ENERGY PERFORMANCE EVALUATION OF A PHOTOVOLTAIC WINDOW

6.BV.1.26

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INTRODUCTION

The growing increase in energy consumption in developed and developing countries is an important task that must be addressed by the economic policies of these countries. The percentage of energy consumption of buildings relative to the overall energy use has grown in the last years due to the increasing amount of electrical devices.

The photovoltaic windows as an integrated system in the building façades can contribute to generate clean energy to meet the needs of the inhabitants of these buildings.

WINDOW PV CHARACTERISTICS

An amorphous silicon photovoltaic module encapsulated between two transparent glass sheets, an air chamber and a second double glass sheet with an air chamber form the photovoltaic window. The effective dimensions of the a-Si photovoltaic module are 0.57 m x 1.17 m, equivalent to a standard measurement of 0.60 m x 1.20 m. The frame of the window is a PVC structure as is shown in Figure 1.

The IV characteristic in standard test conditions were determined in a solar simulator according to 61646 IEC standard. The climatic values and the electric results are shown in Table 1. A power uncertainty of ± 6.78% was found. Figure 2 presents the I-V curve of the PV window.

Figure 1. PV window

Table 1. Climatic test conditions and electric parameters.

T_{max}(ºC)	23,3
T_{min}(ºC)	21,3
RH_{max} (%)	54,3
RH_{min} (%)	51,1
RH_{limit} (%)	<70
I_{sc} (A)	0,71
V_{oc} (V)	113,19
V_{max} (V)	87,18
I_{max} (A)	0,58
Peak power (W_p)	50,74

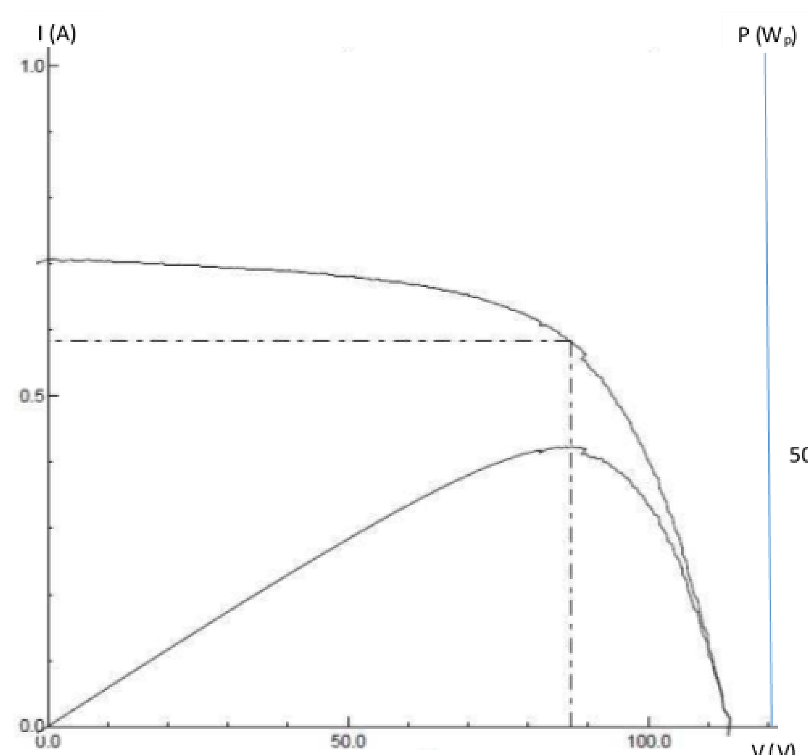

Figure 2. I-V curve of the photovoltaic window.

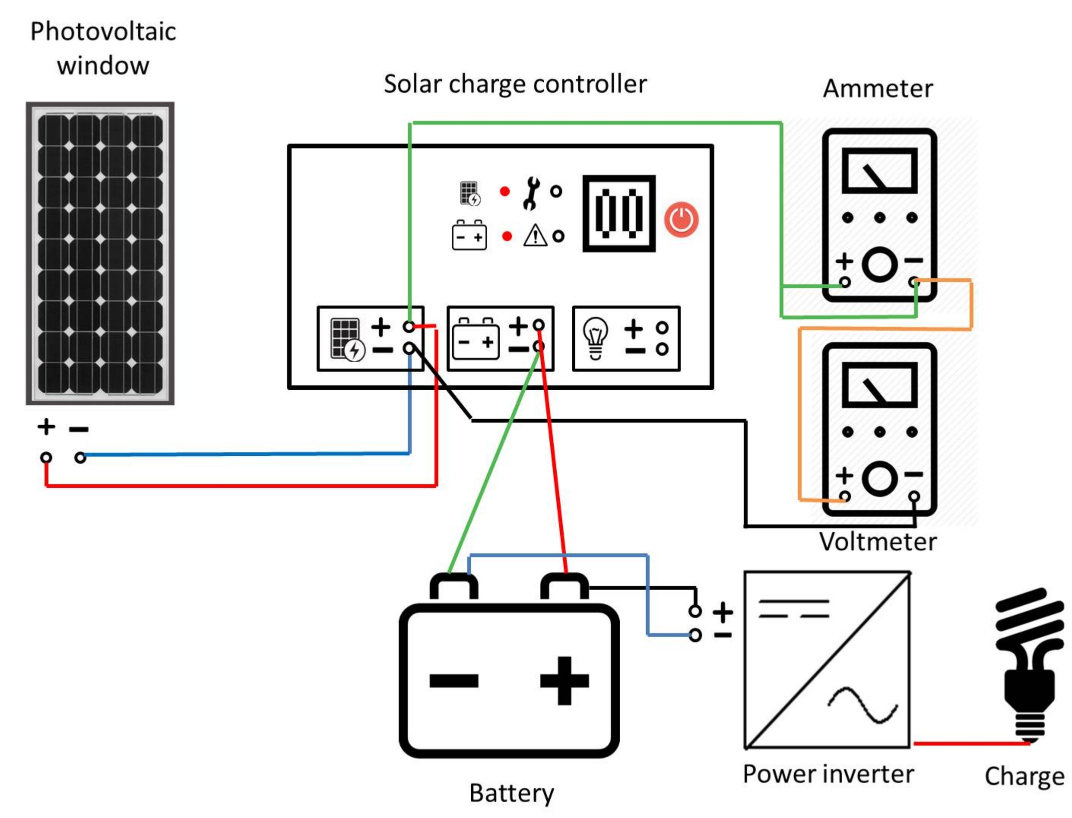

Figure 3. Experimental arrangement.

ENERGY PRODUCTION OF PV WINDOW

The photovoltaic window was placed in a test bench in vertical position facing South. A protocol for data collection that allows knowing the instantaneous power generated by the photovoltaic window has been developed. The figure 3 shows a scheme of the experimental arrangement.

To know the energy produced by the window in vertical position, the voltage and current generated by the photovoltaic window in sunny days as well as the solar irradiance, module temperature and ambient temperature are collected every ten minutes from sunrise to sunset. The irradiance received on the plane of the photovoltaic window at daytime was 4114 Wh/m^2 and the energy produced was 71.2 Wh. So the photovoltaic power of a window of one square meter of useful surface will be 76.1 W/m$^2_{window}$.

With the PV window placed in vertical position, the monthly yield production for one year has been obtained. Efficiency values of 0.75, 0.80 and 0.85 and radiation data from the Energy Agency of the Junta de Andalucia for Malaga are considered. Figure 4 graphically compares these results.

The annual yield for 0.85 efficiency has been obtained when the PV window is vertically placed, and tilted 60º or 30º. Figure 5 shows the monthly result of one square meter of PV window. As can be seen the tilt angle affects the yearly energy production of PV window. The bigger production correspond to a tilt of 30º, so the best use of this window in BIPV is as a part of an atrium in a latitude like that of Malaga. In Figure 6 are presented the annual yield for different efficiencies and different tilting position of the PV window.

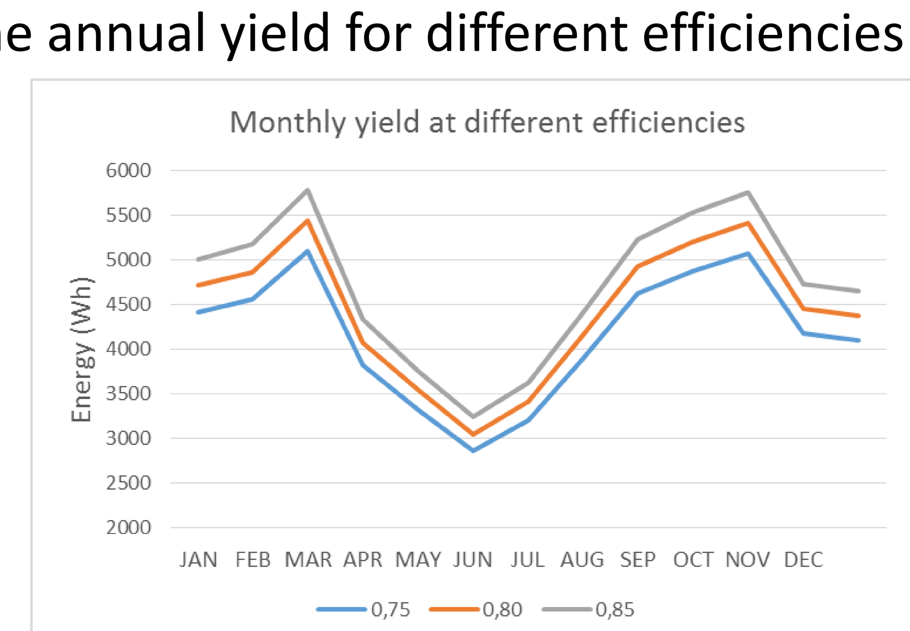

Figure 4. Monthly yield at different efficiencies.

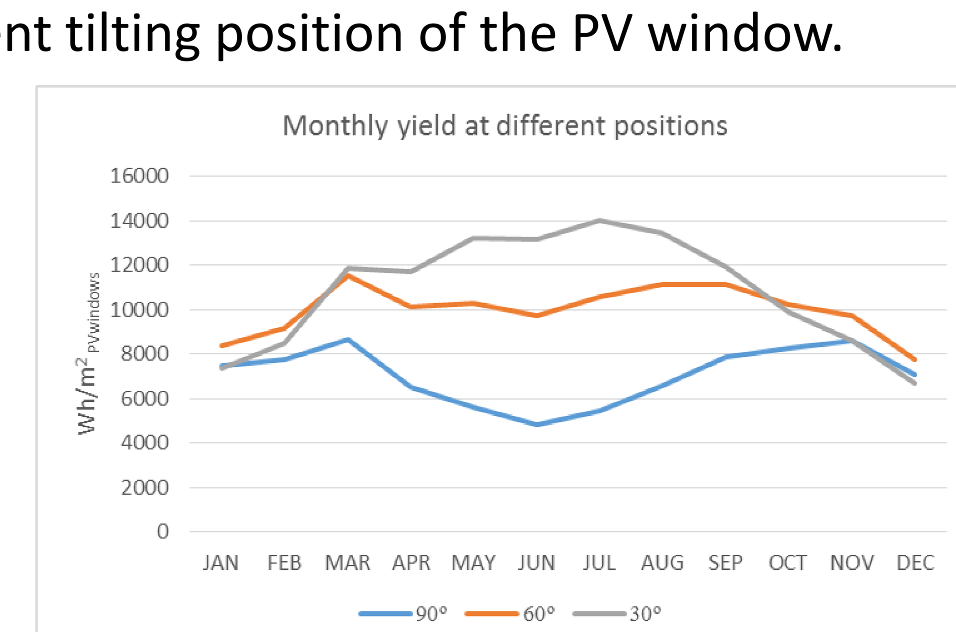

Figure 5. Monthly yield of window at different positions.

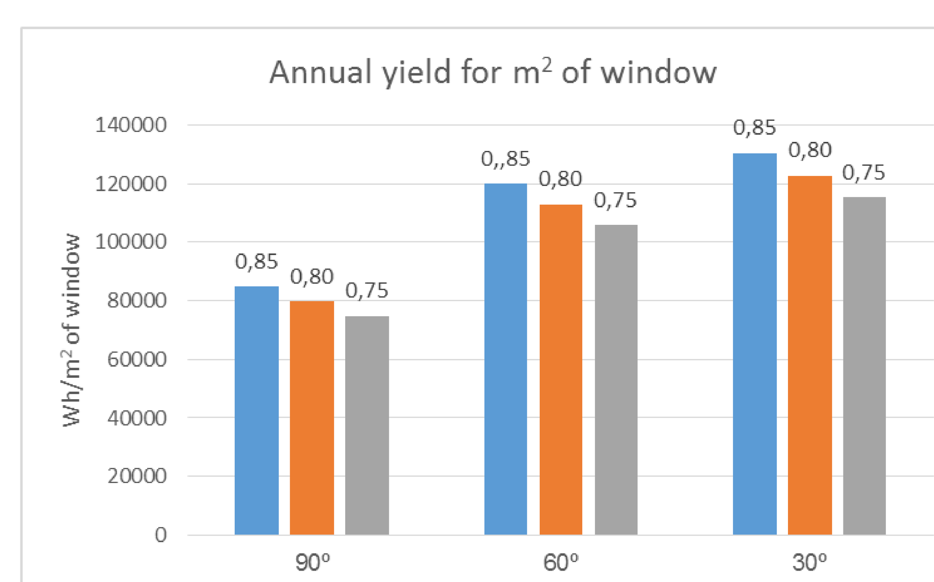

Figure 6. Annual yield for one square meter of window.

DISCUSSION

The integration of the photovoltaic window in a building has several advantages over conventional systems: energy saving, economic savings and environmental advantages. A residential building with 68 apartments is considered. All apartments are equipped with appliances, air conditioning and electric stove. The glazed surface of the building facing south is supposed to be 4320 m^2.

Energy saving: if the PV window cover all glazing surface the yield obtained for the BIPV system would be 345030 kWh/year. This production excess the electricity demand of the building. The energy surplus could be sold to the network or to other users.

Economic savings: if an efficiency of 0.80 is considered, the saving in electricity bill of the houses of the building would be 59279 €/year when a daily average electricity price of 0.25 €/kWh is supposed. If the energy surplus produced by the BIPV system is sold to the network at 50 €/MWh, an additional yearly profit of 5396 € would be obtained.

CO_2 emissions avoided: if a conversion factor of 0.30 kg of CO_2 emitted per each electric kWh consumed is considered, the BIPV system avoids the emission of 240278 kg of CO_2 into the atmosphere per year.

CONCLUSIONS

An experimental arrangement was built to obtain the daily production at real sun conditions of a PV window. A value of 71.2 Wh was obtained when the window is placed vertically facing south. The production depends on the overall efficiency of the system and on the inclination of the window. The integration of the PV window in a building allows to obtain energy, economic and environmental advantages. The use of semi-transparent BIPV elements will become more and more popular to combine various functions, namely electricity generation, thermal insulation, shading, and even satisfy aspects of architectural design.

ACKNOWLEDGEMENT
This work is partially derived from the contract nº 8.06/5.31.4644 Libre Evolución de Energía S.L. The authors wish to thank to Universidad de Málaga. Campus de Excelencia Internacional Andalucía Tech the support for presenting this work.