Integration of renewable energy systems in buildings in the line of sustainable construction and energetic efficiency

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Abstract

Being Portugal an extremely active country on the renewable energy area, one of technology niches experiencing a growing interest from investors and population in general are domestic micro-generation systems, especially when integrated in a building's architecture. As a response to the expectations developed among domestic end-users of distributed renewable-based micro-generation systems, by the end of 2007, the Portuguese government published new legislation to regulate and clarify terms and tariffs for the installation of these small systems. To fulfill the needs of these users - essentially domestic and small and medium companies - INETI initiated the development of tools to characterize the wind resource in urban areas, the wind technological solutions adapted to urban environment – e.g. T.Urban small wind turbine - and tools to assess the viability of the micro-generation systems installation in buildings. This work presents and analyses scenarios for building energetic sustainability, by using a wind (SWT) system, a photovoltaic (PV) system and sizing a hybrid system (SWT+ PV) in a domestic building. Economic and energetic issues of the new legislation are presented and discussed. The results obtained demonstrate that it is very advantageous to become a micro-producer in Portugal, if the region of interest is suitable for wind energy exploitation.

1. Introduction

The burning of fossil fuels is one of the largest sources of carbon dioxide emissions. This gas is an important active contribution for the greenhouse effect and global warming on the planet. In this context and with the increasing awareness for the use of renewable energy, this form of energy assumed special relevance in the last few years. The scarcity of the fossil fuels resources and the increase on electricity consumption are some of the reasons that justify the changing route in the energetic paradigm. The decentralized production of electricity using renewable energy, beyond the preservation of natural resources, allows energy security and supply without environmental impact, and contributes for the decrease of national energy dependence. The energy systems face today a huge challenge related with the growing and eminent increase of the production in small scale, known by micro-generation. Due to environmental and economical questions, there is a growing concern in the construction sector referring to sustainable and energetic efficiency in the urban and building environment, where the energetic consumptions are significant. These urban areas present optimal conditions for the natural resources exploitation and energy production.

In Portugal, the figure of consumer-producer initialed appeared in Dec. Law 68/2002 [1]. The late established the production of electric energy of self-consumption and allowed to sale 50% to the electric grid, with a tariff similar to the multi-megawatt wind park promoters, and a maximum capacity of 150 kW. Five years after the publication of this Dec. Law, there were no significant numbers of systems licensed by this legislation. It is in this context, the Portuguese Government published new micro-generation legislation through Dec. Law 363/2007 [2]. In this Decret of Law the licensing procedures are made easier (by Internet application) and tariffs are far more attractive than the previous.

1.1 Dec.Law 363/2007 - Micro-generation

The micro-generation law regulates the micro-production of electricity from renewable energy sources. It provides a simplified licensing regime for connecting renewable energy producers to the with low-voltage grid. Any entity that has a contract for purchasing electricity can become a producer of electricity from renewable energy sources (e.g. solar, wind, hydro, cogeneration, biomass, and fuel cells using hydrogen from renewable energy micro-production).

Micro-production systems can have only one renewable source or be a combination (hybrid system) as long as that does not exceeded the annual limit production per kW installed of 2.4 MWh for solar energy and 4.0 MWh for others energy sources. There are two types of regime in this legislation: the general and the special regimes.

In the general regime, the maximum capacity that it possible to install is 5.75 kW and the tariff is equal to the cost of electricity sold under the purchasing contract.

In the special regime ("additional benefits"), micro-producers can inject a maximum of 50% of the power mentioned in the purchasing contract, this limited to 3.68 kW. However, to have access to these benefits, in case of single houses it is also necessary to have $2m^2$ installation of solar collectors, and in case of condominiums an energetic certification is required. The reference tariff is guaranteed for the first five years following the installation. It is defined as 650€/MWh for the first 10 MW installed and decreases 5 % for each additional 10 MW registered in the Registration System of Micro-producers (SRM) per year. The reference tariff depends on the renewable energy technology used. It is 100% for solar, 70% for wind, and 30% for hydro, cogeneration, biomass and others.

Licensing is conducted through the internet, via SRM, an electronic platform through which producers apply for and register their installations [3].

The law application has begun in April of 2008 with the first call for registry of micro-generation systems. Until the end of February, 5 MW were already waiting for inspection, among the 25. MW already registered. The Portuguese government goal for 2010 is to have 165 MW of these small systems installed, assuming a growing of 20% per year.

Although the application of the new legislation has been a success so far, the reduced adhesion of the domestic consumers, now also producers of energy to small wind turbines a almost an exclusive installation of PV systems was somehow a surprise, taking into consideration both the good wind resource in some urban areas and the fact that the ration of tariffs either puts the two technologies in similar economic conditions or may slightly benefit the wind systems. Therefore, the main objective of this work is to demonstrate the advantages in becoming a micro-producer of electric energy using renewable sources under the new legislation, with a particular focus on micro wind turbines.

2. Methodology

In order to find out the advantages of installing a micro-generation system, the potential producer must in a first phase analyze its monthly or annual consumption and estimate production so that he can select the adequate system and source of renewable energy - photovoltaic, small wind turbine, or both. After choosing the system, an energy production assessment must be performed and it is extremely important to know the local wind and solar potential resources with acceptable errors. Unfortunately, in these types of campaigns the resource must be monitored at least for one year and these costs as much as the micro-generation systems themselves. In response to this issue, and followed in this paper, INETI published tools that allow to identify potential resources in Portugal, namely SolTerm [4] for solar resource and EOLOS [5, 6] and Atlas [7, 8] for the wind resource.

The methodology developed for the systems dimensioning were based in only one type of application foreseen in the current legislation: the special regime - maximum power of 3.68 kW, assuming that every year the bound national power of 10 MW installed was accomplished. In these terms the tariff decreases 5% per year.

The economic evaluation is based on the calculation of some common economic parameters [9] where a discount rate of 3% was considered and the annual maintenance of the systems, namely; NPV – the net present value of an investment by using a discount rate and a series of future payments (negative values) and income (positive values); IRR – Internal rate of return; ROI – Return of the investment and Payback (P) period in years. Calculated by the usual expressions that follow:

$$NPV = -C_0 + \sum_{j=1}^{n} \frac{CF}{(1+r)^j}; \quad (1)$$

$$ROI = \frac{\sum_{j=1}^{n} \frac{R_j}{(1+i)^j}}{I_T}; \quad (2)$$

$$P = \frac{\ln\left(1 \Big/ \left(\frac{1}{r} - \frac{I}{R}\right) \times r\right)}{\ln(1+r)}; \quad (3)$$

Where:

r - discount rate;

I_t - total investment;

R - gain per year;

C_0 - investment in year zero;

CF – difference between gains and payments per year;

$$C_0 = \frac{I_T}{(1+r)^0} \quad \text{and} \quad CF = R - D. \quad (4)$$

Also an indicator of the yearly profits is calculated. In these evaluations it is necessary to analyze the tariff to apply. According to Dec.Law and with what was been mentioned above, the reference tariff is different for each source of energy. In a hybrid system, this tariff is calculated by the following expression [3]:

$$T_v = \frac{LME_{PS}(T_R \times P_S) + LME_{RP}[0{,}7(T_R \times P_E)]}{LME_{PS}P_S + LME_{RP}P_E} \quad (5)$$

LME_{PS} - the maximum production of solar energy

LME_{RP} - the maximum production of the other renewable energy

T_R - reference tariff

P_S – solar power

P_E – other renewable energy power

3. Case Study

This work studies different technical configurations in scope of the integrated micro-generation systems. Four scenarios are presented for a domestic building located in a region with both high levels of sun radiation and good wind potential conditions.

The building chosen is located in the so-called Western Region in Portugal (just North of Lisbon), being this region one of the areas with higher wind potential in the country and only one with strong steady strong winds at relatively low altitudes. In fact several wind parks are already operating in the region. The area where the house is placed has 1200m^2 of free yard and it was built in a strand of a hill. It is an area with few small buildings mostly with lower heights. This location has a mean wind speed value of 6.9 m/s at 15 m a.g.l. and a mean solar radiation of 214 Wm^{-2}.

The energetic consumptions and the evolution per year of tariff are represented in figure 1 and figure 2, respectively.

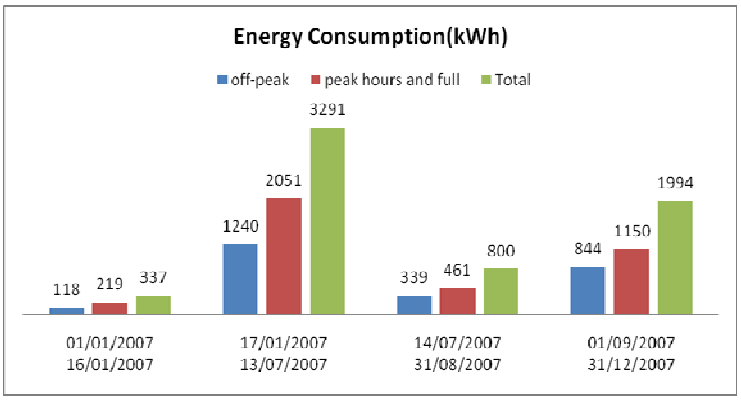


Figure 1 – Electric Consumption during 2007 in the case study building.

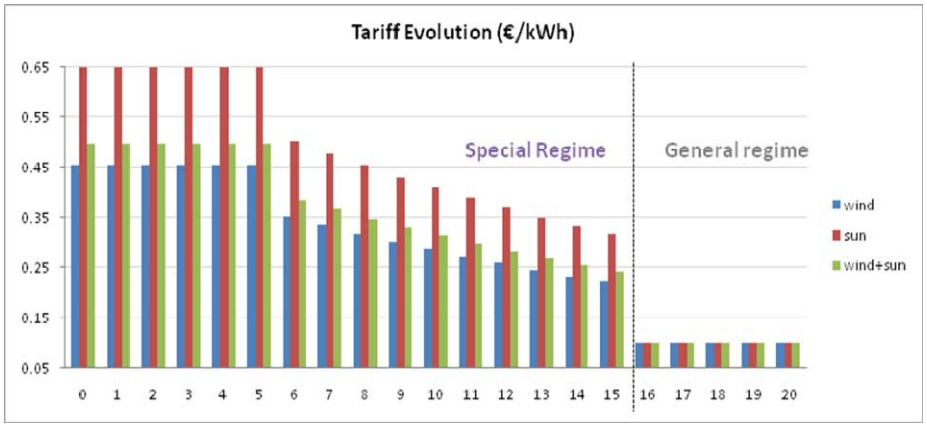


Figure 2 –Tariff evolution in the project lifetime.

For this building, four scenarios were studied and are presented in table 1.

Table 1 – System characteristics for each scenario.

Scenario	System	Power (kw)
A	1 T.Urban 2.5H	2.5
B	1 T.Urban 2.5H + 7 BP 170W (SB 1100)	2.5 + 1.9
C	2 T.Urban 2.5H (limited)	3.68
D	21 BP 170W (SB3300)	3.57

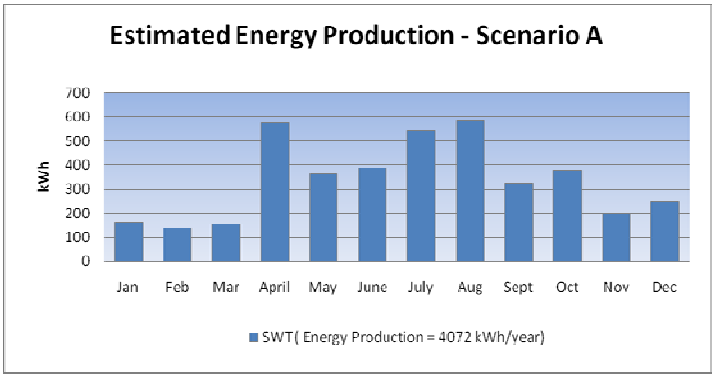
3.1 Production Results

Four scenarios were simulated for the first year of the new Dec.Law. In table 2 are represented the results for each system chosen.

Table 2(continuation) – Annual production of solar and wind potencial for each scenario.

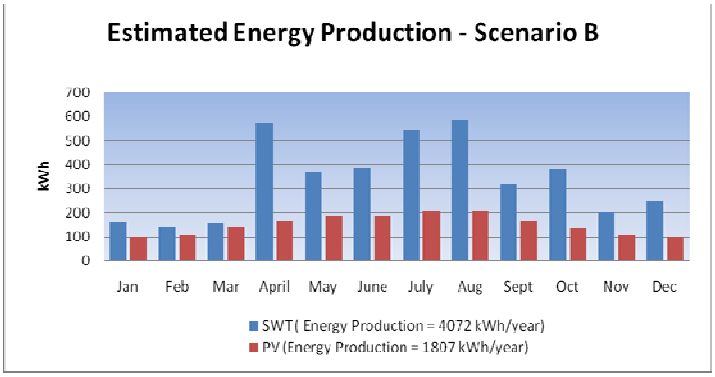
Scenario A (2.5 kW SWT)

Annual energy production: 4072 kWh



Scenario B (2.5 kW SWT +1.19 kWp PV)

Annual energy production: 5879 kWh



Scenario C (3.68 kW SWT)

Annual energy production: 7695 kWh

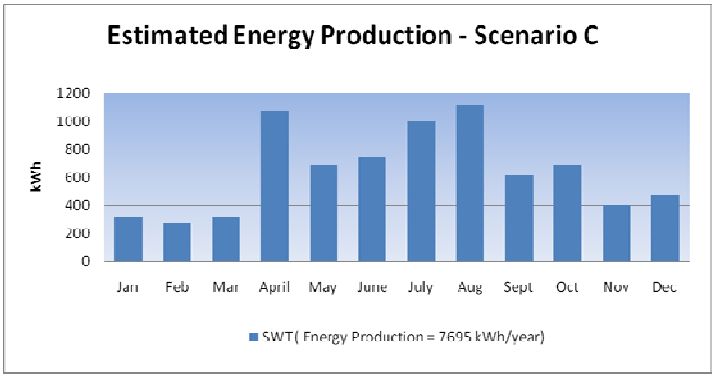
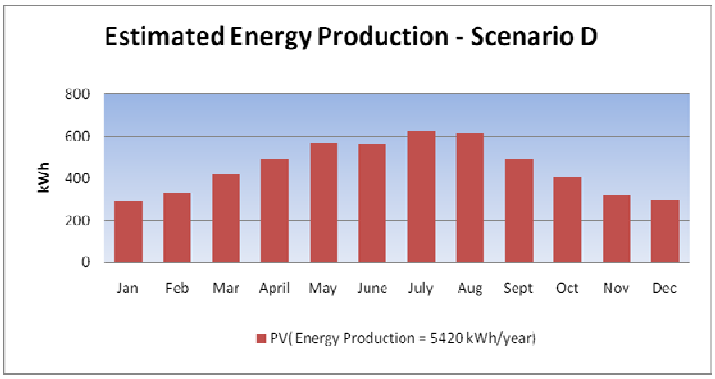


Table 2 (continuation) –Annual energy production of solar and wind potencial for each scenario.

Scenario D (3.57 kWp PV)

Annual energy production: 5420 kW



3.2 Economic Evaluation

An economic viability study was performed considering the life of the system equal to 15 years for SWT and hybrid (SWT+PV) systems and 20 years for PV system alone. Tariffs estimated for the following 15 or 20 years were according to the previously mentioned and presented in figure 2 (5% decrease per year after the first 5 years of the system life). The results present did not consider the price of solar collector and his installation, since they are equal for all scenarios and already exist in most domestic buildings considering micro-generation of electricity.

Table3 – Economic parameters for each scenario .

Economic parameters	A	B	C	D
Annual Production (kWh)	4072	5879	7695	5420
Investment	9,643 €	17,672 €	19,285 €	22,991 €
NPV (15 years)	6712	8632	11543	9444
IRR (%)	13	10	12	10
PAYBACK (year)	6	7	6	8
% ROI (15 years)	69.61	48.85	59.85	41.08
NPV (20 years)	-	9163	-	11038
% ROI (20 years)	-	51.85	-	48.01

Table4 – Energetic invoice analyses for each scenario.

Energetic Invoice	A	B	C	D
Annual Consumption (kwh)	6422	6422	6422	6422
Annual Production (kwh)	4072	5879	7695	5420
Annual Energetic Invoice (consumption)	558 €	558 €	558 €	558 €
Profit over 15 years of this consumption	51 €	1429€	4882€	2783€
Profit over 20 years of this consumption**	-	320 €*	-	2736 €

* In the last five years only were considered profits of photovoltaic system with an annual production of 1807kWh.
** In the last five years the tariff is the same as general regime (100€/MW).

4. Conclusions

The micro-generation legislation arises in Portugal in the line of other energetic efficiency and sustainability regulation, responding to the European efforts to reduce the greenhouse gases emissions and walks towards the European objectives both for renewable energy use and reduction of CO2 emissions. Initial assessments indicate that the micro-generation domestic sector may contribute with more than 30% of this sector electricity consumption.

The case study presented here shows that the legislation currently in use in Portugal adequately supports electricity end-users who wish to become micro-producers of electricity, generating quite acceptable economic indicators for the return of investment both for PV, wind and hybrid system. This is a long term investment (20 years for PV systems and 15 years for SWT systems) where, in general, profits results are 50% above of investments. Unfortunately, the reference tariff decrease over the years to the reference value of the general consumption regime and the investment becomes less profitable.

References

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