ADVANCED RESULTS OF MODELLING, EXPERIMENTS, AND INNOVATIVE SOLAR ENERGY COMPONENTS CONCEIVED AT FTA LABORATORIES

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ABSTRACT

The paper presents the most interesting results recently obtained at FTA Laboratories of the University of Tor Vergata in the field of solar energy applications, in the framework of an integrated approach using both simulation, experimental and theoretical tools. The paper aims to stress the relevance of a system approach as a methodology.

INTRODUCTION

The FTA Laboratories, estasblished in '90 years, belong to the Department of Enterprise Engineering of the University of Tor Vergata. The activities of the FTA Laboratories are devoted to the following specific fields: meteoclimatic measurements, climate models and simulation, solar and wind energy availability prediction, outdoor monitoring of FV panels performances together with studies on causes of worsening of their behaviour by means of simulation models, enhancements in studies of cloudiness effects on energy availability at the ground, determination of new targets for materials affordable by means of innovation, system studies for optimal coupling between climatic local conditions and thermal or PV panels technologies, based on spectral responses and selectivity affinities.

Other FTA Lab activities, like cost-benefit analyses and energy policy evaluations, exceed the subject of this paper.

METHODOLOGY AND TOOLS

The key of our activities is a system approach adopted in all the mentioned fields, thanks to the availability, since the '80 years, of original simulation codes and of experimental heat transfer internationally shared procedures, like those implemented in the framework of the EU CEC Solar Storage Testing Group joined in 1982 by Spena [1].

As a matter of fact, scientific and technological aspects of sustainable energy systems [2], concentrating [3] on the power obtainable from solar devices, involve either thermal and photovoltaic components, as much as possible embedded in building structures.

As will be exposed in the following, all our researches are coordinated in order to improve the potential for analysis given by synergies among the different activities, in view of a comprehensive vision of the overall problem of the real availability at ground of solar energy. In Fig.1 a pictorial of the outdoor ESTeR device [4] for PV modules testing is reported.

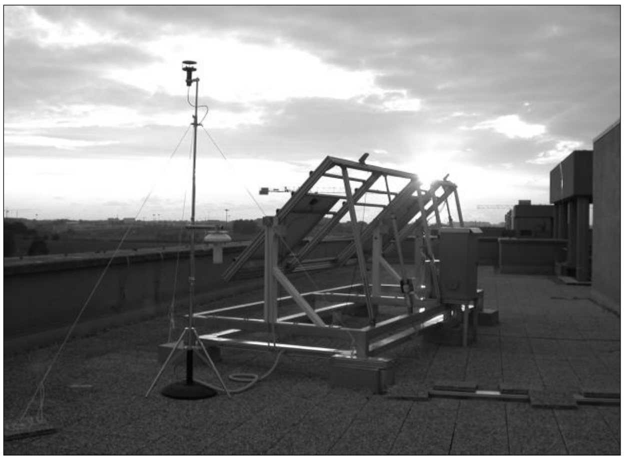

Figure 1. The ESTeR Stand for the Outdoor Testing of Solar PV Panels.

OBTAINED RESULTS

Photovoltaics

One of the topics of any realistic assessment of potential for PV is the estimate of effective energy that can be collected on field. As a matter of interest, here are depicted the results of a comparison between measured and simulated efficiencies of a Kyocera mSi PV panel (Fig.2), obtained by means of a model based on a three correction factors [5] simulating each respectively reflectance, air mass spectrum (see Fig.3) and temperature effects (see Fig.4).

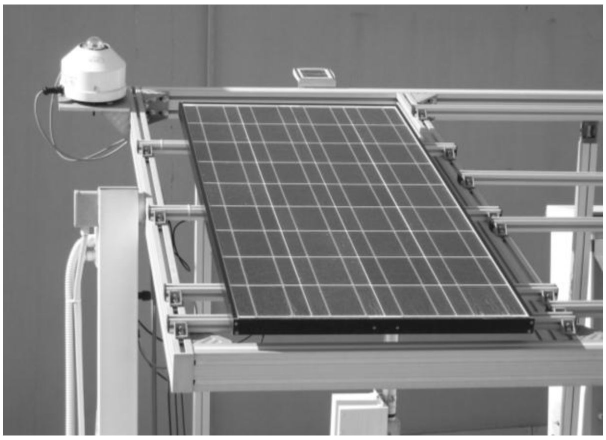

Figure 2. View of the reference PV panel used for experimental validation of the simulation model.

Our second item of interest is to forecast the potential for PV by side of materials of the ultimate generation, namely the third, especially the organic ones. To do this, a wide cooperation with the CHOSE (Center for Hybrid and Organic Solar Energy) center of the University of Tor Vergata has been established since year 2006. As the behaviour of dye solar cells is concerned, typical tracks [6] of an outdoor characterization of cells (Fig.6) built by CHOSE are reported in Figure 7.

Climate

The meteoclimatic station of FTA Laboratories is operating since year 2003. Together with wind, rain, thermal and hygrometric data, the simultaneous values of direct, diffuse and reflected irradiance are separately measured; and, starting from spring 2010, also the spectrum of the incident radiation in the range 0,3 to 1,7 µm-

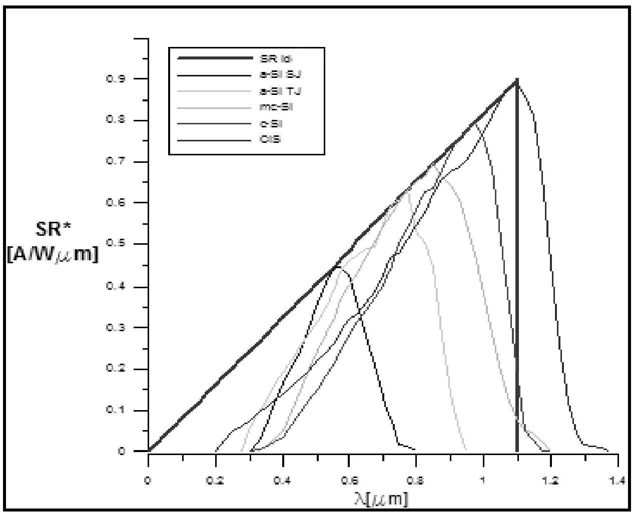

Figure 3. Spectral response of various PV cells.

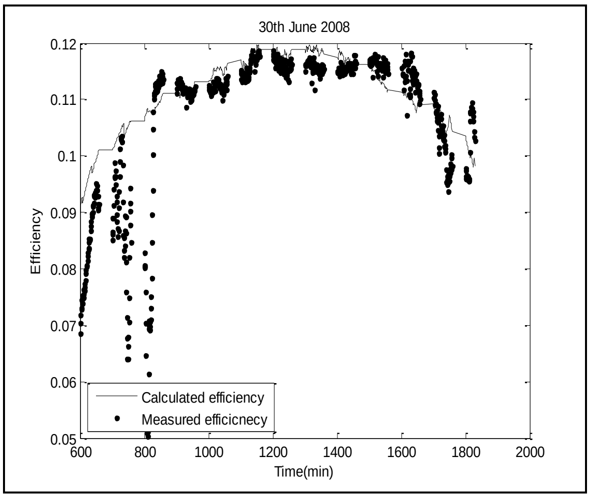

Figure 4. Comparison of simulated and measured efficiencies, tilt 20° facing South, FTA Lab, June 30th, 2008.

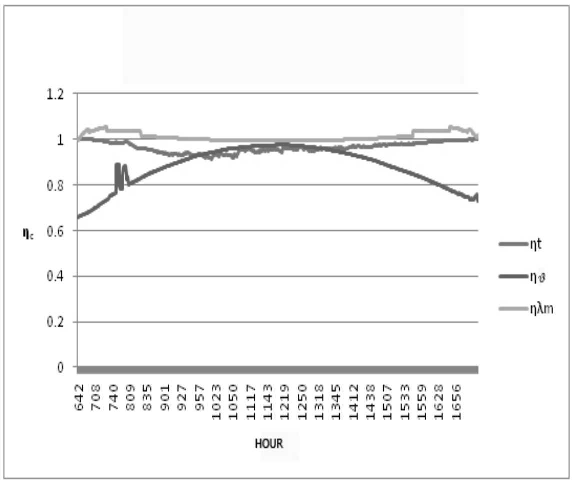

Figure 5. Single effects of the corrective coefficients on the nominal efficiency, FTA Lab, September 4th, 2008.

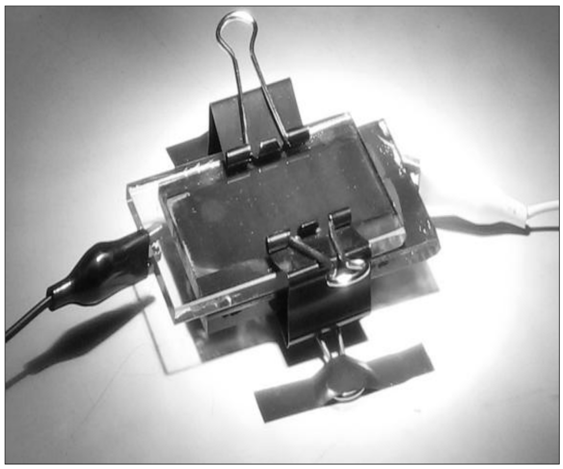

Figure 6. A DSC PV Cell built at the CHOSE Lab of Tor Vergata, 2008.

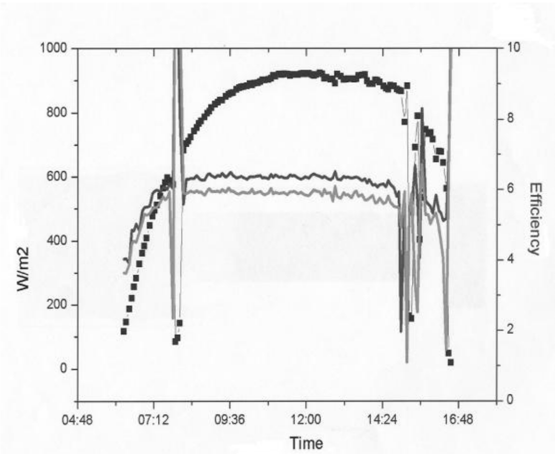

Figure 7. Outdoor Performance of a DSC PV Cell During a Sunny Summer Day. FTA Lab, September 2009.

As known, separated values of the radiation components must be used to evaluate local solar energy potential and to optimize the inclination of a solar device. Different transposition models can be found in the literature [7] to calculate the global irradiance on a surface with various tilt with respect to the horizontal, starting from the three abovementioned components. A tool has been built that allows to use the almost 7 years of data collected at our facility to calculate irradiance and irradiation over various period of time (hours, days, months) at whatever orientation or inclination of using the most usual transposition models. Also radiation potential over a tracked surface can be evaluated. Fig.9 shows an example of monthly energy calculation, using all the available dataset, for a surface tilted 30° facing South. The incoming energy has been calculated for all the models implemented in the tool.

Figure 8. FTA Lab Meteoclimatic station.

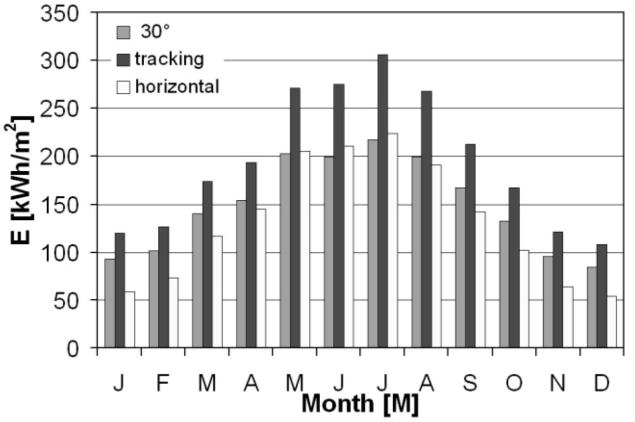

Figure 9. FTA Lab, Energy Monthly Collected at Different Tilts.

Comparisons have also been made between transposed data and irradiance measured at different inclinations (the measurement uncertainty for irradiance is of the order of ±3% at 1000 W/m^2). A general underestimation of the models has been observed, while the Klucher model resulted the most suited for data transposition. This model has then been used to compare the incoming energy on a surface tilted 30° facing South (near the most used angle at our latitude for all-year exploitations) with the incoming energy on a horizontal surface and a tracking surface. Fig.10 shows the results.

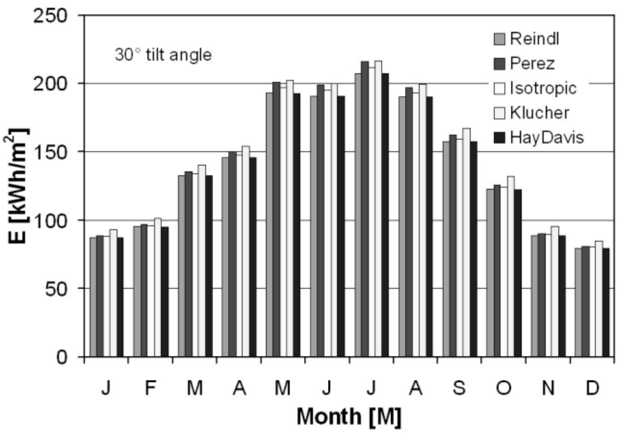

Figure 10. FTA Lab, Energy Monthly Collected: Comparison of the Models.

The above results lead us to the consideration that differences among the different kind of climates could be intrinsic reason of departures between our and models results (mainly related to North-American typical sky).

As a matter of fact, clouds play a key role in the radiative energy balance at the ground. Due to the great variety and variability of cloudiness and to the lack of methods to measure cloudiness quantitatively, the dependence of radiation fluxes on cloud amount and type has been parameterized by means of a model described elsewhere [8].

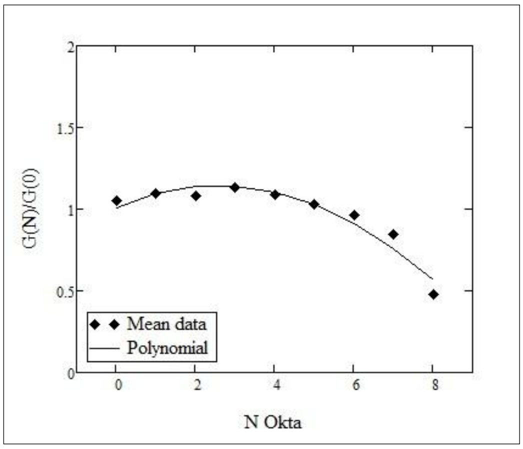

Figure 11. Correlations between the Global Radiation over Clear Sky Global Radiation, and cloudiness N. FTA Lab, 2009.

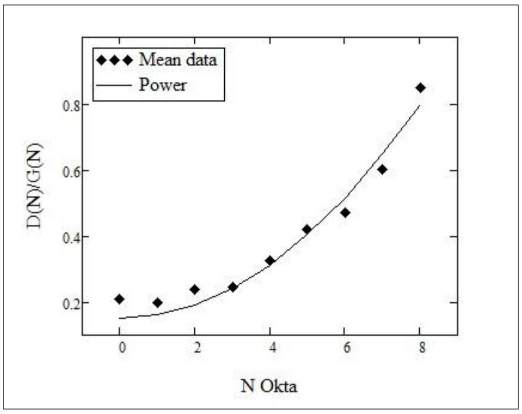

Figure 12. Correlations between the Clear Diffuse Radiation over Clear Sky Global Radiation, and cloudiness N. FTA Lab, 2009.

Satisfactory correlations have been obtained for the site of Rome (see Figs 11 and 12). It confirms that departures from results obtained in different European sites appear due to meaningful climatic reasons: a realistic explanation of this fact is given by the role played by the simultaneous effects of either water vapour content of the air (high), and wind speed (low), both at the ground level. So implemented, the simulation model appears a useful tool for weather predictions.

Wind Energy

Statistical knowledge of the wind parameters of a site is an important issue to foresee the potential for a wind farm. This is particularly true in Italy, where wind characteristics are often not suited to those applications. The combined uses of measurements and models enabled us recently (see Fig. 13) to demonstrate how the site of Rome is unfit for wind energy applications [9], while Fig.14 shows our forecasts well confirmed by experimental results published by GSE, the national manager of the electrical services [10].

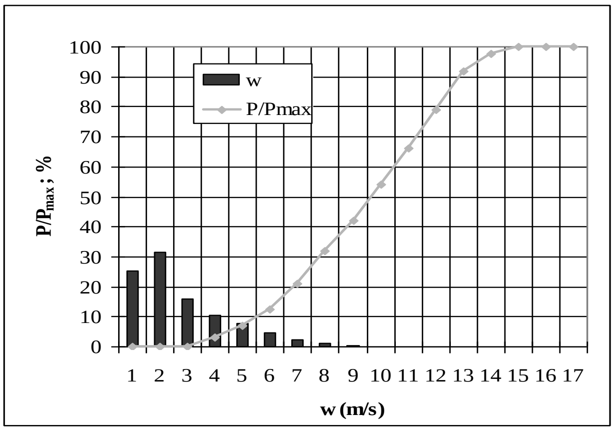

Figure 13. Wind Speed Statistical Distribution and Wind Generators Load. Rome, years 2004-2007

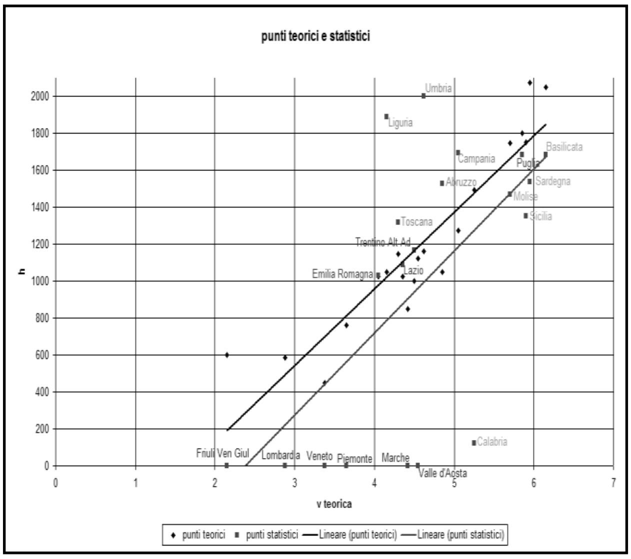

Figure 14. Predicted and Measured Wind Energy Production in Major Italian Sites, vs Mean Statistical Wind Speed.

Figure 15. TiO_2 Coating Facility at FTA indoor Laboratories.

FURTHER IMPROVEMENTS AND RESEARCH

Materials

Glass covers highly affect the performances of both thermal and photovoltaic devices, mainly acting on their reflective optical properties [11]. As those materials are concerned, a first attempt is going to be on the use (see Fig. 15) of TiO_2 coated glass covers, to obtain self-polishing surfaces as an extension of works already done on ceramic materials.

Another field of study is presently the selectivity of the flat-plate thermal solar collectors, in order to investigate the effects of tilt, mainly on vertical surfaces, of the different on-field effective coupling conditions between solar radiation and response of the surface. Preliminary studies have been carried out on this subject [11], obtaining the plots of Fig.16.

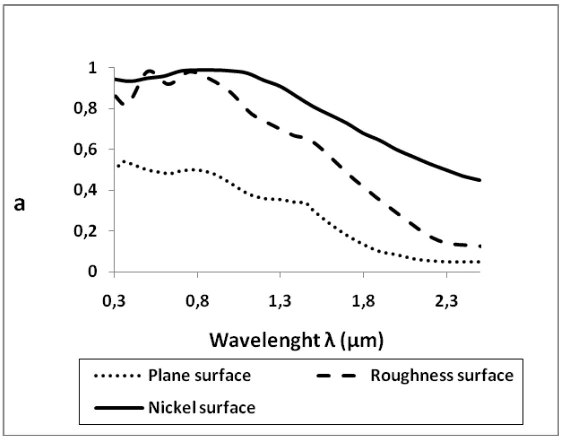

Figure 16. Absorbance of Different Flat-Plate Thermal Solar Collectors vs Wavelenght.

Systems

As preliminary said, the obtained results encouraged us to extend the set of the applications of our methodology, mainly to the most promising uses of solar energy, namely the development of building and construction components, able to perform both structural or closure functions, and energy picking up in a useful form for the building system. In Fig. 17 is depicted a sketch of the already built stand devoted to trials of thin flexible FV films suited for temporary and fixed covers, i.e. as an example those used in archaeological sites [13].

A complementary facility for testing both evacuated and plane thermal collectors has been designed (see Fig.18).

Finally, in order to fulfill trials on any inclination and orientation surfaces for either PV, thermal and hybrid panels, is going to be realized (see Fig.19).

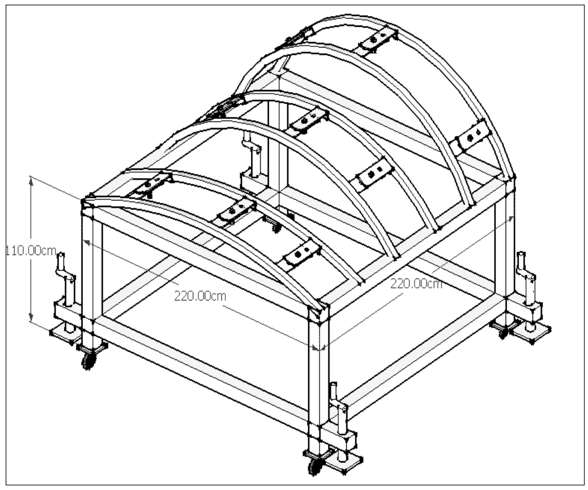

Figure 18. Sketch of the Experimental Stand for Testing Thin Flexible PV Films.

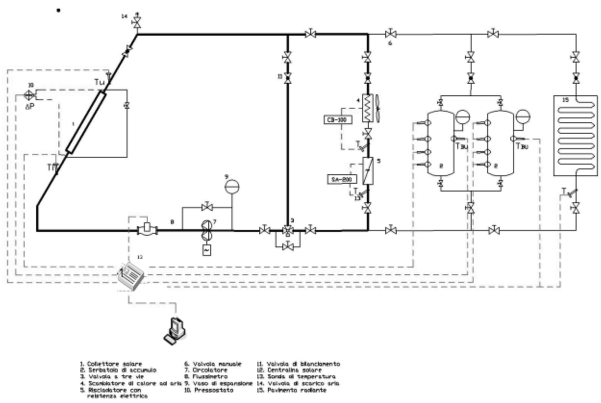

Figure 17. Thermo-hydraulic Circuit of the Experimental Stand Devoted to Trials on Thermal Solar Energy Capture and Storage.

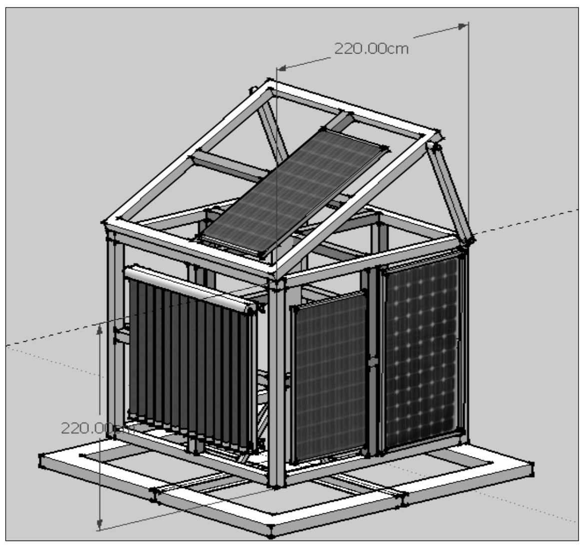

Figure 20. Sketch of the Cube facility for testing Solar Components on vertical Surfaces.

CONCLUSIONS

The ultimate results obtained show how an integrated approach to the linked items relating to solar energy applications can be a useful tool to improve the potential for solution of several problems. The availability of the three solar radiation components intensities, together with climatic data since year 2003, enabled us to implement simulation models of the climate at the ground. The correlations obtained for cloudiness conditions, in addition, enabled us to study via simulation the behaviour of solar captators (both thermal and PV) in a large amount of different weather conditions. As a matter of fact the most important result appears the consciousness that only an optimal coupling between climatic conditions on one hand, and technologies on the other, mainly in terms of spectral response of the materials, could be a way of optimizing solar energy applications. This will be studied using either experiments, either simulations. To do this, a station for testing thermal and hybrid panels in going to be installed. It will be used also for experiments on new materials and technologies (as an example, self-cleaning surfaces or embedded panels).

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