SOLARIMETER Vs. PYRANOMETER

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An analytical comparison between the two irradiation sensors technologies

Abstract

For the photovoltaic systems performances correct functioning to some one born the questions: it is more right to use a silicon sunmeter or a pyranometer?
The answer is: it is more functional to use a solarimeter (or silicon cell sensor).

This is based on the following assumptions and concepts:

1. The silicon cell surveys the same radiation that a Photovoltaic system is able to convert in energy
2. Some solarimeters have a technology able to return an irradiation value purified from the temperature effects
3. The solarimeters have a plane surface and so similar to the Photovoltaic modules surface. Besides they are placed with the same orientation and inclination of the plant Photovoltaic modules.
4. The high band solarimeters have an output with high immunity to the disturbances and in systems of certain greatness where many modules strings are present, electromagnetic induction phenomenons to the detriment of the cables of the signal, are frequent. On the contrary the pyranometers being designed for areas without disturbances such as the meteorological stations have usually outputs of 10-20mV and the signal that passes on the wire up to the monitoring system has a certain vulnerability to these disturbances
5. The solarimeters have a low cost respect the pyranometers.

Obviously the pyranometers have some advantages. In the successive paragraphs each of these four points is developed in analytical way; in the last paragraph there is a comparative table between the different solar sensors.

1. The solar radiation part subjected to the photovoltaic conversion

The sun emits an electromagnetic radiation with different wavelengths and with a peak centered in the visible spectrum.

This radiation to arrive to the earth ground must go through the earth atmosphere, where suffer absorptions, refractions, reflections and emissions that work in selective way.

Every element in the atmosphere in fact reacts in different way to the various electromagnetic radiation wave lengths that is every component absorbs and emits the radiation to a different wave length (absorbing the radiation it heats in accordance with the reached temperature and emits a different one).

This fact provokes that the solar radiation to the ground level has a spectrum much different (and energy inferior) from the extra atmospheric level, as you see in the picture 1 the main differences are in the maximum values and in the “disappearance” (or a accentuated decrease) of whole and specific wave lengths.

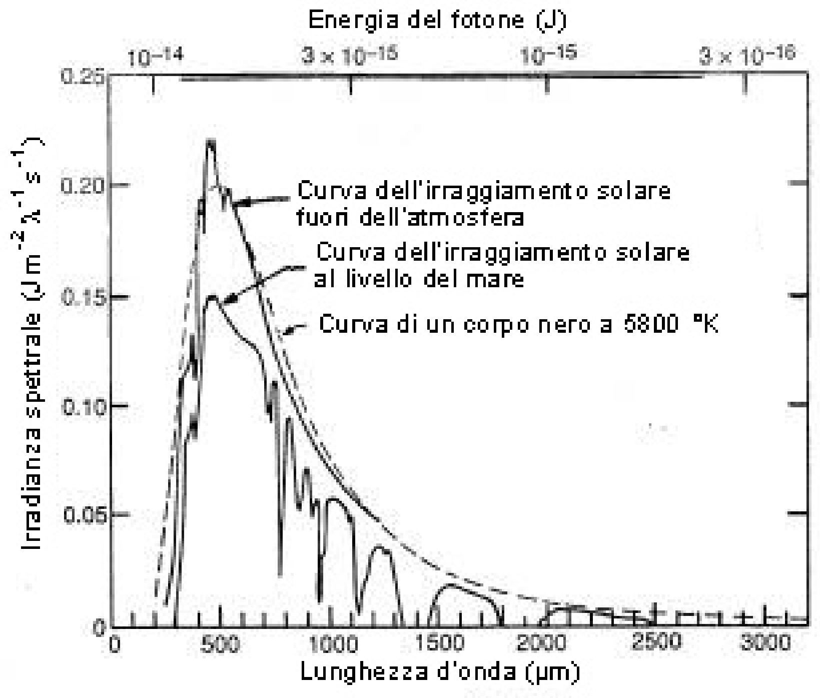

Fig1: Typical spectrum of solar radiation at sea level

You can understand that to perform a correct value measure of the whole radiation it is necessary to consider the entire spectrum.

The system that fits to survey the entire spectrum is the one based on the thermal batteries technology ((pyranometers) that is able to absorb fully the solar radiation, as treated in detail in the article "Pyranometers v. Reference Cells for PV Installations" that you can download from the Kipp&Zonen web site.

The picture 2 shows the optimum quality pyranometers response capacity; (taken from the "secondary standard' pyranometer technical card by Kipp&Zonen)

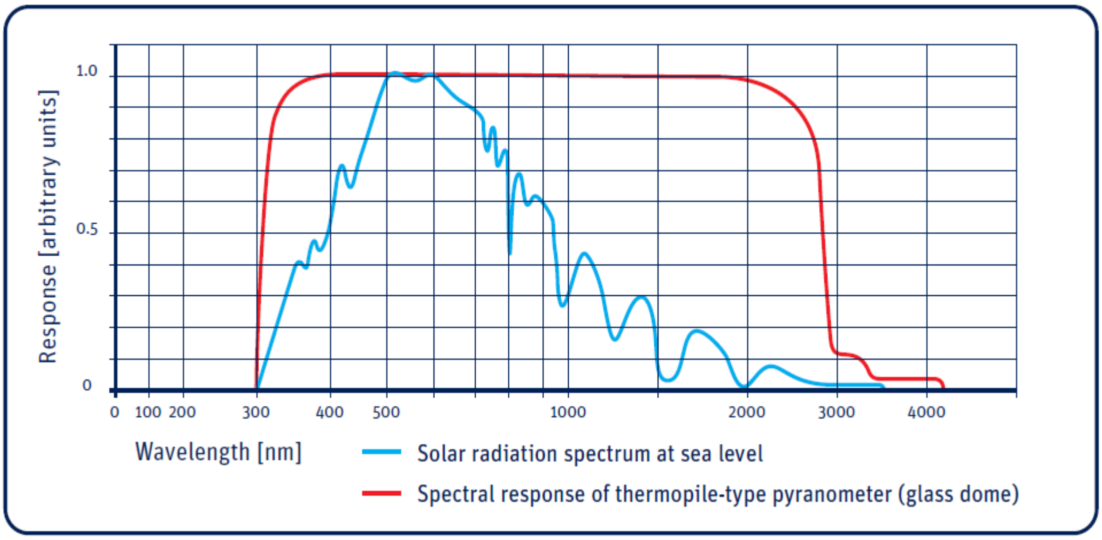

Fig. 2: Spectrum of solar radiation at sea level compared with the absorption of a thermal batteries

So, to have a correct estimation of the global radiation, widespread or direct, the best system is without doubt to use a pyranometer.
Instead if you want to evaluate the photovoltaic system production and so to evaluate the investments cash flows or "to evaluate if the photovoltaic system works correctly and in line with the performance foreseen in the design phase" so the pyranometer isn't the instrument suitable to your needs.

This because a mono (poly) crystalline silicon conventional photovoltaic system doesn't absorb the entire solar radiation, but only a minimum part of the spectrum. The picture 3 represents the absorbed radiation (red area).

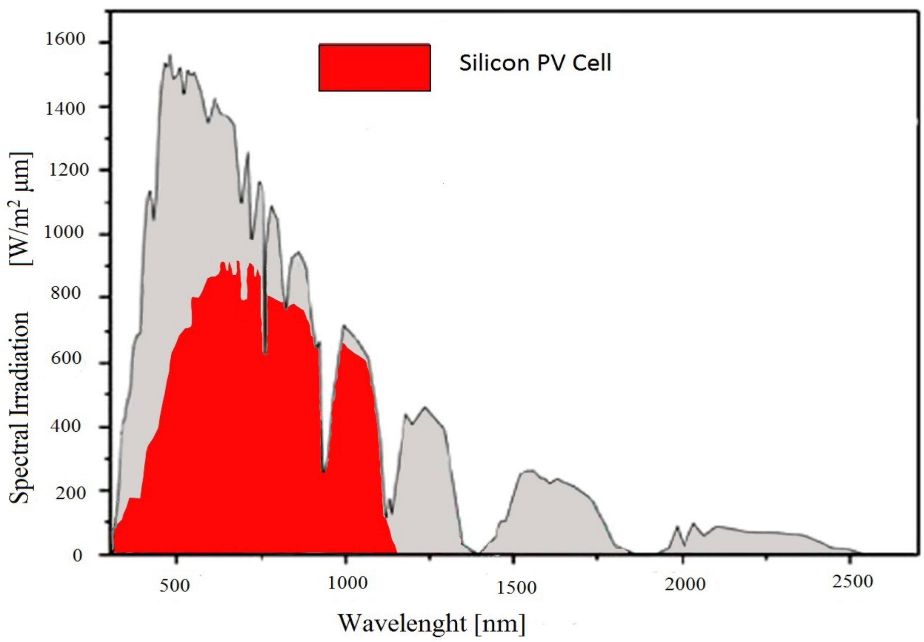

Fig.3: Spectrum of solar radiation absorbed by a monocristalline silicon cell

As you observe and it is easily deducible, to evaluate the photovoltaic system production with a pyranometer, which captures the entire solar spectrum, is an error because you could overestimate sensitively the production.
Paradoxically, if we have to measure the radiation outside the atmosphere, if we have hypothetically a sensor able to survey also the γ and X, it can be more easy to understand that this sensor cannot return to us a careful 'benchmark' than a FV plant can produce given that the photovoltaic technology answer band is much more limited (0,3 µm at 1,0 µm)

You can see the picture 4 to have a numerical magnitude order of the underestimation.

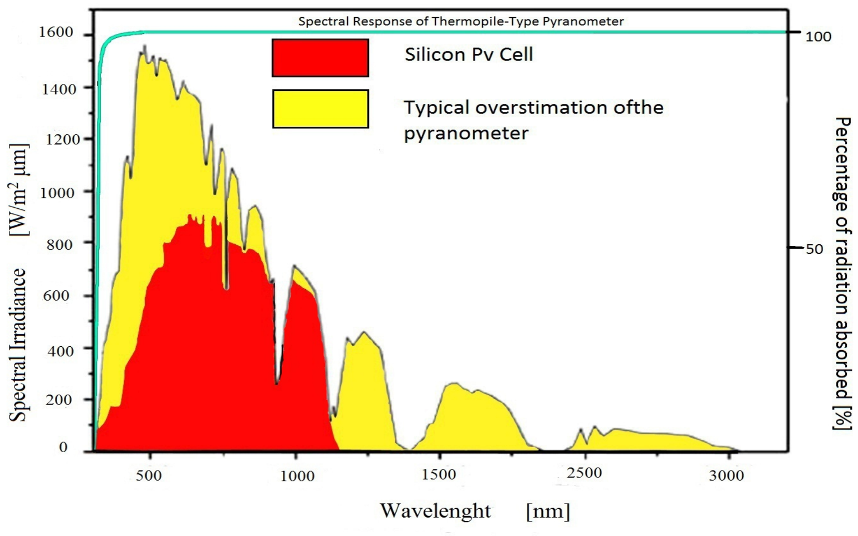

Fig.4: Underestimation in the evaluation of a crystalline silicon photovoltaic system production performed from a thermal battery pyranometer.

If the physics isn't the matter suitable for you, it is possible to explain this concept making the comparison with an investment funds benchmark.

A benchmark is a reference objective parameter, constituted making reference to financial indicators processed by third parties and of common use, as the stock indexes.

In short in the financial world to evaluate the fund profitability or other products, one of the most widespread system is that to refer the parameters of our fund to a reference fund, which is the benchmark.

If we take as reference value the irradiance surveyed in a certain geographic place a value measured with a pyranometer, we will obtain an imprecise value for the plant production.

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The sunmeters use for the solar radiation measure resets this problem because the sensor used from the sunmeters with crystalline silicon cell absorbs the same wave length of a silicon commercial module, and so it supplies the system production correct value without decrease it taking into account of the infrared fraction and so without taking into consideration of the top condition indexes and using complex numerical methods that a data logger would be able to process with difficult if not with additional sophisticated instrumentation (spectral analysis, etc..).

So we can summarize saying that measure the solar radiation with a pyranometer allows to us to evaluate entirely the physic phenomenon, while if we measure with a sunmeter allows to us the phenomenon useful for the energy production and so the phenomenon is functionally and economically interesting.

We underline that the sunmeter is not the more careful instrument for the solar radiation evaluation; instead it is the more effective and simple instrument to evaluate the photovoltaic system production.

Nevertheless the sunmeter if is treated with the help of a pyranometer, it is useful as instrument for the solar radiation evaluation, also if due to the above mentioned points, will have always a doubt due to its not sensitivity to the infrared and to the not total absorption of the visible radiation, which will make it as much as precise respect the thermal battery instruments. The sunmeter calibration with a pyranometer must be performed under particular conditions.

2. The temperature effect on the solar radiation measure

The pyranometers doesn't need of a temperature correction on the performed measure, or at least the temperature effect is so limited that it isn't worth it to perform this operation.

More exactly some pyranometers foresee the possibility to perform the temperature correction supplying the correction curve inside the calibration certification, but in the more precise and expense pyranometers there are widths corrections around the 1%.

Usually this curve is supplied in the high band pyranometers because they are designed and developed to work in unfavorable climatic conditions where the temperature effect can be very important.

To our latitudes and however in similar climatic zones, the error could be so limited to be interesting only for academic studies.

Nevertheless we underline as the effect is so limited only for very expense and sophisticated instruments, while for lower band instruments the error tends to increase sensitively.

The normal crystalline silicon cells suffer of the temperature affecting the tension and current values. This fact due to the silicon characteristics subjected to drugging to increase the photovoltaic conversion effect.

Today, the medium high band sunmeters perform the measured value temperature correction thanks to the valuable on board electronic. In this way the temperature effect on the cell current value reading is corrected from the electronic or from algorithms if there is a micro controller. These corrections reach values around to 8% in correspondence of summer high temperatures.

(respect to the measured value in conditions S.T.C. at 25°C).

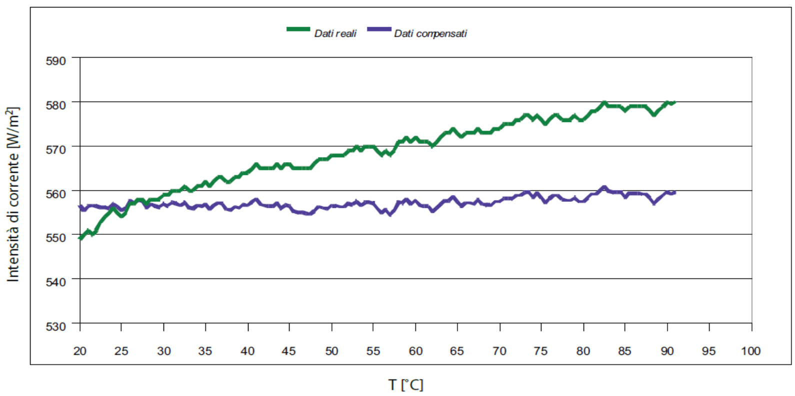

Fig. 5: Comparison between correct and incorrect irradiation at various temperatures of a solarimeter.

3. sensor orientation and inclination effect

The pyranometers are designed to suffer as little as possible of the effects due to the cosines effect (experimental doubt due to not perpendicular between the solar rays direction and the considered surface) through constructive solutions as the semi spherical dome presence and the glasses use of high quality.

The photovoltaic systems for the major part are planes and so suffer majorly of the above mentioned effect.

Conceptually if there isn't this effect, if we measure the direct radiation on the orthogonal plane and multiply for the zenith angle cosine, we will have to obtain the same direct radiation value measured on the horizontal plane, but in the practical way isn't so because when the solar height angle value decreases, the ray records in a more inclined way on the surface and so an its fraction will be reflected and will not be absorbed.

Also if we incline a pyranometer with the same modules angle, the error performed from the pyranometer will be minor of that one performed from the modules, because these ones are a plane surface while the pyranometer is equipped with glass domes and a set of systems to minimize the above mentioned error.

Always starting again the comparison with a fund, place an irradiating sensor in horizontal position or use an instrument which doesn't suffer (or suffers very little) of the cosines error; it is as if the reference benchmark works on the same section but it is composed from bonds of different nature from the funds ones that we are monitoring; so the effect would be to not "repeat" well your fund trend.

4. disturbances produced from the high tension and current passage of FV systems.

Information transmitted in analogical way from a source device to a user device (for example data logger or monitoring system) is subjected to different factors which can compromise the integrity.

In some cases the analogical signal can be changed from a disturbance or 'noise', so that the signal which arrives to the user device is different from that one started from the source device.

This is as evident and significant as the original signal width is little respect to the disturbances level potential that can connect, and the path is longer that the signal has to do to arrive at destination.

In some cases the original signal and the disturbance have a harmonic content sufficiently different and clear to be able effectively separated with appropriate filters inside the user device, but also in this case part of the disturbance will be present in the final signal and part of the original information will be however changed from the filter action.

To the successive page the pictures 6 and 7 show a disturbance didactic example (background noise) to an only harmonica with signals width of 1/10 of the sampled signal. The picture 7 shows the receiving signal, given from the two electric signals overlapping.

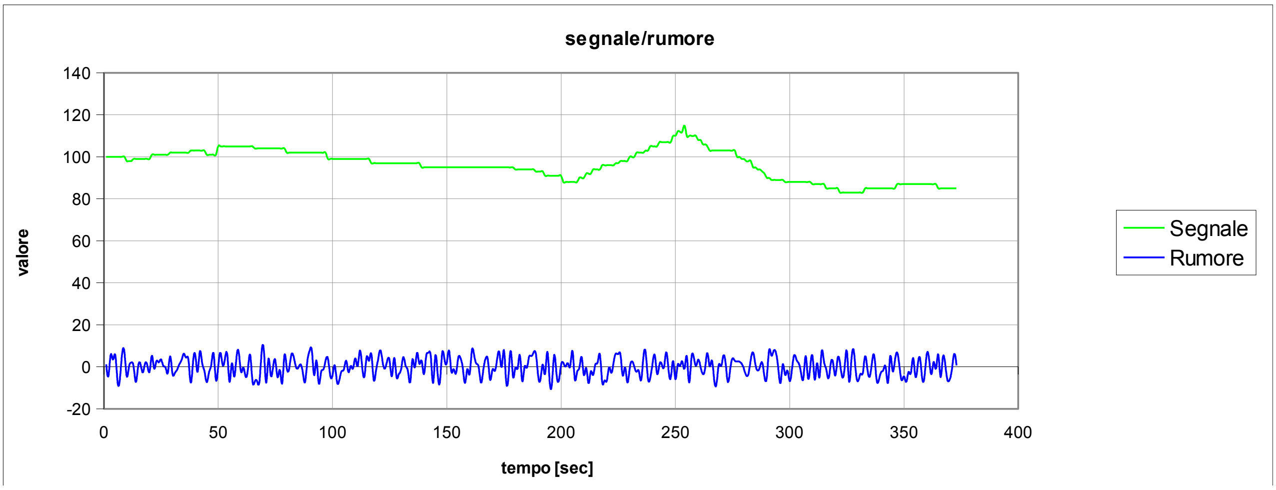

Fig.6 : a signal from a probe and a disturbance coming from the system itself

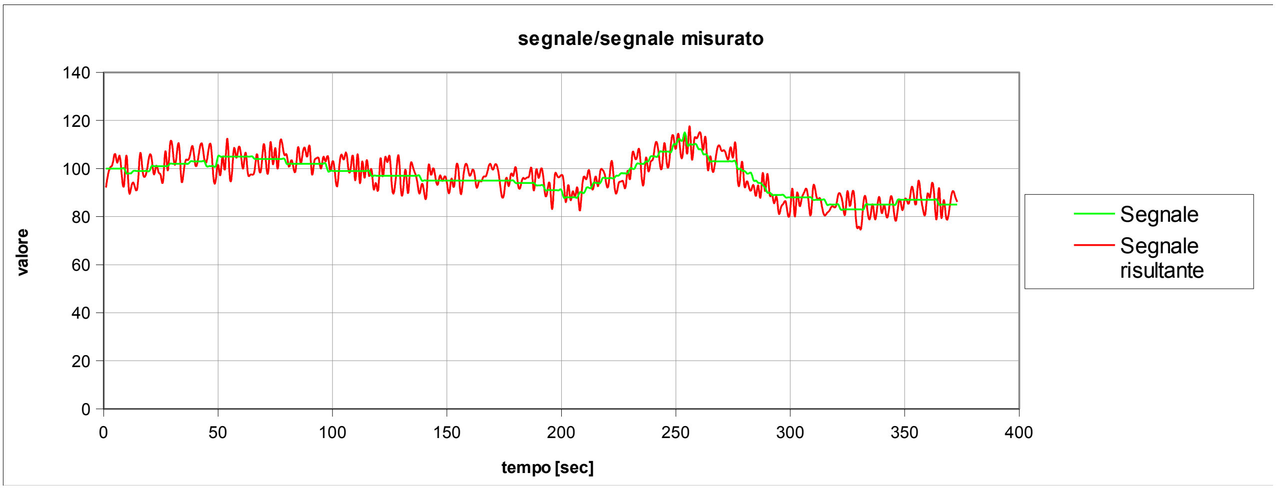

Fig.7 : light red in the combined effect of signal + noise

Besides the user system is subjected to systematic errors (for example, saving error, offset, linearity, etc) in the information transformation process in the final format managed from the user.

In general, every stage where the analogical signal passes contributes to the original information corruption.

At the end, you can note that the analogical signals “in tension” are more easily changeable respect to the “in current” ones.

In the case of the radiometric sensors for the photovoltaic field, it is very common to find pyranometers or sunmeters with direct exit, not amplified, whose full scale is in the range of 50-100mV.

This is the category more subjected to measure errors due to the disturbances, because the information is completely analogical, in tension and width very low.

The situation improves surely in the sensors with amplified exit: exit range with full scale of 1 or 5 or 10V, with signal widths that can be also besides to 100 times superior to the not amplified devices widths.
If the enlarging foresees that the signal is transmitted "in current", typical cases are the exits 0-20mA or more often 4-20mA, the system results to have a rejection (immunity) to the disturbance further increased.
Summarizing, with the amplified exit sensor use, surely the relationship signal / noise is better, but a quantity of disturbance is possible and in every case are always valid the considerations on the signal corruption made from every treatment range of the analogical signal.
In the practice, in a photovoltaic system to perform investigations on the possible disturbances performed form the cables bearer of energy would be onerous and could remain however some uncertain components; in this way it is more simple to perform the following evaluation: "More the system is great, more it is necessary to equip it with sensors with high relation exit between signal and noise (signal/noise).
Then if you want the reliability and a better precision 'apart', the answer is a sensor with serial bus exit with standard protocol.
Nella pratica, in un impianto fotovoltaico effettuare indagini sui possibili disturbi indotti dai cavi portatori di energia sarebbe oneroso e rimarrebbero comunque delle componenti aleatorie, così è più semplice fare la seguente valutazione: "Più l'impianto è grande, più lo devo dotare di sensori con uscita ad elevato rapporto tra segnale e rumore (signal/noise).
Transmit the information in digital way resolves the major part of the highlighted problems: in particular the digital signal is transmitted electrically using only two signal levels (corresponding to a bit of value 0 or 1) generally of values very distant between them and with a good tolerance margin around the nominal values: so possible disturbances or are directly ignored because have a width so that not to modify the signal in consistent way (and so the information is unharmed through the transmission channel and arrives integer at destination), or, if the disturbances intensity is so that to generate a signal outside the allowed levels the signal recognizes that the information is corrupted and can request again the transmission.
Also in the case that the disturbance is so that to change the information resulting however in a level considered valid (in this way transforming one 0 in 1 or vice versa), normally the communication protocol foresees codification systems that allow to survey (and in some cases also correct) the possible error.
In every case, with the digital transmission, or the information arrives integer or there is at least the error signaling and so there is the possibility to try again the transmission.
We underline besides that, independently as the signal has been transmitted and transformed during the various passages from the user source, the information that arrives integer at destination is exactly equal to that one sent from the source: there aren't any type of changes. In practice, is as if the information has been acquired directly from the user system!
RS485 bus and the Modbus protocol are born in industrial field properly to transmit signals and controls in disturbed environments. They are standards universally recognized for the strongly, convenience, flexibility and economically.

This description finishes with a COMPARISON TABLE of the sensors peculiarities, with thermal battery and with photo voltaic cell.
We intend to point out that this table has been written on the basis of our experiences, unlike of the above mentioned points that have an analytical approach with the help of bibliographies correctly published.

Features / Characteristics	**Pyranometer**	**Solarimeters with calibrated cell**	**Solarimeter with electronics for amplified output**	**Solarimeter with correction temperatur and output bus (Es. Sunmeter)**
• High accuracy of the entire solar spectrum	**X**			
• Suitable for scientific research	**X**			
• Suitable for photovoltaic investment evaluation		**X**	**X**	**X**
• Suitable for environments with large electric fields			**X**	**X**
• Same absorption spectrum of the photovoltaic modules on the market		**X**	**X**	**X**
• Response to the cosine equal to the PV modules		**X**	**X**	**X**
• Suitable for use in extreme environmental conditions*	**X**			
• Immunity to thermal drift	**X**			**X**
• Immunity to time drift	**X**			**X****
• Cost effective		**X**	**X**	**X**
• Fast response time		**X**	**X**	**X**
• Immunity to type of radiation to be measured	**X**			

* : we assume that the pyranometers are more lasting in the time. Nevertheless not all manufacturing companies manufacture lasting pyranometers, as observed c/o research centres from one of the writers.

**: Sunmeter Pro isn't subjected to the time drift of the first 12 months because it suffers a pre conditioning before to be sold.