery. The IRR value in California is four times higher than the interest rate in the United States (3.45%) making the investment very attractive in this State. Portugal presents bad results on all three scenarios, since breakeven takes place after 25 years, and this is mainly due to high investment prices and low electricity tariffs since the solar production values are very similar to the ones in the USA.

3. Conclusion

Scenarios 2 and 3 in the USA are the only investments that are economically viable while Portugal did not present any attractive investments. The off-grid PV system and Powerwall solution in Hawaii (scenario 2) generates triple the investment by the end of a 25-year period with a payback time of 6 years due to the savings made from being off-grid by not paying the power distribution charges nor the high grid electricity prices. Surprisingly, the Powerwall grid charging solution without the PV system in California (scenario 3) makes double the investment during the 25-year period with a 7 year payback time because of the savings made from the gap between the on-peak and super off-peak hourly tariffs. The payback takes place before the 10-year warranty of the Powerwall battery in scenarios 2 and 3, making the investment even more attractive.

The Powerwall solution is not viable in any scenario in Portugal due to the high investment cost and low difference between the daily tariffs. The Tesla Powerwall battery is a separate component that is connected to the PV system, adding extra costs to the initial investment since it does not have an incorporated AC/DC inverter. Some scenarios turned out to be viable investments even though the hybrid inverter and Powerwall battery replacement costs are also considered in year 10 and 20.

The attractiveness of these kinds of investments only improves if the PV system costs decrease and the electricity prices increase, which is predicted for the coming years. The PV system cost and electricity prices as well as the solar radiation values, play a big role on making double the investment during a 25-year period, as seen in the off-grid scenario that involves the State of Hawaii.

The Tesla Powerwall battery solution is a viable investment in regions where the electricity tariff is over 0.25€/kWh just as seen for the State of Hawaii.

Acknowledgments

The authors would like to acknowledge the Portuguese Foundation for Science and Technology for supporting the project PEst-OE/EEI/LA0009/2011. Also acknowledged is the Funding Program +Conhecimento II: Incentive System for Research, Technological Development and Innovation of Madeira Region II, through the project “Smart Solar” – MADFDR-01-0190-FEDER-000015.

References

[1] A.E.-M.M. Abd El-Aal, “A Comparative Study Between Energy Storage Batteries and Hydrogen Fuel Cells for Photovoltaic Power Systems,” *International Journal of Power and Energy Systems*, *vol. 29*,

no. 3, Jan. 2009.

[2] Tesla Motors, “Powerwall Tesla Home Battery,” 2015. [Online]. http://www.teslamotors.com/powerwall. [Accessed: 15-May-2015].

[3] Wikipedia, “Tesla Powerwall,” Wikipedia, the free encyclopedia, 2015. [Online]. https://en.wikipedia.org/wiki/Tesla_Powerwall. [Accessed: 15-Feb-2015].

[4] Sandy Rodrigues Abreu; Marco Leça; Xiaoju Chen; and Fernando Morgado-Dias, “On the Current Payback Time for Small Investors in the Photovoltaic Systems in the Region of Madeira,” *In CONTROLO’2014–Proceedings of the 11th Portuguese Conference on Automatic Control, Springer International Publishing,* pp. 375–384, 2014.

[5] *Ordinance 363/2007 of 2 of November*, "Establishes the legal framework for the production of electricity by micro units of production". *Diário da República*, n.º 211, Série I de 2 de Novembro de 2007, pp. 7978–7984

[6] Edision International Electricity Company Southern California, “SCE Introduces a New Residential Time-Of-Use Rate Plan,” 2015. [Online]. http://on.sce.com/1SJh5J4. [Accessed: 15-May-2015].

[7] ERSE, “Electricity prices to the final consumer in Portugal”, [Online]. http://bit.ly/1QPvsha [Accessed: 02-Feb-2015]

[8] *Ordinance 153/2014 of 20 of October,* "Distributed Energy Production ". *Diário da República* n.º 202, Série I de 2014-10-2014, pp. 5298–5311.

[9] S. Rodrigues, F. Faria, N. Cafôfo, X. Chen, and F. Morgado-dias, “Small Scale Photovoltaic Analysis for the Residential and Commercial Market in Portugal,” *International Journal of Chemical and Environmental Engineering (IJCEE), vol. 6*, no. 4, 2015.

[10] EIA, “Electric Power Monthly,” The U.S. Energy Information Administration (EIA), 2015. [Online]. http://1.usa.gov/1TRIdFj. [Accessed: 15-May-2015].

[11] DSIRE, “Database of State Incentives for Renewables & Efficiency,” N.C. Clean Energy Technology Center, 2015. [Online]. http://www.dsireusa.org/. [Accessed: 15-May-2015].

[12] Dan Hahn and Dave Llorens, “2015 United States Solar Power Rankings,” Solar Power Rocks, 2015. [Online]. http://bit.ly/1zkj7oI. [Accessed: 15-May-2015].

[13] J. L. Bernal-Agustín and R. Dufo-López, "Economical and environmental analysis of grid connected photovoltaic systems in Spain," *Renewable Energy, vol. 31*, no. 8, pp. 1107–1128, Jul. 2006.

[14] A. Campoccia, L. Dusonchet, *et al*, "An analysis of feed ' in tariffs for solar PV in six representative countries of the European Union," *Solar Energy*, vol. 107, pp. 530–542, 2014.

[15] T. Lang, E. Gloerfeld, and B. Girod, "Don′t just follow the sun – A global assessment of economic performance for residential building photovoltaics," *Renewable and Sustainable Energy Reviews, vol. 42*, pp. 932–951, Feb. 2015.

[16] C. Obaidullah Jan, ACA, "Profitability Index," 2013. [Online]. http://bit.ly/1HfEyh9. [Accessed: 01-Feb-2015].

[17] ERSE, "Ciclo Horário"[Online]. http://bit.ly/1QPvvcX.[Accessed: 02-Feb-2015].

[18] Hawaii Public Utilities Commission, "Effective Rate Summaries," 2015. [Online]. http://bit.ly/1YmXgYN. [Accessed: 15-May-2015].

[19] Retscreen International, "Renewable energy project analysis software," 2014. [Online]. http://www.retscreen.net/. [Accessed: 01-Jan-2015].

[20] Paul Stackhouse; John Kusterer, "Surface meteorology and Solar Energy," 2014. [Online]. https://eosweb.larc.nasa.gov/sse/. [Accessed: 14-Mar-2014].

[21] PV Magazine, "Tested: SolarWorld Sunmodule Plus SW 245 poly," 2013. [Online]. http://bit.ly/1ZeHhyi. [Accessed: 10-Mar-2015].

[22] L. Granata, G., Pagnanelli, *et al*, "Recycling of photovoltaic panels by physical operations," *Solar Energy Materials and Solar Cells, vol. 123*, pp. 239–248, Apr. 2014.

[23] K. Zweibel, "Should solar photovoltaics be deployed sooner because of long operating life at low, predictable cost?," *Energy Policy*, vol. 38, no. 11, pp. 7519–7530, Nov. 2010.

[24] Damia Solar, "Multiplus Ecosolar 3Kva 2400W 24v," 2015. [Online]. http://bit.ly/1Kc7Cse. [Accessed: 15-May-2015].

[25] J. Peng, L. Lu, and H. Yang, "Review on life cycle assessment of energy payback and greenhouse gas emission of solar photovoltaic systems," *Renewable and Sustainable Energy Reviews, vol. 19*, pp. 255–274, Mar. 2013.

[26] M. Mani and R. Pillai, “Impact of dust on solar PV performance: Research status, challenges and recommendations,” *Renewable and Sustainable Energy Reviews, vol. 14*, pp. 3124–3131, Dec. 2010.

[27] V. Fthenakis, Frischknecht, R., *et al* . "Methodology guidelines on life cycle assessment of photovoltaic electricity." *IEA PVPS Task*, 2011, 12.

[28] Eurostat, “Electricity prices by type of user,” 2015. [Online]. http://ec.europa.eu/eurostat/web/products-datasets/-/ten00117. [Accessed: 02-Feb-2015].

[29] YCharts, “US Average Retail Price of Electricity,” YCharts, 2015. [Online]. http://bit.ly/1dfBZPQ. [Accessed: 02-Feb-2015].

[30] IECONOMICS, “Interest Rate,” 2015. [Online]. http://www.tradingeconomics.com/. [Accessed: 20-Jan-2015].

[31] P. Koner, V. Dutta, and K. Chopra, “A comparative life cycle energy cost analysis of photovoltaic and fuel generator for load shedding application,” *Solar Energy Materials and Solar Cells, vol. 60*, no. 4, pp. 309–322, Feb. 2000.

[32] Retscreen developers, “Retscreen software help,” 2014. [Online]. http://www.retscreen.net/ [Accessed: 01-Jan-2015].

Biography

Sandy Rodrigues received her Master's degree in Telecommunications and Networks from the University of Madeira, Portugal in 2009, and just enrolled in a PhD program in IST-Lisbon and Madeira Interactive Technologies Institute in Portugal. Her research interests include Renewable Energy, Automation, Wireless Sensor Networks and Artificial Neural Networks.

Biographies

Fábio Faria received his Master's degree in Renewable Energy - Electric Conversion and Sustainable Use from the Faculty of Science and Technology of the Universidade Nova de Lisboa, Portugal, in 2012 and currently works in a research project called "Smart Solar" at the Madeira Interactive Technologies Institute. His research interests include Renewable Energy.

Nuno Filipe Vieira Cafôfo received his degree in Electrical and Computer Engineering from the University of Coimbra, Portugal in 2005. In the last 5 years he is working in Renewable Energy, in household PV system installation.

Xiaoju Chen received her Master's of Science with major in Civil and Environmental Engineering from Carnegie Melon University in Pittsburgh, United States in 2012 and is currently pursuing her PhD in Civil and Environmental Engineering at the same university and she is also a researcher at the Green Design Institute.

Herlander Mata-Lima received his MSc in Environmental Management Policies from the New University of Lisbon in 2004, his PhD in Engineering Sciences from the University of Lisbon in 2006, and, since 2007, he is a Researcher at CERENA – Instituto Superior Técnico, University of Lisbon (Portugal). His research focus on the areas of Environment, Development and Sustainability.

Fernando Morgado-Dias received his Master’s degree in Microelectronics from the University Joseph Fourier in Grenoble, France in 1995 and his PhD from the University of Aveiro, Portugal, in 2005 and is currently Assistant professor at the University of Madeira and Researcher at Madeira Interactive Technologies Institute. His research interests include Renewable Energy and Artificial Neural Networks.