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PERIODO VII: 2003-2006

Annual Report 2006

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ABSTRACT

The sixth quality audit, for the ISO17025 accreditation maintenance of the I-V measurements at STC, supervised by the Swiss Accreditation Service, was successfully passed. Moreover, a new test was verified and accredited ISO17025: the determination of the temperature coefficients of PV modules. During 2006 more than 4900 flashes were performed with the ISAAC-TISO sun simulator, in particular for research programmes.

The new electronic device MPPT was successfully outdoor installed and the MPPT was also tested in static and dynamic condition at BFH Burgdorf.

At present, the fourteen different module types chosen for the test cycle 10 (7 mc-Si, 3 sc-Si, 1 HIT, 2 a-Si and 1 CdTe) have been exposed outdoor for 8 months.

The temperature coefficient has been determined on the 3rd sample of each type of c-Si modules.

The accuracy of power declarations of c-Si modules improved constantly. This lead to unceasingly smaller discrepancies between modules when comparing their energy output in basis of its nominal power (differences in Wh/Wp-nominal power: $\pm 10.9\%$ in 2000 and $\pm 4.9\%$ in 2006). The divergence between commercial to technological comparison diminished to only 1.7% ($\pm 3.2\%$ with P3 as reference and $\pm 4.9\%$ with Pn as reference). All thin film technologies seems to outperform the crystalline silicon technologies.

For architects and designers visual aspects of a PV integration are important. PV modules from the outdoor test cycle 10 are characterised by shape, size and color (colour palettes NCS S and 4041 Sikkens). Impact tests were carried out with PV samples of amorphous silicon module on flexible substrate according to the standard IEC 1646 and SIA V280.

PV modules can be used as shielding elements for Non Ionising Radiation (NIR). The measurement of photovoltaic NIR attenuation show that thin-film photovoltaic modules have really good NIR attenuation properties (more than 30dB) as have low-emissivity glasses (more than 20dB).

The laboratory of Energy Ecology and Economy (LEEE) has been promoted to the rank of institute with the new name: Istituto di Sostenibilità Applicata all'Ambiente Costruito - ISAAC (Institute for applied sustainability to the built environment).

1 Aim of the project

The aim of the project is to control the quality and reliability of photovoltaic modules. The ISAAC-TISO (ex-LEEE) testing centre offers designers, installers and architect its expertise regarding module measurements (indoor and outdoor), PV systems and BiPV for a better quality of PV plants.

The goals for 2006 were:

- ISO17025 accreditation maintenance for I-V measurements with sun simulator.
- Accreditation procedure of performance measurements at different temperatures (thermal box).
- Installation and test of new MPPT electronics.
- Light soaking and stabilization on modules of test cycle 10.
- Energy Rating analysis of test cycle 10
- Collection of BiPV systems/products on the market (work in progress).
- Call for BiPV projects with Swiss Italian Municipalities.
- Synthesis of common problems for architects willing to pursue BiPV projects.
- BiPV appearance analysis (color, form, dimension).
- Thermal properties of BiPV modules (U-values and g-values).
- RNI attenuation.
- Mechanical test (impact test).

2 Project description

The main activities of the "ISAAC-TISO Test Centre" are: indoor measurements carried out with a class A flash sun simulator, outdoor analysis of the behaviour of PV modules under environmental conditions and study of the main obstacles encountered by architects within the relatively new photovoltaic building integration (BiPV) sector.

ISAAC's pulsed Sun Simulator allows measurement of I-V characteristics under standard test conditions, in accordance to (IEC 60904-1), and dependent on module temperature. The measurements of crystalline silicon modules are accredited ISO 17025 by the Swiss Accreditation Service (SAS). Measurements of thin-film modules with different reference cells and spectral mismatch corrections are also performed.

The ISAAC-TISO centre carried out systematic outdoor tests, under real operating conditions, on the most important modules currently on the market. Up to 18 modules for each test cycle were purchased anonymously. The modules were exposed for 15 months. Initial, intermediate and final I-V measurements @STC were carried out. Each module is equipped with a Maximum Power Point Tracker (MPPT) adapted to its voltage and current range to optimise measurement accuracy. A new MPPT was developed and installed during this project in order to satisfy the increasingly higher power of new modules. An outdoor module characterisation system with sun-tracking capabilities allow a fast and flexible characterisation under real operating conditions and the measurement of thin film modules.

The building integration of PV products (BiPV) needs a new approach from both, architects and PV operators. Within this project, different alternatives on how to overcome difficulties encountered by architects willing to work with photovoltaic (BiPV) are examined.

Moreover, mechanical, thermal (U and g-values), visual (colours, forms and dimensions) properties and others like RNI attenuation of BiPV modules are investigated.

3 Work carried out and results achieved

3.1 INDOOR I-V MEASUREMENTS (I)

During 2006, more than **4900 flashes** were performed (+88% with respect to 2005) for research programmes (test centre, EU projects and other projects), I-V measurements for third-parties and maintenance measurements (accreditation maintenance, initial tests with the new thermostatic chamber, multiframe measurements).

Maintenance measurements were performed in order to verify stability and reliability of all indoor measurements. **Annual inter-comparison** measurements with two European reference laboratories (ESTI-JRC and ECN) were also performed. Results confirmed the reliability of the ISAAC sun simulator.

In order to increase the accuracy of the absolute value @ STC of a-Si and CdTe modules, a filtered crystalline silicon reference cell is now used and a IV curve spectral mismatch correction is performed (see Annual Report 2005 for details).

In November 2005 the sixth quality audit, for the **ISO 17025 accreditation maintenance**, supervised by the Swiss Accreditation Service, was successfully passed. Moreover, a new test was verified and accredited ISO 17025: **the determination of the temperature coefficients of PV modules**.

The results of the audit was positive and the official accreditation of this measurement was in June 2006.

Listed below are the parameters analysed during the test and their relative uncertainties:

- **Current (α):** ± 187 [ppm/°C]
- **Voltage (β):** ± 213 [ppm/°C]
- **Power (γ):** ± 267 [ppm/°C]

Table 1 shows the mean values of the temperature coefficients performed at ISAAC during this year for different technologies (32 modules measured). For crystalline silicon devices (c-Si), the γ value is higher than the thin-film one, which for this reason are more interesting for BIPV applications.

Table 1: mean value of the temperature coefficients for different technologies:

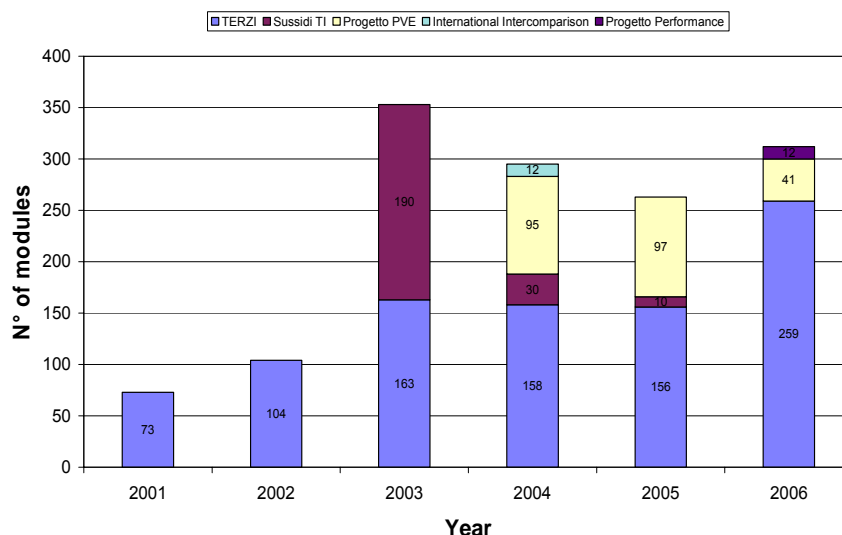
	α (ppm/°C)	β (ppm/°C)	γ (ppm/°C)	N° of measured modules
mc-Si	644	-3414	-4327	12
sc-Si	158	-3549	-4913	8
Thin Film	708	-3255	-2467	6
<i>a-Si Triple-junction</i>	1383	-4159	-1923	2
<i>a-Si Double-junction</i>	657	-3887	-3069	1
<i>CIS</i>	-41	-2758	-2635	1
<i>CdTe</i>	543	-1760	-2016	1
<i>HIT</i>	323	-2806	-3233	1

Service measurements:

In 2006 a total of 312 modules were tested for :

- 1) third-parties (259 modules),
- 2) "PV-Enlargement" project of the 5FP (41 modules) and
- 3) PV-Performance project of the 6FP (12 modules).

Figure 1: evolution of service measurements at ISAAC-TISO since the ISO accreditation.



3.2 MEDIUM TERM OUTDOOR MODULE CHARACTERISATION (OA, OB)

3.2.1 New MPPT

The new electronic device consists of a power unit (a DC-DC converter for normal MPPT operation and a linear MOSFET electronic load for I-V measurement), a measurement unit, a RS485 network, data loggers and a master PC unit.

In particular, the new MPPT3000 - developed by ISAAC-TISO - includes several enhanced features, like wider voltage and current ranges, a settable I-V tracer, timer functions and a built-in data acquisition system. The core of the system is a Digital Signal Processor (DSP) and the program was written in C and Assembler (VisualDSP++). Simultaneous and synchronous measurements (U and I) allow a better accuracy. Daily and total energy productions are recorded in the built-in memory.

A specific microcontroller for meteorological measurements (temperatures with PT100, pyranometer CM11, etc.) has been added (AD μ C845 microconverter).

For the new test cycle, 28 new MPPT systems have been installed on the ISAAC test stand and 5 at the university of Lecce.

The MPPT was tested in static and dynamic conditions at the Berne University of Applied Science (BFH) – Division of Electrical and Communication Engineering [3]. It was possible to accurately verify the performance in a wide range of voltage and current conditions. Using manual range selection, from 100% to 10% of **all current range** the MPPT has a static efficiency ranging from **99.99% to 99.75%**. Auto-range was introduced in order to increase the accuracy under 10% of current range.

The dynamic test consists in changing the working condition from 25% to 100% of maximum power and back to 25% several times using the linear PV array simulator. The change of power is done in two steps during 200 ms. After a power change, the PV simulator waits 10 seconds (P_{MPPn}). The

$\eta_{MPPT_{dyn}}$ measured is the ratio between the energy that the MPPT absorbs from the PV simulator and the energy that the simulator can provide [4]. **The dynamic efficiency is 98.40 %**, thus very high.

3.2.2 Test cycle 10

Measurements on outdoor exposed modules (2 per type)

At present, the fourteen different module types chosen for the test cycle 10 (7 mc-Si, 3 sc-Si, 1 HIT, 2 a-Si and 1 CdTe) have been exposed outdoors for 8 months.

Crystalline silicon technologies were measured indoors before exposure and after a light soaking of about 40 kWh/m², firstly to compare the real power with the one declared by the manufacturers and then to estimate the initial degradation. After 3 months of exposure they were tested again. Results are reported in Table 2.

	MODULE	P _n [W]	P _a [W]	P ₀ [W]	P ₃ [W]	(P _a -P _n)/P _n (%)	(P ₀ -P _a)/P _a (%)	(P ₃ -P ₀)/P ₀ (%)	Warranty
mc-Si	Mitsubishi PV-MF130EA2LF	130	132.5	129.6	132.1	1.9%	-2.2%	1.9%	+ 10 / - 5%
	Suntech STP150-24	150	151.1	149.4	150.2	0.7%	-1.2%	0.5%	N/A
	Kyocera KC125GHT-2	125	124.3	122.3	123.0	-0.6%	-1.6%	0.5%	+ 10 / - 5%
	RWE ASE-165-GT-FT	165	163.2	158.7	158.7	-1.1%	-2.7%	0.0%	± 4%
	Solarwatt MHHplus220	210	204.8	198.8	196.5	-2.5%	-2.9%	-1.2%	± 3%
	IBC-215S Megaline	215	210.6	211.8	211.5	-2.0%	0.6%	-0.1%	± 2.5%
	Solar World SW165	165	164.8	164.6	164.1	-0.1%	-0.1%	-0.3%	± 3%
sc-Si	Sunpower STM210 F	210	204.6	205.0	202.7	-2.6%	0.2%	-1.1%	- 0 / + 3%
	Sharp NT-175E1	175	172.8	171.0	172.6	-1.3%	-1.0%	0.9%	± 5%
	BP Solar BP7180	180	175.8	173.1	173.6	-2.3%	-1.6%	0.3%	- 0 / + 2.5%

Table 2: Comparison with nominal power and initial degradation of c-Si modules in cycle 10.

As for c-Si modules, thin-film devices were initially tested to verify the acquired power.

They have not been exposed for a light soaking, but were measured after 3 and 6 months of exposure. Their performance will be checked again after 9 and 12 months and, together with c-Si modules, at the end of the cycle, which means after 15 months of exposure at real operating conditions.

Results of measurements performed on thin-film modules are shown in Table 3, where Sanyo HIP180NE1 results have been included even if HIT cells consists also of c-Si (as c-Si devices, HIP were tested for initial degradation, but no power decrease was noticed).

Due to problems with measurement settings, initial results for CdTe First Solar module are not available.

MODULE	P _n [W]	P _a [W]	P ₃ [W]	P ₆ [W]	(P _a -P _n)/P _n (%)	(P ₃ -P _a)/P _a (%)	(P ₆ -P ₃)/P ₃ (%)	Warranty
Sanyo HIP180NE1	180	180.5	180.0	179.3	0.2%	-0.3%	-0.4%	+ 10 / - 5%
Kaneka K60	60	84.0	61.2	58.1	39.9%	-27.2%	-5.1%	+ 10 / - 5%
UniSolar ES-62T	62	64.3	57.1	55.8	3.6%	-11.1%	-2.3%	± 5%
First Solar FS-60	60	N/A	59.3	60.8	--	--	2.5%	± 5%

Table 3: Comparison with nominal power and initial degradation of thin film modules in cycle 10.

Remarks regarding the measurement of some module types:

- Electrical characterization of Sanyo HIP180NE1 modules, with HIT solar cells is made by means of multflash method due to the presence of capacitance effects;
- Measurements on amorphous silicon devices (Kaneka K60 and UniSolar ES62-T) are performed with filtered reference cell (nominal power P_n refers to stabilized power);
- For CdTe samples (First Solar FS-60), spectral mismatch correction has been applied.

Measurements on the 3rd module

The temperature coefficient has been determined on the 3rd sample of each type of c-Si modules. The test consists in the carrying out of I-V measurements at different temperature (from 25°C to 60°C, every 5°C). Temperature coefficients are calculated (interpolation) for current (α), voltage (β) and power (γ).

Results are reported in Table 4. Data concerning module Suntech STP150-24 are not reported due to problems occurring during the measurements (to be repeated).

	MODULE	Values @ 25°C & 800 W/m ²			Temperature coefficients @ 800 W/m ²		
		Isc [A]	Voc [V]	P [W]	α (ppm/°C)	β (ppm/°C)	γ (ppm/°C)
					± 187	± 213	± 267
c-Si	Mitsubishi PV-MF130EA2LF	5.87	24.70	106.0	510	-3456	-4541
	Kyocera KC125GHT-2	6.24	22.02	100.3	502	-3256	-4438
	RWE ASE-165-GT-FT	3.87	43.93	126.8	599	-3277	-4072
	IBC 215	6.06	36.80	167.8	584	-3398	-4256
	Solarwatt MHH plus 220	6.07	36.70	161.8	574	-3358	-4550
	Solar World SW165	4.01	43.60	130.4	594	-3281	-4159
c-Si	Sunpower STM210F	4.50	47.28	164.2	127	-2879	-4186
	Sharp NT-175E1	4.23	44.48	134.5	317	-3348	-4666
	BP Solar BP7180	4.13	43.78	139.0	497	-3401	-4366

Table 4: Temperature coefficients of c-Si modules in cycle 10.

3.2.3 Wh/Wp Comparison

The energy rating measurements of the 28 modules of the new test cycle started in April 2006. In order to get a whole year of energy production at stable power, the whole exposure has been extended to 15 months ending in July 2007. So real energy rating analysis only starts at month 4 (July 2006) after 3 months degradation period. Having identical irradiation conditions for all modules, the comparison can be simply done by dividing the measured energy (in Wh) by module STC power (in Wp). As shown before, the nominal power, as declared by the manufacturer, rarely corresponds to the real stabilised power due to: 1) manufacturing process related power differences, 2) declaration strategies, 3) measurement uncertainties and 4) initial degradation effects. Our laboratory generally differentiates between two points of view. The first is more consumer oriented, as it looks at the energy output in relation to the nominal power (name plate value) and the second one is a purely technological inter-comparison, where the real stabilised power measured by an accredited laboratory is used as reference, in this case our own test results (see Table 2 and 3). The first approach, shown in Figure 2, gives an idea about the Wh per invested CHF and the second one about the product quality (Figure 3). For the technological comparison, the power measured after 3 months of outdoor exposure was used (P3). The preliminary results presented here are representative for Lugano and open-rack mounted modules.

Compared to previous years the following changes and observations were made:

Crystalline silicon technologies (red bars)

During the last few years the accuracy of power declarations has improved constantly. This leads to unceasingly smaller discrepancies between modules when comparing their energy output on the basis of its nominal power. In fact, some years ago, the main difference was mainly due to the high tolerance declarations ($\pm\%$), usually of $\pm 10\%$, and infrequent power verifications. From 2000 the differences in Wh/Wp nominal power, of the crystalline silicon modules investigated by our laboratory, changed from $\pm 10.9\%$ to $\pm 4.9\%$. As a result, the divergence between commercial and technological comparison also always diminished. In the first month, the new test cycle demonstrated an effective difference in module energy output of the c-Si modules in the range of only **$\pm 3.2\%$ (with P3 as reference)**, which compared to the afore-mentioned **$\pm 4.9\%$ (with Pn as reference)** leads to a very small difference of 1.7%. The percentages are today so little that considering the measurement uncertainties involved, it is getting increasingly difficult to tell which technology is better than another, but it is clear that the high efficiency modules available on the market today are among the best. Figures 2 and 3 show the single uncertainties in energy evaluation for each module type. In the first case (Fig. 2), the uncertainty is on the one hand due to the energy measurement itself ($\pm 0.5\%$) and on the other hand due to the uncertainty in power declarations ($\pm\%$). In the technological comparison, it is only due to measurement uncertainties, the STC power measurement accuracy ($\pm 2\%$) and the energy measurement accuracy ($\pm 0.5\%$).

Thin film technologies (blue bars)

All thin film technologies seem to outperform the crystalline silicon technologies, independent of which power value is used. As described in the precedent chapter, the STC power measurement at ISAAC has significantly improved within the last year, but it is still difficult to quantify the exact measurement uncertainty. For this reason, the thin film error bars are here marked by a question mark. The amorphous silicon technologies includes a further uncertainty, which is due to the natural degradation and recovery cycles the technology undergoes during 1 year. For this graph, the power measured on 20 June was used as reference.

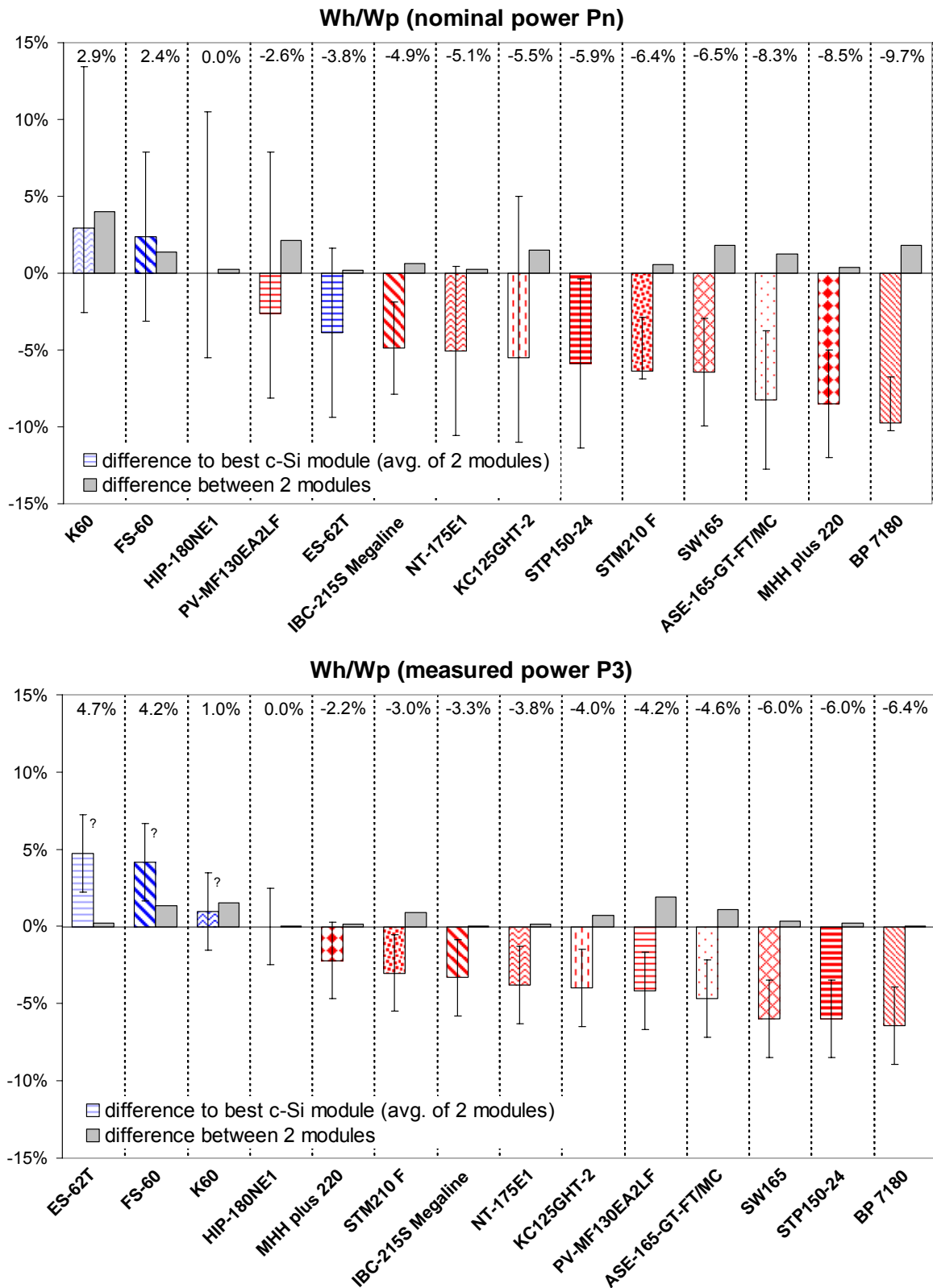


Figure 2,3: Coloured bars: Difference in energy production (average of 2 modules), expressed as percentage of Wh/Wp, of 14 different module types compared to their best crystalline silicon module with a) **nominal power Pn** as reference or b) **real power P3** as reference. (in red: crystalline silicon technologies; in blue: thin film technologies). Grey bars : Wh/Wp Difference (in percent) between the 2 modules.

3.3 BUILDING INTEGRATED PV (BIPV)

In a building integrated PV system all considerations regarding the architectural quality of the system have to be contemplated like for any other building element; the architectural quality of the whole building will be the result of a careful study of each and every part of it, including PV modules.

Similarly, technical aspects regarding the mechanical features and the performance of the PV plant have obviously to be satisfied for a project to be considered BiPV. The main BiPV aspects dealt with in the project concern mechanical and visual functionality of the modules and architectural obstacles and problems *Gli aspetti BiPV principali affrontati nel progetto riguardano le funzionalità meccaniche e visive dei moduli e le barriere e difficoltà architettoniche.*

By constructive or architectural function, we consider: building envelope, sunshades, noise barrier, visual barrier, any part of the building that fulfil a proper function, part of urban structures (vehicles covers, sport structures, playground structures,...). To synthesise, the definition of BiPV is:

BiPV plants are those where PV components - modules - fulfil at least one constructive (or architectural) function in addition to electricity production.

In June 2006, ISAAC together with the Cantonal Office for Energy Saving invited all municipalities of the Italian part of Switzerland to submit architectural projects where BiPV plants could be developed. To date, six municipalities have announced projects for possible BiPV realisations (Chiasso, Cugnasco, Massagno, Paradiso, Roveredo e Stabio).

Moreover, within the sphere of subsidies granted to BiPV projects, ISAAC provides support for 5 other private-sector projects as well as two promoted by ISAAC itself.

ISAAC is supporting them to find appropriate solutions and partners.

3.3.1 Synthesis of common problems for the architects willing to realise BiPV projects

Synthesis of common problems for the architects willing to realise BiPV projects

While going through the research of solutions for BiPV projects, some difficulties have risen, most of them are linked to the fact that BiPV market is still marginal in terms of volume. In fact, it appears that almost every BiPV project is tailor made and that only few PV modules producers propose standard solutions for BiPV realisations, this situation makes the task difficult for the architects willing to work with photovoltaic, in particular for small size projects. A synthesis of the common problems has been elaborated, it includes a list of "Difficulties" put together with the relative "Consequences" and possible "Measures" for improvement:

- Difficult access to technical and cost information about BiPV products
- Problematic use of PV simulation software with special BiPV modules
- BiPV modules generally available only "tailor made"
- Lack of competency and knowledge about BiPV among PV professionals and architects
- Difficult identification and choice of PV products for BiPV solutions
- Representatives of BiPV producers not locally present and available (as advisors for architects and engineers)
- Architectural limitations for PV plants imposed by planning regulation, particularly in historical area (variable because it depends upon Municipalities)

This list of "obstacles" will be the main topic of the interactive session of an ISAAC workshop which should take place in February 2007 in Lugano. The event will get together a selected group of professionals from various horizons (architects, PV specialists and scientists, PV industrials, public institutions and real estate managers) providing a wide interdisciplinary point of view.

3.3.2 Collection of BiPV systems/products on the market

This under progress work aims at providing an overall view on what is presently available in BiPV market for helping architects, owners, engineers and planners to know who does what and where to find the product they look after. It is presented as an *Excel* table which allows to classify the list considering different criteria (producer, plant typology/application). The table is organised in 4 columns, namely: the producer's name and complete address, the plant typology, pictures of application, notes about the technology. Since the PV market in general and BiPV market in particular are developing very fast, this list will have to be frequently updated to be really useful, this updating process should be ideally done in collaboration with the producers of BiPV solutions.

3.3.3 PV module appearance

In architecture, visual aspects of a PV integration are really important. We are used to seeing around us examples, which we can call "patchwork", where all colours, forms and dimensions are mixed

together. To help the architects and designers to choose a good combination, we characterize, amongst others, the PV modules' colours (cells) with the standard palettes that are commonly used by architects, painters, etc.

The use of a colour and luminosity meter CS-100 of Konica Minolta and the colour-meter COLOR-CATCH of the Swiss company Colorix were not successful. The measurement of colour through glasses does not reproduce the colour impression of the human eyes.

On the other hand, colours palettes covers all the range in a logical way and allow satisfying characterisation with human eye comparison.

Initial characterizations were undertaken on PV modules from the outdoor test cycle (10). The colour palettes used were the NCS S, 4041 Color Concept Sikkens. The palette RAL K5 didn't contain enough colours.



Figure 4: colour palettes and PV module characterisation

All other appearance characterisation such as the colour background of the modules, the framed colour, the forms of the cells, the dimensions of cells, the space between the cells, the electrical grids, and PV module reflexion were indexed.

3.3.4 PV modules thermal aspects (U-value and g-value)

Some trials were made to measure thermal conductivity of glass samples with a system composed of thermal baths. We obtain some uncertainty flux measurement due to the high conductivity of glass materials. This test is more suitable for building materials such as concrete. Moreover, the PV adaptation of this test will increase inaccuracy. Hot box test facilities for U-value and outdoor test facilities for g-value, like in EMPA, require space and experience and are expensive like an EMPA service.



Figure 5: thermal baths to measure thermal conductivity



For this reason we tried to measure in situ the U and g-value (on real cases: i.e. newly built houses) on special glasses and in dynamic conditions [6]. The analysis method gives good results and will be extended by measurement on integrated PV modules.



Figure 6: U and g value measurement in situ in dynamic conditions

In collaboration with the ESCA Group of the Physics Institute of the University of Basel, indoor measurements were carried out to determine the "g" value in function of the incidence angle. Initial

measurements of optical properties were made with simple glass Schott Solar PV modules. A database of glasses has been made by the ESCA (<http://pages.unibas.ch/phys-esca/>) and contains optic properties based on EN410 and g value measurement.

3.3.5 PV modules NIR Attenuation

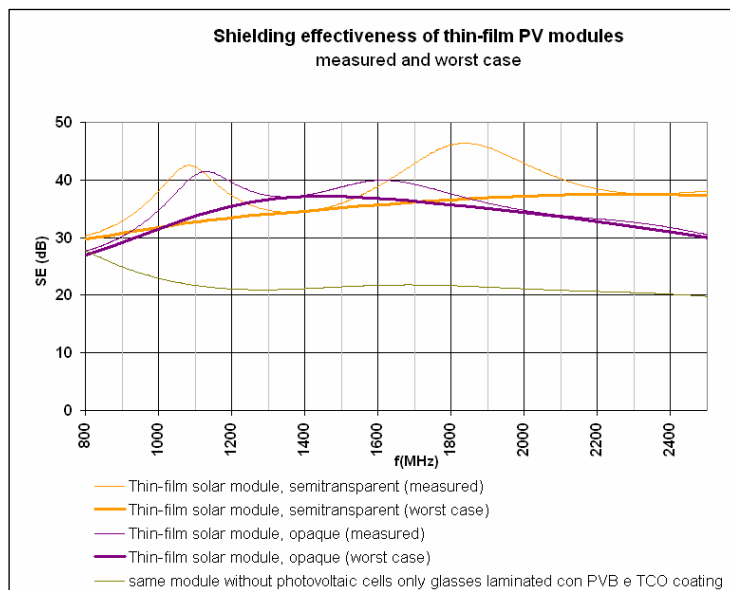
Non Ionising Radiation (NIR), commonly called Electrosmog, emitted by telecommunication installations is always present nowadays. The quantity of NIR to which the population is exposed will increase as well as the intensity and diversity. In the population, fears and resistance towards NIR transmitted installation are becoming more and more common. Therefore, PV modules can be used as shielding elements. Some new building materials to shield liveable space against NIR can be already found on the market. For example: 20dB (means an attenuation of 99%) is considered as a good degree of

attenuation and typical values of attenuation for building materials are generally between 6dB (75%) and 20dB (99%).

In collaboration with the TTHF (Telecom, Telematics and High Frequency) laboratory of our school, we are developing a reliable test procedure for the characterization of radio frequency attenuation, also called shielding effectiveness (SE) for various PV modules and glasses. The main technologies of mobile telephony (GSM/DCS/UMTS) are situated in the interval of frequencies from 800MHz to 2500MHz .

The measurement of photovoltaic NIR attenuation show that thin-film photovoltaic modules have really good NIR attenuation properties (more than 30dB) as have low-emissivity glasses (more than 20dB). Thin-film photovoltaics modules is really suitable for replacing building glass. Besides having the capability of being thermally isolated and a safety glass, it can also have really good properties of RNI attenuation.

Figure 7: RNI shielding effectiveness of thin-film PV modules.



3.3.6 PV modules mechanical test

In collaboration with the EPFL of Lausanne impact tests were carried out with PV samples of two types of amorphous silicon module deposited on flexible substrate and laminate together with flexible waterproofing membrane . The test is based on the international standard IEC 1646 and SIA V280.

4 National and International collaborations

Berne University of Applied Science (BFH), Prof. H. Häberlin ; Accademia di Mendrisio ; BELVAL SA P.-R. Beljean, VHF Tech. A. Closset, P. Goulpié, D. Fischer, SOLTERRA SA Dir. S. Zappa, CUEPE A. Mermoud ; University of Basel, ESCA, Prof. Oelhafen, R. Steiner ; EPFL, Laboratoire de Technologie des Composites et Polymères, S. Lavanchy ; Cantone ticino ; Azienda Elettrica Ticinese. Politecnico di Milano (I), Arch. Niccolò Aste ; Università di Lecce (I), Prof. L. Vasanelli, Dr. A. Cola, M. Pierro ; CREST (UK), R. Gottschlag; NREL (USA), S. Rummel; ECN (NL), M. Jansen; JRC Ispra (I) W. Zaïman, Dr. E. Dunlop, R. Kenny.

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