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THE ECONOMIC FEASIBILITY OF PHOTOVOLTAIC SYSTEMS IN THE MALTESE ISLANDS THROUGH MATLAB MODELLING

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ABSTRACT: This research was aimed at the development of a mathematical model in MATLAB which can be used to analyze the performance of different photovoltaic systems available on the Maltese market. The model uses data regarding the solar radiation patterns of the Maltese islands and technical specifications of the photovoltaic systems to estimate the energy output and economic feasibility of a particular system. The model integrates a number of practical non-idealities such as inverter inefficiencies and yearly panel degradation and estimates their economic effects.

Keywords: Photovoltaic, Feasibility Study, MATLAB model.

1 OBJECTIVES

The aim behind this research was to conduct a study that takes into consideration the current prices of photovoltaic (PV) systems for household applications, current feed in tariffs and typical system performances. A mathematical model was developed in MATLAB to receive multiple inputs and calculate the payback period for the recovery of capital and installation costs.

2 APPROACH

For this work, data was collected from a number of suppliers across the Maltese islands so as to generate inputs for the MATLAB model developed. The data collected included, among other factors, the cost and performance characteristics for a typical 2.5 kWp PV system. This data was fed to the model in the form of a structure, such that the comparison between the various systems being offered by different suppliers could be facilitated.

The operation of the MATLAB model is shown in the flow chart of Figure 1. The inputs applied were the solar radiation patterns for the Maltese islands, obtained from literature [1-3], and technical data about the PV system that was being modelled. This data included the following:

- PV panel efficiency
- PV panel surface area
- Size of PV array
- Total capital cost (incl. PV cells, inverters, mechanical structure and labour)
- Feed-in tariff for the current period (2014-2015)

The model calculates the total system energy output depending on the average solar radiation for each month of the year and the efficiency of the system. The model also factors in system inefficiencies, such as inverter losses and yearly PV panel degradation which also have an economic impact [4].

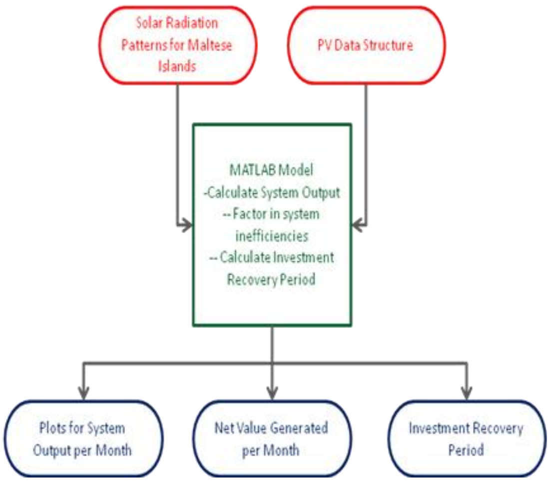

Figure 1 – Flow Chart for MATLAB model

Once all necessary calculations were performed, the number of daily energy units, monthly cost savings, and yearly net present value for a particular PV system were plotted. Hence a typical investment recovery period; that is the payback period could be calculated. Such mathematical calculations are essential in order to support the decision making framework regarding photovoltaic technology on both micro and macro levels [5-7].

3 CALCULATION AND RESULTS

The average monthly solar radiation patterns [1-3] driving the calculations in the model are presented in Figure 2, while the relevant PV system data obtained from a number of suppliers is shown in Table 1.

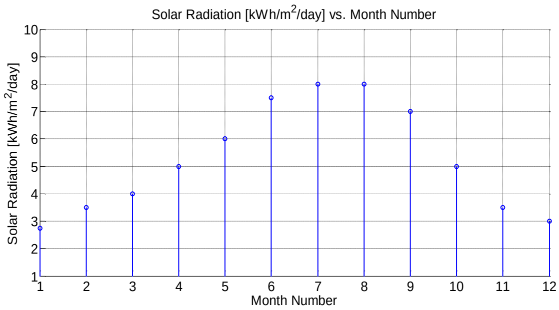

Figure 2 – Plot of Solar Irradiation input to MATLAB model [kWh/m^2/day] vs. Month

Supplier Ref.	1	2	3
Panel Efficiency	15.2 %	15.6 %	14.4 %
Panel Output	2.5 kWp	2.46kWp	2.52 kWp
System Cost	€ 5,832	€ 6,150	€ 5,670

Table 1 – PV System input data including efficiency, rating and capital costs.

The following assumptions were included in the model:

- Typical inverter efficiency of 96% (based on typical solar inverter efficiencies available on the market) [8].
- Typical linear panel degradation 0.7% per year [9].
- €0.155 feed-in tariff for 20 years (without any capital grants) [10].

The daily units (in kWh) generated by each of the systems being reviewed were generated through the MATLAB model. The results for the daily units generated by the system of Supplier 1 at Year 1 corresponding to each month of the year are shown in Figure 3. The monthly return in Euros from the feed-in tariff was also calculated for each system. The return for the system proposed by Supplier 1 at Year 1 is shown in Figure 4. The MATLAB model generates data over a 20-year period. The results obtained for the following years are similar to those presented in Figures 3-4, however the output will be reduced due to the yearly panel degradation, which was estimated at 0.7% per year for the purposes of this research.

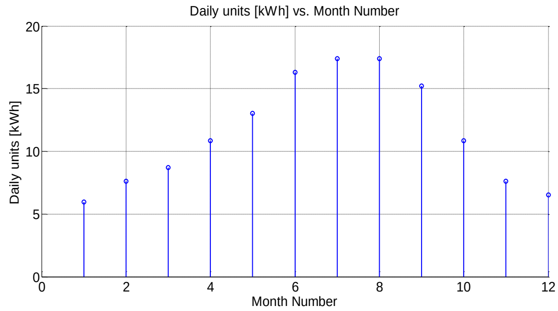

Figure 3 – Daily units [kWh] vs. Month for Supplier 1 (Year 1)

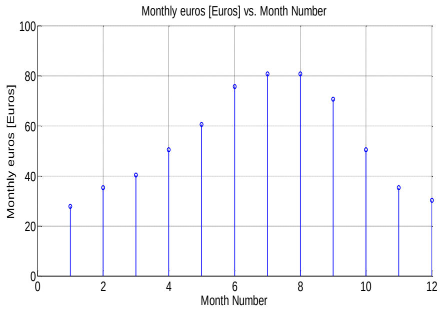

Figure 4 – Monthly revenue (€) from feed-in tariff [Euros] vs. Month for Supplier 1 (Year 1)

In order to estimate the investment recovery period and actual return of investment over a 20-year period with respect to Year 0 the following assumptions were taken:

- 6% Discount Rate [11]
- Yearly operational and maintenance cost of 1.47% of initial system cost [11]

The net present value (NPV) over a 20-year period is calculated by (1) as a function of the discount rate *i* :

$$NPV(i,N) = \sum_{t=0}^{N} \frac{R_t}{(1+i)^t} \quad (1)$$

where:

i is the discount rate (6%)
N is the total number of periods (set for a 20-year period calculation).
R_t is the net cash flow (cash inflow – cash outflow)
t is the time of cash flow (year number)

The net present value was calculated for the three PV systems being reviewed using the MATLAB model over a 20 year period. The calculations performed in the model for the system proposed by Supplier 1 for Years 0-2 are shown below to better demonstrate the calculation. The yearly net present value for the 20-year period for the three systems is shown in Table 2. The cumulative net present value for the three systems is plotted in Figure 5 against the year number.

At Year 0:

$$NPV(0.06,\mathbf{0}) = \frac{-5{,}832\text{ €}}{(1+0.06)^{0}} = -5832\text{ €}$$

At Year 1:

$$NPV(0.06,\mathbf{1}) = \frac{638.81 - 85.73}{(1+0.06)^{1}} = 522.15\text{ €}$$

At Year 2:

$$NPV(0.06,\mathbf{1}) = \frac{636.90 - 85.73}{(1+0.06)^{2}} = 490.54\text{ €}$$

Year	**NPV System 1 (€)**	**NPV System 2 (€)**	**NPV System 3 (€)**
1	-5,832	-6,150	-5,670
2	521	555	497
3	490	522	467
4	461	491	439
5	433	461	413
6	407	434	388
7	383	408	365
8	360	383	343
9	338	360	322
10	318	339	303
11	299	318	285
12	281	299	268
13	264	281	252
14	248	265	237
15	233	249	222
16	219	234	209
17	206	220	196
18	194	207	185
19	182	194	174
20	171	182	163

Table 2 –Yearly net present value (NPV) calculation

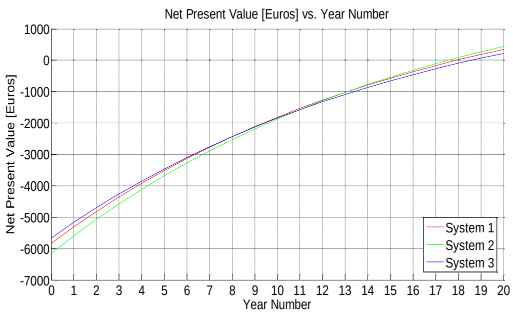

Figure 5 – Net present value (€) vs. Yyar number (i = 6%)

The data presented for the net present value in Table 2 and Figure 5 indicates that the most economically viable solution is System 2, which has an investment recovery period with respect to Year 0 of 17.6 years. The three systems reviewed in this research have comparable performances. System 1 has an investment recovery period of 18 years while System 3 stands at 18.6 years. Over the 20-year period modelled, the most viable system resulted in a profit of €434 while the least efficient system resulted in a profit of €216 with respect to Year 0.

Although the 6% discount rate used in the above calculations is a common value quoted in literature, it may not fully reflect the investment scenario for the average Maltese household. Hence the net present value calculation above was repeated for System 2 with an adjusted discount rate of 2%. All remaining assumptions have been left unchanged. This discount rate is based on the typical interest rate for a fixed term deposit greater than 5 years. The net present value against the year number is plotted in Figure 6.

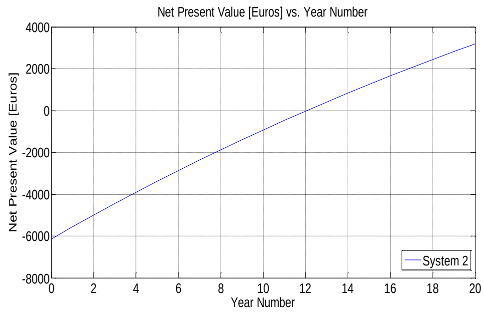

Figure 6 – Net Present Value (€) vs. Year Number (i = 2%)

When using a discount rate of 2% the investment recovery time is reduced to 12 years. Over a 20-year period a total profit of €3,197 with respect to Year 0 is projected. This is a significant improvement compared to the first case that yielded a profit of only €434. Hence this shows that the calculation is highly susceptible to the value used for the discount rate. When the only available options of alternate investment are bank current and fixed term deposit accounts, it is more feasible to use a lower discount rate.

The model used takes into consideration a yearly maintenance cost of 1.47% of the initial system. While this value caters for cleaning and general system maintenance, it does not take into consideration a change in the inverter which is typically suggested after 10-15 years from the initial installation. Given such a consideration the aforementioned investment recovery periods may be slightly offset.

4 CONCLUSIONS

The purpose of the MATLAB model developed for this research was to generate estimates with which different PV systems available on the market could be compared. The outputs of the model itself are heavily dependent on a number of factors which are difficult to predict and therefore have not been specifically quantified and considered such as:

- Changes in solar radiation patterns

- Technological advancement in PV systems
- Variation of feed-in tariffs

If one considers the NPV which is the main tool used to analyze the economic viability of the photovoltaic investment; one must note that it is heavily dependent on the percentage discount rate used. Such a parameter is difficult to quantify, hence a typical value from photovoltaic related literature of 6% was used at first. This discount rate was reduced from 6% to 2% in order to better approximate the Maltese investment scenario for the average household. A percentage variation in this value has been shown to significantly affect the net present value results.

Given the assumptions and data used for this research, it was found that when high return investments are available (6% discount rate), the investment is typically recovered in a period of between 17.6 – 18.6 years. When one considers a 20-year lifetime for a typical system the return on investment is minimal. However, when such alternative investments are not available and the reduced discount rate is used the breakeven period was calculated to be approximately 12 years. A return on investment of €3,197 compared to Year 0, was also projected which is significant when considering an initial investment in the €6,000 range at Year 0.

5 FURTHER WORK

In order to improve the MATLAB model presented in this paper, the following modifications may be implemented to better approximate real world scenarios:

- Inclusion of a projected percentage increase in the kWp available for typical household systems over time.
- Use of a wider supplier dataset.
- Consideration of the decrease in the overall system output due to non-ideal conditions (such as shading).
- Consideration of the variation in overall system performance in coastal areas when compared to inland regions.

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